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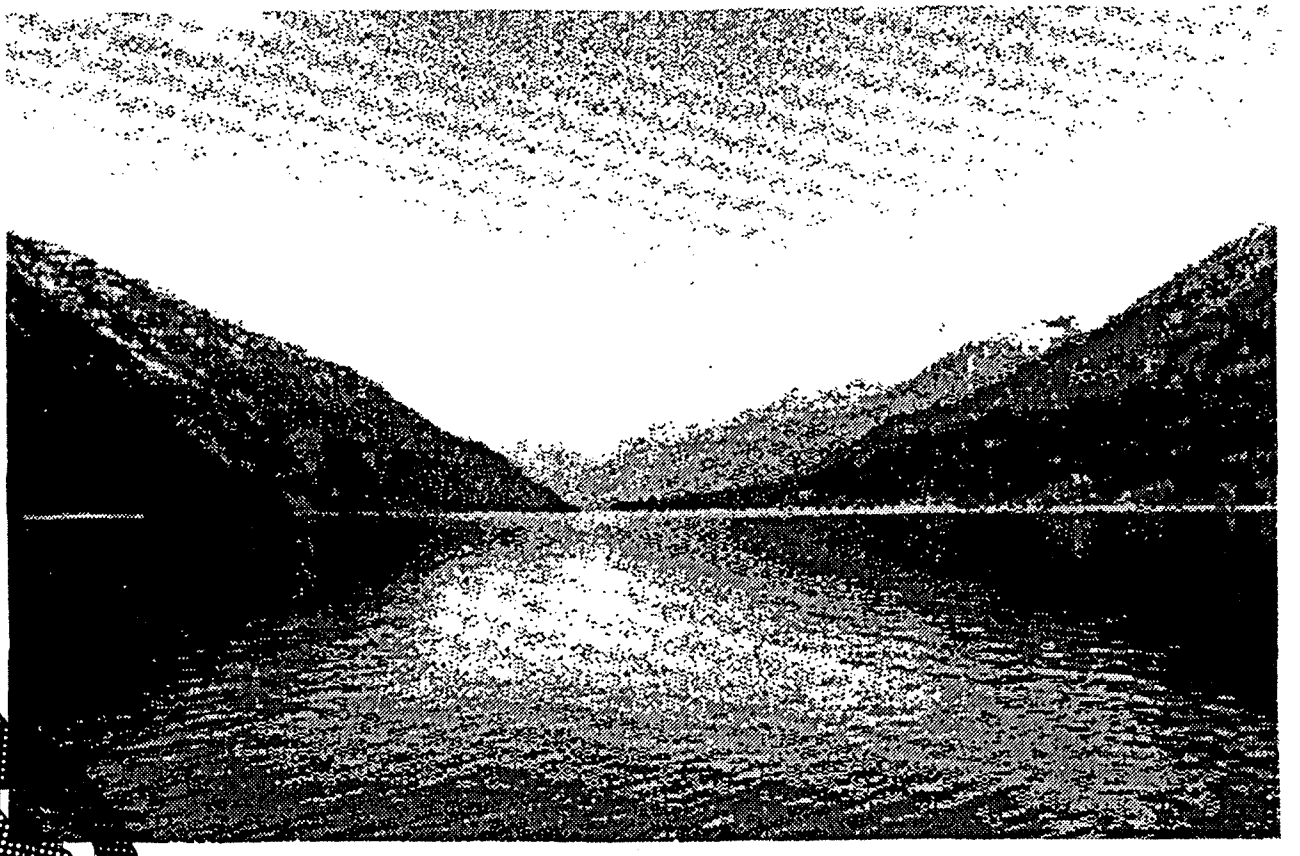
LAKE CHELAN



WATER QUALITY ASSESSMENT

EXECUTIVE SUMMARY

DEPARTMENT OF ECOLOGY
WASHINGTON STATE

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LAKE CHELAN WATER QUALITY ASSESSMENT

EXECUTIVE SUMMARY

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Final Report

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PREFACE

Lake Chelan represents a very unique resource in Washington. It is the longest and deepest natural lake in the state. Lake Chelan's great depth and largely undisturbed watershed have preserved its pristine qualities. Qualities which are admired, cherished and responsible for the allure of the area. It is the need to preserve the excellent quality which prompted the Washington State Department of Ecology to begin a study of the lake. The results of the study are included in the document. The purpose of the work was threefold. The first was to perform a comprehensive investigation of the lake's quality for the future comparisons. This had not been accomplished earlier. The second objective was to evaluate the existing and potential nutrient sources and their impacts. As watersheds develop, nutrients can significantly alter water quality by reducing clarity through increasing the microscopic algae (phytoplankton) in the lake, and aesthetically changing the beach by promoting algal growth on the rocks (periphyton). Lake Chelan's present nutrient concentrations classify it in the best category, ultra-oligotrophic. The final objective of the project was to integrate the information and provide recommendations.

Knowledge of the effect of nutrient inputs from human development is critical to foster responsible growth. It is understood that growth will occur, however movement from the ultra-oligotrophic category in Lake Chelan is not acceptable. This document contains information and recommendations to protect the lake's existing quality. Local authorities are now faced with decisions which will affect them and their future quality of life.

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LAKE CHELAN WATER QUALITY ASSESSMENT

EXECUTIVE SUMMARY

The Purpose Of This Study

The Washington State Department of Ecology recognizes the unique, near pristine water quality conditions of Lake Chelan. It is committed to maintaining these conditions and considers deterioration of these conditions - as the result of man-made development - to be unacceptable. To this end Ecology has commissioned this assessment not only to understand the dynamic forces at work in Lake Chelan but to establish a baseline against which to measure the effects of future develpment in the lake area.

Lake Chelan is the largest and deepest natural lake in Washington State and is recognized throughout the region as an extremely valuable water resource. Selected characteristics of Lake Chelan have been studied previously. But the restricted scope of these studies has limited the evaluation of overall water quality in the lake and the understanding of possible future changes in the lake. In response to these concerns, the Department of Ecology retained Harper-Owes and its principal subcontractors (Hart Crowser, the University of Washington, Golder Associates, and Evans-Hamilton) to conduct an extensive investigation of Lake Chelan. The investigation had three primary objectives:

1) To provide a baseline study of the lake.

2) To evaluate the suitability of on-site wastewater disposal systems (septic tanks and drain fields) within the developing Lower Chelan Basin.

3) To estimate principal sources and potential impacts of bacteria and chemicals of concern to Lake Chelan.

Investigator Activities

The investigators were in the field frequently from November 1986 through December 1987 and performed the following activities:

- Data compilation and mapping of the near-surface geology and hydrogeology of the Lower Chelan Basin;

- Installation of twenty-three (23) groundwater monitoring wells in selected areas of the Lower Basin believed to be influenced by agricultural and septic system inputs;

- Quarterly water quality sampling and analysis of the monitoring wells and selected existing domestic wells;
- Monitoring of selected hydrologic, chemical, and bacteriological inputs to Lake Chelan from a variety of sources during thirteen (13) surveys;
- Nearly continuous monitoring of circulation processes within Lake Chelan using both direct and indirect methods;
- Collection and analysis of water quality samples obtained throughout Lake Chelan during thirteen (13) lake surveys;
- Intensive investigations of lake productivity, and nearshore algal accumulation consisting of periphyton. As well, they assessed bacteriological conditions during three (3) surveys; and
- Collection of fourteen (14) samples each of lake sediments and fish tissue for detailed chemical analyses.

In all, more than 100,000 data observations were obtained during this investigation.

Existing Conditions: The Lucerne and Wapato Basins

Lake Chelan is divided into two distinct basins which occur on either side of a prominent bisecting sill. The sill is a glacial moraine rising to within 41 meters (135 ft) of the lake's surface. The larger Lucerne Basin contains over 92 percent of the total lake volume and has a maximum depth of 453 meters (1,486 ft). The Lucerne Basin is fed by tributaries that originate in the forested and glacial areas of the Cascade Mountains. Water flowing into the Lucerne Basin will reside there for approximately 10 years.

To the southwest, the smaller Wapato Basin is at its deepest at 122 meters (400 ft) and receives most of its water input from the upper lake. Because of the smaller volume, water in the Wapato Basin resides there only approximately 0.8 year. This estimation excludes the effects of inter-basin mixing. Although the Wapato Basin represents only a small portion of the lake, most of the developed areas within the lake's watershed occur in this region.

Since lake uses (e.g. water supply and recreation) are also most extensive within this area, water quality characteristics of the Wapato Basin are a principal concern.

Seasonal Stratification. During the spring and summer months, seasonal warming causes the waters of both basins of the lake to develop a pronounced vertical stratification where colder,

deeper waters are isolated. This is because the warmer surface water is lighter than the colder water below. Wind generated waves cause these surface waters to mix to depths of 30 to 40 meters (100 - 130 ft). This is called the thermocline depth.

During the winter when surface and subsurface waters approach the same temperature, thorough mixing occurs. Winter overturn (i.e. complete vertical mixing) of the lake was nearly accomplished during the 1986-1987 study period, although deeper regions of each basin remained isolated throughout the year. Full circulation is likely to occur every few years.

Surface temperatures during the summer are considerably warmer in the Wapato Basin than in the Lucerne Basin.

Seiche: The Internal Rocking of the Lake

The elongated shape of the lake and the strong winds which act on its surface cause a significant water movement phenomenon known as a seiche. This is a slow but very large internal rocking motion of the lake during the summer months. Although the surface elevation of the lake changes only slightly during this motion, the internal seiche tilts the thermocline. It can raise and lower the thermocline by 30 to 40 meters (100 - 130 ft) at the two ends of the Lucerne Basin every few days. The rocking motion of the seiche creates significant currents in the lake.

Currents associated with these and other seiche movements are most pronounced at the sill. There, velocities at depth (i.e. 30 m) regularly approach 0.30 meters/second (0.7 mph). The alternating seiche currents result in the nearly complete mixing of waters some 5 kilometers (3 mi) on either side of the sill and effectively minimize the importance of the sill as a barrier to interbasin exchange. This highly energetic sill zone exhibits a mixing intensity comparable to tidal waters of Puget Sound.

Variable Mixing. Although the seiche currents result in considerable water exchange between the Lucerne and Wapato Basins, parts of the lake are nevertheless relatively isolated from such mixing, particularly during the summer stratification. For example, reduced mixing occurs seasonally within the lake near Twentyfive Mile Creek. During summer months, this region of the lake (about five miles northwest of the sill) functions as a partial barrier to uplake mixing.

Reduced mixing also occurs over the lower 15 kilometers (9 mi) of the lake. This lower lake region acts like a river during the summer months, with circulation occurring almost solely in the direction of the lake outlet. The very different circulatory and mixing regimes observed between regions of the

lake is in part attributable to different seiche characteristics. These different mixing properties, in turn, effect the lake's response to pollutant inputs.

Limited Phosphorus for Algal Growth

The lack of significant supplies of phosphorus (P) is responsible for limiting algal growth in the open waters of Lake Chelan. This conclusion was based on the very low amounts of P in lake water relative to other plant nutrients and previous algal assay experiments. Limited supplies of P to the lake control both open water and nearshore algal productivity and result in the near pristine conditions that exist.

The concentrations of P within Lake Chelan during the study period were well below reported levels in most other lakes throughout the Northwest. Due to proximity to agricultural sources, concentrations tended to be highest at shallow depths near the sill and lowest at greatest depths within the lake. Overall, P concentrations were equivalent between the Wapato and Lucerne Basins. All areas of Lake Chelan can be classified as extremely nutrient-poor and unproductive, or ultraoligotrophic.

Other measures also characterize the open waters of Lake Chelan as extremely unproductive. These include algal species and biovolume, water concentrations of the primary plant pigment chlorophyll a, and direct measurements of algal photosynthesis within the lake. The photosynthetic productivity of Lake Chelan was similar to that of Crater Lake (Oregon) and Great Central Lake (British Columbia), but lower than that of Lake Tahoe (California). Fish production in Lake Chelan (determined in previous studies) was similarly quite low. Lake Chelan was also characterized by good water clarity (13 meters; 44 ft), but was somewhat lower than other ultraoligotrophic lakes. This is due to glacial silts suspended in the water.

No substantial differences in biological productivity and related water quality characteristics were observed between different areas of the lake. During summer months, however, the Lucerne Basin tended to support a greater and more stable algal population. The higher algal levels in the Lucerne Basin are in part due to greater turbulent mixing induced by the seiche activity. This keeps the algae in suspension and allows for greater nutrient recycling.

In contrast, bottom waters of the Wapato Basin exhibited slightly larger depletions of dissolved oxygen which result from algal sedimentation and decay. The greater sensitivity of the Wapato Basin to oxygen depletion is due to the smaller volume of this basin. All measured concentrations of dissolved oxygen were within the optimal range for fish growth.

Measured concentrations of pathogen (disease causing) indicator bacteria, such as coliforms, were highest near the lake outlet. Elevated bacterial levels in this area are at least partially due to reduced water mixing, resulting in greater sensitivity to contaminant inputs at this location. Bacterial levels near the lake outlet exceeded recommended levels for water supply, but were well within limits established for recreational uses.

Nearshore Water Quality

A concern exists regarding nearshore water quality. Many local residents obtain their drinking water from the nearshore area, and local increases in coliform densities above recommended drinking water levels have been reported previously for some shoreline locations. In addition, nutrient-rich tributaries which enter the Lower Chelan Basin cause a 10 to 50-fold increase in local algal periphyton accumulations compared to undisturbed areas. Much of this increase is attributable to P inputs from upland watershed sources.

Both the composition and density of periphyton adjacent to some of the more enriched streams exceed general nuisance thresholds. The extent of these nearshore affected areas, however, is limited. Periphyton not only affect nearshore water quality but are also useful as sensitive, early indicators of nutrients which could affect the main body of Lake Chelan.

Sources of Phosphorus Entering the Lake

Approximately 75 to 90 percent of the current P input to Lake Chelan comes from natural sources within the basin. This includes undeveloped forested areas and direct precipitation onto the lake. Of the roughly 10 to 24 percent of the lake P input attributable to man, approximately half (i.e. 4 to 12 percent of the total) comes from agricultural sources, primarily from orchard activities. The potential agricultural inputs of P within the basin are considerably greater than this total, but are partially reduced within the Dry/Roses/Wapato Lake system before they discharge into Lake Chelan. These lakes act as a sink for P. Agricultural inputs represent a major component of nearshore inputs and associated periphyton accumulations.

Stormwater runoff. Stormwater runoff which enters the Wapato Basin during the winter contributes significant P input, representing roughly 1 to 12 percent of the lake total. However, most of the stormwater inputs are in particulate form and settle near the outfall discharges. The seasonal nature and low availability of these discharges minimizes their importance to lake quality.

Septic system inputs. Septic system inputs of P represent approximately 1 to 5 percent of the effective lake total. In

contrast to stormwater inputs, nearly all of the P attributable to septic sources is available for algal uptake. It enters the lake at a constant rate throughout the year. Although these inputs are small relative to lake totals, they are a significant component of nearshore supplies and thus may influence nearshore algal accumulations. Most of the septic system P input is attributable to drainfields installed in areas with relatively shallow groundwater. Future septic system P inputs could be controlled by regulating the location and/or design of new systems.

Metal Inputs. The largest inputs of metals to Lake Chelan come from an abandoned tailings pile and mine portal near Holden Village and adjacent to Railroad Creek. For example, existing discharges of zinc from the area represent more than 80 percent of the total lake input of this metal. It may cause localized aquatic life toxicity where Railroad Creek flows into Lake Chelan. Because leaching appears to be occurring at a uniform rate, metals discharged from the tailings area are not likely to diminish in the near future.

Open water concentrations of all metals are low and well below applicable drinking water standards and criteria for aquatic life. Similarly, residues of metals in fish tissues of the lake fall within normal ranges.

Groundwater and surface water drainage from agricultural areas of the Lower Chelan Basin exhibit elevated concentrations of nitrate and arsenic. These periodically exceed existing and proposed drinking water standards. These excesses are apparently the result of pesticide and fertilizer applications. Existing use of affected groundwaters and drainage flows for domestic consumption, however, is limited. Agricultural drainage discharges may result in elevated nitrate and arsenic concentrations in some nearshore areas of the lake. These inputs appear to diffuse rapidly to acceptable levels within a short distance from the outfalls.

DDT Residues. Although use of the pesticide DDT was prohibited nearly 15 years ago, residues of this substance still remain within lake sediments and fish tissues. Concentrations of DDT and its principal degradation products in surface sediments of the lake were approximately twenty times higher in the Wapato Basin than in the Lucerne Basin. It is likely that this reflects past inputs to the lake resulting from orchard applications. Total DDT concentrations in fish tissues, on the other hand, were relatively similar throughout the lake and varied little among fish species. DDT residue concentrations in Lake Chelan fish are similar to concentrations in other regional waters. None of the fish sampled exceeded the FDA guideline level of 5,000 ug/kg wet weight. Individuals who consistently consume large quantities of fish (0.4 lb per day) from the lake may increase their lifetime risk of contracting cancer by as

much as 1:1,000. Wildlife may also be somewhat at risk from DDT exposure.

Recommended Management Actions

Through past and current regulatory and funding actions, Ecology has striven to preserve Lake Chelan's excellent water quality. As mentioned above, the long term maintenance of water quality conditions was a primary goal of Ecology's funding of this study. Development will occur within the drainage basin, but significant change in the lake's near-pristine condition is not considered acceptable. This general water quality objective forms the basis for more specific recommended management actions.

In consideration of inherent data uncertainties in water quality assessments, and also because of the high degree of importance placed on the water quality of Lake Chelan, Ecology's present management guideline is as follows: only to allow future development within the basin to a level which has a low risk of altering the existing near-pristine or ultraoligotrophic status of the lake. Additional development within the Lake Chelan basin is considered acceptable only if there is less than a five percent chance that such development will cause in-lake nutrient (P) concentrations to exceed the established ultraoligotrophic threshold. This management guideline protects both open-water and nearshore water quality characteristics.

The Predictive Value of an Analytical Model. To evaluate possible changes in lake water quality which might result from future development, the investigators in this study constructed an analytical model of phosphorus movement within the Lower Chelan Basin. The model was developed from the extensive data collected during this study. It included assessments of seasonal conditions and prediction uncertainties.

Based on the model, a fifteen percent or less increase in the average amount of P discharged to the lake from the lower basin drainage area would protect the lake and thus continue to preserve its ultraoligotrophic quality. This protection will be maintained if additional development is limited to 500 or fewer dwellings with septic systems. Given current population trends, this additional development could conceivably occur within 20 to 60 years, depending upon development pressures and on how many new dwellings will connect to the regional sewer system.

Control septic system input to limit phosphorus in the lake. Most of the potential P input associated with residential development is attributable to septic system discharges. Furthermore, septic system discharges of P to the lake were found to be greatest in areas where saturated soils predominated beneath the drainfield. Thus, implementation of additional

regulations designed to minimize such occurrences would likely result in large reductions in the amount of P discharged to the lake from future development.

The investigators recommend a regulatory approach that designates the Chelan drainage basin as a "geologically sensitive area" under state water pollution control laws. Following this designation, the investigators recommend more stringent septic system regulations which require additional consideration of siting, testing, and analysis. Ecology concurs with this recommendation. A scope of appropriate regulations was developed and is included in the report. If such additional regulations are implemented, approximately 2,600 additional dwellings using septic systems could be built in the basin while still protecting the lake's ultraoligotrophic quality. This "saturation development" level is unlikely to occur in the near future but needs strong consideration for the long-term stewardship of Lake Chelan.

Control of septic system sources of nutrients is recommended as an important major component of an overall Lake Chelan protection program. As well, longer-term basin planning efforts should also include the following:

o Management of agricultural, urban, and mine-related runoff to control potential nutrient, pathogen, and hazardous waste emissions to the lake.

o Consideration of future extensions of the existing sewage collection and treatment system.

o Assessment of appropriate water supply intake locations and treatment requirements.