CHAPTER 4: BASIN HYDROLOGY AND WATER QUALITY

This chapter summarizes the results of a study of the basin's hydrology and water quality. A state-of-the-art computer model called "Hydrologic Simulation Program-Fortran" (HSPF), developed by the EPA, was calibrated to simulate the Chambers basin. The model calibration used four years of continuous flow data for Chambers Creek, as well as precipitation data collected in the basin. The Thurston County Environmental Health Department conducted a two-year water quality study of the streams and lakes in the basin. Separate final reports on the studies are available from the Thurston County Department of Water and Waste Management. This chapter summarizes the significant findings, and appendices D and E contain the supporting data.

4.1 BASIN HYDROLOGY

The "basin hydrology" describes the behavior of the lakes, streams and ditches in response to precipitation. Land cover, soil characteristics, and ground water interactions determine how the water bodies absorb and store precipitation, and convey it to receiving waters. Flooding, erosion, habitat loss and water quality degradation can result from the basin's hydrologic behavior. This section explains how rainfall in the basin interacts with the water bodies.

Continuous flow data measured for four years in Chambers Creek at Rich Road, stream flows measured once per month for one year from five stations on the creek and ditch, and precipitation recorded at 60th Loop SE provided the basis for this analysis. Table 4-1 contains the monthly flow data. Map 11 shows the location of flow monitoring stations.

Volunteers read the staff gauges and recorded the lake level data for the lakes in the basin from 1990 through 1993. Complete data for all the lakes began in August 1990. The data was reported according to "water year", which runs from the beginning of October through the end of September. Lake levels were graphed and correlated with precipitation data from the National Weather Service station at the Olympia Airport.

4.1.1 HYDROLOGY OF CHAMBERS DITCH AND CHAMBERS/LITTLE CHAMBERS LAKE

Chambers Lake, Little Chambers Lake, and Chambers Ditch constitute a connected, hydrologic system. The hydrology of this drainage area is complicated by interactions between groundwater and surface water throughout the area (Aqua-Terra 1994). The groundwater interactions are the key to understanding the hydrology.

Aqua-Terra's 1994 report on the basin hydrology states: "Approximately two-thirds of the watershed is covered with outwash soils. These soils have a high infiltration capacity. As a result, most of the runoff from these soils is water that goes to groundwater. Some of the groundwater contributes to Chambers Lake, Chambers Ditch, and Chambers Creek. Some of it flows directly into Puget Sound to the north and Spurgeon Creek to the south of the Chambers watershed."

Table 4-1 Monthly stream flows (cfs) in Chambers basin

Date	CK-13: South Trib	CK-14: mouth	CK-12: Rich Road	CK-10: Herman Rd	CK-11: Yelm Hwy
2/19/92	0.12	8.78	5.39	4.75	5.38
3/25/92	0.00	3.66	1.14	1.47	1.40
4/22/92	0.07	5.50	2.50	1.89	1.57
5/19/92	0.00	2.32	0.64	0.54	0.27
6/30/92	0.00	1.02	0.10	0.04	0.00
7/20/92	0.00	0.92	0.02	0.00	0.00
8/17/92	0.00	0.86	0.00	0.00	0.00
9/22/92	0.00	0.43	0.00	0.00	0.00
10/20/92	0.00	0.50	0.00	0.00	0.00
11/23/92	0.01	1.38	0.18	0.97	0.39
12/21/92	0.17	1.59	1.50	1.57	1.51
1/25/93	0.62	8.01	7.82	3.47	7.59
AVERAGE	0.08	2.91	1.61	1.23	1.51
% of flow at mouth	03		55	42	52
% of flow @ Rich Rd	05			76	94

Station numbers and locations are as follows:

CK10 = Chambers Ditch at 37th SE (Herman Road)
CK11 = Chambers Ditch at Yelm Highway
CK12 = Chambers Creek at Rich Road
CK13 = South Tributary east of Rich Road
CK14 = Chambers Creek mouth

Chambers Lake flows into Little Chambers Lake via a ditch through the causeway of the Chehalis-Western railroad, and Little Chambers Lake flows into Chambers Ditch through an outlet weir. Neither lakes have feeder streams. Groundwater, direct precipitation, and stormwater runoff are the only sources of water in Chambers Lake, because no surface streams drain to the lake. Aqua-Terra states that "the flow into Chambers Lake only occurs when the groundwater table rises and begins to interact with Chambers Lake." Groundwater, flow from Chambers Lake, and several stormwater systems feed Little Chambers Lake.

The two lakes rise and fall at different rates. Little Chambers Lake responds more quickly than Chambers Lake to rainfall because the stormwater systems from suburban developments drain runoff quickly into Little Chambers Lake. Little Chambers Lake levels rose and fell in correlation with rainfall events throughout the monitoring period, particularly during autumn months. The lake had less response to rainfall in the winter and early spring months, probably because the groundwater table kept the lake levels up during rainless periods. Figures 4-1 and 4-2 illustrate lake levels and precipitation for Chambers and Little Chambers Lakes.

Chambers Lake tends to reach slightly higher elevations than Little Chambers Lake because the ditch draining Chambers Lake is a little higher and smaller than the outlet of Little Chambers Lake. Chambers Lake maintains consistently higher summer levels than Little Chambers Lake, and does not drop as quickly following winter storms. As Chambers Lake rises, it spreads out over a 100+ acre wetland surrounding the northwest end of the lake, which substantially increases the lake's capacity.

According to Aqua-Terra: "Based on lake elevations and outlet flows, the groundwater table appears to interact with Chambers Lake on an intermittent basis. This means that during extended periods of rainfall the groundwater table (rises) to where it starts to contribute flow to Chambers Lake. During extended dry periods the groundwater table falls below Chambers Lake and stops contributing flow to the lake."

For the purposes of modeling the lake/ditch interactions, Aqua-Terra combined both lakes and developed a stage-discharge relationship, figure 4-3, which shows the outflows to Chambers Ditch according to the lake elevation. According to the observed flows, the lake begins to drain to Chambers Ditch when it reaches an elevation of 191.6′ above sea level, and outflows increase as the lake level rises above that elevation.

Flows in Chambers Ditch vary widely from year to year. Groundwater contributes to flows in Chambers Ditch both indirectly, by feeding Little Chambers Lake, and through direct input to the ditch. Groundwater only contributes to flows in Chambers Ditch when the groundwater table rises above the level of the bottom of the lake and ditch (Aqua-Terra 1994).

During dry years, Chambers Ditch stops flowing in early to mid-summer. After the groundwater table drops, rainfall draining to Chambers Ditch infiltrates into the ground before it reaches Chambers Creek. According to Aqua-Terra, "in dry years...the groundwater level never gets high enough to provide much water to the ditch and creek system and the

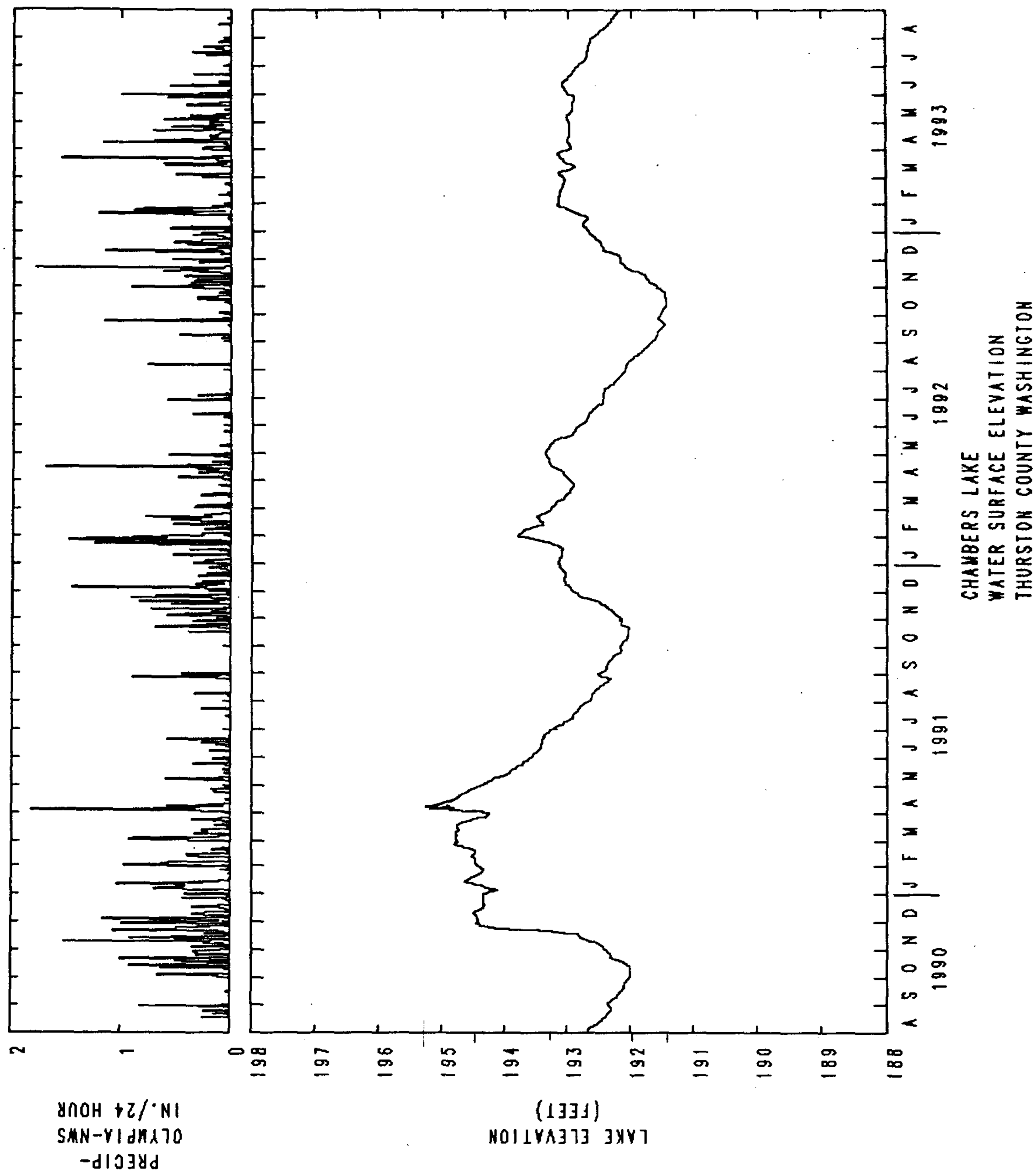

Figure 4-1 Chambers Lake surface elevation, August 1990 - August 1993

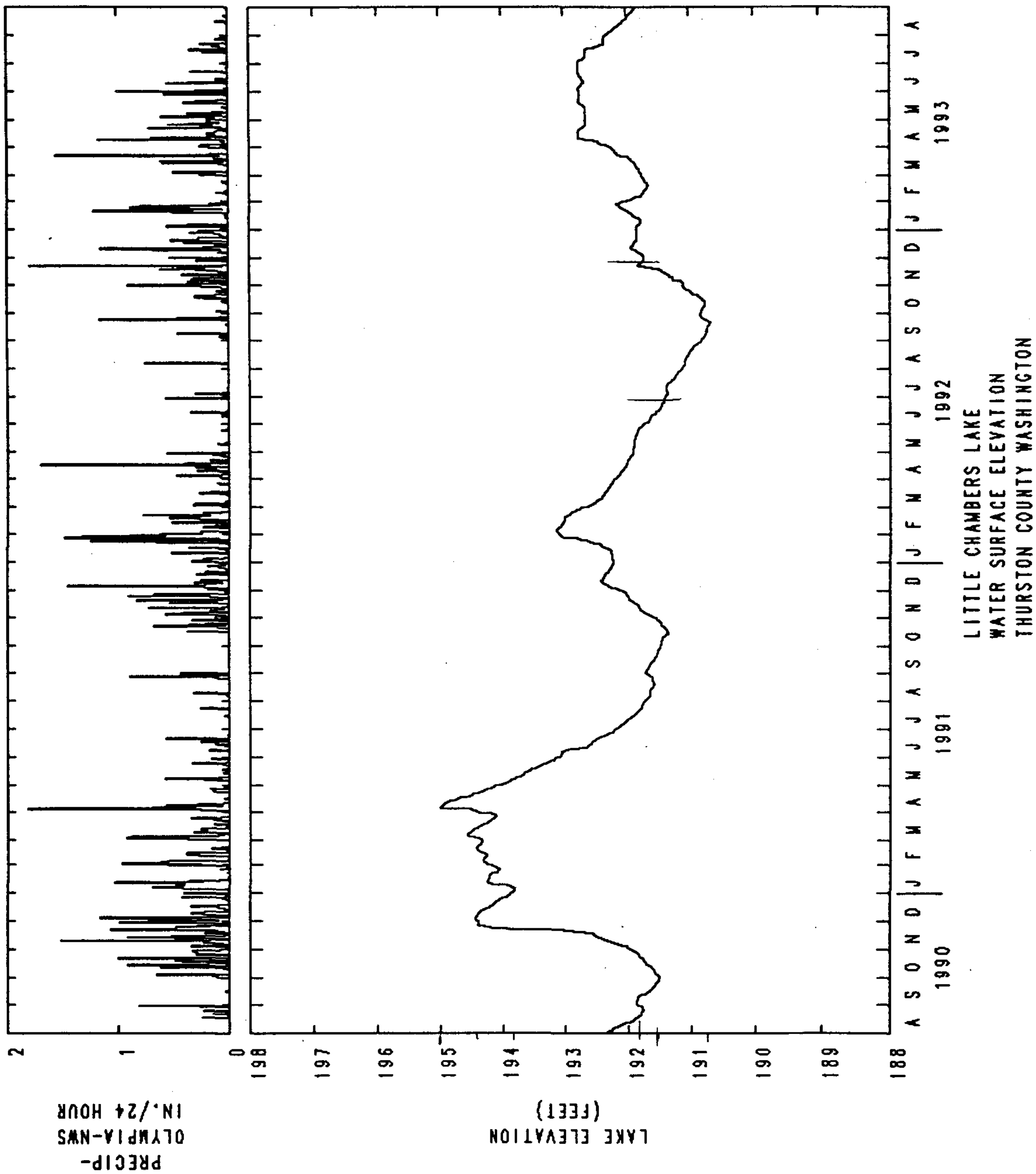

Figure 4-2 Little Chambers Lake surface elevation, August 1990 - August 1993

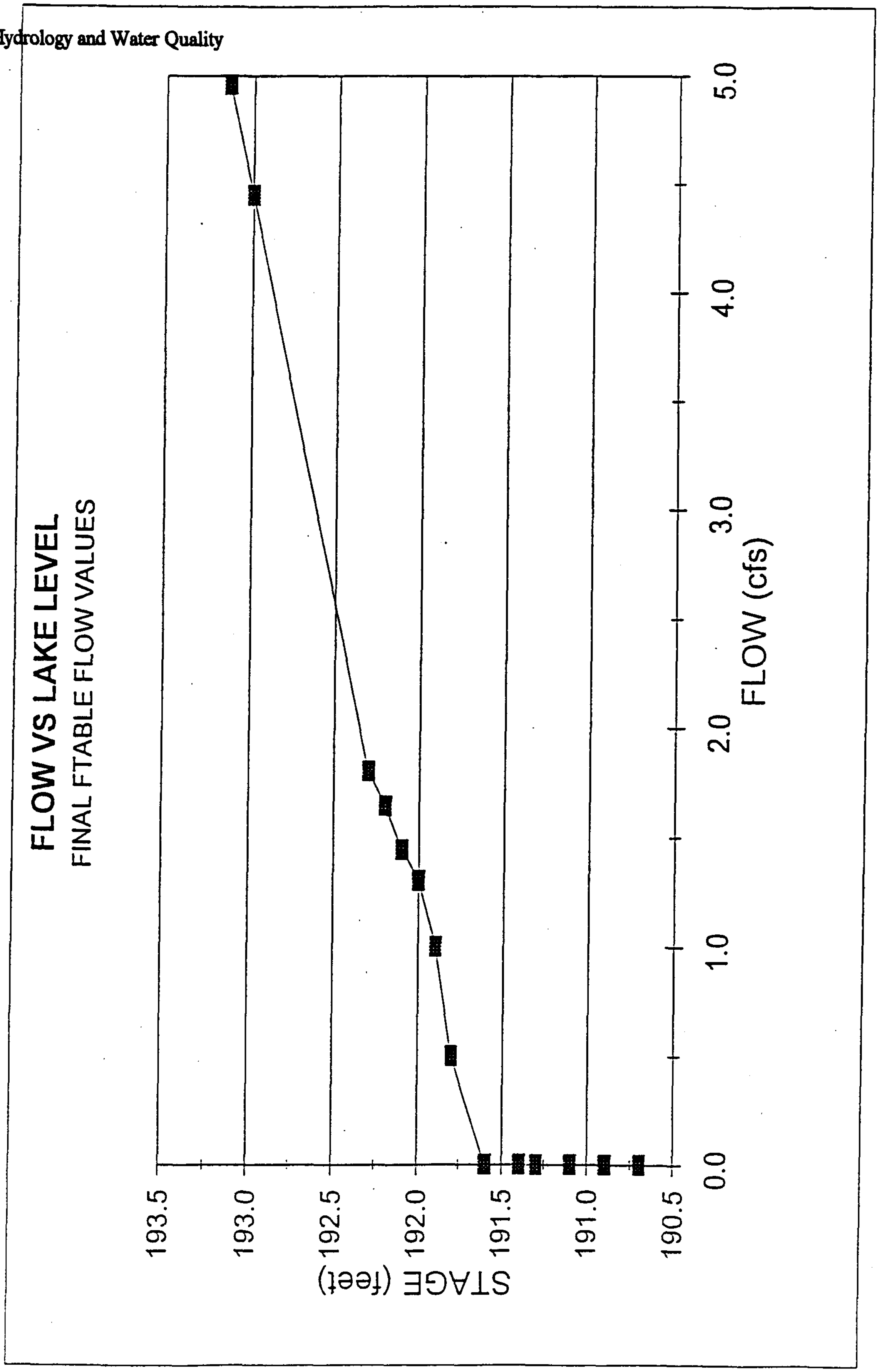

Figure 4-3 Little Chambers Lake Stage-Discharge Relationship

groundwater contribution ends in May or June." For instance, in May 1992 half of the slight flow at Herman Road had disappeared by the time it reached Yelm Highway (see table 4-1). By June 1992, the slight flow at Herman Road disappeared completely by Yelm Highway. The autumn flows in Chambers Ditch repeated this pattern until the end of the year, when the groundwater table rose enough to feed the ditch.

During wet years, Chambers Ditch flows throughout most of the year, drying up for a short period in September. The Aqua-Terra report explains: "Each year this cycle of groundwater level rise and fall repeats. The size of the rise and fall depends on the amount of precipitation and when it occurs. In wet years (water years 1990 and 1991, for example) the groundwater level stays high enough to contribute to Chambers Ditch and Chambers Creek through August. The majority of the annual runoff is from this groundwater contribution."

4.1.2 Hydrology of Chambers Creek and the South Tributary

The South Tributary, which conveys flow from extensive wetlands in the southern basin, remained virtually dry for nine months, from March 25, 1992 through November 23, 1992. The maximum flow from the tributary was 0.6 cfs for the entire year. The South Tributary does not appear to have a significant hydrologic effect on Chambers Creek. However, the sub-basins draining to the tributary encompass 3,703 acres, or 45% of the entire Chambers/Ward/Hewitt basin. The southern wetlands are clearly capturing and storing a tremendous amount of rainfall which could have an enormous impact on the downstream system if alterations in the basin increased runoff to the South Tributary. The model calibration final report said that "the wetlands have a major impact on stormwater runoff because runoff is retained by the wetlands and infiltrated" (Aqua Terra 1994).

The South Tributary joins Chambers Ditch in the wetlands just above Rich Road, which feed the main stem of Chambers Creek. Flows were measured on the South Tributary near the power lines that cross Rich Road; just below the confluence of Chambers Ditch and the South Tributary at Rich Road; and at the mouth of the creek.

The mouth station was the only station that contained year-round, measurable flow. Flow at the mouth averaged 2.9 cfs, with a maximum flow of 8.8 cfs and a minimum flow of 0.4 cfs. The creek was dry or almost dry less than a mile upstream, at Rich Road, for six months, from June 30, 1992 through November 23, 1992. The flows recorded during monthly sampling in June and November were too small to register on the continuous recording gage, which recorded no flow in the creek from May 27, 1992 through December 9, 1992.

The flow data indicate that the mouth station is fed primarily by groundwater. Follow-up investigation in October 1993 revealed two separate springs flowing into the creek between Rich Road and the mouth, while there were no flows at the upstream stations. The spring flows were not measured. One spring appears to originate on a slope just south of the Glenmore subdivision at Boulevard Loop, and flows under the railroad tracks to the creek. The origin of the second spring is unknown, but it flows to the creek from the east.

Modeling indicated that peak flows in the creek at Rich Road increased from 0 cfs during the 1-year flow to about 36 cfs during the 2-year flow. Chambers Ditch appears to contribute about 71% of the 2-year flow in the creek, and the South Tributary contribution is about 27%. The remaining flow comes from direct runoff, stormwater discharges, and groundwater. Peak flows at the mouth are slightly higher than the flows at Rich Road.

Modeling indicated that the relative contributions of Chambers Ditch and the South Tributary remain the same for extreme peak flow conditions. However, the model calibration report noted that "Little is known about the behavior of the wetlands located in the (South Tributary) sub-basins... The wetland surface outlets' stage-discharge relationships are unknown, as is the interaction with the groundwater table" (Aqua Terra 1994).

Groundwater table fluctuations influence flows in Chambers Ditch, and the extensive wetlands provide evidence of significant shallow groundwater in the southern basin. Therefore, ground water also probably influence flows in the South Tributary and the model may underestimate the flows there during high groundwater conditions.

4.1.3 Hydrology of Ward Lake

Ward Lake occupies a closed pothole with no surface feeder streams and no surface outlet. Volunteers read the staff gauges to collect the lake level data for Ward Lake from August 1990 through September 1993. Figure 4-4 illustrates lake levels and precipitation for Ward Lake.

Ward Lake exhibited a trend of slightly declining lake levels over the monitoring period. The November 1990 storms caused the lake level to rise from a low of 119.8′ above sea level to about 122′ in about two months. The lake level eventually peaked at 123.1′ in April 1991, then declined steadily through October.

During 1992, the level of Ward Lake rose back to 122.5′ in February. The lake level remained high until mid-April, then declined steadily for the rest of the water year. The lake level dropped to about 119.6′ above sea level in late October 1992, then began to climb as soon as the fall rains began.

The lake level changes corresponded directly to rainfall patterns in 1993, flattening out during dry spells and climbing during rain storms. The lake rose to 121.2′ in May and declined steadily after that.

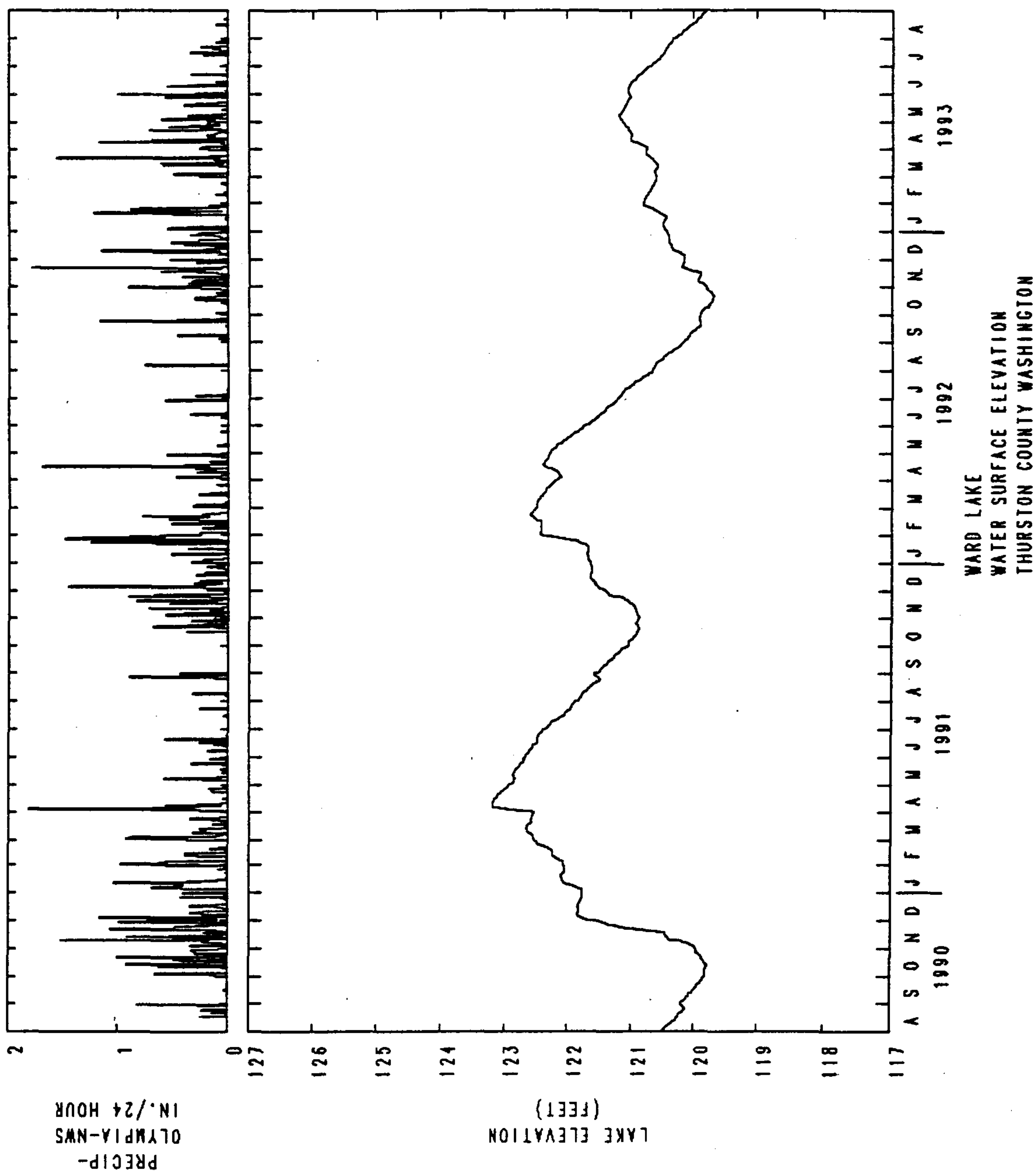

Figure 4-4 Ward Lake surface elevation, August 1990 - August 1993

Ward Lake levels exhibited similar patterns to other Thurston County lakes. The lake was lower in 1993 than 1992, which was true of most lakes in the county. The dry winter and wet spring of 1993 caused Ward Lake to peak in May. Ward Lake rose fairly quickly from rain storms, which is probably due to the several uncontrolled storm drains discharging to the lake. The lake also occupies a large area relative to the surrounding drainage (21%), which means that a large portion of rainfall in the sub-basin lands directly on the lake surface. The lake level corresponded closely with rainfall, although the level declined surprisingly quickly after the rains stopped, considering that the lake has no outlet. This could indicate that the lake bed remains fairly pervious, allowing water to infiltrate rapidly to ground water. The fine, sandy soils around the lake drain rapidly, which supports this conclusion.

4.1.4 Hydrology of Hewitt Lake

Hewitt Lake occupies a closed pothole less than a quarter-mile from Ward Lake, with no surface feeder streams and no surface outlet. Volunteers read the staff gauges to collect lake level data for Hewitt Lake from August 1990 through August 1993. Figure 4-5 illustrates the lake levels and precipitation for Hewitt Lake.

Hewitt Lake levels showed a significant decline throughout the monitoring period. The lake level responded more slowly than Ward Lake to the November 1990 storms, but it continued to rise dramatically throughout the rainy season. The lake rose almost 5.5′ from a season low of 120′ above sea level, to a peak level of 125.4 in May 1991, well after the rains began to taper off. The lake level then fell steadily through November, and declined at a slower rate through late January 1992, almost three months after fall rains began.

Hewitt Lake levels fluctuated mildly, staying at about 121′ above sea level throughout the winter of 1991-1992. The lake reached a peak of 121.4′ above sea level in April 1992, then dropped steadily through October 1992, to a low of about 118′ above sea level. The lake level fluctuations were virtually identical with Ward Lake for this period, but somewhat less pronounced.

The level of Hewitt Lake remained fairly low throughout 1993, reaching a peak of 118.7′ above sea level in April. The lake level began to decline in May, and reached a low of 117.5′ above sea level at the end of August. The lake level fluctuations were similar in pattern to Ward Lake for this period, but the curves were generally flatter.

Hewitt Lake levels declined more than Ward Lake during the dry season in 1992, and did not recover as well as Ward Lake in 1993. Hewitt Lake levels exhibited a marked delay of two to three months in responding to rainfall. These patterns indicate that runoff to Hewitt Lake does not occur in large amounts until the soils in the surrounding sub-basin become saturated. Stormwater infiltration systems in the basin reduce direct runoff into the lake. Hewitt Lake

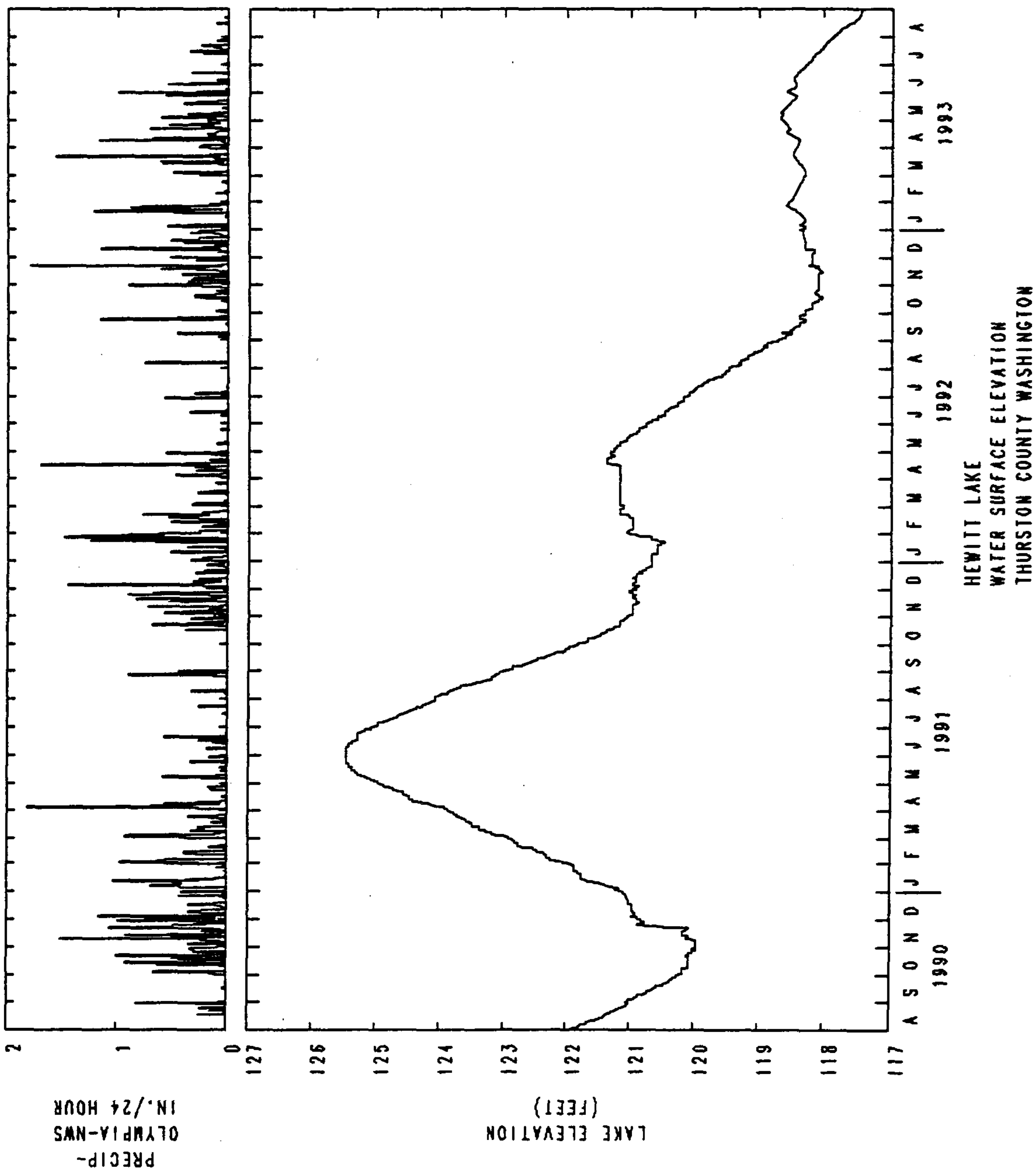

Figure 4-5 Hewitt Lake surface elevation, August 1990 - August 1993

levels appear to respond primarily to groundwater and interflow fed by rainfall in the surrounding basin.

4.1.5 Hydrology of Smith Lake

Smith Lake lies in a small depression southeast of Little Chambers Lake. Smith Lake was not investigated in detail for this basin plan, because it lies in a closed depression and has very little development. However, the lake level was monitored and modeled from December 1990 through September 1992, which included a major storm in April 1991.

The lake level exhibited little change throughout the monitoring period. The April 1991 storm caused the lake to rise about one foot, to its maximum elevation of about 186' above sea level. The lake level remained fairly stable throughout the period, staying at about 184' above sea level. The lake level declined slightly to about 182' above sea level by the end of the monitoring period, which reflects the same declining trend exhibited more substantially by other lakes in the county. Smith Lake did not respond significantly to any rainfall events during the monitoring period. The lake's small, flat surrounding drainage area and significant ground water influence reduce the effect of runoff.

4.2 WATER QUALITY

Water quality concerns are a major focus of the basin plan because water quality affects human health, natural resources, recreational opportunities and the economic health of the basin. This section begins with a general overview of water quality concerns, then summarizes the water quality of the basin. Readers who are familiar with water quality parameters may want to skip to the study results in section 4.2.2. Chapter 5 discusses specific problem sites and chapter 6 contains follow-up recommendations.

4.2.1 Overview of Water Quality Concerns

The water quality assessment of Chambers basin evaluated "conventional" parameters, sediments, benthic macroinvertebrates, and phytoplankton. Conventional parameters indicate the general water quality with respect to human health and natural resources. Sediment analysis provides additional indications of specific contaminants contained in stormwater runoff, and helps explain lake ecology. Benthic macroinvertebrates indicate the impact of water quality on aquatic food and habitat, and phytoplankton (algae) help explain the aging processes occurring in the basin's lakes.

Washington State has established stream and lake water quality standards for several conventional parameters (contained in appendix E). The state classifies Chambers Creek and Chambers Ditch as water quality Class A. The standards do not apply directly to stormwater runoff, but they indicate the relative contamination of stormwater. The state has not established standards for sediment, but the EPA and the state have developed recommended criteria for some of the pollutants found in sediments. Researchers have developed indices that relate macroinvertebrate and phytoplankton species to overall stream and lake conditions.

Conventional Water Quality Parameters

Fecal Coliform. Fecal coliform refers to bacteria contained in human and warm-blooded animal feces. Certain types of fecal coliform can cause severe illnesses, and, in extreme cases, death. Fecal coliform also indicates that other contaminants contained in feces may be present, such as pathogens and nutrients. Stream and lake water quality standards include a two-part standard for fecal coliform. The first part defines the maximum geometric mean value (GMV) allowed for all samples, expressed as the number of organisms per 100 milliliters of water (#/100 ml). The second part of the standard defines the maximum number of samples allowed to exceed a higher threshold, defined as a percentage of the total number of samples (for example, 10% > 100/100 ml).

Temperature. Water temperature regulates the metabolism, growth rate, and all internal chemical reactions of aquatic plants and animals, and directly affects the ability of fish species to survive. Anadramous fish such as salmon and steelhead generally require colder water than resident fish such as perch and bass. Temperature indirectly affects fish health by limiting the amount of dissolved oxygen; colder water can hold more oxygen. Temperature in lakes indicates the degree to which lake water circulates and mixes, and affects the level of aquatic plant growth. Stream and lake water quality standards include temperature. The stream temperature standard is expressed as a maximum temperature not to be exceeded due to human activities. The lake temperature standard prohibits any change from natural conditions.

Dissolved Oxygen. Aquatic plants and animals rely on oxygen dissolved in water. Plants add oxygen to water during the daytime, but they deplete dissolved oxygen at night. Aquatic organisms breathe dissolved oxygen, either by absorbing it directly or by breathing through gills. Water contains less than one percent oxygen, so even small changes in oxygen levels have a profound impact on aquatic life. Three factors control the amount of dissolved oxygen in water: **temperature** limits the total amount of oxygen; **respiration and decay** of aquatic organisms remove oxygen; and **aeration and photosynthesis** add oxygen. Stream and lake water quality standards include dissolved oxygen (DO). The stream DO standard is expressed as a minimum DO in milligrams per liter (mg/l). The lake DO standard prohibits any decrease from natural conditions.

pH. pH is a measure of the amount of free hydrogen in the water, which indicates the relative acidity of water. pH affects the solubility of several nutrients and toxic chemicals in water, which affects those chemicals' impact on aquatic plants and animals. Acidic water can interfere with the metabolism of aquatic organisms. Alkaline water has a higher ability to absorb, or "buffer" acidic runoff without injuring the aquatic life. Streams and lakes in our area tend to be slightly acidic, due to the soil conditions of the surrounding coniferous forests. pH is expressed as a number from 0 to 14. A lower number indicates higher acidity; 0 is totally acidic, 7 is neutral, and 14 is totally alkaline. Stream and lake water quality standards include pH. The stream pH standard is expressed as an allowable range of pH values. The lake pH standard prohibits any change from natural conditions.

Alkalinity. Alkalinity is a measure of the amount of calcium carbonate in water, expressed in milligrams per liter (mg/l). Alkalinity indicates the water's ability to buffer acidic runoff and precipitation. There is no water quality standard for alkalinity.

Hardness. Hardness is a measure of the amount of minerals in water. Hardness is another indicator of water's ability to buffer acidic runoff and precipitation. There is no water quality standard for hardness.

Turbidity. Turbidity is a measure of the cloudiness in water. Turbidity may be caused by algae or plants which stain water, but it usually indicates fine particles of soil and sediments which are suspended in the water. Sediments harm fish gills, eggs and aquatic insects. Sediments also affect aquatic plant growth by reducing the available sunlight in water, and cloudiness affects the recreational and aesthetic uses of lakes and streams. Stream water quality standards include turbidity, expressed as a maximum allowable amount or percentage of NTUs (nepthlometric turbidity units) above background turbidity levels.

Total Suspended Solids (TSS). TSS is another measure of sediments in water, which can be used to help differentiate between turbidity caused by water stained with algae or root tannins and water clouded by sediments. There is no TSS water quality standard.

Nutrients. Nutrients refer to the substances required for plant growth, especially nitrogen, phosphorous, and, of lesser importance, potassium. Nutrients are contained in chemical fertilizers and in human and animal feces.

Elevated nitrates in drinking water can cause an infant blood disorder called methemoglobinemia (blue baby syndrome), and has also been linked to certain forms of cancer. Nitrogen dissolves into water and is not readily absorbed, filtered, or degraded, so it usually ends up in receiving waters. The forms of nitrogen available to plants are nitrate, nitrite, and ammonia. Most commonly used fertilizers contain nitrates or ammonia. Land uses which employ fertilizers, such as agriculture and residential development, often employ other potential contaminants such as pesticides. Consequently, increased nitrate levels may indicate that other pollutants that were not monitored have entered the ground water system. Stream and lake water quality standards do not include nitrogen, but drinking water standards set a maximum of 10 mg/l.

Phosphorous is also critical to plant growth. Phosphorous levels are often the limiting factor for aquatic plant growth in lakes. Total phosphorous measurements include all forms of the element, including phosphorous contained in plant tissue and sediments. Ortho phosphorous is that fraction of total phosphorous which is available for plant growth. There is no water quality standard for phosphorous, but the EPA recommends a maximum of 0.10 mg/l to prevent weed growth.

Conductivity. Conductivity is a measure of water's ability to conduct an electrical charge. Conductivity can be used to trace inorganic pollutant sources, because inorganic pollutants (pollutants that do not contain carbon) often raise conductivity. There is no water quality standard for conductivity.

Sediment

Sediment often contains metals and organic pollutants, which "adsorb" or attach themselves to the sediment particles. Sediment from streets, parking lots and construction sites collects in storm drains and subsequently washes into receiving waters during storms, if it is not periodically cleaned out.

Metals. Metals include copper, lead, zinc, cadmium, chromium, arsenic, and other trace metals which come largely from vehicle traffic. Metals attach to sediment and accumulate at points where streams and runoff slow down. Metals present health threats to humans, fish and wildlife. Metals occur naturally in trace amounts, in all soil and water. The Washington Department of Ecology (DOE) has established background levels for metals in soil and fresh water (see appendix E). There are currently no water quality standards for sediments, although the DOE has compiled guidelines for metals and organics in the *Summary of Criteria and Guidelines for Contaminated Freshwater Sediments*.

Organics. Although the term "organic" is commonly applied to substances derived from natural plants and minerals, in a chemical sense, organic compounds are defined as compounds which contain carbon. Several organic pollutants are known to cause a variety of health problems. Organic compounds include the substances called polynuclear aromatic hydrocarbons (PAH) and phthalates. PAHs are found in fossil fuels, and commonly enter streams and lakes through petroleum spills, atmospheric fallout, and road wear. Phthalates are found in plastics, industrial oils, cosmetics, fragrances and pesticides, and are commonly used in several manufacturing processes.

Benthic macroinvertebrates

Benthic macroinvertebrates are the aquatic insects which live in lake and stream beds and form the basis for the aquatic food chain. Benthic macroinvertebrates are sensitive to water quality changes. The EPA has developed protocols for assessing macroinvertebrates, which look at the structure, variety, and population of aquatic insect communities.

In general, streams and lakes with good water quality have diverse and plentiful aquatic insect population. Also, specific families of aquatic insects cannot thrive in poor water quality conditions, so their absence can indicate a water quality problem. Benthic macroinvertebrate populations in streams can be evaluated along with other habitat characteristics, such as stream bed composition and vegetation cover, to provide an overall index of habitat quality. Benthic macroinvertebrate populations in lakes can also help indicate a lake's trophic condition, which is defined below.

Phytoplankton

Phytoplankton are the algae found in lakes and streams. Phytoplankton can indicate the trophic state of a lake. Lakes go through a series of "life stages" or trophic states, described below (Wetzel 1983; Cole 1983) as they age and change.

New lakes, such as lakes recently formed by glaciers, contain very few life forms of any kind. They are low in aquatic plants and insects, low in nutrients, and usually do not contain fish unless they have been planted with fish by humans. Such lakes are classified as "oligotrophic" (from the Greek word meaning "low in nutrients"), and they generally have low concentrations of nitrogen and phosphorous. Aquatic plant growth and algae in oligotrophic lakes is generally low, and they are very clear.

As lakes age, natural processes increase the nutrient concentrations in the water, and aquatic life forms increase correspondingly. Lakes in this "middle age" are called "mesotrophic". Mesotrophic lakes generally have enough nutrients to support fish and a variety of aquatic plants and insects, but they still have good water clarity, so they are often highly valued for recreation.

The final life stage of a lake is called "eutrophic" (from the Greek for "well nourished"). Eutrophic lakes are rich in nutrients and support a large amount of plant and algae growth, as well as other aquatic life forms. Eutrophic lakes are often shallow, as a result of the original landform or from sedimentation, and water clarity is generally low, which usually interferes with recreational uses such as swimming and fishing. Eutrophic lakes, however, contain a rich variety of insects, fish, and organisms which support the food chain.

The trophic states do not have sharply defined boundaries; they tend to blur together. Determination of a lake's trophic state requires interpretation of a complex web of aquatic life forms and conditions. There are several systems for rating a lake's trophic state. The Carlson Trophic State Index (TSI) is one widely accepted system used to assess the trophic state of lakes with low phytoplankton levels. The index uses Secchi disk clarity (the lake depth below which clarity is obscured), total phosphorous, and chlorophyll a to define the trophic state of a lake. However, the TSI cannot be applied to shallow lakes, because water clarity in shallow lakes does not necessarily correlate with trophic state. Shallow lakes are frequently categorized according to the specific algae and diatom associations found in them.

Water Quality and Stormwater

Stormwater collects all sorts of materials as it washes over the landscape and pours into streams and lakes. Pollution carried by stormwater runoff is called "nonpoint source pollution", or simply "nonpoint pollution", because it originates from many dispersed sources rather than from a single point such as a sewage treatment plant discharge pipe. Pollutants accumulate over the landscape during the dry season, because there are few storms to carry them away. The initial storms in the autumn carry the highest levels of contamination as the first flush of runoff scours catch basins, lawns, fields and streets.

Stormwater runoff in agricultural areas often contains fecal coliform bacteria from manure. Runoff from residential areas often contains pet wastes containing fecal coliform. Stormwater conveys the bacteria from these sources into streams and inlets. Flood waters can carry large amounts of fecal coliform into receiving waters.

Manure and chemical fertilizers contains nutrients. Over-application of fertilizers, inadequate fertilizer and/or manure storage facilities, and application of fertilizers immediately before or during rainfalls can result in nutrient-contaminated stormwater runoff.

Stormwater runoff collects sediments from streets and impervious areas as well as from bare construction sites and eroding banks. Landscaping and construction practices that apply inadequate erosion controls, and extensive vegetation clearing and grading can increase sediments in runoff. Inadequate maintenance of catch basins and stormwater facilities can also contribute to sediment loads. If the sediments are not periodically removed from stormwater facilities, they can become resuspended in runoff and discharge farther downstream.

Stormwater also affects on-site septic systems which rely on aerobic, non-saturated soils to remove bacterial and viral contamination. A well-maintained, properly functioning septic system requires at least 2-4′ of unsaturated, relatively fine soil for removal or absorption of contaminants. Coarse soils drain rapidly without filtering pollutants out of the septic effluent, and provide a direct route to ground water. Conversely, fine soils can become saturated quickly by stormwater and flood septic systems, causing septic effluent to flow directly into surface and ground water. Thin soils underlaid by compacted till saturate rapidly in winter months and no longer provide effective septic effluent treatment. Ground water tables which rise during the rainy season can also flood septic systems.

Stormwater systems can worsen septic failures and/or provide pathways for effluent to contaminate other waterbodies. Stormwater runoff infiltrated into the ground through dry wells and ponds can increase soil saturation and cause septic system failures, or make septic systems ineffective at treating wastewater. French drains and perimeter drains located too close to septic systems can collect leaking effluent and convey it to streams or lakes.

Even properly functioning septic systems release nitrates. When septic systems fail, fecal coliform and nitrates can reach the ground water. Development increases runoff and wastewater, so the risk that pollutants will enter the ground water in sufficient quantities to contaminate drinking water supplies increases with development.

4.2.2 Water Quality of Chambers Basin

Environmental Health Department staff characterized the water quality in the Chambers basin for this basin plan. The *Chambers Basin Comprehensive Drainage Basin Plan Water Quality Assessment* (Hansen 1994) contains the complete results of the water quality study. This section summarizes the overall water quality conditions in the basin. Table 4-2 summarizes the water quality data for Chambers Creek, Chambers Ditch, and the South Tributary, and map 10 shows the sampling locations.

Water quality sampling spanned the period from February 1992 through April 1993. The sampling program included the following elements:

1) In-lake column sampling on Chambers, Little Chambers, Ward and Hewitt lakes
2) In-lake sediment sampling on Chambers, Little Chambers, Ward and Hewitt lakes
3) In-lake benthic organism survey of Chambers, Little Chambers, Ward and Hewitt lakes
4) Chambers Ditch, Chambers Creek and South Tributary monitoring
5) Chambers Ditch, Chambers Creek and South Tributary benthic organism assessment
6) Stormwater sampling at storm drain outfalls
7) Sediment sampling at major storm drain outfalls
8) Follow-up investigation of areas where water quality problems were discovered.

Chambers Creek and Chambers Ditch Water Quality

Fecal coliform contamination is present throughout the ditch and creek system. The fecal coliform GMV increases from each station to the next downstream station. The only monitoring site which met both parts of the water quality standard was the station located on the small South Tributary (CK13). All other sites failed the second part of the water quality standard, and the mouth station (CK14) failed both parts of the standard. The drainage ditch sites contained the highest loadings of fecal coliform (loading indicates the amount of contamination relative to the amount of total stream flow).

Table 4-2 Summary of Sampling Results, February 1992 - January 1993

PARAMETER	STATION:	CK10	CK11	CK12	CK13	CK14
FLOW	AVG	1.84	2.59	2.14	.198	2.91
	MIN	.04	.27	.02	.01	.43
	MAX	4.75	7.59	7.82	.62	8.78
OXYGEN	AVG	7.69	10.93	6.41	8.23	10.79
	MIN	.25	9.28	2.40	7.20	9.55
	MAX	10.90	12.10	10.20	9.40	12.10
pH	Median	6.34	7.03	6.38	6.29	7.01
	MIN	6.05	6.56	6.00	5.83	6.38
	MAX	7.37	7.42	6.77	6.33	7.66
TEMP	MIN	4.2	3.80	3.80	4.00	6.00
	MAX	18.00	16.44	15.90	8.30	13.10
COND	AVG	48	44	71	119	104
	MIN	38	38	41	71	59
	MAX	82	54	140	213	140
FECAL COLIFORM	GeoMn	29	51	94	14	146
	MIN	5	0	30	0	15
	MAX	620	440	400	130	895
	% >200	25%	29%	30%	0%	50%
TURBIDITY	AVG	8.1	3.5	2.6	2.58	1.9
	MIN	1.4	1.6	1.2	1.3	0.7
	MAX	28.0	8.0	6.6	4.0	8.0
TSS	AVG	12.9	5.1	4.1	9.2	3.1
	MIN	0.8	2.5	0.7	*<.5	*<.5
	MAX	50.0	16.0	19.0	2.0	13.0
TOTAL-P	AVG	0.071	0.045	0.080	0.045	0.029
	MIN	0.025	0.031	0.038	0.031	0.014
	MAX	0.212	0.060	0.181	0.057	0.054
ORTHO-P	AVG	0.004	0.007	0.027	0.013	0.013
	MIN	*<0.001	0.003	0.007	0.009	0.006
	MAX	0.006	0.013	0.057	0.025	0.020
NITRATE+ NITRITE	AVG	0.164	0.475	0.537	1.97	1.33
	MIN	*<0.010	0.102	*<0.010	0.053	0.362
	MAX	0.816	1.54	1.90	6.14	2.71
AMMONIA	AVG	0.082	0.048	0.069	0.047	0.033
	MIN	0.020	*<0.010	*<0.010	*<0.010	*<0.010
	MAX	0.222	0.126	0.343	0.141	0.116

Station # and location:

CK10 = Chambers Ditch at Herman Rd
CK11 = Chambers Ditch at Yelm Hwy
CK12 = Chambers Creek at Rich Rd
CK13 = South Tributary east of Rich Road
CK14 = Chambers Creek mouth

* When calculating averages, values reported below detection limits were added at half the detection limit.
< = less than detection limit

Temperatures remained within the water quality standard at all sites, although the temperatures were higher at the upstream locations. Cold ground water entering Chambers Ditch and stream helps to compensate for heating from sunlight where the tree canopy has been removed.

Dissolved oxygen dropped below the water quality standard at several locations, but only when flows were very low (less than 2 cfs), which would not indicate a problem. Dissolved oxygen levels were fine during most flows. Dissolved oxygen levels measured consistently higher at Yelm Highway (CK11) than Herman Road (CK10), located upstream, and Rich Road (CK12), downstream. Dissolved oxygen levels were low in the South Tributary (CK13), where the flow was barely discernible (maximum 0.6 cfs). The sites at Herman Road, Rich Road and the South Tributary are also heavily influenced by upstream wetlands which have naturally low dissolved oxygen levels.

Mean pH levels violated the water quality standard at Herman Road (CK10), Rich Road (CK12), and the South Tributary (CK13), even though they remained at acceptable levels at the Yelm Highway location (CK11). This pattern mimics the DO readings. Low pH (acidic) levels are often associated with the low DO levels that occur naturally in most wetland-dominated systems.

Overall turbidity was highest when the flows were highest, in January. This is normal for creeks and ditches. The water quality standard for turbidity relates to the background turbidity level, which is not known for Chambers Creek or Chambers Ditch. However, the maximum background turbidity found in any stream in the upper Deschutes watershed is 6.0 NTU (Davis et al 1993). Using 6.0 NTU as the background, all the stations met the water quality standard.

Total phosphorous levels in Chambers Ditch were generally similar or slightly higher than total phosphorous levels in Little Chambers Lake, which feeds the ditch. Ortho phosphorous levels were consistently higher in the ditch. Elevated total phosphorous readings at Rich Road (CK12) during the summer months occurred when water was stagnant, with no flow, and the elevated readings were probably due to decomposing plant material and/or animal manure. Generally, total phosphorous levels in the creek and ditch were below the EPA recommended limit. Phosphorous was a problem at a few stormwater sampling sites, which are discussed in chapter 5.

Average nitrate+nitrite readings were highest at the mouth (CK14) and the South Tributary (CK13), although the average value for the South Tributary was skewed by one extremely high reading that corresponded with high conductivity and probably resulted from a specific event. The high readings at the mouth did not correspond with high phosphorous readings, which indicates that "there is a groundwater source of the nutrient. While phosphorous is removed from water as it filters through the soil, nitrogen (as nitrates) migrates through the soil to reach ground water" (Davis et al 1993). Nitrate+nitrite levels were high at individual stormwater sampling sites, which are discussed in chapter 5.

Macroinvertebrate surveys and habitat assessments indicated that overall habitat is poorest above the Wilderness subdivision, and improved steadily downstream toward the mouth. Habitat was generally poor above and below Wilderness, good at Rich Road and excellent at the mouth.

Overall water quality in Chambers Ditch and Creek appears to be fair. Fecal coliform standards were exceeded at all sites but one, which could present a health hazard in the residential neighborhoods. Elevated nutrient levels at the upstream sites could accelerate weed growth in the ditch, requiring increased maintenance to prevent flooding. Dissolved oxygen levels and pH are naturally low as the ditch dries up, especially near wetland-influenced sites, but fish (which need adequate dissolved oxygen) do not use the ditch much at those times. Naturally poor substrate further limits fish use in the ditch. Groundwater inputs above Yelm Highway and above the mouth appear to dilute degraded surface water downstream where healthier macroinvertebrate communities and better substrate support more fish use.

Ward Lake Water Quality

All conventional water quality parameters fell within water quality standards for Ward Lake. Temperature, dissolved oxygen levels, and pH all indicated that the lake remained stratified from May through October, meaning that very little mixing occurred between water near the top of the lake and water at the bottom. Mixing began to occur in November, and the lake remained mixed through the winter.

Temperatures remained near 7°C throughout the year in the bottom layer of Ward Lake. Temperature near the surface reached a high of about 23°C in the summer, and dropped to about 7°C in the winter. The water temperature in deep lakes like Ward Lake typically varies significantly between surface and bottom layers, in contrast with shallow lakes which warm up throughout in the summer.

Dissolved oxygen levels at the bottom of Ward Lake dropped to near zero in the summer, and climbed back to 9.6 mg/l by December, which is natural for deep lakes. Surface dissolved oxygen varied from 8.3 mg/l in July to 11.7 mg/l in February.

Ward Lake's pH levels corresponded with DO, dropping to the 5-6 range in July. According to the EPA, pH levels of 5-6 or lower may be toxic to fish. Alkalinity and hardness values for Ward Lake were very low, which indicates a low buffering capacity and helps explain the low pH values in the lake.

Nitrate+nitrite levels in Ward Lake were average for healthy lakes. Nitrate nitrogen levels in healthy lakes are less than 0.05 mg/l, nitrite nitrogen levels are less than 0.005 mg/l, and ammonia is usually present in very low concentrations (Hansen 1994). The maximum nitrate+nitrite level in Ward Lake was 0.042 mg/l.

The bottom of Ward Lake had its highest phosphorous levels in the late summer. Phosphorous is typically bound up in the plant material that collects on the lake bottoms, as well as in the sediment surrounding aquatic plant roots. Phosphorous usually becomes more available as plant materials decay. Changes in nutrient levels often result from the cycling of nutrients into and out of plant materials. Deep lakes frequently exhibit increased phosphorous levels near the surface in the winter, when mixing brings up sediments from the bottom.

Most of the Trophic State Indices for Ward Lake fell in the low mesotrophic range, with the remainder in the high oligotrophic range. Ward Lake also contained blue-green algae for most of the year, which are typically associated with older, eutrophying lakes, although the particular blue-green algae/diatom combinations in Ward Lake did not match up with other typical eutrophic lakes in western Washington. The evidence generally indicates that Ward Lake is becoming mesotrophic, or middle-aged.

Ward Lake sediments contained arsenic levels above severe health effects criteria but below the levels in Chambers Lake, and lead above background levels. Ward Lake sediments also contained the highest levels of cadmium, chromium, copper, and nickel of any lakes in the basin. A parallel study by the Washington Department of Ecology in 1994 had similar results. The DOE study found that Ward Lake sediments had the highest concentrations of copper and second highest concentrations of chromium, nickel and arsenic of five western Washington lakes studied. Lead, arsenic and cadmium levels were found to exceed statewide levels by five times. The source of the arsenic is unknown and arsenic is not typically contained in runoff. The metals concentrations in sediment could be naturally elevated due to background levels in the basin's soils, which have not been determined.

The DOE study also analyzed tissues of large mouth bass and rainbow trout in Ward Lake. The study found elevated mercury levels in Ward Lake bass, compared to bass from other western Washington lakes, although mercury levels did not exceed FDA action levels. Rainbow trout contained levels of PCB-1260, a carcinogen, that exceeded EPA human health criteria. The source of PCBs is unknown. These findings caused the Washington Department of Ecology to list Ward Lake as "water quality limited" under the federal Clean Water Act.

Overall, nutrients in stormwater appear to be the top water quality concerns in Ward Lake. Nutrient levels could cause problematic algae or weed growth in the future, interfering with the lake's recreational uses. Metals could be a concern but their sources and significance are not clear. Metals-contaminated sediments could come from untreated stormwater discharges into the lake, from overflow from the large nursery above the lake to the southwest, or from some other source, or they could be remains of the old sawmill on the lake. In addition, the PCB levels raise concern because the Washington Department of Fish and Wildlife manages the lake for recreational fishing.

Hewitt Lake Water Quality

All conventional water quality parameters fell within water quality standards for Hewitt Lake. Temperature, dissolved oxygen levels, and pH all indicated that the lake remains stratified from May through October, meaning that very little mixing occurs between water near the top of the lake and water at the bottom. Mixing began to occur in November, and the lake remained mixed through the winter.

Temperatures ranged from 6.5°C to 10°C throughout the year in the bottom layer of Hewitt Lake. Temperature near the surface reached a high of about 23°C in the summer, and dropped to about 6.5°C in the winter. The water temperature in deep lakes like Hewitt Lake typically varies significantly between surface and bottom layers, in contrast with shallow lakes which warm up throughout in the summer.

Dissolved oxygen levels at the bottom of Hewitt Lake dropped to near zero in the summer, and climbed back to 6.8 mg/l by December. Surface dissolved oxygen varied from 8.7 mg/l in July and September to 10.8 mg/l in May.

Hewitt Lake's pH levels stayed within the 7-8 range for much of the year, increasing to a maximum of 9 in May, which is typical for the peak growing season. Alkalinity and hardness values for Hewitt Lake were low-average, which indicates reasonably good buffering capacity and helps explain the higher pH values, compared to nearby Ward Lake.

Nitrate+nitrite levels in Hewitt Lake were average for healthy lakes. Nitrate nitrogen levels in healthy lakes are less than 0.05 mg/l, nitrite nitrogen levels are less than 0.005 mg/l, and ammonia is usually present in very low concentrations (Hansen 1994). The maximum nitrate+nitrite level in Ward Lake was 0.054 mg/l at the surface, although nitrate+nitrite levels reached as high as 0.193 mg/l on the bottom. Ammonia levels at the bottom of Hewitt Lake included one high (1.24 mg/l) sample in July, which probably indicated a chemical shift caused by the lack of oxygen (Hansen 1994).

Total phosphorous and ortho phosphorous levels were slightly higher in Hewitt Lake than in Ward Lake. Increased phosphorous can encourage aquatic weed growth. Phosphorous is typically bound up in the plant material that collects on the lake bottoms, as well as in the sediment surrounding aquatic plant roots. Phosphorous usually becomes more available as plant materials decay. Changes in nutrient levels often result from the cycling of nutrients into and out of plant materials. Deep lakes frequently exhibit increased phosphorous levels near the surface in the winter, when mixing brings up sediments from the bottom.

Most of the Trophic State Indices for Hewitt Lake fell in the high oligotrophic range, with the remainder in the low mesotrophic range. Phytoplankton in Hewitt Lake include a blue-green/diatom combination for much of the year, indicating that the lake may be rapidly changing and aging (Hansen 1994). The evidence generally indicates that Hewitt Lake is becoming mesotrophic, or middle-aged, although it has not advanced as far as Ward Lake.

Hewitt Lake sediments did not contain any metals that exceeded the freshwater sediment criteria. Hewitt Lake was the only lake in the basin with sediments which did not contain arsenic or copper levels above background levels. Hewitt Lake sediments also contained the lowest concentrations of zinc. Lead levels slightly above background were the only metals that exceeded background levels in Hewitt Lake.

Overall, the water quality study found that Hewitt Lake appears to have good water quality with few observable impacts from stormwater, possibly due to properly functioning stormwater systems around the lake. However, the study was completed in the spring of 1994, and several basin residents reported severe algae blooms in the summer of 1994 (see chapter 2 for more details). Water samples collected by residents were dark green and murky with algae. The algae blooms persisted into the fall and could signify that the lake is becoming more nutrient-rich than indicated by the water quality study. Nutrients appear to be the top water quality concern in Hewitt Lake, because of the resultant algae and weed growth.

Chambers Lake Water Quality

All conventional water quality parameters fell within water quality standards for Chambers Lake. Temperature, dissolved oxygen levels, and pH all indicated that Chambers Lake does not stratify, unlike Ward and Hewitt Lakes, meaning that mixing does occur between water near the top of the lake and water at the bottom throughout the year.

Temperatures in Chambers Lake ranged from winter lows around 5°C to summer highs of about 22°C, and temperatures were nearly identical between the surface and the bottom of this very shallow lake. The water temperature in shallow lakes is usually fairly uniform throughout, and shallow lakes are likely to warm up to higher temperatures than deep lakes. Surprisingly, Chambers Lake's temperature did not rise higher than Ward and Hewitt Lakes, which may result from cold ground water entering Chambers Lake.

Dissolved oxygen levels in Chambers Lake dropped to 3.6-3.7 mg/l in July, and climbed back to 12.1-12.3 mg/l by December. Surface and bottom dissolved oxygen levels generally stayed within 0.3 mg/l of each other. The lowest oxygen levels corresponded directly with periods of high water temperatures, when water has less oxygen-holding capacity.

Chambers Lake's pH levels dropped to the 5-6 range in July. According to the EPA, pH levels of 5-6 or lower may be toxic to fish. Median pH values were always below 7.5 and frequently below 7.0, except for the September sampling. This somewhat acidic range is typical of shallow, eutrophic lakes in the northwest. Alkalinity and hardness values for Chambers Lake were low, which indicates a low buffering capacity and helps explain the low pH values in the lake.

Nitrate+nitrite levels in Chambers Lake were average for healthy lakes. Nitrate nitrogen levels in healthy lakes are less than 0.05 mg/l, nitrite nitrogen levels are less than 0.005 mg/l, and ammonia is usually present in low concentrations (Hansen 1994). Nitrate+nitrite levels in Chambers Lake remained at or below 0.022 mg/l.

Chambers Lake contained generally higher levels of available phosphorous than Ward or Hewitt Lakes. Available, or ortho phosphorous, excludes that portion of phosphorous which is bound up in the plant material and sediments.

Chambers Lake was not rated using the Trophic State Indices, because they do not accurately portray shallow lakes. Chambers Lake rates as eutrophic according to the algae sampling. The lake contains several blue-green algae and diatoms for most of the year.

Chambers Lake sediments contained arsenic levels above severe health effects criteria, and lead and copper above background levels. Chambers Lake sediments contained the highest levels of arsenic, lead, mercury and zinc of any lakes in the basin. Lead and zinc levels were higher in the more developed northern lake than in the undeveloped southern portion.

Overall, nutrients and metals in stormwater appear to be the top water quality concerns in Chambers Lake. Nutrient levels, combined with shallow depths, already cause aquatic plant growth in the lake. Untreated stormwater discharges probably deposit sediments that contain metals into the lake. The city of Lacey has already begun to design a treatment system for one stormwater outfall discharging to Chambers Lake.

Little Chambers Lake Water Quality

All conventional water quality parameters fell within water quality standards for Little Chambers Lake. Temperature, dissolved oxygen levels, and pH all indicated that Little Chambers Lake did not stratify, unlike Ward and Hewitt Lakes, meaning that mixing occurred between water near the top of the lake and water at the bottom throughout the year.

Temperatures in Little Chambers Lake ranged from winter lows around 5° C to summer highs of about 22.5° C, and temperatures were nearly identical between the surface and the bottom of this very shallow lake. The water temperature in shallow lakes is usually fairly uniform throughout, and shallow lakes are likely to warm up to higher temperatures than deep lakes. However, Little Chambers Lake's high temperature did not rise higher than Ward and Hewitt Lakes, which may result from cold ground water entering the lake. Little Chambers Lake's maximum temperature exceeded Chambers Lake's maximum temperature slightly.

Dissolved oxygen levels in Little Chambers Lake dropped to 5.9-6.3 mg/l in July, and climbed back to 12.7-12.8 mg/l by December. Surface and bottom dissolved oxygen levels usually stayed within less than 0.1 mg/l of each other. The lowest oxygen levels occurred during periods of high water temperatures, when water has less oxygen-holding capacity.

Little Chambers Lake's pH levels remained between 6.3-6.9 except for an increase to 8.6 in September. This somewhat acidic range is typical of shallow, eutrophic lakes in the northwest. Alkalinity and hardness values for Little Chambers Lake were low, which indicates a low buffering capacity and helps explain the low pH values in the lake.

Nitrate+nitrite levels in Little Chambers Lake were average for healthy lakes. Nitrate nitrogen levels in healthy lakes are less than 0.05 mg/l, nitrite nitrogen levels are less than 0.005 mg/l, and ammonia is usually present in very low concentrations (Hansen 1994). The maximum nitrate+nitrite level in Little Chambers Lake was 0.025 mg/l.

Little Chambers Lake contained generally higher levels of available phosphorous than nearby Ward and Hewitt Lakes (which are relatively deep). This is typical of shallow, wetland-influenced lakes. Available, or ortho phosphorous, excludes that portion of phosphorous which is bound up in the plant material and sediments.

Little Chambers Lake was not rated using the Trophic State Indices, because the TSIs do not accurately portray shallow lakes. Little Chambers Lake rates as eutrophic according to the algae sampling. The lake contains several blue-green algae and diatoms for most of the year.

Little Chambers Lake sediments contained arsenic levels above severe health effects criteria, and lead and copper above background levels. Little Chambers Lake sediments contained the highest levels of antimony and selenium of any lakes in the basin.

Overall, nutrients and metals in stormwater appear to be the top water quality concerns in Little Chambers Lake. Nutrient levels, combined with shallow depths, already cause aquatic plant growth in the lake. Untreated stormwater discharges probably deposit sediments containing metals into the lake. The city of Lacey has already begun to design treatment systems for stormwater outfalls discharging to Little Chambers Lake.