Clover Creek Basin Plan

Volume 1 – Basin Plan & SEIS

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Pierce County
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CHAPTER 2.
EXISTING PROGRAMS AND INFORMATION

2.1 EXISTING 1991 STORM DRAINAGE AND SURFACE WATER MANAGEMENT PLAN

Pierce County's 1991 *Storm Drainage and Surface Water Management Plan* identified stormwater issues and recommended capital improvements for each major drainage basin in Pierce County. All major drainage facilities, lakes, ponds, and stream channels were inventoried. Existing (1990) and future (2010) hydrologic conditions were modeled to assist in the selection of appropriate solutions to flooding problems. Structural improvements were recommended for most existing flooding problems; non-structural solutions, such as higher regulatory standards to protect existing wetlands, were recommended to prevent future problems.

At the time of the study, a large percentage of land use in the Clover Creek/Steilacoom watershed was low-density residential, with industrial and commercial uses along the Interstate 5 corridor and McChord Air Force Base. The southern and eastern sections of the basin were primarily agricultural and low density residential. Rapid development was expected in the upper basin. Most identified flooding problems were related to floodplain encroachment, loss of floodplain storage, small storm drain pipelines, and increased flows due to an increase in basin impervious area. The most significant problem was the loss of floodplain storage due to development. An important non-structural recommendation for the watershed was the application of good land use measures, as continued loss of flood storage areas would increase peak discharges and could negate the effects of many of the projects recommended to solve current flooding problems.

The cost of all capital improvement projects (CIPs) was estimated to be $11.5 million (1990 dollars). CIPs were distributed into high, medium, and low priority projects. Proposed capital improvements in the Clover Creek/Steilacoom basin fell into the following categories:

- *Culvert and pipeline upgrades*—Upgrades proposed for 19 culverts and three storm drains
- *Water quality projects*—Retrofits to existing storm drain outfalls and dry wells
- *Protection of roads*—Raising five roads to maintain emergency access during flood events
- *Improving open channel conveyance capacity*—Dredging a section of Clover Creek and also a ditch on 128th Street East.
- *Floodproofing structures*—that were frequently inundated during Clover Creek floods

- *Detention facilities*—Acquiring six parcels for use as detention or infiltration sites, and expanding and improving two existing detention facilities.

The hydraulic capacities of 51 County-owned culverts and 17 storm drains were analyzed. Of these, 28 culverts and three storm drainage networks did not meet 25-year capacity requirements. Upstream detention was proposed for three of the culverts, while 19 culverts were recommended for replacement. The three undersized storm drains included segments along Canyon Road, Hipkins Road, and 4th Avenue South.

Five of the selected detention or retention sites were identified as high priority projects due to existing downstream flooding problems, the increasing value of the properties, and their potential to eliminate the need for upgrades to downstream drainage structures. These sites included two properties on the North Fork of Clover Creek, and sites on Clover Creek and Midland Creek, and near Rogers High School. Medium to low priority detention sites included two properties that could be used to infiltrate runoff tributary to Zongas Pond, and a site at Green Meadows Mobile Home Park to prevent downstream flooding.

Over 800 County-owned dry wells were identified during the inventory of the Clover Creek/Steilacoom basin. Infiltration was also implemented through the use of numerous retention ponds. Although infiltration is an effective way of reducing surface runoff and recharging groundwater stores, traditional dry wells can also discharge pollutants directly into the aquifer. As a result, a long-term retrofit plan for all dry wells was recommended. To meet current surface water quality standards, the retrofitting of 26 storm drain outlets with oil/water separators was recommended.

The County has implemented a number of the recommended projects over the last ten years, which have included the following:

- Construction of four regional detention or retention facilities including the Sand Pit Retention Facility, E-1 Detention Pond, W-1 Detention Pond, and Afdem Detention Pond.
- Replacement of the culvert at 160th Street, east of Canyon Road, and the 132nd Street East culvert, replaced during construction of the E-1 detention pond.
- Elevation of 136th Street South.
- Replacement of dry wells with a two stage dry well system in conjunction with roadway improvements.
- Purchase of three repetitive loss properties.
- Channel maintenance of the main stem of Clover Creek between the confluence of the North Fork and McChord Air Force Base.

In 1988 the Pierce County Storm Drainage and Surface Water Management Advisory Board (SWMAB), a County-wide group of individuals representing each major watershed of the County was established to assist in the development of the Pierce County surface water utility plan and to assist in guiding the program. After the 1991 Plan was adopted, the Board dissolved. The County Council reestablished the SWMAB in 2004. There are nine board members, representing the major watershed basins within the County, who review the surface water utility program. SWMAB meetings are open to the public.

2.2 OTHER PROGRAMS, POLICIES AND REGULATIONS

Numerous laws, regulations, policies, and programs affect surface water management in the Clover Creek watershed. *Table 2-1* summarizes pertinent federal and state laws and regulations and the associated implementing programs for the Clover Creek Basin.

TABLE 2-1.
FEDERAL AND STATE LAWS AND REGULATIONS
AND CORRESPONDING CLOVER CREEK PROGRAM

Law or Regulation	Application to the Clover Creek Basin
Federal Laws	
Clean Water Act	
Section 402 National Pollutant Discharge Elimination System (NPDES)	Pierce County NPDES stormwater permit
Section 303(d) Total Maximum Daily Load (TMDL) Listing	Listing of Clover Creek; TMDL for phosphorus in Steilacoom Lake (withdrawn January, 2002) and copper in Chambers Creek
Section 404 Permit Requirements for Wetland Filling	Pierce County direction for basin plans to avoid recommendations that would have negative impacts on wetlands
Endangered Species Act	Tri-County Endangered Species Act Response Implementation of the Chambers-Clover Creek WRIA Conservation Plan
National Flood Insurance Program	Pierce County Flood Hazard Management Code
Safe Drinking Water Act	EPA sole-source-aquifer designation for Chambers-Clover aquifer
Magnus-Stevens Fishery Conservation and Management Act (MSA) & Essential Fish Habitat (EFH)	
State Laws	
Water Quality Standards	Water quality criteria for Clover Creek and Steilacoom Lake
Puget Sound Water Quality Management Plan	Drainage development standards; Stormwater Management Manual; Stormwater Pollution Control Manual
Growth Management Act	Critical areas regulations
State Environmental Policy Act	SEPA review for basin plan and individual projects
Shoreline Management Act	Pierce County Shoreline Master Program
State Hydraulic Code	Hydraulic Project Approvals required for in-stream work
Regulation of Public Ground Waters (RCW 90.44)/Ground Water Management Areas and Programs (WAC 173-100)	Clover/Chambers Creek Basin groundwater management program
Watershed Management Act	Chambers-Clover Creek WRIA watershed plan
State Shellfish Management Regulations	Shellfish protection districts. May affect water quality solutions implemented in Clover Creek basin.
The Non-Point Rule	Chambers-Clover Creek WRIA watershed plan

2.2.1 Federal Programs

Clean Water Act

Section 402 National Pollutant Discharge Elimination System Permit

Under the federal Clean Water Act, discharges from municipal separate storm sewer systems serving populations of 100,000 or more are covered under the National Pollutant Discharge Elimination System (NPDES) and must obtain a Phase I NPDES permit. In Washington State, the State Department of Ecology administers NPDES permits. Systems serving populations under 100,000 will require permits in the future under the Phase II NPDES program, currently under development by Ecology.

Pierce County's storm drainage system meets the Phase I criterion and requires a permit. Ecology issued a Phase I NPDES permit to Pierce County in 1995, which was administratively extended in 2000 pending development of a new permit. The Pierce County permit applies only to unincorporated areas of the County. It does not include tribal reservations, federal lands, such as military reservations and parks, incorporated areas, or state lands. It also does not cover areas controlled by the 10 state-chartered drainage districts operating in Pierce County. In the Clover Creek Basin, land under other NPDES permit coverage includes Tacoma, McChord Air Force Base, and Fort Lewis.

Pierce County has implemented a Stormwater Management Program (SWMP) under its NPDES permit to control discharge of pollutants in stormwater. Ecology approved this program in 1998. The program addresses stormwater quality monitoring, commercial and residential areas, industrial areas, illicit discharges, and construction activities. The SWMP encompasses a wide range of new and previous stormwater programs, including County operations and maintenance; stormwater pollution control requirements for new development, redevelopment, and construction; industrial inspection; investigation of illicit discharges; and public education.

Section 303(d) Total Maximum Daily Load List

Section 303(d) of the Clean Water Act requires Ecology to prepare a list of water bodies that do not or soon will not meet water quality standards after application of required technology-based effluent limits. Ecology's most recent candidate Section 303(d) list is based on 1998 data. Clover Creek is listed for fecal coliform, dissolved oxygen, and temperature. Steilacoom Lake is listed for sediment bioassay and total phosphorus.

Under the 303(d) listing, a total maximum daily load (TMDL) must be calculated for out-of-compliance pollutants. This value specifies the maximum load of the pollutant that can be introduced into the water body. Effluent limits for all pollutant sources discharging to the water body are adjusted downward until the TMDL can be met.

The U.S. Environmental Protection Agency (EPA) established a TMDL in February 2000 for phosphorus in Steilacoom Lake and copper in Chambers Creek. In January 2002, EPA withdrew the phosphorus portion of the TMDL, stating that errors had been made in the initial load calculations. The copper TMDL remains. The maximum copper load for Chambers Creek is 8.2 µg/L (acute) and 5.8 µg/L (chronic).

Section 404 Wetland Permitting

Wetland filling is regulated by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. A permit is required for many projects that involve filling or other alteration of wetlands. The mitigation costs, time delays, and other uncertainties associated with obtaining authorization for projects that affect wetlands greatly increase the difficulty of implementing these projects. Because of the difficulty in obtaining permits, and because of wetlands' value for habitat, water quality and flood water storage, Pierce County has specified that capital projects with adverse effects on wetlands should be avoided (Pierce County Water Programs, 2000). If no reasonable alternatives exist, recommendations for such projects should include an evaluation of potential project impacts and of the cost of obtaining permits.

Endangered Species Act

The 1999 Endangered Species Act (ESA) listing of the Puget Sound chinook salmon prompted local governments to include salmon recovery efforts in all aspects of operations. The more recent listing of the bull trout brought further urgency to endangered species issues. Pierce County is participating with King and Snohomish Counties in a coordinated "Tri-County ESA Response." This effort will establish a framework for the National Marine Fisheries Service (NMFS) to use in evaluating local compliance with the ESA. The Tri-County ESA response has developed a model program for achieving salmon recovery in an urban environment. The NMFS has not yet approved the program, but it is being used as a template by Pierce County and other jurisdictions for updating regulations and operations to comply with ESA.. The federal 4(d) rule took effect January 8, 2001. NMFS has approved the Tri-County salmon protection plans for road maintenance and repair and is in the process of reviewing the draft Tri-County biological review. Information on the Tri-County ESA response can be found on the *Salmon Information* web site, http://www.salmoninfor.org/.

Pierce County has numerous policies, regulations, and programs that help preserve and restore salmon habitat (Pierce County Web Site, 2002). The County is also implementing early actions to preserve and restore salmonid habitat, in coordination with jurisdictions around Puget Sound. These early actions include structural measures, such as culvert replacements to improve fish passage and restoration of key habitats, and non-structural measures, such as land acquisition to preserve habitat. The County intends to play a key role in developing plans that will provide for long-term conservation and restoration of salmonid habitat. The County has estimated that the early actions will cost in excess of $7 million. Table 2-2 summarizes the key early action efforts.

National Flood Insurance Program

In 1968, the U.S. Congress initiated the National Flood Insurance Program (NFIP) (Chapter 44 CFR) under the National Flood Insurance Act to relieve the burden of disaster relief on the national treasury and state and local tax bases. The NFIP is administered by the Federal Insurance Administration (FIA), which is part of the Federal Emergency Management Agency (FEMA). The NFIP makes available affordable flood insurance to communities that adopt approved floodplain management regulations. Communities that do not participate in the NFIP do not qualify for certain flood disaster relief. FEMA's Flood Insurance Rate Maps (FIRMs) form the basis for critical area zoning for flood hazards.

TABLE 2-2.
PROPOSED PIERCE COUNTY EARLY ACTIONS
TO PRESERVE AND RESTORE SALMONID HABITAT

Category	Early Actions
Planning	Pierce County Surface Water Management Framework Plan Pierce County Basin Planning Process Salmon Conservation Plans Growth Management Act Comprehensive Plan Update Environmental Quality Commission Open Space
Development Regulations	Stormwater Design Standards Critical Areas State Environmental Policy Act Shorelines On-Site Waste Disposal Water Quality Forest Practices
Enforcement of County Codes	Level of Service Training Guarantees and Penalties Interdepartmental Coordination
Capital Projects & Land Acquisition	Stormwater Management Facilities Fish Passage Projects Road Construction Projects Habitat Impacts of Bridge Construction Habitat Protection High Priority Habitat Identification
Public Outreach & Education	Involve Public in Watershed Monitoring Puyallup Spring Fair Water Festival General Environmental Educational Activities
Scientific Inventory, Analysis & Monitoring	Habitat Assessment Mapping Flow Gaging Water Sampling Database Management
Facility Operations & Maintenance	Detention/Retention Pond Maintenance Material Stockpile Management Roads Maintenance Herbicide Use Reduction Program Road De-icing Operations Review Road Maintenance Best Management Practices Park Maintenance River Maintenance

Pierce County participates in the NFIP. Flood hazard management regulations are codified in Title 17A.50 of the County Code, and criteria and procedures are laid out in Chapter 9 of the *Pierce County Stormwater Management and Site Development Manual*. Federally subsidized flood insurance is available to local residents. To continue coverage, the County must remain in the NFIP and maintain minimum floodplain management regulations. FEMA requires a certification letter for any revisions to a FIRM. Certification activities include stream channel modifications, installation of culverts, and bridge construction.

Safe Drinking Water Act

Under the Safe Drinking Water Act, the EPA has designated the Clover/Chambers Creek aquifer as a sole source aquifer. The region's Ground Water Management Program, described in a later section, recommended obtaining this designation status from EPA. The designation applies to aquifers that meet two criteria: they supply 50 percent or more of the drinking water consumed in their service area; and available alternative sources of drinking water are inadequate to replace them. The designation provides several benefits:

- Special review requirements for any federally financially assisted projects to prevent contaminating the aquifer
- Access to EPA funding for aquifer protection demonstration projects
- Stricter siting restrictions for solid waste landfills or expansion of existing landfills
- Increased public awareness.

2.2.2 State Programs

Water Quality Standards

Washington Administrative Code (WAC) 173-201A classifies rivers and streams by the beneficial uses that they should be able to support and the level of support they should provide. It also specifies standards for water quality sampling. Classification identifies the standards that a stream *should* meet, and not whether it does so at the time of classification. These classifications, which are listed in Table 2-3, and their associated numerical criteria are described in Chapter 173-201A of the Washington Administrative Code. Class AA waters are expected to support all identified beneficial uses and with greater consistency than any other classifications, therefore the Class AA standards are most stringent. Class C waters support the fewest beneficial uses and the Class C standards are more lenient (Pierce County Public Works 1997). The WAC 173-201A criteria are primarily measures of water bodies' ability to support aquatic life and human contact activities, such as swimming.

Major water bodies in the Clover Creek watershed have been classified as follows:

- Clover Creek from the outlet of Lake Spanaway to the inlet of Steilacoom Lake: Class A
- Steilacoom Lake: Lake class

- Clover Creek tributaries: Class A.

TABLE 2-3.
WASHINGTON STATE WATER QUALITY CLASSES

Class	Rating
AA	Extraordinary
A	Excellent
B	Good
C	Fair
Lake	All lakes

Table 2-4 describes the water quality criteria for Class A and Lake Class surface water bodies in Washington State.

In response to the Federal Clean Water Act (CWA) of 1987 section 305(b), the Washington State Department of Ecology prepared the *1988 Statewide Water Quality Assessment*. Ecology developed several designations for state waters to indicate whether they support their expected uses (such as swimming, fishing and shellfishing): "Fully Supported," "Partially Supported," "Threatened," "Not Supported," and "Not Attainable." Designations are assigned based on water quality sampling results, using the standards set in WAC 173-201A (Pierce County Public Works 1997).

Each beneficial use is evaluated separately for each water body. The beneficial uses examined include: fish consumption, primary contact recreation (swimming), secondary contact recreation (boating), aesthetics, CWA fishable, clam harvesting, fish spawning, clam spawning, crab spawning, salmonid spawning, salmonid and fish migration, and wildlife. If part, but not all, of a stream is clean enough to support a use, then it is designated "partially supported." A stream is "threatened" for a given use if it can support that use only for short periods or is showing signs of deterioration (Pierce County Public Works 1997).

Water quality testing reports prepared under guidelines defined in the *1988 Water Quality Assessment* define the "supported" status of individual water bodies. They also identify causes and sources of pollutants that may be limiting a stream's or lake's ability to support certain uses. Ecology relies on a variety of sources to make determinations about the causes and sources of pollutants. In addition to testing by local agencies, Ecology has established a fixed-station ambient monitoring network for sampling water quality. Ecology's Environmental Investigations and Lab Services Program provides field investigations and laboratory analyses to support their conclusions (Pierce County Public Works 1997).

Portions of Clover Creek and Steilacoom Lake have routinely failed to meet the water quality criteria described above, resulting in them being listed on the state's 303(d) list of impaired water bodies. Clover Creek is listed for fecal coliform, dissolved oxygen, and temperature. Steilacoom Lake is listed for sediment bioassay and total phosphorus.

TABLE 2-4.
WASHINGTON STATE WATER QUALITY CRITERIA FOR CLOVER CREEK AND LAKE STEILACOOM

Parameter	Class A Criteria (freshwater)	Lake Class Criteria
Characteristic Uses	Water supply (domestic, industrial, agricultural) Stock watering Fish and shellfish: salmonid migration, rearing, spawning and harvesting; Other fish migration, rearing, spawning, and harvesting; Clam, oyster, and mussel rearing, spawning, and harvesting; Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning, and harvesting Wildlife habitat Recreation (primarily contact recreation, sport fishing, boating, and aesthetic enjoyment) Commerce and navigation	Water supply (domestic, industrial, agricultural) Stock watering Fish and shellfish: salmonid migration, rearing, spawning and harvesting; Other fish migration, rearing, spawning, and harvesting; Clam and mussel rearing, spawning, and harvesting; Crayfish rearing, spawning, and harvesting Wildlife habitat Recreation (primarily contact recreation, sport fishing, boating, and aesthetic enjoyment) Commerce and navigation
Fecal Coliform Organisms	Shall not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL	Shall both not exceed a geometric mean value of 50 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL
Dissolved Oxygen	Shall exceed 8.0 mg/L	No measurable decrease from natural conditions
Total Dissolved Gas	Shall not exceed 110 percent of saturation at any point of sample collection	Shall not exceed 110 percent of saturation at any point of sample collection
Temperature	Shall not exceed 18.0°C due to human activities. When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Limitations on the cumulative temperature increase from each incremental point source and nonpoint source activities are also specified.	No measurable change from natural conditions

Source: Chapter 173-201A Washington Administrative Code

TABLE 2-4 (continued).
WASHINGTON STATE WATER QUALITY CRITERIA FOR CLOVER CREEK AND LAKE STEILACOOM

Parameter	Class A Criteria (freshwater)	Lake Class Criteria
pH	6.5 to 8.5	No measurable change from natural conditions
Turbidity	Not exceed 5 nephelometric turbidity units (NTU) over background when background is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more than 50 NTU	Not exceed 5 NTU over background conditions
Toxic, Radioactive, or Deleterious Material	Specific criteria described in WAC 173-201A-(040-050)	Specific criteria described in WAC 173-201A-(040-050)
Aesthetic values	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste

Source: Chapter 173-201A Washington Administrative Code

Water Quality Parameters

WAC 173-201A sets criteria for the following water quality parameters, based on the type of water body (e.g., lake or river), its classification, and whether it is fresh or saltwater (WAC 173-201A also protects aesthetic values, but they cannot be measured using scientific methods):

- Fecal coliform organisms
- Dissolved oxygen
- Total dissolved gas
- Temperature
- pH
- Turbidity
- Toxic material concentrations.

Criteria for other substances known to be toxic are described in the document *USEPA Quality Criteria for Water, 1986* (the "Gold Book"). The state regulation defines levels that must be met for all these parameters. The levels vary depending on the water body's classification. For some toxic materials, different levels are established for "acute" and "chronic" toxicity. Acute toxicity is a pollutant concentration high enough to kill aquatic life within four days of exposure. Chronic toxicity is a level of contamination at which fish will die if contamination continues over an extended period of time. WAC 173-201A lists metals and organic compounds that are considered toxic and either provides numerical acute and chronic limits for each or defines a formula to derive the limits for a specific water body. The formula defining acute or chronic toxicity for pollutants varies with the hardness of the water (Pierce County Public Works 1997). Table 2-5 summarizes stream and lake classifications from WAC 173-201A.

TABLE 2-5.
COMPARISON OF WAC 173-201A CLASS CRITERIA

Test	Streams				Lakes
	Class AA	Class A	Class B	Class C	
Fecal Coliform Organisms (organisms/100 mL) (maximum)	50	100	200	200	50
Dissolved Oxygen (mg/L) (minimum)	9.5	8.0	6.5	4.0	No change from natural conditions
Total Dissolved Gas (% of saturation) (maximum)	110	110	110	—	110
Temperature (°C) (maximum)	16.3	18.3	21.3	22.3	No change from natural conditions
pH (range)	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	No change from natural conditions
Turbidity (NTU[a] over background) (maximum)	5	5	10	10	5

a. NTU = nephelometric turbidity units, the standard unit for measuring turbidity

Source: Pierce County Public Works, 1997

Puget Sound Water Quality Management Plan

The Puget Sound Water Quality Management Plan is a comprehensive planning document that enumerates critical elements of responsible management for the Puget Sound region. This document was developed by the Puget Sound Water Quality Authority in 1986 and has been revised and updated several times since then. The 2000 Plan is the most recent update. Elements of this plan form the basis for many local and state resource management programs today.

The Puget Sound Water Quality Authority has been reorganized into the Puget Sound Water Quality Action Team. This group functions as a sub-agency of the governor's office, consisting of 10 state agency heads, a city and county representative, a representative of federally recognized tribes and ex-officio non-voting representatives of three federal agencies.

The Puget Sound Water Quality Management Plan outlines steps that communities around Puget Sound should take to ensure the protection of the Sound's water quality. The following measures in Pierce County address the guidelines of the Puget Sound Water Quality Management Plan:

- Regulations for drainage development in Pierce County are codified in Title 17A and 17B of the County code.
- The *Pierce County Stormwater Management and Site Development Manual* provides guidance for analysis and design of conveyance and detention facilities for managing stormwater quantity. It establishes storm drainage control standards and erosion control practices.
- The *Pierce County Stormwater Pollution Prevention Manual* is a guide for best management practices (BMPs) for industries, businesses and homeowners to reduce pollution caused by everyday activities.
- The Pierce County Pubic Works Department has review and approval authority over design of facilities to manage stormwater quantity and quality in unincorporated Pierce County.
- Stormwater quantity and quality design requirements for incorporated and federal areas, including Lakewood, Tacoma, McChord Air Force Base and Fort Lewis are subject to the requirements of the respective jurisdictions.

Growth Management Act

The Washington Legislature passed the Growth Management Act (RCW 36.70A) in 1990, and amended it in 1991 and 1993, in order to manage growth in the state's fastest growing counties. The Washington State Department of Community, Trade and Economic Development administers the Growth Management Act (GMA). The GMA defines 13 goals to guide development of comprehensive plans and regulations for counties and cities, including the following:

- Reduce the inappropriate conversion of undeveloped land into sprawling, low-density development.

- Encourage the retention of open space and development of recreational opportunities; conserve fish and wildlife habitat; increase access to natural resource lands and water; and develop parks.
- Maintain and enhance natural resource-based industries, including productive timber, agricultural, and fisheries industries. Encourage the conservation of productive forests and productive agricultural lands, and discourage incompatible uses.
- Protect the environment and enhance the state's high quality of life, including air and water quality and the availability of water.

Local governments are required to classify and designate "resource lands of long-term commercial significance" and "critical areas." Resource lands of long-term commercial significance include agricultural, forest, and mineral resource lands. Critical areas include wetlands, fish and wildlife habitat areas, aquifer recharge areas, frequently flooded areas, and geological hazardous areas.

The Pierce County Comprehensive Plan was developed and adopted in 1995 in response to the requirements of the GMA, and is codified in Title 19A of the County code. The Comprehensive Plan provides county-wide policies in 11 areas in cooperation with all cities and towns in the County. Community plans are being developed for the Parkland-Spanaway-Midland Subarea, the South Hill Subarea, the Graham Subarea, and the Frederickson Subarea within the Clover Creek Basin. The community planning process uses the County Comprehensive Plan as a foundation, with specific community elements for local conditions and objectives. Municipalities such as Lakewood, Steilacoom, and Tacoma are required under the GMA to coordinate on matters of county-wide growth management policy. McChord Air Force Base and Fort Lewis are not subject to the GMA.

The status of each Community Plan is listed below; further information is available from the Planning and Land Services Advanced Planning Division (798-2785):

- Parkland-Spanaway-Midland has been completed and has been reviewed by the Planning Commission. It is scheduled to go before the County Council in 2002.
- Frederickson has completed the policies for the Natural Environment and the Parks elements of the Community Plan and hopes to complete the Land Use sections next. Estimated completion date for the entire plan is the end of 2002.
- South Hill has completed the policies for the Economic Development, Natural Environment, and Parks elements of the plan. Estimated completion date for the entire plan is the end of 2002.
- Graham has just started meeting for its plan and the effort is estimated to take two years.

State Environmental Policy Act

The Washington State Environmental Policy Act (SEPA) (Chapter 43.21C RCW) was passed to ensure that environmental values are considered in decisions by state and local government officials. The County acts as the lead local agency in the SEPA process. SEPA requires an environmental assessment for basin plans. The consistency of a proposal with existing plans and policies (e.g., local shoreline master programs, comprehensive plans, zoning codes, floodplain management) may also be evaluated. Completion of the SEPA process is necessary before decisions may be made on a number of local and state permits.

Shoreline Management Act

The Washington State Shoreline Management Act (SMA) (RCW 90.58) protects public resources such as water, fish and wildlife, and supporting habitat by regulating public and private development in shoreline areas. The SMA defines shoreline designations; provides guidance to Ecology and local jurisdictions for developing procedures, rules, and plans for shoreline activities; establishes timelines for the development of local shoreline management plans; and identifies activities generally exempt from shoreline permits. SMA gives primary authority over shoreline development to local governments following review from the state. Shorelines of the state governed by the SMA include the following:

- All water areas of the state, including reservoirs and their associated wetlands, together with the lands underlying them, except
  - Shorelines of statewide significance
  - Shorelines on segments of streams upstream of a point where the mean annual flow is 20 cubic feet per second or less and the wetlands associated with such upstream segments
  - Shorelines on lakes less than 20 acres in size and wetlands associated with such small lakes.
- Shorelines of statewide significance, which include rivers downstream of where mean annual flow is 1,000 cubic feet per second or greater, adjacent lands within 200 feet of the ordinary high water mark, areas within the floodway, contiguous floodplain areas 200 feet landward from the floodway, and all associated marshes, bogs, and swamps.

The SMA defines wetlands as "lands extending landward for 200 feet in all directions as measured on a horizontal plane from the ordinary high water mark; floodways and contiguous floodplain areas landward 200 feet from such floodways; and all marshes, bogs, swamps, and river deltas associated with the streams, lakes, and tidal waters which are subject to the [Shoreline Management Act]."

The SMA requires permits for substantial development along shorelines of the state. Substantial development is defined as any development for which the total cost, or fair market value, exceeds $2,500, or any development that materially interferes with normal public use of the water or shorelines of the state. Exceptions include normal maintenance or repair of existing structures, construction of residential bulkheads, emergency construction, construction of barns or similar agricultural structure on wetlands, construction or modification of navigational aids, construction of a single-family residence on a wetland, construction of docks for pleasure boats, irrigation systems, and pre-existing agricultural drainage and dike systems.

The Department of Ecology recently completed a significant revision to the SMA in response to the Section 4(d) regulation for endangered species under the ESA. These revisions are under review by the State Court of Appeals. Until a final ruling is issued, the County will continue to regulate shorelines based on existing regulations.

State Hydraulic Code

The Washington State Hydraulic Code (RCW 75.20.100-140) regulates activities affecting the state's salt and fresh waters. The purpose of the Hydraulic Code is to preserve fish and wildlife habitat in and around the waters of the state. The Washington State Department of Fish and Wildlife administers the Hydraulic Code.

Any work that falls within the definition of a hydraulic project requires a Hydraulic Project Approval (HPA) from the Department of Fish and Wildlife. Hydraulic projects are defined as work that will use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters of the state. Application consists of a form submitted to the Department of Fish and Wildlife accompanied by project plans and specifications. Each of the following constitutes application for an HPA:

- A completed hydraulic project approval application submitted to the Department of Fish and the Department of Wildlife
- A completed forest practice application submitted to the Department of Natural Resources if the project is part of a forest practice as defined in WAC 222-16-010(19)
- A Section 10 or 401 public notice circulated by the U.S. Army Corps of Engineers or U.S. Coast Guard.

Verbal approval for emergency work may be granted immediately upon request to repair existing structures, move obstructions, restore banks, or protect other property that is subject to immediate danger by weather, flow, or other natural conditions.

A hydraulic project application may be denied when the Department of Fish and Wildlife rules it is directly or indirectly harmful to fish and adequate mitigation cannot be assured by conditioning or modifying the proposal. The code states that protection of fish life is the only grounds for denying or conditioning an application.

The Hydraulic Code is currently being revised. The revised code may include provisions for regulating the quality and quantity of stormwater discharges to fish-bearing waters. Proposed changes also provide greater emphasis on bioengineering. For example, vegetative bank stabilization would be incorporated to provide riparian cover for fisheries.

The County will be required to obtain an HPA for most structural flood control activities, including stream bank protection; construction of bridges, piers or docks; culvert installation; gravel removal; channel realignments; placement of outfalls; debris removal;

and pipeline crossings. HPAs are required for activities in natural drainage corridors as well as in flowing stream corridors.

Ground Water Management Program

Approximately 70 percent of Pierce County's population relies on groundwater as a source of potable water. The Tacoma-Pierce County Health Department (TPCHD) is the lead in establishing and administering groundwater management programs in Pierce County to promote public health through the protection of vital groundwater resources. Two areas of the County have been identified for special groundwater-management consideration: the Clover/Chambers Creek Basin and the Gig Harbor Peninsula.

Ecology declared the Clover/Chambers Creek Basin to be a Ground Water Management Area in 1986. The groundwater management program for the basin provides protection and responsible management of the area of influence for the aquifer system. The plan was completed in 1991. The program addresses the following:

- Hazardous material/waste
- On-site sewage disposal
- Well construction and abandonment
- Solid waste disposal
- Land application of sludge
- Stormwater
- Agricultural practices
- Coordinated water system plan
- Long-term monitoring
- Tacoma Water Division Pipeline 5
- Groundwater reservation
- Water conservation program
- Environmentally sensitive area designation
- Sole-source aquifer designation.

Watershed Management Act

The Watershed Management Act was enacted in 1998 to provide a framework for local citizens, interest groups, and government organizations to collaboratively identify and solve water resource-related problems in each of the 62 Water Resource Inventory Areas (WRIAs) in the state. The planning process consists of three phases:

- Phase 1—Formation of a planning unit, developing ground rules, establishing expectations for the watershed management plan, preparing a mission statement, outlining goals and objectives, and drafting a scope of work for the second phase

- Phase 2—Develop a technical assessment of the watershed using existing data and identifying data gaps. If data gaps are determined to be critical, more data may be collected.
- Phase 3—Develop a Watershed Management Plan that identifies and describes preferred alternate strategies for water resources management in the WRIA

Phase 1 of the watershed management planning process for WRIA 12, the Chambers/Clover Creek Watershed, is complete. The WRIA 12 Planning Unit is currently undertaking Phase 2, the technical assessment.

State Shellfish Management Regulations

The State Department of Health, in cooperation with local health departments, regulates and monitors recreational shellfish harvesting and beaches under WAC 246-280, and commercial shellfish activities under WAC 256-282 and RCW Chapter 69.30. The Department of Health or the health officer for each local health jurisdiction classifies shellfish beaches based on the risk to public health from consuming shellfish and specified water quality conditions. RCW 90.72 authorizes organization of shellfish protection districts to implement programs to protect shellfish tidelands from water quality pollutants.

Pierce County has formed the Rocky Bay and Burley Lagoons Shellfish Protection Districts. Other districts may be formed in the future. Presence of shellfish beds at the downstream end of basins could be a factor in prioritizing basins for planning and in selecting solutions to water quality problems within those basins.

The Non-Point Rule

WAC Chapter 400-12 establishes criteria and procedures for ranking watersheds and for developing and implementing action plans for watersheds in need of corrective and/or preventive actions. The purpose of WAC 400-12 is to reduce pollutant loading from non-point sources, prevent new sources from being created, enhance water quality, and protect beneficial uses, relying on voluntary actions, local ordinances, and state and federal laws regulations and programs for implementation.

Pierce County has prepared action plans for the Lower Puyallup, Chambers/Clover Creek, and Key Peninsula/Gig Harbor/Islands watersheds, and is currently preparing a plan for the Upper Puyallup watershed. The Chambers/Clover Creek plan is to be considered in the preparation of the basin plan for Clover Creek.

2.2.3 Public Education Program

Federal, state, and regional agencies offer a variety of public education programs. General water quality information is available to the public at following internet web sites:

- EPA—www.epa.gov/OW/
- State Department of Ecology—www.wa.gov/ecology/

- Pierce County—www.co.pierce.wa.us/services/home/#Environment

Public education programs related to watershed and water quality issues include the following (Pierce County 1996):

- Through the Clean Water Act and the Superfund List, the U.S. EPA passes funding for educational activities to state and local entities. Some educational programs are administered regionally.
- The Puget Sound Water Quality Action Team has several environmental educators/public information specialists and a strong emphasis on public involvement/education.
- The U.S. Army Corps of Engineers supports education and training programs primarily developed for wetland biologists, wetland delineation specialists, and other environmental professionals specializing in wetlands.
- The Washington State Department of Ecology participates in two state agency education planning committees, employs various educators and public information specialists, and operates limited statewide education efforts on a variety of environmental topics. Ecology negotiates with the federal government, recognized Indian tribes, and units of local governments and special districts concerning environmental education. Ecology administers a variety of state/federal grants, loans, and technical assistance programs for governments focusing on environmental education.
- The Office of State Superintendent of Public Instruction is charged with developing an environmental curriculum to be made available to local districts. The office receives federal funding for this purpose, assists local school districts, and advises state agencies.
- The Metropolitan Park District and other jurisdictions have formed a surface water quality educational coalition funded by a 1993 Ecology Centennial Clean Water Grant. The other entities include the Pierce County Water Programs, the Pierce Conservation District (PCD), the City of Puyallup Public Works, and the City of Tacoma Public Works. Programs in the project include a middle school curriculum on non-point pollution, an after-school water stewardship program for elementary students, and instruction to high school teachers on water quality testing. These curricula are available to most school districts in Pierce County.
- Pierce County Solid Waste Division educators provide about 250 classroom presentations each year. The presentations *No Time To Waste* (about waste reduction, recycling, composting, and wastewater) and *Waste & Water* (about water, how it becomes polluted, and ways people can avoid stressing it) are offered to K-12 schools as well as home schools. Solid Waste works in cooperation with Ecology to provide teacher workshops dealing with effects of waste on water. Curricula and training on household hazardous is also provided. The Solid Waste Division has provided materials on waste reduction, recycling and hazardous products to the Pierce County Public Library system. Educational displays on household hazardous products are

for loan. The Solid Waste Division staffs an information line about recycling, waste reduction, composting and household waste.

- The Pierce Conservation District (PCD) operates programs independently and in cooperation with other agencies. Programs include farm inventories, farm plans, best management practices for farmers, stream signing projects, newsletter publication, school presentations, and legislative tours. PCCD manages the Pierce County Stream Team program and provides office support for its coordinator.
- The City of Tacoma Refuse Utility offers presentations on recycling and hazardous waste management to public schools, an information line on the same subjects, and provides tours, informational literature, and educational displays and videos for loan.
- Educational efforts by City of Tacoma Water include technical advice for conservation, water reuse, industrial conservation incentives, landscaping, and educational displays.
- The TPCHD conducts educational efforts relating to nonpoint pollution and public health and safety in its Water Resources and Waste Management sections. Water Resources educational activities include one-on-one contact with the public, on-site septic system function and maintenance, fish and shellfish, groundwater and surface water quality, land development, and drinking issues. Quarterly newsletters are developed and mailed to water purveyors and professionals in the on-site septic system industry. Classroom presentations are given upon request based on staff availability. Public meetings are conducted if a particular need arises, and brochures are available as needed.
- Waste Management educates in the areas of household hazardous waste, waste spill response, removal of underground storage tanks, and landfills. Waste Management provides waste reduction guidance, referral for hazardous waste, technical assistance, a waste directory, on-site consultations, workshops, written materials, posters, video displays, portable exhibits, and public service announcements.

2.3 EXISTING STUDIES AND REPORTS

Data from dozens of relevant documents were reviewed for integration into this basin characterization report. The original sources (listed in the reference list at the end of this report) should be consulted for comprehensive presentations of the overview provided here. A substantial amount of the information summarized in this report is taken from the following sources:

- *Chambers/Clover Creek Watershed Characterization.* Pierce County Public Works and Utilities Water Programs Division. 1997.
- *Chambers/Clover Creek Watershed Action Plan.* Pierce County Public Works and Utilities Water Programs Division. 1996.

- *Clover/Chambers Creek Basin Groundwater Management Program*. Brown and Caldwell. 1991.
- *Pierce County Storm Drainage and Surface Water Management Plan (Volumes 1 and 2)*. James M. Montgomery. 1991.
- *Clover/Chambers Creek Geohydrologic Study for Tacoma-Pierce County Health Department.* Brown and Caldwell. 1985.

Other primary documents that were reviewed in preparation of this basin characterization report include the following:

- *North Fork Clover Creek Basin Preliminary Design Report for Surface Water Control*. David Evans and Associates. 1993.
- *Steilacoom Lake Phase I Restoration Study (Volumes I and II)*. KCM. 1996.
- *Surface-Water Hydrology and Runoff Simulations for Three Basins in Pierce County, Washington*. United States Geological Survey. 1996.
- *Surface-Water Quality Assessment of the Clover Creek Basin, Pierce County, Washington, 1991-1992*. United States Geological Survey. 1993.
- *Closed Landfill Study,* Tacoma-Pierce County Health Department, Waste Management Section. 1993

CHAPTER 4.
CURRENT CONDITIONS

Clover Creek lies in the Chambers-Clover Creek watershed. The Chambers-Clover Creek system extends 18.6 miles from its mouth at Puget Sound to the Clover Creek headwaters 6 miles east of Spanaway (see Figure 1-1). The Clover Creek Basin contains portions of unincorporated Pierce County, including the Parkland and Spanaway communities, significant portions of the City of Lakewood, a small portion of the City of Tacoma, and portions of McChord Air Force Base and the Fort Lewis Military Reservation. Urban development is concentrated in the northern and western areas of the basin and near freeway and highway corridors. The basin's land cover is a mixture of developed area, agriculture, forest, and other natural cover.

The Clover Creek basin covers 47,400 acres, or 74 square miles. Major creek systems tributary to the main stem of Clover Creek include Morey Creek, Spanaway Creek, and North Fork Clover Creek. Within the Clover Creek Basin are several lakes, the largest of which are Spanaway Lake, Tule Lake, and Lake Steilacoom.

The natural drainage system has been extensively modified over the years, and is augmented by man-made collection systems, including detention facilities, conveyance pipelines, and infiltration facilities. Because of the basin's highly porous soils, most surface runoff in the basin is discharged to the subsurface system, particularly in the western half of the basin (Montgomery 1991).

The climate in the Clover Creek Basin area is typical of the coastal to upland areas of Puget Sound, with average winter temperatures above freezing and summer temperatures generally below 80°F. The basin experiences a frost-free growing season of approximately 250 days per year. (Soil Conservation Service 1979; KCM 1993)

The basin typically receives about 38 to 40 inches of precipitation per year, which falls almost exclusively as rain (Brown & Caldwell 1985). About two-thirds of the area's annual precipitation falls between October and March (KCM 1993). Because a large portion of the basin is covered by highly permeable gravelly soils derived from glacial outwash, it is estimated that 50 to 60 percent of the area's precipitation becomes groundwater recharge (USGS 1962). Precipitation falls occasionally as snow, but only in slight amounts and with little or no accumulation (Consoer, Townsend, & Assoc. 1977).

4.1 TOPOGRAPHY AND LAND FORMS

4.1.1 Topography

Figure 4-1 shows the topography and hydrologic soil groups of the Clover Creek basin. Topography in the basin consists of level flatlands in the lower portion of the basin and gently rolling hills and flatlands in the uplands (Montgomery 1991). Elevations in the basin range from approximately 210 feet at Lake Steilacoom to 600 feet in the eastern uplands. The terrain was formed as the result of glacial deposition or erosion. Distinct channels cut through the area by high-velocity glacial meltwater streams include the Clover Creek channel. Such channels often are lined by steep slopes or bluffs. The Clover Creek channel starts near Puyallup's South Hill on the northeast boundary of the basin and runs southwest to the Brookdale and Canyon Road area and into the current floodplain of Clover Creek. (Pierce County 1997)

4.1.2 Planning Units

The first step in basin planning is to divide the basin into manageably sized planning units for analysis. The appropriate size of the planning units depends on the types of analyses to be performed for the basin plan. For the Clover Creek Basin Plan, the following analyses were conducted:

- Determination of the existing percentage of impervious surface
- Stream assessment and biological assessment
- Hydrologic analysis of Clover Creek and its tributaries
- Analysis of future land use as it relates to water quality
- Total maximum daily load (TMDL) analysis.

Table 4-1 summarizes appropriate watershed planning unit sizes as defined in *Rapid Watershed Planning Handbook* (Center for Watershed Protection, 1998). The handbook recommends that a planning unit be divided for analysis into units the size of the next smaller unit. Under the handbook's definitions by size, the Clover Creek Basin should be divided into units of 1 to 10 square miles (or 640 to 6,400 acres). Drainage characteristics of these units, called subwatersheds in the handbook, are strongly influenced by the amount of impervious surface; and measures to classify and manage their streams are appropriate approaches for management of the planning unit.

TABLE 4-1.
DESCRIPTION OF WATERSHED MANAGEMENT UNITS

Watershed Planning Unit	Typical Area (square miles)	Influence of Impervious Cover	Sample Management Measures
Catchment	0.05 to 0.50	Very strong	Best management practices and site design
Subwatershed	1 to 10	Strong	Stream classification and management
Watershed	10 to 100	Moderate	Watershed-based zoning
Subbasin	100 to 1,000	Weak	Basin planning
Basin	1,000 to 10,000	Very weak	Basin planning

These features make the size of the subwatershed the best choice for division of the Clover Creek Basin into planning units. Although this is the size of the units that is used for this study, the handbook's nomenclature is not being used; to be consistent with other Pierce County planning efforts, Clover Creek's total drainage area is referred to as a basin and the planning units are referred to as subbasins.

Subbasin Planning Units

Two resources were used to aid in the delineation of the Clover Creek Basin: *Pierce County Storm Drainage and Surface Water Management Plan* (James M. Montgomery, 1991) and *Surface Water Hydrology and Runoff Simulations for Three Basins in Pierce County,*

fig 4-1 and 4-15.apr February 2005

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Figure 4-1
Topography and Soils

Washington (U.S. Geological Survey, 1996). Both studies include a hydrologic analysis and detailed delineation of the Clover Creek Basin. The computer modeling and analysis conducted for the Montgomery report accounted only for surface water runoff. The hydrologic modeling for the USGS study accounted for both groundwater and surface water. Both reports delineated basins and subbasins based on 5-foot contour intervals, which was the best available topographical information at the time.

New subbasin delineations were developed for the Clover Creek Basin Plan based on recently developed 2-foot contour data, using the delineations from the previous studies as guidelines. Since the Clover Creek Basin Plan initially focused on surface hydrology and land uses, the subbasin delineations were based strictly on surface topography. Later phases of the planning incorporated the effect of groundwater contributions to the creek system.

Five major subbasins were delineated in the Clover Creek Basin, each tributary to one of the major water bodies in the basin. The five major subbasins, shown in Figure 4-2, are Lake Steilacoom, Lower Clover Creek, Spanaway Creek, North Fork Clover Creek, and Upper Clover Creek. This is consistent with previous Clover Creek studies.

The major subbasins were further divided into 31 minor subbasins using the 2-foot contour data. Where 2-foot contour information was not available, subbasin delineations were estimated using delineations from the Montgomery report and USGS reports. Figure 4-2 shows the 31 subbasins, and Table 4-2 lists the area of each.

Although not tributary to the Clover Creek watershed, the Wards Lake subbasin to the north has also been incorporated into this plan. This subbasin was included in the Clover Creek Basin Plan for convenience because of its location adjacent to the Clover Creek basin, and because numerous flooding and drainage issues exist within the area. The focus of the work on the Wards Lake subbasin was limited solely to the analysis of previously identified flooding and drainage issues and selection of appropriate solutions to resolve these issues. This work did not include delineation of subbasin boundaries for this basin.

The five major Clover Creek subbasins and the Wards Lake subbasin are described below.

Lake Steilacoom Subbasin

The Lake Steilacoom Subbasin includes 5.9 square miles of the Clover Creek Basin, and is located at the most downstream end of the Clover Creek system. The subbasin is bounded by I-5 on the east and by other small drainages that empty into Lake Steilacoom. It is entirely within the jurisdiction of the City of Lakewood. Lake Steilacoom is the receiving water body for Clover Creek and Ponce De Leon Creek.

TABLE 4-2.
CLOVER CREEK SUBBASINS

Subbasin Identification	Area (sq. miles)	Subbasin Identification	Area (sq. miles)
Lake Steilacoom		**Lower Clover Creek**	
SL-1	3.98	LCC-1	0.73
SL-2	1.95	LCC-2	3.35

Spanaway Creek		LCC-3	0.77
SC-1	0.56	LCC-4	2.64
SC-2	0.41	LCC-5	0.96
SC-3	3.45	**Upper Clover Creek**	
SC-4	5.92	UCC-1	2.23
SC-5	14.92	UCC-2	0.88
SC-6	0.33	UCC-3	1.79
North Fork Clover Creek		UCC-4	2.46
NF-1	1.14	UCC-5	0.35
NF-2	1.06	UCC-6	2.27
NF-3	0.44	UCC-7	0.93
NF-4	1.15	UCC-8	1.77
NF-5	0.43	UCC-9	0.16
NF-6	2.09	UCC-10	9.61
		UCC-11	2.16
		UCC-12	3.14

Lower Clover Creek Subbasin

The Lower Clover Creek Subbasin encompasses 8.5 square miles of the Clover Creek Basin, and includes the portion of the basin that contributes surface runoff to the reach of Clover Creek that is bounded by I-5 and the confluence. The western portion of the Lower Clover Creek subbasin is urban/industrial in character, with McChord Air Force Base and other commercial/high density residential land uses predominating. The eastern portion of the subbasin is more rural, with low to medium density residential land uses prevailing.

Much of Clover Creek has been extensively modified throughout the Lower Clover Creek subbasin. The most dramatic example of this is the set of twin 12-foot-diameter corrugated metal pipe (CMP) culverts that convey Clover Creek under the airport runways on McChord Air Force Base. Each of the culverts is 2,500 feet long, and they were constructed in 1939. Other channel modifications include relocation of the creek to a constructed channel, and channelization and asphalt lining of several sections during the 1960s. A segment of the bypass channel is shown in Photo 4-1.

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Figure 4-2
Subbasin Delineation

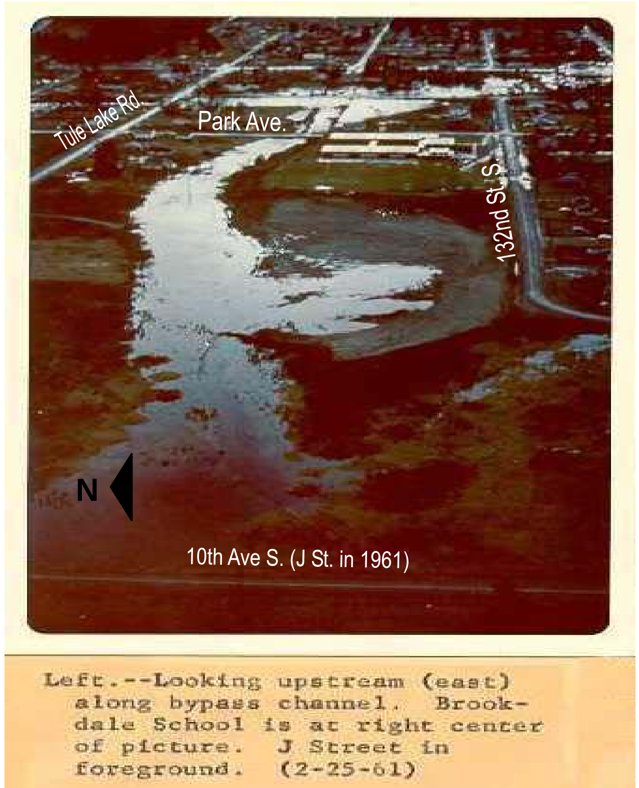

Photo 4-1. Bypass channel near Brookdale School

Spanaway Creek Subbasin

The Spanaway Creek subbasin includes 25.6 square miles of the Clover Creek Basin, and is located in the southwestern portion of the basin. The surface drainage system consists of a number of small streams, including Coffee Creek, which feed into Spanaway Lake. There is no formal outlet control for Spanaway Lake. However, there is an in-stream weir structure approximately 2,200 feet downstream of the lake outlet that is maintained by the Washington Department of Fish and Wildlife. This in-stream structure has been identified as a barrier to fish migration. Habitat upstream and downstream of the weir is generally good. Much of the riparian canopy has been preserved in Bressmann Forest which provides abundant shade and habitat for terrestrial species. Spanaway Creek splits into Morey Creek and Spanaway Creek approximately a mile below the lake; the uncontrolled flow split results in approximately 60 percent of the flow going down Spanaway Creek and 40 percent following Morey Creek. Both Spanaway Creek and Morey Creek are tributary to the main stem of Clover Creek, downstream of Spanaway Loop Road.

The groundwater component of the hydrologic system is significant in the Spanaway Creek subbasin. The soils are very permeable, and most of the upper portion of the subbasin does not have a well-defined drainage system, as most precipitation percolates into the groundwater. Numerous potholes mark the land surface; many of these fill with groundwater during wet periods. Groundwater flow direction is generally from the southeast to the northwest.

Intense development in the subbasin is clustered along Pacific Avenue, a north-south arterial just east of Spanaway Lake. Aside from this commercial corridor, development and zoning are primarily moderate-density single-family development.

North Fork Clover Creek Subbasin

The North Fork Clover Creek Subbasin includes 6.3 square miles of the Clover Creek Basin and is located in the north central portion of the basin. Surface runoff from the North Fork Subbasin is conveyed to Lake Steilacoom by means of the North Fork Clover Creek and its six tributaries.

The main stem of the North Fork of Clover Creek conveys surface and subsurface runoff from the north central portion of the subbasin, in the vicinity of the communities of Midland and Parkland. It originates in the vicinity of 97th Street East and McKinley Avenue East, and flows south for approximately 3 miles through a series of deep channelized, county drainage ditches that flow intermittently. At approximately 128th Street East, the main stem enters a steep sloping ravine to the floor of the Clover Creek valley at Brookdale Road. From there, it flows west through the urbanizing residential areas of Parkland to its confluence with the main stem of Clover Creek. Except for the perennial channel in the ravine, the main stem of the North Fork and the six associated tributary channels are all intermittent.

Upper Clover Creek Subbasin

The Upper Clover Creek Subbasin includes 27.8 square miles of the Clover Creek Basin, and is the largest of the five subbasins. Approximately 6.8 miles of the main stem of Clover Creek meanders through this subbasin, from approximately 160th Street East to the confluence with the North Fork. The 6.8 mile reach of the main stem is a spring-fed system, with the headwaters located near the community of Frederickson at 160th Street East. Numerous freshwater springs along the reach provide a connection between the shallow groundwater aquifer and Clover Creek. The entire 6.8 mile reach still possesses an active floodplain, and includes some of the best fish habitat in the basin.

Between the confluence and the Brookdale Golf course, the channel has undergone man-made alterations, the most significant of which was the rechanneling of the reach of the creek between 138th Street East and Brookdale Golf Course. This action was taken prior to 1940 and resulted in two parallel channels that were initially used for hop farm irrigation. Upstream of the Brookdale Golf Course, the creek has not undergone any significant man-made alterations.

As is the case in the Spanaway Creek subbasin, the groundwater component in the Upper Clover Creek Subbasin hydrologic system contributes significantly to the creek system. The soils are very permeable, and most of the upper portion of the subbasin does not have a well-defined drainage system, as most of the precipitation percolates into the groundwater. Numerous potholes mark the land surface; many of these fill with groundwater during wet periods. Groundwater flow direction is generally from the southeast toward the northwest.

Wards Lake Subbasin

The Wards Lake Subbasin is an area of unincorporated Pierce County between the Clover Creek Basin and the Tacoma City limits. The major surface water body is the Parkland Ditch, which runs northwest through the area, ending at Hosmer Holding Pond. The drainage system in this basin is primarily open ditch with culverts under roadways and driveways. The terrain draining to Parkland Ditch is very flat, which has played a key role in drainage problems tributary to the ditch. Recently the County constructed drainage improvements along 107th Street South, 5th Avenue South, and 106th Street South tributary to the ditch. The County also recently completed a drainage inventory for the subbasin. Zoning in this basin is primarily moderate density residential, with the exception of the Pacific Avenue corridor, which is zoned for commercial and high density residential uses.

Stream Reach Planning Units

Dividing a stream into reaches provides a structure for recording stream habitat information and for prioritizing improvement projects. For the Clover Creek Basin Plan, the following portions of the Clover Creek system were divided into reaches as the first step in a stream assessment:

- **Main Stem of Clover Creek** from **Lake Steilacoom** to the headwaters in the vicinity of 144th Street East and 86th Avenue East.
- **North Fork of Clover Creek** from the confluence with the Main Stem to the E-1 detention pond at 132nd Street East and Waller Road East.
- **North Fork Tributary No. 5** from the confluence with the North Fork to Aqueduct Road East.
- **Morey Creek** from the confluence with the Main Stem to the confluence with Spanaway Creek.
- **Spanaway Creek** from the confluence with the Main Stem to Spanaway Lake.

Stream reaches were defined as segments of streams with uniform hydraulic characteristics such as channel gradient, width, and alignment. Stream reaches with uniform hydraulic characteristics generally have uniform fish habitat features. Primary resources for the delineation were the 1990 FEMA creek profiles and topography and hydrography data from the Pierce County Geographic Information System (GIS). Photographs from previous site visits to the creek were also used to visually assess fish habitat characteristics and features.

A field survey was conducted to refine the stream reach delineations and verify that the stream reaches had uniform fish habitat characteristics. Fish passage barriers were noted, and reach delineations were modified to include the barriers as downstream endpoints. Delineated reaches were combined when appropriate. Figure 4-3 shows the preliminary upstream and downstream reach boundaries.

The Washington Department of Natural Resources' (DNR) classification system for water bodies in forested regions (Washington Administrative Code Section 222-16-030) was applied to the stream reaches. The DNR stream types are as follows:

- Type 1—Waters defined as "shorelines of the state" within their ordinary high water mark
- Type 2—Segments of perennially flowing natural waters that have a high fish, wildlife, or human use.
- Type 3—Segments of perennially flowing natural waters that have a moderate fish, wildlife, or human use.
- Type 4—Perennially or intermittently flowing natural waters more than 2 feet wide between the ordinary high water marks and generally without significant fish, wildlife, or human uses.

- Type 5—All other natural waters, including streams with or without well-defined channels, areas of perennial or intermittent seepage, ponds, natural sinks, and drainageways with short periods of spring or storm runoff.

A key parameter in determining the DNR stream type is whether a stream reach is perennial or intermittent. The document*, Intermittent Flow on Clover Creek: Causes and Possible Solutions (Ecology, 1986)* was used as a reference in making this assessment for each reach. Nearly half of the stream reaches in the Clover Creek system are classified as Type 4 streams because they have intermittent flow. Table 4-3 lists the stream reaches, their DNR classification, and their boundaries.

4.2 LAND USE

Land use is a major factor affecting a basin's water quality. Forested land produces the lowest rate of pollutant loadings. Agricultural lands contribute the highest rates of nutrient loadings and may contribute high sediment levels but have low rates of other pollutants. Urban or developed land uses produce high pollutant loadings.

Existing land use information provides a picture of the types of activities and sources of pollution currently occurring in an area. Future land use data indicate potential sources of nonpoint pollution to local water bodies as future development occurs. These projections help identify future threats to the overall health of the area, including the health of aquatic habitat and groundwater.

The Clover Creek Basin is a developing basin with concentrations of urban development to the north and west and along major transportation corridors. The basin includes portions of the Cities of Lakewood and Tacoma. Unincorporated communities in the basin include Lakeview, Parkland, Midland, Summit, Brookdale, Spanaway, Frederickson, Elk Plain, and north Graham. McChord Air Force Base and the Fort Lewis Military reservation cover a large portion of the southwestern part of the basin.

TABLE 4-3.
STREAM REACH BOUNDARIES AND DNR CLASSIFICATION

Stream Reach Identifier	Length (feet)	Upstream Boundary	Downstream Boundary	DNR Stream Type	Comments
Main Stem Clover Creek					
MS1	2,150	Gravelly Lake Road	Lake Steilacoom	3	—
MS2	6,460	Bridgeport Way SW	Gravelly Lake Road	3	—
MS3	10,800	Confluence with Spanaway Creek	Bridgeport Way SW	3	Large populations of resident cutthroat have been identified in this reach
MS4	7,040	C Street South	Confluence with Spanaway Creek	4	Asphalt-lined creek bottom; Intermittent stream reach
MS5	2,320	Confluence with North Fork	C Street South	4	Intermittent stream reach
MS6	1,480	138th Street East	Confluence with	4	Intermittent stream reach

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Figure 4-3
Stream Reach Delineation

			North Fork		
MS7	4,900	12th Avenue East	138th Street East	3	Resident trout have been identified in this reach
MS8	4,640	25th Avenue East	12th Avenue East	3	—
MS9	11,890	Military Road East	25th Avenue East	3	Large populations of resident cutthroat have been identified in this reach
MS10	7,900	Southern extension of 62nd Avenue East	Military Road East	3	Coho salmon have returned as far upstream as 49th Street East. Not included in the habitat evaluation.
MS11	5,490	160th Street East	Southern extension of 62nd Avenue East	4	Not included in the habitat evaluation
MS12	3,570	156th Street East	160th Street East	4	Not included in the habitat evaluation
MS13	4,270	134th Street Court East	156th Street East	4	Not included in the habitat evaluation
North Fork Clover Creek					
NF1	2,320	McKinley Avenue East	Confluence with the Main Stem	4	Intermittent stream reach
NF2	1,920	Golden Given Road East	McKinley Avenue East	4	Intermittent stream reach
NF3	1,040	Confluence with North Fork Tributary #5	Golden Given Road East	4	Intermittent stream reach
NF4	1,900	Brookdale Road East	Confluence with North Fork Tributary #5	4	Intermittent stream reach

TABLE 4-3 (continued).
STREAM REACH BOUNDARIES AND DNR CLASSIFICATION

Stream Reach Identifier	Length (feet)	Upstream Boundary	Downstream Boundary	DNR Stream Type	Comments
NF5	2,400	Waller Road East	Brookdale Road East	4	Brookdale Road culverts may prevent salmon migration into this reach; intermittent stream reach
NF6	1,600	30th Avenue East	Waller Road East	4	Waller Road culvert may prevent salmon migration into this reach; intermittent stream reach
NF7	3,040	132nd Street East	30th Avenue East	4	Intermittent stream reach not included in habitat evaluation
North Fork Tributary No. 5					
T1	3,220	128th Street East	Confluence with North Fork	3	Smolts have been spotted in this reach; intermittent stream reach. Not included in the habitat summary.
T2	2,400	122nd Street East	128th Street East	3	Smolts have been spotted in this reach; intermittent stream reach. Not included in the habitat summary.
T3	1,620	Aqueduct Drive East	122nd Street East	3	Intermittent stream reach. Not included in the habitat summary
Morey Creek					
M1	4,500	Confluence with Spanaway Creek	Confluence with Main Stem	2	Not included in the habitat summary
Spanaway Creek					
S1	1,300	Spanaway Loop Road South	Confluence with the Main Stem	3	—
S2	1,000	Outlet of Tule Lake	Spanaway Loop Road South	3	—
S3	3,200	138th Street South	Outlet of Tule Lake	3	—
S4	1,630	Confluence with Morey Creek	138th Street South	3	—
S5	2,350	Spillway	Confluence with Morey Creek	3	—
S6	2,500	Outlet of Spanaway Lake	Spillway	4	Existing spillway prevents upstream fish migration

4.2.1 Existing Land Use

Development Patterns

The northwestern portion of the basin is highly urban in areas near the City of Lakewood. Urban development is focused along the major transportation corridors of the basin, including 112th Avenue East, Canyon Road East, and Pacific Avenue. Beyond these main transportation routes, most land uses within the basin are residential. The density of residential development varies widely. The central portion of the basin, between Pacific Avenue and Canyon Road, supports the highest level of agricultural activities, mostly in the form of small farms, with concentrations of dense residential development.

Significant commercial and industrial developments include Lakewood Mall, Lakewood Industrial Park, and McChord Air Force Base. The junction of I-5 and Highway 512 is a central focus for development in the region. Commercial areas are clustered along main thoroughfares such as Pacific Highway, Pacific Avenue (State Route 7), and 112th Street. Clover Park Vocational College and Pacific Lutheran University are also in the basin. The Boeing Company established a major parts manufacturing complex in the central eastern portion of the basin in the community of Frederickson.

Public open space facilities include the Harry Sprinker Recreation Center, Spanaway County Park, and the Lake Spanaway Golf Course, all operated by the Pierce County Parks Department. The Brookdale Golf Club is a private golf course in the central portion of the basin.

Land cover assessments were conducted by other agencies in earlier studies where smaller basin areas were reported compared to the current study. The reported land cover percentages are descriptive of the general land use within the basin. The *Chambers-Clover Creek Watershed Characterization Report* (Pierce County, 1997) presented 1993 land cover data from the Puget Sound Regional Council. The data, obtained from satellite imaging, was used to distinguish between broad categories of land activities affecting water resources, such as agriculture, forest, urban development, and water. Thirteen classes of land cover originally developed from the satellite-generated images were consolidated into five land cover classifications, as listed in Table 4-4.

TABLE 4-4.
LAND COVER IN THE CLOVER CREEK BASIN

Land Cover Category	Area (acres)	Percentage of Total
Built Up	15,862	35.1
Agricultural	137	0.3
Forest Land	8,771	19.4
Other Natural Cover	19,875	44.0
Water	516	1.1
Total	**45,161**	**100.0**

Source: Pierce County, 1997, Puget Sound Regional Council

In 1991-92, the U.S. Geological Survey (USGS) conducted a land use study of the Clover Creek Basin for Pierce County Surface Water Management. The USGS study excluded Lake Steilacoom resulting in a total basin area of 42,400 acres. The study used aerial photographs and established nine land use classes. Table 4-5 summarizes the results of the USGS study, with land uses associated with low levels of impervious area listed first.

TABLE 4-5.
LAND USE DISTRIBUTION IN CLOVER CREEK BASIN

Land Use	Area (Acres)	Percent of Total
Forest	9,053	21.3
Grassland	6,804	16.0
Houses & Grassland (1 unit/2 to 5 acres grassland)	8,382	19.8
Houses & Forest (1 unit/2 to 5 acres of forest)	4,846	11.4
Suburban Development (1 to 4 units/acre)	4,727	11.2
Medium Development (1 unit/acre)	4,940	11.7
High Density Development (multifamily or >4 units/acre)	1,208	2.9
Commercial/Industrial/Transportation Facilities	2,061	4.9
Lakes	392	0.9
Total	**42,413**	**100.0**

Source: USGS, 1992

The two studies concluded that approximately one-third of the Clover Creek Basin is built up with residential, commercial, industrial, and other significant urban development. Much of the undeveloped land in the basin is to the east and south, and large tracts of land have been converted to other uses since the time of the USGS study. The future of undeveloped areas will be largely affected by local jurisdiction planning and regulation.

Impervious Surface Area Percentage

Human alteration of the landscape, including clearing, grading, paving, building construction, and landscaping, changes the physical and biological features that affect hydrologic processes. Soil compaction and paving reduce the infiltration and storage capacity of soils. When this occurs, a larger percentage of the precipitation that falls travels as surface runoff. Surface runoff accumulates and travels much faster than subsurface flow, and is rapidly transferred to conveyance systems and into streams. Impervious surfaces transfer water much faster than vegetated ground. A large increase in the percentage of surface runoff and impervious surfaces in a watershed causes significant increases in peak stream flows. Development also changes annual and seasonal runoff volumes. By quantifying the percentage of the basin that is covered with impervious surface, the rainfall-runoff relationship in a basin can be described.

As part of the new work for the Clover Creek Basin Plan, the percentage of surface covered with impervious surface (generally referred to as "percent impervious") was computed for each of the 31 subbasins using the ArcView GIS software program. The Pierce County Assessor's office provided a GIS data set of land use information. The GIS software was used to compute the land-use categories' percentage breakdown by area for each subbasin. Tables 4-6 through 4-10 show the results of this computation.

TABLE 4-6.
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—LAKE STEILACOOM SUBBASINS

	Percentage of Total Subbasin Area	
Land Use	SL-1	SL-2
Agricultural Land	–	–
College	0.1	0.1
College/Higher Education	–	7.3
Commercial	9.5	14.7
Communication	–	–
Elementary School	1.2	1.8
Fort Lewis	–	–
Group Home	–	–
High Density Residential	0.2	–
Industrial	0.3	13.0
Local Roads	–	0.1
Low Density Residential	47.5	17.3
Major Highway	–	0.2
McChord Air Force Base	–	–
Mobile Home	0.1	0.1
Multi-Family Residential	–	–
Open Space	6.4	11.9
Public Places	15.4	14.1
Quasi-Public Places	0.2	–
Religious Center	3.2	7.1
Resource Land	0.4	1.1
RV Park	0.3	4.8
Secondary School	1.6	–
Surface Water	10.2	–
Transportation	–	–
Unclear	0.5	0.4
Undefined	0.1	0.2
Unknown	2.1	3.9
Utilities	0.9	1.9

TABLE 4-7.
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—SPANAWAY CREEK SUBBASINS

	Percentage of Total Subbasin Area					
Land Use	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6
Agricultural Land	–	–	0.8	–	1.2	–
College/Higher Education	–	–	–	–	0.3	–
Commercial	–	–	1.1	–	2.4	–
Elementary School	–	–	–	–	0.1	–
Fort Lewis	–	–	–	96.2	27.4	–
High Density Residential	–	–	0.1	–	0.1	–
Industrial	–	–	0.1	0.2	0.3	–
Local Roads	–	–	0.2	–	0.1	–
Low Density Residential	58.2	43.1	50.6	1.3	28.4	39.7
Major Highway	–	–	–	–	–	0.2
Mobile Home	0.6	0.2	1.8	0.7	6.0	6.6
Open Space	14.8	26.8	15.9	1.2	12.4	21.6
Public Places	12.3	13.2	9.6	–	7.2	3.1
Religious Center	0.5	0.6	0.3	0.1	0.4	–
Resource Land	7.7	9.2	10.9	–	6.5	8.6
RV Park	3	0.0	2.8	–	1.5	–
Secondary School	–	–	3.6	–	0.9	–
Surface Water	–	–	–	–	2.6	–
Unclear	1.4	1.2	0.7	0.1	0.9	3.0
Undefined	0.3	0.1	0.1	0.1	0.1	14.4
Unknown	0.4	0.2	1.1	0.1	0.8	2.9
Utilities	0.6	5.3	0.3	–	0.3	–

TABLE 4-8.
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—
NORTH FORK CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area					
Land Use	NF-1	NF-2	NF-3	NF-4	NF-5	NF-6
Agricultural Land	0.7	–	–	–	–	–
Commercial	0.7	6.2	4	0.8	4.1	0.9
Communication	–	0.1	0.3	0.8	–	–
Elementary School	0.1	0.4	–	–	0.9	0.6
High Density Residential	–	0.1	–	–	–	–
Industrial	1.3	4.2	1	0.1	–	0.4
Local Roads		0.0	0.3	0.6	0.4	0.0
Low Density Residential	55.6	30.0	31	50.4	65	57.6
Major Highway	0.1	1.2	–	–	–	–
Mobile Home	2.5	3.0	1.2	4.8	1	5.3
Open Space	14.3	24.1	23.9	25	9.9	18.1
Public Places	18.5	17.6	16.8	8.3	11.8	7.1
Quasi-Public Places	–	–	–	0.1	–	0.1
Religious Center	1.9	1.1	6	–	–	0.2
Resource Land	0.7	0.4	7	5.3	3.2	4.8
RV Park	0.7	2.0	–	0.1	–	0.4
Secondary School	–	6.9	–	–	2.3	–
Unclear	1.7	1.3	3.2	1.8	–	3.3
Undefined	0.2	0.7	–	0.2	0.1	0.1
Unknown	0.5	0.6	5.3	1.8	1.2	0.5
Utilities	0.4	0.2	–	–	0.2	0.6

TABLE 4-9.
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—
LOWER CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area				
Land Use	LCC-1	LCC-2	LCC-3	LCC-4	LCC-5
College	–	–	–	0.0	–
College/Higher Education	–	–	–	3.0	3.2
Commercial	4.2	0.6	4.4	3.7	6
Communication	–	–	0.2	0.0	–
Elementary School	–	–	–	0.4	–
High Density Residential	0.5	–	0.1	0.1	–
Industrial	13.5	0.5	1.7	0.9	1.1
Local Roads	0.1	–	–	0.1	–
Low Density Residential	1.0	3.2	30.8	40.0	38.9
Major Highway	0.0	0.2	0	0.2	–
McChord Air Force Base	2.9	86.8	21.7	0.4	–
Mobile Home	0.1	0.1	0.1	–	0.4
Open Space	21.9	3.9	4.8	14.5	16.8
Public Places	31.0	1.2	20.9	24.0	12.3
Quasi-Public Places	–	–	–	0.2	0.2
Religious Center	6.3	1.8	8.3	5.1	14.2
Resource Land	1.6	0.5	–	3.6	2.6
RV Park	0.8	0.2	0.6	0.3	2
Secondary School	–	–	–	2.3	–
Unclear	0.5	0.2	1.7	0.5	1.3
Undefined	–	–	0.1	0.1	0.4
Unknown	12.7	0.6	2.8	0.3	0.8
Utilities	2.8	0.1	1.7	0.5	0.1

TABLE 4-10.
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—
UPPER CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area					
Land Use	UCC-1	UCC-2	UCC-3	UCC-4	UCC-5	UCC-6
Agricultural Land	–	–	0.3	1.5	–	0.3
Commercial	–	–	0.9	2.0	–	0.1
Communication	–	–	–	–	–	–
Elementary School	1.1	0.3	0.9	–	–	1.7
Industrial	–	0.4	0.2	1.2	–	–
Local Roads	0.1	0.1	–	0.1	–	0.3
Low Density Residential	55.4	52.0	45.9	54.1	19.0	47.9
Major Highway	–	–	–	–	–	0.2
Mobile Home	1.2	9.9	5.1	9.1	8.9	2.1
Open Space	23.2	25.0	21.6	20.3	60.7	27.1
Public Places	11.5	5.6	8.2	7.0	5.8	8.7
Religious Center	0.3	–	–	0.3	0.4	2.1
Resource Land	3.7	3.7	11.9	1.1	–	3.5
RV Park	1.2	–	0.4	0.5	1.6	–
Secondary School	–	–	–	–	–	0.3
Unclear	0.7	2.0	2.5	2.2	2.7	1.9
Undefined	–	0.5	–	0.1	–	0.2
Unknown	0.5	0.3	1.6	0.2	0.9	2.5
Utilities	1.2	0.2	0.4	0.3	–	1.1

TABLE 4-10 (continued).
DISTRIBUTION OF EXISTING LAND USE TYPES BY SUBBASIN—
UPPER CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area					
Land Use	UCC-7	UCC-8	UCC-9	UCC-10	UCC-11	UCC-12
Agricultural Land	0.4	–	–	1.3	4.9	1.2
College	0.8	–	–	–	–	–
Commercial	0.8	0.9	0.7	2.0	1.8	0.4
Elementary School	–	–	29.4	0.5	0.4	–
High Density Residential	–	0.7	–	–	–	–
Industrial	0.3	0.9	–	3.0	1.0	14.0
Local Roads	–	0.4	–	–	0.1	0.5
Low Density Residential	30.8	34.9	18.8	22.4	48.0	10.7
Major Highway	–	0.1	–	0.1	–	0.0
Mobile Home	9.8	13.6	–	11.3	6.2	7.9
Open Space	21.3	24.6	26.7	39.7	18.3	40.3
Public Places	10.5	6.6	11.9	4.9	5.5	8.3
Religious Center	–	0.4	–	–	1.5	–
Resource Land	14.5	6.5	5.1	3.5	8.5	8.6
RV Park	1.4	3.6	2.3	2.7	0.2	
Unclear	–	1.4	–	0.9	1.2	3.8
Undefined	0.5	0.3	–	0.2	–	–
Unknown	7.3	4.5	5.1	3.4	0.2	1.2
Utilities	1.7	0.5	–	4.2	2.3	3.0

The land use codes from the Assessor's office were grouped into more general categories outlined in *Guidance for Basin Planning* (Pierce County 2000). Tables 4-11 and 4-12 show the total and effective percent impervious values for each general land use type, as defined in the document. Knowing the amount of each existing land use type in each subbasin, and knowing the percent impervious value for each type, it was possible to directly compute the total percent impervious for each subbasin. The results are shown in Table 4-13.

TABLE 4-11.
EXISTING-CONDITION GENERAL LAND USE CATEGORIES AND ASSOCIATED TOTAL PERCENT-IMPERVIOUS VALUES

Land Use	Total Percent Impervious Value	Effective Percent Impervious Value
Low Density Residential	*See Table 4-12*	*See Table 4-12*
High Density Residential	44%	44%
Multi-Family Residential	50%	50%
Mobile Home	23%	18%
RV Park	55%	50%
Group Home	26%	21%
College	37%	30%
Secondary School	28%	30%
Elementary School	24%	30%
Religious Center	50%	50%
Public Places	47%	50%
Quasi-Public Places	79%	79%
Industrial	67%	84%
Commercial	83%	85%
Agricultural Land	4%	0%
Resource Land	5%	5%
Open Space	7%	5%
Roads	48%	47%
Surface Water	100%	100%

Source: Pierce County Water Programs, 2000

TABLE 4-12.
EXISTING-CONDITION LOW DENSITY RESIDENTIAL TOTAL PERCENT-IMPERVIOUS VALUES BY LOT SIZE

Lot Size (acres)	Total Percent Impervious Value
<0.25	35.0%
0.25-0.35	30.0%
0.35-0.45	35.0%
0.45-0.55	20.0%
0.55-0.65	19.0%
0.65-0.75	17.5%
0.75-0.85	16.0%
0.85-0.95	15.0%
0.95-1.10	14.0%
1.10-1.20	13.0%
1.20-1.40	12.0%
1.40-1.60	11.0%
1.60-1.80	10.0%
1.80-2.00	9.5%
2.00-2.50	8.5%
2.50-3.00	7.5%
3.00-3.50	7.0%
3.50-4.50	6.0%
4.50-6.00	5.0%
6.00-7.00	4.5%
7.00-9.00	4.0%
9.00-10.00	3.5%
10.00-14.00	3.0%
14.00-19.00	2.5%
19.00-35.00	2.0%
35.00-45.00	1.5%
45.00-100.00+	1.0

Source: Pierce County Water Programs, 2000

TABLE 4-13.
EXISTING TOTAL PERCENT IMPERVIOUS VALUES
FOR CLOVER CREEK SUBBASINS

Subbasin Identification	Percentage of Total Impervious Surface	Percentage of Effective Impervious Surface	Subbasin Identification	Percentage of Total Impervious Surface	Percentage of Effective Impervious Surface
Lake Steilacoom			**Lower Clover Creek**		
SL-1	41%	39%	LCC-1	34%	36%
SL-2	44%	45%	LCC-2	36%	29%
Spanaway Creek			LCC-3	28%	26%
SC-1	21%	18%	LCC-4	33%	30%
SC-2	21%	18%	LCC-5	31%	29%
SC-3	20%	17%	**Upper Clover Creek**		
SC-4	13%	5%	UCC-1	21%	18%
SC-5	18%	9%	UCC-2	13%	10%
SC-6	11%	39%	UCC-3	16%	13%
North Fork Clover Creek			UCC-4	16%	13%
NF-1	24%	21%	UCC-5	16%	13%
NF-2	29%	28%	UCC-6	18%	16%
NF-3	22%	21%	UCC-7	19%	17%
NF-4	15%	13%	UCC-8	20%	17%
NF-5	27%	23%	UCC-9	23%	23%
NF-6	14%	11%	UCC-10	18%	16%
			UCC-11	15%	12%
			UCC-12	23%	22%

4.2.2 Future Land Use

Development Patterns

The Pierce County Comprehensive Plan was developed and adopted in 1994 in response to the requirements of the Washington State Growth Management Act. The Comprehensive Plan, codified as Title 19A of the Pierce County Code, indicates a general intention to allow development to the basin boundary with residential densities ranging from one unit per 10 acres to six units per acre. A significant amount of acreage in the Frederickson area has been designated for industrial use.

The Pierce County Zoning Ordinance is codified in Title 18A of the Pierce County Code. Figure 4-4 shows the zoning of the Clover Creek Basin that was developed to implement the comprehensive planning process. Current zoning indicates that most of the central portions of the Clover Creek basin are to be Moderate Single Family, with densities of about four units per acre. The north central area is zoned Rural Separator (2.5 acres per dwelling unit), as a buffer between urban areas. Much of the southern portion of the basin is under the jurisdiction of the

Fort Lewis Military Reservation. The rest of the land is in rural or reserve zoning with low development densities (5 to 10 acres per dwelling unit). The western and northwestern areas are under the jurisdiction of McChord Air Force Base, the City of Lakewood, and the City of Tacoma. The pattern is one of gradual intensification of urban development in the vicinity of urban centers, and gradual intensification and infilling of residential lands in unincorporated areas.

The Growth Management Act provides goals and guidelines for development of growth management plans addressing urban growth. The Growth Management Act mandates consistency between county comprehensive plans and plans of all municipalities in the county. The Pierce County Comprehensive Plan provides county-wide policies in 11 policy areas in cooperation with all cities and towns in the County: affordable housing; agricultural lands; economic development; education; historic, archaeological and cultural preservation; natural resources; open space and protection of environmentally sensitive lands; siting of public capital facilities of a county-wide or state-wide nature; transportation facilities and strategies; urban growth areas; and amendments and transition. The Growth Management Act includes the following goals for development:

- Urban Growth—Encourage development in urban areas where adequate public facilities and services exist or can be provided in an efficient manner.
- Reduce Sprawl—Reduce the inappropriate conversion of undeveloped land into sprawling, low-density development

Pierce County has an additional goal of containing urban sprawl by designating an urban/rural boundary, and focusing infrastructure development in proposed employment centers and near cities and towns where a full range of urban services is available.

Community Planning Efforts

Four community-plan subareas are within the boundaries of the Clover Creek Basin; the Parkland-Spanaway-Midland (PSM) Community Plan Subarea, the South Hill Community Plan Subarea, the Graham Community Plan Subarea and the Frederickson Community Plan Subarea. The City of Lakewood was incorporated in 1996, and a portion of incorporated Lakewood is within the boundaries of the Clover Creek Basin. Figure 4-5 shows the boundaries of the two community planning subareas and the city limits of the City of Lakewood relative to the Clover Creek Basin boundaries.

The community planning process uses the existing County Comprehensive Plan as a foundation and allows citizens to make specific recommendations regarding such things as environmental protection, infrastructure development, transportation, housing densities, and land use patterns; all things that can directly affect surface water and groundwater resources. The community plans for the Parkland-Spanaway-Midland, South Hill, and Frederickson communities will be finalized and adopted within the next few years. Details of how the Clover Creek Basin Plan will incorporate the findings of these community plans are outlined in Chapter 2.

The Parkland-Spanaway-Midland Community Plan Subarea covers approximately 15,000 acres (23.5 square miles), mostly within the boundaries of the Clover Creek Basin. The community plan is being developed by local citizens and Pierce County, and a final document is expected to be adopted by the Pierce County Council by early 2002. The plan goals include the following:

Tetra Tech / KCM
1917 First Avenue
Seattle, Washington 98101

PIERCE COUNTY

Pierce County
Clover Creek Basin Plan

Figure 4-4
Zoning

Tetra Tech / KCM
1917 First Avenue
Seattle, Washington 98101

PIERCE COUNTY

Pierce County
Clover Creek Basin Plan

Figure 4-5
Community Planning Areas

- Develop an area-wide vision for the Parkland-Spanaway-Midland region.
- Develop an area-wide vision for each individual community.
- Develop policies and actions that reflect the needs, concerns, and desires of the region and communities today.
- Make sure that the actions developed by each of the communities mesh with the vision and policies for the entire area and the other two communities.
- Refine the Pierce County Comprehensive Plan to more closely reflect the desires of the communities while making sure that what the communities desire will fit with the "big picture" for all of Pierce County.
- Identify actions necessary to implement the community plan, including adopting or revising land use regulations and identifying priorities for use of public funds to develop physical improvements.

The Frederickson Community Plan Subarea covers 7,532 acres (11.8 square miles) and is entirely within the Clover Creek Basin. Approximately 44 percent (3,300 acres) of the plan area is undeveloped. Future land use in the subarea is expected to be 62 percent residential, 37 percent employment, and 1 percent commercial. A 16-member Community Planning Board has been established to draft the Frederickson Community Plan, and it is expected that the plan will be completed by the end of 2002 (Pierce County Web Site).

The South Hill Community Plan Subarea covers 13,316 acres (20.8 square miles) and covers the northeast portion of the Clover Creek Basin. Future land use in the subarea is expected to be 66 percent residential, 8 percent employment, 8 percent commercial and 18 percent planned community. A 16-member Community Planning Board has been established to draft the South Hill Community Plan, and it is expected that the plan will be completed by the end of 2002 (Pierce County Web Site).

The Graham Community Plan Subarea covers the southern portion of the Clover Creek basin. The planning process began in August of 2001 and expected to take about two years to complete (Pierce County Web Site).

The City of Lakewood Comprehensive Plan, required by the Washington State Growth Management Act, was adopted in 2000. Lakewood's Comprehensive Plan provides a policy structure to guide decisions facing the community as it grows over the next 20 years. Many of the goals and policies identified in the City's Comprehensive Plan will have a direct effect on water bodies within the Clover Basin, and as such, the City of Lakewood is a key participant in the basin planning process. The Comprehensive Plan contains several policies that focus on the restoration of aquatic habitat and water quality in Clover Creek.

Future Percent Impervious

The future percent impervious values for the 31 subbasins in the Clover Creek Basin were computed using the ArcView GIS software program, with the assumption that the basin would be fully developed according to the County's current zoning plan and the City of Lakewood's zoning plan.

Percent-impervious values were assigned to the future-conditions zoning categories for the Clover Creek Basin, based on the Pierce County GIS zoning layer and the City of Lakewood

GIS zoning layer. Table 4-14 lists the land use categories and their associated percent-impervious values, as developed from the Pierce County and City of Lakewood comprehensive plans and Appendix F of the *Guidance for Basin Planning* (Pierce County Water Programs, 2000).

TABLE 4-14.
FUTURE-CONDITION GENERAL LAND USE CATEGORIES AND ASSOCIATED EFFECTIVE PERCENT-IMPERVIOUS VALUES

Land Use	Effective Percent Impervious (%)
Pierce County Zoning	
Mixed Use District	85
Moderate Density Single Family	40
High Density Residential	55
Activity Center	50
Agriculture	5
Employment Based Planned Community	45
Master Planned Community	40
Rural Neighborhood Center	35
Rural Activity Center	55
Reserve 10	6
Rural 5	6
Community Center	50
Rural Separator	8
Employment Center	75
Fort Lewis	5
City of Lakewood Zoning	
Open Space/Recreation	5
Moderate Density Single Family Residential	40
High Density Residential	55
Mixed Use District	85
Major Urban Center	80
Employment Center	90
Office and Limited Business – 1	55
Office and Limited Business – 2	55
Open Water	100

Tables 4-15 through 4-19 show the percentage breakdown by area for the land use categories in each subbasin. City of Lakewood zoning categories are shown only for the Lake Steilacoom and Lower Clover Creek subbasins because no other subbasins have area within the Lakewood city limits; the Lake Steilacoom subbasins are completely within the City of Lakewood, so no Pierce County land use is shown for them. The overall effective percent-impervious values for each subbasin are shown in Table 4-20. Total impervious percentages are not given for future land use as the County's development codes and standards related to surface water management are based on effective impervious area.

TABLE 4-15.
DISTRIBUTION OF FUTURE LAND USE TYPES BY SUBBASIN—LAKE STEILACOOM SUBBASINS

Land Use	Percentage of Total Subbasin Area SL-1	SL-2
City of Lakewood Zoning		
Employment Center	0.1	37.1
High Density Residential	–	–
Major Urban Center	17.0	22.6
Mixed Use District	7.0	18.7
Moderate Density Single Family Residential	63.7	17.5
Office and Limited Business – 1	–	0.2
Office and Limited Business – 2	–	–
Open Space/Recreation	0.2	3.9
Water	12.0	–

TABLE 4-16.
DISTRIBUTION OF FUTURE LAND USE TYPES BY SUBBASIN—SPANAWAY CREEK SUBBASINS

Land Use	Percentage of Total Subbasin Area SC-1	SC-2	SC-3	SC-4	SC-5	SC-6
Pierce County Zoning						
Agriculture	–	–	–	–	0.7	–
Activity Center	–	9.2	1.0	–	–	–
McChord Air Force Base	–	–	–	–	0.2	–
Community Center	–	–	–	–	1.3	–
Employment Center	0.3	–	–	–	2.1	14.2
Fort Lewis	–	–	–	95.4	34.6	–
High Density Residential	–	–	4.2	–	0.2	–
Lakewood	–	–	–	–	0.7	–
Moderate Density Single Family	99.7	90.2	92.3	4.6	24.7	85.8
Mixed Use District	–	0.6	2.5	–	6.8	–
Rural 5	–	–	–	–	2.9	–
Rural Neighborhood Center	–	–	–	–	0.1	–
Reserve 10	–	–	–	–	25.6	–

TABLE 4-17.
DISTRIBUTION OF FUTURE LAND USE TYPES BY SUBBASIN—
NORTH FORK CLOVER CREEK SUBBASINS

Land Use	Percentage of Total Subbasin Area NF-1	NF-2	NF-3	NF-4	NF-5	NF-6
Pierce County Zoning						
Agriculture	–	–	–	2.5	–	1

Community Center	–	–	–	–	–	0.6
High Density Residential	–	–	–	–	–	0.2
City of Lakewood Zoning						
Moderate Density Single Family	97.3	47.1	65.2	2.6	89.7	3.5
Mixed Use District	2.7	41.2	30.3	1.7	–	0.1
Rural Separator	–	11.6	4.5	93.2	10.3	94.4

TABLE 4-18.
DISTRIBUTION OF FUTURE LAND USE TYPES BY SUBBASIN—
UPPER CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area					
Land Use	UCC-1	UCC-2	UCC-3	UCC-4	UCC-5	UCC-6
Pierce County Zoning						
Agriculture	0.9	1.8	–	–	–	–
Employment Center	–	–	18.1	–	69.2	–
High Density Residential	–	–	–	–	–	0.6
Master Planned Community	–	–	–	–	–	8.0
Moderate Density Single Family	92.7	0.8	65.4	63.0	27.7	91.4
Mixed Use District	0.2	0.2	6.5	24.8	3.1	–
Rural Separator	6.2	97.2	10.1	12.2	–	–
Employment Based Planned Community	–	–	–	9.7	–	–
Employment Center	–	–	12.4	17.2	19.1	79.8
High Density Residential	–	12.4	–	0.7	0.1	–
Master Planned Community	32.3	9.4	87.6	5.8	–	–
Moderate Density Single Family	67.7	78.3	–	36.7	80.7	20.0
Mixed Use District	–	–	–	9.2	0.1	–
Rural 5	–	–	–	6.4	–	–
Rural Activity Center	–	–	–	0.4	–	–
Reserve 10	–	–	–	14.0	–	0.2

TABLE 4-19.
DISTRIBUTION OF FUTURE LAND USE TYPES BY AREA—
LOWER CLOVER CREEK SUBBASINS

	Percentage of Total Subbasin Area				
Land Use	LCC-1	LCC-2	LCC-3	LCC-4	LCC-5
Pierce County Zoning					
Activity Center	–	–	–	4.3	15.3
Employment Center*	17.7	88.1	21.2	9.0	–
Moderate Density Single Family	–	3.6	–	78.9	58.0
Mixed Use District	7.3	–	–	7.5	26.7
City of Lakewood Zoning					
Employment Center	72.5	0.9	–	–	–
High Density Residential	–	7.2	23.2	–	–
Major Urban Center	–	–	3.1	–	–
Mixed Use District	2.6	0.1	15.8	–	–
Moderate Density Single Family Residential	–	–	34.9	–	–
Office and Limited Business – 1	–	–	0.7	–	–
Office and Limited Business – 2	–	–	1.1	–	–
Water	–	0.1	0.1	–	–

* Includes McChord Air Force Base

TABLE 4-20.
FUTURE EFFECTIVE PERCENT IMPERVIOUS VALUES
FOR CLOVER CREEK SUBBASINS

Subbasin Identification	Percentage of Impervious Surface (%)	Subbasin Identification	Percentage of Impervious Surface (%)
Lake Steilacoom		**Lower Clover Creek**	
SL-1	57	LCC-1	87
SL-2	75	LCC-2	73
Spanaway Lake		LCC-3	60
SC-1	40	LCC-4	47
SC-2	41	LCC-5	54
SC-3	42	**Upper Clover Creek**	
SC-4	49	UCC-1	38
SC-5	38	UCC-2	8
SC-6	45	UCC-3	46
North Fork Clover Creek		UCC-4	47
NF-1	41	UCC-5	66
NF-2	55	UCC-6	40
NF-3	68	UCC-7	43
NF-4	10	UCC-8	47
NF-5	37	UCC-9	34
NF-6	10	UCC-10	44
		UCC-11	47
		UCC-12	68

4.2.3 Population

Pierce County has experienced substantial growth recently and is expected to support more growth over the next 20 years. From a 1980 population of 485,667, Pierce County grew by 21 percent to 586,203 in 1990, and then by another 21 percent to an estimated 707,745 in 2000. The County population is expected to increase another 20 percent, to 850,483, by 2020.

Population growth in Pierce County has historically spread from city centers outward to rural areas. U.S. Census Bureau figures indicate that in 1920, 23 percent of Pierce County's population lived in unincorporated areas. By 1990, census data indicated that 57 percent of the County's population lived in unincorporated areas. During the 1980s, 84 percent of population growth occurred in unincorporated areas. Incorporation and annexation has shifted some of the County's population from unincorporated areas to new cities (Pierce County 1997).

Figure 4-6 compares the population projections for the Clover Creek Basin to those for the rest of Pierce County. The estimated 2000 population in the Clover Creek Basin is about 96,000 and represents about 14 percent of the total County population of 707,745. The population in the Clover Creek Basin is projected to increase by about 19,000, to 115,000, over the next 20 years and is expected to stay in proportion to the overall Pierce County population (Pierce County 1997).

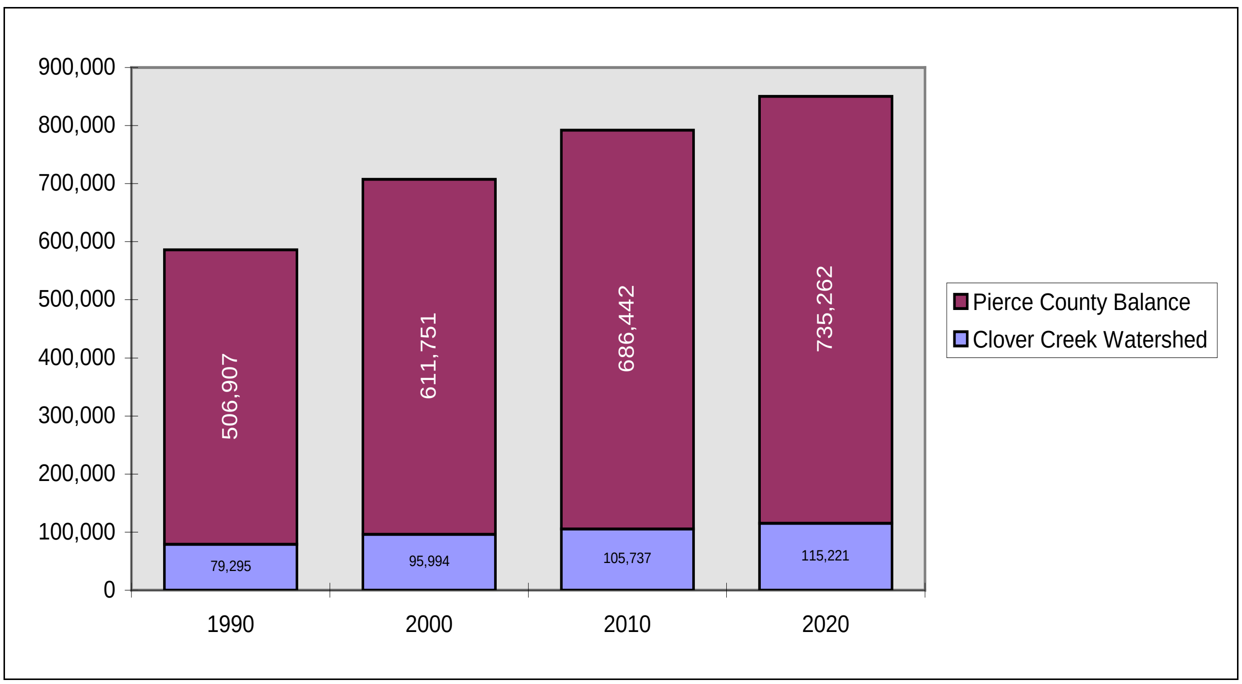

Figure 4-6. Population Trends in the Clover Creek Basin

4.3 SOILS

The Clover Creek basin geology is the result of sedimentation, folding, volcanic activity and glacial advances and retreats. Glacial activity from 2.5 million to 11,000 years ago resulted in glacial scour, till (a layer of soil formed by glacial compression, often referred to as hardpan, which is impermeable with the presence of clay or fines) and outwash (rocks and soil deposited by advancing and retreating glaciers). Layers of glacial outwash and till are the most significant glacial structures in the Clover Creek area.

Significant amounts of medium-size rounded rocks in soils often indicate glacial outwash and very well drained soil. The presence of till and gravel can form aquifers and lenses where water can move horizontally but has limited or no vertical mobility. The Clover Creek Basin has areas where lack of clay content has resulted in permeable till layers. Because the area has experienced a number of glacial events, several alternating layers of till and outwash of varying depths form the geologic structure of the basin (Brown & Caldwell 1985).

Associations are groups of soil series commonly found in the same region. The principal associations in the Clover Creek Basin are the Alderwood-Everett association, which is typically found in the eastern portion of the basin, the Kapowsin association, which is typically found in the northern portion of the basin, especially in the North Fork tributary, and the Spanaway association, typically found in the southwestern and western portions of the basin (KCM 1996).

The Alderwood-Everett association consists primarily of Alderwood gravelly sandy loam and Everett gravelly sandy loam. Moderately well drained Alderwood soils are underlain at depths of a few feet by glacial till, which restricts the downward movement of water and causes the formation of perched, seasonal water tables. The somewhat excessively drained Everett soils are formed in loose, gravelly and sandy glacial outwash deposits (KCM 1996).

The Kapowsin association consists primarily of Kapowsin gravelly loam, a moderately well drained soil formed, like the Alderwood soils, in glacial till. The association also contains incursions of Alderwood gravelly sandy loam, and several types of poorly drained hydric soils that normally support wetlands, including Tish silt, Dupont muck, McKenna gravelly loam, and Bellingham silt loam (KCM 1996).

The Spanaway association is composed mainly of Spanaway gravelly sandy loam, a somewhat excessively drained soil formed in very coarse sandy and gravelly outwash. The association also includes areas of Alderwood and Kapowsin soils, as well as a poorly drained hydric soil, Spana loam, which occupies much of the floodplain of Clover Creek and its tributaries. Together with Dupont muck, Spana loam serves as a substrate for many of the creek system's extensive wetlands (KCM 1996).

The southern and eastern portions of the Clover Creek Basin are characterized by somewhat excessively drained soils. Pollutants released from development in this area probably enter groundwater rather than surface water. However it is not certain how much of the pollutant load that infiltrates into the ground is captured by binding to soil particles. This is of particular concern because the well-drained soils overlie the Chambers/Clover Creek aquifer, the source of drinking water for more than 168,000 people (KCM 1996).

Hydrologic soil group classifications are often used in hydrologic analysis to compute surface runoff. The four basic hydrologic soil groups are described as follows:

Group A: deep sand; deep loess; aggregated silts; characterized by rapid infiltration

Group B: shallow loess; sandy loam; characterized by moderate infiltration rates

Group C: clay loams; shallow sandy loams; soils low in organic content; soils usually high in clay; characterized by moderate to slow infiltration rates

Group D: soils that swell significantly when wet; heavy plastic clays; certain saline soils; characterized by slow infiltration rates.

Hydrologic soil group classifications in the Clover Creek basin are shown in Figure 4-1. Coarse sandy till soils, such as the Spanaway soils, are classified as Hydrologic soil group A, and are found in much of the basin. Alderwood soils are classified in hydrologic soil group C. The North Fork subbasin and isolated outcroppings in the Upper Clover Creek subbasin, where Kapowsin and Alderwood soils dominate, have less pervious soils belonging to hydrologic soil groups D and C, respectively.

Stormwater infiltration systems work well where infiltration rates are high. In addition the quantity of overland runoff is reduced by subsurface infiltration, which reduces sizing requirements for stormwater facilities. As this applies to the majority of the Clover Creek basin, stormwater infiltration techniques are widely applied. As shown in Figure 4-1, soils with slower infiltration rates (hydrologic soil groups C and D) are located in isolated outcroppings in the Upper Clover Creek subbasin, and in much of the North Fork subbasin. In these areas, stormwater detention and piped conveyance systems are the primary means of handling stormwater drainage. A drawback to using infiltration systems in soils with high infiltration rates are the potential for rapid subsurface transport of pollutants such as petroleum, nutrients and other contaminants commonly found in surface runoff. Advanced design techniques and retrofitting methods, such as dry well retrofits currently being implemented by Pierce County, are one means of addressing this issue.

Soils in the Clover Creek Basin limit the use of on-site sewage systems. Unless carefully designed, systems installed in soils such as Alderwood and Kapowsin (hydrologic soil groups C and D), which are underlain by glacial till and high water tables, have a relatively high risk of failure due to hydraulic overload. Soils formed in glacial outwash deposits, such as Everett and Spanaway series, allow rapid drainage from on-site sewage systems, but may not provide adequate treatment of septic tank effluent before it reaches underlying groundwater. This may result in elevated nitrate concentrations in groundwater, and potentially, fecal coliform contamination. Similarly, stormwater infiltration systems installed in such soils may allow migration of contaminants to underlying groundwater (KCM 1996).

4.4 NATURAL AND CONSTRUCTED DRAINAGE SYSTEM

4.4.1 Natural Drainage System

The Clover Creek Basin's natural drainage system consists of Clover Creek and its major tributaries, including North Fork Clover Creek, Spanaway Creek, and Morey Creek, as well as a number lakes, of which the largest are Spanaway Lake, Tule Lake, and Lake Steilacoom. Current GIS mapping indicates that the total length of Clover Creek and its major tributaries is nearly 20 miles.

Stream System

Clover Creek's headwaters are in the vicinity of South Hill, near Puyallup. The main channel of the creek flows generally northwest for 13.8 miles through a wide valley of mostly farmland, through the Parkland community, through McChord Air Force Base, through the City of Lakewood, and finally into Lake Steilacoom.

Minor Tributaries

The main channel has eight minor tributaries identified as point sources of surface runoff into Clover Creek (Consoer, Townsend, and Associates 1976):

- Clover Creek First Tributary (CC1T) is generally north of the main channel and entirely within the community of Parkland. This tributary provides surface drainage for all land east of McChord Air Force Base and west of C Street in Subbasin LCC-4, and for land south of the basin boundary and north of Pacific Lutheran University. A series of wetlands along this tributary provide storage for surface runoff. The wetlands to the north of 116th Street South have been disconnected from the wetlands to the south by a development on the south side of the street.
- Clover Creek Second Tributary (CC2T) is located in Subbasin UCC-2 and connects to MS9 of Clover Creek north of 152nd Street East and east of Waller Road.
- Clover Creek Third Tributary (CC3T) is located in Subbasin UCC-4 and drains to a County owned retention pond known as Brookdale Pit. It drains runoff from Canyon Road north of 160th and from a significant area of pasture land that is zoned for conversion to single-family residential.
- Clover Creek Fourth Tributary (CC4T) is located in Subbasin UCC-5 and connects to Clover Creek just west of Canyon Road near the Tacoma Sportsman's Club. This tributary provides surface and subsurface drainage from an area between Military Road and Canyon Road.
- Clover Creek Fifth Tributary (CC5T) is generally south of the main channel near the Tacoma Sportsman's Club and provides surface and subsurface drainage from a high marshy area in the vicinity of 176th Street East.
- Clover Creek Sixth Tributary (CC6T) is generally south of the main channel near the springs area and provides surface and subsurface drainage from a high marshy area in the vicinity of 176th Street East.
- Clover Creek Seventh Tributary (CC7T) is generally southeast of the main ephemeral channel and provides surface and subsurface drainage from an area between 144th Street East and 176 Street East. This tributary is in Subbasin UCC-7 and drains to a regional County owned retention pond at the NW corner of 78th Avenue East and 156th Street East, known as Sandpit Pond. Runoff infiltrating in this pond appears to follow a glacial outwash channel and connects with Clover Creek via sub-surface flow.
- Clover Creek Eight Tributary (CC8T) is generally southwest of the main ephemeral channel near Rogers High School and provides surface and subsurface drainage from an area south of 128th Street east and from 85th Avenue East to the basin boundary. This tributary is in Subbasin UCC-6. The runoff from this tributary drains to two regional retention ponds, Zongas pond and Afdem pond. These ponds also are located along the glacial

outwash channel and as such the runoff appears to connect to Clover Creek via subsurface flow paths.

Major Tributaries

The three main Clover Creek tributary systems are the North Fork system, the Spanaway Creek system, and the Morey Creek system (Consoer, Townsend, and Associates 1976).

The North Fork system conveys surface and subsurface runoff from the north central portion of the basin, in the vicinity of the communities of Midland and Parkland. The creek flows south for approximately 4 miles through deep, channelized, county drainage ditches that flow intermittently. It continues through a steep sloping ravine to the floor of the Clover Creek valley at Brookdale Road. The North Fork then flows west through the urbanizing residential areas of Parkland to its confluence with the main stem of Clover Creek. Except for the perennial channel in the ravine, the North Fork channels are all intermittent. Surface runoff is carried rapidly to the Clover Creek valley. The main channel of the North Fork of Clover Creek has six tributaries (NF1T through NF6T) identified as major point sources for flow (Consoer, Townsend, and Associates 1976). Many of these tributaries have been realigned or altered by land use changes and therefore it is difficult to ascertain which channels are natural or manmade.

Spanaway Creek flows generally north from the north end of Spanaway Lake. It flows under Old Military Road and then north for 2.2 miles through urbanizing residential portions of Parkland, and eventually into a large marsh formerly known as Smith Lake, where it enters Clover Creek. Spanaway Creek splits to form Morey Creek and Spanaway Creek just north of Bresemann Forest before continuing to the southern end of Tule Lake. Spanaway Creek's main channel is a perennial stream carrying considerable flow, which in the summer months is the only flow that continues into Clover Creek and on to Lake Steilacoom. The flow out of Spanaway Lake appears to be predominately groundwater fed and the attenuation effects of Spanaway Lake help prevent sharp flow fluctuations in the creek. During rainfall events, there is a moderate rise in flow rates and an extended gradual drop-off of the rates after the event.

Morey Creek's headwaters are at the main Spanaway Creek channel in the southwestern part of the basin. It carries local surface and subsurface drainage from a small tributary area in the immediate vicinity of its perennial channel. It flows generally west for 1.1 miles, under the major arterials Spanaway Loop Road, East Airport Road, and Perimeter Road (on McChord Air Force Base), and into the Clover Creek main channel. The confluence of Morey Creek with Clover Creek is just upstream from the twin 12-foot diameter CMP culverts under the McChord Air Force Base runways and downstream of the large marsh area formerly known as Smith Lake. A concrete weir at the end of Morey Creek forms a pond at the end of the creek. The weir is a fish passage barrier. Morey Creek has no tributaries except for Spanaway Creek. At the fork where Morey Creek splits from Spanaway Creek, approximately 60 percent of the storm flow is conveyed into Spanaway Creek and the remaining 40 percent is conveyed to the Morey Creek channel (Consoer, Townsend, and Associates 1976).

Main Channel

The Clover Creek channel has been modified many times over the past century. In the early 1900s, a half-mile-long canal was constructed adjacent to the creek to supply the City of Tacoma with drinking water. The canal was never used for this purpose, but it now is reported to carry the creek's flow, according to a study by the Department of Ecology. This finding has not been verified by Pierce County's Water Programs. Prior to the 1940s, a mile of the creek in the vicinity of Golden Given Avenue and 138th street was rechanneled into two large canals to irrigate an extensive hop-farming operation. The farm is no longer in operation but the creek still flows in the irrigation channels. A number of small marshes are adjacent to the creek in this area (Consoer, Townsend, and Associates 1976).

After McChord Air Force Base was dedicated as a military installation in the 1940s, several sections of Clover Creek were extensively dredged, channelized, and diked. The creek now flows through 12-foot-deep channels before entering two 12-foot diameter CMP culverts under the McChord Air Force Base runway that are over 2,500 feet long (Consoer, Townsend, and Associates 1976).

Because of stormwater flooding, Clover Creek was diverted off the Pacific Lutheran University campus in the late 1960s through a deeper, wider, asphalt-lined ditch for a mile and a half. The creek now flows in a straight channel about 10 blocks south of its original course from C Street to Spanaway Loop Road (Consoer, Townsend, and Associates, 1976).

Private property owners have reported vertical culverts being installed in the main channel for infiltrating high flows into the medium depth aquifer, approximately 30 feet beneath the creek bottom. The installations were reported to be east of Pacific Avenue and just north of the east end of Cherry Lane in the creek at the base of the ridge. Pierce Couunty Water Programs staff conducted a field investigation to locate these culverts and determine if they were also siphoning off summer low flows. They were unable to locate them, however it is possible that they have been subsequently buried.

Further modifications to the course of the creek have resulted from the construction of at least 15 creek-fed ponds in the eastern and central portions of the basin. These ponds were privately built for a variety of reasons, including irrigation, fish rearing, stormwater control, and aesthetics. Most of the ponds are unlined and do not have established water rights (Ecology 1986).

Clover Creek is perennial upstream of the Brookdale Golf Course and is fed by the Upper Clover Creek subbasin. This portion of the channel appears to be unaltered for the most part and still exhibits a wide floodplain. During rainfall events, there is only a gradual rise in the creek flow for this area due to the groundwater-dominated flow regime. Downstream of the golf course the creek is intermittent and the channel has possibly been relocated as it is in an area known to have had several channel modifications. This intermittent flow area continues until the main channel connects with Spanaway Creek, which provides year-round flow. The contribution of flow from North Fork Clover Creek to this section of Clover Creek produces much more erratic flows in response to rainstorms. During fall storms, rapid rises in North Fork Clover Creek can backflow up into areas of the main channel that are typically dry during that time of year. Usually by late December enough rainfall has occurred in the upper basin to create a constant flow in the upper main steam reaches.

Lakes

In addition to the Clover Creek Basin's largest lakes—Lake Steilacoom, Spanaway Lake, and Tule Lake—there are five smaller, unnamed lakes in the Spanaway Creek and North Fork Clover Creek drainages. Lakeshores in this region are typically highly developed residential areas, but fair-to-good habitat for waterfowl, fish, amphibians, and invertebrates (snails, freshwater clams, etc.) may still be provided (KCM 1996).

Lake Steilacoom, located in Subbasin SL-1, was created in 1852 when a dam was constructed across Chambers Creek, resulting in the inundation of a wetland. The resulting 320-acre lake is shallow (mean depth 11.2 feet; maximum depth 20.0 feet), with a volume of 3,500 acre-feet. The water surface elevation is 226 feet above sea level. The ratio of watershed area to lake surface area is very high (167:1). However, due to the high permeability of the glacial deposits that cover much of the watershed, the area of the watershed contributing surface runoff into the lake is limited. Surface inflow to the lake is from Clover Creek on the south end and Ponce de Leon Creek on the southeast end. Inflows have ranged from 8 to 140 cubic feet per second (cfs). Outflow is via Chambers Creek, which has an estimated minimum average flow of 17 cfs in September and an estimated maximum average flow of 271 cfs in January. Lake Steilacoom is used heavily by lakeshore residents for recreation. The lake is regarded as an amenity to the local community, and the values of properties around the lake are affected by its condition. The 5.7-mile shoreline has over 280 dwellings around it (KCM 1996 and Brown and Caldwell 1985).

Spanaway Lake, located in Subbasin SC-5, has a drainage area of 17 square miles, a surface area of 272 acres, and a maximum depth of 27.9 feet. The water surface elevation is 320 feet above sea level. Spanaway Lake is used heavily for recreation and contains a large County park facility (Harry Sprinker Recreation and Community Center). The lake's headwaters are in the Spanaway Marsh area, an extensive series of wetland systems south of the lake. The marsh is hydraulically connected to Spanaway Lake by Coffee Creek, a perennial creek draining from the marsh into the southern end of the lake. Outflow from Spanaway Lake is through Spanaway Creek (KCM 1996 and Brown and Caldwell 1985).

Tule Lake, located in Subbasin SC-1 on Spanaway Creek, is a small, shallow lake of approximately 18 acres. The lake appears to be the remnant of a larger marsh area that is possibly connected hydraulically with the marshy area formerly known as Smith Lake, just west of Spanaway Loop Road. Although water is impounded near the outlet, the open water component of the lake is limited by heavy vegetation at the south end of the lake. Residential flooding has been reported along the lake, primarily along the south end of the lake. This has been mostly due to encroachment into the floodplain of the creek and extremely heavy years of rainfall. The flooding is likely linked to groundwater movement due to the alignment of groundwater movement in the Spanaway Creek subbasin.

Stoney Lake is a small lake of approximately 40 acres in subbasin UCC-11 between 208th Street East and 182nd Street East. Stoney Lake is located along an ephemeral stream in the Upper Clover Creek basin. The lake is fed primarily by groundwater, although surface water also drains to the lake during months of heavy precipitation. The depth and extent of the lake can fluctuate significantly as the water table rises during periods of high precipitation. The lake tends to grow to the north, extending to 176th Street East and beyond.

Surface Water Flows

Stream flow data has been collected in the Clover Creek Basin since as early as 1939, most of it by the U.S. Geological Survey (USGS). Until 1990, only instantaneous peak flow data was collected. The USGS installed data recorders capable of collecting continuous flow data in October of 1990. Currently, the USGS maintains two continuous stream flow stations, one on the main stem of Clover Creek and one on the North Fork.

The data that has been collected serves several functions. FEMA used some of the collected data to develop tables showing the frequency of different levels of peak discharge for the Clover Creek system. These tables were used to establish the Clover Creek flood profiles, floodplain and floodway boundaries presented in the *Flood Insurance Study for Pierce County, Washington* (FEMA 1987). In 1996, the USGS used several years of continuous stream flow data to create a hydrologic model of the Clover Creek Basin; this model was updated and used as a primary resource in the Clover Creek Basin planning process.

As part of the Clover Creek Basin Plan, five additional sites were identified for installation of new continuous stream flow data recorders. Recorders at these sites will augment the two existing stations and provide years of continuous stream flow data. The collected data will be added to the existing stream flow data and provide a scientific basis for recommended improvements to the stream system.

Historical Stream Flow Data

Clover Creek suffers from severe winter flooding and from low (often nonexistent) summer flows at certain locations. Available stream flow measurements in Clover Creek near Tillicum~~Bridgeport Way~~, gage #12090500, indicate an annual mean stream flow of 47.5 cfs. Recorded monthly mean flows for this site vary from a low of 4.19 cfs in September to a high of 125 cfs in February. Recorded daily mean flows have ranged from a low of 0 cfs on October 20, 1949 to a high of 532 cfs on February 12, 1951. The highest recent peak flow was 418 cfs on February 9, 1996.

Stream flow data available from USGS was recorded by continuous water stage recorder gauges, crest-stage gauges, and stream flow meters. Between 1939 and 1990, all stream flow data was collected using crest gauges and stream flow meters. In 1990, the USGS began collecting 15-minute, instantaneous data at six sites. In 1992, four of those sites were discontinued, and currently, only two sites are in operation. The locations of the continuous water stage recorder gauges and crest-stage gauges in the Clover Creek Basin are described in Table 4-21 and shown on Figure 4-7. Table 4-22 summarizes the period of record for the USGS gauges.

TABLE 4-21.
USGS STREAM GAUGE LOCATIONS

Gauge No.	Location	Type	Latitude	Longitude	Tributary Area (sq. mi.)[a]	Datum
12090330	Clover Creek at Military Road Near Spanaway	Crest	47 06 17	122 22 32	18.0	322
12090340	Unnamed Tributary to Clover Creek at Bingham Road	Continuous	47 07 33	122 22 00	—	—
12090355	Clover Creek at 25th Avenue E. Near Parkland	Continuous	47 07 40	122 23 43	—	—
12090360	Clover Creek Below 138th Street South Near Parkland	Crest	47 07 55	122 25 32	42.6	302
12090365	Unnamed Tributary to NF Clover Creek at Waller Road	Continuous	47 08 02	122 23 16	0.14	397

12090370	NF Clover Creek at Brookdale Road Near Parkland	Crest	47 07 58	122 24 07	—	316
12090380	Unnamed Tributary to NF Clover Creek at 99th Avenue Near Tacoma	Continuous	47 10 03	122 24 39	—	
12090395	Unnamed Tributary to NF Clover Creek at Brookdale Road Near Parkland	Crest	47 08 04	122 24 28	—	331
12090400	North Fork Clover Creek Near Parkland	Continuous	47 08 05	122 24 50	6.25	—
12090430	Clover Creek at 17th Ave. South Near Parkland	Crest	47 08 38	122 27 28	49.7	283
12090500	Clover Creek near Tillicum~~south of I-5 on Bridgeport Way SW~~	Continuous	47 08 40	122 30 10	73.8	270
12090602	Clover Creek at Gravelly Lake Drive Near Tacoma	Crest	47 09 23	122 31 20	75.9	242
12090448	Spanaway Creek at Spanaway Loop Road	Crest	47 06 03	122 26 55	—	330
12090452	Spanaway Creek at Spanaway Lake Outlet	Crest	47 07 21	122 26 42	17.2	320
12090460	Spanaway Creek at Tule Lake Outlet	Crest	47 08 24	122 27 18	—	290
12090480	Morey Creek Above McChord Air Force Base	Crest	47 07 49	122 27 42	—	288

a. Tributary area as reported by USGS

Tetra Tech / KCM

1917 First Avenue
Seattle, Washington 98101

PIERCE COUNTY

Pierce County
Clover Creek Basin Plan

Figure 4-7
Stream Gauge
Locations

TABLE 4-22.
PERIOD OF RECORD FOR USGS STREAM GAUGES

Gauge No.	Location	Peak Flow Data		Mean Daily Flow Data Record	15 Minute Instantaneous Data Record
		Period of Record	Comments		
12090330	Clover Creek at Military Road	1991	1 Peak Value		
12090340	Unnamed Tributary to Clover Creek at Bingham Road	—			10/1/90-9/30/92
12090355	Clover Creek at 25th Avenue E.	—			10/1/90-9/30/92
12090360	Clover Creek Below 138th Street South	1991-1992	2 Peak Values		
12090365	Unnamed Tributary to NF Clover Creek at Waller Road	1991-1994	4 Peak Values		10/1/90-9/30/92
12090370	NF Clover Creek at Brookdale Road	1991-1992	2 Peak Values		
12090380	Unnamed Tributary to NF Clover Creek at 99th Avenue				10/1/90-9/30/92
12090395	Unnamed Tributary to NF Clover Creek at Brookdale Road	1992	1 Peak Value		
12090400	North Fork Clover Creek	1960-1998	20 Peak Values	10/1/95-4/30/98	10/1/90-9/30/92 10/1/94 – Present
12090430	Clover Creek at 17th Ave. South	1991-1992	2 Peak Values		
12090500	Clover Creek Near Tillicum	1950-1998	29 Peak Values	7/1/49-9/30/54 10/1/90 – 9/30/92 10/1/94 – 9/30/98	10/1/90-9/30/92 10/1/94 – Present
12090602	Clover Creek at Gravelly Lake Drive	1991-1992	2 Peak Values		
12090448	Spanaway Creek at Spanaway Loop Road	1991-1992	2 Peak Values		
12090452	Spanaway Creek at Spanaway Lake Outlet	1991-1992	2 Peak Values		
12090460	Spanaway Creek at Tule Lake Outlet	1991-1992	2 Peak Values		
12090480	Morey Creek Above McChord Air Force Base	1991-1992	2 Peak Values		

In addition to the stream flow data shown in Table 4-22, the USGS collected stream flow data at 28 miscellaneous sites throughout the Clover Creek Basin between 1939 and 1960. Most of this data was collected from 1939 through 1941. Copies of this data are contained in Appendix B.

In 1999, the Washington State Department of Ecology issued a report entitled, *Estimated Base Flow Characteristics of Selected Washington Rivers and Streams* (Ecology 1999). In this document, base flow contributions to streams were estimated using a hydrograph separation software program to divide a stream hydrograph into a base flow component and a surface runoff component. The study was undertaken to improve the understanding of the hydrologic interactions between groundwater and surface water for selected streams in Washington. Data from active and discontinued USGS stream gauging stations were used to define the groundwater component, or base flow component, of the measured stream flow (Ecology 1999).

For the Clover Creek stream system, monthly mean base flow estimates and annual mean base flow estimates were computed at the two currently operating USGS gauging stations—Station 12090400 on the North Fork at Golden Given Road (Photo 4-2) and Station 12090500 on the Main Stem at Bridgeport Way SW.

Photo 4-2. USGS Stream Gauge 12090400 on Golden Given Road

Four years worth of flow data were used for the analysis at Station 12090400 and 10 years worth of flow data were used for the analysis at Station 12090500. Table 4-23 summarizes the monthly mean data and Table 4-24 summarizes the annual mean data.

TABLE 4-23
MONTHLY SUMMARY STATISTICS FOR BASE FLOW AND STREAM FLOW

Month	Mean Base Flow (cfs)		Mean Stream Flow (cfs)		Mean Base Flow as Percentage of Stream Flow	
	Station 12090400	Station 12090500	Station 12090400	Station 12090500	Station 12090400	Station 12090500
October	0.08	4.9	1.4	6.1	6	79
November	2.4	10	9	14	26	71
December	8.4	41	21	55	41	76
January	14	72	23	99	60	73
February	6.6	90	22	126	30	71
March	7.3	91	14	105	52	86
April	3.8	64	11	76	33	84
May	0.83	42	2.1	44	41	94
June	0.26	24	0.58	27	45	90
July	0.01	14	0.12	15	5	89
August	0	6	0.04	6.7	0	89
September	0.01	3.8	0.18	4.4	6	85

Source: Ecology, 1999

TABLE 4-24.
ANNUAL SUMMARY STATISTICS FOR BASE FLOW AND STREAM FLOW

USGS Station No.	Annual Mean Base Flow (cfs)			Annual Mean Stream Flow (cfs)		
	Minimum	Median	Maximum	Minimum	Median	Maximum
12090400	2.0	2.7	6.8	4.2	9.3	12.0
12090500	12	46	62	18	55	82

Source: Ecology, 1999

New Stream Gauges

Like the two existing USGS sites, the five gauging stations installed in the Clover Creek watershed as part of developing the Clover Creek Basin Plan will collect instantaneous stream level data at 15-minute intervals. The stream level values will be converted to stream flow values using rating curves developed for each site. The locations of these stations are shown in Figure 4-7, and each is described below.

Gauging Station Site #1—Site #1 is on the Main Stem of Clover Creek downstream of the Spanaway Loop Road South bridge. The data recorder is collecting continuous data for the Main Stem of Clover Creek immediately upstream of two significant tributaries, Morey Creek and Spanaway Creek.

Existing USGS gauging station #12090500 is downstream of this site and measures flows that include contributions from Spanaway Creek, Morey Creek, and McChord Air Force Base. The data collected at Site #1 can be used in conjunction with the data from USGS Station #12090500 to better understand the interrelationship of peak flow rates and volumes upstream and downstream of these major contributors to the Main Stem.

This site will be discontinued as the flow information it has collected has proved to be very similar to that at Gauging Station #2. The gauge will be moved to just upstream of the confluence with North Fork Clover Creek to collect information on where base flows go dry during the summer.

Gauging Station Site #2—Site #2 is at the C Street Bridge on the Main Stem of Clover Creek. Summer flows along the stretch of creek between C Street South and Spanaway Loop Road South are typically very low or nonexistent. The continuous data collected at Site #2 can be used in conjunction with continuous data from Site #1 to gain knowledge about flow rates and volumes during the low-flow season in this reach of the Main Stem.

During severe storms, much of the flow in the creek overtops the banks between Pacific Avenue, and the confluence with the North Fork. Site #2 is far enough downstream of this area that flows from all storm events are contained within the channel. Therefore, the data collected at Site #2 will help define how much attenuation is provided by storage of overflows in the overbank areas upstream of Pacific Highway South.

Gauging Station Site #3—Site #3 is on North Fork Tributary No. 5, downstream of the Brookdale Road East bridge and about 200 feet upstream of Tributary No. 5's confluence with Tributary No. 1. Data collected at Site #3 can be used to estimate flow rates from the entire 3.8-square-mile (2,430-acre) North Fork Tributary No. 5 subbasin.

Existing USGS gauging station #12090400 is on the North Fork at Golden Givens Road, approximately 1,200 feet downstream of the confluence. The continuous flow data collected at Site #3 can be used in conjunction with the data from USGS Station #12090400 to compute flow rates in Tributary No. 1 of the North Fork.

There is a detention pond on Tributary No. 1 called the E-1 pond. A second detention pond, called the W-1 pond, was constructed in the summer of 2001 in the North Fork subbasin on Tributary No. 5. Data collected at Site #3 will be used to monitor the hydrologic effectiveness of the two ponds.

Gauging Station Site #4—Site #4 is on the main stem of Clover Creek upstream of the 25th Avenue East bridge. Only two years of continuous flow data are currently available for the main stem upstream of its confluence with the North Fork. Nearly 10 years of continuous flow data are available for North Fork flows. A thorough knowledge of the relative hydrologic patterns of both branches of this system is needed to or mitigate the frequent flooding problems downstream of their confluence. Therefore, locating a gauge on the main stem upstream of the North Fork confluence was a priority.

During significant storm events, there is a strong backwater influence on the main stem from the North Fork, and the new gauge had to be far enough upstream to avoid this influence. The gauging station also must be upstream of 12th Avenue East because Clover Creek flows through two distinct channels between 12th Avenue East and 138th Street East, making flow measurements difficult. The selected site upstream of the 25th Avenue East bridge meets both these criteria and is the site of a USGS station that was in operation from October 1990 through September 1992.

Gauging Station Site #5—Site #5 was chosen to provide long-term flow monitoring of Spanaway Creek immediately downstream of Spanaway Lake. At this time, no continuous flow data for Spanaway Creek are available. The site is immediately upstream of the Military Road culvert to provide ease of access. Consideration was given to locating the site near an existing concrete spillway approximately 1,000 feet downstream of Military Road. However, this site was abandoned due to potentially difficult access, possible difficulties in obtaining agency permission, and local interest in removing this obstruction to fish passage. The spillway could be removed in the next three to five years (Don Nauer, Department of Fish and Wildlife, Personal Communication).

FEMA Flow Values

As part of the Flood Insurance Study performed by FEMA for Pierce County (FEMA 1987), a hydrologic analysis was carried out to establish peak discharge values for locations in the Clover Creek Basin. Regression equations based on historically collected precipitation and flow data were the primary tools used to establish the peak discharge-frequency relationships for the creek system Table 4-25 summarizes the results.

TABLE 4-25.
PEAK DISCHARGE-FREQUENCY RELATIONSHIP (FEMA, 1987)

	Peak Discharge (cfs)			
Reach	10-Year	50-Year	100-Year	500-Year
Clover Creek				
At Mouth	408	618	693	863
Downstream of Spanaway Creek Confluence	292	446	496	606
At 136th Street South	158	228	260	332
At Waller Road	98	140	158	201
At Grieler Road	73	104	118	148
North Fork Clover Creek				
At Mouth	176	195	202	218

USGS Computer Simulated Flow Values

The USGS previously described the surface water hydrology of the Clover Creek Basin with a conceptual model of its runoff processes and simulated it with the Hydrological Simulation Program-FORTRAN (HSPF). To calibrate and validate the simulation model, stream discharge was measured at 28 sites and precipitation was measured at six sites for three years in two overlapping phases from October 1989 through September 1992. Using the calibrated model, long-term models were run using precipitation data from 1961 through 1992. The investigation showed the importance of defining the groundwater flow boundaries and demonstrated a simple method of simulating the influence of the regional groundwater aquifer on stream flows (USGS 1996). The HSPF model was updated to include additional precipitation data through 1999. The updated model was used in the design of the regional detention facility on the North Fork of Clover Creek (Site E-1).

A detailed discussion of the development of the model and its results is presented in *Surface-Water Hydrology and Runoff Simulations for Three Basins in Pierce County, Washington* (USGS 1996). Table 4-26 summarizes the peak discharge-frequency relationship for select reaches, including the additional historical data from the updated model and without the impact of either pond on the North Fork.

Groundwater and Ephemeral Streams

The Central Pierce County Sole Source Aquifer, designated by the U.S. EPA in 1993, encompasses the Chambers-Clover Creek watershed, including the Clover Creek Basin. The aquifer is the sole source of drinking water for approximately 63 percent of the population in the watershed, about 168,000 people. The other 37 percent of the population obtains water from the Green River.

TABLE 4-26.
PEAK DISCHARGE-FREQUENCY RELATIONSHIP (USGS, 1993)

		Peak Discharge (cfs)			
Reach Description	Reach Identifier	10-Year	50-Year	100-Year	500-Year
Clover Creek					
At Mouth	24	242	340	381	477
Downstream of Spanaway Creek Confluence	23	234	337	384	497
At 136th Street South	15	141	225	268	390
North Fork Clover Creek					
At Mouth	13	267	427	507	726
Morey Creek					
At Mouth	22	19	28	32	43
Spanaway Creek					
At Mouth	21	68	92	101	123

The region's geological history determined the characteristics of groundwater bodies and aquifers in the basin. Shallow aquifers are perched on top of layers of impermeable glacial till and are overlain with permeable gravels, which allow precipitation and surface water flows to infiltrate and recharge the aquifers. Infiltration from precipitation is estimated to be the primary mechanism for recharging the groundwater, with stormwater, septic tank outflow, and surface water bodies being secondary mechanisms (Pierce County 1997).

The depth to groundwater, which can be considered the thickness of unsaturated sediments, is an important parameter to consider when relating land use activity to water quality. Downward-percolating surface waters pass through this unsaturated zone, and some contaminants are subjected to biological breakdown, thus reducing the amount of pollutants reaching the groundwater table. The predominantly granular nature of the geologic materials in the Clover

Creek Basin does not provide for very effective pollutant interception (Brown and Caldwell 1985).

The depth to groundwater in the basin ranges from 0 to 100 feet—generally 50 feet or more in the north and less than 20 feet around Lakewood and Parkland. Around Spanaway and Graham in the southern portion of the basin, depths to groundwater are highly variable. Most of the groundwater in the basin moves west toward Puget Sound; however, groundwater along the northeastern boundary of the basin flows north toward the Puyallup River valley (Pierce County 1997).

The speed of groundwater movement in the basin is relatively high. Velocity estimates for shallow groundwater range from 0.02 feet per day to 63 feet per day. The average rate for the basin is 4.4 feet per day. A recent gasoline leak in Parkland indicated a contaminant flow velocity of 93 feet per day (Pierce County 1997). Figure 4-8 shows the locations of Pierce County's 24 groundwater monitoring wells in the Clover Creek Basin.

The runoff from some drainage areas southeast of the Clover Creek basin infiltrates into the ground. The surface movement of the water is from the southeast to the northwest and it is likely that the infiltrated runoff continues into the Clover Creek basin.

Groundwater/Surface Water Interactions

Springs are surface manifestations of groundwater flow and provide insight about its flow and distribution. Most of the Clover Creek basin is covered with gravel, which maximizes infiltration and minimizes runoff. Of notable exception is the north and northeast portions of the basin, which are covered by low-permeability materials. For most of its length, Clover Creek is a discharge zone for the basin's shallow groundwater system. Springs are typically concentrated along the edges of the Clover Creek floodplain. The total discharge of major springs in the Clover Creek Basin is unknown however it was characterized as approximately 7,500 gallons per minute (gpm), ~~with some individual springs producing as much as 3,500 gpm (~~in Brown and Caldwell (1985). Recent field observations by Al Schmauder and Don Russell have confirmed reaches where springs are feeding both Clover and Morey creek however yields were not quantified. Figure 4-9 shows the locations of the springs in the Clover Creek Basin.

The aquifer system in the Clover Creek basin consists of alternating layers of higher and lower permeability. The most transmissive of these are the glacial outwash layers, which consist of highly permeable material with high infiltration capacity. These layers make up the principal aquifers in the basin, and are generally unconfined, meaning that aquifer pressure is in equilibrium with atmospheric pressure and that the water level in a well is at the elevation of the top of the aquifer. The glacial layers are generally separated by non-glacial layers, which are characterized by densely packed, low permeability materials. These layers tend to be confined (i.e., a well in these zones will show a standing water level higher than the elevation of the top of the aquifer layer). Where layers of impermeable soils are present between the shallow and deep systems, little downward migration of water into the deep aquifers occurs. Where low-permeability soil layers exist between shallow and deep aquifers, interchange does occur, greatly increasing the likelihood of contamination from surface pollution sources.

The Upper Clover Creek drainage and the Spanaway drainage are underlain primarily with Steilacoom gravels, a highly permeable coarse glacial outwash material. Spanaway soils are formed in the Steilacoom gravels, and Spanaway gravelly sandy loam forms as a thin soil layer

(2 to 3 feet deep) at the top of the gravels. Because this material allows water to infiltrate readily into the subsurface, these drainages are characterized by a limited number of surface drainage channels. Figure 4-10 shows the ephemeral channels located in these basins, which are characterized by broad glacial outwash channels where groundwater movement is concentrated. During years of high annual rainfall, groundwater will surface in topographical low spots along these channels as the groundwater moves to the northwest from the southeast.

The Lower Clover Creek drainage is underlain by the highly permeable Steilacoom gravels, and some stream channels have been lined with impermeable materials to minimize seepage into the subsurface. Such channel modifications, combined with the increasing amount of impervious sources being constructed in the basin (e.g., rooftops, roadways, parking lots), have changed the hydrological response of the basin (PCPW&U 1994).

The North Fork Clover Creek drainage is dominated by a layer of highly compacted glacial tills (hardpan) near the surface. Alderwood and Kapowsin soils are formed in glacial till and minor amounts of glacial debris are deposited on the till. Surface weathering of the till and related soil development has progressed to a depth of only a few feet. Below this, the compact till is intact. The slowly permeable till inhibits the downward movement of precipitation and promotes lateral movement of perched water toward surface discharge points and drainage-ways. In contrast to the Steilacoom gravels, this soil layer generates high levels of surface runoff, resulting in a larger number of surface drainage channels in the North Fork drainage which respond quickly to rainfall and produce flashy peak flows.

Groundwater Recharge

The USGS published a study in 1997 on aquifer recharge from precipitation through low-permeability glacial till. The annual rate of direct percolation from precipitation through the till is of major importance in estimating annual recharge to the aquifers of the region (USGS 1997). The study was conducted for three small drainage areas in Pierce County, one of which is in Subbasin NF6 in the Clover Creek Basin. Detailed water budgets were computed for the three areas to estimate direct groundwater recharge from precipitation through glacial till. The water budget calculations used time-series precipitation, stream flow, solar radiation, and temperature data for 2- and 3-year periods (1991-1993). Two of the report's conclusions are significant for the Clover Creek Basin Plan:

- For the 1991-1993 water years, the area-weighted average annual groundwater recharge rate in the drainage area in Subbasin NF6 was 1.46 inches per year, or 4 percent of the average annual precipitation. This compared with computed values of 5.44 and 6.79 inches per year, or 13.9 percent and 16.7 percent of the average annual precipitation for the two other drainage areas. The Clover Creek drainage area was 36 percent mixed forest and 64 percent pasture area; the other two drainage areas were 94 percent mixed forest and 100 percent Douglas fir forest. Estimates of recharge made in this investigation are generally less than half those of most other investigations in the Puget Sound lowland (USGS 1997).
- Interception loss is defined as the portion of precipitation that is retained by the leaves and stems of vegetation. Although it is intuitively obvious that higher interception losses occur when there is more vegetation, the relative magnitudes presented in the report were significant. Table 4-27 compares the

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Figure 4-8
Pierce County
Monitoring Wells

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Figure 4-9
Clover Creek
Spring Locations

percentage of total annual rainfall accounted for by interception losses for the four land covers in the study.

TABLE 4-27.
INTERCEPTION LOSS VERSUS LAND COVER

Land Use	Percent of Annual Precipitation Lost to Interception (%)
Douglas Fir Forest	46 - 47
Mixed Forest	38 - 46
Pasture	13 - 18
Riparian	11 - 15

4.4.2 Constructed Drainage System

The natural drainage system is modified by collection, detention, discharge, and infiltration facilities, which concentrate toward the northern, more urbanized portion of the Clover Creek basin (Montgomery 1991). Regional County detention and retention ponds are shown in Figure 4-11.

Upper Clover Creek

In the northeast portion of the Clover Creek basin are three large retention facilities that follow the alignment of an historical glacial outwash channel. Afdem, Zongas, and Sandpit are the three ponds along this channel. Afdem and Zongas ponds drain Subbasin UCC-6. Sandpit pond drains Subbasin UCC-7. An additional regional infiltration pond, Brookdale Pit, is an old gravel pit west of Canyon Road and south of Brookdale Road. Brookdale Pit receives all the surface water flow from Subbasin UCC-4. The Clover Creek Holding Basin, a natural depression covering over 100 acres, is located on Clover Creek just upstream of McChord Air Force Base (Montgomery 1991).

There are numerous County-owned and -operated dry wells, particularly in the western half of the basin, where over 800 were identified in an earlier study. The dry wells were constructed to allow for the widespread infiltration of stormwater into the ground. Through the use of dry wells, the County has lessened the need for extensive pipe drainage, and helped provide for aquifer recharge. Because of their location in industrial and commercial developments, as well as along streets, these dry wells may allow contaminants to directly enter the aquifer unless they are modified to prevent this (Montgomery 1991).

North Fork Clover Creek

In 1998, Pierce County completed the North Fork Clover Creek Site E-1 Stormwater Basin, east of Waller Road East between 128th Street East and 132nd Street East. The need for this facility was identified in the *North Fork Clover Creek Basin Preliminary Design Report* (David Evans and Associates 1993). This facility provides 100 acre-feet of detention storage for the 100-year design storm event, with a design release rate of 110 cfs. The surface area of the facility is approximately 17 acres.

Pierce County has completed construction of another regional water quality/detention facility in the North Fork tributary area. The site was identified as Site W-1 in the *North Fork Clover Creek*

Basin Preliminary Design Report (David Evans and Associates 1993). It is on a triangular parcel bounded by 121st Street East, Aqueduct Drive East, and Golden Givens Road. This facility was sized in the preliminary design report to provide 90 acre-feet of detention storage for the 3.11-square-mile tributary area.

4.5 AQUATIC AND RIPARIAN HABITAT

4.5.1 History of Fish Usage

The Clover Creek Basin has historically supported large populations of anadromous and resident fish in its upper and lower reaches. Runs of coho, chinook, and sockeye salmon formerly passed through Lake Steilacoom heading from Chambers Bay to the upper Clover Creek stream system. The current location of the Brookdale Golf Course, approximately 11 miles upstream of Lake Steilacoom, was reportedly a salmonid spawning area in the 1850s. By 1949, chinook and sockeye no longer reached Lake Steilacoom. By 1975, use of Clover Creek and its tributaries by salmonids was no longer documented. A dam built to control flow at the outlet of Lake Steilacoom created a complete impediment to anadromous fish passage. In the 1980s, a fish ladder was installed at the dam, making salmonid migration possible upstream from the lake. Table 4-28 lists the salmonid and freshwater fish documented in streams and lakes in the Clover Creek basin (KCM 1996). Figure 4-12 illustrates the extent of current fish usage in the Clover Creek basin.

TABLE 4-28.
SALMONID AND FRESHWATER FISH SPECIES PRESENT
IN STREAMS AND LAKES WITHIN THE CLOVER CREEK BASIN

Water Body	Salmonids	Freshwater Fish
Clover Creek	Coho salmon	Cutthroat trout, rainbow trout
Morey Creek	None	Cutthroat trout
North Fork Clover Creek	Coho salmon	Cutthroat trout, rainbow trout
Spanaway Creek	None	Cutthroat trout, rainbow trout
Lake Steilacoom	Coho salmon	Rock bass, large-scale sucker, kokanee, yellow perch, cutthroat trout, rainbow trout
Spanaway Lake	None	Rainbow trout

Source: KCM, 1996

In November 1997, hundreds of coho salmon returned to spawn in Clover Creek, near the community of Parkland, where salmon had not been seen for decades. The return of Coho salmon was attributed to the restoration efforts of citizens, students, service organizations, businesses, land owners, Pierce County, and the Clover Creek Council. Temporary fish ladders were installed to bypass existing obstructions in the main stem just downstream of Gravelly Lake Drive SW, stream banks were repaired throughout the basin, and trees were planted. Gravel, rocks, and large woody debris were also placed in the stream bed to cover the asphalt-lined channel. In 1999, the temporary fish ladders were replaced with permanent, concrete fish ladders.

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Figure 4-10
Ephemeral, Intermittent, and Perennial Streams

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Figure 4-11
Detention Ponds

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Figure 4-12
Clover Creek
Fish Presence

4.5.2 Clover Creek Stream Assessment

A two-phase stream reconnaissance survey was conducted in the spring of 2000 by Tetra Tech/KCM to document existing Clover Creek conditions for fish habitat, fish passage, riparian vegetation and connections between the creek and adjacent wetlands. The report of this assessment is provided in full in Appendix C and is summarized below. The stream reconnaissance report includes the following:

- Calculation of percent-impervious coverage of the Clover Creek Basin and tributary areas of individual stream reaches for existing land use conditions and for full buildout under current zoning.
- A field assessment of the level of channel and watershed alteration as a result of human activities. The following parameters were assessed for each reach:
  - The tributary area to the reach
  - The percent-impervious values for the tributary area
  - The extent of channel or flow modifications (such as culverts, bank armoring, straightening, etc.)
  - The number of breaks in the riparian zone
  - Whether the reach is listed on the state 303(d) list of impaired water bodies for one or more water quality parameters.
- A ranking of existing habitat in each reach as poor, fair or good, depending on the strength or weakness of observed habitat parameters such as riparian condition, substrate composition, bank condition, benthic invertebrate community, passage barriers, pool frequency, and water temperature. The results of the habitat ranking are shown in Figure 4-13.
- The results of benthic invertebrate sampling from 13 sites in the Main Stem, North Fork Clover Creek and Spanaway Creek (see Figure 4-14).

The draft Tri-County Urban Stream Baseline Evaluation Method (USBEM) developed by R2 Resource Consultants (1999) was used for the stream reconnaissance. The method includes two phases: an office assessment of the condition of the stream and watershed; and a field evaluation of stream characteristics.

In Phase 1, the stream system is divided into reaches based on slope and uniformity of habitat characteristics, and habitat quality is classified based on channel type, amount of channel and watershed alterations, and fish distribution. Three habitat categories are defined: highly suitable to support the species of concern (in this case, chinook salmon); unlikely to provide habitat that would be used by the species of concern due to geomorphic constraints or natural barriers (negligible habitat); and secondary habitat use that requires additional effort in Phase 2 to determine habitat quality.

Phase 2 consists of a field evaluation of riparian condition, substrate composition, bank condition, embeddedness, benthic invertebrate community, passage barriers, channel form and connectivity, pool frequency, and large woody debris distribution. Based on the field-collected information, habitat is classified as good, fair, or poor for supporting the species of concern. The USBEM recommends that professional judgment be used to classify habitat once all parameters have been measured (for example, if the habitat is good but there is no access it would be classified as poor). For this assessment, habitat was classified based on professional judgment and whether most parameters met target ratings.

Phase 1 Analysis

Reach Delineation

The limits of the Clover Creek stream assessment extended from the headwaters of the creek to the mouth at Lake Steilacoom. The reach definitions described in Section 4.1.2 were used for the assessment (see Figure 4-3).

Channel Type Definition

Of nine common definitions of channel type, all reaches in the Clover Creek system were categorized either as floodplain or palustrine, both of which are low-gradient channels in lowlands and alluvial floodplains. Floodplain channels are ranked as high use for fish habitat for all species of anadromous salmon. Palustrine channels are ranked as high use for coho, sockeye, chum, and pink salmon and secondary use for chinook, steelhead, sea-run cutthroat and bull trout. Table 4-29 summarizes the channel type, channel slope and fish presence for each reach.

TABLE 4-29.
SUMMARY OF STREAM REACH, CHANNEL TYPE, FISH HABITAT USE, AND FISH DISTRIBUTION

Reach	Reach Identifier	Channel Type	Slope (%)	Salmonid Presence
Main Stem 1	MS1	Floodplain	2.23	Y
Main Stem 2	MS2	Floodplain	0.18	Y
Main Stem 3	MS3	Palustrine	0.07	Y
Main Stem 4	MS4	Floodplain	0.19	Y
Main Stem 5	MS5	Floodplain	0.25	Y
Main Stem 6	MS6	Floodplain	0.16	Y
Main Stem 7	MS7	Palustrine	0.17	Y
Main Stem 8	MS8	Palustrine	0.02	Y
Main Stem 9	MS9	Palustrine	0.08	Y
Main Stem 10	MS10	Palustrine	0.17	N
Main Stem 11	MS11	Palustrine	<0.01	N
Main Stem 12	MS12	Floodplain	2.8	N

TABLE 4-29 (continued).
SUMMARY OF STREAM REACH, CHANNEL TYPE, FISH HABITAT USE, AND FISH DISTRIBUTION

Reach	Reach Identifier	Channel Type	Slope (%)	Salmonid Presence
Main Stem 13	MS13	Floodplain	<0.01	N
Spanaway Creek 1	S1	Palustrine	0.11	Y
Spanaway Creek 2	S2	Floodplain	1.23	Y

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Figure 4-13
Habitat Conditions

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Figure 4-14
Clover Creek
Field Observations

Spanaway Creek 3	S3	Palustrine	<0.01	Y
Spanaway Creek 4	S4	Palustrine	0.4	Y
Spanaway Creek 5	S5	Palustrine	0.55	Y
Spanaway Creek 6	S6	Floodplain	0.7	Y
Morey Creek 1	M1	Palustrine	0.13	N
North Fork 1	NF1	Palustrine	0.2	Y
North Fork 2	NF2	Palustrine	0.15	Y
North Fork 3	NF3	Floodplain	0.51	Y
North Fork 4	NF4	Floodplain	0.96	Y
North Fork 5	NF5	Floodplain	2	Y
North Fork 6	NF6	Floodplain	0.74	Y
North Fork 7	NF7	Palustrine	0.63	N
North Fork Tributary 1	T1	Floodplain	1.12	N
North Fork Tributary 2	T2	Palustrine	0.24	N
North Fork Tributary 3	T3	Palustrine	0.12	N

Percent-Impervious Values and Land Use

Projected land use changes and projected changes in percent-impervious values can be used to assess future impacts of development on existing fish habitat. Reaches where a large increase is expected in percent-impervious, or where a dramatic change in land use is projected, may need to be focused upon first in a basin-wide habitat restoration effort, even if their existing habitat is categorized as good or fair.

The Clover Creek subbasins tributary to each stream reach were identified, as shown in Tables 4-30 through 4-32, and the existing and future subbasin percent-impervious values were used to calculate values for each reach's total tributary area. The results are shown in Table 4-33. Tables 4-34 through 4-36 summarize the existing and future general land uses in the areas tributary to each reach.

Stream Channel Modifications

Most of the stream reaches are modified with a variety of structures, such as weirs, asphalt substrate, bank armoring, culverts, bridges, and dams. Figure 4-14 shows the locations of the observed fish passage barriers. In many reaches, most of the native riparian vegetation has been removed for landscaping with ornamentals and grass or for agricultural purposes. The level of channel and watershed alteration is high for the watershed as a whole, and for all but five reaches—Spanaway Creek Reaches S2 and S3 and the North Fork Tributary No. 5 Reaches T1 through T3—which have a moderate level of alteration.

Water Quality Listing

The entire main stem of Clover Creek and the North Fork are listed on the 303(d) list for dissolved oxygen, fecal coliform, and temperature. Spanaway Creek is listed for temperature only.

Habitat Type

Table 4-37 shows the USBEM habitat rating system based on fish habitat use and level of alteration. All reaches of the Clover Creek system have a high level of alteration, therefore, no reaches have highly suitable habitat use with fish present. Main Stem Reaches MS10 through MS13, Morey Creek Reach M1, North Fork Reach NF7, and Reaches T1 through T3 were determined to have negligible habitat use for migrating salmonids. All other reaches have secondary habitat use with fish present or potentially present. Reaches rated with either highly suitable habitat or negligible habitat are not carried into Phase 2, therefore, only the 21 secondary-habitat reaches were carried forward to Phase 2, for field reconnaissance.

TABLE 4-30.
CLOVER CREEK SUBBASINS TRIBUTARY TO MAIN STEM STREAM REACHES

Reach	Tributary Subbasins																																Total Tributary Area (acres)
	SL-1	SL-2	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	NFCC-1	NFCC-2	NFCC-3	NFCC-4	NFCC-5	NFCC-6	LCC-1	LCC-2	LCC-3	LCC-4	LCC-5	LCC-6	UCC-1	UCC-2	UCC-3	UCC-4	UCC-5	UCC-6	UCC-7	UCC-8	UCC-9	UCC-10	UCC-11	UCC-12	
MS1	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X		X	X	X	X	X	X			40,700
MS2			X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X		X	X	X	X	X	X			38,153
MS3			X	X	X	X	X	X	X	X	X	X	X	X		X		X	X		X	X	X		X	X	X	X	X	X			37,663
MS4									X	X	X	X	X	X				X	X		X	X	X		X	X	X	X	X	X			19,136
MS5									X	X	X	X	X	X					X		X	X	X		X	X	X	X	X	X			17,449
MS6																					X	X	X		X	X	X	X	X	X			12,791
MS7																					X	X	X		X	X	X	X	X	X			12,791
MS8																					X	X	X		X	X	X	X	X	X			12,791
MS9																							X		X	X	X	X	X	X			10,799
MS10																							X		X	X	X	X	X	X			10,799
MS11																										X	X	X	X	X			9,431
MS12																										X	X						2,048
MS13																										X	X						2,048

TABLE 4-31.
CLOVER CREEK SUBBASINS TRIBUTARY TO SPANAWAY AND MOREY CREEK STREAM REACHES

	Tributary Subbasins						Total Tributary Area (acres)
Subbasin	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	
Spanaway Lake							
S1	X	X	X	X	X		16,167
S2	X	X	X	X	X		16,167
S3	X	X	X	X	X		16,167
S4	X	X	X	X	X		16,167
S5		X	X	X	X		15,807
S6			X	X	X		15,545
Morey Creek							
M1		X	X	X	X	X	16,021

TABLE 4-32.
CLOVER CREEK SUBBASINS TRIBUTARY TO NORTH FORK TRIBUTARIES 1 AND 5 STREAM REACHES

	Tributary Subbasins						Total Tributary Area (acres)
Subbasin	NF-1	NF-2	NF-3	NF-4	NF-5	NF-6	
Tributary No. 1							
NF1	X	X	X	X	X	X	4,045
NF2	X	X	X	X	X	X	4,045
NF3	X	X	X	X		X	3,768
NF4						X	1,338
NF5						X	1,338
NF6						X	1,338
NF7						X	1,338
Tributary No. 5							
T1	X	X	X	X			2,430
T2	X	X	X	X			2,430
T3	X	X	X				1,695

TABLE 4-33.
PERCENT IMPERVIOUS VALUES FOR DELINEATED STREAM REACHES

Reach Identifier	Existing Total Percent Impervious	Existing Effective Percent Impervious	Future Effective Percent Impervious
Main Stem Clover Creek			
MS1	21	18	44
MS2	20	17	43
MS3	20	17	42
MS4	20	18	40
MS5	19	16	40
MS6	20	18	46
MS7	20	18	46
MS8	20	18	46
MS9	18	16	45
MS10	18	16	45
MS11	18	16	43
MS12	20	18	41
MS13	19	17	40
Spanaway Creek			
S1	17	14	41
S2	17	14	41
S3	17	14	41
S4	17	14	41
S5	17	14	41
S6	17	14	41
Morey Creek			
M1	17	14	41
North Fork Clover Creek (Tributary No. 1)			
NF1	20	18	29
NF2	20	18	29
NF3	20	17	28
NF4	14	11	10
NF5	14	11	10
NF6	14	11	10
NF7	14	11	10
North Fork Clover Creek (Tributary No. 5)			
T1	23	20	39
T2	23	20	39
T3	26	24	51

TABLE 4-34.
EXISTING AND FUTURE LAND USE DISTRIBUTION
IN MAIN STEM STREAM REACH TRIBUTARY AREAS

Stream Reach	Percent of Total Tributary Area							
	Agriculture	Commercial	Industrial	Military	Open Space	Residential	School/ Public	Transpor-tation
MS1								
Existing	0.6	2.2	0.8	17.9	24.9	39.7	10.9	2.9
Future	0.3	18.5	0.0	14.8	0.7	64.7	0.8	0.0
MS2								
Existing	0.7	1.8	0.9	19.0	25.4	39.1	10.2	2.9
Future	0.3	18.2	0.0	15.7	0.0	65.0	0.9	0.0
MS3								
Existing	0.7	1.7	0.9	19.0	25.6	39.2	10.0	2.9
Future	0.3	17.7	0.0	16.1	0.0	65.2	0.9	0.0
MS4								
Existing	0.6	1.8	1.4	0.0	32.6	47.4	12.2	3.9
Future	0.3	18.6	0.0	0.0	0.0	80.3	0.9	0.0
MS5								
Existing	0.6	1.7	1.5	0.0	33.9	48.0	10.2	4.2
Future	0.3	18.7	0.0	0.0	0.0	80.4	0.5	0.0
MS6								
Existing	0.8	1.3	1.6	0.0	37.4	46.6	8.1	4.3
Future	0.2	20.7	0.0	0.0	0.0	79.1	0.0	0.0
MS7								
Existing	0.8	1.3	1.6	0.0	37.4	46.6	8.1	4.3
Future	0.2	20.7	0.0	0.0	0.0	79.1	0.0	0.0
MS8								
Existing	0.8	1.3	1.6	0.0	37.4	46.6	8.1	4.3
Future	0.2	20.7	0.0	0.0	0.0	79.1	0.0	0.0
MS9								
Existing	1.0	1.5	1.8	0.0	38.8	44.6	7.6	4.7
Future	0.0	24.1	0.0	0.0	0.0	75.9	0.0	0.0
MS10								
Existing	1.0	1.5	1.8	0.0	38.8	44.6	7.6	4.7
Future	0.0	24.1	0.0	0.0	0.0	75.9	0.0	0.0
MS11								
Existing	0.9	1.5	2.1	0.0	42.3	40.6	7.5	5.1
Future	0.0	23.9	0.0	0.0	0.0	76.1	0.0	0.0
MS12								
Existing	0.3	0.3	0.1	0.0	33.4	47.7	12.4	5.9
Future	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
MS13								
Existing	0.3	0.3	0.1	0.0	33.4	47.7	12.4	5.9
Future	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0

TABLE 4-35.
EXISTING AND FUTURE LAND USE DISTRIBUTION
IN NORTH FORK TRIBUTARIES 1 AND 5 STREAM REACH TRIBUTARY AREAS

Stream Reach	Percent of Total Tributary Area							
	Agriculture	Commercial	Industrial	Military	Open Space	Residential	School/ Public	Transpor- tation
Tributary No. 1								
NF1								
Existing	0.1	2.4	1.2	0.0	23.6	54.1	14.6	4.0
Future	0.9	10.2	0.0	0.0	0.0	88.7	0.2	0.0
NF2								
Existing	0.1	2.4	1.2	0.0	23.6	54.1	14.6	4.0
Future	0.9	10.2	0.0	0.0	0.0	88.7	0.2	0.0
NF3								
Existing	0.1	2.3	1.3	0.0	24.4	53.2	14.6	4.2
Future	0.9	11.0	0.0	0.0	0.0	87.8	0.2	0.0
NF4								
Existing	0.0	0.9	0.4	0.0	23.5	63.3	8.0	4.0
Future	1.1	0.1	0.0	0.0	0.0	98.1	0.6	0.0
NF5								
Existing	0.0	0.9	0.4	0.0	23.5	63.3	8.0	4.0
Future	1.1	0.1	0.0	0.0	0.0	98.1	0.6	0.0
NF6								
Existing	0.0	0.9	0.4	0.0	23.5	63.3	8.0	4.0
Future	1.1	0.1	0.0	0.0	0.0	98.1	0.6	0.0
NF7								
Existing	0.0	0.9	0.4	0.0	23.5	63.3	8.0	4.0
Future	1.1	0.1	0.0	0.0	0.0	98.1	0.6	0.0
Tributary No. 5								
T1								
Existing	0.2	3.1	1.8	0.0	24.9	47.2	18.5	4.3
Future	0.8	17.5	0.0	0.0	0.0	81.7	0.0	0.0
T2								
Existing	0.2	3.1	1.8	0.0	24.9	47.2	18.5	4.3
Future	0.8	17.5	0.0	0.0	0.0	81.7	0.0	0.0
T3								
Existing	0.3	3.8	2.6	0.0	22.4	43.3	23.4	4.2
Future	0.0	25.1	0.0	0.0	0.0	74.9	0.0	0.0

TABLE 4-36.
EXISTING AND FUTURE LAND USE DISTRIBUTION
IN SPANAWAY AND MOREY CREEK STREAM REACH TRIBUTARY AREAS

Stream Reach	Percent of Total Tributary Area							
	Agriculture	Commercial	Industrial	Military	Open Space	Residential	School/ Public	Transpor-tation
Spanaway Creek								
S1								
Existing	0.9	1.8	0.2	34.0	19.5	33.7	8.2	1.6
Future	0.5	6.3	0.0	38.8	0.0	53.3	1.1	0.0
S2								
Existing	0.9	1.8	0.2	34.0	19.5	33.7	8.2	1.6
Future	0.5	6.3	0.0	38.8	0.0	53.3	1.1	0.0
S3								
Existing	0.9	1.8	0.2	34.0	19.5	33.7	8.2	1.6
Future	0.5	6.3	0.0	38.8	0.0	53.3	1.1	0.0
S4								
Existing	0.9	1.8	0.2	34.0	19.5	33.7	8.2	1.6
Future	0.5	6.3	0.0	38.8	0.0	53.3	1.1	0.0
S5								
Existing	0.9	1.8	0.3	34.8	19.4	33.0	8.1	1.6
Future	0.5	6.5	0.0	39.7	0.0	52.2	1.2	0.0
S6								
Existing	0.9	1.8	0.3	35.4	19.1	32.9	8.0	1.6
Future	0.5	6.6	0.0	40.3	0.0	51.6	1.0	0.0
Morey Creek								
M1								
Existing	0.9	1.8	0.3	34.8	19.4	33.0	8.1	1.6
Future	0.5	6.5	0.0	39.7	0.0	52.2	1.2	0.0

TABLE 4-37.
HABITAT RATING SYSTEM

Level of Channel or Watershed Alteration	Presence of Fish		
	Present	Potentially Present	Unlikely to Be Present
Low	Highly Suitable Habitat	Secondary Habitat	Negligible Habitat
Medium	Secondary Habitat	Secondary Habitat	Negligible Habitat
High	Secondary Habitat	Secondary Habitat	Negligible Habitat

Source: Pierce County, 2000

Phase 2 Analysis

Criteria for the Phase 2 field assessment of habitat condition vary depending on the channel type being assessed:

- Palustrine channels—Riparian condition, bank condition, channel pattern, and connectivity are assessed.
- Floodplain channels—Riparian condition, substrate composition in spawning areas, embeddedness, bank condition, benthic invertebrate community, pool frequency, channel pattern and connectivity and large woody debris are assessed.

For the Clover Creek field reconnaissance, all parameters needed for both channel types were recorded for all reaches, even though not all were required for the palustrine channels. Bank-full width, temperature data, and fish barrier information were also collected for each reach.

Using the data collected in the field and the USBEM definitions, habitat for each reach was rated as good, fair or poor. Good habitat is able to support salmon production. Fair habitat has reduced value for salmon production, but may support some use. Poor habitat is generally unsuitable for salmon use and production due to a high amount of degradation. Reaches ranked as having negligible habitat use by salmon in Phase 1 are automatically considered to be poor habitat. For reaches surveyed in the field reconnaissance, habitat is generally classified as poor if any recorded parameter is rated poor. Otherwise, reach habitats are classified in the category for which the majority of the reach's recorded parameters were rated, unless a fish barrier existed or some other major problem was apparent, in which case the reach was classified as poor.

The field reconnaissance habitat ratings are shown in Table 4-38, along with the surveyed reaches' existing and future percent effective impervious values. Lower percent-impervious values were calculated for future conditions than for existing conditions for reaches NF4, NF5, and NF6. These minor inconsistencies occurred from using two different sources of land use maps for existing and future conditions. The Pierce County assessor's map was used for existing land use conditions, while the County's future zoning map was used for future conditions. Field evaluation forms for each reach are included in Appendix C. The general findings for the 21 surveyed reaches are as follows:

- Three reaches were ranked as good habitat (NF6 and S4 and S5) and probably provide rearing habitat for coho and possibly chum salmon, as well as resident cutthroat trout. Cutthroat trout juveniles were observed in the North Fork and the main stem of Clover Creek.
- Five reaches were ranked as fair habitat (MS6, MS7, MS9, S3 and S6) and may seasonally provide rearing habitat for salmon and trout species.
- Thirteen reaches were ranked as poor habitat, and would not likely serve any habitat function for salmon or trout species currently. The fish can migrate through many of the reaches, but would not be able to spawn or rear in these areas; many of these reaches are lined with asphalt or otherwise so highly altered as to provide no habitat for fish.

TABLE 4-38.
FIELD RECONNAISSANCE HABITAT RATINGS AND CALCULATED PERCENT-IMPERVIOUS VALUES

	Habitat Condition	Effective Percent Impervious	
Reach	Rating	Existing	Future

TABLE 4-38.
FIELD RECONNAISSANCE HABITAT RATINGS AND
CALCULATED PERCENT-IMPERVIOUS VALUES

Reach	Habitat Condition Rating	Effective Percent Impervious	
		Existing	Future
MS1	Poor	18	44
MS2	Poor	17	43
MS3	Poor	17	42
MS4	Poor	18	40
MS5	Poor	16	40
MS6	Fair	18	46
MS7	Fair	18	46
MS8	Poor	18	46
MS9	Fair	16	45
NF1	Poor	18	29
NF2	Poor	18	29
NF3	Poor	17	28
NF4	Poor	11	10
NF5	Poor	11	10
NF6	Good	11	10
S1	Poor	14	41
S2	Poor	14	41
S3	Fair	14	41
S4	Good	14	41
S5	Good	14	41
S6	Fair	14	41

Conclusions

It is not likely that chinook salmon get into the Clover Creek system at all due to the weirs and inadequately designed fish ladders in the lowest reach (Reach MS1). Additionally, no suitable spawning habitat for chinook was observed in the system. Generally, riffle areas with gravel that might be suitable for spawning had very shallow water during May, which would be even shallower or non-existent during the typical time for fall-run chinook to spawn (August through October).

It is unlikely that any anadromous salmon species access the upper three reaches of the main stem (Reaches MS10 through MS13), North Fork (Reach NF7), Morey Creek, or the North Fork Tributary No. 5 because these reaches appear to go dry (or nearly dry) for several months of the year. Coho and chum salmon may use the creek system as predicted on the fish distribution map, however none were observed during this field survey. Resident cutthroat are present in the creek and juveniles were observed.

Overall, the field-assessed reaches have very little spawning habitat available for salmon or trout species. There are few areas of riffles, and the substrate has a high amount of fine sediment in most reaches. There are many sources of sediment to the creek: construction activities, pasturelands, and eroding banks in some locations. The wetlands in Clover Creek and Spanaway Creek tend to accumulate the fine material, but there are many sediment sources in between the wetlands. The wetland reaches provide rearing habitat, and cutthroat trout were observed in some reaches of cobble substrate, but rearing habitat is limited. Clover Creek and its tributaries have been moved and straightened many times and native riparian vegetation is lacking.

Since Clover Creek and the North Fork are listed on the 303(d) list for temperature, dissolved oxygen, and fecal coliform, one of the most beneficial enhancement efforts that could be undertaken would be to remove non-native riparian vegetation (primarily reed canary grass, blackberries, yellow flag iris, and Scotch broom) and replace them with native trees and shrubs. As observed in the field, water temperature is significantly higher in reaches of the creek where the water flows over asphalt and through unshaded reaches (68°F) than in shaded reaches (52ºF to 56°F). Where the streams are connected to wetlands, the water temperature is significantly lower, likely due to shading and recharge/discharge of groundwater.

Reconnecting the creek to its floodplain wherever possible would be beneficial in lowering temperatures by recharging the groundwater table. The soils in significant portions of this watershed are dominated by gravelly outwash soils with high rates of percolation. It is likely that one reason so much of the channel is lined with asphalt is that flow disappeared into the ground when the creek was moved from its natural alignment. Removing the asphalt lining would create a need for some other lining, such as a buried clay liner, to prevent the creek from disappearing in areas of gravelly outwash. However, a lined channel will prevent groundwater interactions, which could reduce the value of the channel for spawning habitat.

4.5.3 Wetland Habitat

Wetlands are important habitats for plants and animals. Waterfowl, birds of prey, amphibians, fish, and certain wetland-adapted mammals (e.g., beaver and muskrat) depend on wetlands for food, forage, nesting, cover, and resting. Wetlands also maintain water quality through sedimentation, floodwater storage, and biofiltration, and provide groundwater recharge for streams. Wetlands have cultural and societal value in offering educational or recreational opportunities to the public or private landowners (KCM 1996).

The U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) (1985) identifies 3.6 square miles of wetlands in the Clover Creek Basin (See Figure 4-15). The NWI is a broad-brush inventory of wetland habitats interpreted from aerial photographs; it generally omits wetlands smaller than one-third of an acre and underestimates forested wetland areas. Wetlands identified in the NWI are primarily freshwater, emergent, and scrub-shrub wetlands associated with creek channels and the headwaters of North Fork Clover, Clover, and Spanaway Creeks (KCM 1996). The wetlands shown in Figure 4-15 are classified as follows, according to *Chapter 18E.30 Wetlands*, in the Pierce County Code:

- **Category I Wetlands—**Category I wetlands are regulated wetlands of exceptional resource value based on significant functional value and diversity, wetland communities of infrequent occurrence, and other attributes that may not be adequately replicated through creation or restoration.
- **Category II Wetlands—**Category II wetlands are regulated wetlands of significant resource value based on significant functional value and diversity, wetland communities of infrequent occurrence, and other attributes that may not be adequately replicated through creation or restoration.

- **Category III Wetlands—**Category III wetlands are regulated wetlands which of important resource value based on vegetative diversity.
- **Category IV Wetlands—**Category IV wetlands are regulated wetlands of ordinary resource value based on monotypic vegetation of similar age and class, lack of special habitat features, and isolation from other aquatic systems.

In 1985, an estimated 50 percent of the wetland area in the Clover Creek Basin was in the Spanaway Creek drainage area. Large tracts of forested and scrub-shrub wetland are located south and southwest of Spanaway Lake, forming the headwaters of Spanaway Creek. This wetland complex extends well onto the Fort Lewis Military Reservation (KCM 1996). There are also remnants of large wetlands in the headwater areas of the North Fork Clover systems and in UCC-2, UCC-4, and UCC-6.

Limited information is available regarding wetland loss trends in Pierce County or the Clover Creek Basin, but development pressures in the Puget Sound region generally have resulted in an overall loss of wetland area.. In a 1983 study conducted by Ecology, USGS topographic maps for Pierce County were compared with similar maps from 1880. This comparison showed that in the Tacoma South Quadrangle, for example, approximately 75 percent of probable wetland areas were lost between 1880 and 1983 due to dredging, draining, and filling. Approximately 13 square miles of the Clover Creek Basin is in this quadrangle. Given these historical estimates of wetland loss in the South Tacoma area, it is likely that significant wetland areas have been lost or altered in the Clover Creek Basin (KCM 1996).

4.6 UPLAND HABITAT

Upland habitat types in the Clover Creek Basin include primarily coniferous and deciduous forest, pasturelands, landscaped residential areas, and urban areas (e.g., commercial, industrial, and retail developments). Most of the upland areas have been developed. Undisturbed native habitats remaining include fragmented areas of Douglas-fir forest, red-alder forest, and big-leaf-maple-dominated forest. Small native prairie communities and oak woodland dominated by Oregon white oak and ponderosa pine also occur near Lakewood, on McChord Air Force Base, and on the Fort Lewis Reservation (KCM 1996).

Historically, the Lakewood area, including McChord Air Force Base and Fort Lewis, supported a mix of habitats considered rare in Washington. Native prairie habitat and oak woodlands were found intermixed with ponderosa pine and scattered “islands” of Douglas fir. These areas have been extensively affected by human development, resulting in the invasion of Scotch broom and the encroachment of Douglas fir into former prairie and oak woodland sites (KCM 1996).

The lower end of the drainage basin is primarily urbanized (near Lakewood Mall, McChord Air Force Base, and Lake Steilacoom) and lacks significant upland habitat. The upper part of Clover Creek, however, consists of rural residential areas, pasturelands, and small areas of forest. Pasture lands with fragmented forest habitats provide fair habitat values to native wildlife, supporting raptors, small mammals, songbirds, and other species. Pastures may also be occupied by domestic animals and livestock or disturbance-tolerant animals such as skunk, opossum, raccoon, starling, and American robin (KCM 1996).

fig 4-1 and 4-15.apr February 2005

Tetra Tech / KCM
1917 First Avenue
Seattle, Washington 98101

PIERCE COUNTY

Pierce County
Clover Creek Basin Plan

Figure 4-15
Wetlands

The sole Western Washington population of Ponderosa pine is on Fort Lewis, with scattered outlying individuals in Spanaway and other areas near the Fort. The Ponderosa pine occurs near the edges of prairies and in forests with Douglas fir that have invaded former prairies. There are also some scattered groves of lodgepole pine around prairies on Fort Lewis (Pierce County Public Works and Utilities, 1997).

4.7 WATER QUALITY

Water quality in the Clover Creek Basin has been a topic of concern for many local residents. Lake Steilacoom is being overrun by invasive plant growth and several fish kills have occurred in recent years. The USGS and others have conducted extensive water quality sampling on Clover Creek. The Tacoma-Pierce County Health Department has examined local groundwater and is currently studying Lake Steilacoom because of the lake's excessive plant growth and toxic algae blooms.

Tributaries north of Brookdale Road seem to be contributing the highest rates of pollutants to Clover Creek. Zinc levels have been the most problematic, with concentrations exceeding acute toxicity levels on the North Fork of Clover Creek at Waller Road. Dissolved oxygen levels in Clover Creek repeatedly have dropped below state standards. Copper levels exceeding chronic toxicity levels have been detected just upstream of I-5. Lead concentration in excess of chronic toxicity levels have been detected on the North Fork, as well as on the main stem of Clover Creek at the Spanaway Loop Road, and just downstream of McChord Air Force Base.

Four small but significant fish kills have been documented and associated with "first flush" conditions in Clover Creek. "First flush" is a rain event that occurs after an extended period of little or no rainfall. Stormwater runoff typically contains higher concentrations of pollutants during first flush events (Pierce County Public Works Department 1996). First flush conditions in the Clover Creek Basin generally occur in September.

4.7.1 Key Water Quality Characteristics in Clover Creek Basin

The characteristics most likely to affect water quality in the Clover Creek Basin are the permeability of surface soils, land use, sewage and storm water disposal methods, and the presence of lakes in the basin.

Soil Permeability

The permeability of surface soils has two important influences on surface water quality: it governs the infiltration of precipitation, and it determines the rate of groundwater flow through the subsurface before discharge as surface water. Areas underlain by impermeable materials such as tills tend to discharge more quickly and directly into surface streams. In areas underlain with highly permeable materials, such as glacial outwash, the subsurface soils act as a buffer, absorbing water and constituents, allowing filtration and dilution, slowing surface water movement, and attenuating peak flows and constituent transport. Permeable soils can facilitate subsurface chemical and biological transformations on water quality. However, highly permeable soils also can also facilitate pollutant transport from septic systems and dry wells into the groundwater.

Land Use

Land use can affect surface water quality in two important ways: land cover changes can increase impervious cover, resulting in increased and accelerated runoff; and land activity changes can introduce pollutants from operation and maintenance activities, as well as biological wastes. Table 4-39 compares typical levels of pollutants from three general land use types, based on information collected in the Newaukum Creek Basin near Enumclaw. Forested land produces low concentrations of pollutants. Urban land uses, which include residential, commercial, and some industrial uses, produces the highest nutrient and metal contaminant concentrations for all the constituents listed. Agricultural land supporting pasture and grazing for dairy cows and other livestock also contributes high nutrient concentrations, but otherwise produces metal concentrations at a rate only slightly higher than forested land.

Sewage and Stormwater Disposal

Wastewater disposal from septic tanks and dry wells is a potential source of local surface water degradation. There has historically been extensive use of subsurface on-site disposal systems for both wastewater and stormwater in the Clover Creek Basin. When disposal systems are on soils underlain with impermeable layers, the water and entrained constituents may travel horizontally and eventually emerge to affect surface waters.

Lakes

Lakes are commonly classified on the basis of their nutrient content. Lakes rich in nutrients are classified as *eutrophic*; those containing few nutrients are *oligotrophic*; those containing intermediate concentrations are *mesotrophic*. The lakes in the Clover Creek basin are predominately mesotrophic and eutrophic. Increased nutrient loading from urban and agricultural runoff over prolonged periods of time can have a great impact on lake water quality by increasing biotic productivity in the lake. Higher nutrient concentrations can support larger and more sustained algal blooms and aquatic plant communities, which are incompatible with many recreational activities. Other water quality problems may include toxic algal blooms, low levels of dissolved oxygen, and pH spikes, which can lead to ammonia toxicity in fish.

TABLE 4-39.
MEAN POLLUTANT LOADING RATES BY LAND USE CATEGORY

	Land Uses		
Pollutant	Forested	Agriculture	Urban
Temperature (ºF[ºC])	46 [7.8]	45.5 [7.5]	50.5 [10.3]
Turbidity (NTU)	2.7	3.6	20
Dissolved Oxygen (mg/L)	9.9	9.6	8.1
BOD (mg/L)	0.6	3.2	8.1
Total coliform (organisms/100 mL)	7.1	7	7.5
Fecal coliform (organisms/100 mL)	480	990	35,000
Suspended Solids (mg/L)	28	310	4,000
Dissolved Ammonia (mg/L)	10	12	50
Dissolved NO2+NO3 (mg/L)	0.009	0.17	0.11

TABLE 4-39.
MEAN POLLUTANT LOADING RATES BY LAND USE CATEGORY

Pollutant	Land Uses		
	Forested	Agriculture	Urban
Ortho Phosphorus (µg/L)	21	61	100
Total Phosphorus (µg/L)	39	130	360
Total Lead (µg/L)	30	24	130
Total Copper (µg/L)	12	14	19
Total Zinc (µg/L)	14	18	57

Abbreviations:
BOD = biochemical oxygen demand
NO2+NO3 = nitrate + nitrite
NTU = nephelometric turbidity unit
µg = microgram

Source: Prych and Brenner 1983.

Lakes can be a source of water quality degradation to streams because of hydraulic effects and biological processes. In most cases, lakes provide hydraulic detention of incoming flows, allowing more time for suspended solids to settle from the water, for mixing of dissolved constituents, and for biological processing. Lakes also can produce biota and accumulate wastes, which can be flushed during runoff events. In lakes that stratify and undergo seasonal turnover, nutrients incorporated in bottom sediments are periodically mixed back into the water column.

4.7.2 Impacts in Individual Clover Creek Basin Drainage Areas

Table 4-40 shows the land-use distribution for the primary drainage areas in the Clover Creek Basin (USGS 1996). The Upper Clover Creek and Spanaway Lake drainage areas are less urbanized than the North Fork and Lower Clover Creek drainage areas. The Lower Clover Creek drainage area has the largest proportions of high-density housing, commercial and industrial development, and transportation facilities. Upper Clover Creek and Spanaway Lake have large areas, in roughly equal proportions, of forest and grass cover, and of low-density housing. The North Fork subbasin is primarily residential, with a large proportion of low-density housing.

TABLE 4-40.
LAND USE CATEGORIES IN CLOVER CREEK BASIN IN 1991-92

		Land Use Distribution by Area (%)				
Drainage Area	Area (sq. mi.)	Lakes	Forest and grass cover	Low density housing	High density housing	Commercial, Industrial, and Transportation
Upper Clover Creek	34.8	0	41	48	10	1
Spanaway Lake	18.8	2	42	37	16	2
North Fork	6.2	0	21	63	13	4
Lower Clover Creek	7.1	0	23	18	28	31

Source: USGS 1996

Upper Clover Creek

The two characteristics with the greatest impact on water quality in the Upper Clover Creek drainage area are the highly permeable nature of the glacial outwash material and the extensive area still served by subsurface waste disposal systems. In the Upper Clover Creek drainage area, highly permeable glacial outwash soils allow rapid infiltration and promote interaction between surface and groundwater. Water quality data from the 1996 USGS report indicate that levels of bacteria, metals, and other constituents in surface water were relatively low compared to the other three drainage areas, due to the attenuating effect of infiltration to the groundwater system. Landscaping activities, particularly the use of fertilizers, and the extensive use of subsurface waste-disposal systems may have a substantial effect on surface water nutrient concentrations. Because groundwater is the major source of stream flow in this drainage area, relatively little change in either stream discharge or the concentrations of water quality constituents was observed between base flow and storm flow conditions (USGS 1996).

Spanaway Lake

The presence of lakes in the Spanaway Creek subbasin has a significant impact on surface water quality. Spanaway and Tule Lakes have an attenuating effect on stream discharge in response to rainfall, therefore stream discharge in the drainage area increases only moderately in response to rainfall. Due to the long residence times of the lakes, a large percentage of incoming nutrients and contaminants are taken up by lake sediments (USGS 1996). This tends to stabilize constituent water quality parameters such as chloride concentrations, suspended sediment, and nutrients in Spanaway Creek. Water quality data from the 1996 USGS report showed only moderate levels of nutrient concentrations and fecal coliform concentrations, and low levels of metals in the surface waters of this drainage area.

North Fork Clover Creek

In the North Fork drainage area, base-flow and storm-flow conditions yield large differences in stream discharge and water quality. These differences are primarily due to the low-permeability glacial till that underlies most of the drainage area, limiting infiltration of rainfall and resulting in substantial increases in stream discharge in response to storms. Water quality data from the 1996 USGS report found that suspended sediment, ammonia, phosphorus, and fecal coliform levels increased during storm events, indicating that these constituents result largely from the wash-off of surface accumulations (USGS 1996).

Lower Clover Creek

The Lower Clover Creek drainage area receives all discharge from the upstream drainage areas, so water quality in the Lower Clover Creek drainage area reflects an integration of the upstream factors affecting water quality. Under base-flow conditions, outflows from the Upper Clover Creek and North Fork drainage areas are similar in magnitude, with the result that stream flow and pollutant concentrations in the Lower Clover Creek drainage area are intermediate between those two drainage areas. During storm events, increased flow from the North Fork drainage area dominates the flow rate and water quality characteristics in the Lower Clover Creek drainage area. The Lower Clover Creek drainage area is characterized by high-density residential and commercial development. Subsequently, a higher concentration of stormwater outfalls are found along this part of the creek, which contribute high concentrations of urban pollutants (USGS, 1996).

4.7.3 Stream Water Quality

Stream Water Quality Resources

Extensive water quality sampling has been conducted in the creeks and tributaries of the Clover Creek system. This section summarizes data from the following resources on water quality sampling data for Clover Creek and its tributaries:

- *Department of Ecology River and Stream Water Quality Monitoring Program Web Site*. 1959 – Present.
- *Chemical Analyses for Water Quality Determination of Clover Creek*. Barker, King, Knapp, Vinciguerre. 1993.
- *Chemistry of Clover Creek*. Pagel, Lusk, Adair, Nelson, Washington. 1994.
- *Lake Steilacoom Phase I Restoration Study*. KCM. 1996.
- *Surface-Water Quality Assessment of the Clover Creek Basin, Pierce County, Washington, 1991-1992*. USGS. 1996.
- *Chambers-Clover Creek Watershed Characterization Report*. Pierce County Public Works and Utilities. 1997.
- *The Effect of Channelization on the Diversity of Benthic Macroinvertebrate Communities in Clover Creek*. Stiefel, Montgomery, Tremoulet, Kullnat. 1998.

Ecology has conducted a monthly water quality monitoring program for rivers and streams throughout the state since 1959. Monitored attributes include temperature, pH, conductivity, dissolved oxygen, turbidity, total suspended solids, fecal coliform, ammonia-nitrogen, nitrate+nitrite-nitrogen, total nitrogen, total phosphorus, soluble reactive phosphorous, and discharge (flow rate). Dissolved metals are monitored bimonthly at a few stations. One of these monitoring stations (Station 12A110) is on the main stem of Clover Creek, just upstream of Lake Steilacoom. The program’s web site, *www.ecy.wa.gov/programs/eap/fw_riv/data*, includes records for the 1995-98 water year and has information for obtaining records for the 1963-65 and 1976 water years. Limited water quality data for Spanaway Lake is also available at this web site.

In 1996, the Tacoma-Pierce County Health Department funded a two-phase lake restoration study for Lake Steilacoom. The study was conducted in response to citizens' concerns about phytoplankton blooms, which are sometimes toxic, and dense beds of aquatic plants, which limit boating and water sports. The report that was issued presents a review of surface water quality data for Lake Steilacoom and surface and groundwater quality for the Clover Creek Basin. Water quality characteristics of Lake Steilacoom were assessed using a combination of field and laboratory analyses. Monitoring of the lake and tributaries was conducted monthly from May 1994 through April 1995.

The USGS conducted water quality sampling in the Clover Creek Basin during 1991 and 1992 to investigate the effects on water quality of increasing urbanization and land use changes in the area (USGS, 1996). Water quality and stream flow data were collected from 19 surface water sites in the basin over 16 months and evaluated in conjunction with geology, land use practices, and wastewater disposal practices. The sampling sites were existing USGS stream flow stations (see Table 4-21). Data from the study were compared with the water quality standards for Class A streams for dissolved oxygen, fecal coliform, ammonia, copper, lead, and zinc.

Students from the Environmental Investigations program and the biology department at Pacific Lutheran University sampled Clover Creek in the summers of 1993, 1994, and 1998 and presented the results in three reports.

Stream Water Quality Data

This section summarizes available water quality data for Clover Creek and its tributaries. A brief discussion is provided for each water quality parameter. Where extensive documentation makes it difficult to summarize the data, specific documents are referenced for more detail.

Fecal Coliform Bacteria

The resources reviewed for this report indicate that fecal coliform bacteria frequently exceed the state limit for Class A waters of 100 colonies/100 mL. Key findings are as follows:

- Department of Ecology River and Stream Water Quality Monitoring Program for water year 1996—Six of the 12 monthly fecal coliform counts exceeded state Class A water quality standards. Recorded data ranged from a low of 29 colonies/100 mL (12/19/95) to a high of 1,100 colonies/100 mL (4/24/96).
- 1991-1992 USGS Study:
  - Main Stem and North Fork of Clover Creek—Fecal coliform counts exceeded the Class A maximum at 11 of the 12 sampled sites. Fifty percent of the nearly 120 samples that were taken in the 16-month study exceeded the maximum. Fecal coliform counts in excess of 1,000 organisms/100 mL were documented at Bingham Avenue East (Site 340), Brookdale Road (Site 370), Brookdale Road (Site 395), Golden Given Road (Site 400), 17th Avenue South (Site 430), and Gravelly Lake Drive (Site 602).

  - Spanaway Creek—Fecal coliform counts exceeded the Class A maximum at both sampled sites (at the outlet of Spanaway Lake (Site 452) and the outlet of Tule Lake (Site 460)). Six of the 18 samples taken in the 16-month study exceeded the maximum. The highest fecal coliform count recorded was 390 colonies/100 mL, at the outlet of Tule Lake.
  - Morey Creek—Fecal coliform counts exceeded the maximum at the single site monitored, above McChord Air Force Base (Site 480). Four of the 10 samples taken in the 16-month study exceeded the maximum. The highest fecal coliform count recorded was 650 colonies/100 mL.
- Pacific Lutheran University Sampling:
  - 1993—Fecal coliform samples were fairly low, with only one sample above the Class A maximum. A reading of 1,060 organisms/100 mL was taken from Clover Creek at Pacific Avenue and 133rd Street.
  - 1994—Fecal coliform counts were very high, with averages for the five sites ranging from 440 to 2,653 organisms/100 mL. Out of 13 samples taken, only one met Class A standards.

Dissolved Oxygen

The resources reviewed for this report indicate that dissolved oxygen concentrations sometimes failing to achieve the state minimum for Class A waters of 8 mg/L. Key findings are as follows:

- Department of Ecology River and Stream Water Quality Monitoring Program for water year 1996—Dissolved oxygen concentrations consistently exceeded the state water quality minimum. The recorded data ranged from a low of 9.4 mg/L (4/24/96) to a high of 11.7 mg/L (3/20/96).
- USGS 1991-1992 Study:
  - Main Stem and North Fork Clover Creek—Dissolved oxygen levels dropped below the Class A minimum at three of the eight sampled sites: at Military Road (Site 330), at 25th Avenue (Site 355), and at Bridgeport Way (Site 500). However, only 11 of the 43 samples taken in the 16-month study dropped below the minimum. The lowest dissolved oxygen levels were 5.6 mg/L and 5.8 mg/L, both measured at 25th Avenue (Site 355).
  - Spanaway Creek—Dissolved oxygen levels exceeded the Class A minimum at both sampled sites. Levels ranged from a low of 8.8 mg/L to a high of 13.8 mg/L.
  - Morey Creek—Dissolved oxygen levels dropped below the minimum at the sampled site. Nearly half of the nine samples taken in the 16-month study failed to achieve the minimum. The lowest dissolved oxygen level was 7.4 mg/L. Creeks associated with marsh and wetland areas, such as Morey Creek, often have low dissolved oxygen levels because plant decomposition in wetlands consumes oxygen at higher rates than usually occurs in creeks.

- Pacific Lutheran University Sampling:
  - 1993—Dissolved oxygen levels were below the minimum at the 133rd and Pacific Avenue site and the site downstream of McChord Air Force Base. Levels fell as low as 4.6 mg/L at the McChord site.
  - 1994—Concentrations of dissolved oxygen failed to achieve the minimum only at the site downstream of McChord Air Force Base.
  - 1998—Average dissolved oxygen levels at all four study sites were above the minimum.

Temperature

The resources reviewed for this report indicate that Clover Creek Basin stream temperatures generally remain below the state Class A maximum of 18.3ºC. Key findings are as follows:

- Department of Ecology River and Stream Water Quality Monitoring Program for water year 1996—Only one monthly temperature measurement exceeded the Class A standard; the observed temperature was 19.8ºC on 7/24/96.
- USGS 1991-1992 Study:
  - Main Stem and North Fork of Clover Creek—Temperature at all 15 monitored sites were consistently less than the Class A maximum.
  - Spanaway Creek—During one week in early September 1991, measured temperatures consistently exceeded the state maximum at two of the three monitored sites, with temperatures as high 21.5ºC.
  - Morey Creek—Temperatures reached as high as 19.0ºC during one week in September 1991.
- Pacific Lutheran University Sampling:
  - 1993 and 1994—Temperature readings complied with the state standard at all Clover Creek sites.
  - 1998—The average temperature at the Tule Lake Road site was 19.7ºC, which exceeded the Class A maximum. The average temperature at the other three sites was below the maximum.

Acidity and Alkalinity

State standards for Class A streams require pH to remain between 6.5 and 8.5. Exposure to higher pH levels in water inhibits the excretion of ammonia in fish, which can cause ammonia toxicity. Ammonia toxicity causes loss of equilibrium, leaving fish more susceptible to predation. Ammonia toxicity can also make fish more susceptible to toxicity from heavy metals. In extreme cases, ammonia toxicity can be the direct cause of death. pH spikes are usually the result of high rates of photosynthesis in algal blooms in lakes and streams. USGS sampling records indicate the following readings outside this range:

- pH readings of 6.4 at two locations on the North Fork
- A pH of 9 on one occasion in Clover Creek at Spanaway Loop Road
- pH levels of 8.9 and 8.7 at the outlet for Tule Lake (Site 460)

- pH samples measuring 8.6, 8.6, and 8.9 at the outlet for Spanaway Lake (Site 452); this is probably due to over-enrichment of nutrients resulting in high photosynthetic activities by algae and other aquatic plants (KCM 1996).

Heavy Metals and Trace Elements

Table 4-41 summarizes results from the 1991-1992 USGS study for total recoverable copper, lead, and zinc concentrations from 11 locations in the Clover Creek Basin. One copper concentration greater than the chronic criterion was measured at Bridgeport Way (Site 500). Lead concentrations below the acute criterion but greater than the chronic criterion were measured at Waller Road (Site 365), Golden Given Road (Site 400), 17th Avenue South (Site 430), and Bridgeport Way (Site 500). Two measured zinc concentrations exceeded both the chronic and acute criteria, one at Brookdale Road (Site 395) and one at Golden Given Road (Site 400) (USGS 1996).

TABLE 4-41.
CONCENTRATION OF METALS IN CLOVER CREEK BASIN STREAMS

	Range of Sampled Metal Concentrations (µg/L)		
Subbasin	Copper	Lead	Zinc
Upper Clover Creek	2 – 3	<1 - 31	<10 - 20
North Fork Clover Creek	1 – 23	<1 - 12	20 - 140
Spanaway Creek	3 – 6	<1 - 6	<10 - 50
Lower Clover Creek	3 – 10	<1 - 14	<10 - 60
Freshwater Acute Criteria[a]	18 ~~(maximum)~~	82 ~~(maximum)~~	120 ~~(maximum)~~
Freshwater Chronic Criteria[a]	12 ~~(maximum)~~	3.2 ~~(maximum)~~	110 ~~(maximum)~~

a. Criteria are dependent on hardness. Values shown assume a hardness of 100 mg/L

Metals were also measured in fine-grained streambed sediments (smaller than 63 micrometers in diameter) in Upper Clover Creek, Spanaway Creek, and Lower Clover Creek near the mouth at Lake Steilacoom. Concentrations of copper, lead and zinc in Upper Clover Creek sediments were 24, 23, and 59 µg/g, respectively. Concentrations of copper, lead, and zinc in the Spanaway Creek subbasin sediments were 94, 90, and 610 µg/g, respectively. In two locations in Lower Clover Creek, sediment concentrations of copper were 7 and 9 µg/g, lead concentrations were 170 and 180 µg/g, and zinc concentrations were 190 and 210 µg/g (KCM 1996).

Nutrients

Nitrogen and phosphorus are the primary nutrients utilized by algae for growth and reproduction. Nitrogen is typically abundant in natural fresh water bodies, while phosphorus concentrations are low and therefore act as the limiting nutrient. The form of phosphorus used most readily by plants and microorganisms is orthophosphate (PO_4), also called soluble reactive phosphorus (SRP). The EPA (1986) suggests that total phosphorus (TP) should not exceed 50 µg/L in any stream, or 25 µg/L in any lake (KCM 1996).

Nitrogen is often measured as nitrate-plus-nitrite ($N0_2$+NO_3) and ammonium. Nitrate levels in groundwater are used to identify water quality degradation because they can indicate the presence of more hazardous contaminants. Increased levels of ammonium can increase microbial activity, which consumes dissolved oxygen in the water. Ammonium is more likely to be present in waters with low dissolved oxygen levels because as the oxygen becomes depleted, the bacteria can no longer process the ammonium into nitrate and nitrite. The EPA ammonium criterion for four day exposure is 91 µg/L at pH 9.0, at 20ºC. Nutrient findings from studies of the Clover Creek Basin are summarized below.

Key nutrient findings from the resources reviewed for this report are summarized below.

Lake Steilacoom Phase I Restoration Study—For the Lake Steilacoom Phase 1 restoration study, sampling for phosphorus and nitrogen was conducted from May 1994 through April 1995 for Clover Creek and Ponce de Leon Creek, the lake's tributaries, for Chambers Creek, the lake's outlet, and for the lake itself. Analytical results are presented in Table 4-42. Clover Creek TP concentrations ranged from 22 to 32 µg/L, with an average of 26 µg/L. Clover and Chambers Creeks were below the EPA suggested limit of 50 µg/L, while Ponce de Leon Creek was near or above the level for most sampling events. TP concentrations in Clover and Chambers Creeks appeared to follow similar patterns over time, although Clover Creek was dry for most of the summer. Ponce de Leon Creek TP levels were highest during late summer and early fall, and lowest in the winter. There was more variability in SRP concentrations. Overall, there were consistently higher levels of TP and SRP in Ponce de Leon Creek than in the other streams. Ammonium levels monitored in 1994-95 varied from less than 10 µg/L (the detection limit) to a high of 63 µg/L in the creek samples, and 107 µg/L in the composite lake samples. Nitrate+nitrite levels were significantly higher than ammonium levels, with a low of less than 10 µg/L to a high of 2,710 µg/L in Clover Creek in February 1995. Ten of 40 samples collected had nitrate+nitrite levels of 2,000 µg/L or greater, and 15 additional samples had concentrations between 1,000 and 2,000 µg/L, including the composite lake samples.

TABLE 4-42.
LAKE STEILACOOM NUTRIENT MONITORING DATA

	Measured Concentration (µg/L)			
	Chambers Creek	Ponce de Leon Creek	Clover Creek	Composite Lake
Total Phosphorus				
5/27/94	20	45	24	66
7/12/94	21	46	24	27
8/1/94	23	45	n/s	37
9/1/94	50	50	n/s	67
10/6/94	36	53	n/s	60
10/28/94	16	66	n/s	69
12/2/94	38	43	22	61
1/9/95	36	43	32	32
2/6/95	22	40	25	22
3/2/95	33	48	29	30
4/28/95	39	44	24	23
Soluble Reactive Phosphate				
5/27/94	5	36	3	10
7/12/94	13	48	12	3
8/1/94	10	51	n/s	10
9/1/94	2	49	n/s	3

10/6/94	5	52	n/s	1
10/28/94	4	48	n/s	38
12/2/94	5	49	14	3
1/9/95	4	40	22	4
2/6/95	9	45	20	8
3/2/95	4	43	21	9
4/28/95	3	37	10	3
Ammonium				
5/27/94	29	22	33	107
7/12/94	22	25	39	25
8/1/94	19	27	n/s	16
9/1/94	<10	16	n/s	<10
10/6/94	<10	<10	n/s	24
10/28/94	21	<10	n/s	102
12/2/94	23	29	11	19
1/9/95	34	13	10	47
2/6/95	63	<10	<10	60
3/2/95	25	22	41	24
4/28/95	22	<10	13	31
Nitrate+Nitrite				
5/27/94	460	1,087	2,000	713
7/12/94	29	2,160	1,780	149
8/1/94	30	2,190	n/s	171
9/1/94	<10	1,560	n/s	89
10/6/94	29	1,750	n/s	50
10/28/94	36	1,450	n/s	88
12/2/94	<10	1,940	1,430	101
1/9/95	1,330	2,540	2,590	2,000
2/6/95	1,630	2,270	2,710	1,870
3/2/95	1,650	2,320	2,690	1,870
4/28/95	949	1,380	1,500	1,130
n/s = not sampled				

USGS 1991-1992 Study—In its 1991-1992 study, the USGS found nutrient levels in the Clover Creek system to vary widely. The highest concentrations of nutrients were measured in a tributary to Clover Creek that drains a residential development northeast of Brookdale and Canyon Road. Samples containing high nutrient levels were also collected in Midland, on the North Fork, and on Clover Creek just west of Waller Road. However, samples taken from Clover Creek at Gravelly Lake Drive, just before the creek enters Lake Steilacoom, found fairly low nutrient concentrations. TP and SRP concentrations were slightly higher in the North Fork and Lower Clover Creek than in Upper Clover and Spanaway Creeks; however, the differences did not appear to be significant.

Department of Ecology River and Stream Water Quality Monitoring Program—Data collected from Clover Creek by Ecology from October 1975 through September 1976 showed ammonium levels ranging from 30 to 180 µg/L, with no temporal pattern of ammonium concentrations. Nitrate levels monitored from 1962 to 1965 ranged from 140 to 1,630 µg/L, with typical values between 500 and 900 µg/L and an average of 713 µg/L. Nitrite levels were not included in the data because all collected samples had nitrite levels below the detection limit of the analytical equipment then available (KCM 1996).

Total Dissolved Gas

State standards for Class A streams set a maximum level of 110 percent saturation for total dissolved gas. There are no data for total dissolved gas in the Clover Creek Basin. However, the percentage of saturation in Chambers Creek, downstream of Lake Steilacoom, was measured in August and September 1993 at 117.3 percent and 116.7 percent, respectively, which exceeded state standards. Previous analyses (PCPW&U 1994) found no sources of large-scale turbulence in the basin to account for these levels, but turbulence downstream of the outlet structure or high photosynthesis in Lake Steilacoom could result in high saturation of dissolved gases (KCM 1996).

4.7.4 Lake Water Quality

Most of the lakes in the Clover Creek Basin are highly productive systems, with large populations of algae and other plants. Many of the lakes have experienced nuisance algae blooms, some of which contain toxic blue-green algae. Common environmental problems affecting lakes in the basin include toxic algae blooms, excessive growth of macrophytes (non-microscopic plants), accelerated sedimentation, and low oxygen availability (PCPW&U 1994).

Lake Steilacoom was treated with copper sulfate in the past to control blue-green algae blooms and to reduce lake productivity (PCPW&U 1994). Copper sulfate treatments were paid for by the homeowners surrounding Lake Steilacoom and were performed by licensed aquatic herbicide applicators almost annually from the early 1950s until 1991. The amount of copper used for each application depended on several factors, including the amount of algae present in the lake, and the temperature and pH of the water.

Lake Steilacoom is eutrophic, based on water quality studies in 1989 by Ecology and in 1981 by Litter, Aden, and Johnson. The shallowness of the lake, runoff from the developed watershed, and rich organic sediments create a physical and chemical environment that can support large algae blooms and nuisance densities of aquatic plants over about 80 percent of the lake bottom, impairing swimming, boating, fishing, water quality and fish habitat.

Sampling of Lake Steilacoom water quality was conducted from May 1994 through April 1995 as part of the Lake Steilacoom Restoration Study. Key findings were as follows:

- *Secchi Disk Transparency*—A Secchi disk is a tool used to determine water clarity. At most locations, water clarity was lowest in September and October, when blue-green algae blooms occurred throughout the lake. During January and February, water clarity was highest in the south basin and lower in the north basin due to a diatom bloom. Clarity in the north basin was highest from May through August.
- *Temperature*—Lake water temperatures ranged from a high of 24.8ºC in August to a low of about 5.0ºC in January, with an average of 14.5ºC. Some weak thermal stratification at selected locations occurred during the summer.
- *Dissolved Oxygen*—The study found Lake Steilacoom to be generally well-oxygenated at the locations sampled. Average dissolved oxygen concentration ranged from a low of 7 mg/L in October, (about 75 percent saturation) to about 14 mg/L in March (about 130 percent saturation). The highest concentrations coincided with algae blooms. Monitoring results from other sources indicated

dissolved oxygen concentrations outside this range at different locations and depths, particularly in shallow areas.

- *pH*—Hydrogen ion activity, or pH, is commonly used as an index of acidity. A pH of 7 is neutral; lower pH values indicate acidic waters, and higher pH values indicated basic waters. The pH of most natural waters falls between 4 and 9.

  The study found pH in Lake Steilacoom ranged from a low of 6.8 to a high of 9.7, both measured on May 27, at two different depths. The average pH through the water column at all lake stations was over 8 from the end of March to the beginning of October. The pH of the upper 6.6 to 9.8 feet of the water column exceeded 9 between May and September, coinciding with a time of high aquatic plant and algal activity. A pH greater than 9 can be directly lethal to fish. The pH in Lake Steilacoom during the summer was high enough to be detrimental to aquatic animals (EPA 1986).

  Locations in the north basin of the lake tended to have a higher pH than locations in the south basin throughout the year, possibly due to differences in water depth (the waters in the south basin are deeper, and not as affected by temperature and light as the north basin). The pH was uniform throughout the water column at all locations during the winter, generally between 7 and 8.

- *Nutrients*—The range of nitrate+nitrite-nitrogen concentrations measured in the whole-lake composite was from 50 to 2,000 µg/L, with lowest concentrations from May through December, and highest concentrations from January to April. The study concluded that groundwater was the major source of increased nitrate+nitrite-nitrogen levels once precipitation recharged the shallow aquifer. Surface water did not appear to be a significant source of nitrate.

  Peak ammonia concentrations in Lake Steilacoom were potentially harmful to fish and other animals when water temperature and pH were also high. These conditions frequently co-existed in the summer during algal blooms. While whole-lake composites did not exceed EPA criteria for toxicity to salmonids, one location (Ice Rink Cove) had an ammonia-nitrogen concentration exceeding the EPA criterion for four-day exposure. The criterion is 91 µg/L at pH 9.0, at 20ºC, the temperature of the cove at the time (May 27, 1994). In May and October, ammonia levels in the whole-lake composite samples exceeded 100 µg/L, the maximum concentration that water used to culture aquatic animals should contain (Prosser 1973).

  The study found total phosphorus in Lake Steilacoom was high throughout the year, with an average annual concentration of 40 µg/L. The range was 20 µg/L in February to 70 µg/L in October. Concentrations of soluble reactive phosphorus in whole-lake composites were generally low, with one noticeable peak in October of 38 µg/L that could have resulted from phosphorus from “first flush” or dying blue-greens.

- *Copper*—The study found copper content in sediments to exceed the criteria specified by several agencies for highly contaminated freshwater sediments. The greatest concentrations were found in the shallow sediment layers, exceeding 100 mg/kg in the upper 0.6 feet of sediment. Copper concentrations were generally higher in the north basin. The concentration patterns appeared to follow the historical application of copper sulfate. Most of the copper appeared to have accumulated since the 1970s. While copper concentrations were high, the bioavailability of copper was not at levels that would result in toxicity to algae or rooted aquatic plants. The density of plant beds and abundance of phytoplankton in Lake Steilacoom suggest that the copper in the lake sediments is bound to organic and particulate substances, and is neither reactive, nor being taken up by the biota.

Limited water quality information is also available from Ecology for Spanaway Lake. The lake was sampled by volunteers in conjunction with the Ecology's lake monitoring program from 1990 to 1997. A more extensive analysis was conducted between 1998 and 1999 at three stations in the lake. The purpose of this study was to assign water quality standard criteria for the water body.

Based on the water quality sampling that has been conducted by volunteers and by Ecology over the last decade, Spanaway Lake is listed as meso-eutrophic. It is relatively shallow with an average depth of 16 feet. Aquatic plants that thrive in shallow depths are abundant. Records show that the lake was dredged once, which maintained the clarity of the lake for many years. In recent years, the clarity of the lake has deteriorated and numerous blue-green algae blooms have been reported. A large zooplankton bloom was also observed in 1998. The cause of these blooms is most likely internal nutrient recycling. In the summer months, the unmixed lowest layer in the lake, the hypolimnion, tends to become anoxic, which causes phosphorus trapped in the bed sediment to be released into the water column. Once the lake mixes in the autumn, these nutrients are distributed throughout the water column, which can cause rapid algal blooms. Sources of nutrients to the lake are listed as the adjacent park and golf course, and the wetland that feeds into the lake via a stream. Spanaway Lake supports a productive population of bass and trout, although the anoxic conditions in the hypolimnion during the summer are not conducive to a healthy trout fishery. Key findings of the monthly water quality sampling and volunteer monitoring efforts conducted on Spanaway Lake between May and October of 1998 include the following:

- *Secchi Disk Transparency*— Secchi disk depth measurements were variable, however there was a trend of decreased water clarity below 10 feet in late June and again during late July and August.
- *Temperature*—Temperatures ranged from 13.3ºC in May to a high of 25.6ºC in July, with a mean temperature between May and October of 19.3ºC.
- *Nutrients*—Nutrient concentrations were measured from June to September. A marked increase in internal phosphorus loading in the hypolimnion was recorded in late July and in late August. Phosphorus concentrations increased from 29.3 µg/L in June to 340 µg/L in late July. This appears to have been mixed upwards into the upper lake layer, or epilimnion, at some point as the next hypolimnetic phosphorus measurement in early August was 15.3 µg/L. Another marked increase was recorded in late August with hypolimnetic phosphorus concentrations measuring 318 µg/L. In the epilimnion, phosphorus concentrations ranged from 12.8 µg/L in early June to 21.3 µg/L in late September.

  Chlorophyll-a concentrations, a measure of algal productivity, increased from 6.8 µg/L in July to 15.5 µg/L in August, which is likely an indication of algae reacting to the increased availability of phosphorus. Generally, chlorophyll-a concentration increased as the concentration of the limiting nutrient, phosphorus, increased. Volunteer monitors noted algal blooms in late June and mid-October (possibly a blue-green algae bloom), and a zooplankton bloom in mid-August.

- *Fecal coliform*—Fecal coliform concentrations exceeded water quality standards during July and August and the Tacoma Health Department closed the lake to swimming until mid-September.

4.7.5 Groundwater Quality

Groundwater Quality Resources

Groundwater quality surveys and explorations have been conducted in the aquifers of the Clover Creek Basin and the neighboring Chambers Creek Basin since the early 1980s. These surface water basins are connected to one another by what is known as the Clover/Chambers Creek aquifer, which is a source of drinking water for 238,000 residents of Pierce County. For over 168,000 of these residents, it serves as a sole source drinking water supply (Brown and Caldwell 1991).

This section summarizes data from the following resources on groundwater quality sampling data for the Clover/Chambers Creek aquifer:

- *Clover/Chambers Creek Geohydrologic Study*. Brown and Caldwell. 1985.
- *Lake Steilacoom Phase I Restoration Study*. KCM. 1996.
- *Clover/Chambers Creek Basin Groundwater Management Program*. Brown and Caldwell. 1991.
- *Chambers-Clover Management Plan and Technical Assessment*. Tacoma-Pierce County Health Department. To be completed by 2003.

Studies conducted by the Washington State Department of Social and Health Services (DSHS) at the end of the 1970s indicated general deterioration of water quality in the Clover/Chambers Creek aquifer. Levels of nitrates and chlorides were increasing and bacteriological contamination of wells was becoming a common occurrence (Brown and Caldwell 1991).

In the early 1980s, a number of significant site-specific groundwater contamination problems, generally involving toxic chemicals, were discovered in the Clover/Chambers Creek Basin. These problems included the contamination of wells in South Tacoma, Lakewood, Tillicum, Parkland, American Lake Gardens, and University Place (Brown and Caldwell 1991).

In response to the deterioration in groundwater quality, the Tacoma-Pierce County Health Department (TPCHD) and the Washington State Department of Ecology commissioned a geohydrologic study of the Clover/Chambers Creek Basin. The study, completed in 1985, provided information on the geologic and hydrologic make-up of the groundwater system, documented the vulnerability of the aquifer system to contamination from overlying land use activities, and identified the geographic areas subject to the highest risk of groundwater contamination. The study also provided the foundation for the development of a groundwater management and protection program (Brown and Caldwell 1991).

At the request of the TPCHD and in response to the documented groundwater quality problems, Ecology declared the Clover/Chambers Creek Basin to be a Groundwater

Management Area under authority of WAC 173-100. Designation of the Clover/Chambers Creek Basin as a Groundwater Management Area initiated the development in 1991 of a Groundwater Management Program (Brown and Caldwell 1991).

The TPCHD is in the process of developing the Chambers-Clover Management Plan, which is a comprehensive water plan required by the Watershed Management Act. The primary emphasis of the plan will be on water quantity, but the plan will also address water quality and fish habitat concerns. The goal of the plan is to ensure that the water resources in the Chambers-Clover Watershed are managed to balance competing resource demands. This is to be accomplished in a manner that combines and coordinates data collection efforts, ensures that water quality and quantity are adequate for the beneficial uses of all surface and ground water in the watershed, meets or exceeds ESA requirements, ensures viable and healthy aquatic and wildlife habitat, and ensures public water supply to the extent possible within habitat requirements.

Groundwater Quality Data

Early reports of shallow aquifer contamination in the Clover/Chambers Creek Basin date to 1939. In the 1940s, wells were being constructed to tap into the deep groundwater system in order to bypass the contaminated shallow groundwater. By the early 1970s, the Clover/Chambers Creek Basin was supporting one of the largest unsewered, urbanized population centers in the United States. In 1973, the Pierce County Commissioners voted to establish Utility Local Improvement District 73-1, enabling construction of the Chambers Creek-Clover Creek Sewerage System. Beginning in 1985, the sewer system replaced on-site sewage systems over most of the western portion of the basin (KCM 1996).

A groundwater quality survey of the Clover/Chambers Creek Basin conducted in 1981 by DSHS found coliform bacteria in 30 percent of the 117 wells sampled. State coliform bacteria standards (at that time 2.2 organisms/100 mL) were exceeded in 21 percent of the wells on at least one occasion during the study. In the southeastern portion of the basin, which showed the highest levels of contamination, coliform were present in 47 percent of the samples, 39 percent of which exceeded state limits (Littler, et al. 1981).

The DSHS study found that nitrate-nitrogen levels in groundwater appeared to be increasing over time. Average aquifer nitrate-nitrogen levels were approximately 0.5 mg/L in the 1960s and 1.6 mg/L in 1981. Eight survey sites had levels greater than 5 mg/L; the state standard for drinking water is 10 mg/L (Littler, et al. 1981).

TPCHD's 1985 geohydrologic study of the Clover/Chambers Creek Basin included a 13-month groundwater quality monitoring program. Thirty-five wells throughout the basin were tested in this monitoring program. The 1985 report presented the following conclusions:

- Assuming predevelopment or background levels for nitrate of 1.1 mg/L and a current mean nitrate concentration of 1.8 mg/L for the shallow groundwater system, there has been a 67 percent increase in nitrate concentrations for the entire Clover/Chambers Creek Basin over the last 20 years.
- Assuming predevelopment or background levels for nitrate of less than 1.0 mg/L for the deep groundwater system, there has been little or no increase in nitrate concentrations in the deep aquifer over the last 15 to 20 years.

TABLE 7-1.
STORMWATER OUTFALLS IN THE CLOVER CREEK BASIN

ID	Pipe Diameter	Location	Land Use in Area Tributary to Pipe
1	Two 18-inch pipes	Clover Creek at Gravelly Lake Dr.	Commercial/Roads
2	18-inch	Clover Creek and Nyanza Rd. SW	Commercial/Roads
3	Three 12-inch and one 18-inch pipes	Clover Creek at Pacific Highway S	Commercial/Roads
4	30-inch	Spanaway Creek at Military Rd.	Commercial/Roads
5	18-inch	Clover Creek at “C” St.	Residential/Roads
6	36-inch	Clover Creek at Pacific Avenue	Commercial/Roads
7	24-inch	North Fork Clover Creek at “B” St.	Residential/Roads
8	24-inch	Clover Creek at Golden Given	Residential/Roads
9	24-inch	Clover Creek at 25th Ave E	Residential/Roads
10	18-inch	Clover Creek just east of 25th Ave. E	Residential/Roads
11	Six 12-inch pipes	North Fork Clover Creek near 8th Ave. E	Residential/Roads
12	One 24-inch and one 18-inch pipe	North Fork Clover Creek Golden Given Rd.	Residential/Roads
13	18-inch	North Fork Clover Creek at Brookdale Rd.	Roads
14	24-inch	North Fork Clover Creek at 128th St. E.	Pastures/Roads
15	One 12-inch and two 15-inch	North Fork Clover Creek at 112th St. E.	Commercial/Roads
16	24-inch	North Fork Clover Creek at 121st St. E.	Pastures/Roads

- **Nonpoint Pollution; Brookdale Golf Course (WQ-2)—**The Brookdale Golf Course is on the main stem of Clover Creek, and downstream riparian habitat and water quality are vulnerable to landscaping and maintenance activities on the course. Further information about golf course management and landscaping practices should be developed to assess potential impacts.
- **On-Site Sewerage Systems (WQ-3)**—Sewage disposal for most of the eastern half of the Chambers/Clover Creek Basin relies on septic tanks and drainfields. The coarse sand and gravel nature of the Spanaway soil series allows it to readily accept the septic tank effluent, but does not provide for adequate treatment of the pollutants present in the sewage. A general deterioration of water quality throughout the basin, most notably since 1970, appears to be most closely linked to high-density residential areas using septic tanks and stormwater recharge systems.
- **Fish Mortality (WQ-4)—**Recorded and documented fish kills are often wide-reaching, killing a large number of fish. Most fish kills are small and unknown because the carcasses of fish go unnoticed or are rapidly consumed by predators. The most recent recorded fish kills in Clover Creek were reported in 1991 to 1992. Fish kills can be caused by sedimentation, high biological or

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Pierce County
Clover Creek Basin Plan

Figure 7-1
Stormwater Outfalls

chemical contamination, or dewatering of stream systems. They threaten spawning adults, smolts moving downstream to sea, and residential fish.

- **Existing Dry Wells Do Not Comply with State Water Quality Standards (WQ-5)**—Dry well systems are subsurface stormwater disposal facilities, and as such are potential sources of groundwater contamination. Given the hydraulic connection between the shallow groundwater aquifer and Clover Creek, groundwater contamination can lead to surface water contamination. The infiltration, seepage, and recharge stormwater disposal systems used in the Clover Creek Basin provide little or no pollutant removal because of the highly permeable nature of the Steilacoom gravels.
- **Degradation of Groundwater Quality Due to Landfills (WQ-6)**—Solid waste disposal facilities are potential sources of groundwater contamination from leachate, which typically contains significant concentrations of soluble constituents, including volatile organics, phenols and hydrocarbons. Three landfills currently operate in the vicinity of the Clover Creek Basin, and there are a number of inactive landfills in or near the basin as well.
- **Low Benthic Invertebrate Population (WQ-7)**— Benthic (bottom-dwelling) invertebrates are key biological indicators of stream water quality. Invertebrates are slow-moving creatures and receive all the effects of in-stream pollution. An assessment performed for this basin plan indicates that the stream system is not biologically stable. Future management actions should be taken with the understanding that the stream invertebrate community has little ability to recover from adverse conditions and may degrade if steps are not taken to stabilize the overall stream environment.
- **Underground Storage of Hazardous Materials (WQ-8)**— Underground storage tanks may represent the most significant potential hazardous materials threat to basin groundwater. Leakage from tanks is often not easily detected and relatively small amounts of some compounds can have serious impacts on groundwater. The coarse soils covering much of the Clover Creek Basin compound the threat of contamination by allowing rapid migration to groundwater. There are over 4,000 commercial and industrial underground storage tanks installed in Pierce County, but the number in the Clover Creek Basin is not known. The highest potential for groundwater contamination from leaking underground storage tanks is in areas of the basin with the longest history of urbanization.
- **Turbidity/Sedimentation (WQ-9)**— Citizens in the Clover Creek Basin have noticed that turbidity levels in the creek have increased steadily over the last 25 years. High levels of sedimentation hinder the ability of salmon to spawn. There are many sources of sediment to the creek, from construction activities, pasturelands and eroding banks in some locations.

7.1.2 Potential Solutions

Programmatic Actions

- Adopt NPDES program priorities for the following:
  - 303(d)-listed water bodies (WQ-1)
  - Outfall deficiencies (WQ-2)

- Nonpoint pollution from open spaces, recreational areas, and other sources (WQ-3)
- On-site sewerage systems, including septic tanks and drainfields (WQ-4)
- Fish mortality (WQ-5)
- Non-conforming dry wells, including wells used for sanitary disposal (WQ-6)
- Low benthic invertebrate populations (WQ-8)
- Turbidity and sedimentation in surface waters (WQ-10).

The targeting of the NPDES program should include all appropriate aspects of the program, including, but not limited to, the following:

- Public education
- Program for commercial and residential areas
- Program for construction activity
- Program for illicit discharge detection and elimination
- Municipal waste program, including industrial facilities.

- Tri-county ESA program: Promote coordination and implementation, as specific program items, such as the Regional Road Maintenance Program, are approved by NMFS. (WQ-1,3,5,8,10)
- Encourage voluntary retrofits and their maintenance. (WQ-1,3,5,8,10)
- Encourage low impact development to minimize stormwater runoff pollution and quantities. (WQ-1,3,4,5,8,10)
- Coordinate the County program in groundwater management and monitoring with the basin planning process. (WQ-1,4,7,9)
- Upgrade older septic systems where septic systems are appropriate for density, such as in urban growth areas.
- Encourage tie-ins to the public sanitary sewer system where feasible. (WQ-1,4)
- Encourage efficient application of fertilizer on lawns and pastures. Reapplication of the fertilizer every year often causes phosphorus and nitrogen to build up in the soil since the vegetation often uses only a portion of the nutrients that are applied. Nutrient build up increases the amount of excess nutrients transported to open waters. This alternative would require a public education program to raise awareness of this issue and educate the public on efficient and cost-effective methods of applying fertilizer.

Regulatory Restrictions

- Adopt the new stormwater quality standards in Ecology's *Western Washington Stormwater Manual*. The new standards include provisions for stormwater runoff flow control. This will help maintain in-stream flows over longer periods, reduce stream temperatures, and reduce erosion and sediment transport. (WQ-1,3,5,8,10)
- Implement approved TMDLs into the basin and water quality management program. (WQ-1,2,3,4,5,6,7,8,9,10)

- Restrict development in stream and riparian corridors to protect the tree canopy and vegetative cover. This will help lower water temperatures in affected water bodies. This will also help reduce erosion and sediment transport. (WQ-1,3,5,8,10)
- Incorporate results of the low benthic invertebrate study conducted for this basin plan as part of the reference data for evaluation of projects that may impact wetlands in the Critical Areas Ordinance. (WQ-8)

Capital Improvements

- Continue to fund and implement the scheduled capital facilities budget for stormwater outfall retrofitting as part of the NPDES program. Prioritize locations with known fish kills, and with turbidity and sedimentation problems. (WQ-1,2,5,8,10)
- Maintain and retrofit existing detention facilities to ensure effective reduction of first flush pollutants. (WQ-1,2,5,8,10)
- Continue to retrofit existing dry wells with the two-stage design that allows infiltration with minimum impact on beneficial uses of stormwater. (WQ-1,2,5,6,8,10)

Maintenance

- Provide street sweeping in urbanized areas with high traffic. Require street sweeping for construction sites that generate runoff and sediment. (WQ-1,3,5,8,10)

Study and Future Action

- Review golf course management and landscaping practices, including the practices at the Brookdale course and other courses, to address potential habitat loss and nonpoint pollution contributions. (WQ-1,3,5,8,10)
- Continue groundwater contamination studies of landfills in order to evaluate the level of contamination and develop remediation plans if appropriate. (WQ-4,6,7,9)
- Coordinate with federal installations (McChord Air Force Base and Fort Lewis) to obtain groundwater data and coordinate investigations or clean up work if needed. (WQ-4,6,7,9)
- Coordinate with the Department of Ecology to monitor underground storage tanks in the Clover Creek Basin. (WQ-9)

7.2 SPANAWAY CREEK SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

The presence of lakes in the Spanaway drainage area has a significant impact on surface water quality. Spanaway and Tule Lakes have an attenuating effect on stream discharge in response to rainfall, therefore stream discharge in the drainage area increases only moderately in response to rainfall. Due to the long residence times of the lakes a large percentage of incoming nutrients and contaminants are taken up by lake sediments (USGS 1996). This tends to stabilize constituent water quality parameters such as chloride concentrations, suspended sediment, and nutrients in Spanaway Creek. The 1996 USGS report showed only moderate levels of nutrient concentrations and fecal coliform concentrations, and low levels of metals in the surface waters of this drainage area. The long residence time in lakes, however, can contribute to higher temperatures in downstream waters.

7.2.1 Stream Issues

WQ-11—Washington State Section 303(d) Listings

Spanaway Creek is 303(d) listed for temperature. During one week in early September 1991, measured temperature consistently exceeded the state maximum at two of the three monitored sites, with temperatures as high as 21.5ºC. Possible causes include loss vegetative or tree cover in the riparian area, or retention and warming of water in the lakes that feed the stream.

Morey Creek is 303(d) listed for temperature and dissolved oxygen.

WQ-12—Temperature Excursions

The 303(d) temperature excursions on Morey Creek and Spanaway Creek occurred at the outlets of Spanaway Lake and Tule Lake, respectively. A likely cause is the lakes serving as heat sources as they detain water over extended periods.

WQ-13—Sedimentation

Pierce County staff have documented sedimentation in Spanaway Creek between 138th Street and Tule Lake. The 2000 stream assessment of Spanaway Creek also identified a significant amount of silt upstream of 138th Street East. The sedimentation problem could contribute to a backwater problem at 138th Street and to the destruction of salmon spawning habitat in a portion of the creek that was assessed as having good habitat conditions.

WQ-14—Fecal Coliform

Fecal coliform counts exceeded the Class A maximum of 100 organisms/100 mL on Spanaway Creek at the outlets of Spanaway Lake and of Tule Lake.

WQ-15—Alkalinity

A pH of 9 was reported on one occasion in Clover Creek at Spanaway Loop Road. pH levels of 8.9 and 8.7 were reported at the outlet for Tule Lake, and samples measuring 8.6, 8.6, and 8.9 were reported at the outlet for Spanaway Lake. These exceeded the state range for Class A streams (6.5 to 8.5). pH spikes are usually the result of high rates of photosynthesis in algal blooms in lakes and streams.

WQ-16—Metals

Sampling of metals in Spanaway Creek indicated lead concentrations up to 6 µg/L, exceeding chronic (3.2 µg/L) criteria. Total or dissolved?

7.2.2 Groundwater Issues

WQ-17—On-Site Sewerage Systems

On-site sewerage systems pose an elevated risk for groundwater contamination because of the permeable soils in this subbasin. However, existing data are unclear as to the specific degree of risk.

Mean nitrate and chloride concentrations have increased most significantly in the central portion of the Clover/Chambers Creek Basin, most notably in the Lakewood, Parkland, and Spanaway areas. The southeastern portion of the basin, south and east of Spanaway, appears to be the least contaminated area. The eight monitor wells with the highest nitrate concentrations (ranging from 3 to 6 mg/L) are all in the central portion of the basin. These concentrations were measured in the shallow aquifer.

A 1995 study conducted by the Tacoma-Pierce County Health Department (TPCHD) concluded that the majority of the regional nitrate loading is from residential septic tanks and drainfields, and that unsewered residential and non-residential development causes elevated nitrate levels significantly higher than background levels.

The Lakewood Water District, which has been serviced by a sewer system for over a decade, found that the shallow aquifer in the Lakewood area contained elevated nitrate levels, and the deep aquifer had relatively low nitrate. Since the addition of nitrate from on-site sewer systems in the Lakewood area mostly stopped a decade ago, the nitrate concentration was expected to decrease, contrary to the findings.

WQ–18—Existing Dry Wells Do Not Comply with State Water Quality Standards

Dry wells belonging to businesses along the Pacific Avenue corridor used for disposal of wastewater and stormwater present a potential risk for groundwater quality in the subbasin.

7.2.3 Lake Issues

WQ-19—Lack of Baseline Water Quality Data

Limited water quality data is available for Spanaway Lake and Tule Lake. Lack of baseline water quality data for Spanaway Lake is a problem because of the susceptibility of the lake to algal and zooplankton blooms, and fecal coliform excursions, and the need to develop a better understanding of potential causes and solutions. The outlet of Tule Lake reported fecal coliform counts exceeding the Class A maximum.

WQ-20—Lake Nutrient Recycling and Nonpoint Source Pollution

Spanaway Lake is listed as mesotrophic and is susceptible to algal and zooplankton blooms and decreased water clarity during summer months. The cause of the blooms is most likely internal nutrient recycling. In the summer, the unmixed lowest layer in the lake, the hypolimnion, tends to become anoxic, which causes phosphorus trapped in the bed sediment to be released into the water column. Once the lake mixes in the autumn, these nutrients are mixed throughout the water column, which can cause rapid algal blooms. Fecal coliform concentrations exceed water quality standards during July and August. Sources of nutrients to the lake are listed as the adjacent park and golf course and the wetland that feeds into the lake via a stream. Spanaway

Lake supports a productive population of bass and trout, although the anoxic conditions in the hypolimnion during the summer are not conducive to a healthy trout fishery.

7.2.4 Potential Solutions

Regulatory Restrictions

- Adopt regulatory restrictions for development in stream and riparian corridors to protect the tree canopy and vegetative cover and help lower water temperatures in Spanaway Creek. This will also help reduce erosion and sediment transport into Spanaway Creek. (WQ-11,12,13)

Sanitary System Upgrades

- Convert existing on-site sewer systems to tie into the publicly owned treatment system as feasible. This includes conversion of septic tanks and of drywells being used for sanitary disposal. (WQ-17,18)

Vegetation and Maintenance

- Inspect the County detention pond, with special focus on the condition of vegetation and sediment. Maintain as needed. (WQ-11)

Study and Future Action

- Study the feasibility of periodic maintenance dredging of Spanaway Lake to remove accumulated nutrients in order to reduce algal and zooplankton blooms and anoxic conditions and promote water clarity in the late summer. (WQ-20)
- Develop a volunteer effort to collect baseline water quality data for Spanaway Lake and Tule Lake, using such tools as a web site for data uploading and viewing and a public education program. (WQ-19,20)
- Conduct a study of potential sources of fecal coliform in the park and golf course adjacent to Spanaway Lake (birds, pets, etc.), and areas near Tule Lake. Implement regulations and programs as needed to reduce or eliminate such sources (scoop law enforcement, control of bird populations, etc.). (WQ-20)

7.3 WARDS LAKE SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

The Wards Lake Subbasin is not part of the Clover Creek Basin. This subbasin is included in the Clover Creek Basin Plan for convenience because of its location adjacent to the Clover Creek basin and because numerous flooding and drainage problems exist in the area. No water quality issues specific to this subbasin were identified.

7.4 STEILACOOM LAKE SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

The Steilacoom Lake Subbasin is entirely within the jurisdiction of the City of Lakewood. Steilacoom Lake is the receiving water body for Clover Creek and Ponce De Leon Creek. Problems and issues were identified for this subbasin, but alternative solutions were not developed because it is outside Pierce County jurisdiction.

7.4.1 Stream Issues

WQ–21—Retrofitting of Existing Outfalls

Pierce County identified runoff controls in 1994 as part of its NPDES capital facilities program for stormwater outfalls from Gravelly Lake Drive and the Pacific Highway. These outfalls are now within the City of Lakewood and will be subject to the Lakewood NPDES permit requirements when the Lakewood NPDES Phase II program comes into place, which is expected to be in 2003. Discharges from these outfalls were thought to be linked to fish mortality and/or toxic to aquatic life, especially during first-flush conditions.

WQ-22—303(d) Listing

Chambers Creek downstream of Chambers Lake is 303(d) listed for copper and temperature. Possible causes include the historical use of copper sulfate for aquatic plant control in Steilacoom Lake and warming of water retained in the lake prior to discharge into Chambers Creek.

Clover Creek in this vicinity is 303(d) listed for fecal coliform, dissolved oxygen, and temperature. Causes may include lack of adequate cover, lack of protection of riparian area from domestic animals, and oxygen deficits from adjoining wetlands.

7.4.2 Groundwater Issues

WQ-23—On-Site Sewerage Systems

While this area is mostly sewered, on-site sewerage systems could pose an elevated risk of groundwater contamination because of the predominance of highly permeable Spanaway series soils.

7.4.3 Lake Issues

WQ–24—Washington State Section 303(d) Listings (TMDL)

As a result of 303(d) listings, Steilacoom Lake has been the subject of TMDL studies for phosphorus in the inflow and copper in lake sediments and the outflow. In February 2000, the EPA set TMDL criteria for total phosphorus in Steilacoom Lake. In February 2002 the TMDL for Phosphorus was vacated due to disputed data in the studies. The City of Lakewood is expected to be required to apply for an NPDES Phase II permit for stormwater discharge in 2003.

7.5 NORTH FORK CLOVER CREEK SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

In the North Fork drainage area, base-flow and storm-flow conditions yield large differences in stream discharge and water quality. These differences are primarily due to the low-permeability glacial till that underlies most of the drainage area, limiting infiltration of rainfall and resulting in substantial increases in stream discharge in response to storms.

7.5.1 Stream Issues

WQ-25—303(d) Listing

The North Fork is 303(d) listed for fecal coliform.

WQ-26—Fecal Coliform

Fecal coliform counts in excess of 1,000 organisms/100 mL were documented at several North Fork subbasin sites. Although specific sources were not identified, nutrient sources may include adjacent open areas accessible to birds and domestic animals, as well as leaky septic tanks. The 1996 USGS report found that suspended sediment, ammonia, phosphorus, and fecal coliform levels increased during storm events, indicating that these constituents result largely from the wash-off of surface accumulations.

WQ-27—Acidity

At two locations of the North Fork, USGS sampling indicated two pH readings of 6.4, which was below the state range for Class A streams (6.5 to 8.5).

WQ-28—Metals

Sampling of metals in the North Fork indicated copper concentrations up to 23 µg/L, which exceeds both chronic (12 µg/L) and acute (18 µg/L) criteria. Lead concentrations were up to 6 µg/L, exceeding chronic (3.2 µg/L) criteria. Zinc concentrations were in the range of 20 µg/L to 140 µg/L, with the upper range exceeding chronic (110 µg/L) and acute (120 µg/L) criteria. Do you know if these figures are total or dissolved and were they adjusted for hardness as per 13-201-A?

7.5.2 Potential Solutions

Potential solutions to the identified water quality problems in this subbasin include the following:

Regulatory Restrictions

- Adopt regulatory restrictions for development in stream and riparian corridors to protect the tree canopy and vegetative cover, and limit access to birds and domestic animals in order to help reduce nutrient loads. (WQ-25,26)

Study and Future Action

- Conduct a study of potential sources of fecal coliform (birds, pets, etc.) in the subbasin near the North Fork and main stem. Implement regulations and programs as needed to reduce or eliminate such sources (scoop law enforcement, control of bird populations, etc.). (WQ-25,26)
- Study potential acidic and metal contaminant sources in the North Fork and other locations in the Clover Creek Basin, and develop source controls to minimize pollution. (WQ-27,28)

7.6 LOWER CLOVER CREEK SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

The Lower Clover Creek drainage area receives all discharge from the upstream drainage areas, so water quality in the Lower Clover Creek drainage area reflects an integration of the upstream factors affecting water quality. Under base-flow conditions, outflows from the Upper Clover Creek and North Fork drainage areas are similar in magnitude, with the result that stream flow and pollutant concentrations in the Lower Clover Creek drainage area are intermediate between those two drainage areas. During storm events, increased flow from the North Fork drainage area dominates the flow rate and water quality characteristics in the Lower Clover Creek drainage area. The Lower Clover Creek drainage area is characterized by high-density residential and commercial development. Subsequently, a higher concentration of stormwater outfalls are found along this part of the creek, which contribute high concentrations of urban pollutants

7.6.1 Stream Issues

WQ-29—Fish Mortality

Fish mortality has been a problem in Lower Clover Creek just upstream from Steilacoom Lake. Fish kills have been documented in this reach on three occasions since 1990. While not proven conclusively, the suspected cause for these fish kills is contaminated stormwater runoff, occurring with the first flush following a prolonged dry period.

WQ-30—303(d) Listing

Clover Creek in this vicinity is 303(d) listed for fecal coliform and temperature. Possible causes for elevated temperature are lack of adequate cover and warming from conveyance of runoff over impervious urban surfaces.

WQ-31—Fecal Coliform

Fecal coliform counts in excess of 1,000 organisms/100 mL were documented at a sampling station at 17th Avenue South, and at several sites immediately upstream and downstream of the Lower Clover Creek subbasin. Other locations had counts exceeding the state standard for Class A waters of 100 organisms/100 mL, including Morey Creek, which feeds directly into lower Clover Creek. Although specific sources were not identified, nutrient sources may include adjacent open areas accessible to birds and domestic animals, as well is leaky septic tanks.

WQ-32—Dissolved Oxygen

Dissolved oxygen sometimes failed to meet the state minimum standard. The 1991-92 USGS study found that dissolved oxygen levels dropped below the Class A minimum of 8 mg/L at Bridgeport Way. In 1994, Pacific Lutheran University sampling indicated that concentrations of dissolved oxygen were below the minimum at a site downstream of McChord Air Force Base. During Ecology's 1996 River and Stream Water Quality Monitoring Program, dissolved oxygen levels consistently achieved the state minimum. Possible natural causes of low dissolved oxygen concentration include biochemical oxygen demand (BOD) or chemical oxygen demand (COD) loading through plant decomposition or increased biological activity.

WQ-33—Metals

Sampling of metals in Lower Clover Creek indicated lead concentrations up to 14 µg/L, exceeding chronic (3.2 µg/L) criteria.

7.6.2 Groundwater Issues

WQ-34—On-Site Sewerage Systems

Much of this subbasin is underlain by permeable Spanaway soils, making any on-site sewerage systems likely to contaminate the groundwater.

WQ-35—Degradation of Groundwater Quality Due to Landfills

Numerous active and abandoned landfills and disposal sites that pose a risk to groundwater are located within this subbasin. The most concentrated area is McChord Air Force Base, where 62 sites were previously identified. The abandoned Cascade Pit Landfill between McChord Air Force Base and Highway 512 is another potential groundwater contamination site. No significant groundwater contamination studies have been conducted in the Cascade Pit Landfill.

7.6.3 Potential Solutions

Regulatory Restrictions

- Adopt regulatory restrictions for development in stream and riparian corridors to protect the tree canopy and vegetative cover and help lower water temperatures in Clover Creek. This will also help reduce erosion and sediment transport into Clover Creek. (WQ-29,30)

Sanitary System Upgrades

- Convert existing on-site sewer systems to tie into the publicly owned treatment system as feasible. (WQ-30,31,34)

Source Controls

- Provide street cleaning, particularly in commercial areas where street and parking surfaces can accumulate first-flush pollutants. (WQ-29,30,31,32,33)

Capital Improvements

- Provide stormwater outfall retrofits as part of the County's NPDES program. The retrofits can provide stormwater quality improvements to remove oils, greases, and sediments. Retrofits could range from low-cost installations such as catchbasin filters to special on-line systems, such as vortex or swirl chambers, or oil/water separators. (WQ-29,30,31,32,33)

Programmatic Actions

- Use public education to increase public awareness of ways to prevent fish kills, such as use of household best management practices, elimination of chemical usage for vehicle washing and other outdoor cleaning, and reduction of pesticide and fertilizer use for lawn and garden care. (WQ-29,30,31,32,33)

Study and Future Action

- Conduct a groundwater contamination study of the Cascade Pit Landfill between McChord Air Force Base and Highway 512. (WQ-35)

7.7 UPPER CLOVER CREEK SUBBASIN ISSUES AND POTENTIAL SOLUTIONS

7.7.1 Stream Issues

WQ-36—Non-Point Source Pollution—Brookdale Golf Course

The potential for nonpoint source pollution from the Brookdale Golf Course was identified as an issue because of the golf course’s position straddling Clover Creek. Fertilizers have reportedly not been applied near the creek in its 64 years of operation. However, further information about fertilizer practices at the golf course is not available.

WQ-37—Turbidity and Sedimentation

A local resident identified turbidity and sedimentation as a problem at the Waller Road crossing and upstream from the confluence with the North Fork for approximately a mile. The source of the sediment could not be identified at the time.

WQ-38—303(d) Listing

Clover Creek in this subbasin is 303(d) listed for fecal coliform, dissolved oxygen, and temperature. Possible causes include lack of adequate cover, warming of runoff conveyed over impervious urban surfaces, lack of protection of riparian area from domestic animals, and oxygen deficits from adjoining wetlands.

WQ-39—Fecal Coliform

Fecal coliform counts in excess of 1,000 organisms/100 mL were documented at Bingham Avenue East and Brookdale Road sampling sites. Although specific sources were not identified, nutrient sources may include adjacent open areas accessible to birds and domestic animals, as well as leaky septic tanks.

WQ-40—Dissolved Oxygen

Dissolved oxygen sometimes failed to meet minimum state standards. During the 1991-92 USGS study, dissolved oxygen levels dropped below the 8 mg/L Class A minimum at sampling sites at Military Road and 25th Avenue. The lowest levels were 5.6 mg/L and 5.8 mg/L, both measured at 25th Avenue. During Ecology’s 1996 River and Stream Water Quality Monitoring Program, dissolved oxygen levels consistently achieved the state minimum. Possible natural causes of low dissolved oxygen concentration include BOD or BOD loading through plant decomposition or increased biological activity, or groundwater inputs..

WQ-41—Metals

Sampling of metals in Upper Clover Creek indicated lead concentrations up to 31 µg/L, exceeding chronic (3.2 µg/L) criteria.

7.7.2 Groundwater Issues

WQ-42—On-Site Sewerage Systems

On-site sewerage systems have an elevated risk of contaminating groundwater in the southwest portion of the subbasin which is underlain by permeable Spanaway series soils.

WQ-43—Degradation of Groundwater Quality Due to Landfills

Two landfills, one active (Hidden Valley) and one abandoned (Starvation Valley), pose a risk to groundwater quality.

7.7.3 Potential Solutions

Regulatory Restrictions

- Adopt regulatory restrictions for development in stream and riparian corridors to protect the tree canopy and vegetative cover, and to limit access to birds and domestic animals. This will help reduce temperature in surface waters, nutrient loads, and turbidity and sedimentation. (WQ-37,38,39,40)

Sanitary System Upgrades

- Convert existing on-site sewer systems to tie into the publicly owned treatment system as feasible. (WQ-38,39,40)

Study and Future Action

- Conduct a groundwater contamination study of the Starvation Valley landfill and continue monitoring the Hidden Valley landfill for groundwater contamination. (WQ-43)
- Conduct a study of fertilizer use at the Brookdale Golf Course, and develop recommendations for stormwater quality improvement. (WQ-36,37,38, 39,40)

CHAPTER 10.
SUMMARY OF BASIN PLAN RECOMMENDATIONS

This chapter summarizes the solutions recommended for implementation in the Clover Creek Basin. These recommendations include regulatory and programmatic measures as well as a prioritized list of capital projects to reduce existing flooding problems, improve water quality, improve fish habitat and accommodate projected future development while complying with federal and state regulations.

10.1 BASIN PLAN RECOMMENDATIONS

Tables 10-1 through 10-4 summarize the recommended actions. Basin-wide measures are described separately from the subbasin specific measures. Capital improvements, recommended studies, and inter-related projects are prioritized as high, medium, or low priority to indicate the relative significance of projects and the order in which they should be implemented. Chapters 6, 7, 8, and 9 provide background information about each recommendation and the problems and issues they address.

The plan has been designed with a broad range of solutions to ensure flexibility and resilience in meeting its goals and objectives. The plan should be updated periodically as projects are implemented and with changes in the regulatory and political climate. Most capital improvement projects, such as construction of infiltration facilities or culvert replacements, will require additional planning and design before implementation. The cost estimates presented for projects in this plan will aid the County in planning future projects and in allocating sufficient funds.

10.2 RECOMMENDATIONS FOR MONITORING AND ADAPTIVE MANAGEMENT

Adaptive management is a conservative experimental approach to watershed management. The key components of this approach are to apply measures based on the best available information or science known at the time and to adjust the application of these measures over time based on knowledge gained from the measures' implementation. This approach allows for flexibility in management policies as science and technology advance. Key areas in which adaptive management techniques can be applied in this basin plan include the following:

- Use of low-impact development standards
- Restoration of streams and wetlands
- Restoration of riparian corridors
- Use of BMPs to enhance surface water quality
- Flood hazard reduction.

A monitoring program should be set up to gather data and analyze the outcomes of these categories of projects after they are implemented. Knowledge gained from the outcomes of these projects, as well as improvements in applied science, can be used to make adjustments to watershed management policy in the County.

10.3 COMPARISON TO 1991 PLAN

The 2002 Clover Creek Basin Plan has a much broader range and scope than the chapter that applied to the Clover Creek basin in the 1991 Plan. This basin plan includes environmental components that were not previously addressed, including surface water quality and stream and riparian habitat. These added components reflect the significant changes in environmental policy that have occurred in Western Washington over the past decade. These policy changes have come about due to changes in environmental legislation, as well as the value society has placed on the preservation and protection of natural resources. The current emphasis of watershed policy is on the reduction of development and land use impacts on natural resources. Therefore, the 2002 Clover Creek Basin Plan was crafted to balance the public's need for drainage infrastructure with the protection and enhancement of natural resources.

The 1991 Plan focused primarily on reducing flooding problems and improving water quality entering the sole source aquifer. The goals and objectives of the 2002 Clover Creek Basin Plan were crafted to protect surface water quality and habitat in lakes, wetlands and streams in addition to flood hazard reduction. Solutions to identified problems, which include regulatory and land use measures, were analyzed based on their potential impact on flooding, water quality and habitat. A greater emphasis was placed on selecting non-structural recommendations and on solutions with multiple uses, such as performing stream restoration to reduce flooding in nearby developments. This plan provides a greater level of flexibility that can be used during the adaptive management process to incorporate new knowledge and advances in applied science and technology.

10.4 IMPLEMENTATION STRATEGY

Implementation of the recommended actions will generally follow the prioritization groupings of high, medium, and low. However, implementation will not follow the exact sequence of the first project to the last project in the High category, followed by the first action in the Medium category, and so forth. Several factors exist that will result in implementation of actions that are not in the exact sequence as depicted in Tables 10-1, 10-2, and 10-3. These factors include the following:

- **Available funds.** Adoption of the Basin Plan will occur with a pre-existing approved Capital Facilities Element. Under the Growth Management Act, Counties annually update this Element which includes surface water management capital projects. While the County has taken into consideration projects identified in the basin planning effort, funding decisions have already been made for other projects which reduces available funds for year one of basin plan implementation.

- **Contingent projects.** Some of the projects are contingent on other projects being implemented first. For example, several culvert replacements to reduce flood hazard and open up habitat are contingent on sequencing with other culvert projects within the same watershed and/or on the same stream.

- **Available staff and professional service needs.** Various types of projects and programs have specific expertise needs. For example, developing a public education program requires a different skill set than designing a retention pond. Aligning the needed skill sets with the recommendations will result in projects selected out of the sequence suggested in the tables.

- **The best implementer may be someone other than Pierce County Public Works and Utilities.** Some of the recommended actions may be more appropriately conducted by other parties. For example, stream fencing could be better implemented by conservation corps or Conservation District personnel. In these cases, the sequence of action implementation needs to be coordinated with other priorities and work loads of those non-Public Works and Utilities Department entities.

- **New information or emerging issues.** These factors will influence the annual capital and work plans designed to implement the Basin Plan.

In light of these and other factors, following action on the Basin Plan, Pierce County will develop an implementation strategy designed to sequence, schedule and assign resources for the various recommended actions. This implementation strategy will be developed in collaboration and coordination with other potential implementers and in consideration with available financial and staff resources. The implementation strategy with include performance measurements and provide for periodic evaluation of progress.