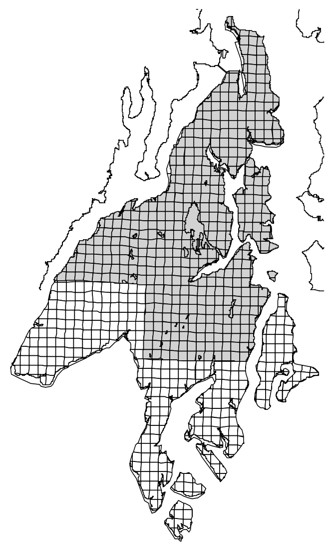
Kitsap County Initial Basin Assessment

October 1997

Open File Technical Report No. 97-04



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Section 1 Introduction

1.1 Initial Watershed Assessments

The Washington Department of Ecology (Ecology) Water Resources Program (Program) is charged with managing the State's water resources to ensure they are protected and used to the greatest extent possible for the public's benefit. One of the components of this water management is permitting for the use of surface and ground water. Historically, the Program has evaluated most water right applications on a case-by-case basis. This has increasingly become an inefficient way to deal with the large numbers of applications received. Furthermore, individual permit review usually required relying on the results of relatively short duration pump tests in order to make long-term resource decisions. This approach frequently has resulted in ignoring the cumulative impacts that many individual pumping wells may have on aquifer systems and surface water flows. Sixteen Initial Watershed Assessments (IWAs) were conducted in certain parts of the State in an effort to evolve the decision-making process on water right applications to consider the environmental health of water resources over a wide area.

These assessments focused on assembling and reviewing existing information; no new data were collected. The information assembled was chosen to broadly indicate the overall condition of water resources within the area. The information included ground water, surface water, climatic, hydrogeology, water demand, allocated water (rights and claims), and water quality, as well as the relative health of area aquatic ecosystems.

1.2 Kitsap County Portion of Water Resource Inventory Area 15

The State of Washington is divided into 62 Water Resource Inventory Areas (WRIAs) delineating the major drainage networks that flow into the Columbia River, the Pacific Ocean, and Puget Sound **(Exhibit 1-1)**.

Most IWAs are being conducted for an entire WRIA. Kitsap County (County) makes up a large portion of WRIA 15, with smaller portions of the area located in King, Mason, and Pierce Counties, as shown on **Exhibit 1-1**. A combination of the demographics and hydrogeographic properties of this particular WRIA, the political boundaries, funding, and the location and extent of data have narrowed the initial scope of this IWA to Kitsap County (County). Kitsap Public Utility District (KPUD) has funded the direct, and most of the indirect, expenditures of this effort and manages much of the County's water data. Although initial efforts are limited to the County boundaries, future efforts will expand this IWA to the full WRIA 15 boundaries when funding has been identified.

This assessment has been conducted in accordance with the January 1995, Memorandum of

Agreement (MOA) between Ecology and KPUD (See Appendix A). For consistency with the MOA, this assessment is referred to as a "Basin" rather than "Watershed."

1.3 Information Sources

Information sources for this assessment are primarily published documents. As indicated by the partial Reference listing (Appendix D) and the Fish and Habitat Annotated Bibliography (Appendix E), the water and related resources for much of the County have been extensively studied and investigated. The most comprehensive County-wide work in recent years has been done (and is on-going) as part of the Kitsap County Ground Water Management Plan (GWMP) process. The GWMP was initiated in 1986. Volumes I and II, April 1991 (Background Data Collection and Management Issues) for the GWMP and subsequent data collection and analysis have been a primary data source for this assessment, except for Section 8, Fisheries Habitat and Stream Assessment.

This assessment recognizes that additional unpublished sources of data exist for areas throughout the County. Water purveyors, County and Tribal offices, and consultants are just a few of the organizations which may have valuable data that was not identified and therefore was not incorporated into this initial assessment but which should be part of subsequent, subarea assessments.

Section 2
Basin Description

2.1 Area Description

Kitsap County (County), shown in **Exhibit 2-1**, encompasses approximately 400 square miles, and occupies a peninsula and several islands in Puget Sound. It is bounded on the east and north by Puget Sound and Admiralty Inlet, and on the west by Hood Canal. The County is adjoined by Pierce and Mason Counties on the south, Jefferson County on the west, and King County on the east.

The physiographic and topographic characteristics of the county are similar to much of the surrounding Puget Sound area consisting of remnants of a glacial drift plain. The surface is composed of generally flat-topped rolling hills and ridges (drumlinal hills) which rise to approximately 400 to 600 feet above mean sea level (MSL), and are separated by long valleys and marine embayments. The Green and Gold Mountains are a prominent group of rugged volcanic rock hills in the west-central portion of the County which rise to an elevation of approximately 1,700 feet above MSL. Much of the upland areas terminate along the coast in steep bluffs created by wave action. Since the close of the last glaciation (Vashon Glaciation), the landscape has been slightly modified by stream erosion, landslides, and wave action. Upland areas occupy approximately 75 percent of the County, flat valley floors occupy about 5 percent of the County, and the remaining 20 percent is occupied by transitional valley slopes, sea cliffs, and the Green and Gold Mountain area.

The uplands are predominantly recharge areas in which water percolates downward to water bearing strata and eventually migrates to discharge areas. Numerous surface water drainage features, such as Gorst and Big Beef Creeks, provide internal drainage for the shallow ground water systems that occur within the uplands. The larger drainage features within or adjoining the County such as Liberty Bay, Sinclair and Dyes Inlets, Hood Canal, and Puget Sound, are predominantly regional discharge areas for the deep ground water that originates within the uplands. Much of the discharge is submerged in Hood Canal, Puget Sound, and their inlets.

2.2 Subareas

Due to the physiography of the County and the dominance of localized ground water and surface water flow systems, the most logical method for study of the hydrology or water resources is to subdivide the County into smaller subareas. Based upon the local geology, hydrology, and topography, 18 subareas have been identified within the County. When identifying a subarea, the surface water drainages were integrated with identified ground water features or explicit aquifers. This enables the ground water/surface water budget and interrelationships to be considered as a distinct hydrologic system with reasonable control over estimates of inflow and outflow. **Exhibit 2-1** shows the 18 subareas designated for this basin assessment. The subareas are listed below:

Kitsap County Subareas	
1. Hansville	10. Stavis
2. Kingston	11. Manchester
3. Port Gamble	12. Gorst
4. Poulsbo	13. Union
5. Bangor	14. Tahuya
6. Bainbridge	15. Anderson
7. Manette	16. Olalla
8. Chico	17. McCormick
9. Seabeck	18. Dewatto

The designation of these subareas involved evaluation of both surface and subsurface information. The County aquifer map was overlain by the watershed boundary map developed during the Phase 1 hydrogeologic study of the Kitsap Ground Water Management Plan (GWMP). Based upon these two maps, probable ground water/surface water interactions and other hydrologic data were utilized to define subareas for future study. The boundaries of the 18 subareas are generally defined by the topographic divide between surface water drainages, but in most cases, several surface drainages have been combined. Combinations of surface drainages were based primarily on identified, underlying principal aquifers. Major aquifers were included in a single subarea, although there are instances where the local topography dictated that an aquifer overlap into more than one subarea. This occurred in the North Lake and Bucklin Hill aquifers, with minor overlaps in the Seabeck system, Port Gamble, Port Gamble South, and Port Orchard Deep Aquifers. Additionally, in some instances, a physiographic boundary containing several aquifers and surface drainages were combined to make a single, logical study area. A review of the original subarea boundaries which are used throughout this initial basin assessment revealed that several streams originated in one subarea and drained into another. Revisions to subarea boundaries have been made to resolve this problem. Future studies and evaluations will use the revised subarea boundaries **(Exhibit 2-1a)**.

2.3 Land Cover and Land Use

From a regional viewpoint, Kitsap County contains abundant forestry areas. The County contains numerous government owned and operated facilities, including Submarine Base Bangor, Keyport Naval Undersea Warfare Center, Puget Sound Naval Shipyard, Department of Defense Supply Center, and the Manchester Fuel Depot. Outside of the urbanized centers of Bremerton, Port Orchard, Silverdale, Poulsbo, Kingston, and Bainbridge Island, the County is generally characterized by scattered, small communities, homes on acreage, and large parcels of undeveloped land. Low density, single-family dwellings and small farms are scattered throughout the County, and there are large areas of pasture and forest land.

Kitsap County is working toward compliance with the requirements of the Growth Management Act. The County is currently developing a new comprehensive plan to meet the County's needs and the requirements of the GMA and the Central Puget Sound Growth Management Hearings Board October, 1996 Final Decision and Order (Consolidated Case No. 95-3-0039). The Board of County Commissioners approved the new plan in October 1996 and it has been forwarded to the state for review (see **Exhibit 2-2** for the associated land use map).

The maximum residential density within the designated rural area outside the UGAs would be one unit per five acres. Sizable portions of the rural area would be designated for development at densities not to exceed one unit per ten acres and one unit per twenty acres. The plan does contain two provisions, a “Grandfather Clause” and a Rural Infill Area, that would allow certain property owners to obtain a maximum density of one unit per two and one half acres if they meet certain criteria.

The plan will increase development in designated urban areas. Shoreline development would be restricted to one dwelling unit per acre. Urban development would be concentrated in the central portion of the county near Sinclair and Dyes Inlets and Liberty Bay. Concentration of development adjacent to these areas could further degrade the water quality of each. Streams and creeks in the central portion of the county would experience continuation (or possibly exacerbation) of present, periodic water quality problems.

The plan would allow for less rural residential development outside the urban area as compared to other alternatives that were considered. The Rural Infill and Grandfather provisions of the plan will allow for increased densities (one dwelling unit per two and one half acres) in the rural areas. The 50% open space requirement in the Rural Infill Area would mitigate most of the impacts to water resources caused by the increased density. It is expected that water quality impacts relative to surface resources (streams, creeks, lakes, wetlands, flooded areas) and groundwater resources would be lessened due to the less intense development associated with the plan.

Although there are no Forest Resource designation under this plan, 55,238 acres are designated as Rural Forest with a density of one dwelling unit per twenty acres. In addition, major stream corridors and sensitive areas are designated as Rural Low Density Residential with development allowed at a density of one dwelling unit per ten acres. Areas affected by these designations include stream corridors, drainage basins, wetland areas, and other sensitive areas.

In the urban areas, sensitive areas are designated as Urban Restricted with residential development allowed at from one to five dwelling units per acres. The net effect on water resources, therefore, would be a lessening of the potential for water quality and water quantity impacts. The plan is expected to have less impact on the water quantity and quality of streams, creeks, lakes, wetlands, flooded areas, and groundwater than most other alternatives that were considered during plan development.

Waterfront development could occur throughout the county. The density of such waterfront development with a maximum density of one dwelling unit per acre would be substantially less than other alternatives that were considered. Additional growth will result in some degradation of surface water quality and possibly groundwater quantity and quality.

Analysis of land cover from satellite imagery (Kitsap PUD, 1994) show approximately 10 percent of the County in a developed state. The remaining area is largely coniferous forest (50 percent), other natural cover (34 percent), or mixed forest land (5 percent) **(Exhibits 2-3 and 2-4)**.

An analysis of land use codes utilized by the County Assessor show a similar pattern with about 75 percent open, forested, or rural, and another 10 percent classified as suburban. According to County Assessor's data, about 14 percent of the area is classified as urban, commercial, or industrial **(Exhibit 2-5)**.

2.4 Climate

The Kitsap Peninsula has a characteristically marine climate which is typified by short, cool, dry summers and prolonged, mild, wet winters. This seasonal variation results from the position of the Pacific High, a high pressure air mass that varies in position seasonally along the Pacific Coast. The Pacific High reaches its northernmost position during the summer months and brings with it typically clear and sunny days. During the winter months, the Pacific High recedes to the south and is replaced by a low pressure system associated with rainstorms which cover paths several hundred miles in width. Transitions between the wet and dry seasons occur in early fall and late spring.

Winter storms generally approach western Washington from the southwest. The southwestern portion of the Kitsap Peninsula receives relatively high winter rainfall from storms which enter the area through a topographic gap between the Olympic Mountains and the Black Hills. Locally elevated precipitation occurs in the vicinity of the Green and Gold Mountains due to orographic effects. The northern portion of the Peninsula experiences drier winter weather because it is situated in the rain shadow of the Olympic Mountains. Wet and dry seasons in the northern areas of the Peninsula are less distinct. More detailed descriptions of precipitation patterns on the Peninsula are found in Section 3.

Temperatures on the Kitsap Peninsula are moderated by the Pacific Ocean and local marine waters. Temperatures infrequently drop below freezing, or exceed 80^oF.

2.5 Water Balance

A water balance is an assessment of the major components of a hydrologic system and includes the interactions between surface water and ground water systems.

A water balance assessment provides a general understanding of the magnitude of the recharge and discharge components. It does not provide an accurate assessment of surface water/ground water interactions and quantities, and should not be relied on as the sole tool for ground water management. The components of a simplified water balance equation can be expressed as:

$$\text{Precipitation} = \text{Evapotranspiration} + \text{Runoff} + \text{Recharge}$$

Appendix I further discusses water balance, outlines Kitsap County water balance components and provides a conceptual hydrologic cycle for Kitsap County **(Exhibit I-1)**.

2.6 Population

Although the land cover and land use discussion under 2.3 correctly indicates that a large part of the County is rural and forested, it is important to note that the County is second, only to King County, in population density of all counties in the State, as shown on **Exhibit 2-6**, with 562 persons per square mile in 1995.

The County ranks sixth in total population (220,600 in 1995) and has experienced a 31 percent increase in population since 1985, ranking 8th in the State (see **Exhibit 2-6**).

Section 3 Precipitation

3.1 Introduction

Quantification of precipitation is an important component of the watershed assessment process. Precipitation provides the input that supplies stream runoff and ground water recharge. Variation in precipitation must be taken into account when assessing trends in streamflow and ground water levels. Long-term values for precipitation, averaged over specific subareas, are necessary for performing subarea water-budget analyses. A discussion of the spatial distribution and temporal trends of precipitation within Kitsap County (County) is presented below.

3.2 Spatial Distribution

A long term average isohyetal map of Kitsap County **(Exhibit 3-1)** was compiled based on that precipitation data from 21 gages on and surrounding the Kitsap Peninsula. The isohyetal map shows that average precipitation varies over the County from just under 30 inches/year in the north to almost 70 inches/year in the southwest. The accuracy of precipitation estimates is believed to be relatively high in most areas (+ 5%), with the exception of the Green-Gold Mountains where orographic effects are likely significant and precipitation gages are absent. The Green-Gold Mountains occupy portions of the Chico, Gorst, Tahuya, and Union sub-basins. The degree of error caused by orographic effects in these sub basins is unknown. The isohyetal map shows dashed contours in the area to reflect this uncertainty, as well as slightly elevated precipitation associated with orographic effects measured at the McKenna Falls gage. It should be noted that this analysis of available data suggests that precipitation on the northern tip of the Peninsula (at Hansville) is higher and less in the Southwest portion of the County, than shown in the Kitsap County Ground Water Management Plan (GWMP) (1991), and closer to the values shown by Garling (1962).

A summary of precipitation monitoring stations in the County is presented in **Exhibit 3-2**. A summary of the data used to prepare the isohyetal map is included in **Exhibit 3-3**. Fourteen of the gaging stations which lie within the County had adequate data and were used in the analysis. The other seven stations are regional monitoring points that are located in Jefferson, King, Mason, and Pierce Counties. Most of the monitoring stations within the County are relatively new and consequently have relatively short-term records. Three long-term stations exist including the Bremerton Fire Station, McKenna Falls, and Seabeck-Monroe. The long-term records at Bremerton Fire Station and McKenna Falls were used to normalize annual values from short-term records (1991-1993) at the other stations to the long-term average. Normalization involved determining the annual percent departure from the long-term average for the Bremerton and McKenna Falls stations, and adjusting 1991-1993 annual values from the other stations by these average percent departures to obtain values representative of the long-term average. The normalized values are presented as "adjusted" values in **Exhibit 3-3**. The "plot" values in **Exhibit 3-3** represent an average of the adjusted values for 1991-1993 or long-term values for those stations in Kitsap County where long-term data are available. The plot values also include the data for the regional stations for the period 1951-1980. The plot values were processed through a contouring package (SURFER-mincurve fitting technique) to produce the isohyetal map shown in **Exhibit 3-1**. The locations of the precipitation gaging stations are also presented on **Exhibit 3-1**.

3.2.1 Precipitation Trends

Temporal variation and trends in precipitation occur on seasonal, short-term, and long-term scales. On a seasonal basis, 79 percent of the precipitation at the Bremerton Fire Stations occurs in the six-month period from October through March. Additionally, total rainfall for the driest months of June, July, and August is seven percent of the annual total. Departures from these seasonal statistics, such as "dry winters" or "wet summers" occur.

Long-term precipitation trends are demonstrated on **Exhibit 3-4**, which presents precipitation at the Bremerton Shipyard between 1900-1951 followed by precipitation at the Bremerton Fire Station between 1952-1994 (data were missing for March 1993, but were estimated based on other gages). An obvious difference exists between the two records, as record averages show significant contrast (36.2 in/yr. and 51.5 in/yr., respectively). The explanation for this discrepancy may be related to faulty data at one of the gages. The Bremerton Shipyard record average appears to be inconsistent with other gage averages on the isohyetal map. Additional comparison with long term data at Seattle confirms this difference and shows that it is not related to climatic causes.

Despite questions regarding the accuracy of the Shipyard data, the entire record can be used to discern temporal trends. Above-average precipitation is shown on **Exhibit 3-4** between 1900-1910, and an overall declining trend is noted between 1910-1944. Short-term variations occur over periods of several years, and are also demonstrated on **Exhibit 3-4**. Between 1957-1983, short-term (3-8 year) "sawtooth" cycles are noticeable which begins with below-average precipitation, build up to above-average values, and then drops back down again. During this period, the largest departures from the long-term average occurred in the early 1970s (above average) and the late 1970s (below average). Other short-term variations generally do not follow discernible patterns.

Recent (post-1991) precipitation trends are compared to ground water level and streamflow trends in other sections of this report (Sections 4 and 5). It is worth noting that precipitation data from the Bremerton Fire Station show a decreasing trend between 1991-1993, followed by relatively high rainfall years in 1994 and 1995. Decreasing rainfall between 1990-1993 may be correlated to other observed trends.

Similar precipitation trends are observed among the Bremerton Fire Station, Seabeck-Monroe, and McKenna Falls gages. **Exhibit 3-5**, a comparison plot of precipitation records, shows relative agreement between the gages. One exception occurs at the Seabeck-Monroe gage after 1984. Post-1984 data show a cumulative departure from the long-term annual average which is not evident (or less pronounced) at the other two gages.

3.3 Fog Drip

In areas of the Pacific Northwest, fog drip (condensation of fog on vegetation) can be a significant source of precipitation input. However, research by the USGS indicates that fog drip is not a significant source of precipitation in the Puget Lowland (personal communication, Bill Bidlake, 1996).

Section 4
Surface Water Hydrology

4.1 Description of Drainage Network

The Kitsap Peninsula contains a multitude of creeks, only a few of which drain extensive land areas. The largest drainages in the Water Resources Inventory Area (WRIA) include the Tahuya River, Union River, and Dewatto Creek. The Kitsap WRIA in total includes approximately 521 identified rivers and creeks providing over 665 linear miles of drainage. In general, drainages on the western side of the Peninsula are larger than those on the eastern side. Excellent detailed descriptions of the river systems and most tributary streams in the Kitsap Peninsula may be found in the November 1975 Washington Department of Fisheries publication, "A Catalog of Washington Streams and Salmon Utilization; Volume 1, Puget Sound Region." That publication was a principal source of information for the brief drainage network overview presented above.

This section provides an evaluation of streamflow data for drainages within Kitsap County (County). Data from streams with headwaters in the County but with watersheds primarily in other portions of the WRIA (e.g., Dewatto River) are not evaluated because they are not representative of County conditions. A map of rivers and streams in the County is presented as **Exhibit 4-1**.

The County's surface water development is primarily based on individual stream diversions rather than large dams with associated reservoirs. The Casad Dam, located at McKenna Falls on Union River, is the only major diversion structure in the County, and is used for municipal supply by the City of Bremerton. The Dam provides about 60 percent of the City’s water supply (pers. comm., F. Reinke, 1995). The geographic distribution of surface water rights in the County is included in Section 8.2.3. In addition, a number of small dams have been identified throughout the County (e.g., Big Beef Creek, Gorst Creek, Barker Creek, tributaries to the Tahuya River and Sinclair Inlet, and on Bainbridge Island). These dams are assumed to be associated with small, private diversions and lake enhancements (e.g., Lake Symington on Big Beef Creek).

4.2 Established Regulatory Instream Flows

Instream flow regulations, and other rules which limit surface water withdrawals in the Kitsap WRIA, are published in the Washington Administrative Code (WAC) Chapter 173-515, titled "Instream Resources Protection Program - Kitsap Water Resource Inventory Area (WRIA) 15." These rules were promulgated in 1981 pursuant to the Revised Code of Washington (RCW) Chapter 90.54 (Water Resources Management Act of 1971), Chapter 90.22 RCW (Minimum Water Flows and Levels), and Chapter 173-500 WAC (Water Resources Management Program). A copy of Chapter 173-515 WAC is included in Appendix B of this report.

Instream flows have been established for 18 locations in the Kitsap WRIA, 14 of which occur within the County. The instream flows are established on a bi-weekly basis over the periods specified in WAC Chapter 173-515 (Appendix B). The locations of control points (established measurement location as per Chapter 175-515 WAC) and stream reaches regulated for instream flows within the County are shown on **Exhibit 4-2**. Only six control points (five within Kitsap County) have associated stream gaging stations, several of which are no longer active. General comments by various hydrogeologists that some of the minimum instream flows in Kitsap County may have been set unrealistically high seems to have been confirmed by a recent study of the Gorst Creek basin by AGI Technologies. As more data and analysis on county streams is submitted as part of the Basin Assessment open file, the state Department of Ecology could take action to set more valid minimum instream flows where appropriate. This action would require new rulemaking in accordance with Chapter 34.05 RCW.

Regulatory closures have been established for 67 streams, lakes and drainage systems in the Kitsap WRIA, as presented in WAC Chapter 173-515 (Appendix B). Thirteen streams have partial closures with instream flow requirements during other times of the year. The remainder of closures are applied year-round. In Kitsap County alone, there are approximately 32 year-round closures and ten partial closures. Major drainages with regulatory closures include Union, Tahuya, Dewatto Rivers and Big Beef Creek. A complete summary of closures and instream flow requirements for the County is presented in **Exhibit 4-3**.

4.3 Quantification of Streamflow

Streamflow data considered in this preliminary assessment include long-term data collected by the US Geological Survey (USGS), recent data collected by Kitsap Public Utility District (KPUD), and miscellaneous or short-term data collected by tribal organizations and various other parties. This assessment is limited to streams which occur within the County. A summary of continuous stream gaging stations within the County is presented in **Exhibit 4-4**. In total, the USGS has established ten continuous recording stream gage sites in the County and currently maintains a gage at only one of these sites (Big Beef Creek during the low flow period). Streamflow measurements were initiated by the KPUD at nine sites within the County beginning as early as 1990 **(Exhibit 4-4)**. Additional sites have been added since then. In some cases (at both new gage sites and former USGS sites), rating curves are still being established and reported flow rates may involve some inaccuracy.

The quality of data for the nine KPUD gaging stations for the period from 1990 to 1994 is limited by the accuracy of the rating curve analysis used to produce the discharge estimates. Rating curves for these stations during this time period were developed on the basis of simplified best curve fits on log-log graph paper. The rating curves did not incorporate shift factors and other corrections which reflect changing conditions within the stream channel. Since 1994, KPUD has been using standard USGS protocol for streamflow surveys, rating curve analysis, and computation of streamflow records.

Recent data from several of the KPUD gaging stations may also be effected by poor hydraulic control. A USGS review of gaging stations on Chico, Gorst, and Barker Creeks indicated various problems associated with backwater conditions, unstable channel morphology, and debris buildup. KPUD plans to relocate these stations at more suitable control points in 1998.

KPUD is currently using Western Hydrologic Systems software for storage, analysis, and retrieval of streamflow data and for maintenance of rating curves. USGS personnel are providing oversight and review of KPUD's streamflow monitoring program.

The main objectives in reviewing and quantifying the streamflow data were:

- To assess whether there is any obvious indication of declining annual streamflows and summer low-flows; and

- To compare actual streamflows to the established regulatory instream flows and to assess the frequency with which the regulatory instream flows are actually met.

Streamflow data are published by the USGS following a "water year" convention - where water year 1990, for example, begins on October 1, 1989, and ends September 30, 1990. The water year convention is useful to many aspects of hydrologic analysis, but may confuse readers not familiar with the convention. To minimize confusion, all data presented for this section are expressed based on the calendar year convention (January 1 through December 31).

Streamflow data were processed in several ways to achieve the objectives listed above. Average and minimum annual flows were evaluated in time-series plots along with annual precipitation at Bremerton. Where only recent data were available (i.e. post-1990), continuous streamflow hydrographs were plotted directly from KPUD records and evaluated for trends over time. Historic flow exceedence probabilities were calculated based on USGS records and plotted over the calendar year. Recent (post-1990) hydrographs were plotted along with the historic flow exceedence probabilities for purposes of comparison. Finally, regulatory minimum instream flow requirements (listed in WAC 173-515) were compared to historic and recent streamflows by plotting the annual flow requirements together with flow exceedence probability curves and recent hydrographs.

Some of the streamflow data collected within the County were unsuitable for the analyses described above. Non-continuous flow data (spot measurements) have been collected for various streams in the County, but are not sufficient for these analyses. Appendix C presents spot measurement data collected by the Suquamish Tribe, KPUD, and various other parties. In addition, continuous data collected at two KPUD gages and three USGS gages were not used for the analyses described above. KPUD data records from Anderson Creek #96 and Anderson Creek #272 were too short (less than one year) for such analyses. USGS data from the Union and Tahuya Rivers near Bremerton and from Huge Creek were not used for reasons discussed in Appendix C.

4.4 Streamflow Trends and Critical Indicators

Time series trends were analyzed for nine gages in the WRIA to assess whether there are any indications of declining streamflow over time. Trends in average annual streamflow and minimum streamflows (summer low flow) were addressed. In addition, recent flow hydrographs were compared to historic streamflow statistics to detect changes over time. Finally, flow data from gages with regulatory flow requirements were assessed to ascertain the extent to which recent (and historic) flows satisfy the regulatory requirements.

The following three sections assess trends in average annual streamflows, trends in minimum streamflows, and compliance with instream flow requirements. A fourth section is presented to summarize the conclusions.

4.4.1 Annual Streamflow Trend Analysis

Annual precipitation and annual streamflow volumes are hydrologically related. In a natural system, precipitation which does not emerge as streamflow must be attributed to either evapotranspiration, losses to ground water which emerges outside the drainage basin, or changes in the volume of ground water storage. Human development activities may significantly affect annual streamflow volumes, independent of climatic fluctuations. Basin land development activities such as logging, paving, construction, and other creation of impervious areas will cause an increase in the annual volume of runoff, reduce plant transpiration, and decrease infiltration to ground water. Water development activities, particularly withdrawals from streams or from shallow ground water, will cause a decrease in the annual volume of runoff, especially if the water-use is consumptive (e.g. sewage discharge to sea) or if water is exported outside the drainage basin.

Development activities may also influence the timing of runoff, and might cause annual flows to increase but simultaneously cause minimum flows to decrease. For example, if large areas of a basin were paved and converted to impervious surfaces, the annual streamflow volume would increase because more of the rainfall would go directly to runoff. Simultaneously, however, the minimum annual flows would decrease because less of the rainfall would infiltrate to ground water which is the source of stream base flows during periods of no rain. This sub-section of the report deals with an assessment of annual flow volumes only. Minimum flows are presented and discussed in Section 4.4.2.

Annual average streamflow volumes were plotted over time for Chico, Burley, Big Beef, Dogfish, and Gold Creeks **(Exhibits 4-5 through 4-9)**. The plots present streamflow data from USGS records, streamflow data from more recent KPUD records (where available), and annual precipitation measured at Bremerton. Trends in annual streamflow volumes were assessed and compared with precipitation. As mentioned above, precipitation is a necessary component in considering potential causes for changes in annual streamflow.

In general, the utility of the annual streamflow trend analysis is limited by the quantity of available data. Data records are short, available only for isolated periods, and/or available prior to the rapid water-resource development which began in the early 1970s **(Exhibit 8-1)**. Long-term data records (over 25 years) are best suited to streamflow trend analysis given inherent natural variabilities in the timing of precipitation and associated antecedent soil saturation.

Discernible trends in annual average streamflow are not evident over the period of record for Chico Creek near Bremerton **(Exhibit 4-5)** and Burley Creek at Burley **(Exhibit 4-6)**. Identification of long-term trends is difficult for both data sets because short isolated periods of record are separated by longer periods of no available data. For Chico Creek, two isolated periods of record (1948-49 and 1992-94) are too short to draw conclusions about streamflow trends. For Burley Creek, there are no discernible differences in annual average streamflow between the three isolated periods of available record.

A declining trend in annual average streamflow is indicated for the 11-year period of record (1970-80) at Big Beef Creek near Seabeck **(Exhibit 4-7)**. Annual average streamflows associated with years of similar precipitation appear to be higher in the early 1970s then in the late 1970s. It should be noted that 11-year record is relatively short, and conclusions should be drawn with caution. Such a short record may not account for natural variability in the timing of precipitation, a factor which controls how much precipitation goes to runoff versus recharge.

A relatively long period of record is available for Dogfish Creek near Poulsbo **(Exhibit 4-8)**. A fairly stable average annual streamflow trend is apparent during the 1948-70 continuous record, followed by similar average streamflows in the short isolated period between 1991 and 1996. A comparison of annual precipitation values for years of similar average annual streamflow was performed in an attempt to discern whether equivalent streamflows required increased precipitation input over time. Such a trend would imply either precipitation loss to runoff or withdrawal, or increased ground water recharge. Although there was a slight suggestion of this type of trend, the data contained too much noise to make reliable conclusions. It should also be noted that differences in rating curve error between the two periods of record may account for relatively high estimates of post-1990 flows (see Section 4.4.2). If this is the case, reduced annual streamflow over time is even more likely. Re-evaluation of the rating curves and additional analysis of the precipitation and annual streamflow data is required to improve the accuracy of the conclusions above.

A similarly long period of record is available for Gold Creek near Bremerton **(Exhibit 4-9)**. Visual inspection of the annual average streamflow data does not suggest a significant trend over the period of record (1946-69). Precipitation, however, exhibits a slightly increasing trend between 1957 and 1969 which is not reflected in the streamflow data. A more sophisticated analysis is required to better evaluate the role of precipitation in this case.

4.4.2 Minimum Flows and Trend Analysis

Trends in minimum flows may differ from trends in annual flows, due to changes in land use and the timing of rainfall events. Under certain scenarios of basin land development, for example, it is possible that average annual flows could increase over time while minimum daily flows could decrease over the same period (see discussion, Section 4.4.1). This section attempts to identify trends in minimum streamflows (and summer low-flows) using simple visual analysis of flow data. Annual precipitation was not considered in assessing minimum flow trends. Adjustment of minimum flows (and summer low-flows) for climatic variability requires a sophisticated analysis which incorporates the cumulative influences on antecedent soil moisture conditions. Such an analysis was beyond the scope of this assessment.

Trends in minimum streamflows were assessed by three different methods. For the five gages analyzed above, streamflow data were processed to identify the minimum daily average flow for each year ("minimum daily flow"), and these values were plotted over time. In addition, changes in the minimum flow regime for three of these gages (Chico, Burley and Dogfish Creeks) were assessed by comparing streamflow probability statistics for earlier periods of record (based on USGS gaging) with annual hydrographs from recent (KPUD) gaging. Finally, minimum streamflow trends between 1990 and 1994 were assessed by inspection of continuous hydrographs based on KPUD gaging data.

Trends in minimum daily flow are assumed to be similar to trends in seven-day low flow, a measure of the average flow recorded during any continuous seven-day period. This relation is commonly the case for basins without large, sporadic stream diversions (such as diversions for agricultural irrigation). Initial inspection of average daily flow data did not reveal any anomalous single day low flow during the summer months. Comparison of one-day and seven-day minimum flows for Big Beef Creek over 24 years of record showed that although 1-day minimum flows were less than seven-day flows, differences between the two flows were generally small.

Streamflow probability statistics are a measure of the occurrence probability of any particular streamflow during the calendar year. In this assessment, streamflow probability statistics (“exceedence probabilities”) were calculated for weekly average flows based on data collected over the entire stream gage record. For instance, a 90 percent exceedence probability indicates that for a given week, the average flow is likely to exceed this value nine times in every ten years. Similarly, the 50 percent exceedence probability indicates that for a given week, the average flow is likely to exceed this value once in every two years. Streamflow probability statistics for selected streams are discussed below and in Section 4.4.3.

It should be noted that reports of declining baseflows are common for streams throughout the Puget lowlands, including the Kitsap Peninsula. Such reports are largely anecdotal and data are generally unavailable to substantiate these reports. Fisheries habitat studies on the Kitsap Peninsula are known to cite anecdotal evidence of declining summer flows (see Section 8). In this report, trend analysis is limited by the quantity and quality of available data. Data from three of the five gages (Chico, Burley and Dogfish creeks) contain short, isolated periods of record which are insufficient for trend analysis. Minimum flow trends were largely inconclusive for these three gages. Declining trends were suggested at the Big Beef and Gold creek gages.

Inspection of annual minimum daily flows over time **(Exhibits 4-5 through 4-9)** shows varying trends between gages. No discernible trends in minimum streamflows were observable for Chico Creek at Bremerton **(Exhibit 4-5)** and Burley Creek at Burley **(Exhibit 4-6)**. For Chico Creek, three of the most recent four years of record (1991-94) show minimum streamflows substantially lower than previous record (1961-74). Although this comparison implies declining low flows, a trend cannot be established due to the brevity of the recent record. Recent record at Burley Creek (1991-94) suggests increased minimum flows relative to previous record. However, the four-year period is too short on which to base solid conclusions. The disparity between minimum flows measured by the USGS and by the KPUD (post-1990) suggests that there may be a slight discrepancy between rating curves for the two periods of record.

Minimum daily flows on Big Beef Creek near Seabeck show a slightly declining trend between 1969 and 1994 **(Exhibit 4-7)**. These data were collected entirely by the USGS, thus eliminating the potential for differential measurement error between the two data collection agencies. Minimum daily flows on Dogfish Creek near Poulsbo show no apparent decline between the two periods of record (1947-71 and 1991-94, **(Exhibit 4-8)**). Similar to Chico and Burley Creeks, however, conclusions are limited due to the relatively short recent record. Minimum daily flows on Gold Creek near Bremerton show a declining trend between 1946 and 1970 **(Exhibit 4-9)**. This historic decline appears to be on the order of 0.1 to 0.2 cfs, approximately 25 to 50 percent of the 1946-1970 minimum daily flow average. Data were not available to assess whether the declining trend has extended to present times.

The conclusions gained from the minimum daily flow analysis are generally supported by comparisons between historic (USGS) streamflow statistics and recent (post-1990; KPUD) streamflow hydrographs. The comparisons are presented on **Exhibits 4-10 through 4-12**. **Exhibit 4-10** presents recent streamflow hydrographs for Chico Creek overlain on 1947-74 weekly streamflow exceedence probabilities. The plot shows that recent flows were consistently less than the statistical 1-in-10-year low flow (90 percent exceedence) between May and mid-October during one of the four years of record; and were intermittently less than the 1-in-10 year low flow during the summer months for two of the recent years. Years showing intermittent summer flows below the 1-in-10 year low flow, however, also show remaining summer low-flows generally between the 10 percent and the 90 percent exceedence probability curves. Intermittent low baseflows contribute to the apparently reduced minimum daily flows between 1991-94 shown on **Exhibit 4-5**. Due to the short period of recent record, additional flow data must be collected to determine whether this reduced condition is representative and whether it is related to a change in baseflow regime (e.g. added variability) or to a consistent reduction in ground water discharge.

A similar comparison for Burley Creek is presented on **Exhibit 4-11**, based on 1947-65 streamflow statistics. The comparison shows that recent summer low-flows range between the 10 percent and 50 percent exceedence curves for historic summer low flows. The same comparison for Dogfish Creek shows that recent summer streamflows exhibit considerable variation relative to exceedence probability curves. **Exhibit 4-12** shows that over four years of recent record, streamflows exceeded the 10 percent exceedence probability curve during significant portions of three of four summers and fell near or below the 90 percent exceedence probability curve during portions of two of four summers.

Recent trends in summer low-flows were assessed based on continuous hydrographs from the seven gages currently monitored by the KPUD **(Exhibit 4-4)**. **Exhibits 4-13 through 4-19** present (post-1990) average daily streamflow versus time for the seven gages. Relatively stable trends are noted on Chico, Clear, and Burley Creeks **(Exhibits 4-13 through 4-15)**. Variability obscures any noticeable or significant trend on Dogfish Creek **(Exhibit 4-16)**. A noticeable decline is apparent on the Barker Creek hydrograph **(Exhibit 4-17)**, and variability of summer streamflow tends to obscure any observable trend on Gorst Creek **(Exhibit 4-18)**. Finally, the data record for Blackjack Creek **(Exhibit 4-19)** is too short to draw significant conclusions.

It must be emphasized that the periods of record used for the above assessment are too short to indicate long-term trends. Climatic variability may be partially accountable for observed short-term trends. Recent precipitation exhibits a downward trend between 1990 and 1993, followed by an above average value in 1994 (discussed in Section 3.2). Recent (short-term) declines in summer low-flows are not conclusive indicators of additional stress on the hydrologic system, but they do suggest that increased attention is warranted. Continued data collection is required for all seven gages to make defensible conclusions pertaining to current low flow trends.

4.4.3 Regulatory Instream Flows and Actual Flows

An assessment was made to compare flow statistics and recent hydrographs to regulatory instream flow requirements. Three of the gages with available streamflow data are currently associated with regulatory instream flow requirements. One of these gages is coincident with the instream flow control points specified in WAC 173-515, and two are located near to specified control points **(Exhibit 4-2)**. Historic USGS streamflow data are available for two of the gages (Big Beef Creek and Tahuya River at Belfair), and recent KPUD streamflow data are available for one gage (Gorst Creek). Probability statistics derived from USGS streamflow data are compared to regulatory instream flow requirements on **Exhibits 4-20 and 4-21**. Recent streamflow hydrographs are compared to regulatory instream flow requirements on **Exhibit 4-22**.

It should be noted that in establishing instream flows by regulation, Ecology recognizes that the recommended regulatory flows are not, and probably have never been met, 100 percent of the time. The intent of the regulation, however, is to protect streams from further depletion (e.g. through subsequent appropriations) when flows approach or fall below the recommended discharges.

Big Beef Creek is subject to minimum instream flow requirements between November 15 and May 15. A stream closure is in effect at other times. Streamflow probability statistics for Big Beef Creek between 1969-1993 **(Exhibit 4-20)** suggest that instream flow requirements would not have been met on any given week during the period of record in more than 50 percent (and less than 90 percent) of all years. It should be noted that these statistics compare the instream flow requirements to a period of record that begins before the requirements were enacted.

The Tahuya River is subject to minimum instream flow requirements between November 1 and June 15, and a stream closure exists at other times. Streamflow probability statistics for the available record (1945-1956) suggest that current instream flow requirements would not have been met on any given week between mid February and late November in more than 50 percent of all years **(Exhibit 4-21)**. Additionally, the requirements would not have been met on any given week between early May and the beginning of closure (July 1) in over 90 percent of all years.

Gorst Creek is subject to minimum instream flow requirements throughout the year. Recent hydrographs on Gorst Creek **(Exhibit 4-22)** show that instream flow requirements were not met during portions of the year for all recorded years (1990-1994). Instream flow requirements were not met for three of the four years during the late spring and summer (May through September). Instream flows were not met during all four years in late December, and were not met during all four years between major runoff events between January and May.

4.4.4 Summary of Streamflow Analyses

The reliability of the annual average streamflow trend analysis is limited by availability of streamflow data. No trends were evident for Chico and Burley Creeks, however, available data did not support an intensive analysis. A declining trend was suggested for Big Beef Creek, however the ten-year period of record is not of sufficient length to decipher long-term trends. Relatively stable streamflow trends were suggested for both Dogfish and Gold Creeks, and a more sophisticated analysis is recommended to determine if a decline in runoff efficiency (ratio of annual streamflow to precipitation) has occurred.

Several different techniques were used to assess trends in minimum streamflows (summer low-flows). The minimum flow analyses were limited by the quantity and quality of available data. Long-term minimum flow trends were not evident for Dogfish and Burley Creeks. The Burley Creek data suggests a possible discrepancy between the USGS and KPUD rating curves which should be investigated. Minimum flows on Big Beef Creek showed a slight decline, and minimum flows on Gold Creek showed significant decline. Minimum flows at Chico Creek showed potential indications of decline which warrant further attention.

Short-term assessment of recent (post-1990) minimum flow trends showed stable trends at Chico and Clear Creeks, slightly declining trend on Burley Creek, and a declining trend on Barker Creek. Variability of summer low flows obscure any short-term trends on Dogfish and Gorst Creeks. Short-term trends should not be interpreted as indications of long-term trends, especially since stretches of low precipitation appear to occur during the period of record. Short-term trends indicate the need for additional streamflow monitoring and future assessment of longer trends.

Comparison of regulatory instream flow requirements and historic flow exceedence probability curves for Big Beef Creek and Tahuya River showed that current instream flow requirements were not satisfied to varying degrees throughout the year either recently or historically (before the requirements were enacted). Comparisons between recent (post-1990) hydrographs and instream flow requirements on Gorst Creek showed that the requirements were not met during much of the year throughout this (short) period of record.

Section 5
Hydrogeology

5.1 General Hydrogeology

The general geology, hydrogeology, and water resources of Kitsap County have been described by others (Sceva, 1954, Garling, 1965). Much of the discussion in this section is excerpted from the Kitsap County Ground Water Management Plan (GWMP); Volumes I and II (EES, et al., 1991). Kitsap County (County) lies in the center of the Puget Sound Lowland (Lowland). The Lowland lies between the Olympic Mountains to the west and the Cascade Range to the east. The Lowland is part of a large glacial drift plain formed by multiple glaciations over the area. This history of complex glacial erosion and deposition events, separated by long periods of non-glacial deposition, has created a very complex mixture of unconsolidated sediments beneath the area. This sediment blanket ranges in thickness from zero to over 3,600 feet. It overlays an irregular bedrock surface which is exposed in the central and eastern portions of the county on south Bainbridge Island, Bremerton, Port Orchard, and the Green and Gold Mountain highlands.

The majority of ground water in the County is contained in the unconsolidated sediments. A conceptual model of unconsolidated sediments is depicted in **Exhibit 5-1a**, a generalized hydrogeologic cross-section for the County. The exhibit shows a layered system of water-bearing units (aquifers) and low permeability units which retard water flow (aquitards). For the purpose of simplification, aquifers and aquitards are generalized into regionally extensive units. In actuality, textural variability within the units may result in a more complex assemblage of interfingered aquifers and aquitards occurring on scales ranging from regional to local. **Exhibit 5-1b** provides nomenclature and regional correlation of the associated stratigraphy.

The ground water flow system is recharged by precipitation falling on the land surface. Precipitation also becomes surface runoff to the County's rivers and streams, evaporation from above-ground surfaces, and transpiration from plants that intercept water infiltrating the root zone. Ground water recharge is areally distributed throughout the county, whereas ground water discharge is concentrated around surface-water features such as streams, rivers, lakes, wetlands, and marine bodies. Discharge tends to occur at lower elevations to both surface water and springs, but also occurs to wells regardless of their location.

Ground water flow within aquifers is predominantly horizontal, beginning at recharge areas and flowing towards discharge areas. Ground water flow between aquifers is predominantly vertical, and typically much slower due to the lower permeability of aquitards. In portions of Kitsap County, uppermost (shallow) aquifers are commonly "perched" above aquitards and local in areal extent. Perched conditions occur where unsaturated sediments separate the bottom of the aquitard from the regional water table below. Ground water in perched aquifers reaches deeper aquifers either by slowly percolating through the underlying aquitard or by flowing (more quickly) around it's edge. The deeper sediments are typically fully saturated, especially below sea-level. Although vertical flow across aquitards is typically slow, discontinuities within aquitards (windows) allow more rapid transfer.

In coastal areas, aquifers below sea-level are exposed to marine water bodies. This allows for potential interaction between the fresh water flowing within the aquifer and adjacent seawater. In some cases, seawater can be found in inland locations within the aquifer. The saltwater occurs as a "wedge" along the coast, and the interface between salt and fresh water is often diffuse. The position of the saltwater wedge depends on water levels (hydraulic head) within the aquifer, and can be influenced by pumpage. Discussion of seawater intrusion can be found in Section 5-6.

The geologic units in the County range in age from Tertiary (1.6 - 66 million years before present) to Recent. Two lithified rock units of Tertiary age are exposed in the County. The oldest is the unnamed igneous rocks that compose the Gold and Green Mountains west of Bremerton. These rocks have been age dated at between 50 and 55 million years (Duncan, 1982) and may be correlative with the Crescent Formation (Tabor and Cady, 1978) located on the Olympic Peninsula. The younger lithified geologic unit is the Blakeley Formation, which is between 20 and 40 million years old (Fulmer, 1954). The unit consists of a thick sequence of marine and non-marine sandstone, shale, and conglomerate. The Blakeley Formation is exposed on the southern portion of Bainbridge Island, across Rich Passage around Point Glover, and north of Bremerton at Rocky Point and Sulfur Spring. Bedrock units are not major sources for ground water in the County.

The Tertiary rock units are overlain by a thick sequence of glacial and inter-glacial deposits of Pleistocene age. Much of the upland area of the County is mantled by a veneer of glacial till with the valleys containing predominantly glacial outwash and Recent alluvium. Nearly all of the region's ground water is produced from these Quaternary (Recent and Pleistocene) sediments.

In the Pleistocene Epoch of the last 15 million years, the Lowland was occupied by at least five successive continental ice sheets. The youngest of these, which receded about 15,000 years ago, was the Vashon Stade of the Fraser Glaciation. During this period, an ice sheet 1,000 to 1,400 feet thick covered Kitsap County.

5.2 Geologic Units

Geologic units have been identified based on the interpretation of the County's deeper well logs. A superpositioned sequence of the 15 identified units is presented in **Exhibit 5-1b**. The oldest units (Tv or Tb) have a "T" designator indicating Tertiary age. All others have a "Q" designator, indicating Quaternary age. Both of these designators are according to geologic mapping convention. The "Q" units are further subdivided as to nonglacial deposits ("n") and glacial deposits ("g"). These are then designated 1, 2, 3, etc., with the numerals ranking each similar deposit from younger to older. Thus, Qn3 is the third nonglacial (interglacial) deposit which underlies the second youngest glacial deposit (Qg2).

Glacial units, designated by the letter "g," are generally coarse grained materials (sand and gravel) deposited in high energy environments such as meltwater streams and margins of glaciers. Most major aquifer zones occur within these coarse-grained, glacial deposits. Nonglacial units, designated by the letter "n," are generally fine-grained materials (silt and clay) that were deposited in low energy environments such as still or deep water. A few aquifer zones occur within the nonglacial units, but they typically have low yields.

All Quaternary glacial and non-glacial units in the County are discontinuous in nature. Rarely, if ever, is the entire sequence found at one place. A unit, or several units, are generally absent at specific locations due to the complex erosional and depositional history of the area. The depth ranges quoted in the following description of geologic units, refer to the maximum known elevation of the top and the bottom of the unit respectively. The range is not implied to represent the total, or maximum, thickness of the unit or preclude the identification of the top or bottom of the unit outside this stated range.

Names originating from glacial stratigraphic descriptions (i.e., Salmon Springs Drift) would be more traditional but are not advised due to the uncertain state of the stratigraphic nomenclature at this time. Nonetheless, **Exhibit 5-1** does give suggested regional correlation for the units designated. These units, from oldest to youngest, are described below. To aid the reader, seven generalized geologic cross sections from the GWMP are presented as **Exhibits 5-19 through 5-25** to show the relative position, thickness, and areal extent that is typical of the units. The location of the cross sections is given on **Exhibit 5-2**.

Unit Tv represents the Tertiary volcanic rocks correlated with the Crescent Formation found on the Olympic Peninsula. The unit consists mostly of basaltic lava flows and diabases of unknown thickness. This rock crops out west of Bremerton, forming the Gold and Green Mountains, which are the highest points in the County. Although several wells have been drilled in unit Tv, none are known to be major producers of ground water.

Unit Tb is the Blakeley Formation which consists of a thick sequence (8,000 feet) of marine and non-marine sandstone, shale, and conglomerate. This unit is exposed on wave-cut platforms along the south shore of Sinclair Inlet and both shores of Rich Passage. The unit also is exposed on the north end of Rocky Point and on Bainbridge Island. Like the Tv unit, this unit is not a significant source of ground water.

Unit Qn6 is the oldest recognized unconsolidated unit above the previously mentioned lithified rocks. This nonglacial unit, of late Tertiary or early Pleistocene age, is of unknown area extent and thickness. It is not a ground water source and is not correlative with any unit identified in other ground water studies located outside the County area. This unit has been informally termed the Fletcher Bay formation (Noble, 1990).

Unit Qg5 is the oldest glacial unit encountered. This unit is of unknown areal extent and is up to 100 feet thick. This unit has been found to be highly productive when penetrated, as in the City of Bainbridge Island deep well located at Fletcher Bay. The unit has been tentatively identified in approximately 12 other locations throughout the County. Unit Qg5 is located quite deep, occurring at elevations between -600 to -900 feet mean sea level (MSL).

Unit Qn5, the fifth interglacial deposit, is generally a fine grained formation consisting of silt and clay with occasional peat and wood. The unit is believed to be up to 600 feet thick. There is insufficient deep well data to define the areal extent of the unit. The unit generally has very low ground water productivity.

Unit Qg4 is a glacial deposit of the fourth oldest episode of glaciation. This unit is up to 150 feet thick and has numerous wells completed in it throughout the County. The unit is a complex mixture of several sediment types ranging from sand and gravel to fine grained glacial lake deposits. It is capable of producing ground water yields ranging from 25 to 700 gpm. Outside of the Port Orchard area, this unit is commonly not utilized as a major water producer and is generally bypassed to tap the deeper unit Qg5.

Interbedded with Qg4 is a marine or glaciomarine deposit, designated unit Qg4m. Clam shells of marine origin have been noted in some wells that penetrated Qg4m. The unit, which may be up to 100 feet thick, has an unknown but probably limited extent. The unit is generally located in the central portion of the County from Bangor to Bainbridge Island.

Unit Qn4 is a nonglacial deposit of the fourth interglacial episode. This fine grained deposit, up to 200 feet thick, is laterally extensive and is found throughout the central and southern Lowland. It is probably correlative to the Clover Park Formation (Noble, 1990) of the southern Puget Sound area. Because of its fine grained nature, unit Qn4 is generally an aquitard which restricts flow between the Qg4 and Qg3 aquifers. Qn4 does not yield substantial amounts of ground water.

Unit Qg3 represents the deposits of the third oldest glacial episode. This unit generally consists of sand, sand and gravel, and till. The unit is found between 200 feet above or below sea level and is up to 200 feet thick. This extensive unit is an extremely important aquifer for the County. A large percentage of the wells in the County are completed in this unit. The unit is tentatively correlated with the Double Bluff Drift (Easterbrook, 1968) to the north.

Unit Qn3 is an interglacial deposit of fine grained material (clay, silt, sand and sometimes peat) and generally acts as an aquitard. The unit is intermittently present throughout the County. Wells are very rarely completed in this unit, and the few that are have low yields. The unit is up to 300 feet thick. This unit can likely be correlated in the southern part of the County with the Kitsap Formation (Garling and others, 1965) and the Whidbey Formation (Easterbrook, 1968) to the north.

Unit Qg2, sometimes referred to as the mid-cliff drift, has sporadic deposits throughout the County. The formation is generally poorly sorted and contains sand, gravel silt, and clay. It is generally found from +100 to +300 feet MSL and is up to 150 feet thick. This unit is not very extensive and only a relatively small amount of wells are completed in this unit. This elusive formation is likely correlative with the Possession Drift of Easterbrook and others (1967).

Unit Qn2 is a fine grained, interglacial deposit up to 150 feet thick. The unit is generally an aquitard with very few wells completed in it. The unit is probably correlative with the unnamed sediments below the Lawton clay of Mullineaux (1965) which have been designated as the Discovery Formation by Noble (1990).

Unit Qgla was deposited by meltwaters from the advancing glaciers during the last (Vashon) glacial episode. This thick extensive unit of sand and sand with gravel is up to 250 feet thick. Numerous wells, both public and domestic, are completed in this productive aquifer. This unit can be correlated with confidence to the Colvos and Esperance sands.

Unit Qgl is Vashon glacial drift. This unit was deposited as a veneer of till over the entire County as the ice flowed south. Qgl yields minor amounts of ground water in perched aquifer systems. This unit covers the largest amount of surface area of all geologic units in the County. When present, its thickness varies dramatically up to 200 feet.

The Vashon recessional deposits have been included in unit Qgl. These deposits are usually less than 50 feet in thickness and often much thinner. Some shallow domestic wells are completed in this localized unit in a few areas in the County.

All deposits younger than the Vashon glaciation are also grouped into unit Qnl. These consist of peat and recent alluvium, both of which are generally thin. The recent alluvium can be a source of ground water in some valley floors, particularly if in hydraulic continuity with surface water.

5.3 Principal Aquifers

Within the County, the more permeable zones that are aquifers are separated by finer grained, less permeable layers called aquitards, which generally conduct ground water, albeit at a significantly slower rate. Since the key phrase in defining an aquifer-- “to yield economically significant quantities” -- is highly qualitative, the explicit identification of aquifers is difficult. For example, a water bearing zone that produces several gallons per minute for a domestic well would hardly be considered an aquifer for a city that requires several hundred gallons per minute.

Principal aquifers throughout the County were initially defined and identified in the Kitsap County Ground Water Management Plan (GWMP); Volumes I and II (EES, et al., 1991). An aquifer is defined as “a geologic unit which contains sufficient saturated, permeable material to conduct ground water and to yield economically significant quantities of water to wells and springs” (Glossary of Geology, 1977). These principal aquifers were determined by the following characteristics: several proven, major water supply wells or springs, primarily drilled by the large purveyors; sufficient test data to evaluate aquifer characteristics; and sufficient correlation of geologic characteristics to justify the assumption of continuity between wells. The definition of aquifer boundaries was accomplished by interpretation of the geologic data available for wells in proximity to the major production areas. In those instances where the presence or absence of the aquifer can be confidently identified, the boundary is represented by a solid line. Where insufficient data exist to accurately define the boundary, an interpretation was made and the boundary represented by a dashed line. As can be seen in **Exhibit 5-2**, in many cases aquifers are bounded by dashed lines. In several locations, the principal aquifer area comprises two or more vertically separated aquifers. For example, the Kingston Aquifer System is actually comprised of at least three primary production zones in hydrostratigraphic layers Qg3, Qg4, and Qg5 (as discussed in Section 5.2). This listing by no means implies a complete identification of all aquifers within the County.

In 1991, the Kitsap County GWMP (Volume I) identified 27 principal aquifers. The identified aquifers ranged from near-surface units at elevations as high as +300 feet MSL to aquifers identified at elevations below -900 feet MSL and are comprised of pre-Vashon geologic units. Since these units were defined in 1989, several of them have been subject to more intensive hydrogeologic study to better define their characteristics as well as their vertical and lateral extent. Additionally, new aquifer systems have been identified through ground water exploration programs. At the present time, 28 principal aquifers are identified and their location is shown on **Exhibit 5-2**, with general information provided in **Exhibit 5-3**.

It should be noted that it is unlikely that all the aquifers in the County have been identified. Even with an improved definition of the principal aquifers the level of understanding varies considerably between aquifers. Many of the areas in the County lack enough information to make principal aquifer distinction. Also, in all subareas of the County, many aquifer zones are known to exist but are not designated as principal aquifers. Perched aquifers are saturated zones with an impermeable bottom that are underlain by additional permeable, unsaturated materials. Perched aquifers are capable of producing water to wells, although some are quite large (encompassing several square miles), they are generally localized and are laterally discontinuous on a County and subarea scale.

The description of each principal aquifer which follows are excerpted from the GWMP Volume I), 1991. The descriptions include some new information where available. The reader should refer to the cited references if more details on specific aquifers is desired. Most of the references will include some level of aquifer characterization data, such as aquifer head, transmissivity, and storage coefficient. **Exhibits 5-19 to 5-25** provide generalized geologic cross sections which show the stratigraphic relationship between the hydrostratigraphic units (discussed in Section 5.2) and the principal aquifers that are discussed below. For greater cross-section detail and discussion refer to the GWMP. Location of the cross sections are shown on **Exhibit 5-2**.

Hansville Aquifer

The Hansville Aquifer was evaluated in 1990 (Robinson & Noble, January 1990) for the Hansville Water District (now part of KPUD's North Peninsula Water System). The study assessed hydrology of the area, the vulnerability of the aquifer to future land uses, and alternatives for future ground water development. Two principal aquifers were actually identified. A perched aquifer, the Hansville Aquifer, supplied water to the spring collectors of the old Hansville Water District system. The Hansville Aquifer occurs above +200 feet MSL, within the Qgla hydrostratigraphic unit, and the unit is exposed at the surface in some areas (GWMP, Vol. I & II). A Sea Level Aquifer was also identified that occurs from +50 to -100 feet MSL in the Qg3 unit. Water quality of the Sea Level Aquifer is typically poor in that area (Fe/Mn/Cl).

Kingston Aquifer System

The Kingston Aquifer System is characterized by complicated geology and is actually comprised of three or more aquifers (Robinson and Noble, Oct. 1988, personal communication, M. Sebren, KPUD). The shallow aquifer (Qg3) generally occurs -25 to -150 feet MSL and tends to occur in the northern portion of the area. The middle aquifer (Qg4) occurs between -240 and -300. The deep aquifer (Qg5) generally occurs between -600 to -725 MSL and is only well documented in the southern portion of the area. More information is needed to determine the level of continuity(if any) between the two deeper aquifers as well as the characteristics of the leaky aquitard separating them. The aquifer boundaries are reasonably well known to the west. The north and south boundaries are less certain but may extend further in both directions.

Port Gamble South Aquifer

Port Gamble South Aquifer is composed primarily of sand that occurs from approximately -50 to -175 feet MSL in the Qg2 hydrostratigraphic unit and produces moderate amounts of water. The aquifer likely does not extend much further southeast than is indicated on **Exhibit 5-2**. The other boundaries of the aquifer are less certain but apparently overlap with those of the Port Gamble Aquifer to the west and northwest. The elevation (production zone) of the aquifer has similarities with the Port Gamble Aquifer. Further study of the two aquifers was undertaken by KPUD in early 1996 (in progress). (**Exhibit 5-19** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Port Gamble Aquifer

Drilling and testing of wells (PUD 1993, 1994) immediately west of Port Gamble Bay helped to document the presence of the Port Gamble Aquifer. The aquifer is defined as a substantial sand aquifer which extends from approximately +100 feet to below -220 feet MSL and is interpreted to be located in the Qg1a hydrostratigraphic unit. Test pumping demonstrated well capacities in excess of 1 million gallons per day (Robinson & Noble, March, 1994).

Previous investigation on the lateral extent of the unit was accomplished based upon the evaluation of local domestic and public well logs surrounding the area (AGI, 1989; Robinson & Noble, 1994). Subsequent study of the Port Gamble area by KPUD in 1996 in progress) has added some additional understanding. The north, west and east boundaries of the aquifer have been reasonably well defined as shown on **Exhibit 5-2**. Significant changes in these boundaries are not anticipated. The southern portion of the east boundary, and the southern boundary of this aquifer require additional study and these portions of the aquifer boundary could change significantly as better data are obtained. The Port Gamble and Port Gamble South Aquifers have similar elevations (production zones) and overlapping boundaries at the south end of Gamble Bay. Further evaluation is required to determine the relationships between the aquifers.

Edgewater Aquifer

This sand and gravel aquifer occurs from approximately +130 feet to -170 feet MSL in unit Qg3 and has pockets of very high productivity (Robinson and Noble, November 1987). The boundaries of the aquifer are poorly defined, but the formation may be hydrostratigraphically related to the Bangor Aquifer System located to the southwest. (**Exhibit 5-19** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Suquamish - Miller Bay Aquifer System

This aquifer system contains several potentially high-yield zones at various depths. The aquifer is contained within the Qg3 unit and is located from sea level to -300 feet MSL. The aquifer thickness and productivity are highly variable. The lateral extent is reasonably well defined to the east and west but less clear on the north and south. (**Exhibit 5-20** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.) Hydrogeologic characterization information is contained in the GWMP, 1991 and miscellaneous consultant reports (Robinson & Noble, AGI).

Poulsbo Aquifer

The characteristics of the Poulsbo Aquifer were refined in 1992 as part of the investigation of the potential for impacts on Dogfish Creek associated with pumping of the City of Poulsbo's Pugh Road Well (Robinson and Noble, November 1992). Based upon an evaluation of local domestic and public well log data, the Poulsbo Aquifer was found to occur from +225 to +50 feet MSL in the Qg3 unit. The aquifer has an areal extent of approximately 5 square miles. This study also concluded that the Poulsbo Aquifer has a relatively low continuity with Dogfish Creek because of the occurrence of a significant aquitard between the two. (**Exhibit 5-20** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Bangor Aquifer System

Hydrogeologic analysis and a three-dimensional, numerical ground water model have been completed for the Bangor Aquifer System through studies commissioned by KPUD (Robinson & Noble; Becker, 1995). The aquifer system consists of three interrelated aquifers labeled in previous works as: the semi-perched, the sea level, and the deep. The upper two aquifers exist in a channel deposit that extends across the Bangor Naval Submarine Base. The channel is interpreted to be part of the Qn3 and Qg3 units. The deep aquifer generally occurs in the Qg4 unit. The aquifer system occurs from approximately +100 to -300 feet MSL. (**Exhibit 5-20** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Keyport Aquifer

The Keyport Aquifer occupies a small area centered on the Naval Undersea Center. The aquifer consists primarily of sand and gravel and occurs between -675 and -800 feet MSL in units Qg5 and Qn6. There are only several deep wells that define the aquifer and therefore, the lateral extent of the aquifer is not well defined. However, water level and production information indicate that the areal extent of the aquifer may be significantly larger than that shown on **Exhibit 5-2**. **Exhibit 5-21** shows a generalized hydrogeologic cross section through the vicinity of the aquifer. Hydrogeologic characterization information is contained in the GWMP, 1991 and miscellaneous consultant reports.

Island Lake Aquifer

In 1990, the Island Lake Aquifer was reevaluated as part of a study for Silverdale Water District (Robinson and Noble, Jan. 1991). The study was initiated to evaluate whether water level declines in Island Lake were related to pumping from Silverdale's nearby Island Lake Well. The local surficial and subsurface geology was studied, and a geologic model, which demonstrated a partial connection (separated by a leaky confining layer) between the lake and the aquifer, was proposed. As a result of this study, the Island Lake Aquifer was found to occur from approximately +150 feet MSL to sea level in geologic units Qg2 and Qg3. The lateral extent of the aquifer, as seen on **Exhibit 5-2**, is approximately 3 square miles. The Department of Ecology (Ecology), being concerned about declining water levels, has halted further water development from this system. (**Exhibit 5-21** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Meadowmeer Aquifer

As part of an aquifer definition and protection study in 1990, the Meadowmeer Aquifer was better defined (Purdy, Nov. 1990). The aquifer occurs from +125 to +70 feet MSL in the geologic unit designated Qg2. The northern and southern limits of the aquifer are dictated by topography and are drawn along the 70-foot elevation contour. The remaining boundaries are drawn based upon well log information. The recharge area for the Meadowmeer Aquifer has been estimated to be about 2.5 square miles.

Wardwell Aquifer System

The Wardwell Aquifer System contains two zones with differing heads (Robinson and Noble, Aug. 1988). The shallow zone is located between -75 and -175 feet MSL in unit Qg3. The deep zone is located between -650 to -975 feet MSL in unit Qg5. More information is needed to determine the level of continuity between the two zones as well as the characteristics of the leaky aquitard which separates the zones. The lateral extent of both zones is poorly understood except for the southwest portion of the deep zone. **Exhibit 5-25** shows a generalized hydrogeologic cross section through the vicinity of the aquifer system.)

Gilberton - Fletcher Bay Aquifer System

The hydrogeology of the Gilberton-Fletcher Bay Aquifer System is relatively complex, consisting of two aquifer zones (Robinson and Noble, 1978). The shallow zone, which lies between -300 and -650 feet MSL, occurs mostly in unit Qg4. It is found on both Bainbridge Island and the Manette peninsula. The deep zone, which lies between -850 and -900 feet MSL, occurs in unit Qg5. The deep aquifer zone is found only on Bainbridge Island. Our understanding of the areal extent of the aquifers is improving. Wellhead protection and related studies for the North Perry Avenue Water District and Bremerton Water Utilities (AGI, October 1996, November 1996) have further refined the Gilberton-Fletcher Bay Aquifer System. Those studies did not address the Fletcher Bay portion of the system, they have subdivided the Gilberton Aquifer System into two irregularly-shaped aquifers called Meadowdale and Parkwood East. The Meadowdale Aquifer is located from -150 to -450 feet MSL with transmissivity that ranges between 5,000 and 39,000 gpd/ft. The Parkwood East Aquifer is encountered from -450 to -650 feet MSL and has transmissivity that ranges from 1,200 to 36,000 gpd/ft. The Parkwood East Aquifer includes the GWMP 1991 Bucklin Hill Aquifer. Modifications to the principal aquifer map **(Exhibit 5-2)** have not been made at this time but should be considered in the future to reflect new aquifer interpretations. (**Exhibit 5-25** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Bucklin Hill Aquifer

This deep aquifer is located between -400 to -700 feet MSL and occurs within unit Qg5. Additionally, the aquifer appears to occur beneath the shallower Silverdale Aquifer in some areas. Recent study of the aquifer for the North Perry Avenue Water District and Bremerton Water Utilities (AGI, October 1996, November 1996) have referred it as the Parkwood East Aquifer. Those studies suggest that the aquifer is irregularly-shaped and has greater areal extent than the GWMP 1991 definition of the Bucklin Hill Aquifer. The Parkwood East Aquifer extends further west toward Port Orchard Bay than did the original Bucklin Hill Aquifer. The Parkwood East Aquifer is encountered from -450 to -650 feet MSL and has transmissivity that ranges from 1,200 to 36,000 gpd/ft (AGI, November 1996) (GWMP, 1991). (**Exhibit 5-22** shows a generalized hydrogeologic cross section through the vicinity of the aquifer.)

Silverdale Aquifer

This aquifer, located at the head of Dyes Inlet, is moderately productive and occurs between sea level and -250 feet MSL in unit Qg4. The southwest edge of the aquifer is the only well-defined boundary.

Seabeck Aquifer System

The Seabeck Aquifer System, formerly named the Big Beef Aquifer, has been more fully characterized as a result of further test well drilling and development of a Seabeck Aquifer Protection Plan. The aquifer occurs from +100 feet above to -250 feet MSL, mostly in the Qg3 unit. Detailed study has defined the hydraulic gradient and probable recharge area for this aquifer system (Purdy, 1995). Estimates have been made of ground water infiltration based upon an analytical computer model of the aquifer system calibrated to the observed water level information from the aquifer. The recharge area of the Seabeck Aquifer System is approximately 20 square miles. (**Exhibit 5-22** shows a generalized hydrogeologic cross section through the vicinity of the aquifer system.)

Bayhead Aquifer

The Bayhead Aquifer is found at the head of Eagle Harbor on Bainbridge Island. This sand and gravel aquifer occurs from sea level to -150 feet MSL in unit Qg3. The aquifer boundaries are well defined on the north and east but poorly defined to the west and south. Hydrogeologic characterization information is contained in consultant reports (Robinson & Noble).

Eagle Harbor Aquifer

This aquifer, formerly named the Creosote Aquifer, occurs between -600 and -800 feet below sea level in units Qg4 and Qn5. The lateral extent of this deep aquifer is poorly defined, except for the southern edge which is controlled by consolidated bedrock. Hydrogeologic characterization information is contained in consultant reports (Robinson & Noble).

Lynwood Center Aquifer

This sand and gravel aquifer system occurs from approximately -25 to -125 feet MSL within unit Qg3. The wells in this unit produce moderate amounts of water. The lateral extent of the Lynwood Center Aquifer is poorly defined. Hydrogeologic characterization information is contained in consultant reports (Robinson & Noble).

Manette-North Bremerton Aquifer

This aquifer is located in the Qg3 unit and occurs between sea level and -250 feet MSL. This aquifer has a substantial lateral extent, however, the boundaries are poorly defined. Study of aquifers in the area for the North Perry Avenue Water District and Bremerton Water Utilities (AGI, October 1996, November 1996,) have referred to a portion of the Manette-North Bremerton Aquifer as the Sea Level Aquifer. The Sea Level Aquifer occurs from 50 to -150 feet MSL, is discontinuous and has transmissivity ranges from 3,100 to 23,000 gpd/ft.

Clam Bay Aquifer

This rather small, silty sand and gravel aquifer is located at the head of Clam Bay in the Manchester area and is situated in unit Qg3 from a depth of sea level to -150 feet MSL. The lateral extent of this aquifer is limited by the occurrence of surrounding bedrock.

Hydrogeologic characterization information is contained in consultant reports (Robinson & Noble).

Port Orchard Deep Aquifer System

This deep, sand and gravel aquifer system is found between -650 to -1,100 feet MSL in the Qg5 unit (GWMP, 1991). Due to the depth of the unit, the lateral extent of the aquifer is poorly understood. Recent work in the Annapolis area distinguishes upper and lower portions of this aquifer which are separated by a leaky aquitard (AGI, 1994).

Yukon Aquifer

This small aquifer, located in the Manchester area, consists of a sand and gravel zone between sea level and -150 feet MSL in unit Qg3 (GWMP, 1991). The northern boundary of the aquifer is moderately well defined, but the lateral extent in other areas is poorly understood.

Anderson Creek Aquifer System

The Anderson Creek Aquifer System was previously defined as a portion of the North Lake - Bremerton South Aquifer (GWMP, 1991). It now refers only to the deep aquifer defined entirely by the City of Bremerton wells in their Anderson Creek wellfield. The aquifer is located between -450 and -525 feet MSL within unit Qg5. In recent studies by Bremerton Water Utilities (AGI, November 1996) the Anderson Creek Aquifer System is referred to as the deep artesian aquifer. The aquifer may have a large areal extent to the south and has tentatively been correlated with deep wells in the Port Orchard area. Those studies also define a sea level aquifer from 100 to -250 feet MSL in unit Qg3, a Shallow Artesian Aquifer from -100 to -250 feet MSL in unit Qg4 and a Lower deep Artesian Aquifer below -650 feet MSL in previously unidentified unit Qg6.

Gorst Aquifer System

Considerable new work has been completed in the Gorst subarea on the Gorst Aquifer System (GWMP, 1991)by Bremerton Water Utilities (KPUD sponsored study by AGI, October 1996, November 1996) including new evaluation of hydrology and hydrogeology of the basin.

Four ‘effective’ aquifers were identified in the area that was previously identified and is generally shown by the Gorst principal aquifer (GWMP, 1991). These aquifers are encountered from about 250 to -100 feet MSL and are called the Upland Aquifer, the Twin Lakes Aquifer, the Gorst Creek Valley Aquifer and the Sea Level Aquifer. All of these aquifers, except for the Upland Aquifer, are defined as being within the Gorst Aquifer System. The Upland Aquifer underlies that Sunnyslope Uplands to the south. The area is complex and includes glacial and inter-glacial hydrostratigraphic units Qg1a through Qg4.

Salmonberry Aquifer

This sand and gravel aquifer is encountered in the Qg4 unit between -150 and -250 feet MSL. The lateral extent of this aquifer is poorly defined. Recent work has suggested that this aquifer is the middle zone of an aquifer system with three lithologically similar water bearing zones (AGI, 1994). This aquifer has been tentatively correlated with portions of the Anderson Creek Aquifer System (AGI, October 1996).

Wilson Creek Aquifer

This small, shallow sand and gravel aquifer occurs within unit Qg2 at an elevation between +150 to +50 feet MSL. The aquifer is primarily defined by Manchester Water District wells and the areal extent of the aquifer is poorly understood. Hydrogeologic characterization information is contained in GWMP, 1991, and consultant reports (Robinson & Noble).

North Lake Aquifer

The North Lake Aquifer boundaries were refined as part of preliminary hydrogeologic study of the area (Purdy, personal communication). The aquifer exists within the Qg1a and Qg2 units between +300 and +150 feet MSL. The lateral extent of the aquifer is based primarily upon the wells utilized by the McCormick Woods area developments and other private domestic wells. This aquifer is referred to as the Upland Aquifer in recent studies by Bremerton Water Utilities (AGI, October 1996).

5.4 Ground Water Flow System

Ground water flow within the County is controlled by a large number of factors including water level elevation, topography, geology, soil properties, recharge rates, and recharge/discharge features. Ground water systems are usually composed of several types of flow cells. Localized flow cells often exist in shallow ground water zones where the distance between recharge and discharge areas may be on the order of a mile or less. Larger regional flow cells occur within the deeper ground water zones where the distance between the recharge and discharge areas may be miles to tens of miles.

Topography and geology can have profound effects on water levels and ground water movement. Where local relief is negligible and soil properties are uniform, regional flow systems will predominate. On the other hand, where there is significant local relief and complex geology, such as layering of high and low permeability material, then primarily local flow systems will develop in the shallow ground water zones. Geologic heterogeneity can affect the interrelationship between local and regional flow cells, the surficial pattern of recharge and discharge areas, and the quantities of flow that are discharged through the system.

Ground water movement within the flow system is three dimensional in nature. Regional ground water flow systems with significant layering of hydrostratigraphic units show predominantly horizontal flow within aquifers and vertical flow across aquitards. Ground water flow occurs from areas of high hydraulic head (or water level) to areas of low hydraulic head. **Exhibit 5-1a** generally depicts these flow relations between aquifers and aquitards. Water-level maps typically present equipotential lines, contour lines which define where hydraulic head is equal. Flowlines define the direction of ground water movement within the system and are oriented perpendicular to the ground water elevation contours.

Exhibit 5-4 shows ground water elevation contours and flow direction in the shallow aquifer systems. The shallow aquifer systems are comprised of Vashon glacial drift (Qgl) and Vashon advance deposits (Qgla), which include Vashon advance outwash (Colvos sand and Esperance sand). Approximately 25 percent of Kitsap County residents are served by domestic wells. The vast majority of these wells are screened in shallow aquifer systems. Vertical ground water flow between shallow and deeper aquifers is generally downward in recharge areas and upward in discharge areas. Sufficient data was not available to assess the flow within deeper water bearing zones over the majority of the county. Detailed reports specific to particular subareas, however, have been conducted and much work is in progress. The subareas with completed studies include Bangor, Seabeck, and Manchester (Becker, 1995a, b; Purdy, 1995b; AGI, 1994), and subareas with in-progress studies include Port Gamble, Gorst, and Manette. These studies contain potentiometric surface and ground water flow maps for sea level and deeper aquifers. In general, the ground water flow is from the center of the peninsula toward the shoreline.

5.5 Ground Water Recharge

Ground water recharge occurs when water infiltrated into the soil passes through the root zone and migrates downward to a local or regional water table. Rates of recharge are dependent on a variety of factors, including: soil infiltration potential, incident precipitation, and features of the land surface such as vegetation and slope. Physiography and subsurface conditions control whether recharge at the land surface (areal recharge) continues downward to deeper aquifers or discharges to local surface water bodies. The following sections describe the processes of soil infiltration, areal recharge, and deep recharge as they occur in Kitsap County. The distribution of soil infiltration potential is described qualitatively, wheras areal recharge is quantitatively estimated on a sub-area basis. Finally, approaches to evaluating recharge to deep regional aquifers are discussed.

5.5.1 Soil Infiltration Potential

Infiltration potential is a measure of a soils capacity to transmit water. The infiltration potential of surficial soils on the Kitsap Peninsula has been assessed based on soil properties identified in a soil survey by the USDA (1980). The USDA soil survey identified sixty three different “soil map units” based on grain size, typical soil profile, and surface slope. These units were further divided into four “hydrologic soil groups” to distinguish the runoff and infiltration properties of County soils. The “hydrologic soil groups” are based on field classification and laboratory testing of soils, and are described below:

Group A soils have a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B soils have a moderate infiltration capacity when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained to well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C soils have a slow infiltration rate when thoroughly wet. These consist of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D soils have a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Exhibit 5-5 presents a location map of soils identified as having high to moderate infiltration potentials (Groups A and B). In Kitsap County, Group A soils are much more common than Group B soils, and are particularly prevalent in the northern County above Suquamish. Group A soils typically occur where advance and recessional glacial outwash is exposed at the land surface. Where Vashon till is largely absent (e.g., north of Suquamish), Vashon advance outwash deposits are exposed. Vashon recessional outwash deposits are exposed in areas such as the valleys of Gorst Creek and north of Lynwood Center on Bainbridge Island. Group B soils are identified in the vicinities of the Green-Gold Mountains, East Bremerton and Big Valley (north of Poulsbo).

The USDA did not attempt to quantify actual rates of water transmission associated with hydrologic soil groups. Soil groupings are relative, and thus reflect relative rates of soil water transmission. Although transmissive soils (Groups A and B) will infiltrate water more quickly than less transmissive soils (Groups C and D), the total volume infiltrated to a particular soil unit may ultimately be controlled by water loading rates. Where incident precipitation is considerably less than the infiltration capacity of local soils, actual infiltration volumes may be rainfall controlled.

Infiltration rate can be related to ground water vulnerability from surface contamination. Where subsurface conditions allow rapid, unimpeded infiltration from the root zone to the water table, spills and leaks on the land surface can be transported to the water table relatively quickly. Greatest concern is warranted where rapid infiltration occurs to a regional water table.

5.5.2 Areal Ground Water Recharge

Areal ground water recharge occurs via downwards transmission of water infiltrated at the land surface. In this assessment, areal recharge is defined as all water which passes beyond the root zone. Rates of areal recharge vary depending on incident precipitation, the infiltration potential of surficial soils, evapotranspiration from plant cover, and subsurface soil properties. Long term average precipitation varies from about 26 to 68 inches/year across the County (Section 3). Infiltration potential varies across the County because surficial soils are derived from low permeability till, relatively high permeability outwash, and other original materials. Water not infiltrated to soils will occur as surface runoff. Evapotranspiration depends on plant type, water storage capacity in the root zone, and the timing of precipitation and temperatures. Finally, subsurface soils may restrict or facilitate the downward flow of soil water depending on their permeability and saturation.

Areal recharge can be limited either by soil properties or by available infiltration (water not taken up by evapotranspiration). In the first case, a low-permeability soil layer located at or beneath the land surface can restrict recharge to underlying aquifers. For example, a shallow till layer may restrict downward flow of recharge even though the soil horizon above the till can accommodate all infiltration passing through the root zone. In this case, locally perched conditions occur above the till. A portion of the ground water passes vertically through the till, while the remainder flows above the till surface (as shallow interflow) towards streams and lowlands.

Where areal recharge is limited by available infiltration, precipitation rates are insufficient to approach the infiltration capacity of the soils above the water table. Some areas of the County have surficial and subsurface soils which can accommodate greater fluxes than the precipitation entering the root zone. Additionally, a portion of this precipitation is removed from the root zone by evapotranspiration, further reducing the water available to areal recharge.

Rates of areal recharge are typically estimated using a soil-moisture balance. In this approach, areal recharge is equivalent to precipitation minus water “lost” to runoff and evapotranspiration. Typically, only a portion of areal recharge is available for ground water development. Areal recharge which becomes shallow interflow may never reach underlying aquifers, ultimately discharging to springs and surface water features. Areal recharge which reaches uppermost aquifers may follow shallow flow paths to discharge to streams, wetlands, lakes and springs, or deeper flow paths to discharge to marine waters. Evaluation of proposed ground water development must consider the impact on stream baseflows, wetlands and the potential for seawater intrusion.

A soil-moisture balance was used to estimate areal recharge for each sub-area in the County. Estimated rates range from 10 to 34 in/yr, and are documented in **Exhibit 5-6 a and b**. The balance employs a computerized soil-moisture accounting procedure which calculates inflow from precipitation, outflow to evapotranspiration, change in storage, and outflow to areal recharge for the root zone over four time periods per month. During times when the moisture capacity of the root zone is full, the portion of precipitation entering the root zone not lost to evapotranspiration is attributed to areal recharge.

Climatic inputs (temperature and rainfall) are distributed evenly over four "weeks" of the month. Average monthly temperature was assumed equivalent to long-term averages from the Bremerton weather station. Monthly rainfall was estimated by multiplying average annual rainfall for each sub-area (see isohyetal map in Section 3) by a monthly weighting index based on long-term precipitation records from Bremerton. Approximately 20 percent of the precipitation input was assumed lost to storm runoff. This value is consistent with studies performed by the USGS in Kitsap and King Counties. Preliminary streamflow separation for catchments in the Bangor sub-area (Gamble and N. Fork Johnson creeks) showed that storm runoff represents between 17-23 percent of total precipitation (personal communication, Bill Bidlake, 1996). Studies conducted in South King County (Woodward et al, 1995), also suggested storm runoff values averaging around 20 percent of total precipitation.

Evapotranspiration (water evaporated by soil and transpired by plants) was estimated on a weekly basis using the Blaney-Criddle method (Dunne and Leopold, 1978). This method uses crop, latitude and temperature to calculate potential evapotranspiration. The weekly soil moisture balance was used to relate potential to actual evapotranspiration. In this balance, actual evapotranspiration equals potential as long as rainfall is sufficient to keep the soil moist enough to provide plants with sufficient water. When the soil is drier, the actual rate decreases below the potential rate. A linear function based on the ratio of actual water content to soil moisture holding capacity was used to relate actual to potential evapotranspiration. The relation (described below) is one of at least five methods reported in Dunne and Leopold (1978).

When precipitation is equal to or greater than potential evapotranspiration:

$$ET = PET$$

When precipitation is less than potential evapotranspiration:

$$ET = PET \quad \text{or,} \quad ET = PET * 1.333 * (SM/SMC)$$

$$(\text{if } SM/SMC \geq 0.75) \qquad (\text{if } SM/SMC < 0.75)$$

Where:

ET = Actual evapotranspiration (in/yr)

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

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

SMC = Soil moisture holding capacity (in)

The soil moisture holding capacity over the Kitsap Peninsula varies and has not been delineated per sub-area. ET was calculated for all 18 sub-areas using a holding capacity of six inches. This value represents a loam soil with rooting depths on the order of 3 feet. Representative "crop factors" for grass were used in the soil moisture budget. Although much of the peninsula is vegetated by coniferous trees, accurate crop factors for coniferous trees are not available for the Puget Lowland climate. Crop factors for grass are generally greater than for coniferous trees, and use of the grass crop factor may overestimate ET.

Resulting estimates of ET are presented in **Exhibit 5-6 a and b**, and vary from 14 to 19 in/yr on a sub-area basis. The accuracy of ET estimates is difficult to quantify. Sensitivity analyses were performed for both soil moisture holding capacity and runoff. Soil moisture holding capacity was varied from four to eight inches, and runoff was varied from 15 to 25 percent. The comparisons were made for two low-precipitation sub-areas (Hansville and Kingston) and two high-precipitation sub-areas (Anderson and Dewatto). Higher holding capacities would allow for more ET, whereas higher runoff values would allow for less ET. In all cases, varying soil moisture holding capacity caused less than two inches change in estimated ET. Varying runoff caused less than 1.5 inches change in the low precipitation sub-areas and less than three inches change in the high precipitation sub-areas.

Estimates of ET have been made for selected portions of the Kitsap Peninsula using other approaches. The USGS calibrated their “Deep Percolation Model (DPM)” to rainfall and runoff conditions in several catchments within the Bangor sub-area. The DPM is a sophisticated approach which calculates both the transpirative and evaporative components of ET individually. Preliminary estimates of ET for the Johnson Creek and Gamble catchments averaged 22 in/yr (personal communication, Bidlake, 1996). This value, if assumed representative of the whole sub-area, is six in/yr higher than the value estimated with the soil moisture budget. The higher value may be due to the fact that evaporation from wet vegetative surfaces is higher than transpiration when the surfaces are dry. The USGS DPM estimates are currently under review, after which they will be issued in publication.

Assessments of PET in the Bangor and Seabeck sub-areas were performed by Robinson & Noble (Becker, 1995b and Purdy, 1995). R&N estimated PET using the method of Thornthwaite (Dunne and Leopold, 1978), and calculated values of 21 in/yr for both basins. The values of PET are larger than values of actual ET estimated with the Blaney-Criddle soil moisture budget (above). This is because PET is not reduced during periods when low soil moisture content limits plant uptake. R&N’s PET estimate for the Bangor area compares favorably to the USGS preliminary estimate, although the USGS estimate is higher for different reasons.

5.5.3 Deep Ground Water Recharge

Ground water availability in deep, regional aquifers is of major interest on the Kitsap Peninsula. Wells used for public supply and fish production typically withdraw water from deep regional aquifers. Deep aquifers are more likely to discharge to marine waters, and therefore less likely to show relatively high hydraulic continuity with rivers and streams. On the Kitsap Peninsula, where rivers typically show a net inflow from ground water discharge, deep recharge is likely limited to a small portion of areal recharge. The deep recharge passes from surficial aquifers downward through underlying aquitards. A higher proportion of areal recharge likely discharges to local springs and surface water bodies. The availability of ground water beneath the County is controlled by these recharge pathways and possibly, in the case of deep aquifers, by ground water subflow from distant recharge areas.

Recharge to deep aquifers is typically estimated using ground water flux analyses, computer modeling, or the water balance approach. In the water balance, deep recharge is considered to be the "unknown" term, and is calculated based on an accounting of other "known" (measured or estimated) components of the hydrologic cycle. The effectiveness of water balance analysis is limited where more than one term is unknown, or where compounded error associated with "known" terms overshadows the "unknown" term. Additionally, deep recharge estimates from the water balance do not differentiate how the recharge is distributed between (deep) aquifers.

Water balances are commonly based on the assumption of dynamic equilibrium - that is, over the long-term hydrologic systems are in steady state. In steady state, inflows are equivalent to outflows with negligible changes in system storage. The following water balance equation can be used to estimate deep recharge for sub-areas in Kitsap County:

$$P + S_{in} = SF + D + ET + W + G_m + S_{out} + MISC$$

Where: P = precipitation input to the sub-area

SF = total flow in sub-area streams (baseflow + storm runoff)

D = stream diversions

ET = evapotranspiration averaged over the sub-area

W = ground water withdrawals by wells

G_m = ground water discharging to marine waters (via deep recharge)

$S_{in,out}$ = ground water subflow entering, exiting the sub-area

MISC = miscellaneous outflows

The water balance assumes that ground water subflow across sub-area boundaries is negligible. This is consistent with the choice of sub-area boundaries, which follow surface-water and shallow ground-water divides. However, water-level data from deep aquifers are insufficient to confirm that sub-area boundaries conform to deep ground water divides. In some areas, subflow across sub-area boundaries may introduce inaccuracies to the water balance. The water balance also assumes that miscellaneous outflows such as coastal springflow and evaporation from seeps, riparian areas, lakes and wetlands are negligible.

The applicability of water balance analysis was severely limited for most (16 of 18) sub-areas by availability of streamflow data. Where streamflow data are lacking, the water balance equation includes two unknowns and cannot be solved for deep recharge. The term total streamflow (storm runoff + baseflow) eliminates the need to estimate ground water discharge to streams baseflow. However, in most sub-areas, available data were insufficient to provide representative values of total streamflow. Optimally, sub-areas would be equipped with stream gages which afford coverage of the majority of the subarea. In addition, data records should be long enough to provide a representative average over time. Although gages in these 16 sub-areas are generally located near the mouths of streams, sub-area coverage is typically inadequate to be considered representative (i.e. less than 50% of the drainage area). Additional analysis, such as hydrologic modeling, could be used to estimate streamflows on ungaged catchments and increase the applicability of water balance assessment. The USGS is currently applying such an approach in the Bangor sub-area (pers. comm., B. Bidlake, USGS).

Sufficient streamflow data were available in the Chico and Seabeck sub-areas, however application of the water balance showed that the potential errors currently associated with the “known” terms overshadowed the magnitude of the residual (deep recharge) term. Precipitation and streamflow data can be as accurate as ± five percent. Precipitation accuracy is reduced in the Chico sub-area, where undocumented orographic effects near the Green-Gold Mountains are likely significant. Streamflow accuracy may suffer where significant portions of the watershed are not gaged and hydrologic modeling has not been performed. A comparison of runoff efficiency (total annual streamflow divided by annual precipitation, in like units) for 13 streams is presented in **Exhibit 5-7**, and shows high variability with values ranging from 33 to 89 percent. Runoff efficiency values may be influenced by steepness of the catchment, soil permeability, variability in stream-aquifer continuity, and the occurrence of ground water subflow to/from external sub-areas. Where these factors are not accounted for, additional error in the total streamflow term may result. Gaged coverage is approximately 52 percent in the Seabeck sub-area, and 78 percent in the Chico sub-area.

Other potential sources of error are associated with estimation of evapotranspiration (described in the preceding section) and withdrawals/ diversions. Potential error associated with evapotranspiration estimates may be relatively high (± 30 percent). Well withdrawals and stream diversions are difficult to estimate. While these withdrawals appear to represent a relatively small portion of the overall water balance (based on water rights allocations in Section 4), potential error in the withdrawal estimates is relatively high. The fact that cumulative potential error surpassed the water balance residual (deep recharge) suggests that the water balance approach may be inherently limited in some sub-areas. Preliminary analysis suggests that under typical Puget Sound conditions and assuming most-accurate estimates, the water balance approach is viable only where runoff efficiency and evapotranspiration are sufficiently low that deep recharge is at least 30-40 percent of precipitation.

Water balance analyses have been performed by other researchers and consultants for areas on the Kitsap Peninsula.

Recharge to individual deep aquifers can be evaluated using estimates of flux between aquifers or within aquifers. Flux between aquifers is estimated based on vertical gradients between aquifers and estimates of aquitard permeability, whereas flux within aquifers is estimated based on horizontal gradients and aquifer permeability. The accuracy of permeability estimates is sometimes as low as ± one order of magnitude. Flux estimates vary proportionally, and therefore associated recharge ranges can be rather large. Use of flux estimation on the Kitsap Peninsula is also complicated by the fact that hydrogeologic data is typically insufficient to characterize conditions in deep aquifers/aquitards required for the analysis. This may, in part, be due to locally complex environments of deposition resulting in non-layered hydrostratigraphy. Flux estimates can be used in conjunction with water balances as a check on the water balance results and to differentiate recharge to successive layered aquifers.

Recharge to deep aquifers can be estimated by numerical modeling(an expensive process) for areas where sufficient hydrogeologic data are available to characterize the ground water flow system. Modeling allows direct evaluation of ground water availability, because impacts associated with pumping can be estimated. Data requirements for modeling include aquifer/aquitard occurrence and properties, water-level elevations, occurrence of surface water features (streams, lakes, wetlands, seawater bodies), and estimates of areal recharge. Numerical modeling can be used to evaluate stream/aquifer continuity, seawater intrusion, and general flow system response to pumping.

5.6 Ground Water - Surface Water Interaction

Hydraulic continuity refers to the interconnection between water bearing units, including ground water and surface water. An aquifer is typically in hydraulic continuity with lakes, streams, rivers, or other surface water bodies where saturation is continuous to the edge of these water bodies. Hydraulic continuity typically occurs where ground water discharges to surface water, such as in spring-fed lakes and gaining rivers (rivers that receive ground water); or where surface water discharges to ground water, such as from riverbed seepage to an adjacent alluvial aquifer. Where hydraulic continuity exists, changing hydraulic conditions in a ground water body will result in changes to connected surface water bodies. Pumping a well may result in reduced ground water discharge to adjacent surface water or increased seepage from surface water. Similarly, where hydraulic continuity exists, lowering the water level in a river or lake will result in decreased seepage to ground water or increased discharge from adjacent aquifers.

Determining or predicting cause-and-effect stream/aquifer relations can be simple or complex depending on hydrogeologic conditions. In the case of ground water withdrawals, potentially impacted surface water bodies must first be identified. Because shallow aquifers are generally dominated by local ground water flow systems, withdrawals from shallow wells are more likely to influence local surface water bodies. Most simplistically, a shallow well in an alluvial aquifer will likely affect flow in an adjacent river or stream. For the purpose of this report, this example shows a “relatively high degree” of hydraulic continuity. Deeper aquifers are more typically part of regional flow systems. The effects of pumping from a deep confined aquifer could therefore be manifested on distant river reaches, discharge rates to coastal seawater bodies typical of Kitsap County, or could be spread diffusely over a large area to affect numerous surface water bodies. For the purpose of this report, such a situation represents a “relatively low degree” of hydraulic continuity.

The timing and magnitude of stream/aquifer interactions depends on many factors, including: the distance between the well and the surface water body; the geometry and hydraulic properties of aquifers and aquitards between the well and the surface water body; patterns of ground water flow and recharge; and the hydraulic properties of riverbeds and lakebeds. Based on these factors, ground water withdrawals may affect surface water bodies almost instantaneously or may be delayed by months, years, or even decades.

Specific studies conducted in the Manchester, Seabeck and Bangor subareas (AGI, 1994; Purdy, 1995b; Becker, 1995a, b) investigated the ground water - surface water interaction. In the Annapolis area of the Manchester subarea, the perched aquifers (A1 and A2) discharge as baseflow to streams in the area. Aquifers near or below sea level (A3, A4, A5, and A6) appear to discharge to Sinclair Inlet or infiltrate downward. In the Seabeck subarea, the shallow, perched aquifers were found to directly contribute to the baseflow of the streams, whereas the deeper Seabeck Aquifer System does not. In the Bangor study it was found that the upper two aquifers (Perched and Semi-Perched) lose ground water to streams and lakes. The Sea Level and Deep Aquifers discharge largely to Hood Canal. Studies accomplished in the Gorst Subarea by the City of Bremerton (AGI, 1996) demonstrates that the Sunnyslope Upland Aquifer discharges to local streams and the Twin Lakes Aquifer. The Twin Lakes Aquifer partially discharges to Gorst Creek and the Union River. The Twin Lakes, Gorst Creek Valley, and Sea Level Aquifers are in communication with each other and Sinclair Inlet.

5.7 Seawater Intrusion

Seawater intrusion is the inland movement of marine water into an adjacent coastal aquifer. In aquifers that are hydraulically connected to the sea, the boundary between fresh ground water and seawater is marked by a transition zone referred to as the “zone of diffusion.” The position of this boundary largely depends on the properties of the aquifer and the amount of fresh ground water flushing through the system. The zone of diffusion extends to greater depths further inland, thus forming a characteristic “seawater wedge” within the aquifer. Freshwater overlies the (denser) seawater, and higher salinities occur with greater depth.

The position of the zone of diffusion depends on the dynamic balance between sea level and water levels in the aquifer. The rate of ground water flow is also controlled by water levels in the aquifer. The fact that the zone of diffusion is not a sharp interface, but is rather a mixing zone, is due to shifts in the equilibrium which result from diurnal variations in sea level (tides) and longer-term variations in ground water levels. The zone of diffusion can migrate inland when ground water levels reach a seasonal low, and recede seaward when ground water levels recover.

The dynamic balance between freshwater and seawater can be altered by human activities which influence ground water levels. Ground water levels are lowered by pumping and by land use practices which reduce recharge to underlying aquifers. Both of these activities intercept water which would naturally flow through the aquifer and contribute to freshwater flow "flushing out" seawater along the zone of diffusion. Lowered ground water levels will cause the seawater wedge to migrate landward, causing "lateral intrusion." If pumping (and localized aquifer drawdown) occurs directly above the zone of diffusion, deep seawater can be drawn upward towards the pumped well, a process called "upconing."

Seawater intrusion is indicated by increasing salinity in ground water. Monitoring for seawater intrusion often involves regular measurement of electrical conductivity or chloride concentration in wells. Although seawater intrusion is a reversible process, longer periods of time are typically required to flush saline water out of the system than for intrusion to occur. Reversal is especially slow where intrusion occurs on a regional scale. Prevention of seawater intrusion is by far the preferred option.

There is no evidence of extensive seawater intrusion in Kitsap County. Evidence for localized seawater intrusion is found in a few areas such as Jefferson Beach (Kingston subarea). Elevated chloride and electric conductivity, indicator parameters for seawater intrusion, occur in several coastal areas (Sections 5.10.1 and 5.10.2). Although relatively high, chloride and specific conductance in coastal areas are generally not high enough to suggest significant seawater intrusion. Analysis of chloride and electrical conductivity (as an indicator of sewater intrusion) is included in Section 5-10.

5.8 GWMP Ground Water Monitoring Network

The GWMP established an extensive network of monitoring sites throughout the County in 1990. The network which includes wells for monitoring water levels, water quality, and water use, will continue to be expanded and upgraded over time.

5.8.1 Water Levels

Approximately 100 wells were identified within the County for water level monitoring under the GWMP. The sites were selected to provide coverage within the principal aquifer systems as well as other areas where trend data was generally absent. Wells selected for the network are completed over a wide range of depths to assess trends in both shallow, intermediate, and deep ground water flow systems.

In addition to the wells used for water level monitoring by the GWMP program, other wells are being incorporated into the network on an on-going basis. Over 150 wells make up the current network that the PUD has access to. Water purveyors throughout the County are expanding their monitoring efforts to include wells that were not monitored in the past. It is hoped that these new wells and data can be coordinated into a better monitoring network for the future.

The GWMP established a protocol under which purveyors would voluntarily collect and distribute the computerized water level data to a KPUD data-base management system. The basic plan called for water levels to be measured on a monthly basis using electric well sounders. The responsibility for the success of the water level monitoring network was to be shared between local purveyors and KPUD personnel, though each water purveyor is primarily responsible for collecting data for their systems. KPUD collects water level data from wells that they operate as well as certain other public and private wells that are a part of the network. The monitoring network has been generally successful but has fallen short of its goals in certain areas of the county.

5.8.2 Water Quality

Water quality data provide a basis for understanding the natural variability of ground water quality, assessing land use impacts and health concerns, and evaluating trends associated with ground water development. Major anion/cation chemistry can be used to gain a better understanding of regional flow systems. Biological, inorganic, and organic parameters can be used to assess potential water quality problems associated with industrial, agricultural, and residential contaminant sources. Indicator parameters such as nitrate, chloride, and electrical conductance (EC) can be used to evaluate impacts associated with septic systems or seawater intrusion within coastal areas.

A considerable amount of water quality data has been developed for Kitsap County as part of special studies, compliance monitoring programs, building permit requirements, and other on-going efforts. A summary of some of the many water quality data sources is presented in Section 5.10.

Both spatial and temporal water quality data are needed to assess regional water quality conditions and changes in water quality over time. Water quality data collected as part of the Ground Water Management Program, KPUD's private well sampling program, and Bremerton Kitsap County Health Department (BKCHD) building permit requirements, provide valuable data for characterizing the spatial distribution of water quality. Washington Department of Health (WDOH) compliance monitoring requirements for water purveyors provide useful data for assessing temporal trends in water quality. In addition, on-going sampling of selected wells by KPUD provides useful time series data.

Future monitoring efforts will be directed towards expanding time series sampling in order to assess long-term trends in water quality. This will be particularly true in coastal areas where there is potential for seawater intrusion or in urbanizing areas where land use impacts are of concern.

5.8.3 Water Use

Water use data are of critical importance in evaluating water resource issues associated with potential overdraft of aquifer systems, seawater intrusion, sustainable ground water yield, and water balance relationships. Most water purveyors within the County collect water production data from metering systems that are installed at the wellhead or the surface source. The frequency of data collection and methods of reporting the data vary widely depending upon the individual requirements of the water system. The amount of water use by private domestic and group B water system wells is currently unknown because a standardized method of evaluation has not been established (most are restricted to 5000 gallons/day under the current water right permitting process).

Recognizing the need to facilitate and standardize the reporting of water use data, the Kitsap GWMP in 1990 developed a computerized software package for entering and managing data. The water use package was distributed to the purveyors along with PC computer systems and spreadsheet software. The computer package included options for data entry, reporting, plotting, and transfer. The original program has been modified considerably. Purveyors and others that collect water use data, as well as water level and quality data, have customized the format to meet their needs, which has required some modification in operating the central data bank. Although extensive, valuable data has been collected through this program, the lack of participation by some purveyors has been disappointing. The program will continue to be revised to encourage wider participation and more comprehensive analysis.

5.9 Water Level Trends

Water level monitoring provides a basis for evaluating impacts on the ground water system that may be associated with ground water development, land use changes, and precipitation patterns. Water levels are affected primarily by climatic trends and amount of ground water withdrawal. Climatic trends include changes in precipitation and drought periods, ground water withdrawal includes water pumped from public and *private* wells. Seasonal water level changes (months) and long-term water level changes (years to decades) are typically caused by these primary factors. The importance of water level trend data cannot be overemphasized. The data is required to understand the seasonal variations in aquifer levels, to evaluate the effects of pumping on aquifer levels, to identify areas where possible overdraft (mining) of an aquifer is occurring, and to assess areas where seawater intrusion or stream depletion may be of concern.

Seasonal and long-term trends in water levels are superimposed in all water level hydrographs. Fluctuation in water levels result from changes in rainfall, barometric pressure, marine tide, local pumping, and other factors that cause seasonal and long-term water level trends. The hydrograph shows the averaged effect of all such factors on the water levels in a well or aquifer with time. Amounts of water level fluctuation from strictly natural factors can vary from a few inches to ten or more feet from seasonal factors, and similar effect can be produced from drought or wet conditions that may occur over years or decades. Water level trends should be evaluated with climatic as well as manmade factors in mind. Parameters that effect seasonal and long-term trends in water levels are superimposed on water-level hydrographs to assist analysis

Water naturally discharges from aquifers at a rate which is controlled to a large extent by the amount of recharge. In a geological area like Kitsap County, some fresh water flows directly from aquifers to seawater. Aquifer mining and over-drafting are general terms used to denote the condition caused by extracting more water from an aquifer than is being recharged. Well pumping can cause aquifer levels to drop without causing mining to occur. A lowered aquifer water level reduces the differential pressure between the aquifer and Hood Canal or Puget Sound. The reduced differential pressure results in a decreased flow from the aquifer to seawater. When the reduced flow to sea balances the increased extraction through wells, the aquifer water level will stabilize at a new lower level. If extraction reaches too great a rate, a steady lowering of the aquifer water level will occur over time, causing over-drafting or mining.

Over-drafting ground water from the shallower aquifers can have an adverse impact on surface waters and wetlands. In an aquifer in continuity with a stream, a reduced differential hydraulic gradient may cause a decrease in flow from the aquifer to the stream or wetland.

To determine if mining is occurring, monitoring must be conducted over an extended period of time. The County has numerous shallow and deep aquifers, some of which may be connected vertically as well as horizontally. As a result, determining with accuracy the amount of water that can be safely withdrawn from an individual aquifer before over-drafting will occur is complex. Monitoring aquifer water levels is important to prevent over-drafting. Predicting the capacity of the County's aquifers is difficult and expensive using existing data and analysis capabilities. Changing factors, such as land use modifications which impact recharge rates, complicate the process. The current best means of detecting aquifer overdraft conditions are to record and analyze static water level over a period of time and to relate these trends to pumping and precipitation.

Data that was collected by the GWMP monitoring network and on file with KPUD as of January 1, 1997 was used to compile a set of 149 water-level hydrographs for this basin assessment. The data includes water level and production information collected by water purveyors such as Bremerton Water Utilities, City of Bainbridge Island, Silverdale Water District, and Kitsap PUD, just to name a few. The data also includes information from private groups and individuals.

Wells with hydrographs that are presented in this assessment are listed in **Exhibit 5-8**. The exhibit lists the wells sorted by subarea and includes the principal aquifer the well is completed in (if identified), the unique well identification number, well location, owner and well name, year drilled, the site elevation, and the well's completion elevation. Hydrographs for each well are presented in Appendix H. **Exhibit 5-9** shows the geographic distribution of the well and where the wells are located relative to principal aquifers and subareas.

Most of the hydrographs show water level elevation (in feet above mean sea level) versus time. About 30 hydrographs for Bremerton Water Utility and Silverdale Water District are in depth to water below measuring point versus time, instead of elevation, and are so noted in the remarks. The hydrographs typically show static (non-pumping) water level, but may also include pumping water levels (where noted). The water level and time scales for each hydrograph were selected to fit the specific data set for each well and therefor the scales may vary considerably from one hydrograph to the next. Most of the hydrographs were prepared by KPUD, though some are copied from other reports. Some of the hydrographs include a bar-graph of monthly total production data when the data was sufficient to warrant presentation. Note that gaps in a particular hydrograph's record may indicate that data was not collected for that time period, data was not reported to KPUD, well production was zero, KPUD has yet to process some of the data in its files, or a combination of factors.

The quality of available water-level and production data varies considerably. Few wells prior to 1985 have water level records that were accurately collected and recorded on a regular basis. Some examples of older wells with better-than-average water level records are AAA728, AAA111 and AAC759 (**Exhibit 5-8** and Appendix H page numbers 40, 61 and 70). For most of the well hydrographs, the historical data consist of a single static water level at the time of well construction, followed by occasional to monthly water levels that began in the 1990 time frame and continue to present. Therefore, water level data, was reviewed over two time periods: 1) for water year 1991 to 1996 and 2) over the entire period of record that includes all historical water-level records (i.e.: the earliest static water level and or the construction static water level). The trends were reviewed taking into account geographic location and completion elevation. An exhaustive review comparing in-well and regional production data, precipitation, and water levels has not been conducted. A more comprehensive review of individual wells is recommended when in-depth assessments are completed for specific subareas.

5.9.1 Apparent Change In Water Level Elevation For Water Year 1991 To 1996

Water years 1991 to 1996 are a period when more water level data from potable wells was collected for more wells throughout the county than at any other time in county history. This is a direct result of the GWMP which increased the awareness of the importance of water level trend data for the evaluation of water resources. Water level data from water years 1991 to 1996 and the associated water level trends can be compared for many parts of the county. The water year convention is used because it reasonably correlates with natural climatic variations of wet and dry seasons. Water year refers to the time period beginning on October 1st of a year and ending on September 30th of the following year (e.g., water year 1991 began on October 1, 1990 and ended on September 30, 1991).

Of the 149 hydrographs, 71 had records for water years 1991 through 1996. Apparent change in water level was determined for each hydrograph by selecting the highest level on record (rounded to the nearest foot) for both water years 1991 and 1996. These values are listed in **Exhibit 5-8** as apparent change in water level elevation from water year 1991 to 1996. The apparent change in water level elevation for the entire period of record is also listed.

It should be noted that in some cases it is likely that the data set for a well may not include the 'true' highest water level for the water year. The water level changes are called 'apparent' because of these types of uncertainties in the data set for each well. Also the error bounds for this discussion of apparent change in water level was assumed to be plus or minus one foot and therefor, a plus or minus one foot change is considered no change for the time period. Based on this interpretation, hydrographs of 33 out of 71 wells (46 percent) had little or no change in water level. Records for 19 wells (27 percent) showed declines of 2 to 10 feet, and 2 wells (3 percent) suggest declines of greater than 10 feet. Hydrographs of 15 wells (21 percent) indicate the water levels have risen from 2 to 10 feet, and 2 wells (3 percent) have risen greater than 10 feet. Putting it in slightly different terms, 30 percent of the records have shown declines while 70 percent have risen or stayed the same. The reader is encouraged to review individual hydrographs in Appendix H. Many of the hydrographs that lacked water year 1996 data, and are therefore are not figured into the percentages above, have trends that would likely have included them with hydrographs that have risen. It is anticipated that future data will show that a significantly greater percentage of wells will of have rises in water levels for water years 1991 to 1996 due to the winter of 1995 and 1996 that supplied substantial recharge compared to previous years. Effects on hydrographs by precipitation are discussed further in Section 5.9.3.

Exhibit 5-10 presents a scatter-plot of apparent change in water level versus the completion elevation for the 71 wells with water year 1991 to 1996 data (wells without known completion elevations are not shown). As previously discussed, wells showing higher water levels or lower water levels than in the past are found throughout the county and at a wide range of completion elevations. In general, of wells completed at or above sea level, about twice as many have risen more than 1 foot since 1991 than have declined by the same amount. Of the wells completed at or below sea level, about 40 percent have risen more than 1 foot and 60 percent have declined by the same amount since 1991.

To look at the change in water level versus completion elevation on a geographical basis, the data set for **Exhibit 5-10** was separated by subareas and is shown **in Exhibits 5-11A through 5-11O** (wells without known completion elevations are not shown). Individual well identification numbers are shown on the exhibits for cross-referencing with **Exhibit 5-8**.

Evaluating where and why water levels have risen is as important as where water levels have declined. Two wells completed below sea level in the Bangor subarea are the only ones which show notable (10 feet or greater) declines **(Exhibit 5-11D)** during water years 1991 to 1996.

An important aside to **Exhibits 5-11A-O** is the identification of subareas that may not be adequately monitored for water level data. Subareas that do not have hydrographs presented in this assessment are Hansville, and Stavis. The Manette, Union, Tahuya, Olalla, McCormick and Dewatto subareas have only one to several hydrographs. KPUD plans to add wells to the network in the Hansville subarea. The low population densities of the Union, Tahuya and Dewatto subareas will probably delay addition of monitoring wells in those areas. In the Manette subarea, Bremerton Water Utilities and North Perry Avenue Water District have conducted wellhead protection and related studies which include summaries of water level and related data. Data for the Manette subarea will probably be available in the near future (personal communication Doug Dow, AGI Technologies).

5.9.2 Apparent Changes In Water Level Elevation For All of Record

To evaluate the apparent changes in water level over the entire period of record requires that some assumptions be made that are not necessarily needed for review of water year 1991 to 1996 data. The primary assumption is that the original static water level of record was referenced to the same measuring point (MP) as the subsequent measurements. The subsequent measurements may be separated in time by a year or two or as much as several decades. For hydrographs in this basin assessment water level records from one well to the next vary over a considerable time span, ranging from 2 to 3 years of record to over 30 years of record. The standard MP is typically the top of the well casing. However, the MP may change several times, particularly for wells that are several decades old and may be quite different from the measuring point used with the current monitoring program. This uncertainty is not as great for wells in the GWMP network and for the records that began in 1990-1991. In addition, water level measurements collected at the time of construction are usually reported to the nearest foot (the nearest 0.1 foot is desirable), and are subject to error because of poorly calibrated equipment and collection practices. Despite these limitations, the following review of the trends was attempted if only to look for geographically specific areas where water level declines may be significant. See Appendix H for individual well hydrographs. For the entire water level record of the 149 hydrographs, the following are general observations of the apparent change in water levels. Hydrographs of 23 out of 149 wells (15 percent) had little or no change in water level. Records for 50 wells (34 percent) showed declines of 2 to 10 feet, and 30 wells (20 percent) suggest declines of greater than 10 feet. Hydrographs of 34 wells (23 percent) indicate the water levels have risen from 2 to 10 feet, and 12 wells (8 percent) have risen greater than 10 feet. Therefor about 46 percent of the hydrograph records show no apparent trend or a rising trend over their period of record and about 54 percent have shown a decline over their period of record. Scatter plots of the apparent changes in water level are shown on **Exhibit 5-10**, and are broken down by subarea on **Exhibits 5-11A to 5-11O**.

The Kingston, Poulsbo, Bangor, Bainbridge, Chico, and Manchester subareas have one or more hydrographs that suggest apparent declines in water level of 10 feet or more. These apparent declines involve aquifers above and below sea level. In the Kingston subarea wells with large declines are AAB406, AAA014 and AAA710. All three wells have completion elevations generally -100 to -300 feet MSL. Water levels have declined in these areas primarily in response to ground water withdrawl for potable supply and to a lesser extent for fish propagation. Currently all three hydrographs suggest that declines have moderated and a new equilibrium may have been established for the aquifers involved.

In the Poulsbo subarea, well AAB254 has declined according to records through 1994. The Bangor subarea has the most records for wells which show larger declines. The wells include AAA728, AAA730, AAA734, AAA746, AAA748, AAA749 AAC629 and AAA639. The wells range in elevation from 200 to -200 feet MSL. Most of the wells are associated with centers of ground water withdrawal except AAC629 and AAC639. As in the Kingston subarea, aquifers may have established new equilibrims, though mining is not ruled out as a factor.

The Bainbridge subarea has a good record set for one well (AAA111) completed below -800 MSL, where water levels have declined but apparently stabilized at their lower level. Wells AAA112, AAB455 and other deep wells on the island have apparent declines which need further review. In the Chico subarea well AAB476 shows a decline and it is not associated with nearby withdrawal.

In the Manchester subarea hydrographs AAA119, AAA118, and AAB486 (all with completion elevations near sealevel) have notable declines. Well AAA117, is completed below -1000 MSL and also has an apparently large decline.

5.9.3 Comparison With Precipitation Trends

To evaluate the degree to which the water level trends are related to climate, precipitation trends were compared with non-pumping water level trends. Three example hydrographs, **Exhibits 5-12, 5-13, and 5-14**, were developed to show relationships between precipitation and non-pumping water levels. The location of the wells can be seen on **Exhibit 5-9**. Precipitation was plotted using data taken from the NOAA station at the Bremerton Fire Station. Although precipitation gages exist nearer to two of the examined wells, the Bremerton data was presented for each well because over the period of record the precipitation data is more complete at Bremerton. It should be pointed out that the magnitude of precipitation is different at local gages that are relatively close to the wells (i.e.: 1991-1996 water year precipitation averages at Bremerton, Grovers Creek and Bloedel Reserve precipitation stations were 56.6, 39.4 and 37.7 inches per year respectively).

Precipitation was plotted three different ways: 1) as annual precipitation over a water year, 2) effective precipitation for a water year, and 3) monthly effective precipitation. Annual precipitation over a water year is the total precipitation recorded at the Bremerton Fire Station for the water year. The water year convention is used because it reasonably correlates with local natural climatic variations of wet and dry seasons. Water year refers to the time period beginning on October 1st of a year and ending on September 30th of the following year (e.g., water year 1991 began on October 1, 1990 and ended on September 30, 1991). The long-term average water year precipitation for the period 1952 to 1996 was 52.1 in/yr at the Bremerton Fire Station.

Effective precipitation as used herein is the total precipitation minus evapotranspiration. Effective precipitation is therefore the amount of rainfall that is potentially available to surface and ground water systems. The term total inflow is also used for effective precipitation. For this discussion, all rainfall from June to September is assumed to be lost to evapotranspiration. Thus, only a percentage of the precipitation during the “wet” season is included for effective precipitation. The depletion of soil moisture content, assumed in this analysis to be 5 inches, is factored into and shown graphically as a linear accumulative progression of 1 inch per month for each month from June to September (totaling 5 inches by the end of October). The first 5 inches of rainfall after October 1 are taken up as soil moisture recharge.

Production data is included in **Exhibits 5-12 and 5-14** for comparison with the water-level hydrographs and precipitation trends. The production data indicates that for each well the annual production rate has been fairly uniform over the period of record shown. On a month to month basis the production data shows the typical pattern of relatively low production in the winter months and higher production rates during summer months when there is greater demand due to irrigation.

Exhibit 5-12 presents data for KPUD’s Eldorado Hills Well 4 (AAB471) located in T25N/R1E-31B in the Chico subarea. The well is completed at an elevation of +301 to +311 feet MSL in an as yet unnamed perched aquifer. The water levels suggest a strong correlation with annual and effective precipitation. For Example, between 1992 and 1994, when rainfall was below normal, water levels declined approximately 6 feet. In 1995 during a period of above normal rainfall, water levels rose approximately 4 feet. During the period of record, in-well production has generally been increasing, yet water levels have risen in 1995.

Exhibit 5-13 shows data for Island Center Well (AAA110) located in T25N/R2E-21G in the Bainbridge Island subarea. The well is completed at an elevation of -83 to -98 feet MSL, possibly in the sea level zone of the Wardwell Aquifer System. The water levels suggest a strong correlation with seasonal precipitation variations with a several month time lag. The onset of effective precipitation each year is reflected in rises in water levels, and the declines in water levels correlate with the periods of no effective precipitation. This hydrograph illustrates the rapid response in water levels to precipitation trends typical for some aquifers in Kitsap County. The seasonal variations in water levels seen in this well could also be influenced by seasonal production trends. Since no production data is available for this well, the effect of pumping can not be evaluated.

Exhibit 5-14 shows data for KPUD’s Ritter Lane Well (AAA015) which is located in T27N/R2E-29J in the Port Gamble subarea. The well is completed at an elevation of -102 to -159 feet MSL in the Port Gamble South Aquifer. The water level data for this well shows a “noisy” record, probably because many of the static water levels are effected by recovery from recent well pumping. Despite the variable data, the overall water level trend suggests a general correlation with annual and effective precipitation. The rise from early 1990 to early 1991, and the subsequent overall downward pattern until a rise in 1995, are correlative to precipitation trends. The annual in-well production increased from 1990 to 1994, and since 1994 has remained fairly steady. Despite production variations, the water levels appear to respond to long-term precipitation trends and not pumping trends.

The reader is encouraged to look through other hydrographs in Appendix H for wells which have accompanying production data. As in the above examples, a significant number of hydrographs show water level trends which may be contrary to in-well production trends and can be intuitively correlated with wetter or dryer water years. Even without the benefit of comparing local precipitation data to water levels, an appreciation of the importance of precipitation to recharge can be seen.

5.10 Water Quality

Water quality concerns in Kitsap County were assessed by assembling five water quality databases into a single "study database," and evaluating the geographic occurrence of selected water quality parameters. The databases are individually associated with specific ground water sampling programs, and vary with regard to water quality parameters analyzed and the number of sampling events per well. The table below summarizes the databases compiled for this analysis. Most of the ground water analyses were based on a single sampling event. Time series analyses were not performed as part of this water quality assessment, although data series based on multiple sampling events have been evaluated in other reports. Discussions of existing time-series analyses are included in this section.

Data Source	Sampling Program	Number of Wells	Number of Samples	Analytical Parameters
Kitsap PUD	private well sampling program	~1,000	~1,000	conductivity, nitrate, iron, manganese, temperature, pH, BacT
Bremerton-Kitsap County Health Department	new wells (building permit requirements)	~1,000	~1,000	iron, manganese, conductivity, chloride, nitrate, coliform bacteria
USGS	Bainbridge Island Study	46	~400	chloride
USGS WATSTORE (1988 database dump)	various programs	unknown	~3,000	various parameters
Kitsap County Ground Water Management Plan	wet season/ dry season sampling of purveyors wells	67	134	State drinking water organic, inorganic, and bacterial required analyses

The County's ground water is generally of good quality and suitable for most purposes. A comparison of reported water quality results (from the study database) to State drinking water standards was performed and is summarized in **Exhibit 5-26**. With only a few exceptions, most of the water sampled was within State drinking water standards for the constituents evaluated. Standards for iron and manganese were frequently exceeded, as is expected for glacial aquifers of western Washington. Appendix J contains summaries of water quality problems associated with the various National Priority List and Superfund and other hazardous waste sites in the county.

Water quality parameters that are commonly measured and are useful in evaluating ground water quality on a regional basis are chloride, specific conductance, nitrate, iron and manganese. Geographic distribution plots were prepared for each of these parameters. Chloride and specific conductance are commonly used as indicators of seawater intrusion (specific conductance is a measure of total dissolved solids). High concentrations of nitrate typically indicate contamination from sewage, animal wastes, and/or fertilizer applications. Iron and manganese occur from natural sources, and can compromise aesthetic qualities of water at higher concentrations.

Exhibit 5-15 is a geographic distribution plot showing the locations of sampled wells in the study database. Nearly all of these wells were sampled for the five parameters discussed above. Geographic distribution plots are shown in **Exhibits 5-16, 5-17, and 5-18** for chloride, specific conductance, iron and manganese, and were prepared by plotting the location of wells with analyte concentrations above selected cutoff limits. Where individual wells were sampled multiple times, as in the United States Geological Survey (USGS) Bainbridge Island Study, the maximum recorded value was plotted. Concentration values are displayed on the plots adjacent to the well symbols.

5.10.1 Chloride

Chloride concentrations are plotted for samples with over 50 mg/l on **Exhibit 5-16**. The State drinking water maximum contaminant level (MCL) is 250 mg/l, above which water begins to taste salty. Concentrations of 50 mg/l (Dion et. al., 1994) and 100 mg/l (Sinclair & Garrigues, 1994 and Dion & Sumioka, 1984) have been proposed as a threshold for identifying seawater intrusion. Non-intruded ground water typically contains 30 mg/l or less, while chloride concentrations in highly-intruded ground water can approach 19,000 mg/l, the average concentration of seawater (Hem, 1985; Sinclair & Garrigues, 1994). The majority of wells sampled in the study database (87 percent) had maximum chloride concentrations of 10 mg/l or less.

Based on the chloride data, seawater intrusion does not appear to be a serious (or extensive) problem in Kitsap County. **Exhibit 5-16** shows only 11 wells, out of 752 sampled with chloride concentrations above 100 mg/l. Some of these wells are located along the coast and are most likely affected by localized seawater intrusion. Examples include relatively high chloride concentrations near Eglon (1425 mg/l), west of Winslow (351 mg/l), and near Jefferson Beach (270 mg/l). Relatively high chloride concentrations, however, are also found in inland locations such as near Panther Lake and one mile west of Miller Bay. The apparent lack of correlation between high chloride concentrations and distance from the coast may partly be related to the fact that the distribution plot does not distinguish between completion aquifers of wells. High chloride concentrations in aquifers not coupled with coastal water can be due to connate or stagnant waters. More extensive analysis would be required to postulate a cause of high chloride concentrations in inland locations.

5.10.2 Electrical Conductivity

Electrical conductivity (EC) values are plotted for samples which measured over 250 umhos/cm on **Exhibit 5-16**. EC is commonly used as a measure of total dissolved solids (TDS). In ground water, the primary contributors to TDS typically include calcium, magnesium, sodium, bicarbonate, sulfate, chloride and silica. Water with high TDS can corrode plumbing, may taste bad, and can have laxative affects. People on salt restricted diets are warned to avoid water with high TDS due to the potential for high sodium content. High TDS (i.e. high EC) can occur in ground water from a number of sources, including seawater intrusion. EC is a less accurate indicator of seawater intrusion than chloride, however, because a variety of constituents may be responsible for high values. A comparison between EC values and chloride concentrations for samples in the study database revealed a poor correlation between the two constituents. For this reason, selection of an empirical EC threshold for identifying seawater intrusion (e.g., correlative with 100 mg/l chloride) was not possible. The State (secondary) drinking water MCL for electrical conductivity is 700 umhos/cm, based on aesthetic (rather than health) considerations. Seawater, in comparison, measures approximately 50,000 umhos/cm.

The geographic distribution of electrical conductivity values **(Exhibit 5-16)** shows that samples with EC values exceeding 250 umhos/cm most commonly occur in wells along the coast. This pattern appears to be directly associated with freshwater/seawater relationships that occur along the margins of coastal aquifers. Although EC values of 250 umhos/cm are not indicators of seawater intrusion, their occurrence along the coast suggests that they are associated with the zone of diffusion (mixing zone) which forms a transition between fresh ground water flowing towards the sea and underlying seawater. Higher EC values, some of which occur in similar locations to high chloride values, may be indicators of localized seawater intrusion. Similar to chloride, high EC values are not limited to coastal locations. Particularly high EC values (e.g., greater than or near 1,000 umhos/cm) occured in 5 of the 776 wells sampled, at locations near Jefferson Point, along Fletcher Bay (on Bainbridge Island), northeast of Four Corners, near Panther Lake, and west of Wildcat Lake.

5.10.3 Nitrate

The geographic distribution of nitrate can reflect the occurrence of ground water contamination from sewage, animal waste, industrial waste, and/or nitrogen rich fertilizers. The State primary drinking water MCL for nitrate (N) is 10 mg/l. Concentrations above this limit can inhibit the oxygen-carrying capacity of blood and may cause methemoglobinemia (blue baby syndrome) in infants. Precipitation typically contains between 0.3 and 2.5 mg/l, although coastal areas commonly show values between 0.15 and 0.5 mg/l (Matthess, 1982). Concentrations above typical rainfall values are often considered to be impacted by human (or animal waste) sources of contamination. For the purpose of this analysis, nitrate concentrations above 4 mg/l will be treated as indicators of contamination, and concentrations above 10 mg/l will be highlighted as cause for special concern.

Nitrate concentrations are plotted for samples with over 2.5 mg/l on **Exhibit 5-17**. The exhibit shows that fourteen wells (out of 765 wells sampled for nitrate) had concentrations exceeding 4 mg/l and four wells had concentrations exceeding 10 mg/l. The well locations are scattered throughout the County, and do not appear to be associated with higher concentrations of population. The “spotty” distribution of samples with nitrate concentrations above 2.5 mg/l (relative to all wells sampled for nitrate) reflects the localized nature of nitrate contamination. Localized contamination is a typical mode of occurrence for high nitrate concentrations. This is likely a function of the localized nature of sources, dilution over the ground water flow path, and (possibly) microbial degradation in organic rich sediments.

The geographic representation of nitrate concentrations shown on **Exhibit 5-17** does not distinguish between the source aquifers of ground water samples. High nitrate concentrations are considered more likely in shallow aquifers due to surficial (or shallow sub-surface) sources of contamination. A comparison between nitrate concentration and well depth did not show any visible correlations (nor did nitrate concentration versus well completion elevation). Conclusions could not be drawn as to whether the local occurrences of nitrate contamination in the County are restricted to shallow aquifers.

5.10.4 Iron and Manganese

Iron and manganese are commonly occurring constituents of ground water in western Washington. They are derived naturally from the weathering of minerals within the ground water flow system. Although manganese is much less abundant than iron in rocks and minerals, the two are similar in chemical behavior and are frequently found in association. The solubility of iron and manganese is strongly influenced by the pH and oxidation state of ground water. Dissolved iron and manganese are typically limited to trace concentrations in oxygenated ground water, but occur at significant concentrations under reducing conditions. Anthropogenic ground water contamination which alters the pH and oxidation state of ground water (e.g., landfill leachate) can cause particularly high concentrations of iron and manganese. Iron and manganese are regulated as secondary (aesthetic) contaminants to drinking water, with MCL's of 0.3 mg/l and 0.05 mg/l, respectively. Concentrations above these MCL's are generally not considered health problems, but can encrust plumbing and stain laundry.

Iron concentrations are plotted for samples with over 0.3 mg/l on **Exhibit 5-18**. The exhibit shows that many wells within the County had iron concentrations exceeding the State MCL. The majority of these wells (92 percent) had concentrations below 1 mg/l. There is no apparent pattern to the locations of samples which exceeded the MCL, nor is there an apparent pattern to the locations of samples with relatively high (greater than 1 mg/l) iron concentrations. Iron concentrations were not differentiated by aquifer of occurrence, however an initial evaluation was made to determine whether iron was any more prevalent at identifiable depths or elevation zones. Comparison of iron concentration versus well depth (and well completion elevation) did not reveal any pattern in the vertical distribution of iron concentrations above the MCL.

Manganese concentrations are plotted for samples with over 0.05 mg/l on **Exhibit 5-18**. The exhibit shows that while exceedences of the manganese MCL are common, they are not as plentiful as exceedences of the iron MCL. It is worth noting that several areas which showed exceedences of the iron MCL (west of Dyes Inlet, the northern half of

Bainbridge Island, south of Fernwood and the northernmost tip of the peninsula) did not show proportional exceedences of the manganese MCL. The majority of samples which exceeded the manganese MCL (93 percent) had concentrations below 0.2 mg/l. Similar to iron, there is no apparent pattern to the locations of samples which exceeded the MCL, nor is there an apparent pattern to the locations of samples with relatively high (greater than 0.2 mg/l) manganese concentrations. Differentiation of aquifers was not included as part of this manganese evaluation.

5.10.5 Time-Series Analyses

Long-term water quality monitoring is generally lacking in Kitsap County, however, several studies have made comparisons of selected water quality parameters over time. The USGS Bainbridge Island study evaluated long-term trends in chloride concentration in 26 wells based on four sampling events between 1967 and 1985. The study also evaluated seasonal trends by monitoring chloride in 22 observation wells on a monthly basis between October 1984 to September 1985. In both cases, the USGS found no significant changes in chloride concentration over the periods of record. The study notes, however, that seawater intrusion constitutes a potentially serious threat to the ground water resources of the island; and suggests that water levels and chloride concentrations should be monitored on a continuing basis. This conclusion is equally true for the rest of the County, which has a similar hydrogeologic framework.

Seawater intrusion (and partial recovery) was documented at the Bangor Submarine Base during construction of the Delta Pier. The Bangor Aquifer System was temporarily dewatered and the resulting water level declines and seawater intrusion were monitored. Following completion of construction, the dewatering wells were turned off and chloride concentrations returned to near-background levels in most wells. The relatively quick reduction of chloride concentrations (in all but one well) may have been aided by diversion of part of the dewatering discharge to an injection well upgradient which could have provided additional “flushing” of the aquifer system. Changes to the flow system, associated with increased withdrawals and ground water discharge from deep “pressure relief” wells, may account for the continued elevated chloride concentrations in the single well.

Time series evaluation of water quality data from Kitsap County was performed as part of the Kitsap County GWMP in 1991. The analysis employed water quality data provided by the EPA (including data from the USGS and from Group A wells), by Ecology (Group A wells), by DOH (Group A and B wells), and by the BKCHD. The data generally ranged from the late 1970s to the late 1980s, although data from the early 1970s were available in some cases. Volumes I and II of the GWMP designated the five sub-areas (Hansville-Indianola, Bainbridge Island, Poulsbo-Bremerton, West Kitsap, and South Kitsap) for which water quality data were plotted on a quarterly basis for trend analysis. Data from multiple wells were plotted (individual wells were not distinguished), although in many cases time series data were available for only one well within a given subarea. Trend analyses were performed for a number of major inorganic and trace metal constituents. The trend analyses were based on statistical regressions of all available quarterly data. Data collected at known ground water contamination sites were not included in the trend analyses, which were intended to reflect trends in regional (background) conditions rather than localized, discrete areas. In general, the analyses found no significant trends in any of the indicator parameters evaluated. Very few observations above MCL's were found, with the exception of naturally occurring iron and manganese.

Section 6
Water Demand

6.1 Land Use

Land use within Kitsap County (County) can be categorized largely as rural (e.g., forest, agricultural, open space). According to satellite interpretation and County Assessor data, the County is nearly 90 percent rural land. **(Exhibits 2-3, 2-4, and 2-5)**. However, there are several highly urbanized centers with their associated population, commercial centers, and industrial areas at various locations along the transportation corridors of the County. Kitsap County ranks second only to King County as the most densely populated county in the State with 562 people per square mile of land.

Land use was evaluated using both County Assessor Data and satellite imaging. Because urban areas include some sections with high vegetation, the data sets do not exactly compliment each other. The general assessment that the county is approximately 90% "rural" is supported by both approaches.

Examination of land use within the various subareas based on County Assessor data, clearly shows the extent of the urban centers. For example, the Bainbridge subarea (Bainbridge Island) has combined urban and suburban land use types (not forested, open space, or natural cover) equaling 32 percent, Manette (which includes East Bremerton) has 45 percent, Manchester has 28 percent, Gorst has 25 percent, Olalla has 22 percent, Bangor has 21 percent, Poulsbo and Kingston both have 17 percent. In contrast, the Anderson subarea has about 1 percent in urban and suburban land use types, Tahuya and Union are under 5 percent, and Seabeck, Stavis, McCormick, Hansville, Chico, Dewatto, and Port Gamble are between 5 and 15 percent **(Exhibit 6-1)**.

Land cover data (satellite data) shows areas in forest, natural cover, and mixed forest to vary from 98 percent of the land in the Anderson subarea to about 71 percent for the Manette subarea. Specifically, the following subareas have over 90 percent of the land in forest, natural cover, or mixed forest: Anderson, Hansville, Kingston, McCormick, Olalla, Port Gamble, Seabeck, Stavis, Tahuya, Union, and Dewatto. Subareas with between 80 and 90 percent include Bainbridge, Chico, Manchester, and Poulsbo. Those between 70 and 80 percent include: Bangor, Gorst, and Manette **(Exhibit 6-2)**.

6.2 Population

Population forecasts are constantly being updated and derived through a variety of means. Forecasts were used in development of Volume 1 of the 1991 Ground Water Management Plan (GWMP) and in the development of the 1991 Coordinated Water System Plan (CWSP). Since those documents were prepared, planning activity under the Growth Management Act (GMA) has been initiated. Because of the specific requirements of the GMA, considerable attention has been focused on the methodology and basis for the County's forecast. As of October 1995, there were still significant issues to be resolved.

According to Washington State Office of Financial Management (OFM), population projection for the year 2015, range from 280,910 to 337,089 (11/17/95 preliminary OFM projections). Population for the County in 1990 was 184,500. These numbers yield and average yearly growth rate for the County between 2.1 percent and 3.3 percent. The annual percentage change in population for Kitsap County from 1990 to 1994 was 3.1% (SounData, March/April 1995). Kitsap County population increased by 31.47% for the ten years between April 1, 1985 and April 1, 1995 (OFM 6/30/95 report).

6.3 Water Use

Water use patterns were reviewed during the development of Volume 1 of the GWMP (1991). Since that time, there have been no comprehensive reevaluations. According to the GWMP, on a County-wide basis, about 80 percent of water use, excluding instream uses, is municipal, domestic, or single family supply. Fish propagation is the next largest user with about 17 percent. **(Exhibit 6-3)**. This pattern does vary somewhat seasonally, with irrigation demanding a slightly higher percentage during the summer, but the general dominance of municipal/domestic use remains the same.

Based on 1990 census data, population density has been calculated by subarea and is shown in **Exhibit 6-4**. The patterns of density have no doubt changed somewhat over the last six years. However, the general pattern of rural and urban density has remained.

As population density and land use varies throughout the County, so does the water use pattern for a given area. The pattern described above is predominant in the more urban areas of the County (central portions). In the more rural areas fish propagation is the dominant water use (50 to 80 percent). Municipal and domestic water use drops to between 20 and 40 percent in rural areas.

6.4 Current and Future Demand

A summary of average and peak day water demand for the County was provided in Volume I of the GWMP and is graphically depicted in **Exhibit 6-5**. The water demand projections shown include municipal and domestic, commercial/industrial, irrigation, fish propagation, and heat exchange. Instream uses are not included.

The total, average day, existing water resource requirement was about 31 MGD in 1990 **(Exhibit 6-3 and 6-5)**. It is projected to increase to approximately 45 MGD by 2020, assuming water consumption habits and lifestyles do not change from existing conditions. If an increase in multi-family housing units is assumed to occur in the urban areas of the County, and a municipal and domestic water conservation program is initiated or expanded at the County and local utility levels, then the average day demand in 2020 is projected to be about 39 MGD. An additional water resource requirement of 8 to 13 MGD (9,125 to 14,600 Acre Feet per year) over 1990 production quantities is estimated to be necessary by the year 2020 to support the average day demand.

Total peak day demand was approximately 74 MGD in 1990 **(Exhibit 6-5)**. By 2020 peak day demand is anticipated to reach nearly 114 MGD (existing life styles) or 100 MGD (with conservation). The additional water resource requirement, over 1990 numbers, for a peak day in 2020 would be approximately 26 MGD. The GWMP water demand projections were based on a population projection for 2015 of approximately 275,000, which is lower than the more current OFM projections listed above. Water demand therefore, is expected to be correspondingly greater **(Exhibit 6-5)**.

The Department of Ecology defines non-consumptive use of water as a use that returns the same quantity and quality of water to the source (e.g., a hydroelectric power project). Kitsap County has no significant non-consumptive water use projects and none are currently planned.

6.5 Water Reuse in Kitsap County

Millions of gallons of secondary treated wastewater effluent and fish farm discharge, flow to the sea from Kitsap County every day. Other than providing grounds irrigation at the treatment plants, no large-scale reuse projects are currently in place in the County. Over the next several years, the potential exists for several water reuse projects to be in operation in the County for applications, such as irrigation, which do not require drinking water quality standards. The City of Bremerton is conducting a feasibility study of reuse options including golf course irrigation and industrial uses (Kathleen Cahall, Bremerton Public Works). Kitsap County Public works is looking for opportunities for reuse from its treatment plants (George Mason, Kitsap County Public Works). Annapolis Water District is conducting a study to evaluate the feasibility of a reuse project in its area (Dennis Coburn, Annapolis Water District).

Sources of Waste Water in Kitsap County

The following is a summary of the amount of waste water generated in Kitsap County by various sources. The first set of data shows where water is being used and therefore gives an indication of where reuse efforts might be focused.

Category	MGD	Percentage
Municipal/Domestic	17.06	51%
Commercial	5.07	15%
Industrial	3.52	11%
Irrigation	2.21	7%
Fish Farming	5.20	16%
Stock Watering	0.02	0.06%
Total	33.08	

NOTES: Water usage in Kitsap County (1992 data)
Data extrapolated from GWMP Vol. 1, , Table II-9
Industrial includes Puget Sound Naval Ship Yard.
Irrigation relates only to farming practices.

Not all of the water currently being used in the county is available for reuse. Water discharged to on-site septic fields is not available for processing but is effectively being recycled.

Wastewater Treatment Plants

Eight secondary wastewater treatment plants are in operation in Kitsap County. They discharge as follows:

Plant	Operator	Design Discharge (Avg. MGD*)	Actual Discharge 1995 (Avg. MGD)
City of Bremerton	City of Bremerton	10.1	6.0
Central Kitsap Plant	Kitsap County	4.8	3.593
Annapolis	Sewer District #5	2.8	1.815
Manchester	Kitsap County	0.233	.1856
Winslow	City of Bainbridge Is.	1.0	0.5
Suquamish	Kitsap County	0.2	.1735
Kingston	Kitsap County	0.15	.0994
	Totals	19.283	13.2611

* Bremerton Plant limit is on the maximum monthly average flow.
NOTE: The Port of Bremerton Industrial Park has a treatment plant with a capacity of 72,000 GPD and a current discharge rate of approximately 20,000 GPD. The discharge goes to a septic field so it is not included in the totals above.

Exhibit 6-6 provides a map of sewage treatment plant locations.

Several factors must be considered when evaluating the practicality of reusing water:

- The cost of further treating wastewater effluent to meet standards for specific reuse applications.
- The availability and cost of water from other sources.
- The expense of transferring water between water processing sites and reuse sites.
- The volume of water available for reuse at a given location versus the demand for reused water in the vicinity.
- Public acceptance of reused water for the uses proposed.
- Regulatory and policy barriers to reuse.
- Quality control.

6.6 Summary and Implications for Future Allocations

This section has provided an overview of the general character of the County, which gives some indications of likely patterns of water use, and general indications of demand for the future. This section has not provided a much needed analysis of demand by subarea, because at this time (October 1995) population growth figures are a focus of controversy, and under revision with respect to allocations to subareas.

New sources and water rights for some existing public water systems will be needed in the future. While this statement seems apparent, given the general growth expected, the size and extent (geographical) of this need is unknown. For example, it is not known whether existing rights for various purveyors are adequate for future needs. It is not known whether specific areas (such as Bainbridge Island) pose significant water rights questions because of a collective deficiency of water rights within that area compared with predicted demand. It is also not known what percentage of population in each of the subareas can be expected to be served by public water supplies, and which can be expected to be served by private domestic wells.

Clearly, follow up studies will be required. Existing supply versus demand, data requirements, funding, etc. will be evaluated to set appropriate priorities for future studies by subarea. For example, if specific subareas show significant discrepancies when future demand is compared with existing capacity (water rights), then priority for future supply study should be focused in areas which could provide for the increased demand. If studies raise significant policy issues relating to use of private wells, integration of water systems, etc., then these issues can be given priority and addressed in the appropriate forum.

Section 7 Fisheries Habitat and Water Quality Assessment

7.1 Resources

Rivers and other streams in Kitsap County (County) with salmonid use are shown on **Exhibits 7-1, 7-2 and 7-3**. The fisheries assessment and stream water quality information available for the County are summarized in the attached matrix table **(Exhibit 7-2)** and annotated bibliography (Appendix E). Information on **Exhibit 7-2** is organized first by the large watersheds identified under the Nonpoint Rule (WAC 400-12) for the watershed planning process. Surface waters within these watersheds are organized within the subareas developed for this project. The agency which sponsored each study and the author(s) of each report are identified, as well as the parameters investigated. The annotated bibliography is organized by author of the report, or agency which sponsored the study if no author is cited. Streamflow trends are discussed in **Section 4** and miscellaneous measurements are presented in **Appendix C.**

Existing information for much of the County is limited and does not provide an in-depth assessment of the overall availability of habitat for utilization by the many fish populations identified. While many sources were reviewed, the primary comprehensive sources are listed below.

- ❑ Data on fish stocks is contained primarily in the State Salmon and Steelhead Stock Inventory (SASSI 1994) and the Washington Rivers Information System Database (see **Appendix E).** However, escapements (the number of salmonids that make it back to spawn) to many creeks in Kitsap County are generally not documented

- ❑ The systematic collection of habitat information has only recently been initiated through habitat assessment surveys sponsored primarily by the Northwest Indian Fisheries Commission and initiated through the Timber Fish and Wildlife Program.

- ❑ Water quality information has been documented primarily through the watershed planning process (WAC 400-12), which requires a watershed characterization and water quality assessment. Water quality information is generally limited to fecal coliform bacteria concentration and documentation of the State health standards. Little data has been collected with fish health in mind.

- ❑ Watershed plans completed in the last few years include a characterization of stream corridors conducted by the Puget Sound Cooperative River Basin Team (PSCRBT). These watershed characterizations contain a qualitative discussion of fisheries resources and major stream systems have been evaluated for potential sources of nonpoint pollution and riparian habitat conditions. Where watershed characterizations have not been completed, the WRISD by the Washington Department of Fish and Wildlife provides the most in-depth information of salmon utilization, though some of the information may not be current.

- Kitsap Public Utility District No. 1 (KPUD) has completed assessments of some of the subareas within the County in the last few years. The fisheries aspect of these studies has been limited, in most cases, to the review of existing data and has not involved extensive fisheries habitat surveys.

It is important at this level of evaluation to point out the definition of fish habitat assessment in relation to much of the work which has been referenced in this study. An accurate assessment of habitat, as has been completed on the large river systems and their tributaries outside WRIA 15, is a very complex study. The reference to habitat does not simply evaluate riparian cover and general stream bank conditions. These in-depth habitat assessments include a review of the ratio of pools to riffles, the quality of the streambed material in terms of gravels and fines and the abundance of desirable benthos as a food base. In addition, the reference in this document to published data refers to technical documents and publications which have gone through a review process. Newspaper and magazine articles do not qualify as published data.

7.2 Fisheries Assessment

While there are no large river systems within the boundaries of the County, there are many small streams which are highly influenced by ground water. These small streams collectively have supported populations of coho and chum salmon and searun cutthroat trout. There has been some limited natural production of chinook in Kitsap County drainages. Reduced flows in the late summer and early fall significantly influence the productivity of these streams for coho and cutthroat and impact the availability of spawning habitat for fall chinook.

The anadromous fish stocks of the Kitsap Peninsula utilize two distinct major watersheds, Hood Canal on the West and Puget Sound on the East. On the East side, the coho management is for hatchery coho, while coho on the Hood Canal side are being managed for natural (wild) production. The implication of these two different management systems is that Hood Canal stocks are at reduced levels. These reduced levels are controlling the harvest and fishing regulations in the Straight of Juan De Fuca and off the Coast of Washington and coho are being considered for listing by the National Marine Fisheries Service (NMFS). On the Puget Sound side of Kitsap Peninsula there are more abundant returns of coho and seasons are only impacted by closures to protect Hood Canal stocks.

If water allocation causes a reduction in critical flows for coho production on the Hood Canal side of Kitsap Peninsula, the impact on a listed species could require action to reduce withdrawal or implement mitigating measures.

Chinook stocks on both sides of the peninsula are managed for hatchery stocks.

Following is a brief summary which describes the fisheries habitat within the major stream systems for each subarea. Quantitative stream habitat assessment surveys, such as those initiated through the Timber Fish and Wildlife Program, are also noted.

7.2.1 Fisheries Habitat Within the Major Stream Systems

Upper Hood Canal Watershed -Hansville, Port Gamble, Bangor, Seabeck, Stavis, Anderson Subarea

Hansville - No information was found regarding fisheries habitat within this subarea.

Port Gamble - Gamble Creek is accessible to salmonids for nearly four miles, with suitable spawning in the upper one-half of the stream and excellent rearing habitat throughout (Williams, et. al., 1975). The habitat of a tributary downstream of Rova Road which used to support salmon has been extremely impacted and is now too degraded to support fish (PSCRBT 1993).

Stream surveys were conducted by the Northwest Indian Fisheries Commission along Gamble Creek in 1990.

Bangor - The Bangor subarea includes drainages into the Upper Hood Canal Watershed, Liberty Bay Watershed, and Dyes Inlet Watershed. For simplicity, creeks which drain into other watershed areas (i.e., Big and Little Scandia Creeks, Clear Creek, Barker Creek, Strawberry Creek) are included here.

Clear and Barker Creeks have important runs of chum and coho (WRISD, Williams, et. al., 1975). Coho and chum salmon have also been noted in Strawberry Creek. Low summer flows affect production of coho in these drainages.

Coho and chum salmon as well as cutthroat trout are known to utilize both Big and Little Scandia Creeks. The Scandia Creeks are impacted primarily by poor riparian zone management resulting in little or no streamside vegetation and heavy sedimentation.

There are two major drainages within the Bangor Naval Submarine Base, Devil's Hole Lake and Cattail Lake. Fisheries management plans have been developed for both of these drainages. Streamflow from the main stem entering Devil's Hole Lake averages 4.0 cfs. Devil's Hole Lake and the main stem both contain good fish habitat and have adequate riparian habitat. A fish ladder constructed in 1981 allows fish passage into and out of the lake from Hood Canal. The lake contains native cutthroat trout and coho salmon. A small hatchery was used to raise coho salmon, and a net pen in the lake allows rearing the juvenile coho to a larger release size. Cattail Lake drains into Hood Canal by culverts that do not allow fish passage. However, Cattail Lake and its feeder streams are well vegetated and provide good fish habitat.

Seabeck - One of the most important streams in the County is Big Beef Creek located within the Seabeck subarea. Big Beef Creek is used as an indicator stream for Hood Canal coho and chinook stocks. The University of Washington has a research station situated at the mouth of the creek. There is a barrier weir which controls the upstream and downstream movement of fish in this system. Returning adults and juveniles out-migrating are counted as they pass through the system. Based on the numbers of juveniles counted in relation to the number of adults which spawned in the watershed, an estimate of adult return is calculated. This information is used to forecast the entire Hood Canal salmon escapement and projected adult return.

At one time, Big Beef and Seabeck Creeks provided exceptional spawning and rearing habitat for salmon (Williams, et. al., 1975). Sections of Big Beef Creek still contain good habitat, however, development has degraded the stream. Construction of Lake Symington resulted in waters being warmed by the impoundment and thereby increased downstream temperatures and degraded habitat. Seabeck Creek provides fairly good habitat but low streamflows limit fish production.

Little Anderson Creek has fair habitat for coho and chum salmon production. This stream is probably one of the most impacted streams in the watershed. Development in the area has resulted in large amounts of sedimentation. Little Beef Creek is known to have some chum salmon and resident trout production.

Habitat surveys have been conducted along Big Beef and Seabeck Creeks by the Timber Fish and Wildlife Monitoring Program (1990-1990), and on Big Beef Creek by the Washington Department of Fisheries (1984) and the University of Washington (1991) (Tabor and Knudsen, 1993). Little Anderson Creek was surveyed in 1993 by the Northwest Indian Fisheries Commission. Methodology of the surveys varied according to the agency.

Stavis - The Stavis subarea is largely undeveloped and provides excellent habitat for spawning and rearing salmon. Several years ago, pink salmon were witnessed migrating up this creek (PSCRBT 1993). Protection of this Creek is very important as it is one of the few "semi-pristine" stream systems left in the Puget Sound area.

Boyce Creek is a 2.2 mile long stream which drains into Frenchman's Cove. Boyce Creek is known to be utilized by both coho and chum salmon.

A habitat survey was conducted along Stavis and Boyce Creeks by the Northwest Indian Fisheries Commission in 1993.

Anderson - Because there has been a limited amount of development within the Big Anderson Creek drainage, the return of coho to this system has been an important factor in the abundance of coho in Hood Canal. While logging activities have altered the area, the riparian cover and in-stream habitat is in good condition. The Creek supports both an early and a late run of chum salmon.

Harding Creek drains into Hood Canal north of Tekiu Point. This Creek is known to be utilized by both chum and coho salmon, as well as resident searun cutthroat trout.

The Northwest Indian Fisheries Commission has recently completed habitat surveys of Big Anderson and Harding Creeks.

Bainbridge Island Watershed and Subareas

The streams on Bainbridge Island are typical of small, low-gradient streams in the Puget Sound area. Natural limiting factors for successful salmon reproduction are stream size, passage barriers, and lack of suitable spawning gravels. None of the streams have been officially named. Fletcher Bay drainages support out-migrating searun cutthroat trout, coho and chum salmon. Stream No. 0344 which drains into Manzanita Bay supports cutthroat trout, coho, and chum salmon. Coho and cutthroat trout utilize the largest stream in the Port Madison drainage. The primary stream (No. 0321) which drains into Murden Cove contains some of the best fish habitat on the Island and supports cutthroat trout, coho, and chum salmon. All of the streams in the Blakely Harbor drainage, except the one draining Mac's Dam, have insufficient flow to support salmonids. The Mac's Dam stream supports coho and cutthroat trout. Chum salmon and cutthroat trout have been identified in stream No. 0324 in the Eagle Harbor drainage. There is no flow data available for any of the Bainbridge Island streams.

Liberty/Miller Bay Watershed - Kingston, Poulsbo Subareas

Kingston - The Suquamish Tribe operates a fish culture facility on Grovers Creek which drains into Miller Bay. Coho, chum, and chinook salmon which return to this facility are used as the source of eggs for enhancement activities on several small streams. The Suquamish Tribe operates another hatchery along Cowling Creek which provides a source of chum eggs

Martha John Creek, which is a tributary to Miller Lake Creek, supports a year-round population of resident cutthroat trout, chum and coho salmon. In some years, Martha John Creek has a very healthy run of coho.

Chum and coho production has been reported in several of the smaller independent drainages. Natural limiting factors within the Kingston subarea are the small size and restricted accessibility of the streams.

Poulsbo - Coho and chum salmon are the predominant species found in Dogfish Creek, however, chinook also have been noted to return (Williams, et. al., 1975). The Suquamish Tribe stocks chinook in Dogfish Creek. Johnson Creek supports chum and coho salmon as well as trout species. Coho salmon and cutthroat trout have been noted in both Lemolo and Klebeal Creeks. Big and Little Scandia Creeks drain into Liberty Bay but are considered part of the Bangor subarea and are discussed in that section.

Dyes Inlet Watershed - Manette, Chico Subareas

Manette - Limited documented information is available for creeks in this drainage.

Chico - Chico Creek has an important run of both coho and chum salmon, with spawning occurring throughout the entire mainstream and lower portions of all tributaries. Low summer and fall flows impact production in this drainage. Some years the low flow conditions have extended into late fall and have interfered with the up-stream migration of the early portion of the major chum run to Chico Creek.

Low summer and fall flows have affected production of coho and chum salmon in these drainages. Diversion of additional water from streams during low flow periods would be particularly detrimental.

Sinclair Inlet Watershed - Gorst, Manchester Subareas

Gorst - Gorst Creek which drains into Sinclair Inlet is part of the City of Bremerton's water supply and restrictions are in place regarding development within the watershed. A fish lader is installed in Gorst Creek. Coho and chum salmon have been noted to utilize Anderson Creek where a fish ladder was installed in 1994 through a cooperative effort between the City of Bremerton and Trout Unlimited.

The Suquamish Tribe has a cooperative effort with a sport fishing organization for the rearing and release of approximately 2 million chinook juveniles into Gorst Creek. This release provides a terminal fishery for both the Tribe and sport fishermen.

Manchester - Streams in this area are extremely important for chum and coho salmon (Williams, et. al., 1975). The lower two miles of Blackjack Creek and the lower 1.25 miles of Curley Creek are utilized by early stocks of chum salmon. Blackjack, Curley, and Salmonberry Creeks are important coho areas. Blackjack and Curley Creeks have had occasional plants of coho made. Coho have been reared in Clam Bay, and chum salmon have been reared in a pond on Beaver Creek.

Burley Minter Watershed - Olalla Subarea

Olalla - Burley Creek has returns of coho and chum salmon, and as of 1975, the only wild stock of chinook salmon in Henderson Bay drainage. Both early and late chum salmon runs were returning to this Creek. Returns of coho and chum salmon to Purdy Creek were reported in 1975 to be below their potential (Williams, et. al., 1975). Personal communications with Washington State Department of Fish and Wildlife (WDFW) indicate a natural run of chinook continue to utilize Burley Creek. However, water quality conditions in the estuary when adults are returning often result in fish kills due to low dissolved oxygen.

Olalla Creek supports returns of coho salmon. Habitat deterioration from past logging and current farming practices has occurred. Olalla Creek has received plants from the Minter Creek Hatchery, however, production has been predominantly natural. Due to the small size of the stream, all future water diversions should be carefully examined prior to approval (Williams, et. al., 1975).

Mason County Drainages - Tahuya, Union, McCormick Subareas

Tahuya - The Tahuya River has very important runs of coho and chum salmon, as well as moderate chinook production. Chinook salmon production is limited to the lower four miles of the river due to flow conditions and accessibility during migration. Three distinct stocks of chum salmon return annually to the Tahuya River; an early run during September and early October in the lower three miles of the river; an entirely intertidal run in late October and early November, and a late run during November; and December. The last run utilizes the upper river area from miles 5 to 10, as well as lower reaches of a few tributaries (Williams, et. al., 1975). Low summer flows is a limiting factor for coho production.

Habitat surveys have been conducted along the Tahuya River, Little Tahuya, Gold, Panther, and Tin Min Creeks by the Washington Department of Wildlife (1984), Washington Department of Fisheries (1984), US Fish and Wildlife Service (1992-93), Northwest Indian Fisheries Commission (1990), Point No Point Treaty Council (1992), and Washington State Department of Ecology (1974, 1992-93). Methodology of the surveys varied with agency (Tabor and Knutsen, 1993).

The primary land use in the drainage is commercial and private forest land. The major source of sediment found within the stream corridors of the river and tributaries are the boot-leg or illegal trails and crossings used for off-road recreation.

Union - Coho and chum salmon are produced in the Union River and Big Mission Creek. A small chinook run returns to the lower two miles of the Union River Mckenna Falls, located between river mile 6 and 7, is a natural barrier to salmon production in the upper reaches of the Union River. Low streamflow during the summer months in the Big Mission Creek limit salmon production there. Strict adherence to the fisheries code relative to hydraulic projects, and close evaluation of any proposals for removal of water from the streams is essential for maintaining the existing high production of these streams (Williams, et. al., 1975).

Habitat surveys have been conducted along the Union River, Big Mission and Bear Creeks by Point No Point Treaty Council (1992), Washington Department of Fisheries (1984), US. Fish and Wildlife Service (1992), and Washington Department of Ecology (1970 and 1992). Survey methodology varied with the agency (Tabor and Knutsen, 1993).

McCormick - The Minter Creek Hatchery provides annual releases of chinook and coho fingerlings to many of the streams of the Kitsap Peninsula and other Puget Sound river systems. Natural production of chinook totals approximately 600 spawners annually, plus a small population of wild chum salmon (Williams, et. al., 1975).

Dewatto Subarea

The Dewatto River produces important runs of steelhead, coho and chum, as well as a small chinook population. Three distinct stocks of chum salmon enter Dewatto River at different times of the year and spawn in different sections of the stream. The earliest run enters the lower 2 miles of the river during September with as many as 4,000 spawners per year (Williams, et. al., 1975). A second run enters in late November and spawn in tributaries and mainstream areas above mile 1.5. The third run enters in late December and early January and spawns intertidally and in the lowermost portion of the stream. Thomas Creek, a small creek to the north of the Dewatto River, is known to support coho and chum salmon, as well as resident Trout (PSCRBT 1993).

Stream surveys have been conducted along the Dewatto River by the Northwest Indian Fisheries Commission (1989), Washington Department of Wildlife (1984), and the US. Fish and Wildlife Service (1992) (Tabor and Knudsen 1993). Survey methodology varied with agency.

Summary

In the early 1990s, coho stocks in creeks from Port Gamble to Anderson Creek were considered depressed due to a short-term severe decline in spawning escapements, as evidenced by trap counts at Big Beef Creek (SASSI 1993). Escapements (the number of salmonids that make it back to spawn) to many creeks in the County are generally not documented. Chum salmon returning during late November through December are considered healthy in the County portion of Hood Canal. Early-arriving chum salmon are considered depressed. Escapements in this region have ranged from 500 to 8,000 fish. Other salmon species are less abundant in the County creeks and their status was not documented in the (SASSI) report.

Current status of salmonid populations in the County is a concern to all the agencies and organizations involved in water resources. Because of the poor returns of coho and chinook to Hood Canal there have been restrictions placed on the harvest of these stocks. The total closure of commercial and sport fishing for salmon in the Straight of Juan de Fuca in 1994 was due primarily to the status of Hood Canal coho. At the present time, the National Marine Fisheries Service (NMFS) is considering listing the Puget Sound coho stocks as threatened under the Endangered Species Act (ESA).

A major factor in the decline of coho stocks has been the reduced summer and fall flows in small streams associated with urban growth and the drought cycles which have been evident as shown in the precipitation data in Section 3. Although the general trend in the greater Puget Sound Basin shows rainfall has been near the long-term average, there are individual trends which have impacted the availability of the small streams to support a level of coho production similar to the period prior to 1975. All three gages shown on **Exhibit 3-5** indicate a drought condition from 1975 to 1978. In addition, the annual rainfall at all three stations was equal to, or below, the long-term average approximately 70 percent of the time from 1975 to 1994. The overall trend during this period does not fall into a drought condition. However, the recording station at Seabeck-Monroe shows a decline in precipitation in the period following 1984. In addition, if the average annual rainfall for the Seabeck gage is calculated for the last 16 years this average is five inches less than the long-term average. This decline in rainfall since 1975 is a situation that fisheries evaluators have commented on in other areas of Western Washington.

Exhibit 7-3 indicates the wetlands that have been included in the US Fish & Wildlife Service National Wetlands Inventory. This summary only includes those wetlands of significance that have been delineated and documented. There are, however, a large number of additional smaller wetlands, associated with small streams and watersheds, that are critical to the continued function of these systems in supporting the salmon and trout populations that utilize these watersheds. These areas, adjacent to the streams and at the headwaters, are the point of transfer from groundwater aquifers to a surface water system. The wetlands are additional indicators of the health of the watershed. When combined with the known wetlands, as shown on the exhibit, it is evident that these areas play an important role in the health of the groundwater/surface water interface.

The quality of fish habitat is greatly reduced by non-point pollution. Stormwater runoff from construction sites, roadways, and cleared land continue to cause siltation of streams removing critical juvenile rearing habitat. Other factors which are affecting the survival of all salmonid species are the influence of hatchery fish on natural spawning stocks and interception in the Alaska and Canadian ocean fisheries of fish returning to this area. The impact of the harvest on returning adults was well demonstrated by the closure in 1994 and the significant increase in coho adults spawning the streams of Hood Canal in the fall and winter of 1994/1995.

Section 8
Water Allocations

The State of Washington manages ground water and surface water withdrawals through a system of permits. Water withdrawals for all but limited small ground water uses must be authorized by Department of Ecology (Ecology). Upon receiving an application for a water right, Ecology conducts an evaluation, which may currently take in excess of five plus years, to determine whether or not they should issue a permit to develop the water resource. Water right certificates are issued after the water withdrawal has been perfected (actually put to beneficial use). In this report, permits and certificates are collectively referred to as water rights. Water rights have been recognized by existing water laws since 1917 for surface water and 1945 for ground water. Not all uses of water developed before these dates were registered as part of the water-rights process. In order to preserve active withdrawals developed prior to these two dates, the State required individuals to register withdrawals during a "claims period" between 1969 and 1974. A water-right claim is not an authorization to use water, but rather a statement in claim to a water withdrawal developed prior to 1917 or 1945 and uses developed under RCW 90.44.050 from 1945 through the Claims Registration Act. All claims are valid if they are on Ecology's registry. However, only the courts can decide through a formal adjudication whether or not the claims represent a vested right. The Washington State Legislature has reopened the Claims Registry from September 1, 1997, to June 30, 1998.

Quantities of water allocations are not necessarily equal to quantities of water use. Allocations state maximum legally permissible quantities of withdrawal. Some studies have shown that permissible quantities are seldom used and a significant discrepancy can exist between allocation and use. A distinction between allocation and use must be drawn in assessing stress on the hydrologic system due to withdrawals. Actual use cannot be enumerated through water-allocation statistics, but must be arrived upon by surveying major water users and estimating the sum of minor uses. Although total allocation may differ from actual use, total allocation is a significant value because it represents the maximum legally permissible withdrawal from the hydrologic system.

8.1 Instream Resource Protection Program - Kitsap (WRIA)

The Instream Resource Protection Program (IRPP) for the Kitsap Water Resource Inventory Areas (WRIA) (Chapter 173-515 WAC) was enacted in 1981. The intent of Chapter 90.54 RCW and Chapter 90.22 RCW, is to retain base flows in perennial streams, rivers and lakes at levels necessary to protect wildlife, fish, scenic, aesthetic, recreation, environmental and navigational values. Due to the large number of control stations and associated limitations, it is a very complex law to administer.

The IRPP for the Kitsap WRIA establishes instream flow requirements at 18 control stations within the WRIA. The IRPP also lists 71 streams, lakes, or drainage systems which are closed to diversions year-round or during specific periods of the year. Thirteen of these are seasonal closures on streams which have instream flow requirements during other times of the year. Additional discussion of these regulatory requirements is provided in Section 4.2 of this report.

The IRPP is based on Ecology's methodology for selecting minimum instream flow requirements. This methodology involved statistical analysis of streamflow records and consideration of other instream values. In choosing streams for regulatory protection, each stream was rated by Ecology and the Departments of Fisheries and Game (now Department of Fish and Wildlife). A stream rated to have greater environmental and scenic values required higher levels of flow protection. Ecology could initiate a review of the IRPP whenever new information, changing conditions, or statutory modifications make it necessary to consider revision. Rule making would be required.

An instream flow established under an IRPP is effectively a water right, senior to all water rights issued thereafter. The subject IRPP states that from its establishment forward, all consumptive water rights shall be expressly subject to the instream flows, and that no surface water right granted thereafter shall be in conflict with the instream flows and closures established in that chapter. With respect to ground water, the IRPP states that future withdrawals will be affected by these regulations only if determined to have clear adverse impacts upon surface water contrary to the IRPP intents. The IRPP also states that no water rights in existence at the time of its establishment shall be affected.

It should be noted that the minimum instream flow requirements specified in the IRPP collectively represent the largest quantifiable water right currently in existence. Individually allocated (private) water rights are compared to minimum instream flow requirements on a subarea basis in Section 8.2.5. Other water rights such as federal reserve, tribal, and exempt rights, are discussed in Section 8.3.

8.2 Water Rights and Claims

Water permits and certificates within the Kitsap WRIA are recorded in Ecology's Water Rights Information System (WRIS) database. The database contains specific information for each entry, including: point of withdrawal or diversion, date of application and approval, maximum allowable withdrawal, purpose(s) of use, and irrigated acreages where applicable. There are 12,500 surface water permits/certificates which were issued statewide that have no annual quantity specified on the document. For this reason, discussion of surface water permits and certificates as annual withdrawals may involve some underestimation. Withdrawal quantities are also often unspecified for a large number of claims. Estimation techniques (described below) were used to approximate total annual quantities associated with claims.

This section presents several analyses based on data obtained from the WRIS database. Some of the more generalized analyses (water rights vs. time; water rights by use; water right applications by use) present data for the entire WRIA. Conclusions of these analyses may differ from similar analyses specific to Kitsap County (County); however, County-wide data could not be extracted from the WRIS output files provided by Ecology. Spatial analyses of WRIS data, however, allowed evaluation on a County-wide basis. Analysis of the geographic distribution of water rights, claims and applications, and comparison between allocations and total inflows were confined to the County.

Water right permits and certificates are issued with permissible quantities of instantaneous and annual withdrawals. The instantaneous allocation (Qi) represents the limit on the rate at which the system may divert/withdraw water from the source. Qi's are expressed in cubic feet per second (cfs) for surface water and gallons per minute (gpm) for ground water (448.8 GPM=1 CFS). The annual allocation (Qa) represents the maximum amount of water allowed over a year's time for a specified use(s), and is expressed in acre-feet per year (af/yr.). Research of water right records indicates that for most permits/certificates, the Qa does not represent a continuous withdrawal throughout the year at the maximum authorized Qi; rather, it generally represents the total of intermittent withdrawals at rates approaching or equal to the authorized Qi. The implications of this difference are greatest for certain surface water withdrawals. Some rates of withdrawal also vary seasonally as a function of demand. Municipal withdrawals are typically correlated to residential demand, and irrigation diversions (though uncommon in Kitsap County) often divert their entire allocated Qa from streams during the summer growing season (approximately 4-6 months).In addition the effect of a surface diversion is immediately imposed on a stream. In contrast, the effects of ground water pumping on streamflows while sometimes rapid, are frequently delayed and spread out over time.

8.2.1 Water Rights and Claims Over Time

The cumulative increase in water permits and certificates over time in the Kitsap WRIA is shown in **Exhibit 8-1**. This cumulative increase has also increased the stress on the hydrologic system due to withdrawals. Quantities are reported as maximum allowable withdrawal volumes (Qa) in af/yr. As previously mentioned, the surface water allocations may be underestimated due to database entries without registered Qa values. Reported Qa’s for surface water rights in the Kitsap WRIA have grown to 17,673 af/yr. from the first registered right in 1919 to 1992, the priority date of the last-issued surface water right. Reported Qa’s for ground water permits/certificates have grown to 87,239 af/yr. from the earliest priority right in 1920 to 1994, the priority date of the last-issued ground water right. Note that since 1990, cumulative ground water allocations have not significantly increased, inkeeping with the fact that water rights have not generally been issued.

Many claimed water rights have been in use long before the first water rights were granted. Water was claimed primarily for agricultural purposes, yet claim quantities were not always consistent with potentially irrigable acreages. In order to better estimate irrigation claims and assign water duties to the claims, the following irrigation relation was applied:

Qi = Acreage x 9 gpm = Acreage x 0.02 cfs

Qa = Acreage x 2 af/yr.

Claims for domestic and stock uses, which include up to half an acre non-commercial lawn and garden, were assigned a Qi of 0.02 cfs and a Qa of 0.5 af/yr. These approximations are consistent with Ecology's current allocation processes for water rights issued in Western Washington (Culvert, 1994). Claims within the WRIA, based on these water duty assignments, are summarized in the following table. Comparisons between current claims and permits/certificates are also summarized in the following table and presented graphically on **Exhibit 8-2**.

	Rights			**Claims**			**Totals**
	Qi cfs (gpm)	Qa af/yr	Irrigated Acres	Qi cfs (gpm)	Qa af/yr	Irrigated Acres	Qa af/yr
Surface Water	131.7 (59,107)	17,673 (11,014 gpm)*	3,085	104 (46,675)	8,702 (5,385 gpm)*	3,489	26,375
Ground Water	297.2 (133,383)	87,239 (53,856 gpm)*	1,039	310 (139,128)	20,907 (12,970 gpm)*	5,428	108,146
Totals	428.9 (192,490)	104,912 (64,870 gpm)*	4,124	414 (185,803)	29,609 (18,355 gpm)*	8,917	134,521

gpm= gallons per minute, cfs= cubic feet per second, af/yr= acre feet per year

* Value represent continuous average or continuous instantaneous rate required to produce annual allocations.

Currently, ground water withdrawals dominate water rights (and to a lesser extent water-right claims) within the Kitsap WRIA. Ground water rights (as Qa) account for 83 percent of current total allocations, and ground water claims (as Qa) account for 71 percent of current total claims. Issued water rights exceed water right claims for both ground water and surface water. Note that, due to differences in the regulatory function of annual withdrawals (Qa's) and instantaneous withdrawals (Qi's) discussed above, values of Qa do not bear a consistent relationship to values of Qi.

As previously mentioned, the quantity of water allocated within the County differs from the quantity allocated within the WRIA. Comparison between current water allocations for the WRIA (above) and the County (discussed in Section 8.2.5) show that County-wide ground water rights account for 73 percent of WRIA ground water rights, and County-wide surface water rights account for 50 percent of WRIA surface water rights (as Qa). Similar comparison shows that County-wide ground water claims account for 67 percent of WRIA ground water claims, and County-wide surface water claims account for 16 percent of WRIA surface water claims.

8.2.2 Water Rights and Claims by Use

All water rights are registered by purpose of use. Within the WRIS database, water rights typically have one, if not several, stated purposes. Examining the distribution of water rights by purpose provides understanding of how water is used within the WRIA. Discerning the major uses can assist in formulating policy for water conservation and water-rights administration.

In order to present water rights by use, current permits and certificates were classified according to the larger of their stated purposes. The relative distribution of surface water rights by use in the WRIA is presented on **Exhibit 8-2b**. Percentages of total use are calculated in terms of maximum allowable annual withdrawals (Qa's). Surface water resources in the WRIA are primarily allocated for municipal (40 percent) and domestic multiple (39 percent) use. Irrigation uses comprise 17 percent of the total Qa, and other uses comprise the remaining 4 percent.

The relative distribution of ground water rights by use is presented on **Exhibit 8-2c**. Ground water resources in the WRIA are also primarily allocated for domestic multiple (57 percent) and municipal (31 percent) use. Fish propagation comprises 8 percent of the total Qa, and other uses comprise the remaining 4 percent.

Water resources associated with water rights claims appear to be primarily associated with irrigation use. This reflects the historical circumstances of claims registration. Based on the irrigated acreages and the formulas for water-duty assignments discussed above, at least 49 percent of the surface water claims (as Qa) and 91 percent of the ground water claims (as Qa) can be attributed to irrigation. Percentages attributable to irrigation would be greater, however irrigated acreages are not reported on a number of claims. The portion of claimed water resources not attributable to irrigation is assumed to be for domestic or stock purposes.

8.2.3 Spatial Distribution of Water Rights and Claims

Evaluation of the spatial distribution of water rights and claims provides a rough approximation of where water is used within the study area. This section discusses and presents the geographic distribution of water rights and claims throughout the County. **Exhibits 8-3 through 8-6** are maps of total water rights and claims on a section-by-section (square mile) basis throughout the County. **Exhibit 8-7b** summarizes the volumes of water rights and claims (as Qa) on a subarea basis.

The spatial distribution of surface water rights (permits/certificates) and claims are depicted in **Exhibits 8-3 and 8-4**. Surface water rights **(Exhibit 8-3)** occur primarily in the eastern portions of the County, and are variably distributed among the County's smaller and larger streams. The largest surface water allocations occur in the Union and Bangor subareas **(Exhibit 8-7b)**. The distribution of surface water claims also shows higher concentrations in eastern portions of the County. The largest (total) surface water claims occur in Manchester and Stavis subareas **(Exhibit 8-7b)**.

The spatial distribution of ground water rights (permits/certificates) and claims are depicted in **Exhibits 8-5 and 8-6**. Ground water rights are largely associated with population density, and primarily occur in the eastern portions of the County. The largest ground water allocations occur in the Manchester and Manette subareas **(Exhibit 8-7b)**. Other subareas with relatively large ground water allocations include Bangor, Gorst, Bainbridge and Kingston. Ground water claims **(Exhibit 8-6)** are more evenly distributed throughout the eastern County.

8.2.4 Water Right Applications

There are currently 220 applications for new water rights within the Kitsap WRIA on file with Ecology (1995). Maximum withdrawal information for water right applications is generally limited to instantaneous extraction rates (Qi), largely because Ecology has not made final decisions as to maximum allowable annual withdrawals. The table presented below provides a summary of water-right applications in the Kitsap WRIA, expressed as Qi. Applications cannot be directly compared to allocations where allocations are reported as Qa.

Source	Number of Applications	Total Qi (cfs) / (GPM)
Surface Water	20	5.2 / 2,334
Ground Water	200	114.9 / 51,567
Total	220	120.1 / 53,901

Applications for ground water rights comprise the largest component of potential future water allocations. Currently, 200 ground water applications exist for 51,567 gpm and 20 surface water applications exist for 5.2 cfs. **Exhibit 8-2d** shows the distribution of applications by stated purpose. The majority of the total requested Qi (68 percent) is for domestic multiple use. Municipal use account for 21 percent of the total requested Qi, and other uses account for 7 percent. Surface water applications account for only 4 percent of the total requested Qi. The current total surface water request is primarily divided between irrigation (31 percent), municipal (27 percent), domestic multiple (23 percent), and fish propagation (17 percent) uses.

Evaluation of the distribution of water right applications shows where additional demand is occurring. The geographic distribution of water-rights applications is presented in **Exhibits 8-8 and 8-9**. Surface water applications **(Exhibit 8-8)** occur within about ten (square-mile) sections within the County. Sections containing the largest surface water requests occur along Grover's Creek (north of Indianola), near Barker Creek (east of Silverdale), near Gazzam Lake (on western Bainbridge Island), and along Annapolis Creek (east of Port Orchard). The Manette, Bainbridge, Manchester and Kingston subareas have the largest requests (as Qi) for surface water rights **(Exhibit 8-7b)**. Ground water applications **(Exhibit 8-9)** are predominantly distributed throughout the eastern County. The Bangor and Manchester subareas have the largest requests (as Qi) for ground water rights **(Exhibit 8-7b)**. Isolated applications for relatively large allocations may be associated with small communities or fish propagation facilities**.**

8.2.5 Comparisons Between Allocations and Total Inflows

The relative degree of water resource development for each subarea within the County can be roughly indicated by comparing water allocations to "total water inflow". Total inflow (TI) was estimated for each subarea by calculating the precipitation input (P) from the isohyetal map (discussed in Section 3), and subtracting a value for evapotranspiration (ET). Estimation of ET was based on Blaney-Criddle evaluation of potential evapotranspiration and a soil moisture balance, as described in Section 5.8.4. The remaining water (P-ET) is found in either the ground water or surface water flow system and, for the purpose of this analysis, is considered "available" to support a wide variety of hydrologic and environmental values. A portion of this total inflow is available for water supply development, while the remainder (and likely the majority) must be maintained to support baseflows in streams and provide sufficient ground water flux to prevent saltwater intrusion along the coast.

Exhibit 8-7b summarizes the relative degree of water resource development in each of the 18 subareas designated within the County. The exhibit also presents the precipitation, evapotranspiration, water rights and water claims data used to make the comparisons. Values of relative development range from less than one percent to just over 40 percent. The Manette and Bainbridge subareas have the highest degrees of water resource development, whereas the Anderson, Dewatto, Tahuya and McCormick subareas have the lowest degrees of water resource development. Relative development for most (11 of 18) of the subareas is between 5 and 25 percent. It should be noted that the relative development percentage for the Gorst, Union, Chico, and Tahuya subreas may be overestimated, since the isohyetal map used to calculate the precipitation input does not show elevated (orographic) rainfall in the Green-Gold Mountains. As discussed in Section 3, precipitation data from the mountains were not available as input to the isohyetal contouring package.

Exhibit 8-7b also indicates whether there are minimum instream flow requirements and/or stream closures in effect for each subarea. In many cases, not all of the streams in a subarea have regulatory protection. The regulatory protections, therefore are not a complete indication of total instream flow needs.

8.3 Undetermined Water Rights

Three categories of water rights, although recognized, can not be quantified as a part of this assessment. The first category relates to ground water withdrawals in small quantities (i.e., exempt from permit requirements pursuant to RCW 90.44.050). This category would include all small withdrawal (not to exceed 5,000 gpd) wells that were constructed and put to use prior to July 1, 1974, and upon which no water right claim was filed under Chapter 90.14 RCW; and any such wells put to beneficial use after June 30, 1974, without having a standard permit.

The second and third categories relate to federal reserved rights associated with either US Reservations (e.g., military) or Indian Reservations. Any appropriation of surface and ground water in Washington is subject to the federal reserved water rights on military and Indian reservations, and may be affected by Indian Tribe aboriginal water rights. The doctrine of reserved water rights combines both the common law riparian water rights doctrine and prior appropriation. Under the doctrine of reserved water right, when a federal reserve (e.g. military, Indian) is created, there is an implied reservation of water to fulfill the purpose of the reservation. The priority date of the water right is the date the reservation is created. Use of water does not create and disuse does not destroy or suspend a federally reserved water right.

Another source of Indian water rights may be tribal aboriginal water rights. It is claimed that, when an Indian tribe has never moved from its aboriginal area, and its tribal title has never been extinguished, the tribe holds an unbroken and unfettered property right to the use and occupancy of the land and the water. The priority date for aboriginal water rights is considered to be "time immemorial" and like reserved water rights cannot be lost or destroyed by non-use. In Kitsap County, the Tribes claim Indian aboriginal water rights including the right to an adequate water supply to maintain an Indian fishery.

Indian, aboriginal water rights may take priority over state-issued water rights. Federal reserve water rights may take priority over state-issued rights appropriated subsequent to the establishment of the federal facility or creation of an Indian reservation. These brief summaries of federally and treaty protected water rights are not intended to be exhaustive statements of federal and Indian water rights, but are presented in order to give a general overview of aboriginal and federal reserve water rights.

The above described water rights can be determined with certainty only through the State's general adjudication process (see RCW 90.01.110.243 and RCW 90.44.220) or in some cases through the federal court system.

Section 9 Subarea Characteristics and Water Availability Summary

Water Right Decision Considerations

Water right decisions, by law, are based on: availability of water for appropriation, the proposed use being beneficial, non-impairment of existing rights, and no resulting detriment to the public welfare. In addition, in making water right decisions, consideration is given to existing basin management plans, stream closures, instream flows, hydraulic continuity, seawater intrusion, protests, and availability of alternative water supplies. Water rights decisions require sufficient understanding of the hydrologic system and consideration of potential impairment to existing (senior) water rights. Given the multitude of drainage systems in Kitsap County (County), water rights decisions are best evaluated on a subarea basis, as subareas generally represent discrete portions of the hydrologic system with little hydrologic interaction. Optimally, decisions should be based on direct quantification of water availability within a given subarea. However, direct quantification of ground water availability is limited by the complexity of subsurface conditions relative to current levels of hydrogeologic characterization. In addition, direct quantification of surface water availability is inherently limited by the spatial and temporal variability of precipitation and evapotranspiration. Therefore, determination of water availability must be based on a best understanding of the hydrologic system and indirect indicators of water availability. Within each subarea discussion, considerations for making water allocation decisions are presented. For specific water right decisions, additional, individual considerations and local conditions will have to be taken into account.

Data gaps - summary information and relative importance to future water rights decisions

Nature and severity of data gaps

All subareas have data gaps which vary in degree. The data, which can be organized into data sets, combine to provide a level of understanding of water resources in both a static and dynamic sense.

The level of understanding is likely to never reach a perfect state. Acknowledgment of data gaps, therefore, is an important part of an assessment process. Also, recognition of the magnitude and context of these gaps is critical to a decision making framework.

Outlined below are key elements of the decision making framework for water rights and a description of the data sets of this assessment which support it. The general relationship of these data to the framework is also described. This information provides a general outline for identifying work that will be needed to fill the data gaps.

Data gaps and necessary data gathering activity

Data gaps have been categorized into the following areas of data need*:*

- Aquifer Analysis
- Hydraulic Continuity and streamflows
- Seawater Intrusion
- Precipitation
- Water Balance
- Fisheries Resource and Habitat Quality
- Current and Future Water Demand

To address the data needs in each subarea, the specifics of the subarea and relationship and status of all data sets need to be considered. For example, in an area where little is known about groundwater movement, and there are a limited number of pending applications for small quantities of water, yet the level of development is quite low, a modest effort at aquifer analysis might be adequate. By contrast, a similar situation where there are indications of over allocation (e.g., decreasing water levels or interference), would prompt a more focused and intensive groundwater investigation.

Water rights decision framework

All water right applications in the State are investigated by evaluating four areas, (sometimes referred to as "tests") (RCW 90.03.290). They are:

1. ". . . .what water, if any, is available for appropriation. . . . "
2. ". . . . to what beneficial use or uses it can be applied."
3. " . . . . the application will not impair existing rights . . . ."
4. ". . . . the application will not . . . be detrimental to the public welfare . . . ."

Not much has been written on these tests. Perhaps that is because of the need for flexibility in decision making and because the "tests" are sufficient for their purpose which is to provide a priority listing of access to available water. Flexibility is necessary due to the varied hydrological conditions throughout the state and differences between water uses. The

Department of Ecology is administratively responsible to interpret data and administer these tests.

The data needs outlined in this document are perceived as areas where additional data would help address one or more of the basic tests mentioned above. The relationship of data categories to the tests are outlined in **Exhibit 9-1**.

Relationship of data gaps to decision framework

A major question for decision makers is: "How significant is the data gap when compared to available data and the potential impact of the proposed allocation?" The significance of the data gaps relative to water rights decisions can be evaluated according to their relationship with other data sets and data gaps (level of understanding), and in relationship to indicators of over allocation.

In general, the significance of data gaps are directly related to the degree or assumed degree of water allocation. In other words, if the degree of water allocation is high in a subarea, it would be expected that the data gap would take on more significance or be more important. Thus, more data is likely to be required.

The significance of data gaps, however, can be increased or decreased by the relative level of other information (data sets). For example, a gap in fisheries data might be less significant if the level of aquifer understanding were high, and the impact of the proposed withdrawal were known to a higher degree. **Exhibit 9-2** outlines water rights decision data requirements.

Summary of findings

As a result of this Assessment, the relative importance of the data gaps in each of the subareas should be established. **Exhibit 9-3** suggest a format that could be used by Ecology to indicate the importance and degree of resources that should be applied to fill in the data gaps for a specific subarea as part of follow-on assessments.

Subarea Evaluations

The hydrologic characteristics of the principal aquifers within the 18 subareas have been discussed, in part, in preceding sections of this assessment. This section provides more in-depth descriptions of the hydrologic characteristics of the subareas, specifically in regard to information necessary for making water right decisions. Several factors can be considered in making water right decisions. Analysis should include factors such as: the potential for stream-aquifer continuity, the potential for seawater intrusion, and the degree of water resource allocation. Additional indicators that reflect the "health" of the hydrologic system include: ground water level trends, streamflow trends, and the health of the fisheries resource.

The following sub-sections apply the tests described above to each of the Kitsap subareas. Available data and degrees of hydrologic understanding vary between subareas. In addition, each sub-section includes a description of general subarea characteristics (land-use development, aquifers, soils, precipitation, and drainage), a recommendation for making allocation decisions, and other recommendations for additional hydrologic evaluation and water resource management.

Washington Department of Fish and Wildlife (WDFW) has not developed a standardized method for cataloging habitat and water quality information on small streams. Unlike the major salmon producing streams such as the Union and the Tahuya Rivers, the smaller systems are usually evaluated on the basis of presence or absence, and as in the other subareas, there is limited information on resident salmonids.

Because of the specific requirements of the Growth Management Act, considerable changes have occurred in the County's population forecast and comprehensive plan allocations. As of October 1997, significant issues remained to be resolved. Discussion in this document of population density, land cover, and land use has provided an overview of the general character of the County, which gives some indications of likely patterns of water use, and general indications of demand for the future. This document has not provided a much needed analysis of demand by subarea, because at this time (October 1997), the County Comprehensive Plan has been rejected by the Growth Management Hearings Board, urban growth areas are being re-designated, and population allocation figures may change.

New sources and water rights for some existing public water systems will be needed in the future. While this statement seems apparent, given the general growth expected, the size and extent (geographical) of this need is unknown. For example, it is not known whether existing rights for various purveyors are adequate for future needs. It is also not known what percentage of population in each of the subareas can be expected to be served by public water supply, and which can be expected to be served by private domestic wells.

Clearly, follow up studies will be required. Existing supply versus projected demand, data requirements, funding, etc. will be evaluated to set appropriate priorities for future studies by subarea. For example, if specific subareas show significant deficiencies when future demand is compared with existing capacity (water rights), then priority for future supply study should be focused in areas which could provide the increased demand. If studies raised significant policy questions relating to water resource management, then these issues can be addressed in the appropriate forum.

Recommendations

With any follow-up study, the following recommendations should be considered for all subareas:

- ❑ Additional analysis of land use, population, public water system capacity, and future demand
- ❑ Develop more comprehensive aquifer descriptions including:

- Discussions of general aquifer/aquitard properties and characteristics.

- A description of hydraulic relationships of recharge and discharge (including an adequate understanding of the hydraulic head relationships, gradients, and flows) between aquifers, within aquifer systems, and with surface water.

- Estimates of the ranges of T, K, S, or Sy for various aquifers and aquitards.
- An evaluation to identify recharge areas.
- Justification for estimates of aquifer boundaries, including summary tables of the wells used to establish boundaries for the principal aquifers, and relevant test data.
- An outline of the data used for geologic interpretation of aquifers, indicating sources and level of confidence.

- ❑ Evaluate the options of all water rights including those recently not in use.
- ❑ Develop a more accurate flow balance for each subarea, with particular attention to estimates of runoff.
- ❑ Identify desired, future monitoring sites.
- ❑ Conduct a more detailed analysis of water quality data for each subarea.
- ❑ Conduct an analysis of land use, population, public water system capacity, and the ability to meet future demand.
- ❑ Incorporate estimates of commercial/industrial water demand growth and single family vs. multi-family construction trends when they are available.
- ❑ Develop an estimate of actual water production from exempt wells and estimates of future changes in exempt well production, when post comprehensive land use projections become available.
- ❑ Enhance estimates of the degree of water resource allocation.
- ❑ Develop more comprehensive tracking and analysis of water levels in the various aquifers and evaluate the correlation of water level trends with the various causative factors (e.g. precipitation, production, land use change, etc.).

9.1 Hansville Subarea

The Hansville subarea is located at the northernmost extent of the County. The Hansville subarea is one of the most rural and forested subareas in the County. According to satellite data (1994) analyzed by Kitsap Public Utility District No. 1 (KPUD), the Hansville subarea covers approximately 17 square miles (about 4 percent of the County) and is about 94 percent forested or natural cover. An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Hansville subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 160 persons/square mile.

A detailed study in the Hansville subarea identified the Hansville and Sea Level Aquifers (Robinson and Noble, January 1990). The study concentrated on the Hansville Aquifer and defined the boundaries of this perched aquifer. The Hansville perched aquifer has a recharge area of approximately three square miles and is found above +200 feet mean sea level (MSL). Less is known about the extent and characteristics of other perched aquifers or the Sea Level Aquifer which occur between +50 to -100 feet MSL.

No detrimental ground water quality trends have been identified. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in some wells in the Hansville subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Existing data provide no evidence for significant nitrate contamination of the ground water beneath the Hansville subarea.

Surficial soils in the Hansville subarea are primarily Group A (very high infiltration potential), although areas of Group C and D soils (low to very low infiltration potential) occur. Precipitation is low relative to the rest of the County, ranging from about 26 to 33 inches/year. Drainage in the subarea occurs to a number of small streams, none of which have catchments larger than 2.5 square miles.

Existing and proposed land-use do not appear to represent significant threats to the water quality of this subarea.

9.1.1 Stream-Aquifer Continuity

The Hansville Aquifer is in relatively high continuity with surface water (Robinson and Noble, January 1990). The Hansville Aquifer is located within parts of six small drainage basins. Continuity between all streams and the Sea Level Aquifer is not well understood.

Under WAC 173-515-040, year-round closure of one stream, Little Boston Creek, has been established in the Hansville subarea. Little Boston Creek is located to the south of the Hansville Aquifer and appears to be in relatively low continuity with the Hansville Aquifer. It may be locally in continuity with the Sea Level Aquifer. Continuity may also exist between shallow ground water and non-closure streams with salmonid populations.

9.1.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the Hansville Aquifer because the entire aquifer occurs considerably above sea level. Seawater intrusion could occur in the Sea Level Aquifer if excessive ground water development were to occur. Elevated chloride concentrations are documented in only one location (south of Eglon) (Section 5.10.1). Relatively high values of electrical conductivity occur in various coastal and inland locations (Section 5.10.2). Although relatively high, they are not sufficiently high to suggest significant seawater intrusion is a wide spread problem throughout the subarea.

9.1.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Hansville subarea is relatively low compared to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 8 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Streamflows in the subarea are not subject to minimum instream flow requirements. Protection of streamflows is accomplished through a regulatory closure of Little Boston Creek.

Total inflow to the hydrologic system is estimated to be 14,100 acre-feet/year. Water right allocations in the Hansville subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 811 acre-feet per year. Ground water permits and certificates comprise 43 percent of these allocations. Water right claims in the subarea are on the order of 312 acre-feet/year. The claims are almost entirely registered for ground water sources.

9.1.4 Ground Water Level Trends

Insufficient data exist to evaluate ground water level trends in the Hansville subarea.

9.1.5 Streamflow Trends

No long-term streamflow data exist within the subarea. Only spot measurements of low flow are available.

9.1.6 Fisheries and Habitat

Although data on the small streams of this subarea is limited, a number of creeks which probably support populations of resident cutthroat trout. The importance of these small streams should not be overlooked and they should at least be cataloged by the County for future reference.

9.1.7 Allocation Decision Considerations

The Hansville subarea, one of the most rural subareas, has one of the lowest population densities in the County. Although the Hansville subarea has the least amount of rainfall in the County, the relative level of development of the water resource is very low at about 7 percent of estimated total inflow. Currently, ground water applications for the Hansville subarea request 301 GPM (0.7 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 3 percent of the total in flow. There are no surface water applications pending in the subarea.

Additional ground water development from the Hansville Aquifer will ultimately be limited by available recharge, given the limited areal extent of the recharge area and available precipitation. To accurately determine the total availability of additional ground water from the aquifer, more data collection and analysis will be required.

Available information for the Sea Level Aquifer is marginal for making additional water right decisions. Questions concerning the potential for seawater intrusion needs to be evaluated.

Water right allocation decisions in the Hansville subarea need to address hydraulic continuity and seawater intrusion concerns.

9.1.8 Recommendations

- ❑ Make significant development of the Hansville Aquifer contingent on water level monitoring and a water budget analysis which compares estimated recharge to current allocations.

- ❑ Require hydrogeologic characterization for the Sea Level Aquifer, including evaluation of stream-aquifer continuity and the potential for seawater intrusion. If the aquifer has a high seawater intrusion potential, water level and water quality monitoring should accompany ground water development.

- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

- ❑ Install a stream gage in the subarea if favorable conditions can be found. A probable location would be KPUD's spring site No. 2 on Hansville Creek.

- ❑ Include water level monitoring of suitable wells in the Hansville and Sea Level Aquifers as part of the GWMP water level monitoring network.

9.2 Kingston Subarea

The Kingston subarea is located in the north portion of Kitsap County. The Kingston subarea is one of the more rural and forested subareas in the County. A growing commercial and suburban area does exist in the vicinity of the ferry terminal in the unincorporated town of Kingston. Covering approximately 31 square miles (about 8 percent of the County), the Kingston subarea is about 94 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Kingston subarea has a moderately low population density relative to the other County subareas. Based on 1990 census data, the area had a population density of about 295 persons/square mile.

Three principal aquifers have been identified in the Kingston subarea: the Kingston Aquifer System, Suquamish-Miller Bay Aquifer System, and the Port Gamble South Aquifer (GWMP Vols. I and II). Discontinuous perched aquifers also exist in the subarea. The Port Gamble and Port Gamble South Aquifers particularly overlap into Port Gamble subarea. The Suquamish Tribe and KPUD are conducting on-going data collection and aquifer analysis on the Suquamish-Miller Bay System, Port Gamble South Aquifer, and the Kingston System. A number of studies provide varying amounts of hydrogeologic characterization information for these aquifers (GWMP 1991, AGI, 1989, Robinson & Noble, 1994).

The ground water in the Kingston subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in some wells throughout the Kingston subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. There is no evidence of significant nitrate contamination beneath the Kingston subarea. However, some localized nitrate and seawater contamination has been documented.

Surficial soils in the Kingston subarea are almost evenly distributed between Group A and Groups C and D. The soils, therefore, range from having very high infiltration potentials to very low infiltration potentials. Precipitation is low relative to the rest of the County, ranging from about 31 to 37 inches/year. Drainage in the subarea occurs primarily to Grovers and Thompson creeks. A number of other creeks drain relatively small catchments of the subarea.

Development and the location of urban activities in direct proximity to the Kingston Aquifer System could result in threats to aquifer quality. Most of the urban area is or is proposed to be sewered, and urban runoff will go to Puget Sound unless diverted to recharge. Most of the subarea is expected to remain suburban or rural with minimal threats to ground water other than those associated with private domestic land uses. The existence of a major transportation route through the recharge area does represent a risk to the aquifer.

9.2.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity varies between the three aquifers identified. Two aquifers in the subarea, the Kingston Aquifer System and Port Gamble South, are located entirely below sea level and have relatively low potential for continuity. The Suquamish-Miller Bay Aquifer System, located from sea level to 300 feet below sea level, does have potential for continuity to Grovers Creek and other streams discharging into Miller Bay. The characteristics of the possible continuity are not well understood. The potential for surface water continuity with perched aquifers is relatively high.

Instream flows have been established for Grovers Creek under WAC 173-515-030 during portions of the year. A seasonal stream closure has also been established for Grovers

Creek. Year-round closures have been established for Thompson Creek, Cowling Creek, and several smaller streams in the subarea.

9.2.2 Seawater Intrusion Potential

Seawater intrusion could occur in the aquifers in the subarea if excessive ground water development were to occur. There is no evidence of extensive seawater intrusion beneath the Kingston subarea; however, relatively high values of electrical conductivity (EC) at coastal locations suggest that ground water quality is affected by nearby seawater. Elevated chloride concentrations also tend to occur in coastal locations, but (similar to EC) may occur at inland areas and therefore are not necessarily indicative of seawater intrusion. Significant localized seawater intrusion has been identified in the Jefferson Beach vicinity where the wells are generally shallow and have completion elevations that range from slightly above to slightly below sea level.

9.2.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Kingston subarea is relatively high in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 24 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. In addition, minimum instream flow requirements and regulatory closures may also limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 31,200 acre-feet/year. Water right allocations in the Kingston subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 6,471 acre-feet per year. Ground water permits and certificates comprise 97 percent of these allocations. Water right claims in the subarea are on the order of 1,020 acre-feet/year. Approximately 95 percent of this volume is claimed from ground water sources.

9.2.4 Ground Water Level Trends

The apparent water level trends for water years 1991 through 1996 show a relation to natural variability in precipitation for aquifers located above and below sea level. Apparent water level declines of 10 feet or more have been identified in the Suquamish-Miller Bay Aquifer System (KPUD monitoring data, wells AAB406, AAA014 and AAA710). All three wells have completion elevations generally -100 to -300 feet MSL. Probable causes of declines include precipitation deficits, ground water withdrawal for potable supply and to a lesser extent for fish propagation. Currently all three hydrographs suggest that declines have moderated and a new equilibrium may have been established for the aquifers involved.

9.2.5 Streamflow Trends

Though no long-term streamflow data exist within the subarea and no stations are monitored on a continuous basis, the Suquamish Tribe has established on-going streamflow monitoring at a number of sites in the subarea. Spot measurements for stream flow (primarily low - flow measurements) are available .

9.2.6 Fisheries and Habitat

With the exception of a small, unnamed creek which enters the east side of Port Gamble Bay, there is a limited amount of data on the quality of fisheries habitat in the Kingston subarea. Information concerning flow and water quality on Grovers Creek is available. It is the major source of water for the Suquamish Tribal hatchery. The hatchery is located within 400 yards of the high tide level of Miller Bay, and there is a total blockage to any migration beyond that point. The only data on the stream are in the environmental impact studies for two proposed large projects. Logging and agricultural practices have reduced the quality of the habitat.

9.2.7 Allocation Decision Considerations

The Kingston subarea has a moderately low population density relative to the other County subareas. Water resource development in this subarea, which is 24 percent of total inflow, is the fourth highest in the County. Currently, water right applications for the Kingston subarea request 3250 GPM (7.2 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 17 percent of the in flow. Ground water applications comprise 93 percent of these applications.

Additional data will be needed to make most water rights decisions for the Suquamish-Miller Bay Aquifer System. The cause for water-level declines in this aquifer system should be identified, and improved understanding of stream-aquifer continuity is warranted.

Available data for various production zones that make up the Kingston Aquifer System and Port Gamble South Aquifer could be improved. Upon further analysis of certain portions of these aquifers, adequate data may exist to enable Ecology to make water right decisions. Questions remain concerning seawater intrusion potential and sustainable yield.

9.2.8 Recommendations

- ❑ Continue comprehensive water level monitoring network for the subarea in coordination with Tribal efforts.

- ❑ Conduct preliminary evaluation of KPUD and Tribal data for the Suquamish/Indianola area.

- ❑ Continue periodic water quality monitoring of KPUD subarea wells, monitoring of coastal wells at Jefferson Beach and other areas of interest, and coordinate with Tribal efforts in coastal locations to provide early warning for potential seawater intrusion.

- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

- ❑ The Suquamish Tribe (Grovers Creek) should continue making spot measurements of flow and recording at least daily staff gage readings.

9.3 Port Gamble Subarea

The Port Gamble subarea is located in the northern portion of the County along Hood Canal. The Port Gamble subarea is among the more rural and forested subareas in the County. Covering approximately 19 square miles (about 5 percent of the County), the Port Gamble subarea is about 95 percent forested or natural cover (Satellite data analysis- KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in rural, forested, or open space categories.

The Port Gamble subarea has a moderately low population density compared to other subareas in the County. Based on 1990 census data, the area had a population density of about 220 persons/square mile.

Three principal aquifers have been identified in the subarea: Edgewater, Port Gamble, and Port Gamble South Aquifers. The Port Gamble and Port Gamble South Aquifers partially overlap into the Kingston subarea. The extent of the Edgewater Aquifer is poorly defined (GWMP Vol. I and II). The Port Gamble Aquifer is newly identified (Robinson and Noble, March 1994) with a recharge area of approximately eight square miles. Discontinuous perched aquifers also occur in the subarea. The cited references contain varying amounts of hydrogeologic characterization data for these aquifers.

The ground water in the Port Gamble subarea is generally of good quality and suitable for most purposes. Limited water quality data were available from the northern and central portions of the subarea. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in areas of data availability throughout the Port Gamble subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Existing data provide no evidence of nitrate contamination beneath the Port Gamble subarea.

Surficial soils in the Port Gamble subarea are largely Group A (very high infiltration potential), although significant areas of Group C and D soils (low to very low infiltration potential) occur. Precipitation is moderately low relative to the rest of the County, ranging from about 33 to 41 inches/year. The primary drainages in the subarea (Gamble Creek and an unnamed creek) originate outside of the subarea. Several other creeks with smaller catchments drain to Port Gamble Bay and Hood Canal. A review of the original subarea boundaries which are used throughout this initial basin assessment revealed that several streams originated in one subarea and drained into another. Revisions to subarea boundaries have been made to resolve this problem. Future studies and evaluations will use the revised subarea boundaries **(Exhibit 2-1a)**.

Exhibit C-13 of GWMP, Vol. III, Appendix C shows a large surface mine overlying a part of the Edgewater Aquifer, as well as an adjacent wetland. This may constitute a threat to the aquifer. Based on existing and proposed future land use patterns, threats to the newly identified Port Gamble Aquifer appear negligible.

9.3.1 Stream-Aquifer Continuity

Because they have zones located above sea level, both the Edgewater and Port Gamble Aquifers have relatively high potential to be in continuity with surface water. This potential continuity should be investigated. Perched aquifers in the subarea are also likely to be in continuity with surface water.

A year-round stream closure has been established for Gamble Creek under Chapter 173-515 WAC.

9.3.2 Seawater Intrusion Potential

The potential for seawater intrusion in the subarea exists. Seawater intrusion could occur in the Edgewater and Port Gamble Aquifers if excessive ground water development were to occur. Seawater intrusion is not possible for the perched aquifers because these aquifers occur above sea level. There is no evidence for extensive seawater intrusion beneath the Port Gamble subarea. However, relatively high values of EC and chloride along Hood Canal suggest that ground water quality is affected by nearby seawater.

9.3.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Port Gamble subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 11 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. No minimum instream flow requirements have been established in the subarea. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 21,300 acre-feet/year. Water right allocations in the Port Gamble subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 1,440 acre-feet per year. Ground water permits and certificates comprise 94 percent of these allocations. Water right claims in the subarea are on the order of 913 acre-feet/year. Approximately 89 percent of this volume is claimed from ground water sources.

9.3.4 Ground Water Level Trends

A hydrograph of well AAA103 shows no apparent water level decline in the Edgewater Aquifer for water years 1991 to 1996 but a possible 10 foot decline since late 1987 (KPUD monitoring data). Natural variability in precipitation is a probable factor in the apparent long-term decline, and has yet to be evaluated. Lack of long-term data for other wells in the Port Gamble Aquifer will hamper an analysis of water level trends.

9.3.5 Streamflow Trends

No long-term streamflow data exist within the subarea. Only spot measurements of low flow in streams are available (see Appendix C).

9.3.6 Fisheries and Habitat

With the exception of Gamble Creek, there is a limited amount of data on the quality of fisheries habitat in the Port Gamble subarea. The summary data documented by Puget Sound Cooperative River Basin Team (PSCRBT 1993) indicates that a tributary of Gamble Creek which once supported salmon has limited utilization and that habitat degradation has occurred.

9.3.7 Allocation Decision Considerations

The Port Gamble subarea has a moderately low population density compared to other subareas in the County. The subarea has a moderate level of development of the water resource at 11 percent of total inflow. Currently, water right applications for the Port Gamble subarea request 3395 GPM (7.6 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 26 percent of the total inflow. Ground water applications comprise 99 percent of the requested withdrawal.

Apparent water level declines in the Edgewater Aquifer may limit the potential for additional supply.

Based on preliminary studies, the Port Gamble Aquifer shows good potential for additional supply. Additional information is needed to better estimate the total amount of resource available.

9.3.8 Recommendations

- ❑ Conduct a hydrogeologic study and test drilling program to better define the extent, potential, and characteristics of the Port Gamble Aquifer.

- ❑ Make arrangements, prior to conclusion of the Bangor Study, with the United States

Geological Survey (USGS) to continue measurement of surface water flows on Gamble Creek using equipment erected by the USGS for the Bangor Study.

- ❑ Collect water levels for both aquifers to determine long-term trends.
- ❑ Add additional wells to the water level monitoring network for the subarea.
- ❑ Continue collecting wet season/dry season chloride data from production wells in the Gamblewood and Vinland water systems to evaluate seawater intrusion potential.

9.4 Poulsbo Subarea

The Poulsbo subarea is located in the north-central portion of Kitsap County. The Poulsbo subarea is an urbanizing subarea. Covering approximately 19 square miles (about 5 percent of the County), the Poulsbo subarea is about 87 percent forested or natural cover (Satellite data analysis- KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories with about 7 percent in urban classification.

The Poulsbo subarea has a medium population density compared with the rest of the County's subareas. Based on 1990 census data, the area had a population density of about 450 persons/square mile.

A hydrogeologic study of the Poulsbo Aquifer, the only principal aquifer so far identified in the subarea, has been conducted for the City of Poulsbo (Robinson and Noble, November 1992). Discontinuous perched aquifers also occur in the subarea. Cited references contain hydrogeologic characterization information for the aquifer.

No detrimental water quality trends have been noted. The ground water in the Poulsbo subarea is generally of good quality and suitable for most purposes. Only limited water quality data were available in the southwestern portion of the subarea. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits at various locations within the Poulsbo subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. There is no evidence of nitrate contamination beneath the Poulsbo subarea. Elevated nitrate concentrations are noted along the boundary between the Poulsbo and Kingston subareas.

Surficial soils in the Poulsbo subarea are predominantly classified as Group C or D, and, therefore, have low to very low infiltration potentials. Precipitation is moderately low compared to the rest of the County, ranging from about 36 to 41 inches/year. Drainage in the subarea occurs primarily to Dogfish and Johnson creeks. A number of other creeks (some with very small catchments) drain to Liberty Bay.

The proposed growth scenarios for lands overlying the Poulsbo Aquifer shows an increase in urban and semi-urban development. Although part of the aquifer area will likely be sewered, threats to the aquifer will result from stormwater and drainage impacts on recharge and water quality. Additionally, the urban activities and development can present potential threats to the underlying aquifer.

9.4.1 Stream-Aquifer Continuity

A study of the stream-aquifer continuity for the Poulsbo Aquifer (Robinson and Noble, November 1992) showed that the aquifer has relatively low continuity with Dogfish Creek due to the occurrence of thick, fine-grained aquitard. The perched aquifers are likely to be in continuity with surface water in the subarea.

Year-round stream closures have been established for Dogfish and Johnson Creeks under Chapter 173-515 WAC.

9.4.2 Seawater Intrusion Potential

The perched and Poulsbo Aquifers occur entirely above sea level. Seawater intrusion is not possible for these aquifers. There is no evidence for extensive seawater intrusion beneath the Poulsbo subarea. Based on hydrogeologic considerations, seawater intrusion could constitute a threat to coastal areas if excessive ground water development were to occur.

9.4.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Poulsbo subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 19 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. No minimum instream flow requirements have been established in the subarea. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 22,000 acre-feet/year. Water right allocations in the Poulsbo subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 2,708 acre-feet per year. Ground water permits and certificates comprise 95 percent of these allocations. Water right claims in the subarea are on the order of 1,433 acre-feet/year. Approximately 90 percent of this volume is claimed from ground water sources.

9.4.4 Ground Water Level Trends

Short-term (water year 1991 to 1996) apparent water level trends for wells in the Poulsbo Aquifer suggest water levels have declined several feet (wells AAB481, AAB482). A single hydrograph for a deep well completed below the Poulsbo Aquifer at -200 feet MSL (AAA254) suggests a decline of approximately 16 feet between 1976 and 1995 (1976 to

1990 was a period of no data). Between water year 1991 to 1995 the apparent decline was about 1 to 3 feet for the deep well. Unfortunately no other data are available from other deep wells to substantiate aquifer changes.

9.4.5 Streamflow Trends

KPUD is currently collecting streamflow data for Dogfish Creek. Earlier data were collected continuously by the USGS between 1948 and 1970. The data show a relatively stable annual streamflow trend, although there is some suggestion that, in later years, higher rainfalls may have been required to get similar streamflow volumes (Section 4.4.1). The data do not suggest discernible trends in minimum flow. Dogfish Creek is protected by a regulatory stream closure under Chapter 173-515 WAC.

Only spot measurements of low flow are available for other streams (see Appendix C).

9.4.6 Fisheries and Habitat

Coho, chinook, and chum salmon are the predominant species found in Dogfish Creek. Chinook and chum salmon are currently stocked in Dogfish Creek by the Suquamish Tribe. Johnson Creek supports chum and coho salmon, as well as trout species. Coho salmon and cutthroat trout have been noted in both Lemolo and Klebeal Creeks.

Some data are available on Dogfish Creek from the Suquamish chinook salmon enhancement for a terminal Tribal fishery in Liberty Bay. Limited quantified data is available on the actual habitat of the streams in this unit and low flow data should be collected.

9.4.7 Allocation Decision Considerations

The Poulsbo subarea has a medium population density compared with the rest of the County's subareas. The relative level of development of the water resource is moderate at 19 percent of total inflow. Ground water right applications for the Poulsbo subarea request 2794 GPM (6.2 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 20 percent of the total inflow.

The available information on the Poulsbo Aquifer does address stream-aquifer continuity but does not resolve the quantity of water available from the aquifer. The Poulsbo Aquifer's lateral extent and usage suggests limited potential for additional future supply. Apparent water-level declines in a deep aquifer in the subarea should also be reviewed.

Available information for the perched aquifers is less than adequate for making water right decisions. Questions concerning potential stream-aquifer continuity need to be resolved in order to make additional water right decisions.

9.4.8 Recommendations

- ❑ Evaluate the subarea for the existence of other aquifers.

- ❑ Continue the established ground and surface water monitoring network.

- ❑ KPUD, Tribe, and others should continue to collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

9.5 Bangor Subarea

The Bangor subarea is located in the central portion of Kitsap County. It is a growing area that includes the unincorporated urban center of Silverdale, the United States Navy's Subase Bangor, and the Keyport Naval Undersea Center. The Bangor subarea covers approximately 36 square miles (about 9 percent of the County). Silverdale is the largest unincorporated urban area in the County and the largest commercial center. An industrial area is developing west of Silverdale. Because of Silverdale and the cleared sections on the Subase, the forest and natural cover for the area is only about 80 percent (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows a significant amount of land (about 35 percent) as industrial, but shows over half of the remaining land in open, forested, or water classifications with only 10 percent in an urban classification.

The Bangor subarea has a medium population density compared to other County subareas. Based on 1990 census data, the area had a population density of about 636 persons/square mile.

Four principal aquifers have been identified in the Bangor subarea: the Island Lake, Silverdale, and Keyport Aquifer, and the Bangor Aquifer System. Substantial amounts of data have been collected while studying the Island Lake Aquifer (Robinson and Noble, January 1991). The boundaries of the Silverdale and Keyport Aquifers are not well defined. A comprehensive evaluation of the Bangor Aquifer System, including a three-dimensional numerical model, has been completed (Becker, 1995a, 1995b). Numerical modeling of the Bangor Aquifer System by the USGS is in progress. The Bucklin Hill Aquifer is described in the Manette subarea section (9.7). The cited references contain considerable hydrogeologic characterization information for these aquifers.

The ground water in the Bangor subarea is generally of good quality and suitable for most purposes. Iron and manganese concentrations which exceed recommended aesthetic limits occur throughout the Bangor subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Nitrate concentrations did not exceed primary drinking water standards in any of the Bangor subarea wells sampled. Several wells along Liberty Bay had concentrations which appeared to be affected by localized nitrate contamination.

Surficial soils in the Bangor subarea are predominantly classified as Group C or D, and therefore, have low to very low infiltration potentials. Precipitation is average compared to the rest of Kitsap County, with annual values between 37 and 49 inches/year. Drainage in the subarea occurs primarily to Strawberry, Clear, Scandia, and Barker Creeks. Numerous other streams in the subarea have more limited catchments.

The larger threats to the Bangor subarea aquifers probably relate to past land use activities rather than future authorized land uses. However, assuming that the remediation programs for the various identified contamination sites (e.g., those on the Bangor Subase and Keyport) are successful, the threats should be reduced to a large degree. The rail system to Subase Bangor could be of concern. In recent years it has not been used for transporting materials which are potential hazards to the aquifer. The continuing increase in urbanization of the Silverdale area creates a need for monitoring to assure that the underlying Silverdale Aquifer is adequately protected.

9.5.1 Stream-Aquifer Continuity

Potential for stream-aquifer continuity varies between the four aquifers identified. The Island Lake Aquifer, located primarily above sea level, has varying degrees of continuity with surface water in Island Lake and Barker Creek. The Silverdale and Keyport Aquifers, located below sea level, have relatively low continuity with surface water. The continuity of the Bangor Aquifer System is variable for different zones within the system. The perched aquifer of the Bangor Aquifer System is in relatively high continuity with surface water. The Sea Level and Semi-perched Aquifers of the Bangor Aquifer System have relatively low continuity with surface water (Becker, 1995a). The Deep Aquifer has relatively low continuity with surface water.

Instream flows have been established for Strawberry Creek under WAC 173-515-030. Seasonal or year-round stream closures have been also been established for Strawberry, Barker, Clear, and Scandia Creeks.

9.5.2 Seawater Intrusion Potential

The potential for seawater intrusion varies between the four aquifers identified. Seawater intrusion is not possible for the perched and Island Lake Aquifers because these aquifers occur above sea level. Seawater intrusion could occur in the Keyport and Silverdale aquifers, and Bangor Aquifer Systems if excessive ground water development were to occur. There is no evidence for extensive seawater intrusion beneath the Bangor subarea. However, relatively high values of EC along Liberty Bay suggests that ground water quality is affected by nearby seawater and some chloride values above background levels have been observed in the Keyport Aquifer (KPUD data). Seawater intrusion (high chloride concentrations) was documented in the Sea Level Aquifer of the Bangor Aquifer System during the dewatering event for dry-dock construction at Bangor Subase (Paterson, 1981). Chloride concentrations in the Subase wells have generally returned to near-background levels (Becker, 1995b).

9.5.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Bangor subarea is moderately high compared to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 23 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. An important further note is that these totals do not include unquantified federal rights for the Bangor Subase or Keyport Naval Undersea Center. In addition, minimum instream flow requirements and regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 47,600 acre-feet/year. Water right allocations in the Bangor subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 9,039 acre-feet per year. Ground water permits and certificates comprise 88 percent of these allocations. Water right claims in the subarea are on the order of 1,797 acre-feet/year. Approximately 96 percent of this volume is claimed from ground water sources.

9.5.4 Ground Water Level Trends

Over the short-term (water year 1991 to 1996) only several well hydrographs have notable declines. However, a relatively large number of hydrographs for wells in the Bangor subarea have long-term declines of 10 feet or more. These wells include AAA728, AAA730, AAA734, AAA746, AAA748, AAA749 AAC629 and AAA639. Most of the wells are associated with centers of ground water withdrawal, but natural variability in precipitation is also an important factor in the declines. Data show a decline in water levels in the Island Lake Aquifer (Robinson and Noble, January 1991). At this time, long-term data already collected for the Silverdale and Keyport Aquifers have not been formally evaluated. Water levels in the Bangor Aquifer System showed relatively stable water levels in all aquifers from 1981 to 1993. Since 1993, a decline of 2 to 5 feet has occurred which appear to be solely a result of corresponding changes in precipitation (Becker, 1995a).

9.5.5 Streamflow Trends

No long-term streamflow data exist within the subarea. KPUD is currently collecting streamflow data for Barker and Clear Creeks. Silverdale Water District records staff gage readings twice daily, Monday through Friday on Strawberry Creek. Short-term continuous streamflow records for Barker Creek (1991-1994) indicate a decline in (summer) minimum flows which may be attributable to climatic or other causes. Short-term, continuous streamflow records on Clear Creek (1991-94) show relatively stable trend in (summer) minimum flows. Barker Creek is protected year-round by regulatory stream closure under Chapter 173-515 WAC.

Only spot measurements are available for other streams.

9.5.6 Fisheries and Habitat

The Bangor subarea includes drainages into the Upper Hood Canal Watershed, Liberty Bay Watershed, and Dyes Inlet Watershed. For simplicity, creeks which drain into other watershed areas (i.e., Big and Little Scandia Creeks, Clear Creek, Barker Creek, Strawberry Creek) are included here.

Clear and Barker Creeks have important runs of chum and coho (Williams, et. al., 1975). Coho and chum salmon have also been noted in Strawberry Creek. Low summer flows affect production of coho and chum salmon in these drainages.

Coho and chum salmon as well as cutthroat trout are known to utilize both Big and Little Scandia Creeks. The Scandia Creeks are impacted primarily by poor riparian zone management resulting in little or no streamside vegetation and heavy sedimentation.

There are two major drainages within the Bangor Subase, Devil's Hole Lake, and Cattail Lake. Fisheries management plans have been developed for both of these drainages. Stream flow from the main stem entering Devil's Hole Lake averages 4.0 cfs. A second smaller stream has been diverted. Devil's Hole Lake and main stem both contain good fish habitat and have adequate vegetation. A fish ladder constructed in 1981 allows fish passage into and out of the lake from Hood Canal. The Lake contains native cutthroat and coho salmon. A net pen in the lake allows rearing the juvenile coho to a larger release size. Cattail Lake drains into Hood Canal by culverts that do not allow fish passage. However, Cattail Lake and its feeder streams are well vegetated and provide good fish habitat.

Stream flows were recorded for the west fork of Clear Creek from 1947 through 1975. Three measurements were recorded on the mainstream above the confluence of the west fork of Clear Creek in 1975. Flows ranged from 2.2 to 4.6 cfs in the west fork and 0.6 to 1.4 in the main stem. Barker Creek has flows recorded at the outlet of Island Lake ranging from zero to 0.1 cfs from 1969 through 1971. Stream flows recorded in Strawberry Creek for the summer and fall of 1971 ranged from 1.5 to 1.7 cfs. No flow data is available for Big or Little Scandia Creeks.

9.5.7 Allocation Decision Considerations

The Bangor subarea has a medium population density compared to other County subareas. The relative level of development of the water resource is high at 23 percent of total inflow. Ground water applications for the Bangor subarea currently request 8142 GPM (18.1 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 28 percent of the total inflow. There are no surface water applications pending in the subarea.

Information gained from existing studies on the Bangor Aquifer System will help Ecology make informed water rights decisions. Water levels in most aquifers may be in equilibrium with current withdrawals and precipitation trends. Existing data suggest that additional ground water may be available from the aquifer system which could be used for future appropriations.

Information collected by Silverdale Water District since 1992 for the Island Lake Aquifer has not been formally reviewed. Historical water level declines and stream-aquifer continuity are concerns for the area. The water level and production trends for the Island Lake Aquifer should be evaluated to provide information for water right decisions.

Available information for the Keyport and Silverdale Aquifers is insufficient for making water right decisions. Questions regarding water level trends and seawater intrusion need to be resolved for both aquifers concurrent with ground water development in order to make water rights decisions.

9.5.8 Recommendations

- ❑ Complete a comprehensive hydrogeologic analysis of the Silverdale, Keyport, and Island Lake Aquifers. The existing water level data for the Island Lake Aquifer should be compiled, evaluated, and compared them with precipitation trends.
- ❑ Continue and expand hydrogeologic data collection network.
- ❑ KPUD, Tribe, and others should continue to collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Continue to collect water quality data in coastal locations to evaluate seawater intrusion potential.
- ❑ Include when available the data and analysis developed by USGS for the ongoing Bangor area study
- ❑ Evaluate the extent of the other aquifers in the subarea outside of the Bangor Aquifer System. Specifically the deep, below sea level aquifers in the vicinity of the Island Lake Aquifer.

9.6 Bainbridge Island Subarea

The Bainbridge Island subarea encompasses the entire island located in east-central portion of Kitsap County. The Bainbridge subarea is mainly suburban but it does have significant areas of forest and natural cover. The subarea has a growing commercial area near historic Winslow and scattered small industrial areas. Covering approximately 29 square miles (about 7 percent of the County), the Bainbridge subarea is about 87 percent forested or natural cover (Satellite data analysis - KPUD, 1994). Reflecting the incorporation of the Island as a city, an evaluation of land use types classified by the County Assessor shows 100 percent of the island as urban in classification. The City, however, has zoned 48 percent of the island at one unit per 2.5 acres.

The Bainbridge subarea has a medium population density relative to the other County subareas. Based on 1990 census data, the area had a population density of about 540 persons/square mile.

Six principal aquifers have been identified in the subarea: Meadowmeer Aquifer, Eagle Harbor Aquifer, Bayhead Aquifer, Lynwood Center Aquifer, Wardwell Aquifer System, and Gilberton-Fletcher Bay Aquifers System (GWMP, 1991). A comprehensive evaluation of the Meadowmeer Aquifer has been completed (Purdy, 1990). Various studies have been accomplished on the other aquifers and hydrogeologic characterization. Information is contained in numerous consultant reports (Robinson & Noble and others). The USGS has performed a study for the shallow ground water system on Bainbridge Island (Dion and others, 1988).

The ground water in the Bainbridge Island subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in wells throughout the Bainbridge Island subarea. Exceedences of the manganese MCL are less common than exceedences of the iron MCL. Existing data suggest that several areas may have greater likelihood of high iron concentrations. These areas include: an east-west band between Westwood and Eagle Harbor, a band extending between Murden Cove and Manzanita Bay, and the Port Madison Peninsula. Nitrate concentrations did not exceed primary drinking water standards in any of the Bainbridge Island wells considered. Several wells had concentrations which appeared to be affected by nitrate contamination.

Surficial soils in the Bainbridge Island subarea are predominantly classified as Group C or D, and, therefore, have low to very low infiltration potentials. Precipitation is moderately low compared to the rest of the County, ranging from about 34 to 39 inches/year. Most of the streams in the subarea have relatively small catchments.

Development and the location of urban activities in direct proximity to some of the aquifers on Bainbridge Island could result in threats to aquifer quality. While there is one historic landfill on the Island, and there are contaminated sites near (and under) the shoreline in Eagle Harbor, these are predominately in urban areas. Most of the urban area is, or is proposed to be, sewered and urban runoff will go to Puget Sound unless diverted to recharge. Most of the subarea is expected to see limited development in the near term with minimal threats to ground water other than those associated with private domestic land uses. The existence of a major transportation route through the island does represent a risk to some of the aquifers, and should be considered when developing sources for municipal/domestic supply.

9.6.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity varies between the six aquifers identified. Studies suggest that the Meadowmeer Aquifer is in relatively high continuity with small unnamed streams (Purdy, 1990). Because all the other aquifers occur below sea level, the potential for stream-aquifer continuity for the Eagle Harbor, Bayhead, Lynwood Center, Wardwell System, and Fletcher Bay System is relatively low.

Year-round stream closures have been established for two small unnamed streams that are tributary to Murden Cove and Fletcher Bay.

9.6.2 Seawater Intrusion Potential

The potential for seawater intrusion varies between the six aquifer systems identified. Seawater intrusion is not possible for the Meadowmeer Aquifer and other perched aquifers, because these aquifers occur above sea level. Seawater intrusion could occur in the Eagle Harbor, Bayhead, Lynwood Center, Wardwell System, and Fletcher Bay System if excessive ground water development were to occur. However, there is no evidence for significant seawater intrusion beneath the Bainbridge Island subarea. Time trend analyses of chloride levels in individual wells did not indicate that seawater intrusion was occurring (Dion and others, 1988). Relatively high values of electrical conductivity and chloride along the coast, however, suggest that ground water quality is affected by nearby seawater. Individual wells with high EC and chloride values may reflect localized seawater intrusion.

9.6.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Bainbridge Island subarea is relatively high in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 30 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Streamflows in the subarea do not have minimum instream flow requirements. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 31,100 acre-feet/year. Water right allocations in the Bainbridge Island subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 6,737 acre-feet per year. Ground water permits and certificates comprise 94 percent of these allocations. Water right claims in the subarea are on the order of 2,481 acre-feet/year, all of which, is claimed from ground water sources.

9.6.4 Ground Water Level Trends

Water level trends in all aquifers show a relation to natural variability in precipitation. In the Fletcher Bay Aquifer System, a single hydrograph (well AAA111, completed below -800 MSL), has shown notable long-term declines of over 10 feet, though water levels may have now stabilized at their lower level. Wells AAA112, AAB455 and other deep wells on the island have apparent declines which need further review Data has not been evaluated for the Wardwell Aquifer System, Lynwood Center, and Bayhead Aquifers.

One well (AAC832), believed to be in the Meadowmeer Aquifer, with a completion elevation above sea level has shown a notable decline in water level.

9.6.5 Streamflow Trends

No long-term streamflow data exist within the subarea. Spot measurements of low flow are available for some streams. (Garling and Others, 1965, City of Bainbridge Island, City Watershed Assessment Group).

9.6.6 Fisheries and Habitat

Although there are no large streams on Bainbridge Island, there are four streams which support anadromous salmonid populations. All of the streams of the Island are presently being cataloged for the purpose of revising the stream classifications and as part of the activities of the City's Watershed Assessment Group. Water quality data in addition to fisheries habitat are being collected.

Most streams appear to have suffered from the impact of development and below average rainfall. In addition, unauthorized withdrawal of water for irrigation may be occurring on most of the streams on Bainbridge Island (comments in public hearing for Comprehensive Plan).

9.6.7 Allocation Decision Considerations

The Bainbridge subarea has a medium population density relative to the other County subareas. The relative level of development of the water resource is second highest in the County at 30 percent of total inflow. Currently, water right applications for the Bainbridge Island subarea request 4333 GPM (9.7 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 22 percent of the total inflow. Ground water applications comprise 90 percent of these applications.

Available information for the Fletcher Bay Aquifer System, Wardwell Aquifer System, Lynwood Center, Eagle Harbor, and Bayhead Aquifers require more formal review than the current assessment. Individual study has been conducted on the Meadowmeer Aquifer and sufficient data may be available to make water right decisions. Questions regarding water level trends and seawater intrusion need to be resolved for these aquifers in order to make water right decisions.

9.6.8 Recommendations

- ❑ Complete a comprehensive hydrogeologic analysis of below sea level aquifers to complement the USGS study.

- Continue and expand hydrogeologic data collection network.

- Install stream gages in the subarea if favorable conditions exist.

- Collect and document stream flow, temperature, and dissolved oxygen for appropriate large streams during the low flow period from mid-June to the end of September (or until the fall rains begin).

- Catalogue the fisheries resource of the subarea.

9.7 Manette Subarea

The Manette subarea is located in the east-central portion of Kitsap County. The Manette subarea is the most urbanized subarea in the County. Covering approximately 18 square miles (about 5 percent of the County), the Manette subarea is about 70 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows a lower total percentage of the area in suburban, forested, or open space categories (62 percent) than the satellite data. Urban and commercial classifications for this area are the highest in the County at 37 percent.

The Manette subarea has the highest population density of the County's subareas. Based on 1990 census data, the area had a population density of about 2,000 persons/square mile.

Three principal aquifers have been identified in the subarea: Bucklin Hill Aquifer, Gilberton-Fletcher Aquifer System, and Manette-Bremerton North Aquifer. The extent of the Bucklin Hill Aquifer is poorly defined. The Gilberton-Fletcher Aquifer System is a two-aquifer system (GWMP, 1991). The extent of the aquifer system is poorly defined. The boundaries of Manette-Bremerton North Aquifer are not well defined. Additional study is being accomplished on all of these aquifers (AGI, 1996) and hydrogeologic characterization information is available.

Ground water quality data from the Manette subarea are only available from several wells in the northern portion of the subarea. Much quality data, required by State and local health departments, that is taken by major purveyors of the subarea was not reviewed. General statements as to water quality in the subarea are limited by data availability. The occurrence of iron and manganese in the Manette subarea appears to be similar to neighboring subareas, based on the limited amount of water quality data that was reviewed. The data do not reveal nitrate contamination, and are insufficient to characterize seawater intrusion.

Surficial soils in the Manette subarea are largely Groups C and D (low to very low infiltration potentials), although localized areas of Group A soils (very high infiltration potential) occur. Precipitation is average compared to the rest of the County, ranging from about 37 to 46 inches/year. Drainage in the subarea occurs to Steel Creek and many other small streams.

The present high urban and commercial development in the Manette subarea is expected to increase substantially, resulting in a commensurate increase in threats to the three aquifers identified in this subarea. The threats include stormwater and drainage impacts, increased potential for transportation material spills, potentially adverse impacts from urban and associated commercial service activities, and reductions in recharge as impervious surface increases.

9.7.1 Stream-Aquifer Continuity

The Gilberton-Fletcher Bay System and Bucklin Hill Aquifer, both located greater than 300 feet below sea level, have relatively low potential for stream-aquifer continuity. Potential continuity between the Manette-Bremerton North Aquifer, located from sea level to 250 feet below sea level, and surface water is not well understood.

Instream flows have been established for Steel Creek during portions of the year under WAC 173-515-030. Seasonal or year round stream closures have been also been established for Steel and Mosher Creeks.

9.7.2 Seawater Intrusion Potential

The potential for seawater intrusion varies between the three aquifer systems identified. Seawater intrusion could occur in all aquifers if excessive ground water development were to occur. The potential for seawater intrusion for the Bucklin Hill Aquifer is relatively low, because it is located inland and 400 to 700 feet below sea level.

9.7.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Manette subarea is relatively high in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 43 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. This is the highest value of all subareas which range from less than 1 to 43 percent. In addition, minimum instream flow requirements and regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 22,700 acre-feet/year. Water right allocations in the Manette subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 8,819 acre-feet per year. Ground water permits and certificates comprise 99 percent of these allocations. Water right claims in the subarea are on the order of 881 acre-feet/year. Approximately 93 percent of this volume is claimed from ground water sources.

9.7.4 Ground Water Level Trends

Unfortunately, no water-level hydrographs for the Manette subarea are included in this basin assessment. There are many important wells in portions of the Manette subarea that are operated by Bremerton Water Utilities and North Perry Avenue Water District. Studies are being completed by those purveyors to evaluate the water resources in their portions of the Manette subarea (AGI, in progress). The studies will presumably include review of water-level trend data.

9.7.5 Streamflow Trends

No long-term streamflow data exist within the subarea. Only spot measurements of low flow are available. (Garling and Others, 1965).

9.7.6 Fisheries and Habitat

Limited fisheries or stream flow information is available for creeks in this subarea.

9.7.7 Allocation Decision Considerations

The Manette subarea has the highest population density of the County's subareas. The relative development of the water resource is highest in the county at 43 percent of total inflow. Water right applications for the Manette subarea request 3251 GPM (7.2 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 23 percent of the total inflow. Ground water applications comprise 86 percent of the requested withdrawal.

Current studies in this subarea may provide insight on questions concerning water level trends, water usage and other data required for water right decisions.

9.7.8 Additional Recommendations

- ❑ Characterize and define areal extents of all aquifers.
- ❑ Conduct a study of recharge and production potential for all aquifers.
- ❑ Continue and expand hydrogeologic data collection network.
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect and document streamflow, temperature, and dissolved oxygen during low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Install a stream gage in the subarea if favorable conditions exist.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.
- ❑ Expand water quality data and analysis.

9.8 Chico Subarea

The Chico subarea is located in south-central portion of Kitsap County. The Chico subarea is a largely rural and forested subarea. Covering approximately 20 square miles (about 5 percent of the County), the Chico subarea is about 87 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows the effect of the Silverdale area expansion. The Assessor's data show an additional 20 percent of the land as urban in classification over that provided by satellite data. This could be reflective of land poised for development in the area.

The Chico subarea has a medium population density relative to the other County subareas. Based on 1990 census data, the area had a population density of about 480 persons/square mile.

No principal aquifer has yet been identified in the subarea. Based on the wells drilled, perched and shallow aquifers reliably supply groundwater in the subarea. Understanding of the perched and shallow ground water systems in the subarea is limited.

Available ground water quality data from the Chico subarea are limited to the northern portions of the subarea. In general, ground water in this portion of the subarea is of good quality and suitable for most purposes. Iron concentrations which exceed recommended aesthetic limits are common on the Kitsap County as a whole, and occur in areas of the Chico subarea where water quality data are available. High manganese concentrations were not encountered from wells sampled in the subarea. There is no apparent pattern to the areal distribution of documented high iron concentrations. Existing data provided no evidence of nitrate contamination beneath the Chico subarea.

Surficial soils in the Chico subarea are predominantly classified as Groups C or D, and, therefore, have low to very low infiltration potentials. Precipitation is average relative to the rest of the County, ranging from about 48 to 59 inches/year. Drainage in the subarea occurs primarily to Chico Creek and its many tributaries. A few other small streams occur within the subarea.

Threats to aquifers in the Chico subarea stem mainly from urban and suburban development around urban centers of Bremerton and Silverdale, and from transportation along major transportation routes to and around Bremerton and on the west side of Dyes Inlet to Silverdale.

9.8.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched and shallow aquifers in the subarea appears relatively high. Deeper aquifers are likely to occur beneath the subarea. However, deep aquifers have yet to be identified and issues such as continuity between surface and ground waters cannot currently be addressed. Streamflow depletion from ground water pumping is of greatest concern for streams with regulatory closures. Year-round closures have been established for Chico Creek, Kitsap Creek, and an unnamed stream tributary to Kitsap Lake under Chapter 173-515 WAC.

9.8.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. The potential for seawater intrusion in other ground water systems in the subarea is not known. There is no evidence of seawater intrusion beneath the Chico subarea. Based on hydrogeologic considerations, however, seawater intrusion could constitute a threat to coastal areas if excessive ground water development were to occur.

9.8.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Chico subarea is relatively low in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 7 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. No minimum instream flow requirements have been established in the subarea. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 37,900 acre-feet/year. Water right allocations in the Chico subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 2,292 acre-feet per year. Ground water permits and certificates comprise 96 percent of these allocations. Water right claims in the subarea are on the order of 276 acre-feet/year. Approximately 92 percent of this volume is claimed from ground water.

9.8.4 Ground Water Level Trends

Water level trends in perched aquifers show a relation to natural variability in precipitation (Section 5.8.3). The hydrograph for well AAB476 (completed below sea level) has an apparent long-term decline of over 20 feet. The decline is likely related to ground water withdrawal but a likely withdrawal point is not readily apparent. Little other water level data for the subarea has been compiled or evaluated.

9.8.5 Streamflow Trends

KPUD is currently collecting streamflow data for Chico Creek. Earlier data were collected by the USGS over 14 years between 1948 and 1973. Comparison of early and current (1991-1995) data indicate no discernible trends in average annual streamflow over the period of record. Relatively low minimum streamflows in recent years (1991-1995) warrant greater attention. Chico Creek is protected by year-round regulatory stream closure under Chapter 173-515 WAC.

Only spot measurements of low flow are available for other streams (see Appendix C and

Garling and Others, 1965).

9.8.6 Fisheries and Habitat

The Chico subarea has four streams (Chico, Dickerson, Kitsap, and unnamed) which support significant returns of anadromous salmonids. In addition, there are a number of small streams which probably support resident salmonids.

The four streams which support salmon returns are suffering from the results of urban growth, variability of recent precipitation, and reduced flows during late summer and early fall. Storm water peaks have also caused significant flooding in some areas during major events.

9.8.7 Allocation Decision Considerations

The Chico subarea has a moderate population density relative to the other County subareas. The relative level of development of the water resource is low at 7 percent of total inflow. Ground water applications for the Chico subarea currently request 296 gpm (0.7 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 1 percent of the water resource. There are no surface water applications pending in the subarea.

Available information for the perched and shallow aquifers in the subarea are insufficient for making additional water right decisions. Questions concerning water level trends, stream-aquifer continuity, and seawater intrusion need to be resolved for the perched and shallow aquifers in the subarea in order to make water right decisions. However, given the relatively low level of water resource allocation, ground water development of deeper aquifers may be possible while simultaneously gathering data and conducting analysis.

9.8.8 Recommendations

- ❑ Conduct a preliminary hydrogeologic evaluation of the subarea to determine ground water development potential.

- ❑ Continue to collect and document stream flow of Chico Creek and add flow observation on the smaller creeks. For all pertinent creeks, measure temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

9.9 Seabeck Subarea

The Seabeck subarea is located in the southwest portion of Kitsap County along the shoreline of Hood Canal. The subarea is one of the most rural and forested in the County. Covering approximately 27.3 square miles (about 7 percent of the County), the Seabeck subarea is about 95 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Seabeck subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 130 persons/square mile.

An extensive study has been completed in the Seabeck subarea identifying three aquifers: the Seabeck Aquifer System, Perched Aquifers, and Bedrock Aquifer (Purdy, 1995 a, b). The study of the Seabeck Aquifer System indicates that it is extensive (20 square miles) and productive (wells yield up to 1200 gpm). Less is known about extent and characteristics of the Perched and Bedrock Aquifers. The Perched Aquifers tend to be local and discontinuous, and are generally found above 100 feet MSL. The Bedrock Aquifer occurs in the southern portion of the subarea, and provides only low well yields.

The ground water quality in the Seabeck subarea is generally of good quality and suitable for most purposes. Iron concentrations which exceed recommended aesthetic limits are common in the County as a whole, and occur in areas of the Seabeck subarea where water quality data are available. Exceedences of the manganese MCL are less common than exceedences of the iron MCL. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Exceedences of the iron MCL are notably absent in the general vicinity of lower Big Beef Creek. Existing data provide no evidence of nitrate contamination beneath the Seabeck subarea.

Surficial soils in the Seabeck subarea are predominantly classified as Groups C or D, and, therefore, have low to very low infiltration potentials. Precipitation is high compared to the rest of the County, ranging from about 48 to 64 inches/ year. Precipitation may be considerably higher on the northern side of Green Mountain due to orographic effects. Drainage in the subarea occurs primarily to Big Beef, Seabeck, and Anderson Creeks. Several other creeks (Little Beef, Spring, Johnson) drain relatively small catchments of the subarea.

9.9.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity varies between the three aquifer identified. Studies suggest relatively low continuity between the Seabeck Aquifer System and surface water (Purdy, 1995a). The Perched Aquifers, however, are in relatively high continuity with surface water such as Big Beef Creek (Purdy, 1995a). Continuity between the Bedrock Aquifer and surface water is not well understood.

Instream flows have been established for Big Beef and Anderson Creeks during portions of the year under WAC 173-515-030. Seasonal or year-round stream closures have also been established for Big Beef, Anderson, and Seabeck Creeks.

9.9.2 Seawater Intrusion Potential

The potential for seawater intrusions varies between the three aquifer systems identified. Seawater intrusion is not possible for the perched aquifers, because these aquifers occur considerably above sea level. Seawater intrusion could occur in the Seabeck Aquifer System if excessive ground water development were to occur. The aquifer system occurs between 100 feet above sea level and 250 feet below sea level. The Bedrock Aquifer is not developed as a significant ground water source in coastal areas, and therefore, is not likely to experience seawater intrusion (Purdy, 1995 a, b).

There is no evidence of significant seawater intrusion beneath the Seabeck subarea based on assessment of ground water samples analyzed for chloride and EC (Section 3.9).

9.9.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Seabeck subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 10 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. In addition, minimum instream flow requirements and regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 50,966 acre-feet/year. Water right allocations, reported as maximum annual withdrawals (Qa’s), are on the order of 4,872 acre-feet/year. Ground water permits and certificates comprise 92 percent of these allocations. Water right claims in the subarea are on the order of 923 acre-feet/year. Approximately 88 percent of this volume is claimed from ground water sources.

Water balance analysis of the Seabeck subarea (Purdy, 1995b) suggests that estimated current ground water use represents a small percentage (9 percent to 15 percent) of the estimated ground water resource. This percentage was arrived at by comparing the recharge of the ground water system to the usage in the area.

9.9.4 Ground Water Level Trends

Water level trends in all aquifers show a relation to natural variability in precipitation. Long-term water level data for well AAA005 indicate a decline of 5 feet in the Seabeck Aquifer System since 1980, with much of the decline likely due to precipitation trends (Purdy, 1995b). Short-term data (water years 1991 to 1996) from wells completed both above and below sea level indicate variable but stable water levels.

9.9.5 Streamflow Trends

A declining trend in average annual stream flow is suggested for the ten-year period (1970- 1980) at Big Beef Creek near Seabeck. This period of record is too short to evaluate long-term trends. Minimum annual (daily average) flows show a slightly declining trend between 1969 and 1993. Big Beef Creek is protected by regulatory stream closure between May 15 and October 31, and by minimum instream flow requirements during the rest of the year (Chapter 173-515 WAC). Streamflow statistics indicate that summer minimum instream flow requirements were not met in 50 percent of all years between early August and mid-October, for the years 1970 to 1993.

Only spot measurements of low flow are available from other streams within the subarea. Visual observations during fisheries assessments indicate the lower reach of Seabeck Creek is occasionally dry from the period of mid-June until the fall rains begin.

9.9.6 Fisheries and Habitat

The streams within the Seabeck subarea have the most current and detailed information in the County from the standpoint of fisheries utilization criteria. Utilization by anadromous salmonids is well documented and the stream habitat is also cataloged (Tabor and Knudsen, 1993; Lestell and others, 1993). However, small streams which feed into lakes in the subarea have less information available and little emphasis has been placed on resident salmonids, particularly resident cutthroat trout. Big Beef Creek continues to be monitored for the purpose of predicting salmon returns to Hood Canal.

Limited returns of coho salmon to Hood Canal and the Puget Sound Basin have resulted in a total closure of the sport and commercial salmon fishery in 1994 and 1995.

Seasonal monitoring data for all the streams in the subarea for temperature and dissolved oxygen is not available as published or documented data.

9.9.7 Allocation Decision Considerations

The Seabeck subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is moderate at 10 percent of total inflow. Currently, ground water applications in the Seabeck subarea are requesting 2524 GPM (5.6 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 7 percent of total inflow. There are no surface water applications pending in the subarea.

The information gained from existing studies on the Seabeck Aquifer System appears to be adequate to make informed water rights decisions for the sea level aquifer. Analysis indicates that ground water exist which Ecology could consider in making water right decisions. In addition, demand in the subarea is currently low. However, relatively small declines in ground water levels and streamflows (Big Beef Creek) have been observed. Monitoring would provide additional insight on the role of climatic variability on observed trends. Mitigation proposals will be required and evaluated if the application for water resource development indicates impairment on stream flows or seawater intrusion.

Available information for the Perched and Bedrock Aquifers is insufficient for making additional water rights decisions. Questions concerning potential stream-aquifer continuity need to be resolved for the sea level and perched aquifers in order to make water rights decisions.

9.9.8 Recommendations

- ❑ Evaluate the data collected from the current Seabeck Aquifer System monitoring network periodically, as water development occurs to insure that the aquifer system is not over-utilized. Data collection should include water levels and coastal chloride and EC measurements.

- ❑ Evaluate recharge management and enhancement strategies for the Seabeck Aquifer System.

- ❑ Collect additional data to refine understanding of the potential for stream-aquifer continuity before additional development of the Perched and Bedrock Aquifers occurs.

- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

9.10 Stavis Subarea

The Stavis subarea is located in the western portion of the County along the shoreline of Hood Canal. The Stavis subarea is one of the most rural and forested subareas in Kitsap County. Covering approximately 10 square miles (about 2.5 percent of the County), the Stavis subarea is about 97 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Stavis subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 75 persons/square mile.

Very little data from deep wells is available and no principal aquifer designations have been made. Based on the wells drilled, perched and shallow aquifers exist in the subarea but these aquifers are not well understood.

The ground water in the Stavis subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits at various locations within the Stavis subarea. Exceedences of the manganese MCL are much less common than exceedences of the iron MCL. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Existing data provide no evidence for significant nitrate contamination beneath the Stavis subarea. One well is documented as having a nitrate concentration at the MCL.

Surficial soils in the Stavis subarea are predominantly classified as Group C or D, and, therefore, have low to very low infiltration potentials. Group A soils (very high infiltration potential) are associated with drainages near to the coast. Precipitation is high compared to the rest of the County, ranging from about 60 to 67 inches/year. Drainage in the subarea occurs primarily to Stavis and Boyce Creeks. Several other Creeks drain relatively small catchments of the subarea.

Existing and projected land use patterns pose no serious threat to the ground water.

9.10.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is likely to be relatively high. Continuity between streams and deeper ground water systems in the subarea is not understood.

Instream flows have been established for Stavis Creek during portions of the year under WAC 173-515-030.

9.10.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. The potential for seawater intrusion in other ground water systems in the subarea is not understood. There is no evidence of seawater intrusion beneath the Stavis subarea. Based on hydrogeologic considerations, seawater intrusion could constitute a threat to coastal areas if excessive ground water development were to occur.

9.10.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Stavis subarea is relatively low in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 3 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. No minimum instream flow requirements have been established in the subarea. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 24,500 acre-feet/year. Water right allocations in the Stavis subarea, reported as maximum allowable annual quantities

(Qa's), are on the order of 157 acre-feet per year. Ground water permits and certificates comprise 94 percent of these allocations. Water right claims in the subarea are on the order of 501 acre-feet/year. Approximately 60 percent of this volume is claimed from ground water sources.

9.10.4 Ground Water Level Trends

Unfortunately no water level data for the subarea have been compiled or evaluated.

9.10.5 Streamflow Trends

No long-term streamflow data exist within the subarea. Only spot measurements of low flow (see Appendix C and Garling and Others, 1965) are available from streams within the subarea.

9.10.6 Fisheries and Habitat

The Stavis Creek subarea is largely undeveloped and provides excellent habitat for spawning and rearing salmon. Protection of this creek is very important as it is one of the few "semi-pristine" stream systems left in the Puget Sound area.

Boyce Creek is a 2.2 mile long stream which drains into Frenchman's Cove. Boyce Creek is known to be utilized by both coho and chum salmon.

Harding Creek drains into Hood Canal north of Tekiu Point. This creek is known to be utilized by both chum and coho salmon, as well as resident Trout.

9.10.7 Allocation Decision Considerations

The Stavis subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is very low at 3 percent of total inflow. Ground water right applications for the Stavis subarea currently request 165 gpm (0.4 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 1 percent of total inflow. There are no surface water applications pending in the subarea.

Although no principal aquifer has been delineated in this subarea, the probability that aquifers are present is high. Because the water usage in the subarea is minimal, and the precipitation rate is high, ground water may be available for future water right decisions. The amount of available information for the perched and other aquifers is minimal. Questions regarding potential stream-aquifer continuity and seawater intrusion need to be resolved as the resource is developed.

9.10.8 Recommendations

- ❑ Include a few wells from the subarea in the monitoring network to establish baseline ground water conditions in the subarea.

- ❑ Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea.
- ❑ Conduct a test drilling program to establish aquifer characteristics.
- ❑ Continue the gauging of Anderson Creek and add gauging sites where conditions are favorable.
- ❑ Collect temperature and dissolved oxygen during the low flow period from mid-June to the end of September where conditions are favorable (or until the fall rains begin
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

9.11 Manchester Subarea

The Manchester subarea is located in the southeast portion of Kitsap County. The Manchester subarea is a largely rural and forested subarea. Covering approximately 45 square miles (about 11 percent of the County), the Manchester subarea is about 85 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Manchester subarea has a medium population density relative to the other County subareas. Based on 1990 census data, the area had a population density of about 660 persons/square mile.

Six principal aquifers have been identified in the large complex area that makes up the Manchester subarea: Port Orchard Aquifer System, Salmonberry, Clam Bay, Yukon, North Lake, and Wilson Creek Aquifers (GWMP, 1991). (Note that the Port Orchard System extends into the Gorst subarea, and the North Lake aquifer extends into the Gorst and McCormick subareas.) Besides these identified aquifers, there are discontinuous perched aquifers in the subarea. A preliminary study of the Port Orchard System and Salmonberry Aquifer has been completed (AGI, December, 1994). A number of studies provide varying amounts of hydrogeologic characterization information for these aquifers (GWMP 1991, AGI, 1989, Robinson & Noble, 1994).

Surficial soils in the Manchester subarea are largely classified as Group C or D (low to very low infiltration potential), although a north-south trending band of Group A soils (very high infiltration potential) occurs south of Annapolis. Precipitation is average compared to the rest of Kitsap County, ranging from about 38 to 53 inches/year. Drainage in the subarea occurs primarily to Blackjack, Curley and Salmonberry creeks (the latter two drain inland to Long Lake). Numerous other creeks drain relatively small catchments of the subarea.

No detrimental ground water quality trends have been noted in the aquifers in the Manchester subarea. The ground water in the Manchester subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, sporadically occur at concentrations above recommended aesthetic limits in wells throughout the Manchester subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. There is no evidence for extensive nitrate contamination beneath the Manchester subarea, however localized contamination has been documented. Among the detections of elevated nitrate concentrations, a particular grouping of slightly elevated concentrations (<5 mg/l) is noted in the area southeast of Fernwood.

The potential impact from future land conversion and urban activities pose several threats. Stormwater drainage can impact ground water recharge quantity and quality. Improperly maintained septic systems can provide a contamination source. Commercial and industrial activities are located along the shoreline and, for the most part, do not represent significant threats to the aquifers, except in those areas were the activity is located directly over an aquifer and where susceptibility to contamination is high.

9.11.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity varies between the six aquifer systems identified. The Wilson (perched) and North Lake Aquifers are located entirely above sea level and are likely in relatively high continuity with surface water in the subarea. There is the relatively high potential for stream-aquifer continuity for the Clam Bay and Yukon Aquifers, both located from sea level to 150 feet below sea level. There is relatively low potential for continuity between the Port Orchard System or Salmonberry Aquifer and surface water, because these aquifers occur below 150 feet below sea level.

Instream flows have been established for Curley Creek during a portion of the year under WAC 173-515-030. A seasonal stream closure has also been established for Curley Creek. Year-round stream closures have been established for Blackjack, Sullivan, Beaver, and Salmonberry Creeks.

9.11.2 Seawater Intrusion Potential

The potential for seawater intrusions varies between the six aquifer systems identified. Seawater intrusion is not possible for the perched aquifers (Wilson Creek and North Lake), because these aquifers occur considerably above sea level. There is potential for seawater intrusion in the Port Orchard System and Yukon Aquifer if excessive ground water development were to occur. The Salmonberry Aquifer has relatively less potential for seawater intrusion at its inland location. Well testing of the Clam Bay Aquifer shows a high susceptibility to seawater intrusion (Robinson and Noble, August 1992).

There is no evidence for significant seawater intrusion beneath the Manchester subarea. Relatively high values of electrical conductivity occur at several coastal locations and in an inland area southeast of Fernwood. Elevated chloride concentrations were documented at two inland locations. Seawater intrusion could constitute a threat to coastal areas if excessive ground water development were to occur.

9.11.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Manchester subarea is moderately high in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 24 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. In addition, minimum instream flow requirements And regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 64,800 acre-feet/year. Water right allocations in the Manchester subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 12,998 acre-feet per year. Ground water permits and certificates comprise 98 percent of these allocations. Water right claims in the subarea are on the order of 2,578 acre-feet/year. Approximately 90 percent of this volume is claimed from ground water sources.

9.11.4 Ground Water Level Trends

Water level trends in all aquifers show a relation to natural variability in precipitation. In addition, long-term water level declines have been identified in some areas. In the Manchester subarea hydrographs AAA119, AAA118, and AAB486 (all with completion elevations near sealevel) have notable declines. Well AAA117, is completed below -1000 MSL and also has an apparently large decline. Water level declines of 15 to 30 feet in the Port Orchard System and Salmonberry Aquifer (AGI, December 1994) may be cause for concern. Water levels in the North Lake Aquifer appear to be stable relative to seasonal and annual precipitation trends (Robinson and Noble, February 1994). Some water level data is available for the Clam Bay, Yukon, and Wilson Creek Aquifers but trend analysis has not been accomplished for those aquifers.

9.11.5 Streamflow Trends

No long-term streamflow data exist within the subarea. KPUD is currently collecting streamflow data for Blackjack Creek. Blackjack Creek is protected by year-round regulatory stream closure under Chapter 173-515 WAC.

Only spot measurements of low flow are available from other streams within the subarea. (See Appendix C and Garling and Others, 1965).

9.11.6 Fisheries and Habitat

There are a number of streams which support anadromous salmonids in the Manchester subarea (Blackjack Creek, Annapolis Creek, Beaver Creek, and Curley Creek). However, with the exception of Beaver Creek (tributary to Clam Bay), there is limited documentation which quantifies the condition of the habitat on these streams.

9.11.7 Allocation Decision Considerations

The Manchester subarea has moderate population density relative to other subareas. The subarea has the third highest level of development of the water resource, at 24 percent of total inflow. Currently, water right applications for the Manchester subarea request 8228 gpm (18.3 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 20 percent of the total inflow. Ground water applications comprise 95 percent of these applications.

Information gained from previous studies in the subarea appear to be adequate to make informed water right decisions on some of the aquifers. Water level declines in the Port Orchard System and Salmonberry Aquifers suggest the aquifers are developed at or near capacity. The relatively small extent of the Clam Bay, Yukon, and Wilson Creek Aquifers may restrict the future development potential for these aquifers. Any future development from the Wilson Creek Aquifer must also address stream-aquifer continuity.

Available information for the North Lake Aquifer requires assessment and questions regarding potential stream-aquifer continuity need to be resolved, in order to make water right decisions.

9.11.8 Recommendations

- ❑ Coordinate with the major purveyors of the area to enhance the water level monitoring efforts so that all the major aquifers of the area are appropriately monitored..
- ❑ Conduct more detailed studies of all aquifers within the Manchester subarea.
- ❑ Collect and analyze stream flow (except for Blackjack Creek which is permanently monitored), temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.
- ❑ Expand water quality data and analysis.

9.12 Gorst Subarea

The Gorst subarea is located in the south-central portion of Kitsap County surrounding Sinclair Inlet. The Gorst subarea is an urbanizing subarea that includes the City of Bremerton, the Bremerton Naval Shipyard And Supply Center, and an industrial park at the Bremerton Airport. Covering approximately 24 square miles (about 6 percent of the County), the Gorst subarea is about 76 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories. However, urban and commercial classifications make up about 17 percent of the Assessor codes.

The Gorst subarea has one of the higher population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 1,150 persons/square mile.

Two principal aquifers were identified in the subarea, the Gorst Aquifer System and Anderson Creek Aquifer Systems (GWMP, 1991). Considerable new work has been completed in the Gorst subarea by Bremerton Water Utilities (KPUD sponsored study by AGI, October 1996, November 1996) including new evaluation of hydrology and hydrogeology of the basin. Four 'effective' aquifers were identified in the area that is generally shown by the Gorst principal aquifer. Several studies of the Anderson Creek Aquifer System have been accomplished (Robinson and Noble, AGI), and the definition and lateral extent of the aquifer is improving.

Ground water quality data from the Gorst subarea were available from several wells. Existing data on which to base general statements on water quality in the subarea were not compiled and reviewed for this assessment but data regarding the Gorst and Anderson Creek Aquifer Systems is available through Bremerton Water Utilities. .

Surficial soils in the Gorst subarea are largely classified as Group C or D (low to very low infiltration potential), although a east-west trending band of Group A and B soils (high to very high infiltration potential) roughly follows Gorst Creek. Precipitation is average compared to the rest of the County, ranging from about 44 to 57 inches/year. Drainage in the subarea occurs primarily to Gorst, Ross, and Anderson Creeks (and associated tributaries). A few other creeks drain relatively small catchments of the subarea.

The eastern portion of the Gorst Aquifer System will be subjected to increased ground water quality threats associated with a continuing increase of urban, suburban, commercial and light industrial growth. The threats will be alleviated somewhat if proposed sewers are installed.

9.12.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity varies between the two aquifer systems identified. Because the Anderson Creek Aquifer System occurs from 450 to 525 feet below sea level, potential for continuity between surface water is relatively low. Earlier studies suggest a potential for continuity between the Gorst Aquifer System and surface water bodies of Gorst Creek and Twin Lakes (Robinson and Noble, May 1988). More recent analysis has demonstrated continuity between the Gorst Aquifer System and Gorst Creek (AGI, October 1996).

Instream flows have been established for Gorst Creek under WAC 173-515-030. Year-round stream closures have been also been established for Anderson and Ross Creeks.

9.12.2 Seawater Intrusion Potential

Seawater intrusion could occur in both the Anderson Creek and Gorst Aquifer Systems if excessive ground water development were to occur. Existing data provide no evidence for seawater intrusion beneath the Gorst subarea.

9.12.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Gorst subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 18 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Minimum instream flow requirements And regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 42,600 acre-feet/year. Water right allocations in the Gorst subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 7,247 acre-feet per year. Ground water permits and certificates comprise 98 percent of these allocations. Water right claims in the subarea are on the order of 313 acre-feet/year. Approximately 94 percent of this volume is claimed from ground water sources.

9.12.4 Ground Water Level Trends

Long-term water level data for the Gorst and Anderson Creek Aquifer Systems has been collected (primarily by Bremerton Water Utilities) but have not been compiled or evaluated as of this report. Short-term water level data since 1991 tends to show variable water levels for Gorst Aquifer System wells with no apparent declines over the short time period.

9.12.5 Streamflow Trends

No long-term streamflow data exist within the subarea. KPUD is currently collecting streamflow data for Gorst and Anderson Creeks. Short-term continuous streamflow records for Gorst Creek (1991-1994) suggest a possible decline in (summer) minimum flows. The cause of this decline cannot be determined given the short period of record. The records also show that instream flows were not met during significant portions of all (four) recorded years. Recent studies of the area (AGI, 1996) indicate minimum instream flows are set at unrealistically high values. Instream flows have been established for Gorst Creek under WAC 173-515-030.

Only spot measurements of low flow are available from other streams within the subarea. (See Appendix C and Garling and Others, 1965)

9.12.6 Fisheries and Habitat

Gorst Creek which drains into Sinclair Inlet is part of the City of Bremerton's water supply and restrictions are in place regarding development within the subarea. The Suquamish Tribe has a cooperative effort with a sport fishing organization for the rearing and release of approximately 2 million chinook juveniles into Gorst Creek. This release provides a terminal fishery for both the Tribe and sport fishermen.

Coho and chum salmon have been noted to utilize Anderson Creek.

9.12.7 Allocation Decision Considerations

The Gorst subarea has one of the higher population densities of the County's subareas. The relative level of development of the water resource is moderate at 19 percent of total inflow. Ground water applications for the Gorst subarea currently request 1470 GPM (3.3 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 6 percent of the total inflow. Surface water applications pending in the subarea are less than 0.1 cfs.

Current information on the Gorst and Anderson Creek Aquifer Systems appears to be adequate for making additional water right decisions. Information gained from the ongoing study of the Gorst Aquifer System has provided insight regarding that aquifer. Available information for the Anderson Creek Aquifer System is marginal. Proposed studies in the neighboring Manchester subarea may provide some insight on the aquifer's lateral extent and potential for additional supply.

9.12.8 Recommendations

- ❑ Continue water level monitoring on both aquifers.
- ❑ Conduct additional studies (over that which is in progress) for both of these very important aquifers. Study should include a test drilling program.
- ❑ KPUD, City of Bremerton, the Tribe and others should continue to collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin) as enhancement to work in progress by the City of Bremerton.
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

- ❑ Expand water quality data and analysis.

9.13 Union Subarea

The Union subarea is located in the southern portion of Kitsap County along the border of Mason County. The Union subarea is one of the more rural and forested subareas in the County. Covering approximately 17 square miles (about 4 percent of the County), the Union subarea is about 94 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Union subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 52 persons/square mile.

No principal aquifer has been identified in the subarea. Based on existing wells perched and shallow aquifers exist in the subarea. There is a limited amount of understanding of the perched and shallow ground water systems in the subarea and no understanding of deep ground water systems.

Ground water quality data from the Union subarea were available only from a few wells in the northern portion of the subarea. Existing data on which to base general statements on water quality in the subarea are insufficient. Existing data provide no evidence of nitrate contamination beneath the Union subarea.

Surficial soils in the Union subarea are largely classified as Group C or D (low to very low infiltration potential), although an area of Group A and B soils (high to very high infiltration potential) occurs in the vicinity of the upper stretches of the Union River near the Kitsap County Airport. Precipitation is moderately high compared to the rest of the County, ranging from about 57 to 62 inches/year. Precipitation may be considerably higher in the vicinity of the Green-Gold Mountains due to orographic effects. Drainage in the subarea occurs primarily to the Union River and Mission Creek (including tributaries). The catchments of these two streams occur mainly outside the County.

Existing and projected land use patterns pose no serious threat to the ground water.

9.13.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is relatively high. Continuity between the other ground water systems in the subarea is not known.

Year-round closures have been established for the Union River, Mission Creek, Little Mission Creek, and Mission Lake under WAC 173-515-040.

9.13.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. There is little potential (and no evidence) for seawater intrusion beneath the Union subarea due to its inland location.

9.13.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Union subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 15 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Streamflows in the subarea are not allocated as minimum instream flow requirements. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 35,100 acre-feet/year. Water right allocations in the Union subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 5,198 acre-feet per year. Ground water permits and certificates comprise 1 percent of these allocations. Water right claims in the subarea are on the order of 196 acre-feet/year. Approximately 74 percent of this volume is claimed from ground water sources.

9.13.4 Ground Water Level Trends

Unfortunately the amount of water level data for the subarea is very limited. No comments on water level trends are possible at this time

9.13.5 Streamflow Trends

Streamflow data were collected for the Union River by the USGS between 1945 and 1959. Although the Union River is closed to further appropriations, comparison of the historic data to present instream flow requirements (WAC 173-515-040) shows that instream flows would not have been met during 50 percent of all years between mid-May and mid-September.

Only spot measurements of low flow are available from other streams within the subarea. (Garling and Others, 1965)

9.13.6 Fisheries and Habitat

Coho and chum salmon are produced in the Union River and Big Mission Creek. A small chinook run returns to the lower two miles of the Union River. McKenna Falls located between river mile 6 and 7, is the most limiting factor for salmon production in the upper reaches of the Union River. Low streamflow during the summer months in the Big Mission Creek limit salmon production there.

Recent habitat surveys have been conducted along the Union River, Big Mission, and Bear Creeks by Point No Point Treaty Council (1992), Washington Department of Fisheries (1984), US. Fish and Wildlife Service (1992), and Washington Department of Ecology (1970 and 1992).

9.13.7 Allocation Decision Considerations

The Union subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is moderate at 15 percent of total inflow. Ground water right applications for the Union subarea currently request 564 GPM (1.3 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 3 percent of the total inflow. There are no surface water applications pending in the subarea.

Although no principal aquifer has been delineated in this subarea, the possibility that significant aquifers are present is high. Because water production in the area is minimal and the precipitation rate is high, ground water is probably available for appropriation.

Limited information is available concerning stream-aquifer continuity in the subarea, so associated concerns need to be considered when making water right decisions for shallow aquifers.

9.13.8 Recommendations

- ❑ Increase water level monitoring network to establish baseline ground water conditions in the subarea.

- ❑ Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea. Include a test drilling program if appropriate.

- ❑ Re-establish Union River gauging station and collect and document stream flow, of other major streams. Include temperature and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).

- ❑ Catalogue the fisheries resource of the subarea.

- ❑ Complete recommendations in cooperation with Mason County where appropriate.

9.14 Tahuya Subarea

The Tahuya subarea is located in the southwestern portion of Kitsap County along the Mason County border. The Tahuya subarea is a rural and forested subarea. Covering approximately 14 square miles (about 4 percent of the County), the Tahuya subarea is about 96 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Tahuya subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 57 persons/square mile.

No principal aquifer has been identified in the subarea. Based on the wells drilled, perched and shallow aquifers exist in the subarea. There is a limited amount of understanding of the perched and shallow ground water systems in the subarea and no understanding of deep ground water systems.

Ground water quality data from the Tahuya subarea are available only from a few wells. Existing data on which to base general statements on water quality in the subarea are insufficient.

Surficial soils in the Tahuya subarea are predominantly classified as Group C or D (low to very low infiltration potential), although localized areas of Group A and B soils (high to very high infiltration potential) occur. Precipitation is high compared to the rest of the County, ranging from about 58 to 66 inches/year. Precipitation may be considerably higher in the vicinity of the Green-Gold Mountains due to orographic effects. Drainage in the subarea occurs primarily to the Tahuya River and its tributaries, some of which flow into Tahuya Lake.

Existing and projected land use patterns pose no serious threat to the ground water.

9.14.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is relatively high. Continuity between the other ground water systems in the subarea is not understood.

Instream flows have been established for the Tahuya River during portions of the year under WAC 173-515-030. A seasonal stream closure has been also been established for the Tahuya River.

9.14.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. There is little potential (and no evidence) for seawater intrusion beneath the Tahuya subarea due to its inland location.

9.14.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Tahuya subarea is relatively low in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 1 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Minimum instream flow requirements And regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 32,100 acre-feet/year. Water right allocations in the Tahuya subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 200 acre-feet per year. Ground water permits and certificates comprise 93 percent of these allocations. Water right claims in the subarea are on the order of 65 acre-feet/year. Approximately 29 percent of this volume is claimed from ground water sources.

9.14.4 Ground Water Level Trends

No long-term water level data for the subarea have been compiled or evaluated.

9.14.5 Streamflow Trends

Streamflow data were collected for the Tahuya River by the USGS between 1945 and 1956. According to the historic data, current instream flow requirements would not have been met during 50 percent of all years between mid February and late November. The Tahuya River is currently protected by regulatory stream closure between June 15 and October 15. Instream flow requirements in effect during this period would not have been met during 90 percent of all years. (See Appendix C).

Only spot measurements of low flow are available from other streams within the subarea. (Garling and Others, 1965)

9.14.6 Fisheries and Habitat

The Tahuya River has very important runs of coho and chum salmon, as well as moderate chinook production. Chinook salmon production is limited to the lower four miles of the river due to flow conditions and accessibility during adult migration. Low summer flows is a limiting factor for coho production.

Recent habitat surveys have been conducted along the Tahuya River, and Little Tahuya, Gold, Panther, and Tin Mine Creeks by the Washington Department of Wildlife (1984), Washington Department of Fisheries (1984), US Fish and Wildlife Service (1992-93), Northwest Indian Fisheries Commission (1990), Point No Point Treaty Council (1992), and Washington State Department of Ecology (1974, 1992-93).

9.14.7 Allocation Decision Considerations

The Tahuya subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is very low at 1 percent of total inflow. Ground water right applications for the Tahuya subarea currently request 642 GPM (1.4 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 43 percent of total inflow.

Information on stream-aquifer continuity in the subarea is limited. This needs to be considered when making additional water right decisions for shallow aquifers.

9.14.8 Recommendations

- Include a few wells in the monitoring network to establish baseline ground water conditions in the subarea.

- Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea. Include a test drilling program if appropriate.

- Re-establish regular monitoring of the Tahuya River, including temperature and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin). Include other streams if practical.

- Catalogue the fisheries resource of the subarea.

- Complete recommendations in cooperation with Mason County where appropriate.

9.15 Anderson Subarea

The Anderson subarea is located in the southwest portion of Kitsap County along Hood Canal. The Anderson subarea is one of the most rural and forested subareas in the County. Covering approximately nine square miles (about 2 percent of the County), the Anderson subarea is about 98 percent forested or natural cover (Satellite data analysis- KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Anderson subarea has the lowest population density of the County's subareas. Based on 1990 census data, the area had a population density of about 12 persons/square mile.

No principal aquifer has been identified in the subarea. Based on the wells drilled, perched and shallow aquifers exist in the subarea. There is a limited amount of understanding of the perched and shallow ground water systems in the subarea but no understanding of deep aquifer systems.

Ground water quality data are available only from the northeastern portion of the Anderson subarea. In general, ground water in the Anderson subarea is of good quality and is suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits at various locations within the Anderson subarea. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Existing data provided no evidence of nitrate contamination beneath the Anderson subarea.

Surficial soils in the Anderson subarea are predominantly classified as Group C or D (low to very low infiltration potential), although Group A soils (very high infiltration potential) occur in the vicinity of Tekiu Point. Precipitation is high compared to the rest of the County, ranging from about 65 to 68 inches/year. Drainage in the subarea occurs primarily to the Anderson and Harding Creeks. Several other creeks drain relatively small catchments of the subarea.

Existing and projected land use patterns pose no serious threat to the ground water.

9.15.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is relatively high. Continuity between the other ground water systems in the subarea is not understood.

Instream flows have been established for Anderson Creek under WAC 173-515-030. A year-round stream closure has also been established for Harding Creek.

9.15.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. The potential for seawater intrusion in other ground water systems in the subarea is not known. Seawater intrusion has not been identified as a problem based on available water quality data. Nevertheless, seawater intrusion could threaten the quality of coastal ground water if excessive ground water development were to occur in the subarea.

9.15.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Anderson subarea is the lowest in comparison to all the other subareas in the County. Based on the analysis presented in Section 8.2.5, less than 1 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from (also) less than 1 to 43 percent. In addition, minimum instream flow requirements And regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 23,300 acre-feet/year. Water right allocations in the Anderson subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 14 acre-feet per year. Ground water permits and certificates comprise 51 percent of this allocated volume. Water right claims in the subarea are on the order of 34 acre-feet/year. Approximately 64 percent of this volume is claimed from ground water.

9.15.4 Ground Water Level Trends

Two wells in the Holly area are being monitored. No formal assessment has been made of the data.

9.15.5 Streamflow Trends

KPUD is currently collecting streamflow data for Big Anderson Creek. Stream flows have been recorded at several locations along Big Anderson Creek; the north fork, south fork, and two locations near the mouth.

No long-term streamflow data exist within the subarea. Only spot measurements of low flow are available from streams within the subarea. (See Appendix C and Garling and Others, 1965)

9.15.6 Fisheries and Habitat

Because there has been a limited amount of development within the Big Anderson Creek drainage the return of coho to this system has been an important factor in the abundance of coho in Hood Canal. While logging activities have altered the area, the riparian cover and instream habitat is in good condition. The creek supports both an early and a late run of chum salmon.

The Northwest Indian Fisheries Commission has recently completed habitat surveys of Big Anderson and Harding Creeks.

9.15.7 Allocation Decision Considerations

The Anderson subarea has the lowest population density of the County's subareas. The relative level of development of the water resource is the lowest in the County at less than one percent of total inflow. There are currently no water right applications for the Anderson subarea.

Due to the large amount of rainfall in the subarea, it has substantial potential for ground water production. As deeper production and test wells are drilled, associated data should be analyzed for water level trends and seawater intrusion. Limited information is available concerning stream-aquifer continuity in the subarea so associated concerns should be considered when making additional water right decisions for the shallow aquifers.

9.15.8 Recommendations

- ❑ Include a few wells in the monitoring network to establish baseline ground water conditions in the subarea.
- ❑ Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea.
- ❑ Conduct a test drilling program to establish aquifer characteristics.
- ❑ Collect and document stream flow, temperature and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin) in streams with favorable conditions for monitoring.
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

9.16 Olalla Subarea

The Olalla subarea is located in the southeastern portion of Kitsap County along Colvos Passage. The Olalla subarea is mostly rural and forested with some urbanizing locations. Covering approximately 25 square miles (about 6 percent of the County), the Olalla subarea is about 90 percent forested or natural cover (Satellite data analysis- KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Olalla subarea has a moderately low population density compared to the County's other subareas. Based on 1990 census data, the area had a population density of about 340 persons/square mile.

No principal aquifer has been identified in the subarea. Based on the wells drilled, perched and shallow aquifers exist in the subarea. There is a limited amount of understanding of the perched and shallow ground water systems in the subarea and no understanding of deeper systems.

The ground water in the Olalla subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in wells throughout the Olalla subarea. Exceedences of the manganese MCL are less common than exceedences of the iron MCL. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. There is no evidence for extensive nitrate contamination beneath the Olalla subarea.

Surficial soils in the Olalla subarea are largely classified as Group C or D (low to very low infiltration potential), although localized areas of Group A soils (very high infiltration potential) occur (especially in the western subarea). Precipitation is average compared to the rest of the County, ranging from about 42 to 49 inches/year. Drainage in the subarea occurs primarily to

Burley, Olalla, and Purdy Creeks. In addition, several creeks with relatively small catchments drain into Colvos Passage.

Based on existing and future land-use projects, it appears that existing hazardous waste sites (e.g., Strandley Scrap Metal) and the Olalla dump site provide the largest threats to water resources in this subarea.

9.16.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is relatively high. Continuity between the other ground water systems in the subarea is not understood.

Instream flows have been established for Purdy Creek during portions of the year under WAC 173-515-030. Seasonal or year-round stream closures have been also been established for Purdy, Burley and Olalla Creeks.

9.16.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. The potential for seawater intrusion in other ground water systems in the subarea is not well understood. There is no evidence of seawater intrusion beneath the Olalla subarea. Relatively high values of electrical conductivity and chloride are limited to inland locations. Based on hydrogeologic considerations, however, seawater intrusion could constitute a threat to coastal areas if excessive ground water development were to occur.

9.16.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Olalla subarea is moderate relative to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 11 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. In addition, minimum instream flow requirements and regulatory closures may limit water availability in this area.

Total inflow to the hydrologic system is estimated to be 37,900 acre-feet/year. Water right allocations in the Olalla subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 2,926 acre-feet per year. Ground water permits and certificates comprise 93 percent of these allocations. Water right claims in the subarea are on the order of 1,178 acre-feet/year. Approximately 85 percent of this volume is claimed from ground water sources.

9.16.4 Ground Water Level Trends

Water level trends in the limited number of available hydrographs show a relation to natural variability in precipitation. Water level data suggests a decline of about 13 feet in one well (AAA228) in the shallow ground water system since 1985 (KPUD monitoring data). Other wells completed above and below sea level have shown variable water levels but no obvious declining trends overall.

9.16.5 Streamflow Trends

KPUD is currently collecting streamflow data for Burley Creek. Earlier data were collected by the USGS over nine years between 1947 and 1964. The combined data record is comprised of short, isolated periods of record. There are no discernible trends in the streamflow data for Burley Creek. Burley Creek is protected by a year-round regulatory closure under Chapter 173-515 WAC.

Only spot measurements of low flow are available for other streams within this subarea (See Appendix C and Garling and Others, 1965).

9.16.6 Fisheries and Habitat

Burley Creek and Purdy Creek have returns of coho, chinook, and chum salmon. However, development and agriculture practices in the subareas are probably limiting the number of adult fish which return. Olalla Creek supports returns of coho and chum salmon. Habitat deterioration from past logging and current farming practices has occurred and is limiting the production of both streams. There is no current published habitat data for these subareas.

9.16.7 Allocation Decision Considerations

The Olalla subarea has one of the lower population densities of the County's subareas. The relative level of development of the water resource is moderate. Water rights and claims in the subarea total 4,105 af/yr. Comparing this amount with the estimated total inflow of 37,900 af/yr., the relative development is 11 percent of total inflow **(Exhibit 4-7)**. Ground water right applications for the Olalla subarea currently request 1651 GPM (3.7 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 7 percent of total inflow. Surface water applications pending in the subarea are less than 0.1 cfs.

Limited information is available concerning stream-aquifer continuity, or seawater intrusion in the subarea. The subarea may have potential for additional supplies but additional data will probably be required for most water right decisions.

9.16.8 Recommendations

- ❑ Continue to monitor wells in the subarea and add wells in appropriate aquifers to the monitoring network.

- ❑ Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea with a test drilling program if appropriate.
- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.

9.17 McCormick Subarea

The McCormick subarea is located in south-central portion of Kitsap County along the border of Mason County. The McCormick subarea is a rural and forested subarea. Covering approximately 33 square miles (about 8 percent of the County), the McCormick subarea is about 94 percent forested or natural cover (Satellite data analysis- KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The McCormick subarea has one of the lowest population densities of the County's subareas. Based on 1990 census data, the area had a population density of about 120 persons/square mile.

The North Lake Aquifer is the only principal aquifer identified in the subarea. The aquifer boundaries were recently refined (Robinson and Noble, February 1994). Aquifer characterization information is contained in miscellaneous consultant reports (Robinson & Noble).

The ground water in the McCormick subarea is generally of good quality and suitable for most purposes. Iron and manganese, which are naturally occurring ground water constituents, occur at concentrations above recommended aesthetic limits in wells throughout the McCormick subarea. Exceedences of the manganese MCL are much less common than exceedences of the iron MCL. There is no apparent pattern to the areal distribution of documented high iron and manganese concentrations. Existing data provide no evidence for nitrate contamination beneath the McCormick subarea. Localized contamination has been documented at one well within the subarea.

Surficial soils in the McCormick subarea are predominantly classified as Group C or D (low to very low infiltration potential), although localized areas of Group A soils (very high infiltration potential) occur (especially in the eastern subarea). Precipitation is average compared to the rest of the County, ranging from about 50 to 57 inches/year. Drainage in the subarea occurs primarily to Coulter Creek and Rocky Creek (including tributaries). Both of these streams discharge to Case Inlet, which is located in Mason County. A number of small streams in the subarea drain to small inland wetlands or marshes.

Existing and projected land-use patterns for the subarea will result in minimum threats to its underlying ground water.

9.17.1 Stream-Aquifer Continuity

The potential for continuity of the North Lake Aquifer with other perched aquifers and with streams such as Anderson and Coulter Creeks is relatively high, but is not well understood. Continuity between the other ground water systems in the subarea and surface water is also not well understood.

A year round stream closure has been established for Minter Creek under Chapter 173-515 WAC.

9.17.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the North Lake and perched aquifers, because these aquifers occur well above sea level. There is little potential (and no evidence) for seawater intrusion beneath the McCormick subarea due to its inland location.

9.17.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the McCormick subarea is relatively low in comparison to other subareas in the County. Based on the analysis presented in Section 8.2.5, approximately 2 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from less than 1 to 43 percent. Streamflows in the subarea are not allocated as minimum instream flow requirements. Protection of streamflows is accomplished through regulatory closures.

An important note relative to resource allocation in this subarea relates to the waters of Coulter Creek which is an important drainage basin in the subarea. A settlement agreement between Peter E. Overton, et al. and Washington State Department of Fisheries, both groups with major interests in the water resources of the basin, is cited in WAC 173-515-040. The WAC indicates that Ecology intends to give full consideration to the agreement in the event of any future water right actions involving said parties, and presumably others in the basin. This could have significant impacts on future resource allocations in the subarea.

Total inflow to the hydrologic system is estimated to be 61,600 acre-feet/year. Water right allocations in the McCormick subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 926 acre-feet per year. Ground water permits and certificates comprise 97 percent of these allocations. Water right claims in the subarea are on the order of 467 acre-feet/year. Approximately 86 percent of this volume is claimed from ground water sources.

9.17.4 Ground Water Level Trends

Evaluation of water level trends show a large seasonal variation in water levels of up to 5 feet (Robinson and Noble, February 1994). More recent data indicates some seasonal variations may exceed 10 feet. The available data suggest no overall declining trends for any wells with records.

9.17.5 Streamflow Trends

Spot streamflow data from 1979 to present has been collected on Coulter Creek for Peter E. Overton (Robinson and Noble). Only spot measurements of low flow are available from streams within the subarea (Garling and Others, 1965).

9.17.6 Fisheries and Habitat

The Minter Creek Hatchery provides annual releases of chinook and coho salmon fingerlings to many of the streams of the County and other Puget Sound river systems. Natural production in the stream is limited by the number of adults allowed to pass upstream beyond the hatchery. The creek also produces searun cutthroat trout. There are no published data available on any of the remaining small streams within this subarea.

9.17.7 Allocation Decision Considerations

The McCormick subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is very low at 2 percent of total inflow. Ground water right applications for the McCormick subarea currently request 2080 GPM (4.6 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 5 percent of total inflow. There are no surface water applications pending in the subarea.

The North Lake Aquifer shows potential for development. However, the continuity of the North Lake Aquifer, located above sea level, with surface water may limit the sustainable yield of the aquifer. Questions concerning stream-aquifer continuity need to be considered when making additional water rights decisions.

9.17.8 Recommendations

- ❑ Conduct a detailed study of the North Lake Aquifer focusing on areal extent and surface water continuity.
- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Catalogue the fisheries resource of the subarea.

- ❑ Complete recommendations with cooperation from Mason County where appropriate.

9.18 Dewatto Subarea

The Dewatto subarea is located in the southwest portion of Kitsap County along Hood Canal. The Dewatto subarea is one of the most rural and forested subareas in the County. Covering approximately 6 square miles (about 2 percent of the County), the Dewatto subarea is about 98 percent forested or natural cover (Satellite data analysis - KPUD, 1994). An evaluation of land use types classified by the County Assessor shows about the same total percentage of the area in suburban, forested, or open space categories.

The Dewatto subarea has one of the lowest population densities of the county's subareas. Based on the 1990 census data, the area has a population density of about 21 persons per square mile.

No principal aquifer has been identified. Based on the wells drilled, perched and shallow aquifers exist in the subarea. There is a limited understanding of the perched and shallow ground water systems in the subarea but no understanding of deep systems.

Ground water quality data from the Dewatto subarea are only available from a few wells. Existing data on which to base general statements on water quality in the subarea are insufficient.

Surficial soils in the Dewatto subarea are predominantly classified as Group C or D, and, therefore, have low to very low infiltration potentials. Precipitation is very high relative to the rest of the County, ranging from about 66 to 68 inches/year. Drainage in the subarea occurs to the headwaters of Dewatto River (most of its catchment occurs outside Kitsap County), and to several other creeks with relatively small catchments.

Existing and projected land use patterns pose no serious threat to the ground water.

9.18.1 Stream-Aquifer Continuity

The potential for stream-aquifer continuity of the perched aquifers in the subarea is relatively high. Continuity between the other ground water systems in the subarea is not known.

The Dewatto subarea includes several small streams which are tributary to Hood Canal, and may also include a portion of the headwaters to the Dewatto River. Seasonal instream flows and a seasonal closure have been established for the Dewatto River under Chapter 173-515 WAC.

9.18.2 Seawater Intrusion Potential

Seawater intrusion is not possible for the perched aquifers, because these aquifers occur well above sea level. The potential for seawater intrusion in other ground water systems in the subarea is not well understood.

9.18.3 Relative Degree of Water Resource Allocation

The degree of water resource allocation in the Dewatto subarea is very low compared to other subareas in the County. Based on the analysis presented in Section 8.2.5, less than 1 percent of total inflow (precipitation minus evapotranspiration) to the hydrologic system is associated with water right permits, certificates, and claims. Values for other subareas range from (also) less than 1 t to 43 percent. Streamflows in the subarea are not allocated as minimum instream flow requirements. Protection of streamflows is accomplished through regulatory closures.

Total inflow to the hydrologic system is estimated to be 16,000 acre-feet/year. Water right allocations in the Dewatto subarea, reported as maximum allowable annual quantities (Qa's), are on the order of 40 acre-feet per year. Ground water permits and certificates comprise 69 percent of these allocations. Water right claims in the subarea are on the order of 6 acre-feet/year. Approximately 85 percent of this volume is claimed from ground water sources.

9.18.4 Ground Water Level Trends

Water level data is only available for two well in the Holly area. No long-term water level data for the subarea is available. Short-term data for water years 1991 to 1996 show variable water levels but no declining trends.

9.18.5 Streamflow Trends

The Dewatto subarea includes several small streams which are tributary to Hood Canal, and also includes a small portion of the headwaters to the Dewatto River. No long-term streamflow data exist within the subarea, however historic data are available from a gauging station located 1.8 miles from the mouth of the Dewatto River (1947-1954 and 1958-1974). These data were not evaluated for this study because streamflows at the gage are primarily influenced by the drainage basin outside of the County. Seasonal instream flows and a seasonal closure have been established for the Dewatto River under Chapter 173-515 WAC. (Garling and Others, 1965)

Only spot measurements of low flow are available from other streams within the subarea.

9.18.6 Fisheries and Habitat (Including Surface Water Quality)

The Dewatto River produces very important runs of coho and chum salmon, as well as a small chinook salmon population. Three distinct stocks of chum salmon enter Dewatto River different times of the year and spawn in different sections of the stream. The earliest run enters the lower two miles of the river during September, with as many as 4,000 spawners per year (Williams, et al., 1975). A second run enters in late November and spawn in tributaries and mainstream areas above mile 1.5. The third run enters in late December and early January and spawns intertidally and in the lowermost portion of the stream. Thomas Creek, a small creek to the north of the Dewatto River, is known to support coho and chum salmon, as well as resident trout (PSCRBT, 1993).

Stream surveys have been conducted along the Dewatto River by the Northwest Indian Fisheries Commission (1989), Washington Department of Wildlife (1984), and the US. Fish and Wildlife Service (1992) (Tabor and Knudsen, 1993). Survey methodology varied with agency.

9.18.7 Allocation Decision Considerations

The Dewatto subarea has one of the lowest population densities of the County's subareas. The relative level of development of the water resource is very low at less than 1 percent of total inflow. Surface water right applications for the Dewatto subarea currently request 45 GPM (0.1 cfs) of maximum instantaneous withdrawal (Qi), or a maximum of an additional 1 percent of the total inflow. There are no ground water applications pending in the subarea.

Due to the large amount of rainfall in the subarea and minimal ground water development, there is potential for ground water development. However, limited information is available concerning stream-aquifer continuity and seawater intrusion in the subarea. These concerns need to be considered when making additional water right decisions.

9.18.8 Recommendations

- ❑ Include a few wells in the monitoring network to establish baseline ground water conditions in the subarea.
- ❑ Conduct an initial hydrogeologic assessment to identify the aquifers in the subarea with a test drilling program if applicable.
- ❑ Collect and document stream flow, temperature, and dissolved oxygen during the low flow period from mid-June to the end of September (or until the fall rains begin).
- ❑ Catalogue the fisheries resource of the subarea.
- ❑ Collect water quality data in coastal locations to evaluate seawater intrusion potential.
- ❑ Complete recommendations in a cooperative effort with Mason County where appropriate.

References

AGI Technologies, July 3, 1989, Groundwater Availability Study, Port Gamble, Kitsap County, Washington. Report prepared for Pope Resources, Poulsbo, WA.

AGI Technologies, December 12, 1994, Source of Supply and Basin Assessment for the Annapolis Basin, a part of Water Resource Inventory Area 15, for Annapolis Water District.

AGI Technologies, October 8, 1996, Final Report Gorst Creek Basin Study Phase I. Report prepared for City of Bremerton Public Works, Bremerton, WA.

AGI Technologies, November 18, 1996, North Perry Avenue Water District Wellhead Protection Investigation. Report prepared for North Perry Avenue Water District, Bremerton, WA.

AGI Technologies, March 5, 1997, Annapolis Water District Wellhead Protection Investigation.

AGI Technologies, October 11, 1996, City of Bremerton Wellhead Protection Investigation Final Report.

Becker, J.E., (Robinson and Noble) 1995A, Hydrogeological analysis of the Bangor Aquifer System, Kitsap County, Washington.

Becker, J.E., (Robinson and Noble) 1995B, Numerical modeling of the Bangor Aquifer System.

Central Puget Sound Growth Management Hearings Board October 1996 Final Decision and Order. Consolidated Case No. 95-3-0039.

Culvert, John. October, 1994. Personal communications with Peter Schwartzman (PGG) concerning the WRIS database. Washington State Department of Ecology, Eastern Regional Office.

Dion, N.P. and Sumioka, S.S. 1984. Saltwater Intrusion into Coastal Aquifers in Washington, 1978. U.S. Geological Survey, Water Resources Division. Water-Supply Bulletin 56. 12 pp, 14 plates.

Dion, N.P., Olsen, T.D., and Payne, K.L., 1988, Preliminary evaluation of ground-water resources of Bainbridge Island, Kitsap County, Washington, U.S. Geological Survey, Water-Resource Investigations Report 87-4237.

Dion, N.P., G.C. Turney and M.A. Jones. 1994. Hydrology and Quality of Ground Water in Northern Thurston County, Washington. U.S. Geological Survey. Water Resources Investigations Report 92-4109. Prepared in cooperation with Thurston County Department of Health.

Duncan, R. A., 1982, A captured island chain in the Coast Range of Oregon and Washington: Journal of Geophisical Research, v. 87, p. 10,827-10,837.

Dunne and Leopold, 1978. Blaney-Criddle method.

Easterbrook, D. J., D. R. Crandell, and E. B. Leopold, 1967, Pre-Olympic Pleistocene stratigraphy and chronology in central Puget Lowland: Geological Society of America, v. 78, p. 13-20.

Easterbrook, D. J., 1968, Pleistocene stratigraphy of Island County, Washinton Department of Water Resources Water-Supply Bulletin 25, part 1, 34 p., 1 plate.

Ecology, Department of, 1991, Chapter 173-515 WAC, Instream Resources Protection Program Kitsap Water Resource Inventory Area (WRIA) 15.

Economic and Engineering Services, Inc. (EES) et. al., April, 1991, Vols. I and II, Background Data Collection and Management Issues, Grant No. 1, Kitsap County Ground Water Management Plan (GWMP).

Fulmer, C. V., 1954, Stratigraphy and paleontology of the type Blakeley Formation of Washington (abs.): Geological Society of America, v. 65, n. 12, pt. 2, p. 1341.

Garitone, J., 1993, farm inventory conducted by the Kitsap Conservation District.

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

Geraghty & Miller, Feruary 1992, The Hydraulic and Water Quality effects of pumping the Deep Azuifer at the Old Mill Road Well field at a proposed deep well west of the Wyckoff site, Bainbridge Island, Washington.

Glossary of Geology, 1977, Third Edition, American Geologic Institute.

Hansen, A.J. Jr., Molennar, December 1976. Availability of ground water in the area surrounding the Trident Submarine Construction Facility, Kitsap County, Washington, U.S. Geologic Survey Open File Report No. 76-351.

Hansen, A.J., and Bolke, E.L., 1980, Ground-water availability on the Kitsap Peninsula, Washington: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1186.

Hem, John M., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. Third Edition. U.S. Geological Survey Water Supply Paper 2254. 263 pp.

Hill and Ingman, September 1966, Comprehensive Water Study of Kitsap County for Public Utility District No. 1 of Kitsap County.

Kennedy/Jenks Consultants, November 1996, Water Reuse Study for Annapolis Water District, Kitsap County, Washington.

Kitsap County Coordinated Water System Plan Regional Supplement, November 3, 1992.

Kitsap County Ground Water Management Plan (Draft) Volumes I and II, April 1991, Volumes III, May 1997, and Volume IV, April 1996.

Kitsap Sub-regional Council, Puget Sound Council of Governments, October 4, 1979, Issue Paper on Water Supply in the Kitsap County-wide Area.

Kitsap Public Utility District. Streamflow and precipitation data for Kitsap PUD water resources monitoring stations.

Kocan, Richard M. History and Function of Production Well-1 located at the Big Beef Creek Research Station, Seabeck, Washington.

Lestelle, L.C., and others, December 1993, Evaluation of natural stock improvement measures for Hood Canal Coho Salmon: Point No Point Treaty Council Technical Report TR 93-1, 173p.

Matthess, Georg. 1982. The Properties of Groundwater. John Wiley & Sons, New York. Translated by John C. Harvey.

Mullineaux, D. R.; Waldron, H. H.; Rubin, Meyer, 1965, Stratigraphy and chronology of late interglacial and early Vashon glacial time in the Seattle area, Washington: U.S. Geological Survey Bulletin 1194-0, 10 p.

Noble, J. B., 1990, Proposed revision of nomenclature for the Pleistocene stratigraphy of coastal Pierce County, Washington: Washington Division of Geology and Earth Resources Open File Report 90-4.

Patterson, W.D., 1981, Groundwater hydrology at the Naval Submarine Base, Bangor, Washington, Volumes I and II.

Puget Sound Cooperative River Basin Team Watershed Plans.

Purdy, J.W., (Robinson and Noble) November 1990, Meadowmere Aquifer Protection Study for Kitsap Public Utility District.

Purdy, J.W., (Robinson and Noble) October 1994, Interpretation of a 60-day pumping test on PUD #1 of Kitsap County's Seabeck Well 3.

Purdy, J.W., (Robinson and Noble) 1995a, Hydrogeologic characterization of the Seabeck Aquifer System for PUD #1 of Kitsap County.

Purdy, J.W., (Robinson and Noble) 1995b, Preliminary evaluation of the water resources on the Seabeck Subarea for PUD #1 of Kitsap County.

Reinke, Fred. July 21, 1995. Personal communication with Peter Schwartzman (PGG) concerning City of Bremerton diversions. City of Bremerton.

Robinson and Noble, Inc., May 1978, Construction report, Fletcher Bay Test Well for PUD No. 1 of Kitsap County.

Robinson and Noble, Inc., November 1987, Construction of Edgewater Well 3B for PUD No. 1 of Kitsap County (File No. 5708).

Robinson and Noble, Inc., May 1988, Gorst Creek and Twin Lakes.

Robinson and Noble, Inc., August 1988, Construction of Wardwell Road Test Well for PUD No. 1 of Kitsap County.

Robinson and Noble, Inc., October 1988, South Kingston Test Well for PUD No. 1 of Kitsap County.

Robinson and Noble, Inc., January 1990, Hansville Aquifer Protection Study for Hansville Water District.

Robinson and Noble, Inc., January 1991, Island Lake Aquifer study of Silverdale Water District.

Robinson and Noble, Inc., August 1992, Evaluation of Manchester Naval Supply Center/Watauga Beach Aquifer for National Marine Fisheries Service.

Robinson and Noble, Inc., November 1992, Investigation of impacts on Dogfish Creek from the use of the City of Poulsbo's Pugh Road Well.

Robinson and Noble, Inc., February 1994, Interpretation of ground water monitoring data for Tallamach Partners (North Lake Aquifer).

Robinson and Noble, Inc., March 1994, Construction of Port Gamble Production Well for Kitsap PUD #1.

Robinson and Noble, Inc., 1973, Kingston Test Well No. 2, 27N/02E-34C.

Robinson and Noble, Inc., July 1974, Island Center Well No. 1.

Robinson and Noble, Inc., 1974, Bayhead Well No. 3 for Bainbridge Island.

Robinson and Noble, Inc., 1974, Silverdale Well No. 1.

Robinson and Noble, Inc., 1975, Keyport Well No. 1.

Robinson and Noble, Inc., 1975, Kingston Well No. 2.

Robinson and Noble, Inc., June 1976, Results of Drilling Gamblewood No. 2.

Robinson and Noble, Inc., May 1973, Fletcher Bay Production Well.

Robinson and Noble, Inc., August 1976, Edgewater Replacement Well No. 2.

Robinson and Noble, Inc., 1978, Silverdale Water District - Central Kitsap School District Test Well Construction.

Robinson and Noble, Inc., 1979, Edgewater Well No. 3, Kitsap County.

Robinson and Noble, Inc., 1981, Gazzam Lake Test Well.

Robinson and Noble, Inc., 1981, Keyport No.2 Test Well.

Robinson and Noble, Inc., 1980, Kingston Well No. 3.

Robinson and Noble, Inc., July 1981, Groundwater Hydrology at the Naval Submarine Base Bangor, Volume One, Text, Volume Two, Appendices and Plates.

Robinson and Noble, Inc., May 1989, South Kingston Production Well, Kitsap County PUD No. 1.

Robinson and Noble, Inc., November 1980, Meadowmeer Aquifer Protection Study for Kitsap PUD.

Robinson and Noble, Inc., March 1991, Construction and Testing of the Zukowski Site Well for Central Kitsap School District.

Robinson and Noble, Inc., September 1991, Construction and Testing of Westwind Well for Silverdale Water District.

Robinson and Noble, Inc., June 1985, Construction Report for Chena Raod Well 2 for Silverdale Water District.

Robinson and Noble, Inc., September 1991, Construction Report for Ridgetop Well for Silverdale Water District.

Robinson and Noble, Inc., September 1981, Construction Report for Selbo Raod Well 1 for Silverdale Water District.

Robinson and Noble, Inc., February 1993, Frontier Woods Well Construction and Testing for Silverdale Water District.

Robinson and Noble, Inc., Public Utility District No. 1 of Kitsap County, Economic and Engineering Services, Inc., Washington State Department of Ecology, April 1996, Seabeck Aquifer Protection Plan.

Robinson and Noble, Inc., June 1973, Groundwater investigation of Bill Point Development, Bainbridge Island.

Robinson and Noble, Inc., August 1982, Groundwater Feasibility Study for the Port Blakely Mill Co. on Bainbridge Island.

Robinson and Noble, Inc., February 1992, Construction and Testing of Well 3 at Old Mill Road and Analysis of the Deep Aquifer.

Robinson and Noble, Inc., December 1993, Hydrograph Analysis of Port Blakely True Farm Old Mill Road Wells.

Robinson and Noble, Inc., June 1990, Results of Aquifer and well test concerning your well on Bainbridge Island (Due Application GI-25471).

Robinson and Noble, Inc., May 1981, Groundwater Exploration at Big Beef Creek Fisheries Research Center, Seabeck, Washington.

Robinson and Noble, Inc., November 1981, Construction Report Well #5 for P.U.D. No. 1 of Kitsap County.

Robinson and Noble, Inc., August 1992, Evalution of Manchester Naval Supply Center / Watauga Beach Aquifer for National Marine Fisheries Service.

Robinson and Noble, Inc., March 1980, Design and Testing of Meadowmere Well #2 Bainbridge Island, Washington.

SASSI 1994. State Salmon and Steelhead Stock Inventory.

Sceva, Jack E., September 1954, Geology and Ground Water Resources of Kitsap County, Washington.

Sebren, Martin B., October 1997, Construction and Testing of Manchester Monitor Well (ACD373), T23N/R02E-04R.

Sebren, Martin B., February 1995, Construction and Testing of Seabeck Aquifer System Test Well 4 (AAC377), T25N/R01W-25E.

Sebren, Martin B., December 1994, Construction and Testing of Kingston Well 7.

Sinclair, Kirk A. and Garrigues, Robert S. 1994. Geology, Water Resources, and Seawater Intrusion Assessment of Marrowstone Island Jefferson County, Washington. Washington State Department of Ecology. Water Supply Bulletin No. 59. 73 pp.

SounData, March/April 1995. Population Figures for Kitsap County.

Tabor, R. W., and W. M. Cady, 1978, Geologic map of the Olympic Peninsula, Map I-994: U.S. Geologic Survey.

Tillson, David S., June 1971, Suquamish Test Well No. 1.

U. S. Department of Agriculture, Soil Conservation Service. Septembert, 1980. Soil Survey of Kitsap County Area, Washington. Prepared in cooperation Washington State Department of Natural Resources, and Washington State University Agricultural Research Center. 127 pp.

U.S. Geological Survey. Water Resources Data, Washington. Water Data Report Series, prepared by the USGS Tacoma office.

U.S. Geological Survey. Report 96-4309, 1995, Ambient Quality of Groundwater in the Vicinity of Naval Submarine Base Bangor, Kitsap County, Washington.

U.S. Geological Survey. 1976, Availablitiy of Groundwater in the Area surrounding the Trident Submarine Construction Facility, Kitsap County, Washington.

Washington State Office of Financial Management (OFM) Report dated June 30, 1995.

Williams and Riis, 1989. Port Gamble Streamflow Study.

Woodward et al, 1995. South King County Precipitation.