Supplement to the Issaquah Creek Valley Ground Water Management Plan:

Area Characterization

March 1999
Final

Data and information contained in this document are current as of the period of project performance: 1989 - 1995.

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WASHINGTON STATE DEPARTMENT OF ECOLOGY

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AREA CHARACTERIZATION

1.0 INTRODUCTION

This report provides an updated characterization of the Issaquah Creek Valley Ground Water Management Area and includes information from the 1993 Lower Issaquah Valley Wellhead Protection Plan. The report also summarizes the results of ground water data collection and analysis activities conducted between 1989 and 1992 as part of the Issaquah Creek Valley Ground Water Management Plan (IGWMP). Information developed by USGS for the East King County ground water management program relating to the Sammamish Plateau is included, as this area was added to the Issaquah Creek Valley Ground Water Management Area in 1996, after the data collection and analysis had been done for both areas.

This updated area characterization is a compilation of information from previous water investigations conducted in the Issaquah Creek Valley Ground Water Management Area, and data collected as part of this ground water planning process. The physical characteristics of the Issaquah Creek Valley Ground Water Management Area are described and regulatory agencies with authority in the area are discussed. Section 2 presents a detailed description of the boundaries of the Issaquah Creek Valley Ground Water Management Area. Section 3 identifies and describes the various federal, state, and local agencies that have political jurisdiction over the Issaquah Creek Valley Ground Water Management Area.

Section 4 discusses climate, topography and drainage. The plans and policies affecting the ground water resource, and the impacts of present and future land use on ground water quality and quantity are discussed in Section 5. Water applications including sources, services, water rights, population projections and water supply and demand are discussed in Section 6. Section 7 discusses hydrology, geology, hydrogeology, new wells, the wellhead protection plan study by Golder Associates, data collection and analysis, and data needs. Section 8 contains conclusions and recommendations for protecting the ground water resource.

Data Collection

The data collection and analysis task included ground water quality and quantity data, rainfall data and stream flow data. Data were collected by various entities, including personnel from the City of Issaquah and Sammamish Plateau Water and Sewer District, Seattle-King County Health Department, King County Surface Water Management Division, King County Solid Waste Division, volunteers, and the environmental firms of Carr/Associates, Pacific Ground Water Group, and Parametrix. For the Sammamish Plateau area, the U.S. Geological Survey collected data from a network of public and privately owned water wells as part of data collection activities for the East King County Ground Water Management Plan (the Sammamish Plateau area was later added to the

Issaquah Creek Valley Ground Water Management Area). These activities are described in the "Data Collection and Analysis Plan for East King County, Washington, Ground Water Management Area Study", July 1, 1991.

The data collection effort was based on recommendations by project consultants Carr & Associates, Pacific Ground Water Group and Parametrix, Inc. as defined in the Data Collection and Analysis Report (February 1990 and 1992) and the U.S. Geological Survey. This report was reviewed and approved by Ecology, the Seattle-King County Health Department, the Sammamish Plateau Water and Sewer District, and the Issaquah and East King County Ground Water Advisory Committees. All data collected were handled and saved as instructed by the July 1989 Data Management Plan approved by Ecology and the Issaquah Creek Valley Ground Water Advisory Committee (GWAC), and the "Data Collection and Analysis Plan for East King County, Washington, Ground Water Management Area Study", July 1, 1991.

The objective of the data collection and analysis task in the development of the Issaquah Creek Valley Ground Water Management Area plan was to further public understanding of the entire Issaquah Creek Valley water resource (quantity and quality) and to identify data gaps that are needed to determine baseline conditions and facilitate protection of the Issaquah Creek Valley Ground Water Management Area ground water. This was accomplished through the generation and interpretation of historical and new data collected during this study, as described below. The first area characterization reports (July 1990 and December 1991) examined existing information on physical climate, surficial geology, geography, climate, water use and land uses. The draft Ground Water Management Plan (March 1996) updated the 1990 and 1991 reports and included a description of new data collected and an analysis of these data, information from new wells drilled, and a summary of the wellhead protection study conducted by Golder Associates for the City of Issaquah and the Sammamish Plateau Water and Sewer District in 1993. This final version of the Plan presents little new data but accomodates the report to the changes in the boundary of the Ground Water Management Area.

Rainfall data were collected from 1988 to 1990 from eighteen stations by personnel from the King County Surface Water Management and Solid Waste Divisions of King County Department of Natural Resources, the Washington State Department of Natural Resources, and volunteers living in this area. Stream gauge data were collected from 1988 to 1990 from seventeen sites by personnel from the King County Surface Water Management Division, the Washington State Department of Natural Resources, and the U.S. Geological Survey. Ground water levels were measured from 1989 to 1992 from forty-eight well sites by personnel from the City of Issaquah, Sammamish Plateau Water and Sewer District, and the Seattle-King County Health Department. Ground water levels on the plateau were initially documented by USGS from well logs, and were subsequently measured by Seattle-King County Health Department for 2.5 years at ten sites.

Ground water quality samples were collected from nineteen wells by personnel from the City of Issaquah, Sammamish Plateau Water and Sewer District, and the Seattle-King County Health Department. Ground water quality data were also collected at the Cedar Hills Landfill by personnel from the Department of Natural Resources, Solid Waste Division. Ground water quality data were collected in the area surrounding the Cedar Hills Landfill by personnel from the Solid Waste Section of the Environmental Health Division of the Seattle-King County Health Department. Ground water quality samples on the plateau were initially collected by USGS, and were subsequently collected by Seattle-King County Health Department at one site. As part of this study, one monitoring well was drilled in the central part of the Issaquah Creek Valley Ground Water Management Area to collect data to evaluate hydrostratigraphy, ground water flow and water quality. Three wells were later drilled in the lower Issaquah valley as part of the City of Issaquah and the Sammamish Plateau Water and Sewer District's Wellhead Protection study.

2.0 ISSAQUAH GROUND WATER MANAGEMENT AREA BOUNDARIES

The Issaquah Creek Valley Ground Water Management Area (GWMA, Figure 2.1) is a 94 square-mile area about 15 miles east of Seattle (Figure 2.2). The GWAM consists of the Issaquah Creek and Tibbetts Creek drainage basins and the Sammamish Plateau and forms the southern and eastern portion of the larger Lake Sammamish watershed. The Sammamish Plateau, east of Lake Sammamish, at the boundary of the service area of the Sammamish Plateau Water and Sewer District and the former Cascade View Water District, was added to the Issaquah Creek Valley Ground Water Management Area in 1996, at the request of the Sammamish Plateau Water and Sewer District (Figure 2.3). This change was made in March 1996, after the publication of the Draft Ground Water Management Plan.

This final version of the Ground Water Management Plan includes a number of text and graphics changes required by this boundary change. However, since most of the Area Characterization analysis had been completed for the March 1996 Draft Ground Water Management Plans, there may be some minor discrepancies in the data for the area of the change.

The GWMA boundaries were primarily defined by the natural divides of the Issaquah Creek and Tibbetts Creek drainage basins. All drainage basins in the Issaquah Creek Valley Ground Water Management Area flow into Lake Sammamish including the Issaquah, North Fork, East Fork, Tibbetts, Mason, Fifteen Mile, Carey, and Holder Creek drainage basins (Carr Associates 1986). However, 1.5 square miles of the Issaquah Creek basin were excluded from the Issaquah Creek Valley Ground Water Management Area because they fell within the boundaries of the City of Seattle's Cedar River Watershed. The current boundary assumes that ground water contours conform to the surface topography of the Issaquah and Tibbetts Creek drainage basins and that the existing study area demarcates a ground water confluent that eventually flows into Lake Sammamish. Future changes to the current Issaquah Creek Valley Ground Water Management Area boundary may be made if necessary, after additional documentation of the hydrogeologic characteristics of the Issaquah Creek Valley Ground Water Management Area.

3.0 JURISDICTIONS IN THE ISSAQUAH GROUND WATER MANAGEMENT AREA

This section discusses the role of public agencies with jurisdiction in the Issaquah Creek Valley Ground Water Management Area. The ground water-related policies and activities of the agencies in the Issaquah Creek Valley Ground Water Management Area are organized below by federal, state, county and local agencies, respectively.

3.1 Federal Agencies

Federal agencies influence ground water management in various ways, both as regulatory bodies and as policy makers. Federal agencies with jurisdiction in the Issaquah Creek Valley Ground Water Management Area are discussed below.

3.1.1 United States Environmental Protection Agency

The U.S. Environmental Protection Agency administers numerous programs that influence ground water management in the Issaquah Creek Valley Ground Water Management Area, provides technical assistance to state and municipal officials on a variety of ground water-related issues, and acts as a regulatory agency. As a lead agency, the U.S. Environmental Protection Agency deals with water pollution, underground storage tanks, pesticide and herbicide use, liquid waste, landfills, hazardous waste management (including Comprehensive Environmental Response, Compensation, and Liability Act, Superfund Amendments and Reauthorization Act of 1986 sites and generators), and drinking water management. As a support agency, the U.S. Environmental Protection Agency is involved with regulation of lagoons and holding ponds, sewage waste disposal, sludge application, spill control and prevention, solid waste handling, storm-water runoff, ground water, surface water, wetlands, and wells and water rights. The U.S. Environmental Protection Agency administers the Sole Source Aquifer Program, the Pesticides in Ground Water Survey, and the Agricultural Chemicals in Ground Water Strategy. The U.S. Environmental Protection Agency also oversees the cleanup investigation and ground water monitoring of the Queen City Farms Superfund site.

3.1.2 U.S. Department of Agriculture

The U.S. Department of Agriculture provides technical assistance to landowners and communities concerning municipal sludge applications, livestock, crops, irrigation design, wildlife, and animal-waste ponds. The U.S. Department of Agriculture is a lead agency for pesticide and herbicide programs, and it administers programs such as fish and wildlife conservation programs and watershed projects.

3.1.3 The Soil Conservation Service/Natural Resources Conservation Service

As part of the U.S. Department of Agriculture, the Soil Conservation Service, currently known as the Natural Resources Conservation Service, provides technical assistance in soil erosion control and pesticide and herbicide use. It also plays a support role in agriculture, diking and drainage, forestry, lagoons, surface water, and wetlands.

3.2 <u>Washington State Agencies</u>

Some agencies operate at the state level but also influence ground water issues at a local level. The following discussion cites those state agencies that will influence the Issaquah Creek Valley Ground Water Management Area.

3.2.1 Washington State Department of Ecology (Ecology)

Ecology is charged with protecting the waters of the state; therefore, Ecology's activities affect ground water management decisions in the Issaquah Creek Valley Ground Water Management Area both directly and indirectly. Funding for the development of the Issaquah Creek Valley Ground Water Management Plan came from the Centennial Clean Water fund, a grant administered by Ecology. Ecology issues discharge permits, performs compliance monitoring, enforces discharge regulations, and responds to pollution incidents. Ecology serves as a lead agency in over 20 environmental categories, including aquifer depletion, seawater intrusion, water resources, well construction and abandonment, and water rights. As a regulatory agency, Ecology is responsible for the cleanup of leaks and spills of hazardous materials, except in navigable waters, oversight of Resource Conservation and Recovery Act facilities and state hazardous waste cleanup sites, and the regulation of underground storage tanks. Ecology is working with the U.S. Environmental Protection Agency on the remediation of the Queen City Farms site.

3.2.2 Washington State Department of Health, Office of Environmental Health Programs

The Washington State Department of Health is involved in a variety of programs that influence ground water management. As part of the Northwest Drinking Water Operations Programs, the Washington State Department of Health is responsible for plan approval for Group A public water supplies, including well site inspections and final system certificate of completion review and it administers the wellhead protection program. The Washington State Department of Health conducted an area wide ground water monitoring project in the spring of 1995. This project included a statewide sampling of 1326 wells for pesticides and herbicides including 77 sites in King County. Results of the analysis indicated two wells in King County exceeded the U.S. Environmental Protection Agency's detection limit for pesticides/herbicides. The results of this project has allowed the Washington State Department of Health to grant area wide waivers to purveyors for ongoing monitoring.

Under the heading of On-Site Sewage Program, the Washington State Department of Health is the state agency responsible for enforcing Chapter 248-96 Washington Administrative Code (WAC), the regulations that prescribe design and installation standards for septic systems. These regulations are currently under revision to increase effectiveness in protecting public health and water quality. The Washington State Department of Health is also responsible for guideline development and performance review of alternative sewage disposal systems.

3.2.3 Washington State Department of Natural Resources

The management of state lands for coal and timber production in the Issaquah Creek Valley Ground Water Management Area is the responsibility of the Washington State Department of Natural Resources. The Washington State Department of Natural Resources also collects hydrologic data as part of its timber management program.

3.2.4 Washington State Department of Transportation

The Washington State Department of Transportation is involved in highway planning and in the Issaquah Basin carries out shoulder and ditch maintenance as well as roadside spraying for plant control. Interstate 90 and State Routes 900, 18, and 202 are the only roads maintained by the Washington State Department of Transportation in the study area.

3.2.5 Washington State Department of Trade and Economic Development

The Washington State Department of Trade and Economic Development provides guidelines for implementing the Growth Management Act.

3.2.6 King Conservation District

The King Conservation District works with the urban and agricultural community to implement animal management and land use practices that increase productivity while minimizing soil erosion and water pollution. The King Conservation District is neither a branch of county government nor an enforcement agency, but rather a political subdivision of state government authorized by Chapter 89.08 RCW. The King Conservation District is dedicated to the conservation and best uses of the natural resources of King County.

3.3 <u>King County Agencies</u>

King County agencies, which operate in the Issaquah Creek Valley Ground Water Management Area, conduct activities that either directly or indirectly affect ground water management in the area.

3.3.1 The Metropolitan King County Council

The Metropolitan King County Council has legislative authority to enact ordinances and regulations governing protection of ground water resources, including land use provisions. In the past, the Metropolitan King County Council administered water resource, land use, and wetlands programs in addition to assisting in community plan reviews. The Metropolitan King County Council has adopted the King County Comprehensive Plan, and the community plans for Tahoma/Raven Heights, East Sammamish, Newcastle, Bear Creek, and Snoqualmie (See Figure 3.1).

3.3.2 King County Office of Strategic Planning

The Office of Strategic Planning is primarily involved in developing the King County Comprehensive Plan, subarea land use plans, affordable housing, and economic development. Additionally, this Office is involved in coordinating King County's review of comprehensive plans for all water and sewer systems operating in unincorporated King County.

3.3.3 King County Department of Development and Environmental Services

The King County Department of Development and Environmental Services regulates and enforces land development and zoning in the Issaquah Creek Valley Ground Water Management Area. Its specific duties include development control, commercial and residential permitting, sensitive area monitoring, and environmental review. The Department of Development and Environmental Services also implements the community plans for Tahoma/Raven Heights, East Sammamish, Newcastle, and Snoqualmie by issuing building permits and by administering rezones and plats.

3.3.4 Seattle-King County Health Department, Environmental Health Division

The Seattle-King County Health Department is an advisory and regulatory body involved in a wide variety of related topics, including regulation of Group B public water systems. The Seattle-King County Health Department was the lead agency for the Issaquah Creek Valley Ground Water Management Plan through December of 1995. The Seattle-King County Health Department coordinated the activities necessary for ground water management plan development. Additionally, the Seattle-King County Health Department collected ground water quality and quantity data, managed the ground water database, drafted technical issue papers, and prepared the budget for development of the Issaquah Creek Valley Ground Water Management Plan. On January 1, 1996, the King County Department of Natural Resources, Surface Water Management Division replaced the Seattle-King County Health Department as lead agency for completion and implementation of the Issaquah Creek Valley Ground Water Management Plan.

The Seattle-King County Health Department is responsible for evaluating soil quality preparatory to permitting for on-site wastewater disposal systems. The Seattle-King

County Health Department issues permits for proposed on-site sewage systems; responds to complaints about, and regulates the repair of, failing systems; reviews all subdivision proposals for which on-site sewage disposal is proposed; and educates homeowners in the proper maintenance of their systems. The Solid Waste Section of the Seattle-King County Health Department is responsible for permitting landfills, overseeing and permitting sludge applications, and sampling ground water in areas around the Cedar Hills Landfill.

The Local Hazardous Waste Management Program in King County helps businesses and households in identifying hazardous wastes, reducing the amount of hazardous waste and in managing these wastes properly. This Program is a joint effort by the Seattle-King County Health Department, King County Department of Metropolitan Services, King County Department of Natural Resources Solid Waste Division, the Seattle Solid Waste Utility, and 32 cities in King County. The goal of the program is to divert the maximum amount of household hazardous waste and small quantity generator waste from disposal in the municipal waste stream and from the environment.

The Local Hazardous Waste Management Program in King County covers these areas: household hazardous waste education and collection; small quantity generator education/technical assistance; collection; compliance; and program evaluation. The household hazardous waste education coordinator is housed at the Seattle-King County Health Department, and staff in the other agencies collaborate on the household hazardous waste education activities. Household hazardous waste collection and waste handling is coordinated by both the King County Department of Natural Resources Solid Waste Division and the Seattle Solid Waste Utility. There are two fixed collection sites and one mobile collection facility. Small quantity generator education and technical assistance consists of a telephone information line, printed material, seminars and workshops, an industrial materials exchanges (IMEX), and on-site consultation. The coordinator for this section is at King County Department of Natural Resources, Water and Land Resources Division. Small quantity generator collection activities include providing waste collection facilities, operated by private firms under contract to local government, and encouraging licensed private sector hazardous waste handlers to take small quantity generator waste. These collection activities are coordinated by Solid Waste. The compliance coordinator is housed at King County Department of Natural Resources, Water and Land Resources Division. Compliance activities include the Interagency Regulatory Advisory Committee, which review proposed regulations, the field teams perform on-site audits and other advisory visits and respond to complaints about businesses. Evaluation of the program is accomplished by implementation of the evaluation strategy developed by Seattle-King County Health Department. The actual data analysis is carried out by consultants, overseen by Seattle-King County Health Department. (*Local Hazardous Waste Management Plan*, November, 1990, Final Plan and EIS and *Local Hazardous Waste Management Plan Annual Report*, Calendar Year 1994, June 1995.)

3.3.5 King County Department of Natural Resources

The following divisions of the Department of Natural Resources conduct the activities described below in the Issaquah Creek Valley Ground Water Management Area.

Solid Waste Division

The Solid Waste Division operates and maintains the Cedar Hills Landfill. The Solid Waste Division responsibilities include on-site ground and surface water quality monitoring.

Surface Water Management/Water and Land Resources Division

On January 1, 1996, the Surface Water Management Division became a part of the new King County Department of Natural Resources and assumed the lead agency role for the ground water program. Subsequently, the Surface Water Management Division was renamed the Water and Land Resources Division. Given the continuity between surface water and ground water in much of King County, the Water and Land Resources Division's management of surface water has a direct influence on the quantity and quality of water infiltrating to ground water.

The King County Water and Land Resources Division is responsible for a variety of programs that address surface water quality and quantity in the Issaquah Creek Valley Ground Water Management Area. The programs include basin planning, non-point source pollution control, wetlands, and the construction and maintenance of drainage and water quality facilities.

Wastewater Treatment Division

The Wastewater Treatment Division oversees most of the sewage collection and treatment for sewered areas in the Issaquah Creek Valley Ground Water Management Area, and is the designated regional water quality planning agency under the 1972 Clean Water Act. The Wastewater Treatment Division provides sewage treatment services to the City of Issaquah and the Sammamish Plateau Water and Sewer District.

Resource Lands and Open Space

The Water and Land Resources Division also includes the Open Space and Resources Lands Sections. These Sections provide resource planning services, administers County open space acquisition programs, public benefit rating system and other agriculturally related programs. The Resource Planning Section, Environmental Division was the lead agency for compilation of the natural environment chapter of the King County Comprehensive Plan. The Resource Planning Section also studies the interaction of wetlands and surface runoff and is involved in drainage basin planning.

3.3.6 Department of Transportation

The Department of Transportation consists of the former Department of Metropolitan Services (formerly Metro) and the former King County Department of Natural Resources, Roads Division.

Road Services Division

In addition to construction and maintenance of roads and associated drainage, the Department of Transportation, Road Services Division is responsible for vegetation control along the roadside.

3.4 <u>Local Agencies</u>

3.4.1 City of Issaquah

The City of Issaquah Planning Department, Environmental Community Services (SEPA), Parks Department and Natural Resources are the agencies primarily responsible for all issues related to ground water management within city limits. The Planning Department and Environmental Community Services are responsible for policy development and the permitting and review of new development(s) in the city. The City of Issaquah Public Works has responsibility for water and sewer system planning and administration, road maintenance, plant control on city property, and local water quality monitoring and protection.

3.4.2 Sammamish Plateau Water and Sewer District

The service area of the Sammamish Plateau Water and Sewer District is in the northern portion of the Issaquah Creek Valley Ground Water Management Area. Its role is to provide water and sewer service within this specific area as well as to advise on matters relating to ground water quality and quantity. Sammamish Plateau Water and Sewer District's legal mandate was provided under state statutes, Chapters 56 and 57 RCW (Little 1989).

3.4.3 City of Sammamish

Incorporation of the City of Sammamish was voted on and passed on November 3, 1998. The incorporation is scheduled to go into effect on August 31, 1999, which is after the finalization of this document.

4.0 PHYSICAL GEOGRAPHY

This section describes the Issaquah Creek Valley Ground Water Management Area's geographic setting, topography, and climate.

4.1 Geographic Setting

The Issaquah Creek Valley Ground Water Management Area is located in King County, Washington, east of the urbanized Seattle-Bellevue areas. The study area lies generally east and southeast of Lake Sammamish. The boundaries of the southern portion of the approximately 94-square-mile Issaquah Creek Valley Ground Water Management Area are largely defined by the natural drainage divides of the Tibbetts Creek and Issaquah Creek watersheds (see Figure 4.1). The Sammamish Plateau drains to Lake Sammamish by several small creeks. The major lakes on the Plateau include Pine, Beaver, Yellow, Laughing Jacobs and Allen Lakes. About 1.5 square miles (3.9 km^2) of the Issaquah Creek watershed southeast of State Route 18 (which lies within the boundary of the city of Seattle's Cedar River Watershed) is excluded from the Issaquah Creek Valley Ground Water Management Area.

The northern portion of the Ground Water Management Area is defined by the service area of the Sammamish Plateau Water and Sewer District, and includes portions of the watersheds for East Lake Sammamish (including several sub-basins), Evans Creek, Patterson Creek, and Ames Lake (Figure 4.1).

4.2 Topography

Much of the Issaquah Creek Valley Ground Water Management Area lies above 400 feet (122 m) elevation and can be described as hilly, uneven uplands or mountainous. Rugged, steeply sloped hillsides and a group of peaks locally known as the Issaquah Alps dominate the landscape.

To simplify later descriptions and establish geographic references, local terrain is subdivided into three physiographic units: mountains, uplands and valleys. The mountains and uplands are forested or partially cleared. Lower valleys are partially or completely cleared as pasture or residential/commercial areas. Figure 4.2 depicts Issaquah Creek Valley Ground Water Management Area physiographic units.

Mountain areas include all or portions of Grand Ridge, Cougar Mountain, Squak Mountain, West Tiger Mountain, Tiger Mountain, South Tiger Mountain, and Taylor Mountain. Peak elevations are between 1,400 and 3,000 feet (427 to 914 m). Tiger Mountain is the tallest peak at 3,004 feet (916 m). The various Tiger Mountain peaks and Taylor mountain area will hereafter be collectively referred to as the Tiger Mountain peak complex. Numerous peaks, pinnacle-like hilltops, steeply sloped ridges, cliffs, and sharply cut canyons typify the relief.

The uplands are generally situated between 400 to 700 feet (122 to 213 m) elevation and include several residential areas. The upland surface is shaped by small hills, gently sloping areas, and depressions. Drainage is not well-defined. Significant upland features include portions of the Sammamish Plateau, Union Hill Plateau, the lower western slope of Grand Ridge, Tradition Lake Terrace, Cedar Hills, and Hobart Plateau. Several small lakes are situated on the uplands; these being Pine, Beaver, Yellow, Laughing Jacobs, Allen, Tradition, MacDonald, Francis, and Webster Lakes.

The valleys are bordered by the steep slopes and bluffs of the uplands and mountains. Valley areas are generally situated below 400 feet (122 m) elevation. The Lake Sammamish shoreline defines the lowest elevation at 25 feet (8 m) above mean sea level. Surface relief varies and includes features such as short canyon-like cuts, irregular hills, depressions, ponds, terraces, alluvial fans, and narrow to broad floodplains. Drainage in the valleys is dominated by the major streams described below. In addition, there is a portion of Patterson Creek Valley included to the northeast.

Tibbetts Creek and various unnamed streams and ditches drain about 6 square miles (16 km^2) in the northwest part of the Issaquah Creek Valley Ground Water Management Area, beneath Cougar and Squak Mountains. The lower reach of Tibbetts Creek joins a channelized drainage system that empties into Lake Sammamish.

Issaquah Creek and its tributaries drain approximately 60 square miles (155 km^2) of the Issaquah Creek Valley Ground Water Management Area. Six major streams feed Issaquah Creek. Fifteen-mile Creek, Mason (sometimes called MacDonald) Creek, Holder Creek, and Carey Creek join Issaquah Creek and drain the entire southern half of the Issaquah Creek Valley Ground Water Management Area. Issaquah Creek flows northward through a narrow gap between Squak Mountain and West Tiger Mountain to the City of Issaquah, where it is joined by its two remaining tributaries, the East Fork and the North Fork.

Below 400 feet (122 m) elevation, Issaquah Creek and certain stretches of its tributaries flow through somewhat broadened valleys, bordered by sharply rising slopes. During the rainy season and storm events, numerous unnamed, intermittent streams and springs rush down these slopes and contribute substantial flows to perennial streams. The valley widens to form a flat plain from the City's downtown to the shore of Lake Sammamish. Issaquah Creek and Tibbetts Creek flow across opposite sides of this valley and empty into the south end of Lake Sammamish.

4.3 Climate

Maritime air masses from the Pacific Ocean influence the climate year round and result in moderate temperatures. Short periods of hot, dry weather are caused by continental air masses brought by easterly winds. Likewise, short periods of cold winter temperatures are usually caused by frigid continental air masses.

Temperature data for the closest weather station at Landsburg (located south of the Issaquah Creek Valley Ground Water Management Area) are indicative of the cool, moderate climatic conditions associated with the region. July and August are typically the warmest months of the year, with an average temperature of 62° Fahrenheit (16.7° C).

Warm season temperatures from June through September average 60° (15.6° C). The colder months are November through March with temperatures averaging 40° (4.4° C). January is the coldest month, averaging 37° (2.8° C). The average annual temperature is 49° (9.6° C) with the extreme temperatures ranging from -27° to 100°F. For elevations above Landsburg's 535 feet (163 m), average temperatures are expected to be cooler.

During the fall and winter months, prevailing winds from the southwest bring in moist air about the same temperature as the ocean's surface. Precipitation is typically of light to moderate intensity and long duration. About 75 percent of the annual precipitation occurs from October through March. Winter precipitation occasionally falls as snow at the higher elevations. Refer to Figure 4.3.

In the spring and summer prevailing winds are from the northwest. The summer can be described as the dry season. Typically, less than 5 percent of the annual rainfall occurs in July and August. Although infrequent, thunderstorms are more likely to occur during the summer months.

5.0 LAND USE IMPACTS ON GROUND WATER

The following discusses land use plans and policies, and the impacts of various land use activities on the ground water resource in the Issaquah Creek Valley Ground Water Management Area.

5.1 Existing and Proposed Land Use

This section discusses plans and policies relating specifically to ground water management for each agency in the Issaquah Creek Valley Ground Water Management Area and the impacts to ground water from the various land use activities.

5.1.1 Plans and Policies Affecting Land Use

An understanding of existing land use activities and development trends in the Issaquah Creek Valley Ground Water Management Area requires a discussion of local and state land use policies influencing these factors. A summary of the King County Comprehensive Plan, Community Plans; City of Issaquah comprehensive plan, subarea plan, and ground water ordinance is included in this section. The Sammamish Plateau Water and Sewer District's authority does not permit it to adopt or enforce ground water regulations (Little, 1989).

King County Comprehensive Plan. The King County Comprehensive Plan establishes countywide policies and goals as well as a framework for policy making at the local level. The King County Comprehensive Plan is concerned with land use in the county and directs decisions affecting growth and land development. The King County Comprehensive Plan was revised in 1994 to comply with the Growth Management Act and the King County Countywide Planning Policies. The King County Comprehensive Plan is updated annually.

The King County Comprehensive Plan establishes policy priorities for ground water management for all of King County, including the Issaquah Creek Basin. The Comprehensive Plan calls for the implementation of these policies through land use plans and development reviews. Ground water policies should also be used to guide the County's review of the plans prepared for water and sewer purveyors and other government projects.

The King County Comprehensive Plan establishes countywide policies and goals as well as a framework for policy making at the local level. The King County Comprehensive Plan is concerned with land use in the county and directs decisions affecting growth and land development. The King County Comprehensive Plan includes the following policies revised to comply with the Growth Management Act and the King County Countywide Planning Policies.

NE 332 In unincorporated King County, areas identified as sole source aquifers or as areas with high susceptibility for ground water contamination where aquifers are used for potable water are designated as Critical Aquifer Recharge Areas as shown on the map, entitled Areas Highly Susceptible to Ground Water Contamination. Since this map focuses primarily on water quality issues, the county shall work in conjunction with cities and ground water purveyors to designate and map recharge areas which address ground water quantity concerns as a new information from ground water and wellhead protection studies adopted by county or state agencies becomes available. Updating and refining the map shall be an ongoing process.

NE-333 King County should protect the quality and quantity of ground water countywide by:

a. Placing a priority on implementation of adopted Ground Water Management Plans;
b. Developing a process by which King County will review, and implement, as appropriate, adopted Wellhead Protection Programs in conjunction with cities and groundwater purveyors;
c. Developing, with affected jurisdictions, best management practices for new development and for forestry, agriculture, and mining operation recommended in adopted Ground Water Management Plans and Wellhead Protection Programs as appropriate. The goals of these practices should be to promote aquifer recharge quality and to strive for no net reduction of recharge to ground water quantity; and,
d. Refining regulations as appropriate to protect critical aquifer recharge areas when information is evaluated and adopted by King County.

NE-334 King County should protect ground water recharge quantity in the Urban Growth Area by promoting methods that infiltrate runoff where site conditions permit, except where potential ground water contamination cannot be prevented by pollution source controls and stormwater pretreatment.

NE-335 In making future zoning and land use decisions which are subject to environmental review, King County shall evaluate and monitor ground water policies, their implementation costs, and the impacts upon the quantity and quality of ground water. The depletion or degradation of aquifers needed for potable water supplies should be avoided or mitigated, and the need to plan and develop feasible and equivalent replacement sources to compensate for the potential loss of water supplies should be considered.

NE-336 King County should protect ground water in the Rural Area by:

a. Preferring land uses that retain a high ratio of permeable to impermeable surface area, maintain or augment the infiltration capacity of the natural soils and;
b. Requiring standards for seasonal and maximum vegetation clearing limits, impervious surface limit, and, where appropriate, infiltration of surface water. These standards should be designed to provide appropriate exceptions consistent with Policy R-216.

King County Community Plans. Community plans represent another legally binding policy document with jurisdiction in the Issaquah Creek Valley Ground Water Management Area. King County is divided into community planning areas allowing citizens and planning officials to develop local area goals, plans, and policies. Once adopted by the Metropolitan King County Council, a community plan becomes an official document affecting development and municipal expenditures in the community.

The King County Comprehensive Plan requires that within one year of adoption of the 1994 Plan that the County Executive should report to the Council with a work program to revise, replace, or repeal existing community plans within three years. The Council adopted the following King County Comprehensive Plan policies:

I-301 Existing community plans shall remain in effect and continue as official County policy until reviewed and revised to be consistent with the 1994 Comprehensive Plan and adopted as elements of the Comprehensive Plan, or until repealed or replaced. In the case of conflict or inconsistency between applicable policies in existing community plans and the 1994 Comprehensive Plan, the Comprehensive Plan shall govern.

I-302 The King County Executive will report to the Council by December 31, 1995 or by the time the first amendments to the Comprehensive Plan are adopted, whichever is sooner, with a work program to review and revised existing community plans to make them consistent with the Comprehensive plan, or to replace or repeal them, within three years of adoption of this Plan. Any such review shall include extensive citizen participation and the participation of adjacent or affected cities.

King County Community Planning Areas in the Issaquah Creek Valley Ground Water Management Area are Tahoma/Raven Heights, East Sammamish, Newcastle, Snoqualmie, and a small portion of Bear Creek (Figure 3.1). Policies are developed for each community and, if adopted by the Metropolitan King County Council, they are included in the community plan.

Since the majority of the study area falls within the boundaries of the Tahoma/Raven Heights Community, land use policies for this community have a greater influence on land use in the Issaquah Creek Valley Ground Water Management Area than do policies for other communities. The Tahoma/Raven Heights Plan (King County Planning 1984) lists four general elements that describe the most important land use priorities in the area:

- The rural character should be preserved and balanced with new development;
- The compatibility of adjacent land uses should be maintained, especially with regard to new development and rural uses;
- Public services should meet existing demand before expanding to serve new development;
- Sensitive areas should be permanently protected, and development should be redirected whenever it poses a threat to sensitive areas.

The East Sammamish Community Plan was updated and adopted by the Metropolitan King County Council on May 25, 1993. The East Sammamish Community Plan includes Grand Ridge, which is located in the northeast area of the Issaquah Creek Valley Ground Water Management Area. The majority of Grand Ridge was designated rural with some quarry mining designations. The natural environment chapter of the East Sammamish Community Plan includes policies to implement the Issaquah Creek Valley Ground Water Management Plan (see Appendix B).

Ground water plans and policies specific to the Issaquah Creek Basin are developed in each of the four King County Community Plans with jurisdiction in the area. The key features of these plans relating to ground water include:

- The demand for water in Tahoma/Raven Heights should not exceed the area's ability to provide clean, plentiful ground water.
- As in the King County Comprehensive Plan, the Tahoma/Raven Heights Plan maintains that ground water recharge areas and watersheds should be identified and protected from potentially harmful land uses.
- The Snoqualmie Plan specifies that underground storage tanks holding potential water pollutants should have special containment and leak detection systems.

- The East Sammamish Plan includes the following key features related to ground water:

NE-8 Upon adoption, the recommendations of the Issaquah Creek, Redmond-Bear Creek and East King County Ground Water Management Program(s) should be implemented through zoning and other mechanisms to protect ground water resources.

GM-16 The eastern portion of Grand Ridge should retain its Rural designation and is not included within the UGA. Zoning for this eastern portion shall require rural clustering. The western portion of Grand Ridge that is less environmentally constrained shall also keep a Rural designation and is not within the UGA. Residential development within the western portion of Grand Ridge should require rural clustering. The western portion is substantially less constrained than the balance of Grand Ridge, and redesignation to Urban may be considered through a plan amendment study, once the Issaquah Wellhead Protection Study is complete. Such plan amendment study also must comply with the Ground Water Management Plan when approved by the Department of Ecology. Land use decisions should be compatible with the findings of the Wellhead Protection Study and the adopted Ground Water Management Plan.

GM-16 has been superseded by the 1994 King County Comprehensive Plan. Policy I-301 of the Plan states that existing community plans shall remain in effect and continue as official county policy until reviewed and revised to be consistent with the 1994 Plan and adopted as elements of the King County Comprehensive Plan or until repealed or replaced. In the case of conflict or inconsistency between applicable policies in existing community plans and the 1994 King County Comprehensive Plan, the Comprehensive Plan shall govern.

Policy U-510 of the Comprehensive Plan, designates the Grand Ridge site as an Urban Planned Development. The Grand Ridge area includes an Urban Planned Development, public open space and rural areas. The exact uses and development standards for the urban and rural areas will be determined upon agreement to an Urban Planned Development conditions by the Metropolitan King County Council.

NE-6 Public sewers are the preferred method for wastewater treatment in Urban Areas, including Urban Reserve Areas. Within Rural Areas, and Urban Areas where sewers are not yet available, proper siting and maintenance of septic systems should continue to receive special attention for new and existing land development to reserve the valuable ecological functions and beneficial public uses of water resources.

NE-11 All golf course proposals shall be carefully evaluated for their impact on surface and ground water quality and quantity, sensitive areas, and fish and wildlife resources and habitat.

NE-12 Water used for irrigating golf courses should come from non-potable water sources whenever possible. Use of natural surface water sources, such as streams, should be avoided due to impacts on fish and other wildlife habitat. A water conservation plan must be submitted with golf course applications and should address measures such as the use of drought-tolerant plant species.

FS-8 Areas identified as recharge areas should be protected. Methods to be considered should include use of clustered development, maintaining or redesignating the area for low-density development conditions, the amount of clearing and impervious area restrictions, and requiring stringent adherence to drainage and surface water runoff protection guidelines.

The Issaquah Creek Basin and Nonpoint Action Plan is one of a series of basin plans being completed within the Issaquah Creek Valley Ground Water Management Area. The plan focuses on drainage and flooding, water pollution, and programs with fish and wildlife habitat in the 61-square mile Issaquah Creek basin. The plan recommends a set of regulatory, programmatic, and capital improvement actions to address these problems. While the plan focuses on surface water issues, the maintenance of ground water quality and recharge was considered in the development of the recommendations. The plan was adopted by the Metropolitan King County Council on July 10, 1995 and the Issaquah City Council has incorporated sections of this plan into the Issaquah Comprehensive Plan.

City of Issaquah

Issaquah Comprehensive Plan. The Issaquah Comprehensive Plan is one of the guiding policy documents for the City of Issaquah. In accordance with the guidelines mandated by the Washington State Growth Management Act (GMA), Issaquah adopted its Comprehensive Plan on April 17, 1995. Additional documents related to the Issaquah Comprehensive Plan include: Environmental Impact Statement for the Comprehensive Plan, released to the public in February 1995; an updated Critical Areas Ordinance, adopted July 17, 1995; and a Shorelines Master Program, to be updated in 2000. The GMA requires the protection of Critical Aquifer Recharge Areas as well as many other critical areas. (Lewine, J. 1995)

Sub-Area Plans. In 1999 Issaquah adopted the Olde Town Subarea Plan. This plan includes an integrated Environmental Impact Study addendum document intended to provide programmatic environmental review and impact analysis.

Subarea Plans adopted prior to 1995 are being examined by the Planning Department for consistency with the Issaquah Comprehensive Plan. The 1983 I-90 Subarea Plan and the

1985 Newport Subarea Plan have been repealed. The existing 1989 Tibbetts-East Cougar Subarea Plan is not repealed; however, it is to be used for policy direction and for the community input that it contains, and not as a GMA consistent plan.

Natural systems, including surface water and ground water, are examined in all of the above plans. It will continue to be a major component in Issaquah's new and updated Subarea Plans. (Lewine, J. 1999)

Ground Water Ordinance. The City of Issaquah has a non-degradation ordinance for ground water quality protection at its wellheads.

State Policy Documents

The Shoreline Management Act, adopted by the legislature in 1971, protects shoreline resources according to the environmental designation of the shoreline. Each environmental designation represents a particular land use emphasis and approach to development. Policies and recommendations within each designation encourage land uses that enhance the natural character of the shoreline. In the study area, the Act applies only to Lake Sammamish and Issaquah Creek.

Ecology enforces the water quality standards for ground water of the State of Washington (Chapter 73-200 WAC. See Appendix C). Under these standards, the Ecology antidegradation policy ensures the purity of the state's ground water and protects the natural environment. Existing and future beneficial uses must be maintained and protected, and degradation of ground water quality that would interfere with or become injurious to beneficial uses is not allowed.

5.1.2 Existing Land Use and Development Trends

The City of Issaquah and the I-90 corridor represent the primary centers of development in the study area. The majority of the area, however, is rural in character.

Existing Land Use. Residential development is concentrated in the City of Issaquah, the Mirrormont area, and in the area northeast of Lake Sammamish State Park. In the City of Issaquah, the highest density of single-family and duplex residences is east of Front Street, whereas multi-family residences are found near Hobart Road and Wildwood Boulevard. Most of the western half of the City is zoned for single-family medium-density housing. In the Issaquah Creek Valley Ground Water Management Area there are approximately 6,295 single-family residences and 2,387 multi-family units (King County LDIS October 1993). Figure 5.1A shows existing land use in the Issaquah Creek Valley Ground Water Management Area as indicated by LandSat imagery.

The primary commercial and industrial zones in the Issaquah Creek Valley Ground Water Management Area are located within Issaquah's city limits. Industrial activities include a milk processing plant, a state-owned fish hatchery, and various manufacturing activities in industrial parks located along the I-90 corridor. Issaquah also supports a variety of technical, retail, and professional services.

Industrial land use in unincorporated sections of the Issaquah Creek Valley Ground Water Management Area is limited to resource extraction and a regional landfill. Sand and gravel pits are located north of I-90 along the North Fork of Issaquah Creek and in the southwestern part of the study area near Cedar Grove Road. In addition, the Cedar Hills Regional Landfill is located in the study area on a 920-acre site north of Cedar Grove Road.

Issaquah Creek Valley's undeveloped portions include forest and agricultural lands. Logging operations take place in timber parcels to the northwest and east of Mirrormont. Agriculture in the Issaquah Creek Valley Ground Water Management Area is primarily pastoral with small farms each keeping 10 to 15 head of livestock scattered along the Issaquah-Hobart Road and in the Hobart area. Small-scale horticulture exists in individual plots throughout the study area, while a limited amount of row crops, orchards, and nurseries are located on the Hobart Plateau (Scheer 1988).

Residential Development Trends. Housing development in the Issaquah Creek Basin has increased in proportion to growth experienced in the rest of King County in the 1980s. Residential trends are reflected in Table 5.1 for the Issaquah Creek Valley Ground Water Management Area and in Table 5.2 for the City of Issaquah. In the City of Issaquah there were 29 single-family applications in 1991, 41 in 1992 and 81 in 1993. Household population forecasts are also discussed in Section 6.5 and in Table 6.5. The King County Comprehensive Plan designated the Issaquah Area as an Urban Area, where new development will be directed.

Commercial and Industrial Development Trends. With the exception of scattered markets and service stations, commercial development in the Issaquah Creek Valley Ground Water Management Area is contained within Issaquah city boundaries. Included in these plans are added retail facilities and office complexes (Issaquah/DDR 1989). Industrial development in Issaquah is limited to light assembly manufacturing and retail.

Growth of commercial and industrial services in the Issaquah Creek Valley Ground Water Management Area will increase the potential for ground water contamination. In addition, placement of these facilities over ground water recharge areas may reduce the quantity of ground water available for future use.

Agricultural Trends. Small-scale grazing and horticulture may drop off slightly in rural areas in the Issaquah Creek Valley Ground Water Management Area due to the increase in single-family housing development. The Tahoma/Raven Heights Communities Plan and the King County Comprehensive Plan designate the Hobart Plateau as rural. This designation may slow, or stop, the transition from agricultural uses to residential development.

Areas of Concern and Future Information Needs. Additional information is needed to enable accurate commercial and industrial development projections for the Issaquah Creek Basin. Figure 5.1B shows projections for future land use in the Issaquah Creek Valley Ground Water Management Area. Figure 5.1C shows proposed future land use specifically for the City of Issaquah. Information on the specific type and location of existing activities and new development occurring in the Issaquah Creek Valley Ground Water Management Area would also help to indicate where ground water contamination is likely to occur and to what extent the demand for ground water is likely to increase in the future.

5.2 <u>On-Site Septic Systems</u>

On-site septic systems can be found throughout the Issaquah Creek Valley Ground Water Management Area. They occur, to a limited extent, in those areas served by the City of Issaquah and Sammamish Plateau Water and Sewer District sanitary sewer collection systems. All on-site septic systems in the study area are regulated by the Seattle-King County Health Department. New on-site septic systems in the Issaquah Creek Valley Ground Water Management Area must conform to location and design guidelines established by the King County Board of Health Regulations, Title 13. On-site septic systems, if properly designed, installed, and maintained, may be the preferred alternative to sewers because of lower water use and reinfiltration of wastewater to the ground. The costs of installation and repair of on-site septic systems are minor when compared to the environmental and economic costs of installing and maintaining sewer systems. Depending on lot sizes and soil types these repairs may or may not conform to current regulations.

5.2.1 Soils and Sewage Effluent

According to the *Issaquah Creek Basin Current/Future Conditions and Source Identification Report,* King County Surface Water Management Division (October 1991), some soils, such as those in the Kitsap series, are more suitable for treating and absorbing sewage effluent than others. Clays and clay loams filter and attenuate contaminants well, but they do not absorb effluent adequately. Soils with a coarse texture, such as those in the Everett series, absorb effluent well, but do not remove contaminants because of their high permeability.

Soil depth is also important when determining the proper function of a sewage system. At least three feet of unsaturated soil is required to protect potable ground water aquifers. If a design reviewed by the Seattle-King County Health Department indicates that the soil depth and soil type on a proposed site are not appropriate for a conventional subsurface soil absorption system, an alternative type of system, such as a mound system or sand filter may be needed.

5.2.2 Areas of Concern and Future Information Needs

In 1990, the Seattle-King County Health Department reviewed on-site septic system records, past field surveys, and a field survey of 192 septic systems in the Issaquah Creek Basin. The file review of 1,432 systems provided an estimated on-site septic system failure rate of 5.5 percent; that is, 78 of the 1,432 systems are either currently failing or have failed in the past (Anderberg, 1991). The field survey indicated an overall 9 percent failure rate. Roughly 32 percent of the systems reviewed were installed before 1970, when the focus was on design for disposal, not treatment of wastewater. "Lack of septic system maintenance (pumping) may contribute to an increase in the number of failures in the future as only 10 percent of all systems have records of being pumped in the last 20 years" (*Issaquah Creek Basin Current/Future Conditions and Source Identification Report,* King County Surface Water Management Division (October 1991)).

These systems may be a source of nonpoint pollution to ground water if they are located in extremely permeable soils or within high recharge areas above ground water. The Issaquah Creek Valley Ground Water Management Area has limited areas of extremely permeable (Everett) soils and large areas of shallow (Alderwood) soils. Figure 5.2 shows where failing on-site septic systems are concentrated in relation to existing soil types. Many of the failure areas are located in Alderwood soils.

Another research priority should be locating all on-site septic systems, especially those with a history of failure and those located in potential ground water recharge zones. Septic drainage fields are a potential contributor of phosphates, nitrates, and synthetic organic chemicals to surface and ground water. More research is needed on the actual threat to ground water posed by drainage fields in the study area.

5.3 <u>Sewers</u>

The City of Issaquah, the Sammamish Plateau Water and Sewer District, and a small portion of the Northeast Sammamish Sewer and Water District, are the only sanitary sewer providers in the Issaquah Creek Valley Ground Water Management Area. The boundaries of these sewer service areas are shown in Figure 5.3. All other development in the study area operates on on-site septic systems. Information about existing sewered areas, capital improvement program areas, septic system areas within sewer utilities, and non-sewered areas with the Issaquah Creek Valley Ground Water Management Area can be found in the Technical Appendices of the King County Comprehensive Plan.

5.3.1 City of Issaquah

The City of Issaquah provides sanitary sewer service to most developed areas of the city. Older homes constructed before the installation of the sanitary sewer are not required to connect to the sewer system if their septic systems meet the Seattle-King County Health Department standards. The City of Issaquah has planned to extend sanitary sewers to the southern part of the city and has evaluated the impacts of extending service to Grand

Ridge and part(s) of Cougar Mountain as part of the Sewer Comprehensive Plan update. The City of Issaquah is not planning to extend the sanitary sewer to Mirrormont (Lynne 1994). Leaks have been detected in some of Issaquah's older sewer lines which were installed more than 30 years ago. Leaks in the Issaquah system are located by using cameras; leaks are repaired by grouting. Since the shutdown of a small sewage treatment facility on Issaquah Creek in 1962, the City of Issaquah has routed all sewage to King County Department of Natural Resources, Wastewater Treatment Division's treatment facility in Renton via a trunk line.

5.3.2 Sammamish Plateau Water and Sewer District

The Sammamish Plateau Water and Sewer District serves the majority of the Plateau in the northern portion of the Issaquah Creek Valley Ground Water Management Area. The Sammamish Plateau Water and Sewer District began to construct a sanitary sewer system in 1970. The Sammamish Plateau Water and Sewer District sewer system serves residences and also businesses north of the City of Issaquah limits. Future connections will be made to all new buildings constructed in this area and to those homes found to have inadequate septic systems by the Seattle-King County Health Department (Phillips 1989). As with the City of Issaquah's sewer system, all sewage from the Sammamish Plateau Water and Sewer District sewer system is sent through a trunk line to King County Department of Natural Resources, Wastewater Treatment Division's treatment facility in Renton.

5.3.3 Areas of Concern and Future Information Needs

For both of the referenced sanitary sewer collection systems, additional information is needed on existing and projected sewer quantities, as well as a detailed account of future service options and system expansion plans. This information, together with data on sewer line leaks, would provide a more complete picture of Issaquah Creek Valley Ground Water Management Area sewer service in relation to sensitive ground water areas.

5.4 <u>Stormwater</u>

5.4.1 Existing Systems

Storm water is important to ground water management for two reasons. First, storm water has the potential to carry contaminants, such as oil and grease found along roadways and other impervious surfaces, to ground water recharge zones. In addition, stormwater management can affect ground water quantity if stormwater is directed to ground water recharge areas.

There are several major roads in the Issaquah Creek Valley Ground Water Management Area: Interstate 90, State Routes 900, 18, and 202 the Issaquah-Hobart Road, Vaughn Hill Road and SE 56th Street. Common contaminants found in stormwater runoff from roads include petroleum products, heavy metals, and soot. In areas where existing roads cross streams, untreated road runoff may be discharged directly to local streams in the Issaquah Creek Valley Ground Water Management Area. For example, untreated roadway runoff is discharged into the North Fork of Issaquah Creek at river mile 0.2 and 1.2 (*Issaquah Creek Basin Current/Future Conditions and Source Identification Report*, King County Surface Water Management Division, October, 1991).

The only stormwater systems in the Issaquah Creek Valley Ground Water Management Area are operated by the City of Issaquah and the King County Water and Land Resources Division. Storm sewers for the City of Issaquah conform to the same boundaries as its sanitary sewer system. Some portions of the storm system include oil and water separators and these are required in all parking area drainage systems. The city has recently established a Stormwater Management Utility to direct the improvement of stormwater systems in Issaquah (Rothnie 1989). Stormwater sewer services, provided by the King County Surface Water Management Division, are located in a limited number of areas in the remainder of the Issaquah Creek Valley Ground Water Management Area, including the Mirrormont area (Eckel 1989). Single line storm drains are also located throughout the study area, especially along most roadways, and empty into local surface water bodies.

Ecology has developed stormwater management guidelines, under the 1989 Puget Sound Water Quality Management Plan. The guidelines, which became effective in mid-1994, are directly relevant to I-90, and State Routes 18, 900, and 202, in the Issaquah Creek Basin. The guidelines will be implemented by local jurisdictions and the State Department of Transportation (King County Surface Water Management Division 1991). In addition, King County and the City of Issaquah, with partial funding from Ecology have prepared a basin plan for the Issaquah Creek watershed. This plan, which includes recommendations for the management of stormwater quality and quantity, will be submitted to the City of Issaquah and the Metropolitan King County Council for adoption in February 1995.

5.4.2 Areas of Concern and Future Information Needs

One problem associated with urban runoff is the complexity of the contaminants. Typical pollutants associated with forested areas are sediments and nutrients, whereas urban runoff carries more complex and variable pollutant types. The most common land use changes in the Issaquah Creek Basin are forest land to residential development and non-forested lowland to commercial development. The result is that more complex and variable contaminants may be seeping towards the ground water.

A research priority in this area should be to determine the extent to which storm water runoff represents a threat to ground water quality. This research would also locate those areas where a significant amount of vehicular oils and greases are channeled by storm water systems into sensitive ground water recharge zones.

5.5 Landfills and Industrial Waste Sites

Improperly managed landfills and industrial waste sites can represent a significant potential threat to ground water quality in the study area. Both the Cedar Hills Landfill and the Queen City Farms industrial waste site are located in the study area; however, there are no known buried or abandoned landfills.

There have been numerous cases of the illegal dumping of non-hazardous wastes throughout the Issaquah Creek Valley Ground Water Management Area, consisting of household trash, furniture, appliances, and car parts. The Seattle-King County Health Department has investigated these incidents and contacted the applicable agency, such as King County Roads, to remediate the site (for example, collect household garbage). In other instances, such as the dumping of oil and antifreeze near a creek on High Point Road, the case has been referred to the appropriate agency, in this instance, King County Surface Water Management (Slagle, K. October 1995).

Table 5.3 lists businesses in the Issaquah Creek Valley Ground Water Management Area where Ecology is investigating or monitoring the cleanup of toxic material spills. In most instances, ground water contamination is either suspected or confirmed.

5.5.1 Cedar Hills Landfill

Cedar Hills Landfill covers 920 acres in the southwestern portion of the study area, between the May Valley and Cedar Grove Roads. This regional landfill is closed to self-haulers, but accepts waste from the seven County-operated transfer stations located outside the Issaquah Creek Valley Ground Water Management Area and commercial collection companies. In 1992, 909,833 tons of solid waste were disposed, an average of approximately 2,500 tons per day (*King County Solid Waste Division Tonnage Report*, December, 1992). The expected life capacity of Cedar Hills is projected to be approximately 27 years (*1992 Comprehensive Solid Waste Management Plan and EIS*, Solid Waste Division, August 1993).

The wastes accepted at Cedar Hills are strictly in accordance with all applicable federal, state, and local regulations. The waste is municipal solid waste, except for the special wastes which are cleared through the Seattle-King County Health Department's waste clearance process. The Solid Waste Division also has a program to screen wastes coming into the system to minimize acceptance of unwanted materials.

The *Cedar Hills Draft Site Development Plan* was completed in 1987 (King County Solid Waste Division, 1987); its purpose was to ensure that the landfill: (1) meets the disposal needs of King County; (2) meets all applicable federal, state, and local laws and regulations; and (3) provides a method of waste disposal that protects the human health and safety and minimizes environmental impacts.

Under the guidance of the Site Development Plan, the Solid Waste Division had made significant engineering and operational changes to Cedar Hills to reduce environmental impacts and to meet new federal, state, and local regulations. Major improvements included: (1) construction of a storm water control system; (2) installation of an active gas collection and flare system; (3) installation of a leachate collection, pretreatment, and transmission system; (4) interim and final closure of all past refuse disposal areas; (5) installation of a composite clay and synthetic liner system under all new refuse disposal areas; and (6) expansion of the ground water and landfill gas monitoring programs.

Ground water quality at Cedar Hills has most recently been documented in the *Evaluation of Ground Water Quality Data* (EMCON April 1991) and the *1994 Annual Ground Water Data Evaluation Report* (King County Solid Waste Division, February, 1996). These annual reports evaluate data collected from monitoring wells completed in two separate ground water systems at Cedar Hills, including a shallow local system encompassing Vashon age deposits and a deeper regional system encompassing pre-Vashon deposits.

The local ground water system consists of discontinuous perched saturated lenses within five distinct stratigraphic units including the alluvium, recessional outwash, glacial till, stratified drift, and advance outwash deposits. Ground water impacts have been identified in perched lenses within the stratified drift on the east side of the landfill. These impacts have consisted primarily of the detection of vinyl chloride with sporadic detection of other compounds. A series of ground water extraction wells have since been installed to remediate the impacts and follow-up monitoring in the area is ongoing. Ground water impacts have also been observed in the stratified drift to the south of the landfill. Although concentrations of typical leachate indicator parameters have been dramatically reduced, there have most recently been detection of vinyl chloride. A consultant is presently under contract to evaluate possible remedial measures for this southern area, if they are determined to be necessary (Komorita 1994).

The deeper regional system below Cedar Hills consists of an aquifer of limited extent (Aquifer 2) and one of regional extent (Aquifer 3). There have been no landfill impacts identified in the regional system; however, as will be discussed in the following section, ground water impacts have been confirmed in the regional system at the Queen City Farms site located immediately to the south of Cedar Hills. The general ground water flow direction below Cedar Hills is to the north (Komorita 1994).

The hydrogeologic conditions at Cedar Hills have been extensively studied and most recently documented in the *Expanded Aquifer Monitoring Project Phase I Report* (EMCON November 1992). The Phase I Report summarizes all available hydrogeologic information about the landfill and the surrounding areas, and it identified data gaps which were completed as part of the Phase II portion of the project. The Phase II Report focused on characterization of the uppermost aquifer below the site (Komorita 1994).

The direction of ground water flow below Cedar Hills in this deep regional aquifer (Aquifer 3) has been documented to be in an northerly to north easterly direction. (*South Cedar Hills Remedial Investigation*, Sweet-Edwards/EMCON, January 1991, *Evaluation of Ground Water Quality Data*, Sweet Edwards/EMCON, April, 1991; *1992 Annual Ground Water Data Evaluation Report, Solid Waste Division*, July 1993; and *Expanded Aquifer Monitoring Phase I Report*, EMCON Northwest, February, 1994). Rural residential areas exist to the west, north, and east of Cedar Hills with Queen City Farms to the south. The residences immediately to the east have potable wells which are on the Solid Waste Division's quarterly ground water monitoring program (Komorita 1994).

The Seattle-King County Health Department, Solid Waste Section samples four wells biannually, around the Cedar Hills Landfill, for priority pollutants. None of these off-site monitoring wells, to date, has exhibited levels above primary drinking water standards for the constituents analyzed (Hickok 1994).

5.5.2 Queen City Farms Industrial Waste Site

Queen City Farms is located immediately south of the Cedar Hills Landfill and north of Cedar Grove Road. Before Queen City Farms was closed, the Boeing Company was a primary user of the farm as an industrial waste site in the 1950's and 1960's. Industrial liquid waste and drums were deposited at the site in three ponds (numbers 1 - 3) and in a trench. An additional three ponds (numbers 4 - 6) were used to contain unacceptable pig feed from the farm itself (Wall 1989).

After the designation of Queen City Farms as an U.S. Environmental Protection Agency Superfund site, ten ground water monitoring wells were drilled and contamination was found in water drawn from wells located near ponds 1 - 3. To mitigate the threat to ground water, Boeing and Queen City Farms have undertaken three cleanup measures: (1) the ponds have been backfilled with clean soil; (2) each pond has been capped with a liner; and (3) efforts have been made to intercept contaminants before they reach the shallow aquifer (Wall 1989).

Subsequent to these cleanup actions the King County Solid Waste Division conducted a remedial investigation of the portion of the Cedar Hills Landfill adjoining the Queen City Farms property. The remedial investigation concluded that the landfill was not contributing to ground water contamination at the Queen City Farms site (King County Solid Waste Division 1991).

The King County Solid Waste Division is monitoring surface water and ground water flow and quality on the portion of the landfill adjoining the Queen City Farms property (Orlean 1994). The King County Solid Waste Division provides the data collected from this site to the U.S. Environmental Protection Agency.

In addition, Queen City Farms, Inc. and the Boeing Company have conducted a remedial investigation of the Queen City Farms site. This remedial investigation concluded that there are three shallow aquifers beneath the site. The upper two aquifers are contaminated with volatile organic compounds due to the past waste disposal practices on the property. The U.S. Environmental Protection Agency is currently negotiating with Queen City Farms, Inc. and the Boeing Company for cleanup of the two contaminated aquifers (Orlean 1994).

Further mitigation on the site was carried out in summer 1995. In the buried drums area it was found that soils were contaminated with polychlorinated biphenyls. Six hundred and twenty two tons of soil with polychlorinated biphenyls exceeding 100 parts per million were identified and will be hauled off site in drums. The remaining contaminated soil under 100 parts per million of polychlorinated biphenyls will be backfilled under the cap. This soil is presently stockpiled with a liner beneath it and a plastic cover over it. Wells monitored in the buried drum area determined that TCE and vinyl chloride are still prevalent in the ground water on site. Boeing has also been monitoring wells off site.

In the Initial Remedial Measure Area, a barrier (slurry) wall is to be erected to contain any contamination and prevent it migrating off site. This wall was to be erected in spring/summer 1996 and will include soil from the buried drums area. The design of this wall was to be finalized by the end of 1995.

The results of samples taken at the 4-Tek Industries site on the Queen City Farms were satisfactory. More monitoring wells are to be installed by Boeing for monitoring both on and off site. Monitoring of the site is ongoing by the U.S. Environmental Protection Agency (McPhillips, L. October 23, 30, 1995).

Presently, the Cedar Grove composting facility operates on the Queen City Farm site. While the composting operation is on the same property as the industrial waste site, it is outside the Issaquah Creek Valley Ground Water Management Area.

5.5.3 Areas of Concern and Future Information Needs

To better understand the potential risk to ground water posed by landfill activities in the Issaquah Creek Valley Ground Water Management Area, specific information is needed in the following areas:

- Ground water quality on and surrounding both the Cedar Hills Landfill and Queen City Farms, Inc. sites should continue to be evaluated. Data should be shared with the Seattle-King County Health Department's Drinking Water Program and entered into their database.
- The report findings and proposed future activities concerning ground water quality impacts both off- and on-site.
- The direction of ground water flows in the area of the landfills, as well as the depth and range of aquifers exposed to leachate contaminants.

5.6 Underground Storage Tanks

5.6.1 Description

Underground storage tanks represent another potential threat to ground water quality and quantity in the Issaquah Creek Basin. Faulty underground storage tank system components and poor facility management practices are the most cited causes of leaks and spills, collectively and commonly referred to as releases, from underground storage tanks. Releases from underground storage tank systems are especially problematic in areas with shallow aquifers or where ground water drawn from private wells is the primary source of drinking water (Knowlton 1994).

Ecology maintains a list of underground storage tanks in the Issaquah Creek Valley Ground Water Management Area. There are presently 78 underground storage tanks operational in the Issaquah Creek Valley Ground Water Management Area (see Table 5.4). The 1989 Ecology list had 123 operational underground storage tanks (1991 Issaquah Area Characterization report). This is consistent with a statewide trend toward fewer underground storage tanks in operation. This list is not all-inclusive, as it reflects only those systems reported to Ecology. The list does represent the majority of regulated underground storage tank systems in the area. Table 5.5 lists the age ranges of the underground storage tanks in the Issaquah Creek Valley Ground Water Management Area, and Table 5.6 lists the types of substances found in those underground storage tanks. Table 5.7 summarizes the sizes of underground storage tanks.

Figure 5.4 shows some of the underground storage tank locations on Ecology's list. While underground storage tanks are concentrated in the City of Issaquah, some are also found at the Cedar Hills Landfill, along the Issaquah-Hobart Road, near quarries and mines, in Hobart, at Lake Sammamish State Park, and at other commercial and industrial locations (Ecology 1989). The locations of underground storage tanks such as small, home heating oil tanks have not been identified.

Ecology implements Washington's Underground Storage Tank Regulations (Chapter 173-360 WAC). Written into this regulation are performance standards that must be achieved for all operational systems. These standards address released detection for tanks and ancillary piping, corrosion protection for tanks and ancillary piping; spill and overflow prevention and financial responsibility (i.e., an insurance policy that covers the costs for cleaning up a release). An annual underground storage tanks permit is issued for each system whose owner certifies compliance with Chapter 173-360 WAC. The cost of the annual permit is $75 (in 1995). The purpose of underground storage tank regulation is to preserve the quality of ground water (i.e., a pollution prevention program). The responsibility of complying with Chapter 173-360 WAC is that of the underground storage tank system's owner or operator. Ecology does not maintain underground storage tanks, but it does work to facilitate the owner's comprehension of the regulation. By regulation design compliance with performance standards translates into pollution prevention. Ecology regularly coordinates facility inspections to ensure compliance with Chapter 173-360 WAC (Ecology 1994).

State regulation requires that underground storage tanks be upgraded to include a leak detection system (water tanks are exempt). The initiative to regulate underground storage tanks started with a federal law passed by the U.S. Congress (Hazardous and Solid Waste Amendments to Resource Conservation and Recovery Act, 1984) gave the U.S. Environmental Protection Agency the responsibility of writing federal regulations (40 CFR Parts 280 and 281, 1988). Within the federal regulation was the opportunity for states to pass and implement their own laws and regulations that would be no less stringent than the federal. The State of Washington took advantage of the opportunity and now has its own law and regulation in place (90.76 RCW, 1989 and Chapter 173-360 WAC 1990, respectively). Ecology received final authority from the U.S. Environmental Protection Agency to implement its regulation in summer, 1993. It is very similar to, but not identical to, the federal regulation. As of December 1993, all regulated underground storage tank systems were required to employ an approved method of release detection for tanks and piping. The only exception is any underground storage tank used for emergency power generation that was installed between 1980 and 1988. The release compliance dates for these underground storage tank systems is December 1995 (Ecology 1994).

5.6.2 Potential Ground Water Impacts

Underground storage tanks without special leak containment or leak detection systems represent a potential threat to ground water quality. At some point during the active life of any underground storage tank without environmental controls, hazardous substances stored in ground water recharge zones will probably lead to some form of ground water contamination.

Ground water in the City of Issaquah is presently susceptible to contamination from an underground storage tank leak or accident. In 1987, several service stations experienced gasoline leaks from their tanks. Where required, contaminated soil from around the leaking tanks was excavated to Ecology standards and taken to the Cedar Hills Landfill. A soil venting system was installed to exhaust gasoline vapors from the soil, and the leaking tanks were repaired or replaced. In addition, ground water monitoring wells were installed to detect petroleum hydrocarbons in the ground water. Drinking water wells for the City of Issaquah, located less than one-half mile away from one of the service stations, have been tested. Thus far, no petroleum hydrocarbon based contamination has been detected.

Since January 1989, Ecology has maintained a database of current and former underground storage tanks that have caused known contamination. Table 5.8 (Ecology 1994) lists 18 sites in the Issaquah Creek Valley Ground Water Management Area where underground storage tank cleanups are in progress or have taken place. Under the Model Toxic Control Act, underground storage tank owners are responsible for site cleanup and for sending the report to Ecology, which gives them a cleanup status. Ecology is not an active participant; the sites are independently remediated by the owners(s). Of the 18 sites, seven (7) have completed remediation. Of these seven, only one had caused known ground water contamination. Four of the remaining sites have only soil contamination. Seven sites have ground water contamination. At one of these sites where Ecology is awaiting a report, Ecology is not aware that any remedial action and cleanup is necessary. At the remaining sites, cleanup is in progress or has occurred and site monitoring is ongoing.

5.6.3 Areas of Concern and Future Information Needs

Although underground storage tanks represent a potential threat to ground water in the Issaquah Creek Valley Ground Water Management Area, some incidents are either unreported or undetected. The documentation of unregulated home heating oil tanks is difficult not only due to the hidden nature of the tanks, but also because not enough is known about the location, composition, and contents of many of the abandoned underground storage tanks in the area. Homes that once used or still rely upon fuel oil stored in underground storage tanks are common in western Washington. Home heating oil tanks are small (between 300-500 gallons) compared to most regulated underground storage tanks, but more common. Smaller tanks were typically constructed of thinner gauge steel and provide shorter service than larger, regulated systems. The average useful life of a 500-gallon steel tank that does not have corrosion prevention (i.e. cathodic protection) has been estimated at about 20 years. Most underground home heating oil tanks in western Washington are old and not cathodically protected. Ecology does not regulate nor track information about underground home heating oil tanks (Knowlton 1994).

A priority of future research should be the identification of both commercial and residential underground storage tanks located in areas where there is significant recharge to aquifers. Special guidelines may be designed for the location and monitoring of underground storage tanks in these recharge zones. Oil tanks that have not been permanently decommissioned, whether by removal or closure on-site, may pose a serious threat to ground water resources in the Issaquah area. Improperly closed heating oil tanks (i.e. those which still contain petroleum products or have not been secured from reuse) are the greatest concern (Knowlton 1994).

5.7 Quarries and Mines

5.7.1 Description

Quarries and mines can pose problems for ground water management in that they often leave large portions of an aquifer directly exposed to surface water and industrial contaminants. These areas may be significant ground water recharge zones. Coal, peat, sand, and gravel resources are all found in the Issaquah Creek Valley Ground Water Management Area. Although coal mining drew most of the original settlers into the area in the late 1800's, in recent decades, sand, gravel and bulk-fill activities have been the primary industries in the Issaquah Creek Valley Ground Water Management Area (King County Planning 1984).

Sand and gravel resources are located primarily northeast of the City of Issaquah, north of Mirrormont, and along Cedar Grove Road. Sand and gravel extraction currently takes place north of I-90 along the Issaquah-Fall City Road, at the crest of the Issaquah-Renton Road, and in the Cedar Grove area (King County Planning 1980). The largest sand and gravel pit in the Valley, the Lakeside site, north of I-90, now operates using surface water control measures that limit the ability of surface contaminants to reach ground water. Surface and industrial wastewater is contained on-site by transporting the water to a series of ponds where it percolates down through gravel and sand (Devitt 1989).

The Tibbetts Creek Basin west of the City of Issaquah contains two rock quarries. Surface water runoff from the Sunset quarry is turbid; however, it is not known whether this runoff carries pollutants or contaminates ground water. In addition, the Hazen Quarry, a new quarry, operates just south of the Sunset Quarry.

Although there are no active coal mines in the Issaquah Creek Valley Ground Water Management Area, coal resources are known to exist in many parts of the Issaquah Creek Valley. Abandoned coal mines are located primarily within the city limits of Issaquah, in the hills southwest and east of the city, and in the Tiger Mountain area (Walsh 1989).

5.7.2 Potential Ground Water Impacts

The gravel mines north of the city have a recorded history of surface water contamination. It is likely that contaminants do reach ground water at some point in the operation of a quarry. However, the quantity and type of pollutants that reach aquifers and their impacts on water quality are not yet known.

Abandoned coal mines represent additional points where an aquifer may be exposed to surface water contaminants. However, because they are either sealed or located in isolated areas, abandoned coal mines pose little known threat to water quality in the Issaquah Creek Valley Ground Water Management Area (Walsh 1989).

Short-term ground water fluctuations were clearly observed at the Lakeside Gravel Pit in response to wells pumping on an eight-hour work-day schedule. Short-term and longer-term declining and rising water level trends were due to climate and the effect of pumping at the Sammamish Plateau Water and Sewer District's well number 9 (*Lower Issaquah Valley Wellhead Protection Plan,* Golder Associates, November 1993). This indicates a level of hydraulic connection between the ground water at the gravel pit and the District's Drinking Water Well Number 9.

5.7.3 Areas of Concern and Future Information Needs

Future quarry and mine development should be of special concern to ground water management in the area. However, additional information is needed to show how existing operations affect ground water quality. At this time, little is known about the impacts of industrial contaminants that seep into exposed aquifers at quarries, or of the potential ground water impacts of an accidental hazardous material spill at a quarry. The impacts on ground water quantity caused by recharge and pumping in the vicinity of mines should also be assessed.

5.8 Agriculture

5.8.1 Description

Agricultural activities causing nonpoint pollution can be divided into two groups: (1) practices associated with livestock keeping and (2) practices associated with crop production. Pollutants most identified with farming activities are sediment, nutrients, organic materials, pesticides, and pathogens. Activities that can generate these pollutants in crop production are soil tillage, improper application of fertilizers and pesticides, and irrigation. Animal production activities that generate these pollutants include: animal confinement, overgrazing of pastures, unrestricted livestock access to streams, and improper application of fertilizers and pesticides (Fitch 1994).
Livestock keeping is the primary agricultural activity in the Issaquah Creek Valley Ground Water Management Area, consisting of approximately 30 percent cattle, 55 percent horses, and 0.7 percent sheep. The remainder is equally divided between goats and llamas. Most of the livestock keeping is in hobby farming (Fitch 1994).

The background of these rural residents is varied and includes people from all professions and walks of life. The sizes of their operations may range from less than one acre to more than forty acres. Some residents are there just for the rural setting, while others treat five acres as a large backyard where they can keep horses. Other types of land uses include hobby farms, gardeners, part-time farmers and "alternative" farmers.

Prime agricultural land is formed on soils that were derived from alluvium or Vashon outwash. The alluvium is mostly unconsolidated silt, sand, and gravel valley fill with some clay. Because of this mix of material, the soil has variable permeability and water-holding capability. More often than not soils formed in alluvium are considered to be hydric. Soils that formed in the Vashon Outwash are composed of advance and recessional outwash, stratified drift, and associated deposits. Soils that developed in this material have high permeability and are considered recharge soils. Both soil formations are highly vulnerable to pollution resulting from poor animal keeping and crop-management practices (Fitch 1994).

Based on several hydrogeologic factors that influence the behavior and movement of contaminants in the ground, it is unlikely that the present livestock practices in the

Issaquah Creek Valley Ground Water Management Area threaten ground water quality. These hydrogeologic factors (seepage) are (1) the horizontal distance between the site and the point of water use; (2) slope of the land; (3) the depth to water table; (4) the vadose zone material; (5) the aquifer material; (6) soil depth and; (7) the attenuation potential of the soil. However, the same is not true for their impact on surface waters, streams and ponds. For example, there is very little use of fertilizers on pastures and/or hayfields in the area. The potential ground water threat from fertilizers is from truck crop farms, nurseries, Christmas tree farms, etc. Generally, this type of operation is commercial in nature. Fertilizer is generally applied once or twice a year and is applied in accordance with the requirements of the crop. When applied according to label directions there should not be a pollutant source (Fitch 1994).

The Washington State Department of Agriculture requires all commercial applicators and all applicators applying restricted-use pesticides (includes all aquatic applications) to be licensed. As licensed applicators, they are required to keep records for seven years including the type of chemical applied, quantities, location of applications, and other such information. The Department of Health is the agency responsible for public health effects and possible emergency measures in case of poisoning and Ecology regulates spill response requirements (Fitch 1994).

The Washington State Department of Agriculture can request records from anyone required to keep records. A general record call-in from a significant land area, however, is financially unfeasible unless there is significant cause. Record availability outside the agency (Washington State Department of Agriculture) may be constrained by legal requirements also. Since the basin is changing from rural to urban, a record request may not provide the type of information needed by a given plan (Fitch 1994).

5.8.2 Areas of Concern and Future Information Needs

Additional research is needed on the types and quantities of agricultural fertilizers and pesticides used in the Issaquah Creek Basin. This information would allow for a complete analysis of how agricultural activities affect ground water quality.

5.9 Residential and Golf Course Fertilizer and Pesticide Use

Residential use of fertilizers and pesticides can cause increases in the levels of nitrate in ground water in highly susceptible areas. This is especially true for cases where 1-5 acre residential lots are kept in turf and irrigated regularly in the summer months. Landscaping practices such as keeping portions of large lots in native growth can help to reduce risk of nitrate contamination from residential fertilizer use.

The one private golf course and one proposed golf course in the Issaquah Creek Valley Ground Water Management Area are the Sahalee Golf & Country Club (private, Sammamish Plateau); and the Beaver Lake Golf Course (proposed near Beaver Lake on the Sammamish Plateau). Fertilizer is used by turf applications at public golf courses.

Turf fertilizers are a source of two potential contaminants, nitrate and phosphate. Of the two, nitrate represents the greatest risk to ground water contamination because of its high water solubility and high mobility in the soil column.

Phosphates in turf fertilizers generally do not pose a significant threat to ground water for a number of reasons. First, the water solubility of phosphate is low and much of the available phosphorus will be utilized within the root zone. The pH of the turf and underlying soil is conducive to the rapid binding of phosphate with aluminum ions found in abundance in western Washington soils (Braun, 1989). The use of phosphate on turf is essentially self-limiting. Only a relatively small amount of phosphate is used by grasses and little of that is undesirable seed head growth, diminishing the aesthetic quality of the turf.

Fertilizing practices are essentially the same for most golf courses in western Washington. Nitrogen is applied to the fairways at relatively low rates, about 2 to 2.5 pounds per 1,000 square feet. The 2 to 2.5 pounds is split into two annual applications. The greens receive nitrogen at a much higher rate, about 6 pounds per 1,000 square feet, split into 10 to 12 annual applications. These application practices are generally consistent with those recommended by the Washington State University Cooperative Extension Service. The Cooperative Extension Service suggests that nitrate contamination of both ground and surface water associated with turf fertilizers can be avoided through frequent, low-level applications of no more than 4 to 6 pounds of nitrogen per 1,000 square feet per year in 0.5 pound increments. Over-watering the turf after fertilizer application should be avoided to reduce the opportunity for nitrate wash-through. Use of urea should be avoided since it converts rapidly to nitrate. Ammonia sulfate is the recommended form of nitrogen because it is assimilated quickly, becomes tied up in the organic matter of the turf, and converts slowly to nitrate. (USGS 1995)

Fertilizer use may not pose a significant threat to ground water in the GWMA. Future data collection efforts should focus on obtaining information on the types and quantities of fertilizers and pesticides used by golf courses and nurseries, and other non-agricultural businesses and monitoring ground water quality from wells in the vicinity of these establishments.

5.10 Transportation

5.10.1 Roadside Spraying

Description

Roadside spraying usually attempts to accomplish one of four objectives: (1) to control excess weed growth; (2) to limit the spread of brush and trees; (3) to protect newly planted beds from disease and insects; and (4) to control insects and weeds at specific spots (Uyeda 1988). Within the state of Washington, labeling, distribution, transportation, application, use restrictions, and disposal of pesticides are governed by Chapter 16-288 WAC. The issuance and monitoring of statewide pesticide use permits is the responsibility of the Washington State Department of Agriculture.

Three public agencies conduct roadside spraying in the Issaquah Creek Valley Ground Water Management Area: the Washington State Department of Transportation, the King County Department of Transportation, and the City of Issaquah. Each of these agencies is required by law (RCW 17.21) to record the details of each spraying event and to retain those records for a period of 7 years. Spraying records, showing specific quantities and locations of herbicidal applications in the Issaquah Creek Valley Ground Water Management Area, may be obtained from the Department of Transportation's Bellevue office, from the Road Services Division in the King County Department of Transportation, and from the City of Issaquah Department of Public Works

The State Department of Transportation is responsible for vegetation control on I-90, State Routes 18, 900, and 202. The Department of Transportation sprays weeds appearing within 2 feet of roadsides, around fire hydrants and manholes, and in drainage ditches. The amount of herbicide sprayed by the Department of Transportation fluctuates between 4 and 5 pounds per acre and is heavily diluted with water when applied. State roadsides in the Issaquah Creek Valley Ground Water Management Area are sprayed once a year, usually during the month of April, primarily using three herbicide products: Karmex, Krovar, and Roundup. (The above are trade-name formulations containing herbicides diuron, bromacil, and glyphosate.)

The King County Road Services Division of the Department of Transportation serves unincorporated portions of the Issaquah Creek Valley Ground Water Management Area. The King County Roads Division applies herbicides to control noxious weeds on right of ways and weed and grass growth on gravel shoulders and around guard rails. Either Escort or Garlon is used for broad leaf control. Oust or Roundup is used for the non-selective control on the shoulders. The use of the chemicals simazine and atrazine was discontinued after 1989 because they are water soluble and can't be used in permeable soils. All herbicides, including those not on a "restricted use," are applied by certified pesticide applicators (Matsuno 1994).

The City of Issaquah Department of Public Works does not have an active roadside spraying program. The spraying of herbicides is limited to around tanks, pump stations (not well houses), fire hydrants, and some guard rails. Roundup is the herbicide being used, except in certain areas where Arsenol is being used.

The City of Issaquah Parks Department uses herbicides to control unwanted vegetation in turf and for spot weed control in landscape beds and tree wells. Confront is used over turf areas to control broadleaf weeds. Roundup, Crossbow, some Surflan/Gallery, and very little Casaron is used for spot control of weeds in the landscaped beds and tree wells.

The Seattle-King County Health Department conducts soils and water monitoring to determine the residual levels of pesticides over time. According to the 1989 monitoring report, no residuals for simazine and atrazine were found in surface water samples. As expected, low levels of herbicide residuals were found in soil samples taken at a depth of 4 inches. The results indicate that roadside spraying does not appear to pose a significant threat to water quality. Further, the amount of herbicides applied in the area has decreased over the years through improved application methods, such as overall decreased application rates (*Issaquah Creek Basin Current/Future Conditions and Source Identification Report*, King County Surface Water Management Division, October, 1991).

Potential Ground Water Impacts

The application of herbicides for roadside plant control can threaten ground water quality in two ways: (1) chemicals may be transported by storm water into high ground water recharge areas and, (2) pesticides may percolate into shallow aquifers through fissures or dry and sandy soils. Vegetation and clay soils along roadsides in the Issaquah Creek Valley Ground Water Management Area may act to effectively absorb some pesticides before they reach ground water. Particular attention should be paid to the quantity and type of chemical applied, especially if a chemical is likely to destroy or inhibit grass growth (Horner and Mar 1982). However, the preferred method of vegetation control is the use of machinery or manual removal.

Areas of Concern and Future Information Needs

Additional information on ground water impacts from roadside chemical applications are needed in four areas:

- The location of dry and sandy soils and any exposed aquifers that may facilitate the contamination of ground water by chemicals applied at roadsides;
- The types of roadside chemicals most likely to percolate through soils to an aquifer, as well as those that inhibit grass growth;
- The quantities and locations of chemical applications;

- Reports of any accidents or improper storage, handling or transport of pesticides and herbicides used for plant control in the Issaquah Creek Valley Ground Water Management Area.

5.10.2 Highway Runoff

Description

As rain washes over a roadway, it carries away contaminants depositing them into soils and storm water systems. Runoff of this kind is likely to occur on highways and heavily traveled roads. As noted earlier, there are several major roads in the Issaquah Creek Valley Ground Water Management Area: Interstate 90, State Routes 900, 18, and 202, the Issaquah-Hobart Road, Vaughn Hill Road, and SE 56th Street. Common contaminants found in storm water runoff from roads include petroleum products, heavy metals, and soot. In areas where existing roads cross streams, untreated road runoff may be discharged directly to local streams in the Issaquah Creek Valley Ground Water Management Area. For example, untreated roadway runoff is discharged into the North Fork of Issaquah Creek at river miles 0.2 and 1.2 (*Issaquah Creek Basin Current/Future Conditions and Source Identification Report*, King County Surface Water Management Division, October, 1991). Trucks transporting waste to the Cedar Hills Landfill on the Cedar Grove and May Valley Roads may also account for significant highway runoff.

Potential Ground Water Impacts

Ground water infiltration by highway runoff is possible in very porous earth and in areas of exposed aquifer. Studies of highway runoff in Western Washington have shown that vegetation may effectively capture pollution in upper soil layers (Horner and Mar 1982). However, the precise conditions under which runoff pollutants may be contained in surface soil is not yet known. Highway runoff for Interstate 90 and other heavily traveled roads in the Issaquah Creek Valley Ground Water Management Area flows into vegetated storm water channels thus decreasing the chances of ground water contamination. However, some channels are maintained with mechanical blades that may clear soil and vegetation allowing highway runoff to infiltrate into ground water.

Areas of Concern and Future Information Needs

The most comprehensive study of highway runoff in Washington State was conducted by the Washington State Department of Transportation between 1977 and 1982 (Horner and Mar 1982). Although these reports discuss the conditions under which runoff may lead to ground water contamination, the degree and impact of potential contamination is never quantified. Since the 1982 study no comprehensive studies of highway runoff have been conducted in Washington State. However, the Washington State Department of Transportation will be conducting a highway runoff characterization and Best Management Practices effectiveness monitoring program in King County for the National

Pollutant Discharge Elimination System Permit Program and the highway runoff Rule, Chapter 173-270 WAC. Samples will be collected for a complete range of parameters including metals and priority pollutants (Schaftlein 1994).

Additional research is necessary to determine the type and quantity of contaminants that flow from road surfaces. In addition, more information is needed on storm water drainage for major roads in the study area.

5.10.3 Hazardous Material Spills

Description

The term "hazardous material" refers to "hazardous waste" as well as "hazardous substances," both generally defined as materials that pose a substantial present or potential threat to human health or the environment (Horner and Mar 1982). The majority of hazardous substances traveling on Issaquah Creek Valley Ground Water Management Area roads are petroleum products. These products are most frequently transported in the Issaquah Creek Valley Ground Water Management Area along Interstate 90, the Issaquah-Hobart Road, and State Route 18.

Potential Ground Water Impacts

The exact frequency and routes of hazardous material traffic is not yet known. Preliminary information from Ecology indicates that for the Interstate 90 portion of the Issaquah Creek Valley Ground Water Management Area there was only one hazardous material accident from January 1985 through September 1988, with no resulting spill. Future research should determine the probability of a hazardous material accident occurring in the study area and the circumstances under which such an accident would threaten ground water quality.

The Ecology office in Bellevue responds to reports of petroleum or hazardous material spills in the Issaquah Creek Valley Ground Water Management Area. A spill response team is available on a 24-hour basis to implement and monitor cleanup operations for accidents that occur on highways or roads, at manufacturing plants, or any location in the Issaquah Creek Valley Ground Water Management Area. Ecology's procedure for responding to spills depends on the substance spilled as well as on the severity and location of the accident (Baker 1990).

Areas of Concern and Future Information Needs

The goal of evaluating the risk of a hazardous material spill is to provide information to decision makers in the following areas:

- The location of accident zones where hazardous material spills are likely to occur;

- A description of sensitive areas where spills would threaten ground water quality; and,
- An estimation of the resources needed in any remediation effort resulting from a spill.

To complete this evaluation, the following research process may be followed:

- State traffic volume data will estimate the number of trucks that have used major roads in the Issaquah Creek Basin in past years;
- Accident statistics will then help to determine the probability of a truck accident occurring on these roads;
- Additional data is then needed to determine the percentage of trucks carrying hazardous materials in high physically susceptible areas in order to locate principal accident zones and the likelihood of a hazardous material accident occurring;
- Further research will indicate the number of hazardous material accidents that result in spills, as well as the quantity and substance of those spills; and
- Research is needed to estimate the probability of spilled hazardous materials reaching and contaminating ground water.

5.11 Hazardous Waste

5.11.1 Description

Hazardous waste is a material that is ignitable, corrosive, reactive, or toxic. Inadvertent or intentional discharges to storm water disposal systems represent another release mechanism. To be regulated under the state Dangerous Waste Regulations Chapter 173-303 WAC, a commercial or industrial facility must generate at least 220 pounds per month of hazardous waste; transport dangerous/hazardous waste; treat, store or dispose of dangerous/hazardous waste; or burn or blend dangerous waste fuels. Several commercial and industrial facilities located within the Issaquah Creek Valley Ground Water Management Area generate quantities of hazardous or extremely hazardous waste regulated under Resource Conservation and Recovery Act.

Small quantity generators produce less than 220 pounds of hazardous waste per month. The Local Hazardous Waste Management Program assesses how small quantity generators store, use and dispose of hazardous waste. The Seattle-King County Health Department and the King County Water and Land Resources co-staff the Local Hazardous Waste Management Program field unit that inspects any business that has the potential to generate hazardous waste. Hazardous waste spillage at small quantity generators is a high priority. Businesses where hazardous waste spillage is observed are referred to Ecology for follow-up. These businesses must still handle their waste properly according to Chapter 173-303 WAC and Title 10 of the King County Board of Health.

There is one site listed in the U.S. Environmental Protection Agency Superfund Program List within the Issaquah Creek Valley Ground Water Management Area. Queen City Farms, and industrial waste site, is currently under investigation and remediation. This site is discussed in further detail in Section 5.5.2.

5.11.2 Potential Ground Water Impacts

Hazardous waste can be introduced to the environment, including ground water, in a number of ways. If hazardous wastes are discharged to septic systems (through sinks, toilets or floor drains) the wastes discharged may contaminate soil and ground water. Any hazardous wastes that are discarded from households or businesses to the environment along with normal solid waste refuse can be placed in landfills and contributed to leachate contamination of underlying ground water. Finally, hazardous wastes that are deposited on exposed ground surfaces from traffic accidents, spills, or from improper storage can percolate into the soil and may migrate via recharging precipitation into the ground water environment.

5.11.3 Areas of Concern and Future Information Needs

Ecology maintains a record of businesses that identify themselves as generating, storing, treating or transporting hazardous waste in the state. This list (notifier's list) was reviewed to identify business that may generate hazardous waste in the Issaquah Creek Valley Ground Water Management Area. Businesses shown on Ecology's notifier's list that are also located in the Issaquah Creek Valley Ground Water Management Area are listed in Table 5.9. At least one type of hazardous waste is associated with the normal operations of each type of generator listed in Table 5.9. For example, automotive repair shops typically handle large quantities of volatile solvents and oil-based products containing organic compounds such as benzene, chlorinated ethylenes, toluene, and methylene chloride. Dry cleaners use solvents and cleaning solution containing chlorinated ethanes and ethenes, especially trichloroethane and tetrachloroethylene. Paint supply stores sell products containing heavy metals, phenols, and toluene. When these materials are discarded because their usefulness has diminished due to age or contamination (e.g., spent solvents), they will probably be classified as hazardous wastes. There are potential hazardous waste generators, including small quantity generators, that have not notified Ecology (because they don't have to) and businesses that don't generate waste now but could because they store or use hazardous materials. If hazardous waste is improperly managed, they may cause damage to the environment and/or human health. The Seattle-King County Health Department should monitor data collected by Ecology and the Local Hazardous Waste Program, regarding hazardous waste generator impacts on ground water quality.

5.12 <u>Ground Water Quantity</u>

The amount of ground water available and the amount of water available to recharge ground water is affected by precipitation, land use, population growth, and water use.

Ground water recharge is naturally affected by the amount of vegetation, soil, and surficial geologic conditions, and the topography of the potential recharge area. Vegetation decreases the velocity of stormwater runoff as water is diverted around plant stems and roots. This is a benefit to recharge because slowing the runoff increases the time available for infiltration and thereby increases infiltration. By clear-cutting the land and removing vegetation, ground water recharge can be diminished.

Soils composed of coarse-grained material such as sand and gravel are generally more porous and better for recharge than those composed of fine-grained particles such as clay. Sealing over these recharge areas with parking lots, and residential and commercial buildings reduces the amount of ground water recharge. The slope of the surface upon which precipitation falls affects the amount of precipitation that recharges into the ground. More rain tends to run off a steep slope than off a level plain.

With population growth there is an increase in the number of residential and commercial buildings, roads, and parking lots that are impervious surfaces that decrease or prohibit ground water recharge. There is also an increased demand for water. Ground water withdrawals from the aquifer, when combined with an increase in impervious surface area in a recharge area, can lead to a diminished ground water supply for drinking water purposes. Because ground water and surface water are interconnected, surface water features such as lake levels and the base flow of creeks are impacted by diminished ground water levels.

With the demands for more ground water, agencies and purveyors need to implement methods to protect this valuable finite resource. A method to retain recharge is to maintain portions of residential areas in their natural state or permit the planting of vegetation in these areas. Storm water facilities can be constructed to promote recharge of ground water provided that the storm water is first adequately treated so as not to contaminate ground water. The State of Washington is also currently investigating ways to treat and reuse wastewater.

5.13 Summary of Land Use Information Needs

From the descriptions of land use activities in the Issaquah Creek Valley Ground Water Management Area, it is clear that the effects of existing and potential water and land use activities on ground water are still uncertain. This section of the report presents information relevant to the Issaquah Creek Valley Ground Water Management Plan and points to areas where additional information will provide decision makers with a complete picture of ground water management issues in the study area. Future research priorities should address the topics discussed below:

5.13.1 Ground Water Recharge Zones

Locating those surface areas where aquifers are most heavily recharged is important to every land use activity previously described, because these are areas where surface contamination is most likely to lead to ground water contamination. Also, ground water loss can occur if these areas are covered over by parking lots, buildings, or if other changes are made to the soil mantle.

A map of aquifer susceptibility to contamination based on three factors (surficial soils, surficial geology, and ground water depth) is presented in Figure 5.5. Efforts to minimize the possibility of contaminants reaching these areas and to prevent the paving over of these areas should be undertaken. Land use activities are relevant to ground water management only as they affect ground water quality and quantity. Surface activities described in this report will have the greatest impact on ground water when they take place in ground water recharge zones. The map (Figure 5.5) should be further refined as more information becomes available from wellhead protection studies and SEPA reviews.

5.13.2 Future Development

A detailed analysis of existing land use activities in the Issaquah Creek Valley Ground Water Management Area, together with projected residential, commercial, and industrial development trends, is needed to assess land use activities that account for ground water contamination and to determine to what extent the demand for ground water is likely to increase in the future.

5.13.3 On-Site Septic Systems

Improper discharges to on-site septic systems (e.g. industrial discharges) and the overloading and inadequate treatment of sewage in on-site septic systems threaten ground water quality and should be of particular concern whenever development occurs where sewer service is unavailable. The location of all on-site septic systems, especially those receiving improper discharges or with a history of failure and located in potential ground water recharge zones, should be tabulated and evaluated. Homeowners and businesses should be reminded to maintain their on-site septic tanks and to pump their on-site septic tank every 3 to 5 years, depending on use.

5.13.4 Sewers

Additional information is needed on existing and projected sewer quantities, and sewer line leaks. Also needed is a detailed account of future service options and system expansion plans.

5.13.5 Underground Storage Tanks

Without proper prevention or detection systems in place, there is a high risk of ground water contamination due to an underground storage tank leak or accident. Additional information on appropriate commercial underground storage tank locations and safety measures is needed to minimize this risk. Underground storage tanks research should also focus on smaller privately owned tanks, especially those installed to hold heating oil.

Although no known record of these tanks exists, parallel studies in other areas may help to estimate potential ground water threats posed by residential underground storage tanks.

An additional research priority should be to identify the extent and type of contamination from leaking underground storage tanks.

5.13.6 Stormwater

The extent to which stormwater runoff represents a threat to ground water quality should be researched, particularly in sensitive recharge areas where significant amounts of vehicular oil and grease occur in runoff.

5.13.7 Landfills

Evaluating the extent of ground water contamination from landfills is a complex process. Water quality information from ground and surface water monitoring stations at Cedar Hills Landfill and Queen City Farms would help determine the extent of ground water contamination and the effectiveness of past and current remediation efforts. A complete hydrologic analysis of the areas surrounding the landfills is also needed to measure the impact of landfill leachate on surrounding land uses. The direction of ground water flow beneath the landfills, and the depth and range of aquifers exposed to contaminants, should be evaluated.

5.13.8 Quarries and Mines

Additional information is needed on how existing operations affect ground water quality. Mines and quarries, while opening the ground surface to potential higher recharge, also increase the potential for contaminants entering the aquifer. The operation of and reclamation of quarries and mines should be evaluated for their potential impacts on ground water.

5.13.9 Hazardous Waste

It is also necessary to monitor and evaluate the impacts on ground water quality caused by hazardous waste generators. Data collected about these facilities can help with such monitoring evaluation.

5.13.10 Hazardous Material Spills

The potential catastrophic impact of a hazardous materials spill in the study area warrants further investigation. Specifying accident zones where spills are most likely to occur and estimating the severity of contamination that may result from a spill should be the two initial priorities of this research effort.

5.13.11 Plant Control

Use of pesticides and fertilizers could pose a future threat to ground water quality in the Issaquah Creek Valley Ground Water Management Area. These chemicals are applied in a broad range of activities including: residential, agriculture, the maintenance of powerline corridors, roadside clearing, and park and landscape maintenance. Additional information is needed on the quantities and applied location of chemical applications, the types of roadside chemicals most likely to percolate through soils and the location of exposed aquifers that may facilitate contamination of ground water by chemicals applied at roadsides.

6.0 WATER APPLICATIONS

This section discusses sources of water and water service providers in the Issaquah Creek Valley Ground Water Management Area, water rights, aquifer capacity, existing and potential water demand, and the need for further analysis of aquifer capacity and the combined effects of pumping on the ground water system.

6.1 Water Sources

6.1.1 Ground Water

Ground water currently provides 100 percent of the potable water supply in the Issaquah Creek Valley Ground Water Management Area. Ground water investigations to date in the lower Issaquah Creek Valley indicate the presence of what appears to be a hydraulically interconnected system of aquifers. A description of the aquifers and their primary sources of recharge is provided in Section 7.3.

New data, collected as described in the Recommendations Section of this Plan (Section 8), will help to more clearly define the ground water resource in the Issaquah Creek Valley Ground Water Management Area.

6.1.2 Surface Water

Surface water is not known to be used as a source of potable water in the Issaquah Creek Valley Ground Water Management Area. Surface water and ground water within the Issaquah Creek Basin are, however, believed to be hydraulically connected. Issaquah Creek, with its system of tributaries, and Tibbetts Creek represent the primary sources of surface water in the ground water management area. Issaquah Creek extends 17.35 miles (27.8 km) from the Hobart Plateau to Lake Sammamish. Elevations for Issaquah Creek range from 2,500 feet mean sea level at headwaters to 25 feet mean sea level at Lake Sammamish. King County rates both general water quality and habitat suitability for Issaquah Creek as good. With a length of 4.3 miles (6.8 km), Tibbetts Creek covers a comparatively smaller area than Issaquah Creek. The headwaters for Tibbetts Creek are measured at elevation 1,080 feet mean sea level, while the mouth of the creek at Lake

Sammamish is at an elevation of 25 feet mean sea level. King County lists general water quality for Tibbetts Creek as good and habitat suitability as fair (Metro 1988).

6.2 Water Services

The boundaries for all water service areas in the Issaquah Creek Valley Ground Water Management Area are shown in Figure 6.1. In addition, data from some of the major producing wells in the study area are provided in Table 6.1. Existing water rights granted to each water purveyor that provides service in the Ground Water Management Area are listed in Table 6.2. The East King County Coordinated Water System Plan (August 1989) lists all the major water suppliers (Group A) in the Issaquah Creek Valley Ground Water Management Area and the quantities of water drawn from these wells. The plan also describes future expansion plans for each water purveyor, water level depths of each Group A well, and the number of service connections for these wells. More detailed plans for expansion and additional supply can be found in individual purveyors' Water System Plans and subsequent Plan updates.

City of Issaquah

The City of Issaquah has historically relied upon ground water to meet its potable water supply needs. Recently, increased demands on the ground water resource combined with concerns of the State of Washington Department of Ecology (Ecology) about hydraulic continuity between ground water and surface water, and other issues have resulted in closure of the Issaquah Valley Aquifer to development of additional new sources of ground water (City of Issaquah, Water System Plan Update, 1996). Continued growth within the existing City limits, combined with requests for service outside the existing City limits, have prompted the need to develop strategies for providing additional supply capacity. These strategies include demand management (e.g., water conservation) and development of conventional and nonconventional supply alternatives.

The City of Issaquah water service area extends beyond the city limits to include Grand Ridge, Lake Sammamish State Park, a large portion of the Tibbetts Creek Valley, and the area around the Issaquah-Hobart Road between the City's boundary and the Mirrormont area (see Figure 6.1). However, some residences located on steep hillsides in the City of Issaquah use wells that are not included in the City's service area (Rothnie, 1989).

The City of Issaquah operates a Group A public water system. The City has five wells ranging in depth from 97 to 412 feet. These wells are located in the lower Issaquah Valley aquifer. Water rights allow water to be pumped at rates of 250 gpm to 1,200 gpm depending on which well is being pumped (Lynne 1994). However, water rights do not necessarily reflect the true capacity of the aquifer. The City of Issaquah also holds certified water rights on the Gun Club wells, which are currently inactive. These water rights may be reactivated in the future.

Sammamish Plateau Water and Sewer District

The Sammamish Plateau Water and Sewer District service area forms the northern boundary of the Issaquah Creek Valley Ground Water Management Area, as shown in Figure 6.1. Sammamish Plateau Water and Sewer District merged with Cascade View (Water District 122) in 1995. The Cascade View area is now included in the Issaquah Creek Valley Ground Water Management Area. Water provided by Sammamish Plateau Water and Sewer District serves commercial uses, light industrial activities, and residential areas. The Sammamish Plateau Water and Sewer District has 9,191 service connections. Currently the Plateau has a supply of 1.65 million gallons per day and forecasts they will exceed their supply by 0.93 million gallons per day (2.48 million gallons per day estimated) by the year 2000 (King County Comprehensive Plan, Technical Appendices, 1994). The Plateau's water source is eight groundwater wells, and they hold water rights equal to 9.28 million gallons per day or 4,936 acre feet per year. The Sammamish Plateau Water and Sewer District and Northeast Sammamish Water and Sewer District have an intertie, and they plan to intertie with Issaquah in the future (East King County Coordinated Water System Plan, 1989). The District projects that five additional aboveground storage facilities need to be constructed to serve the growing demand for water in their area. The land use in the District's area includes primarily single family residences on former timber production and agricultural lands, golf courses, parks, and equestrian trails.

Prior to merging with the Sammamish Plateau Water and Sewer District in 1995, Cascade View Water District completed a Water Comprehensive Plan in January 1992 and has water rights equal to 0.28 million gallons per day or 12 acre feet per year (East King County Coordinated Water System Plan 1989). As of March 16, 1995, Cascade View comprised 367 service connections and a population of 910 (Cox, J., Personal Communication). Cascade View Water District interties with Union Hill Water Association. Their Water Comprehensive Plan recommends significant commitment to future interties with the Union Hill and the Ames Lake water system.

Sammamish Plateau Water and Sewer District draws all of its water from wells. Wells 7, 8, and 9 operate in the Lower Issaquah Valley aquifer system and serve approximately 70 percent of the water demand of the Sammamish Plateau Water and Sewer District. Located between Interstate 90 and East Lake Sammamish Parkway, wells 7 and 8 have an actual depth of 150 feet and carry a potential capacity of 2,000 and 3,500 gpm, respectively. Well 9 is located north of Interstate 90 and east of East Lake Sammamish. It is completed to a depth of 200 feet and has a potential capacity of 3,500 gpm (Little, 1994). However, Well 9 has only been approved for supplemental winter time rights in the case where wells 7 and 8 must shut down, due to the fact that it is located in what is considered a closed basin by Ecology. Sammamish Plateau Water and Sewer District also operate wells on the Sammamish Plateau including wells 1, 2, 3, 4, 5, 6, 10, and 11-2 and in the area previously served by Cascade View (Water District 122) (wells 12 - 14).

King County Water District #90

Water District #90 operates a Group A water system serving the King County community of Newcastle. Only a small portion of this district lies within the boundaries of the Issaquah Creek Valley Ground Water Management Area. The Lake MacDonald residential area represents the largest area served by District #90 in the Issaquah Creek Valley Ground Water Management Area. No Group A source wells for this district are located in the Issaquah study area (King County Planning, 1983).

King County Water District #123

District #123 operates a Group A water system serving Preston. Only a small portion of this district falls within the boundaries of the Issaquah Creek Valley Ground Water Management Area.

Other Purveyors

The largest private Group A water system in the study area serves the Mirrormont area. Water provision in the Mirrormont area is from five Group A wells that range in depth from 209 feet to 325 feet; these wells have a combined potential capacity of 1,000 gpm (Nordie/Heintze 1994).

In addition to the purveyors listed in Table 6.1, there are numerous Group B water systems and individual wells in the Issaquah Creek Valley Ground Water Management Area.

Areas of Concern and Information Needs

Additional data are needed to complete the analysis of water users and for conservation planning in the Issaquah Creek Valley Ground Water Management Area:

- Map Group B water system locations within the ground water planning area.
- Identify the key private wells in the basin and develop an estimate of water use in the basin. Key private wells will be those wells within 1-, 5-, and 10-year time of travel of the major Group A public water supplies, and those private wells in the physically susceptible areas.

6.3 Water Rights

A water right is a purveyor's permitted right to withdraw water. A water right is specified in two ways:

- A maximum pumping rate (expressed in gallons per minute or GPM) is specified based on the capacity of the well (note that well capacity is a function of construction specifications and the pump, and not an indication of aquifer capacity).
- A maximum annual volume of ground water that can be withdrawn from the well (typically expressed as Acre Feet per Year). This volume is based upon the water needs of the population served by the well and is not a function of well or aquifer capacity.

Ecology is the state agency responsible for granting or denying a water right application. In a review of technical reports for the Issaquah Creek Basin, Ecology concluded that ground water and surface water are in direct continuity. Further, they have denied water right applications in areas where ground water is in hydraulic continuity with a closed surface water body. Because Issaquah Creek flows into Lake Sammamish, which feeds the Sammamish River and eventually Lake Washington, all wells within the Issaquah Creek drainage are assumed to be in some degree of hydraulic continuity with Lake Washington. Therefore this basin is considered to be closed by Ecology, and many water right applications have been denied with justification that pumping would decrease surface water flows.

Sammamish Plateau Water and Sewer District also operates wells above the Issaquah Valley on the Sammamish Plateau and in Cascade View (previously serviced by Water District 122), where hydraulic continuity with Issaquah Creek is not an issue. Sammamish Plateau Water and Sewer District has been granted water rights in this Plateau region. Table 6.2 lists the current water rights held by the Sammamish Plateau Water and Sewer District.

Currently, the State does not require a water rights claim for wells that withdraw less than 5000 gallons per day, or irrigate less than one-half acre. Therefore, some individual wells associated with rural residences are not accounted for by existing water right volumes. An estimation of total ground water withdrawal from wells without water rights will be necessary to allocate future ground water resources.

Table 6.2 lists the major permitted water rights in the study area. These figures represent the total amount of water a supplier is appropriated. However, they do not necessarily reflect the capacity of the aquifer.

6.4 Aquifer Capacity

The actual capacity of an aquifer to provide ground water cannot be determined without an in-depth study of cumulative impacts of pumping on the aquifer system. However, long-term water level data for the Lower Issaquah Creek Valley Aquifer indicate a downward trend in water table elevations. This declining trend in ground water elevation may indicate that the aquifer system is being pumped (cumulatively by all water users) beyond its capacity, or the trend may be a result of climatic influences. The capacity of the aquifer systems from which the Sammamish Plateau Water and Sewer District and the City of Issaquah withdraw their water is unknown. (Lynne 1994)

A comparison of withdrawal volumes specified by water rights (Table 6.2) and annual water demand (current and projected) from each purveyor (Table 6.3) indicates that future demands may not be met by the current water right. It is unknown at this time whether actual aquifer capacity could sustain projected demands. Purveyors are beginning to use creative alternatives to maximize their current water appropriation and increase the overall annual volume of water pumped from the aquifers in the valley to accommodate accelerated growth in the area. These alternatives include aquifer storage and recovery (known as ASR) techniques and use of peak day pumping rates coupled with reservoir storage. In both cases, a greater volume of ground water will be withdrawn from the aquifers involved.

Some preliminary testing of specific wells screened in the Lower Valley Aquifer System has been performed. In September 1990, the Sammamish Plateau Wells 7 and 8 were pumped for 3 days. Analysis of pumping tests on Wells 7 and 8 indicated that the zone of influence from pumping of Well 8 extended in a northwest-southeast direction along the valley margin for a distance of 7,000 feet from the pumping wells. In July 1992, Carr & Associates conducted a 9½-day pump test of Sammamish Plateau Water and Sewer District Well 9. Extensive water level and water quality data were collected from 51 ground water monitoring sites, 15 surface water stations and two precipitation gauges. Test results suggested that pumping of Well 9 should have little impact on surface waters and only limited impact on other production wells.

6.4.1 Areas of Concern and Future Information Needs

The following water rights analysis elements will require further investigation during implementation of the Issaquah Creek Valley Ground Water Management Plan:

- Estimate the capacity of the aquifer system.
- Determine the numbers and locations of Group B and individual wells without water rights in the Issaquah Creek Valley.

6.5 Existing and Potential Water Demand

6.5.1 Major Suppliers and Water Demand

Existing and anticipated future water demand for major suppliers in the Issaquah Creek Valley Ground Water Management Area is reflected in Tables 6.3, 6.4 and 6.4A. These data show an average annual increase in water demand (between 1986 and 2000) of 3.9 percent for Issaquah, 5.1 percent for Sammamish Plateau Water and Sewer District, and 2.6 percent at Mirrormont. If this period is extended from 1986 to 2040, the average annual increase becomes 2.5 percent in Issaquah, 3.5 percent with Sammamish Plateau Water and Sewer District, and stays at 2.6 percent for Mirrormont.

Water demand projections used in the report prepared by Economic and Engineering Services, Inc. (1988) for the East King County Coordinated Water System Plan are estimates based on variables such as individual utility data, weather projections, the price of water, and demographic data. These demand estimates are derived from base assumptions that reflect the projections most likely to occur for each category. The most significant variations from base estimates range from 20.4 percent with a low scenario to 9.8 percent using the highest possible projections.

The City of Issaquah in 1990 had a population of 7,786 within its corporate boundaries. The average annual water demand in 1990 was 1.22 million gallons per day (MGD), with a maximum day demand of 3.1 MGD (see Table 6.4A). In the year 2020, the population of the corporate area is projected to be 12,815, with the total population for the City of Issaquah, including annexation, to be 58,643. The maximum day demand in 2020 is projected to be 8.0 MGD (City of Issaquah Water System Plan Update, August 1995). The current water right for the city of Issaquah is 5.6 MGD. Use of conservation measures will slightly reduce demand figures. The Department of Ecology has closed the Issaquah Creek Basin to further water right appropriations due to the interconnection of ground water and surface water in the basin.

6.5.2 Demographic Projections for the Issaquah Creek Valley Ground Water Management Area

Demographic indicators are helpful in estimating the amount and types of increased water demand predicted for the Issaquah Creek Valley Ground Water Management Area. Small Area Zones (SAZs) are used by King County transportation planning for the purpose of transportation analysis. These SAZ numbers were used for the purpose of population forecasting in the Issaquah Creek Valley Ground Water Management Area. SAZ projections are taken from the King County Comprehensive Plan, and are current as of February of 1995. SAZ projections include only those areas that lie within unincorporated King County. Therefore, they do not include the City of Issaquah. Projections for the City of Issaquah were provided by growth target numbers taken from the City of Issaquah Comprehensive Plan.

SAZ projections were used to estimate household growth in the Issaquah Creek Valley Ground Water Management Area between 1990 and 2012. Table 6.5 indicates estimated growth between 1990 and 2012 by number of households. Data indicate that the total number of households requiring water in the Issaquah Creek Valley Ground Water Management Area was 24,820 in 1993 and projected to be 35,502 in the year 2012, reflecting a 43% increase in water demand within the Ground Water Management Area .

Another predictor of future population and development patterns in the study area is available through the Puget Sound Regional Council. Projections are presented in terms of forecast and analysis zones. Six different forecast and analysis zones fall within the boundaries of the Issaquah Creek Valley Ground Water Management Area, these being Klahanie/Pine Lake (4605); Beaver Lake (4607); Issaquah (4300); Cougar Mountain (4225); Maple Valley/Hobart (3330); and the Renton Plateau (4230) (see Figure 6.2). All six forecast and analysis zones are not entirely within the Issaquah Creek Valley Ground Water Management Area.

6.5.3 Areas of Concern and Future Information Needs

Research in the following areas will provide a more complete understanding of existing and future water demand and supply in the Issaquah Creek Valley Ground Water Management Area:

- Future research involving the City of Issaquah and Sammamish Plateau Water and Sewer District water demand projections should focus on determining the type and magnitude of demands to be made on all sources in the Issaquah Creek Valley Ground Water Management Area.

- Assess the capacity of both the Lower Issaquah Valley Aquifer System and the Sammamish Plateau Aquifer System(s). Determine whether increased pumping to provide service to growing areas will begin to deplete the ground water resource before certificates of water availability are granted for large supply requests. Assess long term trends in ground water levels in these systems.

7.0 HYDROGEOLOGY

7.1 Geology

This section briefly describes the geology of the area using generalized geologic units appropriate for an analysis of surface and ground water movement. The geologic units of significance in the Issaquah Creek Valley Ground Water Management Area were deposited since the early Tertiary period (approximately 60 million years ago). The composition of these units is characterized by a complex history, that indicated the Issaquah Creek Valley Ground Water Management Area was related for some time to advancing and retreating oceans and glaciers. This history also included earth's internal processes of volcanism (tectonics) and mountain building (orogeny), and currently involves erosive forces from stream and rivers.

Much of the development of the Cascade mountains is due to their regional tectonic setting. This orogenic event occurred as a result of the subduction of an oceanic plate under a less dense continental plate. As a result, the topographic features in the Issaquah Creek Valley Ground Water Management Area formed from mountain building processes. The Issaquah Creek Valley Ground Water Management Area is underlain by Eocene age (approximately 40 million years old) igneous and sedimentary rocks. The igneous rocks include magma that solidifies underground (intrusive andesite) and magma that solidifies on or near the ground surface (extrusives like volcanoclastics and lavas). The consolidated sediments (bedrock) in the Issaquah Creek Valley Ground Water Management Area consist of sedimentary rocks like sandstone, siltstone, coal, conglomerate, and shale. These formed from geologic processes characterized by shallow ocean, near shore, and estuarine environment. The rocks are exposed at the surface in the surrounding highlands of Cougar Mountain, Squak Mountain, Tiger Mountain, and Grand Ridge. Locally, they are overlain by younger sedimentary rocks, exposed mainly in the northern upland areas of the basins.

This sequence of rocks, many thousands of feet thick, has been folded along northwest-trending horizontal axes. The dominant fold here is the Lake Sammamish syncline, a pronounced downwarp that extends from Lake Sammamish through the City of Issaquah, and which is truncated by faulting east of West Tiger Mountain. The syncline is flanked on the southwest by the Newcastle Hills anticline, whose axis and corresponding bedrock uplift now separate the lower Issaquah valley from the May valley and the May Creek Basin to the southwest. On the northeast side of the Issaquah Creek Basin, rocks climb up the southwest limb of the Raging River anticline, a less pronounced fold near the eastern basin boundary.

The surface and subsurface expression of the Lake Sammamish syncline dominates the structure in the basins. Particularly in the northern third of the basin, not only the bedrock structure but also the glacial sedimentation and the surface topography follow the trend of this trough. Glacial ice has scoured out a valley in the rock, filling it with unconsolidated sediment; these sediments were again scoured to form the yet narrower valley now occupied by the south end of Lake Sammamish and the Issaquah Creek floodplain.

In the remainder of the basin, the structure of folds in the bedrock is still discernible in the rocks themselves. Yet the contact between the rocks and the later glacial and nonglacial sediments that overlie them does not follow the folds in the strata. Instead, erosion of the rock surface follows a much larger subsurface valley extending southeast out of the Issaquah Creek basin, crudely along the modern Cedar River valley, at a maximum depth of over 500 feet below ground level (Hall and Othberg 1974). The southwest part of the Issaquah Creek basin lies on the northeast flank of that valley, presumably an infilled arm of an ancestral Puget Sound (*Issaquah Creek Basin Report,* October 1991).

In the Puget Lowland, the geologic record indicates discontinuous periods of Pleistocene glacial and interglacial processes. In the basins of the Issaquah Creek Valley Ground Water Management Area, glacial deposits can be assigned to the Vashon stage of the Fraser glaciation. The effects of the glaciation lasted 2,000 years and were gone from the area about 13,000 years ago. During these glacial periods an advancing thick mass of ice inched southward for thousands of years. The mechanics of a glacier work like a giant conveyor belt. The ice sheet plucks and plows chunks of soil and rock from the countryside and incorporates them into its mass. The effect of the glacier is to scour and scrape the landscape, then transport its load in melt water and deposit it in three typical geologic units.

In the front of the advancing glacier, water from melting glaciers deposited a sheet of sand and gravel known as advance outwash. The advance outwash was subsequently covered by the glacier, which left a deposit of compact silty-sandy gravel known as "Till." As the glacier retreated, the till was subsequently covered by sand and gravel (deposited from the meltwater stream) known as recessional outwash deposits. In some places, areas of ice-contact deposits occur. These sediments were deposited on the surface of the melting glacier and are silty sand and gravel that can resemble till.

The last glaciation left a mantle of advance outwash, till, recessional outwash, and ice-contact deposits over older glacial deposits on the uplands and in some valleys; it left thick deposits of recessional outwash in most valleys.

7.2 Soils

Knowledge of soil properties and distribution is essential to understanding relationships between ground water distribution, movement, and contamination processes. Given the diverse physical and biological nature of the Issaquah Creek Valley Ground Water Management Area, a large number of widely varying soils are present. Each presents a unique set of considerations in developing future management alternatives.

Approximately three-quarters of the Issaquah Creek Valley Ground Water Management Area, excluding the Tiger Mountain peaks complex, has been mapped (Figure 7.1A). The four main soil associations mapped in the Issaquah Creek Valley Ground Water Management Area are the Alderwood, Beausite-Alderwood, Everett and Puget-Earlmont-Snohomish Association Soil series. (There are also smaller areas of Oridia-Seattle-Woodinville and Alderwood-Kitsap-Indianola Associations - see Figure 7.1A). For more detailed information on these four soils and other soils, see Table 7.1 and Appendix A. Soils that appear in several associations are described only once. Water quality and ground water recharge factors related to soil series characteristics are also presented. These factors are interpreted from the information extensively researched and prepared by the U.S. Natural Resources Conservation Service. The Conservation Service produces maps with greater detail about the location of various soil types. The maps are too large in scale to reproduce for this report.

Alderwood Association

The Alderwood association blankets a large part of the Issaquah Creek Valley Ground Water Management Area. It is found in upland areas, including most of the Sammamish Plateau and Cedar Hills and Hobart Plateau in their entirety. It is composed of 85 percent Alderwood soils, 8 percent Everett, and 7 percent less extensive soils. In general they are moderately well drained, variable sloped soils underlain by very low permeability glacial till at a depth of 20 to 40 inches.

Beausite-Alderwood Association

The Beausite-Alderwood association is another extensive association in the Issaquah Creek Valley Ground Water Management Area, covering primarily the mountainous areas (Cougar and Squak Mountains, Grand Ridge, and likely the mostly unmapped Tiger Mountain peak complex). Major soils represented include approximately 55 percent Beausite soils, 30 percent Alderwood soils, 10 percent Ovall soils, and 5 percent miscellaneous soils. These soils are found on rolling to very steep surfaces underlain at 20 to 40 inches depth by sandstone, shale, or dense glacial till. In general, these soils do not contribute any significant recharge to the ground water.

Everett Association

Everett association soils are found on northern upland units in the vicinity of Tradition Lake Terrace, lower Grand Ridge, and an adjacent portion of the Sammamish Plateau. A substantial portion of the City of Issaquah and the upstream valleys also consists of Everett soils. The association typically consists of 70 percent Everett soils, 15 percent Neilton soils, 7 percent Alderwood soils and 8 percent less extensive soils. The dominant soils are found on both gently undulating surfaces, and steep terrace faces. They are underlain by sand and gravel, and are exceedingly well drained.

Valley Soils

A number of soils are represented in the valleys, including: Sammamish, Bellingham, Briscot, Puyallup, Puget, Oridia, and Sultan. Most of the above soils are found in developing areas of the lower Issaquah Valley.

Although not extensively distributed elsewhere in the Issaquah Creek Valley Ground Water Management Area, these soils are significant due to the industrial, urban, and residential development that has occurred or is planned in their vicinity. Large scale development is likely to include drainage rerouting or enhancement, and substantial earth moving or placement of fill. Such activities greatly disrupt the natural drainage and permeability related properties of native soils. The number of potential contaminant sources also increases with intensive land use activities.

Puget Soils

Puget soils are formed in valley alluvium and are composed of a silty clay loam. Slopes are very flat, less than 1 percent, and permeability is low. The seasonal water table is at or near the surface. Recharge to shallow aquifers is slow, yet significant.

7.3 Ground Water

Ground water hydrology, or hydrogeology, the study of the interrelationship of geologic materials and processes with water, is both a descriptive and an analytic science (Fetter 1994). The development and management of water resources is also an important part of hydrogeology. Hydrogeology is recognized as an important part of environmental planning.

Most of the ground water in the Issaquah Creek Valley Ground Water Management Area comes from direct precipitation onto the ground surface. Precipitation that is neither evaporated, transpired by plants, nor lost rapidly by surface flow enters the ground water system. Ground water is accessible for water use or discharge to surface water bodies only where it can move freely through subsurface deposits. In the Issaquah basin, the various outwash deposits of the last glaciation form the most common aquifers. Some shallow aquifers and many major ground water recharge areas are formed in recessional outwash and ice-contact deposits. These are characterized by relatively large pore spaces and they freely transmit water (*Issaquah Creek Basin, Current/Future Conditions and Source Identification Report*, King County Surface Water Management, October, 1991).

The infiltration, movement, and storage of ground water is controlled by the characteristics of the surficial and subsurface geology. Infiltration at the surface depends on the permeability of the surface sediments and the accessibility of those sediments to precipitation. Thus outwash deposits, consisting of silt-poor sand and gravel, provide the best opportunities for infiltration. In contrast, Vashon Till has a much higher percentage of silt and clay and so offers significantly more resistance to flow. It acts as the uppermost aquitard, with rates of infiltration through the unweathered deposit of approximately 1 inch per month (Olmstead 1969). The soil layer developed on top of the till, however, has much greater infiltration, but the movement of water is largely restricted to that thin upper zone.

In the Lower Issaquah Valley, a large ice-dammed lake formed south of the retreating glacier front. Meltwater rivers flowing down to the lake formed a large delta. This delta is the eastern margin of the Lower Issaquah Valley; its coarse-grained deposits grade westward and northward into finer-grained lake deposits. The major aquifer system providing ground water to wells in the City of Issaquah and the Sammamish Plateau Sewer and Water District receives a substantial amount of recharge from these deltaic deposits (Carr/Associates 1993; Golder Associates 1993).

Subsequent to the lowering of Lake Sammamish to its present level, Issaquah Creek began flowing through the Tiger Mountain Gap and down the Lower Issaquah Valley. It eroded some of the lake and deltaic deposits and deposited a mantle of silty-sandy alluvium over the older, more permeable deposits.

7.3.1 Surficial Geologic Deposits

Geologic deposits form the basis for the different hydrogeologic units in the study area. A map of surficial geology showing post-glacial, glacial, and bedrock deposits is presented in Figure 7.1B. The deposits beginning with the most recent, are listed below:

POSTGLACIAL DEPOSITS

Recent Bog Deposits (or wetland deposits, Qw)

Bog deposits are found in both upland and valley depressions and contain organic material such as peat, muck, and decaying vegetable matter. Drainage is poor because of factors such as poor surface drainage, impervious subsoils, a discharge zone for higher gradient aquifers, or simply a depression in an unconfined aquifer with a high water table. Because of the accumulation of water, these areas could contribute to local recharge.

Bog deposits can have an important, natural influence on water quality because decaying organic materials produce humic acids, and associated geochemical conditions are highly reducing. As a result, adverse effects to local ground water quality can include:

- increased corrosivity,
- elevated concentrations of dissolved iron, manganese, hydrogen sulfide and nitrates, and,
- undesirable color, taste, and odor characteristics.

Alluvium (including Qb, Qf, Qyal, and Qoal)

Alluvium consists of stream deposits ranging from cobble-sized gravel through sand to sandy silts. The deposits are found in valley fill, along stream channels, floodplains, and as alluvial fans where steep gradient streams meet lower gradient valley floors. Many wells are completed in alluvium and are capable of yielding large quantities of water. Permeability of alluvial materials varies considerably. Depending on grain size and sorting, alluvial aquifers can be perched, unconfined, and confined. Hydraulic continuity between aquifer zones varies laterally and with depth. Surface water and downslope drainage provide ample recharge to alluvium. Where thick and extensive upper aquitards are absent, alluvial aquifers are vulnerable to contamination from surface sources, or from vertical and horizontal movement of contaminated water from one aquifer to another.

Landslide Deposits (Qls and Qmw)

Landslide deposits are found along the side and base of slopes. Geologic materials are variable. These deposits are not known to be an exploitable source of ground water.

VASHON STADE GLACIAL DEPOSITS

Table 7.2 summarizes the characteristics of these deposits, and Figure 7.1B shows their locations.

Vashon Recessional Outwash (Qvr and Qvrg)

Recessional outwash is predominantly gravel, sand, and minor amounts of silt that were deposited by melt water from the retreating ice. Large delta deposits are exposed in bluffs east of Issaquah. Other similar deltaic deposits are located southwest of Cedar Hills and north of Hobart. A typical thickness of this unit is 60 feet, however, the unit can vary from a veneer overlying till to an accumulation greater than 300 feet. This coarse-grained unit can be a productive aquifer in places where relatively thick sequences of sand and gravel are saturated.

Most of the recessional outwash is highly permeable. Much of these deltaic deposits lie above the water table, but provide an important recharge medium to adjacent inter-connected aquifers. Unpredictably distributed lenses of silt intercept downward percolating ground water and redirect it laterally, creating locally perched water table zones and surface weeps. Where saturated and endowed with a good source of recharge, recessional outwash readily yields large quantities of water. In areas where the unit is thin or lies above the water table, little water is available, such as the Sammamish Plateau. In these areas, the aquifer is under water table conditions, and the wells produce moderate yields for domestic purposes.

Due to the unit's high permeability and exposure to the surface environment, recessional outwash is vulnerable to contamination. Interconnected aquifers are vulnerable to contamination transported through this unit.

Vashon Recessional Lacustrine Deposits (Qvrl)

These fine-grained materials were deposited in the ancestral Lake Sammamish. Unit materials are predominantly clay and silt, but include sand and rare occurrences of gravel. Individual textural layers such as clay, sand, or silt are probably not laterally continuous. Vertical hydraulic continuity between textural layers and more permeable deposits probably varies widely. In general, the unit likely functions as a leaky aquitard.

Vashon Ice Contact Deposits (Qvi)

Ice contact deposits are a heterogeneous (complex) mixture of till and outwash deposits. Grain size changes abruptly. Due to this physical variability, characteristics such as permeability and recharge cannot be generalized.

Vashon Till (Qvt)

Till is a massive, compact, heterogeneous mixture of silt, sand and gravel. Random sand and gravel lenses are present. Much of the upland and mountainous areas are covered with till varying in thickness from a thin veneer to 30 feet or more. The permeability of till at the surface is low and tends to decrease with depth. Downward percolation is slow.

Upper portions can contain perched and semi-perched water tables. Isolated lenses of sand and gravel yield limited quantities of water to shallow, domestic wells. Recharge to these lenses is usually slow. Seasonal fluctuations in water level occur, and some wells are vulnerable to drought or overdrafting. Shallow wells are very susceptible to contamination. Permeable areas in the till surface provide an avenue for local recharge and migration of contaminants to underlying materials.

Vashon Advance Outwash (Qva)

Advance outwash is composed principally of sand to cobble-sized gravel. Thin beds of silt are present. Materials in the advance outwash range from well sorted to poorly sorted. The unit is irregularly distributed throughout the basin, although exposed only in the north part of the Issaquah Creek Valley Ground Water Management Area. Permeability is generally high. Where saturated, the unit yields large quantities of water. Surface exposures or shallow deposits may be vulnerable to contamination.

Unconsolidated pre-Vashon Deposits (Qtb, Qpf, and Qob)

The following unconsolidated sediments are not found exposed at the surface, but local drilling records and exposures outside the Issaquah Creek Valley Ground Water Management Area confirm their presence. Some deep wells in these sediments are known to yield significant amounts of water.

Table 7.2 briefly summarizes the composition of the pre-Vashon units and general hydrogeologic properties. The unit names are informal.

Bedrock (Tsc, Tb, Ti, Tv, Tp, Tpr, Tpt, Trr, and br + Qvt)

Bedrock units present in the Issaquah Creek Valley Ground Water Management Area are not known to yield large quantities of water to wells. However, in some areas they may be the only available source for domestic supply. Descriptions of the bedrock units are summarized in Table 7.2.
Saturated thicknesses of sandstone and conglomerate have yielded usable water supplies, yet declining water levels indicate that recharge may be insufficient to sustain discharge for an extended period. The potential presence of mineralized, saline, or brackish connate water in these units diminishes their potability and usefulness for irrigation.

Fractured, porous, volcanic rocks can yield significant water; however, the volcanic rocks in the Issaquah Creek Valley Ground Water Management Area are easily weathered and decomposed along fractures. Thus, it is unlikely that any productive volcanic rock aquifers occur in the Issaquah Creek Valley Ground Water Management Area.

Low-permeability bedrock is not expected to readily transmit ground water or potential contaminants to aquifers; however, two potential contamination processes should not be overlooked:

- Contaminant migration through porous layers, joints, and fractures to wells completed in relatively shallow bedrock.
- Intrusion of poor quality (mineralized, brackish, saline) ground water from bedrock to aquifers in hydraulic continuity through pumping influences.

7.3.2 Aquifers

Information describing hydrostratigraphy, ground water movement, and the supply potential of aquifers is available only for small portions of the Issaquah Creek Valley Ground Water Management Area where major sources have been developed. Future project drilling, monitoring, data collection and analysis efforts will substantially improve the present knowledge and provide a basis for further investigations. For this discussion, aquifer systems and flow direction are described according to physiographic situation.

Mountain Aquifers

Mountain aquifers are mostly bedrock which is capable of providing only individual domestic water supplies. However, in saturated, permeable glacial sediments, small public supply wells may be possible. For example, the Mirrormont subdivision is a Group A public supply system with several wells completed in permeable glacial sediments. One Mirrormont well is reportedly capable of producing 330 gpm.

Mountain aquifers located well above the regional water table are expected to have steep ground water gradients. Where low-permeability layers laterally redirect the flow, water erupts as springs or surface weeps. Beneath the unconsolidated sediments, flow would logically follow along buried erosional surfaces, bedding planes, faults, and fractures. Shallow ground water flow that does not emerge as runoff likely recharges lower elevation upland and valley aquifers.

Upland Aquifers

Numerous domestic wells are completed in unconsolidated materials with highly varying degrees of success. There are no known large production wells completed in upland aquifers. Two wells located in and next to Cedar Hills Landfill produce 127 gpm and 50 gpm. Most upland aquifer wells are completed in unconsolidated sediments, and a few are completed in sandstone.

Deep and shallow upland aquifer flow patterns may not be in similar directions. Valley aquifers are the likely recipients of recharge from upland ground water. Deep upland aquifers may be continuous with valley aquifers in some areas.

<u>**Valley Aquifers**</u>

Drilling reports and well logs indicate that unconsolidated sediments in the Issaquah Creek valley may be present at depths of over 650 feet below ground surface (Robinson & Noble, Inc. 1986). A narrow gap in the Issaquah Creek valley south of Issaquah is bounded by bedrock. Deep unconsolidated sediments are found in the valley north and south of this gap. The degree or manner of interconnection is unknown. Some wells drilled near the valley gap encountered bedrock at relatively shallow depths. If a bedrock sill or barrier is present, it could restrict or alter deep ground water flow.

Aquifers north of the gap are hereafter referred to as lower valley aquifers and are discussed in the following sections. Those aquifers south of the gap are referred to as upper valley aquifers. In addition to the upper and lower valley aquifers (see Figure 7.2), there may be distinguishing characteristics for aquifers found in the tributary stream valleys drained by East Fork, North Fork, Mason Creek, and the unnamed drainage along the Cedar Grove Road.

In the lower valley, at least three major aquifer zones have been identified. They are informally designated A1 - Upper Zone, A2 - Lower Zone, and A3 - Deep Zone. Their known characteristics are summarized in Table 7.3.

Several high-yield production wells are completed in these zones. (Table 7.4. lists wells indicating yields and aquifer characteristics. Figure 7.2 shows the location of Sammamish Plateau Water and Sewer District and City of Issaquah Production Wells.) All three aquifer zones have been demonstrated to be in hydraulic continuity with Sammamish Plateau Water and Sewer District's Well 9. Production testing of Well 9, completed in zone A3, created drawdown interference observed in all 3 aquifer zones within 4 hours. In zones A1 and A2, wells up to 6,000 feet away had less than 1 foot of drawdown, and wells with over 1 foot of drawdown were within 3,400 feet of Well 9. One well with over 2 feet drawdown interference is located just over 3,000 feet from Well 9. The general ground water gradient is toward Lake Sammamish (Carr/Associates 1988, 1992/93).

In the upper valley there are no known high-capacity production wells. However, given the relatively sparse population of the area, there has not been an economic incentive to develop high yield wells, and so the potential productivity of ground water resources is unknown.

Flow in shallow aquifers is expected to follow in the approximate direction of surface drainage. The direction of ground water movement in deeper aquifers in the upper valley is not fully understood. There is some flow from the upper to lower valley.

7.3.3 Lower Issaquah Valley Aquifer System

Hydrogeologic Boundaries. Hydrogeologic boundaries can restrict ground water flow (e.g. bedrock boundaries) or enhance it (e.g. stream boundaries). They also constitute the ultimate source areas and discharge areas of the aquifer system. The boundaries recognized in the Lower Issaquah Valley Aquifer system are:

- The lower Issaquah valley system aquifer is bounded on the south by low-permeability bedrock, at the Tiger Mountain Gap, and by bedrock outcrops occurring in the higher elevations along the margins of the ground water basin. The assumed low permeability of the bedrock constitutes a no-flow boundary to the base of the aquifer system;
- The lower Issaquah valley aquifer system is bounded on the north by Lake Sammamish, which is a regional discharge area. All ground water flowing through the area ultimately discharges either to Lake Sammamish, the wetland area directly south of the Lake, or to Issaquah Creek which drains into Lake Sammamish;
- The uppermost boundary to the aquifer system is the most complex, consisting of wetlands, streams, lakes, open-space (recharge areas), and urbanized areas. The water entering the ground water flow system originates from precipitation within the confines of the ground water basin. Streams may "lose" water to the aquifer, "gain" water from the aquifer, or have no interaction with the aquifer. Lake Tradition likely contributes water to the lower Issaquah valley aquifers through vertical infiltration from the Tradition Lake Plateau to the lower Issaquah valley aquifer. Urbanized areas tend to reduce the natural infiltration to the ground water through stormwater collection. Undeveloped open areas and rural residential areas represent potential recharge areas (Lower Issaquah Valley Wellhead Protection Plan, Golder Associates 1993).

Ground Water Flow in the Lower Issaquah Valley. Ground water generally flows to the northwest through the lower Issaquah Creek valley area and discharges to Lake Sammamish, or the wetland area immediately south of the Lake. Ground water flow converges on the central valley area from the North Fork, East Fork and Lower Fork Subbasins of Issaquah Creek. Flow directions in the western lower Issaquah valley (near Newport Way) are not well known. The deltaic sediments of the North and East Forks readily transmit ground water downwards into the lower Issaquah valley from the upland areas, causing steep hydraulic gradients at the margins of the valley, then the gradients flatten within the delta itself. A water table contour map was constructed using water level data from selected wells and USGS topographic maps. Figure 7.2 shows the general topography of the area and the wells used for constructing the water level contour map. Figure 7.3 shows ground water levels, indicating that ground water moves from higher elevations toward the lower valleys and lowlands in the Issaquah Creek Valley Ground Water Management Area.

Ground water flow directions in the Grand Ridge and Tradition Lake areas are less certain, owing to a lack of wells and water-level measurements. It is presumed that flow mimics topography and is primarily westward toward the Issaquah valley, with components of flow directed towards the North Fork (particularly the wetland areas) and the East Fork valleys. Near the western margins of these areas, vertical infiltration through the deltaic sediments probably dominates. Quasi-horizontal flow may occur along distinct delta strata, but the continuity of individual strata within deeper zones in the lower Issaquah valley aquifer cannot be substantiated.

Ground water elevations vary throughout the year in response to winter and spring recharge. The direction of ground water flow within the valley appears to shift from a primarily northern direction during the summer and fall, to a northwestern direction during the winter and spring (see Figure 7.4). This was noted in the Wellhead Protection Plan wells as well as the monitoring wells at the ARCO site (Geraghty and Miller 1991). This westward shift in flow direction indicates a large influx of ground water from the east during the winter and spring. This has important implications with regard to the source of recharge to the aquifers within the valley and well capture zones (*Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates 1993).

A ground water pollution study of the Issaquah Plateau was conducted by the Puget Sound Power and Light Company in 1978. This study identified the existence of two standing water bodies, Lake Tradition and Round Lake, in the upper water table. The surrounding geology, the near identical lake body elevations and corresponding seasonal fluctuations of the lake's levels indicate the hydraulic continuity between the two lake systems. Test borings between the lakes encountered large quantities of ground water at depths of less than 6 feet, and deeper borings located ground water closely corresponding to the nearby lake elevations. The ground water appears to be the seasonal overflow progressing north from Lake Tradition. The study also showed that the major movement of this upper ground water table is west-southwest from Round Lake.

Surface runoff from the northwest side of Tiger Mountain and the Plateau migrates and concentrates in the Lake Tradition trough and moves westward and to some minor degree, northward. Most of the ground water movement continues west, showing up as a surface exposure in Round Lake and vicinity. From here, ground water flows in a southwest direction (*Ground Water Pollution Study*, Puget Sound Power and Light Company 1978).

Ground Water Flow through the Gap. The Tiger Mountain Gap is located in the south central part of the Issaquah Creek Valley Ground Water Management Area between Squak and Tiger Mountains (Figure 4.2). In April of 1992, resource protection well RP-1 was installed near the Tiger Mountain Gap (Carr/Associates, Inc. 1992) to determine the extent of ground water resources in this vicinity and the depth to bedrock. An aquifer encountered between depths of 27 to 42 feet yielded a transmissivity of 30,000 gallons per day per foot (gpd/ft). Bedrock was encountered at a depth of 63 feet below ground surface.

As shown by the water level contours on Figure 7.3, the Tiger Mountain Gap appears to act as a restricting ground water conduit, limiting drainage from the southern portion of the Issaquah Creek Valley Ground Water Management Area. To quantify the effect of the Tiger Mountain Gap on ground water movement, two calculations were performed. First, to determine the amount of ground water discharge available to flow through the Tiger Mountain Gap, a water balance was calculated for the area south of it. Second, to determine how much water can potentially move through the Tiger Mountain Gap, its hydrogeological capacity was calculated using Darcy's Law. Results are discussed below.

Available Discharge (Water Balance). The ground water discharge from the upper basin (GDu) that is available to move through the Tiger Mountain Gap can be estimated from the relationship of:

$$Gdu = P - ET - (SF + BF)$$

where upper basin values are:

P	=	148 cfs (precipitation)
ET	=	47 cfs (evapotranspiration)
(SF+BF)	=	87 cfs (stream outflow)
GDu	=	14 cfs (ground water discharge)

As shown, the ground water discharge of the basin upstream from the Tiger Mountain Gap is 14 cfs. This represents about 50 percent of the total discharge from the lower Issaquah valley drainage basin (24.5 cfs), as calculated in the water budget section (Section 7.5).

Discharge Capacity (Darcy's Law). Darcy's Law was used to calculate the amount of possible ground water flow through the Tiger Mountain Gap, based on permeability (hydraulic conductivity), area, and gradient.

$$Q = K A \, dh/dx \text{ (Darcy's Law)}$$

where values for the Tiger Mountain Gap are:

K	=	400 ft/day (hydraulic conductivity estimated from well RP-1; Carr/Associates, Inc. 1992)
A	=	36,000 sq. ft. (area = 480 ft. wide x 75 ft. deep)
dh/dx	=	0.01 (gradient)

$$Q = (400)(36{,}000)(0.1)$$
$$= 144{,}000\ ft^3/day$$
$$= 1.7\ cfs\ \text{(capacity for ground water discharge)}$$

This calculation indicates that the Tiger Mountain Gap's ground water discharge capacity is about 1.7 cfs of the 14 cfs of available discharge from the upper basin. These results indicate an order of magnitude difference between the available ground water and the amount that could move through the Tiger Mountain Gap. Three possible explanations for these differences are evaluated below:

Data used to calculate the water balance and hydraulic capacity were inaccurate. The water balance calculation is as reliable as that done for the entire basin. The values used in Darcy's equation are conservative and probably overestimate underflow through the Tiger Mountain Gap. The extent of the aquifer in the Tiger Mountain Gap may be underestimated. Additional monitoring wells are needed to provide better data on actual ground water flow through the Tiger Mountain Gap.

Ground water exits via paths other than the Tiger Mountain Gap. Ground water may also exit the Issaquah Creek basin via shallow valleys south of Squak Mountain. South of Cedar Hills Landfill, the ground water gradient is very flat and the flow intermittent. Here, ground water may recharge deeper sediments and flow southwest toward the Cedar River. Further investigation of the valleys north and south of the Cedar Hills landfill is needed to determine the amount of ground water leaving the Issaquah Creek Valley Ground Water Management Area. If upper basin ground water actually flows toward the Cedar River basin, then estimates of the ground water discharge to Lake Sammamish could be reduced by 50 percent.

Ground water emerges as surface water. Ground water could be forced to the surface at the Tiger Mountain Gap, flow through the Tiger Mountain Gap in Issaquah Creek, and reenter the lower valley aquifer downstream. This potential exfiltration and reinfiltration could be evaluated by additional stream monitoring stations, above, in, and below the Tiger Mountain Gap.

Ground Water Elevations. Ground water elevations (or water-table elevations) determine, in part, the rate and direction of ground water flow. Elevations are referenced to mean sea level. Ground water flows from high to lower elevations at a rate proportional to the slope of the water-table and the hydraulic characteristics of the aquifer. Ground water elevations fluctuate in a somewhat predictable fashion because of annual fluctuations in precipitation and ground water recharge. The annual high and low ground water elevations are typically used to evaluate general aquifer behavior. The high and low water-table configuration, based on observed water levels, is shown on Figure 7.4. Water level contours for both the Upper and Lower Valley are shown in Figure 7.3. Water-level elevations are extrapolated to the western portion of the valley based on assumed conditions. There are very little data on ground water conditions in the western lower Issaquah valley.

Seasonal high ground water elevations in the lower Issaquah valley occur in February, based on 1992 data, and range from 150 to 200 feet in the South Issaquah/Hobart area to approximately 50 feet about two miles south of Lake Sammamish. Ground water elevations in the immediate vicinity of Lake Sammamish are uncertain, because no wells exist in this area. However, ground water elevations are expected to approach 25 feet near the lake, which is the average elevation of Lake Sammamish. Seasonal high ground water elevations in the central valley area, where most of the wells are located, vary from approximately 60 to 70 feet. Ground water elevations increase to the east to as much as 80 feet or higher.

Seasonal low ground water elevations occur in August and September (based on the 1992 data) and range from 150 to 160 feet in the South Issaquah/Hobart area to approximately 47 feet approximately two miles south of Lake Sammamish. Seasonal low ground water elevations in the central valley area, where most of the wells are located, vary from approximately 55 to 60 feet.

Little data are available on Grand Ridge and the Tradition Lake Plateau. Recently installed shallow wells at the proposed Grand Ridge development indicate that ground water elevations vary from about 400 feet to over 800 feet, and are likely representative of shallow perched aquifers over low-permeability bedrock or till. Ground water levels in a private well (Dean Well) located west of the proposed development are relatively constant at approximately 338 feet. This well is completed below till (*Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates, 1993).

Ground Water Level Fluctuations. Fluctuations in ground water levels are often indicative of the overall behavior of the aquifer, the location of recharge/discharge areas, and the response to recharge/infiltration. In general, the lower Issaquah valley aquifer responds very quickly to precipitation events. These water-level responses are seen in both shallow and deep wells. This response suggests continuity with the ground surface and/or stream network. Additionally, the wells in the lower Issaquah valley respond to pumping of the various production wells in the area. Short-term fluctuations are clearly observed in response to the Lakeside Gravel Pit, which operates wells on an eight-hour work-day schedule. Figure 7.5 shows a hydrograph of one shallow monitoring well at the ARCO site. The hydrograph shows the short-term fluctuations in water levels caused by pumping at Lakeside, short-term and longer term declining and rising water level trends due to climate, and the effect of pumping at Sammamish Plateau Water and Sewer District's well 9. The various responses result in "noise" in long-term water-level observations caused by these short-term effects.

Within the valley area, the annual change in ground water elevations was between 7 and 10 feet in 1992. Greater annual fluctuations of up to 15 feet occurred in the vicinity of Sammamish Plateau Water and Sewer District's wells 7 and 8. The annual change in water elevations appears to decrease to 7 feet or less north towards Lake Sammamish, while higher annual water-level fluctuations of 10 feet or more occur south and east of the central valley area (*Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates 1993).

Water levels in wells are related to rainfall, however, the relationship has been modified by significant ground water withdrawals in some areas. Long term rainfall trends should be assessed with long term well water level data. Then pumping effects could be compared to water level data. Pavement as a result of urbanization has also affected this relationship due to a higher volume of rainfall lost to storm flows which have decreased ground water recharge (Liszak, 1995).

Hydraulic Gradients. Hydraulic gradients indicate the rate of ground water movement. Gradients are unitless parameters, equivalent to a slope. The average horizontal hydraulic gradient within the central valley area, based on data from 14 wells, is relatively flat at between 0.001 and 0.002. Hydraulic gradients are less well known on Grand Ridge and in the Tradition Lake area. Within the proposed Grand Ridge development, the horizontal gradient is about 0.067, 10 times higher than in the lower valley.

Vertical gradients are also important, because they indicate the upward or downward component of ground water flow. In general, downward gradients are expected in recharge areas and upward gradients are expected in discharge areas.

The vertical hydraulic gradients vary considerably throughout the lower Issaquah valley area. In general, the vertical gradient is, as expected, directed upward in the northern area near Lake Sammamish. Primarily downward vertical gradients occur in the central valley area, probably as a result of the high-volume pumping within this area. Locally, both upward and downward gradients may be created because of the completion interval of the production wells, which may induce downward leakage from above and upward leakage from below. At Sammamish Plateau Water and Sewer District's wells 7 and 8 the vertical hydraulic gradient appears to be downward from the surface to the 117-foot completion interval and upward from the deeper 177-foot completion to the 117-foot completion interval.

Vertical gradients on Grand Ridge and Tradition Plateau are unknown. However, the vertical gradient is directed upward along the flanks of the Tradition Lake area (near well WH-1, and wells COI 1 and 2). The upward gradients in this area may be the result of infiltration originating from higher elevations at a high head and discharging to the lower valley area.

In general, the vertical hydraulic gradients observed within the lower Issaquah valley in 1992 appeared to remain relatively constant throughout the year, with the exception of wells COI 1 and 2 and SPVT6. At these sites, the vertical gradient decreased between the winter/spring recharge period and summer/fall period, when the vertical gradients are at a minimum. This trend suggests that recharge to the deeper sediments during the winter/spring may increase the upward vertical gradient in places and then decay during the ensuing dry period (*Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates, 1993).

Aquifer System Characteristics. The present understanding of the aquifer system indicates the total sediment thickness ranges from over 600 feet in the central lower Issaquah valley near wells COI 4 and 5, to 300 feet at the Grand Ridge margin of the Lower Issaquah Valley (Sammamish Plateau Water and Sewer District's well 9), to 150 feet at the Lake Tradition margin of the lower Issaquah valley (well WH-1), to 63 feet at the Hobart Gap (well RP-1). Actual aquifer thicknesses are assumed to be similar to sediment thicknesses, since there is little regional geologic continuity between strata.

Production wells within the lower Issaquah valley tap highly permeable aquifers. Testing of these wells has provided data on the hydraulic characteristics of the aquifer. Carr/Associates conducted a 3-day pumping test of Sammamish Plateau Water and Sewer District's wells 7 and 8 between September 12 and 15, 1990. The wells were pumped at a combined rate of 5,600 gpm. During the test, water-levels were monitored in 17 wells and at 6 surface water stations. The 17 monitoring wells included 11 piezometers and 6 production wells. During the test, water-levels in the observation wells were drawn down between 1 and 3 feet, and the cone of depression extended a distance of approximately 7,000 feet from the pumping wells. Analysis of the pumping test was complicated to some degree by interference resulting from the pumping of other production wells, and by the complex hydrogeology of the valley. Based on the test, a transmissivity of approximately 67,000 ft^2/d was calculated (Carr/Associates 1990). Assuming an aquifer thickness of between 200 and 300 feet, a bulk hydraulic conductivity of between 220 and 330 ft/day for the aquifer is estimated. The calculated storativity varied from 0.2 to 1×10^{-4}. During the test, the Reid Pond, located over 1,300 feet to the northwest of the pumping wells, demonstrated over 1½ feet of drawdown interference due to pumping (Liszak, 1995).

A long-term pumping test of Sammamish Plateau Water and Sewer District's well 9 was conducted at a rate of 2,340 gpm for about 9.5 days by Carr/Associates in July 1992. During the test, water-levels were monitored in 55 observation wells. In addition, 15 surface water monitoring stations were established and monitored. The test was designed to minimize interference from surrounding, pumping wells and attempt to achieve steady-state conditions in the aquifer through an extended test length. Analysis of the well 9 test (Carr Associates 1993) suggests the following:

- Well 9 is completed in a thin (50-foot) isolated aquifer zone (termed Zone C), with a high transmissivity, separated from the overlying sediments by a leaky aquitard;
- Pumping of Well 9 caused drawdowns of between 1.4 and 0.2 feet in shallower zones of the aquifer;
- Flow paths towards Well 9 do not intersect the known contamination at the ARCO site;

- Steady-state conditions were not achieved;
- Transmissivity of the aquifer as a whole is similar to that observed at Sammamish Plateau Water and Sewer District's wells 7 and 8 at 70,000 ft^2/day based on a late-time drawdown analysis of all wells monitored; and
- Strong, downward vertical gradients are established from the water table towards the deeper portions of the aquifer.

In July 1992, Golder Associates conducted a series of slug tests in the monitoring wells. The tests were analyzed using the Bouwer/Rice (1967) method and the method of Van der Kamp (1976). The hydraulic conductivity calculated from the tests ranged from 100 to 470 ft/day, which is consistent with the pumping test results (*Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates 1993).

Stream/Aquifer Interaction. Stream-aquifer interaction is important in an aquifer system and can be a source of recharge to the ground water. It is often difficult to measure the "hydraulic continuity" between a stream and aquifer and, in most cases, indirect assessments of stream-aquifer interaction are necessary. The parameters controlling stream-aquifer interaction are:

- The elevation difference between the stream and the ground water; and
- The hydraulic characteristics of the streambed.

Three major streams traverse the lower Issaquah valley (Figure 4.1). The North Fork and East Fork Issaquah Creek descend from elevated upland areas into the lower Issaquah valley, losing more than 200 feet of elevation over a relatively short distance. The Lower Fork of Issaquah Creek gradually descends through the lower Issaquah valley from the Hobart Gap to Lake Sammamish, losing about 100 feet of elevation. From a hydraulics standpoint, it is expected that the steep sections of the North and East Forks of Issaquah Creek would provide coarser bedload (sands and gravels), and have a higher hydraulic conductance. When the stream enters the lower Issaquah valley, its gradient decreases and finer sediments (sands and silts) are deposited, potentially reducing the hydraulic connection between the streambed and the underlying aquifer.

Stream gauging was performed in March 1992 on the North Fork and East Fork of Issaquah Creek. On the North Fork, three stations were gauged between the McDonald Well and 60th Street (approximately 1,000 feet apart). On the East Fork, two stations were gauged (approximately 1,000 feet apart) near the Sunset Overpass of I-90. The objective of the stream gauging was to determine whether significant stream/aquifer interaction was occurring at the edge of the upland areas surrounding the lower Issaquah valley. The accuracy of the survey is estimated at +/- 1 cfs, due to the shallow stream depth and low velocity of water flowing through the stream. On the North Fork, measured streamflow decreased from 3.3 cfs upstream of the McDonald well to 2.8 cfs downstream of the McDonald well, and then increased to 4.1 cfs below the 60th Street bridge farther downstream. These results do not indicate large streamflow losses or gains and are within the accuracy of the survey.

At that streamflow, stream/aquifer interaction of less than 1 cfs per 1,000 feet of streambed was estimated along the North Fork at its confluence with the valley floor. Along the East Fork, a similar conclusion was reached. Streamflows measured upstream and downstream of the Sunset overpass were 9.8 and 9.3 cfs, respectively. These values are within the accuracy of the survey and are consistent with streamflows used by King County Surface Water Management. Thus, stream/aquifer interaction along the East Fork between the Sunset overpass and confluence with the Lower Fork Issaquah Creek is estimated at less than 1 cfs per 1,000 feet of streambed. Because of the limited extent of stream gauging, these streamflow relationships may not be representative for all seasons or flow regimes. Additional stream gauging data are needed to fully characterize stream/aquifer interaction along the edge of the lower Issaquah valley.

Mini-piezometers were installed at six locations in the lower Issaquah valley (four on the Lower Fork and two on the North Fork) in June 1991. These piezometers were placed in or directly adjacent to the streambed to a depth of 5 to 8 feet. They measure the relative water levels in the stream and underlying shallow ground water. The results at four of the six locations indicated that stream water levels were "perched" 1 to 3 feet above the ground water level, indicating little interaction between the stream and aquifer. At two of the stations, ground water levels were equal to or higher than the stream water level, suggesting continuity between the systems.

Monitoring of streamflow and shallow ground water levels during the pumping test at Sammamish Plateau Water and Sewer District's Well 9 also indicated limited hydraulic continuity with the streams. The cone of depression created by the 9-day pumping test extended over nearly two square miles, and the drawdowns observed at the water-table (based on a hand-contoured drawdown map) can account for over 80 percent of the water pumped from the aquifer during the test assuming a bulk porosity of 20 percent. If stream infiltration provided a significant contribution to the water pumped from the well, drawdowns in distant observation wells would be much less. Thus, infiltration from the stream to the aquifer is interpreted to be a minor component of the water drawn to the well when it is pumped. There is still a long-term impact to surface waters during pumping, but this impact occurs at the discharge areas (i.e. the wetlands directly adjacent to Lake Sammamish) of the ground water system because there is less ground water moving through the aquifer as a result of pumping *(Lower Issaquah Valley Wellhead Protection Plan*, Golder Associates, 1993).

Data Sources. Data for generating hydrostratigraphic cross sections were obtained from copies of Ecology's well logs supplied by King County, well logs from Carr/Associates and other consultants' project files, and the Issaquah Creek Valley Ground Water Management Area well log database file. Issaquah Creek Valley Ground Water Management Area database incorporates data from all these sources and includes files for water levels, well construction data, and lithologic logs. Most of the well logs were originally recorded by the well drillers. This information was entered into the database by Seattle-King County Health Department personnel as part of this project. Selected well logs are included in Appendix E (available upon request). The locations of wells included in the database are shown in Figure 7.2.

Hydrostratigraphic Units. The lithologies described in the well logs were categorized into three hydrostratigraphic units. These units are described in Table 7.5 and illustrated in cross sections as Figures 7.6 through 7.9. The location of each cross section is shown in Figure 7.10.

Extent and Significance of Hydrostratigraphic Units. To illustrate the extent and significance of these hydrostratigraphic units, four hydrogeologic cross sections were generated from the well logs. The locations of the four cross sections are shown on Figure 7.10. Cross sections A-A' and A'-A" (see Figures 7.6 and 7.7) parallel the main stem of Issaquah Creek from Lake Sammamish south to Hobart. Cross section B-B' (see Figure 7.8) begins in the Tibbetts Creek Valley, crosses Lower Issaquah Valley, extends up the North Fork of Issaquah Creek, and ends on the south flank of the Sammamish Plateau. Cross section C-C' (see Figure 7.9) begins at the City of Issaquah's Gun Club Well (34F03), bisects the Lake Tradition Plateau, and follows the East Fork of Issaquah Creek toward the town of Preston.

The well numbers (i.e., 34F03) for each well used in the sections are shown on the map (Figure 7.10) and the cross sections (see Figures 7.6 through 7.9). Logs for all wells used in the cross sections are included in Appendix E (available upon request). Some wells near the cross sections with duplicative, incomplete, or inadequate logs were not included in the figures.

The extensive topographic relief in the study required use of relatively high vertical exaggeration (28x) on the cross sections. This exaggeration makes some bedrock and sedimentary shapes appear very steep and unnatural. For example, the steep chevron-shaped aquifer in cross section A-A' (see Figure 7.6) looks unlikely. However, this correlation accurately depicts coarse-grained aquitard sediments, deposited at about 10 degrees, opposite flanks of the ancestral North Fork delta. Hydrostratigraphic relationships in the Lower Issaquah Valley were confirmed by water levels and drawdown interference measured during recent extensive aquifer tests (Carr/Associates, Inc. 1990 and 1993).

Cross Section A-A'-A." Cross section A-A'-A" is segmented into north (A-A') and south (A'-A") illustrations (see Figures 7.6 and 7.7). The section shows significant changes in depth to bedrock along the main valley of Issaquah Creek. Wells located near the southern end of Lake Sammamish, where the modern delta of Issaquah Creek is forming, have the lowest ground surface elevations and exhibit flowing artesian conditions (i.e., water levels above ground surface).

Multiple aquifer zones of high permeability sand and gravel were encountered by numerous Lower Issaquah wells, such as 28A06, 27E03, and 27E04. These include a shallow aquifer zone (depth less than 60 feet below ground surface), a middle aquifer zone (depth 80 to 170 feet), and a deep aquifer zone (depth 195 to 220 feet). These major aquifer zones are used by production wells of the Sammamish Plateau Water and Sewer District and the City of Issaquah. At Sammamish Plateau Water and Sewer District's Well 9 (27E03) a substantial layer of silt separates the middle and deep aquifer zones. The deeper sediments logged at well 34F03, east of Issaquah High School, may be related to these sediments of the lower Issaquah valley.

At well 27E03, bedrock was encountered at a depth of 301 feet. Most other lower valley wells were not drilled deep enough to encounter bedrock. Bedrock was found at a depth of 18 feet below ground surface at well 15P02. The ground surface elevation at this well is 330 feet above sea level. Within the Section 15 area, the depth to bedrock is highly variable ranging from 18 feet to 194 (Well 15A02) feet below ground surface. At monitoring Well 15E08, bedrock is encountered at 65 feet below ground surface.

South of the Tiger Mountain Gap (see Figure 7.10), the bedrock basement deepens at well 26B02 and then rises sharply at well 05N03 near Hobart. Limited available data indicated that aquifers south of the Gap are less productive than the permeable deltaic sands and gravels in the lower Issaquah valley. Lacustrine silt and clay aquitards occur both north and south of the Tiger Mountain Gap and, where present, impede the vertical migration of ground water.

Cross Section B-B'. Cross section B-B' illustrates the sediments southwest to northeast from Tibbetts Creek up the North Fork of Issaquah Creek. As shown in Figure 7.8, a series of deltaic sands and gravel was deposited from the North Fork of Issaquah Creek into ancestral Lake Sammamish. Test drilling at City of Issaquah well 5 (28B04) showed the presence of shallow aquifer zones and a deep silty-sand aquifer.

The upland east of the lower Issaquah valley consists of bedrock mantled by glacial deposits. Although numerous wells are shown along the North Fork Valley (see Figure 7.10), few of them encounter extensive aquifers.

Cross sections through the deltaic deposits south of the North Fork appear in reports by Carr/Associates 1993 and Golder Associates 1993.

Cross Section C-C'. Cross section C-C' (see Figure 7.9) shows the bedrock that is beneath Lake Tradition Plateau and that is overlain by about 100 feet of sediments in the upper East Fork Valley. Relatively permeable aquifers separated by silty aquitards are present in the upper East Fork Valley and in Issaquah Valley at wells 27P02 and 34A01. In the eastern part of the East Fork Valley, the more productive wells are completed in these aquifers. Shallow bedrock penetrated by wells 25P01, 25J01, and 30L01 contains shale with some coal seams. This bedrock provides limited water to a few domestic wells.

Data Limitations. In the Issaquah Creek Valley Ground Water Management Area, the quality and quantity of reliable data are extremely varied. Ground water resources of the lower Issaquah valley have been explored extensively and evaluated professionally on several projects, including the Lower Issaquah Valley Wellhead Protection Plan (November 1993). By contrast, very little ground water exploration or professional evaluation has occurred in upstream parts of the Issaquah Creek Valley Ground Water Management Area (the Upper Valley) other than at the Cedar Hills Landfill. In the remaining parts of the Issaquah Creek Valley Ground Water Management Area where development can occur, domestic wells drilled only as deep as necessary have been installed. As a result, limited geologic data are available in areas where shallow aquifers are adequate (typically in the valleys), and geologic data are abundant where shallow aquifers are inadequate (typically in the foothills).

Drillers' and geologists' descriptions of sedimentary units are subjective and can produce inconsistencies in descriptions of similar units. For example, soft shale bedrock has been mistakenly identified as "silt" or "clay." The three hydrostratigraphic units used in this report accommodate some of these potential problems. However, future, more detailed analysis should recognize the potential differences in nomenclature.

The locations of some of the wells shown in the cross sections have been verified. However, other wells may be mislocated by the incorrect entry of a quarter-quarter section. More than one-third of the wells used in the cross sections have been accurately surveyed to provide locations and elevations. For other wells, Seattle-King County Health Department personnel entered the estimated elevations and locations with the designated 40-acre quarter-quarter section. Consequently, some locations may not be accurate, and well elevations for non-surveyed wells may be inaccurate.

Cross sections illustrating hydrostratigraphy generally are not impaired by imprecise elevations as long as reasonable values are used. However, evaluation of ground water gradients based on inaccurate elevations is not appropriate. In addition, many of the test wells have different water levels for each zone of completion, and seasonal changes of more than 10 feet are not reflected by water levels measured only once when the well was completed.

Future analysis could benefit from greater detail on wellhead and surface water elevations. These data would help refine the surface/ground water relationships in various parts of the study area. Moreover, the location of wells should be verified and noted in latitude and longitude coordinates to facilitate entry into computerized data banks.

7.3.4 Sammamish Plateau Aquifer System

The USGS reported on the Sammamish Plateau aquifer system in the *Geohydrology and Ground Water Quality of East King County, Washington* (USGS 1995) and in the 1995 draft of the *East King County Ground Water Management Plan.* The following discussion is from those reports.

Ground water in the upland area of the Sammamish Plateau moves vertically downward and laterally to discharge points (such as Lake Sammamish). The amount of time required for an individual molecule of water to travel through the system is roughly proportional to the permeability of the unit and amount of precipitation that reaches the unit. Flow into and out of the study area can be qualitatively assessed by evaluating the ground water conditions along the study boundaries. Along the Lake Sammamish boundary, ground water flows out of the study area to the west and in some areas deeper ground water flow may be to the west also. Confirmation of these hypotheses require additional investigation and a phased approach to additional investigation is recommended.

The USGS identified individual aquifers in the Sammamish Plateau: Vashon advance outwash (Qva); upper coarse grained unit (Q(A)c); bog and alluvium (Qal-Qvr); lower coarse grained unit (Q(B)c); oldest unconsolidated unit (Qc); and bedrock (Br). These are described below.

Vashon advance outwash (Qva): These deposits are labeled on geologic maps as Vashon advance (Qva) and typically consist of well-graded gravelly sand to fine-grained sand. The Vashon advance coarsens upward through the sequence; in other words, the particle grain size is larger in the upper-part of the formation than in the bottom. The meltwater from the encroaching ice mass increased in velocity in the study area during the deposition of the Vashon advance. As a result, the formation is configured by a basal unit (lacustrine silt, clay, and very fine sand), a medium sand and sandy, cobbly gravel (characteristic of a high energy environment), and an ice marginal deposit (interbedded sands, silt, and gravels) (Snoqualmie Ridge Project, February 1995).

Ground water flow in Qva is toward Patterson Creek from the eastern Sammamish Plateau and Ames Lake areas. Flow from the western Sammamish Plateau is toward Lake Sammamish. The flatter gradients are less than 100 feet/mile in areas such as the Sammamish. Steeper gradients in excess of 500 feet/mile are present near Patterson Creek (USGS, 1995).

Upper coarse-grained unit (Q(A)c): Underlying the upper-fine grained unit, but discontinuous in the study area, is the upper-coarse grained unit (Q(A)c). This unit consists of interglacial sand and gravel from the pre-Fraser (Qpf) unit, including strongly oxidized sand and gravel. The average thickness of the unit is approximately 140 feet (Plate 1, U.S. Geological Survey, 1995). The top of the unit varies from 300 feet below to 700 feet above sea level (Plate 2, U.S. Geological Survey, 1995).

In Q(A)c, ground water flow is is determined by a ground water divide in the Sammamish Plateau, with ground water in the western part flowing to Lake Sammamish and ground water in the eastern part flowing toward the Snoqualmie River. Gradients in the river valley and east of the Sammamish Plateau are less than 50 feet/mile in some places (USGS, 1995).

Bog and alluvium (Qal-Qvr): The youngest geologic units in the study area are bog deposits (Qb), and alluvium (Qal). Flow within this unit on the Sammamish Plateau is not well defined because of a lack of data points and because much of the unit is completely unsaturated there. Vertical flow directions are difficult to ascertain because the Qal-Qvr and Qva are discontinuous, and in some areas the heads are similar from one unit to the next. In general, vertical flow is downward in upland areas. This is apparently the case in the Sammamish Plateau, where heads in Qva are generally larger than those in the underlying Q(A)c. Water level elevations in a set of five piezometers on the Plateau decreased with piezometer depth, also indicating downward flow. The data are from wells 24N/06E-09A11 through 09A15, and are listed in Table 7.6 B.

Lower coarse-grained and oldest unconsolidated units (Q(B)c, Q(C)): Little information exists about the productivity and extent of the lower coarse-grained unit (Q(B)c) and the oldest unconsolidated units (Q(C)). The lower coarse-grained unit consists of sand and gravel with minor percentages of clay and silt. The unit, though saturated, is rarely used as a ground water source. The ground water in this unit is probably confined.

Bedrock (Br): Most of the consolidated rocks that make up the bedrock (Br) consist of andesite with minor amounts of basalt and diorite. The consolidated Tertiary and pre-Tertiary rocks that constitute the bedrock contain small quantities of water in fractures and joints that are probably more numerous near the top of the unit. In general, however, the bedrock is an unreliable source of ground water, and many wells drilled into that unit yield insufficient or poor-quality water. In areas where the aquifer used is bedrock, bedrock is either exposed at land surface or is covered by a thin, low water bearing layer of unconsolidated deposits. Where the bedrock is exposed at land surface, the ground water is likely to be under water-table conditions; where the bedrock is covered by a significant thickness of unconsolidated deposits, especially clays and silts, the ground water is likely to be confined.

The lowest median hydraulic conductivity (0.88 ft/day) was for the Br unit. Because ground water in bedrock is present primarily in the fractures, a low median hydraulic conductivity suggests that the Br unit generally is not fractured enough to produce large quantities of water. This low hydraulic conductivity is the primary reason the bedrock is generally a poor source of water.

For all of the upland aquifers, the presence of downward vertical flows indicates that some water may be moving into the deeper regional geohydrologic system, possibly even the bedrock (USGS, 1995). Although this water would probably tend to flow north and west, it would also flow within the deeper geohydrologic units not mapped, such as Q(B)c, Qc, and possibly Br. The ground water in these units could easily flow beneath surface waters such as Lake Sammamish, and ultimately flow to surface water bodies (such as Puget Sound) outside the study area. The results of a seepage study conducted in September 1991 showed that an estimated 3.3 $feet^3$/second discharges from the Sammamish Plateau to Lake Sammamish. (USGS, 1995).

Ground Water Withdrawals

More than 98 percent, or 1,110 acre-ft, of the total ground water withdrawals in the Sammamish Plateau went to public supply systems, reflecting the area's suburban nature. Although most of the water withdrawn for public supply is used for individual households, undetermined quantities are used for commercial, institutional, industrial, or municipal uses. Also, a significant quantity of water can be lost through leakage from distribution systems. There is a marked seasonal variation in the demand for, and therefore withdrawal of, water for public supply purposes. The greatest demand is in late summer and early fall, when temperatures are high, precipitation is at a minimum, and ground water levels are relatively low (USGS, 1995).

7.3.5 Data Collection Activities for Hydrogeologic Characterization

Water Level Measuring. Water level measurement data are critical to both ground water flow patterns and to trend analysis of impacts of climate, water use, and regional growth on the aquifer system.

Water levels in wells were monitored on a monthly basis between 1989 and 1992 at 48 well sites. The data were collected by personnel from the City of Issaquah, Sammamish Plateau Water and Sewer District, the Seattle-King County Health Department and Carr and Associates. Water level data collected between 1989 and 1992 are listed in Appendix F (available upon request).

On the Sammamish Plateau, water level information was collected by the USGS and the Seattle-King County Health Department. The USGS interpreted water quantity information from a collection of well logs and springs on the Sammamish Plateau, as part of the data collection for the East King County Ground Water Management Program. (See Table 7.6 B) The data collection effort of USGS was based on field data collection activities described in the *Data Collection and Analysis Plan for East King County, Washington, Ground Water Management Area Study*, July 1, 1991. The USGS Technical Report (1995) identified the Sammamish Plateau as one of three areas with data gaps in the East King County Ground Water Management Area. Subsequently, ground water levels were measured monthly at 10 well sites by Seattle-King County Health Department personnel (Figure 7.3). The Seattle-King County Health Department continued the data collection the USGS began, and used equivalent methodology as the US Geological Survey.

The well sites were selected based on the following criteria:

- Hydrogeologic Significance - Appropriate location for defining ground water flow directions, gradient, divides, as well as water level trends.
- Representative - The water level measurements are representative of a single aquifer (i.e., well is not completed over several aquifer zones).
- Well Log - The well has a complete and reliable well log.
- Locatable - The well can be located in the field and verified with the well log.
- Easily Measurable - the well is accessible with a sounder.
- Non-Pumping Water Levels - The well should have limited use to facilitate obtaining static water level measurements.

Selection of monitoring wells was restricted to wells having geologic logs and well completion information. The process for site selection included the following:

- The project database was queried for all wells having geologic logs, and a well summary table and well location map were prepared.
- General areas where additional hydrogeologic data were needed were identified on the well location map.
- Field surveys and interviews were conducted by the project consultants to locate wells that satisfy the above criteria and whose owner agreed to allow access for periodic measurements.
- The selected sites were reviewed by the Issaquah Creek Valley Ground Water Advisory Committee.

Well construction and hydrogeologic information has been entered into the database for all monitoring wells. All monitoring wells were surveyed in 1991. Water levels from wells included in the Issaquah Creek Valley Ground Water Management Area monthly monitoring program were plotted to view seasonal water level trends. Figure 7.11 shows the monitoring wells included in the monitoring program, and Figures 7.12A through 7.12H show the water level changes in these wells. The apparent variations in water level may arise from seasonality in precipitation and the effects of prior pumping. Thus, general trends should be sought without undue emphasis on small variations.

As indicated in Figures 7.12A through 7.12H, high water levels occur during the months of February through May, while low water levels occur from September through December. Water levels can fluctuate seasonally as much as 15 feet. Because high precipitation periods generally occur during the months of November through February, a time lag of two to four months is presumed to occur for ground water recharge. The length of this lag period depends on the depth to ground water and the type of overlying sedimentary material.

Long term data collection from these 48 wells is needed to determine ground water level trends. The City of Issaquah Wells #1 and #2 monitored as part of the well network have data available from 1981 to 1994 (Appendix F, available upon request). The water level in Well #2 has declined 3 feet between 1981 and 1994 (Liszak, J. 1995).

The water level in one of the deep wells, 24N/06E - 09A15, declined from 1982 to 1986. The National Oceanic Atmospheric Administration has historic records for rainfall in the Puget Sound region. Although there is no site specific information, the available historic information indicates for years 1982 - 84, 1986, 1988, and 1990 rainfall was above the average, so the decline was not likely related to precipitation. Pumping may be a factor, as this well is located on the Sammamish Plateau where the population is rapidly increasing. In contrast, the shallow ground water in another well on the Sammamish Plateau, showed little year-to-year variation (USGS, 1995).

Exploratory/Test Wells. An electrical resistivity survey was conducted in the lower Issaquah valley (Carr/Associates November 1989) to make a preliminary evaluation of the ground water potential of the area, and to help select sites where test drilling would have the greatest opportunity for success. Electrical resistivity surveying is a geophysical technique for measuring electrical properties of subsurface geologic materials. By measuring these electrical properties, subsurface hydrogeologic features can be identified. The Wenner Array resistivity method was used.

Results of resistivity surveying in the lower Issaquah valley showed permeable sediments present as isolated lenses and short channel segments. Less permeable, fine sediments are widely distributed and increase in dominance to the west and north.

The recommendations from the survey were for the Sammamish Plateau Water and Sewer District to drill five 8-inch-diameter test wells of approximately 200 feet deep. The five test sites recommended were:

- One well site in the vacant lot immediately north of the Meadow Creek Office Park.
- Two wells in the I-90 Corporate Park greenbelt.
- One well in the I-90 Corporate Park "tailpiece property."
- One well in the pastures east of 230th Avenue South East.

The three new exploratory/test wells were installed in 1990 and one in 1992 to provide additional information with which to evaluate hydrostratigraphy, ground water flow, and water quality. The three wells VT-1, VT-2 and VT-3 drilled in 1990 were based on the 1989 Carr/Associates resistivity recommendations and the criteria below.

The criteria used to select the test well sites include the following:

- Hydrogeologic Significance - Aquifers, ground water flow directions and water quality are of interest and satisfy the program objectives.
- Property Accessibility - The property is accessible to heavy drilling equipment and access for long-term monitoring is available.
- Property Availability - The property is publicly owned or the owner is agreeable to terms of drilling and long-term monitoring at no cost.

- Site integrity - The site is secure from vandalism and free from contamination or any disturbance from future land use activities (e.g., road construction, gravel pit expansion, etc.).

Three of the new wells (VT-1, 2, 3) were drilled, using the cable tool method for the City of Issaquah and Sammamish Plateau Water and Sewer District as part of their ongoing efforts to characterize and manage the ground water resources within their local service areas (Sections 21 and 27, Township 24 North, Range 6 East). These sites lie in the lower Issaquah valley. The wells have a casing depth of 160 feet (well VT-1), 79 feet (well VT-2) and 158 feet (well VT-3), respectively.

These three wells were drilled to:

- Determine the potential of the alluvium for 1,000 to 3000 gallons per minute production well (VT-1).
- Determine aquifer characteristics and install piezometers for future water level monitoring. The results of the drilling and testing were used to evaluate the suitability of the site for a future production well. The exploration also provided additional information on the relationship between the shallow aquifer system and the aquifer penetrated by the City of Issaquah's deep well 5 (VT-2).
- Determine the suitability of well VT-3 site for construction of one or more high-yield production wells.

The fourth site (RP-1) lies in the Squak/Tiger Mountain Gap area and within Section 10 of Township 23 North, Range 6 East. The new well was drilled using the air rotary method to a depth of 80 feet. Bedrock was encountered at 63 feet below ground surface. Two piezometers of 2-inch and 4-inch diameter were installed to 59 feet (2 inches) and 39 feet (4 inches), respectively. The gap area represents a narrow constriction between the upper Issaquah Creek Valley and the lower Issaquah Creek Valley. Data collected from this well will help evaluate horizontal and vertical ground water gradients, seasonal and long-term ground water trends, and ground water quality relationships in the valley. An access agreement for long-term water level and water quality monitoring was established for a period of 10 years by Seattle-King County Health Department.

The wells were installed in accordance with Ecology's guidelines for "Data Collection from Wells used in the Ground Water Management Area Program, May 1989" as well as according to "Standards for the Construction and Maintenance of Wells, Chapter 173-160 WAC."

The results of the drilling of these four wells were:

- Drilling at the VT-1 site revealed a permeable aquifer which is used by the Sammamish Plateau Water and Sewer District wells 7 and 8. This production well is capable of producing 2,000 to 3,000 gallons of potable water per minute.

- At the VT-2 site, the low permeability of the aquifer zones limits the productivity of any future productions wells. The maximum yield of such wells probably would not exceed 200 gallons per minute.

The high iron and manganese content of the water from the shallow aquifer zone has been observed in other shallow aquifer zones in the valley. Most of these occurrences are associated with wetlands.

These water level and water quality relationships suggest a lack of continuity between the shallow and deep ground water. The VT-2 site will be useful for water level and water quality monitoring.

The RP-1 well is screened in a thin, water-bearing zone consisting of gravel and sand. This zone is not considered a major water-bearing zone, with production limited to about 25 gallons per minute. The upper 4-inch piezometer installed to a depth of 39 feet is hydraulically connected to the 2-inch deeper piezometer, installed to a depth of 59 feet. The hydraulic relationship between this well and the nearby Hayes Nursery well cannot be determined because the Hayes well was pumping during the testing of this well. Available data suggest complex hydrogeologic relationships between existing wells and surface water features in the vicinity of the RP-1 well.

Water chemistry results indicate that the water samples for this well meet the state drinking water standards, with the exception of manganese. Manganese is a secondary health constituent which has an undesirable taste and discolors water. Manganese occurs naturally in the ground. It is an essential trace element for humans. Manganese toxicity from drinking water has not been reported. (Drinking Water and Health National Academy of Sciences, Washington D. C. 1977).

Wells VT-1 and VT-2 are being monitored for water levels by the Sammamish Plateau Water and Sewer District, and data are forwarded to Seattle-King County Health Department for inclusion in the Issaquah Creek Valley Ground Water Management Area database (Table 7.6).

7.4 <u>Aquifer Recharge and Protection</u>

This section summarizes ground water recharge in the Issaquah Creek Valley Ground Water Management Area. It describes the source of ground water and how it enters the system, compares the relative physical susceptibility of ground water to contamination in various parts of the basin, provides an estimate of the amount of recharge, and evaluates the vulnerability of the ground water resource to various potential sources of contamination.

This information is important for developing an effective program of ground water management in the basin. The ground water recharge described here considers the water which reaches the water table. The deeper aquifers generally are recharged from shallow aquifers. However, deep aquifer recharge is more complex and merits further investigation.

7.4.1 Sources of Ground Water

The available information indicates that all ground water in the Issaquah Creek basin originates as precipitation on the basin. In perimeter areas where data are sparse, some contribution may occur from outside the topographic basin which forms the boundary of the study area. Precipitation falling on the basin's land surfaces above the water table infiltrates the unsaturated zone to the saturated zone and then moves downgradient. Once infiltrated, ground water may re-emerge to form springs and streams or enter other surface water bodies. Part of the infiltrated water also may migrate through deeper sediments to underlying aquifers. The ground water in the lower basin discharges to Issaquah Creek, Tibbetts Creek, and finally to Lake Sammamish. Ground water in the upper basin may discharge to the lower basin through the Tiger Mountain Gap or to the Cedar River.

7.4.2 Recharge and Aquifer Susceptibility

The potential for ground water recharge varies from one part of the Issaquah Creek basin to another. Ground water recharge occurs when precipitation infiltrates and reaches the water table of the uppermost aquifer. This process is influenced by many factors, including land use, precipitation, vegetation, topography, soil permeability and moisture, and the permeability of geologic materials between the ground surface and the water table. Some of these factors have been incorporated into ranking schemes that estimate relative recharge potential, such as those used in the Vashon/Maury Island Water Resource Study (Carr/Associates 1983), the Redmond Ground Water Management Report (EMCON 1992), and the DRASTIC method (USEPA/600-2-85/018).

A map of infiltration potential for the Issaquah Creek Valley Ground Water Management Area was created and presented in the December 1994 Draft Issaquah Creek Valley-GWMP. The physical parameters (criterion) used to prepare this map included soils, slope and geology. Subsequent to the December 1994 Draft, a county-wide methodology was adopted to define and rank areas that are physically susceptible to ground water contamination (King County Department of Development and Environmental Services, August, 1995). The county map of physically susceptible ground water supersedes the previous infiltration potential map. The King County Department of Natural Resources has plans to develop a county-wide map of critical ground water recharge areas based on the strategies used to rank areas in the ground water susceptibility mapping process coupled with precipitation data and impervious surface coverage.

The county wide map of physically susceptible ground water areas is shown in Figure 5.5. This map shows areas where ground water is ranked by its relative susceptibility to contamination. Areas are ranked as being of high, medium, and low susceptibility to ground water contamination. The map, initially published in the 1994 King County Comprehensive Plan, was created under requirements of the Growth Management Act. Since the initial map was published, a revised county wide map has been created using criteria specifying surficial geology, soils and depth to ground water. Each criteria was rated individually as high, moderate, or low according to the protocols listed in Tables 7.7 through 7.9. The three individual scores were combined to yield an overall rating of aquifer susceptibility. It should be noted that soils were assigned one-quarter of the weight assigned to geology and depth to ground water because their occurrence is a result of the physical and chemical weathering processes of surficial geology. A full rating for soils would duplicate surficial geology in the mapping equation.

Soils that are excessively drained or are somewhat excessively drained are rated highly susceptible; soils that are well drained or moderately well drained are rated moderately susceptible; and soils that are somewhat poorly drained, poorly drained or very poorly drained are rated low in susceptibility. Table 7.7 indicates the susceptibility ranking of the USDA, NRCS soil units.

For surficial geology, a clean sand and/or gravel were rated as highly susceptible, tight silt or clay were rated low, and materials (mixtures of and, silt or clay) that fall between the two categories were rated as moderate. Table 7.8 indicates the susceptibility ranking of the USGS geologic units.

The data used to determine depth to ground water was obtained from well logs from the Department of Ecology. Only wells with water levels less than or equal to 100 feet were used in constructing water level contour maps. This reflects the assumption that where depth to water was greater than 100 feet, a relatively impermeable layer would likely exist above the water table. The susceptibility ranking for the depth to ground water criterion is presented in Table 7.9.

Precipitation and land use are not considered in this study of physical susceptibility, but should be considered at a later date in the determination of critical aquifer recharge areas. The Issaquah Creek Valley Ground Water Management Area, ranked by the physical susceptibility of the aquifer, is shown schematically in Figure 5.5.

The areas where ground water is most physically susceptible to contamination in the Issaquah Creek Valley Ground Water Management Area are those areas of soils with very high permeability. They overlie sand and gravel, which were deposited by meltwaters from the receding Vashon glacier. Here, the topography is generally level, although occasionally it is hummocky or steeply sloping, as on the scarps of terraces. In these high-infiltration areas, most surplus water recharges ground water, as little surface runoff occurs. The most important of these areas lies east of the City of Issaquah on the uplands between the East and North Forks of Issaquah Creek.

Most areas mantled with Vashon Till have a low potential for infiltration, and hence, ground water recharge. The local till is a dense mixture of sediment sizes with low permeability. Some water infiltrating the till's surface layer, which has a slightly higher permeability, percolates downslope on the top of the unweathered till to discharge into wetlands. Some of the water in the soil slowly percolates through the till or along scattered fractures in the till to deeper zones. The till is usually underlain by outwash sand and gravel, which forms an important aquifer in the area. Over large areas, the slow recharge through the till can provide substantial quantities of water to the deeper aquifers. Till-covered areas probably provide most of the recharge in the southwestern portion of the Issaquah Creek Valley Ground Water Management Area.

Areas of steep bedrock slopes probably have a low potential for infiltration. Many of the soils in this area have a high permeability, which promotes infiltration. Below the soil, the water encounters low-permeability bedrock, which sheds the water downslope along the bedrock surface to the valleys where it either enters streams or recharges the valley aquifers. Some of the percolating water may enter fractures to recharge deeper bedrock aquifers of limited extent and importance.

The valley floors are underlain by diverse sediments ranging from fine sand and silt to coarse sand and gravel. These deposits are oftentimes overlain by silt and muck, which seal them from surface infiltration. Some areas with coarser-grained surface deposits and a water table below the land surface receive local recharge. In most of the lower valley, a high water table and fine-grained surface deposits located above underlying aquifers prevent local recharge.

Land use, both current and historic, influences actual recharge. Precipitation also affects the actual quantity of recharge. These effects were not included in determination of physically susceptible ground waters (see Figure 5.5). These criterion will be included in critical aquifer recharge maps for King County which are expected to be produced using the physical susceptibility maps in conjunction with land use information and precipitation data.

7.4.3 Ground Water Vulnerability

Aquifer vulnerability is a composite of susceptibility and contaminant loading. Susceptibility refers to the ease with which contaminants can move from the land surface to the ground water. The greater the susceptibility, the more readily a contaminant can reach the water table. Contaminant loading refers to the actual presence of activities with the potential to contaminate. Thus, a vulnerable aquifer is one under an area with high susceptibility which has a high contaminant loading, without an upper confining layer.

Aquifer susceptibility is assessed by the same factors that were used to delineate potential recharge areas: soils, geology, and ground water levels. Areas with high recharge potential are highly susceptible because the recharging water may transport contaminants to the water table.

A map showing potential sites where contaminant loading may occur is shown in Figure 5.4. These maps show where contamination sources have occurred in the basin to 1991.

Activities with the potential to contaminate are listed in Table 7.10. Appropriate mitigation should be associated with these activities. These activities should be discouraged in sensitive aquifer recharge areas, as should activities which reduce recharge (Table 7.11).

Lower Issaquah Creek Valley

Lower valley aquifers are a productive source of ground water used for the Issaquah Creek Valley Ground Water Management Area's major public supply systems. Soils in the area are subject to fluctuating high water table conditions. The degree of hydraulic continuity between the surface and aquifer zones is largely unknown. On the east side of the lower valley, there is evidence that the upper aquifer zone A1 recharges the lower A2 zone under pumping conditions, thus raising concerns that surface contaminants may have hydraulic access to lower aquifer zones.

Several potential contaminant sources are present in the City of Issaquah and surrounding areas. These potential contaminant sources, such as underground storage tanks, are likely to increase in number due to growing development pressures. Most large supply wells are located near major transportation corridors and in the vicinity of high-intensity land uses. The potential impact to water quality from upstream contaminant sources in the upper Issaquah Creek valley and Cedar Hills area is unknown. Monitoring of on-site and off-site wells and springs between the Cedar Hills Landfill and Issaquah Creek is conducted by King County. This is discussed in detail in Section 5.5 of this report (Landfills and Industrial Waste Sites).

During the period of this study, several spills and related events have occurred in the lower Issaquah Creek Valley. These events have threatened the water quality in some existing high-capacity production wells. The actual impact of these spills has been lessened by rapid remedial response and modified withdrawal patterns from the potentially affected wells.

At the present time, the lower Issaquah Creek valley is probably the most vulnerable part of the ground water resource. In this area, high-capacity wells have been completed at relatively shallow depths in coarse-grained sediments that generally are not separated from the surface by impermeable sediments.

Upper Issaquah Creek Valley

Upper valley aquifers are used primarily for small community and domestic supply systems. Soils and geologic materials vary greatly in permeability and properties affecting vulnerability to contamination. Water tables are high in some areas and the extent of surface water and ground water interconnection is not documented.

Septic tank systems, animal keeping, isolated commercial and industrial sites, and transportation corridors represent the more obvious potential sources of ground water contamination. Development activities in the area are likely to result in introduction of a number of additional contaminant sources. Upgradient contaminant sources such as Cedar Hills Landfill and Queen City Farms Superfund Site are also a potential threat to water quality.

Upland and Mountain Areas

With the exception of Mirrormont, water is provided by Group B public water systems and individual domestic wells. Contamination of a mountain or upland aquifer would result in serious problems for rural residents because alternative water supply sources are not readily available. Here too, the incidence of ground water contamination is less likely to be discovered because water quality monitoring is not routinely performed.

Upland and mountain aquifers vary greatly in their susceptibility to contamination. Mountain soils and some upland soils are typically thin, steeply sloping, and poorly suited for septic tank systems. In general, wells completed in shallow aquifers are subject to contamination, especially from septic tank systems and animal-keeping practices. Many mountain and upland wells are completed in shallow, relatively unprotected aquifers.

Residential development in these areas is expected to intensify; thus, the number and density of potential contaminant sources will increase. The Cedar Hills Landfill and the Queen City Farms Superfund sites represent contaminant sources with potential for great impact upon the water quality of shallow and lower aquifers in the Cedar Hills area.

7.5 Water Budget

Ground water used in the Issaquah Creek Valley Ground Water Management Area is only replenished by precipitation. The following sections describe processes influencing the Issaquah Creek Valley Ground Water Management Area hydrologic cycle. A water budget was prepared to put these processes into a quantified relationship with each other.

This budget is a hydrologic accounting tool used for estimating the annual quantity, availability and movement of water entering and exiting a basin. Components of the budget include precipitation, evapotranspiration, storm runoff and baseflow, ground water basin transfers, ground water discharge, and change in storage. These processes are in reality far more complex than the variables represented in the water budget equation. Values used in the equation are derived from estimates and imperfect data, but nonetheless are useful for developing a general sense of the water regime. Future investigations and ground water management decision-making should be mindful of the limitations of these estimates.

A simplified equation for this budget is: Inflow = Outflow + Change in Storage

The water balance equation can be expressed in greater detail by the following equation:

$$P = ET + SF + BF + GT + GD + dS \quad (1)$$

where:

P	=	Precipitation
ET	=	Evapotranspiration
SF	=	Storm Runoff
BF	=	Baseflow
GT	=	Ground Water Basin Transfers
GD	=	Ground Water Discharge
dS	=	Change in Storage

7.5.1 Precipitation

Precipitation data, a critical component in all water balance calculations, are available for 18 local monitoring stations within or near the study area and for six regional monitoring stations. The local monitoring stations include four Department of Natural Resources sites, five King County Surface Water Management sites, eight sites that were established through the Issaquah Creek Valley Ground Water Management Area program, and King County's Cedar Hills Landfill station. The four Department of Natural Resources sites are Fifteen Mile Creek, Tiger Mountain, Preston and the Issaquah Fish Hatchery. Data have been collected at these sites since 1986. The five King County Surface Water Management sites set up in 1988 are located at upper Tibbetts Creek, Grand Ridge, East Fork of Issaquah Creek, McDonald Creek and Holder Creek. The eight sites established in 1989 by Seattle-King County Health Department are Francis Lake, LeRoux, Rothnie, Maple Hills Park, Cougar Mountain, Grand Ridge, High Valley and Issaquah. These sites were selected to provide additional coverage within the planning area. The precipitation measurements at these sites are collected by volunteers. Locations of the rain gages are depicted on the map in Figure 7.13. The list of the location of precipitation and stream gaging stations, numbered in Figure 7.13, can be found in Table 7.12. The criteria used to select precipitation gauging sites include:

- Site Distribution - Establish sites in areas where data are not presently being collected. Focus data collection on higher elevation sites where existing data are limited.
- Representative - The site is not obstructed in a 45 degree cone projecting from the orifice of the gauge, shielded from nearby ground turbulence, and is offset from roof spray and gutter splash.
- Orographic Significance - Establish sites where terrain and seasonal storm directions are likely to influence precipitation patterns.
- Accessibility - The site is easy to measure on a regular basis (e.g. backyard, work place, or routine checkpoint).

- Security - The site is protected from vandalism, animals, and accidental damage.
- Permanency - The location of the gauge is not likely to change.
- Commitment and Responsibility - The data collectors must be committed to collecting data for the term of the project.

Data for these stations are presented in Appendix G (available upon request). The regional monitoring stations include SeaTac Airport, Kent, Cedar Lake, Snoqualmie Falls, Sand Point, and Landsburg.

The Cedar Hills station has the longest period of record in the project area (1974 to present). The average annual precipitation at this station is 54.44 inches per year (in/yr). Because precipitation for 1988 was very close to the long-term average conditions (98 percent of normal), this period was selected to assess the distribution of average precipitation within the study area. Precipitation data were available for all local and regional stations during 1988 with the exception of the Issaquah Creek Valley Ground Water Management Area monitoring stations established in 1989. Estimates of 1988 precipitation for Issaquah Creek Valley Ground Water Management Area sites were derived by normalizing 1990 values by the ratio of 1988 to 1990 values available from other sites.

A contouring program (Surfer) was used to generate a precipitation isohyetal map showing lines of equal precipitation for the area. The results of this analysis are presented in Figure 7.14, along with the station locations and 1988 precipitation totals.

Precipitation inflow within the Issaquah Creek Valley Ground Water Management Area was calculated by adding the amounts of precipitation in each precipitation interval and averaged over a year. Based on this analysis, the total precipitation inflow for 1988 is 244.4 cfs. The adjusted precipitation inflow for a normal year is 249.4 cfs.

7.5.2 Evapotranspiration

Evaporation and transpiration, collectively referred to as evapotranspiration, represent a loss of liquid water from the water budget through its transformation to vapor. Transpiration is performed by living plants (such as trees) when water is taken up through the roots, processed and released as vapor through tissue cells in the leaves and bark. Evaporation includes the vaporization of water from the soil, parking lots and rooftops, forest canopies and plant surfaces, or open water such as lakes and streams.

This component was estimated using the Blaney-Criddle method (USSCS 1970). This method uses crop, latitude, and temperature to calculate potential evapotranspiration. A simple water balance within the soil, based on rainfall and potential evapotranspiration, was then used to relate potential evapotranspiration to actual evapotranspiration. In this balance, actual evapotranspiration equals potential evapotranspiration as long as precipitation is sufficient to keep the soil moist enough to provide plants with water. When the soil is drier, actual evapotranspiration is less than the potential rate.

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

When precipitation was equal to or greater than potential evapotranspiration:

AET = PET

When precipitation was less than potential evapotranspiration:

AET = PET (when $SM/SMC \geq 0.75$)

or

AET = PET * 1.333 * (SM/SMC) (when $SM/SMC < 0.75$)

where:

AET	=	Actual evapotranspiration (in/yr)
PET	=	Potential evapotranspiration (in/yr), calculated by the Blaney-Criddle method
SM	=	Soil moisture content from the previous week (in)
SMC	=	Soil moisture holding capacity (in)

This linear function of the ratio of actual water content to soil moisture holding capacity is one of at least five methods used to relate actual evapotranspiration to potential evapotranspiration, reported in Dunne and Leopold (1978). The soil moisture holding capacity over the project area varies and is not accurately known. This analysis assumes a soil moisture holding capacity of six inches.

The choice of values for representative evaporation and transpiration estimates related to crops is problematical. It is related to variable climatic conditions and the amount of sunlight received and soil moisture utilized by vegetation over an annual year. Figures for crops in eastern Washington will be higher than those in western Washington. It is expected that conifers in western Washington will produce more evapotranspiration than most crops under unirrigated conditions. This is because the conifers will intercept more precipitation and evaporate it away than conventional crops in our geographic location, and because their rooting depth is generally greater than most grass crops. This allows for greater moisture extraction during low moisture conditions. In addition, conifers are capable of transpiring some moisture during periods of relatively low sunlight. This grass crop factor was used in this analysis because of the availability of the data from eastern Washington studies. Comparison of this data with US weather service information on evapotranspiration that is 40 years old is similar. Updated information on evapotranspiration is needed. (Martin, W., Fisher, J., DeBell, D., and Handson, J., personal communications, and Kelliher and Lenning, *Evaporation and Canopy Characteristics of Conifer Forests and Grasslands,* US Weather Bureau, *Normals of Precipitation and Evaporation, and* Dunne, Leopold, *Water in Environmental Planning.*)

Based on the above-stated methods and assumptions, the average calculated evapotranspiration rate for the basin is 18.8 in/yr. Based on Issaquah Creek's total basin drainage area of 56.6 square miles, the total evapotranspiration outflow from the system is 78.3 cfs based over one year.

7.5.3 Storm Runoff and Baseflow

Stream flow data are critical elements in evaluating a water balance relationship and when providing an insight into possible hydrogeologic impacts related to ground water development. The interrelationship of ground water and surface water is a crucial concept in the management of these resources. This is particularly true to maintaining streamflow and wetlands given that ground water development can reduce inflow to these features.

Historical stream flow data are available for 17 gauging stations within or near the study area. The gauging stations include four Department of Natural Resources sites, seven King County Surface Water Management sites, and six United States Geological Survey sites. Continuous recording data loggers are used to record stage data at most of the sites. The United States Geological Survey sites generally provide the longest period of recorded data. The Surface Water Management stations were installed in 1988. The stream gauging stations are summarized in Table 7.13, and station locations are shown on Figure 7.13. Data for these stations are presented in Appendix G (available upon request).

Storm runoff and baseflow quantities were evaluated using the stream gauging data for USGS Station 121216. This station is located near the mouth of Issaquah Creek just upstream from Lake Sammamish. All surface water runoff for the Issaquah Creek basin discharges through this point. The total drainage area above the gauge is 56.6 square miles.

A 3-year hydrograph for Station 121216 is presented in Figure 7.15. Included on the hydrograph is the baseflow curve that reflects the ground water discharge input to the stream. Storm runoff is the difference between the total stream flow and the baseflow curves. A portion of this baseflow is a diversion of the Cedar River watershed.
Average stream flow (total flow) from 1988 through 1990 was 115.2 cfs. Baseflow for this same period was 79 cfs, or about 69 percent of the total average stream flow. The average storm runoff during this period was 36.2 cfs, or about 31 percent of the total.

7.5.4 Interbasin Transfers - Imports and Exports

Imports of water to the Issaquah Creek Valley Ground Water Management Area are not thoroughly identified or quantified. USGS stream records indicate that flow from 1.9 square miles of the upper Rock Creek watershed (Cedar River drainage), south of the Issaquah Creek Valley Ground Water Management Area, is diverted into Issaquah Creek.

How this diversion takes place is beyond the scope of this study. However, Issaquah Creek basin discharge calculations already take into account contributions from the upper Rock Creek watershed.

Some public water supply systems on the periphery of the Issaquah Creek Valley Ground Water Management Area are importing relatively small quantities. King County Water District No. 90 serves residential development in the May Valley area and near Lake McDonald with water purchased from the Seattle Water Department. The water originates in the Cedar River Watershed.

Export of water from the Issaquah Creek Valley Ground Water Management Area basin is significant. The City of Issaquah, Sammamish Plateau Water and Sewer District, Darigold Dairy, and various small public supply systems use a supply entirely derived from ground water. After use for water supply purposes, most of this water becomes wastewater. Wastewater from these areas, where sewered, is pumped out of the Issaquah Creek Valley Ground Water Management Area to King County Department of Natural Resources, Wastewater Treatment Division's Renton sewage treatment plant. The remaining percentage is lost to consumption as evapotranspiration, runoff, or system leakage (see Table 7.14).

Infiltration and inflow into sewer systems within the City of Issaquah and Sammamish Plateau service areas also represent potential export losses. Another export is the leachate collected at Cedar Hills Landfill and sent to King County Department of Natural Resources, Wastewater Treatment Division's Renton treatment plant (see Table 7.14 for estimated exports based on King County Department of Natural Resources, Wastewater Treatment Division and water use records). Table. 7.14 includes only the most significant exports.

7.5.5 Intrabasin Translocation

Intrabasin translocation is water artificially moved from one hydrologic location to another or the distribution of ground water to areas not in direct hydraulic continuity with their source. For example, the provision of drinking water to distant homes and the subsequent disposal of this water through on-site septic tank systems may result in loss of water from one aquifer system, and artificial recharge to another shallow aquifer.

Except for losses to consumption or runoff, the net effect on the basin is minor. Intrabasin translocations are not computed in the basin water budget because they are not sufficiently known. Although they are suspected not to be significant overall, nonetheless they should be recognized as a potential local ground water management concern.

7.5.6 Change in Storage

Analysis of short-term water level trends (see Figures 7.12A through 7.12H) indicates that water levels within the basin are stable at this time. It appears that present ground water withdrawals are not causing significant changes in storage. Thus, changes in basin storage are assumed to be zero in the water balance assessment. However, long term collection of water level data is needed to determine water levels trends in the basin.

7.5.7 Ground Water Discharge

Ground water discharge (GD) consists of the subsurface underflow that exits the Issaquah basin. It is estimated by the residual or unaccounted for portion of the water balance and is calculated from Equation 1 as follows:

$$GD = P - ET - SF - BF - GT - ds \quad (2), \text{ or}$$
$$GD = 249.4 - 78.3 - 42.9 - 96.2 - 7.5 - 0 = 24.5$$

Based on the above analysis, the calculated ground water discharge from the system is 24.5 cfs. This discharge is to Lake Sammamish and possibly the Cedar River.

7.6 Water Quality

Historical ground water quality was compiled from the Washington Department of Health, the U.S. Environmental Protection Agency, and the Department of Ecology data sources. Little long-term data are available for the area. Monitoring of organic compounds is almost non-existent outside the limits of the Cedar Hills Landfill and Queen City Farms.

Data collection efforts were directed towards achieving the following:

- Long-term trend data
- Identification of potential sources of contamination
- Baseline organic and inorganic ground water chemistry for the project area
- Water quality of shallow ground water systems
- Assessing water chemistry of public water supplies as it relates to primary maximum contamination limits.

The monitoring network's purpose was to provide adequate background data to assess the impacts of land use activities on ground water quality. The type of land use activity can have a direct impact on water quality parameters found in ground water. For example, measuring a trend of increasing nitrate, chloride, or conductivity levels may indicate the failure of on-site sewage facilities. Likewise, detecting a pesticide in ground water quality samples would imply the possibility of nearby agricultural activity.

Group A sampling and analysis is oriented towards definition of the general inorganic ground water chemistry within the project vicinity. Monitoring for Group A parameters was carried out in 19 wells (see Table 7.6). The King County Department of Natural Resources, Solid Waste Division samples four wells for Group A and B parameters at the Cedar Hills landfill and Queen City Farms. The Seattle-King County Health Department Solid Waste Division samples seven wells for Group A and B parameters around the Cedar Hills landfill and Queen City. A listing of the Group A parameters is presented in Table 7.15.

The process for site selection was similar to that used to select water level monitoring sites. The criteria used in site selection included the following:

- Site Distribution - Establish sites in areas where data are not presently being collected.
- Hydrogeologic Significance - Appropriate location/depths for defining horizontal/vertical variability of ground water chemistry.
- Sampling Access - Select sites where a sampling tap exists or can be easily installed.
- Well Log - The well has a complete and reliable well log.
- Locatable - The well can be located in the field and verified with the well log.

Three sampling rounds for Group A parameters were collected in March 1990, June 1990, and December 1990.

Group B sampling and analysis is oriented towards detection of ground water contamination in the project area and the evaluation of the extent to which land use patterns affect ground water quality. Monitoring for Group B parameters was carried out in eight wells. The list of Program B water quality monitoring sites is presented in Table 7.6. The locations of the sampling wells are shown on Figure 7.16. A list of the Group B parameters is presented in Table 7.16 (volatiles), Table 7.17 (semi-volatiles), Table 7.18 (pesticides, PCBs) and Table 7.19 (priority pollutants).

The criteria used in the Program B site selection was similar to that used for Program A, with the exception that new sites (i.e., in addition to the on-going Program B monitoring in vicinity of Cedar Hills Landfill and Queen City Farms) were primarily located in the northern portion of the study area where urbanization and land use activities pose the greatest threat to water quality. Additional Group B sampling sites were not selected in the vicinity of the Cedar Hills Landfill or Queen City Farms because water quality monitoring is currently being conducted by King County Solid Waste Division and Seattle-King County Health Department.

Group B (volatiles) samples were collected from eight wells in March 1990 and December 1990. Samples were collected in accordance with the procedures listed in the Issaquah Creek Valley Ground Water Management Plan, Quality Assurance Project Plan, March 1990. Samples collected were analyzed by AmTest, a laboratory certified by the

Washington Department of Health. Samples results and laboratory procedures were validated by the Pacific Ground Water Group.

On the Sammamish Plateau, water quality sampling and analysis was carried out under the East King County Ground Water Management program. Sources for water quality data include samples collected by the USGS in July and August 1991 and samples collected by the Seattle-King County Health Department from June 1994 through May 1995.

The USGS study included the one-time collection and analysis of samples from 121 wells and 3 springs during July and August 1991. The samples from all these sites were analyzed for bacteria, metals, inorganics, and physical characteristics. A subset of 11 sites were sampled for volatile organic compounds and another subset of 12 for selected pesticides. Other subsets were tested for boron, dissolved organic carbon, methylene blue active substances and radon.

Based on the USGS recommendations, the Seattle-King County Health Department collected samples from a 23-well network. Five quarterly rounds of samples were collected, beginning in June 1994 and ending in May 1995. All these wells were tested for bacteria, metals, physical and inorganic parameters. A subset of 9 wells were tested in June 1994 for volatiles and semi-volatiles. Eleven wells were sampled for pesticides, polychlorinated biphenyls, and herbicides in June and December 1994. The wells tested for organic compounds were chosen based on location and potential for certain types of contamination.

The criteria used by the Seattle-King County Health Department followed the USGS criteria for site selection, which included the following:

- availability and access permission by well owner;
- practicality and feasibility of collecting samples from wellhead;
- wells previously sampled by the U. S. Geological Survey that were out of compliance with State Board of Health Drinking Water Quality Standards for arsenic, fecal coliform, and pesticides;
- wells where contamination is present from other sampling efforts;
- areas of potential contamination;
- wells that are used for municipal, irrigation and domestic purposes and that have been previously inventoried;
- areal distribution; and
- the geohydrologic unit in which the well is completed.

Samples from the Sammamish Plateau wells were collected in accordance with the procedures listed in the *East King County Ground Water Management Plan, Quality Assurance Project Plan/Data Collection and Analysis Plan*, December 1994. Samples were analyzed by AmTest Laboratory which is certified by the Washington State

Department of Health. Sample results and laboratory procedures were validated by the Seattle-King County Health Department.

Water quality data collected during the course of this study and available from earlier analyses indicate that the ground water quality in the Issaquah Creek Valley Ground Water Management Area basin is generally excellent. The ground water generally meets all State of Washington Department of Health standards for public drinking water supplies. The iron and manganese results from a few wells exceeded the Washington Department of Health Standards. However, manganese and iron are naturally occurring elements which effect taste and cause fixture staining. They are only a health concern in that they can interfere with the treatment of drinking water.

7.6.1 Organic Compound Results

Of the 130 volatile and semi-volatile organic, pesticide, and PCB compounds analyzed, only two, acetone and methylene chloride, showed concentrations which were slightly above detection limits. Reported concentrations near detection limits are difficult to interpret because such results can be influenced by other sources, such as laboratory or other errors. Data from other sources have shown the presence of hydrocarbon compounds in shallow ground water at some locations in lower Issaquah Creek valley (Geraghty & Miller March 1991 and 1992; Applied Geotechnology 1989; Rittenhouse-Zieman & Associates 1990; EA Engineering 1990; Kleinfelder 1991). These contaminants are present as a result of spills and leaks which have occurred at local service stations. To date, no such compounds have been identified in production wells in the lower valley. The real potential for similar, future incidents mandates continued monitoring and analysis for volatile and semi-volatile organic compounds.

7.6.2 Inorganic Compound Results

The inorganic analyses showed the presence of ions characteristic to Puget lowland ground water. These include inorganic compounds, such as iron and manganese, which can occur naturally in local ground water. Such metals are present in the soils and sediments of the basin and can be dissolved by contact with ground water. Key inorganic indicators have been evaluated during this testing period, as shown in Figures 7.17 through 7.23.

Figure 7.16 shows the locations of sampled wells by number and owner name. The key inorganic indicators evaluated here include:

- Total Dissolved Solids Sodium
- Total Hardness Nitrate
- Calcium Chloride
- Magnesium Arsenic

These parameters represent some of the important ions and indicators of dissolved constituents. Total dissolved solids, hardness, calcium, and magnesium are indicators of the amount of time ground water has been in contact with the sediments. Sodium also can be an indicator of residence time, sea water intrusion, or contamination by septic effluent. Nitrate and chloride can be indicators of effluent contamination. Arsenic occurs in some similar settings in the Cascade foothills and merits more detailed analysis in the Issaquah Creek Valley Ground Water Management Area.

7.6.3 General Discussion of Water Quality

As ground water infiltrates through the soil and moves through sediments and rocks, its quality changes. These changes result from the exchange of gases, such as oxygen and carbon dioxide, and the solution of minerals from surrounding rocks. The type(s) and degree(s) of change are effected by differences in geology and residence time. Geologic differences can produce different ionic ratios, such as the calcium to potassium ratio and the chloride to sulfate ratio.

Concentrations generally increase with residence time, because the longer the ground water is in contact with mineral matter, the greater the opportunity for dissolution to occur. Ground water that has moved over a long distance, or to great depths, or traveled more slowly will have higher concentrations of dissolved minerals than ground water which has flowed only a short distance, to shallow depths, or at high rates.

These influences can be assessed by comparing water quality in wells located in different parts of the basin and those completed at different depths and in different materials. In the study area, these influences were analyzed using the results from three sampling episodes for selected wells. These results are illustrated in Figures 7.17 through 7.23. The data are presented in Appendix H (available upon request).

Comparison of water quality data is complicated by temporal variations of some parameters that are larger than the differences between wells. For instance, the variation in concentration between sampling episodes for total dissolved solids (TDS) ranges from 30 to 200 mg/L. For hardness, the temporal variation is 40 mg/L, and for sodium, it is 20 mg/L. These variations may reflect the influence of seasonal recharge patterns or other causes. The duration of the sampling period was too short to fully evaluate seasonal water quality variation.

However, some generalizations are possible. Water from wells completed in bedrock tends to have higher concentrations of sodium and lower concentrations of calcium than those of water from wells completed in sand and gravel. The Agnew, Mitchell, and Preston wells are completed in bedrock. Water analyses show the sodium concentration in two of them (Agnew and Mitchell) exceeds 80 mg/L, and the calcium is less than 20 mg/L. The Adams, Greening, Overdale, and Pommer wells are completed in sand and gravel, and analyses of water samples show sodium concentrations below 20 mg/L and calcium concentrations above 20 mg/L. Some exceptions exist. Samples from the

Preston well, completed in bedrock, show only 4 to 6 mg/L sodium and 10 to 30 mg/L of calcium. Samples from the Pommer Well, completed in sand and gravel, show over 30 mg/L sodium and less than 20 mg/L calcium. These differences in sodium probably result from the weathering of sodium-rich minerals in the igneous rocks.

The available water quality data show no spatial variations. No definitive changes in water quality are apparent in the downstream direction. The water quality of water from the Greening and Adams wells in the southern portion of the basin is similar to the water quality of the Overdale well in the northern portion of the basin.

In the Issaquah Creek Valley Ground Water Management Area, local land use can influence water quality. Slightly elevated concentrations of nitrate and chloride in the Greening Well (see Figure 7.19) may be related to septic tank effluent or runoff from livestock pens. As shown in Appendix H (available upon request), similarly elevated concentrations of nitrate appear in several other sampled wells, including Leroy, 23N/6E-33; Jackson, 23N/6E-27C01; Hall, 23N/6E-03K02; Zetech, 24N/6E-28F02; and others.

In the March 1990 sampling event, nitrate levels were detected in 19 of the 24 wells sampled. The nitrate results ranged from 0.10 to 2.5 mg/l.

In the June 1990 sampling event, no nitrate levels were above the 0.2 mg/l detection level in the 19 wells sampled. As nitrates were not detected in the June 1990 sampling event, this suggests that winter conditions, due to precipitation, may allow local nitrates to infiltrate the aquifer while summer conditions, due to a lack of precipitation, arrest infiltration. In the December, 1990 sampling event, 7 of the 19 wells sampled were above the nitrate detection level with results ranging from 0.96 to 2.1 mg/l.

The wells where nitrate levels were detected are scattered throughout the Issaquah Creek Valley Ground Water Management Area. Further monitoring of these wells to assess and determine the nitrate source(s) is necessary. Table 7.10 shows the causal linkage between land use activities and potential resultant contaminants.

Ground water contamination investigations have been conducted by the U.S. Environmental Protection Agency at the Queen City Farms Superfund Site. Studies have also been conducted by Ecology at sites in and outside the City of Issaquah where underground storage tanks were discovered leaking. Surface water quality studies have been performed by Ecology, King County Department of Natural Resources, Water and Land Resources Division, and King County Surface Water Management. King County Solid Waste Division has an extensive water quality data base for Cedar Hills landfill.

7.6.4 Wellhead Protection Study

As part of the Lower Issaquah Valley Wellhead Protection Plan (Golder Associates 1993) three rounds of water quality samples were taken from wells located throughout the lower Issaquah valley between May 1992 and April 1993, as summarized on Table 7.20. The samples were analyzed for various constituents, including the major anions and cations, priority pollutant metals, iron and manganese, nitrate, turbidity, volatile organics, pesticides, herbicides, and PCBs. Additionally, water quality sampling was performed between 1990 and 1992 (Geraghty and Miller 1992) in 18 monitoring wells around the ARCO Station at the corner of Gilman Blvd. and Front Street after a leak in one of the underground storage tanks was detected. These data were provided to the Wellhead Protection Plan study. The Department of Ecology also performed sampling at six sites in Issaquah and analyzed for lead and organic compounds (The Department of Ecology 1992).

Four of the eleven City of Issaquah and Sammamish Plateau Water and Sewer District's wells monitored in the Issaquah Creek Valley Ground Water Management Area program were monitored for water quality parameters in the Wellhead Protection Study (see Table 7.21). The remaining seven wells monitored in the ground water study were monitored for water levels only in the wellhead protection study (see Table 7.21).

The ground water within the lower Issaquah valley generally contains few dissolved solids, and is classified as a calcium bicarbonate type of water. In general, the ground water quality from production wells within the lower Issaquah valley is excellent, with only slightly elevated iron and manganese concentrations. Pesticides or PCBs were not detected within the lower Issaquah valley, and priority pollutant metals are below regulated limits. The pesticides sampled for were the same as those listed in Table 7.18. Shallow ground water contamination from volatile organic compounds associated with underground gasoline storage tanks has been documented above drinking water standards in shallow monitoring wells in the lower Issaquah valley. The organic compounds (benzene, toluene, ethylbenzene, and xylene) have been detected in other monitoring wells and are discussed in the City of Issaquah's and the Sammamish Plateau Water and Sewer District's Wellhead Protection Plan (Golder Associates 1993).

Surface water quality in the lower Issaquah valley is important to ground water quality since it is often indicative of the quality of storm water runoff, which may reach ground water through direct infiltration. Stream water quality is summarized briefly below, with an emphasis on drinking water constituents rather than toxicity to fish or riparian habitat.

During baseflow conditions, King County Department of Natural Resources, Water and Land Resources Division monitors several sites within the watershed on a monthly basis. The monitoring is part of its annual quality of local lakes and streams program. Three sites on Issaquah Creek and one site on Tibbetts Creek are monitored. In addition, King County Department of Natural Resources, Water and Land Resources Division has collected grab samples during high flows and storms since 1987 from one site on Issaquah Creek. King County Department of Natural Resources, Water and Land Resources Division further collected five samples from five sites within the Issaquah basin during 1989 and 1990 as part of a storm water quality sampling program.

Between 1989 and 1990 dry season fecal coliform geometric means of four of the five stream locations exceeded state water-quality standards. The East Fork Issaquah Creek location did not exceed the standard. Yearly geometric means exceeded state standards in three of the five sites, while the wet-season state standard was exceeded in only Tibbetts Creek. An evaluation of baseflow metal concentrations indicated that copper, chromium, iron, nickel, and zinc concentrations were below their respective aquatic standards, and cadmium, mercury, and lead concentrations were below detection limits. There is hydraulic continuity between surface and ground water, with ground water providing the baseflow for streams during periods of low or no rainfall. Constituents found in streams can infiltrate into the ground and may impact ground water quality.

Two fish kills occurred on the North Fork Issaquah Creek in March and April, 1990. Water and tissue samples indicated the fish kill was due to a combination of elevated metal, ammonia, sulfides, 1,2 benzenedicarboxylic acid, and diisonyl ester along with low hardness (Lower Issaquah Valley Wellhead Protection Plan, Golder Associates 1993).

7.7 Conclusions

The results presented in this report are based on previously existing data, data collected as part of the Lower Issaquah Valley Wellhead Protection Plan, (Golder Associates 1993) and data collected during the course of this Ground Water Management area study. Current regional planning suggests that ground water resources of the Issaquah Valley will remain a primary source of subregional public and private domestic water supplies for the foreseeable future. Maintenance and enhancement of the existing quantity and quality of water will require careful management of the resource. The findings of this project have resulted in the following conclusions:

1. Precipitation inflow within the Issaquah Creek Valley Ground Water Management Area was calculated by adding the amounts of precipitation in each precipitation interval. The precipitation inflow for 1988 was 244.4 cfs. The adjusted precipitation inflow for a normal year is 249.4 cfs.

2. The average stream flow (total flow) from 1988 through 1990 was 115.2 cfs. Baseflow for this same period was 79 cfs, or about 69 percent of the total average stream flow. The average storm runoff during this period was 36.2 cfs, or about 31 percent of the total.

3. The average stream flow from 1988 through 1990 (115.2 cfs) was 82 percent of normal conditions (140.7 cfs). Therefore, the storm runoff and baseflow quantities were adjusted to reflect long-term average conditions. Assuming that the ratio of baseflow to total runoff remains constant over time, the normalized storm runoff and baseflow quantities are 42.9 cfs and 96.3 cfs, respectively.

4. The 56.6 square-mile Issaquah Creek drainage basin produces an estimated ground water discharge of 25 cfs (not including baseflow). The actual discharge may be less than this estimated amount if drainage from the upper basin above the Tiger Mountain Gap is being naturally diverted toward the Cedar River drainage.

5. The basin has three distinct hydrostratigraphic units. These are bedrock, aquitard and the aquifer as described in Table 7.5. Local bedrock forms a basement aquitard which retards ground water movement from the basin. The bedrock's structural features, coupled with its recent glacial erosion, have created a highly variable bedrock surface.

6. The major aquifers of the basin are present as deltaic and alluvial sediments and are located adjacent to the valleys. In the lower valley, these aquifers are capable of supplying in excess of 1,000 gallons per minute to properly constructed wells. Other parts of the basin with less permeable aquifers allow development of wells capable of producing 5 to 100 gallons per minute.

7. In most parts of the basin, the major aquifers are separated by discontinuous aquitards of silt and clay and low-permeability, glacial sediments.

8. Water quality in the basin is generally excellent. Volatile organic compounds have been found in shallow ground water at spill sites in the lower valley. To date no volatile organic compounds have been found in major aquifers or wells. Analyses of inorganic ions show the presence of parameters characteristic to those of Puget Sound area ground waters. At some locations, iron, manganese, and other naturally occurring contaminants occur in excess of the secondary maximum contaminant levels. Water quality in the bedrock is typically inferior to water quality in the unconsolidated aquifers. Some seasonal variation in water quality has been noted. Local land use activities appear to influence local water quality and could impair it.

9. The basin has areas of low, medium, and high infiltration potential. Most of the ground water recharge occurs in high infiltration potential areas. These areas are present along permeable outwash slopes of the lower valley and in areas of coarse-grained deltaic sediments in the upper and lower parts of the basin. The total ground water recharge in the basin is estimated to be between 21 and 51 cubic feet per second (13 to 33 million gallons per day), normalized over a one year period.

10. From well logs, cross sections A-A'-A", B-B' and C-C' were constructed to define the distribution and extent of aquifers and aquitards. These cross sections show some of the geology and extent of the aquifers. New wells drilled will further refine the geology, the extent of aquifers and directional flow of ground water.

11. The four wells drilled in the Issaquah Creek Valley Ground Water Management Area in 1990 and 1992 provide data on aquifer permeability, quality and the hydraulic connection between aquifers. Two wells were drilled in permeable zones, while two wells were drilled in zones not considered major water-bearing zones.

12. Two wells had manganese levels above the maximum contamination level and one well had iron levels above the maximum contamination level. In one well there was a lack of continuity between the shallow and deep aquifers while in another well the peizometers were hydraulically connected.

13. The results of drilling these four wells show the complexity and diversity of the ground water resource and geology in the Issaquah Creek Valley Ground Water Management Area. More data from these wells and new monitoring wells drilled in the Issaquah Creek Valley Ground Water Management Area will further refine the characterization of the aquifers in the Issaquah Creek Valley Ground Water Management Area.

14. The well water levels monitored monthly from forty-eight well sites in the Issaquah Creek Valley Ground Water Management Area had variations resulting from seasonal fluctuations and the effects of pumping of the aquifer. Monitoring of water levels for trends over a long period to assess the impacts of recharge, pumping, and population growth on the ground water resource, is needed.

The Lower Issaquah Valley Wellhead Protection Plan study by Golder Associates in 1993 concluded that:

1. The stratigraphy within the lower Issaquah valley is highly complex, consisting of shallow alluvium, recessional outwash, delta, till, lacustrine, and undifferentiated glacial deposits. The delta deposits are highly permeable and are the most important source of ground water within the lower Issaquah valley. Recessional outwash is also highly permeable, and occurs in the eastern higher elevations providing an important media for ground water recharge. The shallow alluvial deposits vary in permeability, and may or may not be fully saturated. The other hydrogeologic units are less permeable, and may provide local aquitards within the lower Issaquah valley.

2. The lower Issaquah valley hydrogeologic system is bounded at depth and along the border of the ground water basin by low-permeability bedrock; on the south by the Tiger Mountain gap, which allows only a limited quantity of ground water to pass from the upper Issaquah valley; on the north by Lake Sammamish where the ground water within the lower Issaquah valley discharges; and at the surface by streams, lakes, and permeable and impermeable areas.

3. Ground water elevations within the lower Issaquah valley vary from about 25 feet mean sea level near Lake Sammamish to about 200 feet mean sea level in the Tiger Mountain Gap. In the central valley area, ground water elevations are generally between 50 and 70 feet. In the Grand Ridge area ground water elevations vary from 400 to over 800 feet.

4. Ground water levels fluctuate annually between 7 and 15 feet within the lower Issaquah valley. The timing and magnitude of the fluctuations is the same for shallow zones and deeper zones. Ground water levels respond rapidly to precipitation events.

5. The direction of ground water flow within the lower Issaquah valley is generally northwestward toward Lake Sammamish, but varies annually within the central valley area from a northwestern direction during periods of high ground water levels to a more northern direction during periods of low ground water levels.

6. Within the central valley area of the lower Issaquah valley, the horizontal hydraulic gradient is relatively flat at between 0.001 and 0.002 ft/ft. Vertical hydraulic gradients are generally directed upwards except in the vicinity of the City of Issaquah's and Sammamish Plateau Water and Sewer District's production wells (COI 4/5, and wells 7/8). On Grand Ridge the horizontal hydraulic gradient is 0.067 ft/ft. A steep vertical hydraulic gradient exists between the Grand Ridge terrain and the valley floor.

7. Transmissivity in the lower Issaquah valley is estimated at 67,000 to 70,000 ft^2/d, based on two long-term pumping tests. Average hydraulic conductivity is estimated at between 200 and 300 ft/day.

8. Streams are a minor source of water to the wells in the central portion of the lower Issaquah valley.

9. The average annual recharge to the lower Issaquah valley aquifer system is between 20 and 25 cubic feet per second. The eastern plateau areas (Grand Ridge and Lake Tradition) may provide up to 30 percent of the direct recharge to the lower Issaquah valley, with the remainder occurring within the main valley. Average annual discharge to Lake Sammamish and the adjacent wetland area is between 10 and 20 cubic feet per second.

10. There appears to be little stream/aquifer interaction in the central lower Issaquah valley area. Stream gauging, mini-piezometer installations and pumping test results suggest limited hydraulic continuity between surface and ground water within the central valley area. Additional stream gauging data are needed to further assess hydraulic continuity with the central lower Issaquah valley.

11. Analysis of pumping tests and long-term water-level fluctuations indicates that ground water withdrawals in the lower Issaquah valley affect shallow ground water levels and cause downward vertical gradients from the water-table toward the completion zones of the wells.

12. The lower Issaquah valley aquifer system behaves as an unconfined to locally semi-confined aquifer. Analyses of pumping tests, water-levels, and hydraulic

gradients do not suggest that significant regional confining layers are present within the aquifer system. As such, the aquifer is highly vulnerable to contamination from surface sources.

13. The ground water sampled from wells by the City of Issaquah and Sammamish Plateau Water and Sewer District as part of the Lower Issaquah valley Wellhead Protection Plan were generally excellent with only slightly elevated iron and manganese concentrations. Herbicides, pesticides and PCBs were not detected and priority pollutants were below the regulated limits.

8.0 RECOMMENDATIONS

Future ground water management of the Issaquah Creek Valley Ground Water Management Area needs reliable data on ground water quality and quantity impacts. Information on ground water quantity can be used to determine aquifer recharge, ground water/surface water continuity and source capacity. Information on ground water quality can be used to determine appropriate land use and, if needed, remediation priorities. Information on both ground water quality and quantity can be used to better manage the ground water resource in the Issaquah Creek Valley Ground Water Management Area and to educate the public in protecting this valuable finite resource.

Additional ground water quantity information will require an expanded monitoring program and additional test and monitoring wells. These should be cooperative endeavors between the Seattle-King County Health Department, King County Surface Water Management Division, the Washington State Department of Natural Resources, Washington State Department of Ecology, Washington State Department of Health, particularly its Wellhead Protection Program, the City of Issaquah, the Sammamish Plateau Water and Sewer District, and private interests. A monitoring program is expensive, and care should be taken to select stations that provide the most useful data.

Ground water quantity determination relies on information on precipitation, ground water levels, stream discharge, and water levels in selected lakes and wetlands, as well as information from existing wells.

8.1 Precipitation Stations

The meteorological monitoring network provided by the existing Washington State Department of Natural Resources and King County Water and Land Resources Division stations appears adequate to define precipitation variations within the area. Additional data should be obtained from stations maintained by the water purveyors and the City of Issaquah, King County, and the Washington State Highway Department. The eight sites monitored by volunteers for Seattle-King County Health Department should be provided with automatic data logger rain gauges.

8.2 Surface Water Monitoring

The stream gauging stations within the Issaquah Creek Valley Ground Water Management Area are maintained and operated by others and, with one exception, provide adequate coverage. Data are lacking for the Tiger Mountain Gap, where three additional stations are required upgradient from, within, and downgradient from the Gap.

The Lower Issaquah Valley Wellhead Protection Plan recommends additional stream gauges be installed in the central lower Issaquah valley to determine the hydraulic conformity between surface and ground water.

Water level monitoring stations should be considered for selected wetlands and lakes. Data collected from these stations will allow assessment of the long-term combined impact of climatic variations and ground and surface water utilization. These stations should be located in the southern and northern portions of the basin.

The continuity between ground water and surface water should be evaluated by identifying gaining and losing stretches of streams, and the role of the ground water system, through the interpretation of nearby ground water levels.

8.3 Ground Water Monitoring Network

Additional monitoring wells are required in several areas, particularly along Tibbets, Fifteen Mile, and Holder creeks; along the divide between the Cedar River and Issaquah Creek drainage basins in the southern portion of T23N; and in the Tiger Mountain Gap. In most of these localities, wells exist and could be used if long-term permission to measure can be obtained. The latter two localities are critical. Here, new monitoring wells may need to be installed to define the ground water flow and the extent of aquifers. They should be located in areas with transmissive sediments, as indicated by a resistivity survey. The criteria used to select wells in this study phase shall be the basis used for well selection.

- Tiger Mountain Gap: Two to three additional monitoring wells should be located along a north-south line with an existing Issaquah Creek Valley Ground Water Management Area monitoring well to determine the stratigraphy, transmissivity, and hydraulic gradient of the sediments within the Gap. These data are required to assess the potential ground water contribution of the southern portion of the Issaquah Creek Basin to the northern portion.
- Cedar River - Issaquah Creek Divide: Further exploration should be done in sections 17, 18, 28 and 33 (T23N, R6E) to determine whether ground water is discharging from the Issaquah Creek Basin into the Cedar River Basin.
- The degree to which Lake Sammamish serves as a recharge reservoir to lower valley aquifers should be further evaluated through the interpretation of hydraulic gradients and conductivities in the lake vicinity.

- Additional research is required of water purveyors' wells about the types of activities the wells support (i.e., residential commercial, industrial or agricultural).
- Future research on the Sammamish Plateau Water and Sewer District's water demand projection should focus on determining the type and amount of demands to be made on all sources in the Issaquah Creek Valley Ground Water Management Area, whether or not those demands come from within Issaquah Creek Valley Ground Water Management Area boundaries.
- Information on the number and location of individual wells presently without water rights and metering of individual wells is necessary to more accurately determine actual withdrawals from source aquifers.

8.4 Ground Water Quality

Ground water quality information should be obtained from existing and new data sources. The existing monitoring network of wells and new wells drilled should be sampled twice yearly (wet and dry seasons) for inorganic and where necessary for organic, pesticide, and PCB parameters pertaining to relevant land use activities; to establish ground water quality trends and to provide data of potential contamination sources.

All the wells within the monitoring network should be accurately located and have accurate elevations located using the Global Positioning System. Most of the existing monitoring wells have surveyed elevations, but these have not been located with equal accuracy.

- The location of all septic tank failures in the Issaquah Creek Valley Ground Water Management Area should be researched to determine the ground water quality impacts.
- The water quality of stormwater outlets during storm events should be monitored where these outlets discharge to ground water and creeks.
- The water quality (and water quantity) of ground water at and around sand and gravel mines should be monitored.
- The water quality data collected from wells at and surrounding the Cedar Hills Landfill and Queen City Farms by King County Solid Waste Division and Seattle-King County Health Department Solid Waste Section should be assessed and entered into the Seattle-King County Health Department database. The shallow and deep aquifers should be assessed to see whether they are interconnected and whether ground water quality is being impacted.
- The location of commercial and residential underground storage tanks needs to be identified to determine the extent and type of ground water contamination.
- The types and quantities of fertilizer and pesticide applications, including roadside spraying, need to be monitored for their impacts on ground water quality.
- Hazardous material spills, particularly transportation spills, need to be monitored for their impacts on ground water.

- Data collated by the Department of Ecology, the Seattle-King County Health Department Local Hazardous Waste Management Program, and King County Department of Natural Resources, Water and Land Resources Division on hazardous waste generators' impacts on ground water quality needs to be monitored.

8.5 Use of Data Analysis

The results of future ground water and surface water quality monitoring should be analyzed periodically as data become available to determine whether ground water contamination has occurred or is occurring. If any contamination is discovered, recommendations should be made as to what modifications and/or additions to the monitoring system would enable increased definition of the extent of contamination. Also, the natural geochemistry of the water sample analyses should be analyzed to determine the water quality characteristics of specific aquifers and areas where ground water exchange or mixing may be occurring. These data should be entered into the Seattle-King County Health Department database.

- An aquifer susceptibility map for the Issaquah Creek Valley Ground Water Management Area has been produced based on the physical factors of soils, slope, and geology. A recharge map should be produced and updated periodically for the Issaquah Creek Valley Ground Water Management Area based on the spatial distribution of factors such as potentially hazardous land use activities, depth to ground water, precipitation, recharge potential and well head protection data studies by purveyors in the Issaquah Creek Valley Ground Water Management Area. Determination of recharge areas within the drainage basin will be accomplished by comparative weighing and ranking of these factors. The vulnerability assessment could be further refined through use of contamination scenarios and risk assessments.
- The aquifer recharge map, susceptibility map, a water level contour map, and the estimates of total ground water recharge should be updated as new information becomes available.
- Future data collection should also focus on the characterization of, and recharge to, the deep aquifers in the Issaquah Creek Valley Ground Water Management Area.
- The management plan should include efforts to evaluate the impacts of continued development on the ground water resources. The ground water recharge areas in the Issaquah Basin are located on the uplands, with the area of highest potential recharge being in the northeast portion of the Issaquah Creek Valley Ground Water Management Area along the East Fork. This is the area currently undergoing extensive development and designated for continued development under the Growth Management Act. An extensive ground water monitoring program should be established to guide evaluation of the future impacts. These

monitoring results could be used to assess the potential impacts of much larger developments.

- The Issaquah Creek Valley Ground Water Management Area aquifer source capacities should be estimated. This information is necessary for water right evaluation and land use planning.
- Maximum (aquifer-specific) water source capacity data are necessary for all future water sources in the Issaquah Creek Valley Ground Water Management Area. Water rights capacities must be derived from the same data used to determine maximum water source capacities.
- Peak usage requirements for water suppliers would also help to determine their ability to deliver water under existing water rights and source capacities.

8.6 Public Awareness

The ground water resources of the Issaquah Creek Valley Ground Water Management Area are limited. Although the estimated total discharge from the basin appears large, this water is not available everywhere, and some areas have insufficient ground water resources. The ground water management program should include an extensive education program to encourage water conservation and protection.

City officials, government agencies, businesses, purveyors, schoolchildren and the public need to be educated about protecting the ground water resources from contamination and depletion. Moreover, the protection strategies should be updated regularly as new information becomes available.

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Glossary

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10.0 GLOSSARY

ALLUVIAL. Pertaining to or composed of alluvium or deposited by a stream or running water.

ALLUVIUM. A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

AQUIFER. A soil or geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

AQUIFER SYSTEM. A body of permeable and relatively impermeable materials that functions regionally as a water-yielding unit. It comprises two or more permeable units separate at least locally by confining units that impede groundwater movement but do not greatly affect the regional hydraulic continuity of the system. The permeable materials can include both saturated and unsaturated sections.

AQUIFER TEST. A test involving the withdrawal of measured quantities of water from or addition of water to a well, and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition, e.g., a bailer or pump test. (These are withdrawal tests)

AQUITARD. An essentially impermeable geologic formation, group of formations, or part of a formation through which virtually no water moves.

AREA OF INFLUENCE. Area surrounding a pumping well within which the water table or potentiometric surface has been changed due to the well's pumping or recharge.

ARTESIAN WELL. A well deriving its water from a confined aquifer in which the hydraulic water level stands above the ground surface; synonymous with flowing artesian well.

ATTENUATION. The general process of reducing the amount and concentration of contaminants in water. Includes physical, chemical and biological processes as well as dilution.

BASALT. A general term for dark-colored iron- and magnesium-rich igneous rocks. It is the principal rock type making up the ocean floor and is easily seen in exposed cliffs in Eastern Washington.

BASE FLOW. That part of stream discharge not attributable to direct runoff from precipitation or snowmelt, usually sustained by ground water discharge.

BEDROCK. A general term for the rock, usually solid, that underlies soil or other unconsolidated material.

BENTONITE. A colloidal clay, largely made up of the mineral sodium montmorillonite, [a hydrated aluminum silicate] used in sealing the annular space to create a surface or sanitary seal.

CAPILLARY ACTION. The movement of water within the interstices of a porous medium due to the forces of adhesion, cohesion, and surface tension acting in a liquid that is in contact with a solid.

CAPILLARY FRINGE. The zone at the bottom of the vadose zone where groundwater is drawn upward by capillary force.

CARBONATE. A sediment formed by the organic of inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron.

CHLORIDE. A compound of chlorine with one other positive element or radical.

CLEAN WATER ACT. Basic federal legislation regulating surface water quality.

COLIFORM BACTERIA. Bacteria (*E. coli*) associated with human and warm-blooded animal waste.

CONE OF DEPRESSION. A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines the area of influence of a well.

CONFINED AQUIFER. A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

CONFINING BED. A geologic unit with low permeability (hydraulic conductivity) which restricts movement of water into or out of the aquifer. See also aquiclude, aquitard.

CONTAMINATION. The degradation of natural water quality as a result of anthropogenic activities.

CROSS-SECTION. A schematic representation of geologic layers as seen in a side view.

DISCHARGE. Ground water that flows out of an aquifer into an adjacent aquifer or to the surface into a spring or river.

DISCHARGE AREA. An area in which there are upward components of hydraulic head in the aquifer. In the discharge area ground water flows toward the surface, and may escape as a spring, seep, or base flow, or by evaporation and transpiration.

DISPERSION. The spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

DRAINAGE BASIN. The land area from which surface runoff drains into a stream channel or system of channels, or to a lake, reservoir, or other body of water.

DRAWDOWN. The distance between the static water level and the top surface of the cone of depression during pumping of a well.

DRILLERS LOG. A record of the geologic and aquifer conditions encountered by a driller during drilling of a water supply well. The State of Washington requires that a log be completed for each well.

DRINKING WATER STANDARDS. Federal or state water quality regulations that limit the contaminant levels of certain compounds for drinking water.

DYNAMIC EQUILIBRIUM. A condition of which the amount of recharge to an aquifer equals the amount of natural discharge.

EFFLUENT. Liquid waste discharged from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment.

EROSION. The general process or group of processes whereby the materials of the Earth's crust are moved from one place to another by running water (including rainfall), waves and currents, glacier ice, or wind.

EVAPOTRANSPIRATION. Loss of water from a land area through transpiration of plants and evaporation from the soil.

FLOODPLAIN. The surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river and covered with water when the river overflows its banks. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current.

FLOW LINES. On a hydraulic gradient diagram, the lines indicating the direction followed by groundwater toward points of discharge. Flow lines are perpendicular to equipotential lines.

FLOW RATE. The volume of flow per time (e.g., gallons per minute).

FLOWING ARTESIAN WELLS. Wells which tap confined aquifers which flow at ground surface without the necessity of pumping.

GEOLOGIC MAP. A map showing the aerial distribution of geologic units and the altitude or structure of those units.

GLACIAL DRIFT. A general term for unconsolidated sediment transported by glaciers and deposited directly on land or in the sea.

GLACIOFLUVIAL. Pertaining to the meltwater streams flowing from melting glacier ice and especially to the deposits and landforms produced by such streams.

GLACIOLACUSTRINE. Deposits created in lake environments from glacial silts and clays.

GROUND WATER. All water that is located below the ground surface; more specifically, subsurface water below the water table.

GROUND WATER DIVIDE. A ridge in the water table, or potentiometric surface, from which ground water moves away at right angles in both directions.

GROUND WATER MODEL. A simplified conceptual or mathematical image of a ground water system, describing the feature essential to the purpose for which the model was developed and including various assumptions pertinent to the system. Mathematical ground water models can include numerical and analytical models.

GROUNDWATER TABLE. The surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

HARDNESS. A property of water causing formation of an insoluble residue when the water is used with soap. It is primarily caused by calcium and magnesium ions.

HAZARDOUS WASTE. Federally regulated man-made waste that is ignitable, corrosive, reactive, or toxic.

HYDRAULIC CONDUCTIVITY. The rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft).

HYDRAULIC CONNECTION. The condition in which two water-bearing layers or bodies may freely transmit water between them.

HYDROGEOLOGIC. Those factors that deal with subsurface waters and related geologic aspects of surface water.

HYDROLOGIC CYCLE. The cyclical movement of water from the oceans to atmosphere to the land and back to the oceans.

HYDROSPHERE. All waters of the Earth, as distinguished from the rocks (lithosphere), living things (biosphere), and the air (atmosphere).

HYDROSTRATIGRAPHY. The assemblage of layers of aquifers and aquitards.

IGNEOUS. A type of rock solidified from molten material.

IMPERMEABLE. An adjective used to describe rock, soils, or sediments that impede the flow of water.
INFILTRATION. The downward movement of rain water or surface water into soil.

LACUSTRINE. Referring to a lake environment.

LAMINATED. The layering or thin bedding in sedimentary rocks.

LANDFILL. A general term indicating a disposal site of refuse, and dirt from excavations.

LEACHATE. The liquid that has percolated through solid waste and dissolved soluble components.

MAXIMUM CONTAMINANT LEVEL (MCL). The maximum permissible level as required by the Safe Drinking Water Act regulations, of a contaminant in water that is delivered to the users of a public water system.

METAMORPHIC. A rock that has been physically and/or chemically changed from an original texture and/or composition, usually by very high temperatures or pressures below the earth's surface.

MG/L. Milligrams per liter; a unit of concentration in water equivalent to a part per million or 0.0001 percent.

MICROORGANISMS. Microscopic organisms such as any of the bacteria, protozoans, or viruses.

NITRATE. A compound commonly associated with domestic and agricultural waste, and formed by nitrogen.

OUTWASH. Stratified sand and gravel removed or washed out from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of an active glacier. The coarser material is deposited nearer to the ice.

OUTWASH PLAIN. A broad, gently sloping sheet of outwash.

PEAT. A non-compacted deposit of organic material commonly developed from bogs or swamps.

PERCOLATE. The act of water seeping or filtering through soil without a defined channel.

PERMEABILITY. The property or capacity of a porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.

pH. A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. Originally stood for "potential of hydrogen".

PLUME. A contaminated portion of an aquifer extending from the original contaminant source.

POLLUTION. When the contamination concentration levels restrict the potential use of groundwater.

POROSITY. The percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.

POTABILITY. Ability to be used as drinking water.

POTENTIOMETRIC SURFACE. The surface to which water will rise in an aquifer under hydrostatic pressure.

PPM. Parts/per million. A unit of concentration equivalent to 0.0001 percent.

RECHARGE. The addition of water to the zone of saturation; also, the amount of water added.

RECHARGE AREA. Area in which water reaches the zone of saturation by surface infiltration.

RUNOFF. That part of precipitation flowing overland to surface streams.

SANDSTONE. A sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material.

SEAWATER INTRUSION. The entry of seawater into a fresh water aquifer.

SEDIMENTARY ROCKS. Rocks resulting from the consolidation of loose sediment that has accumulated in layers.

SHALE. A fine-grained sedimentary rock, formed by the consolidation of clay, silt, or mud. It is characterized by finely laminated structure and will not fall apart on wetting.

STORAGE COEFFICIENT. The volume of water released from storage per unit-volume of porous medium per unit change in head.

STRATIGRAPHIC. Pertaining to the composition and position of layers of rock or sediment.

TERTIARY. A period of earth's history estimated to have occurred between 65 and 2 million years ago.

TILL. Predominantly unsorted and unstratified drift, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

TOPOGRAPHIC. Pertaining to the general configuration of a land surface.

TOTAL DISSOLVED SOLIDS (TDS). A term that expresses the quantity of dissolved material in a sample of water, either the residue on evaporation, dried at 356°F (180°C), or, for many waters that contain more than about 1,000 mg/l, the sum of the chemical constituents.

TRANSMISSIVITY. The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values are given in gallons per minutes through a vertical section of an aquifer one foot wide and extending the full saturated height of an aquifer under a hydraulic gradient of 1 in the English Engineering system; in the International System, transmissivity is given in cubic meters per day through a vertical section of an aquifer one meter wide and extending the full saturated height of an aquifer under a hydraulic gradient of 1.

TRANSPIRATION. The process by which water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface.

TURBULENT FLOW. Water flow in which the flow lines are confused and heterogeneously mixed. It is typical of flow in surface-water bodies.

UNCONFINED AQUIFER. An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.

UNSATURATED ZONE. The subsurface zone containing both water and air. The lower part of the unsaturated zone (capillary fringe) does not actually contain air, but is saturated with water held by suction at less than atmospheric pressure.

VADOSE ZONE. The zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

VISCOSITY. The property of a substance to offer internal resistance to flow. Specifically, the ratio of the shear stress to the rate of shear strain.

WATER TABLE. The surface between the vadose zone and the groundwater, where the pressure is equal to that of the atmosphere.

WEATHERING. The destructive process(es) by which the atmosphere and surface water chemically change the character of a rock.

ZONE OF CONTRIBUTION. The area surrounding a pumping well that encompasses all areas or features that supply ground water recharge to the well.

ZONE OF INFLUENCE. The area surrounding a pumping well within which the water table or potentiometric surfaces have been changed due to ground water withdrawal.

Sources:

Driscoll, F., *Groundwater Wells*, Johnson Division, 1986.

Groundwater Resource Protection, King County Planning and Washington State Department of Ecology.

Redmond-Bear Creek Ground Water Management Program, *Draft Hydrogeologic Characterization Report*, prepared by EMCON Northwest, Inc., November, 1992.

Northern Thurston County Ground Water Management Plan, February, 1992.

Tables

Issaquah Creek Valley
Ground Water Management Plan

March 1999

Table 5.1 New Lots In Recorded Formal and Short Plats in the Issaquah Ground Water Management Area

	North of I-90		Issaquah		South of I-90		
	Formal	Short	Formal	Short	Formal	Short	Total
1984	0	0	92	0	90	27	209
1985	20	7	100	0	13	72	212
1986	136	4	29	0	41	55	265
1987	107	13	0	4	2	35	161
1988	32	1	8	0	0	18	59
1989	296*	0	31	0	0	14	341*
1990	309*	128	0	0	0	15	452*
1991	256*	14	27	0	0	13*	73*
1992	21*	6	30	3	0	13*	73*
Total	1177*	173	317	7	146	252*	2072
84/85 % of change	2000	700	8.7	0	-85.6	166.7	1.4
85/86 % of change	580	-42.9	-71.0	0	215.4	-23.6	25.0
86/87 % of change	-21.3	225.0	-2900	400	-95.1	-36.4	-39.3
87/88 % of change	-70.1	-92.3	800	-400	-200	-48.6	-63.4

Source: KC/LDIS, Annual Growth Reports 1985-1989
1989-1992: King County Land Development Information System 1994

* These are approximate numbers as the Issaquah Ground Water Management Area boundary dissects certain sections. These are approximate numbers for these sections and does not include recorded plats on the Plateau.

Table 5.2 Permit Applications for the City of Issaquah

	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total
Single-Family Res.	85	80	61	32	20	7	29	41	81	436
Multi-Family Res.	7	5	3	5	3	1	5	5	8	42
Commercial	9	7	7	3	6	5	7	8	11	63
SF/Additions	2	12	20	18	18	36	32	51	54	270
MF/Additions	5	4	0	2	0	3	2	5	6	27
Comm/Additions	54	37	62	44	58	46	36	53	53	443
Total	189	145	153	104	105	98	111	163	213	1,281

Source: City of Issaquah 1989 (1985 to 1988).
City of Issaquah 1994 (1989 to 1993).

Table 5.3 Ecology's Toxic Clean-Up Program

Site Name	Address	Affected Media	Contaminant Status	Site Status	Comments
Bakamus Truck Repair/Rowley	1500 19th Ave. NW, Issaquah 98027	Ground Water	Suspected	Remedial Action Conducted by Ecology.	Final Independent Remedial Action Report received by Ecology.
		Soil	Confirmed	Residual contamination left on site.	
Bell-Fair Aluminum & Steel Inc.	1480 19th Ave. NW, Issaquah 98027	Ground Water Soil Surface Water Air	Suspected Confirmed Suspected Suspected	Independent Remedial Action	Release Report received by Ecology. Awaiting Assessment by potentially liable party.
FOUR TEK Industries	228 Ave. SE; N of Cedar Grove Rd., Issaquah 98027	Ground Water Soil Surface Water	Suspected Suspected Suspected	Awaiting assessment by Ecology	
General Fabrication & Design	1590 NW Maple St., Issaquah 98027	Ground Water Soil Surface Water Air	Suspected Confirmed Suspected Suspected	Independent Remedial Action	Release Report received by Ecology; Awaiting assessment by potentially liable party
Issaquah Tire Service/Rowley	1860 NW Mall St., Issaquah 98027	Ground Water Soil Surface Water	Suspected Confirmed Suspected	Awaiting assessment by Ecology	
Northwest Pipeline/Issaquah	22339 SE 56th, Issaquah 98027	Soil Air Sediment	Confirmed Suspected Suspected	Awaiting assessment by Ecology	

Table 5.3 Ecology's Toxic Clean-Up Program

Site Name	Address	Affected Media	Contaminant Status	Site Status	Comments
Queen City Farms A (4 Tek)	22420 SE 168th Wy., Issaquah 98027	Ground Water Soil	Confirmed Confirmed	Remedial Action in progress	
Queen City Farms A (Buried Drum)	22420 SE 168th Wy., Issaquah 98027	Ground Water Soil	Confirmed Confirmed	Remedial action in progress	
Queen City Farms A	22420 SE 168th Wy., Issaquah 98027	Ground Water Soil	Confirmed Confirmed	Remedial action in progress	

Source: Department of Ecology, Bellevue. List dated October 13, 1993. (Feb. 1994)

Table 5.4 Operational Underground Storage Tanks Reported in the Issaquah Ground Water Management Area

Site Name/Address	Substance	Size	Age (yr)
Warren Iverson/Hobart 20250 276 SE/Box 250	Unleaded Gas	5000-9999	14
Warren Iverson/Hobart 20250 276 SE/Box 250	Diesel Fuel	1101-2000	3
Warren Iverson/Hobart 20250 276 SE/Box 250	Leaded Gas	10000-19999	9
Warren Iverson/Hobart 20250 276 SE/Box 250	Unleaded Gas	10000-19999	9
Preston Maintenance Facility 29726 SE Preston Way	Unleaded Gas	2001-4999	2
Preston Maintenance Facility 29726 SE Preston Way	Diesel Fuel	2001-4999	2
Preston Maintenance Facility 29726 SE Preston Way	Diesel Fuel	2001-4999	2
Preston General Store 30365 SE High Point Way	Leaded Gas	5000-9999	6
Preston General Store 30365 SE High Point Way	Diesel Fuel	5000-9999	6
Preston General Store 30365 SE High Point Way	Unleaded Gas	10000-19999	6
Preston General Store 30365 SE High Point Way	Unleaded Gas	10000-19999	6
Arco 6162 1403 NW Lk. Sammamish Rd.	Unleaded Gas	10000-19999	20
Arco 6162 1403 NW Lk. Sammamish Rd.	Leaded Gas	10000-19999	20
Arco 6162 1403 NW Lk. Sammamish Rd.	Unleaded Gas	10000-19999	20
Tiger Mt. Country Store 14331 Issaquah-Hobart Rd.	Alcohol Blend	10000-19999	11
Tiger Mt. Country Store 14331 Issaquah-Hobart Rd.	Alcohol Blend	10000-19999	11
Tiger Mt. Country Store 14331 Issaquah-Hobart Rd.	Diesel Fuel	10000-19999	11
Tiger Mt. Country Store 14331 Issaquah-Hobart Rd.	Alcohol Blend	10000-19999	11
Grange Supply Inc.	Alcohol Blend	10000-19999	20

Table 5.4 Operational Underground Storage Tanks Reported in the Issaquah Ground Water Management Area

Site Name/Address	Substance	Size	Age (yr)
145 NE Gilman Blvd.			
Grange Supply Inc. 145 NE Gilman Blvd.	Unleaded Gas	10000-19999	20
Grange Supply Inc. 145 NE Gilman Blvd.	Diesel Fuel	10000-19999	20
Grange Supply Inc. 145 NE Gilman Blvd.	Kerosene	5000-9999	20
Grange Supply Inc. 145 NE Gilman Blvd.	Diesel Fuel	10000-19999	20
Grange Supply Inc. 145 NE Gilman Blvd.	Alcohol Blend	10000-19999	20
Grange Supply Inc. 145 NE Gilman Blvd.	Diesel Fuel	5000-9999	20
Texaco Station 15 East Sunset Way	Unleaded Gas	5000-9999	7
Texaco Station 15 East Sunset Way	Unleaded Gas	10000-19999	7
Texaco Station 15 East Sunset Way	Leaded Gas	10000-19999	7
Texaco 63-232-0499 1605 NW Gilman Blvd.	Unleaded Gas	10000-19999	29
Texaco 63-232-0499 1605 NW Gilman Blvd.	Unleaded Gas	10000-19999	21
Texaco 63-232-0499 1605 NW Gilman Blvd.	Leaded Gas	10000-19999	29
Texaco 63-232-0499 1605 NW Gilman Blvd.	Unleaded Gas	5000-9999	21
Texaco 63-232-0499 1605 NW Gilman Blvd.	Leaded Gas	10000-19999	21
Texaco 63-232-0499 1605 NW Gilman Blvd.	Diesel Fuel	10000-19999	29
Texaco 63-232-0499 1605 NW Gilman Blvd.	Unleaded Gas	10000-19999	29
Plateau Texaco 2936 228th Ave SE	Leaded Gas Unleaded Gas Unleaded Gas	10000-19999 10000-19999 10000-19999	29 29 29
King County Water District 1510 228th Ave SE	Unleaded Gas Diesel Fuel	111-1100 111-1100	15 15

Table 5.4 Operational Underground Storage Tanks Reported in the Issaquah Ground Water Management Area

Site Name/Address	Substance	Size	Age (yr)
Fire Station 109 3425 Issaquah Pine Lake Rd.	Diesel Fuel	2001-4999	3
Fedderly Marion Freightlines 1740 NW Maple	Unleaded Gas	2001-4999	7
Maintenance Shops 20500 SE 56th St.	Diesel Fuel	2001-4999	29
Maintenance Shops 20500 SE 56th	Unleaded Gas	2001-4999	29
Maintenance Shops 20500 SE 56th	Used Oil/Waste Oil	111-1100	29
Brown Bear Car Wash 22121 SE 56th	Leaded Gas	5000-9999	1
Brown Bear Car Wash 22121 SE 56th	Unleaded Gas	10000-19999	1
Brown Bear Car Wash 22121 SE 56th	Diesel Fuel	5000-9999	1
Brown Bear Car Wash 22121 SE 56th	Unleaded Gas	10000-19999	1
Chevron 95399 25 NW Gilman Blvd.	Leaded Gas	10000-19999	3
Chevron 95399 25 NW Gilman Blvd.	Unleaded Gas	10000-19999	3
Chevron 95399 25 NW Gilman Blvd.	Unleaded Gas	10000-19999	3
The Southland Corp. 3302 E Lake Sammamish Pkwy.	Unleaded Gas	10000-19999	8
The Southland Corp. 3302 E Lake Sammamish Pkwy.	Unleaded Gas	10000-19999	8
The Southland Corp. 3302 E Lake Sammamish Pkwy.	Leaded Gas	10000-19999	8
James Perry 470 Front St. N		111-1100	45
Issaquah BP 55 NW Gilman Blvd.	Leaded Gas	10000-19999	15
Issaquah BP 55 NW Gilman Blvd.	Diesel Fuel	5000-9999	15
Issaquah BP 55 NW Gilman Blvd.	Unleaded Gas	10000-19999	6

Table 5.4 Operational Underground Storage Tanks Reported in the Issaquah Ground Water Management Area

Site Name/Address	Substance	Size	Age (yr)
Issaquah BP 55 NW Gilman Blvd.	Unleaded Gas	10000-19999	6
Darigold Inc. 611 Front St.	Diesel Fuel	10000-19999	32
Darigold Inc. 611 Front St.	Diesel Fuel	10000-19999	25
Darigold Inc. 611 Front St.	Diesel Fuel	10000-19999	25
Issaquah 070584	Diesel Fuel	111-1100	17
Issaquah 7340	Unleaded Gas	10000-19999	5
Issaquah 7340	Used Oil/Waste Oil	111-1100	5
Issaquah 7340	Unleaded Gas	10000-19999	5
Lakeside Sand & Gravel Co.	Diesel Fuel	10000-19999	5
Lakeside Sand & Gravel Co.	Diesel Fuel	10000-19999	5
Lakeside Sand & Gravel Co.	Leaded Gas	5000-9999	5
Lakeside Sand & Gravel Co.	Used Oil/Waste Oil	5000-9999	6
Harold J. Ruby ARCO 4466	Used Oil/Waste Oil	111-1100	3
Harold J. Ruby ARCO 4466	Leaded Gas	10000-19999	2
Harold J. Ruby ARCO 4466	Unleaded Gas	10000-19999	2
Harold J. Ruby ARCO 4466	Unleaded Gas	10000-19999	2
Harold J. Ruby ARCO 4466	Unleaded Gas	10000-19999	2
Transportation	Unleaded Gas	10000-19999	2
Transportation	Diesel Fuel	10000-19999	2
Transportation	Leaded Gas	10000-19999	2
Bethel Clark	Leaded Gas	10000-19999	10
Bethel Clark	Diesel Fuel	10000-19999	10
Bethel Clark	Unleaded Gas	10000-19999	10
Bethel Clark	Unleaded Gas	10000-19999	10
Kbog N Tiger Mtn/1500	Diesel Fuel	1101-2000	3

Source: Department of Ecology, October 8, 1993.

Table 5.5 Age of Underground Storage Tanks In Operation in the Issaquah Ground Water Management Area

Age (year)	Number of Tanks
1-2	14
3-5	13
6-10	20
11-15	9
16-20	11
21-30	15
Greater than 30	2
Total	**84**

Source: Ecology 1994.

Table 5.6 Substances Contained in Underground Storage Tanks in Operation in the Issaquah Ground Water Management Area

Substance	Number of Tanks
Leaded gas	15
Unleaded gas	35
Diesel fuel	23
Kerosene	1
Used/waste oil	4
Alcohol Blend	5
Unknown	1
Total	**84**

Source: Ecology 1994.

Table 5.7 Size of Underground Storage Tanks in Operation in the Issaquah Ground Water Management Area

Size (gallons	Number of Tanks
111-1,100	8
1,101-2,000	1
2,001-4,999	7
5,000-9,999	12
10,000-19,999	56
Total	**84**

Source: Ecology 1994.

Table 5.8 Ecology Current and Former Contaminated Underground Storage Tank Sites in the Issaquah Ground Water Management Area - January 7, 1994

Site Name	Address	City	Zip Code	Cleanup Status[a]	Media[b]
Texaco Station #004481	825 Front Street North	Issaquah	98027-2508	Awaiting	D
Grange Supply	145 NE Gilman Blvd	Issaquah	98027-2904	Conducted	D
King County Fire District #10	175 Newport Way NW	Issaquah	98027-3104	Conducted	D
Issaquah Feed Service	232 Front St. N	Issaquah	98027-3232	Conducted	D
Shell Station Issaquah	1605 NW Gilman Blvd	Issaquah	98027-5329	In Progress	A,D
Fedderly Marion Freight Lines	1740 NW Maple	Issaquah	98027-8977	In Progress	D
Car Wash Ent Issaquah Landfa	22121 SE 56th St	Issaquah	98027-9237	Conducted	D
Southland 7-II Station #26056	3302 Sammamish Pkwy	Issaquah	98027-9649	Awaiting	A,D
US West Issaquah Soc #01086	1200 12th NW	Issaquah	98027	Monitoring	A,D
ARCO Station #6162	1403 NW Lake Sammamish Rd	Issaquah	98027	Awaiting	D
Dept. of Transportation Newport Way Exit	SR 901 West Bound On-ramp	Issaquah	98027	In Progress	D
King County Issaquah Public Works	23240 SE 74th	Issaquah	98027	Conducted	D
BP Oil Station Issaquah	55 NW Gilman Blvd	Issaquah	98027-2427	In Progress	A
Chevron Station #9-5399	25 NW Gilman Blvd	Issaquah	98027-2427	Conducted	A,D
ARCO Station #4466	800 Front Street N	Issaquah	98027-2507	In Progress	A,D
Mobil Station #10-d6r	30 West Sunset Way	Issaquah	98027-3811	Monitoring	A,D
Texaco Station #0244	15 East Sunset Way	Issaquah	98027-3826	In Progress	A,D
Issaquah School District Bus Garage	805 2nd Avenue SE	Issaquah	98027-4312	Conducted	D
Southland 7-11 Station #26056	3302 E. Lake Sammamish Par	Issaquah	98027-9649	Waiting	A,D

Table 5.9 Hazardous Waste Generators in the Issaquah Ground Water Management Area

Business Name	Address (Issaquah)	RCRA Type Generator[a]
Captain's Cleaners	1025 Gilman Blvd.	3
Quantum Medical Systems, Inc.	1040 12th Ave. NW	2
Ecology's RAS Issaquah	1145 12th Ave. NE, Bldg. C.	2
USWCOM Issaquah	1200 12th Ave. NW	3
ZETEC	1370 NW Mall	3
Silicon Designs Inc.	1445 NW Mall St.	3
Auto Works Two	145 NW Gilman Blvd.	2
Texaco SS 63 232 0280	15 E. Sunset Way	2
Evergreen Ford	1500 18th Ave. NW	2
Bakamus Truck Repair Co.	1500 19th Ave. NW	2
ZETEC Machine Shop 2	1505 NW Mall St.	3
Circuit Partners Inc.	1575 NW Mall St., Bldg. C	1
Autoworks of Issaquah	1590 NW Mall	2
Texaco SS 6323499	1605 Gilman Blvd.	2
United Autobody	1650 NW Mall	2
Midas Muffler & Brake Shop	1655 NW Mall St.	2
Express Tune	1655 NW Mall St., Suite C.	3
Issaquah Honda Kubota	1875 NW Poplar Way	2
Ecology's NRO May Valley Drug Lab	19523 May Valley Rd.	2
Baxter Healthcare Bartels Div.	2005 NW Sammamish Rd.	1
WP & R Maintenance	20500 SE 56th St.	2
Gilman Auto Body	220 NE Gilman Blvd.	2
Brown Bear Car Wash	22121 SE 56th St.	3
Lawson Disposal	22819 SE 64th	2
Dirk's Fine Drycleaning	240 NW Gilman Blvd.	2
Chevron USA Inc. 95399	25 NW Gilman Blvd.	2
City of Issaquah	525 1st Ave. NW	1
CA Carey Corp.	537 NW Locust	2
Stone Dry Cleaners	5614 E. Lk. Sammamish Pky. SE	3
All Tech Collision Ctr.	6018 221st Pl. SE	2
Cadman Premix Co., Inc.	6600 230th Ave. SE	1
Lakeside Ind. Issaquah Div.	6600 230th Ave. SE	2
Daniells Cleaners	730C NW Gilman Blvd., Suite 105	3
Texaco SS 63231468	825 Front St.	2

Source: Department of Ecology, Bellevue. February 1994.

[a]Generator Type Legend:

1 = Generates or accumulates >2,200 lbs. (large quantity generator)

2 = Generates or accumulates <2,200 but >220 lbs.(medium quantity generator)

3 = Generates or accumulates <220 lbs. (small quantity generators)

Table 6.1 Preliminary Data On Major Producing Wells in the Issaquah Ground Water Management Area

Well Owner	Well No.	Yield/Drawdown (gpm/Dd-ft)	Static Water (ft)	Aquifer Material	Aquifer Transmissivity (gpd/ft)
City of Issaquah	1	1000/11.6	67	sand & gravel	NA
	2	NA	67	sand & gravel	NA
	3	275/15.7	33[1]	sand & gravel	NA
	4	225/51	54.5	sand & gravel	25,000
	5	1000/120	52.5	fine sand	50,000
SPW&SD	7	2000/38	64	sand & gravel	110,000
	8	2000/22	64	sand & gravel	150,000
Overdale Water Association	S21J 1	190/NA	flows	sand & gravel	NA
Darigold	S28J 1	400/10	70[1]	sand & gravel	NA
Lakeside Sand & Gravel	S27D 1	650/5	60[1]	sand & gravel	NA
Reid Sand & Gravel	S21R 1	500/NA	62[1]	sand & gravel	NA

Source: Department of Social and Health Services 1989.
[1] not screened entire length
NA = not available
Note: Static water is the level at which water stands in a well or unconfined aquifer when no water is being removed from the aquifer either by pumping or free flow. It is generally expressed as the distance from the ground surface (or from a measuring point near the ground surface) to the water level in the well.

Table 6.2 Existing Water Rights for the Issaquah Ground Water Management Area[1]

Purveyor	Use	Gallons Per Minute (GPM)	Millions of Gallons Per Day (MGD)	Acre Feet Per Year (AF/YR)
Mirrormont	D[2]	110	0.16	118
Four Lakes	D	150	0.22	82
First City Development Corporation	D	800	1.16	260
Overdale	D	190	.27	30
WA St. Parks	D	150	.22	18
Issaquah[3]	D	3,880	5.6	2,800
SPW & SD[6]	D	8,350	9.5	7,442
Consolidated Dairy	C/I[4]	1,100	1.58	1,232
Lakeside Gravel	D/C/I[5]	1,500	2.16	566

Source: Economic and Engineering Services, Inc. 1988, unless otherwise noted.

[1] Public water systems work in million gallons per day.
GPM in this table reflect the sustained yield of a well during a 24-hour pump test.
MGD is calculated based upon GPM. For example, Mirrormont MGD = 110 gpm x 1,440 minutes/day divided by a millions gallons = 0.16 MGD. AF/YR is not based upon GPM.
Acre feet per year is the maximum amount of water that a well can pump in one year under water rights which are determined by the Department of Ecology based upon the population served by the water system and the rate of use by gallons per person per day.

[2] Domestic

[3] Source: Sheldon Lynne, City of Issaquah, personal communication

[4] Commercial/Industrial

[5] Domestic/Commercial/Industrial

[6] Source: Sammamish Plateau Water and Sewer District, does not include SPWSD wells with conditional or supplemental rights

Table 6.3 Annual Water Demand By Use/Forecast By Use In Acre-Feet

Year	Single Family	Multi-Family	Commercial Industrial	Government Education	Total	Total with Conservation	Total with Losses of 15%
[a]City of Issaquah							
1986	420	580	145	50	1195	1195	1374
1990	451	802	188	54	1746	1480	1702
2000	649	1136	298	78	2160	2042	2348
2010	814	1416	390	98	2718	2591	2980
2020	1019	1761	510	122	3413	3282	3774
2030	1238	2127	639	149	4152	3995	4595
2040	1457	2493	767	175	4892	4709	5415
[a]Sammamish Plateau Water and Sewer District							
1986	1141	23	78	13	1255	1255	1443
1990	1440	51	99	16	1605	1583	1821
2000	2353	117	161	26	2658	2512	2889
2010	3247	287	223	36	3793	3616	4158
2020	4478	610	307	49	5445	5236	6022
2030	5823	934	399	64	7221	6980	8027
2040	7168	1258	476	77	8978	8706	10,012
[b]Mirrormont Services							
1986	0.138		0.092		0.413	0.002	0.445
1990	0.185		0.076		0.458	0.002	0.490
2000	0.343		0.074		0.824	0.003	0.907
2006	0.491		0.074		1.179	0.003	1.296

[a]Source: Economic and Engineering Services, Inc. 1988. CWSP.
Notes:
Classes shown as zero may be grouped in other classes.
Conservation Program started in 1990.

[b]Source: Interlake Associates 1994.
Notes:
Classes shown as zero may be grouped in other classes.
Conservation Program started in 1990.

Table 6.4A Population Projections Versus Forecast Demand - City of Issaquah

YEAR	Corporate Area Population	Potential Annexation Area Population	Total Population	Average Annual Demand (MGD)	Maximum Day Demand (MGD)
1990	7,786	16,880	24,666	1.22	3.10
2000	9,492	28,915	38,407	2.60	4.50
2020	12,815	45,828	58,643	4.50	8.00

Source: City of Issaquah Water System Plan Update. City of Issaquah Natural Resources Department, August 1995.

MGD = Million gallons per day

Table 6.4 Total Annual Water Demand Forecast in Acre-Feet

Year	Issaquah	Mirrormont	SPW&SD
1986	1374	0.445	1443
1990	1702	0.490	1821
2000	2348	0.907	2889
2010	2980	1.296	4158
2020	3774	1.296	6022
2030	4595	1.296	8027
2040	5415	1.296	10,012

Source: Economic and Engineering Services, Inc. 1988.
Interlake Associates 1994 (for Mirrormont only).

Table 6.5 Population Forecasts Using SAZ Data

GWMA	Acreage	Jurisdiction	Estimated Growth[a] 1990-2012	1993[a] Population	2012[a] Population
Issaquah	45,672	King County	7988	20,755	28,743
		City of Issaquah	2,694	4,065	6,759
		Total	10,682	24,820	35,502

[a]Population in number of household

Table 7.1 Summary of Soil Characteristics

Name	Type	Location	Important Characteristics
Alderwood Association			
Alderwood soils	Gravelly sandy loams	Common throughout Issaquah Ground Water Management Area on 6% to 35% slopes; 75% Alderwood - 25% Kitsap soil unit occurs on 25% to 75% slopes	Vertical recharge probably slow except that lateral subsurface movement to permeable zones could contribute substantially to recharge; severely limiting to septic tank filter fields; runoff slow to medium (6-15% slopes) to rapid (steep slopes)
Beausite-Alderwood Association			
Beausite soils	Gravelly sandy loams	Concentrated in central portion of Issaquah Ground Water Management Area on 6% to 75% slopes	Underlain by fractured sandstone; recharge probably not significant although lateral movement to permeable zones may contribute substantially to recharge; severely limiting to septic tank filter fields; runoff moderate to very rapid
Ovall Soils	Gravelly loams	Similar location as Beausite	Underlain by weathered andesite breccia; other characteristics same as Beausite
Everett Association			
Everett Soils	Gravelly sandy loam underlain by gravelly sand	South Sammamish Plateau on 0% to 30% slopes	Rapid permeability; recharge is probably significant; few limitations to septic tank filter fields, although these soils offer little protection to ground water quality; runoff slow to rapid; excessively well drained
Neilton Soils	Gravelly loamy sand underlain by stratified glacial drift	Similar location as Everett on 2% to 15% slopes	Runoff slow to medium; other characteristics same as Everett
Valley Soils			
Sammamish Soils	Silt loams stratified with fine sand and clay	Lower Issaquah Creek valley on 0% to 2% slopes	Moderately slow permeability; recharge probably slow, but may be significant in areas underlain by shallow aquifers; severe limitations to septic tank filter fields; seasonal high water table; flooding is a hazard; offers limited protection to underlying shallow aquifers

Table 7.1 Summary of Soil Characteristics

Name	Type	Location	Important Characteristics
Bellingham Soils	Similar to Sammamish	Similar to Sammamish	Similar to Sammamish
Briscot Soils	Silt loam stratified with fine sand	Similar to Sammamish	Moderate permeability; recharge to shallow unconfined aquifers is likely significant; otherwise similar to Sammamish
Puyallup Soils	Fine sandy loams	Similar to Sammamish on slightly convex slopes	Moderately rapid permeability; recharge to shallow aquifers is likely significant; severe limitations to septic tank filter fields; seasonal high water table; flooding potential slight to severe; offers limited protection to water quality
Puget Soils	Silty clay loam	Similar to Sammamish	Similar to, but even more severely limiting than Sammamish
Oridia Soils	Silt loam interspersed with fine sand and clay at depth	Similar to Sammamish	Similar to Sammamish
Sultan Soils	Silt loam with clayey and sandy zones at depth	Similar to Sammamish	Similar to Sammamish

Table 7.2 Characteristics of Geohydrologic Units in the Issaquah Ground Water Management Area

Geohydrologic Unit	Geohydrologic Unit Label	Characteristics
Vashon Stage Glacial Deposits		
Recessional Outwash Deposits	Qvr	Predominantly gravel, sand and minor amounts of silt. Where available it is a good source of recharge that can yield large quantities of water.
Recessional Lacustrinal Deposits	Qvrl	Predominantly clay and silt, with some sand and rarely gravel. Functions as a leaky aquitard.
Ice Contact Deposits	Qvl	A heterogeneous mixture of till and outwash deposits. These units have considerable hydrogeologic variability.
Till	Qvt	A massive heterogeneous mixture of silt, sand and gravel. The upper positions of these units can contain perched and semi-perched water tables. The isolated sand and gravel lenses yield limited quantities of water. Recharge of these lenses is usually slow.
Advance Outwash	Qva	Primary sand to cobble-size gravel with thin beds of silt. Where saturated, this unit yields large quantities of water.
Pre-Vashon Units		
Unnamed Sand		Chiefly well-sorted medium grade sand, lenses of gravel, silt and clay.Yields water to wells where saturated.
Upper Clay Unit		Massive silt and clay, peat beds: probably functions as an aquitard. Lenses of sand and gravel yield water for domestic supplies.
Unnamed Gravel		Cobble gravel, pebbles and sand which is a very permeable, productive aquifer material.
Lower Clay Unit		Almost entirely clay and silt with discontinuous beds of till and peat. Units have an impermeable bottom to upper units and a confining layer to lower aquifers.
Older Unconsolidated Deposits		Interbedded sand, silt, clay, minor gravel, till, volcanic ash with some high yield wells. The incidence of objectionable chloride reported.
Bedrock		
Unnamed Volcanic Rock	Tv	Volcaniclastic sandstone and siltstone which conglomerates with marine fossils. Unit has poor water-bearing potential.

Table 7.2 Characteristics of Geohydrologic Units in the Issaquah Ground Water Management Area

Geohydrologic Unit	Geohydrologic Unit Label	Characteristics
Blakely (?) Formation	Tb	Marine sediments, predominately sandstone and conglomerate which have poor water-bearing potential.
Renton Formation	Tr	Non-marine sandstone, claystone and coal with poor water-bearing potential.
Tukwila Formation	Tt	Volcaniclastic rocks and lava flows with poor water-bearing potential.
Tiger Mountain Formation	Tim	Non-marine arkosic sandstone, siltstone and coal with poor water-bearing potential.
Raging River Formation	Trr	Volcaniclastic sandstone and siltstone which conglomerate with marine fossils. Unit has poor water-bearing potential.
Intrusive Rocks	Ti	Andesites and basalts injected as dikes. Unit has poor water-bearing potential.

Table 7.3 Lower Issaquah Creek Valley Aquifer Characteristics

Aquifer Designation	Elevation (meters (ft))	Material	Transmissivity (m^2/day (gpd/ft))
A1 - upper fluvial sediments	-6.1 to -15.2 (-20 to 50)	Sand and gravel	372.7 (30,000)
A2 - lower glacio-fluvial sediments	-12.2 to -33.6 (-40 to -110)	Lenses of sand and gravel	2484.4 (200,000)
A3 - deep alluvial sediments	-61.0 to -106.7 (-200 to -350)	Sand	496.9 (40,000)

Source: Carr/Associates 1988.

Table 7.4 Selected Lower Valley Wells

Well Owner	Well No.	Zone Completed	Yield (m^3/day (gpm))	Specific Cap. (gpm/ft)	Transmissivity (m^2/day (gpd/ft))
Darigold	2	A1	2180 (400)	40	NA
Reid S&G	21R1	A1	2726 (500)	NA	NA
Lakeside S&G	27D1	A1	3543 (650)	130	NA
SPWD	7-1S	A1	409 (75)	7	508 (41,000)
SPWD	7-1D	A2	2726 (500)	25	2740 (221,000)
SPWD	7-3	A2	1199 (220)	33	1637 (132,000)
SPWD	7	A2	10,629 (1950)	52	3757 (303,000)
SPWD	8	A2	19,081 (3500)	90	2232 (180,000)
SPWD[1]	9	A3	no yield	unknown	unknown
Overdale W.A.	21H	A2	954 (175)	2	1141 (92,000)
City of Iss.	1	A1?	5451 (1000)	86	NA
City of Iss.	2	A1?	5451 (1000)	86	NA
City of Iss.	4	A1	1308 (240)	5	260 (21,000)
City of Iss.	5	A3	5451 (1000)	8	503 (40,600)

Sources: Carr/Associates 1983, 1984, 1988; Robinson & Noble 1986; Washington State Water Well Reports.
Note: Values are measured or reported rates during testing.
NA= Data not available
[1]SPWD is awaiting water rights from the Department of Ecology for well No. 9.

Table 7.5 Hydrostratigraphic Units

Unit	Permeability	Description
Bedrock	Low	Consolidated sedimentary and volcanic sediments including: sandstone, shale (sometimes with coal), andesite, and volcanic tuff. Can provide limited amounts of water to wells.
Aquitard	Low to Moderate	Unconsolidated ice-contact and marginal deposits of very silty sand and gravel, including till, alluvial and lake clay, silt, and fine silty sand.
Aquifer	Moderate to High	Unconsolidated ice-contact, deltaic, and alluvial deposits of sand; sand and gravel, and sand, gravel, and cobbles. All relatively free of silt and clay.

Source: Hydrogeological Report Carr/Associates, Sept. 1993.

Table 7.6 Issaquah Ground Water Management Area Water Level and Water Quality Monitoring Site List

Location No.	Site ID	Owner ID	System Name	Street Address	Altitude	Well Depth	Hole Depth	Diameter of Casing	Water Level	Date (Y-M-D) Measured
22N/07E-05N01	472745121570401	13274B	Crawford Michael	29212 SE 208th Street	746.17	101.00	101.00	6.00	35.00	19920316
22N/07E-06J02	472515121572501	59504E	Rahal Joann	28611 204th Street	591.62	125.00	125.00	6.00	51.78	19920316
22N/07E-07D05	472451121581101		Fire District 43	27605 SE 208th Street	575.25	79.00	79.00	6.00	7.25	19920316
22N/07E-07H02	472438121571601	30125A	Raub Ruth	29004 SE 216th Street	710.25	181.00	181.00	6.00	137.02	19920316
23N/06E-03A02	473049122005701		Allison Ron	10124 238th Way	268.24	144.00	147.00	6.00	111.78	19911108
23N/06E-03B04	473049122011602		Erickson Eric	10029 Issaquah-Hobart Road	158.65	42.00	49.00	6.00	23.20	19911108
23N/06E-03G02	473040122011801		Foothill Baptist Church	10120 Issaquah-Hobart Road	187.03	86.00	86.00	6.00	38.02	19911108
23N/06E-03H05	473039122005801	22777H	Young Ted	10124 238th Way	228.60	99.00	99.00	6.00	77.13	19911108
23N/06E-03K02	473027122011701		Hall Don	10805 Issaquah-Hobart Road	182.77	58.00	58.00	6.00	25.26	19900214
23N/06E-10K03	473023122012201		Brown Lawrence	12123 Issaquah-Hobart Road	184.25	33.00	33.00	6.00	6.62	19911108
23N/06E-10Q05	472924122011503		Hayes Nursery	12504 Issaquah-Hobart Road	194.81	68.00	68.00	6.00	11.13	19911108
23N/06E-15C04	472910122013902		Watson Joan	13116 223rd Street	223.33	53.00	53.00	6.00	10.10	19911108
23N/06E-15L04	472845122013604		Adams Richard	13915 233rd Way SE	298.43	88.00	88.00	6.00	47.00	19911108
23N/06E-15M02	472843122012601	227404	Four Creeks Ranch Water Assoc.	13728 229th SE	250.	133.00	133.00	10	8	19880615
23N/06E-15P03	472831122013702		Cook Jim	14116 233 Place SE	323.95	185.00	185.00	6.00	63.00	19911108
23N/06E-15R03	472830122010102		Jepsky Norm	24266 SE Tiger Mountain Road	419.24	108.00	108.00	8.00	80.00	19920316
23N/06E-16R01	472831122021801		Peek James	13728 229th Avenue SE	500.00	258.00	258.00	6.00	246.67	19860718
23N/06E-17G01	472857122035401		Verschaeve Hector	21207 SE May Valley Road	327.11	60.00	62.00	6.00	10.15	19911108
23N/06E-17H03	472854122034301		Hawes Don	21130 SE May Valley Road	392.35	132.00	132.00	8.00	97.20	19911108
23N/06E-22C01	472816122025401		Mooney Dee	14545 Cedar Grove Road SE	335.20	192.00	192.00	6.00	57.03	19911108
23N/06E-22M01	472750122015801		Stanley Ron Co. (Gene Lyle Comm)	15313 230th SE	420.00	160.00	160.00	8.00	141.00	19731017
23N/06E-22N01	472739122015801	54681R	Miller Dick W		510.00	400.00	405.00	6.00	327.00	19880615
23N/06E-22P03	472703122013301	80810J	Sneva	15729 Cedar Grove Road SE	325.00	85.00	87.00	6.00	10.00	19830311
23N/06E-24R01	472736121582701		Agnew Randy	27241 SE 156th Street	1070.49	271.00	271.00	8.00	8.21	19920316
23N/06E-26E05	472715122003901		Hayes Larry Well #1	16610 246th Place SE	439.04	152.00	152.00	6.00	80.13	19911108
23N/06E-26H01	472710122593801		Hines Donald	16604 Issaquah-Hobart Road	403.12	106.00	109.00	6.00	24.98	19911108
23N/06E-27A02	472720122011202		Greening Jackie	24223 SE 164th Street	388.51	117.00	117.00	6.00	65.81	19920316
23N/06E-27C01	472729122014101		Jackson Gary	16121 Cedar Grove Road	387.81	93.00	93.00	6.00	38.33	19911108
23N/06E-27E03	472720122020301	02996P	Cedar Acres (John Conner Well #1)	230th Ave SE & Cedar Grove Rd	390.00	200.00	200.00	6.00	100.00	19791101
23N/06E-27F02	472714122014101		Mitchell Robert	16231 Cedar Grove Road SE	400.00	360.00	360.00	6.00	77.00	19730411
23N/06E-27R01	472645122005501	52118T	Mazama Woods (Verco)	16918 240th Avenue SE	610.85	155.00	205.00	8.00	88.48	19920316
23N/06E-28B03	472725122023801	119301	Cedar Hills Landfill		580.00	347.00	347.00	8.00	314.00	19660000

Location No.	Site ID	Owner ID	System Name	Street Address	Altitude	Well Depth	Hole Depth	Diameter of Casing	Water Level	Date (Y-M-D) Measured
23N/06E-28Q01	472646122024201	264611	PW-1 / G-1 Cedar Grove Airport		370.00	250.00	250.00	8.00	0.00	
23N/06E-35B06	472636122000101		Brown Dave	25410 178th Street	672.93	320.00	360.00	6.00	74.88	19920316
24N/06E-14K01	473352122000001		Caldwell Laureita	25237 SE Issaquah-Fall City Rd	444.61	94.00	94.00	6.00	60.33	19920316
24N/06E-21J01	473258122022101	65000H	Overdale Park Water Assoc Primary		53.45	150.00	150.00	6.00	-0.0	19920316
24N/06E-21Q01	473243122023301		SPWSD/City of Issaquah Vt-2.1 Test	130 East Sunset Way	59.67	24.00	24.00	2.00		
24N/06E-22A01	473329122010101	65000H	Overdale Park Water Assoc Deep		569.66	510.00	510.00	12.00	112.75	19920316
24N/06E-22J02	473301122005602		Dean James	24109 SE Black Nugget Road	419.04	97.00	97.00	6.00	80.58	19920316
24N/06E-23C01	473322122001401		Matteson Marie	25045 SE Black Nugget Road	434.38	100.00	0.00	6.00	44.68	19920316
24N/06E-25P01	473153121590101		Foster Herb	26415 SE 79th	529.98	136.00	136.00	6.00	114.56	19920316
24N/06E-27D05	473227122020001		SPWD/City of Issaquah Vt-1 Test	130 East Sunset Way	85.95	160.00	187.00	8.00	6.15	19900129
24N/06E-27M01	473205122014101	363505	City of Issaquah Risdon Well #1		92.57	107.00	107.00	12.00	35.70	19911108
24N/06E-27M02	473206122014201	363505	City of Issaquah Risdon Well #2		93.06	97.00	200.00	12.00	34.80	19911108
24N/06E-28A03	473234122021502		SPWD Production Well #7		70.19	151.00	151.00	16.00	9.50	19920316
24N/06E-28A05	473234122021401	409009	Sammamish Plateau SWD #8		73.94	189.00	190.00	16.00	12.16	19920316
24N/06E-28A06	473234122021403		Sammamish Plateau SWD 7-1(D)		72.30	219.50	295.00	8.00	10.50	19920316
24N/06E-28A07	473234122021402		Sammamish Plateau SWD 7-1(S)		72.30	100.00	295.00	8.00	9.98	19920316
24N/06E-28A08	473236122021501		Sammamish Plateau SWD 7-3(D)		70.10	150.00	0.00	8.00	8.99	19920316
24N/06E-28B01	473237122023501	363505	City of Issaquah #4		66.97	112.00	200.00	16.00	6.40	19920113
24N/06E-28B02	473237122023502	363505	City of Issaquah #5		66.96	412.00	412.00	16.00	6.60	19920113
24N/06E-28B03	473236122023101	363505	City of Issaquah Test Well		67.09	450.00	650.00	6.00	12.45	19911108
24N/06E-28B04	473215122024901		Zetec		55.67	78.00	78.00	6.00	-2.00	19821015
24N/06E-29R01	473158122033301		Pommer James	7600 Renton-Issaquah Road	148.82	127.00	127.00	6.00	13.18	19920316
24N/07E-29Q01	473147121561601	188791	Preston Industrial # 2		520.48	50.00	50.00	6.00	20.38	19920316
24N/07E-29Q02	473154121562801	188791	Preston Industrial # 3		505.72	49.00	49.00	8.00	6.40	19920316
24N/07E-32A02	473134121560101	188791	Preston Industrial # 1r		523.40	48.00	83.00	8.00	23.95	19920316
24N/07E-32D03	473141121565703		Pendell Arthur J	29510 SE 82nd Street	607.83	156.00	156.00	6.00	106.50	19920316

Table 7.6B Issaquah Ground Water Management Area Water Level and Water Quality Monitoring Site List -- Sammamish Plateau Area†

Local well number	Latitude (degrees/ minutes/ seconds)	Longitude (degrees/ minutes/ seconds)	Geo-hydrologic unit	Land Surface elevation (feet above sea level)	Depth of well below land surface (feet)	Surface casing diameter (inches)	Use of water	Water level below land surface (feet)	Date of water level measure-ment (month/ day/year)	Hydraulic conductivity (feet per day)	Remarks
24N/06E-02E01	473551	1220042	Qvt	530	40	6	P	11.84	07-09-90	220	LMS
24N/06E-02P01	473520	1220010	--	420	110	10	U	--	--	--	--
24N/06E-02P02	473518	1220011	--	420	100	6	U	--	--	--	--
24N/06E-03E01	473547	1220200	Qva	560.44	176	6	P	--	--	--	L
24N/06E-03P01	473529	1220136	Qva	380	68	6	U	26.68	07-10-90	28	L
24N/06E-03P02	473522	1220142	Qva	375	97	6	H	--	--	63	L
24N/06E-03R01	473519	1220054	Qvr	385	12	30	U	--	--	--	--
24N/06E-04J01	473533	1220220	Qvt	412.65	31.5	1.25	U	12.14	07-10-90	--	L
24N/06E-04K01	473533	1220235	Qvr	426.77	17	72	U	4.82	07-10-90	--	W
24N/06E-04N01	473527	1220302	Q(A)c	449	300	10	U	--	--	--	L
24N/06E-04N01P1	473527	1220302	Q(A)c	449	300	10	U	187.11	09-14-90	--	L
24N/06E-04N02	473527	1220303	Q(A)c	449	346	12	U	--	--	84	L
24N/06E-04N02P1	473527	1220303	Q(A)c	449	316	12	U	191.95	09-14-90	--	L
24N/06E-04N02P2	473527	1220303	Q(A)c	449	265	12	U	187.66	09-14-90	--	L
24N/06E-04P02	473519	1220257	Qvt	406.24	54.1	1.25	U	18.61	07-06-90	--	L
24N/06E-05D01	473606	1220416	Qal	130	6.5	36	U	3.61	07-13-90	--	--
24N/06E-05D02	473605	1220420	Qal	135	12	30	H	9.66	07-13-90	--	--
24N/06E-05H01	473551	1220324	Qva	350	153	6	H	--	--	--	L
24N/06E-08F01	473459	1220413	Q(A)c	355	342	6	H	--	--	--	L
24N/06E-08J01	473451	1220329	Qvt	384.32	25	84	Z	--	--	--	--
24N/06E-08K02	473450	1220343	Qvt	410	47	36	U	24.21	07-19-90	--	--
24N/06E-08P02	473433	1220409	Q(A)f	110	185	8	Z	--	--	--	L
24N/06E-09A07	473511	1220208	Qva	402.27	110	6	H	85.07	07-11-90	--	--
24N/06E-09A09	473517	1220205	Qvr	417.22	29.2	1.25	U	8.71	07-06-90	--	L
24N/06E-09A10	473517	1220214	Qvt	401.19	47.5	1.25	U	31.98	07-06-90	--	L
24N/06E-09A11	473518	1220214	Q(B)f	401.68	424	2	U	158.77	07-06-90	--	LW
24N/06E-09A12	473518	1220214	Qva	401.70	123	2	U	72.81	07-06-90	--	W
24N/06E-09A13	473518	1220214	Q(A)f	401.87	231	2	U	87.96	07-06-90	--	W
24N/06E-09A14	473518	1220214	Qva	401.69	203	2	U	86.16	07-06-90	--	W

Local well number	Latitude (degrees/ minutes/ seconds)	Longitude (degrees/ minutes/ seconds)	Geo-hydrologic unit	Land Surface elevation (feet above sea level)	Depth of well below land surface (feet)	Surface casing diameter (inches)	Use of water	Water level below land surface (feet)	Date of water level measure-ment (month/ day/year)	Hydraulic conductivity (feet per day)	Remarks
24N/06E-09A15	473518	1220214	Qva	401.51	170	2	U	85.34	07-09-90	--	W
24N/06E-09E03	473503	1220306	Qva	385	251	6	H	120.78	07-06-90	4.1	LM
24N/06E-09E04	473504	1220306	Q(A)f	386.27	420	2	U	75.23	07-06-90	--	L
24N/06E-09H02	473502	1220212	Qva	403.53	101	6	H	87.54	07-11-90	--	L
24N/06E-09J01	473449	1220205	Qva	430	130	12	C	115.72 S	07-12-90	3,400	L
24N/06E-09J02	473449	1220207	Qva	430	132.5	12	C	119.20 R	07-12-90	6,100	L
24N/06E-09N02	473429	1220302	Qva	310	199	6	H	99.40	07-11-90	10	LWM
24N/06E-09N03	473428	1220313	Q(A)f	350	202	6	H	99.08	07-11-90	32	L
24N/06E-10C01	473513	1220127	--	370	20	30	Z	--	--	--	--
24N/06E-10D01	473517	1220159	Qvr	387.12	31.7	1.25	U	6.17	07-13-90	--	L
24N/06E-10H01	473502	1220059	Qva	455	150	12	U	119.79	08-22-90	930	L
24N/06E-10H02	473501	1220059	Qva	455	155.2	16	P	120.96	08-22-90	1,400	LMVPS
24N/06E-10H03	473503	1220058	Qva	455	169	8	U	121.29	09-14-90	1,300	L
24N/06E-10L02	473441	1220128	Qvt	360	109	6	U	43.48	07-16-90	32	L
24N/06E-10P02	473430	1220124	Qva	355	72	6	H	--	--	46	LMS
24N/06E-11B01	473506	1215956	Qva	440	92	6	Z	--	--	--	--
24N/06E-11K01	473448	1215954	Qva	430	116	12	P	63.95	08-22-90	200	L
24N/06E-11L01P1	473439	1220016	Qva	420	135	8	U	65.18	09-14-90	--	LW
24N/06E-11L01P2	473439	1220016	Qva	420	95	8	U	66.45	09-14-90	--	LW
24N/06E-11L01P3	473439	1220016	Qvt	420	25	8	U	23.05	09-14-90	--	L
24N/06E-12B01	473510	1215845	Q(A)c	430	160	6	H	119.67	08-10-90	92	LM
24N/06E-12L01	473439	1215909	Q(A)f	440	362	6	H	--	--	12	LM
24N/06E-12N02	473425	1215915	Q(A)c	450	208	6	H	--	--	11	L
24N/06E-12R01	473429	1215819	Qva	450	108	8	P	80.10	07-16-90	1,100	L
24N/06E-13D01	473411	1215918	Qva	475	155	6	H	136.20	07-16-90	310	L
24N/06E-14H02	473410	1215943	Qva	480	124	6	H	91.13	07-16-90	540	L
24N/06E-14N01	473341	1220032	Multiple	460	198	6	U	111.93	07-17-90	--	L
24N/06E-14N02	473337	1220045	Qvr	470	146	6	Z	--	--	230	L
24N/06E-15C01	473420	1220137	Qva	355	79	6	H	19.69	07-17-90	9.6	L
24N/06E-15F01	473403	1220128	Qvt	370	156	6	H	F	07-17-90	.04	L
24N/06E-15N01	473334	1220148	Br	450	160	6	H	--	--	.72	L
24N/06E-16E01	473410	1220312	Q(A)c	125	196	6	H	54.06	09-26-90	--	L
24N/06E-16E02	473406	1220310	--	60	10	48	Z	--	--	--	L

Local well number	Latitude (degrees/ minutes/ seconds)	Longitude (degrees/ minutes/ seconds)	Geo-hydrologic unit	Land Surface elevation (feet above sea level)	Depth of well below land surface (feet)	Surface casing diameter (inches)	Use of water	Water level below land surface (feet)	Date of water level measure-ment (month/ day/year)	Hydraulic conductivity (feet per day)	Remarks
24N/06E-16L02	473354	1220301	--	55	84	6	H	-0.52 F	07-19-90	--	L
24N/06E-21A01	473328	1220216	Br	425	120	8	U	40.87	07-19-90	1.4	L
24N/06E-21B01	473332	1220231	Br	390	200	8	H	63.49	07-19-90	28	L
24N/06E-21J01	473306	1220221	Qva	55	150	6	P	F	10-30-90	150	L
24N/06E-22A02	473327	1220059	Qvt	450	85	6	I	49.53	08-10-90	61	L
24N/06E-22C01	473332	1220133	Br	420	240	6	H	51.90	08-09-90	.21	L
24N/06E-22F01	473319	1220136	Br	555	510	12	P	112.74	10-30-90	--	L
24N/06E-22H02	473311	1220105	Qvr	425	86	6	H	62.38	08-09-90	8.7	LM
25N/06E-20E01	473819	1220427	Q(B)c	70	122	6	H	24.97	05-10-90	--	LWM
25N/06E-26A02	473748	1215945	Qal	115	60	8	H	10.73	06-29-90	1.7	L
25N/06E-26P01	473712	1220020	Qvr	345	63	6	H	8.88	09-14-90	11	L
25N/06E-27J01	473718	1220056	Qvr	405	152	6	P	128.58 R	09-19-90	26	L
25N/06E-27K01	473719	1220108	Qvr	370	150	6	P	87.34	09-19-90	8.3	L
25N/06E-27N01	473712	1220145	Qvr	425	238	6	H	229.93	08-08-90	--	LW
25N/06E-28H01	473728	1220207	Qvr	425	47	6	H	11.26	07-03-90	24	LM
25N/06E-29C01	473742	1220407	Q(B)c	100	178	8	H	F	06-28-90	97	L
25N/06E-32F03	473645	1220403	Q(A)c	50	116	6	H	F	06-28-90	31	LM
25N/06E-32L02	473626	1220406	Q(A)c	100	101	12	H	F	06-28-90	--	L
25N/06E-33K01	473623	1220239	Q(A)c	480	337	6	H	273.72	12-12-90	--	L
25N/06E-33N03	473616	1220310	Qva	410	200	6	H	163.27	08-07-90	--	L
25N/06E-34D01	473659	1220148	Qva	360	214	6	H	174.35 P	07-03-90	860	LMS
25N/06E-34E02	473634	1220144	Q(B)c	370	714	20	P	--	--	37	LM
25N/06E-34M01	473633	1220150	Q(B)c	360	717	12	P	237.15	08-22-90	--	L

Explanation of Terms:

[-- - not determined]

Geohydrologic Unit:

- Qal - alluvium
- Qvr - Vashon recessional outwash
- Qvt - Vashon till
- Qva - Vashon advance outwash
- Q(A)f - Upper fine-grained unit
- Q(A)c - Upper coarse-grained unit
- Q(B)f - Lower fine-grained unit

Water Level (status of well at time of visit):

- F - flowing
- P - pumping
- R - recently pumping
- S - nearby well pumping
- T - nearby well recently pumping

Q(B)c - Lower coarse-grained unit
Br - Bedrock

Use of Water:

- C - commercial
- H - domestic
- I - irrigation
- N - industrial
- P - public supply
- R - recreational
- S - stock
- T - institutional
- U - unused

Remarks:

- L - driller's (lithologic) log available
- W - project observation well for water level
- M - sampled for major ions, bacteria, trace metals and field parameters
- V - sampled for volatile organic compounds
- P - sampled for pesticides
- S - sampled for detergents, boron and dissolved organic carbon

†Source: USGS, *Geohydrology and Ground-Water Quality of East King County, Washington*, Water Resources Investigations Report 94-4082, 1995.

Table 7.7 Susceptibility Ranking of NRCS Soil Units

NRCS Map Symbol	NRCS Soil Unit Name	Relative Physical Susceptibility
EvB	Everett	high
EvC	Everett	high
EvD	Everett	high
InA	Indianola	high
InC	Indianola	high
Pc	Pilchuck	high
RdC	Ragnar-Indianola	high
Re	Renton	high
AgC	Alderwood	moderate
AgD	Alderwood	moderate
AkF	Alderwood	moderate
AmC	Arents	moderate
Br	Briscot	moderate
Ea	Earlmont	moderate
KpB	Kitsap	moderate
KpD	Kitsap	moderate
No	Norma	moderate
Os	Oridia	moderate
So	Snohomish	moderate
Su	Sultan	moderate
Sk	Seattle muck	moderate
Tu	Tuckwila muck	moderate
Bh	Bellingham	moderate
Pu	Puget	low

Table 7.8 Susceptibility Ranking of USGS Geologic Units

Geologic Symbol	Geologic Unit Name	Relative Physical Susceptibility
Qaf	Alluvial fan deposits	high
Qual	Older alluvium	high
Qvr	Recessional outwash	high
Qvrb	Recessional outwash	high
Qvrd	Redmond Delta	high
Qvro	Older recessional outwash	high
Qvry	Recessional outwash	high
Qva	Advance outwash	high
Qc	Colluvium	moderate
Qls	Landslide deposits	moderate
Qmw	Mass wasting deposits	moderate
Qob	Olympia beds	moderate
Qyal	Younger alluvium	moderate
Qsw	Swamp deposits	low
Qtb	Transitional beds	low
Qvrc	Clay	low
Qvt	Glacial till	low

Table 7.9 Susceptibility Ranking for Depth to Water Criteria

DEPTH TO WATER Depth Below Ground Surface (feet)	Relative Physical Susceptibility
0-25	high
>25-75	moderate
>75	low

Table 7.10 Causal Relationship Between Land Use Activities and Water Quality

Contaminant Source	Cause	Potential Contaminants
Public Infrastructure and Utility Services		
Septic tank effluent	Improper site selection, design, construction and/or maintenance	Pathogens, nitrates, chlorides, sodium, inorganic chemicals, hazardous substances (cleaning compounds, solvents, pesticides, petroleum products, organic chemicals, heavy metal(s)
Leaking sewer lines	Improper design, construction and/or maintenance	Same as for septic tank effluent above
Hazardous substance use, storage and disposal (domestic, commercial and industrial)	Improper use, inadequate containment, improper disposal, assimilative capacity of application site exceeded, spills, lack of practical disposal facilities or methods	Hazardous substances (solvents, petroleum products, heavy metals, organic and inorganic chemicals, pesticides)
Pumping-induced ground water contamination	Natural and altered aquifer hydrogeochemical conditions, well location and depth, pumping patterns and rates, alteration of recharge area hydrology, overpumping, inadequate well construction or seals	Iron, manganese and hydrogen sulfide, highly mineralized, saline or brackish water
Introduction of wastes through wells	Improper abandonment of wells, use of wells for waste disposal or injection, use of dry wells for surface drainage	Uncontrolled introduction of hazardous substances and pathogens
Mortuary and cemetery operations and maintenance	Inadequate disposal of wastes, improperly located graveyards, over-fertilization of grounds	Pathogens, organic chemicals, heavy metals, nitrate
Transportation spills of hazardous chemicals	Improper emergency response and cleanup of accidental releases	Hazardous substances (petroleum products, organic chemicals, solvents, pesticides, concentrated toxins, caustics, heavy metals, radioactive materials, pathogens
Vegetation control for right-of-way maintenance	Application of herbicides in excess of surface assimilative capacity	Pesticides
Provision and transmission of electrical power	Leakage of insulating fluids	Organic chemicals (PCBs)

Table 7.10 Causal Relationship Between Land Use Activities and Water Quality

Contaminant Source	Cause	Potential Contaminants
Storm water drainage	Conveyance and infiltration of transportation-related wastes deposited on roadways and streets	Petroleum products, organic chemicals (tire rubber), heavy metals (lead)
Landfill leachate	Inadequate or improper siting, design, construction, operation and closure of facilities, uncontrolled acceptance of hazardous substances for disposal	Pathogens, nitrate, iron and manganese, hazardous substances (organic and inorganic chemicals, pesticides, solvents, petroleum products, caustics, heavy metals and radioactive materials)
Parks, golf courses and landscaping	Over-application of fertilizers and pesticides, leaking fertilizer and pesticide storage containers	Nitrate, pesticides
Commercial Agriculture and Hobby Farms		
Animal feedlots, pens, waste storage	Improper siting, animal density exceeds natural waste assimilative capacity of soils, inadequate waste collection, storage, treatment and disposal, lack of fencing through creeks	Nitrate and pathogens
Nurseries, commercial crops	Leakage from inadequate containers, improper storage practices, over-application of fertilizers and pesticides	Pesticides, nitrates, petroleum products, hazardous substances
Introduction of hazardous substances and wastes through wells	Lack of adequate backwash prevention valves for chemigation and manurigation, improper abandonment of wells, use of wells for waste disposal or injection, use of dry wells for surface drainage	Nitrate, pesticides, pathogens, hazardous substances
Sand and Gravel Mining		
Open pits in or above aquifers	Improper abandonment and filling with unsuitable wastes	Petroleum products, hazardous wastes, pathogens, iron, metals
Equipment fuel tank leakage	Inadequate containment, vandalism	Petroleum products
Illegal "midnight" dumping in excavated pits	Criminal behavior and moral turpitude, inadequate security for active operations and inadequate closure practices or law	Uncontrolled varied wastes - hazardous wastes (sludges, organic and inorganic chemicals) from industrial, agricultural, commercial

Table 7.10 Causal Relationship Between Land Use Activities and Water Quality

Contaminant Source	Cause	Potential Contaminants
	enforcement for abandoned sites	and domestic sources, pathogens and nitrates from septage, animal carcasses and vermin
Timber Harvesting		
Fuel and pesticide storage	Inadequate containment	Petroleum products and pesticides
Control of weeds and pests, fertilization of seedlings	Improper application	Pesticides and nitrates
Removal of timber and vegetation	Stimulated vegetative nutrient release through plant death, combustion and decay	Nitrates

Table 7.11 Potential Impacts To Quantity

Activity	Impact
Residential and Commercial Development	
Using private supply water wells	Increased discharge & translocation of ground water
Using on-site septic tank sewage disposal system effluent	Formation of shallow ground water recharge mounds
Constructing impermeable surfaces (rooftops, pavement, parking lots, drainage systems)	Increased runoff; decreased infiltration & recharge
Excavating cut slopes & fill additions	Altered evapotranspiration, surface drainage, infiltration & recharge; increased discharge for irrigation
Operating & Maintaining cemeteries	Altered percolation of ground water; increased discharge for irrigation
Public Infrastructure and Utilities Services	
Excavating utilities & pipelines	Altered percolation of ground water
Installing grounded bed borings for pipelines & structures	Interconnection of surface drainage & aquifer systems
Constructing streets & roads, highway interchanges, parking lots, facilities with impermeable surfaces & rooftops	Increased runoff; decreased infiltration & recharge; increased ponding & flooding with possible erosion downstream from collection points
Controlling vegetation in rights-of-way	Increased runoff; decreased infiltration & recharge
Constructing storm drainages	Increased runoff; decreased infiltration & recharge; increased ponding & flooding with possible erosion downstream from collection points
Constructing sanitary sewers	Translocation water; increased shallow ground water recharge along leaks; possible ground water infiltration into sewer pipes
Constructing public water supply systems	Translocation of water
Constructing, operating & closing landfills	Altered infiltration, surface drainages, ground water percolation, aquifer interconnections, &

Table 7.11 Potential Impacts To Quantity

Activity	Impact
	recharge mounding
Maintaining vegetation along utility corridors & transportation rights-of-ways	Increased discharge for irrigation; translocation of water; varied evapotranspiration; infiltration & recharge
Commercial Agriculture and Hobby Farms	
High-Density animal husbandry	Increased surface runoff; decreased infiltration & recharge
Irrigation & stock watering	Translocation of ground & surface water; shallow recharge mounding
Field preparation & crop cultivation	Varied evapotranspiration; increased runoff; decreased infiltration & recharge
Operations (removal of overburden, sand & gravel, excavation site dewatering)	Decreased physical aquifer capacity, increased discharge of ground water to surface; altered surface drainage; interconnected aquifer systems
Abandonment of operations	Varied local ground water recharge of discharge; translocation of aquifer water; altered surface drainage
Timber Harvesting	
Tree & vegetation removal	Increased runoff; decreased infiltration & recharge; varied disruption of evapotranspiration processes
Access road construction	Increased surface runoff; decreased infiltration & recharge

Table 7.12 Precipitation and Stream Gauging Stations as Numbered in Figure 7.13

Precipitation Station Number	Stream Gauging Station Number	Site Location	Address	Reporting Agency
71		Upper Tibbets Creek	SE 182	SWM
72		North side of Grand Ridge		SWM
73		East Fork of Issaquah Creek		SWM
74		McDonald Creek		SWM
75		Holder Creek	276 Ave SE	SWM
7		Hobart	PO Box 55	Seattle-King County Health Department - Iverson
8		Francis Lake	23436 SE 192 St.	Seattle-King County Health Department - Short
10		Laughing Jacobs Lake	22905 SE 40 St.	Seattle-King County Health Department - Rothie
15		High Valley/Eastside Squak Mt.	12234 210 Pl. SE	Seattle-King County Health Department - Merrill
16		Issaquah	9506 240th Ave SE	Seattle-King County Health Department - Kees
17		Fifteen Mile Creek		DNR
18		Tiger Mt.		DNR
19		Preston		DNR
20		Issaquah Fish Hatchery		DNR
21		Cedar Hills		King County
22		Mirrormont area	25440 SE 184 St.	Seattle-King County Health Department - Leroux

Table 7.12 Precipitation and Stream Gauging Stations as Numbered in Figure 7.13

Precipitation Station Number	Stream Gauging Station Number	Site Location	Address	Reporting Agency
23		Fire Station 106/Maple Hills Park	20505 SE 152 Ave.	Seattle-King County Health Department - Massena
24		Grand Ridge area	28404 SE 58 St.	Seattle-King County Health Department - Weckwerth
25		Cougar Mt. area	17640 SE Cougar Mt. Rd	Seattle-King County Health Department - Leake
	52	Laughing Jacobs Lake near Lk. Sammamish		USGS
	53	Issaquah Creek near Issaquah	NW Sammamish Rd. Bridge	USGS
	54	Tibbets Creek at Lk. Sammamish State Park	Lake Sammamish ranger station	SWM
	55	Upper Tibbets Creek	Newport Way crossing	USGS
	56	North Fork Issaquah Creek	SE 66 St. bridge	SWM
	57	East Fork Issaquah Creek at Issaquah		SWM
	57	East Fork Issaquah Creek at Issaquah	1st Ave NW	USGS
	58	Fifteen Mile Creek near Issaquah Creek	May Valley Rd. Bridge	SWM
	59	Issaquah Creek above Fifteen Mile Creek		USGS

Table 7.12 Precipitation and Stream Gauging Stations as Numbered in Figure 7.13

Precipitation Station Number	Stream Gauging Station Number	Site Location	Address	Reporting Agency
	60	McDonald Creek	229 Dr. SE	SWM
	61	Carey Creek	Issaquah - Hobart Rd.	SWM
	62	Holder Creek	Issaquah - Hobart Rd.	SWM
	63	Upper Fifteen Mile Creek		WADNR
	64	Issaquah Creek		WADNR
	65	Unnamed stream near Raging River		WADNR
	66	Holder Creek		WADNR
	67	Issaquah Creek	252 Ave SE Bridge	USGS

Table 7.13 Summary of Stream Gauging Stations in the Issaquah Ground Water Management Area

Site Number	Map Ref. Number	T-R-S Location	Site Location	Period of Record	Reporting Agency
12121720	52	T24N-R6E-16M	Laughing Jacobs Cr. near Lake Sammamish	1987-1988	USGS[a]
12121600	53	T24N-R6E-21E	Issaquah Cr. near Issaquah NW Sammamish Rd. Bridge	1963-	USGS
67A SWM	54	T24N-463-20G	Tibbetts Cr. @ Lk. Sammamish State Park, Lake Sammamish Ranger Station	1988-	SWM[b]
12121700	55	T24N-R6E-29G	Upper Tibbetts Cr. Newport Way Crossing	1963-1968; 1971-1976	USGS
46A SWM	56	TW4N-R63-27D	North Fork Issaquah Cr. SE 66th St. Bridge	1988-	SWM
12121510	57	T24N-R6E-28J	East Fork Issaquah Cr. @ Issaquah	1975-1981	USGS
14A SWM	57	T24N-R63-28L	East Fork Issaquah Cr. @ Issaquah 1st Avenue NW	1988-	SWM
25C SWM	58	T23N-R6E-15E	Fifteenmile Cr. near Issaquah Cr. May Valley Rd. Bridge	1988-	SWM
12121000	59	T23N-R6E-15E	Issaquah Cr. above Fifteenmile Cr.	1945-1964	USGS
25D SWM	60	T23N-R6E-15M	McDonald Cr. 229th Dr. SE	1988-	SWM
25F SWM	61	T23N-R6E-25N	Carey Cr. Issaquah-Hobart Rd.		SWM
25E SWM	62	T23N-R6E-25N	Holder Cr. Issaquah-Hobart Rd.	1988-	SWM
	63	T23N-R6E-14J	Upper Fifteenmile Cr.	1987-	DNR[c]
	64	T23N-R7E-22K	Issaquah Cr.	1987-	DNR
	65	T24N-R7E-33M	Unnamed Stream near Raging River	1987-	DNR
	66	T23N-R7E-19R	Holder Cr.	1987-	DNR
12120600	67	T23N-R6E-26B	Issaquah Creek 252nd Avenue S. Bridge	1986-	USGS

[a]U.S. Geological Survey.
[b]King County Department of Natural Resources, Surface Water Management Division
[c]Washington State Department of Natural Resources.

Note: Does not include Sammamish Plateau Stream Gauging Stations

Table 7.14 1988 Estimated Issaquah Ground Water Management Area Major Basin Exports Of Water

Exporter	Form	Quantity m^3/y (MGY)	Basin-mm (Basin-in)
City of Issaquah[a]	waste water	1,362,604 (359.7)	7.9 (0.31)
Darigold	waste water	202,652 (53.5)	1.3 (0.05)
SPWD	water supply	1,515,152 (400)	8.6 (0.34)
Cedar Hills Landfill[b]	leachate	650,000 (171)	3.0 (0.12)

Source: Metro 1988
[a] City of Issaquah estimates are for 1989.
[b] Cedar Hills Landfill estimates are for 1992.

Table 7.15 Group A Parameters

Parameter	Unit	Detection Limit	Preferred Method
Biological Parameters, Group A-1			
Total Coliforms	MPN/100ml	<2.2	EPA (5-tube)[a]
Fecal Coliforms	MPN/100ml	<2.2	EPA (5-tube)[a]
Physical Parameters, Group A-2			
Total Dissolved Solids	mg/L	1	EPA 160.1
Total Hardness, $CaCO_3$	mg/L	1	EPA 130.2
Alkalinity			
Bicarbonate	mg/L	1	EPA 310.1
Carbonate	mg/L	1	EPA 310.1
Inorganic Parameters, Group A-3			
Calcium	mg/L	.5	EPA 215.2
Iron	mg/L	.03	EPA 236.1
Manganese	mg/L	.01	EPA 243.1
Magnesium	mg/L	.5	EPA 242.1
Potassium	mg/L	.5	EPA 258.1
Sodium	mg/L	.5	EPA 273.1
Chloride	mg/L	1	EPA 325.1,.2,.3
Nitrate-N	mg/L	1	EPA 352.1
Silica	mg/L	2	EPA 370.1
Sulfate	mg/L	5	EPA 375.2,.3,.4
Zinc	mg/L	.02	EPA 289.1
Silver	mg/L	.01	EPA 272.1
Selenium	mg/L	.005	EPA 270.2,.3
Mercury	mg/L	.0002	EPA 245.1,.2
Fluoride	mg/L	.1	EPA 340.1,.2,.3
Barium	mg/L	.2	EPA 208.1
Copper	mg/L	.1	EPA 220.1
Cadmium	mg/L	.001	EPA 213.2
Lead	mg/L	.005	EPA 239.2
Chromium	mg/L	.005	EPA 218.2,.3,.5

Table 7.16 Volatiles'Group B-1 Parameters'EPA Method 624

Volatiles	Detection Level µg/L
Acrolein	5
Acrylonitrile	5
Chloromethane	1
Bromomethane	1
Vinyl Chloride	1
Chloroethane	1
Methylene Chloride	1
Acetone	1
Carbon Disulfide	1
1,1-Dichloroethene	1
1,1-Dichloroethane	1
Trans-1,2-Dichloroethane	1
Chloroform	1
1,2-Dichloroethane	1
2-Butanone	1
1,1,1-Trichloroethane	1
Carbon Tetrachloride	1
Vinyl Acetate	1
Bromodichloromethane	1
1,2-Dichloropropane	1
Trans-1,3-Dichloropropene	1
Trichloroethene	1
Dibromochloromethane	1
1,1,2-Trichloroethane	1
Benzene	1
cis-1,3-Dichloropropene	1
2-Chloroethylvinylether	1
Bromoform	1
4-Methyl-2-Pentanone	1
2-Hexanone	1
Tetrachloroethene	1
1,1,2,2-Tetrachloroethane	1
Toluene	1
Chlorobenzene	1
Ethylbenzene	1
Styrene	1
Total xylenes	1

Table 7.17 Semi-Volatiles'Group B-2 Parameters'EPA Method 625

Semi-Volatiles	Detection Level µg/L
N-Nitrosodimethylamine	2
Phenol	2
Aniline	2
bis(-2-Chloroethyl)Ether	2
2-Chlorophenol	2
1,3-Dichlorobenzene	2
1,4-Dichlorobenzene	2
Benzyl Alcohol	2
1,2-Dichlorobenzene	2
2-Methylphenol	2
bis(2-chloroisopropyl)Ether	2
4-Methylphenol	2
N-Nitroso-Di-n-propylamine	2
Hexachloroethane	2
Nitrobenzene	2
Isophorone	2
2-Nitrophenol	2
2,4-Dimethylphenol	2
Benzoic Acid	2
bis(2-Chloroethoxy)Methane	2
2,4-Dichlorophenol	2
1,2,4-Trichlorobenzene	2
Naphthalene	2
4-Chloroaniline	2
Hexachlorobutadiene	2
4-Chloro-3-Methylphenol	2
2-Methylnaphthalene	2
Hexachlorocyclopentadiene	2
2,4,6-Trichlorophenol	2
2,4,5-Trichlorophenol	2
2-Chloronaphthalene	2
2-Nitroaniline	2
Dimethyl Phthalate	2
Acenaphthylene	2
3-Nitroaniline	2
Acenaphthene	2
2,4-Dinitrophenol	2
Dibenzofuran	2

Table 7.17 Semi-Volatiles'Group B-2 Parameters'EPA Method 625

Semi-Volatiles	Detection Level µg/L
2,4-Dinitrotoluene	2
2,6-Dinitrotoluene	2
Diethylphthalate	2
4-Chlorophenyl-phenylether	2
Fluorene	2
4-Nitroaniline	2
4,6-Dinitro-2-Methylphenol	2
N-nitrosodiphenylamine (1)	2
4-Bromophyenyl-phenylether	2
Hexachlorobenzene	2
Pentachlorophenol	2
Phenanthrene	2
Anthracene	2
Di-n-Butylphthalate	2
Fluoranthene	2
Benzidine	2
Pyrene	2
Butylbenzylphthalate	2
3,3-Dichlorobenzidine	2
Benzo(a)anthracene	2
bis(2-Ethylhexyl)Phthalate	2
Chrysene	2
Di-n-OctylPhthalate	2
Benzo(b)Fluoranthene	2
Benzo(k)Fluroranthene	2
Benzo(a)Pyrene	2
Indeno(1,2,3-cd)Pyrene	2
Dibenz(a,h)Anthracene	2
Benzo(g,n,i)Perylene	2
1,2 Dipheneylhydrazine	2

Table 7.18 Pesticides/PCBs'Group B-3 Parameters'EPA Method 608

Pesticides	Detection Level µg/L
Alpha-BHC	0.05
Beta-BHC	0.05
Delta-BHC	0.05
Gamma-BHC (Lindane)	0.05
Heptachlor	0.05
Aldrin	0.05
Heptachlor Epoxide	0.05
Endosulfan I	0.05
Dieldrin	0.10
4-4 DDE	0.10
Endrin	0.10
Endosulfan II	0.10
4-4 DDD	0.10
Endosulfan Sulfate	0.10
4-4 DDT	0.10
Methoxychlor	0.50
Endrin Ketone	0.10
Chlordane	0.50
Toxaphene	1.00
Aroclor-1016	0.50
Aroclor-1221	0.50
Aroclor-1232	0.50
Aroclor-1242	0.50
Aroclor-1248	0.50
Aroclor-1254	1.00
Aroclor-1260	1.00

Table 7.19 EPA Priority Pollutant Metals'Group B-4 Parameters

Element	CAS#	Detection Level mg/L	Preferred Method
Total Antimony	7440-36-0	.06	EPA 204.2
Total Arsenic	7440-38-2	.005	EPA 206.2,.3
Total Beryllium	7440-41-7	.005	EPA 210.2
Total Cadmium	7440-43-9	.001	EPA 213.2
Total Chromium	7440-47-3	.005	EPA 218.2
Total Copper	7440-50-8	.025	EPA 220.1,.2
Total Lead	439-92-1	.005	EPA 239.2
Total Mercury	7439-97-6	.0002	EPA 245.1,.2
Total Nickel	7440-02-0	.04	EPA 249.2
Total Selenium	7789-49-2	.005	EPA 270.2,.3
Total Silver	7440-22-4	.01	EPA 272.1
Total Thallium	7440-26-0	.005	EPA 279.2
Total Zinc	7440-66-6	.02	EPA 289.1

Table 7.20 Summary of Water Quality Monitoring in the Lower Issaquah Valley Wellhead Protection Plan

Well Name	Basic Inorganic			Priority Metals (EPA 7000-Series)			Turbidity			Iron and Manganese			Nitrate			Volatile Organics (EPA 524.2)			Pesticides & PCBs (EPA 8080)			Herbicides EPA (8150)			BTEX			Dissolved Oxygen (Field meas.)		
	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93	May 92	Oct 92	Apr 93
SP7-1	X			X		X	X		X				X					X	X		X			X						X
SP7-2	X						X						X																	
SPVT1-1	X	X		X		X	X	X			X		X	X		X		X	X		X			X		X				X
SPVT1-3	X						X						X																	
SPVT2-1	X			X	X		X						X			X	X		X											
SPVT2-2		X	X			X		X	X		X	X		X	X		X							X		X				X
SPVT2-3	X						X						X																	
SPVT5-1	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X		X			X		X				X
SPVT5-2		X						X			X			X																
SPVT6-2	X						X						X																	
SPVT7-4		X			X			X			X			X												X				
SPVT8-1	X	X		X			X	X			X		X			X										X				
SPVT8-4		X						X			X			X			X									X				
SPVT3			X			X			X			X			X			X			X			X						X
SP7																		X												X
WH-1		X	X		X			X	X		X	X		X	X		X						X							X
WH2-1		X				X		X			X			X				X		X	X			X		X				X
WH2-2		X						X			X			X			X			X	X			X		X				X
WH-3-1		X			X	X		X			X			X			X	X		X	X			X		X				X
WH-3-2		X						X			X			X				X								X				X
Lakeside-New		X			X			X			X		X	X												X				
Lakeside-BPW	X						X					X																		
Caldwell		X						X						X																
Bell	X						X						X																	
Darout	X						X						X																	

Source: Golder Associates, 1993

Table 7.21 Issaquah Ground Water Management Area Wells Monitored During the Wellhead Protection Study

Seattle-King County Health Department Database (Issaquah Ground Water Management Area Wells)	Wellhead Protection Wells (Golder Associates)
City of Issaquah Risdon Well #1	COI-1 Water levels only
City of Issaquah Risdon Well #2	COI-2 Water levels only
City of Issaquah Test Well	COI TW Water levels only
City of Issaquah Test #4	COI-4 Water levels only
City of Issaquah Test #5	COI-5 Water levels only
Sammamish Plateau SWD #8	SP8 Water levels only
Sammamish Plateau SWD 7-1 (D)	SP7-2 Water Quality Table 2.6.17.
Sammamish Plateau SWD 7-1 (S)	SP7-1 Water Quality Table 2.6.17.
Sammamish Plateau SWD 7-3 (D)	SP7-3 (Table 1 not shown) Water levels only
SPWD/City of Issaquah VT-1 Test	SPVT 1-1 Water Quality Table 2.6.17.
SPWD/City of Issaquah VT-2.1 Test	SPVT 2-1 Water Quality Table 2.6.17.