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Vashon ground-water management plan:

update area characterization and data analysis

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VASHON GROUND-WATER MANAGEMENT PLAN
UPDATED AREA CHARACTERIZATION
AND DATA ANALYSIS

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Prepared for

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VASHON GROUND-WATER MANAGEMENT PLAN UPDATED AREA CHARACTERIZATION AND DATA ANALYSIS

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Geraghty & Miller, Inc. is submitting this report to the Seattle-King County Department of Public Health (SKCHD) for work performed at Vashon Island, Washington. The report was prepared in conformance with Geraghty & Miller's strict quality assurance/quality control procedures to ensure that the report meets industry standards in terms of the methods used and the information presented. If you have any questions or comments concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

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ABBREVIATIONS

AGR	Annual Growth Report
bls	below land surface
BOD	biological oxygen demand
b.p.	before present
BWC	Burton Water Company
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CES	Cooperative Extension Service
cfs	cubic feet per second
COD	chemical oxygen demand
DDES	Department of Development and Environmental Services
DPW	King County Department of Public Works
DWA	Dockton Water Association
Ecology	Washington State Department of Ecology
FDA	United States Food and Drug Administration
GBWS	Gold Beach Water System
gpd	gallons per day
gpdpc	gallons per day per connection
gpm	gallons per minute
GWAC	Ground-Water Advisory Committee
GWMA	Ground-Water Management Area
GWMP	Ground-Water Management Plan
ID	inside diameter
KCAPP	King County Agriculture Preservation Plan
KCBH	King County Board of Health
KCCD	King County Conservation District
KCPD	King County Planning Division
KCSWR	King County Solid Waste Regulations
LSA	local service area
MCL	maximum contaminant level
mg/L	milligrams per liter
Mgpd	million gallons per day
Mgpy	million gallons per year
MMWC	Maury Mutual Water Company
msl	mean sea level
MTCA	Washington State Model Toxics Control Act
Metro	Municipality of Metropolitan Seattle
PCB	polychlorinated biphenyls
ppm	parts per million

PPR	King County Department of Parks, Planning, and Resources
PSCOG	Puget Sound Council of Governments
PSWQA	Puget Sound Water Quality Authority
RBCGWMP	Redmond-Bear Creek Ground Water Management Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SKCHD	Seattle-King County Department of Public Health
SPA	special protection area
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Department of Environmental Protection
USGS	United States Geological Survey
UST	underground storage tank
VOC	volatile organic compound
VSG	Vashon Sand and Gravel
WAC	Washington Administrative Code
WAVES	Water And Vashon Ecosystems
WDNR	Washington State Department of Natural Resources
WDOH	Washington State Department of Health
WSFS	Washington State Ferry Service
WWA	Westside Water Association

VASHON GROUND-WATER MANAGEMENT PLAN
UPDATED AREA CHARACTERIZATION AND DATA ANALYSIS

1.0 INTRODUCTION

This report will provide an updated characterization of the Vashon-Maury Island (the Island) Ground-Water Management Area (Vashon GWMA) for the Vashon-Maury Island Ground-Water Management Plan (Vashon GWMP). The report also summarizes the results of groundwater and surface water data collection and analysis activities between 1989 and 1992 conducted as part of the Vashon GWMP.

The updated area characterization is a compilation of the information presented as a result of previous water investigations conducted on the Vashon GWMA as well as a presentation of information regarding the physical characteristics of, regulatory agencies over, and regulations concerning the Vashon GWMA. Chapter 2.0 presents a detailed description of the boundaries of the Vashon GWMA. Chapter 3.0 identifies and describes the various federal, state, and local agencies which have jurisdiction over the Vashon GWMA. Chapter 4.0 describes the physical geography of the Island. Chapter 5.0 depicts the general and specific land uses occurring in the Vashon GWMA and their effects on ground water, while Chapter 6.0 delineates the water uses applied across the Island. Chapter 7.0 describes the state and local ground-water policies under which the Vashon GWMP is permitted to operate.

The results of the data collection and analysis activities conducted as part of the Vashon GWMP are presented in Chapter 8.0, Hydrogeology, and Chapter 9.0, Deep Exploration Boring. Chapter 10.0 presents a brief summary of and detailed conclusions drawn from the data collection activities, followed by recommendations concerning future information needs.

The data collection and analysis task involved rainfall, stream flow, springs, surface water, and ground water. Data was collected by various entities, including Island-resident volunteers and personnel from the Seattle-King County Health Department (SKCHD), King County Solid Waste Division, U.S. Army Corps of Engineers (USACE), and the environmental firms of URS Consultants; EcoChem, Inc.; and Geraghty & Miller, Inc. The data collection effort was based on recommendations by J. R. Carr/Associates in their 1983 report (Carr 1983). The following updated characterization of the Vashon GWMA summarizes the results of the data collection task and combines this information with the previous historical reports.

The objective of the data collection and analysis task was and is to further the understanding of the Island's water resources (quantity and quality) and identify data gaps to facilitate protection of the Island's ground-water. The methodology by which this goal was attained is through the generation and interpretation of the following kinds of data:

- Historical record. Hydrogeology background data and water use (Geraghty & Miller 1991) and background land use (Geraghty & Miller 1990) reports examined existing information on physical geography, climate, surficial geology, well logs, water use, land uses, and development trends as well as available past-consultant reports on various aspects of the Island's water resources.

- Rainfall and stream-flow. These data were collected by Island volunteers, agency personnel, and consultant personnel at nine rainfall and nine stream sites located across the Island to assess the amount of water potentially available to the Island (rainfall) and leaving the Island (stream flow). Stream-flow data were collected in an effort to estimate the net volume of rainfall which runs off and is not absorbed into the ground.

•Ground-water levels and water quality. Depth-to-ground-water and ground-water quality data were collected at 21 wells across the Island by SKCHD and the consultants. Information on water quality was also collected from monitoring wells at the Vashon Island Landfill and surrounding area. Finally, information on ground-water quality was collected at the NIKE site by USACE. These data were collected to assess rainfall/recharge relationships, changes in depth to ground water over time (i.e., potential depletion of the water resource), changes in ground-water flow directions seasonally and over time, and water-quality changes over time. The specific water-quality parameters evaluated were chloride (as an indicator of seawater intrusion), nitrate (as an indicator of septic system and/or agricultural contamination), and total dissolved solids (TDS) (as a general indicator of land use impact).

- Surface-water quality. These data were collected by SKCHD at eight stream sites. Surface-water data were interpreted from water and sediment samples collected upstream in the freshwater environment and downstream where the stream enters Puget Sound, i.e., the marine environment. Marine shellfish samples were collected from areas in Puget Sound at the mouth of the stream. The specific water-quality and marine shellfish parameters evaluated were total coliforms, fecal coliforms, arsenic, chloride, mercury, selenium, cadmium, copper, lead, silver, and zinc. Temperature, pH, and chloride were evaluated in freshwater only.

- Spring-water quality. These data were collected by SKCHD at six spring sites. The specific water-quality parameters evaluated were total and fecal coliforms, metals, nitrate (as nitrogen), nitrite (as nitrogen), sulfate, fluoride, and TDS.

- Exploration well (drilled January 1992). These data were collected in an effort to provide information on the water-bearing units in the geologic formations beneath the Island, the viability of a water resource in deep sediment deposits, and the general variations in water quality correlating to depth of water-bearing zone.

2.0 VASHON GWMA BOUNDARIES

The Vashon GWMA (Figure 2-1) comprises approximately 36.7 square miles, of which 29.7 square miles are Vashon Island and 7.0 square miles are Maury Island. The two islands are linked by a narrow isthmus and are not, therefore, two truly independent islands. The boundaries of the Vashon GWMA coincide with the coastline of Vashon-Maury Island.

As part of King County, the linked islands are often referred to throughout the Puget Sound area as "Vashon Island." However, for the purposes of this report, Vashon-Maury Island will be referred to as "the Island." Whenever Vashon Island or Maury Island are referenced in the following chapters, the reference is to that specific portion of the Vashon-Maury Island system.

3.0 JURISDICTIONS IN THE VASHON GWMA

Chapter 3.0 discusses the role of the public agencies with jurisdiction over environmental quality of the Vashon GWMA. The ground-water-related responsibilities and activities of the agencies are discussed only as they pertain to the Vashon GWMA. Many agencies' jurisdictional boundaries (Figure 2-1) include the entire Vashon GWMA, which is unincorporated; such agencies include Fire District No. 13, School District No. 402, and state and federal agencies. Agencies whose jurisdictional boundaries do not extend to the entire Vashon GWMA include the Vashon Sewer District and King County Water District No. 19. The agencies and their jurisdictional boundaries are discussed below by federal, state, county, and local agencies, respectively.

3.1 FEDERAL AGENCIES

The following federal agencies influence ground-water management in various ways, both through their roles as regulatory bodies and in their capacities as policymakers.

(1) U.S. Environmental Protection Agency (USEPA). The USEPA administers numerous programs that influence ground-water management in the Vashon GWMA, 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 USEPA deals with water pollution, underground storage tanks (USTs), pesticide and herbicide use, liquid waste, landfills, hazardous waste management (including Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]/Superfund Amendments and Reauthorization Act of 1986 [SARA] sites and generators), and drinking water management. As a support agency, the USEPA 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 USEPA administers the Sole Source Aquifer Program, the Pesticides in Ground Water Survey, and the Agricultural Chemicals in Ground Water Strategy.

(2) U.S. Department of Agriculture (USDA). The USDA provides technical assistance to landowners and communities concerning municipal sludge applications, livestock, crops, irrigation design, wildlife, and animal-waste ponds. The USDA is a lead agency for pesticide and herbicide programs and administers programs such as fish and wildlife conservation programs, the Resource Conservation and Recovery Act (RCRA), and watershed projects.

The Soil Conservation Service. As part of the USDA, the Soil 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) U.S. Geological Survey (USGS). The USGS is a hydrologic- and geologic-data generation-and-research agency. The USGS is responsible for some of the geological mapping that has led to a better understanding of the two principal aquifers in the Vashon GWMA. The USGS has no regulatory or policymaking authority.

3.2 WASHINGTON STATE AGENCIES

The following agencies operate at the state level, but influence ground-water affairs at a local level as well.

(1) Washington State Department of Ecology (Ecology). Ecology is charged with protecting the waters of the state, and, therefore, the activities of Ecology affect ground-water management decisions in the Vashon GWMA both directly and indirectly. Funding for the development of the Vashon GWMP comes from the Centennial Clean Water Fund, a grant administered by Ecology. Ecology issues discharge permits and performs compliance monitoring at the Vashon Island Sewage Treatment Plant, enforces discharge regulations, and responds to pollution incidents. Ecology is a lead agency in over 20 environmental categories, including aquifer depletion, seawater intrusion, water resources, and wells and water rights (EES, 1988). As a regulatory agency, Ecology is responsible for the cleanup of leaks and spills of hazardous materials except in navigable waters, oversight of RCRA facilities and state hazardous waste cleanup sites, and regulation of USTs.

(2) Washington Department of Health (WDOH), Office of Environmental Health Programs. WDOH is involved in a variety of programs that influence ground-water management. As part of the Northwest Drinking Water Operations Program, WDOH is responsible for plan approval for Group A public water supplies, including well site inspections and final system certificate-of-completion review.

Under the heading of the On-Site Sewage Program, WDOH is the state agency responsible for enforcing Washington Administrative Code (WAC) 248-96, 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. WDOH is also responsible for guideline development and performance review of alternative sewage disposal systems.

The Shellfish Section of WDOH regulates both commercial and recreational shellfish resources. Shellfish Section activities involve monitoring shellfish harvesting areas, including several sites on Vashon Island, and testing shellfish from these sites for the presence of the paralytic shellfish poisoning toxin that causes red tide.

(3) Washington Department of Natural Resources (WDNR). WDNR is the manager of state-owned lands, including approximately 250 acres of land in upland areas of Vashon Island and 115 tideland parcels of the Island. In the recent past, there have been some sales of timber from the upland property, but no land sales for development purposes. The tideland parcels are managed by the Aquatic Lands Division, which is also involved with WDOH in developing regulations governing the recreational harvesting of shellfish.

3.3 KING COUNTY AGENCIES

The following King County agencies operate on the Island. Each of these agencies conducts activities that either directly or indirectly affect water management in the area.

(1) King County Council. The 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 Council has administered water resource, land use, and wetlands programs in addition to assisting in community plan reviews. The version of the Vashon Community Plan currently in use was developed by the King County Community Planning staff and the 13-member Citizen Advisory Committee made up of local Island residents and a non-resident chairperson appointed by the King County Council (King County 1986).

(2) King County Department of Parks, Planning, and Resources (PPR). Divisions of PPR, as discussed below, are involved in implementation of the King County Comprehensive Plan, the 1986 Vashon Community Plan, environmental reviews, and land use development.

Planning and Community Development Division. The Planning and Community Development Division is primarily involved in implementing the King County Comprehensive Plan and in developing zoning and land use policy plans.

Department of Development and Environmental Services (DDES). DDES administers the Critical Water Supply Program, the implementation element of the Public Water Systems Coordination Act of 1978 [Chapter 70.116 RCW (Revised Code of Washington), Chapter 248-56 WAC, and Chapter 248-57 WAC]. The program establishes coordinated planning among water utilities, reducing the creation and proliferation of new public water systems. Vashon Island has been designated as one of four critical water supply service areas for which a Coordinated Water System

Plan was developed in 1990. DDES also implements the 1986 Vashon Community Plan by issuing building permits and by administering rezones and plats.

Resource Planning Division. Resource Planning is directly involved in ground-water planning. It is also the lead agency in the watershed-ranking process, which is a component of the Puget Sound Water Quality Authority's (PSWQA) Nonpoint Source Pollution Program. The Island is 1 of 22 watersheds being evaluated as a part of the watershed-ranking process; the highest-ranked watershed will be the target of a Nonpoint Action Plan. Resource Planning also studies the interaction of wetlands and surface runoff and is involved in drainage basin planning.

(3) Seattle-King County Health Department (SKCHD), Environmental Health Division. The SKCHD is an advisory and regulatory body involved in a wide variety of water-related topics, including regulation of Group B public water-supply systems. The SKCHD is responsible for evaluating soil quality on the Island preparatory to permitting for on-site wastewater disposal systems.

SKCHD administers a number of programs that affect ground-water issues in the Vashon GWMA, including the Vashon Ground-Water Management Plan (EcoChem and Geraghty & Miller 1990), the Surface Water Study and Sewage Facilities Plan (Barrett 1992).

The Vashon GWMP involves the development of ground-water management programs for the Vashon GWMA. The Island was designated as a GWMA by Ecology in 1986. The SKCHD is lead agency for the GWMP. SKCHD coordinates the activities necessary for the development of the groundwater management plan. Additionally, SKCHD collects groundwater quality and quantity data, surface water data, manages the groundwater database, drafts technical issue papers and prepares the budget for development of the GWMP.

The Sewage Facilities Plan was developed from the findings of the SKCHD sanitary survey by Barrett and SKCHD. The Plan determines the feasibility of a community solution for the sewage treatment and disposal problems faced by four Vashon Island coastal communities which have been declared severe public health hazard areas by the Washington State Department of Health. SKCHD issues permits for proposed septic 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 SKCHD is responsible for permitting landfills, overseeing and permitting sludge applications and sampling ground-water in areas around the Vashon Island Landfill.

(4) King County Department of Public Works (DPW). The following divisions of the DPW conduct the activities described below on the Island.

Solid Waste Division. The Solid Waste Division owns the 145-acre site on which the 9-acre Vashon Island Landfill operates. The Division is responsible for ground-water sampling at the landfill and for the construction of the landfill's new leachate control facility.

Roads Division. In addition to construction and maintenance of roads and associated drainage, the Roads Division is responsible for herbicide application along the roadside.

(5) King County Conservation District (KCCD). The KCCD works with the Island agricultural community to implement animal management and land use practices that increase productivity while minimizing soil erosion and water pollution. The KCCD is neither a branch of county government nor an enforcement agency, but rather an organization dedicated to the conservation and best uses of the natural resources of King County.

3.4 LOCAL AGENCIES

(1) Municipality of Metropolitan Seattle (Metro). Metro is the designated regional water quality planner under the 1972 federal Clean Water Act (CWA). Metro oversees a regional sewerage collection and treatment system and is responsible for the disposal of leachate from the Vashon Island Landfill.

From 1983 to 1992, Metro conducted an ambient monitoring program focusing on bacterial contamination at 22 intertidal sampling stations on the eastern shore of the Puget Sound. The PSWQA took over the ambient monitoring program in 1992 (Thrasher, pers. comm. 1993). Both intertidal water and shellfish are sampled. The Island was included in this program in 1988.

(2) Puget Sound Water Quality Authority (PSWQA). The PSWQA awarded a $32,000 Public Involvement and Education grant to Vashon Island

School District No. 402 in 1988. The grant promotes public education and awareness in matters concerning water quality on the Island. The project developed from this grant is entitled WAVES (Water And Vashon Ecosystems).

(3) Vashon Sewer District. The Vashon Sewer District operates the Island's only sewage treatment plant. The facility has been providing secondary treatment since 1976 and serves a population of approximately 600 people.

(4) King County Water District No. 19. Water District No. 19 is a municipal corporation providing drinking water service to over 1,000 connections on the Island. Drinking water is currently obtained from three sources: Beall Creek, Ellis Creek, and a deep well. The Water District is in the process of investigating other ground-water sources.

4.0 PHYSICAL GEOGRAPHY

Chapter 4.0 discusses the geographic setting, topography, and climate, respectively, of the Vashon GWMA.

4.1 GEOGRAPHIC SETTING

The Vashon GWMA is located near the southern end of Puget Sound in the southwestern corner of King County, southwest of Seattle and north of Tacoma, in Washington state. The Island lies in the Puget Lowland, a trough located between the Olympic Mountains to the west and the Cascade Mountains to the east. Vashon Island is roughly 13 miles north-to-south and 4 miles east-to-west, while Maury Island is about 5 miles in a northeast-southwest direction and roughly 2 miles east-to-west (DeLorme 1988).

The Island is separated from the surrounding mainland by narrow channels of Puget Sound. Colvos Passage, about 1 mile wide and 110 to 410 feet deep, separates the Island from the Kitsap Peninsula to the west. The shortest distance between the Island and the mainland is to the south, about 1½ miles across Dalco Passage, which ranges from about 300 to 410 feet deep. The mainland to the east of the Island lies from 2½ to 4 miles across Puget Sound, which is approximately 550 to 800 feet deep in that area. The open water of Puget Sound extends approximately 29 miles from the northern tip of the Island to Whidbey Island; West Seattle lies about 5 miles north-northeast of the northern tip of the Island (DeLorme 1988; Carr 1983). State ferries link the Island to West Seattle and Seattle (foot passenger ferry only), to Southworth on the Kitsap Peninsula, and to Tacoma.

4.2 TOPOGRAPHY

The topography of the Island is well-documented. Mapping by the USGS has resulted in production of the topographic maps upon which Figure 2-1 is based (USGS 1968a and b, 1973, 1981a, b, c). The Island has a total of about 47 miles of seawater shoreline, much of which lies beneath steep, slide-prone slopes. From the shoreline, the Island rises to rolling interior plateaus at elevations 300 to 500 feet above mean sea level (msl). The Island was divided into 27 drainage basins by Carr (1983). Streams have dissected the plateaus and accentuated the drumlinoid (elongated, asymmetric) form of the hills, into which much of the upland area has been molded by repeated glaciation. The Island is largely rural and much of the interior remains forested.

4.3 CLIMATE

According to Carr (1983), the official narrative summary of the Island's climate written in 1962 by State Climatologist E. L. Phillips of the U.S. Weather Bureau, the Vashon GWMA has a mid-latitude, wet-coast marine climate with generally cool, dry summers and mild, rainy winters. Phillips stated that the Olympic Mountains, which rise about 40 miles to the northwest of the Island, protect it from intense winter storms; while the Cascade Mountains, which lie about 50 miles east of the Island, shield the Puget Sound area from the higher summer and lower winter temperatures experienced by eastern Washington. According to Phillips, summer temperatures average in the 70s during the day and 50s at night, while winter temperatures are generally in the 40s during the day and 30s at night. These figures are supported by records kept by the U.S. Weather Bureau's Vashon Island station from 1931 to 1954 (Carr 1983). The station was closed in 1955.

From 1931 through 1954, rainfall data for the Island were also recorded at the Vashon Island station (Carr 1983) (Table 4-1). These data indicate an average annual rainfall of 46.53 inches over the 24-year period. During 1981 and 1982, Carr collected rainfall data at seven Island locations as part of a study of the Island's water resources (Figure 4-1). Over the 1-year period, measured annual rainfall ranged from about 53 inches on the western side of Vashon Island to about 35 inches at Point Robinson on the eastern tip of Maury Island, a difference of over 18 inches, or about 50 percent. During the same period, rainfall recorded on the mainland at Sea-Tac Airport (approximately 5 miles northeast of the easternmost tip of Maury Island) was about 39 inches (Carr 1983). Rainfall monitoring conducted between 1989 and 1991 is discussed in Chapter 8.0, Hydrogeology.

5.0 LAND USE BACKGROUND

Chapter 5.0 discusses the type and extent of land use activities potentially affecting ground water in the Vashon GWMA. Land use activities are first described generally as they are carried out on the Island, followed by specific land uses and their effects on the Island's water sources.

5.1 GENERAL DESCRIPTION

Included in the general description of the Island's land use are existing land uses for both developed and undeveloped land; development trends for residential, commercial/industrial, and agricultural areas; and the plans, policies, and regulations related to land use that have been sanctioned by King County. These areas of discussion are presented below.

5.1.1 Existing Land Use

In 1980, according to the Puget Sound Council of Governments (PSCOG), 933 acres (about 4 percent) of the Island's 23,418 acres were classified as residential and 303 acres (about 1.3 percent) were occupied by places of employment. The remaining land, almost 95 percent of the Island, was undeveloped.

In the Vashon Community Plan (King County 1986), the land use map (Plate 1) indirectly reflects zoning and shows the projected land use on the Island as predominantly low-density rural-residential. Based on the map, the majority of residential, commercial, and industrial development has occurred in the communities of Vashon, Vashon Heights, Burton, and Dockton. Development of the Island, existing and future, is discussed below.

5.1.1.1 Developed Areas

Development in the Vashon GWMA falls into three basic categories: residential, commercial, and industrial. Summaries of each of these categories follow:

Residential: Low-density residential development covers much of the Vashon GWMA. Upper plateau areas are zoned for one single-family dwelling per 10 acres in high recharge areas and one single-family dwelling per 5 acres elsewhere. Higher density single-family residential areas are concentrated in the communities of Vashon, Vashon Heights, Burton, and Dockton. Multi-family housing is concentrated in the Town of Vashon, where sewer facilities are available. Maximum permissible housing density in the unsewered communities of Vashon Heights, Burton, and Dockton is three single-family houses per acre. According to the 1986 Vashon Community Plan, residential developments in high recharge areas must comply with site plan approval conditions in order to protect the aquifers from excessive loss of water infiltration. The conditions stipulate that the maximum surface coverage on all single-family residentially zoned lots shall not exceed 15,000 square feet.

Commercial: The Town of Vashon is designated as a Rural Activity Center in the King County Comprehensive Plan (King County Council 1985). At present, commercial and industrial development is concentrated in the Town of Vashon and in adjacent areas where water, sewers, and other services are available. Again, to protect the aquifers from excessive loss of water infiltration, any new commercial or industrial development in high recharge areas is limited to a maximum of 60-percent surface coverage, as stipulated under the site plan approval conditions established in the 1986 Vashon Community Plan. Small commercial centers exist in other Island communities, including Burton, Vashon

Heights, and Dockton. Ferry terminals are located at Vashon Heights and Tahlequah, near the northern and southern ends, respectively, of Vashon Island.

Industrial: In 1978, there were approximately 44 acres of land zoned as Manufacturing Park and Light Manufacturing on the Island; of these, 18.5 acres were developed. An additional 40 acres were zoned for possible future use as Potential Light Manufacturing. The 1986 Vashon Community Plan's Land Use Map (King County 1986) portrays approximately 170 acres of land in the Vashon GWMA zoned as Manufacturing Park and Light Manufacturing. Current manufacturing operations on the Island include the K-2 Ski Manufacturing Corporation; Pacific Research, which manufactures plastic skeletons; and Island Springs Tofu. All are in or near the Town of Vashon. Four major commercial sand and gravel extraction sites operate along the south shore of Maury Island; a number of smaller resource extraction sites on the Island operate intermittently. The Vashon Island Landfill is located on a gently sloping upland plateau near the headwaters of Judd Creek in the central-western portion of Vashon Island. The Landfill has been in operation for at least 35 years and is still active; in 1989, it was upgraded and redesigned to meet current standards.

5.1.1.2 Undeveloped Areas

Substantial portions of the Vashon GWMA are presently undeveloped. These include both forested tracts and open fields as well as parcels of agricultural land, the latter being the least extensive. No areas are shown as being zoned for timber harvest on the 1986 Vashon Community Plan Land Use Map. According to a 1976 study of agricultural uses, commercial orchards, berry farms, vineyards, nurseries, and small commercial ranches occupied about 900 acres (about 4 percent) of the Island (King County 1986).

According to the 1986 Vashon Community Plan, the entire coastline of the Vashon GWMA as well as many of the drainage basins and most of the surface-water bodies have had development limitations imposed on them because they are classified as erosion hazard areas, flood hazard areas, fish-bearing waters, Class III Landslide Hazard Areas and Wetlands, and/or Class III Earthquake Hazard Areas. All of these areas are mapped as "sensitive areas" in the Sensitive Areas Map Folio published by the King County Planning and Community Development Division (King County 1990). The 1986 Vashon Community Plan suggests that areas so designated should be developed only with great care or should remain undeveloped through the application of a low-density designation. In the past, according to Island residents, some sensitive areas have been developed.

5.1.2 Development Trends

Development trends are discussed in terms of residential, commercial and industrial, agricultural, and other development. Each category is discussed below.

5.1.2.1 Residential

Populations and housing estimate and forecasts were drawn from two sources: (1) the Puget Sound Council of Governments (1988; 1993) and (2) King County annual growth reports (AGR) (1988a; 1989; 1991; 1992). Residential building data was gathered from an annual growth report (King County 1992). The following discussion describes the growth on the Island indicated by this data.

The Island's population continues to grow, accompanied by a greater rise in the demand for housing (Tables 5-1 and 5-2). While the Island's population increased by only about 13 percent from 1970 (6,516) to 1980 (7,377), the total number of households increased by about 36 percent. From 1980 to 1990, the Island's population increased another 26 percent (to 9,309), yet the total number of households increased by 28 percent. The disparity between growth in population and in number of households has arisen from a decrease in the average household size from 1970 to 1980, from 3.05 persons (1970) to 2.53 persons (1980) to 2.50 persons (1990). Single-family dwellings increased in number by 25 percent from 1970 (2,070) to 1980 (2,594) and by 28 percent from 1980 to 1990 (3,488). The number of multi-family households jumped by 466 percent between 1970 (53) and 1980 (300) and then decreased by 28 percent by 1990 (215).

The 1992 AGR (Table 5-2) reports the 1991 population of the Vashon GWMA as 9,800, a 32.4 percent increase over the 1980 PSCOG population estimate. The total number of households in 1991 (4,000) was up 38.4 percent from 1980. The 1988 AGR predicted a population of 8,572 by the year 2000 (Table 5-3); whereas, the 1992 AGR has elevated the prediction to 11,100 (Table 5-4). The 1992 PSCOG prediction of 8,572 (Table 5-3) for the year 2000 is 22.7 percent lower than the 1992 AGR forecast (11,100). Table 5-5 shows the number of residential permits issued and the number of housing units built in the Vashon GWMA from 1980 through 1991, as reported in the 1992 AGR.

As stated in the 1986 Vashon Community Plan, the Vashon Sewer District local service area (LSA) within the Town of Vashon contains planning for intensive residential development, including areas of multi-family development. Communities without sewer systems (including Dockton, Burton, and Vashon Heights) are allowed to develop to a maximum density of three single-family units per acre (King County 1986).

5.1.2.2 Commercial and Industrial

The Town of Vashon is presently and will continue to be the center of the major commercial business interests on the Island. Small commercial centers exist in other communities and will be maintained at their current size, except for the possible limited expansion of Burton's. Mixed business/residential units will be encouraged in the Town of Vashon and its business center. No additional business zoning has been designated, because approximately one-third of the land currently zoned for business is undeveloped. Neighborhood grocery stores and small clusters of business that exist in Island communities are recognized as integral parts of the character of the communities. Home occupations and cottage industries presently operate, and shall continue to operate in the future, provided that they meet the safety, zoning, and aesthetic standards of the community. Table 5-6 shows selected new industrial and commercial permits in the Vashon GWMA for 1980 through 1988 (King County 1989a).

The lack of island-to-mainland transportation other than the public ferry system is one of the factors limiting industrial growth in the Vashon GWMA. At present, approximately half of the land zoned for industrial uses (about 40 acres) is still undeveloped. A maximum of 60 acres total is estimated to be adequate for manufacturing uses under the current 1986 Vashon Community Plan. Future industrial growth will be clustered south and west of the Town of Vashon and near existing industrial sites (Plate 1). Given the rural character of the Island and the limited work force, no large-scale industrial development is foreseen; future industrial uses will generally be for small-scale, light industry.

The four major commercial sand and gravel extraction sites on the south shore of Maury Island and the smaller sites on Vashon-Maury Island will be allowed to continue to operate. Long-range plans for the extraction sites are for residential development at 1 house per 2.5 acres. Gold Beach on Maury Island is an example of a former gravel pit developed as a residential area.

5.1.2.3 Agricultural

The trend among existing farms is to diversify, both to meet local demands and to supply specialty markets on the Island and elsewhere. There is strong community support for encouraging farming and preserving agricultural land, as well as interest in promoting local consumption of Island produce. This support is reflected in the focus of the King County Agriculture Preservation Plan (KCAPP) (Jones, pers. comm. 1989).

The KCAPP has two parts: (1) a land preservation program and (2) an agriculture support program. Under the land preservation program, farmers have the option of selling development rights to 800 acres of commercial farmland on the Island to King County. Properties which are sold to the County under the land preservation program and are zoned as potential agricultural, thereby ensuring that some farmland is preserved. Once the development rights are acquired by the County, the land is re-zoned as agricultural. King County currently owns development rights to 231 acres of agricultural land, 190 acres of which comprise Wax Orchards (Jones, pers. comm. 1989).

Rezoning to agricultural upon the request of individuals is also supported. An Agricultural District, part of the KCAPP, was established in 1977. The District has authority to review and comment on rezone, subdivision, planned unit development, and other land use applications to prevent adverse effects on agricultural activities on the Island. Food processing plants that are important to agricultural uses will continue to be permitted on the Island. Establishment of a permanent farmers' market was recommended in the 1986 Vashon Community Plan.

5.1.2.4 Other

Another development trend is the establishment and protection of historic sites, as recommended in the 1986 Vashon Community Plan. The communities of Burton and Dockton have been nominated as historic districts; development guidelines encourage maintaining compatibility with historic buildings. The 1986 Vashon Community Plan states that a Historic Preservation Officer will review proposals for development to evaluate their potential impact on the character of the community. According to Julie Koler, King County Historic Preservation Officer, a list of historic sites and potential landmarks on the Island was developed after a survey of the Island. The Historic Preservation Office is generally consulted by DDES if a proposed development involves a site on that list (Koler, pers. comm. 1989).

5.1.3 Plans, Policies, and Regulations

Land use activities and development trends evolve within the framework of applicable land use policies. In the case of the Vashon GWMA, the most influential land use policies are those of King County and of the Island. The 1985 King County Comprehensive Plan is the county's long-range, county-wide, comprehensive land use plan. The 1986 Vashon Community Plan contains detailed land use, capital improvement, and zoning plans. In addition, functional plans, which address location, design, and operation of public facilities and services (such as surface-water control and sewage disposal), receive policy direction from the King County Comprehensive Plan and are coordinated with the 1986 Vashon Community Plan. County and community plans, policies, and regulations are presented in the following subsections.

5.1.3.1 King County

Community plans, functional plans, and land use regulations at the county level are designed to be compatible with the King County Comprehensive Plan, adopted in April 1985 (King County Council 1985). Some important features of the 1985 Comprehensive Plan relevant to the Vashon GWMA, which is considered a rural area, are summarized in the following land use goals.

- Resource lands, maintenance of water quality, management of water resources, and identification and protection of ground-water recharge areas should be protected on a long-term basis.

- Commercial and industrial uses in rural activity centers should be developed based on evaluation of local business needs and county-wide economic development needs.

- Adequate facilities for growth and development, including sewers, water, and solid waste disposal, should be planned and provided.

- Service levels in rural areas should be sufficient to support rural residential densities.

- Densities in rural areas should be low enough to protect rural character and avoid the need for expensive facilities and services, such as public sewers, surface-water management, extensive arterial networks, and urban-level fire protection.

- Public open space in rural areas should be planned for and provided.

5.1.3.2 Vashon Community Plan and Area Zoning

The Vashon GWMA falls entirely under the purview of the Vashon Community Plan adopted in October 1986 (King County 1986). The 1986 Plan was based on the Vashon/Maury Island Water Resources Study, which was completed in 1983 by J.R. Carr/Associates (Carr 1983). The water resources study was prompted largely by a recommendation in the 1981 Vashon Community Plan for further research into the Island's water resources. Zoning and policies presented in the 1986 Plan reflect the new information obtained from Carr (1983). A summary of the goals of the 1986 Plan follows:

- The rural nature of the Island should be preserved.
- The most intensive residential, commercial, and industrial development should be restricted to the Town of Vashon and its immediate surroundings, where public utility services are available and adequate.
- Some additional growth should be permitted in the other Island town centers, although multi-family residential development should be limited to the areas of the Island where public sewage facilities are available and adequate.
- Island water resources should continue to be the sole water-supply source in the future.
- Protection of the aquifer is recognized as being of primary importance.

- Commercial and small-scale agriculture should be promoted by compatible land use designations.

- Future transportation facilities should provide efficient, environmentally sound transportation that make new auto facilities less necessary.

- To protect the quantity of water stored in the Island's aquifers, site development in high recharge areas will require site plan approval that will stipulate the surface coverage and amount of runoff permitted.

5.2 SPECIFIC LAND USES AND THEIR EFFECTS ON GROUND WATER

Specific land use activities have the potential to adversely affect ground-water quality in the Vashon GWMA. Figure 5-1 shows the location of the potential point sources of contaminants in the Vashon GWMA that are discussed in detail in the following subsections.

5.2.1 Vashon Island Landfill

The Vashon Island Landfill is owned by King County and serves as the municipal solid waste disposal facility for residents of both Vashon and Maury Islands and for private refuse haulers that serve the Island. The discussion below describes Landfill operations and their effects on ground water quality.

5.2.1.1 Description

The 9.3-acre refuse area of the Landfill is located on a 145-acre site in west-central Vashon Island, primarily in the southwest quarter of Section 36, T23N R2E

(Figures 5-1 and 5-2). Access to the site is by way of 130th Avenue Southwest (Harper-Owes/Golder 1986). In their report, Harper-Owes (1988) states that historic records indicate that disposal at the site may have begun in the early 1900s. The site has been active since the early 1950s, but detailed records are unavailable prior to that date. Currently, all forms of solid waste as defined in the King County Solid Waste Regulations (KCSWR), Title 10, of the King County Code of the Board of Health, Rules and Regulations No. 8, are accepted at the landfill, with the following exceptions:

- Liquids, demolition debris, or flammable materials.
- Dangerous wastes as defined by Ecology under Chapter 173-303 WAC.
- Hazardous wastes as defined by Federal Law 94-580, RCRA 1976.

A monthly inspection is conducted by the SKCHD staff to verify that unacceptable waste is not accepted at the landfill.

In 1984, 1985, and 1986, the landfill accepted approximately 4,800, 5,500, and 5,900 tons of refuse, respectively, representing volumes of approximately 16,000, 18,000, and 19,600 cubic yards, respectively (Table 5-7). The refuse generation rate is expected to increase annually as both population and per-person refuse generation increase (Harper-Owes 1988).

To comply with KCSWR rules and regulations, operations at the Vashon Island Landfill required placement of an impermeable cap and liner over the old refuse fill area and installation of a leachate collection system. The regulations also required installing an aerated lagoon for storing and treating collected leachate. The leachate control system, designed by Harper-Owes and approved by King County DPW, Solid

Waste Division, was completed in 1989 with capping and closing of the old fill area. The zone above the liner acts as the current refuse disposal area (Harper-Owes 1988; Harding Lawson 1991).

5.2.1.2 Effect on Ground-Water Quality

Ground-water quality and hydrogeologic studies have been performed at the Vashon Island Landfill by R.W. Beck and Associates (1984), Harper-Owes/Golder Associates (1986), Harper-Owes Associates (1988), and Harding Lawson Associates (1991). SKCHD has been investigating ground water in off-site landfill wells since 1987. The consultants' conclusions indicate that the Landfill's leachate has potentially impacted ground and spring waters, although the leachate is more dilute than that typically found at Pacific Northwest landfills; however, ground-water quality is improving. During ongoing monitoring of off-site wells, SKCHD has found no evidence of off-site impacts from landfill leachate. The following subsections summarize the results of the investigations previously conducted concerning the Vashon Island Landfill.

Ground-water monitoring wells have been installed for the Vashon Island Landfill on-site and off-site. The boring log from the installation of these wells indicate that ground water beneath the site occurs in two separate perched zones (referred to as "shallow" and "deep" water-bearing zones). Mounding of ground water beneath the landfill was reported by Harding Lawson Associates (1991) (Figures 5-3 and 5-4), although no explanation of this occurrence was included in the study. According to Harding Lawson (1991), the water table in the shallow zone has dropped along the west side of the landfill as a result of the landfill closure, and the primary direction of ground-water flow is to the west.

Approximately 4,000 to 5,000 feet west of the landfill, a steep slope cuts across a silt (aquitard)/sand contact layer (Figure 5-5). Spring water seeps out of the contact and enters an unnamed creek, eventually discharging into Colvos Passage. The quality of the spring water as it leaves the site is unknown. Spring water is probably composed of water from both water-bearing zones (Harding Lawson 1991).

Six monitoring wells (4 shallow and 2 deep) and three ground-water seeps (areas where spring water flows out through exposed seams of sand) have been periodically sampled. The water samples have been submitted to a laboratory to be analyzed for pH, specific conductance, total solids, TDS, total suspended solids, chemical oxygen demand (COD), total organic carbon, total organic halogens, biological oxygen demand (BOD), and dissolved oxygen. Four wells were screened in the shallow zone, and two wells were screened in the deep zone.

Four monitoring wells (MW-1, MW-3, MW-4, and MW-5S) were sampled between 1984 and 1992 by R.W. Beck, Harper-Owes, and Harding Lawson to determine the water quality in the shallow water-bearing zone. Contours of specific conductance data in the shallow zone indicated a potential leachate plume spreading out from the landfill (Beck 1984; Harper-Owes/Golder 1986). The highest specific conductance levels occurred in samples collected from two wells (MW-4 and MW-5) located downgradient (west) of the landfill (MW-4 and MW-5S) (Harper-Owes/Golder 1986).

Harding Lawson's investigation of ground-water in 1991 concluded that "downgradient wells are still impacted by leachate, but trends in water quality improvement exist" (Harding Lawson 1991). Samples collected from at least one downgradient monitoring well screened in the shallow water-bearing zone (Appendix A) have exceeded water-quality standards for total coliforms, arsenic, vinyl chloride, methylene chloride, and 1,1,1-trichloroethane (TCA) during one or more sampling events since 1986.

Monitoring Wells MW-2 and MW-5D were sampled between 1984 and 1992 by Beck, Harper-Owes, and Harding Lawson to determine the water quality in the deep water-bearing zone. Leachate migration was suspected in the deep zone because the highest levels of specific conductance were detected in the western downgradient perimeter wells (MW-2 and MW-5D) (Beck 1984; Harper-Owes/Golder 1986). Samples collected from at least one downgradient monitoring well screened in the deep water-bearing zone (Appendix A) have exceeded water-quality standards for chromium, endrin, arsenic, vinyl chloride, methylene chloride, TCA, and lindane during one or more sampling events since 1986 (Harding Lawson 1991); COD has also been present in MW-5D.

The capping of the old landfill fill area in 1989 may have caused COD concentrations to decrease in Monitoring Well MW-5D. Harding Lawson (1991) concluded that "the trend of dropping COD indicates that vinyl chloride and methylene chloride levels may drop also." In addition, Harding Lawson stated that leachate generation from the old fill has been inhibited by the cap installed in 1989.

Beck (1984) and Harper-Owes/Golder (1986) concluded that spring (seep) water was affected by leachate migration. Harding Lawson (1991) also suggested the possibility of leachate infiltration, based on moderately elevated levels of specific conductance, chloride, and COD.

Eleven off-site wells have been monitored by SKCHD periodically since December 1987 (Figure 5-6). The ground-water samples were analyzed for volatile and semivolatile organic compounds, organochlorine pesticides, and metals (Appendix A).

None of the off-site monitoring wells have exhibited levels above primary drinking water standards for the constituents analyzed. The King County Solid Waste Division continues to sample four wells and five surface-water sources at and around the Landfill on a quarterly basis. It is unknown whether the shallow and deep water-producing zones impacted by the Landfill are interconnected with the aquifers utilized for public water-supply wells.

The Vashon Island Landfill is recorded on Ecology's list of Hazardous Waste Investigations and Cleanup Program dated December 1988 as a state site undergoing long-term monitoring. According to Ecology, the Landfill has apparently affected surface-water quality and may also have affected ground-water quality. Ecology's listing reports contamination as confirmed, suspected, unknown, potential, true, or false for each of 15 contaminant categories. The only contaminants listed as confirmed for the Vashon Island Landfill are "metals - other," which refers to metals other than the priority pollutants. The contaminants listed as suspected include priority pollutant metals, petroleum products, phenolic compounds, and conventional organic and inorganic contaminants (Ecology 1988).

5.2.2 Former NIKE Missile Launch Site

A former missile launch site is located at the northwest intersection of Southwest 220th Street and 119th Avenue Southwest, at the present location of Paradise Ridge Park (Figure 5-1). From 1955 to 1974, NIKE-Ajax and Hercules missiles were deployed from the site. A description of the activities formerly conducted at the site and the effect of those activities on ground water follows.

5.2.2.1 Description

According to J. A. Maas of the USACE (Maas, pers. comm. 1993), the NIKE site was composed of three areas: a family housing area, a missile launch site (Figure 5-7), and a control site approximately 1 mile east of the launch site. The family housing area is now privately owned, the control site was conveyed to the Washington State Department of Health and Education in 1976, and the launch site was transferred from the United States Department of Defense to the King County Parks Department in 1976. The launch site has been an equestrian park since 1976.

According to Shapiro Associates (Shapiro/Applied Geotechnology 1992), diesel fuel; solvents; paints; anti-corrosion products; petroleum, oils, and lubricants; and their associated wastes were stored at the missile launch facility. Solvents, anti-corrosion products, and paints were deposited into the building drainage system and later washed out of the building into a small seepage system. Selected wastes were drummed for off-site disposal. Most fuels were stored in USTs at the launch and control sites.

Additional information concerning the former NIKE missile launch site provided Maas of USACE (Maas, pers. comm. 1993) follows:

- The missile magazines were demolished at the launch site. Only the former missile assembly building and the caretaker's trailer remain.

- Asbestos was removed from selected buildings at the launch site (and control site) prior to their demolition.

- The USTs at the launch site (and control site) were removed between 1988 and 1989.

What was in USTS
how long before Decomm.
Site Assessment?

5.2.2.2 Effect on Ground-Water Quality

The former NIKE missile launch site was investigated for potential toxic and hazardous waste contamination in 1988 and 1992 under the Defense Environmental Restoration Program by Shapiro Associates (Shapiro/Science Applications 1988; Shapiro/Applied Geotechnology 1992). The findings of the 1988 site investigation are as follows:

- Concentrations of TCA were detected at levels below environmental and human health concerns.

- Concentrations of lead and petroleum hydrocarbons were detected in the surficial soils at levels below environmental and human health concerns.

- Concentrations of chlorobenzene, ethylbenzene, and xylene were detected in the soil at the Paint and Fuel Storage Area at concentrations presenting environmental and human health concerns.

- Ground-water samples collected from the on-site well did not contain VOCs, polychlorinated biphenyls (PCBs), petroleum hydrocarbons, or trace metals at concentrations that present a concern for human health or the environment.

The soil at the Paint and Fuel Storage Area was the focus of the 1992 site investigation. The Paint and Fuel Storage Area, located in the southeast-central portion of the facility (Figures 5-7 and 5-8), encompasses 620 square feet of the 66.33-acre launch site. The findings of the 1992 site investigation (Appendix B) are as follows:

- Concentrations of total xylene, trichloroethene (TCE), diesel 6, diesel 2, and gasoline above the 1991 Washington State Model Toxics Control Act (MTCA) Method A cleanup levels for soil were identified in samples collected from the eastern portion of the Paint and Fuel Storage Area (Soil Samples S-9, S-14, S-15, S-23, and S-2) (Figure 5-7).

- The vertical extent of soil contamination at sample locations S-23 and S-24 has not been defined.

Contact with ground water is estimated to occur at 20 feet below land surface (bls). The ground water in the wells closest to the site (W-7, W-13, W-16, and W-17) has not been analyzed for organic constituents.

5.2.3 On-Site Sewage Systems

The King County Board of Health (KCBH) rules and regulations governing on-site sewage disposal systems now recognizes on-site wastewater disposal, i.e., septic systems, as a long-term wastewater disposal method for areas not served by public water service. At present, all of the Island lying outside the Vashon Sewer District LSA in the Town of Vashon (Figure 5-9) uses on-site wastewater disposal systems. A description of activities involving regulation and monitoring of septic systems and the effects of septic systems on ground water are presented below.

5.2.3.1 Description

On the Island, minimum lot sizes for unsewered dwellings are based on soil texture type per unit of volume of sewage (450 gallons per day [gpd]) or whether the lot is zoned for a single-family residence (KCBH 1987). The regulations stipulate a requirement for a drainfield reserve area. The Island's soil quality, which is generally considered fair to poor for septic systems by the federal Soil Conservation Service, together with the results delineated in Carr (1983), resulted in the 1986 zoning regulations for septic systems (King County 1986).

The 1986 regulations require that the maximum housing density in unsewered areas be no more than 3 houses per acre, provided that more than 30 inches of topsoil is present. A 2.5-acre minimum lot is required in unsewered areas with 24 to 30 inches of topsoil. Unsewered areas with 20 to 24 inches of topsoil may support no more than 1 house per 5 acres (King County 1986). Minimum lot sizes for unsewered lots in new subdivisions are regulated as a function of the texture of the underlying soil (Tables 5-8 and 5-9). The type of on-site disposal system permitted on the site then depends on the undisturbed original soil depth and the size of the lot (greater or less than 1 acre).

5.2.3.2 Effect on Ground-Water Quality

SKCHD conducted a sanitary survey of on-site sewage systems in seven coastal communities between December 1988 and January 1991 to determine their condition. Four communities (Bunker Trail, Cove/Beulah Park, Spring Beach, and Burton) were declared "severe public health hazard areas." In addition, three communities (Patten Palisades, Paradise Cove, and Quartermaster Harbor) were determined to be "health caution areas" (Barrett 1991). Barrett (1992) developed a draft Sewage Facilities Plan for the severe public health hazard areas. The SKCHD survey and the sewage facilities plan are discussed in more detail in Subsection 6.5.2, On-Site Wastewater Disposal (Septic Systems).

According to the USEPA, septic systems and cesspools are the most frequently reported sources of ground-water contamination (Freeze and Cherry 1979). Drainfield how much?

Rapid Bio...

effluent has been implicated in producing elevated nitrate and phosphate concentrations in ground water and can contain pathogenic bacteria and viruses. The aerobic bacteria called fecal coliforms is considered the standard indicator parameter for drainfield effluent contamination (Lewis 1980) and is evaluated in the data analysis portion of this report.

5.2.4 Sludge Applications

Sludge now known as biosolids, is a by-product of sewage treatment performed by sewage facilities. In some cases, the sludge produced may be spread in vegetated areas with beneficial effects. How the Vashon Sewage Treatment facility handles its sludge and the effect of those sludge applications on ground-water quality are described below.

5.2.4.1 Description

The Vashon Sewage Treatment facility produces about 10 tons of sludge annually (dry weight), which is currently applied at a future silvacultural site on Maury Island. The treatment facility currently meets the qualifications for small-quantity producers and operates under a site permit issued by SKCHD, for sludge application.

5.2.4.2 Effect on Ground-Water Quality

Total coliforms, fecal coliforms, and inorganic compounds (nitrates and metals) are the indicator parameters typically used to detect ground-water contamination by sewage waste. Due to the small quantities of sludge produced by the Vashon Sewage Treatment facility, extensive ground-water monitoring is not required. However, a site permit is required from SKCHD for any land utilization by sludge. The sludge was analyzed by Laucks Testing Laboratories of Seattle in December 1987; estimates of fecal strep, fecal leaching potential

coliforms, and total coliforms exceeded 160,000 per 100 milliliters of sludge. The sample contained less than 2 percent solid material. Further results of sludge testing are shown in Tables 5-10(a) and (b).

5.2.5 Underground Storage Tanks

The Ecology listing of USTs reported in Washington (Table 5-11) lists 24 tanks in use at commercial locations on the Island; Ecology does not maintain records of residential USTs. The following paragraphs describe the uses of USTs on the Island and associated reported incidents, followed by a description of the effects on ground water of spills or leaks from those USTs.

5.2.5.1 Description

The majority of reported USTs in the Vashon GWMA are located in or near the Town of Vashon, but they are also listed at Burton and at the KING radio tower on Maury Island (Figure 5-1). The USTs range in size from less than 500 gallons to 20,000 gallons and are reported to contain the following substances: diesel fuel, kerosene, leaded gasoline, unleaded gasoline, or heating oil. A representative of the Williams Heating Oil Company in the Town of Vashon estimates that the Williams company serves approximately 700 residential USTs on the Island and that perhaps 50 to 100 more are served by other suppliers or have been abandoned (Murphy, pers. comm. 1989).

In the 1989 records, Ecology found only one report of an incident involving a leaking commercial UST on the Island. The incident involved removal of a UST containing heating oil from a public elementary school. According to Ecology, site evidence indicated that the tank had leaked. A cleanup operation was in progress when the preliminary report was submitted in August 1989, but a final report had not been received.

5.2.5.2 Effect on Ground-Water Quality

Spills and leaks from USTs can be highly detrimental to ground-water quality, and incidents of this nature are not uncommon in urban areas of Washington. The Island, however, has a relatively small population of commercial USTs and has had no major contamination incidents that Ecology can recall with the exception of the leaking UST incident at a public elementary school (1989). As commercial UST owners work to comply with federal regulations regarding UST inspection, replacement, and abandonment, however, previously unrecognized areas of contamination may be discovered.

Residential USTs are not subject to the same scrutiny as commercial USTs. Residential USTs, however, are just as susceptible to corrosion and leakage as are commercial USTs and are, consequently, just as capable of introducing contaminants into the ground water.

5.2.6 Agriculture

The majority of agricultural land in the Vashon GWMA is located in the interior region of Vashon Island, with minor additional acreage and a 55-acre golf course on Maury Island (Figure 5-1). A description of the agricultural land uses on the Island is presented below, followed by the effects on ground-water quality of agricultural operations.

5.2.6.1 Description

According to the 1986 Vashon Community Plan, a 1976 study found that about 900 acres of the Island were devoted to agricultural uses, including commercial orchards, berry farms, vineyards, nurseries, and small commercial ranches. That 1976 study stated that the Island had King County's only large commercial cherry and apple orchards and produced the county's entire harvest of currants. Also, about one-third of the Island's agricultural acreage was devoted to the production of grass and hay. In 1989, at least one commercial orchard was still in operation as well as commercial farms of various sizes, several horse and cattle ranches, and a few greenhouses (Becker, pers. comm. 1989).

5.2.6.2 Effect on Ground-Water Quality

There are two areas of concern for ground-water quality when agricultural operations are present: (1) fertilizer and pesticide use and (2) animal waste products. Fertilizers and pesticides used on crops may present a risk to ground-water quality on the Island. Fertilizers can cause elevated nitrate levels in surface and ground waters, while pesticides can be toxic at relatively low concentrations in ground water. No information regarding fertilizer use on the Island was available in 1989 when this report was prepared.

A 1987 USEPA listing of pesticides used on crops grown on the Island includes nine leachable pesticides known to have been used at least occasionally (generic names: diuron, fenamiphos, pronamide, simazine, dinoseb, dicamba, chloramben, carbofuran, and disulfotan) and an additional three that may have been used at some time (generic names: dalapon, terbacil, and atrazine) (USEPA 1987). The Cooperative Extension Service (CES) in Tacoma provided a slightly different list of herbicides and pesticides (generic names) commonly used on some of the Island's commercial crops: ronilan, carbofuran, dodine, azimphosmethyl, and 2,4-D (Shallow, pers. comm. 1989). According to Bill Shear of the CES in Tacoma, the USDA requires permits for spraying restricted pesticides, but not for spraying those that are unrestricted (Shallow, pers. comm. 1989).

Fertilizers and pesticides are applied to the 55-acre Vashon Golf Course on Maury Island; information regarding quantities applied was not received in time to be incorporated into this version of the report (Bailey, pers. comm. 1989). Bob Newman of the Northwest Division of Ecology recalled one incident in which a truck leaked a small quantity of pesticide on the Island, but said that he did not consider it to be a major contamination event (B. Newman, pers. comm. 1989). The extent of residential pesticide and fertilizer use is not known.

Manure from farm animals may eventually introduce high nitrate levels into the ground water; however, no information is presently available regarding the effects of Island ranching operations on the ground water. Elevated nitrate levels have been detected in ground-water samples collected from the Coast Guard well on Point Robinson. These elevated nitrate levels may be the result of the historic practice of keeping horses in the area where a well is now located (Carr 1983).

5.2.7 Sand and Gravel Extraction

Four major commercial and a number of smaller sand and gravel extraction operations are located in the Vashon GWMA. A brief description of the operations and their effect on ground water is presented below.

5.2.7.1 Description

Approximately 520 acres are zoned for quarrying and mining along the south shore of Maury Island. The four major facilities operate throughout the year in this area. Several smaller sites are operated intermittently across the Island. Figure 5-1 portrays the locations at which extraction operations are conducted.

The Vashon Sand and Gravel (VSG) plant, the largest extraction operation on the Island, has been reported as having on-site a wash plant, a well approximately 500 feet deep with a 7½ horsepower pump capable of pumping 35 gallons per minute (gpm), and a settling pond for wastewater (GWAC, pers. comm. 1989).

5.2.7.2 Effect on Ground-Water Quality

Bob Newman of the Northwest Division of Ecology has no recollection of contamination associated with sand and gravel extraction on the Island (B. Newman, pers. comm. 1989). Only the VSG plant is reported to produce a significant volume of wastewater, which is collected in a settling pond. Further details regarding the integrity of the settling pond are not currently available. Similarly, the quality of ground water in the plant's well is not known.

5.2.8 Seawater Intrusion

Because many of the wells operating on the Island are relatively close to the shoreline, seawater intrusion into ground-water sources is of concern in the Vashon GWMA. Seawater intrusion is first described below, then the results of testing conducted to evaluate the intrusion of saltwater into the ground water are presented.

5.2.8.1 Description

Wells that tap aquifers adjacent to saltwater bodies, such as Puget Sound, may become saline if the freshwater/saltwater interface moves inland in response to high pumpage of groundwater use. Artificial recharge, freshwater injection wells, and other methods have been employed to counter the problem of sea-water intrusion in low-lying coastal areas such as Florida (Driscoll 1986). Chloride is used as the indicator parameter for sea-water contamination in ground water.

5.2.8.2 Effect on Ground-Water Quality

Ground-water samples collected from nine wells on the Island in 1982 by Carr (1983) contained chloride levels above 10 milligrams per liter (mg/L); all of the wells are within about 1/2 mile of the shoreline. The wells with higher chloride levels were located on the northern end of Vashon Island and on the southeastern portion of Maury Island. Carr (1983) states that these wells may be impacted by seawater intrusion; however, the reported chloride levels are substantially lower than the average chloride content of seawater, i.e., approximately 19,000 mg/L (Driscoll 1986).

>200 mg/l is TCL ?!
How much lower?

5.2.9 Roadside Spraying

Vegetation along the roadside is commonly sprayed with herbicides or pesticides, or both, to control weed growth, limit the spread of brush and trees, protect newly planted beds from disease and insects, or control insects and weeds in specific spots. How and when pesticides or herbicides are applied on the Island is described, followed by the effects of roadside spraying on ground water.

5.2.9.1 Description

The Vashon GWMA is a herbicide moratorium area, meaning that pesticides are applied only to the noxious weed tansy ragwort, which is deadly to livestock, (G. Newman, pers. comm. 1989). The DPW uses the herbicides Banvel and Garlon 3-A, typically combined in a ratio of one quart of Banvel to two quarts of Garlon 3-A to 100 gallons of water. DPW personnel drive along every public right-of-way on the Island, selectively spraying each tansy ragwort plant and its surrounding area to a radial distance of approximately 3 feet. The job usually requires 1 to 2 weeks. In July 1989, DPW personnel prepared 200 gallons of diluted herbicide 1 work day before beginning to spray on the Island. They then sprayed on the Island for 8 days, at the end of which time there was an estimated 50 gallons of herbicide remaining in the tank (Easter, pers. comm. 1989).

According to A. Card of the WDNR, WDNR does not currently spray the roadside on the 205 acres of land that it manages on the Island. WDNR conducts only occasional small-scale herbicide application on this acreage, using either "thin-line" hand-held squirt bottles to spray selected plants or a so-called "cut-and-daub" method, in which herbicide is applied by hand to the base of a severed tree limb (Card, pers. comm. 1989).

5.2.9.2 Effect on Ground-Water Quality

Application of herbicides and pesticides for roadside plant control can threaten ground-water quality in two principal ways. First, chemicals may be transported by storm-water runoff into areas of high aquifer recharge. Second, chemicals may percolate into shallow aquifers through fissures or dry and sandy soils. The exposed clay-rich till along the roadside on the Island, however, may absorb some of the chemicals before they reach ground water.

No incidents of contamination from roadside spraying have been reported to Ecology. As discussed in Section 5.2.6.2, Agricultural Effects on Ground-Water Quality, a small pesticide leak from a truck was recorded in Ecology's records, but no other pesticide- or herbicide-related incidents are on record (B. Newman, pers. comm. 1989).

5.2.10 Hazardous Materials

The term "hazardous material" refers to "hazardous waste" as well as to "hazardous substances," both of which are generally defined as materials that pose a substantial present or potential threat to human health or the environment. These include both hazardous wastes generated by commercial operations and hazardous materials used in residential households. The following paragraphs describe the hazardous materials on the Island and their effect on ground-water quality.

5.2.10.1 Description

Importation of hazardous materials to the Island is regulated by the Washington State Ferry Service (WSFS), which provides the only access to the Island. Hazardous materials are required to be shipped aboard ferries that are not carrying passengers and that dock at Fauntleroy, where special ferry runs can be set up to accommodate hazardous loads. The WSFS has no authority to search enclosed vehicles and operates under the assumption that shipping papers prepared by companies correctly describe the hazardous materials being transported. The WSFS can request that the Washington State Patrol inspect shipments of hazardous materials (Baird, pers. comm. 1989).

Under a new King County program, county residents can dispose of household hazardous wastes, such as paint thinners and solvents, at the King County Wastemobile. The Wastemobile is a disposal truck that travels around King County accepting household hazardous waste from County residents at no charge. The Wastemobile which began waste collection on the Island in mid-1989,did not return to the Island until 1990. King County is hoping to add another Wastemobile to the program in order to reduce the waiting time for waste disposal (King County, pers. comm. 1989).

The USEPA and Ecology maintain records of hazardous waste sites and generators, both active and inactive. According to the USEPA listing of March 31, 1989, there are no CERCLA or Superfund sites on the Island (USEPA 1989). The only Island site included on the Ecology list of State Hazardous Waste Investigations and Cleanup dated September 12, 1989 is the Vashon Island Landfill; on the list, the Landfill is characterized as undergoing long-term monitoring after completion of cleanup (Ecology 1989).

The USEPA/Ecology list of Hazardous/Dangerous Waste Notifiers dated January 13, 1989 includes seven Island businesses (USEPA 1989). Three Island businesses -- Sandy Beach-Maury Island, Natural Products Co., and Dilworth Drum -- are small-quantity generators producing less than the regulated amount of hazardous waste each year (220 lbs); two businesses -- Joy's Village Cleaners and K-2 Ski Manufacturing Corporation -- produce 220 to 2,200 pounds annually; one business -- Metro-Oberpark Park-and-Ride -- produces more than 2,200 pounds annually; and one business -- Island Industries, Inc. -- no longer produces hazardous waste, but is still in business at the same location.

5.2.10.2 Effect on Ground-Water Quality

Only a few incidents involving hazardous materials in the Vashon GWMA have been reported. Bob Newman of the Northwest Division of Ecology recalls that a drum of flammable solvent was removed from a roadside several years ago by Ecology (B. Newman, pers. comm. 1989). According to SKCHD (1990), the drum of flammable solvent was from the Stoltz property, which is used as a junkyard and is located adjacent to the Vashon Island Landfill. Ecology was also responsible for disassembling an illegal drug lab at the southern end of Vashon Island and removing stockpiled materials. Neither incident resulted in apparent contamination. According to Newman, the Island Springs Tofu plant at one time discharged wastes to the ground, but has since ceased that practice; no significant contamination resulted (B. Newman, pers. comm. 1989). No spills have been reported at the K-2 Ski Manufacturing Corporation or Pacific Research plants (B. Newman, pers. comm. 1989). According to Island residents, however, fiberglass from the K-2 Ski Manufacturing plant has been used as mulch on the Island (SKCHD 1990).

5.2.11 ASARCO Smelter

The ASARCO smelter and other closed smelters on the mainland may have contributed to elevated contaminant levels reportedly found in soil sampled collected from the southern portions of the Island. Information concerning the suspected contamination and its effect on ground-water are described below.

5.2.11.1 Description

Airborne particulate material from the ASARCO smelter and other closed smelters in Ruston, Washington located on the mainland southeast of the Vashon

GWMA, may have been carried over the Island when the wind blew from the east over the operating smelters. The ASARCO smelter, now a CERCLA site, is one of the suspected sources of elevated arsenic, cadmium, and lead levels reportedly found in soil samples taken at several locations near the southern ends of the Island (Carr 1983; SKCHD 1984).

5.2.11.2 Effect on Ground-Water Quality

In Carr (1983), water samples from 10 springs and streams were analyzed for arsenic, cadmium, and lead. All values were below the laboratory detection limit. Samples collected below the Vashon Island Landfill were also below the limits of detection. Carr (1983) stated that the metals had been retained by the soil and were effectively prevented from infiltrating to the ground water (Carr 1983).

A 1982 through 1984 study of heavy metals in honey bees in the Puget Sound area found arsenic concentrations as high as 18 to 20 parts per million (ppm) in bee colonies near the southern ends of the Island, compared to background levels of 0.1 to 1 ppm in bees on Whidbey Island. The supervisor of the study concluded that the arsenic taken up by the bees was primarily airborne (Bromenshenk, pers. comm. 1989).

In 1984, DOH (formerly the Department of Social and Health Services) conducted a study of unprotected drinking water sources to determine whether arsenic, cadmium, and lead were present, and, if so, whether their presence constituted a health risk. Of the 50 wells, springs, and surface-water sources sampled for the study, 20 wells, 11 springs, and 2 surface-water sources were located on the Island. The DOH concluded that arsenic, cadmium, and lead were not present at significant levels in the unprotected drinking water sources utilized in the study.

The Ruston/Vashon Arsenic Exposure Pathways Study, prepared by the University of Washington under contract with Ecology (University of Washington 1987), was aimed at determining the pathways by which humans are exposed to arsenic and the daily arsenic intake of the population living in the vicinity of the copper smelter in Ruston, Washington. Households in Ruston and on the Island participated in the study, which involved urine and hair sampling and measurement for environmental concentrations of arsenic. Drinking water was sampled in all of the study areas. The final report, issued in March 1987, concluded that the highest concentrations of arsenic were found near the smelter, even though it was closed; demolition activities were thought to be responsible for elevated levels of airborne arsenic. Arsenic concentrations in drinking water samples collected in the study area were lower than state and federal minimum standards and were comparable to concentrations reported from other areas in Puget Sound.

6.0 WATER APPLICATIONS

Chapter 6.0 discusses water applications on the Island in terms of demand, services, rights, and uses. The systems which handle storm water for the Island are also described. Each section below discusses a separate area of concern.

6.1 WATER DEMAND

Future water demand is generally predicted using demographic projections and reasonable values for per-person or per-household daily consumption. Figures for future water demand are then compared to the calculated production capacity of the aquifer(s) to evaluate adequacy of the supply relative to the demand.

6.1.1 Demographic Projections for the Vashon GWMA

Population forecasts for the Vashon GWMA vary considerably. As enumerated in Subsection 5.1.2.1, Residential Development Trends, the PSCOG predicts a 16 percent increase in population on the Island during the years 1980 to 2000 (Table 5-3). The 1988 AGR (Table 5-4) predicts population growth of 46 percent during the same 20-year period. Using these figures, projected water demand can be estimated as follows.

6.1.2 Projected Water Demand in the Vashon GWMA

Projected water demand in the Vashon GWMA has been calculated using a per-person consumption value of 120 gpd and both the PSCOG and AGR population forecasts (Tables 6-1 and 6-2, respectively). Calculations using PSCOG figures yield a value of over 1 million gallons for daily water demand for the entire Island by the year 1990, which translates into an annual demand of 366 million gallons. Calculations using the higher AGR forecasts yield a value of about 474 Mgpy for 1990. The AGR projections forecast an annual demand that is approximately 29.5 percent higher than the PSCOG projections.

6.1.3 Aquifer Recharge and Capacity

The ability of the Island to meet projected water demands depends largely on the supply available from the Principal and Deep Aquifers. The recharge of the Principal and Deep Aquifers was calculated in Carr (1983). The recharge of the Principal Aquifer was estimated to be approximately 8.90 million gallons per day (Mgpd), and that of the Deep Aquifer was estimated to be between 1.73 and 3.46 Mgpd. Far greater uncertainty is associated with estimates for the Deep Aquifer than the Principal Aquifer. Based on the Carr recharge data, the production capacity of the Principal Aquifer was evaluated.

Carr (1983) comments that an estimated 45 percent of recharge occurs in high recharge areas, which represent about 25 percent of the land surface area. Not all the water in the aquifer is available for withdrawal, however; Carr (1983) estimates a total water productivity from the Principal Aquifer of about 578 Mgpy. This figure takes into consideration the effects on production of drought and inefficient withdrawal. Similar calculations for the Deep Aquifer have not been performed. A discussion of the reassessment of potential recharge areas is included in Chapter 8.0, Hydrogeology.

6.2 WATER SERVICE

The 1986 Vashon Community Plan (King County 1986) establishes the entire Vashon GWMA as a Water Service Area, an area in which public water service is permitted. Under this classification, no portions of the Vashon GWMA are restricted to private water systems. As used in the 1986 Plan, "public water service" includes Group A and B water systems, both publicly and privately owned.

The only publicly owned water purveyor on the Island is King County Water District No. 19, but five privately owned Group A purveyors operate to meet additional water demands. The following discussion of the Group A (formerly Class 1) water purveyors is based largely on information contained in the Vashon Coordinated Water System Plan (Horton Dennis 1991). Tables 6-3 and 6-4 list available information regarding the seven major water purveyors on the Island; all are Group A systems. Figure 6-1 illustrates the areas of distribution, sources, and storage facilities of the seven major water purveyors on the Island. The following subsections discuss each purveyor.

6.2.1 King County Water District No. 19

King County Water District No. 19 is the only public water system in the Vashon GWMA. Established in 1925, the District has over 1,000 connections and is the largest water system on the Island. The District's service area covers approximately 6 square miles in east-central Vashon Island (Figure 6-1); consumers range from single-family houses in low-density residential areas to commercial and industrial concerns.

The District obtains water from two plants. Plant No. 1 uses a surface-water source and is located on BeallBealll Creek. The supply averages 200 gpm and continues during dry months because ground-water flows out through seeps, the exposed seams of sand in the walls of the stream valley.

Plant No. 2 uses a surface-water source, a developed spring, and a well. Water from Ellis Creek provides approximately 235 gpm, and the nearby developed spring provides approximately 50 gpm. Well No. 1 is located in the Town of Vashon, near the intersection of 103rd Avenue Southwest and Southwest 176th Street, in the water storage tank area. The well is 670 feet deep and yields an average of 150 gpm. An additional deep well located adjacent to Well No. 1 was completed in 1990. It should provide the same amount of water as Well No. 1 and will be used as a backup source.

The District has a total storage capacity of approximately 1.725 million gallons distributed between two pressure zones. Storage facilities for Pressure Zone 1 consist of two tanks with a combined capacity of 1.625 million gallons. These tanks serve 704 connections. The storage facility for Pressure Zone 2 is a 100,000-gallon reservoir located on Southwest 216th Street near its intersection with 99th Avenue Southwest. The reservoir serves approximately 260 connections. Storage facilities for the two pressure zones are interconnected.

6.2.2 Heights Water Association

The Heights Water Association (HWA) is a private, nonprofit corporation that serves the north end of Vashon Island (Figure 6-1). The HWA maintains approximately 455 connections, most of which are private homes, but which also include the Vashon Nursing Home, the WSFS facilities, and the Vashon Elementary School. The HWA is not currently accepting new water-share applications.

The HWA obtains water from springs and wells located in the northeast quarter of Section 18, Township 23N, Range 3E, where the HWA holds water rights to approximately 17 acres. Two unnamed springs at the base of a steep ravine yield an average of 150 gpm; two wells located on higher ground west of the springs supply about 125 gpm.

The HWA has a total storage capacity of approximately 330,000 gallons in five covered storage reservoirs. Four of the reservoirs are interconnected and supply the majority of the system; the fifth reservoir, at the south end of the system, provides supplemental storage. An additional 40,000 gallons of storage capacity is provided by collection basins located at the spring source; however, this water is not available by gravity flow. The south end of the HWA system is interconnected with King County Water District No. 19; this connection can be opened manually in the event of an emergency.

6.2.3 Westside Water Association

The Westside Water Association (WWA) is a nonprofit cooperative serving an area of approximately 2 square miles in northwest Vashon Island near Fern Cove (Figure 6-1). The WWA has approximately 210 metered connections, all of which are private, with five future connection rights sold.

The WWA maintains a 40-acre watershed area in Cedarhurst Canyon (also known as Shinglemill Creek Canyon or Needle Creek Canyon), one of the Island's largest drainage basins. The WWA obtains about 180 gpm from a number of artesian well points located in the walls of the canyon. The WWA has a total storage capacity of about 253,000 gallons in two aboveground tanks.

6.2.4 Burton Water Company

The Burton Water Company (BWC) is a private company serving the Burton Peninsula and the surrounding area (Figure 6-1). A majority of the estimated 350 BWC customers are private homes, but the BWC also serves a small neighborhood center and an elementary school.

The BWC obtains water from a combination of wells and well points which extend to about 18 feet bls on a 5-acre plot near the intersection of Southwest 232rd Street and 115th Avenue Southwest. Production varies with rainfall, averaging between 125 and 150 gpm during the drier summer months. Runoff to Puget Sound during the winter months is significant.

The BWC has a total storage capacity of approximately 170,000 gallons. Storage facilities include three tanks, all located at the supply site. Four pumps are used to transfer water from the wells and well points to the tanks during peak-demand periods; during winter, the pumps are used only occasionally.

6.2.5 Dockton Water Association

The Dockton Water Association (DWA) is a nonprofit association serving 245 customers on the southern portion of Maury Island (Figure 6-1); all but one of the customers is residential. An additional 71 reserve memberships entitle landowners to service at an unspecified future date.

The DWA obtains water from two springs -- Park and Hake Springs -- and one well -- Sandy Shores -- in the service area. Park Spring, located across Portage-Dockton Road from the Dockton-King County Park in the village of Dockton, yields an average of 100 gpm and is collected from well points scattered over 10 acres of watershed. It has been estimated that up to 50 gpm of additional water may be available from this source if additional well points were added and existing points redeveloped.

The Hake Spring, located on a 25-acre site abutting Southwest 268th Street southwest of Dockton, yields 30 to 40 gpm. The spring is intercepted by plastic pipe before reaching the surface and partially diverted to a DWA storage unit.

The Sandy Shores well, located on 94th Avenue Southwest south of Dockton, is 415 feet deep. Although the bottom of the well appears to be below sea level, the static water level is above sea level. The well is capable of producing 100 gpm with no more than 10 feet of drawdown.

The DWA has a total storage capacity of approximately 381,000 gallons distributed between two pressure zones. Storage facilities for the lower pressure zone, supplied with water from the springs, consist of three ground-level concrete tanks with a combined capacity of 65,000 gallons. Storage facilities for the upper pressure zone, supplied with water from the Sandy Shores well and from lower-level reservoirs, consist of two concrete standpipe tanks with a combined capacity of 316,000 gallons. Storage facilities for the two pressure zones are interconnected.

6.2.6 Gold Beach Water System

The Gold Beach Water System (GBWS) is a privately owned and operated system serving 109 homes in the community of Gold Beach on the southeast shore of Maury Island (Figure 6-1) The GBWS obtains water from two wells, each about 110 feet deep, located on the northern edge of the Gold Beach community. The wells have a combined yield of about 250 gpm. The GBWS has a total storage capacity of about 85,000 gallons, with 50,000 gallons available in a lower pressure zone and 35,000 gallons in an upper pressure zone. The two zones are interconnected.

6.2.7 Maury Mutual Water Company

The MMWC is a privately owned cooperative that supplies 89 single-family homes and one commercial connection on the northern end of Maury Island (Figure 6-1). The MMWC is not currently accepting new memberships into the cooperative.

The MMWC obtains water from eight shallow-driven well points and two springs located on northern Maury Island near Southwest 232nd Street and 59th Avenue Southwest. These sources yield a total of about 35 gpm. The MMWC has a total storage capacity of about 130,000 gallons. A mid-system facility provides about 58,000 gallons of storage, and two upper-level reservoirs provide a combined capacity of 72,000 gallons.

6.2.8 Other Water Systems

The seven systems discussed so far represent only the major water purveyors in the Vashon GWMA. More than 100 Group A (formerly Class 2) and B public water systems also operate on the Island (Figure 6-2). In addition, private wells provide water to a considerable number of houses and to several businesses across the Island. The exact number of private wells on the Island is not known. SKCHD obtained copies from Ecology of approximately 280 well logs for public and private wells on the Island. In most cases, it was not possible to distinguish between logs of public and private wells without prior knowledge.

6.3 WATER RIGHTS

The 1986 Vashon Community Plan establishes that development of new public water sources may occur only if it can be demonstrated that such development will not adversely affect existing water supplies. To ensure this, Ecology requires that a water right be obtained if more than 5,000 gallons of water are to be withdrawn from the new water source per day, if the source is to serve five or more houses (approximately the equivalent of 5,000 gpd), or if more than 1/2 acre of land is to be irrigated (King County 1986).

Ecology maintains water right records for the entire state. The listing of water entities holding a water right includes the names of permit holders, sources of water, places of use, purposes for which the water will be used, permitted instantaneous withdrawal rates, and permitted annual withdrawal quantities. The Ecology listing of existing water right holders includes several hundred Island water right permit holders. Table 6-3 lists the instantaneous withdrawal rates and annual withdrawal quantities permitted for five of the seven major water purveyors discussed in Section 6.2, Water Service. The BWC and GBWS were not listed by name in the Ecology water right listing. The BWC, however, holds a water right which allows 200 gpm (Lasby, pers. comm. 1991).

6.4 WATER USE

For business purposes, commercial water systems maintain records of the amount of water withdrawn from Island sources and the quantity sold to customers during established time periods. Owners of private wells have no such motivation for maintaining similar records, and information regarding actual withdrawal quantities is less readily accessible.

Figures for the amount of water withdrawn annually from Island sources by five of the major water purveyors are presented in Table 6-3. These figures were reported by representatives of the purveyors and represent the actual or estimated amounts of water withdrawn by the purveyor during the period listed.

Table 6-3 permits comparison of permitted water withdrawal quantities and actual water withdrawal figures for these purveyors. It appears from this preliminary comparison that reported withdrawal quantities do not necessarily reflect permitted withdrawal quantities.

6.5 WASTEWATER DISPOSAL

A portion of the Town of Vashon lies within the Vashon Sewer District LSA and is served by the Vashon Sewer District, but the remainder of the Island relies on on-site wastewater disposal systems, primarily septic systems. The following subsections provide a detailed discussion of these two major methods of wastewater disposal on the Island.

6.5.1 Vashon Sewer District

The Vashon Sewer District LSA, established under the 1986 Vashon Community Plan, covers approximately 405 acres (about 0.63 square miles) in the Town of Vashon (Figure 5-9); of the 405 acres, approximately 180 acres remained undeveloped in 1980. Full development of the entire LSA would raise the population to an estimated three times the design capacity of the Vashon Sewer District's treatment plant.

The Vashon Sewer District has been operating since 1955 and underwent major improvements during 1974 and 1975. It was estimated that the district was serving approximately 600 people in 1979. This figure was obtained by dividing the amount of wastewater reaching the treatment plant by the estimated amount of wastewater (in gallons) produced per day per connection (gpdpc); a value of 250 gpdpc is commonly used (Ames, pers. comm. 1989). The number of connections can be converted to an equivalent number of people by using the average housing figure of 2.5 people per residence or per connection (PSCOG 1988).

In 1986, the treatment plant reportedly had the capacity to serve the equivalent of 1,375 people. August 1989 figures indicate that the District is serving the equivalent of about 560 people. This figure was obtained by dividing the average total daily inflow to the treatment plant of 56,000 gallons by a reasonable estimate of wastewater production (250 gpdpc) and converting the resulting figure of 224 connections to 560 people using 2.5 people per connection.

In actuality, the conversion from wastewater production to number of people served is not completely straightforward. The District serves the K-2 Ski Manufacturing plant and the Vashon Nursing Home, which combine to produce almost half the wastewater reaching the treatment plant; in August 1989, the K-2 Ski Manufacturing plant produced over 30 percent of the effluent reaching the treatment plant, while the Vashon Nursing Home contributed 12.5 percent. If the contribution of these two facilities is excluded, the District can be said to serve an estimated 128 connections, or about 320 people. A number of the connections are small businesses and apartments, however, both of which typically account for fewer than 2.5 people (Ames, pers. comm. 1989). The actual number of connections is 332, of which 216 are residential and 116 are commercial.

The amount of wastewater reaching the treatment plant during wet months is reportedly far in excess of the amount of water distributed by King County Water District No. 19. This observation prompted extensive testing of the sewer and storm-water drainage systems, eventually leading to the conclusion that storm-related infiltrating moisture enters the sewer system through numerous leaking joints between sections of sewer pipe. This occurs most readily during winter when the water table is high. Conversely, it is possible that wastewater may leak from the pipes and infiltrate the surrounding soil during dry seasons when the water table is low (Ames, pers. comm. 1989).

6.5.2 On-Site Sewage Systems (Septic Systems)

On-site wastewater disposal, primarily in the form of septic systems, is recognized in the Vashon Community Plan (King County 1986) as a permanent solution to wastewater disposal outside the Vashon Sewer District LSA. Since the LSA covers less than 1 square mile of the Vashon GWMA, the majority of the Vashon GWMA's population relies on septic systems for wastewater disposal. Although septic systems and cesspools are the most frequently reported sources of ground-water contamination (Freeze and Cherry 1979), modern systems are generally designed to filter wastewater extensively so that it may act as a beneficial source of ground-water recharge.

A sewage facilities investigation was initiated by SKCHD in December 1988 to evaluate the incidence of septic system failure in beachfront areas and in selected drainage basins on the Island. The study was used to determine whether communities as a whole would need to update or redesign their treatment systems. The sewage systems were categorized as functioning, failing, or prefailing. The areas surveyed were selected based on complaints to and knowledge by SKCHD of failing systems. Septic system failures reported to SKCHD from 1987 to 1988, prior to the survey, are shown in Figure 5-9. The methodology and results of the Sewage Facilities Plan study (PEI/Barrett 1992, now Barrett) initiated as a result of the septic system survey's findings are summarized below.

Septic tanks were given a visual inspection to check if raw sewage or sewage effluent was surfacing from the ground or if sewage effluent was discharging to surface waters. If raw sewage was observed on the ground surface or discharging to surface waters, fluorescein dye was injected into the tank. If the fluorescein dye was observed where the sewage surfaced, then the tank failed the test. Bacteriological samples of water and/or sediment were collected at select sites that were suspected as failing. The system failed if bacterial levels exceeded regulatory standards. If the system did not fail, but heavy lush grass growth over the drainfield, slowly draining plumbing fixtures, a high seasonal water table, or significant construction over the drainfield area was observed, the system was designated as "prefailing."

Areas with 75 percent or more sewage system failures and prefailures were identified as "severe public health hazard areas." Test results from the septic system study are included in Table 6-5. Five communities on the Island have been declared "severe public health hazard areas" (Figure 6-3): (1) Cove (northwest Vashon Island), (2) Beulah Park (northwest Vashon Island), Spring Beach (southwest Vashon Island), Bunker Trail (north Vashon Island), and Burton (southeast-central Vashon Island) (PEI/Barrett 1992). All of the existing homes at Spring Beach are connected to a common gravity pipe which discharges into Puget Sound at low tide without any treatment.

If the sewage systems for a community had a 25 to 50 percent failure and prefailure rate, then the community was designated as a "health caution area." Three communities on the Island have been declared "health caution areas" (Figure 6-3): (1) Patten Palisades (north Vashon Island), (2) Paradise Cove (southwest Vashon Island), and (3) Quartermaster Harbor (southeast-central Vashon Island).

All or a portion of each of the five severe public health hazard areas are included within the following four sensitive land use areas: (1) Class III landslide hazard areas (except Burton and Beulah Parks), (2) Class III seismic hazard areas, (3) erosion hazard areas, and (4) tidal wetlands. Population in the five hazard communities totals 374.

The sewage discharges near the shore that occur now in the health hazard areas pose little risk to Island potable water supplies (PEI/Barrett 1992). However, areas available for new community drainfields most likely will not be near the shoreline; therefore, ground-water supplies on the Island could be affected by future septic system failures.

The Sewage Facilities Plan by PEI/Barrett Consulting Group (1992) evaluates the types of sewer systems that may be feasible for the Island. The following recommendations were included in the plan:

- Sewer service may be extended only with a LSA and operated by a public agency, although boundary adjustments would need to be made to extend the LSA.

- Community sewer services are recommended, and they need not be in an LSA. The problems encountered with designing these systems include not enough to a limited area on the building lot for a drainfield, a slope that is greater than 40 percent, or the lot's being on the waterfront. A variety of collection, treatment, disposal, and transfer systems have been designed as "alternatives."

- Repairs to the existing sewage systems are not feasible; some form of community sewer system is the only "reasonable" solution.

PEI/Barrett (1992) recommends several community system alternatives for sewage collection, treatment, and disposal. The systems most feasible for each community are outlined below:

Collection Alternatives

Spring w/ pumps & tanks Gravity Sewers - Spring Beach, Burton

Vacuum System	- Beulah Park/Cove, Bunker Trail, Greater Burton
Grinder Pumps	- Beulah Park/Cove, Bunker Trail
Solids Handling Pumps	- Beulah Park/Cove, Bunker Trail, Burton
Holding Tanks	- Spring Beach
STEP System	- Beulah Park/Cove, Burton

Insp. rec. req.?

Treatment Alternatives

Package Plant	- Spring Beach, Beulah Park/Cove, Bunker Trail
Recirculating Sand Filter	- Spring Beach, Beulah Park/Cove, Bunker Trail, Burton
Solar Aquatics	- Burton
Constructed Wetlands	- Burton
Tertiary Plant	- Burton

Disposal Alternatives

Outfall to Puget Sound	- Spring Beach, Beulah Park/Cove, Bunker Trail, Burton
Drainfield Pump to Vashon Sewer District	- Beulah Park/Cove, Bunker Trail, Burton

SKCHD, under WDOH guidance, and the Department of Ecology regulate treatment and disposal of wastewater. Septic systems must incorporate these regulations into their designs. The Burton area on Quartermaster Harbor will need special consideration in septic system design because at least 95 percent removal of BOD is required, and effluent BOD concentrations must be less than 10 mg/L to discharge to Quartermaster Harbor. Nutrient levels of nitrogen and phosphorus will need to be monitored and controlled.

6.6 STORM-WATER SYSTEMS

Many natural storm-water drainage systems in the Vashon GWMA contribute to the flow of storm-water runoff into Puget Sound (Morgan, pers. comm. 1991). In addition, several man-made storm-water systems direct storm-water runoff on the Island.

The DPW Roads Division regulates storm-water management in the Vashon GWMA. Storm water is collected at and transported from various locations on the Island. The man-made systems serving the Town of Vashon and the communities of Burton, Sandy Shores, Gold Beach, Dockton, and North Vashon are described in this section.

Two systems operate to collect and remove storm water in the Town of Vashon: one along Main Street and one for the remainder of the town. Storm water on Main Street is captured in storm drains and travels enclosed to the eastern end of Southwest 171st Street, where it empties into a canyon and flows to the Sound. Storm water captured elsewhere in the town travels enclosed via 100th Avenue Southwest and Southwest 176th Street to Cedarhurst Canyon, where it emerges and flows into Colvos Passage (Figure 2-1) (Morgan, pers. comm. 1989).

Three systems regulate storm-water flow in the Burton area. One system runs south from Vashon Island Highway to about Southwest 238th Street, where it flows into Quartermaster Harbor. Another system consists of three storm-water catch basins which run south along the Vashon Highway from the intersection of Southwest 240th Street to Quartermaster Harbor. The third system begins at Inspiration Point, has collector systems on Southwest 240th Street and 115th Avenue Southwest, and discharges into Quartermaster Harbor (Morgan, pers. comm. 1991).

In the Sandy Shores area, storm water flows from the upper Sandy Shores area to 94th Avenue Southwest to Southwest 275th Street, then into Puget Sound. At Gold Beach, storm water flows into a collector system at the top of 75th Avenue Southwest, then southeast down Gold Beach Drive into Puget Sound. In Dockton, storm water is collected at Vashon Highway and flows west down a county easement (261st Street), then east on Dockton Road Southwest where it crosses to the north at Dockton Park and flows into Quartermaster Harbor. At the north end of Vashon, near Cunliffe Road

Southwest, storm water flows north on Vashon Highway Southwest into Puget Sound. On 103rd Avenue Southwest, a dozen catch basins run north from Southwest 116th Street to the ferry dock.

7.0 GROUND-WATER POLICIES

The following chapter summarizes ground-water policies relevant to the Vashon GWMA. Ground-water policies for Washington state are presented first, followed by specific policies for King County and the Island.

7.1 WASHINGTON STATE

In October,1990 the State adopted Chapter 173-200 WAC Water Quality Standards for Ground Waters of the State of Washington that established statewide ground-water quality goals, defined criteria to measure water quality, and complied with the Water Pollution Control Act of Washington (Chapter 90.48 RCW). The standards were developed by Ecology's Water Quality Program with the assistance of a 20-person citizens' advisory committee and an internal Ecology work group. Ecology's authority to develop the standards is granted by the Water Pollution Control Act.

The standards protect all ground waters of the state to drinking water standards using the most stringent criteria that exist. The standards establish an enforcement capability by instituting minimum standards for ground-water quality against which changes in quality can be measured; the goal of the standards is "no net increase" in ground-water contamination. The point of compliance with the standards is "everywhere in the ground water below the site." Ecology is the enforcement agency.

The standards require new businesses to maintain the existing ground-water quality within the boundaries of their sites (Stern, pers. comm. undated). No addition of contaminants to the ground water is permitted, even if the ground water is already contaminated. Similarly, existing businesses are not allowed to degrade the ground water at all, even if the ground water is already contaminated. If existing ground-water quality is better than the quality of discharge water that can be produced using all known and reasonable methods of treatment (commonly known as AKART), the discharger is required to improve the technology rather than allowed to degrade the ground water by using existing technology. A business that can document that it is causing no net loading of contaminants to the aquifer, will be able to operate over a contaminated aquifer without incrimination provided the operators adhere to Ecology's Best Management Practices.

APAs?

The standards provide for Ecology to establish Special Protection Areas (SPAs), which are areas of beneficial uses that require a level of ground-water protection beyond that offered by the standards. For example, the level of cadmium permitted under the standards would probably be too high for fisheries, according to a spokesperson for Ecology (Stern, pers. comm. undated). A SPA could be proposed by Ecology or a local entity, which would submit data to indicate why the area is special (an area that has federal sole source aquifer status, for example). The final declaration of SPA status would come from Ecology. No specific actions are dictated by SPA designation. When Ecology issues permits for SPAs, however, consideration of the SPA's unique qualities would be required as part of the permitting process. The permits could be more restrictive in response to the specific vulnerabilities and needs of the areas. SPA designation could also provide local entities with an additional tool in restricting certain land use activities.

7.2 KING COUNTY

The two major King County plans guiding the Island's water management decisions are the 1985 King County Comprehensive Plan (King County Council 1985) and the 1986 Vashon Community Plan (King County 1986). Both plans are described below. Vashon Community Plan policies and a synopsis of King County Zoning Codes are provided as Appendix C.

7.2.1 King County Comprehensive Plan

The 1985 King County Comprehensive Plan (King County Council 1985) establishes policies for ground-water management throughout King County, including the Island. The Comprehensive Plan calls for the protection and enhancement of water quality through land use and development activities that preserve the amenity and ecological functions of water features. The Comprehensive Plan includes general policies on water quality and more specific policies concerning drainage systems, rivers, streams, water bodies, wetlands, floodplains, and aquifers. Protection and preservation of existing systems is encouraged, taking precedence over new development.

The 1985 Comprehensive Plan states that public watersheds should be managed primarily for the protection of drinking water, but should allow for multiple uses, including recreation, as long as such uses do not jeopardize the drinking water quality standards. Forestry, according to the Comprehensive Plan, is a favored and permitted land use in rural areas and should not be construed as a public nuisance when carried on in a reasonable manner and in accordance with applicable public regulations, even though it may impact nearby rural residences.

7.2.2 Vashon Community Plan and Area Zoning

The Vashon Community Plan and Area Zoning (King County 1986) designates all of the Island as a water service area and establishes protection of the aquifer as being of primary importance to the Island. The 1986 Vashon Community Plan advocates continued use of Island water resources as the sole water supply, thus emphasizing the requirement that land uses and development densities be planned so that demands on the Island's ground-water resources do not exceed the resources' capacity to provide adequate supplies without deterioration of quality or quantity. In March 1992, SKCHD and J. Dolstad of the Island applied to the EPA for Vashon to be designated as a sole source aquifer. At this time EPA has reviewed the proposal but has not held a public hearing on Vashon as required by the sole source process.

The 1986 Vashon Community Plan supports continued research and monitoring as well as efficient use of domestic water supplies and water systems. As specified by the 1986 Vashon Community Plan, intensive development should be served by a public water district or by an existing Group A water system. In addition, public water systems will not be permitted to expand if it is determined that expansion will decrease the level of service, including water quality, to current users. Similarly, the 1986 Vashon Community Plan states that proposals for development that involve extension of water service to new users will be reviewed with particular attention to ensure that service to current users will not be reduced below minimum state and county standards.

A letter "P" following a zoning classification i.e., a P-suffix, on the Island's zoning map indicates that site plan approval is required for development to proceed at that site; it may be necessary for the developer to meet special conditions designed to protect the public interest in developing the site. Zoning codes for sites in high recharge areas typically include the P-suffix. To protect infiltration to the Island's aquifers, new residential, commercial, and industrial development planned for high recharge areas must comply with zoning regulations that establish the maximum coverage of infiltration surfaces and the relative amount of runoff permitted. Similarly, sites that have been determined to be of historic interest carry zoning codes that typically include a P-suffix; site plan approval of these sites necessitates review by the King County Historic Preservation Officer.

8.0 HYDROGEOLOGY

The following chapter summarizes the background hydrogeologic data, including the geologic setting of the Island and the Island's water resources, historical water levels, and water quality. In addition, stream-flow and rainfall data collected from 1989 through 1992 are presented.

8.1 GEOLOGIC SETTING

The most current geologic information specific to the Vashon GWMA is the geologic investigation conducted by King County Geologist Derek B. Booth for the Vashon GWMA Grant project (Booth 1991). The following paragraphs summarize Booth's report and map (1991) (Figure 8-1). Booth's geologic interpretations are then compared with those included in Carr (1983).

The Island is composed entirely of interbedded glacial and nonglacial sediments that provide a discontinuous record of multiple glaciations during the Pleistocene Epoch (approximately 10,000 to 2,000,000 years before present [b.p.]) in the Puget Lowland. During glacial periods, a lobe of ice advanced from the mountains of British Columbia into the Puget Lowland, depositing a layer of low-permeability till beneath it and permeable advance outwash sands and gravels ahead of it. During previous interglacial periods, drainage from adjacent mountains typically spread across the Puget Lowland, including the present location of the Island.

Deposits of the most recent glaciation, the Vashon stade (a substage of a glacial stage) of the Fraser glaciation (approximately 13,000 to 16,000 years b.p.), are underlain by older deposits, both glacial and interglacial. Establishing consistent nomenclature and regional correlation for stratigraphic units is a continuing project. Correlating units older than those of the Vashon stade between the Island and the remainder of the Puget Lowland has proven difficult.

The main glacial deposits of the Vashon stade as mapped by Booth are as follows:

- Qvr, recessional outwash -- mainly stratified sand and gravel that mantles the upper till surface.

- Qvi, ice contact deposits -- similar in texture to Qvr, but with collapse features and rare till lenses suggestive of deposition near stagnant or active ice.

- Qvt, till -- mainly compact diamicton, typically 40 to 60 feet thick and of low permeability.

- Qva, advance outwash -- sandy gravel to more common medium- and fine-grained sand, typically firm. (The Principal Aquifer on the Island is comprised of Qva.)

Vashon stade deposits are immediately underlain by the interglacial Olympia beds (Qob), which are generally composed of thin-bedded sand and silt with local layers of gravel, massive silt, and clayey silt. The uppermost silt of the Olympia beds represents the contact with the overlying advance outwash (Qva). The Olympia beds act as an aquitard beneath the permeable advance outwash, and, as such, the attitude of their upper surface is of considerable hydrogeologic importance. The elevation of the base of the Qva unit (the Principal Aquifer) as depicted by Booth (1991) has been slightly modified to include data from two wells (VT-1 and Heights #3) that have been drilled subsequent to map construction (Figure 8-2). A widely exposed lacustrine deposit of clay and silt (Qcs) is closely associated with the Olympia beds and may be a basal layer of them rather than a separate unit; elsewhere, it directly underlies the advance outwash (Qva).

Several older, but still of the Pleistocene Epoch, till and interglacial sequences underlie the Olympia beds. The Booth (1991) map's key provides detailed descriptions of these older deposits (Figure 8-1). In general, Vashon stade units are found above mean sea level; older deposits are found near and below mean sea level. Vashon stade till and recessional deposits are exposed over much of the surface of Vashon Island, whereas the surface exposures on Maury Island are predominantly Vashon stade till and advance outwash. The geologic map and accompanying cross sections of the Island (Plate 2) illustrate the lateral variations in the thickness and the somewhat discontinuous nature of most units.

Carr (1983), on the other hand, provides a three-unit classification of the Island's geologic units (Booth's equivalent units given in parentheses). Unit I includes recessional outwash (Qvr) and both lodgment and ablation till (Qvt); ice-contact deposits (Qvi) are not explicitly mentioned. Unit II includes advance outwash sand and gravel (Qva) and is referred to as the Principal Aquifer. Unit III comprises all pre-Vashon stade (approximately 16,000 to 2,000,000 years b.p.) deposits, including silty layers that are presumably the Olympia beds (Qob) and the sandy layer in which the Deep Aquifer is located.

Maps illustrating the surficial geology of the Island and the thicknesses of Units I and II in conjunction with geologic cross sections of selected locations on the Island form the basis for Carr's (1983) interpretation of the area's depositional history. The thickness of Unit I is shown as being highly variable, which is presumed to reflect the chance distribution of materials by direct deposition from ice flow. The thickness of Unit II is shown as being greatest near or at the present Island margins, which is inferred to reflect the location of meltwater channels that flowed from glacial ice on either side of the Island.

Small modifications to Carr's (1983) Unit II thickness map (Figure 8-3) of the Principal Aquifer have been made to include data from Well VT-1. The soil sample descriptions from the boring log for Well VT-1 indicate that the lithology of the first 50 feet encountered in the borehole are comparable to Unit II (Qva).

The geologic maps provided by Booth (1991) (Figure 8-1) and Carr (1983) are very similar. Booth's map shows Unit II near the creek beds with more precision, and this unit is extended into north-central Maury Island (around Mileta Creek). Some coastal areas have been reclassified as landslide or mass wasting areas on Booth's map. In general, Unit III is drawn as a narrower unit near the shorelines on Booth's map. Unit III is not mapped around Upper Judd Creek on Booth's map. The areal interpretation from the Unit II thickness map in Carr (1983) corresponds well to the Base of the Vashon Age Outwash map (Figure 8-2), modified from Booth's map (1991).

8.2 WATER RESOURCES

Water resources of the Vashon GWMA include ground water (aquifers), springs, and surface-water and their associated drainage basins. Much of the available data regarding water resources on the Island is found in Carr (1983). Information presented in Carr (1983) as well as data gathered from other sources are summarized below.

8.2.1 Ground Water

The Island has two known major aquifers. The upper, or Principal, aquifer is located in advance outwash from the Vashon stade glaciation at an elevation of approximately 0 to 400 feet above msl. The lower, or Deep, aquifer is located approximately 100 to 300 feet below msl in a sandy unit (deep sediments) that predates the Vashon stade. The Deep Aquifer may not be continuous under the entire Island, but may instead consist of unconnected water-bearing zones.

About 95 percent of the private wells on the Island tap the Principal Aquifer. Several wells also penetrate the Deep Aquifer. The Island's only publicly owned water supply well, King County Water District No. 19's Well No. 1, is completed to -259 feet msl, although the boring was drilled to -594 feet msl. The well was screened from about 197 to 254 feet below msl, presumably in the Deep Aquifer (Ecology 1979). Island rainfall is the primary known source of aquifer recharge in the Vashon GWMA. The west-central plateaus of Vashon Island are areas of particularly high potential recharge (Figure 8-4).

8.2.2 Spring Water

Springs are abundant on the Island and represent natural ground-water discharge. Springs serve as water supplies for private purveyors, and one is tapped by King County Water District No. 19 (Horton Dennis 1989).

8.2.3 Surface Water

Eight major drainage basins have been identified on the Island (Figure 8-5); these include Beall, Fisher, Green Valley, Judd, Mileta, Needle (Shinglemill), Paradise Cove, and Tahlequah Creeks. Judd and Needle (Shinglemill) Creeks have the largest drainage areas (3,149 and 1,996 acres, respectively) and stream discharges on Vashon Island. They occupy the central and northern interior regions of Vashon Island, respectively. The largest drainage basin on Maury Island, identified as the Mileta Creek basin, covers 1,546 acres. Although other drainage basins on the Island are small, the associated streams have measurable flow during dry months.

Surface-water supply sources include Bealll and Ellis Creeks, located on the east side of Vashon Island. These creeks augment the water supply for King County Water District No. 19, operator of Well No. 1. About eight small ponds and lakes dot the upper plateaus of Vashon Island; none are known to be drinking water sources.

8.3 DATA COLLECTION AND ANALYSIS

As part of the Vashon GWMP, a Data Collection and Analysis Plan (Geraghty & Miller 1990) was developed and implemented. The objectives of this task were to refine the understanding of the Island's water resources (primarily quantity and quality) and to identify data gaps in order to facilitate management and protection of these resources. To accomplish these objectives, rainfall, stream-flow, ground-water, and surface-water data were collected over a 3-year-plus period beginning in 1988 and ending in 1992. The following subsections summarize the data collection and analysis activities and compare the results with the preliminary assessment of the Island's water resources provided by Carr (1983).

8.3.1 Rainfall

Data were collected by Island volunteers at nine rain-gage stations from December 1988 through January 1992 (Table 8-1). Seven rain-gage stations were located on Vashon Island and two on Maury Island (Figures 8-6 and 8-7). The locations of the stations were selected to determine trends in rainfall across the Island. Rain-gage location considerations included areal distribution of rainfall for full coverage of the Island and accessibility for volunteers who monitored the gages. Rainfall data for the Sea-Tac Airport, which is located approximately 5 miles east of the Island, were obtained from the Desert Research Institute in Reno, Nevada to compare rainfall on the mainland with Island rainfall. The data were tabulated by the SKCHD and are included in Appendix D.

8.3.1.1 Methodology

Total monthly rainfall was calculated and hydrographs were prepared for each rain-gage station by summing the daily rainfall data (Appendix E). Total annual rainfall for each station was then calculated by summing the monthly rainfall values (Table 8-2) to compare trends across the Island and with the mainland east of the Island. To evaluate spatial trends in total annual rainfall, isohyetal (total rainfall) maps were prepared for 1989, 1990, and 1991 (Figures 8-8, 8-9, and 8-10). A map combining the 1989, 1990, and 1991 total observed rainfall was constructed to evaluate average spatial rainfall distribution over the entire observation period (Figure 8-11).

8.3.1.2 Results

The total monthly rainfall hydrographs (Appendix E) indicate similar patterns of observed seasonal rainfall fluctuations between the Island stations. Based on these similarities, estimations of total monthly rainfall were made for stations which lacked data for only 1 or 2 months (July 1990 and July 1991 for RG-1, February 1989 for RG-5, and July 1990 and April 1991 for RG-7). The estimated data are qualified in both the tables and graphs in Appendices D and E.

The observed monthly rainfall for the stations monitored at the Island ranged from 0 to approximately 15 inches (Table 8-2). Seasonal trends in the total monthly rainfall data indicate that the months of the year in which the Island received the most rainfall occurred between November and April. The months which received the most rainfall were March and November 1989, January and November 1990, and April and November 1991. The driest months observed were consistently August and September, with September generally drier than August. These seasonal rainfall trends are consistent with historic rainfall data collected at Sea-Tac Airport and are also consistent with seasonal rainfall trends for the Island reported by Carr (1983).

The annual rainfall recorded for the Island ranged from approximately 23 inches per year (RG-5, 1989; January and February data not included) to approximately 62 inches per year (RG-3, 1990). The most rainfall at all stations was recorded in 1990. The observed trends in annual rainfall in 1989 through 1991 were compared to 1974 through 1982 trends reported by Carr (1983) (Figure 8-12). Rain gage RG-7 and the Krimmel rain gage were used for this comparison because they are both located within approximately 1 mile of each other on the southern tip of Vashon Island. Rainfall reported at RG-7 in 1989 was lower than the average rainfall reported at Krimmel between 1974 and 1982; rainfall at RG-7 in 1990 was higher than Krimmel's 1974 to 1982 average; and RG-7 in 1991 and Krimmel during 1974 through 1982 averaged approximately the same.

The spatial distribution of the observed annual rainfall generally varied erratically across the Island. The isohyetal map for 1989 (Figure 8-8), which does not include rainfall during January and February for all stations, shows the highest amount of rainfall to occur in east-central and southwest Vashon Island and northeast Maury Island. The least measurable rainfall in 1989 occurred in north and west-central Vashon Island and south Maury Island. The rainfall distribution in 1990 (Figure 8-9) showed the high rainfall areas in the north and south ends of Vashon Island, while the low rainfall areas were south Maury Island and west-central Vashon Island. Southwest and west-central Vashon Island received the least rainfall in 1991, while northwest Vashon Island and east Maury Island registered the most (Figure 8-10). The relationship between the variable rainfall trend and Island topography (a suspected cause for local spatial rainfall variations) is not clearly defined. Rainfall data collected at Sea-Tac Airport were consistently lower than on the Island. The distribution of annual rainfall across the Island is inconsistent with the simple trend reported by Carr (1983) of decreasing rainfall from west to east.

8.3.1.3 Limitations

The rainfall data have several limitations. Generally, rainfall data were collected at each station on a daily basis; however, the data contain time gaps varying from days to months. The collection of rainfall data from Stations RG-8 and RG-4 was also very sporadic after December 1989 and April 1991, respectively. Therefore, annual rainfall was not calculated for these stations after these respective years (Table 8-2). In addition, rainfall data collection from Stations RG-1 through RG-4 did not begin until March 1989. The total annual rainfall for 1989 for all nine rain gages was calculated using only the March through December data (Figures 8-8 and 8-11).

8.3.2 Surface Water

Stream-gage data were collected from July 1989 through April 1992 by Island volunteers and others at eight stream-gage sites located across the Island (Table 8-3). The gage sites were selected to be representative of the major surface drainage basins across the Island (Figures 8-13 and 8-5). Other criteria for selecting the gage sites included the size of the drainage basin, whether or not the stream was perennial (flowed all seasons), and accessibility for monitoring personnel. The gage sites were selected near the mouths of the streams to record the maximum runoff from each drainage area.

8.3.2.1 Methodology

The data were collected in an effort to further define the amount of stream flow on the Island and to assess the relationship of stream flow to rainfall and ground water. Stream-gage data on seven of the streams were collected using staff gages to record stream-stage data (stream height above an arbitrary datum). Stream-stage data collected using staff gages were converted to stream-flow data by comparing recorded gage heights with the stream discharge rating curves developed by URS Consultants (URS 1992) (Appendix F). For example, a recorded gage height of 0.4 feet for Fisher Creek converts to a flow rate of approximately 0.2 cubic feet per second (cfs) when the gage height is compared to the stream discharge rating curve.

Water-flow data on Beall and Mileta Creeks were collected using 90-degree v-notch weirs. Stream-gage data were collected at each site by volunteers and others who read the staff gages and v-notch weirs on an intermittent basis. A description of the staff gages, the v-notch weirs, and the location of each stream-gage station is included in Appendix F. The collected stream-gage data were tabulated by the SKCHD and is also included in Appendix F.

Stream-gage data collection, begun in 1989, initially involved five streams: Tahlequah, Judd, Needle (Shinglemill), Beall, and Mileta Creeks. In 1991, as part of the Surface Water Management Study (EcoChem/Geraghty & Miller 1991) additional gage stations were installed on Upper Judd, Fisher, Green Valley, and Paradise Cove Creeks. The gage station on Paradise Cove Creek was removed later in 1991 at the request of the property owners.

Trends in stream flow were evaluated by preparing hydrographs for each stream-gage station by graphing observed stream-stage data or calculated flow for gage stations with v-notch weirs. Stream-gage data collected using the v-notch weirs were converted to flow using the methodologies described in Appendix F (URS 1992). Stream discharge rating curves were developed by URS Consultants (1992) for each staff gage to convert recorded stream stages to stream flow. Copies of the stream-flow and stream-stage hydrographs and stream discharge rating curves are included in Appendix G. Two stream discharge rating curves were developed for Tahlequah and Judd Creeks due to adjustments in the installed staff gages. The corresponding data for the stream discharge rating curves are indicated on the bottom of the graphs. A description of the preparation of stream discharge rating curves is also included in Appendix F.

Trends in stream-base flow (the stream flow resulting from ground-water discharge to the creek as opposed to stream flow resulting from direct rainfall) were estimated based primarily on the stream-flow data collected during the drier summer months. Base flow was estimated by converting observed stream-stage heights to flow for the creeks which had relatively continuous stage data for one or more summers (Beall, Fisher, Tahlequah, Judd, Upper Judd, Green Valley, Mileta, and Needle [Shinglemill] Creeks). Base flow data could not be determined for Paradise Cove Creek because insufficient data was collected for the summer months.

8.3.2.2 Results

Trends in stream-stage and water-flow data for the eight monitored creeks are presented in this subsection. Judd Creek has two monitoring sites, Judd and Upper Judd Creek. An evaluation of the general trends in the stream-flow data are discussed first, followed by evaluations of the data collected for each creek.

Trends in the collected stream-gage data tend to correlate with trends in the collected rainfall data (Figures 8-14 and 8-15). The hydrographs for each gage station (Appendix G) show that, predictably, stream flow was highest during the wetter winter months and lowest during the drier summer months. These trends indicate that rainfall appears to be the dominant source of peak stream flow.

A comparison of rainfall and stream-gage trends (Figures 8-14 and 8-15) indicate that during high rainfall events, overland flow appears to be the dominant component of stream runoff, probably because the rate of precipitation exceeds the soil infiltration rate. Stream-level rise is apparent after rainfall events, although the rise in stream levels is not instantaneous (Figure 8-14 and 8-15). Similar relationships between rainfall and stream-flow data were reported by Carr (1983).

The range in the maximum observed flow rates for the streams monitored are difficult to determine because many of the reported stream gage heights exceed the stream discharge rating curves. However, the maximum stream flow that can be determined from the available data was recorded at 91 cfs on Mileta Creek during a storm event using a v-notch weir.

The maximum/minimum (high/low) stream-stage values (Table 8-4) and maximum water-flow values for the Island are discussed below. The maximum values of stream-stage levels were recorded at Upper Judd (3.29 feet) and Needle (Shinglemill) Creeks (2.40 feet) exceeded the stream discharge rating curves. Minimum values were recorded at Fisher and Needle (Shinglemill) Creeks; both creeks were reported as "dry" for periods during the summer months.

Specific trends in stream-flow data for each gage station are described in the following subsections.

Beall Creek

Stream-gage data for Beall Creek were collected from September 1989 through March 1992 using a v-notch weir. The observed stream flow during the period ranged from approximately 0.03 cfs to 4.28 cfs. The average observed flow during the period appeared to range from approximately 0.5 cfs to 1.5 cfs. The observed base flow during the period appeared to range from approximately 0.5 cfs to 1 cfs (117.5 to 235 Mgpy).

Mileta Creek

Stream-gage data for Mileta Creek were collected from July 1989 through March 1992 using a v-notch weir. The observed flow during the period ranged from 0 to approximately 91 cfs. An average flow cannot be determined from the available data because of data gaps between November 28, 1990 and May 9, 1991. The observed base flow during the period appeared to range from 0 cfs to approximately 2 cfs (470 Mgpy).

Fisher Creek

Stream-gage data for Fisher Creek were collected from January 1991 through April 1992 using a staff gage. Base flow during 1991 appeared to be approximately 1 cfs (235 Mgpy). The minimum stream level recorded for gage 1 was 0.2 feet, which correlates to a stream-flow rate of 0.6 cfs on the stream discharge rating curve. The average stream level was 0.43 feet; the corresponding flow rate equaled 2.75 cfs. Flow rates were derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The maximum stream flow during the period cannot be determined from the available data because peak flows exceed the discharge rating curve.

Green Valley Creek

Stream-gage data for Green Valley Creek were sporadically collected from January 1991 through April 1992 using a staff gage. Base flow during 1991 appeared to be approximately 0.45 cfs (105 Mgpy). The minimum stream level recorded was 0.14 feet, which correlates to a stream-flow rate of 0.44 cfs on the stream discharge rating curve. The average stream level was approximately 0.21 feet; the corresponding flow rate equals 0.57 cfs. Flow rates were derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The maximum flow for the period cannot be determined from the available data because peak flows exceed the discharge rating curve.

Paradise Cove Creek

Stream-gage data for Paradise Cove Creek were collected from January 1991 through July 1991 using a staff gage. The base, minimum, average, and maximum flow for the stream cannot be determined from the available data because the data is randomly distributed and was collected for only a 6-month period. However, the observed minimum, maximum, and average stream-flow rates during the 6-month period were approximately 0.12 cfs, 0.45 cfs, and 0.23 cfs, respectively.

Tahlequah Creek

Stream-gage data for Tahlequah Creek were collected from July 1989 through April 1992 using a staff gage. Base flow for the period appeared to be approximately 0.5 cfs (116 Mgpy). The minimum stream level recorded was 0.4 feet, which correlates to a stream-flow rate of 0.18 cfs on the accompanying stream discharge rating curve. The average stream level calculated from the records was 0.56 feet; the corresponding flow equals 0.28 cfs. The maximum stream-flow rate for the period was approximately 0.55 cfs. Flow rates were derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The stream water levels observed for the period ranged from approximately 0.4 to 0.95 feet.

Judd Creek

Stream-gage data for Judd Creek were collected from July 1989 through April 1992 using a staff gage. The base flow for the period appeared to range from 2 cfs to 4 cfs (472 to 944 Mgpy). The flow rate was derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The stream's minimum, average, and maximum flows cannot be accurately determined because the staff gage was washed out on three separate occasions (December 5, 1989; January 9, 1990; and November 23, 1990). However, the average, minimum, and maximum stream-flow values observed between January 17, 1990 and November 21, 1990 have been estimated from the available data to be 1.24 cfs, 1.02 cfs, and 2.00 cfs, respectively.

Upper Judd Creek

Stream-gage data for Upper Judd Creek were collected from January 1991 through January 1992 using a staff gage. The observed base flow during 1991 appeared to be approximately 3 cfs (708 Mgpy). The minimum stream level recorded was 0.29 feet, or a stream-flow rate of 1.5 cfs on the stream discharge rating curve. The average stream level was 0.86 feet, or an average stream-flow rate of 19.5 cfs on the accompanying stream discharge rating curve. The flow rates were derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The maximum flow for the period cannot be determined from the available data because peak flows exceed the discharge rating curve.

Needle (Shinglemill) Creek

Stream-gage data for Needle (Shinglemill) Creek were collected from July 1989 through March 1991 using a staff gage. The base flow appeared to range from approximately 1.5 to 2.5 cfs (353 to 590 Mgpy) during 1989 and 1990. The minimum stream level recorded was 0.13 feet, or a stream-flow rate of 0.3 cfs from the stream discharge rating curve. The flow rates were derived from areas on the discharge rating curve with a sparse number of data points and should be used with caution. The average stream level was 0.9 feet, which exceeds the accompanying stream discharge rating curve; therefore, the maximum flow for the period cannot be determined from the available data.

8.3.2.3 Limitations

The stream data have several limitations. Primarily, the interpretation and application of the collected stream-gage data is restricted because of difficulties associated with maintaining stream-gage records. As a result, the use of the stream-gage data in identifying stream-flow volumes or for preparing Island water-budget calculations is limited. The difficulties encountered which restrict the use of the stream data are listed below, followed by an explanation.

- Storm damage to the staff gages or weir structures.
- Stream-bed erosion and redeposition during storm events.
- Ungaged over-bank stream flow during storm events.

- Logistical problems associated with access to gages/weirs for monitoring actual storm events.
- Data gaps in daily stream-gage readings.

The staff gages located on Judd and Needle (Shinglemill) Creeks were washed out during winter storm events in 1989 and 1990. They were repaired shortly after. A storm event in winter 1991 almost completely buried the Needle Creek staff gage with sediment deposited in the stream bed. Since this occurrence the gage cannot be read for stream flow measurements. The weirs on both Mileta and Beall Creeks were washed out during a large storm event in January 1989. The washed-out weirs were replaced with more rigid structures which withstood the storms during the following winter. Even after the Beall Creek weir was replaced, however, large storm events created stream-flow events which overflowed the weir and eroded the banks around the structure. In addition, periodic maintenance activities (flushing accumulated sand) at the King County Water District No. 19 facility located upstream of the Beall Creek weir caused sand to accumulate in the weir structure.

The stream beds at all of the staff-gage sites were altered during winter storm events. The erosional forces created by the higher flow rates tended to scour out the stream bed in some locations and deposit sediments in others.

The changing stream-bed profile during the winter months made it difficult to produce accurate stream discharge rating curves representing different stages of stream height. The resultant stream discharge rating curves presented in Appendix G are based on assumptions that adjust for stream-bed changes, and the curves have been extrapolated beyond the actual gage heights for which stream-flow measurements were collected. Because many of the staff-gage readings for each stream exceed the data used to develop the discharge rating curves, stream flow cannot be clearly defined for much of the period of record.

Finally, the staff-gage readings were collected sporadically and often with large gaps of time between observations varying from months to years. This sporadic data collection was due to such factors as storm events damaging the weirs and gages, and loss of interest by some of the volunteers. Peak stream flows were often not recorded because of the difficulties volunteer stream observers encountered in being on-site at the proper time after a storm event and in reading the peak flow measurement on the stream gage in the dark.

8.3.3 Ground-Water

The following subsections discuss the methodologies, results, and limitations of the ground-water elevation data collection activities conducted by Island volunteers. A summary of the methodologies is presented first, followed by a discussion of the results of the data analysis. Finally, trends in the recent water-level data are compared with trends reported by Carr (1983). Ground-water level data were collected to aid in assessing rainfall/recharge relationships, long-term trends in water levels (i.e., potential depletion of the ground-water resource), and changes in ground-water flow directions seasonally and over time.

Twenty-five wells on the Island were selected for monitoring ground-water levels from 1989 to 1991 (Table 8-5). The selected wells are labeled W-1 through W-21 (Figure 8-16). At locations which contained two wells (W-2, W-9, W-10, and W-16), the wells were distinguished by adding A and B to the well label (e.g., W-2A and W-2B).

appropriate 7.5 minute USGS topographic map. The ground-water level data collected by Island volunteers and tabulated by SKCHD are included in Appendix H.

Ground-water elevation contour maps for the Principal Aquifer were constructed by modifying the Carr (1983) water-table contour map to incorporate the 1989 and 1991 water-table elevation control points (Figures 8-17 and 8-18). Hydrographs were prepared for each well to evaluate long-term trends in water levels (Appendix I). The trends in water-level elevations that were compared with rainfall trends, well elevations, and well locations within Island drainage basins are discussed below.

8.3.3.2 Results

Water-table elevations for the Principal Aquifer ranged from -3 to 281 feet msl. The elevation of the water table in the Principal Aquifer generally mimicked the surface topography of the Island. The average seasonal change in the ground-water levels observed in the wells ranged from less than 2 foot to 21.72 feet.

Ground water flows from topographic highs toward the coastline. Insufficient well elevations from the Principal Aquifer were available to determine if the flow of the ground water changed seasonally. Different interpretations of the water-table elevation map for each season are possible. The ground-water gradient is generally steeper on the west side of Vashon Island (from Well W-16 west to the shoreline, the gradient was 0.095 in November 1989 and 0.105 in April 1991) than the east side of Vashon Island (from Well W-6 east to the shoreline, the gradient was 0.026 in November 1989 to 0.027 in April 1991). The ground-water gradient is generally steeper in the spring than in the fall as a result of higher water-table and ground-water recharge. No information was available at the time of this study to determine the effects of well pumping on the Principal Aquifer.

The monitoring wells were selected to be representative of ground-water conditions in the Principal Aquifer across the Island. Criteria used to select the wells included well depth, approximate screened interval depth, water-level measuring access, and homeowner availability. The selection criteria were reviewed on available well logs, including logs provided by Carr (1983).

The data available at the time the wells were selected indicated that each selected well was completed in the Principal Aquifer. However, after comparing the depths of the selected wells with the depths of the Base of the Vashon Unit structure map prepared by Booth (1991) during the compilation of data for this report, 13 wells (W-1, W-2A and B, W-6, W-10A and B, W-13, W-14, W-15, W-16A and B, W-19, and W-20) were determined to be completed in the Principal Aquifer (Table 8-5). The other 12 wells that were monitored (W-3, W-4, W-5, W-7, W-8, W-9A and B, W-11, W-12, W-17, W-18, and W-21) appear to be potentially completed in water-bearing zones of the Deep Aquifer.

8.3.3.1 Methodology

With three exceptions, water-level data were collected from the wells selected on a monthly basis from the summer or fall of 1989 through the spring of 1992 (Table 8-5). Measurements were discontinued in Wells W-7, W-9B, and W-20 in October 1991, December 1989, and May 1991, respectively. Wells W-7 and W-9B were discontinued due to the difficulty of accessing the well (i.e. loss of portions of the well probe) and W-20 because of the difficulty of access to the well casing on the property. To determine water-level elevations, the elevation of top of the casing (the measuring point for recording water levels) for each well was estimated relative to mean sea level by SKCHD and Geraghty & Miller personnel using a hand-held altimeter and the

The hydrographs of the monthly water-level data for each well (Appendix I) indicate the following trends in the observed water-table elevations:

- Wells W-1, W-4, W-6, W-10A and B, W-13, W-16A and B, W-17, and W-20 show seasonal fluctuations of water-table elevations of approximately 1 to 22 feet. (Water level values with probable measurement errors were not included in determining these fluctuation ranges.)

- Wells W-2A and B, W-3, W-5, W-7, W-8, W-9A and B, W-11, W-12, W-14, W-15, W-18, W-19, and W-21 show water-level fluctuations of 1 to 3 feet. (Water level values with probable measurement errors were not included in determining these fluctuation ranges.)

- Seasonal fluctuations observed in the wells tend to correlate with rainfall (allowing for a delay of from 1 to 4 months for the water to infiltrate the aquifer). Seasonally high water-table elevations tend to occur during the early summer months, reflecting the increased rainfall and ground-water recharge during the preceding winter and early spring months (Figures 8-19 and 8-20). Seasonally low water-table elevations tend to occur during the fall months reflecting decreased rainfall during the preceding summer and early fall months.

- Wells W-1, W-2A and B, W-13, W-15, W-16A, W-19, and W-21 show long-term trends of increasing water-level elevations of approximately 1 to 2 feet.

- The long-term trends in the hydrographs indicate that the aquifer zones monitored by the selected wells are generally stable and have not been affected by ground-water withdrawals.

- Anomalous spikes of high and low water-table elevations appear on many of the graphs. Possible sources of the anomalous data include well pumping and measurement error.

Carr (1983) prepared contour maps for the Principal Aquifer showing annual and seasonal fluctuations in water-table elevations between fall 1981 and spring 1982 and between spring 1982 and fall 1982. As presented, these data imply an annual gain of over 20 feet in the water-table elevation in some areas of the Island over a 1-year period. In addition, the water table for the Principal Aquifer fluctuated from 1 to 22 feet between seasons. No correlations were apparent between wells with large and small water-level changes. Since the potentiometric map from Carr (1983) (Figure 8-21) was used as a model for the potentiometric maps in this report (Figures 8-17 and 8-18), the observed ground-water flow directions and gradients are similar to the values presented by Carr (1983).

Information regarding the Deep Aquifer on the Island is limited. An evaluation of the Deep Aquifer is based primarily on data presented by Carr (1983) augmented with data collected during the drilling of Exploration Well VT-1 drilled near Burton on Vashon Island. The Deep Aquifer is probably composed of multiple water-bearing zones. The degree to which these zones are interconnected is unknown. The Gig Harbor well on the mainland (completed at approximately -475 feet msl), the KIRO well on the Island (completed at approximately -395 feet msl), and the new VT-1 well (logged at approximately -330 feet msl) most likely breach the lower water-bearing zones of the Deep Aquifer. Carr (1983) did not address the possibility of multiple water-bearing zones.

According to sample descriptions from logs on the Island, the lowermost water-bearing zone of the deep aquifer occurs at depths up to -395 feet msl on the Island. Since the bathymetry (depth) of the Colvos Passage ranges from -114 to -414 feet msl, the possibility exists that the lowermost water-bearing zone in the Deep Aquifer may be connected to the mainland deep aquifer (the aquifer from which the Gig Harbor well produces). Additional wells need to be drilled into the Deep Aquifer on the Island to determine if the deep aquifer is interconnected with the mainland recharge areas.

A Deep Aquifer water-table map was not constructed because of the uncertainty surrounding which water-bearing zone the wells were completed in. Each water-bearing zone may have different hydraulic heads which would affect the water levels for that well. Variations in water levels for wells completed within the same water-bearing zone give an indication of the ground-water flow direction; different water levels measured in wells completed in multiple water-bearing zones are inconclusive. The water-level data used in this study may not characterize any particular ground-water flow system because the deep wells may be completed in more than one water-bearing zone. Therefore, no comparison can be made to the Deep Aquifer potentiometric map included in Carr (1983).

8.3.3.3 Limitations

The water-table contour maps prepared for this study should be used with caution, primarily because to develop a more accurate map, additional wells would have to be included. Additionally, based on limited well construction data, it is not known if the wells monitored for this study are screened in more than one water-bearing zone of the same aquifer.

8.3.4 Aquifer-Sensitive Areas

Aquifer-sensitive (potential recharge) areas are localities on the Island where rainfall replenishes the aquifer most efficiently. Potential recharge areas were identified by creating and analyzing the following maps of the Island:

- Depth to water (Figure 8-22)
- Slope (Figure 8-23)
- Surficial geologic formation permeability (Figure 8-24)
- Soil permeability (Figure 8-25)
- Rainfall (Figures 8-12)

Areas with high, medium, and low potential recharge were designated on each map with respect to their effect on recharge. The specific approach used to evaluate the potential recharge criteria for each map and the differences with the specific approaches used in Carr (1983) are summarized below. The resultant aquifer-sensitive areas are then compared with Carr (1983).

8.3.4.1 Methodology

Average depth to water (Figure 8-22) was calculated from the available water-level data collected between 1989 and 1992 for monitoring wells determined to be screened in the Principal Aquifer. Depth-to-water classifications with respect to potential recharge were assigned using the criteria developed in *Redmond-Bear Creek Ground Water Management Program (RBCGWMP) Draft Hydrogeologic Characterization*

Report, Volume I (1992). Wells with a depth to water of 25 feet bls or less were assigned a high potential recharge classification (Figure 8-22). A low potential recharge was assigned to areas where depth-to-water values were greater than 75 feet bls. A medium potential recharge was assigned to areas where depth to water was between 25 and 75 feet bls. Depth to water was not a recharge criteria considered in Carr (1983).

Slope criteria developed in the RBCGWMP were utilized to determine the effects of slope on potential recharge (Figure 8-23). The percentage of slope was calculated from select areas on the USGS topographic quadrangle maps for the Island (Duwamish Head 1968a; Vashon 1968b; Gig Harbor 1981a; Olalla 1981b; Tacoma North 1981c). Using guidelines presented in the RBCGWMP, areas with a slope between 40 and 80 percent were classified with medium potential recharge. If the slope was a higher or lower percentage, the area was characterized as a low or high potential recharge area, respectively. High potential recharge areas include almost all of the Island, with the exception of steeper areas near the coast. The slope/recharge map included in Carr (1983) includes additional low potential recharge areas not shown in Figure 8-23. High potential recharge areas delineated on the Carr slope map were confined to north-central and south-central Vashon Island and central Maury Island. Carr (1983) did not specify the criteria used in the construction of their slope map.

The effect of the permeability of the surficial geologic units was considered when deriving the aquifer-sensitivity map. Permeability criteria for geologic formations developed in the RBCGWMP were used for the map construction. The permeability of the geologic formations on the Island delineated by Booth (1991) were grouped as follows:

High Permeability (High Potential Recharge)	Qvr, Qal, Qvi, Qpfc
Medium Permeability	Qls, Qmw, Qva, Qob, m, Qb, Qpf, Qpfm,

(Medium Potential Recharge)	Qpo
Low Permeability (Low Potential Recharge)	Qw, Qvt, Qtb, Qvu, Qpff, Qcs, Qpof, Qdi, Qti, Qdu, Qtu

A surficial geologic formation permeability map (Figure 8-24) was prepared based on the three permeability groups defined above. The permeability of the surficial geologic units indicate that the high potential recharge areas are confined to the Judd and BeallBeall Creek drainage basins in north-central and south-central Vashon Island, respectively. In addition, there are some other smaller areas. Carr's (1983) subsurface permeability map is markedly different from Figure 8-24; however, Figure 8-24 was prepared using the most recent geologic map prepared by Booth (1991). The high potential recharge areas defined in the Carr subsurface permeability map included near-central Maury Island; northwest, west-central, south-central, and northwest-central Vashon Island; and the vicinity of the Town of Vashon. Carr (1983) did not address the criteria used to differentiate between high, medium, and low potential recharge areas.

Soil permeability on the Island was a consideration in the construction of the aquifer-sensitivity map. Since the characterization of the soil on the Island has not changed since Carr (1983) and since no new soil surveys of the area have been developed, the soil permeability map constructed in Carr (1983) was used in the composite for the map for soil permeability with respect to recharge (Figure 8-25). High potential recharge areas delineated by soil permeability are located on central Maury Island and south-central Vashon Island away from the coastline.

Rainfall on the Island was the final consideration in the construction of the aquifer-sensitivity map. The cumulative rainfall map was arranged to construct a more accurate picture of areal distribution of rainfall (Figure 8-11). Measurements of rainfall were taken from the annual isohyetal maps included in this report. Some estimates were made for rain-gage data sets containing with incomplete information (Appendix D). The

Nitrate was used as a water-quality indicator because it evidences a potential health hazard. The absence of geologic nitrate sources on the Island implies that elevated nitrate levels, if detected, result from other sources, such as drainfields, drainfield effluent, fertilizer, animal wastes, and decaying vegetation. The only well on the Island with a nitrate as nitrogen level in excess of the MCL of 10 mg/L is located at the Coast Guard station at Point Robinson; however, The Coast Guard well was reportedly installed near the previous site of a horse corral. Nitrate as nitrogen concentrations in the remaining wells ranged from less than the laboratory detection limit to 5.3 mg/L (Carr 1983). Nitrate levels were below 3.5 mg/L in the wells sampled in 1989 and 1990 (Carr 1983). Nitrate (as nitrogen) monitoring will be especially important in the future as new drainfields are constructed in the severe public health hazard or health caution areas on the Island (PEI/Barrett 1992).

of septic system and/or agricultural contamination), and TDS (as a general indicator of land use impact). The laboratory results for concentrations of chloride, nitrate, and TDS were tabulated (Table 8-8) and graphed (Appendix L) to evaluate trends in these specific parameters. The areal distribution for chloride, nitrate, and TDS is presented in Figure 8-27. In addition, the water-quality data were compared with Safe Drinking Water Act maximum contaminant levels (SDWA MCLs) (Table 8-9).

8.4.3.2 Results

The laboratory results for samples collected from 21 Island wells indicate that chloride and nitrate concentrations were consistently low [chloride less than 10 mg/L and nitrate less than 3.5 mg/L; Table 8-8]. These concentrations were relatively constant with the exception of Well W-10B, which had a slight increasing trend of chloride (Appendix L). TDS levels were generally low (less than 400 mg/L), but increased with time for ground-water samples collected from Wells W-1, W-2A , W-6, W-9B, W-10B, W-14, W-16A, and W-21. The TDS levels in the samples collected from the other wells were either relatively constant or showed decreasing trends (Appendix L). The levels of chloride, nitrate, and TDS are too low to suggest any impact from land or ground-water use. The low levels of chloride indicate none of the wells have been impacted by seawater intrusion; the average chloride content of seawater is approximately 19,000 mg/L (Driscoll 1986).

Comparison of the ground-water-quality data with SDWA MCLs indicate lead was detected above the SDWA MCL (Table 8-9) in samples collected from Wells W-13 and W-15 in one or more of the three sampling events (Table 8-10). Iron and manganese are present in many of the wells, as they were in 1982 (Carr 1983), but the presence of these constituents is not considered a health hazard.

quality trends reported by Carr (1983). A discussion of the data limitations concludes the ground-water quality subsection.

8.4.3.1 Methodology

A discussion of the criteria for selecting the monitoring wells to be sampled is provided below, followed by a discussion on the specific water-quality parameters that were assessed and how the data was evaluated. Analytical data and ground-water quality graphs are included in Appendices K and L, respectively.

Ground-water quality data were collected by SKCHD and the consultants from 21 of the 25 selected monitoring wells (Table 8-5). Criteria used to select wells for monitoring included availability of well logs, areal distribution of wells, screened interval, representative of geology in the area, and representation of major surface-water drainage areas.

Water-quality data were collected during three sampling events: October/November 1989, April 1990, and October 1990. At sites which contained two wells (W-2, W-9, W-10, and W-16), only one well was selected for water-quality monitoring (Table 8-8). For consistency, the same selected wells were sampled for each sampling event with the exception of Well W-9B, which was sampled only during the first round of sampling in 1989. The second- and third-round samples were collected from Well W-9A because of difficulties with sampling Well W-9B. Ground-water samples were collected and submitted for laboratory analysis for standard drinking water parameters including coliform bacteria, alkalinity, TDS, and hardness (Appendix K).

Specific water-quality parameters evaluated to assess land and ground-water use impacts include chloride (as an indicator of seawater intrusion), nitrate (as an indicator collected from the southeastern edge of Vashon Island on Quartermaster Harbor. The highest level of TDS (280 mg/L) was detected in Sample S-2 (Ober Beach), collected from the northwestern Vashon Island shoreline. During one or more sampling events, samples collected from at least one spring equaled or exceeded water quality standards for iron, manganese, mercury, lead, and nitrate (as nitrogen). Total and fecal coliforms were present in at least two springs during each sampling event. The water quality of the springs tested on the Island is good, although the list of analytes was not comprehensive.

Spring- and surface-water samples (undifferentiated) were collected in 1982 by Carr (1983) and analyzed for specific conductance, TDS, chloride, nitrate as nitrogen, iron, total hardness, alkalinity, arsenic, cadmium, and manganese. Chloride, nitrate, and TDS values did not exceed federal or state drinking water standards. The analytical results for nitrate as nitrogen ranged from nondetected to 3.0 mg/L at "Judd-Above Land." Arsenic levels at "Cove Sp. Box" exceeded drinking water standards (6.4 mg/L). The sampling locations are not displayed in Carr (1983).

Spring-water samples could not be collected at all sampling locations during every sampling event because of the intermittent nature of the spring flow. Consequently, only springs S-1, S-3 and S-6 are currently being monitored for measuring the spring flow of water flowing off the island (Shallow, pers. comm. 1993).

8.4.3 Ground-Water Quality

Ground-water quality data were collected to identify trends in ground-water quality over time and to assess the potential impacts to ground water from land and ground-water use. The following subsections discuss the methodologies and results of the water quality sampling. In addition, the results are compared to ground-water

- Morningside
- Manzanita

The lower Judd Creek spring was sampled in October 1989 then discontinued at the owners request and replaced for the April 1990 and October 1990 sampling events by the North Vashon spring.

The following subsections summarize the methodology, results, and limitations of the spring-water quality investigation. Included in the results subsection is a summary of the Carr (1983) spring-water quality results.

8.4.2.1 Methodology

The methodology used in spring-water sample collection is similar to the method of surface-water collection discussed in the surface-water sample collection work plan (EcoChem/Geraghty & Miller 1991). Spring-water samples were collected in October 1989, April 1990, and October 1990 and analyzed in a laboratory for total and fecal coliforms, metals, nitrate (as nitrogen), nitrite (as nitrogen), sulfate, fluoride, and TDS (Table 8-7; Appendix K). Spring sampling locations (Figure 8-26) were selected from areas where contamination sources were suspected and where ground-water data is sparse, since springs represent a natural discharge of ground water.

8.4.2.2 Results

To assess the sampling results, analytical data for water samples (Appendix K) were compared to Washington State water-quality criteria (WAC 173-201A-030) for Class AA streams (discussed in Subsection 8.4.1, Surface-Water Quality). Chloride, nitrate and TDS values were all below Washington State regulatory standards. The highest level of nitrate (4.4 mg/L) was detected in Sample S-4 (Magnolia Beach), For the marine-shellfish samples analyzed, fecal coliform levels exceeded FDA standards in Beall, Fisher, Judd, Paradise Cove, and Tahlequah Creeks.

Associations of high levels of potential contaminants were not observed between freshwater, freshwater sediment, marine-water, marine-water sediment, and marine shellfish. Therefore, specific potential contaminant sources or specific contaminant transport pathways could not be identified.

8.4.1.4 Limitations

The surface-water quality data presented above should be used with caution. This data was by the laboratory analyzed prior to the implementation of a number of regulatory guidelines for water quality. Therefore, detection limits for mercury in freshwater and marine-water samples were above the chronic regulatory limits. Similarly, the detection limit for silver in marine-water samples was above the acute regulatory limit. In addition, pH values reported for many of the streams were unnaturally low (below 3 standard units) for surface water. These measurements may reflect errors in the field readings.

8.4.2 Spring-Water Quality

Samples of spring water were collected by SKCHD personnel from the following six spring locations (Figure 8-26):

- North Vashon
- Ober Beach
- Klahania
- Magnolia Beach

No regulatory standards have been established for freshwater sediments. On a relative basis, however, similar constituent levels were detected in all of the freshwater sediment samples with the exception of the chromium levels detected in freshwater-sediment samples collected from Judd Creek. Total coliform levels were highest in Mileta Creek for freshwater-sediment samples. Concentrations of the remainder of the constituents detected in freshwater-sediment samples from the other creeks were within similar ranges of values.

Concerning marine-water samples, a variety of metals were detected above Washington marine-water standards. Lead was the most predominant metal, having been detected in at least one sampling event for all marine-water samples. Copper was present above regulatory standards at least once in Beall, Judd, Mileta, Needle (Shinglemill), and Tahlequah Creeks. Zinc and silver were detected above regulatory standards at least once in Beall and Mileta Creeks, respectively. Tahlequah and Judd Creeks exhibited fecal coliforms above regulatory levels; Judd Creek also demonstrated total coliforms above regulatory standards.

No regulatory standards have been established for marine-water sediments. On a relative basis, however, constituent levels of marine-water sediment samples were similar to each other with the following exceptions. High chromium and lead levels were detected in samples collected from Judd Creek; arsenic levels in Judd Creek were also higher than those in other marine-water sediment samples. Total coliform levels in the marine-water sediment samples were highest in Tahlequah Creek, although high levels were also recorded in Mileta Creek. Fecal coliform levels were highest in Mileta Creek. Zinc and mercury levels were highest in Paradise Cove and Needle (Shinglemill) Creeks, respectively.

Marine-Water Sediment (Tahlequah Creek)

The highest total coliform concentration detected in any of the marine-water sediment samples was measured in Tahlequah Creek (July 1992). Other constituent concentrations were generally similar to those measured in the other streams sampled.

Marine Shellfish (Tahlequah Creek)

Fecal coliform concentrations in marine shellfish exceeded the FDA standard in five of the six samples analyzed (August and November 1991, and July and August 1992).

8.4.1.3 Summary of Results

The surface-water quality data is summarized below. Freshwater, freshwater sediments, marine-water, marine-water sediment, and marine-shellfish data are discussed first, followed by a discussion of the associations between the sampling results and the different environments sampled.

In the samples collected from freshwater streams, high fecal coliforms were present above regulatory levels within seven of the freshwater streams; Beall Creek was the exception. These high values may be indicative of wildlife in the area and not necessarily septic system contamination (Shallow, pers. comm. 1993), although many septic systems have failed, resulting in the creation of severe public health hazard areas (PEI/Barrett 1992). TDS levels in Green Valley Creek and mercury and chromium levels in Judd and Mileta Creeks, respectively, exceeded Washington freshwater standards for streams.

Tahlequah Creek

Freshwater, marine-water, marine-water sediment, and marine-shellfish samples were collected for analysis from Tahlequah Creek. The results are presented below.

Freshwater (Tahlequah Creek)

Concentrations of arsenic, chloride, and selenium were below Washington State criteria for freshwater. Chromium and mercury were not detected. Concentrations of fecal coliforms did not exceed the geometric mean limit, but more than 10 percent of the samples exceeded the maximum limit value. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. TDS, lead, and nitrate concentrations were below Federal Drinking Water Standards.

Marine Water (Tahlequah Creek)

Total coliforms, arsenic, chromium, selenium, and zinc concentrations did not exceed Washington State criteria for marine water. Cadmium, mercury, and silver were not detected. Lead exceeded the chronic level once (April 1992). Copper exceeded the acute level once (August 1991). Concentrations of fecal coliforms exceeded the geometric mean limit and more than 10 percent of all the samples exceeded the maximum limit value.

fecal coliforms did not exceed the geometric mean limit, but more than 10 percent of the samples exceeded the maximum limit. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. TDS, lead, and nitrate concentrations were below Federal Drinking Water Standards.

Marine Water (Needle/Shinglemill Creek)

Concentrations of total coliforms, fecal coliforms, arsenic, chromium, selenium, and zinc did not exceed Washington State criteria for marine water. Cadmium, mercury, and silver were not detected. Copper exceeded the acute limit in three samples (all from July 1992), and lead exceeded the chronic limit in three samples (August 1991, April 1992, and August 1992).

Freshwater and Marine-Water Sediments (Needle/Shinglemill Creek)

All constituent concentrations in freshwater-sediment samples and all but mercury concentrations in marine-water sediment samples were generally similar to those measured in the other streams sampled. The highest mercury concentration measured in any of the marine-water sediment samples was measured in Needle (Shinglemill) Creek.

Marine Shellfish (Needle/Shinglemill Creek)

Fecal coliforms were detected in the one marine-shellfish sample collected. The detected concentration was below the FDA standard. No shellfish were found at subsequent sampling events.

Marine Water (Paradise Cove Creek)

Total coliforms, fecal coliforms, arsenic, chromium, selenium, and zinc concentrations did not exceed Washington State criteria for marine water. Cadmium, copper, mercury, and silver were not detected. Lead exceeded the chronic limit in one sample (November 1991).

Marine-Water Sediment (Paradise Cove Creek)

The highest zinc concentration in any marine-water sediment sample was detected at Paradise Cove Creek (November 1991). Other constituent concentrations were generally similar to those measured in the other streams sampled.

Marine Shellfish (Paradise Cove Creek)

Fecal coliform concentrations in marine shellfish exceeded the FDA standard in 4 of the 11 samples analyzed (August 1991 and August 1992).

Needle (Shinglemill) Creek

Freshwater, marine-water, freshwater sediment, marine-water sediment, and marine-shellfish samples were collected for analysis from Needle (Shinglemill) Creek. The results are presented below.

Freshwater (Needle/Shinglemill Creek)

Concentrations of arsenic, chloride, and selenium were below Washington State criteria for freshwater. Chromium and mercury were not detected. Concentrations of

The highest fecal coliform concentration of any of the marine-sediment samples was measured at Mileta Creek (August 1991), and the level of total coliforms was significantly higher than levels detected in the other marine-sediment samples. Other constituent concentrations were generally similar to those measured in the other streams sampled.

Marine Shellfish (Mileta Creek)

Fecal coliform concentrations in marine shellfish did not exceed the FDA standard.

Paradise Cove Creek

Freshwater, marine-water, marine-water sediment, and marine-shellfish samples were collected for analysis from Paradise Cove Creek. The results are presented below.

Freshwater (Paradise Cove Creek)

Arsenic and chloride concentrations did not exceed Washington State criteria for freshwater. Chromium, mercury, and selenium were not detected. Fecal coliform concentrations did not exceed the geometric mean limit, but more than 10 percent of the samples exceeded the maximum limit. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. TDS, lead, and nitrate levels were below Federal Drinking Water Standards.

sediment sample was collected and submitted for analysis for pesticides and PCBs. The results are presented below.

Freshwater (Mileta Creek)

Arsenic, chloride, and selenium concentrations did not exceed Washington State criteria for freshwater. Mercury was not detected. Chromium concentrations exceeded the chronic limit in three samples (August 1991 and June and August 1992). Fecal coliform concentrations did not exceed the geometric mean limit, but more than 10 percent of the samples exceeded the maximum limit. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. TDS, lead, and nitrate levels were at or below Federal Drinking Water Standards.

Marine Water (Mileta Creek)

Concentrations of total coliforms, fecal coliforms, arsenic, chromium, selenium, and zinc did not exceed Washington State criteria for marine water. Cadmium and mercury were not detected. Copper and silver exceeded the acute levels in two and one samples, respectively (all from August 1991). Lead exceeded the chronic level in two samples (August 1991 and July 1992).

Freshwater and Marine-Water Sediments (Mileta Creek)

The highest total coliform concentrations of any of the freshwater-sediment samples was measured at Mileta Creek. Other constituent concentrations were generally similar to those measured in the other streams sampled. No pesticides or PCBs were detected in the freshwater-sediment sample analyzed for these constituents.

Freshwater and Marine-Water Sediments (Judd Creek)

The highest chromium level detected in any of the freshwater sediment samples was detected at Judd Creek; other constituents in freshwater sediment samples were generally similar to those measured in the other streams sampled.

Acetone, methylene chloride, and TCA were detected in the freshwater sediment samples for August and September 1991; acetone and methylene chloride were also detected in the trip blank and laboratory quality control blank in September 1991. No pesticides or PCBs were detected in the two freshwater sediment samples analyzed.

The highest chromium and lead levels detected in any of the marine-water sediment samples were detected at Judd Creek; arsenic levels were also slightly higher than in the other streams sampled. The level of total coliforms was significantly higher than levels detected in the other main-sediment samples. Other constituent concentrations in marine-water sediment samples were generally similar to those measured in the other streams sampled.

Marine Shellfish (Judd Creek)

Fecal coliform concentrations in marine shellfish exceeded the FDA standard in one of the eight samples analyzed (July 1992).

Mileta Creek

Freshwater, marine-water, freshwater sediment, marine-water sediment, and marine-shellfish samples were collected for analysis from Mileta Creek. One freshwater-

Freshwater (Judd Creek)

Concentrations of arsenic, chloride, chromium, and selenium did not exceed the Washington State criteria for freshwater. Mercury was detected in one sample (September 1991) at a concentration exceeding the chronic limit. Fecal coliform values exceeded the geometric mean value and more than 10 percent of the samples exceeded the maximum standard value. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. Methylene chloride and acetone were detected in two and one freshwater samples, respectively, collected for VOC analysis (August and September 1991); these compounds were also detected in the trip blank and laboratory quality control blank for the September 1991 sampling event. Data validation of the methylene chloride and acetone samples resulted in a nondetect status for the samples. No pesticides or PCBs were detected. No semivolatile compounds were detected in the one freshwater sample analyzed. TDS, lead, and nitrate levels were below Federal Drinking Water Standards.

Marine Water (Judd Creek)

Concentrations of arsenic, chromium, selenium, and zinc did not exceed the Washington State criteria for marine water. Cadmium, mercury, and silver were not detected. Concentrations of copper exceeded the acute limit in two samples (both from August 1991). Lead exceeded the chronic limit in two samples (August 1991 and April 1992). Total coliform and fecal coliform levels did not exceed the geometric mean limits, but did exceed the maximum limit in more than 10 percent of the samples.

of fecal coliforms did not exceed the geometric mean limit, but more than 10 percent of the samples exceeded the maximum limit. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. Lead and nitrate were below Federal Drinking Water Standards, but TDS exceeded the Federal Drinking Water Standard in one sample (August 1991).

Marine Water (Green Valley Creek)

Concentrations of total coliforms, fecal coliforms, arsenic, selenium, and zinc did not exceed Washington State criteria for marine water. Lead exceeded the Washington State chronic standard in one sample (April 1992). Cadmium, chromium, copper, mercury, and silver were not detected.

Marine-Water Sediment (Green Valley Creek)

Concentrations of constituents in marine-water sediment samples were generally similar to those measured in the other streams sampled.

Judd Creek

Freshwater, marine-water, freshwater sediment, marine-water sediment, and marine-shellfish samples were collected for analysis from Judd Creek. Two freshwater samples and two freshwater-sediment samples were collected for analysis for VOCs, pesticides, and PCBs. However, one freshwater sample was inadvertently analyzed for semivolatiles instead of pesticides and PCBs. The results of the laboratory analysis on samples from Judd Creek are presented below.

Marine Water (Fisher Creek)

Concentrations of total coliforms, arsenic, chromium, and zinc did not exceed the Washington State criteria for marine water. Cadmium, copper, mercury, selenium, and silver were not detected. Lead exceeded the Washington State chronic standard once (August 1991). Concentrations of fecal coliforms during the monitoring period did not exceed the geometric mean limit and less than 10 percent of the samples exceeded the maximum limit.

Marine-Water Sediment (Fisher Creek)

Concentrations of constituents in marine-water sediment samples were generally similar to those measured in the other streams sampled.

Marine Shellfish (Fisher Creek)

Concentrations of fecal coliforms in marine shellfish exceeded the FDA standard in 4 of the 12 samples analyzed (April, July, and August 1992).

Green Valley Creek

Freshwater, marine-water, and marine-water sediment samples were collected for analysis from Green Valley Creek. The results are presented below.

Freshwater (Green Valley Creek)

Concentrations of arsenic, chloride, chromium, and selenium were below Washington State criteria for freshwater. Mercury was not detected. Concentrations standard in three samples (all from July 1992), and zinc exceeded the acute standard in one sample (August 1991).

Marine-Water Sediment (Beall Creek)

Concentrations of constituents in marine-water sediment samples were generally similar to those measured in the other streams sampled.

Marine Shellfish (Beall Creek)

Concentrations of fecal coliforms in marine shellfish exceeded the FDA standard in 3 of the 10 samples analyzed (all from July 1992).

Fisher Creek

Freshwater, marine-water, marine-water sediment, and marine-shellfish samples were collected for analysis from Fisher Creek. The results are presented below.

Freshwater (Fisher Creek)

Concentrations of arsenic, chloride, and selenium did not exceed the Washington State criteria for freshwater. Chromium and mercury were not detected. Concentrations of fecal coliforms during the monitoring period exceeded the geometric mean limit and more than 10 percent of the samples exceeded the maximum limit. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. Concentrations of TDS, lead, and nitrate were below the Federal Drinking Water Standards.

8.4.1.2 Results

An evaluation of the data collected for each stream is provided below, followed by a discussion of limitations of the sampling data. The sample results exceeding regulatory limits and the highest levels recorded for sediment samples with respect to the other streams sampled are summarized in Table 8-6. The laboratory analytical report is included as Appendix J.

<u>Beall Creek</u>

Freshwater, marine-water, marine-water sediment, and marine-shellfish samples were collected for analysis from Beall Creek. The results are presented below.

Freshwater (Beall Creek)

Results of analysis for fecal coliforms, selenium, arsenic, and chloride detected concentrations below the Washington State criteria for freshwater. Chromium and mercury were not detected. Temperature and pH values measured in the field were within Washington State criteria, with the exception of pH values as discussed below in Subsection 8.4.1.4, Surface-Water Quality Data Limitations. TDS, lead, and nitrate levels were all below Federal Drinking Water Standards.

Marine Water (Beall Creek)

Analyses for total coliforms, fecal coliforms, arsenic, and chromium detected concentrations below the Washington State criteria for marine water. Cadmium, mercury, selenium, and silver were not detected. Concentrations of lead exceeded the chronic standard in one sample (August 1991), copper levels exceeded the acute

Regulatory surface-water quality standards are determined using not-to-exceed, geometric mean, chronic, and acute values. Results for all samples from each stream were used to calculate the geometric mean. Chronic values are levels that may result in injury or death to an organism as a result of repeated or constant exposure over an extended period. Acute values are levels which may result in injury or death to an organism as a result of short-term exposure. The regulatory criteria for total coliforms and fecal coliforms consist of a geometric-mean value not to be exceeded and a maximum value which no more than 10 percent of the samples may exceed. The regulatory criterion for pH is a range of values not to be exceeded. Other regulatory criteria are not-to-exceed values, some of which include a chronic value and an acute value.

To provide an additional indicator of quality for freshwater samples, analytical results for TDS, lead, and nitrate were compared to Federal Drinking Water Standards. This comparison was for purposes of general evaluation only, as Federal Drinking Water Standards do not necessarily apply to water in these streams.

According to SKCHD, no standards exist for freshwater or marine-water sediments. Results of sediment sampling, therefore, were evaluated only for relative differences among the streams.

Additionally, no standards exist for recreational harvested marine shellfish, according to SKCHD. Shellfish sampling results were, therefore, compared to U.S. Food and Drug Administration (FDA) standards for marine shellfish in commercial growing areas. Of the parameters analyzed, an FDA standard exists only for fecal coliforms. According to SKCHD, the standard is a not-to-exceed value. Comparison of shellfish sampling results to FDA standards was for purposes of general evaluation only; these standards do not necessarily apply to the marine-shellfish areas sampled.

Freshwater sediment samples were collected in August and September 1991 from Judd, Mileta, and Needle (Shinglemill) Creeks.

All samples were analyzed for bacteriological, metal, and inorganic parameters. In addition, freshwater samples from Judd Creek and freshwater-sediment samples from Judd and Mileta Creeks were analyzed for VOCs and/or pesticides and PCBs in August and September 1991. VOCs, pesticides, and PCBs were analyzed for in samples from creek basins where historical land use information indicated it might be useful (SKCHD, pers. comm. 1993).

To evaluate the sampling results, analytical data for water samples were compared to Washington State water-quality criteria (Chapter 173-201A WAC) for Class AA streams and marine water. At the time of this study, surface-water standards were limited or not adopted by the state until after these sampling events were completed (SKCHD, pers. comm. 1993). The following water-quality parameters were evaluated against the current Washington State water-quality criteria:

Freshwater	Marine Water
Fecal Coliforms	Total Coliforms
Arsenic	Fecal Coliforms
Chloride	Arsenic
Chromium	Cadmium
Mercury	Chromium
Selenium	Copper
Temperature	Lead
pH	Mercury
Aldrin	Selenium
Heptachlor	Silver
Toxaphene	Zinc
PCB's	

Upper Judd Creek was not specifically designated as one of the creeks from which water-quality samples were collected. Samples were collected at the same site location (adjacent to the weir or staff gage) for the eight creeks. Samples were not collected at the Upper Judd Creek (gage) location.

The following sections summarize the surface-water sampling methodology used, field and laboratory results, and limitations on use of the data.

8.4.1.1 Methodology

The methodology used in sample collection is discussed in detail in the surface-water sample collection work plan (EcoChem/Geraghty & Miller 1991). The following subsection summarizes the sample collection activities conducted in 1991 and 1992.

Freshwater samples were collected adjacent to the staff gage, in the middle of the creek (Figure 8-26). Marine-water samples were collected in the shellfish collection area at three sampling sites twenty feet apart, at a water depth of 3 feet (Shallow, pers. comm. 1993). Freshwater sediment samples were collected above the high marine water tide and downstream from the freshwater collection site. Marine-water sediment samples were collected in the middle of the shellfish collection area. Marine-shellfish samples were collected in the vicinity of the mouths of each creek. In Green Valley Creek, no marine-shellfish community could be located and, therefore, no shellfish samples was collected.

Samples of freshwater were collected monthly from August 1991 through September 1992. Samples of marine water, marine-water sediment, and marine-shellfish were collected in August and November 1991 and April, July, and August 1992.

8.4 WATER QUALITY

The following section describes the surface-, spring-, and ground-water quality of the Island. The surface-water system investigation includes data from freshwater and marine water, freshwater and marine-water sediments, and marine shellfish. Spring- and ground-water quality data were collected from private and public water-supply wells and springs across the Island. The water quality for each system -- surface, spring, and ground -- is discussed in separate subsections below. All laboratory analyses were conducted by AmTest Inc. of Redmond, Washington, a state-certified laboratory. The spring- and ground-water data were validated by EcoChem, Inc. of Seattle, Washington. The surface water was validated by SKCHD.

8.4.1 Surface-Water Quality

Samples of freshwater, marine water, freshwater sediment, marine-water sediment, and marine shellfish were collected by SKCHD personnel from the following eight streams (Figure 8-26):

- Beall Creek
- Fisher Creek
- Green Valley Creek
- Judd Creek
- Mileta Creek
- Paradise Cove Creek
- Needle (Shinglemill) Creek
- Tahlequah Creek

8.3.4.2 Limitations

The map of aquifer-sensitive areas should be used with caution. It is useful for delineating general areas that may have high potential recharge; however, to determine the actual potential recharge of a specific area, more site-specific data is needed.

Insufficient information is available on the Deep Aquifer to conclusively determine its recharge areas for this aquifer. Recharge of the Deep Aquifer is most likely derived from the Principal Aquifer by leakage through the aquitard separating the Principal and Deep Aquifers. The degree of interconnection between the deep aquifer penetrated by the Gig Harbor well and the Deep Aquifer penetrated by in the KIRO well is uncertain. More information is needed to determine the interconnection between the Island's Deep Aquifer and off-Island aquifers or the amount of recharge from the overlying Principal Aquifer.

8.3.5 Water Balance

A total water budget for the Island was presented in Carr (1983). The Island water budget equals the total amount of water coming into the Island through precipitation and potential deep aquifer recharge from off-Island resources versus the amount of water leaving the Island through runoff, consumption, and evapotranspiration. Carr (1983) estimates that approximately 10 percent of the annual rainfall recharges the Principal and Deep Aquifers. It was hoped that this water budget could be further refined using the results from the stream gages; however, due to problems in maintaining the stream gages and insufficient stream-flow data and water-consumption records, the Carr (1983) water budget could not be further refined.

highest potential recharge area determined from the total rainfall map is located between northwest-central and east-central Vashon Island. Rainfall was not a recharge criteria considered in Carr (1983)

8.3.4.2 Results

Based on the composite of the five potential recharge maps (Figure 8-4), the largest areas which show the highest aquifer sensitivity for the Principal Aquifer are (1) west and northwest of Burton, (2) between Paradise Cove and Quartermaster Harbor, (3) west of Heyer Point, (4) Point Robinson, and (5) near the golf course on Maury Island. Several smaller areas of high potential recharge are scattered around the Island.

In general, the aquifer-sensitivity map (Figure 8-4) is similar to the Carr (1983) recharge map. The potential recharge areas defined in Carr (1983) include central Maury Island, south-central and east-central Vashon Island, and the vicinity of the Town of Vashon. The main difference between the areas of recharge defined by Carr (1983) and the areas of aquifer-sensitivity discussed above is the methodology used in development of the maps. The difference in methodologies resulted in differing locations for high potential recharge areas. The criteria Carr (1983) used for the development of the recharge map are slope, surficial geologic formation permeability, soil permeability, and vegetation. The criteria used for developed of the aquifer-sensitivity map presented in Figure 8-4 are depth to water, slope, surficial geologic formation permeability, soil permeability, and rainfall. In addition, Booth's (1991) geologic map of Vashon Island was not available when the Carr recharge map was constructed; the difference in locations of surficial geologic units may also have contributed to the variances between the maps.

9.0 DEEP EXPLORATION BORING

Geraghty & Miller, Inc. drilled an exploration well (VT-1) on Vashon Island, Washington to evaluate the resource potential and quality of the Deep Aquifer underlying the Vashon stade deposits (host of the Principal Aquifer). The following chapter describes the selection of the well site and the methodologies and field activities used to install the well. Also included is a summary of the information gathered as a result of the deep exploratory boring.

9.1 WELL LOCATION

Exploratory Well VT-1 is located on a maintenance road along the south side of Burton Acres Park on Vashon Island, Washington (Figure 8-6) at an approximate elevation of 50 feet msl. Access to the site was granted by the King County Parks Division which operates Burton Acres Park.

Burton Acres Park was selected for location of the exploratory well because of site accessibility and because of the site's position relative to other deep production wells (the KIRO Well on Maury Island, Coho Well on Vashon Island, and the Gig Harbor Well No. 5 on the Kitsap Peninsula) (Figure 9-1). The site was also selected so that drilling would penetrate a minimal amount of Vashon stade deposits (the base of the Vashon stade deposits is estimated to occur at an elevation near sea level at this location; Figure 8-2).

9.2 BOREHOLE DRILLING

Field activities for installing Exploratory Well VT-1 were conducted from January 7 through January 29, 1992. Because of subsurface conditions encountered during drilling, the well was installed using two drilling methods, air-rotary and cable-tool.

Okanogan Drilling, Inc. of Omak, Washington, drilled the initial borehole to a total depth of approximately 430 feet bls using an air-rotary Chicago Pneumatic 650 WS truck-mounted drill rig and tri-cone drill bit. The well was drilled by driving 12-inch inside diameter (ID) steel casing to a depth of approximately 20 feet bls to create a surface seal. Approximately 20-foot lengths of 8-inch ID steel casing were then advanced inside the 12-inch ID casing to prevent the collapse of the unconsolidated sediments surrounding the borehole during drilling.

During drilling, the borehole cuttings were diverted to a series of small temporary settling ponds. At a depth range of approximately 380 to 445 feet bls, a water-bearing zone was encountered which consisted of very-fine- to fine-grained sand. The large volume of fine-grained sediments in the drill cuttings (which have a slow settling rate) and increased water flow (estimated at approximately 40 gpm) caused the capacity of the settling ponds to be exceeded with sediment-laden water. Therefore, drilling with the air-rotary method was suspended at 430 feet bls on January 13, 1992.

Drilling of VT-1 was resumed on January 23, 1992 at 430 feet bls by Tacoma Pump and Drilling Company of Graham, Washington using a Bucyras Erie 22W truck-mounted cable-tool drill rig. The cable-tool drilling method uses temporary steel casing and a percussion drill bit to advance the borehole. The drilling was switched to the cable-tool method because it produces less volume of water when removing drill cuttings in a water-bearing zone than does the air-rotary drilling method. The borehole was advanced to a total depth of approximately 500 feet bls using the cable-tool drilling method and 8-inch ID steel casing.

During the drilling of VT-1, soil samples from drill cuttings were collected and descriptions were recorded continuously on a boring log (Appendix M) for stratigraphic comparison with other nearby deep boreholes. Soils encountered in the borehole for VT-1 consisted of primarily of fine-grained sand, silt, and clay with occasional interbeds of silty to sandy gravel. Fine-grained deposits occurred from approximately 0 to 2 feet bls and from approximately 40 to 485 feet bls and generally consisted of grey to light-grey, interbedded silt and clay with fine-grained sand. A trace of peat fragments was encountered at a depth of approximately 38 feet bls. Coarser-grained sands and gravels were encountered at depths of approximately 2 to 40 feet bls and generally consisted of grey to brown well-graded sand and gravel. Interbedded sands, silts, and gravels were encountered from approximately 485 to 500 feet bls.

Ground water was initially encountered during drilling at approximately 45 feet bls. A water-bearing zone consisting of fine-grained sand was also encountered from approximately 380 to 445 feet bls (approximate elevation of -330 to -395 feet msl). An additional water-bearing zone of interbedded sand, silt, and silty gravel was encountered at approximately 485 to 500 feet bls. After drilling was terminated at 500 feet bls, the static water level recorded in the borehole on January 29, 1992 was 88.25 feet bls (approximate elevation of -38 feet msl).

9.3 DATA COLLECTION AND ANALYSIS

Two grab samples representative of the water-bearing zone encountered from 380 to 445 feet bls (Samples 420 and 435) were submitted to Cascade Testing Laboratory, Inc. of Kirkland, Washington on January 29, 1992 for grain-size analysis to determine the feasibility of constructing an efficient water well in the fine-grained sediments (Appendix N). Soil Sample 420 was collected from the interval of 420 to 430 feet bls, and Soil Sample 435 was collected from the interval of 435 to 445 feet bls. The grain-size analysis was performed by passing the sampled soil through a series of sieves arranged in decreasing order of size opening. The soil retained in each sieve was weighed, and the cumulative percent retained was calculated and plotted for each size (Table 9-1).

The salinity, temperature, and conductivity of the ground water in the borehole was tested in the field. Water samples were collected from 315, 380, 400, 420, 435, and 481 feet bls. Salinity levels were consistently 0 parts per thousand; conductivity values ranged from 320 to 400 micromhos, indicating the water-bearing zones encountered were not affected by seawater intrusion. Values for pH ranged from 8.82 to 9.18 standard units, indicating the waters are slightly alkaline. Temperature values ranged from 9 to 15 degrees centigrade, which is normal for ground water.

9.4 BOREHOLE TERMINATION

The borehole for VT-1 had been proposed to be completed as a production well as part of the evaluation of the Deep Aquifer. The borehole was terminated at approximately 500 feet bls without installing a well primarily because the fine-grained nature of the aquifers encountered precluded installing an efficient well.

The results of the grain-size analysis (Table 9-1) (Appendix N) for the representative soil (silty, very-fine-grained sand) samples collected from 420 to 445 feet bls indicated that more than 50 percent of the aquifer sand would pass through the minimum standard slot opening needed for installing a wire-wrapped well screen (equivalent size opening of the No. 100 sieve). These results precluded installing a well screen suitable for natural development (i.e., no filter pack installed) and are consistent with the field descriptions of the soil samples. In some cases, filter-pack materials can be used to shield the well screen from fine-grained formation materials. To ensure a continuous filter pack is installed around the well screen, the filter pack should be a minimum of 3 inches thick (Driscoll 1986). Given that the borehole for VT-1 was drilled with an 8-inch inside diameter, a 3-inch-thick filter pack would reduce the maximum remaining borehole diameter for a well screen to 2 inches. Reduction of the well's diameter from 8 to 2 inches would decrease the well efficiency, specific capacity, and yield enough that completion of a water-supply well would not be efficient.

The aquifer encountered between approximately 485 to 500 feet bls contained abundant silt, which also precluded installing an efficient production well. Because of financial constraints and the fine-grained nature of this last aquifer, drilling was terminated at approximately 500 feet bls, and the top of the well casing was welded shut without installing a well screen.

9.5 AQUIFER CHARACTERISTICS

Since no pumping or slug (aquifer) tests were performed for Exploratory Well VT-1 and no aquifer tests are known to have been conducted nearby, the aquifer hydraulic characteristics of the Deep Aquifer were estimated based on the grain-size distribution of the soil samples collected (Driscoll 1986). This procedure is described in Appendix O. The grain size distribution of the soil sample collected at a depth of 435 feet bls was used for the calculation of the hydraulic conductivity. This sample was collected from a zone which was characterized during drilling as very fine-grained to fine-grained sand. Other portions of this water-bearing zone were characterized as finer and coarser than this sample, so that this sample may portray a relatively representative average composition.

The hydraulic conductivity and transmissivity of the Deep Aquifer were calculated at approximately 10 to 15 feet per day and 600 to 900 square feet per day, respectively.

(The estimated transmissivity is based on an aquifer thickness of 60 feet. The aquifer thickness was estimated from the boring log for Well VT-1.) The storage coefficient was estimated at 10^{-3} to 10^{-5}, based on typical values for a confined aquifer (Driscoll 1986).

9.6 GEOLOGIC CROSS SECTION

The hydrostratigraphy encountered in the borehole for VT-1 was compared with that of other deep production wells on the Island (the KIRO Well on Maury Island and the Coho Well on Vashon Island) and a deep production well on the Kitsap Peninsula (Gig Harbor Production Well No. 5). A geologic cross section was prepared using these wells to compare hydrostratigraphic relationships of the Deep Aquifer on the Island with the deep aquifer on the Kitsap Peninsula (Figures 9-1 and 9-2).

Stratigraphic nomenclature from Booth (1991) is applied to the surficial Vashon stade units of the cross section. Also depicted on the cross section are approximate elevations of the aquifers in the wells and the approximate elevation of the bottom of Colvos Passage of the Puget Sound.

The hydrostratigraphy shown on the cross section suggests that there may be some stratigraphic correlation between the VT-1, Coho, and KIRO Wells. Similar Vashon stade and pre-Vashon stade deposits (primarily interbedded fine-grained sand, silt, and clay with occasional interbeds of silty to sandy gravel) were reported for the VT-1, Coho, and KIRO wells, although the elevations of the correlative units vary. The first 50 feet encountered in the VT-1 well were most likely advance outwash (Qva) deposits. The interbedded fine- and coarse-grained materials encountered from 50 to 485 feet bls may be equivalent to the Kitsap clay (Appendix M). The wide variety of geologic deposits and complex stratigraphic relationships between deposits precludes correlation of the units reported for VT-1 with the units reported for Gig Harbor Well No. 5 on the Kitsap Peninsula (Booth, pers. comm. 1992).

The cross section shows deep freshwater aquifers occur on the Island and on the Kitsap Peninsula at similar ranges in elevation (approximately -400 to -600 feet msl) and at elevations below the bottom of Colvos Passage of the Puget Sound (approximately -300 feet msl). However, the interconnection of the Deep Aquifer on the Island with potential off-Island sources cannot be clearly defined based on the available data.

10.0 CONCLUSIONS AND RECOMMENDATIONS

Chapter 10.0 briefly states the circumstances of the data analysis portion of this report and presents the conclusions that can be drawn from these data. In addition, this chapter identifies data gaps and makes recommendations for filling those gaps based on the information presented in previous investigations of the Vashon GWMA plus the conclusions derived from the most recent data. The summary and conclusion section is presented first, followed by the future data needs and recommendations.

10.1 SUMMARY AND CONCLUSIONS

Data concerning rainfall, surface water, ground water, and deep sediments for the Vashon GWMA were collected from late 1989 through early 1992 to further refine the understanding of the Island's water resources. Based on the latest data collection efforts, the following conclusions can be drawn.

10.1.1 Rainfall

Nine rain-gage stations were monitored during the three-plus-year observation period. The following rainfall trends for the Island are derived from the rainfall data collected.

- Similar seasonal trends in rainfall fluctuations occur across the Island. The Island receives the most rainfall between November and April and the least between August and September.

- The annual rainfall for the Island may range from approximately 23 to 62 inches per year.

- Annual rainfall trends vary erratically across the Island; however, the highest amount of rainfall generally falls in the north-central portion of Island.

- Annual rainfall accumulations at Sea-Tac Airport on the mainland are consistently lower than on the Island.

10.1.2 Surface Water

Eight creeks were monitored during the observation period to determine trends in stream flow and the quality of surface water on the Island. Stream-flow data were developed from stream-gage readings. Water quality was evaluated from laboratory analysis of samples of freshwater, marine water, freshwater sediments, marine-water sediments, and marine shellfish. The following conclusions were drawn from this data collection effort.

- Stream levels increase after high rainfall events, though not instantaneously.

- Predictably, stream flow tends to correlate with rainfall. Stream flow is highest during the wetter winter months and lowest during the drier summer months.

- Estimated stream-base flow ranges from 0 cfs to 4 cfs (944 Mgpy).

- High fecal coliform levels appear throughout the stream system; however, these elevated levels may reflect local wildlife rather than septic system failures. No correlations were observed between contaminant levels

GW ? Shallow ?

detected in freshwater, freshwater sediments, marine water, marine-water sediments, and marine shellfish. In other words, contaminants detected in a stream were not necessarily detected in marine sediments or shellfish at the mouth of the stream.

- The quality of spring water on the Island appears to be good.

10.1.3 Ground Water

During the observation period, 21 wells were monitored. Trends in water levels, ground-water quality, and aquifer characteristics were derived from the data collected and are presented below.

- Depth to ground water varies across the Island. In general, the deepest depths to ground water are associated with the central axis of Vashon Island, while the shallowest depths to ground water occur near the coastlines in the approximate middle of Vashon Island.

Cls

- Ground water is mounded on the Island and flows from the higher topographic areas toward the coastlines.

- Observed water levels in wells across the Island fluctuated seasonally between 1 and 22 feet.

- ? Most of the wells in which water levels fluctuated only between 1 and 3 feet may be completed the Deep Aquifer.

- The water-bearing zones monitored by the selected wells generally showed a stable or a slight rise in the water level during this study and, therefore, do not have appear to have been affected by ground-water withdrawals.

- The largest areas showing the highest potential recharge are (1) west and northwest of Burton, (2) between Paradise Cove and Quartermaster Harbor, (3) west of Heyer Point, (4) Point Robinson, and (5) near the golf course on Maury Island. Several smaller recharge areas are scattered around the Island.

- Most of the high potential recharge areas are situated in low-density, single-family residential land use areas. A portion of the high potential recharge areas are located in high-density, single-family residential and manufacturing land use areas.

- The concentration levels of chloride, nitrate, and TDS do not suggest any impact from land use.

- Seawater does not appear to be intruding on the Island's freshwater resources.

- Lead concentrations exceed the SDWA MCL in water sampled from Wells W-13 and W-15. It is uncertain whether this is due to actual concentrations in the ground water or a result of lead leached from the pipes.

- Based on soil grain-size analysis, the hydraulic conductivity and transmissivity for the Deep Aquifer is estimated to be 10 to 15 feet per day and 600 to 900 square feet per day, respectively. The storage coefficient is estimated to be 10^{-3} to 10^{-5}.

- Freshwater aquifers occur on the Island and on the Kitsap Peninsula at similar ranges in elevation (approximately -400 to -600 feet msl) and at elevations below the bottom of Colvos Passage of the Puget Sound (approximately -300 feet msl). However, an interconnection between the Deep Aquifer on the Island and potential off-Island sources cannot be verified based on the available data.

- The water budget presented by Carr (1983) cannot be further refined or estimated, primarily because of the limitations of the stream-flow data and the lack of accurate water-consumption records.

10.1.4 Deep Aquifer

The results of drilling Exploration Well VT-1 revealed the following information concerning the deep water-bearing zones of the Island.

- The pre-Vashon stade deposits encountered consist primarily of fine-grained sand, silt, and clay with occasional interbeds of silty to sandy gravel. Similar stratigraphy reported for the Island's Coho and KIRO wells suggests some stratigraphic correlation between the wells.

- The wide variety of geologic deposits on the Island and the complex stratigraphic relationships between deposits preclude correlation of the hydrostratigraphy of the Island with that of the Kitsap Peninsula.

- Ground water on the east-central coast of Vashon Island occurs at approximately 45 feet bls. Additional water-bearing zones consisting primarily of fine-grained sand occur from approximately 380 to 445 feet bls and 485 to 500 feet bls.

- Exploratory Well VT-1 was terminated at approximately 500 feet bls without installing a well, primarily because the fine-grained nature of the aquifers encountered precluded installing an efficient well.

10.2 RECOMMENDATIONS CONCERNING FUTURE INFORMATION NEEDS

During the compilation of updated area characterization and data analysis information presented in this report, several data gaps were identified. Section 10.2 summarizes the identified data gaps and makes recommendations for obtaining the missing information in the most cost-effective manner.

10.2.1 Water Resources

To further understand the available water resources for the Island and to develop a more accurate water budget, more data need to be generated for the major components of the water budget. Accurate records of precipitation, runoff, aquifer recharge, and water withdrawal are critical in assessing the productive capacity of the Island's aquifers. To accomplish this objective, the following activities should be initiated.

- Install permanent staff gages approved by the USGS in selected watersheds. These gages should be strong enough to withstand storm events. In addition, automatic stream-flow recorders should be installed to monitor daily and storm-event water levels of surface water in the major drainage basins. The recorders will need to be checked periodically to retrieve the finite amount of information the recorder can retain and to ensure continued proper operation.

- Monitor rainfall daily in selected areas across the Island. Automatic rain-gage recorders would provide a more complete record of rainfall. The recorders will need to be checked periodically to retrieve the finite amount of information the recorder can retain and to ensure continued proper operation.

- Obtain historical and current data on water use from all classes of purveyors.

10.2.2 Water Quality

The following activities should be conducted to continue the assessment of the effects of land use on water quality.

- Monitor the water quality in shallow and deep wells on a long-term basis.

- Monitor water quality in wells at and near the landfill, NIKE missile launch site, failing/prefailing septic systems, and UST sites.

- Monitor the water quality of the surface water in the major drainage basins most likely to be impacted by potential point sources of contamination.

- Complete the survey on the condition of septic systems and determine their influence on the surrounding drainage basins. High fecal coliform levels found near failed septic systems are potentially dangerous for contraction of disease.

- Monitor possible contaminants in marine shellfish near identified severe public health hazard and health caution areas.

10.2.3 Hydrogeology

The map and report by Booth (1991) provide a detailed geologic picture of the Island, particularly in the coastal areas and along stream channels where extensive exposures are available. This information could be augmented through a thorough review of Island well logs. Correlation of strata recorded during well drilling operations could assist in determining the location and volume of the Island's aquifers in areas where exposures are scarce, particularly of deeper water-bearing zones not exposed above mean sea level.

The ability of the two known aquifers, Principal and Deep, to meet water demands in the coming years is a fundamental concern in the Island's future ground-water management. To develop a deeper understanding of the Principal Aquifer, more data and more data points are needed concerning ground-water levels in the Principal Aquifer. To further this understanding also, the characteristics of the Principal Aquifer should be further defined by performing the following activities:

- Continue monitoring water levels in wells screened in the Principal Aquifer. To provide a more complete record, install automatic water-level recorders. The recorders will need to be checked periodically to retrieve the finite amount of information the recorder can retain and to ensure continued proper operation.

- Monitor water levels in an additional set of wells screened in the Principal Aquifer for further definition of water-table elevations.

- Conduct a pumping test on a well screened in the Principal Aquifer to determine the Principal Aquifer characteristics of transmissivity, hydraulic conductivity, and storativity.

The water-resource potential of the Deep Aquifer has been difficult to estimate, largely because of complexities associated with establishing its degree of continuity, volume, and recharge capacity. To further the understanding of the potential production capacity of the Deep Aquifer, the following activities should be conducted.

- Conduct a pumping test on a well screened in a deep water-bearing zone to refine the knowledge of the transmissivity, hydraulic conductivity, and storativity of the Deep Aquifer.

- Install another "deep" well on the southwest side of Vashon Island to investigate further the potential that the Deep Aquifer is connected to the mainland's deep aquifer and to explore the production potential below the Principal Aquifer.

- Collect, maintain, and analyze the records of all the other deep wells which have been and will be drilled on the Island.

10.2.4 Public Awareness

Maintain a high level of public awareness by implementing a system through which data are collated and retained in a usable manner. The results of the continuing data collection efforts can be conveyed to the public on a regular basis to preserve high levels of public awareness and "grass-roots" responsibility for the Islands water resources.

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GW/AC

VASHON GROUND-WATER MANAGEMENT PLAN
UPDATED AREA CHARACTERIZATION
AND DATA ANALYSIS

PROJECT NO. WA028.02

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ABBREVIATIONS

AG~~R~~ D	Annual Growth ~~Report~~ Databook
bls	below land surface
BOD	biological oxygen demand
b.p.	before present
BWC	Burton Water Company
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CES	Cooperative Extension Service
cfs	cubic feet per second
COD	chemical oxygen demand
DDES	Department of Development and Environmental Services
DPW	King County Department of Public Works
DWA	Dockton Water Association
Ecology	Washington State Department of Ecology
FDA	United States Food and Drug Administration
GBWS	Gold Beach Water System
gpd	gallons per day
gpdpc	gallons per day per connection
gpm	gallons per minute
GWAC	Ground-Water Advisory Committee
GWMA	Ground-Water Management Area
GWMP	Ground-Water Management Plan
ID	inside diameter
KCAPP	King County Agriculture Preservation Plan
KCBH	King County Board of Health
KCCD	King County Conservation District
KCPD	King County Planning Division
KCSWR	King County Solid Waste Regulations
LSA	local service area
MCL	maximum contaminant level
mg/L	milligrams per liter
Mgpd	million gallons per day
Mgpy	million gallons per year
MMWC	Maury Mutual Water Company
msl	mean sea level
MTCA	Washington State Model Toxics Control Act
Metro	Municipality of Metropolitan Seattle
PCB	polychlorinated biphenyls
ppm	parts per million

PPR	King County Department of Parks, Planning, and Resources
PSCOG	Puget Sound Council of Governments
PSRC	Puget Sound Regional Council
PSWQA	Puget Sound Water Quality Authority
RBCGWMP	Redmond-Bear Creek Ground Water Management Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SKCHD	Seattle-King County Department of Public Health
SPA	special protection area
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Department of Environmental Protection
USGS	United States Geological Survey
UST	underground storage tank
VOC	volatile organic compound
VSG	Vashon Sand and Gravel
WAC	Washington Administrative Code
WAVES	Water And Vashon Ecosystems
WDNR	Washington State Department of Natural Resources
WDOH	Washington State Department of Health
WSFS	Washington State Ferry Service
WWA	Westside Water Association

5.0 LAND USE BACKGROUND

Chapter 5.0 discusses the type and extent of land use activities potentially affecting ground water in the Vashon GWMA. Land use activities are first described generally as they are carried out on the Island, followed by specific land uses and their effects on the Island's water sources.

5.1 GENERAL DESCRIPTION

Included in the general description of the Island's land use are existing land uses for both developed and undeveloped land; development trends for residential, commercial/industrial, and agricultural areas; and the plans, policies, and regulations related to land use that have been sanctioned by King County. These areas of discussion are presented below.

5.1.1 Existing Land Use

In 1990, according to the Puget Sound Regional Council (PSRC), 1194 acres (about 5 percent) of the Island's 23,659 acres were classified as residential and 439 acres (about 1.9 percent) were occupied by places of employment. Approximately 63 percent was classified as vacant developable land which is the total acreage of land that is physically developable according to the standards and policies currently applicable to local governments. The remaining land, almost 30.3 percent of the Island, was classified as balance which consists of unbuildable land, streets and parks. ~~In 1980, according to the Puget Sound Council of Governments (PSCOG), 933 acres (about 4 percent) of the Island's 23,418 acres were classified as residential and 303 acres (about 1.3 percent) were occupied by places of employment. The remaining land, almost 95 percent of the Island, was undeveloped.~~

5.1.2 Development Trends

Development trends are discussed in terms of residential, commercial and industrial, agricultural, and other development. Each category is discussed below.

5.1.2.1 Residential

Populations and housing estimate and forecasts were drawn from two sources: (1) the Puget Sound Council of Governments (1988; 1993) and (2) King County annual growth reports (AGR) (1988a; 1989; 1991; 1992). Residential building data was gathered from an annual growth report (King County 1992). The following discussion describes the growth on the Island indicated by this data.

The Island's population continues to grow, accompanied by a greater rise in the demand for housing (Tables 5-1 and 5-2). While the Island's population increased by only about 13 percent from 1970 (6,516) to 1980 (7,377), the total number of households increased by about 36 percent. From 1980 to 1990, the Island's population increased another 26 percent (to 9,309), yet the total number of households increased by 28 percent. The disparity between growth in population and in number of households has arisen from a decrease in the average household size from 1970 to 1980, from 3.05 persons (1970) to 2.53 persons (1980) to 2.50 persons (1990). Single-family dwellings increased in number by 25 percent from 1970 (2,070) to 1980 (2,594) and by 28 percent from 1980 to 1990 (3,488). The number of multi-family households jumped by 466 percent between 1970 (53) and 1980 (300) and then decreased by 28 percent by 1990 (215).

The 1993 AGR (Table 5-2) reports the 1992 population of the Vashon GWMA as 9,900, a 33.8 percent increase over the 1980 PSCOG population estimate. The total number of households in 1992 (4,100) was up 41.9 percent from 1980. The 1992 PSRC predicts a population of 11,095 by the year 2000 (Table 5-3); and the 1993 AGD predicts a similar population increase to 11, The 1992 AGR (Table 5-2) reports the 1991 population of the Vashon GWMA as 9,800, a 32.4 percent increase over the 1980 PSCOG population estimate. The total number of households in 1991 (4,000) was up 38.4 percent from 1980. The 1988 AGR predicted a population of 8,572 by the year 2000 (Table 5-3); whereas, the 1992 AGR has elevated the prediction to 11,100 (Table 5-4). Table 5-5 shows the number of residential permits issued and the number of housing units built in the Vashon GWMA from 1980 through 1992, as reported in the 1993 AGD. The 1992 PSCOG prediction of 8,572 (Table 5-3) for the year 2000 is 22.7 percent lower than the 1992 AGR forecast (11,100). Table 5-5 shows the number of residential permits issued and the number of housing units built in the Vashon GWMA from 1980 through 1991, as reported in the 1992 AGR.

As stated in the 1986 Vashon Community Plan, the Vashon Sewer District local service area (LSA) within the Town of Vashon contains planning for an additional 1400 residential units. The Vashon Sewer District currently has 350 connections. Communities without sewer systems (including Dockton, the Vashon Sewer District local service area (LSA) within the Town of Vashon contains planning for intensive residential development, including areas of multi-family development. Communities without sewer systems (including Dockton, Burton, and Vashon Heights) are allowed to develop to a maximum density of three single-family units per acre (King County 1986).

5.1.2.2 Commercial and Industrial

The Town of Vashon is presently and will continue to be the center of the major commercial business interests on the Island. Small commercial centers exist in other communities and will be maintained at their current size, except for the possible limited expansion of Burton's. Mixed business/residential units will be encouraged in the Town of Vashon and its business center. Under the 1986 Vashon Community Plan, there is 21 acres available for commercial/business use within the Town of Vashon. Neighborhood grocery stores and small clusters of business that exist in Island communities are recognized as integral parts of the character of the communities. ~~No additional business zoning has been designated, because approximately one-third of the land currently zoned for business is undeveloped. Neighborhood grocery stores and small clusters of business that exist in Island communities are recognized as integral parts of the character of the communities.~~ Home occupations and cottage industries presently operate, and shall continue to operate in the future, provided that they meet the safety, zoning, and aesthetic standards of the community. Table 5-6 shows selected new industrial and commercial permits in the Vashon GWMA for 1980 through 1990 (King County AGR 1991). ~~Table 5-6 shows selected new industrial and commercial permits in the Vashon GWMA for 1980 through 1988 (King County 1989a).~~

The lack of island-to-mainland transportation other than the public ferry system is one of the factors limiting industrial growth in the Vashon GWMA. The 1986 Vashon Community Plan has zoned approximately 704 acres for industrial and manufacturing uses. Of the total 704 acres, 530 acres are specifically intended for quarrying and mining purposes. Future industrial growth will be clustered south and west of the Town of Vashon and near existing industrial sites (Plate 1). ~~At present, approximately half of the land zoned for industrial uses (about 40 acres) is still undeveloped. A maximum of 60 acres total is estimated to be adequate for manufacturing uses under the current 1986 Vashon Community Plan. Future industrial growth will be clustered south and west of the Town of Vashon and near existing industrial sites (Plate 1).~~ Given the rural character of the Island and the limited work force, no large-scale industrial development is foreseen; future industrial uses will generally be for small-scale, light industry.

be permitted on the Island. Establishment of a permanent farmers' market was recommended in the 1986 Vashon Community Plan.

5.1.2.4 Other

Another development trend is the establishment and protection of historic sites, as recommended in the 1986 Vashon Community Plan. The communities of Burton and Dockton have been nominated as historic districts; development guidelines encourage maintaining compatibility with historic buildings. The 1986 Vashon Community Plan states that a Historic Preservation Officer will review proposals for development to evaluate their potential impact on the character of the community. According to Julie Koler, King County Historic Preservation Officer, a list of historic sites and potential landmarks on the Island was developed after a survey of the Island. The Historic Preservation Office is generally consulted by DDES if a proposed development involves a site on that list (Koler, pers. comm. 1989).

5.1.3 Plans, Policies, and Regulations

Land use activities and development trends evolve within the framework of applicable land use policies. In the case of the Vashon GWMA, the most influential land use policies are the 1985 King County Comprehensive Plan and the 1986 Vashon Community Plan. The 1985 King County Comprehensive Plan is the county's long-range, ~~the most influential land use policies are those of King County and of the Island. The 1985 King County Comprehensive Plan is the county's long-range,~~ county-wide, comprehensive land use plan. The 1986 Vashon Community Plan contains detailed land use, capital improvement, and zoning plans. In addition, functional plans, which address location, design, and operation of public facilities and services (such as surface-water control and sewage disposal), receive policy direction from the King County

5.2.1.1 Description

The 9.3-acre refuse area of the Landfill is located on a 145-acre site in west-central Vashon Island, primarily in the southwest quarter of Section 36, T23N R2E (Figures 5-1 and 5-2). Access to the site is by way of 130th Avenue Southwest (Harper-Owes/Golder 1986). In their report, Harper-Owes (1988) states that historic records indicate that disposal at the site may have begun in the early 1900s. The site has been active since the early 1950s, but detailed records are unavailable prior to that date. Currently, all forms of solid waste as defined in the King County Solid Waste Regulations (KCSWR), Title 10, of the King County Code of the Board of Health, Rules and Regulations No. 8, are accepted at the landfill, with the following exceptions:

- Liquids, demolition debris, or flammable materials.
- Dangerous wastes as defined by Ecology under Chapter 173-303 WAC.
- Hazardous wastes as defined by Federal Law 94-580, RCRA 1976.

A monthly inspection is conducted by the SKCHD staff to verify that unacceptable waste is not accepted at the landfill.

In 1984, 1985, and 1986, the landfill accepted approximately 4,800, 5,500, and 5,900 tons of refuse, respectively, representing volumes of approximately 16,000, 18,000, and 19,600 cubic yards, respectively. In 1991, the landfill accepted 6817 tons of refuse, an increase of 917 tons from 1986 (Table 5-7). ~~respectively (Table 5-7).~~ The refuse generation rate is expected to increase annually as both population and per-person refuse generation increase (Harper-Owes 1988).

Harding Lawson (1991), the water table in the shallow zone has dropped along the west side of the landfill as a result of the landfill closure, and the primary direction of ground-water flow is to the west.

Approximately 4,000 to 5,000 feet west of the landfill, a steep slope cuts across a silt (aquitard)/sand contact layer (Figure 5-5). Spring water seeps out of the contact and enters an unnamed creek, eventually discharging into Colvos Passage. These springs are not used as a drinking water source. These springs are sampled routinely by the King County Solid Waste Division. The quality of the spring water as it leaves the site generally meets the ground water quality standards. ~~The quality of the spring water as it leaves the site is unknown.~~ Spring water is probably composed of water from both water-bearing zones (Harding Lawson 1991).

Six monitoring wells (4 shallow and 2 deep) and three ground-water seeps (areas where spring water flows out through exposed seams of sand) have been periodically sampled. The water samples have been submitted to a laboratory to be analyzed for pH, specific conductance, total solids, TDS, total suspended solids, chemical oxygen demand (COD), total organic carbon, total organic halogens, biological oxygen demand (BOD), and dissolved oxygen. Four wells were screened in the shallow zone, and two wells were screened in the deep zone.

Four monitoring wells (MW-1, MW-3, MW-4, and MW-5S) were sampled between 1984 and 1992 by R.W. Beck, Harper-Owes, and Harding Lawson to determine the water quality in the shallow water-bearing zone. Contours of specific conductance data in the shallow zone indicated a potential leachate plume spreading out from the landfill (Beck 1984; Harper-Owes/Golder 1986). The highest specific conductance levels occurred in samples collected from two wells (MW-4 and MW-5) located downgradient (west) of the landfill (MW-4 and MW-5S) (Harper-Owes/Golder 1986).

Harding Lawson's investigation of ground-water in 1991 concluded that "downgradient wells are still impacted by leachate, but trends in water quality improvement exist" (Harding Lawson 1991). Samples collected from at least one downgradient monitoring well screened in the shallow water-bearing zone (Appendix A) have exceeded water-quality standards for total coliforms, arsenic, vinyl chloride, methylene chloride, and 1,1,1-trichloroethane (TCA) during one or more sampling events since 1986.

Monitoring Wells MW-2 and MW-5D were sampled between 1984 and 1992 by Beck, Harper-Owes, and Harding Lawson to determine the water quality in the deep water-bearing zone. Leachate migration was suspected in the deep zone because the highest levels of specific conductance were detected in the western downgradient perimeter wells (MW-2 and MW-5D) (Beck 1984; Harper-Owes/Golder 1986). Samples collected from at least one downgradient monitoring well screened in the deep water-bearing zone (Appendix A) have exceeded water-quality standards for chromium, endrin, arsenic, vinyl chloride, methylene chloride, TCA, and lindane during one or more sampling events since 1986 (Harding Lawson 1991); COD has also been present in MW-5D.

The capping of the old landfill fill area in 1989 may have caused COD concentrations to decrease in Monitoring Well MW-5D. Harding Lawson (1991) concluded that "the trend of dropping COD indicates that vinyl chloride and methylene chloride levels may drop also." In addition, Harding Lawson stated that leachate generation from the old fill has been inhibited by the cap installed in 1989. Leachate is generated by water percolating through refuse. The cap acts to collect rainfall which falls on the cap thus preventing further leachate generation in the refuse under the cap, and collecting and containing leachate generated by refuse on top of the cap for treatment.

The amount of leachate produced is controlled by the amount of uncapped refuse and rainfall. Leachate produced is collected and transported off the Island for treatment.

Beck (1984) and Harper-Owes/Golder (1986) concluded that spring (seep) water was affected by leachate migration. Harding Lawson (1991) also suggested the possibility of leachate infiltration, based on moderately elevated levels of specific conductance, chloride, and COD. Monitoring results have since indicated dramatic improvements in the overall water quality indicators of leachate impacts for many monitoring wells. Arsenic detection, while sporadically above the ground water quality standards has shown a decreasing overall trend. Vinyl chloride, however, has been detected with greater frequency and at higher concentrations since the closure of the old fill. The King County Solid Waste Division believes the probable source of vinyl chloride is the landfill gas components dissolving into the ground water. The first course of action to be taken will be to control the landfill gas, and then to consider whether additional actions are required to control vinyl chloride.

Eleven off-site wells have been monitored by SKCHD periodically since December 1987 (Figure 5-6). The ground-water samples were analyzed for volatile and semivolatile organic compounds, organochlorine pesticides, and metals (Appendix A).

None of the off-site monitoring wells have exhibited levels above primary drinking water standards for the constituents analyzed. At this time it is unknown whether the shallow and deep water-producing zones impacted by the Landfill are interconnected with the aquifers utilized for public water-supply wells. SKCHD has to date sampled four wells and five surface-water sources around the Landfill on a quarterly and more recently, a bi-annually basis. In the future, SKCHD will be sampling more wells around the landfill especially for heavy metals and volatile organic compounds including vinyl chloride. The

King County Solid Waste Division will install eight additional monitoring wells in 1994. Four wells are planned to be installed to monitor ground water located below the deepest ground water currently being monitored at the site. The other four wells are planned to be installed in the currently monitored ground water lenses to provide an additional upgradient well and to better define downgradient ground water flow directions.

Future Solid Waste Division plans with respect to the landfill are that conceptual development alternatives for the Vashon landfill site will be developed in 1994 which will include; closure of the existing landfill area; development of additional landfill and\or transfer capacity; location, capacity and types of recycling services provided; location, capacity and nature of stormwater control facilities; and location, capacity and nature of any composting operation. Conceptual development alternatives developed will be compared on a basis of cost, service provided, and compliance with any restrictions or conditions resulting from a sole source aquifer designation.

~~None of the off-site monitoring wells have exhibited levels above primary drinking water standards for the constituents analyzed. The King County Solid Waste Division continues to sample four wells and five surface water sources at and around the Landfill on a quarterly basis. It is unknown whether the shallow and deep water-producing zones impacted by the Landfill are interconnected with the aquifers utilized for public water supply wells.~~

The Vashon Island Landfill is recorded on Ecology's list of Hazardous Waste Investigations and Cleanup Program dated December 1988 as a state site undergoing long-term monitoring. This list names known or suspect contaminated sites. From this list, the Toxic Clean-up Program (TCP) ranks sites in an effort to prioritize sites for clean-up under the Model Toxic Control Act. For active landfills such as Vashon, where SKCHD is the permitting authority with assistance from Ecology's Solid Waste Services Division, TCP would not manage any clean-up activities. According to Ecology,

~~According to Ecology,~~ the Landfill has apparently affected surface-water quality and may also have affected ground-water quality. Ecology's listing reports contamination as confirmed, suspected, unknown, potential, true, or false for each of 15 contaminant categories. The only contaminants listed as confirmed for the Vashon Island Landfill are "metals - other," which refers to metals other than the priority pollutants. The contaminants listed as suspected include priority pollutant metals, petroleum products, phenolic compounds, and conventional organic and inorganic contaminants (Ecology 1988). King County Solid Waste Division and SKCHD will be conducting additional investigations at the landfill and the surrounding area to determine the extent of the contamination.

5.2.2 Former NIKE Missile Launch Site

A former missile launch site is located at the northwest intersection of Southwest 220th Street and 119th Avenue Southwest, at the present location of Paradise Ridge Park (Figure 5-1). From 1955 to 1974, NIKE-Ajax and Hercules missiles were deployed from the site. A description of the activities formerly conducted at the site and the effect of those activities on ground water follows.

5.2.2.1 Description

According to J. A. Maas of the USACE (Maas, pers. comm. 1993), the NIKE site was composed of three areas: a family housing area, a missile launch site (Figure 5-7), and a control site approximately 1 mile east of the launch site. The family housing area is now privately owned, the control site was conveyed to the Washington State Department of Health and Education in 1976, and the launch site was transferred from the United States Department of Defense to the King County Parks Department in 1976. The launch site has been an equestrian park since 1976.

The Army Corp of Engineers will mitigate the Paint and Fuel Storage Area by removing five feet of contaminated top soil, then another five feet of clean soil, the diameter of the Paint and Fuel Storage Area. Clean soil will replace the soil removed. No ground water samples were taken. From the studies conducted at the site and the general ground water information in the vicinity of the site, ground water is located quite deep (approximately 100 feet). There is no threat to ground water quality at the site. Once the contaminated soil is removed and replaced with clean soil, this will complete remediation of the site (L. Mann, pers. com.).

~~Contact with ground water is estimated to occur at 20 feet below land surface (bls). The ground water in the wells closest to the site (W-7, W-13, W-16, and W-17) has not been analyzed for organic constituents.~~

5.2.3 On-Site Sewage Systems

The King County Board of Health (KCBH) rules and regulations governing on-site sewage disposal systems now recognizes on-site wastewater disposal, i.e., septic systems, as a long-term wastewater disposal method for areas not served by public water service. At present, all of the Island lying outside the Vashon Sewer District LSA in the Town of Vashon (Figure 5-9) uses on-site wastewater disposal systems. A description of activities involving regulation and monitoring of septic systems and the effects of septic systems on ground water are presented below.

5.2.3.1 Description

The minimum lot size for unsewered lots in new subdivisions are regulated as a function of the texture of the underlying soil by King County's onsite sewage disposal regulations. The type of onsite disposal system permitted on the site then depends on the undisturbed original soil depth and the size of the lots (King County Board of

Health Regulations 1987). The regulations stipulate a requirement for a drainfield reserve area. The Carr study resulted in the 1986 changes in the subdivision regulations for Vashon (King County 1986), often requiring minimum lot sizes for new subdivision much larger than those required by King County's onsite sewage disposal regulations.

The 1986 Vashon Community Plan requires that the maximum housing density in unsewered areas be no more than 3 houses per acre. On the Island, minimum lot sizes for unsewered dwellings are based on soil texture type per unit of volume of sewage (450 gallons per day [gpd]) or whether the lot is zoned for a single family residence (KCBH 1987). The regulations stipulate a requirement for a drainfield reserve area. The Island's soil quality, which is generally considered fair to poor for septic systems by the federal Soil Conservation Service, together with the results delineated in Carr (1983), resulted in the 1986 zoning regulations for septic systems (King County 1986).

The 1986 regulations require that the maximum housing density in unsewered areas be no more than 3 houses per acre, provided that more than 30 inches of topsoil is present. A 2.5-acre minimum lot is required in unsewered areas with 24 to 30 inches of topsoil. Unsewered areas with 20 to 24 inches of topsoil may support no more than 1 house per 5 acres (King County 1986). Minimum lot sizes for unsewered lots in new subdivisions are regulated as a function of the texture of the underlying soil (Tables 5-8 and 5-9). The type of on site disposal system permitted on the site then depends on the undisturbed original soil depth and the size of the lot (greater or less than 1 acre).

5.2.3.2 Effect on Ground-Water Quality

SKCHD conducted a sanitary survey of on-site sewage systems in seven coastal communities between December 1988 and January 1991 to determine their condition.

Four communities (Bunker Trail, Cove/Beulah Park, Spring Beach, and Burton) were declared "severe public health hazard areas." Based on the results of the sanitary survey, the state Department of Health declares an area a "severe public health hazard" where 1) the existing waste water system(s) have resulted in contamination being present on the ground surface in such quantities and locations as to create a potential for public contact; 2) and the problem involves a subdivision, town or county; 3) and the problem cannot be corrected through more efficient operation and maintenance of an existing waste water system; 4) or the potential for contaminating a source of drinking water exists or has been demonstrated. In addition," In addition, three communities (Patten Palisades, Paradise Cove, and Quartermaster Harbor) were determined to be "health caution areas" (Barrett 1991). Barrett (1992) developed a draft Sewage Facilities Plan for the severe public health hazard areas. The SKCHD survey and the sewage facilities plan are discussed in more detail in Subsection 6.5.2, On-Site Wastewater Disposal (Septic Systems).

According to the USEPA, septic systems and cesspools are the most frequently reported sources of ground-water contamination (Freeze and Cherry 1979). Drainfield effluent has been implicated in producing elevated nitrate and phosphate concentrations in ground water and can contain pathogenic bacteria and viruses in areas where more than one residence per acre are present. ~~Drainfield effluent has been implicated in producing elevated nitrate and phosphate concentrations in ground water and can contain pathogenic bacteria and viruses.~~ The aerobic bacteria called fecal coliforms is considered the standard indicator parameter for drainfield effluent contamination (Lewis 1980) and is evaluated in the data analysis portion of this report.

5.2.4 Sludge (Biosolids) Applications

~~4 Sludge Applications~~

Sludge now known as biosolids, is a by-product of sewage treatment performed by sewage facilities. In some cases, the Vashon biosolids may be spread in vegetated areas with beneficial effects. How the Vashon Sewage Treatment facility handles its biosolids and the possible effect of those biosolids applications on ground-water quality are described below.

5.2.4.1 Description

The Vashon Sewage Treatment facility produces about 10 tons of biosolids annually (dry weight), which is currently transported off the island for further treatment and\or disposal at an approved facility. The utilization site currently meets the qualifications for a low application rate project (less than 4 dry tons per acre per year). ~~the sludge produced may be spread in vegetated areas with beneficial effects. How the Vashon Sewage Treatment facility handles its sludge and the effect of those sludge applications on ground water quality are described below.~~

~~**5.2.4.1 Description**~~

~~The Vashon Sewage Treatment facility produces about 10 tons of sludge annually (dry weight), which is currently applied at a future silvacultural site on Maury Island. The treatment facility currently meets the qualifications for small quantity producers and operates under a site permit issued by SKCHD, for sludge application.~~

5.2.4.2 Effect on Ground-Water Quality

Total coliforms, fecal coliforms, and inorganic compounds (nitrates and metals) are the indicator parameters typically used to detect ground-water contamination by sewage waste. Due to the small quantities of biosolids produced by the Vashon Sewage Treatment facility, ~~Due to the small quantities of sludge produced by the Vashon Sewage Treatment facility,~~ extensive ground-water monitoring is not required. However, a site permit is required from SKCHD for any land utilization of bisolids. The biosolids were analyzed by Laucks Testing Laboratories of Seattle in December 1987; ~~a site permit is required from SKCHD for any land utilization by sludge. The sludge was analyzed by Laucks Testing Laboratories of Seattle in December 1987;~~ estimates of fecal strep, fecal coliforms, and total coliforms exceeded 160,000 per 100 milliliters of biosolids.~~000 per 100 milliliters of sludge.~~ The sample contained less than 2 percent solid material. Further results of biosolids testing are shown in Tables 5-10(a) and (b). ~~Further results of sludge testing are shown in Tables 5-10(a) and (b).~~

5.2.5 <u>Underground Storage Tanks</u>

The Ecology listing of commercial USTs reported in Washington (Table 5-11) lists 26 tanks in use at commercial locations on the Island; ~~The Ecology listing of USTs reported in Washington (Table 5-11) lists 24 tanks in use at commercial locations on the Island;~~ Ecology does not maintain records of residential USTs. The following paragraphs describe the uses of commercial USTs on the Island and associated reported incidents, followed by a description of the effects on ground water of spills or leaks from those commercial USTs.

5.2.5.1 Description

The majority of reported commercial USTs in the Vashon GWMA are located in or near the Town of Vashon. The following paragraphs describe the uses of USTs on the Island and associated reported incidents, followed by a description of the effects on ground water of spills or leaks from those USTs.

5.2.5.1 Description

The majority of reported USTs in the Vashon GWMA are located in or near the Town of Vashon, but they are also listed at Burton and at the KING radio tower on Maury Island (Figure 5-1). They range in size from less than 500 gallons to 20. The USTs range in size from less than 500 gallons to 20,000 gallons and are reported to contain the following substances: diesel fuel, kerosene, leaded gasoline, unleaded gasoline, or heating oil.

For residential USTs, according to a representative of the Williams Heating Oil Company it is estimated that the Williams company serves approximately 700 residential USTs on the Island and that perhaps 50 to 100 more are served by other suppliers or have been abandoned (Murphy, pers. comm. 1989).

In 1989 there was only one report of an incident involving a leaking commercial UST on the Island. A representative of the Williams Heating Oil Company in the Town of Vashon estimates that the Williams company serves approximately 700 residential USTs on the Island and that perhaps 50 to 100 more are served by other suppliers or have been abandoned (Murphy, pers. comm. 1989).

In the 1989 records, Ecology found only one report of an incident involving a leaking commercial UST on the Island. The incident involved removal of a UST containing heating oil from a public elementary school. According to Ecology, site evidence indicated that the tank had leaked. The cleanup operation for this site is still in progress. Since 1989, there have been six commercial sites with a confirmed UST leak, involving only contaminated soil. All six sites were cleaned up to Ecology's requirements.

A cleanup operation was in progress when the preliminary report was submitted in August 1989, but a final report had not been received.

5.2.5.2 Effect on Ground-Water Quality

Spills and leaks from USTs can be highly detrimental to ground-water quality, and incidents of this nature are not uncommon in urban areas of Washington. The Island, however, has only twenty six (26) commercial USTs and since 1989 has had seven confirmed incidents of commercial leaking USTs. Six of these sites involved only contaminated soil and have been cleaned up to Ecology's requirements. The cleanup of the 1989 commercial UST at the public elementary school is still in progress. For tanks installed after December 1988 (new tanks), these tanks and their associated piping, when installed, are required to meet Ecology's UST regulations for release detection, corrosion protection and spill\overflow protection. For tanks installed up to December 1988, (existing tanks), these tanks are required to meet Ecology's release detection requirements on a schedule depending on their year of installation with those tanks installed between 1980 and December 1988 required to meet Ecology's UST requirements by December 1993. All existing tanks must meet Ecology's UST requirements for corrosion protection and spill\overflow protection by December 1998. As commercial UST owners work to comply with federal regulations regarding UST inspection, has a relatively small population of commercial USTs and has had no major contamination incidents that Ecology can recall with the exception of the leaking UST incident at a public elementary school (1989). As commercial UST owners work to comply with federal regulations regarding UST inspection, replacement, and abandonment, however, previously unrecognized areas of contamination may be discovered.

Residential USTs are not subject to the regulatory requirements that commercial USTs are unless there is a confirmed leak. Then residential USTs are subject to the same Ecology standards for cleanup as commercial USTs. Although residential USTs are of a smaller size and capacity, they represent a bigger ground water quality concern because of their larger numbers (in excess of 700 residential USTs compared to 26 commercial USTs). In addition to being unregulated, residential USTs are usually older than commercial USTs, and quite often they are not as well constructed. Residential UST owners tend to pay less attention to determine if their tank is leaking, particularly during periods when the tank is not in use (i.e. the summer months). Residential USTs are not subject to the same scrutiny as commercial USTs. Residential USTs, however, are just as susceptible to corrosion and leakage as are commercial USTs and are, consequently, just as capable of introducing contaminants into the ground water.

5.2.6 Agriculture

The majority of agricultural land in the Vashon GWMA is located in the interior region of Vashon Island, with minor additional acreage and a 55-acre golf course on Maury Island (Figure 5-1). A description of the agricultural land uses on the Island is presented below, followed by the effects on ground-water quality of agricultural operations.

5.2.6.1 Description

According to the 1986 Vashon Community Plan, a 1976 study found that about 900 acres of the Island were devoted to agricultural uses, including commercial orchards, berry farms, vineyards, nurseries, and small commercial ranches. That 1976 study stated that the Island had King County's only large commercial cherry and apple orchards and produced the county's entire harvest of currants. Also, about one-third of the Island's agricultural acreage was devoted to the production of grass and hay. In 1989, at least one commercial orchard was still in operation as well as commercial farms of various sizes, several horse and cattle ranches, and a few greenhouses (Becker, pers. comm. 1989).

5.2.6.2 Effect on Ground-Water Quality

There are two areas of concern for ground-water quality when agricultural operations are present: (1) fertilizer and pesticide use and (2) animal waste products. Fertilizers and pesticides used on crops may present a risk to ground-water quality on the Island. Fertilizers can cause elevated nitrate levels in surface and ground waters, while pesticides can be toxic at relatively low concentrations in ground water. The state Department of Agriculture has no mechanisms in place to collect data on the amounts of pesticide or fertilizer used. ~~No information regarding fertilizer use on the Island was available in 1989 when this report was prepared.~~

A 1987 USEPA listing of pesticides used on crops grown on the Island includes nine leachable pesticides known to have been used at least occasionally (generic names: diuron, fenamiphos, pronamide, simazine, dinoseb, dicamba, chloramben, carbofuran, and disulfotan) and an additional three that may have been used at some time (generic names: dalapon, terbacil, and atrazine) (USEPA 1987). The Cooperative Extension

Service (CES) in Tacoma provided a slightly different list of herbicides and pesticides (generic names) commonly used on some of the Island's commercial crops: ronilan, carbofuran, dodine, azimphosmethyl, and 2,4-D (Shallow, pers. comm. 1989). According to Bill Shear of the CES in Tacoma, the USDA requires permits for spraying restricted pesticides, but not for spraying those that are unrestricted (Shallow, pers. comm. 1989).

Fertilizers and pesticides are applied to the 55-acre Vashon Golf Course on Maury Island. Scotts starter fertilizer is applied in the spring, Scotts 15-0-28 in the summer and fall, and lime is applied in the winter. All are applied at the recommended rate. Bob Newman of the Northwest Division of Ecology recalled one incident in which a truck leaked a small quantity of pesticide on the Island, ~~Fertilizers and pesticides are applied to the 55-acre Vashon Golf Course on Maury Island; information regarding quantities applied was not received in time to be incorporated into this version of the report (Bailey, pers. comm. 1989). Bob Newman of the Northwest Division of Ecology recalled one incident in which a truck leaked a small quantity of pesticide on the Island,~~ but said that he did not consider it to be a major contamination event (B. Newman, pers. comm. 1989). The extent of residential pesticide and fertilizer use is not known as the state Department of Agriculture does not have the mechanisms in place to collect this data. ~~The extent of residential pesticide and fertilizer use is not known.~~

Manure from farm animals may eventually introduce high nitrate levels into the ground water; however, there is no mechanism to presently collect information on the effects of Island ranching operations on the ground water. ~~no information is presently available regarding the effects of Island ranching operations on the ground water.~~ Elevated nitrate levels have been detected in ground-water samples collected from the Coast Guard well on Point Robinson. These elevated nitrate levels may be the result of the historic practice of keeping horses in the area where a well is now located (Carr 1983).

that dock at Fauntleroy, where special ferry runs can be set up to accommodate hazardous loads. The WSFS has no authority to search enclosed vehicles and operates under the assumption that shipping papers prepared by companies correctly describe the hazardous materials being transported. The WSFS can request that the Washington State Patrol inspect shipments of hazardous materials (Baird, pers. comm. 1989).

Under a new King County program, county residents can dispose of household hazardous wastes, such as paint thinners and solvents, at the King County Wastemobile. The Wastemobile is a disposal truck that travels around King County accepting household hazardous waste from County residents at no charge. The Wastemobile which began waste collection on the Island in mid-1989, did not return to the Island until 1990.

~~did not return to the Island until 1990. King County is hoping to add another Wastemobile to the program in order to reduce the waiting time for waste disposal (King County, pers. comm. 1989).~~

The USEPA and Ecology maintain records of hazardous waste sites and generators, both active and inactive. According to the USEPA listing of March 31, 1989, there are no CERCLA or Superfund sites on the Island (USEPA 1989). The only Island site included on the Ecology list of State Hazardous Waste Investigations and Cleanup dated September 12, 1989 is the Vashon Island Landfill; on the list, the Landfill is characterized as undergoing long-term monitoring after completion of cleanup.

The USEPA/Ecology list of Hazardous/Dangerous Waste Notifiers dated November 15,1993 lists nine Island businesses (Ecology 1993). Of these nine businesses, only four are active and are regulated generators of hazardous or dangerous waste. These four businesses are Joy's Village Cleaners, K-2 Corporation, Laidlaw Transit Inc.and Metro Park and Ride. The remaining five businesses status is either withdrawn or cancelled. Cancelled status means they have gone out of business. Withdrawn status means the business is no longer conducting hazardous or dangerous waste activities. These business are Island Industries and Olympic Instruments (Withdrawn), the Landfill is characterized as undergoing long-term monitoring after completion of cleanup (Ecology 1989).

The USEPA/Ecology list of Hazardous/Dangerous Waste Notifiers dated January 13, 1989 includes seven Island businesses (USEPA 1989). Three Island businesses — Sandy Beach Maury Island, Natural Products Co. (Cancelled), King County Solid Waste Division (never generated hazardous waste), and Burton-Shell (one time generator). Metro\SKCHD has inspected eight small quantity generator businesses as a result of complaint or request. These businesses are: BP Gas station, Vashon Hardware, Island Auto Wrecking, Engel's Auto Repair and Towing, Doug's Foreign Car Repair, Brennos, Vashon Fire Department and the Vashon Island School District. Small-quantity generators produce less than 220 lbs of hazardous waste each year. SKCHD\Metro assess how hazardous waste is stored, used and disposed of. Hazardous waste spillage at small waste quantity generators is SKCHD's highest priority. Businesses where hazardous waste spillage is observed are reinspected in approximately one month to determine if the site has been satisfactorily cleaned-up (Gerty Coville, per. com. 1993)., and Dilworth Drum — are small-quantity generators producing less than the regulated amount of hazardous waste each year (220 lbs); two businesses — Joy's Village Cleaners and K-2 Ski Manufacturing Corporation — produce 220 to 2,200 pounds annually; one business — Metro Oberpark Park and Ride — produces more than 2,200 pounds annually; and one business — Island Industries, Inc. — no longer produces hazardous waste, but is still in business at the same location.

5.2.10.2 Effect on Ground-Water Quality

Only a few incidents involving hazardous materials in the Vashon GWMA have been reported. Bob Newman of the Northwest Division of Ecology recalls that a drum of flammable solvent was removed from a roadside several years ago by Ecology (B. Newman, pers. comm. 1989). According to SKCHD (1990), the drum of flammable solvent was from the Stoltz property, which is used as a junkyard and is located adjacent to the Vashon Island Landfill. Ecology was also responsible for disassembling an illegal drug lab at the southern end of Vashon Island and removing stockpiled materials. Neither incident resulted in apparent contamination. No spills have been reported at the K-2 Ski Manufacturing Corporation or Pacific Research plants (B. Newman, pers. comm. 1989).

~~According to Newman, the Island Springs Tofu plant at one time discharged wastes to the ground, but has since ceased that practice; no significant contamination resulted (B. Newman, pers. comm. 1989). No spills have been reported at the K-2 Ski Manufacturing Corporation or Pacific Research plants (B. Newman, pers. comm. 1989). According to Island residents, however, fiberglass from the K-2 Ski Manufacturing plant has been used as mulch on the Island (SKCHD 1990).~~

5.2.11 ASARCO Smelter

The ASARCO smelter and other closed smelters on the mainland may have contributed to elevated contaminant levels reportedly found in soil sampled collected from the southern portions of the Island. Information concerning the suspected contamination and its effect on ground-water are described below.

5.2.11.1 Description

Airborne particulate material from the ASARCO smelter and other closed smelters in Ruston, Washington located on the mainland southeast of the Vashon GWMA, may have been carried over the Island when the wind blew from the east over the operating smelters. The ASARCO smelter, now a CERCLA site, is one of the suspected sources of elevated arsenic, cadmium, and lead levels reportedly found in soil samples taken at several locations near the southern ends of the Island (Carr 1983; SKCHD 1984).

5.2.11.2 Effect on Ground-Water Quality

In Carr (1983), water samples from 10 springs and streams were analyzed for arsenic, cadmium, and lead. All values were below the laboratory detection limit. Samples collected below the Vashon Island Landfill were also below the limits of detection. Carr (1983) stated that the metals had been retained by the soil and were effectively prevented from infiltrating to the ground water (Carr 1983).

A 1982 through 1984 study of heavy metals in honey bees in the Puget Sound area found arsenic concentrations as high as 18 to 20 parts per million (ppm) in bee colonies near the southern ends of the Island, compared to background levels of 0.1 to 1 ppm in bees on Whidbey Island. The supervisor of the study concluded that the arsenic taken up by the bees was primarily airborne (Bromenshenk, pers. comm. 1989).

In 1984, DOH (formerly the Department of Social and Health Services) with assistance from SKCHD and the Tacoma Pierce County Health Department conducted a study of unprotected drinking water sources to determine whether arsenic, ~~DOH (formerly the Department of Social and Health Services) conducted a study of~~

~~unprotected drinking water sources to determine whether arsenic,~~ cadmium, and lead were present, and, if so, whether their presence constituted a health risk. Of the 50 wells, springs, and surface-water sources sampled for the study, 20 wells, 11 springs, and 2 surface-water sources were located on the Island. The DOH concluded that arsenic, cadmium, and lead were not present at significant levels in the unprotected drinking water sources utilized in the study.

The Ruston/Vashon Arsenic Exposure Pathways Study, prepared by the University of Washington under contract with Ecology (University of Washington 1987), was aimed at determining the pathways by which humans are exposed to arsenic and the daily arsenic intake of the population living in the vicinity of the copper smelter in Ruston, Washington. Households in Ruston and on the Island participated in the study, which involved urine and hair sampling and measurement for environmental concentrations of arsenic. Drinking water was sampled in all of the study areas. The final report, issued in March 1987, concluded that the highest concentrations of arsenic were found near the smelter, even though it was closed; demolition activities were thought to be responsible for elevated levels of airborne arsenic. Arsenic concentrations in drinking water samples collected in the study area were lower than state and federal minimum standards and were comparable to concentrations reported from other areas in Puget Sound.

6.0 WATER APPLICATIONS

Chapter 6.0 discusses water applications on the Island in terms of demand, services, rights, and uses. The systems which handle storm water for the Island are also described. Each section below discusses a separate area of concern.

6.1 WATER DEMAND

Future water demand is generally predicted using demographic projections and reasonable values for per-person or per-household daily consumption. Figures for future water demand are then compared to the calculated production capacity of the aquifer(s) to evaluate adequacy of the supply relative to the demand.

6.1.1 Demographic Projections for the Vashon GWMA

Population forecasts by the PSRC and King County for the Vashon GWMA are identical. As enumerated in Subsection 5. ~~Population forecasts for the Vashon GWMA vary considerably. As enumerated in Subsection 5.~~1.2.1, Residential Development Trends, the PSRC predicts a 50 percent increase in population on the Island during the years 1980 to 2000 (Table 5-3). The 1993 AGD (Table 5-4) also predicts a population growth of 50 percent during the same 20-year period. ~~the PSCOG predicts a 16 percent increase in population on the Island during the years 1980 to 2000 (Table 5-3). The 1988 AGR (Table 5-4) predicts population growth of 46 percent during the same 20-year period.~~ Using these figures, projected water demand can be estimated as follows.

6.1.2 Projected Water Demand in the Vashon GWMA

Projected water demand in the Vashon GWMA has been calculated using a per-person consumption value of 120 gpd and both the PSRC and AGD population forecasts (Tables 6-1 and 6-2, Projected water demand in the Vashon GWMA has been calculated using a per person consumption value of 120 gpd and both the PSCOG and AGR population forecasts (Tables 6-1 and 6-2, respectively). Calculations using both the PSRC and AGD figures yielded a value of over 1 million gallons for daily water demand for the entire Island in 1990, which translated into an annual demand of 408 million gallons. By the year 2000, the annual demand for Vashon is projected to be 486 million gallons.

Calculations using PSCOG figures yield a value of over 1 million gallons for daily water demand for the entire Island by the year 1990, which translates into an annual demand of 366 million gallons. Calculations using the higher AGR forecasts yield a value of about 474 Mgpy for 1990. The AGR projections forecast an annual demand that is approximately 29.5 percent higher than the PSCOG projections.

6.1.3 Aquifer Recharge and Capacity

The ability of the Island to meet projected water demands depends largely on the supply available from the Principal and Deep Aquifers. The recharge of the Principal and Deep Aquifers was calculated in Carr (1983). The recharge of the Principal Aquifer was estimated to be approximately 8.90 million gallons per day (Mgpd), and that of the Deep Aquifer was estimated to be between 1.73 and 3.46 Mgpd. Far greater uncertainty is associated with estimates for the Deep Aquifer than the Principal Aquifer. Based on the Carr recharge data, the production capacity of the Principal Aquifer was evaluated.

Carr (1983) comments that an estimated 45 percent of recharge occurs in high recharge areas, which represent about 25 percent of the land surface area. Not all the water in the aquifer is available for withdrawal, however; Carr (1983) estimates a total water productivity from the Principal Aquifer of about 578 Mgpy. This figure takes into consideration the effects on production of drought and inefficient withdrawal. Similar calculations for the Deep Aquifer have not been performed. A discussion of the reassessment of potential recharge areas is included in Chapter 8.0, Hydrogeology.

6.2 WATER SERVICE

The 1986 Vashon Community Plan (King County 1986) establishes the entire Vashon GWMA as a Water Service Area, an area in which public water service is permitted. Under this classification, no portions of the Vashon GWMA are restricted to private water systems. As used in the 1986 Plan, "public water service" includes Group A and B water systems, both publicly and privately owned.

The only publicly owned water purveyor on the Island is King County Water District No. 19, but six privately owned Group A purveyors operate to meet additional water demands. ~~but five privately owned Group A purveyors operate to meet additional water demands.~~ The following discussion of the Group A (formerly Class 1) water purveyors is based largely on information contained in the Vashon Coordinated Water System Plan (Horton Dennis 1991). Tables 6-3 and 6-4 list available information regarding the seven major water purveyors on the Island; all are Group A systems. Figure 6-1 illustrates the areas of distribution, sources, and storage facilities of the seven major water purveyors on the Island. The following subsections discuss each purveyor.

6.2.1 King County Water District No. 19

King County Water District No. 19 is the only public water system in the Vashon GWMA. Established in 1925, the District has 1,075 connections and is the largest water system on the Island. ~~the District has over 1,000 connections and is the largest water system on the Island.~~ The District's service area covers approximately 6 square miles in east-central Vashon Island (Figure 6-1); consumers range from single-family houses in low-density residential areas to commercial and industrial concerns.

The District obtains water from two plants. Plant No. 1 uses a surface-water source and is located on Beall Creek. ~~1 uses a surface-water source and is located on BeallBeall Creek.~~ The supply averages 200 gpm and continues during dry months because ground-water flows out through seeps, the exposed seams of sand in the walls of the stream valley.

Plant No. 2 uses a surface-water source, a developed spring, and a well. Water from Ellis Creek provides approximately 235 gpm, and the nearby developed spring provides approximately 50 gpm. Well No. 1 is located in the Town of Vashon, near the intersection of 103rd Avenue Southwest and Southwest 176th Street, in the water storage tank area. The well is 670 feet deep and yields an average of 150 gpm. An additional deep well located adjacent to Well No. 1 was completed in 1990. It should provide the same amount of water as Well No. 1 and will be used as a backup source.

The District has a total storage capacity of approximately 1.725 million gallons distributed between two pressure zones. Storage facilities for Pressure Zone 1 consist of two tanks with a combined capacity of 1.625 million gallons. These tanks serve 704 connections. The storage facility for Pressure Zone 2 is a 100,000-gallon reservoir located on Southwest 216th Street near its intersection with 99th Avenue Southwest.

The reservoir serves approximately 260 connections. Storage facilities for the two pressure zones are interconnected.

6.2.2 Heights Water Association

The Heights Water Association (HWA) is a private, nonprofit corporation that serves the north end of Vashon Island (Figure 6-1). The HWA maintains approximately 571 connections, ~~The HWA maintains approximately 455 connections,~~ most of which are private homes, but which also include the Vashon Nursing Home, the WSFS facilities, and the Vashon Elementary School. The HWA is not currently accepting new water-share applications.

The HWA obtains water from springs and wells located in the northeast quarter of Section 18, Township 23N, Range 3E, where the HWA holds water rights to approximately 17 acres. Two unnamed springs at the base of a steep ravine yield an average of 150 gpm; two wells located on higher ground west of the springs supply about 125 gpm.

The HWA has a total storage capacity of approximately 330,000 gallons in five covered storage reservoirs. Four of the reservoirs are interconnected and supply the majority of the system; the fifth reservoir, at the south end of the system, provides supplemental storage. An additional 40,000 gallons of storage capacity is provided by collection basins located at the spring source; however, this water is not available by gravity flow. The south end of the HWA system is interconnected with King County Water District No. 19; this connection can be opened manually in the event of an emergency.

6.2.3 Westside Water Association

The Westside Water Association (WWA) is a nonprofit cooperative serving an area of approximately 2 square miles in northwest Vashon Island near Fern Cove (Figure 6-1). The WWA has approximately 219 metered connections. ~~The WWA has approximately 210 metered connections,~~ all of which are private, with five future connection rights sold.

The WWA maintains a 40-acre watershed area in Cedarhurst Canyon (also known as Shinglemill Creek Canyon or Needle Creek Canyon), one of the Island's largest drainage basins. The WWA obtains about 180 gpm from a number of artesian well points located in the walls of the canyon. The WWA has a total storage capacity of about 253,000 gallons in two aboveground tanks.

6.2.4 Burton Water Company

The Burton Water Company (BWC) is a private company serving the Burton Peninsula and the surrounding area (Figure 6-1). A majority of the estimated 375 BWC customers are private homes. ~~A majority of the estimated 350 BWC customers are private homes,~~ but the BWC also serves a small neighborhood center and an elementary school.

The BWC obtains water from a combination of wells and well points which extend to about 18 feet bls on a 5-acre plot near the intersection of Southwest 232rd Street and 115th Avenue Southwest. Production varies with rainfall, averaging between 125 and 150 gpm during the drier summer months. Runoff to Puget Sound during the winter months is significant.

The BWC has a total storage capacity of approximately 170,000 gallons. Storage facilities include three tanks, all located at the supply site. Four pumps are used to transfer water from the wells and well points to the tanks during peak-demand periods; during winter, the pumps are used only occasionally.

6.2.5 Dockton Water Association

The Dockton Water Association (DWA) is a nonprofit association serving 294 customers on the southern portion of Maury Island (Figure 6-1); ~~The Dockton Water Association (DWA) is a nonprofit association serving 245 customers on the southern portion of Maury Island (Figure 6-1);~~ all but one of the customers is residential. An additional 71 reserve memberships entitle landowners to service at an unspecified future date.

The DWA obtains water from two springs -- Park and Hake Springs -- and one well -- Sandy Shores -- in the service area. Park Spring, located across Portage-Dockton Road from the Dockton-King County Park in the village of Dockton, yields an average of 100 gpm and is collected from well points scattered over 10 acres of watershed. It has been estimated that up to 50 gpm of additional water may be available from this source if additional well points were added and existing points redeveloped.

The Hake Spring, located on a 25-acre site abutting Southwest 268th Street southwest of Dockton, yields 30 to 40 gpm. The spring is intercepted by plastic pipe before reaching the surface and partially diverted to a DWA storage unit.

The Sandy Shores well, located on 94th Avenue Southwest south of Dockton, is 415 feet deep. Although the bottom of the well appears to be below sea level, the static water level is above sea level. The well is capable of producing 100 gpm with no more than 10 feet of drawdown.

The DWA has a total storage capacity of approximately 381,000 gallons distributed between two pressure zones. Storage facilities for the lower pressure zone, supplied with water from the springs, consist of three ground-level concrete tanks with a combined capacity of 65,000 gallons. Storage facilities for the upper pressure zone, supplied with water from the Sandy Shores well and from lower-level reservoirs, consist of two concrete standpipe tanks with a combined capacity of 316,000 gallons. Storage facilities for the two pressure zones are interconnected.

6.2.6 Gold Beach Water System

The Gold Beach Water System (GBWS) is a privately owned and operated system serving 147 homes in the community of Gold Beach on the southeast shore of Maury Island (Figure 6-1) The GBWS obtains water from two wells, ~~The Gold Beach Water System (GBWS) is a privately owned and operated system serving 109 homes in the community of Gold Beach on the southeast shore of Maury Island (Figure 6-1) The GBWS obtains water from two wells,~~ each about 110 feet deep, located on the northern edge of the Gold Beach community. The wells have a combined yield of about 250 gpm. The GBWS has a total storage capacity of about 85,000 gallons, with 50,000 gallons available in a lower pressure zone and 35,000 gallons in an upper pressure zone. The two zones are interconnected.

6.2.7 Maury Mutual Water Company

The Maury Mutual Water Company (MMWC) is a privately owned cooperative that supplies 88 single-family homes and one commercial connection on the northern end of Maury Island (Figure 6-1). ~~The MMWC is a privately owned cooperative that supplies 89 single-family homes and one commercial connection on the northern end of Maury Island (Figure 6-1).~~ The MMWC is not currently accepting new memberships into the cooperative.

The MMWC obtains water from eight shallow-driven well points and two springs located on northern Maury Island near Southwest 232nd Street and 59th Avenue Southwest. These sources yield a total of about 35 gpm. The MMWC has a total storage capacity of about 130,000 gallons. A mid-system facility provides about 58,000 gallons of storage, and two upper-level reservoirs provide a combined capacity of 72,000 gallons.

6.2.8 Other Water Systems

The seven systems discussed so far represent only the major water purveyors in the Vashon GWMA. More than 100 Group A (formerly Class 2) and B public water systems also operate on the Island (Figure 6-2). In addition, private wells provide water to a considerable number of houses and to several businesses across the Island. The exact number of private wells on the Island is not known. SKCHD obtained copies from Ecology of approximately 280 well logs for public and private wells on the Island. In most cases, it was not possible to distinguish between logs of public and private wells without prior knowledge.

6.3 WATER RIGHTS

The 1986 Vashon Community Plan establishes that development of new public water sources may occur only if it can be demonstrated that such development will not adversely affect existing water supplies. To ensure this, Ecology requires that a water right be obtained if more than 5,000 gallons of water are to be withdrawn from the new water source per day, if the source is to serve five or more houses (approximately the equivalent of 5,000 gpd), or if more than 1/2 acre of land is to be irrigated (King County 1986).

Ecology maintains water right records for the entire state. The listing of water entities holding a water right includes the names of permit holders, sources of water, places of use, purposes for which the water will be used, permitted instantaneous withdrawal rates, and permitted annual withdrawal quantities. The Ecology listing of existing water right holders includes several hundred Island water right permit holders. Table 6-3 lists the instantaneous withdrawal rates and annual withdrawal quantities permitted for five of the seven major water purveyors discussed in Section 6.2, Water Service. The BWC and GBWS were not listed by name in the Ecology water right listing. The BWC, however, holds a water right which allows 200 gpm (Lasby, pers. comm. 1991).

6.4 WATER USE

For business purposes, commercial water systems maintain records of the amount of water withdrawn from Island sources and the quantity sold to customers during established time periods. Owners of private wells have no such motivation for maintaining similar records, and information regarding actual withdrawal quantities is less readily accessible.

Figures for the amount of water withdrawn annually from Island sources by the seven major water purveyors are presented in Table 6-3. These figures were reported by the purveyors and represent the actual or estimated amounts of water withdrawn by the purveyor during the period listed. ~~Figures for the amount of water withdrawn~~

~~annually from Island sources by five of the major water purveyors are presented in Table 6-3. These figures were reported by representatives of the purveyors and represent the actual or estimated amounts of water withdrawn by the purveyor during the period listed.~~

Table 6-3 permits comparison of permitted water withdrawal quantities and actual water withdrawal figures for these purveyors. It appears from this preliminary comparison that reported withdrawal quantities do not necessarily reflect permitted withdrawal quantities.

6.5 WASTEWATER DISPOSAL

A portion of the Town of Vashon lies within the Vashon Sewer District LSA and is served by the Vashon Sewer District, but the remainder of the Island relies on on-site wastewater disposal systems, primarily septic systems. The following subsections provide a detailed discussion of these two major methods of wastewater disposal on the Island.

6.5.1 Vashon Sewer District

The Vashon Sewer District LSA, established under the 1986 Vashon Community Plan, covers approximately 405 acres (about 0.63 square miles) in the Town of Vashon (Figure 5-9); of the 405 acres, approximately 180 acres remained undeveloped in 1980. Full development of the entire LSA would raise the population to an estimated three times the design capacity of the Vashon Sewer District's treatment plant.

The Vashon Sewer District has been operating since 1955 and underwent major improvements during 1974 and 1975. It was estimated that the district was serving approximately 600 people in 1979. This figure was obtained by dividing the amount of water drainage systems, eventually leading to the conclusion that storm-related infiltrating moisture enters the sewer system through numerous leaking joints between sections of sewer pipe. This occurs most readily during winter when the water table is high. Conversely, it is possible that wastewater may leak from the pipes and infiltrate the surrounding soil during dry seasons when the water table is low (Ames, pers. comm. 1989).

6.5.2 <u>On-Site Sewage Systems (Septic Systems)</u>

On-site wastewater disposal, primarily in the form of septic systems, is recognized in the Vashon Community Plan (King County 1986) as a permanent means of wastewater disposal outside the Vashon Sewer District LSA. ~~is recognized in the Vashon Community Plan (King County 1986) as a permanent solution to wastewater disposal outside the Vashon Sewer District LSA.~~ Since the LSA covers less than 1 square mile of the Vashon GWMA, the majority of the Vashon GWMA's population relies on septic systems for wastewater disposal. Although septic systems and cesspools are the most frequently reported sources of ground-water contamination (Freeze and Cherry 1979), modern systems are generally designed to filter wastewater extensively so that it may act as a beneficial source of ground-water recharge.

A sewage facilities investigation, "sanitary survey," was initiated by SKCHD in December 1988 to evaluate the incidence of septic system failure in selected beachfront and near beachfront areas on the Island. The study was used to determine the extent to which failing on-site systems were present in surveyed communities. ~~A sewage facilities investigation was initiated by SKCHD in December 1988 to evaluate the incidence of septic system failure in beachfront areas and in selected drainage basins on the Island. The study was used to determine whether communities as a whole would need to update or redesign their treatment systems.~~ The sewage systems were categorized as functioning, failing, or prefailing. The areas surveyed were selected based on complaints to and knowledge by SKCHD of failing systems. Septic system failures reported to SKCHD from 1987 to 1988, prior to the survey, are shown in Figure 5-9.

Dye was introduced into building drains and septic systems were given a visual inspection to check whether raw sewage or sewage effluent was surfacing from the ground or if sewage effluent was discharging to surface waters. ~~The methodology and results of the Sewage Facilities Plan study (PEI/Barrett 1992, now Barrett) initiated as a result of the septic system survey's findings are summarized below.~~

~~Septic tanks were given a visual inspection to check if raw sewage or sewage effluent was surfacing from the ground or if sewage effluent was discharging to surface waters. If raw sewage was observed on the ground surface or discharging to surface waters, fluorescein dye was injected into the tank.~~ If the fluorescein dye was observed where the sewage surfaced, then the system failed the test. Bacteriological samples of water and/or sediment were collected at select sites that were suspected to be impacted by failing systems. If a system was not failing, but there was heavy lush grass growth over the drainfield~~, then the tank failed the test. Bacteriological samples of water and/or sediment were collected at select sites that were suspected as failing. The system failed if bacterial levels exceeded regulatory standards. If the system did not fail, but heavy lush grass growth over the drainfield,~~ slowly draining plumbing fixtures, a high seasonal water table, or significant construction over the drainfield area was observed, the system was designated as "prefailing."

Areas with 75 percent or more sewage system failures and prefailures were identified as "severe public health hazard areas." Test results from the septic system study are included in Table 6-5. Five communities on the Island have been declared "severe public health hazard areas" by the state Department of Health (Figure 6-3):

Five communities on the Island have been declared "severe public health hazard areas" (Figure 6-3): (1) Cove (northwest Vashon Island), (2) Beulah Park (northwest Vashon Island), Spring Beach (southwest Vashon Island), Bunker Trail (north Vashon Island), and Burton (southeast-central Vashon Island) (PEI/Barrett 1992). All of the existing homes at Spring Beach are connected to a common gravity pipe which outfalls into Puget Sound without any treatment. All of the existing homes at Spring Beach are connected to a common gravity pipe which discharges into Puget Sound at low tide without any treatment.

If the sewage systems for a community had a 25 to 50 percent failure and prefailure rate, then the community was designated as a "health caution area." Three communities on the Island have been declared "health caution areas" (Figure 6-3): (1) Patten Palisades (north Vashon Island), (2) Paradise Cove (southwest Vashon Island), and (3) Quartermaster Harbor (southeast-central Vashon Island).

All or a portion of each of the five severe public health hazard areas are included within the following four sensitive land use areas: (1) Class III landslide hazard areas (except Burton and Beulah Parks), (2) Class III seismic hazard areas, (3) erosion hazard areas, and (4) tidal wetlands. Population in the five hazard communities totals 374.

The sewage discharges near the shore that occur now in the health hazard areas pose little risk to Island potable water supplies (PEI/Barrett 1992). However, areas available for new community drainfields most likely will not be near the shoreline; therefore, ground-water supplies on the Island could be affected by future septic system failures.

The Sewage Facilities Plan by PEI/Barrett Consulting Group (1992) evaluates the types of sewer systems that may be feasible for the Island.

The following recommendations were included in the plan:

- Sewer service may be extended only with a LSA and operated by a public agency, although boundary adjustments would need to be made to extend the LSA.

- Community sewer services are recommended, and they need not be in an LSA. The problems encountered with designing these systems include not enough to a limited area on the building lot for a drainfield, a slope that is greater than 40 percent, or the lot's being on the waterfront. A variety of collection, treatment, disposal, and transfer systems have been designed as "alternatives."

- Repairs to the existing sewage systems are not feasible; some form of community sewer system is the only "reasonable" solution.

PEI/Barrett (1992) recommends several community system alternatives for sewage collection, treatment, and disposal. The systems most feasible for each community are outlined below:

Collection Alternatives

Gravity Sewers	Spring Beach, Burton
Vacuum System	Beulah Park/Cove,
Vacuum System	Beulah Park/Cove, Bunker Trail, Greater Burton
Grinder Pumps	Beulah Park/Cove, Bunker Trail
Solids Handling Pumps	Beulah Park/Cove, Bunker Trail, Burton
Holding Tanks	Spring Beach
STEP System	Beulah Park/Cove, Burton

Treatment Alternatives

Package Plant	Spring Beach, Beulah Park/Cove, Bunker Trail
Recirculating Sand Filter	Spring Beach, Beulah Park/Cove, Bunker Trail, Burton
Solar Aquatics	Burton
Constructed Wetlands	Burton
Tertiary Plant	Burton

Disposal Alternatives

Outfall to Puget Sound	Spring Beach, Beulah Park/Cove, Bunker Trail, Burton
Drainfield Pump to Vashon Sewer District	Beulah Park/Cove, Bunker Trail, Burton

SKCHD, under WDOH guidance, and the Department of Ecology regulate treatment and disposal of wastewater. As a result of the Sanitary Survey findings, SKCHD initiated a facilities plan study to determine the feasibility of replacing the on-site areas with community service systems. The final report of this study conducted by Barrett Consulting is due for final review by site agencies in November, 1993. Septic systems must incorporate these regulations into their designs. The Burton area on Quartermaster Harbor will need special consideration in septic system design because at least 95 percent removal of BOD is required, and effluent BOD concentrations must be less than 10 mg/L to discharge to Quartermaster Harbor. Nutrient levels of nitrogen and phosphorus will need to be monitored and controlled.

6.6 STORM-WATER SYSTEMS

Stormwater management practices, past and present often cause ground water quality and quantity problems. Ground water quality may be impacted if stormwater containing contaminants is recharged intentionally or inadvertently. Also, precipitation is diverted to surface water that, under natural conditions, would be recharged to ground water. As a result there is a decrease in the quantity of water recharged to ground water.

Stormwater management facilities can be designed to maximize infiltration into the ground thereby increasing recharge to aquifers. However, an obvious concern is the potential to contaminate ground water with pollutants carried in stormwater. In the past, stormwater management emphasized flood control and was not particularly concerned with water quality. More recently, however, concern has shifted to the quality of stormwater and how it can impact receiving waters, including ground water. Stormwater management practices use the best technology available at the time for source control and treatment facilities. The most common methods used for both flow control and water quality improvement are detention basins, infiltration facilities, biofilters and coalecsing plate oil water separators. Stormwater should be monitored to ensure that ground water quality is not impacted.

Many natural storm-water drainage systems in the Vashon GWMA contribute to the flow of storm-water runoff into Puget Sound (Morgan, pers. comm. 1991). In addition, several man-made storm-water systems direct storm-water runoff on the Island. The DPW Roads Division regulates storm-water management in the Vashon GWMA. Storm water is collected at and transported from various locations on the Island. The man-made systems serving the Town of Vashon and the communities of Burton, Sandy Shores, Gold Beach, Dockton, and North Vashon are described in this section.

Two systems operate to collect and remove storm water in the Town of Vashon: one along Main Street and one for the remainder of the town. Storm water on Main Street is captured in storm drains and travels enclosed to the eastern end of Southwest 171st Street, where it empties into a canyon and flows to the Sound. Storm water captured elsewhere in the town travels enclosed via 100th Avenue Southwest and Southwest 176th Street to Cedarhurst Canyon, where it emerges and flows into Colvos Passage (Figure 2-1) (Morgan, pers. comm. 1989).

Three systems regulate storm-water flow in the Burton area. One system runs south from Vashon Island Highway to about Southwest 238th Street, where it flows into Quartermaster Harbor. Another system consists of three storm-water catch basins which run south along the Vashon Highway from the intersection of Southwest 240th Street to Quartermaster Harbor. The third system begins at Inspiration Point, has collector

request of the GWAC, SKCHD and J. Dolstad of the Island applied to the EPA for Vashon to be designated as a sole source aquifer. At this time EPA has initially reviewed the proposal for meeting the sole source criteria, but has not reviewed the proposal technically nor held a public hearing on Vashon as required by the sole source process. EPA propose to complete this process by early 1994.
~~At this time EPA has reviewed the proposal but has not held a public hearing on Vashon as required by the sole source process.~~

The 1986 Vashon Community Plan supports continued research and monitoring as well as efficient use of domestic water supplies and water systems. As specified by the 1986 Vashon Community Plan, intensive development should be served by a public water district or by an existing Group A water system. In addition, public water systems will not be permitted to expand if it is determined that expansion will decrease the level of service, including water quality, to current users. Similarly, the 1986 Vashon Community Plan states that proposals for development that involve extension of water service to new users will be reviewed with particular attention to ensure that service to current users will not be reduced below minimum state and county standards.

A letter "P" following a zoning classification i.e., a P-suffix, on the Island's zoning map indicates that site plan approval is required for development to proceed at that site; it may be necessary for the developer to meet special conditions designed to protect the public interest in developing the site. Zoning codes for sites in high recharge areas typically include the P-suffix. To protect infiltration to the Island's aquifers, new residential, commercial, and industrial development planned for high recharge areas must comply with zoning regulations that establish the maximum coverage of infiltration surfaces and the relative amount of runoff permitted. Similarly, sites that have been determined to be of historic interest carry zoning codes that typically include a P-suffix; site plan approval of these sites necessitates review by the King County Historic Preservation Officer.

8.0 HYDROGEOLOGY

The following chapter summarizes the background hydrogeologic data, including the geologic setting of the Island and the Island's water resources, historical water levels, and water quality. In addition, stream-flow and rainfall data collected from 1989 through 1992 are presented.

8.1 GEOLOGIC SETTING

The most current geologic information specific to the Vashon GWMA is the geologic investigation conducted by King County Geologist Derek B. Booth for the Vashon GWMA Grant project (Booth 1991). The following paragraphs summarize Booth's report and map (1991) (Figure 8-1). Booth's geologic interpretations are then compared with those included in Carr (1983).

The Island is composed entirely of interbedded glacial and nonglacial sediments that provide a discontinuous record of multiple glaciations during the Pleistocene Epoch (approximately 10,000 to 2,000,000 years before present [b.p.]) in the Puget Lowland. During glacial periods, a lobe of ice advanced from the mountains of British Columbia into the Puget Lowland, depositing a layer of low-permeability till beneath it and permeable advance outwash sands and gravel ahead of it. ~~depositing a layer of low-permeability till beneath it and permeable advance outwash sands and gravels ahead of it.~~ During previous interglacial periods, drainage from adjacent mountains typically spread across the Puget Lowland, including the present location of the Island.

Deposits of the most recent glaciation, the Vashon stade (a substage of a glacial stage) of the Fraser glaciation (approximately 13,000 to 16,000 years b.p.), are underlain by older deposits, both glacial and interglacial. Establishing consistent nomenclature and regional correlation for stratigraphic units is a continuing project. Correlating units older than those of the Vashon stade between the Island and the remainder of the Puget Lowland has proven difficult.

The main glacial deposits of the Vashon stade as mapped by Booth are as follows:

- Qvr, recessional outwash -- mainly stratified sand and gravel that mantles the upper till surface.

- Qvi, ice contact deposits -- similar in texture to Qvr, but with collapse features and rare till lenses suggestive of deposition near stagnant or active ice.

- Qvt, till -- mainly compact diamicton, typically 40 to 60 feet thick and of low permeability.

8.2.2 Spring Water

Springs are abundant on the Island and represent natural ground-water discharge. Springs serve as water supplies for private purveyors, and one is tapped by King County Water District No. 19 (Horton Dennis 1989).

8.2.3 Surface Water

Eight major drainage basins have been identified on the Island (Figure 8-5); these include Beall, Fisher, Green Valley, Judd, Mileta, Needle (Shinglemill), Paradise Cove, and Tahlequah Creeks. Judd and Needle (Shinglemill) Creeks have the largest drainage areas (3,149 and 1,996 acres, respectively) and stream discharges on Vashon Island. They occupy the central and northern interior regions of Vashon Island, respectively. The largest drainage basin on Maury Island, identified as the Mileta Creek basin, covers 1,546 acres. Although other drainage basins on the Island are small, the associated streams have measurable flow during dry months.

Surface-water supply sources include Beall and Ellis Creeks, ~~Surface-water supply sources include Bealll and Ellis Creeks,~~ located on the east side of Vashon Island. These creeks augment the water supply for King County Water District No. 19, operator of Well No. 1. About eight small ponds and lakes dot the upper plateaus of Vashon Island; none are known to be used as a drinking water source. ~~none are known to be drinking water sources.~~

8.3 DATA COLLECTION AND ANALYSIS

As part of the Vashon GWMP, a Data Collection and Analysis Plan (Geraghty & Miller 1990) was developed and implemented. The objectives of this task were to refine the understanding of the Island's water resources (primarily quantity and quality) and to identify data gaps in order to facilitate management and protection of these resources. To accomplish these objectives, rainfall, stream-flow, ground-water, and surface-water data were collected over a 3-year-plus period beginning in 1988 and ending in 1992. The following subsections summarize the data collection and analysis activities and compare the results with the preliminary assessment of the Island's water resources provided by Carr (1983).

8.3.1 Rainfall

Data were collected by Island volunteers at nine rain-gage stations from December 1988 through January 1992 (Table 8-1). Seven rain-gage stations were located on Vashon Island and two on Maury Island (Figures 8-6 and 8-7). The locations of the stations were selected to determine trends in rainfall across the Island. Rain-gage

Ground water flows from topographic highs toward the coastline. Insufficient well elevations from the Principal Aquifer were available to determine if the flow of the ground water changed seasonally. Different interpretations of the water-table elevation map for each season are possible. The ground-water gradient is generally steeper on the west side of Vashon Island (from Well W-16 west to the shoreline, the gradient was 0.095 in November 1989 and 0.105 in April 1991) than the east side of Vashon Island (from Well W-6 east to the shoreline, the gradient was 0.026 in November 1989 to 0.027 in April 1991). The ground-water gradient is generally steeper in the spring than in the fall as a result of higher water-table and ground-water recharge. (See Table 6-3 for well pumping data from Group A purveyors).

~~No information was available at the time of this study to determine the effects of well pumping on the Principal Aquifer.~~

~~The hydrographs of the monthly water-level data for each well (Appendix I) indicate the following trends in the observed water-table elevations:~~

The hydrographs of the monthly water-level data for each well (Appendix I) indicate the following trends in the observed water-table elevations:

- Wells W-1, W-4, W-6, W-10A and B, W-13, W-16A and B, W-17, and W-20 show seasonal fluctuations of water-table elevations of approximately 1 to 22 feet. (Water level values with probable measurement errors were not included in determining these fluctuation ranges.)

- Wells W-2A and B, W-3, W-5, W-7, W-8, W-9A and B, W-11, W-12, W-14, W-15, W-18, W-19, and W-21 show water-level fluctuations of 1 to 3 feet. (Water level values with probable measurement errors were not included in determining these fluctuation ranges.)

- Seasonal fluctuations observed in the wells tend to correlate with rainfall (allowing for a delay of from 1 to 4 months for the water to infiltrate the aquifer). Seasonally high water-table elevations tend to occur during the early summer months, reflecting the increased rainfall and ground-water recharge during the preceding winter and early spring months (Figures 8-19 and 8-20). Seasonally low water-table elevations tend to occur during the fall months reflecting decreased rainfall during the preceding summer and early fall months.

- Wells W-1, W-2A and B, W-13, W-15, W-16A, W-19, and W-21 show long-term trends of increasing water-level elevations of approximately 1 to 2 feet.

assigned to areas where depth-to-water values were greater than 75 feet bls. A medium potential recharge was assigned to areas where depth to water was between 25 and 75 feet bls. Depth to water was not a recharge criteria considered in Carr (1983).

Slope criteria developed in the RBCGWMP were utilized to determine the effects of slope on potential recharge (Figure 8-23). The percentage of slope was calculated from select areas on the USGS topographic quadrangle maps for the Island (Duwamish Head 1968a; Vashon 1968b; Gig Harbor 1981a; Olalla 1981b; Tacoma North 1981c). Using guidelines presented in the RBCGWMP, areas with a slope between 40 and 80 percent were classified with medium potential recharge. If the slope was a higher or lower percentage, the area was characterized as a low or high potential recharge area, respectively. High potential recharge areas include almost all of the Island, with the exception of steeper areas near the coast. The slope/recharge map included in Carr (1983) includes additional low potential recharge areas not shown in Figure 8-23. High potential recharge areas delineated on the Carr slope map were confined to north-central and south-central Vashon Island and central Maury Island. Carr (1983) did not specify the criteria used in the construction of their slope map.

The effect of the permeability of the surficial geologic units was considered when deriving the aquifer-sensitivity map. Permeability criteria for geologic formations developed in the RBCGWMP were used for the map construction. The permeability of the geologic formations on the Island delineated by Booth (1991) were grouped as follows:

High Permeability (High Potential Recharge)	Qvr, Qal, Qvi, Qpfc
Medium Permeability (Medium Potential Recharge)	Qls, Qmw, Qva, Qob, m, Qb, Qpf, Qpfm, Qpo
Low Permeability (Low Potential Recharge)	Qw, Qvt, Qtb, Qvu, Qpff, Qcs, Qpof, Qdi, Qti, Qdu, Qtu

A surficial geologic formation permeability map (Figure 8-24) was prepared based on the three permeability groups defined above. The permeability of the surficial geologic units indicate that the high potential recharge areas are confined to the Judd and Beall Creek drainage basins in north-central and south-central Vashon Island. ~~The permeability of the surficial geologic units indicate that the high potential recharge areas are confined to the Judd and BeallBealll Creek drainage basins in north-central and~~

~~south-central Vashon Island,~~ respectively. In addition, there are some other smaller areas. Carr's (1983) subsurface permeability map is markedly different from Figure 8-24; however, Figure 8-24 was prepared using the most recent geologic map prepared by Booth (1991). The high potential recharge areas defined in the Carr subsurface permeability map included near-central Maury Island; northwest, west-central, south-central, and northwest-central Vashon Island; and the vicinity of the Town of Vashon. Carr (1983) did not address the criteria used to differentiate between high, medium, and low potential recharge areas.

Soil permeability on the Island was a consideration in the construction of the aquifer-sensitivity map. Since the characterization of the soil on the Island has not changed since Carr (1983) and since no new soil surveys of the area have been developed, the soil permeability map constructed in Carr (1983) was used in the composite for the map for soil permeability with respect to recharge (Figure 8-25). High potential recharge areas delineated by soil permeability are located on central Maury Island and south-central Vashon Island away from the coastline.

Rainfall on the Island was the final consideration in the construction of the aquifer-sensitivity map. The cumulative rainfall map was arranged to construct a more accurate picture of areal distribution of rainfall (Figure 8-11). Measurements of rainfall were taken from the annual isohyetal maps included in this report. Some estimates were made for rain-gage data sets containing with incomplete information (Appendix D). The highest potential recharge area determined from the total rainfall map is located between northwest-central and east-central Vashon Island. Rainfall was not a recharge criteria considered in Carr (1983)

Marine-Water Sediment (Tahlequah Creek)

The highest total coliform concentration detected in any of the marine-water sediment samples was measured in Tahlequah Creek (July 1992). Other constituent concentrations were generally similar to those measured in the other streams sampled.

Marine Shellfish (Tahlequah Creek)

Fecal coliform concentrations in marine shellfish exceeded the FDA standard in five of the six samples analyzed (August and November 1991, and July and August 1992).

8.4.1.3 Summary of Results

The surface-water quality data is summarized below. Freshwater, freshwater sediments, marine-water, marine-water sediment, and marine-shellfish data are discussed first, followed by a discussion of the associations between the sampling results and the different environments sampled.

In the samples collected from freshwater streams, high fecal coliforms were present above regulatory levels within seven of the freshwater streams; Beall Creek was the exception. These high values may be caused by non point sources such as septic tank system discharges and animal wastes from hobby farms and wildlife. ~~These high values may be indicative of wildlife in the area and not necessarily septic system contamination (Shallow, pers. comm. 1993), although many septic systems have failed, resulting in the creation of severe public health hazard areas (PEI/Barrett 1992).~~ TDS levels in Green Valley Creek and mercury and chromium levels in Judd and Mileta Creeks, respectively, exceeded Washington freshwater standards for streams.

During the drilling of VT-1, soil samples from drill cuttings were collected and descriptions were recorded continuously on a boring log (Appendix M) for stratigraphic comparison with other nearby deep boreholes. Soils encountered in the borehole for VT-1 consisted of primarily of fine-grained sand, silt, and clay with occasional interbeds of silty to sandy gravel. Fine-grained deposits occurred from approximately 0 to 2 feet bls and from approximately 40 to 485 feet bls and generally consisted of grey to light-grey, interbedded silt and clay with fine-grained sand. A trace of peat fragments was encountered at a depth of approximately 38 feet bls. Coarser-grained sands and gravel were encountered at depths of approximately 2 to 40 feet bls and generally consisted of grey to brown well-graded sand and gravel. ~~Coarser-grained sands and gravels were encountered at depths of approximately 2 to 40 feet bls and generally consisted of grey to brown well-graded sand and gravel.~~ Interbedded sands, silts, and gravels were encountered from approximately 485 to 500 feet bls.

Ground water was initially encountered during drilling at approximately 45 feet bls. A water-bearing zone consisting of fine-grained sand was also encountered from approximately 380 to 445 feet bls (approximate elevation of -330 to -395 feet msl). An additional water-bearing zone of interbedded sand, silt, and silty gravel was encountered at approximately 485 to 500 feet bls. After drilling was terminated at 500 feet bls, the static water level recorded in the borehole on January 29, 1992 was 88.25 feet bls (approximate elevation of -38 feet msl).

9.3 DATA COLLECTION AND ANALYSIS

Two grab samples representative of the water-bearing zone encountered from 380 to 445 feet bls (Samples 420 and 435) were submitted to Cascade Testing Laboratory, Inc. of Kirkland, Washington on January 29, 1992 for grain-size analysis to determine the feasibility of constructing an efficient water well in the fine-grained sediments

- Annual rainfall trends vary erratically across the Island; however, the highest amount of rainfall generally falls in the north-central portion of Island.

- Annual rainfall accumulations at Sea-Tac Airport on the mainland are consistently lower than on the Island.

10.1.2 Surface Water

Eight creeks were monitored during the observation period to determine trends in stream flow and the quality of surface water on the Island. Stream-flow data were developed from stream-gage readings. Water quality was evaluated from laboratory analysis of samples of freshwater, marine water, freshwater sediments, marine-water sediments, and marine shellfish. The following conclusions were drawn from this data collection effort.

- Stream levels increase after high rainfall events, though not instantaneously.

- Predictably, stream flow tends to correlate with rainfall. Stream flow is highest during the wetter winter months and lowest during the drier summer months.

- Estimated stream-base flow ranges from 0 cfs to 4 cfs (944 Mgpy).

- High fecal coliform levels appear throughout the stream system. These elevated levels may be due to non point sources such as on-site sewage system discharges and animal wastes from hobby farms and wildlife.

~~H i g h fecal coliform levels appear throughout the stream system; however, these elevated levels may reflect local wildlife rather than septic system failures.~~ No correlations were observed between contaminant levels detected in freshwater, freshwater sediments, marine water, marine-water sediments, and marine shellfish. In other words, contaminants detected in a stream were not necessarily detected in marine sediments or shellfish at the mouth of the stream.

- The quality of spring water on the Island appears to be good.

10.1.3 Ground Water

During the observation period, 24 wells were monitored. ~~21 wells were monitored.~~ Trends in water levels, ground-water quality, and aquifer characteristics were derived from the data collected and are presented below.

- Depth to ground water varies across the Island. In general, the deepest depths to ground water are associated with the central axis of Vashon Island, while the shallowest depths to ground water occur near the coastlines in the approximate middle of Vashon Island.

- Ground water is mounded on the Island and flows from the higher topographic areas toward the coastlines.

- Observed water levels in wells across the Island fluctuated seasonally between 1 and 22 feet.

- Install permanent staff gages in selected watersheds.
- ~~Install permanent staff gages approved by the USGS in selected watersheds.~~ These gages should be strong enough to withstand storm events. In addition, automatic stream-flow recorders should be installed to monitor daily and storm-event water levels of surface water in the major drainage basins. The recorders will need to be checked periodically to retrieve the finite amount of information the recorder can retain and to ensure continued proper operation.

- Monitor rainfall daily in selected areas across the Island. Automatic rain-gage recorders should be installed to provide a more complete record of rainfall. ~~Automatic rain-gage recorders would provide a more complete record of rainfall.~~ The recorders will need to be checked periodically to retrieve the finite amount of information the recorder can retain and to ensure continued proper operation.

- Obtain historical and current data on water use from all classes of purveyors.

10.2.2 Water Quality

The following activities should be conducted to continue the assessment of the effects of land use on water quality.

- Monitor the water quality in shallow and deep wells on a long-term basis.

- Monitor the water quality of ground water wells at sand and gravel sites.

- Monitor water quality in wells at and near the landfill, NIKE missile launch site, failing/prefailing septic systems, and UST sites.

- Monitor the water quality of the surface water in the major drainage basins most likely to be impacted by potential point sources of contamination. Conduct basin studies to ascertain the non point sources of contamination.

- Monitor the water quality of stormwater outlets during storm events where these outlets discharge to ground water and creeks .

- Monitor the water quality data of wells at and around the Vashon landfill collected by the King County Solid Waste Division and SKCHD in the vicinity of the landfill to determine if the shallow and deep aquifers are interconnected, and if ground water quality is being impacted.

- Complete the survey on the condition of septic systems and determine their influence on the surrounding drainage basins.

~~High fecal coliform levels found near failed septic systems are potentially dangerous for contraction of disease.~~

- ~~Monitor possible contaminants in marine shellfish near identified severe public health hazard and health caution areas.~~

- Conduct a pumping test on a well screened in the Principal Aquifer to determine the Principal Aquifer characteristics of transmissivity, hydraulic conductivity, and storativity.

The water-resource potential of the Deep Aquifer has been difficult to estimate, largely because of complexities associated with establishing its degree of continuity, volume, and recharge capacity. To further the understanding of the potential production capacity of the Deep Aquifer, the following activities should be conducted.

- Conduct a pumping test on a well screened in a deep water-bearing zone to refine the knowledge of the transmissivity, hydraulic conductivity, and storativity of the Deep Aquifer.

- Install another "deep" well on the southwest side of Vashon Island to investigate further the potential that the Deep Aquifer is connected to the mainland's deep aquifer and to explore the production potential below the Principal Aquifer. Excavate the well drilled at Burton Acres Park in 1992, another 500 feet.

- Collect, maintain, and analyze the records of all the other deep wells which have been and will be drilled on the Island.

10.2.4 Public Awareness

Maintain a high level of public awareness by implementing a system through which data are collated and retained in a usable manner. The results of the continuing data collection efforts can be conveyed to the public on a regular basis to preserve high levels of public awareness and "grass-roots" responsibility for the Islands water resources.