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DEPARTMENT OF
ECOLOGY

Lake Chelan
Water Quality Assessment

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Lake Chelan
Water Quality Assessment

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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.

Lynn R. Singleton, Project Manager
Surface Water Investigations
Washington State Department of Ecology

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Numerous individuals participated in the rather extensive field sampling and analysis activities, and in critical review of the project. We wish to acknowledge their often tireless efforts, without which this project simply would not have been possible. In alphabetical order, we thank the following:

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Robert Wasem, U.S. National Park Service
Elmer Witt, Holden Village
David Zimmer, U.S. Bureau of Reclamation

TABLES

FIGURES

COLOR PLATE

ACRONYMS

APHA - American Public Health Association
As - Arsenic
Ca - Calcium
CDHD - Chelan County Health District
CCPUD - Chelan County Public Utility Division
DDT - Pesticide, Dichloro-diphenyl-trichloroethane
DO - Dissolved Oxygen
DSHS - Washington Department of Social and Health Services
Ecology - Washington Department of Ecology
Eh - Oxidation/Reduction Potential
EPA - Environmental Protection Agency
FC - Fecal Coliform Bacterial
Fe - Iron
FS - Fecal Streptococcus Bacteria
MPN - Most Probable Number
N - Nitrogen
NH_4-N - Ammonia Nitrogen
NOAA - National Oceanographic and Atmospheric Administration
NO_3+NO_2-N - Nitrate Plus Nitrite Nitrogen
NPS - National Park Service
P - Phosphorus
pH - Log scale indicator of water acid or alkali content
PTHM - Potential Tri-Halomethanes
PVC - Polyvinyl Chloride
TC - Total Coliform Bacteria
THM - Tri-Halomethane
TP - Total Phosphorus
TSN - Total Soluble Nitrogen
TSP - Total Soluble Phosphorus
USBR - United States Bureau of Reclamation
USGS - United States Geological Survey
UW/CE - University of Washington Department of Civil Engineering
WPCC - Water Pollution Control Commission (now Ecology)
Zn - Zinc

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 morraine 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 years. 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 near the drain outfalls. 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 lbs 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 uncertain ties 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. <u>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</u>. 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 to preservce its ultraoligotropic quality. This protection will be maintained if additional development is limited to 500 or fewer dwellings. 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 siting, testing, and analysis. Ecology concurs with this recomnmendation. A scope of appropriate regulations is presented. 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 ultraoligotropic 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.

CHAPTER 1

Introduction

1.0 INTRODUCTION

Lake Chelan is the largest natural lake in Washington State, and is recognized throughout the region as an extremely valuable water resource. The lake basin supports a wide variety of land uses, ranging from recreational activities within wilderness areas of the North Cascades National Park, to residential, commercial, and agricultural development near the population centers of Chelan and Manson. Principal uses of the lake include domestic water supply for most of the basin residents, irrigation supply, fisheries production, power generation, transportation, and considerable water-related recreation.

Selected water quality characteristics of Lake Chelan have been studied periodically since 1967, when the Washington Water Pollution Control Commission (WPCC; now the Department of Ecology) examined bacterial, nutrient, and general inorganic characteristics of the lake (Cunningham and Pine, 1968). Subsequent studies included general microbiological and trophic assessments in 1974 by the U.S. Geological Survey (Dion et al., 1976), in 1976 by the U.S. Environmental Protection Agency (EPA, 1977), and in 1981 by Chelan County (R.W. Beck, 1983). More limited investigations of selected lake and tributary quality characteristics have also been performed by USGS (1972), EPA (1984), the National Park Service (Funk et al., 1987; NPS, unpublished data), the U.S. Bureau of Reclamation and U.S. Forest Service (unpublished data available on STORET), WPCC (Pine, 1967), the Washington Departments of Game (Brown, 1984) and Ecology (Hopkins et al., 1985; Kendra, 1986), the University of Washington (Dept. of Oceanography, unpublished data), Chelan-Douglas Health District (CDHD, 1981), Chelan County PUD (Johnstone and Babb, 1986), Holden Village (Anderson and Benjamin, 1982), and the Chelan Hills Maintenance Association (Projects Northwest, 1985). Routine monitoring of major tributary flows and water quality within the lake outlet (i.e. Chelan River) has also been conducted by USGS and Ecology.

The above list of previous investigations of Lake Chelan is substantial, and sufficient to describe general water quality characteristics of the lake. Overall, these prior data characterize Lake Chelan as oligotrophic (low biological productivity, high water clarity), with relatively few discernable water quality problems. Documented water quality deficiencies in the lake have included elevated bacterial levels near water supply intakes, apparent metals toxicity in Railroad Creek, and elevated pesticide residues in lake sediments and fish populations. However, because of the limited scope of the previous studies, prior data may not be directly comparable, which generally limits assessments of the magnitude of apparent water quality deficiencies. Furthermore, pertinent controlling processes operable within the lake system cannot be defined with these previous data. Without such information, possible changes in lake water quality resulting from future development and other activities within the basin cannot be reliably determined.

Based on historical trends and planned developments within the Lake Chelan Basin, both residential and recreational uses within the area are likely to increase markedly (Chelan County, unpublished data; TAMS, 1986). In order to develop appropriate management plans to protect the water quality of Lake Chelan, and to provide a reliable baseline assessment of existing lake conditions, Ecology recognized that a detailed limnological assessment of the lake was required. The adequacy of septic tank drainfields for wastewater treatment within the basin also needed to be addressed.

Ecology retained Harper-Owes and its principal subcontractors Hart Crowser, Golder Associates, the University of Washington, and Evans-Hamilton to conduct the Lake Chelan Water Quality Assessment. Certain project tasks (e.g. fish tissue contaminant assessments) were also performed directly by Ecology. The investigation focused upon three primary project objectives: 1) to provide a baseline limnological study of the lake; 2) to evaluate the suitability of on-site wastewater disposal systems within the developing Lower Chelan Basin; and 3) to estimate principal source contributions and potential impacts of identified bacterial and chemical contaminants of concern within Lake Chelan. The three study objectives are closely interrelated to one another.

This report presents the findings of the investigation, evaluates existing water, sediment, and fish tissue quality, and discusses possible future changes in water quality resulting from several potential development scenarios. Recommendations for future management activities are also presented. The report is intended to provide an information base sufficient to formulate upcoming water quality management and planning decisions.

CHAPTER 2

Study Area

2.0 STUDY AREA

2.1 Regional Geologic Setting

The majority of the geological conditions within the study area are a direct result of the complex interaction between two distinct glacial masses during the last glacial period (Pleistocene epoch). The two glacial masses included; 1) a Pleistocene alpine glacier originating in the Cascade Range to the west which advanced to the east and southeast, deepening and scouring an existing drainage forming the present Lake Chelan and 2) the Okanogan Lobe of the Cordilleran ice sheet.

The Okanogan Lobe originated to the north in British Columbia and gradually advanced southward onto the Columbia Plateau. A portion of the Okanogan Lobe is thought to have entered the Lake Chelan area and, according to Waitt (1972) and Waitt and Thorson (1983), merged with contemporaneous Cordilleran ice that invaded over high divides far to the north and descended into the Chelan trough. The presence of the Okanogan Lobe formed an effective dam for the meltwater originating from the glacial ice located in the Chelan trough, resulting in the formation of a proglacial lake. During the advance of these glaciers, a complex assembledge of sediments was deposited; proglacial lacustrine deposits of silt, clay, and sand; advance outwash sediments of sand and gravel, and tills consisting of sand, gravel, silt, and clay. Eventually water levels rose in this proglacial lake to elevations where overflow was directed to the south through the Chelan Mountains via Knapp and Navarre Coulees. The glaciers subsequently retreated from the Chelan area depositing a complex sequence of recessional outwash and kame terraces, which are evident along the margins of the Chelan trough. Subsequent geologic processes have deposited recent lacustrine deposits, loess, ash originating in the Cascade Range to the west, fluvial deposits from recent stream action, and colluvial deposits associated with recent slope processes.

2.2 Lake Morphometry

Lake Chelan is the largest and deepest natural lake in Washington (Kendra and Singleton, 1987). With a maximum depth of 453 meters (1,486 ft), it is also the third deepest lake within the continental United States, behind Crater Lake (589 m) and Lake Tahoe (501 m). The mean depth of the lake is approximately 144 m (474 ft). The length of the lake along its principal axis (talweg) is 81.1 km (50.4 mi). Selected morphometric characteristics of Lake Chelan are summarized in Table 2.1.

Lake Chelan lies within an elongate fjord basin formed during the last glacial period (Pleistocene epoch; see Section 2.1 above). Interactions between glacial masses within the basin resulted in the formation of a prominent sill within the lake, located approximately 19 km (12 mi) uplake along the talweg (Figure 2.1). Lake width is also constricted in the sill area. The shallow sill region (approximate depth = 41 m; 135 ft) separates Lake Chelan into two distinct morphometric basins. The lower Wapato Basin is characterized by relatively shallow depths (mean depth =

TABLE 2.1

LAKE CHELAN MORPHOMETRIC CHARACTERISTICS
(after Kendra and Singleton, 1987)

Parameter	Wapato Basin	Lucerne Basin	Lake Chelan
Max. Length (km)	19.3	61.8	81.1
Max. Effective Length (km)	15.4	24.8	24.8
Max. Width (km)	2.9	2.3	2.9
Mean Width (km)	1.8	1.6	1.6
Max. Depth (m)	122	453	453
Mean Depth (m)	43	180	144
Shoreline Development	2.1	3.7	4.3
Shoreline Length	44.4	132.4	175.7
Surface Area (sq km)	35.0	99.9	134.9
Percent of Lake Surface Area	26.0	74.0	100.0
Vol. (cu.m x 10^9)	1.49	18.0	19.5
Percent of Lake Volume	7.6	92.4	100.0
Watershed Area (sq km)			2,393
Water Residence (yr)			10.6
Lake Surface Elevation (m)			335

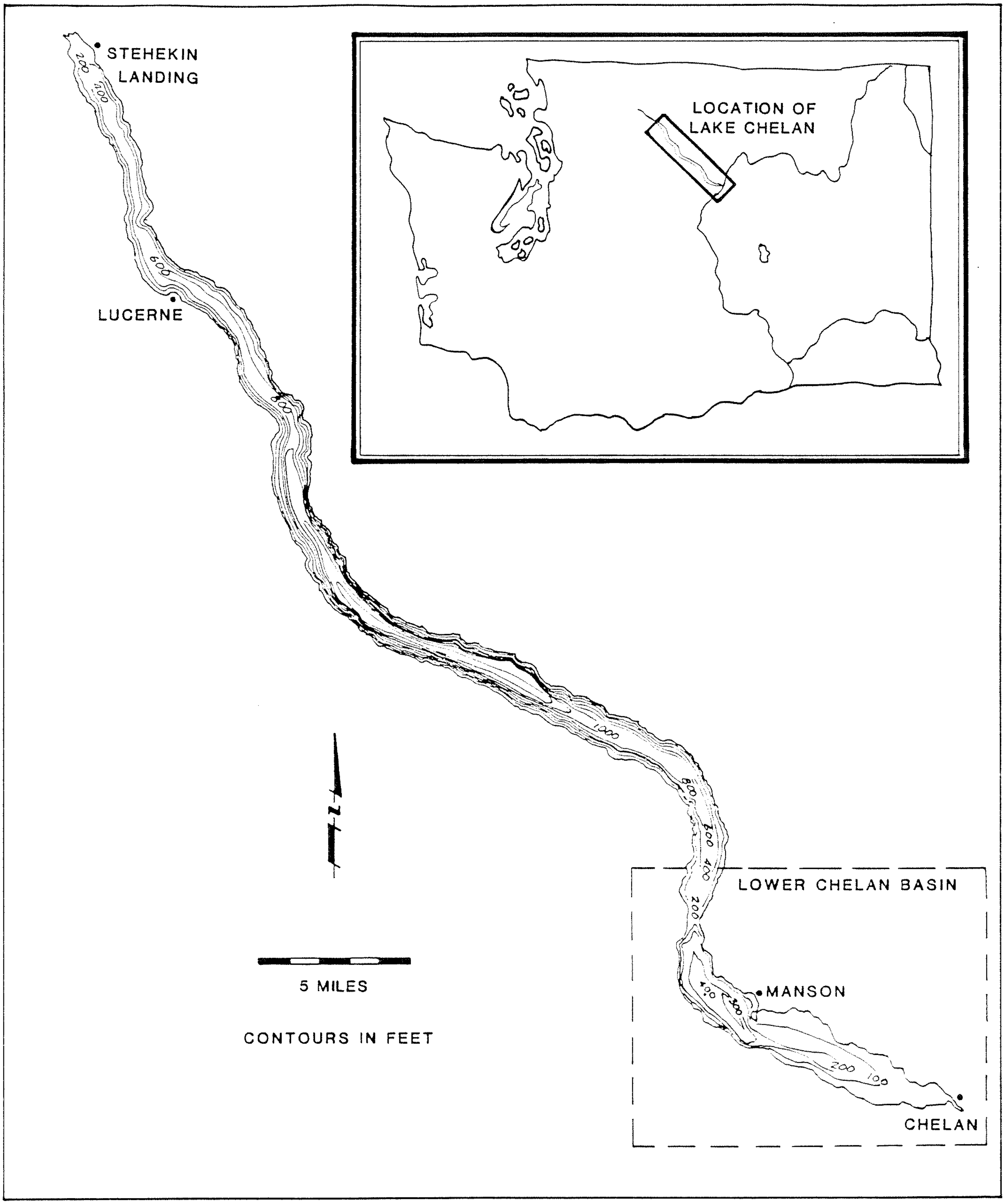

Figure 2.1

BATHYMETRIC MAP OF LAKE CHELAN

43 m; 140 ft), while the upper Lucerne Basin exhibits rather steep basin walls and a mean depth of 180 m (590 ft; Kendra and Singleton, 1987). More than 92 percent of the lake's volume occurs within the Lucerne Basin.

The existing outlet from Lake Chelan is defined by a relatively small concrete dam within the City of Chelan. Constructed in 1927, the dam raised the level of the lake approximately 6.4 m (21 ft) to facilitate power production. Outflow from the lake is directed largely through the power penstocks, with final discharge into the Columbia River. Full-pool water elevations are generally maintained throughout the summer (June - September) period, with lower levels during winter months.

Based on an average annual discharge from Lake Chelan since 1904 of 56.0 m^3/sec (2,050 cfs; Williams and Pearson, 1985), the bulk water residence time within the lake (both basins combined) is approximately 10.6 years. Residence time within the Wapato Basin is likely much shorter than this whole-lake average (0.84 years assuming minimal interbasin mixing). Hydrologic and water exchange processes occurring within Lake Chelan will be discussed in more detail in the sections which follow.

2.3 Population and Land Use

The total resident population within the Chelan Basin in 1987 was approximately 6,600 (U.S. Census, 1980; J. Vodopich, Chelan County, written communication, 1988). However, the population within the basin is characterized by rather large seasonal changes, resulting from fluctuations in the farm labor force, tourism, recreation, and mobile living patterns of retired persons. Many of these seasonal residents were not included in the U.S. Census estimates.

Nearly all of the basin population resides within the Lower Chelan Basin, with almost half of the basin total represented by the City of Chelan (1987 population = 3,100; U.S. Census, 1980; Chelan County, written communication). A smaller population center also occurs in the Town of Manson. Comparatively few individuals live within upper areas of the basin, and the combined resident population within the Stehekin, Lucerne,and Holden regions was estimated in the 1980 census at approximately 130. The population of the upper area of the basin also increases during the summer months.

Historical data on population within the Chelan Basin is available from U.S. Census records and from the Washington State Office of Financial Management. These records, and future projections provided by Chelan County, are presented in Figure 2.2 for the City of Chelan and the Lower Chelan Basin census districts. During earlier years (i.e. 1920 - 1950), a large (but not well documented) number of people within the upper basin were involved in mining-related activities associated with the Holden Village area. Closure of the mine in the following years resulted in a population decline. Overall, the current basin population is likely similar to that which existed in the 1940's. However, the rate of population growth appears to be increasing, and between 1970 and 1980 a

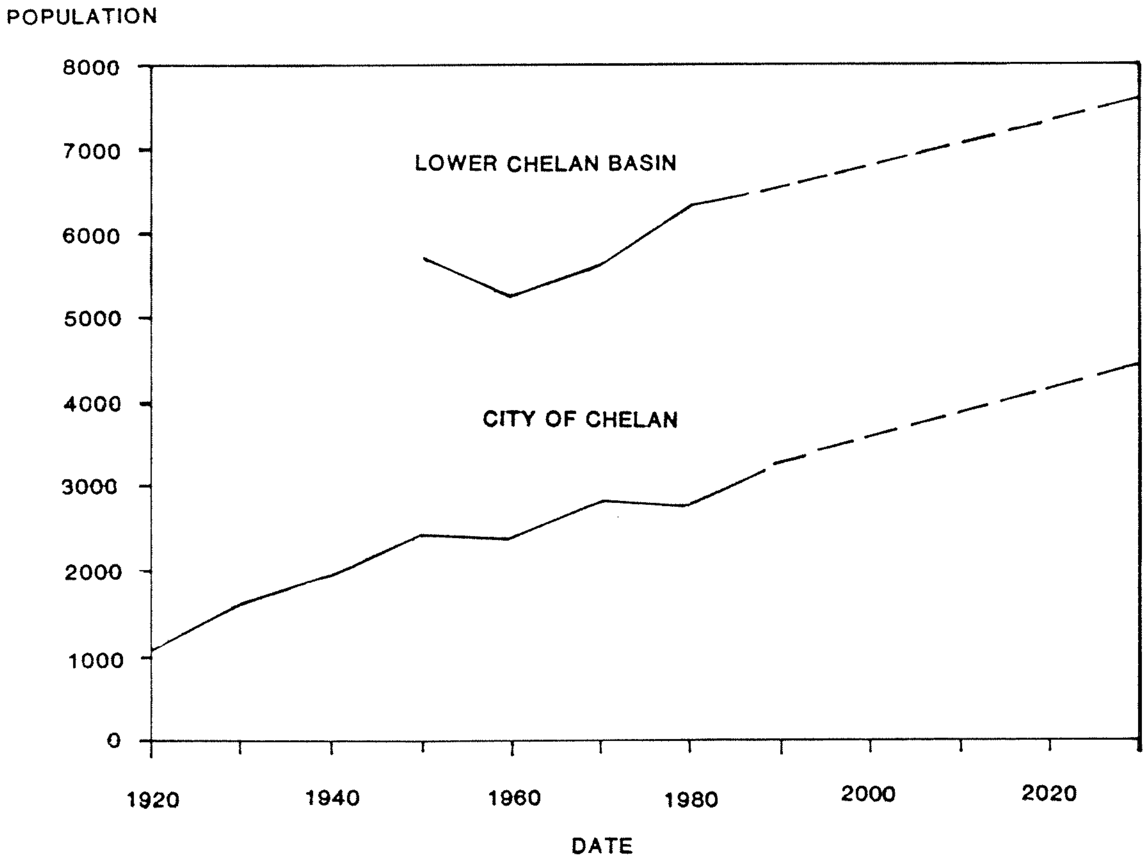

Figure 2.2

HISTORICAL CHANGES WITHIN THE CHELAN BASIN

12.5 percent increase was reported for the Lower Chelan Basin census district (Chelan County, written communication). This rate of increase is likely to be sustained into the future. Recreational demands may increase at a more rapid rate (TAMS, 1986).

Land use data for the study area are available from Dion et al (1976) and Chelan County (J. Vodopich, written communication). These data are summarized in Table 2.2. The dominant land use within the basin is undeveloped forest, most of which is managed by the U.S. Forest Service and National Park Service for recreational activities. Only four (4) percent of the total watershed area of Lake Chelan is currently developed, and the principal land development has been to orchard (primarily apple production) uses. Incorporated areas of the City of Chelan total approximately 13 km^2 (3,200 acres).

Wastewater treatment within the basin occurs by two principal methods: on-site septic systems and treatment at the City of Chelan facility. The existing wastewater collection and treatment system is maintained by the City of Chelan and the Public Utilities District. The collection system extends along both the northern and southern shores of the lake to intercept most of the wastewater discharges from the City of Chelan, Manson, and a number of nearshore residences in unincorporated areas. Approximately 1,600 dwellings and commercial facilities within the lower basin are currently served by the collection system, representing slightly more than one-half of the total basin population (R. Mauch, City of Chelan, written communication, 1986). Secondary (biological) treatment is provided at the City of Chelan facility, with final discharge into the Columbia River adjacent to Chelan Falls. Prior to 1987, final effluent was discharged into the Chelan River immediately below the dam.

On-site septic systems are utilized for wastewater treatment by nearly one-half of the basin's 6,600 residents. New systems are regulated by the Chelan-Douglas Health District (CDHD), with the requirement for a 33 meter (100 ft) setback from surface waters. Other design features are also required. Most of the existing septic systems within the basin, however, were installed prior to CDHD regulations, with generally undocumented designs. A small wastewater treatment plant and drainfield serves the Stehekin Landing area.

TABLE 2.2

EXISTING LAND USE WITHIN THE CHELAN BASIN

LAND USE	AREA (km^2)[a]	PERCENT OF TOTAL
Lake Chelan	135.	5.6
Other Water Bodies	4.	0.2
Forested Public Lands	2,000.	83.6
Forested Private Lands	163.	6.8
Agriculture - Orchard	47.	2.0
Agriculture - Non-Orchard	31.	1.3
Residential[b]	6.	0.3
Roadways	6.	0.2
Commercial and Public Bldgs.	1.	0.0
TOTAL	2,393.	100.0

a) Land use areas obtained from Dion et al (1976) and Chelan County (J. Vodopich, written communication, 1988). Values presented are approximate.

b) There are approximately 3,000 dwellings within the basin; each dwelling occupies an estimated average of 0.5 acres of land.

CHAPTER 3

Methods

3.0 METHODS

3.1 Hydrogeologic Investigations

3.1.1 Geologic Mapping

A geologic investigation was undertaken to delineate surficial soil deposits in the Lower Chelan Basin. The purpose of the investigation was to develop a terrain unit map depicting the relationships of the various surficial deposits as an aid in evaluating the suitability of the Wapato Basin soils for on-site wastewater disposal.

The study area included a several kilometer (1 - 2 mi) wide strip around Lake Chelan, beginning at the southeast end of the lake near the City of Chelan, and ending near the Greens Landing area, approximately 20 kilometers (12 mi) up-lake (Figure 2.1). For the purposes of this report, this area is referred to as the Lower Chelan Basin. Most of the existing development occurs within this area. Future development is also likely to concentrate within the Lower Basin.

Prior to the commencement of the geologic mapping, pertinent literature were reviewed to focus the geologic mapping to areas where either data were lacking or additional clarification of existing data were required (Whetten, 1967; Hopson and Mattinson, 1971; Tabor et al., 1987, Waitt, personal communication). In addition, two sets of aerial photographs were reviewed to focus subsequent field activities (1:25,000 color and 1:60,000 U-2 false color infrared photos available from USGS National High Altitude Program).

The field mapping was conducted from October 8 through 29, 1988. The field mapping consisted of examining soil and rock outcrops and exposures and the excavation of over thirty hand-dug exploration pits. Field mapping data were recorded on translucent mylar overlays attached to the 1:25,000 photos, then transferred to U.S. Geological Survey 15 minute quadrangle maps. Additional field documentation included field notes and 35 mm photographs of pertinent geologic relationships. Field and photographic stations were recorded on the same 15 minute quadrangle base map.

3.1.2 Well Installations

One of the principal objectives of the Lake Chelan water quality assessment was to evaluate the fate and impacts of on-site wastewater disposal systems within the Lower Chelan Basin. Based on preliminary assessments of the variability of wastewater constituent attenuation within other environments similar to the Chelan region (Harper Owes, 1986), it was estimated that approximately 10 to 15 septic systems would need to be assessed in order to reliably determine overall wastewater transport and attenuation within the basin. Accordingly, fifteen (15) monitoring wells were installed downgradient of septic systems within the Lower Chelan Basin. Eight (8) additional reference wells were also installed at upgradient locations and in agricultural areas for comparative purposes. Existing monitoring and water supply wells were utilized to assess upgradient conditions wherever possible.

There were two phases of drilling. Beginning on November 18, 1986, 14 monitoring wells and 4 boreholes were installed by Hokkaido Drilling and Developing Corporation using a mobile B-61 hollow stem auger drilling rig. After encountering gravel and cobbles at a number of sites, which the hollow stem auger could not penetrate, the B-61 rig was demobilized on November 25, 1986. The remaining monitoring wells and boreholes were completed by Colville Confederated Tribe Well Drilling using a Chicago Pneumatic top-drive air rotary drilling rig. This work was carried out between December 14, 1986 and December 22, 1986. The drilling and well installations were continuously monitored. The locations of the monitoring wells and boreholes are shown on Figure 3.1.

Drilling Procedure

The drilling procedure using the hollow stem auger rig was as follows:

- Prior to drilling, the auger flights and split- spoon samplers were cleaned using a high pressure steam cleaner and bleach solution.
- During drilling, soil samples were collected 1.5 meter (5 feet) intervals by driving a split-spoon sampler with a 64 kg (140 pound) hammer.
- Collected samples were retained for visual inspection and classification prior to laboratory storage.
- Measurements of water levels were taken during drilling to determine the location of the well screen.

The air-rotary drilling procedure was as follows:

- Prior to drilling, the steel drive casing and drill rods were cleaned using a high pressure steam cleaner and bleach solution.
- The borehole was advanced by drilling about 0.5 to 1.0 meters (2-3 feet) ahead of the casing and then the casing was driven down using the pneumatic casing hammer.
- During drilling, soil samples were recovered from the return air line on a continual basis. Selected samples were retained for visual inspection and classification prior to laboratorystorage.
- Where groundwater was encountered during drilling, water levels were measured to determine the location for the well screen.

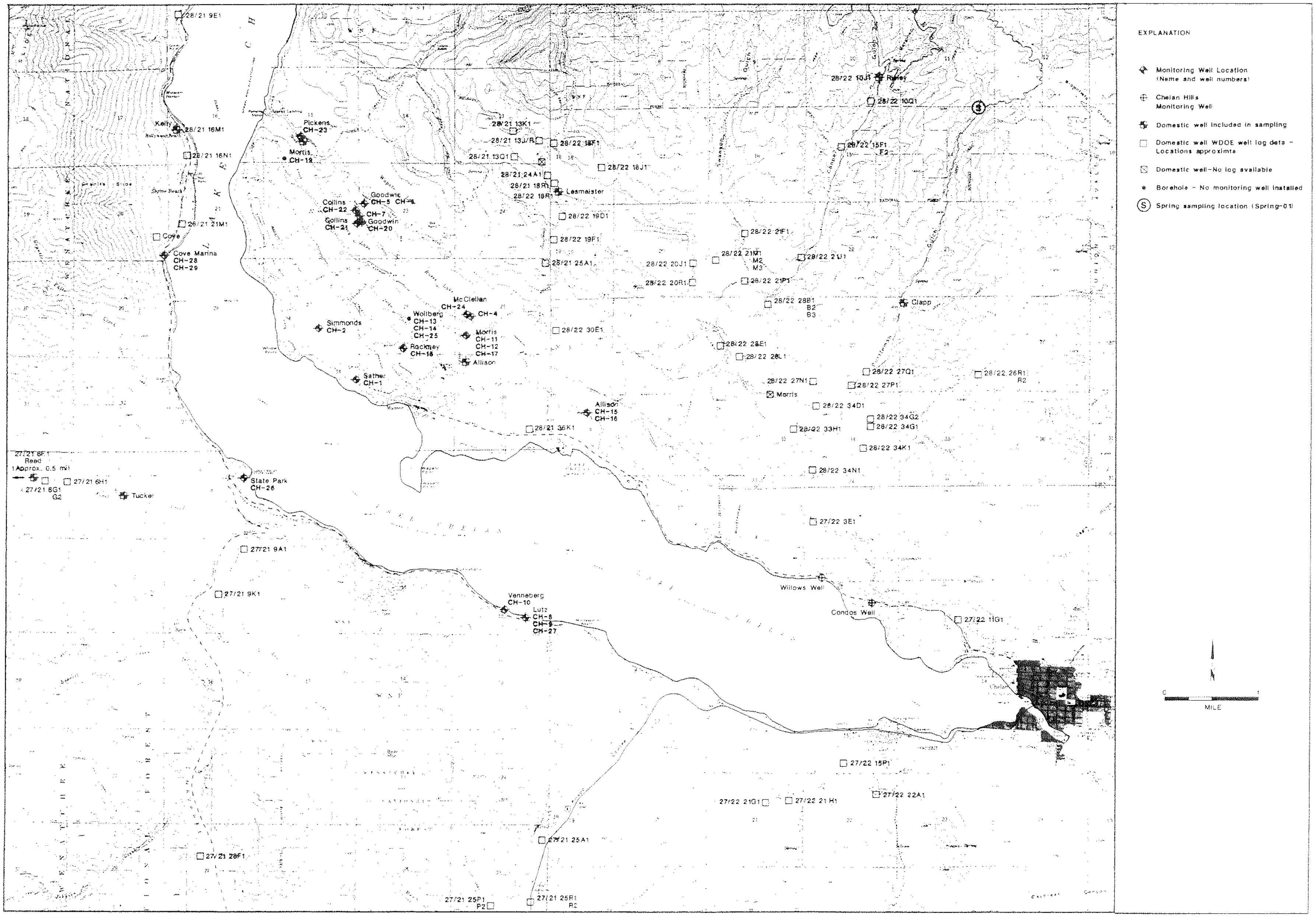

Figure 3.1

WELL LOCATION MAP LOWER CHELAN BASIN

Borehole Completion and Well Development

Following drilling, the boreholes were, in most cases, completed as monitoring wells. In some instances, where refusal was encountered close to the ground surface and above the groundwater level, the borehole was abandoned by withdrawing the augers or leaving the steel casing in place and filling the borehole with gravel and bentonite. Borehole completion details are presented in Table 3.1.

The method of completion of boreholes into monitoring wells was as follows:

- The PVC well casing and well screen were disinfected by soaking in a bleach solution for a minimum of 30 minutes prior to being rinsed with distilled water.
- The borehole completion materials consisted of 5 cm (2 in) schedule 40, flush-threaded PVC pipe and well screen in 1.5 and 3.0 meter (5 and 10 ft) lengths. The pipe joints were equipped with Viton "O" ring seals. The well screens were factory slotted PVC pipe with a 0.051 cm (0.020 in) slot size.
- The well screen and pipe were assembled and lowered into the borehole. A threaded plug was placed at the bottom of the well screen.
- The annulus between the well screen and the borehole wall was then filled with silica sand to approximately 1 to 1.5 meters (3 - 5 ft) above the top of the well screen as the auger flights or drive casing was removed.
- A bentonite pellet seal or bentonite slurry was then placed on top of the sand pack prior to backfilling the borehole annulus to the surface.
- Protective locking steel casings or water-meter type covers were set over some monitoring wells in heavy traffic areas or locations susceptible to vandalism. In other areas, the PVC casing was cut off at or below ground-level and a PVC slip cap set over the casing.

Following installation, all monitoring wells were developed by over pumping and/or bailing to reduce the turbidity of groundwater entering the well. In most cases, the well- water cleared with about one to two hours of pumping. Some wells completed in the finer materials continued to produce some silt and clay particles even after lengthy development.

The monitoring wells were subsequently disinfected to kill any bacteria that may have been introduced during either the drilling or well development procedures. Disinfection was carried out by adding a known quantity of calcium hypochlorite solution to the well to produce 100 mg/L

TABLE 3.1

MONITORING WELL DETAILS

Page 1 of 4

Borehole Number	Location	Depth (ft)	Drilling Method	Measuring Point Elevation (ft) (a)	PVC Well Casing Stick-up (ft) (b)	Screened Interval Depth (ft)	Depth to Water (ft) (c)	Soil Type	Comments
CH-1	Drain 8 Sather Manson	21.5	H.S.A.	1165	0.8	10.0-20.0	11.33	Sandy Silt to Sand	Agricultural Catchment.
CH-2	Drain 6 Simmonds Manson	20.5	H.S.A.	1235	0.7	10.0-20.0	6.09	Sand	Agricultural Catchment.
CH-3	Morris 1097 Loop Rd. Manson	6.0	H.S.A.	1230*	---	---	---	Sand and Gravel	Borehole Abandoned.
CH-4	Drain 11 McClellan Manson	16.5	H.S.A.	1172.56	-0.2	5.0-15.0	7.80	Sand and Silt	Agricultural Catchment Monitoring. Upgradient for septic.
CH-5	Goodwin 4845 Wapato Lk. Manson	7.0	H.S.A.	1280	-0.2	2.0-7.0	Dry	Silty Sand	Refusal at 7 feet. Downgradient for septic.
CH-6	Goodwin 4845 Wapato Lk. Manson	6.7	H.S.A.	1280	-0.1	3.7-6.7	Dry	Gravelly Sand	Refusal at 6.7 feet. Upgradient for septic.
CH-7	Goodwin 988 Dry Lake Manson	7.5	H.S.A.	1190*	-0.2	2.5-7.5	Dry	Silty Sand to Gravel	Refusal at 7.5 feet. Downgradient for septic.
CH-8	Lutz (Shallow) 3050 S. Shore Chelan	26.0	H.S.A.	1114.93	-0.1	8.5-18.5	Dry	Sand and Gravel	Downgradient for septic.

TABLE 3.1(cont.)

MONITORING WELL DETAILS

Borehole Number	Location	Depth (ft)	Drilling Method	Measuring Point Elevation (ft) (a)	PVC Well Casing Stick-up (ft) (b)	Screened Interval Depth (ft)	Depth to Water (ft) (c)	Soil Type	Comments
CH-9	Lutz 3050 S. Shore Chelan	23.0	H.S.A.	1118. 74	-0.1	13.0-23.0	14.47	Gravelly sand	Upgradient for septic.
CH-10	Venneberg 3272 S. Shore Chelan	21.3	H.S.A.	1106.39	0.8	10.0-20.0	8.35	Sand	Downgradient for septic.
CH-11	Morris 87 Roses Ave. Manson	24.0	H.S.A.	1245	-0.1	4.0-14.0	Dry	Silty Sand and Silt	Upgradient for septic (Perched Zone).
CH-12	Morris 87 Roses Ave. Manson	19.0	H.S.A.	1245	-0.1	3.5-13.5	Dry	Silty Sand and Silt	Downgradient for septic (Perched Zone).
CH-13	Wollberg Totem Pole Rd. Manson	12.0	H.S.A.	1400*	---	---	---	Silty Sand and Gravel	Refusal as 12 feet. Borehole abandoned.
CH-14	Wollberg Totem Pole Road Manson	6.0	H.S.A.	1400*	---	---	---	Silty Sand and Gravel	Refusal at 6 feet. Borehole abandoned.
CH-15	Allison 1251 Swartout Manson	25	H.S.A.	1215	-0.1	15.0-25.0	15-25	Clayey Silt/ Sand	Upgradient for septic.
CH-16	Allison 1251 Swartout Manson	24	H.S.A.	1203.5	-0.2	12.5-22.5	15.04	Clayey Silt/ Sand	Downgradient for septic.

TABLE 3.1 (cont.)

MONITORING WELL DETAILS

Page 3 of 4

Borehole Number	Location	Depth (ft)	Drilling Method	Measuring Point Elevation (ft) (a)	PVC Well Casing Stick-up (ft) (b)	Screened Interval Depth (ft)	Depth to Water (ft) (c)	Soil Type	Comments
CH-17	Morris 87 Roses Ave. Manson	60	H.S.A.	1245	0.0	50.0-60.0	55.38	Silt to Sand	Downgradient for septic.
CH-18	Rockney Banks & Chase Manson	13.6	H.S.A.	1410	---	6.6-13.6	Dry	Silty Sand and Gravel	Refusal at 13.6 feet. Downgradient for septic.
CH-19	Morris 1097 Loop Rd. Manson	52	A.R.	1230*	---	---	---	Sand and Gravel	Abandoned at 52 feet. No water encountered.
CH-20	Collins 901 Dry Lake Rd. Manson	18.4	A.R.	1168.17	-0.2	8.4-18.4	4.79	Clayey Silt and Sand	Downgradient for septic.
CH-21	Goodwin 915 Dry Lake Manson	200	A.R.	1171.37	0.0	6.3-16.3	7.92	Clayey Silt and Sand	Downgradient for septic.
CH-22	Collins 901 Dry Lake Manson	33	A.R.	1202.45	0.0	23.0-33.0	15.75	Sandy Gravel and Silty Sand	Upgradient for septic.
CH-23	Pickens 220 Greens Landing Manson	15	A.R.	1165	0.0	5.0-15.0	6.10	Sandy clayey Silt	Downgradient for septic.
CH-24	McClellan Roses Lake Manson	20	A.R.	1173.60	0.8	9.5-19.5	8.94	Sand and Silt	Downgradient for septic.

TABLE 3.1 (cont.)

MONITORING WELL DETAILS

Page 4 of 4

Borehole Number	Location	Depth (ft)	Drilling Method	Measuring Point Elevation (ft) (a)	PVC Well Casing Stick-up (ft) (b)	Screened Interval Depth (ft)	Depth to Water (ft) (c)	Soil Type	Comments
CH-25	Wollberg Totem Pole Rd. Manson	40	A.R.	1400*	---	---	---	Sand and Gravel	Abandoned at 40 feet. No water encountered.
CH-26	Lake Chelan State Park Chelan	70	A.R.	1165	-0.1	59.0-69.0	48.20	Sand and Silty Sand	Downgradient for septic.
CH-27	Lutz (Deep) 3050 S. Shore Chelan	30	A.R.	1115.54	-0.1	19.0-29.0	17.27	Sandy Gravel - some Silt	Downgradient for septic.
CH-28	McClosky Cove Marina Chelan	40	A.R.	1112.45	0.9	28.0-38.0	26.04	Silty Sand and Gravel	Downgradient for septic.
CH-29	McClosky Cove Marina Chelan	6.0	H.S.A.	1112*	---	---	---	Gravel and Cobbles	Refusal at 6 feet. Borehole Abandoned.

Notes:

a) Refer to Table --- for measuring point elevation details.
* indicates ground surface elevation.

b) Depth above ground level (-ve indicates below ground level)

c) Depth from top of PVC (April 1987)

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of chlorine in water that filled the casing and saturated the sand pack. The well was then left overnight. The following day, the well was purged by pumping between five and ten well volumes (including the sand pack volume) to remove the chlorine solution. Following disinfection, those wells that were to be sampled using a vacuum system (i.e., water depths of less than 6 meters; 20 ft) were outfitted with pre-sterilized, dedicated 1 cm (3/8-in) diameter polyethylene sampling tubes, which were placed inside the well casing.

Permeability Testing

Rising-head permeability tests and pump tests were carried out in a number of monitoring wells and existing domestic wells in order to evaluate the hydraulic conductivity of the surrounding geologic materials. Rising-head tests were performed in the following monitoring wells: CH-1, CH-2, CH-4, CH-10, CH-15, CH-21 and CH-23. Short term constant rate pump tests were carried out in the following domestic wells: Kelly, Lesmeister, Clapp, Pickens and Risley. The locations of the monitoring wells and domestic wells are shown in Figure 3.1. The logs of the wells are presented in Appendix A.

Rising-Head Permeability Tests

Rising-head permeability tests were performed by rapidly evacuating a volume of water from the well using a centrifugal pump. The pump was then stopped and the water level recovery monitored over time. Prior to the test, the pump suction hose, which was equipped with a check valve, was placed near the bottom of the well. The water level in the well was allowed to re-equilibrate and then the pump was turned on to draw the water level down to the pump intake. Pumping was carried out for about five to fifteen seconds before shutting off the pump and allowing the well to recover. Water level data and permeability estimates obtained from the tests are presented in Appendix B.

Pump Tests

Pump tests were performed by withdrawing water from each well at a constant rate for a period of 15 to 45 minutes and then shutting off the pump and allowing the well to recover. Prior to each test, the static water level in the well was measured. These wells were then pumped at a near constant rate between 0.04 and 0.07 m^3/min (10 and 19 gpm). In the course of testing the Lesmeister well and the Pickens well, the pumps both broke suction after approximately 15 minutes of pumping. When either near steady-state conditions were observed or suction was broken, the pumps were turned off and the water level allowed to recover. Water level measurements were taken with an electric sounder during the pumping and recovery phases of the test. Pumping rates were gauged by recording the time for the discharge to fill a container of known volume. Water level data and permeability estimates obtained from the tests are presented in Appendix B.

3.1.3 Groundwater Monitoring

Following installation, the elevations of all monitoring wells and domestic supply wells utilized in the monitoring effort were determined using a survey altimeter (accurate to approximately ± 2 meters; 5 ft). Relative elevations of upgradient and downgradient wells at a given site were assessed with greater precision (± 0.03 m; 0.1 ft) using a level instrument. Similarly precise measurements were also made to compare water levels in nearshore wells with the lake surface elevation, as monitored at the PUD Lakeside site.

Water levels in all monitoring wells were measured with an electric sounder at a minimum of quarterly intervals over the study period. The existing "Willows" well, which is located approximately 10 meters (30 ft) from lakeshore near the Chelan Hills Development, was also equipped with a pressure transducer and automatic data acquisition system which recorded water levels every two hours for most of the study period. These data were utilized in the evaluation of lake/groundwater interactions.

Water quality samples were obtained from each monitoring well during January, April, July, and November 1987. For most of the monitoring wells, samples were obtained with a dedicated fluorocarbon tubing/peristaltic pump, following purging with a centrifugal pump unit. The entire assembly was designed to prevent sample contamination. Deeper monitoring wells were sampled with a bladder pump or fluorocarbon bailer. Supply wells were sampled at the well head. A summary of the sampling equipment utilized at each well is presented in Table 3.2. At least three casing volumes were purged from each well prior to sampling.

The procedures for sampling the wells were as follows:

1. Domestic wells with submersible pumps - These wells were generally pumped on a daily basis for in-house use, irrigation, or lawn watering. A faucet closest to the well was selected and allowed to run for between five (5) and fifteen (15) minutes. Immediately upon collection, the sample was analyzed for field parameters (see below). Chemical samples were filtered through 0.45 um membrane filters (Millipore brand) prior to delivery to the laboratory. Wells sampled in this manner included Kelly, Reed, Tucker, Clapp, Risley, Lesmeister and Pickens domestic.

2. Shallow monitoring wells - Wells where the depth to water was generally less than 8 meters (25 ft) were equipped with dedicated, sterilized 1 cm (3/8-in) diameter polyethylene tubing and were sampled using either a centrifugal or peristaltic pump or a combination of both pumping systems. Generally, the centrifugal pump was first used to evacuate three well volumes of water. This quantity was based on the water level in the well. The centrifugal pump was then replaced by the peristaltic pump to sample the well, and to perform field analyses.

Table 3.2

GROUNDWATER SAMPLING EQUIPMENT

	Sampling Round			
Well No.	1	2	3	4
CH-1 Sather (Ag)	CP/P	CP/P	CP/P	CP/P
CH-2 Simmonds (Ag)	CP/P	CP/P	CP/P	CP/P
CH-4 McClellan (Up/Ag)	CP/P	CP/P	CP/P	CP/P
CH-5 Goodwin (Dn)	Dry	Dry	Dry	Dry
CH-6 Goodwin (Up)	Dry	Dry	Dry	Dry
CH-7 Goodwin (Dn)	Dry	Dry	Dry	Dry
CH-8 Lutz (Dn)	--	--	--	--
CH-9 Lutz (Up)	CP/P	CP/P	CP/P	CP/P
CH-10 Venneberg (Dn)	CP/P	P	P	CP/P
CH-11 Morris (Up)	Dry	Dry	Dry	Dry
CH-12 Morris (Dn)	Dry	Dry	Dry	Dry
CH-15 Allison (Up)	CP/P	CP/P	CP/P	CP/P
CH-16 Allison (Dn)	CP/P	CP/P	CP/P	CP/P
CH-17 Morris (Dn)	B	B	B	B
CH-18 Rockney (Dn)	Dry	Dry	Dry	Dry
CH-20 Collins (Dn)	CP/P	CP/P	CP/P	CP/P
CH-21 Goodwin (Dn)	CP/P	CP/P	CP/P	CP/P
CH-22 Collins (Up)	CP/P	CP/P	CP/P	CP/P
CH-23 Pickens (Dn)	CP/P	CP/P	CP/P	CP/P
CH-24 McClellan (Dn)	CP/P	CP/P	CP/P	CP/P
CH-26 State Park (Dn)	BP	BP	BP	BP
CH-27 Lutz (Dn)	CP/P	CP/P	CP/P	CP/P
CH-28 Cove (Dn)	CP/P	CP/P	CP/P	CP/P
Spring 01	--	Grab	--	--
Kelly (Dom)	DP	DP	DP	DP
Reed (Dom)	DP	DP	DP	DP
Tucker (Dom/Up)	DP	DP	DP	DP
Clapp (Dom)	DP	DP	DP	DP
Risley (Dom)	DP	DP	DP	DP

TABLE 3.2 (Cont.)

GROUNDWATER SAMPLING EQUIPMENT

	Sampling Round			
Well No.	1	2	3	4
Lesmeister (Dom)	DP	DP	DP	DP
Pickens (Dom/Up)	DP	DP	Dry	DP
Willows (Dn)	--	B	B	B
Allison (Dom)	DP	DP	Dry	DP
Condos (Dn)	--	--	B	B

Dn = downgradient well from septic system
Up = upgradient well at septic system
Dom = domestic water supply well
Ag = agricultural catchment well
CP = Centrifugal Pump
P = Peristaltic Pump
BP = Bladder Pump
B = Bailer
DP = Dedicated Pump (Submersible/Jet)
--- = Not sampled

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Equipment which came into contact with water during the collection of samples was disinfected and rinsed with distilled water before use. This was done to minimize the risk of cross contamination and inadvertent bacterial contamination. Equipment contacting water during collection of filtered samples was first acid washed then rinsed with distilled water. Samples were filtered through in-line, 0.45 um (Millipore) membrane filters. Wells sampled by the above procedure included: Sather, Simmonds, McClellan (Up), Venneberg (Dn), Lutz (Up), Allison (Up), Allison (Dn), Collins (Dn), Goodwin (Dn), Collins (Up), Pickens (Dn), McClellan (Dn), Lutz (Dn), Cove (Dn) and Allison (Domestic).

3. Deep monitoring wells - Water depths exceeding approximately 8 meters (25 ft) were too deep to sample with a suction-lift pump. Accordingly, the deeper Condos, Willows, and Morris (Dn) wells were evacuated and sampled with a teflon bailer. The State Park well was evacuated and sampled with a nitrogen-operated bladder pump.

   Similar to the shallow well procedures discussed above, sampling equipment which contacted the water was disinfected, washed, and rinsed. Samples were collected with the bailer for both field and laboratory determinations. Filtering was performed using a 0.45 um (Millipore) filter.

Water samples were collected from each well for the following field analyses: temperature, dissolved oxygen (DO), oxidation-reduction potential (Eh), hydrogen-ion activity (pH), and specific conductance. All samples were also submitted to the laboratory for turbidity, chloride, TSP, TSN, FS, FC, and TC determinations. Selected samples were analyzed for alkalinity, calcium, fluoride, soluble iron, soluble aluminum, SRP, NH_4-N, and NO_2+NO_3. As discussed above, samples for soluble constituent determinations (e.g. nutrient parameters) were filtered in the field immediately upon collection using a 0.45 um (Millipore) filter. Filter blanks contained only slight (insignificant) traces of these parameters. All determinations were performed according to methods outlined in Table 3.3. Analytical methodologies and quality assurance results are discussed in more detail in Section 3.2.3.

3.2 Limnological Investigations

3.2.1 Hydrology

The objective of the hydrological monitoring was to provide sufficient data to construct water and material budgets for Lake Chelan. Eight principal components of the water budget were recognized during the initial design of sampling activities. These components included five major identified sources (Stehekin River, Railroad Creek, miscellaneous tributaries, irrigation return flow and direct precipitation) and three major categories of loss (Chelan River, irrigation withdrawal and evaporation). There are some 50 minor (miscellaneous) tributaries

TABLE 3.3

Summary of Analytical Methods for Water Samples

Constituent	Analytical Method	Laboratory[1]
Temperature	Thermistor	Harper Owes, field
pH	Field Probe	Harper Owes, field
Dissolved Oxygen	Field Probe/Winkler	Harper Owes, field
Transparency	Secchi Disk	Harper Owes, field
Light Extinction	Sub. Photometer	Harper Owes, field
Turbidity	Nephelometer	UW - Civ. Eng.
Sp. Conductance	Bridge	UW - Civ. Eng.
Chloride	Argentometric	UW - Civ. Eng.
Alkalinity	Titration	UW - Civ. Eng.
Soluble Reactive P	Ascorbic Acid	UW - Civ. Eng.
Total Soluble P	Persulfate Digestion/ Ascorbic Acid	UW - Civ. Eng.
Total P	Persulfate Digestion/ Ascorbic Acid	UW - Civ. Eng.
Ammonia N	Phenate	UW - Civ. Eng.
Nitrate + Nitrite N	Cadmium Reduction	UW - Civ. Eng.
Total Soluble N	UV Digestion/ Cadmium Reduction	UW - Civ. Eng.
Total N	UV Digestion/ Cadmium Reduction	UW - Civ. Eng.
Chlorophyll _a_	Fluorometric	UW - Civ. Eng.
Phytoplankton Biovolume	Invert Scope	Aquatic Analysts
^{14}C Productivity	Scintillation	UW - Civ. Eng.
Total Coliform	MPN	Laucks/AmTest
Fecal Coliform	MPN	Laucks/AmTest
Fecal Streptococci	Membrane Filtration	Laucks/AmTest
Enterococci	Membrane Filtration	AmTest
Trace Metals (As, Fe, Zn)	Atomic Absorption/ Graphite Furnace	UW-Ocean/Aquatic Res.
Trihalomethanes	EPA 601 (GC; selected compounds)	Laucks

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[1] Designated Laboratories:
UW-Civ. Eng. = Univ. of Wash. Dept. of Civil Engineering
UW-Ocean = Univ. of Wash. Dept. of Oceanography
Aquatic Analysts = Aquatic Analysts Co., Portland, OR
Laucks = Laucks Testing Lab., Inc., Seattle, WA
AmTest = AmTest, Inc., Redmond, WA
Aquatic Res. = Aquatic Research, Inc., Seattle, WA

identified in the Chelan Basin (Figure 3.2 and Figure 3.3). Direct measurements of discharge at all these sites was beyond the scope of the present investigation. Of the major identified components of the water budget, several are monitored continuously by various public agencies. Data were furnished by agencies for the following components: the Stehekin River gage (USGS); precipitation gages at Stehekin, Lucerne and Chelan (cooperative National Weather Service Stations); irrigation withdrawals (Lake Chelan Reclamation District and Chelan County PUD.); Chelan River outflow (Chelan County PUD); and lake storage fluctuations (Lakeside gage-Chelan County PUD; Purple Point gage-USGS).

As a part of this investigation, the accuracy of the reported Chelan River discharge was examined with two independent discharge measurements, since the existing rating table for this gage had not been updated for over 30 years. However, the reported flows on both occasions were within three (3) percent of the measured values and were therefore assumed valid.

The Stehekin River represents the largest hydrologic source to Lake Chelan, and has historically contributed nearly 70 percent of the average annual discharge from the Chelan River (Williams and Pearson, 1985). The (USGS) maintains a gage on this tributary a short distance upstream from the lake. Only a relatively minor tributary input (e.g. Devore Creek; Figure 3.2) enters the Stehekin River between the lake and the discharge rating site. Preliminary discharge data for the Stehekin River available from USGS for the study period, and utilized in this report, were based on an examination of recent rating data. Potential errors in the preliminary data appear to have been quite small (less than 5 %).

The second largest hydrologic source to Lake Chelan was Railroad Creek, which historically has contributed approximately ten (10) percent of the average annual input to the basin (Williams and Pearson, 1985). Although a gage on this creek was maintained between 1928 and 1957, high flows damaged the structures, rendering the gage unusable. The Railroad Creek drainage includes a rather extensive mine tailings pile which is known to leach significant quantities of metals into the creek (Anderson and Benjamin, 1982). In order to assess the significance of metal and other constituent loadings from Railroad Creek into Lake Chelan, a continuous water level gage was installed on an abandoned tailrace approximately 100 meters upstream from the lake. Discharge ratings were performed on seven (7) occasions between April and November 1987. Unstable channel characteristics observed over the study period resulted in an uncertainty in discharge estimates of approximately ten (10) percent.

Continuous data from existing weather stations were supplemented by the addition of a totalizing anemometer (to measure daily total wind movement) and a relative humidity gage at the Chelan Boat Company dock in Chelan. Climatological data from the three cooperative weather stations were used to estimate direct precipitation and evaporation.

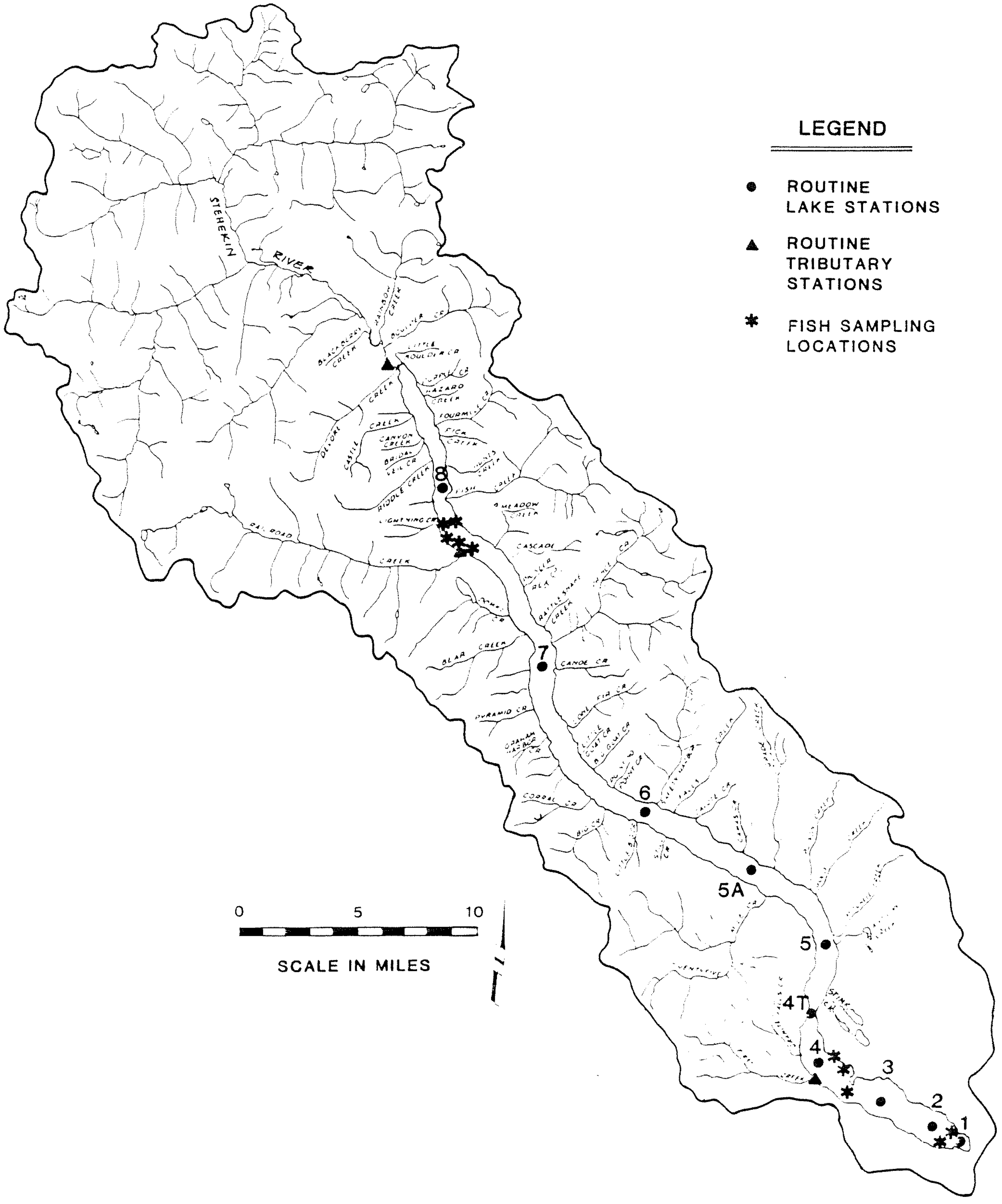


Figure 3.2

LAKE CHELAN BASIN
AND SAMPLING STATIONS

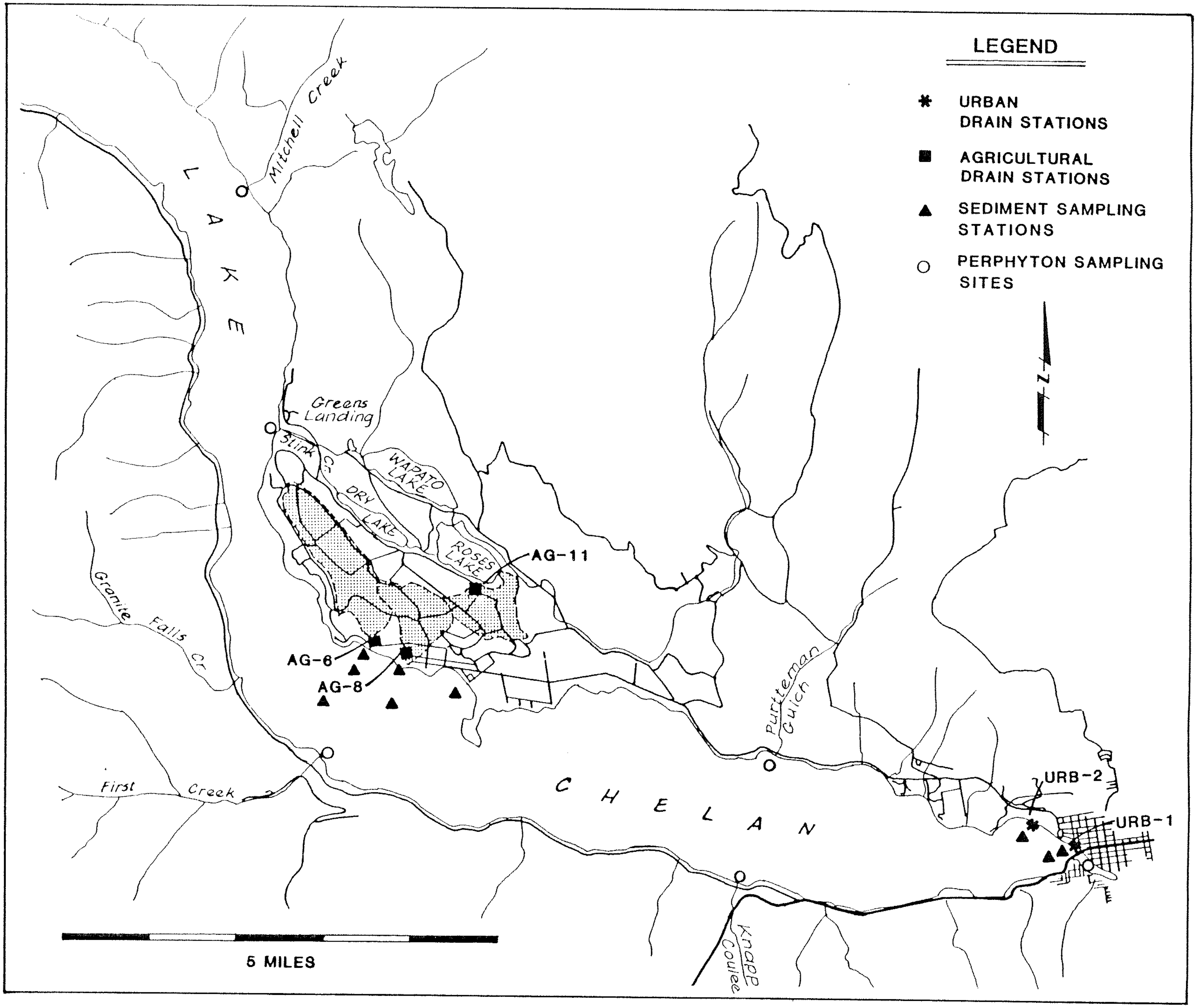


Figure 3.3

LOCATION OF WATER AND SEDIMENT SAMPLING SITES IN THE LOWER CHELAN BASIN

The most difficult component of the water budget to estimate was diffuse input from the more than 50 small tributaries within the basin, located primarily within the Lucerne Basin (Figure 3.2). Many of the smaller streams are ephemeral. Historical runoff data collected by USGS from five (5) watersheds within the Lucerne Basin suggested that areal runoff (i.e. annual discharge per unit watershed area) varies more than ten-fold throughout the basin (Williams and Pearson, 1985). Because of the diffuse and variable nature of these smaller tributary inputs, their contribution was estimated as the residual term of the total water budget equation. Routine discharge measurements were also performed at 13 tributary water quality sampling sites at approximately monthly intervals over the study period (see below). To achieve random sampling, these tributaries were initially tabulated, assigned random numbers and sampled, two per sampling trip, in numerical sequence.

The water budget residual calculation discussed above is based on the assumption that groundwater inputs (and outputs) to Lake Chelan are negligible. Such an assumption is reasonable based on geologic and hydrogeologic characteristics of the basin (see Section 4.0 below). As a test of this hypothesis, all surface inputs and outputs to and from Lake Chelan were monitored over a three day low surface flow period in early September 1987. Surface flows over this period were relatively stable, and lake level had remained nearly constant for several months prior to the survey. Significant groundwater components (if any) would likely be observed in terms of discrepancies in the water budget over this time period.

3.2.2 Hydrodynamics

Several methods were employed to study circulation and mixing characteristics in Lake Chelan. Particular emphasis was placed on describing vertical and longitudinal water movements affecting mixing within and between the two lake basins. Since the extent of vertical mixing is closely associated with the vertical temperature structure, detailed vertical profiles of temperature were determined during each limnological sampling event. The methods for collection of these data are described in Section 3.2.3 below.

A significant process affecting longitudinal mixing in large lakes, such as Chelan, is the internal seiche. A seiche can result in large alternating movements of water along the principal axis of the lake, analogous to tidal exchange (Mortimer, 1974). The extent and magnitude of internal seiches depend on such characteristics as basin morphometry, wind, and thermal stratification. Seiches are generally defined by regular variations in lake temperatures, currents, and surface levels, and are especially evident near the boundaries of the lake basin. To evaluate seiche patterns, two recording thermographs were deployed near the sill at surface and bottom depths (Station 4-T; Figures 3.2 and 3.4). The thermograph locations were selected for study primarily because temperature signals from periodic seiche oscillations within the lake were expected to be most pronounced at these sites. The instruments were

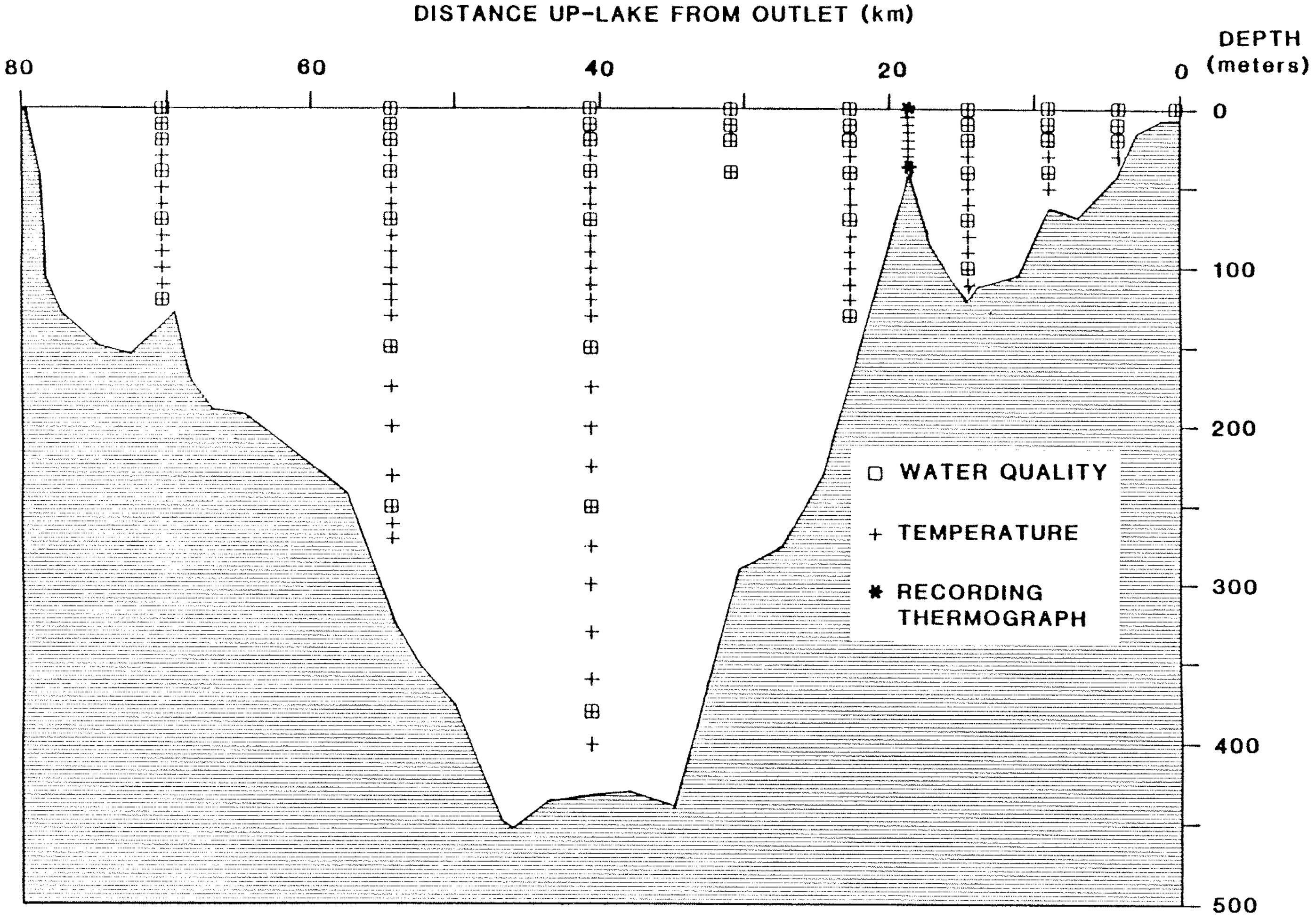


Figure 3.4

LAKE CHELAN DEPTH PROFILE AND SAMPLING STATIONS programmed to record temperature at twenty minute intervals from December 1986 to January 1988.

In order to provide a more direct measure of water movement between the two lake basins, current meters were deployed on two occasions over the study period. Aanderaa RCM-4 current meters were attached to an array deployed below the surface at Station 4-T (Figure 3.5). Temperature, current speed, and current direction were recorded on magnetic tape at fifteen minute intervals. The first deployment consisted of a single instrument mounted five meters above the bottom. It recorded for a 72 day interval from December 1986 through February 1987. The second deployment included two instruments mounted 8 and 28 meters above the sill bottom. The two instruments recorded data during a 75 day interval from August to November 1987.

Preliminary analysis of chemical characteristics in Lake Chelan revealed that the specific conductance of tributary inputs varied more than tenfold from one end of the lake to the other. In the absence of significant water exchange between the two lake basins, this difference could represent about a five (5) percent increase in specific conductance of the Wapato Basin relative to that in the Lucerne Basin. Specific conductance was determined with high precision and sensitivity in the lake investigations (see below) in an effort to evaluate interbasin mixing. Specific conductance was also determined along transects extending radially away from selected tributaries in order to evaluate near-shore dispersion characteristics.

3.2.3 Limnological Monitoring

One of the first tasks completed during the Lake Chelan Water Quality Assessment was the analysis of satellite imagery data available for the lake. Imagery analysis can provide important information on spatial variations of key parameters such as temperature and chlorophyll a (chl a) across the surface of a lake, which in turn can guide the sampling design. Following preliminary review of available imagery data, a single LANDSAT (TM) scene from July 1985 was selected for analysis. The scene was obtained from the Canada Centre for Remote Sensing, and included nearly the entire surface of Lake Chelan with negligible atmospheric interference. The scene provided thermal and chromaticity data at a resolution of approximately 30 meters, and was also utilized for assessment of nearshore characteristics (e.g. periphyton accumulation). Analysis of the satellite imagery data was performed by Dr. Tommy Lindell, SNV Water Quality Laboratory, Uppsala, Sweden. Ground truth calibration data were not available for the specific scene evaluated, and approximate numeric values for surficial temperature and chl a were based on relationships observed in other areas of the region.

On the basis of the imagery data, ten (10) lake stations at approximately equidistant locations throughout the length of each basin were selected for routine water quality monitoring (Figure 3.2). Water samples were collected from a total of 45 discrete locations within the lake, at depths ranging from 1 m to 380 m below the water surface (Figure 3.4). The

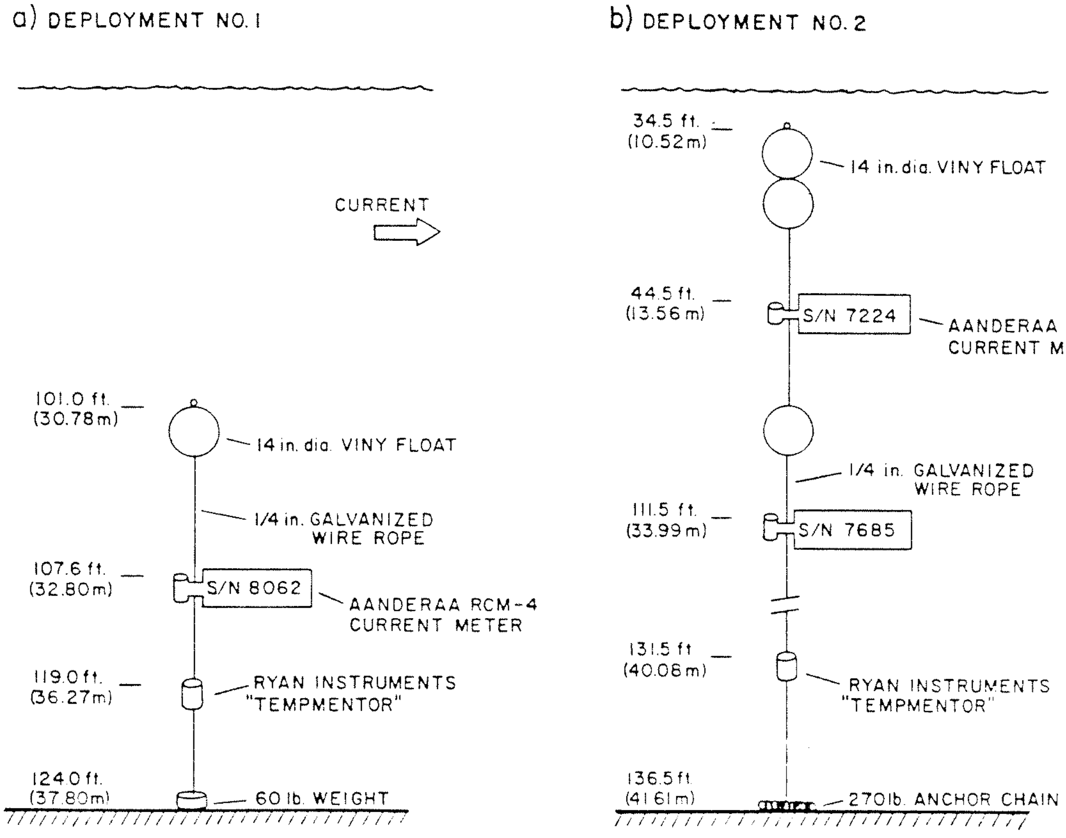


Figure 3.5

CURRENT METER AND THERMISTOR DEPLOYMENTS AT THE LAKE SILL highest sampling frequency with depth occurred over the interval from 0 to 40 meters (0 - 130 ft), which was expected to support the greatest biological activity. Temperature was determined at more frequent depth intervals at each station, resulting in measurements at 105 discrete locations within the lake. Eight (8) lake stations were initially sampled - Stations 4T and 5A were added during the early stages of the study to provide additional information on thermal and specific conductance structure (Station 4T) and better coverage of the Lucerne Basin epilimnion (Station 5A). Lake sampling cruises were conducted approximately once per month from December 1986 through November 1987. The cruise frequency was increased to every three weeks during the spring-summer months. A total of 13 lake surveys were completed over the study period.

All lake lake surveys were conducted over a period of approximately ten (10) hours, using the vessel "Speedway", which was owned and operated by the Lake Chelan Boat Company. Water samples were collected at each lake station using a hydraulic winch and a series of up to eight, four-liter Van Dorn samplers. The sampling cable housed an electrical lead, which served to transmit the thermistor signal from an Aanderaa current meter (RCM-4) connected to the end of the cable. Temperature measurements were recorded aboard the sampling vessel following thermistor equilibration. All temperature data collected throughout the study period were gathered using the same Aanderaa current meter in order to improve data comparability. The reported accuracy of the meter ($\pm$ 0.05 ^{o}C) was verified by periodic comparisons with observations from reversing thermometers.

In addition to the lake sampling discussed above, selected tributaries and precipitation gauges were also sampled. During each of the 13 lake surveys, samples were collected from the Stehekin River, Railroad Creek, two miscellaneous tributaries (which were randomly selected prior to each cruise), Mitchell Creek, First Creek, and three agricultural return flow drains (USBR 6, 8, and 11). Less frequent sampling (primarily between April and September, 1987) was performed at Wapato Lake, Stink Creek, Purtteman Gulch, Knapp Coulee, and at three urban drains. Precipitation samplers, consisting of polyethylene bottles and a 10 cm diameter funnel, were installed and maintained at three locations at the lake shore. These sites included the Chelan Boat Company, 25-Mile Creek, and Lucerne. The contents of the samplers were collected regularly for nutrient determinations.

Water samples obtained from the lake and tributaries were analyzed for a wide variety of chemical and biological parameters. A summary of these determinations is presented in Table 3.3. All samples collected, usually 55 or more locations per cruise, were analyzed for pH, dissolved oxygen (DO), specific conductance, soluble reactive phosphorus (SRP), total phosphorus (TP), ammonia (NH_4-N), nitrate plus nitrite (NO_2+NO_3-N), and total nitrogen (TN). In addition, selected samples were also analyzed for turbidity, chloride, alkalinity, total soluble phosphorus (TSP), total soluble nitrogen (TSN), chl a, phaeopigments, phytoplankton biovolume, ^{14}C photosynthetic productivity, total coliform bacteria (TC), fecal coliform bacteria (FC), fecal streptococcus bacteria (FS), enterococcus bacteria, arsenic (As), iron (Fe), zinc (Zn), and potential trihalomethanes (PTHM). Sampling, handling, and analytical procedures utilized for these determinations are briefly described below.

Field determinations included discharge (tributaries only), temperature, pH, DO, Secchi disk (SD) transparency, and light extinction. Samples for pH and DO determinations were obtained from the Van Dorn samplers and immediately collected into ground-glass stoppered BOD bottles, stored in the dark, and analyzed within several hours of collection using pre-calibrated probes. The DO data were calibrated based on routine analysis of selected samples (generally 3 samples per cruise) using the modified Winkler technique. In all cases the necessary adjustment was minor. Vertical extinction of photosynthetically available light (400 - 700 nm) was determined with a submersible photometer, generally with 3 measurements per station (5, 10, and 15 m depths). The average extinction coefficient was calculated from depth-light regressions.

The program for tracking laboratory precision and accuracy consisted of routinely submitting blind field replicates and blanks at a level greater than five (5) percent of the total number of samples for each constituent. Quality control was maintained throughout the study by comparing observed laboratory precision (estimated as the standard deviation of blind field replicates) to target estimates of precision for each parameter. Batches of samples which exhibited precision significantly in excess of target values were questioned and in some cases rerun (e.g. initial TP analyses from the January and November 1987 groundwater samples). All of the target control limits for precision were ultimately met, with the exception of total N, which was nevertheless performed with adequate precision for the project objectives (see Sections 4 and 5).

In addition to precision, accuracy was checked by blind field blanks and analysis of EPA reference standards. Evaluations of external QA samples revealed no bias for any of the laboratory determinations.

Specific conductance determinations were performed largely to assess longitudinal mixing characteristics within the lake. Water samples were collected into containers with minimal air space and stored cool and in the dark prior to analysis. The values were corrected to 25°C equivalents based on actual sample temperature at the time of the analysis and KCl response coefficients (APHA, 1985). Based on field replicate data, precision of the conductance determinations averaged ± 0.6 umhos/cm.

Samples obtained for soluble nutrient analysis (i.e. SRP, TSP, NH_4-N, NO_2+NO_3-N, and TSN) were stored in the dark and filtered within approximately 8 hours of collection using presoaked 0.45 um Millipore $^{(R)}$ filters. TP and TSP samples were preserved with H_2SO_4 prior to analysis. All nutrient samples were preserved on ice until delivery to the water quality laboratory at the Department of Civil Engineering, University of Washington (UW/CE).

In order to minimize sample degradation, SRP determinations were performed within 2 to 3 days of collection. The analysis was performed manually using the ascorbic acid procedure (APHA, 1985). TSP and TP samples were digested by persulfate oxidation, and the resulting SRP analyzed using the ascorbic acid method following neutralization. P determinations were performed with extreme care to ensure maximum precision and accuracy in view of the very low concentrations in Lake Chelan.

Analytical precision (defined as the average standard deviation of blind field replicates) was excellent for the P determinations, ranging from approximately ± 0.1 ug/L for SRP to ± 0.4 ug/L for TP. This precision was as good or better than reported performance for the method (e.g. see APHA, 1985). Data accuracy of all nutrient determinations was periodically verified by the analysis of EPA reference samples. Analytical blanks prepared by UW/CE were also compared with similar reference waters prepared by the Turnbull Laboratory of Ecological Studies, Cheney, Washington. However, no significant differences were observed between values for the two sources. These data further supported the validity of the low-level determinations.

Like SRP, NH_4-N determinations were performed within 2 to 3 days of collection to minimize sample degradation. NH_4-N was determined manually using the phenate method (APHA, 1985). NO_2+NO_3-N analyses were performed using an automated cadmium reduction method. TSN and TN were digested using UV oxidation, and analyzed for NO_2+NO_3-N by cadmium reduction. Like the P analyses, analytical precision for most the determinations was excellent, with a precision of less than ± 4 ug/L for both NH_4-N and NO_2+NO_3-N. TSN and TN determinations were somewhat more variable, with an average precision of approximately ± 30 ug/L.

One liter samples for chl a and phaeopigment determinations were obtained from the upper 20 meters (0, 10, and 20 m) of Lake Chelan. Samples were filtered through 0.45 um glass fiber filters within approximately 8 hours of collection, preserved with $MgCO_3$, and stored dry, frozen, and in the dark prior to analysis. Because of the low ambient levels, chla determinations were performed fluorometrically, with routine calibration using sample extracts analyzed spectrophotometrically (trichromatic; APHA, 1985). Chl a determinations were performed by UW/CE. All chl a data were corrected for phaeopigments (i.e. representing "active" chl a). Data accuracy was periodically verified with the analysis of reference samples available from EPA. The precision of chl a determinations (based on field replicates) averaged ± 0.08 ug/L, or approximately 10 percent of the observed values.

Samples for phytoplankton enumeration and biovolume estimation were collected from the surface at lake Stations 2, 4, 6, and 8, preserved with Lugol's solution, and stored in the dark prior to analysis. All of the samples were analyzed by Aquatic Analysts, Portland, Oregon. Five (5) subsamples were also submitted to an independent laboratory (EcoLogic, Vancouver, B.C.) as a quality control check. No significant differences were noted in genera identifications or biovolume estimates, which supported the accuracy of these data. Minor differences were observed in the number of picoplankton (algae less than 2 um in size) and in certain species identifications of the samples, although these discrepancies had little consequence for this study. The precision of biovolume estimates, based on the interlaboratory comparisons, was approximately ± 50 percent. Such measurement uncertainty is typical for biological determinations.

Samples for the enumeration of bacteria were collected immediately below the surface at eight lake stations during each of the 13 surveys. The collection method included the attachment of sample containers to an extended grab sampling device, and holding the unit several meters ahead of the boat's bow while underway. This procedure was utilized to prevent vessel-related sample contamination. Samples for bacterial analyses were also collected from all tributaries.

In addition to the routine lake monitoring surveys, bacterial samples were also collected over two holiday periods (July 4 and Labor Day weekends) when the lake was used more intensively. During each of these peak use events, samples were collected daily over a six day period beginning two days prior to the weekend, and ending two days after the weekend. The daily sampling stations included six sites in the Wapato Basin (Stations 1 through 4 plus two nearshore sites) and one in the Lucerne Basin (station 5). All samples were held in the dark on ice and were processed by the laboratories for analysis generally within 24 hours of collection.

All samples collected for microbiological determinations were analyzed for fecal streptococcus (FS) bacteria using membrane filtration. Selected samples were also analyzed for total coliform (TC) and fecal coliform (FC) bacteria using MPN methods. A smaller number of samples were analyzed for enterococcus bacteria. All microbiological determinations were performed by either AMTest or Laucks Laboratories. Both of these laboratories were certified by the Washington Department of Social and Health Services (DSHS) for bacterial analyses in drinking water. Based on probability tables presented in APHA (1985), the uncertainty in MPN determinations may span as much as an order of magnitude. Filtration methods (i.e. FS) may have been subject to a similar (though unquantified) characteristic uncertainty, owing to the inherent variability of this biological determination.

A procedure similar to that used for bacterial sampling (i.e. extended grab sampling) was utilized for the collection of near-surface samples for trace metal determinations (As, Fe, and Zn). Metal samples were collected from lake Stations 2 and 6, and from the Stehekin River, Railroad Creek, Mitchell Creek, and USBR Drain 6 at approximately two month intervals throughout the study period. Samples were collected from the principal stormwater discharge, which originates from the City of Chelan (URB-1) during high runoff periods. In addition, during September 1987 a vertical series of samples for trace metal determinations was collected at lake Station 6 using a non-metallic, trace metal clean Niskin sample bottle (J. Murray, UW, personal communication).

Total recoverable trace metal determinations were performed on acidified (HNO_3 addition to pH 2) samples by graphite furnace atomic absorption spectrometry. The analyses were performed by the University of Washington Chemical Oceanography Laboratory, and achieved detection limits for As, Fe, and Zn of approximately 0.007, 0.06, and 0.07 ug/L, respectively. Selected lake and tributary samples were also analyzed by Aquatic Research, Seattle using a more rigorous digestion procedure (based on EPA/CLP protocol for total metals; EPA, 1986a). No significant differences were observed between the two methods.

On four occasions over the study period, surface samples from Stations 2 and 6 were collected for the determination of potential trihalomethanes (PTHM). The PTHM determinations attempted to simulate the possible production of toxic chlorinated organic compounds such as chloroform resulting from chlorination of lake water for local drinking water supply. Shortly after sampling, a solution of $Ca(OCl)_2$ was added to replicate subsamples to achieve an initial free Cl_2 concentration of approximately 3 mg/L, which was considered a reasonable maximum addition in local supply systems.

The chlorinated samples (and blanks) were then stored in gas-tight VOA vials for one week in the dark at approximately 20 ^{o}C prior to THM analysis, based on EPA protocols (EPA, 1986a). Chlorine analyses performed on replicate vial contents at the end of the reaction period revealed that free CL_2 was maintained in the reaction vials throughout the experiments (i.e. > 0.5 mg/L). Following the reaction period, samples and blanks were analyzed for specific halogenated methane compounds using purge and trap GC techniques with a halogen specific detector (EPA Method 601). The detection limits achieved during these determinations averaged approximately 1 ug/L.

On three occasions during the spring-summer period, photosynthetic activity was measured at four lake stations (two each in the Lucerne and Wapato Basins) using ^{14}C techniques. Water samples were collected into 130 ml borosilicate bottles from depths of 1, 5, 10, 20, and 40 meters at each station, and held cool and in the dark prior to initiation of the experiments. Five uCi of $^{14}CO_3$ was added to each bottle. The bottles were attached to suspension racks, and returned back to their original depths for incubation. The samples were shielded from sunlight during all handling activities. Duplicate samples from each location were exposed to ambient light and temperature levels, while a third sample was incubated in the dark as a control. All 60 samples were incubated simultaneously at a single station (generally Station 7); light levels were monitored throughout an incubation period which ranged from 2 to 6 hours.

Upon retrieval, samples were kept cool and in total darkness, and filtered through 0.45 um Millipore $^{(R)}$ filters within several hours of collection. Filters were washed with lake water (filtered), dried in an HCl fume dessicator, and stored in scintillation vials filled with a toluene-based fluor. The sample activity of ^{14}C was measured over a period of 10 minutes with a scintillation counter (Vollenweider, 1969). Counting efficiency for the samples ranged from 80 - 90 percent. The average precision of the measurements (determined from light bottle replicates) was approximately ± 0.06 mgC/m^3-hr, or approximately 10 - 20 percent of the observed values.

3.2.4 Nearshore Periphyton Sampling

Periphyton biomass was quantitatively collected from natural rock substrata on May 26, July 6, and September 7, 1987. Five primary sampling locations were located in the nearshore area of Lake Chelan near the inflows of Mitchell Creek, Greens Landing, First Creek, Purtteman Gulch, and Knapp Coulee (Figure 3.3). Samples were also collected near the lake outlet. Sampling locations were selected based on previous tributary samplings (Kendra, 1986) and satellite imagery (see above) in order to provide a range of nutrient supply and periphyton biomass conditions.

At each tributary station, periphyton samples were collected at the 0.5 meter (1.5 ft) depth along transects at distances of 2 m, 10 m, 50 m, and occasionally 220 m on both sides (generally east-west) of the midpoint of the in-flowing channel. Two randomly selected rocks were collected at each sampling location and analyzed separately. A cylindrical plexiglass tube was used to isolate a known area (9, 18, or 28 cm^2) of rock surface (Douglas, 1958). Periphyton attached to this area was removed with a stiff brush and washed into an amber glass collection jar. All samples were stored on ice and in the dark. Samples were homogenized, filtered, diluted, and/or preserved within 24 hours of sampling. A total of 186 periphyton samples were collected over the study period. Tributary water quality sampling and nearshore conductance profiling were performed concurrently with periphyton sampling activities.

Periphyton biomass was measured primarily as chl _a_ per square meter of rock surface. In addition, selected samples (generally 12 percent) were also analyzed for organic-P, TP, TN, total organic carbon (TOC), and taxonomic composition. Chl _a_ was determined spectrophotometrically. Organic-P was determined using a UV procedure (Bothwell, 1985), while TP determinations followed methods described previously. TN and TOC were determined with a CHN elemental analyzer. Lugols-preserved periphyton samples were enumerated for taxonomic composition (to genus) and biovolume by direct, random microscopic evaluation. Volumes of each algal form were estimated using basic geometric formulae (Vollenweider, 1974). All periphyton determinations were performed by Aqualimpia Associates, UW/CE, and UW/Fisheries Research Institute (FRI).

3.2.5 Sediment Sampling

Sediment samples were collected to meet two principal objectives: 1) to evaluate the relationships between sediment toxicant accumulation and land use activity; and 2) to estimate sedimentation rates in the Wapato and Lucerne Basins. Eight (8) surficial sediment (upper 5 cm) samples were collected with a stainless steel modified Van Veen sampler along transects extending from out from selected urban runoff and agricultural drain outfall areas at Chelan and Manson (Figure 3.3). Additional Van Veen grab samples were also collected from mid-lake sites within the Wapato Basin (Station 4) and Lucerne Basin (Station 6), and at a nearshore site adjacent to Safety Harbor Creek in the Lucerne Basin (Figure 3.2). Using stainless steel instruments, surficial sediment was transferred from mid regions of the Van Veen samples into clean glass containers. Samples were stored in the dark and on ice, and extracted for analysis within two weeks of collection.

All Van Veen grab samples (11 total) were analyzed for a wide range of constituents, including grain size, total solids, TOC, TN, TP, metals, pesticides/PCBs, and acid/base/neutral (ABN) extractable priority pollutant organic compounds. TOC and TN were determined using a CHN elemental analyzer. TP was analyzed by the ascorbic acid method following digestion with HNO_3, HCl, and H_2O_2. Samples were also digested similarly, and analyzed for 12 metals (Ag, As, Be, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Se, and Zn) using flame, graphite furnace, and hydride atomic absorption spectrometric techniques (EPA, 1986a). Pesticides/PCBs were determined by GC/ECD, and ABN organics by GC/MS, with each determination following EPA protocol. All determinations were performed by Laucks Laboratories, Seattle. The validity of these data was supported with concurrent QA/QC information.

In addition to the surficial sediment samples discussed above, shallow sediment cores (0 to 60 cm) were collected from one site in the Wapato Basin (Station 4) and one site in the Lucerne Basin (midway between Stations 7 and 8) using a polycarbonate piston core apparatus. Sections of these cores were obtained for subsequent total solids, nutrient and metals determinations, using methods discussed above. Sediment cores were also used to estimate sedimentation rates by measurement of ^{210}Pb radioisotope activity. Four sections of sediment, each approximately 2 cm thick, were selected from each core between sediment depths of 0 and 60 cm. Each section was analyzed for total solids. Three selected sections from each core were submitted to Battelle Marine Research Lab, Sequim for ^{210}Pb analysis using an alpha emission spectrum detector.

3.2.6 Fish Tissue Sampling and Analysis

Lake Chelan fish collected and analyzed by Ecology in 1982-1984 as part of a state-wide monitoring effort contained elevated levels of pesticides and metals (Hopkins et al., 1985). In November 1986, the results of the littoral sediment samples described in 3.1.5 showed elevated pesticide and/or metal concentrations. In response to these historical and recent findings, fish were collected from three areas in Lake Chelan over a three-day period in September, 1987 by Washington Department of Ecology (Ecology) staff and were analyzed for pesticide, PCB, and metal contaminants.

The goals of the fish tissue collection and analysis were:

1) Determine if concentrations of pesticides, PCBs, or metals in the general fish populations pose an ecological or human health hazard.

2) Analyze any tissue residue variability for general spatial or species patterns within the lake, and identify those areas or species that have problems.

3) Provide recommendations for future action.

4) Create a fish tissue database as part of the Lake Chelan Water Quality Assessment, and for comparisons in future studies.

The lake was divided into four general areas: lower Wapato, upper Wapato, lower Lucerne, upper Lucerne. Specific locations within the basins were selected with a bias for those in close proximity to agricultural return drains, municipal storm drains, and large tributaries. Special attention was given those drains where sediment contamination had been highest. We also assumed that fish caught near the drains and tributaries would be among the most contaminated in the lake. Description of three collection sites, two in the Wapato basin and one in the Lucerne basin (Figure 3.2), are presented in Appendix D. Fishing was unsuccessful at the lower Lucerne site, so the number and/or variety of samples taken at the three other sites was increased.

Eleven of the fourteen samples were composed of more than one fish to reduce intraspecies residue variability. Individual fish were sampled when no others were caught. At some sites, more suckers and squawfish were caught than needed. When there was such a choice, the medium-sized fish were selected first, then the larger fish, then the smaller.

Both sport and non-game fish were targeted and collected. Sport fish were filleted and non-game fish were kept whole (with viscera) to help assess the human health and ecological questions. Kokanee, a sport species, was the exception, and was analyzed as whole fish. Kokanee are small, and not enough of them were collected to fillet and meet the minimum tissue quantity required by the laboratory for analysis. They are also a key species in the Lake Chelan food web (Brown, 1984).

Most fish were caught using a gillnet set overnight in 10′ to 50′ of water. The rainbow trout from the Railroad Creek site were caught with hook and line. Burbot were caught using set lines and hooks baited with squawfish or sucker portions and placed overnight in 100′ to 300′ of water. Fish were extracted from nets or hooks, separated by species, and placed in buckets lined with plastic bags. Full bags were double wrapped and placed on ice until collection was finished. Fish were taken from the bags within one hour, and those selected for analysis were individually wrapped in aluminum foil, placed in fresh plastic bags, and kept on ice.

They were transported to the Washington State Department of Ecology/U.S. Environmental Protection Agency Region 10 Laboratories at Manchester, Washington within three days and kept frozen for nineteen days. The fish were then slightly thawed, measured, weighed and sexed. Chinook salmon, rainbow trout and burbot were placed on aluminum foil covered benches and filleted with acid and solvent rinsed stainless steel knives. Burbot fillets included skin, salmon and trout did not. Each sample was homogenized in a commercial food grinder with stainless steel blades. All portions of the grinder in contact with the fish tissue were cleaned with acid, deionized water, and solvent, and oven dried between sample processing. Homogenized samples were placed in cleaned virgin glass jars with teflon-lined lids. Samples were frozen for fourteen days before shipping to Enesco/Cal Analytical laboratory for analysis.

Samples were analyzed for twenty-two pesticides, seven PCB cogeners seven metals, percent lipids, and percent solids (Appendix D). The organochlorine pesticide and PCBs method used was developed by the U.S. Fish and Wildlife Service (USFWS) Columbia National Fisheries Research Laboratory (CNFRL) for their National Pesticides Monitoring Program. The CNFRL method outlined in Appendix D, has been previously described in detail in Johnson, Norton and Yake (1986). Metals listed in Appendix D. Method blank results, spike concentrations and spike duplicate recovery data for organic and metals analyses on this sample set are presented in Appendix D.

3.3 Uncertainty Analysis

The information value contained within a given estimated or predicted quantity is only as good as the confidence bounds which surround that estimate. Since the observational data and water quality models developed in this study are based upon determinations of discharge and chemical constituents, as well as upon hypothesized relationships between measured parameters, a variety of potential measurement and modelling errors (both systematic and random) can contribute to the total prediction uncertainty. Quantification and propagation of the uncertainty common to each term in the model is necessary in order to determine the degree of confidence which can be placed on a prediction.

Statistical techniques which describe the effects of contributing uncertainties are broadly categorized as error propagation methods. For this report, we have utilized a first-order uncertainty methodology consistent with generally accepted data analysis methods (Reckhow and Chapra, 1983). The theory and application of first-order uncertainty analysis techniques have been described by Cornell (1973), and Lettenmaier and Richey (1979). Briefly, the technique is based upon the assumption that parameter variations can be propagated about the first derivative (i.e. first order) of a function relative to those variables which make up the function. In general, for any calculated quantity Y which is derived from measured parameters denoted by X,

$$Y = f(X_1, X_2, \ldots., X_n),$$

the first-order variance of Y can be represented as:

$$\text{Var }(Y) = \sum_{i=1}^{n} \frac{Y}{X_i}^{2} \quad \text{Var }(X_i)$$

The quantity y^2/X_i describes the first-order relationship between the calculated value and each measured parameter which describes the function. The equation above is only valid when the variances of each measured parameter (i.e. X_i) are independent, and it is therefore necessary to reduce each function to a form which includes only independently measured parameters.

The true variance of a particular parameter often cannot be calculated explicitly and therefore must be estimated. For example, in the case of a quantity which is estimated from a non-linear relationship (e.g. log transformed regression), it may be desirable to approximate the variance of the estimate as if it were normally distributed. While this practice may inadequately characterize the extreme values of the distributions, it often provides a best estimate of the variance of the mean and may be useful in allowing propagation of variance due to combination of several estimated quantities (e.g. estimating mass flux as the product of flow and concentration). For parameter estimates which were best characterized by non-linear relationships (e.g. stage-discharge rating curves), the variance of the estimated "mean" values were generally estimated as the square root of the mean squared deviation from the predicted values (e.g. the average of the squared differences between predicted and observed values), in order to provide a "normal" variance estimate for mean values from non-normal populations.

CHAPTER 4

Hydrogeological Results

4.0 HYDROGEOLOGICAL RESULTS

4.1 Lower Chelan Basin Geology

As an aid to evaluating the suitability of soils in the Lower Chelan Basin for on-site wastewater disposal, a terrain unit map of surficial deposits within the area was prepared. Terrain mapping methods provide more useful management information than a strict geologic map, primarily since terrain units allow portrayal of three dimensional information on a two dimensional map. A terrain unit is a defined area in which certain geologic conditions are estimated to exist to some depth. Sources of information for delineating terrain units include surface outcrops, drill hole data, test pits and excavations, aerial photographic analysis, and geomorphology. Certain fundamental assumptions are necessary in constructing a terrain unit map; each terrain unit is based on certain characteristic attributes, i.e. geomorphology, lithologic types, and stratigraphy with a characteristic range of soil properties. A terrain unit represents the result(s) of a single geologic process or combination of processes that commonly function together.

Lithologic mapping units are combined to form a terrain mapping unit. A terrain unit designation is indicated by the lithologic symbol and a range of estimated thickness in parenthesis. Underlying materials are denoted in a like manner with a horizontal bar separating them from overlying materials. For example,

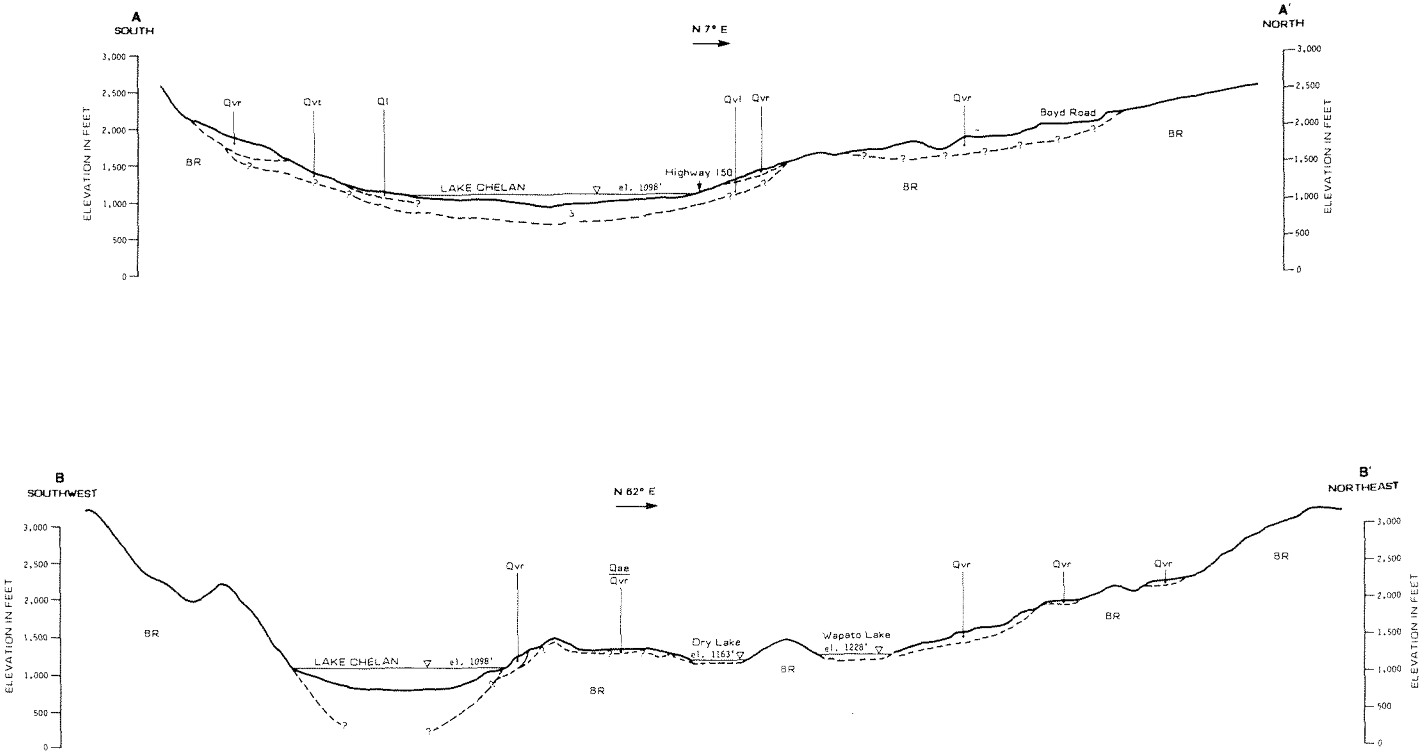
$$\frac{\text{Qae (0-5)}}{\dfrac{\text{Qvr (10-20)}}{\text{Qvt(5-10)}}}$$

would indicate that zero to five feet (0 to 1.5 m) of loess overlie ten to twenty feet (3 to 6 m) of recessional outwash deposits which in turn overlie five to ten feet (1.5 to 3 m) of lodgement till.

The terrain unit map is presented in Figure 4.1. Geologic cross sections of the Lower Chelan Basin are presented in Figures 4.2a and 4.2b. Generally, the terrain within the study area above an elevation of 1800 feet (550 m) consist of either scoured bedrock or bedrock with a thin veneer of soils. The thickest accumulation of glacially derived sediments are generally situated below an elevation of 1600 feet (490 m) due to the localized nature of the glaciers which impacted the Wapato Basin area. The glacial deposits within the areas of the Wapato Basin are highly variable and of limited lateral extent (Figure 4.1). Sediment thickness may range from zero, where local bedrock knobs protrude through the mantle of glacial deposits, to well over 15 meters (50 ft), such as the kame terrace deposits located north and south of the east end of Lake Chelan. The highly variable thickness and nature of the glacial deposits results from the deposition of sediments on a pre-existing topographic surface.

Figure 4.1

TERRAIN UNIT MAP



EXPLANATION

Qae -Loess Deposits

Ql -Lacustrine Sediments

Qvr -Recessional Outwash

Qvt -Till

Qvl -Proglacial Lacustrine Deposits

BR -Bedrock

NOTE: Sub bottom topography and sediment thicknesses of Lake Chelan inferred from Whetten, J.T. (1967)

Figure 4.2

CROSS SECTION A-A AND B-B

The following section describes the lithologic units delineated to form the terrain mapping units. The lithologic units are described from the oldest to the youngest. The mapping unit symbol is shown in parenthesis.

Distribution and Description of Lithologic Units

Bedrock (Br): The bedrock units within the study area are primarily granitic and metamorphic rocks of Late Cretaceous age consisting of tonalites and migmatites belonging to the Chelan Complex as described by Hopson and Mattinson (1971). These rocks form the mountain ridges on both sides of Lake Chelan within the study area and outcrop sporadically in the marginal areas surrounding the lake that are mantled predominantly with glacial deposits. Many of the knolls marginal to Lake Chelan are underlain by bedrock, such as the knoll located northwest of Manson in sections 22, 26, 27, and 35 T28N, R21E (see Figure 4.1).

The granitic and metamorphic rocks are represented by a variety of mineral types, including hornblende, biotite, epidote, allanite, and sphene. The chemical composition of these minerals is summarized in Table 4.1. Calcium is a major constituent of these rocks, a result which has important implications to groundwater quality (see below).

TABLE 4.1 MINERAL COMPOSITION OF BEDROCK UNITS

Mineral	Chemical Composition
Hornblende	$NaCa_2 (Mg,Fe,Al)_5 (Si,Al)_8 O_{22} (OH)_2$
Biotite	$K (Mg,Fe)_3 (AlSi_3 O_{10}) (OH)_2$
Epidote	$Ca_2 (Al,Fe)_3 (AlSi_3O_{10}) (OH)_2$
Allanite	$(Ca,Ce)_2 (AlSi_3O_{12}) (OH)$
Sphene	$Ca,Ti SiO_5$

Proglacial lacustrine sediments (Qvl): These deposits are hard, overconsolidated silt and clay sediments occasionally containing ice rafted drop stones deposited in a proglacial lake ahead of the advancing ice sheet. Although no lower contact relationships were observed, these sediments were probably deposited upon the bedrock or older glacial deposits. Where exposed, these deposits are commonly overlain by loess and/or recessional outwash deposits. These deposits are most commonly exposed in the lower elevations adjacent to Lake Chelan, typically below an elevation of about 1400 feet (430 m). One exception to this is a lacustrine deposit situated at elevations between 430 and 490 meters (1,400 - 1600 ft) in the SE 1/4, SW 1/4, Section 29, T28N, R22E. Lacustrine sediments are exposed at Wapato Point, and along Highway 150 from Manson to Chelan. It is difficult to estimate a thickness of these deposits, as they were deposited within a proglacial lake and would be expected to be highly variable because of the configuration of the topography prior to the formation of the lake. The maximum observed vertical thickness of this unit (approximately 13 meters [40 ft]) is located in Purtteman Gulch in Section 4, T27N, R22E.

Advance outwash (Qva): These are dense, over consolidated sediments of sand and gravel with lesser amounts of fine sand and silt which were deposited in front of the advancing glacier. These deposits are poorly exposed in most of the study area. However, two fairly good exposures provide some insight into their composition within the area. A borrow pit located in the SW 1/4, SW 1/4, SW 1/4, Section 21, T28N, R22E exposes glacial till overlying a sequence of advance outwash sediments. These advance outwash sediments consist of two cross-bedded fine to coarse sand units separated by an approximately 0.6 meter (2 ft) thick bed of very fine sand and silt. The basal portion of the fine sand and silt unit exhibits soft sediment deformation in the form of open low amplitude (several inches) folds. Locally, several small normal faults displace and juxtapose some of the thin sand beds. These faults presumably are the result of stresses induced by the overriding glacial ice.

A second exposure of advance sediments is located in a cut situated in the N 1/2, SW 1/4, SE 1/4, Section 11, T27N, R22E overlooking Spaders Bay. At this location till overlies finely bedded and laminated fine sand and silt. Beneath the fine sand and silt are coarsely cross bedded sand and gravel deposits.

The entire thickness of the advance outwash deposits was not observed in the field. However an inferred thickness, on the order of 60 meters (200 ft), is estimated in the unnamed drainage immediately south of Lakeside on the south side of Lake Chelan.

Lodgement till (Qvt): Lodgement till is a very dense, nonstratified, poorly sorted mixture of gravel sand,silt, and clay deposited directly beneath the glacial ice. Exposures of till are limited and sporadic and are typically overlain by recessional outwash and/or loess deposits (see Figure 4.1). The few good exposures of till observed rarely exceeded 1.5 meters (5 ft) thick, though thicker occurrences of till no doubt exist.

Recessional outwash (Qvr): These primarily sand and gravel sediments are normally consolidated and were deposited as the glacier retreated. Occurrences of recessional outwash deposits are quite widespread and probably underlie most of the study area (see Figure 4.1). Deposits may be primarily sand, gravel, or a combination of both. These deposits are similar to the kame terrace deposits discussed later but lack the terrace morphology and usually occur at lower elevations. The thickest (on the order of 30 meters [100 ft]) exposures of recessional gravels observed during the study are located in the southwest facing bluffs overlooking Lake Chelan.

A distinct geomorphic form of recessional outwash deposits are the kame terraces. The kame terraces generally consist of normally consolidated sand and gravel deposited in ice marginal streams. These deposits form the many terraces evident in the study area. Generally there are three distinct terraces occurring at different elevations, each representing successive positions of the ice as the former glacier melted and thinned. The terraces are discontinuous, commonly interrupted by bedrock ridges or knobs. The terraces are best developed along the south side of Lake Chelan between Knapp Coulee and the town of Chelan and along the north side of the lake between the Wapato Lake area and the town of Chelan. The former meltwater streams have typically eroded now abandoned channels through the bedrock. These abandoned meltwater channels are particularly evident in the area northeast of the Wapato, Dry, and Roses Lakes area.

The recessional outwash deposits are typically overlain by a variable thickness (0.9 to 1.5 meters [3 - 5 ft]) of loess. Owing to the depositional history and environment of these deposits, they may overlie nearly any of the older stratigraphic units.

Loess Deposits (Qae): These deposits generally consist of very fine sand and silt, ash, and pumice fragments with a minor amount of fine gravel. According to Bureau of Reclamation engineering reports, ash content is reported as high as 30 percent. Locally, distinct ash beds 0.6 to 0.9 meters (2 - 3 ft) thick were encountered in hand excavated exploration holes. The loess deposits are widespread and mantle the majority of the surfaces in the study area. The loess deposits are quite variable in thickness but average on the order of 0.9 to 1.5 meters (3 - 5 ft) thick. Local accumulations may reach 3 meters (10 ft) thick or more in areas which contained substantial paleotopographic relief. These deposits are typically overlain by 0.3 to 0.5 meters (1.0 - 1.5 ft) of organic topsoil.

Lacustrine Deposits (Ql): This unit consists of normally consolidated silt and clay deposited after the glaciers retreated and the subsequent lake level was at a higher elevation than at present. These deposits are distinguished from the proglacial lacustrine deposits by lacking the ice rafted drop stones and are normally consolidated and thus less dense. These lacustrine deposits are confined to the lower elevations marginal to Lake Chelan, generally below an elevation of about 400 meters (1,300 ft). The two most widespread exposures are located near the mouth of Knapp Coulee below an approximate elevation of 390 meters (1,280 ft), and the low swale extending to the southeast from Roses Lake to Lake Chelan in area occupying the approximate S 1/2, S 1/2, Section 36, T28N, R21E. These deposits are probably on the order of 3 to 4 meters (10 - 12 ft) thick, and due to their depositional environment, may overlie any of the glacial deposits described so far. The lacustrine deposits are typically overlain by a thin veneer of loess and topsoil, rarely exceeding 1 meter (3 ft) in thickness.

Fluvial Deposits (Qf): These are modern sediments composed primarily of sand and gravel with some silt. These deposits are of limited extent, and are confined primarily to existing drainages and alluvial fans (see Figure 4.1). These deposits include the probable slide deposits in the Granite Slide/Shrine Beach area. The thickness of these deposits is highly variable, ranging from probably over 30 meters (100 ft) thick in the Shrine Beach area to about 3 meters (10 ft) thick in the small local drainages.

Colluvium (Qc): The colluvium is generally a loose heterogeneous mixture of rock debris and soil which accumulates locally on slopes underlain by bedrock. Distinct exposures of the colluvium were observed in the Sunnybank area on the south side of Lake Chelan.

In summary, the Wapato Basin is an area of complex and variable geology as a result of the deposition of sediments on an eroded pre-existing surface. Bedrock or this soil overlying bedrock are present over the major portions of the higher elevations of the basin while at lower elevations advance and recessional outwash sands and gravels, tills, lacustrine and fluvial deposits mantle bedrock. Sediment thicknesses range from zero to in excess of 15 meters (50 ft). Typical geologic cross sections, which depict the approximate thickness of some of the sediments, are presented on Figures 4.2a and 4.2b.

4.2 Basin Hydrogeology

The drainage area of the Lower Chelan Basin study area encompasses over 310 square kilometers (120 sq. mi.; Figure 4.1), twelve (12) percent of which is the lake itself. The drainage area extends up to 13 km (8 mi) north of the lake to elevations of up to 1,650 m (5,400 ft) and 10 km (6 mi) to the south of the lake to elevations of up to 1,950 m (6,400 ft).

Potential Groundwater Recharge

Based on a soil-water balance, relatively little groundwater recharge is expected within natural areas of the Lower Chelan Basin, compared with similarly undeveloped upper areas of the Basin (Soil Conservation Service, unpublished data). This condition is due in part to the relatively high local potential evapotranspiration rates, which approach precipitation quantities. Groundwater recharge in these areas likely occurs only during short periods of snowmelt. Base flow runoff data collected within the Lower Chelan Basin during this investigation support the hypothesized low recharge condition (see Section 5.1 below).

A considerably greater amount of potential groundwater recharge occurs within irrigated agricultural areas of the Wapato Basin, since typical irrigation applications (90 cm/yr) far exceed natural recharge (estimated at less than 5 cm/yr; see Section 5.1). Approximately 10 to 40 percent of the water applied to orchard areas appears available for recharge. Based on these data, potential groundwater recharge in irrigated lands may be much greater than in adjacent natural areas. This increased recharge likely has a pronounced effect on local groundwater flow conditions.

Groundwater Flow Systems

The overall hydrogeological regime in the area of the study area has been determined based on the following:

o Well logs on file with Ecology

o Water level measurements taken in monitoring wells and private wells

- Pump and rising head permeability tests in private wells and monitoring wells

- Geologic maps and borehole logs supplied by the USBR

Based on these data the following general conclusions regarding the hydrogeology of the basin have been developed.

1) Two groundwater flow systems are present: a bedrock flow system and a surficial flow system.

2) The groundwater flow directions are generally toward Lake Chelan with some flow variability in the Manson area.

3) There does not appear to be flow reversal from Lake Chelan to the groundwater in response to seasonally fluctuating lake levels.

4) The diverse geologic environment results in a complex hydrogeologic regime. More data would be required to accurately describe the basin's hydrogeology in detail.

Bedrock Flow System

Granitic and metamorphic bedrock was disturbed and fractured by early mountain building in the Cascades and was subsequently subject to glacial scouring during the last glaciation. Above an elevation of about 490 m (1,600 ft) on the north shore and about 610 m (2,000 ft) on the south shore the bedrock is generally overlain by a thin (less than 1.5 m thick) veneer of soil. Below an elevation of about 490 m and in the upper reaches of the principal drainage courses (for example Purtteman Gulch and Cooper Gulch), the bedrock is overlain with surficial sediments ranging in depth from 3 to in excess of 30 m.

There are many private domestic wells completed in bedrock. Well depths range from about 30 m (100 ft) to greater than 100 m (400 ft) and generally yield less than 0.1 m^3/min (20 gpm). Groundwater is sometimes encountered at the bedrock surface where a thin zone of relatively high permeability weathered bedrock may be present or more frequently in isolated and discontinuous fractured and disturbed zones. A pump test was conducted in the Lesmeister private well (Figure 3.1) which is about 50 m (150 ft) deep and apparently completed in granitic bedrock. Based on the test, the hydraulic conductivity of the bedrock is estimated at about 6×10^{-7} m/s. Freeze and Cherry (1979) provide a range of hydraulic conductivity (K) values for unfractured igneous and metamorphic rocks of between about 1×10^{-10} and 1×10^{-13} m/s and for fractured igneous and metamorphic rocks of between about 1×10^{-4} and 1×10^{-8} m/s. This suggests that the Lesmeister well is probably completed in a fracture zone within the bedrock. Based on these data, the hydraulic conductivity of the bedrock flow system could range from a high of about 1×10^{-5} m/s in fractured or weathered rock to lower than 1×10^{-10} m/s in unfractured rock.

The bedrock flow system is recharged by precipitation and snow melt during the early spring and summer. Recharge to this flow system occurs mainly in the higher elevation areas of the basin where bedrock is exposed or where only thin soil cover exists. Groundwater discharge from this system takes place in the lower reaches of the basin where the groundwater discharges upwards through creek beds or into Lake Chelan.

Surficial Flow System

As indicated above, the bedrock flow system is overlain by between 3 to in excess of 30 m of Quaternary age glacial, proglacial, lacustrine, fluvial, and aeolean deposits in the lower reaches of the basin and also in the valley.bottoms of the principal drainage courses at higher elevations. The surficial deposits range in composition from coarse cobbles and gravels to sands and gravels, sands, silts, and silty clays. The deposits range in thickness to over 60 m (200 ft) in valley bottoms, alluvial fans, and on extensive kame terraces (Figures 4.1 and 4.2).

Several lithostratigraphic units can be combined into single hydrostratigraphic units: advance and recessional outwash (Q_{va} and Q_{vr}) and the coarser facies of the fluvial deposits (Q_f) form potential aquifers, whereas the lacustrine deposits (Q_l), lodgement tills (Q_{vt}), and the finer grained facies of the fluvial deposits (Q_f) constitute potential aquitards. Loess deposits (Q_{ae}), although widespread, are usually thin (less than 2 m in thickness), are generally not saturated and are, therefore, of limited hydrogeologic significance.

Since most domestic and agricultural activities within the Lower Chelan Basin generally are supplied with water from Lake Chelan, there are few private wells available to provide data on this flow system. The private wells are generally completed in the more permeable sands and gravels of the surficial flow system and are generally less than 60 m (200 ft) in depth. The deepest wells completed in the surficial flow system are located on the terraced deposits near the eastern end of the lake. The shallowest wells are generally completed in the valley bottoms of Purtteman, Cooper or Ivan Morse Gulch where well depths are sometimes less than 10 m (30 ft). Yields from wells completed in the surficial flow system range from less than 0.05 m^3/min (10 gpm) to over 0.5 m^3/min (100 gpm).

A number of pump tests were carried out in private wells completed in the surficial flow system to determine the hydraulic conductivity of these materials. The pump tests were supplemented in some of the monitoring wells by rising head permeability tests. The results of the pump tests are presented in Appendix B, and indicate that the hydraulic conductivity of the sands and gravels is about 1×10^{-4} m/s. Based on the rising head tests, the hydraulic conductivity of the fine to coarse sands and silty sands is about 1×10^{-5} to 1×10^{-6} m/s.

It is apparent from the geologic data that there could be significant directional variations in permeability (i.e. anisotropy) within the lacustrine and fine grained fluvial deposits where interbedded sands, silts, and clays are present. This is particularly evident in the area southeast of Roses Lake extending to Lake Chelan and in the Stink Creek drainage northwest of Roses Lake. In these areas, the soils are shallow dipping/bedded fine grained interbedded silty sands, silty clays and clayey silts. The hydraulic conductivity in the direction of the principal bedding (horizontal) is generally much greater than the crossbed (vertical) hydraulic conductivity, especially where there is a high sand content. This ratio of horizontal to vertical permeability could be as much as 10 or 100 indicating a vertical hydraulic conductivity for the siltier zones of about 1 x 10^{-7} m/s or less. This assumption is supported by grain size data from the sandy silts to silts and clays (Appendix C).

The surficial flow system is recharged directly by precipitation and snow melt during the spring and early summer and probably also indirectly by shallow subsurface runoff from the bedrock areas in the higher areas of the basin. In addition, there is some groundwater recharge during the late spring and summer as a result of irrigation on the lower terraces and in the Manson area. The surficial flow system discharges to Lake Chelan and also to Dry, Roses and Wapato lakes. The system may also discharge locally to the bedrock flow system in higher areas of the basin where the bedrock is fractured or weathered.

Conceptual Groundwater Flow Model

Based on the basin hydrogeology and water level information, the groundwater recharge and discharge areas of the basin can be identified. Recharge areas are characterized by decreasing hydraulic head with soil depth (downward hydraulic gradient) which indicates that there is a downward component of groundwater flow to deeper systems. Discharge areas are characterized by increasing hydraulic head with depth (upward hydraulic gradient) which indicates that there is an upward component of groundwater flow to shallower groundwater and surface water flow systems. In between the two areas is a transition zone which is generally characterized by near horizontal groundwater flow paths. Groundwater flow is from the recharge areas to the discharge areas. This is an ideal conceptualization and in the case of the Lower Chelan Basin, the groundwater flow path is complex because of the non-uniform geologic conditions.

Based on our present understanding of the hydrogeology of study area, we believe that the following conceptual flow model describes the basin's groundwater flow system. A generalized flow direction map is presented in Figure 4.3.

Groundwater recharge takes place predominately in the higher elevation areas of the basin during the spring and early summer as a result of snow melt. This water percolates down through the thin soils towards the bedrock. On reaching the relatively low permeability bedrock, the majority of the recharge flows downslope at the bedrock/soil interface or weathered zone towards the surface water drainage courses. A small

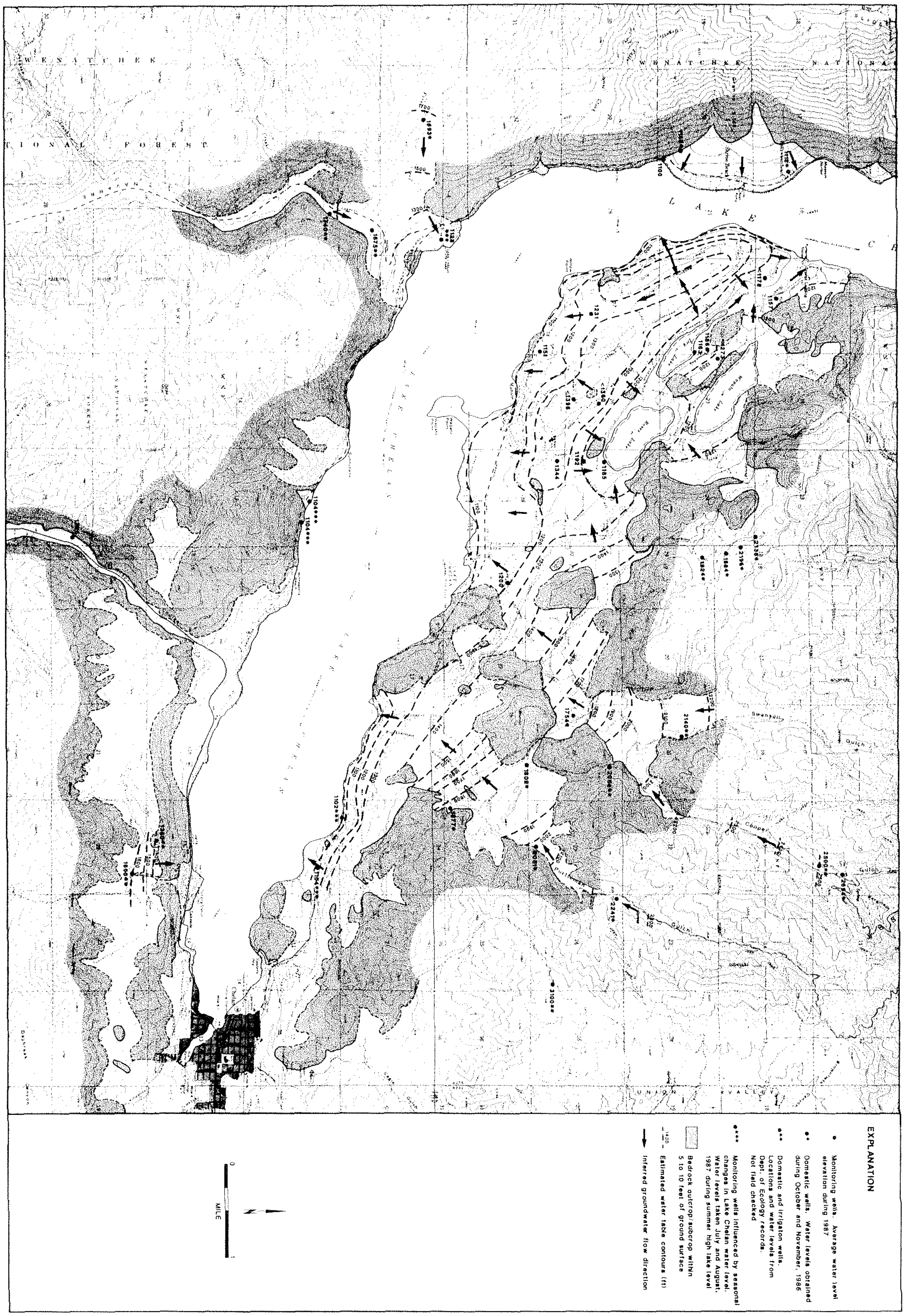


Figure 4.3

GENERALIZED WATER TABLE CONTOURS AND GROUNDWATER FLOW DIRECTIONS SURFICIAL FLOW SYSTEM proportion of the infiltrating water recharges the bedrock flow system and flows downward to greater depths within the system. The surface water drainage courses are typically infilled with relatively permeable coarse grained fluvial, colluvial or glacial fluvial deposits. Shallow subsurface seepage flowing from the valley side slopes discharges into the valley bottom surficial flow system sediments and moves downslope toward Lake Chelan. Some seepage also takes place to the bedrock flow system underlying the surficial valley bottom sediments also occurs.

Below an elevation of about 500 - 600 m (1,600 - 2,000 ft), the basin topography is somewhat different and the narrow upper valleys open out onto broader outwash terraces. The depth to bedrock increases in these areas to in excess of 30 m (100 ft) but locally there are some bedrock highs protruding above the surficial deposits. The groundwater flow directions in these areas is influenced by the areas of lower permeability bedrock and proglacial silts and clays. The downvalley flow within the valley bottom materials is recharged locally by irrigation, especially along the north shore, and discharges towards Lake Chelan. At the lower reaches of the basin, groundwater associated with surficial flow discharges into Lake Chelan together with groundwater discharge from the underlying bedrock system.

The conceptual groundwater flow model is complicated in the Manson area because of the variability of geologic conditions. Groundwater flowing downslope within the surficial flow system may be locally recharged by irrigation water and discharged to Wapato, Roses, or Dry Lakes. Some shallow groundwater may also be perched above the regional water table because of relatively low permeability lacustrine silts and clays and may discharge locally to the drains installed by the USBR. Groundwater within the shallow flow system, which is not intercepted by the drains or does not discharge to either of the three shallow lakes, flows toward Lake Chelan as underflow in a number of local drainages.

Groundwater Fluctuations

The level of Lake Chelan varied approximately 5.2 m (17 ft) over the study period as a result of lake hydropower operations (Chelan PUD, written communication). In order to examine whether this lake level fluctuation resulted in equivalent changes in local groundwater elevations and possible flow reversals, water levels and water quality characteristics were determined in several monitoring wells located close to Lake Chelan. Continuous (2 hr intervals) water level measurements were obtained electronically at the "Willows" well, which is one of the closest monitoring wells to Lake Chelan (approx. 10 m from normal lakeshore; Figure 3.1). The Willows well was installed previously by the Chelan Hills Maintenance Association, and is screened within surficial sand and silt deposits (J. Howton, Projects NW, personal communication, 1986).

Although the electronic water level recording instrument deployed within the Willows well periodically malfunctioned, sufficient data were collected from this site to generally describe water level fluctuations over the 1987 study period (Figure 4.4). Overall, water levels within this well fluctuated approximately 3.0 m (10 ft) over 1987, in general correspondence with lake level variations. However, seasonal water level fluctuations of smaller magnitude were also observed in a number of other wells within the basin. Many of which were located at considerable distances from Lake Chelan, and presumably beyond its influence. These wells may have been responding to seasonal recharge conditions associated with snowmelt. Within the Willows well, and in all other monitoring wells, measured groundwater elevations always exceeded those of Lake Chelan.

The water level data suggest that a continual flow of groundwater entered Lake Chelan regardless of lake level fluctuations. The apparent absence of significant groundwater flow reversals is also supported by the rather consistent water quality characteristics of the nearshore wells. For example, specific conductance within the Willows well ranged from only 325 to 440 umhos/cm over the study period (Figure 4.4). These conductance values were similar to other basin groundwaters, but well above levels within Lake Chelan (55 - 60 umhos/cm). Had significant groundwater flow reversals occurred near this site, a pronounced decline in conductance would have been observed. Conductance was similarly constant within the other monitoring wells examined. Based on these data, therefore, groundwater likely discharges to (but not from) Lake Chelan throughout the year.

4.3 Septic System Monitoring Sites

One of the principal objectives of the Lake Chelan Water Quality Assessment was to evaluate performance characteristics of existing and possible future on-site wastewater disposal systems within the basin. Based on a review of previous wastewater disposal studies, preliminary calculations of the likely variability of wastewater attenuation within the soils of the Lower Chelan Basin were performed in order to determine the number of monitoring wells necessary to adequately characterize on-site wastewater transport.

Previous studies carried out in similar environments to the Chelan area (Harper-Owes, 1986) were initially utilized to estimate local (i.e. 30 m) wastewater attenuation properties expected in the study area. These data are summarized as follows:

Parameter	Expected Wastewater Attenuation (95% Confidence Interval)
Total Phosphorus	4 - 100 %
Total Nitrogen	16 - 91 %
Fecal Coliform	97 - 100 %

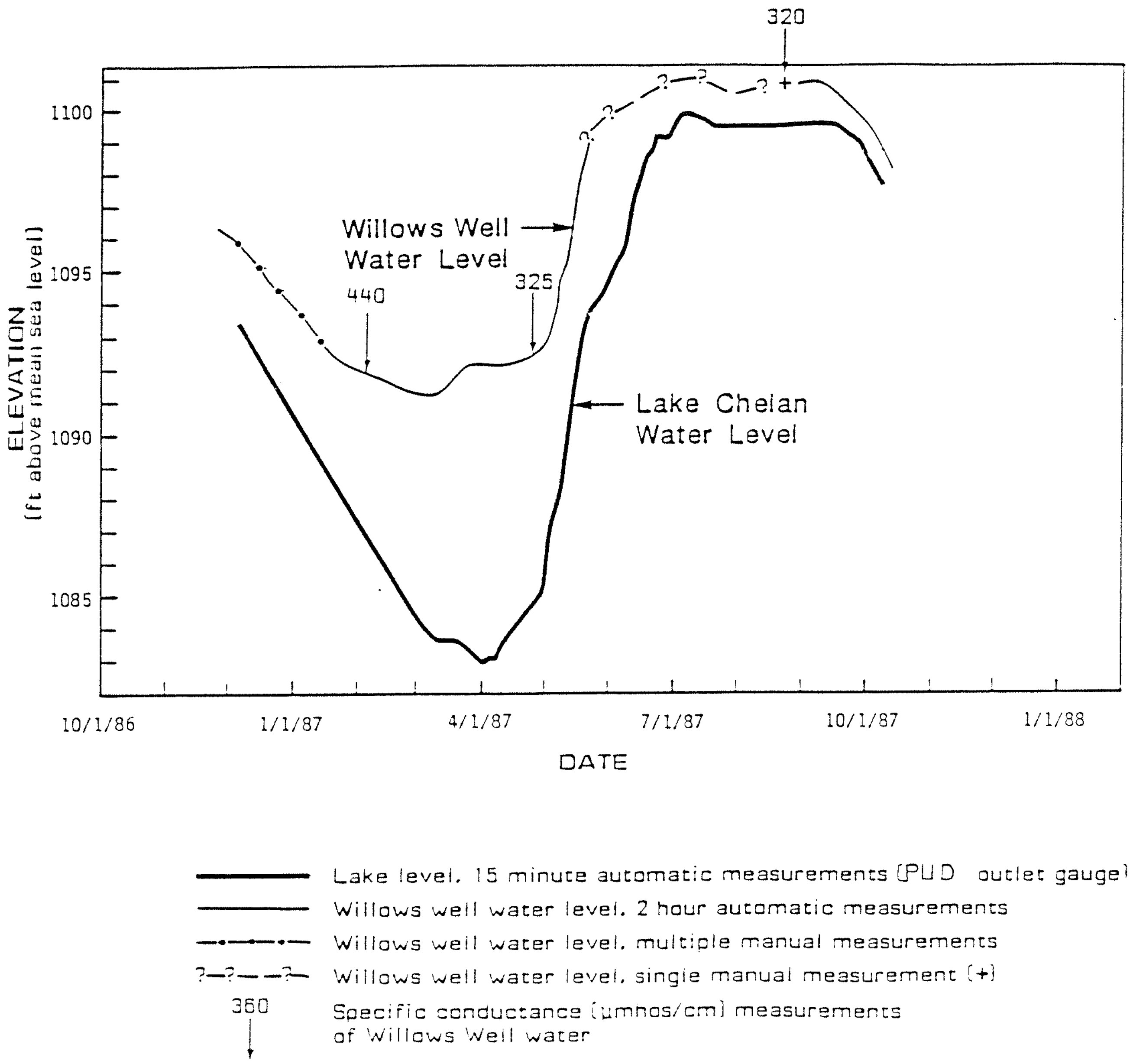


Figure 4.4

LAKE CHELAN AND WILLOWS WELL WATER LEVEL ELEVATIONS

Assuming that the above data were generally representative of conditions likely to be encountered in the study area, the number of monitoring wells required to characterize nitrogen, phosphorus and fecal coliform transport was estimated using statistical procedures (Sokal and Rohlf, 1969) and the following criteria:

1) The desired detection quantity for on-site loading was an amount that would raise the average annual mixed lake concentration (assuming no in-lake loss) by a "measurable" amount from all systems combined (e.g., a 0.5 ug/L increase in total phosphorus or a 1/100 ml increase in fecal coliform).

2) Representative per capita wastewater loadings were 5 kg N/yr, 1.5 kg P/yr and 7 x 10^{11} fecal coliform/yr.

3) The equivalent of 3,000 people use septic systems in the basin throughout the year.

4) The resulting loading increase (from #1 above) would be significant at the five percent level and have a power of detection of 90 percent.

These calculations indicated that about 13 downgradient monitoring wells would be required to adequately characterize phosphorus transport; fewer wells would be required to characterize nitrogen and fecal coliform movement. It was therefore planned to monitor about 10 to 15 septic systems at randomly selected sites in the basin to determine local wastewater attenuation parameters.

Septic System Site Selection Process

The septic systems selected for evaluation were determined based on telephone surveys and interviews with homeowners. Following homeowner interviews, septic systems were selected for monitoring if they met the following criteria:

- The system had been in operation two years or more. (Young systems tend to have limited impact on groundwater because of limited use and slow travel time to downgradient monitoring points).
- The residence was occupied on a year-round basis.
- The systems were located on varying soil types characteristic of the basin.

Based on the above, 13 sites were identified for investigation, and covered a range of hydrogeologic settings. In addition, two existing monitoring wells were available downgradient of the Chelan Hills Development and were included in the study for a total of 15 sites. These sites are summarized in Table 4.2. At each new site, a monitoring well was installed within approximately 30 m (100 ft) of the drainfield

TABLE 4.2

SEPTIC SYSTEM MONITORING LOCATIONS

Site Number	Septic System Owner	Location	Upgradient Monitoring Well	Downgradient Monitoring Well	Soil Type	Comments
1	McClosky	Cove Marina S. Shore, Chelan	Kelly	Cove (Dn) (CH-28)	Silty sand and gravel	
2	State of Washington Parks Dept.	Lake Chelan State Park	Tucker	State Park (Dn) (CH-26)	Sand and gravel	
3	Lutz	3050 S. Shore Chelan	Kelly/Tucker (CH-9)	Lutz (A) (CH-27) Lutz (B) (CH-9)	Sandy gravel/ Silty sand	
4	Venneberg	3272 S. Shore Chelan	Kelly/Tucker (CH-9)	Venneberg (Dn) (CH-10)	Sand	
5	Allison	1251 Swartout Manson	Allison (Up) (CH-15)	Allison (Dn) (CH-16)	Silty clay/ Clayey silt/sand	
6	Morris	87 Roses Ave (Deep) Manson	Allison (Dom)	Morris (Dn) (CH-17)	Sandy silt/ Sand	
7	McClellan	Roses Lake, Manson	McClellan (Up) (CH-4)	McClellan (Dn) (CH-24)	Sand/ Silty sand	
8	Goodwin	915 Dry Lake Rd Manson	Collins (Up) (CH-22)	Goodwin (Dn) (CH-21)	Clayey silt/ Sand	
9	Collins	905 Dry Lake Rd Manson	Collins (Up) (CH-22)	Collins (Dn) (CH-20)	Clayey silt/ Sand	
10	Pickens	220 Greens Landing	Pickens (Dom)	Pickens (Dn) (CH-23)	Sandy Clayey Silt	
11	Chelan Hills	"Willows" Park Chelan	Clapp/Risley	Willows (Dn)	Silts sands, gravels?	
12	Chelan Hills	Lake Chelan Condominiums, Chelan	Clapp/Risley	Condos (Dn)	Sand and gravel	
13	Morris	87 Roses Ave (Shallow) Manson	Morris (Up) (CH-11)	Morris (Dn) (CH-12)	Sandy silt/ Sand	Both wells in perched zone - dry.
14	Goodwin	4845 Wapato Lk Rd Manson	Goodwin (Up) (CH-6)	Goodwin (Dn) (CH-5)	Silty sand and gravel	Both wells at bed rock/ overburden interface - dry.
15	Rockney	Banks and Chase Ave Manson	--	Rockney (Dn) (Ch-18)	Silty sandy/ gravel	Well dry - in perched zone.

location in a potentially downgradient direction. The wells were generally completed within the first groundwater zone encountered below the depth of the drainfield (during late fall installations).

For comparative purposes, a variety of existing domestic wells at upgradient locations were utilized as groundwater sampling points. In areas where existing wells were insufficient to characterize local upgradient conditions, additional wells were installed. As summarized in Table 4.2, six (6) wells were installed as a part of this investigation. Two additional monitoring wells were also installed within orchard areas to assess local agricultural influences on groundwater quality.

Septic System Monitoring Sites: Physical Conditions

Pertinent design and hydrogeologic characteristics of the individual septic systems monitored during this study are summarized in Table 4.3. Discussions of physical and hydrogeological characteristics of each individual system are presented in Appendix E.

Based on available hydrogeologic and engineering data for each of the septic system monitoring sites, the generalized drainfield and groundwater flow system below each site can be described. The flow systems encountered included relatively simple unsaturated vertical flow into an underlying saturated zone (Figure 4.5), perched groundwater systems (Figure 4.6), and saturated and partially saturated groundwater flow (Figures 4.7 and 4.8). Detailed descriptions of flow systems beneath each site are presented in Appendix E.

4.4 Groundwater Quality

Sixteen (16) monitoring wells at potentially downgradient locations from fifteen (15) septic system sites were utilized in this investigation to assess drainfield performance characteristics. However, at three (3) of these well locations an insufficient volume of water was available for sampling, which rendered these wells inoperable throughout the study period. Groundwater samples were therefore collected from a total of thirteen (13) potentially downgradient well locations. Water samples were also collected concurrently at thirteen (13) upgradient and regional reference locations, and from five (5) septic tank or raw wastewater locations. Sampling occurred at quarterly intervals over the one year study period (4 total). Over the course of this study, a total of 108 groundwater samples were collected for analysis, primarily to assess septic system performance. Groundwater quality data are presented in Appendix F.

A summary of selected chemical characteristics of groundwater collected at various locations within the lower Chelan Basin is presented in Table 4.4. In general, groundwaters within this area were characterized by a temperature range of 7 - 15 ^{0}C and relatively neutral pH (6.5 - 7.5). All groundwater samples, including those derived largely from wastewater

TABLE 4-3

SUMMARY OF SEPTIC SYSTEM PHYSICAL CHARACTERISTICS

Monitoring Location	Estimated Drainfield Dimensions		Estimated Wastewater Input $(m^3/d)^1$	Estimated Depth to Water Below Drainfield $(m)^2$	Estimated Hydraulic Conductivity (m/s)	
	Length (m)	Width (m)			Vertical	Horizontal
Site 1 Cove Marina	15	0.6	0.5	2.7 to 6.7	$1x10^{-5}$	$1x\ 0^{-5}$
Site 2 State Park	18	15	5.1	10.1 to 13.7	$1x10^{-4}$	$1x\ 0^{-4}$
Site 3 Lutz	18	1.2	0.68	2.4 to 3.9	$1x10^{-6}$	$1x\ 0^{-6}$
Site 4 Venneberg	13	0.6	0.5	1.7 to 6.6	$1x10^{-5}$	$1x\ 0^{-5}$
Site 5 Allison	18	0.6	0.34	Possibly at Surface	$1x10^{-7}$	$1x\ 0^{-5}$
Site 6 Morris	30	0.6	0.34	Possibly at Surface	$1x10^{-6}$	$1x\ 0^{-5}$
Site 7 McClellan	30	0.6	0.5	1.2	$1x10^{-6}$	$1x\ 0^{-5}$

TABLE 4-3 (cont.)

Monitoring Location	Estimated Drainfield Dimensions		Estimated Wastewater Input (m^3/d)[1]	Estimated Depth to Water Below Drainfield (m)[2]	Estimated Hydraulic Conductivity (m/s)	
	Length (m)	Width (m)			Vertical	Horizontal
Site 8 Goodwin	15	0.6	0.34	Possibly at Surface	$1x10^{-7}$	$1x10^{-6}$
Site 9 Collins	15	0.6	0.34	Possibly at Surface	$1x10^{-7}$	$1x10^{-6}$
Site 10 Pickens	18	0.6	0.34	Possibly at Surface	$1x10^{-7}$	$1x10^{-5}$
Site 11 Willows	--	---	----	----	----	----
Site 12 Condos	--	---	----	----	----	----
Site 13 Morris	30	0.6	0.34	Possibly at Surface	$1x10^{-6}$	$1x10^{-5}$
Site 14 Goodwin	15	0.6	0.34	>1.5 m	$1x10^{-5}$	$1x10^{-5}$

TABLE 4-3 (cont.)

Monitoring Location	Estimated Drainfield Dimensions		Estimated Wastewater Input (m^3/d)[1]	Estimated Depth to Water Below Drainfield (m)[2]	Estimated Hydraulic Conductivity (m/s)	
	Length (m)	Width (m)			Vertical	Horizontal
Site 15 Rockney	15	0.6	0.34	> 2 m	$1x10^{-6}$	$1x10^{-6}$

Note: 1. Wastewater input based on per capita flows of 0.17 m^3/d (USEPA, 1977)

2. Depth to water below drainfield is from bottom of trench estimated at 0.6 m (2 ft) below ground level.

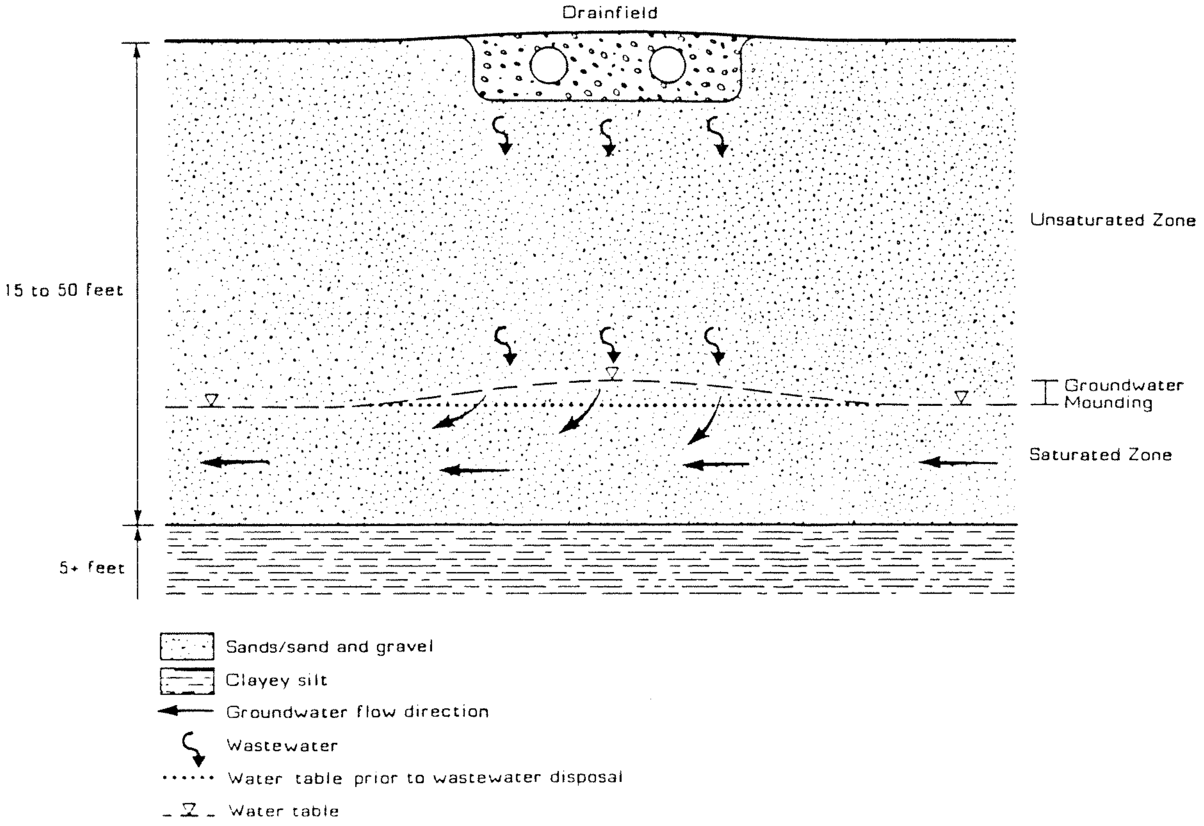


Figure 4.5

CONCEPTUALIZED DRAINFIELD FLOW SYSTEM
COVE / VENNEBERG STATE PARK SITES

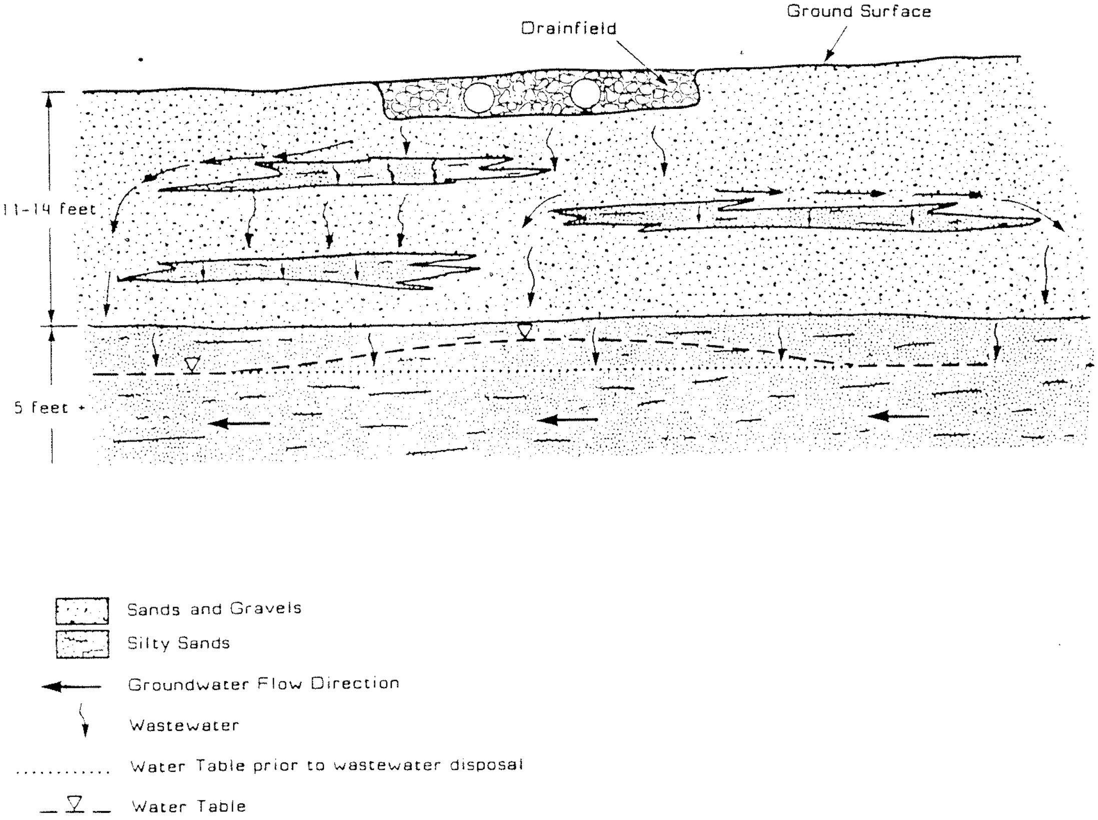


Figure 4.6

CONCEPTULIZED DRAINFIELD FLOW SYSTEM, LUTZ, SITE 3

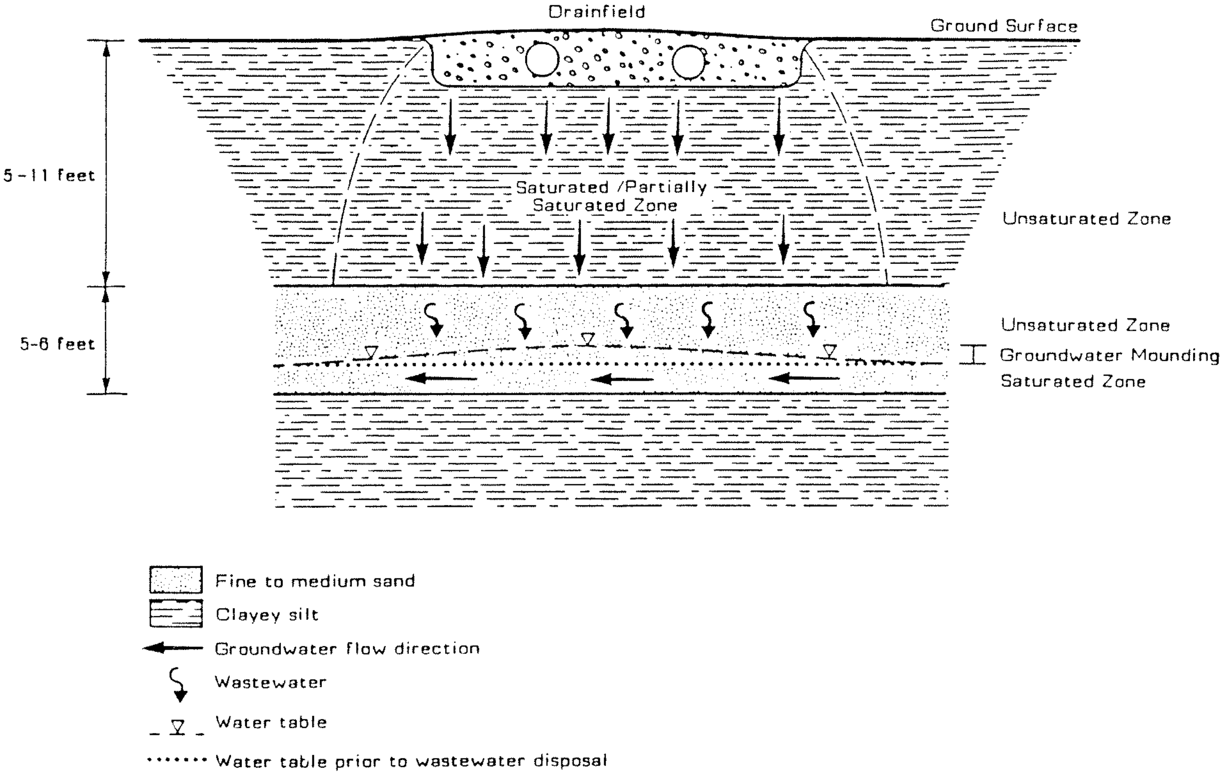


Figure 4.7

CONCEPTUAL DRAINFIELD FLOW SYSTEM
ALLISON, SITE 5
PICKENS, SITE 10

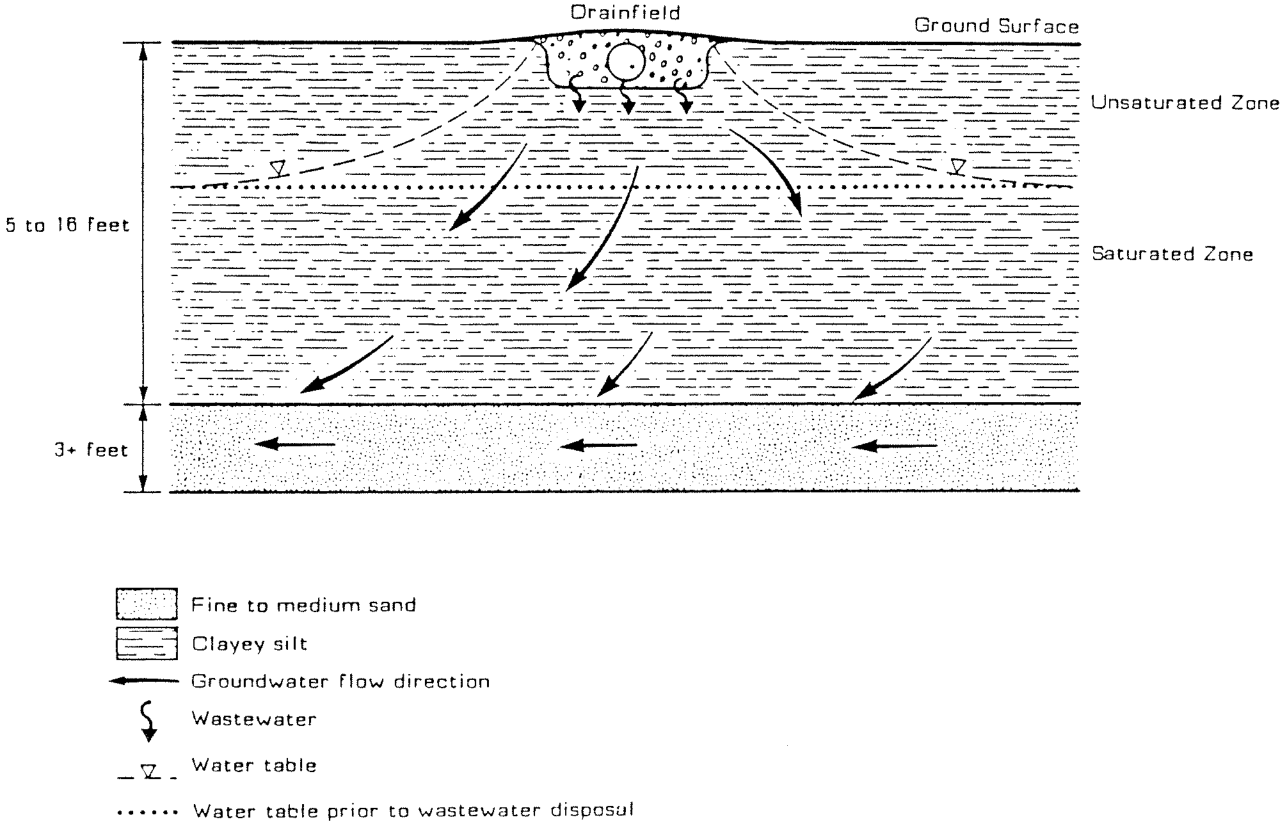


Figure 4.8

CONCEPTUAL DRAINFIELD FLOW SYSTEM
COLLINS, GOODWIN AND PICKENS,
SITES 8, 9 AND 10

Table 4.4 SUMMARY OF GROUNDWATER QUALITY WITHIN THE WAPATO BASIN (mean +/- std. error)

WELL	Mean Static Water Level (ft; MSL)	TEMPERATURE (deg. C)	pH	Diss. Oxygen (mg/L)	Specific Conductance (umhos/cm)
BACKGROUND WELLS: SOUTHERN BASIN					
REED	2,125	7.3 (0.3)	7.01 (.09)	12.4 (0.2)	99 (6)
TUCKER	1,688	11.2 (0.3)	7.23 (.02)	9.5 (0.7)	130 (1)
KELLY	1,110	12.7 (0.1)	7.39 (.06)	12.7 (2.1)	360 (15)
NORTHERN BASIN					
RISLEY	2,635	10.0 (1.0)	7.07 (.04)	8.2 (0.5)	490 (75)
CLAPP	2,245	11.2 (0.9)	7.30 (.10)	8.7 (0.6)	490 (7)
MITCHELL CK. (Surf.)		8.9 (1.5)	8.24 (.07)	11.0 (0.3)	320 (7)
BEDROCK					
LESMEISTER	1,840	12.3 (0.3)	6.95 (.47)	8.4 (0.6)	590 (21)
ORCHARD AREA WELLS: NORTHERN BASIN					
SIMMONDS	1,229	11.1 (1.8)	7.06 (.09)	3.1 (1.0)	880 (200)
SATHER	1,153	13.0 (1.0)	7.03 (.04)	6.8 (0.8)	510 (45)
DRAINS (Surface)		11.6 (0.5)	7.07 (.04)	9.6 (0.2)	510 (11)
SEPTIC SYSTEM WELLS: SOUTHERN BASIN					
COVE	1,094	14.0 (1.4)	6.94 (.10)	5.5 (0.7)	420 (80)
ST. PARK	1,123	11.8 (2.1)	6.82 (.37)	2.4 (0.4)	410 (38)
LUTZ-A	1,105	13.5 (1.5)	7.33 (.22)	6.0 (1.0)	410 (52)
LUTZ-B	1,099	13.5 (1.9)	7.33 (.10)	4.4 (1.1)	370 (53)
VENNEBERG	1,096	12.0 (0.7)	6.91 (.17)	6.4 (1.2)	540 (99)
SEPTIC SYSTEM WELLS: NORTHERN BASIN					
ALLISON-UP	1,200	13.1 (1.7)	6.91 (.06)	7.9 (0.3)	720 (78)
ALLISON-DN	1,189	14.1 (1.4)	6.87 (.12)	4.9 (0.9)	640 (55)
ALLISON-DOM	1,344	11.1 (1.2)	7.35 (.10)	7.8 (1.6)	660 (89)
MORRIS	1,193	11.7 (1.6)	6.82 (.18)	8.7 (0.4)	660 (100)
McCLELLAN-UP	1,165	13.1 (1.2)	7.39 (.10)	6.4 (0.5)	660 (76)
McCLELLAN-DN	1,165	12.7 (1.3)	7.48 (.09)	6.5 (0.7)	760 (190)
COLLINS-UP	1,187	14.1 (0.8)	6.93 (.18)	5.2 (0.5)	430 (34)
COLLINS-DN	1,163	13.4 (2.0)	7.32 (.14)	5.3 (0.8)	780 (76)
GOODWIN-DN	1,163	14.4 (0.5)	7.26 (.14)	5.7 (0.3)	420 (29)
PICKENS-UP	1,159	9.3 (0.8)	7.08 (.12)	6.4 (-)	500 (73)
PICKENS-DN	1,158	13.6 (1.3)	7.07 (.14)	3.6 (1.6)	680 (82)
WILLOWS	1,096	12.5 (0.3)	7.30 (.19)	1.9 (0.2)	340 (13)
CONDOS	1,104	14.5 (0.5)	7.22 (.01)	7.1 (0.6)	640 (110)
SEPTAGE:		20.7 (3.1)	7.00 (.21)	0.0 (0.0)	900

Table 4.4 Continued

WELL	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Soluble Reactive Phosphorus (ug/L)	Total Soluble Phosphorus (ug/L)
BACKGROUND WELLS: SOUTHERN BASIN					
REED	30 (4)	57 (4)	1.7 (0.7)	5 (1)	8 (1)
TUCKER			2.2 (0.7)		13 (1)
KELLY	160	230 (6)	4.9 (1.1)	13 (2)	18 (1)
NORTHERN BASIN					
RISLEY	140 (1)	290 (3)	5.4 (0.6)	60 (1)	66 (15)
CLAPP	120 (38)	280 (5)	5.8 (0.5)	177 (5)	184 (41)
MITCHELL CK.	82	160 (2)		9 (1)	16 (2)
BEDROCK					
LESMEISTER			5.6 (0.9)		13 (2)
ORCHARD AREA WELLS: NORTHERN BASIN					
SIMMONDS			11.3 (3.1)		29 (5)
SATHER			12.5 (2.7)		89 (14)
DRAINS	120 (5)	230 (6)	6.5 (2.1)	200 (22)	210 (19)
SEPTIC SYSTEM WELLS: SOUTHERN BASIN					
COVE		290	11.0 (1.7)		41 (30)
ST. PARK			5.3 (1.1)		43 (9)
LUTZ-A	100 (2)	200 (3)	19.1 (2.3)	44 (6)	51 (8)
LUTZ-B			9.7 (1.0)		36 (6)
VENNEBERG			4.8 (1.2)		29 (7)
SEPTIC SYSTEM WELLS: NORTHERN BASIN					
ALLISON-UP			7.9 (1.0)		170 (23)
ALLISON-DN			7.2 (0.7)		140 (10)
ALLISON-DOM			4.9 (1.8)		210 (15)
MORRIS			5.4 (0.9)		140 (29)
McCLELLAN-UP			7.2 (0.9)		240 (14)
McCLELLAN-DN	110	370 (50)	7.2 (1.0)	780 (120)	920 (120)
COLLINS-UP			5.9 (1.5)		63 (10)
COLLINS-DN	98 (29)	420 (29)	24.1 (3.8)	490 (240)	590 (110)
GOODWIN-DN	104 (2)	230 (4)	7.0 (1.0)	95	100 (16)
PICKENS-UP			7.3 (1.0)	49	56 (6)
PICKENS-DN	108 (67)	400 (9)	17.8 (3.4)	2,020 (220)	3,280 (250)
WILLOWS			7.1 (0.5)		110 (50)
CONDOS			15.1 (1.4)		180 (51)
SEPTAGE:	45 (6)	410 (160)	25.3 (7.2)	9,400 (2,700)	11,900 (2,700)

Table 4.4 Continued

WELL	Total Soluble Inorganic Nitrogen (ug/L)	Total Soluble Nitrogen (ug/L)	Fecal Strep. (#/100 ml)	Fecal Coliform (#/100 ml)	Total Coliform (#/100 ml)
BACKGROUND WELLS: SOUTHERN BASIN					
REED	56 (16)	50 (10)	<1		
TUCKER	13	19 (13)	2 (1)	<2	<2
KELLY	1,590 (30)	1,870 (290)	<1	<2	<2
NORTHERN BASIN					
RISLEY	410 (130)	420 (110)	1 (1)		
CLAPP	1,410 (90)	1,440 (100)	1 (1)	<2	5 (3)
MITCHELL CK.	84 (5)	130 (12)			
BEDROCK					
LESMEISTER	8,600	8,700 (1,600)	1 (1)		
ORCHARD AREA WELLS: NORTHERN BASIN					
SIMMONDS	2,400	2,400 (400)	1 (1)		
SATHER	13,000	13,100 (1,300)	1 (1)		
DRAINS	7,510 (200)	8,200 (280)			
SEPTIC SYSTEM WELLS: SOUTHERN BASIN					
COVE	2,300	8,100 (3,900)	<1	<2	<2
ST. PARK	290	1,900 (530)	2 (1)		
LUTZ-A	1,900 (420)	2,500 (420)	<1	<2	3 (1)
LUTZ-B	1,500	1,300 (430)	<1	<2	<2
VENNEBERG	430	2,500 (1,600)	<1	<2	<2
SEPTIC SYSTEM WELLS: NORTHERN BASIN					
ALLISON-UP	21,000	16,000 (5,800)	4 (2)		
ALLISON-DN	13,600	13,400 (930)	1 (1)		
ALLISON-DOM	21,000	21,900 (2,800)	13 (8)		
MORRIS	8,500	9,900 (2,800)	7 (5)		
McCLELLAN-UP	7,600	9,900 (800)	<1		
McCLELLAN-DN	10,300 (420)	11,000 (680)	1 (1)	<2	2 (2)
COLLINS-UP	9,900	10,300 (1,900)	<1		
COLLINS-DN	6,300 (1,500)	7,000 (1,700)	<1	<2	10 (4)
GOODWIN-DN	7,900 (320)	7,900 (460)	1 (1)	<2	4 (3)
PICKENS-UP	3,000 (440)	3,900 (560)	6 (3)		
PICKENS-DN	2,900 (400)	4,200 (1,000)	1 (1)	6 (2)	350 (160)
WILLOWS	43	240 (20)	18 (6)		
CONDOS		12,200 (1,800)	17 (6)		
SEPTAGE:	75,000 (25,000)	110,000 (38,000)	2E6 (1E6)	2E7 (1E7)	1E8 (5E7)

inputs (see below), contained significant levels of dissolved oxygen (> 1 mg/L), and were thus indicative of aerobic conditions.

The chemical composition of groundwaters within the Chelan Basin appeared to be dominated by the presence of calcium bicarbonate, and most of the specific conductance of the samples was attributable to these ionic constituents (Table 4.4)(APHA, 1985; Stumm and Morgan, 1981). Based on the available chemical data, groundwaters throughout the basin appeared to be in near equilibrium with calcite ($CaCO_3$).

The occurrence and transport of wastewaters from on-site septic systems was assessed during this study by using chloride as a tracer constituent. Chloride is generally conservative (i.e. relatively nonreactive) in groundwater environments, is present at elevated concentrations in wastewater, and has been used successfully as a wastewater tracer in a range of environmental conditions (Johnson et al., 1979; Gilliom and Patmont, 1982).

Observed chloride levels in groundwaters of the lower Chelan Basin ranged from a low of less than 2 mg/L in background headwater areas of First Creek, to a high of 24 mg/L immediately below a septic tank drainfield (Table 4.4). Raw wastewater (septage) samples averaged 25 ± 7 mg/L. For comparison, chloride levels in Lake Chelan averaged approximately 0.5 mg/L over the study period.

In addition to effluent inputs, elevated chloride levels in some groundwaters of the lower Chelan Basin appear to have been caused by other sources, including inputs resulting from agricultural activities. These inputs were apparent in groundwater samples collected within orchard areas (and away from local residential activity; Sather and Simmonds wells), which exhibited chloride levels approximately two times higher than regional background levels (Table 4.4). The presence of other anthropogenic sources of chloride, in addition to septic system effluents, somewhat reduced the sensitivity of this wastewater tracer parameter. This necessitated the monitoring of local upgradient conditions to properly assess wastewater contributions, particularly within orchard areas.

TSP concentrations within the lower Chelan Basin ranged from a low of 5 to 20 ug/L in some of the background wells, to a high of over 3,000 ug/L immediately below a septic tank drainfield site (Table 4.4). Most (i.e. generally greater than 75 %) of the TSP measured within the groundwater samples collected throughout the basin was attributable to SRP forms.

When all groundwater data are pooled by the predominant upgradient land use type, a significant ($P < 0.01$) difference in TSP concentrations between background and agricultural areas is evident (Table 4.5). TSP concentrations downgradient of orchard areas averaged 125 ± 16 ug/L, or approximately five (5) times the local background level. Groundwater collected from monitoring wells downgradient of septic systems also exhibited an elevated ($P < 0.05$) TSP concentration, and averaged nearly twenty (20) times the background concentration. Potential septic system contributions, however, are best addressed on a site-by-site basis to account for local upgradient conditions (see below).

The occurrence of elevated and rather high TSP and SRP concentrations within groundwaters of the Lower Chelan Basin suggests two important conditions: 1) that significant local P sources (i.e. agricultural and/or septic system inputs) are present within the area; and 2) that phosphorus is relatively mobile within this groundwater environment. Both of these conditions have important implications to waste management within the Chelan Basin (see below).

The apparent mobility of TSP within local groundwaters was also evaluated from a chemical reaction viewpoint. Using chemical data available for metal and ionic constituents which may control phosphorus equilibria, the principal chemical reactions which may control P transport can be identified (Stumm and Morgan, 1981). The principal constituents of interest include aluminum (Al), bicarbonate (HCO_3), calcium (Ca), fluoride (Fl), and iron (Fe). Limited chemical analyses for these constituents in selected monitoring wells were performed as an ancillary component of this study (Appendix F).

TABLE 4.5

SUMMARY OF GROUNDWATER NUTRIENT CONCENTRATIONS BY LAND USE TYPE IN THE LOWER CHELAN BASIN

	CONCENTRATION (ug/L; mean ± std. err.)	
Land Use	TSP	TSN
Background[a]	24 ± 7	570 ± 220
Agricultural[b]	125 ± 16	11,400 ± 1,500
Septic System[c]	469 ± 121	6,170 ± 770

a) Background wells included Reed, Tucker, Kelly, and Risley.

b) Agricultural wells included Simmonds, Sather, Allison-UP, Allison-DOM, McClellan-UP, Collins-UP, and Pickens-UP.

c) Wells potentially downgradient from septic systems included Cove, State Park, Lutz-A, Lutz-B, Venneberg, Allison-DN, Morris, McClellan-DN, Collins-DN, Goodwin-DN, Pickens-DN, Willows, and Condos.

Based on the available chemical data, the most stable phosphorus complexes which can be formed under local chemical conditions are likely to be fluoroapatite ($Ca_{10}(PO_4)_6F_2$) and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$)(Stumm and Morgan, 1981). This condition results primarily from the rather high levels of calcium present in local groundwaters (average = 110 ± 10 mg/L; Table 4.4), which in turn appear to be the result of the dissolution of calcium-containing minerals within the basin (see above). Iron and aluminum oxide and hydroxide complexes likely exert a relatively minor influence on P levels in these waters, primarily because of the typically rather low concentrations of these two metals (Fe < 5 ug/L; Al < 1 ug/L) in local groundwaters (Appendix F).

Even though the formation of apatite complexes discussed above could theoretically reduce TSP levels to very low levels in the groundwater (i.e. < 1 ug/L), formation and precipitation of these mineral complexes are often limited by factors such as the available substrate "seed" or reaction kinetics within the groundwater environment (Stumm and Morgan, 1981). As a result, relatively high levels of TSP can persist for extended periods within calcium-rich groundwaters, and particularly at locations close to a P source. A similar condition of relatively high TSP concentrations (100 - 200 ug/L) in apatite-rich groundwaters has been observed in the Rocky Ford Basin of Moses Lake, downgradient from irrigated agricultural lands (Bain et al., 1986).

The rather high apparent mobility of TSP within the Lower Chelan Basin, therefore, appears consistent with a hypothesis that groundwater P concentrations are controlled in large part by chemical reactions involving apatite. Anthropogenic inputs of P to the groundwater from agricultural and wastewater sources would be expected to be transported through the groundwater system to discharge points in Lake Chelan.

Similar to P, groundwater concentrations of nitrogen throughout the Lower Chelan Basin exhibited a consistent relationship with land use (Table 4.5). Concentrations of TSN were lowest in background regions (570 ± 220 ug/L) and were significantly ($P < 0.05$) elevated in developed orchard areas. The average TSN concentration in agricultural areas (11,400 ± 1,500 ug/L) was approximately 20 times greater than the local background level. Potential septic system contributions of N will be discussed below.

Nearly all (i.e. generally greater than 90 %) of the TSN concentration in groundwaters of the Lower Chelan Basin was attributable to NO_3. Five of the fifteen wells sampled within the orchard areas exceeded the 10,000 ugN/L primary drinking water standard for NO_3. The rather high mobility of NO_3 within groundwater environments is well documented in the literature, and its occurrence at elevated levels within agricultural areas of the basin was expected (EPA, 1976).

Fecal streptococcus and the two other indicator bacteria were generally undetectable within groundwaters of the basin, but were encountered at generally low concentrations at a number of domestic and monitoring wells

(Table 4.4). The presence of bacteria in existing wells (e.g. domestic supplies) could have been due to faulty surface seals installed with these wells. However, detectable bacterial levels were also observed in wells installed during this study, which likely represents a real occurrence of bacteria within local groundwaters. Since some of the highest levels of bacteria were observed downgradient of septic systems, wastewater contributions of bacteria may have occurred. Such potential contributions are examined below.

4.5 Septic System Performance Characteristics

The approach used in this investigation to assess septic system performance and potential constituent transport rates to Lake Chelan was based on the determination of local subsurface attenuation parameters (Kerfoot and Skinner, 1981; Gilliom and Patmont, 1982). Briefly, the methodology provides estimates of pollutant removals within the unsaturated and local saturated soil environment by comparing the relative transport of a conservative septic effluent tracer parameter (i.e. chloride) with the constituents of interest. Such an assessment of attenuation properties relies solely on water quality determinations, and not on estimated (and generally highly uncertain) flow rate estimates. This attenuation-based methodology incorporates the effects of a variety of pertinent physical processes such as dilution and diffusion, and allows possible site specific treatment processes to be assessed.

Estimates of subsurface attenuation were also based on the assumption that surface transport of wastewater in the vicinity (i.e. within 30 m; 100 ft) of the drainfield is negligible. The assumed absence of surficial wastewater "failures" is indicated by extensive site inspections performed previously within the basin by the Chelan-Douglas County Health District (A. Jensen, CDHD, personal communication, 1986), and also by limited field reconnaisance activities performed during this study. However, a rather low (but nevertheless identifiable) incidence of surface failure was reported by EPA (1984), based on remote sensing analysis. Although septic system wastewaters ultimately discharge into basin streams and/or into Lake Chelan, local scale transport (i.e. within 30 m of the drainfield) appears to be generally limited to subsurface groundwater components.

Previous studies of septic system performance conducted in a variety of environmental settings have demonstrated that subsurface pollutant removal often occurs in the immediate drainfield vicinity (Dillon and Kirchener, 1975; Jones and Lee, 1977; EPA, 1980; Gilliom and Patmont, 1982; Johnson and Atwater, 1985). Filtration, biological uptake, cation exchange and adsorption are the principal mechanisms which act to attenuate most suspended and some dissolved substances from water which percolates through soil. Filtration through sand, sandy loam, and loam effectively removes suspended solids, including bacteria and viruses, from wastewater after very short travel distances (Thomas, 1973).

N and P are taken up by soil biota and especially by surface plants, and denitrification by bacteria (which converts NO_3 to N_2) reduces total N content somewhat. Biologically mediated attenuation of nutrients occurs in both saturated and unsaturated soils. However, biological attenuation rates tend to be highest within the unsaturated zone, in part due to the greater supply of oxygen available for aerobic metabolism.

The chemical processes of cation exchange and adsorption attenuate dissolved constituents in wastewater, and are strongly controlled by local pH and oxidation/reduction conditions as well as by the soil matrix. In the case of P released from septic systems, changes in oxidation characteristics are particularly important. The anaerobic chemical conditions present within septic tanks promote the mobility of P and also of metals such as iron (Fe). However, when this wastewater is released into unsaturated soils which underlie most drainfields, the wastewater becomes oxidized. Such oxidation, in turn, leads to the formation of relatively insoluble P and Fe complexes which precipitate from solution and onto local soils.

Based on the above discussion, most of the removal (i.e. attenuation) of wastewater constituents within the Lower Chelan Basin likely occurs within the local unsaturated zone. Minimal removal of N and P would be expected in the saturated groundwater zone, particularly given the rather high mobility of these nutrients within the study area (see Section 4.4 above). Attenuation data obtained from monitoring wells within the saturated zone, therefore, are probably representative of removals occurring after more extended transport through the groundwater.

Constituent Attenuation

Only seven (7) of the groundwater monitoring sites utilized in this study appeared to contain a discernable quantity of septic system effluent. This assessment was based on statistical comparisons of appropriate upgradient and downgradient chloride concentrations at each site. The sites which exhibited a significant ($P < 0.05$) local increase in chloride included the Cove Marina, State Park, Lutz-A, Lutz-B, Collins, Pickens, and Condos wells (see Figure 3.1 for locations). Local soil and hydrogeologic characteristics of these sites generally spanned the range of conditions observed throughout the lower Chelan Basin. Two (2) of the sites (Collins and Pickens) were located downgradient of extensive agricultural areas.

Based on the chloride tracer data, the equivalent volumetric fraction of undiluted wastewater present at a given groundwater sampling site can be estimated as follows:

$$\text{Volumetric Fraction} = \frac{Cl_d - Cl_u}{Cl_e - Cl_u}$$

where Cl denotes chloride concentration (mg/L), and subscripts u, d, and e denote upgradient, downgradient, and effluent values, respectively. Using this formulation, the volumetric percentage of effluent at all seven (7) sites which exhibited a significant local increase in chloride levels was calculated.

The wastewater volume calculations are summarized in Table 4.6, and reveal that some of the groundwater samples were composed in large part of septic system effluent. Considering the observed variability in the chloride data, effluent levels of approximately ten (10) percent by volume in the groundwater samples were generally required to reliably determine wastewater contributions. Lower volumetric fractions of effluent were not distinguishable from apparently random variations in background chloride levels. Nearly half of the potentially downgradient monitoring locations (i.e. 6 out of 13 wells) contained less than this minimum detectable effluent fraction, probably because of a relatively high degree of wastewater dilution or diffusion within local groundwater systems, or because of non-uniform flow characteristics.

For the seven (7) downgradient wells which contained a significant wastewater component, fractional constituent (C) removals within the soil system were calculated as follows:

$$\text{C Removal} = 1 - \frac{[C]_d - [C]_u}{\{[C]:Cl\}*\{Cl_d - Cl_u\}}$$

where [C] denotes the measured wastewater constituent (e.g. TP) concentration and [C]:Cl denotes the constituent to chloride ratio. As stated previously, the removal to chloride ([C]:Cl) ratios were very similar among a variety of septic tanks and wastewater collection systems sampled in the Lower Chelan Basin, even though the concentrations of individual constituents varied by more than an order of magnitude. The mean and standard error of the observed constituent ratios for several key parameters (based on 7 observations) are summarized below:

TP:Cl (wt:wt) = 0.52 ± 0.06

TN:Cl (wt:wt) = 3.8 ± 0.5

FS:Cl (#:mg) = $1.7 \pm 1.1 \times 10^5$

TC:Cl (#:mg) = $4.2 \pm 1.9 \times 10^7$

Based on these data and the mass balance removal model described above, constituent removals in each target drainfield system were calculated. These data are summarized in Table 4.6. For five (5) of the seven systems, average P removal over the study period exceeded 98 percent, and downgradient TSP concentrations were only slightly (and often insignificantly) elevated above upgradient values.

The remaining two (2) systems exhibited P removals which were significantly ($P < 0.05$; ANOVA) lower than the other sites. P removal in these systems ranged from 94 ± 1 percent at the Collins site to 41 ± 5 percent at the Pickens location. Both of these drainfield systems were characterized by relatively shallow groundwater conditions, with the local water surface ranging from approximately 0 to 2 meters (0 - 6 ft) below the drainfield trenches (see Table 4.3). Flooding conditions within these

TABLE 4-6

SUMMARY OF CALCULATED CONSTITUENT REMOVALS AT SELECTED MONITORING SITES

MONITORING SITE	ESTIMATED EFFLUENT VOLUME (%)	CALCULATED PHOSPHORUS REMOVAL (%)	CALCULATED NITROGEN REMOVAL (%)
COLLINS	94 ± 41	94 ± 1	100 ± 3
LUTZ-A	70 ± 28	100 ± 1	99 ± 1
PICKENS	58 ± 31	41 ± 5	99 ± 3
CONDOS	48 ± 19	99 ± 2	69 ± 5
COVE MARINA	30 ± 15	99 ± 1	73 ± 17
LUTZ-B	24 ± 11	99 ± 1	100 ± 3
STATE PARK	13 ± 7	98 ± 1	84 ± 4
OVERALL AVERAGE		90 ± 8	89 ± 7

MONITORING SITE	CALCULATED FECAL STREPTOCOCCUS REMOVAL (%)	CALCULATED TOTAL COLIFORM REMOVAL (%)
COLLINS	100.000 ± 0.004	100.000 ± 0.000
LUTZ-A	100.000 ± 0.004	100.000 ± 0.000
PICKENS	99.999 ± 0.004	99.999 ± 0.000
CONDOS	99.989 ± 0.005	-
COVE MARINA	100.000 ± 0.004	100.000 ± 0.000
LUTZ-B	100.000 ± 0.004	100.000 ± 0.000
STATE PARK	99.996 ± 0.005	-
OVERALL AVERAGE	99.998 ± 0.005	

two (2) drainfields is considered possible. The other five (5) systems exhibited considerably greater depths to water, and in all cases exceeded 3 meters (10 ft). The correlation between P removal and depth to water below the drainfield was significant ($P < 0.05$; Kendall and Spearman rank-order tests). No other significant correlations were detected between P removal and physical characteristics.

The finding that on-site P removals are positively correlated with the depth of the unsaturated groundwater zone beneath the drainfield trench is consistent with the results of other investigations (Dillon and Kirchener, 1975; Jones and Lee, 1977; EPA, 1980; Gilliom and Patmont, 1982; Johnson and Atwater, 1985), and also with local chemical conditions. In the Lower Chelan Basin, as in other areas, P removal within the unsaturated zone is probably attributable to adsorption of P onto iron and aluminum oxides on the surface of the soil matrix. The source of these iron and aluminum deposits could be either local soils or wastewater which oxidizes upon discharge into the unsaturated zone. Within the saturated zone, however, groundwater chemical characteristics shift to a calcite-dominated, but still well-oxygenated system. Within this system, P complexes appear to be readily transported through the groundwater.

Assuming the seven (7) sites discussed above were representative of conditions throughout the Lower Chelan Basin, an average basin-wide septic system P removal of 90 ± 8 percent was calculated (Table 4.6). Nearly all of the observed P transport, however, appeared to be associated with systems installed in areas with a relatively shallow depth to water. This result has important management implications (see Section 6.0).

Overall, observed on-site removals of N averaged 89 ± 7 percent, and ranged from 69 ± 5 percent at the Condos site to 100 ± 3 percent at the Collins and Lutz sites (Table 4.6). Significant differences were observed between sites ($P < 0.05$; ANOVA). N removal was not correlated with depth to water ($P > 0.10$), but did appear to be somewhat correlated ($P < 0.05$) with local hydraulic conductivity (Kendall and Spearman rank-order tests using average site values). Drainfields underlain by soils with relatively high vertical permeabilities (10^{-4} - 10^{-5} m/s) exhibited lower N removals than those systems in less permeable materials (10^{-6} - 10^{-7} m/s). The apparently greater N removal afforded by less permeable soils is possibly related to a greater residence time of wastewater within the shallow vegetative root zone, and associated plant uptake. Little additional N removal is anticipated within deeper groundwater zones.

On-site removals of bacterial indicators (FS and TC) were very high at all sites monitored, and averaged 99.998 ± 0.005 percent (Table 4.6). No significant differences ($P > 0.10$; ANOVA) were observed between sites. Based on these data, removal of bacteria and associated pathogens appears to have been nearly complete within local soil environments, even in areas of relatively high permeability (to 10^{-4} m/s). On-site bacterial removals are generally attributable to physical filtering processes within the soil (EPA, 1980). Apparently, all soil types monitored exhibited effective filtering characteristics.

Septic System Loadings

The wastewater characterization and attenuation data discussed above formed the basis for an assessment of constituent loadings to Lake Chelan from on-site septic systems. As discussed in Section 2.3 of this report, approximately 2,900 individuals (or approximately half the total population) likely utilized septic systems within the Chelan Basin during the study period. Nearly all of these individuals appeared to be full-time residents within the Lower Chelan Basin. The seven septic systems monitored were assumed to be representative of this entire basin population.

Total loadings of TP, TN, and FS were calculated based on the following:

$$\text{Load} = \text{POP} \times \text{Cl}_L \times [\text{C}]:\text{Cl} \times (1 - \text{C}_R)$$

where POP denotes the total basin population (2,900), Cl_L denotes the characteristic per capita chloride excretion rate (2.2 ± 0.5 kg Cl/person-year; Metcalf and Eddy, 1972; Brandes, 1978), [C]:Cl denotes the constituent to chloride ratios discussed previously, and C_R denotes the overall average fractional constituent removal (Table 4.6). The results of these calculations are summarized in Table 4.7.

TABLE 4.7

SUMMARY OF ESTIMATED WASTEWATER LOADINGS TO LAKE CHELAN

Parameter	Total Loading
Total Phosphorus	320 ± 270 kg/yr
Total Nitrogen	2,600 ± 1,800 kg/yr
Fecal Streptococcus	22 ± 57 bill/yr

The estimated on-site wastewater loadings for TP, TN, and FS represent an estimated 3 ± 2, 1 ± 1, and 0.04 ± 0.10 percent, respectively, of the total estimated input of these parameters to Lake Chelan (see below). The possible effects of these loadings will be discussed further in subsequent sections of this report.

CHAPTER 5

Limnological Results

5.0 LIMNOLOGICAL RESULTS

5.1 Hydrology

Precipitation within the Lake Chelan Basin varies widely between the mountainous headwaters at the western end of the basin, and the outlet of the lake in Chelan. Gladwell and Mueller (1967) estimated that average annual precipitation within the basin may range from more than 380 cm/yr (150 in/yr) near 2,680 m (8,790 ft) Dome Peak, to approximately 27 cm/yr (11 in/yr) in the City of Chelan (elevation 340 m; 1,100 ft). The estimated isohyetal map of the basin is presented in Figure 5.1, along with the long term average precipitation observed at three cooperative weather stations in Stehekin, Holden, and Chelan.

Precipitation recorded at the weather stations over the 12 month study period (December 1986 through November 1987) was only 64 percent of normal. Monthly precipitation records are summarized in Figure 5.2. Direct precipitation onto Lake Chelan averaged 1.7 ± 0.6 m^3/sec (61 cfs), and accounted for approximately 3 to 4 percent of the total hydrologic input to the lake (Table 5.1). Most of the annual precipitation occurred as snowfall during the winter months.

In contrast to precipitation maxima during winter, most of the runoff volume to the lake occurred over the months of April through June following snowmelt (Figure 5.3). The Stehekin River was by far the largest tributary, accounting for 66 percent of the total lake input (Table 5.1). Discharge from the Stehekin River averaged 33 ± 2 m^3/sec (1,200 cfs) over the study period. Railroad Creek was the second largest input, averaging 5.5 ± 0.5 m^3/sec (200 cfs), and contributing approximately 11 percent of the lake total. Flows from these two tributaries over the study period were lower than average (85 % of normal), but by a considerably smaller margin than precipitation. The difference between precipitation and runoff patterns may reflect the stabilizing influence of relatively constant glacial meltwater discharges from headwater areas of these tributaries.

Flows from a variety of minor tributary and drainage inputs within (or close to) the Wapato Basin were monitored periodically. These surface water streams included Mitchell Creek, Greens Landing (Wapato Lake and Stink Creek combined discharge), First Creek, Purtteman Gulch, Knapp Coulee, USBR agricultural return flow drains Nos. 6 and 8, and several stormwater discharges. The combined annual discharge from these eight streams was only 0.29 ± 0.06 m^3/sec (10 cfs), or less than one percent of the total lake input. An estimated 19 percent of the total lake input was not measured directly during this study; most of this "residual" discharge is likely represented by diffuse tributary inputs into the Lucerne Basin (see below).

Outflow from Lake Chelan is controlled by the Chelan County PUD, which operates a power generation facility along the Chelan River at the Chelan Falls Dam. Generally, outflow from the lake is held nearly constant over

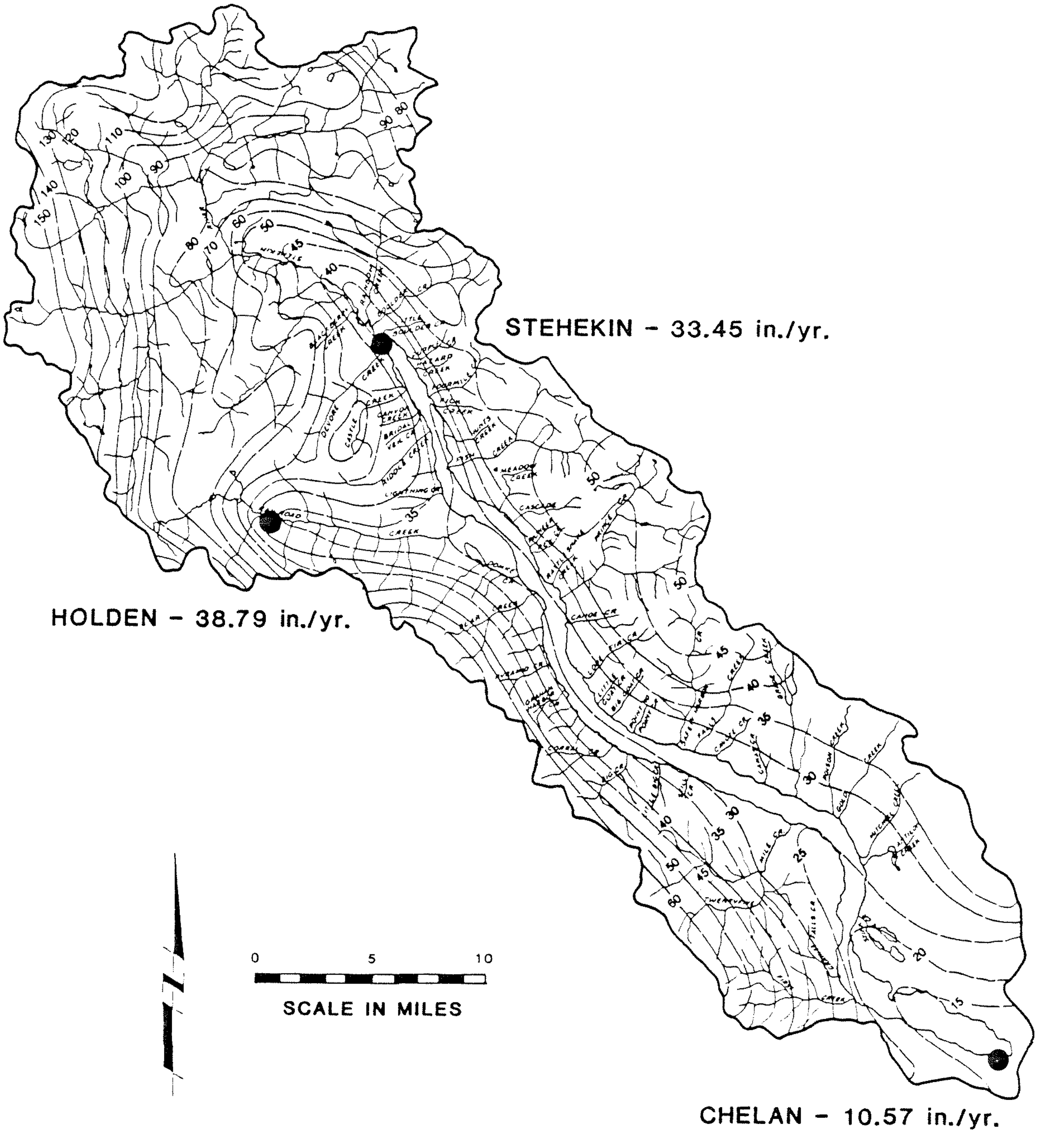


Figure 5.1

ANNUAL AVERAGE PRECIPITATION (in./yr.) IN THE LAKE CHELAN BASIN (CONTOURS BASED ON GLADWELL AND MUELLER, 1967 - CHELAN, HOLDEN AND STEHEKIN DATA BASED ON NATIONAL WEATHER SERVICE RECORDS)

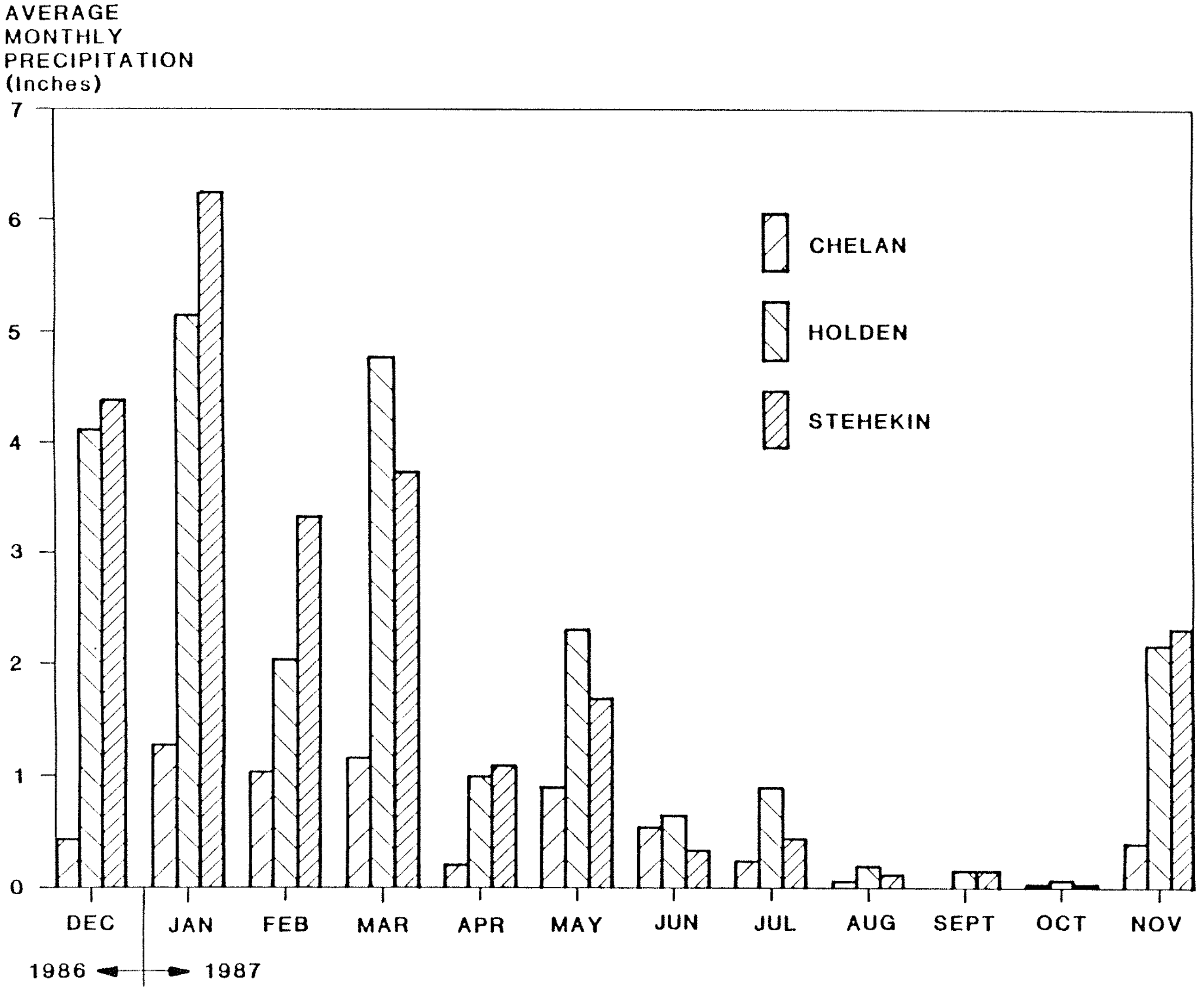


Figure 5.2

AVERAGE MONTHLY PRECIPITATION DURING THE STUDY PERIOD

TABLE 5.1 SUMMARY OF ANNUAL WATER BUDGET FOR LAKE CHELAN

	<--------- DISCHARGE (cfs)	----------	Catchment	Study Period
	Dec 86 - Nov 87 Study Year	Average Annual	Area (sq.mi.)	Annual Runoff (inches/year)
	Mean +/- SE	Mean +/- SE		
LUCERNE BASIN TRIBUTARIES				
Stehekin R. (1)	1,177 +/- 59	1,415 +/- 82	321	49.8 +/- 2.5
Railroad Ck (2)	195 +/- 18	204 +/- 13	65	40.8 +/- 3.7
Mitchell Ck (2)	3 +/- 1	3 +/- 1	13	2.7 +/- 0.8
Greens Landing (2)	1 +/- 1	1 +/- 1	24	0.7 +/- 0.3
Misc. Lucerne Basin Tribs (2)	324 +/- 115	433 +/- 152	376	11.7 +/- 4.1
TOTAL LUCERNE TRIBUTARIES	1,700 +/- 130	2,057 +/- 173	799	29.1 +/- 2.4
WAPATO BASIN TRIBUTARIES				
First Ck (3)	4.5 +/- 1.4	5.3 +/- 1.7	18.7	3.3 +/- 1.0
Purtteman Gulch (3)	0.9 +/- 0.2	1.1 +/- 0.3	6.1	2.1 +/- 0.5
Knapp Coulee (3)	0.1 +/- 0.0	0.1 +/- 0.0	2.8	0.4 +/- 0.1
USBR Drain No. 6	0.5 +/- 0.2	0.5 +/- 0.2	0.8	8.0 +/- 2.9
USBR Drain No. 8	0.4 +/- 0.2	0.4 +/- 0.2	0.4	12.3 +/- 6.8
Measured Stormwater (5)	0.1 +/- 0.1	0.2 +/- 0.1	0.6	3.0 +/- 1.5
Misc. Stormwater (5)	2.7 +/- 1.7	4.3 +/- 2.7	4.5	8.3 +/- 5.2
Misc. Wapato Basin Tribs (6)	5.5 +/- 4.1	6.4 +/- 4.9	39.0	1.9 +/- 1.4
TOTAL WAPATO TRIBUTARIES	14.7 +/- 4.7	18.2 +/- 5.9	72.9	2.8 +/- 0.9
OTHER SOURCES				
Precipitation (7)	61 +/- 22	96 +/- 37	52	20.8 +/- 8.1
TOTAL INFLOWS	1,776 +/- 132	2,171 +/- 177	924	26.5 +/- 2.2
OUTFLOWS OR LOSSES				
Chelan R. (8)	1,749 +/- 87	2,057 +/- 116	-	- -
Irrigation Withdrawal (9)	28 +/- 1	22 +/- 4	-	- -
Evaporation (10)	92 +/- 35	92 +/- 35	-	- -
TOTAL OUTFLOWS	1,869 +/- 94	2,171 +/- 121	-	- -
STORAGE CHANGE (11)	-93 +/- 5	0 +/- 0	-	- -

FOOTNOTES

1) USGS surface water records; average annual estimate based on 1911-79.

2) Average annual estimate based on USGS records from 1911 to 1957. Study year based on Harper-Owes data.

3) Average annual scaled from study year data based on outflow.

4) Calculated as water budget residual.

5) Annual average estimated by rational method with assumed runoff coefficients of 0.8 for developed and 0.1 for undeveloped and estimated uncertainty of +/- 50%. Average Chelan precip of 10.57 in/yr was assumed. Miscellaneous Stormwater based on total developed area in lower Chelan basin (unpubl. Plan. Dept. data) assuming rainfall of 15 +/- 5 in/y and runoff coefficient of 0.8 +/- 0.4. Study year scaled from annual average based on precip.

6) Misc Wapato basin tributaries based on average runoff (in/yr) from First Ck, Purtteman Gulch, and Knapp Coulee applied to Wapato basin catchment area not included in direct estimates.

7) Average annual precipitation based on Gladwell and Mueller, 1967. Study year scaled from Gladwell and Mueller based on deviation of Chelan and Stehekin Cooperative National Weather Service Stations from normal year averages.

8) Average annual estimate based on USGS surface water records for 1904 to 1979. Study year based on PUD data. Includes penstock withdrawals (Chelan Falls and Beebe Orchard Irrig Districts).

9) Lake Chelan Reclamation District withdrawals at Manson.

10) Evaporation estimated by pan method (coeff of 0.7) and Harbeck, 1962.

11) Average annual storage change assumed equal to zero. Study year based on P.U.D. data.

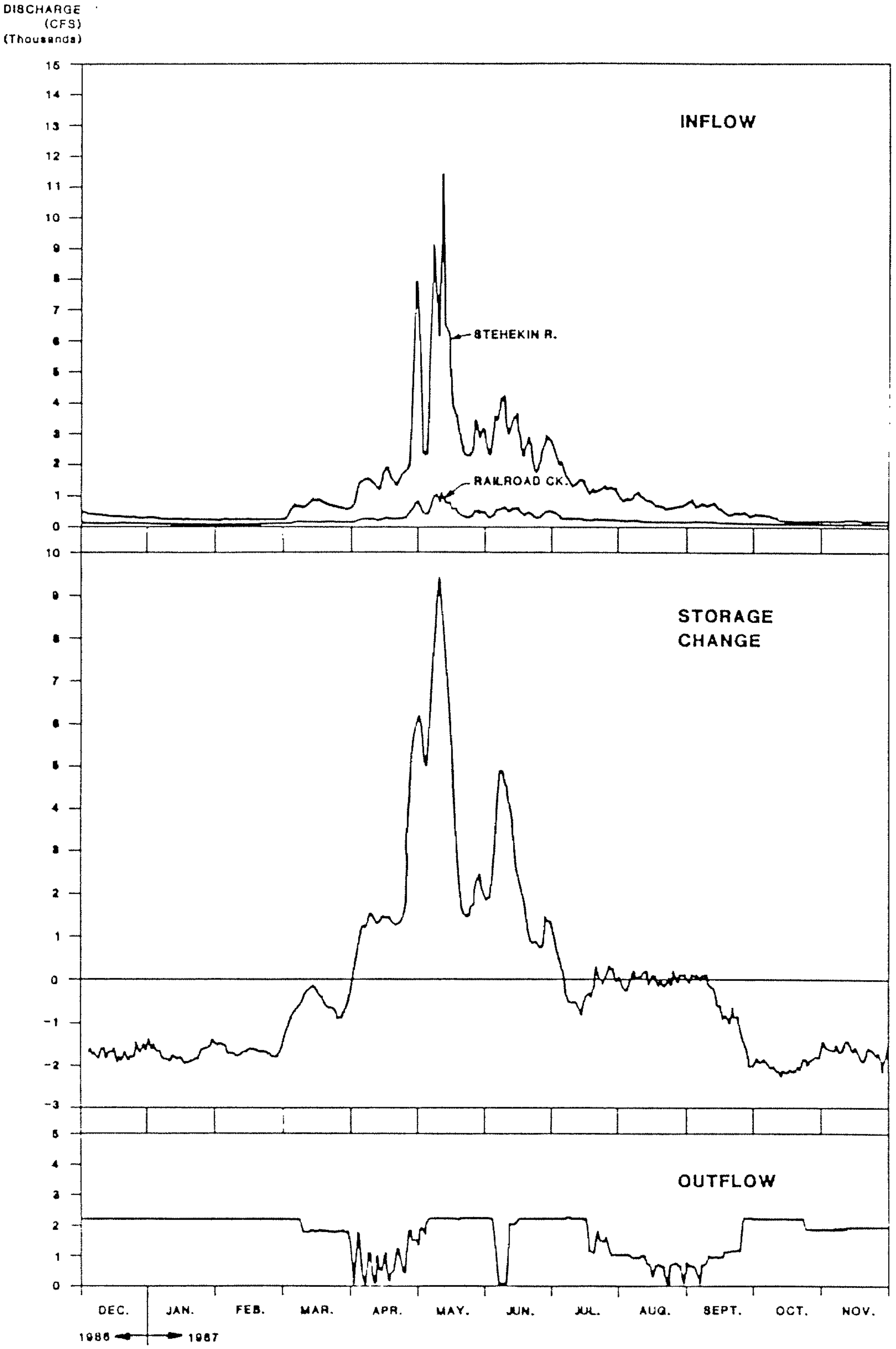


Figure 5.3

MAJOR COMPONENTS OF THE WATER BUDGET FOR LAKE CHELAN DURING THE STUDY PERIOD, DECEMBER 1986 TO NOVEMBER 1987.

the year at approximately 57 m^3/sec (2,000 cfs), and seasonal variations in inflow result in equivalent changes in the lake storage volume (Figures 5.3 and 5.4). As a result of these storage changes, lake level varied 5.2 m (17 ft) over the study period, with full pool maintained from late June to early September.

Although nearly all (98 percent) of the outflow from Lake Chelan entered the Chelan River (and PUD penstocks), evaporation and irrigation withdrawal also represented important discharge components (Table 5.1). Domestic withdrawal volumes were comparatively insignificant. Total outflow from Lake Chelan during the study year was approximately 86 percent of the long term average, and well within the normal (interquartile) range (based on 1904 to 1979 records; Williams and Pearson, 1985). All information considered, the hydrologic regime encountered during the study year was generally representative of normal conditions.

As discussed above, one of the more difficult components of the water budget to evaluate was input from the numerous smaller tributaries in the basin. In general, the areal runoff (i.e. annual average discharge per unit watershed area) within the Lake Chelan Basin declined markedly proceeding down-lake, largely in response to similar changes in precipitation (see Figure 5.1). This variation in runoff is depicted in Figure 5.5, which is the average annual runoff for each tributary monitored within the basin (including all available historical data) versus its position along the lake talweg. Average areal runoff ranged from a high of approximately 150 cm/yr (60 in/yr) in the Stehekin River drainage to less than 5 cm/yr (2 in/yr) in many of the Wapato Basin tributaries. The observed runoff values are similar to estimates based on a soil water balance model for natural areas (Donaldson and Ruscha, 1975).

Over the 1987 irrigation season (March to October), 90 cm/yr (35 in/yr) of water was applied to approximately 27 km^2 (6,700 ac) of irrigated orchard lands north of Manson within the Lake Chelan Reclamation District (LCRD) (S. McDaniel, LCRD, written communication, 1988). Most of the irrigation supply within the basin is obtained from a pump station on Lake Chelan at Mill Bay, 3 km east of Manson. Irrigation return flows are collected within an extensive drain system in the LCRD orchard areas (installed in the early 1970s), and are ultimately discharged back into Lake Chelan.

Relative to normal runoff/recharge rates within natural areas of the Wapato Basin of less than 5 cm/yr (see above), an irrigation water application of 90 cm/yr represents a large potential increase to the local hydrologic loading. In order to determine how much of the irrigation water may be available for runoff, return flow drains serving the three largest orchard areas within the LCRD were monitored throughout the study period. Discharges from these drains were nearly constant throughout the year, and represented an average areal runoff of approximately 25 ± 15 cm/yr (10 in/yr). Based on these data, approximately 10 - 40 percent of the water applied to orchard areas contributed to local return flows.

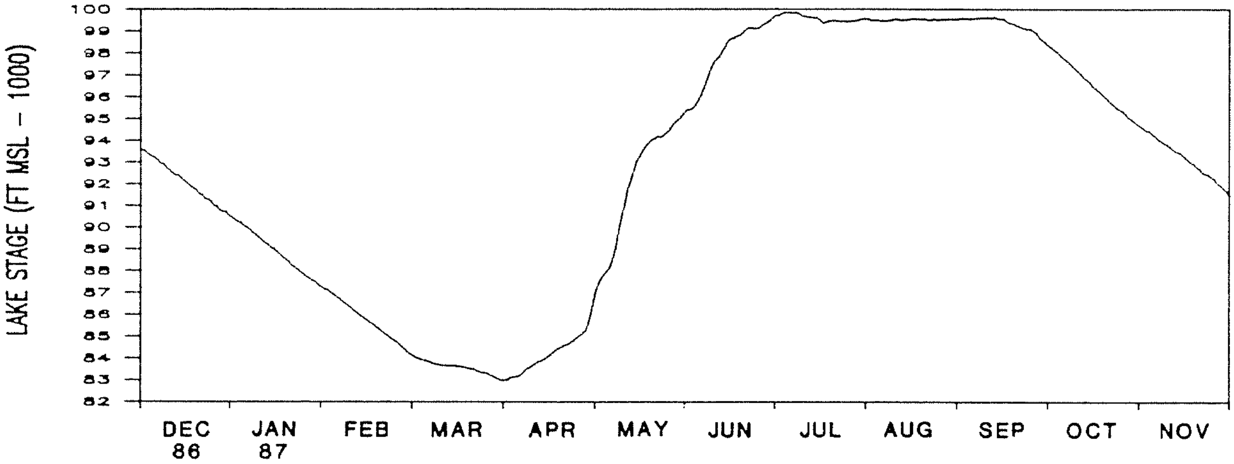


Figure 5.4

ANNUAL VARIATION IN LAKE LEVEL
OVER THE STUDY PERIOD

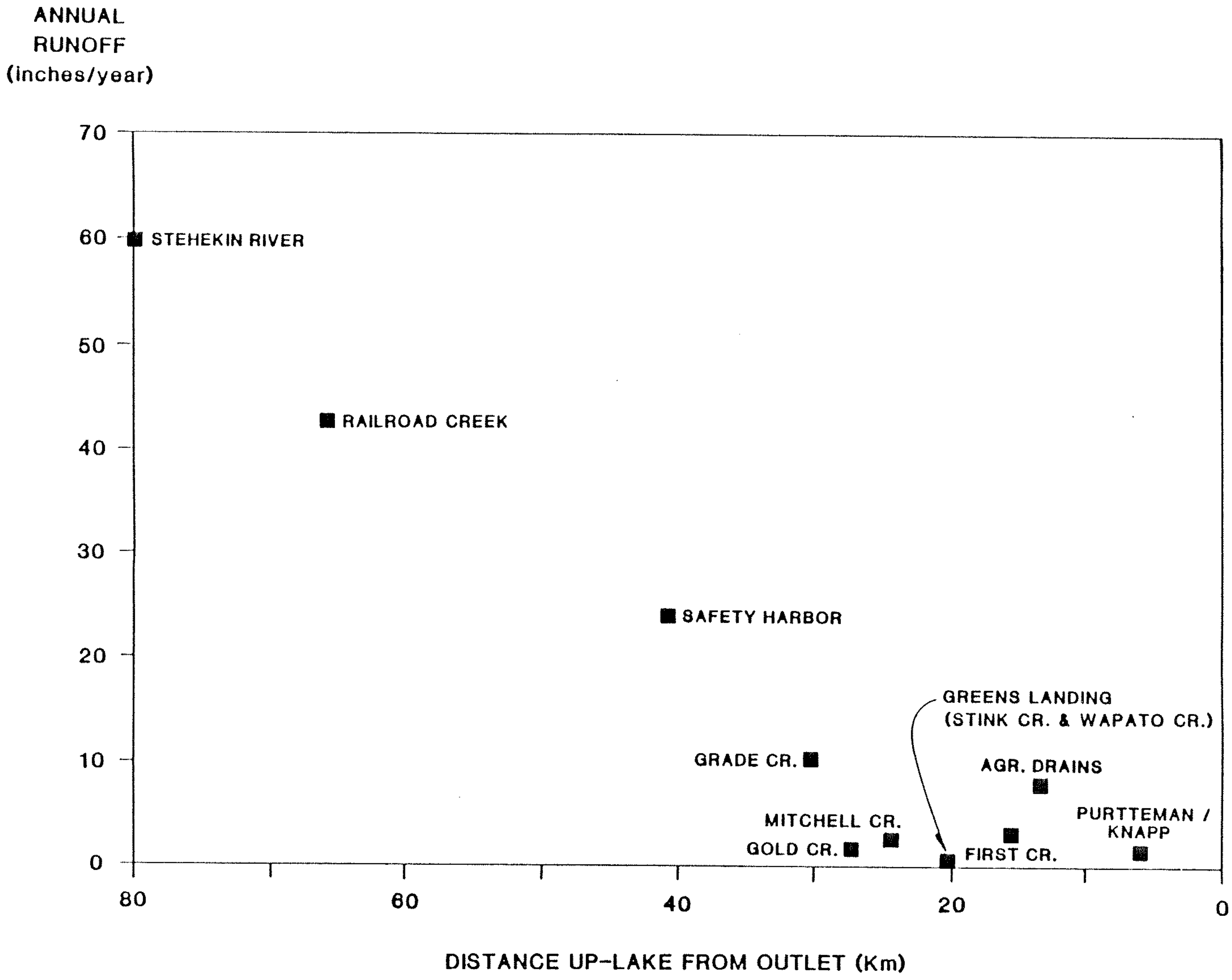


Figure 5.5

RELATIONSHIP BETWEEN ANNUAL RUNOFF AND DISTANCE UP-LAKE

These drainage discharges also contribute significantly to local groundwater flow conditions (see Section 4.2 above).

The water budget (and subsequent materials budgets) developed for Lake Chelan separated inputs to the Lucerne and Wapato Basins. All tributaries which were monitored during the study were handled as discrete inputs (Table 5.1). Runoff from developed areas of the Wapato Basin was estimated based on rainfall data, an assumed runoff coefficient (0.8), and area estimates from the Chelan County Planning Department's draft comprehensive plan (13 km^2; 5.1 mi^2; J. Vodopich, Chelan County, personal communication, 1988). The annual stormwater discharge from these developed areas was estimated at 0.08 ± 0.05 m^3/sec (2.8 cfs).

Flows from unmeasured tributaries and groundwater inputs to the Wapato Basin were estimated based on the measured areal runoff from First Creek, Purtteman Gulch, and Knapp Coulee, which together averaged 4.8 ± 3.6 cm/yr (1.9 in/yr; Table 5.1). The combined discharge from unmeasured drainage areas (100 km^2; 39 mi^2) in the Wapato Basin during the study year was therefore estimated to average 0.16 ± 0.12 m^3/sec (5.5 cfs). The total tributary and/or groundwater discharge to the Wapato Basin was estimated to average 0.42 ± 0.13 m^3/sec (15 cfs), which represents less than one (1) percent of the total annual input to Lake Chelan.

Inputs from unmeasured discharges into the Lucerne Basin were calculated as the residual term in the water budget equation, defined as the difference between total estimated inflows and outflows, corrected for storage changes. Because of this calculation procedure, uncertainties in all the other components of the water budget were propagated to estimate the uncertainty of the Lucerne Basin residual term. The total discharge from unmeasured sources in the Lucerne Basin was estimated to average 9.2 ± 3.3 m^3/sec (320 cfs).

The residual discharge estimates discussed above for both the Wapato and Lucerne Basins include both surface and groundwater components. In order to determine if groundwater inputs to the lake may be a significant discharge component, all tributary inputs and outputs were monitored over a three day low flow period in September 1987. Groundwater inputs (or outputs) would be expected to be most observable during a low flow period.

Out of 68 identified drainages within the basin, 45 were flowing at the time of the low flow survey. The calculated water balance during the low flow study period is presented in Table 5.2. No significant ($P > 0.5$) differences were observed between total inflows and outflows. These results suggest that groundwater flows were likely a relatively minor component of the lake water budget. Materials loadings from various sources within the Lake Chelan Basin (including groundwater inputs) will be discussed in subsequent sections of this report.

TABLE 5.2

SUMMARY OF LOW FLOW WATER BUDGET WITHIN LAKE CHELAN
Based on data collected over September 7-9, 1987

	AVERAGE DISCHARGE (cfs; mean ± std. err.)
INFLOWS	
Stehekin River	690 ± 42
Railroad Creek	133 ± 12
Misc. Lucerne Tribs. (n = 34)	29 ± 6
Misc. Wapato Tribs. (n = 9)	6 ± 1
Precipitation	0 ± 0
TOTAL INFLOWS	858 ± 44
OUTFLOWS	
Chelan River	659 ± 46
Irrigation/Domestic Withdrawals	81 ± 4
Evaporation	110 ± 42
TOTAL OUTFLOWS	850 ± 63
STORAGE CHANGE	-9 ± 10
CALCULATED RESIDUAL OUTFLOW	17 ± 77 (N.S.)[a]

a). The minor calculated residual outflow over this period is not statistically significant; $P > 0.50$.

5.2 Hydrodynamics

5.2.1 Vertical Mixing

One of the more important physical processes which controls water quality characteristics of deep lakes such as Chelan is vertical mixing (Welch, 1980). Vertical density stratification and mixing in temperate lakes are controlled by the thermal regime resulting from (1) heat flux and momentum transfer across the surface, and (2) gravitational forces acting on density differences within the lake (Chapra and Reckhow, 1983). Heat flux may increase or decrease lake temperature, depending upon season. Surface heating during spring and summer results in density stratification, which is acted on by wind-induced mixing. The depth of the upper mixed layer (epilimnion) is determined by a balance between wind energy mixing water downward, and the energy resisting that mixing due to buoyancy resulting from heating.

Seasonal changes in average vertical temperature profiles for the Lucerne and Wapato Basins are presented in Figure 5.6. Typical vertical profiles observed for all stations throughout the lake during periods of minimal and peak stratification are presented in Figures 5.7 and 5.8, respectively. Thermal stratification still existed in December when the study began, but was greatly minimized by the end of January. Isothermal conditions were approached during February and March. However, during both of these lake surveys, a weak but nevertheless discernable thermocline was observed within both the Wapato and Lucerne basins at depths of approximately 80 and 140 meters, respectively. Thus, Lake Chelan apparently did not achieve full circulation during the study period, and deep hypolimnetic waters were at least partially isolated from the rest of the lake throughout 1987. The rather constant temperatures observed within these deep hypolimnetic waters (± <0.1 ^{0}C) are consistent with such isolation. Because the 1986/1987 winter was characterized by relatively mild and warm weather, it is considered likely that complete circulation (i.e. turnover) does occur periodically within Lake Chelan.

The distribution of temperatures across the surface of Lake Chelan during a typical summer day is presented in Plate 1, based on LANDSAT imagery data available from July, 1985. The data are presented in color to illustrate the rather dramatic differences in temperature which exist from one end of the lake to the other. Surface waters of the Wapato Basin were nearly uniformly warm, while waters in the Lucerne Basin were considerably cooler. On this day, the steepest longitudinal surficial temperature gradient occurred within the lower Lucerne Basin, approximately 25 to 30 km (15 - 20 mi) uplake from the outlet. This general area of the lake appears to be characterized by reduced longitudinal mixing, which allows such temperature gradients to become established and persist for extended periods (see below). Longitudinal mixing characteristics of Lake Chelan will be discussed in greater detail in later sections of this report.

During the months of summer stratification, the Stehekin River was often 4 to 5 ^{0}C cooler than surface waters at the nearest lake station (Station 8; Figure 3.2). In the absence of significant nearshore entrainment or dispersion, these cooler, more dense river waters would exhibit an initial tendency to flow downward to lower depths within the lake. This phenomenon is apparent in several temperature profiles determined near the mouth of the river in mid-July by Wassem (1987). These data are presented with those from the July 27 lake survey in Figure 5.8. The data suggest that the 10 ^{0}C river water was warmed slightly (to 11 - 12 ^{0}C) as it entered the rather shallow Stehekin delta area, and then apparently flowed downward to a depth of 20 to 40 m. The apparent equilibration depth represents the location of lower epilimnetic waters with a similar temperature (and density). Based on a comparison of river and lake epilimnion temperatures, it is likely that the Stehekin River exhibited a similar plunge pattern throughout much of the spring, summer, and fall. The other tributaries exhibited temperatures very similar to local lake water, and therefore would have remained in lake surface waters.

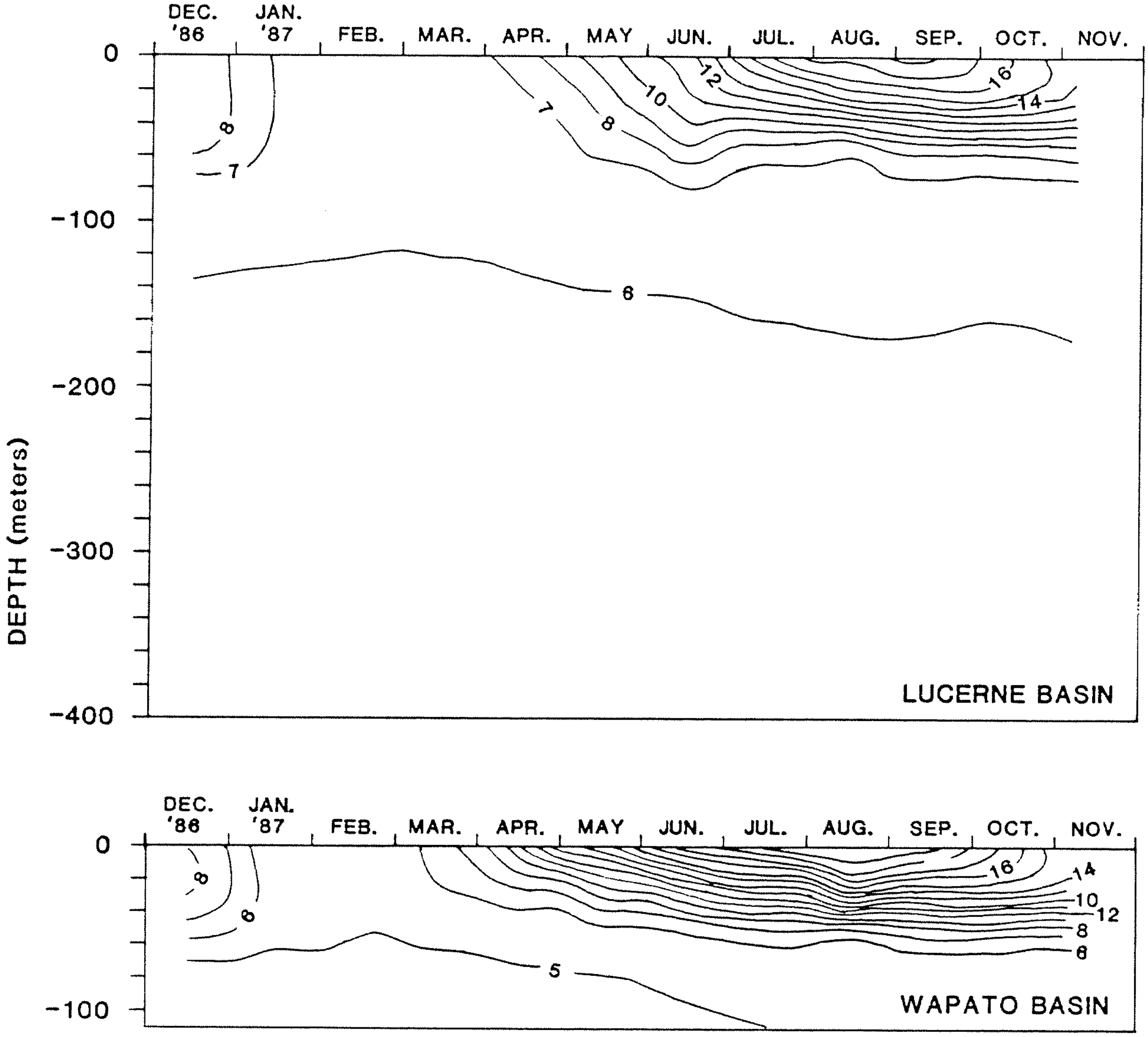


Figure 5.6

AVERAGE TEMPERATURE CONTOURS
(°C) DURING THE STUDY PERIOD

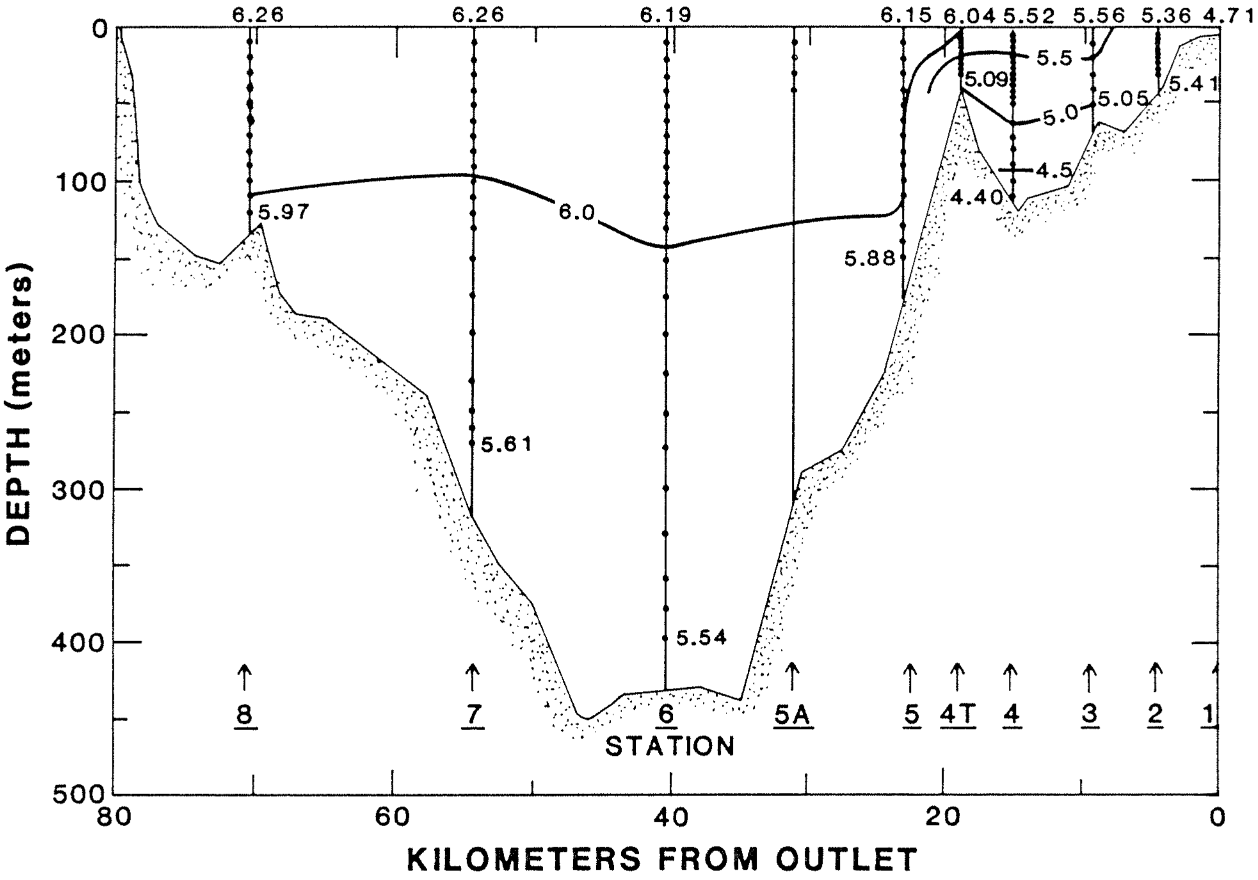


Figure 5.7

LONGITUDINAL TEMPERATURE PROFILE
FEBRUARY 27, 1987

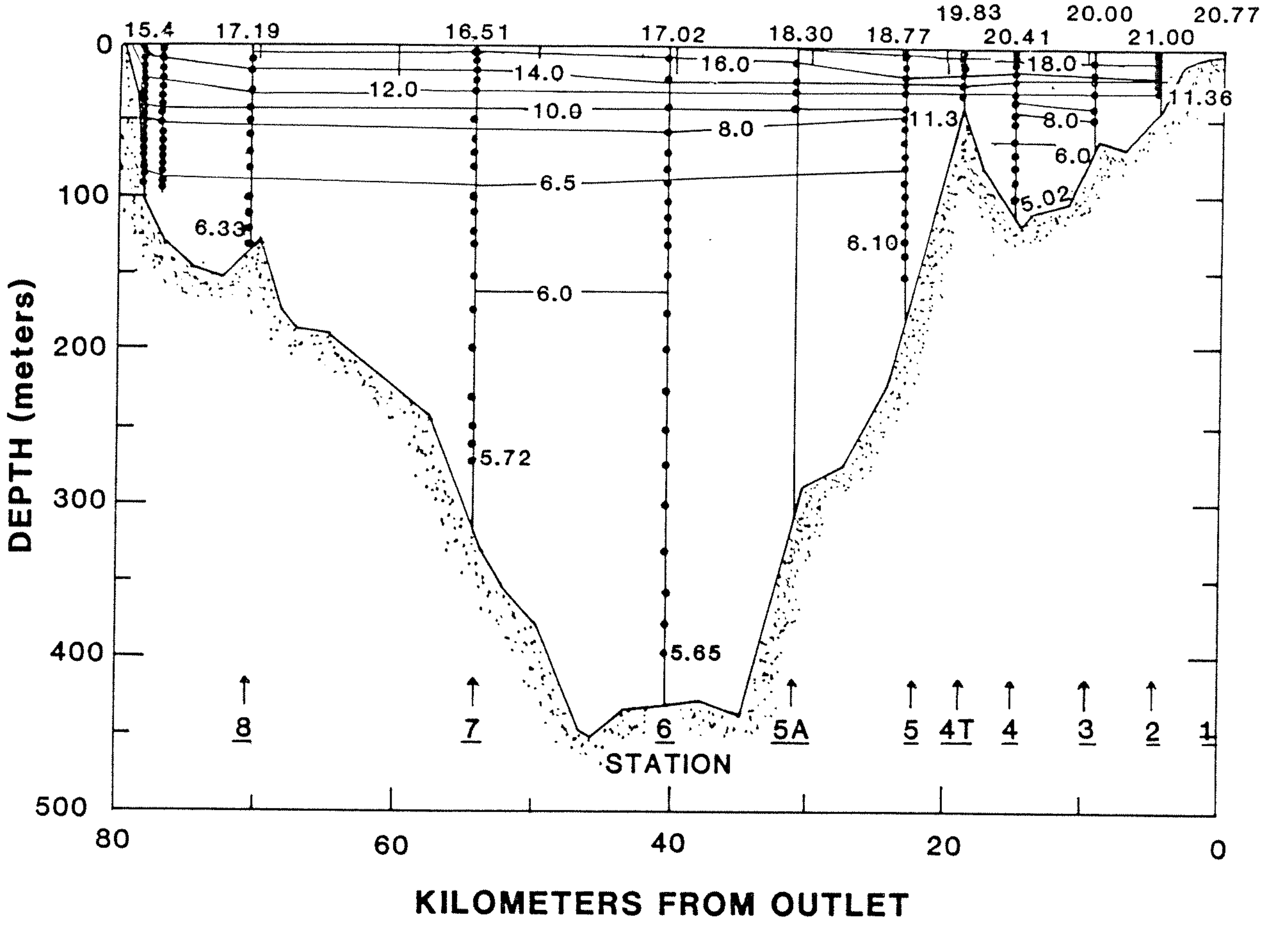


Figure 5.8

LONGITUDINAL TEMPERATURE PROFILE
JULY 27,1987 (WITH STEHEKIN DATA
FROM WASSEM 1987)

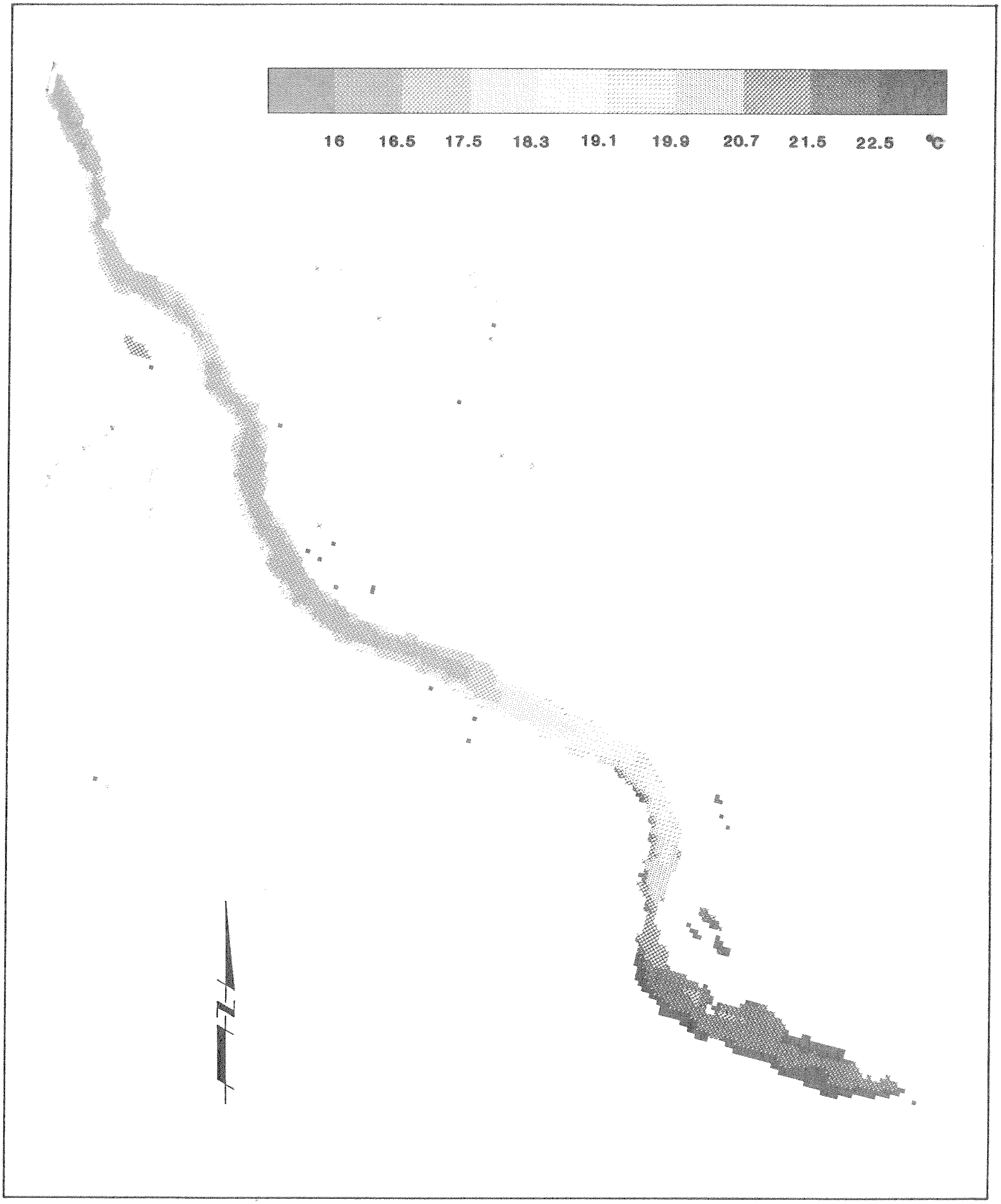


PLATE 1

ESTIMATED SUPERFICIAL TEMPERATURES OF LAKE CHELAN, JULY 15, 1985, AS DETERMINED BY LANDSAT SATELLITE IMAGERY

The budget of heat changes in a lake is a useful indicator of the amount of vertical mixing which occurs during the period of stratification. The vertical heat exchange coefficient is estimated as (Chapra and Reckhow, 1983):

$$v_t = \frac{V_h (dT_h/dt)}{A_t (T_e - T_h)}$$

Where v_t is the thermocline heat exchange (m/day), V_h is the volume of the hypolimnion (m^3), T_h is the temperature of the hypolimnion, T_e is the temperature of the epilimnion (degrees C) and A_t is the surface area of the thermocline depth contour (m^2). The thermocline heat exchange coefficient is an indicator of the magnitude of vertical mixing between the hypolimnion and epilimnion.

A summary of the heat transfer calculations is presented in Figure 5.9. Surface heating began during March, and as stratification developed during spring and summer, the resistance to vertical mixing in both basins increased. However, the thermocline gradient, and therefore the resistance to vertical mixing, was considerably greater in the Wapato Basin throughout the period of stratification.

The rate of vertical mixing can be represented by the bulk vertical diffusion coefficient, which combines both advective and diffusive mixing components. Variation in vertical diffusion with depth was calculated based on heat flux and temperature gradients (Orlob and Selna, 1970) as:

$$E_h = \frac{V_h (dT_h/dt)}{A_z (dT_z/dz)}$$

where E_h is the vertical diffusion coefficient (cm^2/sec), V_h is the volume from the evaluated stratum to the lake bottom (cm^3), T_h is the average temperature from the evaluated stratum to the lake bottom (^0C), A_z is the surface area of the evaluated stratum (cm^2), T_z is the temperature at the depth stratum (^0C), z is depth (cm), and t is time (sec).

A summary of calculated vertical diffusion coefficients is presented in Figure 5.10. Vertical diffusion during spring-summer (April to September 1987) was typically greatest in the epilimnion and reached a minimum at the thermocline. Average vertical mixing at the Lucerne Basin thermocline was approximately three times greater than that in the Wapato Basin. In addition, mixing within the epilimnion (upper 20 m) was approximately ten times greater in the Lucerne Basin. The greater vertical mixing intensity within the Lucerne Basin is consistent with its greater fetch, surface wave action, and internal seiche activity (see below), relative to that in the Wapato Basin.

5.2.2 Water Motions and Seiche Dynamics

Aquatic ecosystems such as Lake Chelan often respond to external forces (e.g. gravity or wind stress) with a variety of water motions which vary

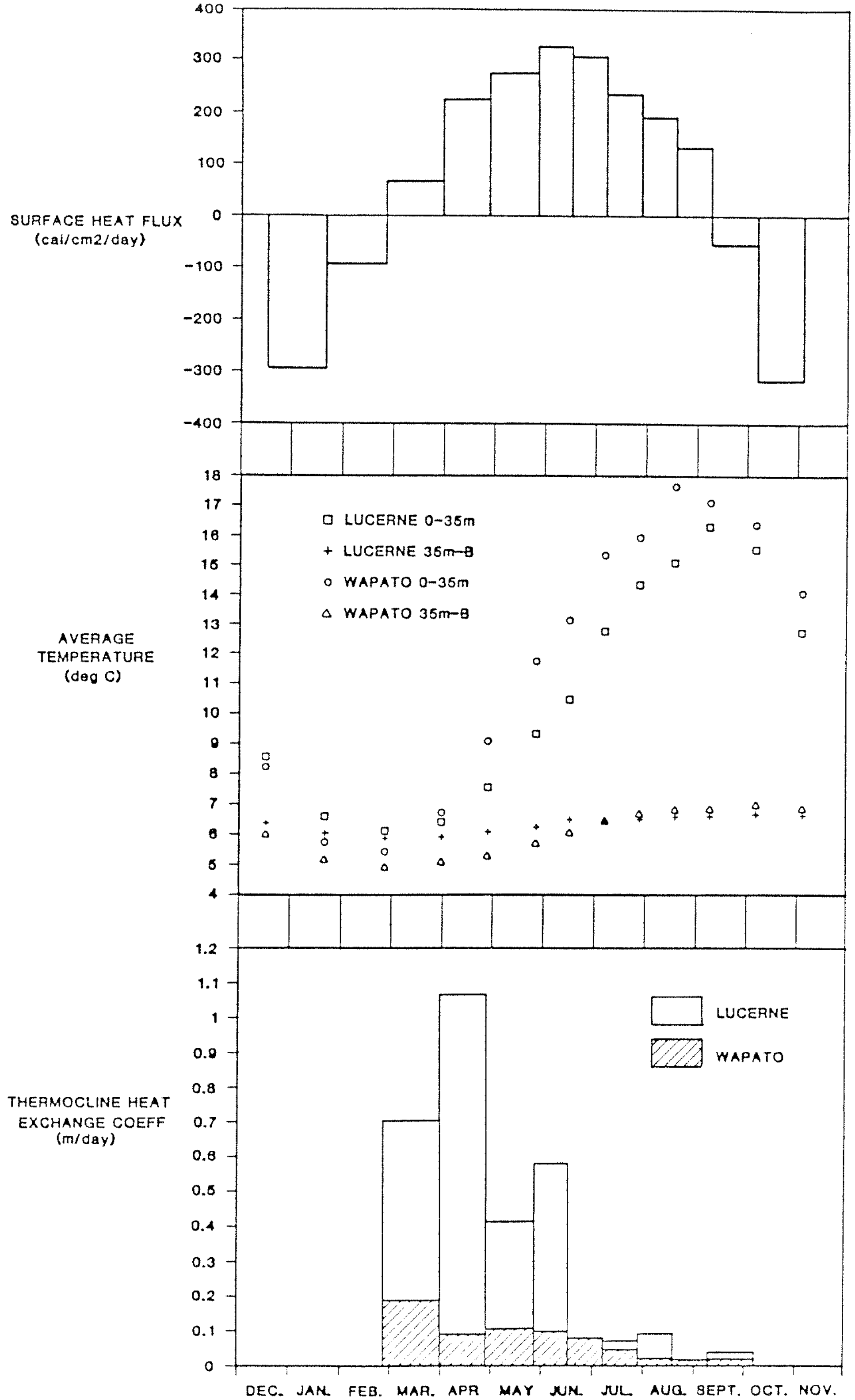


Figure 5.9

THERMAL PROPERTIES AND VERTICAL EXCHANGE RATES FOR LAKE CHELAN (across 35m depth horizon)

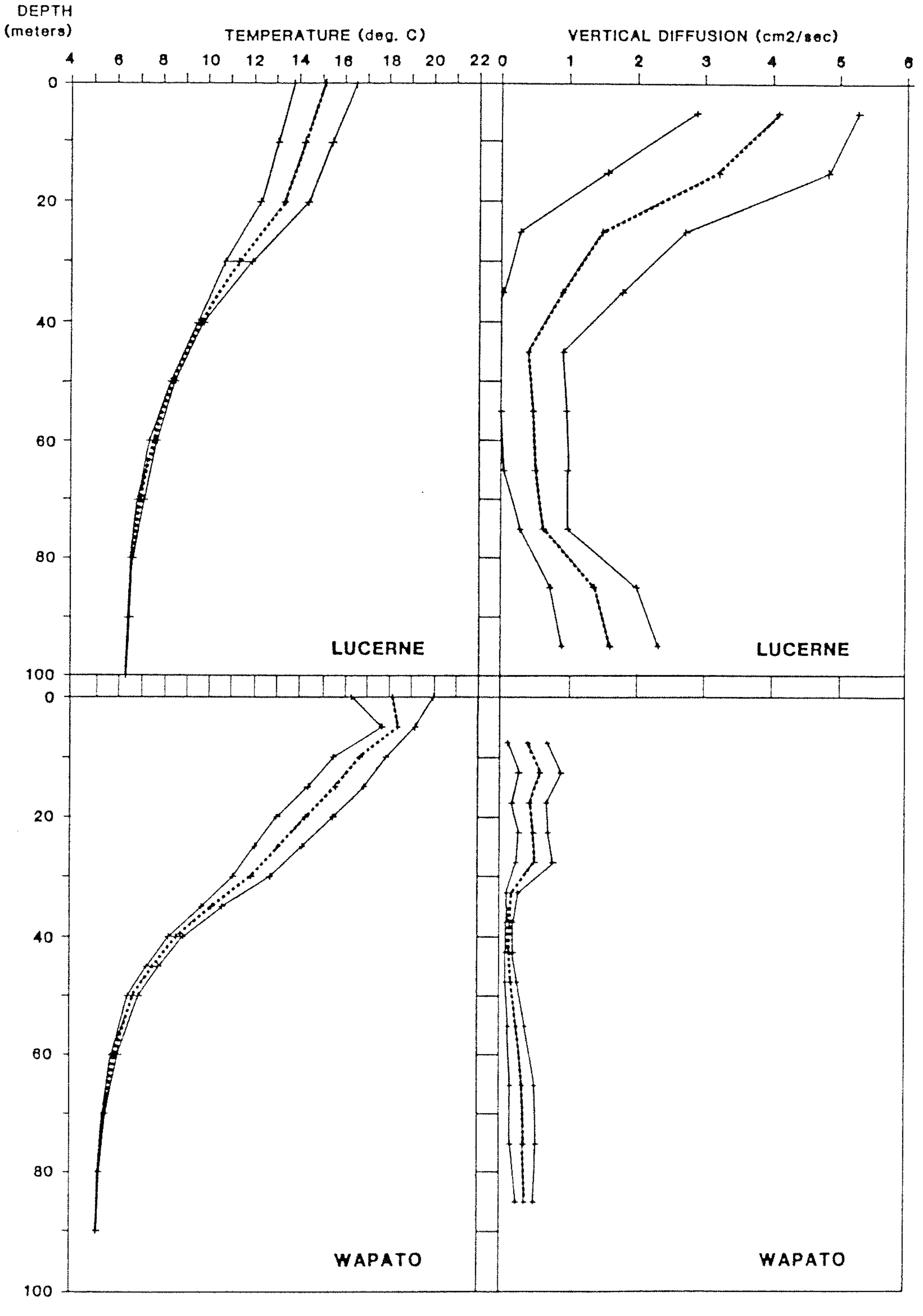


Figure 5.10

THERMAL STRATIFICATION AND
VERTICAL DIFFUSION DURING SPRING-SUMMER
APRIL TO SEPTEMBER, 1987.
(Mean +/- Std. Err.)

both spatially and temporally (Harris, 1980; Denman and Gargett, 1983; Legendre and Demers, 1984). Long deep temperate lakes such as Chelan are especially subject to water movements by wind forcing. In this section, the water motion associated with wind forcing was evaluated for Lake Chelan from a hydraulic standpoint, using field observations.

General Hydraulic Characteristics

A lake's response to forcing is affected by its shape and density stratification. A typical lake has an upper layer (epilimnion) that is usually well mixed by the wind, a thermocline that acts to limit vertical exchange, and a deep layer (hypolimnion) that is usually quiescent and weakly stratified. Often, the thermocline has a small thickness; the structure then consists of two homogeneous layers separated by an interface.

The key variables necessary for assessing a lake's response to the various external forces are described below.

1. Wave Speeds and Periods

Two classes of wave motion are important in describing water movements in lakes. These waves occur at the interfaces of the lake: one at the interface between air and water, often called the free barotropic response or surface seiche; and one at the interface between the epilimnion and hypolimnion, often called the free baroclinic response or internal seiche. Because these waves travel at greatly different speeds, they may be considered as acting independently on lake motion. The time required for a wave to travel from one end of a lake, be reflected at the other end and return, is the wave period. In larger lakes, the surface seiches typically occur at periods of hours, whereas the internal seiches generally have periods on the order of days.

The speed of long waves can be approximated assuming that Lake Chelan and individual subbasins can be represented as relatively shallow, rectangular pools (Imbergen and Hamblin, 1982; also see Figure 2.1). The surface seiche period (T_S) can thus be approximated as $T_S = 2L/(g\underline{h})^{0.5}$, where L is the length of the basin measured approximately along the center of the lake, g is gravitational acceleration, and $\underline{h}$ is the mean depth of the individual basin. For the internal seiche, $\underline{h}$ is replaced with the depth of the epilimnion h_1, and g is replaced with reduced gravity $g' = g \times dp/p$, where p is the average density and dp is the density difference between the epilimnion and hypolimnion. Therefore, the period of the internal seiche is calculated as $T_i = 2L/(g'h_1)^{0.5}$.

Unlike the surface seiche, the period of the internal seiche may be greatly influenced by the shape of each basin, and the internal seiche was therefore approximated using specific bathymetric characteristics of Lake Chelan (calculated as 20 individual subbasins) as input to a simple numeric model (the two-layer Defant procedure; Lemmin and Mortimer, 1986). Previous studies have shown that the model results are successful in predicting internal seiche periods and associated water motions in a variety of lakes.

2. Wind Response

The key variables which express the effects of wind forcing on water movements in a lake include the wind speed immediately above the lake surface, lake fetch, epilimnion depth, and air, epilimnion, and hypolimnion densities (Fischer et al., 1979; Denman and Gargett, 1983; Imbergen, 1985; and Monismith, 1985). A number of analytical formulations have been developed which express the general response to wind forcing in terms of the rate of turbulent overturning of the epilimnion, vertical thermocline displacement, and thermocline erosion. These formulations were applied to Lake Chelan in an effort to describe various wind-related responses. Water motions in long, seasonally stratified lakes such as Chelan are especially subject to the effects of wind.

3. Effect of Earth Rotation

The importance of the earth's rotation on lake dynamics is determined by the horizontal distance over which the Coriolis force balances the pressure gradient generated by a tilted thermocline interface (Fischer et al., 1979). If this distance is less than the width of the lake, it is likely that both wind and buoyancy-driven inflows will follow the shoreline and thus produce a rather complex circulation regime. However, in Lake Chelan, this horizontal distance is at least five times larger than the average lake width (1 to 2 km), and the effect of the earth's rotation may therefore be ignored.

4. Effect of Inflows to the Lake

The circulation regime of a lake may also be greatly influenced by relatively large tributary inputs which can disturb the vertical density structure (Fischer et al., 1979). However, since the water residence time in Lake Chelan is rather long (averaging 10.6 yrs; Table 2.1), the effect of inflows on lake circulation dynamics may generally be ignored. Inflows from the largest tributary, the Stehekin River, appear to have only a localized effect on circulation processes (see Section 5.2.1 above).

Evaluation of Lake Chelan

The key hydraulic characteristics of Lake Chelan were evaluated from measured parameters (Table 5.3).

1. Measured Parameters

The calculated lake motions associated with internal seiches are sensitive to the choices made for the various parameters, including thermocline depth and the densities of the upper and lower layers. As these choices are somewhat subjective, they have been described in some detail.

TABLE 5.3

SELECTED HYDRODYNAMIC DATA FOR THE WAPATO AND LUCERNE BASINS
AUGUST - SEPTEMBER, 1987

Characteristic	Units	Lake Chelan	Basins		Abbreviations
			Wapato	Lucerne	
Talweg length	km	80	19	61	L
Density difference	kg/m^3	1.039	1.039	1.039	Δp
Thermocline depth	m	33	33	33	h_1
Internal wave speed	m/s	0.575	0.575	0.575	c_i
Turbulent friction velocity[a]	m/s	0.0125	0.0125	0.0125	u_*
Wedderburn Number[a]	none	0.87	3.68	1.14	W_e
Time scale for turbulent overturning	hours	0.37	0.37	0.37	T_c
Maximum thermocline displacement	m	38	9	29	a_M
Velocity shear across the thermocline at mid-lake	m/s	0.33	0.078	0.25	dU_s
Rate of mixed layer deepending[b]	m per day	26	26	25	$h(t)$
Seiche period[c]	days	3.22	0.765	2.46	T_i
Seiche frequency[c]	cph	0.0129	0.0545	0.0169	f_i

[a] Computed for a wind speed of 10 m/s.

[b] For a duration of one day and a wind speed of 10 m/s.

[c] First mode of internal seiche.

The depth of the thermocline, where horizontal shearing flow is likely to be most pronounced, was determined from temperature data collected during the lake surveys at Stations 4, 5, 6, 7, and 8 (Figure 3.2). Because a comparison of the observations between the basins did not show a significant spatial difference in stratification depths, the thermocline depths from all stations were averaged. The average thermocline depth in Lake Chelan generally ranged between 30 and 45 meters (100 - 150 ft) throughout the May to November period (Figure 5.11a). These thermocline depths are consistent with the results of heat budget calculations presented earlier (Figure 5.10). During the winter months (December - January) the thermocline eroded to depths of 60 to 80 meters (200 - 250 ft). Thermocline depths could not be reliably determined for the February to April period.

Density differences between the epilimnion and hypolimnion reached a minimum (< 0.2 kg/m^3) during the months of December through March (Figure 5.11b). Peak density differences of approximately 1.2 kg/m^3 were achieved during September.

2. Estimated Parameters

Based on the thermocline depth and density measurements, and using the Seiche period formulation described above, the wave speeds of internal seiches in Lake Chelan were estimated to vary by an order of magnitude from winter to summer (Figure 5.11c). Predicted wave speeds were relatively constant over the summer and fall months, and averaged approximately 0.6 m/sec (1 mph).

The measured parameters were used to estimate the response of Lake Chelan to wind during the summer months when seiche activity is expected to be greatest. Table 5.3 shows estimates of important characteristics described earlier. The interval of July to October was examined most closely because the wave speed was nearly constant and current meter records were available for the same time period. The estimates provided the following description of water movements in Lake Chelan.

A wind speed of 10 m/sec (22 mph) was measured frequently at a variety of stations during the lake surveys, and can be used as a reference speed to estimate likely wind-related water movements. For the Lucerne Basin and Lake Chelan as a whole, 10 m/sec winds appear capable of inducing sizeable internal seiches. The calculated equilibrium amplitude of internal seiches in these basins, for example, is predicted to range between approximately 30 and 40 meters (100 - 130 ft; based on formulations as described by Fischer et al., 1979). However, in the smaller Wapato Basin, the predicted vertical displacement for a 10 m/sec wind is 3 to 4-fold lower, averaging approximately 9 meters (30 ft). Based on these predictions, winds would be substantially less effective in generating internal seiches in the Wapato Basin than in the larger Lucerne Basin.

The predictions of seiche activity in the Lucerne Basin are consistent with field observations. For example, during several of the summer lake

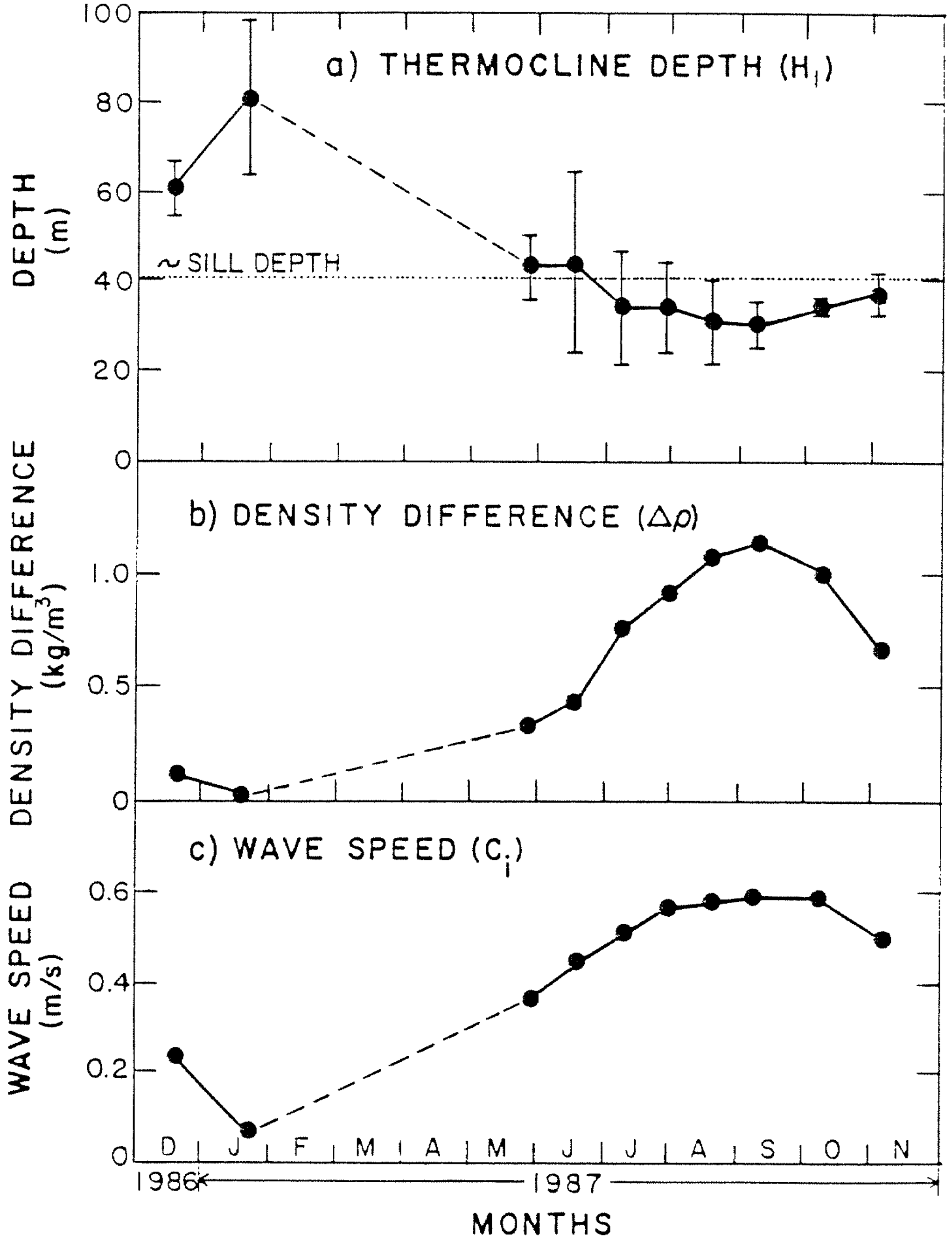


Figure 5.11

SEASONAL CYCLE OF THERMOCLINE DEPTH, DENSITY, AND WAVE SPEED surveys, a significant tilt in the thermocline of the Lucerne Basin was observed (see Appendix G). On June 16, 1987 (Julian day 167), an apparent thermocline tilt of approximately 80 meters (260 ft) was observed between the two ends of the Lucerne Basin, which is equivalent to an apparent amplitude of 40 meters (i.e. one-half the tilt). This value agrees closely with the 30 to 40 meter prediction discussed above. Thermoclines observed within the Wapato Basin were comparatively flat and indicative of reduced seiche activity.

Finally, note that an average of approximately 3 days are required for the thermocline to complete a full cycle or seiche period. This means that wind energy contained in periods of approximately one day or longer (1/4 T_i) will likely drive seiches. Moreover, since the surveys of the lake lasted approximately 10 hours, or approximately 10 to 15 percent of the wave period, the lake surveys provided a reasonable synoptic picture of the thermocline tilt associated with the seiche.

Seiche Currents and Mixing

The previous calculations showed that moderate winds are capable of driving sizeable seiches in Lake Chelan. The amplitude of the seiche in Lucerne Basin is approximately equal to the depth of the upper layer and the sill depth. Internal waves probably are reflected to some extent by the sill so that the basins may act independently to a significant degree. Therefore, currents were explored in each basin as well as Chelan as a whole using observations coupled with a simple seiche model (Lemmin and Mortimer, 1986).

Some indication that the basins act separately was obtained from inspection of the surface seiche. Table 5.4 shows a comparison of the theoretical and observed surface seiche periods for Wapato and Lucerne Basins as if there were a barrier at the sill, and also for the entire lake. The observed periods were taken from spectral peaks computed from the current speeds observed at the sill during the winter of 1986-87 (Figure 5.12; based on Fast-Fourier Transform of velocity data). Of all the time series, this one most clearly shows the signature of the surface seiche, probably because the relatively high energy (and therefore "noisy") internal seiche was poorly developed during the winter months.

The observed surface seiche periods varied only by an average of 10 percent from the theoretical periods (Table 5.4). The observations also show that, as expected, the basins oscillate separately, while the lake also oscillates as an entire system. Since the internal seiche may show a similar result, it was necessary to consider both the individual basins and the entire lake separately.

The calculations discussed previously (i.e. Table 5.3) suggested that water movements associated with internal seiches in the Lucerne Basin (and the whole lake) would likely be most pronounced during the summer stratification period. The period of such seiche movements was predicted to average approximately 2.6 to 3.2 days, which is equivalent to a

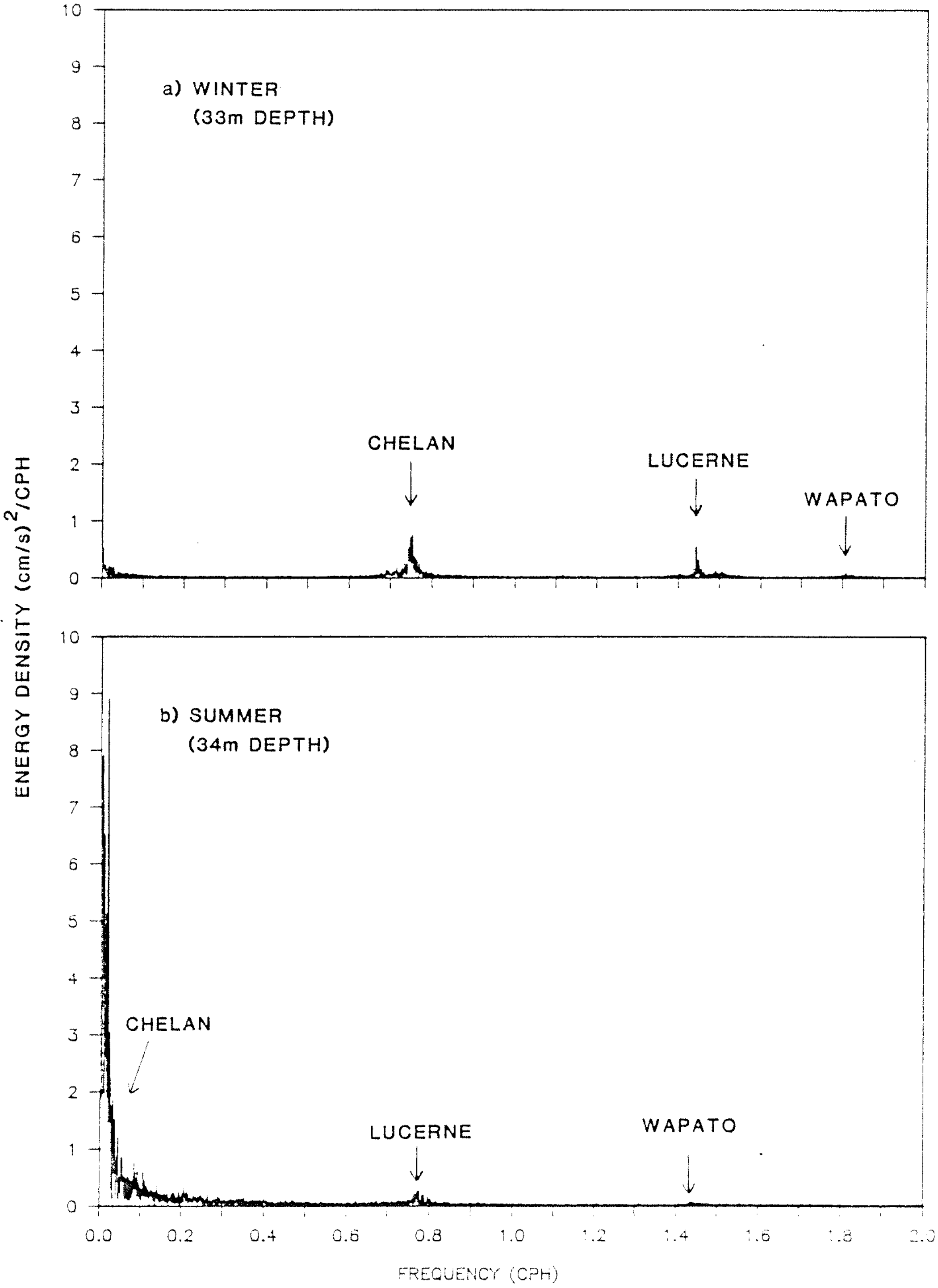


Figure 5.12

SURFACE SEICHE SPECTRA DURING SUMMER AND WINTER PERIODS

TABLE 5.4

SURFACE SEICHE PERIODS AND WAVE SPEEDS

Area	Length (km)	Mean[a] depth (m)	Theoretical period (hours)	Observed period (hours)	wave speed (m/s)
Lake Chelan	81	144	1.2	1.3	34
Lucerne Basin	62	180	0.81	0.69	49
Wapato Basin	19	43	0.52	0.55	19

frequency range of 0.013 to 0.016 cycles per hour (cph). The current meter records from the sill area verify this seiche activity, since the highest energy peaks of currents occurred over a similar frequency range of 0.003 to 0.016 cph (Figure 5.12). Low frequency internal seiche activity was nearly absent during the winter months.

The internal seiche in Lake Chelan can be observed most directly by examining current velocity records from the lake sill during the summer months (Figure 5.13c). Velocities near the bottom of the sill (34 meters depth) regularly approached 0.3 m/sec (0.8 mph), and oscillated at periods ranging from 2 to 10 days. The internal seiche was also recorded in the difference in water surface elevation between the two ends of the lake (Figure 5.13b), and in regular variations in water temperatures at the sill associated with changing lake currents (Evans-Hamilton, unpublished data). The water level oscillation associated with the internal seiche was relatively small, exhibiting an average amplitude of approximately 0.01 meters (0.5 in) over the entire lake. Total daily wind movement recorded in Chelan was also correlated with the water level and current meter observations (Figure 5.13a). Regular wind storms which occurred during the study period at approximately 10 day intervals appeared to at least partially explain the presence of similarly low frequency currents measured at the sill (i.e. to 0.003 cph; Figure 5.12).

Detailed spectral analysis of the sill current meter records did not reveal an internal seiche characteristic of the Wapato Basin. No energy peak which corresponded to the predicted seiche period in this basin (0.8 days; Table 5.3) was observed in the Fast-Fourier Transform analysis. This result further suggests that winds do not excite significant local seiches in the Wapato Basin. This condition may not only be the result of the rather small size of the Wapato Basin, but could be related to a less effective coupling with wind energy. General observations of wind patterns during this study, for example, suggested that much of the wind energy in Wapato Basin is directed perpendicular to the lake axis, while

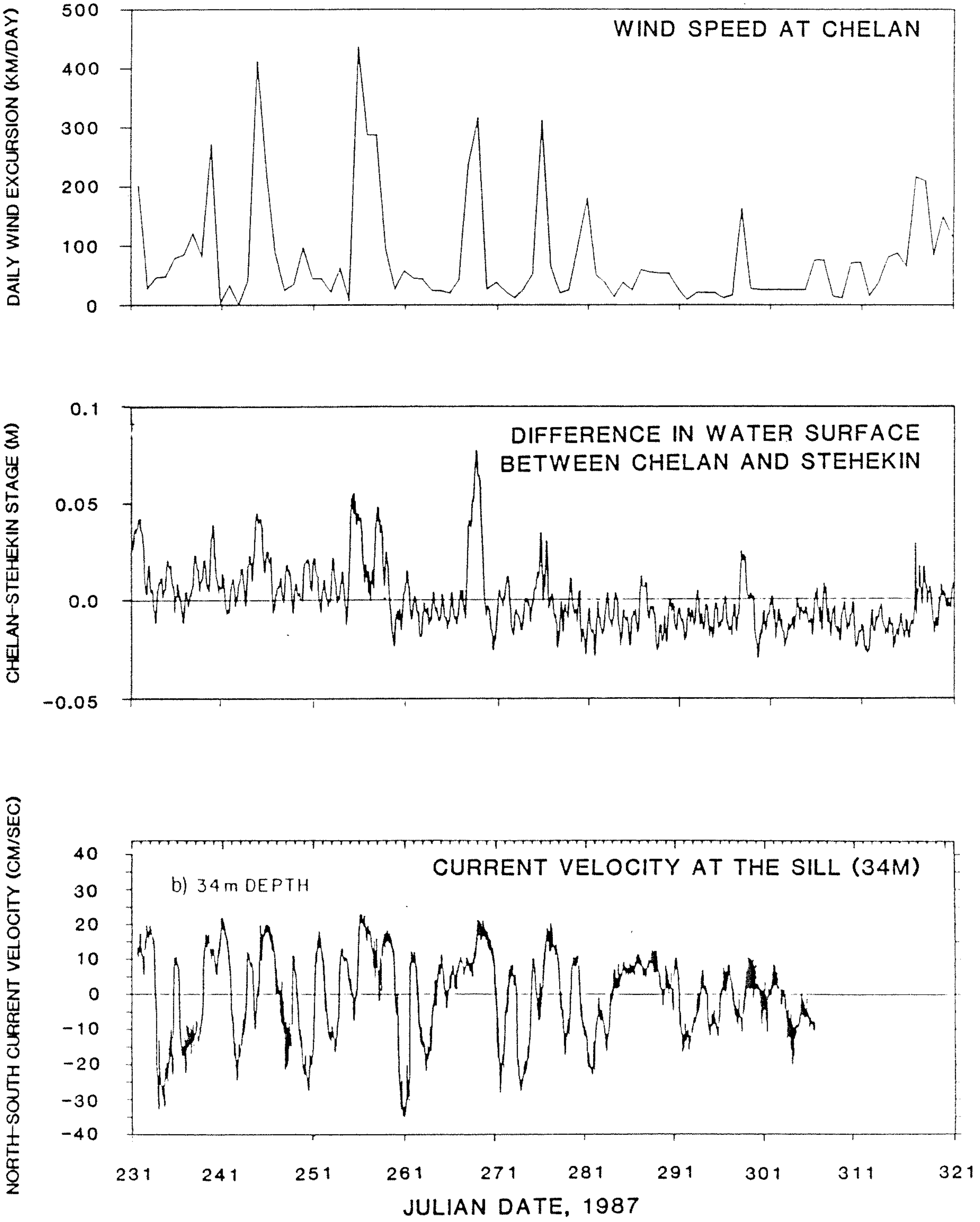


Figure 5.13

TEMPORAL VARIATIONS IN WIND SPEED, LAKE LEVEL, AND CURRENT VELOCITIES DURING AUGUST AND SEPTEMBER, 1987 winds in the Lucerne Basin are predominantly parallel to the talweg. Regardless of the cause, however, internal seiche activity within the Wapato Basin appears minimal.

The spectral peak associated with the greatest amount of energy available for water movement occurred at a period near 2.5 days, which corresponded with the predicted internal seiche frequency in the Lucerne Basin. The peak for Lake Chelan as a whole, however, was two-fold smaller. The relative sizes (i.e. energies) of the spectral peaks suggests the following conceptual model for seiche behavior. Imagine an internal wave beginning with sizeable vertical displacement near Stehekin. When the wave meets the sill, it is primarily reflected because the thermocline depth nearly coincides with the sill depth. However, some energy is nevertheless transmitted through the sill zone and is reflected at the end of Wapato Basin. The time required for the displacement to travel from Stehekin to the sill and back again is the seiche period for the Lucerne Basin. Similarly, the time required for the displacement to travel from Stehekin to the end of Wapato Basin and back again is the seiche period for Lake Chelan as a whole.

To examine the seasonal behavior of the seiches, the period of the seiche in Lucerne Basin was estimated for each lake survey and compared with spectral peaks from the thermographs and current meters (Figure 5.14). In Figure 5.14, the horizontal bars represent the length of record from which the spectral peak was calculated, and the vertical bars represent the range between the frequencies to either side of the frequency associated with the given spectral peak. It can be seen that the observed spectral peaks match the expected seiche periods through most of the year.

2. Seiche Currents

The agreement between the theoretical periods and observed spectral frequencies was sufficiently reasonable to warrant some exploration of theoretical seiche currents throughout Lake Chelan. The distribution of currents and horizontal displacements along the longitudinal axis of the lake were computed using the Lemmin and Mortimer (1986) model assuming that parameters listed in Table 5.3 were representative of hydraulic characteristics within the lake. Model output is summarized in Figure 5.15 for a first mode seiche period of 3.2 days, and presented for a simplified system consisting of an upper mixed layer (i.e. epilimnion) and lower mixed layer (i.e. hypolimnion).

Predicted current speeds away from the sill varied between 0 and 2 cm/sec (0 - 0.04 mph) in the lower layer, whereas at the sill, the speed varied up to 50 cm/sec (1 mph)(Figure 5.15). In the upper layer, current velocities away from the sill varied between 0 and 5 cm/sec (0 - 0.1 mph), whereas at the sill maximum speeds of up to 12 cm/sec (0.3 mph) were predicted. Predicted seiche velocity currents were in general agreement with observations at this location (Figure 5.13). The results of these calculations indicate that currents are generally weak

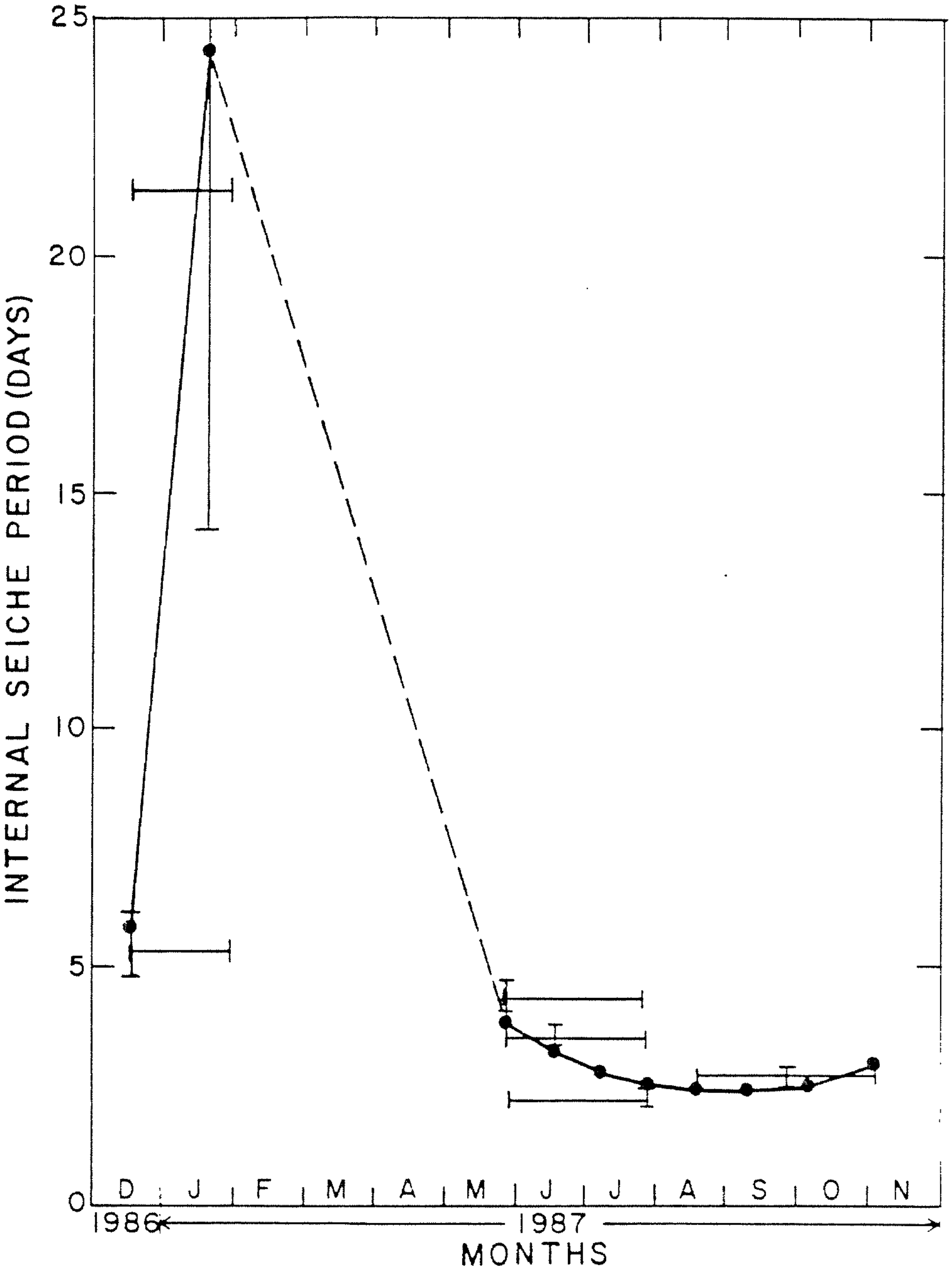


Figure 5.14

SEASONAL CYCLE OF THE INTERNAL SEICHE PERIOD

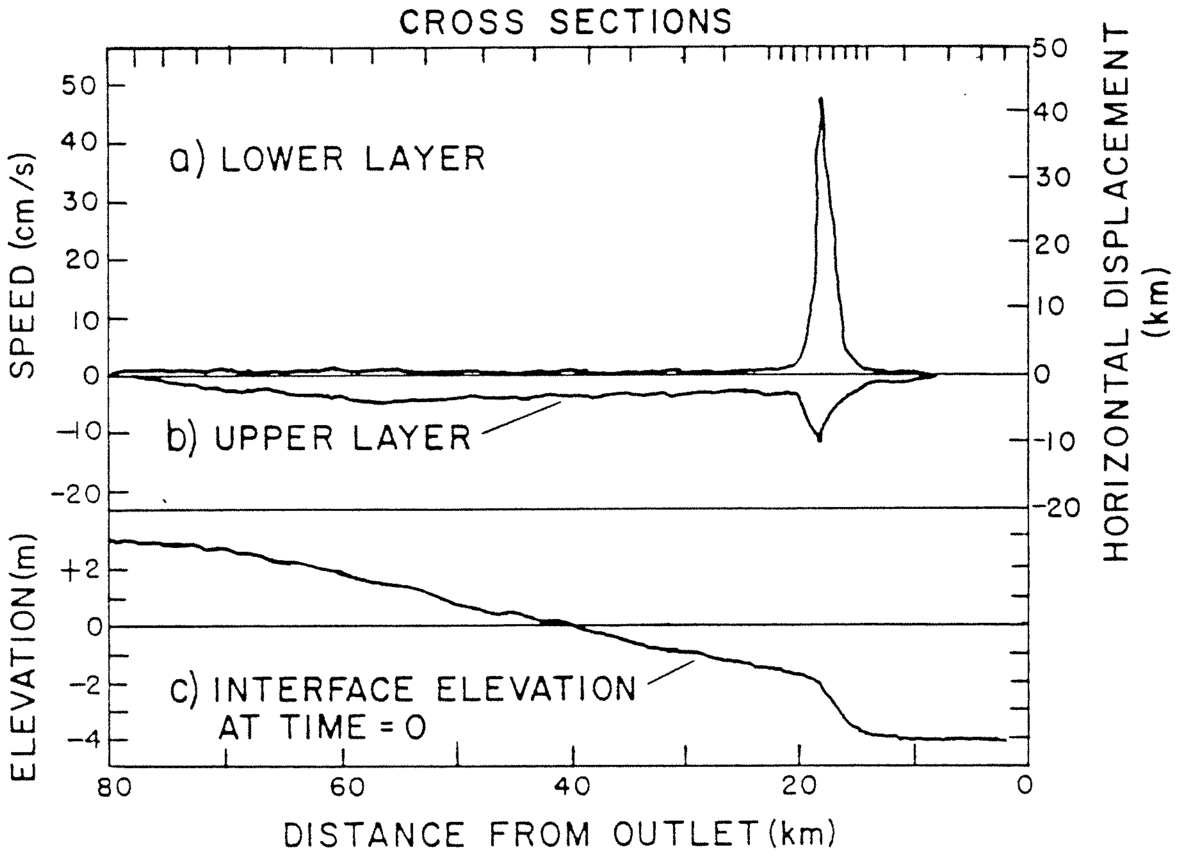


Figure 5.15

DISTRIBUTION OF SEICHE SPEED AND HORIZONTAL DISPLACEMENT throughout the lake, but are greatly magnified near the sill. Observed and predicted seiche currents seen in the sill zone of Lake Chelan are generally comparable in strength and mixing potential to tidal currents in Puget Sound (NOAA, 1988).

The current velocities computed from the seiche model may also be used to estimate horizontal excursions for hypothetical, neutrally buoyant particles (Figure 5.15). For the above noted assumptions, the displacements vary from 0 to 5 km (0 - 3 mi) in the basins, whereas at the sill zone, particles may travel considerably greater distances. The model predicts maximum displacements of 11 and 42 km (7 and 26 mi) for the upper and lower layers, respectively. However, these computations did not consider frictional processes within the lake, which would likely limit these potential excursions to somewhat lower values. Nevertheless, the model results demonstrate that water mixed in the sill zone may travel large longitudinal distances during the several day period of the seiche. As the seiches continue, water near the sill zone will mix and re-mix. Since the excursion represents a substantial fraction of Chelan's length (ca. 1/4 L), the continued mixing by turbulence should quickly mix the upper layer to the depth of the sill. This may explain why, from spring through fall, the thermocline has a depth near that of the sill. Longitudinal mixing will also be discussed in Section 5.2.3 of this report.

Conceptual Models

Several models of flow and mixing within Lake Chelan resulted from inspection of the observations.

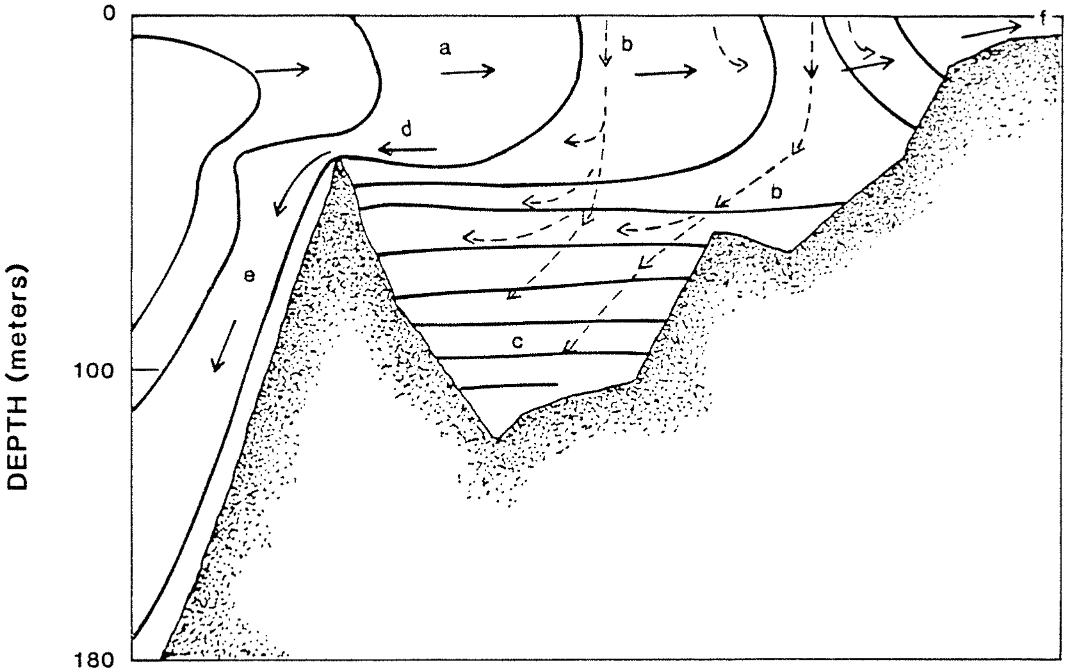
1. Winter Flow

The temperature patterns observed during December, January, and February in the Wapato Basin were similar in a number of respects. They show isotherms descending from the sill to depths of 100 m (300 ft) in the Lucerne Basin. This suggests that cold water flowed from the Wapato Basin across the sill and into the Lucerne Basin. To account for this flow pattern, the conceptual model shown in Figure 5.16 was developed.

To compensate for the outflow of cold water from the Wapato Basin there must be inflows. Undoubtedly, there is some production of cold water in the large shallow areas in the Wapato Basin. This water would tend to sink and provide some replacement water for the outflow over the sill. The tongue of warm water extending from the Lucerne Basin into the Wapato Basin suggests that there is a second source of replacement water.

2. Summer Mixing Process

The results presented earlier indicate that wind-induced seiches are the dominant mechanism causing mixing in the region above sill depth. The current and density structure over the sill lead to substantial mixing, and the substantial horizontal excursions associated with seiches dis-



LEGEND

a–INFLOW FROM LUCERNE TO WAPATO BASIN

b–DOWNFLOW OF COLD WATER PRODUCED IN SHALLOW AREAS NEAR THE SHORE IN WAPATO BASIN

c–DENSE WATER TRAPPED BELOW SILL DEPTH

d–OUTFLOW FROM WAPATO TO LUCERNE BASIN ACROSS THE SILL

e–DOWNFLOW OF COLD WATER FROM THE SILL TO DEPTH IN LUCERNE BASIN

f–OUTFLOW FROM THE DAM

Figure 5.16

CONCEPTUAL WINTER FLOW PATTERN
WITHIN THE WAPATO BASIN

tribute the mixed water over a substantial fraction of the lake within several days (Fig. 5.17). As time progresses, the mixed water may distribute over the entire lake.

5.2.3 Interbasin Mixing - Specific Conductance Mass Balance

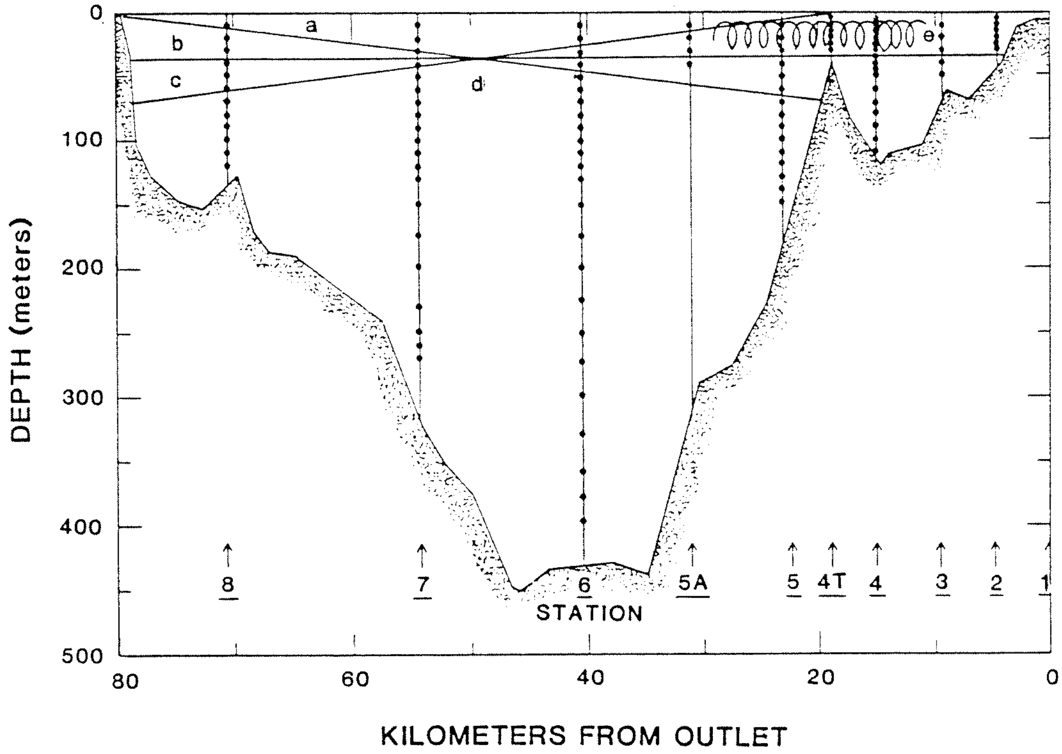
Another approach to evaluating interbasin exchange of water and pollutants is through the use of water mass "tagging", using specific conductance differences. This approach can often provide a direct measure of water exchange associated with relatively low velocity diffusion currents, and has successfully been applied in a wide variety of lakes (Chapra and Reckhow, 1983).

One of the more important physical characteristics which determines the response of a lake to nutrient or contaminant inputs is the water exchange (or flushing) rate (OECD, 1982). The two morphometric basins of Lake Chelan vary more than ten-fold in terms of bulk volume (Table 2.1), and may also exhibit similar differences in water exchange rates. If mixing between these basins was minimal, the Lucerne and Wapato Basins could respond quite differently to changes in nutrient or contaminant loadings. However, considering the rather strong interbasin currents observed during the study period, water from the Wapato Basin may at least partially mix (upflow) into the Lucerne Basin.

In order to further quantify the important interbasin mixing process, specific conductance was used as a natural tracer of water movement. The specific conductance of tributary inputs varies more than ten-fold from one end of the lake to the other (Table 5.5). This variation is largely the result of dramatic climatic changes which occur across the basin (Figures 5.1 and 5.5). The flow-weighted average specific conductance in the Stehekin River over the study period was 44 ± 2 umhos/cm, while the flow-weighted average tributary input into the eastern end of the Wapato Basin (i.e. east of Wapato Point) was approximately 420 ± 280 umhos/cm. By evaluating longitudinal and vertical variations of specific conductance, principal features of a lake's circulation and mixing regime can often be assessed (Chapra and Reckhow, 1983; Welch et al., 1986).

During the months of maximum vertical mixing (i.e. February and March, 1987), no significant longitudinal or depth variations in specific conductance (< 0.5 umhos/cm difference) were observed within Lake Chelan, thus indicating that the lake was rather well mixed. However, soon after stratification, a discernable structure to the specific conductance profiles was apparent (Figure 5.18). Progressive reductions in specific conductance from middle regions of Lake Chelan towards the Stehekin River appeared to be a direct result of the mixing of and dilution by this river input.

The isopleths in Figure 5.18 reveal that both longitudinal and vertical differences in specific conductance were most pronounced within the Wapato Basin. These differences were likely the result of both the higher concentration in inputs to, and reduced mixing within, the Wapato



LEGEND

a - EXTREME POSITION OF THE THERMOCLINE ON THE DOWNSTROKE NEAR THE SILL

b - MEAN DEPTH OF THE THERMOCLINE

c - EXTREME POSITION OF THE THERMOCLINE ON THE UPSTROKE NEAR THE SILL

d - NODE POSITION OF THE FIRST HARMONIC FOR THE INTERNAL SEICHE IN LUCERNE BASIN

e - WATER MIXED BY TURBULENCE OVER THE SILL WHERE THE TURBULENCE EXTENDS HORIZONTALLY OVER THE DISTANCE OF THE EXCURSION ASSOCIATED WITH THE INTERNAL SEICHE FOR LAKE CHELAN

Figure 5.17

CONCEPTUAL MIXING PATTERN
OF LAKE CHELAN DURING LATE SUMMER

TABLE 5.5. SUMMARY OF SPECIFIC CONDUCTANCE VALUES AND DISSOLVED SOLIDS LOADINGS

	<------ TOTAL DISSOLVED SOLIDS (10) ------>								
	Sp. Conductance (umho/cm @25C)			TDS Load (kg/year * 1,000)			Areal TDS Export (kg/km2-yr)		
	Mean	+/-	SE	Mean	+/-	SE	Mean	+/-	SE
LUCERNE BASIN TRIBUTARIES									
Stehekin R. (1)	44.5	+/-	1.7	39,400	+/-	2,750	47,400	+/-	3,310
Railroad Ck. (1)	49.7	+/-	3.5	6,340	+/-	606	37,800	+/-	3,610
Mitchell Ck (2)	314.8	+/-	6.6	579	+/-	180	17,600	+/-	5,470
Greens Landing (2)	529.0	+/-	40.5	467	+/-	201	17,420	+/-	3,190
Misc. Lucerne Basin Tribs (3)	123.3	+/-	33.0	33,400	+/-	11,200	34,267	+/-	11,447
TOTAL LUCERNE TRIBUTARIES	-		-	80,200	+/-	11,550	-		-
WAPATO BASIN TRIBUTARIES									
First Ck (2)	124.3	+/-	2.8	411	+/-	135	8,490	+/-	2,800
Purtteman Gulch (2)	609.7	+/-	5.6	416	+/-	109	26,300	+/-	6,870
Knapp Coulee (2)	636.9	+/-	16.8	35	+/-	13	4,840	+/-	1,810
USBR Drain No. 6 (2)	435.7	+/-	15.0	124	+/-	46	61,400	+/-	22,900
USBR Drain No. 8 (2)	560.7	+/-	7.6	134	+/-	74	123,000	+/-	67,900
Measured Stormwater (4)	-		-	80	+/-	66	55,000	+/-	45,400
Misc. Stormwater (4)	-		-	642	+/-	530	55,000	+/-	45,400
Misc. Wapato Basin Tribs (5)	-		-	1,330	+/-	1,022	13,200	+/-	10,110
TOTAL WAPATO TRIBUTARIES	-		-	3,170	+/-	1,170	-		-
OTHER SOURCES									
Precipitation	-		-	-		-	-		-
TOTAL INFLOWS	-		-	83,370	+/-	11,609	-		-
OUTFLOWS OR LOSSES									
Chelan R. (6)	58.4	+/-	0.8	75,100	+/-	4,350	-		-
Irrigation Withdrawal (7)	57.5	+/-	0.2	791	+/-	129	-		-
TOTAL OUTFLOWS	-		-	75,900	+/-	4,350	-		-
NET UNACCOUNTED LOSSES (8)	-		-	7,500	+/-	12,400	-		-
ESTIMATED IN-LAKE RETENTION (9)	-		-	9.0%	+/-	14.8%	-		-

FOOTNOTES:

1) Stehekin R and Railroad Ck based on average annual flow and regression estimate of concentration.
2) Based on average annual discharge and flow-weighted average concentration.
3) Based on average areal export from Stehekin R, Railroad and Mitchell Cks.
4) Urban runoff based on Draft Comprehensive Planning report estimates of developed area and average areal export rates.
5) Based on average areal export from First Ck, Purtteman Gulch and Knapp Coulee.
6) Chelan R outflow based on annual average flow and lake concentration at outlet.
7) Irrigation withdrawal based on total reported withdrawals and Wapato basin annual average epilimnetic concentrations.
8) Calculated as INFLOWS - OUTFLOWS.
9) Retention calculated as (1-(OUTFLOWS/INFLOWS))*100%
10) Total dissolved solids calculated as TDS (mg/L) = 0.7 * Sp Cond (umhos/cm)(APHA, 1985).

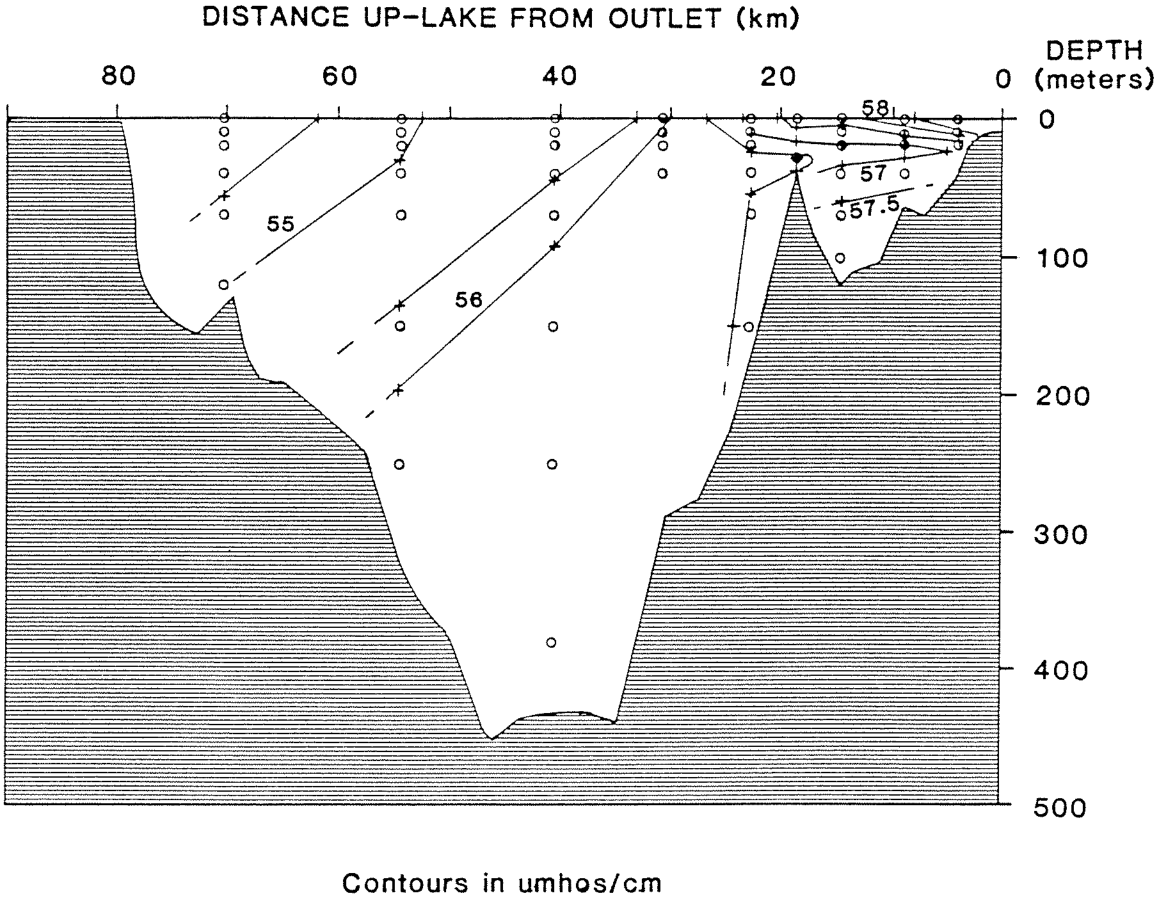


Figure 5.18

LAKE CHELAN AVERAGE SPECIFIC CONDUCTANCE LONGITUDINAL PROFILE APRIL TO SEPTEMBER, 1987

Basin, relative to that in the Lucerne Basin (see above). A relatively low conductance "tongue" of water (at 56.5 to 57.0 umhos/cm) appears to have entered from the Lucerne Basin at a metalimnetic depth of approximately 20 to 40 m. Higher external inputs to the Wapato Basin caused a progressive downstream increase in specific conductance, resulting in a seasonal average level in the lake outlet of approximately 60 umhos/cm.

In order to utilize the specific conductance data to assess the longitudinal mixing intensity within Lake Chelan, a simplified compartmental model of the lake was constructed (Chapra and Reckow, 1983). The compartmental model assumed that each lake sampling station was representative of the surrounding segment of the lake, and that data collected at each station could be simplified into epilimnetic and hypolimnetic components. A schematic of the model is presented in Figure 5.19.

Longitudinal distributions of seasonally averaged epilimnetic conductance values are presented in Figure 5.20, which reveals significant longitudinal variations in this tracer constituent. One of the more interesting features in Figure 5.20 is the rather uniform specific conductance which existed between kilometer 15 and 23 (Stations 4, 4-T, and 5). This occurred despite inputs from tributaries with high conductance within the reach. The uniformity in this area of the lake contrasted markedly with observations on either side of the reach, which exhibited significant ($P < 0.05$) longitudinal increases in conductance. The relative uniformity of values between kilometer 15 and 23 is suggestive of an effective mixing zone, bounded by segments with less longitudinal mixing. Furthermore, the center of the apparent mixing zone coincided with the location of relatively strong and dispersive currents measured within the sill zone of the lake (see Figures 5.13, 5.15, and 5.17). Based on this correspondence, it is likely that the apparent mixing within this zone was directly related to internal seiche currents and their resultant water exchange.

The epilimnetic conductance data suggest that Lake Chelan could be separated into four reaches with potentially different mixing characteristics. These divisions are depicted in Figure 5.20 by different slopes in conductance per unit distance over the April to September period. Assuming that the seasonal conductance data represent steady-state conditions, the longitudinal mixing intensity (represented by the longitudinal bulk diffusion coefficient) within each reach "i" can be calculated after Chapra and Reckhow (1983) as follows:

$$E_i' = \frac{Q_i C_i + W_i - Q_{i+1} C_{i+1} - E_{v,i} \tilde{o} C_{v,i}}{C_{i+1} - C_i}$$

where E_i' is the longitudinal bulk diffusion coefficient (m3/day), Q is the longitudinal advective discharge entering (Q_i) and leaving (Q_{i+1}) reach i (m^3/day), C is the equivalent total dissolved solids (TDS) concentration at each longitudinal end of reach i (mg/L), $E_{v,i}$ is the

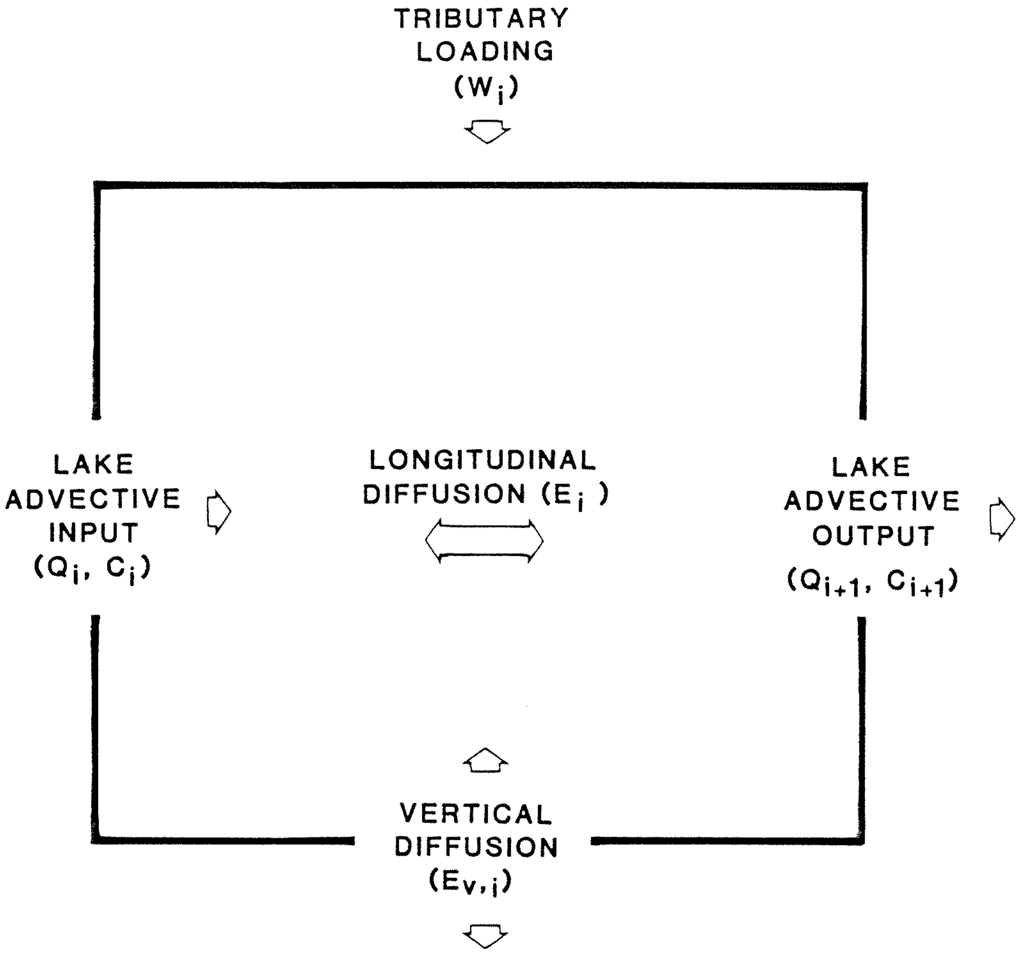


Figure 5.19

SCHEMATIC OF COMPARTMENTAL MIXING MODEL

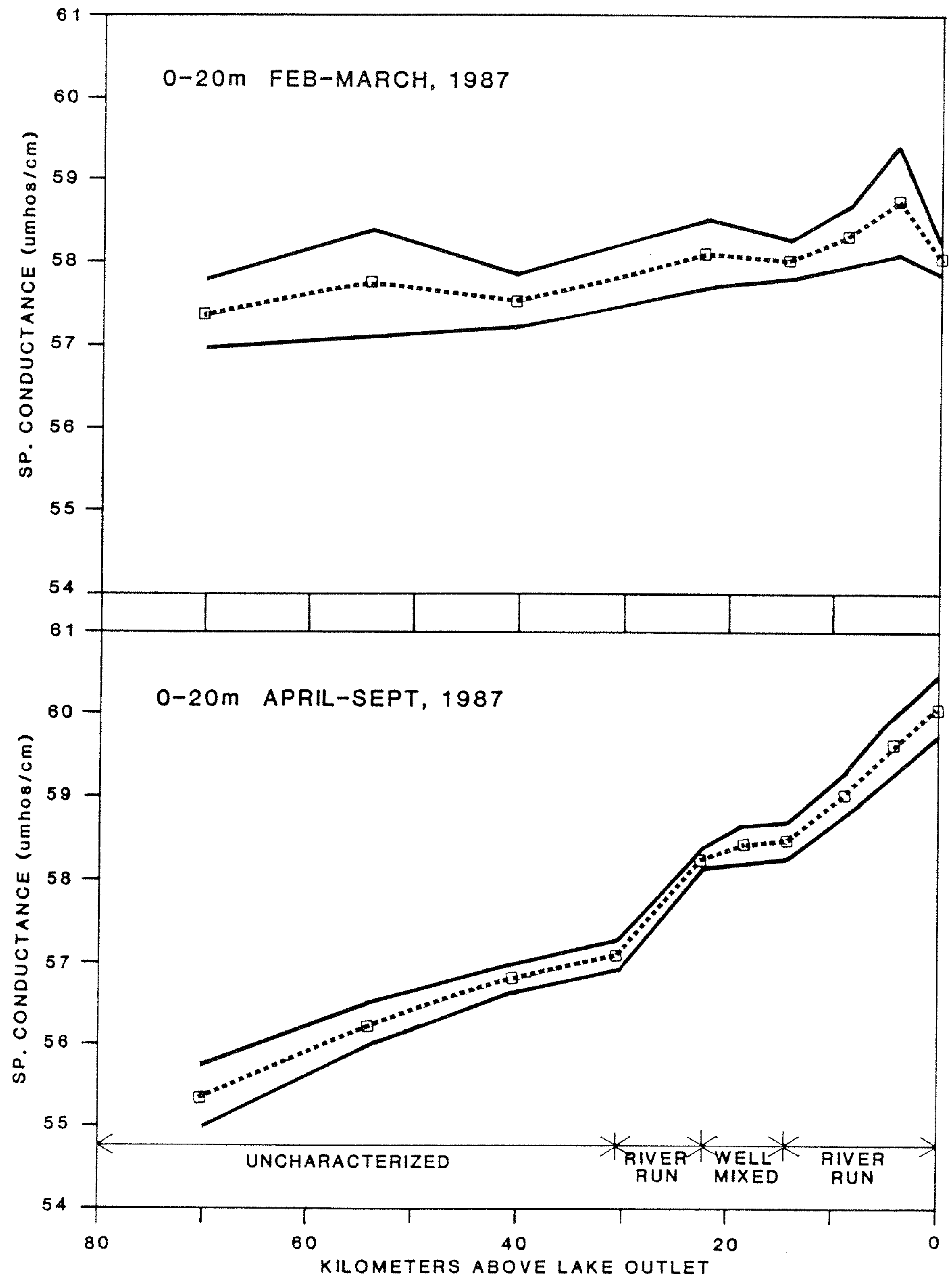


Figure 5.20

LONGITUDINAL VARIATION OF
EPILIMNETIC CONDUCTANCE
(Mean -/- Std. Err.)

vertical bulk diffusion coefficient across the thermocline (m^3/day), $\tilde{o}C_{v,i}$ is the average difference in TDS concentration between the epilimnion and hypolimnion (mg/L), and W_i is the TDS loading into reach i (gms/day). TDS concentrations and loadings were derived directly from the specific conductance data (see Table 5.5). The seasonal (April to September) vertical bulk diffusion coefficient ($E_{v,i}$) was derived from the heat budget calculations, and ranged between 0.5 x 10^6 and 1.5 x 10^6 m^3/day for the three lake reaches examined (see below).

The results of longitudinal bulk diffusion estimates for the three reaches for which sufficient data existed to perform such calculations are summarized in Table 5.6 (i.e. excluding "uncharacterized" reaches uplake of km 31 for which sufficient data were not available).

TABLE 5.6

SUMMARY OF LONGITUDINAL DIFFUSION CALCULATIONS

LAKE REACH	Bulk Diffusion (10^6 m^3/day; mean ± std. err.)
Kilometer 31 - 23	8 ± 6
Kilometer 23 - 15	24 ± 14
Kilometer 15 - 0	1 ± 2

The calculated seasonal average longitudinal diffusion rates can be compared with the average April-September advective discharge through these three reaches of approximately 4 x 10^6 m^3/day (1,700 cfs). Based on this comparison, the sill reach (km 23 - 15) appears to have been sufficiently diffusive to have largely overcome advective flow. Significant longitudinal mixing appears to have been a result of the relatively strong internal seiche currents in this area of Lake Chelan (see Section 5.2.2).

The other two adjacent reaches, especially the eastern Wapato Basin (km 15 - 0), exhibited a much reduced mixing intensity. Circulation within the eastern Wapato Basin appears to have been largely advective, analogous to "river-run" lake conditions (Chapra and Reckhow, 1983). The average residence time of epilimnetic water within the eastern 15 km of Lake Chelan was approximately 3 months over the April to September period. As will be discussed in subsequent sections of this report, these hydrodynamic characteristics have important implications regarding the sensitivity of Lake Chelan to nutrient and contaminant inputs.

5.3 Suspended and Deposited Solids

The transparency of Lake Chelan, as determined with routine Secchi disk measurements, averaged 15 ± 1 meters during the winter months, and 12 ± 1 meters during summer (Table 5.7). No significant differences ($P > 0.10$) were observed among lake stations. Relative to other northern temperate lakes, the transparency of Lake Chelan is rather high, and indicative of oligotrophic (unproductive) conditions (OECD, 1982). Similarly, the turbidity of lake surface waters was consistently low, and averaged 0.4 NTU throughout the study period at all stations.

As stated previously, Lake Chelan receives substantial quantities of glacial meltwater runoff, primarily from the Stehekin River and Railroad Creek drainages. These waters carry large quantities of fine silt materials, which impart an aqua coloration to the uplake area. The clear water allows deep penetration of green and blue light, and the small glacial flour particles tend to scatter relatively more green than blue light (Goldman and Horne, 1983).

Loading calculations suggested that the combined discharge from the Stehekin River and Railroad Creek drainages annually contribute approximately 5,200 ± 700 metric tons (MT; 6,000 short tons) of suspended solid materials to Lake Chelan, or about two-thirds of the total abiotic input (Table 5.8). Inputs from other tributaries were comparatively minor.

Biotic contributions to sedimentation are often quite difficult to determine in a lake such as Chelan. Based on an average ^{14}C incorporation of 30 ± 9 gmC/m^2-yr (see below) and typical cell stochiometries, approximately 10,000 ± 3,000 MT/yr of cell mass may be produced within the lake. However, because of significant (but variable) grazing and decomposition losses, only a fraction of this production may actually contribute to net sediment and, therefore, affect net attenuation. The available data, therefore, suggest that algal inputs may be a significant (but presently unquantified) component of total sediment accumulation.

The largest anthropogenic (man-related) input of suspended solids to Lake Chelan was attributable to stormwater runoff from developed areas of the Wapato Basin (Table 5.8). Assuming monitoring data collected from two major catchments within the City of Chelan were generally representative of stormwater within the basin, approximately 160 ± 130 MT/km^2-yr (0.7 tons/acre-yr) of suspended solids were exported to Lake Chelan from developed lands in the Wapato Basin. Most of this input appeared to be attributable to the runoff of sand and silt materials added to local roadways during the winter months to facilitate transportation. A total estimated stormwater loading to the Wapato Basin of roughly 2,100 MT/yr (25 % of the total) was extrapolated based on available data, although the uncertainty in this estimate is considerable. Shoaling areas were apparent in the vicinity of many of the stormwater outfalls.

TABLE 5.7

AVERAGE EPILIMNETIC WATER QUALITY CHARACTERISTICS

	SPRING/SUMMER								FALL/WINTER							
	April - Sept								Oct - March							
PARAMETER	Lucerne Basin				Wapato Basin				Lucerne Basin				Wapato Basin			
	Mean	+/-	SE	N	Mean	+/-	SE	N	Mean	+/-	SE	N	Mean	+/-	SE	N
Thermocline Depth (m)	35	+/-	3	27	30	+/-	3	7	53	+/-	8	21	49	+/-	9	6
Euphotic Zone Depth (m)	45	+/-	5	-	43	+/-	7	-	47	+/-	6	-	55	+/-	14	-
Secchi Disk Depth (m)	12.1	+/-	0.5	35	11.4	+/-	0.5	7	15.4	+/-	0.5	26	15.4	+/-	1.4	4
Light Extinction (/m)	0.104	+/-	0.005	24	0.112	+/-	0.007	14	0.102	+/-	0.01	12	0.087	+/-	0.013	9
Temperature (deg C)	13.2	+/-	0.4	105	15.9	+/-	0.44	70	10	+/-	4.59	78	9.55	+/-	0.584	60
pH	7.67	+/-	0.02	90	7.85	+/-	0.019	67	7.37	+/-	0.04	78	7.44	+/-	0.043	57
Dissolved Oxygen (mg/L)	10.6	+/-	0.1	90	10.4	+/-	0.077	67	10.3	+/-	0.074	78	10.4	+/-	0.11	57
Dissolved Oxygen (% sat)	105	+/-	1	90	110	+/-	0.6	67	94.6	+/-	0.8	78	93.4	+/-	1.1	57
Turbidity (NTU)	0.412	+/-	0.026	30	0.394	+/-	0.017	28	0.374	+/-	0.048	25	0.437	+/-	0.042	23
Total Suspended Solids (mg/L)	0.1	+/-	0.0	3	0.299	+/-	0.122	10	0.3	+/-	0.1	3	0.303	+/-	0.077	7
Specific Conductance (umho/cm 25C)	56.7	+/-	0.1	105	59.1	+/-	0.16	68	54.8	+/-	0.27	77	55.5	+/-	0.285	58
Soluble Reactive P (ug P /L)	0.331	+/-	0.038	105	0.535	+/-	0.115	68	0.433	+/-	0.102	78	0.297	+/-	0.033	58
Total Soluble P (ug P /L)	1.41	+/-	0.24	14	1.6	+/-	0.433	13	0.842	+/-	0.238	12	1.02	+/-	0.247	13
Total P (ug P /L)	3.01	+/-	0.18	105	3.45	+/-	0.218	69	3.03	+/-	0.266	78	3.41	+/-	0.385	57
Ammonia N (ug N /L)	8.67	+/-	0.76	103	11.3	+/-	1.34	68	16.1	+/-	2.46	78	14	+/-	2.29	58
Nitrate + Nitrite N (ug N /L)	43.6	+/-	1.8	105	44.2	+/-	7.18	67	45.5	+/-	2.65	78	44.4	+/-	2.74	58
Total Soluble N (ug N /L)	70.6	+/-	7.3	14	55.7	+/-	11.8	14	95.5	+/-	17	12	70.5	+/-	9.61	13
Total N (ug N /L)	103	+/-	6	105	105	+/-	7.28	67	78.7	+/-	4.22	78	80.1	+/-	4.19	56
Total N:P Ratio	34.2	+/-	2.8	-	30.4	+/-	2.9	-	26.0	+/-	2.7	-	23.5	+/-	2.9	-
Active Chlorophyll a (ug/L)	0.646	+/-	0.033	103	0.655	+/-	0.04	64	0.614	+/-	0.017	77	0.766	+/-	0.026	54
Phaeopigments (ug/L)	0.331	+/-	0.021	103	0.277	+/-	0.024	64	0.291	+/-	0.023	59	0.342	+/-	0.024	54
Phytoplankton Cell Volume (mm3/m3)	81.8	+/-	11.1	14	58.8	+/-	8.8	19	20.1	+/-	2.5	12	35.1	+/-	4.9	12
Fecal Streptococcus (No./100 ml)	2.3	+/-	0.5	38	3.0	+/-	1.0	97	<2.	+/-	<2.	24	2.5	+/-	1.4	24
Fecal Coliform (No./100 ml)	<2.	+/-	<2.	9	2.6	+/-	0.8	39	<2.	+/-	<2.	12	2.2	+/-	0.4	18
Total Coliform (No./100 ml)	2.2	+/-	0.5	9	4.9	+/-	3.0	39	<2.	+/-	<2.	12	4.2	+/-	1.9	18

TABLE 5.8. SUMMARY OF AVERAGE ANNUAL TOTAL SUSPENDED SOLIDS BUDGET CALCULATIONS

	TOTAL SUSPENDED SOLIDS								
	Concentration (ug/L)			Annual Load (Metric Tons/year)			Areal Export (kg/km2-yr)		
	Mean	+/-	SE	Mean	+/-	SE	Mean	+/-	SE
LUCERNE BASIN TRIBUTARIES									
Stehekin R. (1)	3,257	+/-	384	4,120	+/-	541	4,960	+/-	651
Railroad Ck (1)	5,671	+/-	2,501	1,030	+/-	460	6,140	+/-	2,740
Mitchell Ck (2)	1,454	+/-	338	4	+/-	1	116	+/-	45
Greens Landing (3)	-		-	6	+/-	4	95	+/-	60
Misc. Lucerne Basin Tribs (2)	2,283	+/-	438	884	+/-	353	907	+/-	362
TOTAL LUCERNE TRIBUTARIES	-		-	6,040	+/-	793	-		-
WAPATO BASIN TRIBUTARIES									
First Ck (3)	-		-	5	+/-	3	95	+/-	60
Purtteman Gulch (3)	-		-	2	+/-	1	95	+/-	60
Knapp Coulee (3)	-		-	1	+/-	0	95	+/-	60
USBR Drain No. 6	368	+/-	102	0	+/-	0	74	+/-	34
USBR Drain No. 8 (3)	-		-	0	+/-	0	95	+/-	60
Measured Stormwater (4)	-		-	235	+/-	191	162,000	+/-	132,000
Misc. Stormwater (4)	-		-	1,890	+/-	1,540	162,000	+/-	132,000
Misc. Wapato Basin Tribs (3)	-		-	10	+/-	6	95	+/-	60
TOTAL WAPATO TRIBUTARIES	-		-	2,410	+/-	1,550	-		-
OTHER SOURCES									
Precipitation	-		-	-		-	-		-
TOTAL INFLOWS	-		-	8,450	+/-	1,741	-		-
OUTFLOWS OR LOSSES									
Chelan R. (5)	327	+/-	87	601	+/-	163	-		-
Irrigation Withdrawal (6)	300	+/-	76	6	+/-	2	-		-
TOTAL OUTFLOWS				607	+/-	163	-		-
NET UNACCOUNTED LOSSES (7)	-		-	7,570	+/-	1,750	-		-
ESTIMATED IN-LAKE RETENTION (8)	-		-	92.6%	+/-	2.9%	-		-

FOOTNOTES:

1) Stehekin R and Railroad Ck based on average annual flow and regression estimate of concentration.
2) Based on average annual discharge and flow-weighted average concentration.
3) Based on average areal export from Mitchell Ck and USBR Dr. No. 6.
4) Urban runoff based on Draft Comprehensive Planning report estimates of developed area and average areal export rates.
5) Chelan R outflow based on annual average flow and lake concentration at outlet.
6) Irrigation withdrawal based on total reported withdrawals and Wapato basin annual average epilimnetic concentrations.
7) Calculated as INFLOWS - OUTFLOWS.
8) Retention calculated as (1-(OUTFLOWS/INFLOWS))*100%

The sedimentation rate within deeper areas of Lake Chelan was determined in sediment cores collected from two locations within the Lucerne and Wapato Basins. Based on core analysis of ^{210}Pb activities, the recent (approx. 1976 - 1986) bulk sedimentation rates calculated for these two deep locations were similar, and averaged 0.36 ± 0.10 cm/yr (0.14 in/yr). Sediment flux at these sites was also similar, and averaged 98 ± 21 gm dry wt/m^2-yr. However, because of the small number of sediment cores examined in this large lake (only 2 stations sampled over a 135 km^2 area), and the presence of a large sediment source at one end of the basin (i.e. the Stehekin River), these sedimentation rate values may not be representative of average lake conditions. A considerably greater number of core samples would likely be required to fully evaluate lake sedimentation characteristics.

Surficial (0 - 5 cm) materials encountered within the Lake Chelan core samples were largely represented by clayey silts, with minor quantities of sand. However, a much wider range of material types was observed in surficial sediment samples collected from other locations in Lake Chelan. These samples were obtained for a separate evaluation of contaminant residues (see below). Accumulated materials on the lake bottom ranged from clayey silt to gravel materials, and substantial amounts of woody debris were often encountered within the Lucerne Basin. The heterogeneity in sediment materials, particularly within the Lucerne Basin, likely reflects the occurrence of landslides and other event-related inputs within mountainous areas of the basin.

5.4 Nutrients - Mass Balances

The principal algal nutrients, nitrogen (N) and phosphorus (P), generally control the biological productivity of aquatic systems, and thus indirectly determine a wide range of important water quality characteristics (OECD, 1982; Murray, 1987). Because previous assays performed on Lake Chelan waters identified both N and P as potentially limiting nutrients to algal growth in the lake (EPA, 1977), both of these nutrients were investigated in detail during this study.

In general, the lowest concentrations of both N and P were observed in lake samples. Summaries of average epilimnetic concentrations of various nutrient fractions observed over the study period are presented in Table 5.7, and reflect the ultraoligotrophic character of Lake Chelan (OECD, 1982). In particular, the measured levels of TP, which averaged 3.2 ± 0.2 ug/L in lake surface waters throughout the year, are among the lowest concentrations reported in the Northwest. TN concentrations within lake surface waters averaged 93 ± 6 ug/L, which also represents comparatively low values. However, as discussed below, N does not appear to be as limiting to algal growth in Lake Chelan as P.

In contrast to the rather low concentrations of nutrients observed in Lake Chelan, comparatively high concentrations of these nutrients occurred in many of the tributary inputs, particularly within the Wapato Basin. For example, TP and TN concentrations measured in orchard drainage samples (Agricultural Drains No. 6, 8, and 11) averaged 209 ± 19 ug/L and 8,160 ± 280 ug/L, respectively. Nearly all (> 90 %) of the TP and TN measured at these agricultural drainage sites was attributable to soluble reactive (and bio-available) forms such as SRP and NO_3. Drain samples exhibited P and N concentrations very similar to average levels observed in groundwater collected from orchard areas of the Lower Chelan Basin (Table 4.5).

The extensive tributary monitoring performed during this investigation was conducted largely for the purpose of developing nutrient budgets for the lake, and formed the basis for subsequent assessments of existing and potential cultural eutrophication within the basin. A summary of the lake mass balance calculations for TP and TN are presented in Tables 5.9 and 5.10, respectively. Tributary inputs to the Lucerne Basin and direct precipitation to the lake surface accounted for approximately 90 percent of the total estimated input of these nutrients to Lake Chelan. Based on these data, and considering that the great majority of land in the Lucerne Basin is undeveloped forest, most of the existing nutrient input to Lake Chelan is attributable to natural sources within the basin.

The flow-weighted concentrations calculated for the Lucerne tributaries and precipitation inputs are quite low (7.7 ug/L and 200 ug/L for TP and TN, respectively). The significance of these largely natural sources to lake budget calculations, therefore, is simply a result of their very large discharge. It is interesting to note that the ultimate source of nutrients exported from the Lucerne Basin tributaries may be atmospheric deposition (i.e. versus geologic weathering). This condition is suggested by the measured areal atmospheric deposition of nutrients (28 ± 11 kg P/km^2-yr and 1,100 ± 140 kg N/km^2-yr), which were considerably greater than areal export values (nutrient loading per unit land area) calculated for the Lucerne tributaries (Tables 5.9 and 5.10). The atmospheric deposition rates measured within the Lake Chelan Basin are similar to values reported elsewhere in the Northwest (Funk et al., 1976; Patmont and Leon, 1983).

A portion of the estimated wastewater inputs of phosphorus and nitrogen (320 ± 270 kg P/yr and 2,600 ± 1,800 kg N/yr; Table 4.7) may have been represented in tributary sampling data. However, considering that many of the existing septic systems within the basin were located in close proximity to the lakeshore and generally not in the sampled drainages, potential "double accounting" is expected to be minor. Additionally, the observed uncertainties in wastewater loading rates make refinement of the lake mass balance calculations unwarranted.

Wastewater inputs of TP and TN to Lake Chelan represented approximately 3 ± 2 percent and 1 ± 1 percent, respectively, of the total loadings to Lake Chelan (Tables 5.9 and 5.10). Stormwater loadings were generally similar to these values, and contributed roughly 6 ± 6 percent of the TP loading and 1 ± 1 percent of the TN load. Input loads of TP and TN to Lake Chelan specifically designated to be from agricultural sources to Lake Chelan were difficult to quantify. This is due both to the rather diffuse nature of these inputs and probable attenuation of nutrients within the Roses Lake, Dry Lake, and Wapato Lake systems, which received a large proportion of the agricultural discharges. Nevertheless, based

TABLE 5.9. SUMMARY OF AVERAGE ANNUAL TOTAL PHOSPHORUS LOAD AND AREAL EXPORT

	TOTAL PHOSPHORUS								
	Concentration (ug P/L)			Annual Load (kg P/year)			Areal Export (kg P/km2-yr)		
	Mean	+/-	SE	Mean	+/-	SE	Mean	+/-	SE
LUCERNE BASIN TRIBUTARIES									
Stehekin R. (1)	6.7	+/-	0.4	8,500	+/-	687	10.2	+/-	0.8
Railroad Ck (1)	5.9	+/-	0.5	1,080	+/-	109	6.4	+/-	0.6
Mitchell Ck (2)	22.4	+/-	2.2	59	+/-	19	1.8	+/-	0.6
Greens Landing (2)	82.7	+/-	9.8	104	+/-	46	1.7	+/-	0.7
Misc. Lucerne Basin Tribs (2)	7.5	+/-	1.0	2,880	+/-	1,090	3.0	+/-	1.1
TOTAL LUCERNE TRIBUTARIES	-		-	12,600	+/-	1,290	6.1	+/-	0.6
WAPATO BASIN TRIBUTARIES									
First Ck (2)	11.6	+/-	0.9	55	+/-	19	1.1	+/-	0.4
Purtteman Gulch (2)	186.0	+/-	10.9	181	+/-	48	11.5	+/-	3.1
Knapp Coulee (2)	235.0	+/-	28.6	19	+/-	7	2.6	+/-	1.0
USBR Drain No. 6 (2)	187.0	+/-	15.9	76	+/-	29	37.8	+/-	14.4
USBR Drain No. 8 (2)	120.0	+/-	12.8	41	+/-	23	37.5	+/-	21.1
Measured Stormwater (3)	-		-	138	+/-	143	95.1	+/-	98.9
Misc. Stormwater (3)	-		-	1,110	+/-	1,160	95.1	+/-	98.9
Misc. Wapato Basin Tribs (4)	-		-	510	+/-	463	5.0	+/-	4.6
TOTAL WAPATO TRIBUTARIES	-		-	2,130	+/-	1,260	11.3	+/-	6.7
OTHER SOURCES									
Precipitation (5)	-		-	3,710	+/-	1,500	27.5	+/-	11.1
TOTAL INFLOWS	-		-	18,440	+/-	2,346	7.7	+/-	1.0
OUTFLOWS OR LOSSES									
Chelan R. (6)	2.5	+/-	0.4	4,590	+/-	702	-		-
Irrigation Withdrawal (7)	3.4	+/-	0.2	67	+/-	12	-		-
TOTAL OUTFLOWS	-		-	4,660	+/-	702	-		-
NET UNACCOUNTED LOSSES (8)	-		-	13,800	+/-	2,450	-		-
ESTIMATED IN-LAKE RETENTION (9)	-		-	74.7%	+/-	6.7%	-		-

FOOTNOTES:

1) Stehekin R and Railroad Ck based on average annual flow and regression estimate of concentration.
2) Based on average annual discharge and flow-weighted average concentration.
3) Urban runoff based on Draft Comprehensive Planning report estimates of developed area and average areal export rates.
4) Based on average areal export from First Ck, Purtteman Gulch and Knapp Coulee.
5) Precipation based on areal loading rates applied to lake surface area.
6) Chelan R outflow based on annual average flow and lake concentration at outlet.
7) Irrigation withdrawal based on total reported withdrawals and Wapato basin annual average epilimnetic concentrations.
8) Calculated as INFLOWS - OUTFLOWS.
9) Retention calculated as (1-(OUTFLOWS/INFLOWS))*100%

TABLE 5.10

SUMMARY OF AVERAGE ANNUAL TOTAL NITROGEN LOAD AND AREAL EXPORT

	TOTAL NITROGEN								
	Concentration			Annual Load			Areal Export		
	(ug N/L)			(Kg N/year)			(kg N/km2-yr)		
	Mean	+/-	SE	Mean	+/-	SE	Mean	+/-	SE
LUCERNE BASIN TRIBUTARIES									
Stehekin R. (1)	132	+/-	15	167,000	+/-	21,700	201	+/-	26
Railroad Ck (1)	137	+/-	28	25,000	+/-	5,310	149	+/-	32
Mitchell Ck (2)	53	+/-	6	139	+/-	46	4	+/-	1
Greens Landing (2)	601	+/-	101	757	+/-	345	12	+/-	5
Misc. Lucerne Basin Tribs (2)	100	+/-	8	38,700	+/-	13,900	40	+/-	14
TOTAL LUCERNE TRIBUTARIES	-		-	232,000	+/-	26,300	112	+/-	13
WAPATO BASIN TRIBUTARIES									
First Ck (2)	89	+/-	10	422	+/-	146	9	+/-	3
Purtteman Gulch (2)	5,093	+/-	373	4,960	+/-	1,345	314	+/-	85
Knapp Coulee (2)	4,457	+/-	166	351	+/-	132	48	+/-	18
USBR Drain No. 6 (2)	7,556	+/-	249	3,080	+/-	1,147	1,520	+/-	568
USBR Drain No. 8 (2)	8,653	+/-	317	2,940	+/-	1,630	2,700	+/-	1,500
Measured Stormwater (3)	-		-	302	+/-	263	208	+/-	181
Misc. Stormwater (3)	-		-	2,430	+/-	2,110	208	+/-	181
Misc. Wapato Basin Tribs (4)	-		-	12,500	+/-	13,000	124	+/-	129
TOTAL WAPATO TRIBUTARIES	-		-	27,000	+/-	13,400	143	+/-	71
OTHER SOURCES									
Precipitation (5)	-		-	151,000	+/-	19,300	1,122	+/-	143
TOTAL INFLOWS	-		-	410,000	+/-	35,267	171	+/-	15
OUTFLOWS OR LOSSES									
Chelan R. (6)	91	+/-	15	168,000	+/-	28,600	-		-
Irrigation Withdrawal (7)	94	+/-	5	1,840	+/-	314	-		-
TOTAL OUTFLOWS	-		-	170,000	+/-	28,600	-		-
NET UNACCOUNTED LOSSES (8)	-		-	240,000	+/-	45,400	-		-
ESTIMATED IN-LAKE RETENTION (9)	-		-	58.5%	+/-	9.2%	-		-

FOOTNOTES:

1) Stehekin R and Railroad Ck based on average annual flow and regression estimate of concentration.
2) Based on average annual discharge and flow-weighted average concentration.
3) Urban runoff based on Draft Comprehensive Planning report estimates of developed area and average areal export rates.
4) Based on average areal export from First Ck, Purtteman Gulch and Knapp Coulee.
5) Precipation based on areal loading rates applied to lake surface area.
6) Chelan R outflow based on annual average flow and lake concentration at outlet.
7) Irrigation withdrawal based on total reported withdrawals and Wapato basin annual average epilimnetic concentrations.
8) Calculated as INFLOWS - OUTFLOWS.
9) Retention calculated as (1-(OUTFLOWS/INFLOWS))*100%

on the distribution of agricultural activities within the basin and available loading data, agricultural land uses may have contributed roughly 8 ± 4 percent of the TP loading and 14 ± 8 percent of the TN load to Lake Chelan.

The combined anthropogenic inputs of TP and TN presently represent approximately 10 to 25 percent of the total identified mass loadings to Lake Chelan. These inputs were derived from a relatively small percentage of the total watershed area, since less than four (4) percent of basin lands have been developed (Table 2.2).

The influence of various land use activities on nutrient loadings is best addressed in terms of areal export rates. A summary of observed areal export data from natural areas, agricultural areas, stormwater runoff in developed areas, and septic system leachate areas within the Lake Chelan Basin is presented in Table 5.11. Septic system loadings were calculated assuming a dwelling density of one per acre, and an average 2.4 individuals per household (based on 1980 U.S. Census data).

Phosphorus export rates from all three use categories of developed land were generally 10 to 100 times greater than nearby largely undeveloped drainages (Table 5.11). Nitrogen export rates exhibited similar increases above background within the stormwater runoff and septic system land use categories. Nitrogen loading was by far the highest within the agricultural areas, with observed export rates approximately 100 to 1,000 times greater than estimated natural conditions. These differences in areal export have important implications regarding possible impacts from future development in the basin (see Section 6.0).

Most of the phosphorus which entered Lake Chelan appears to have been deposited and retained in lake sediments. Based on the difference between measured surface inputs and outputs in the mass balance (Table 5.9), an estimated 75 ± 7 percent of the annual average TP load was retained within the lake. This value is in general agreement with the water exchange rate/retention relationship observed in a wide variety of other northern temperate lakes (OECD, 1982).

The rate of TP retention per unit area (102 ± 18 mg P/m^2-yr) obtained from the mass balance is considerably lower than the sedimentation rate calculated from the ^{210}Pb dating and sediment data (980 ± 490 mg P/m^2-yr; based on two sediment cores which correspond to the mean depth of Lake Chelan). However, the difference between these two estimates is not statistically significant ($P > 0.05$), largely because of the uncertainty in the sedimentation rate calculated from the ^{210}Pb data. Although the apparent discrepancy between these two estimates could have been due to a number of possible conditions, it is considered likely that the difference is simply an artifact of variations in sediment accumulation throughout the lake, which were not well represented in the two coring samples (see Section 5.3 above). All information considered, the phosphorus sedimentation rate within Lake Chelan appears to be best estimated using the Table 5.9 mass balance.

TABLE 5.11

SUMMARY OF NUTRIENT EXPORT RATES BY LAND USE TYPE

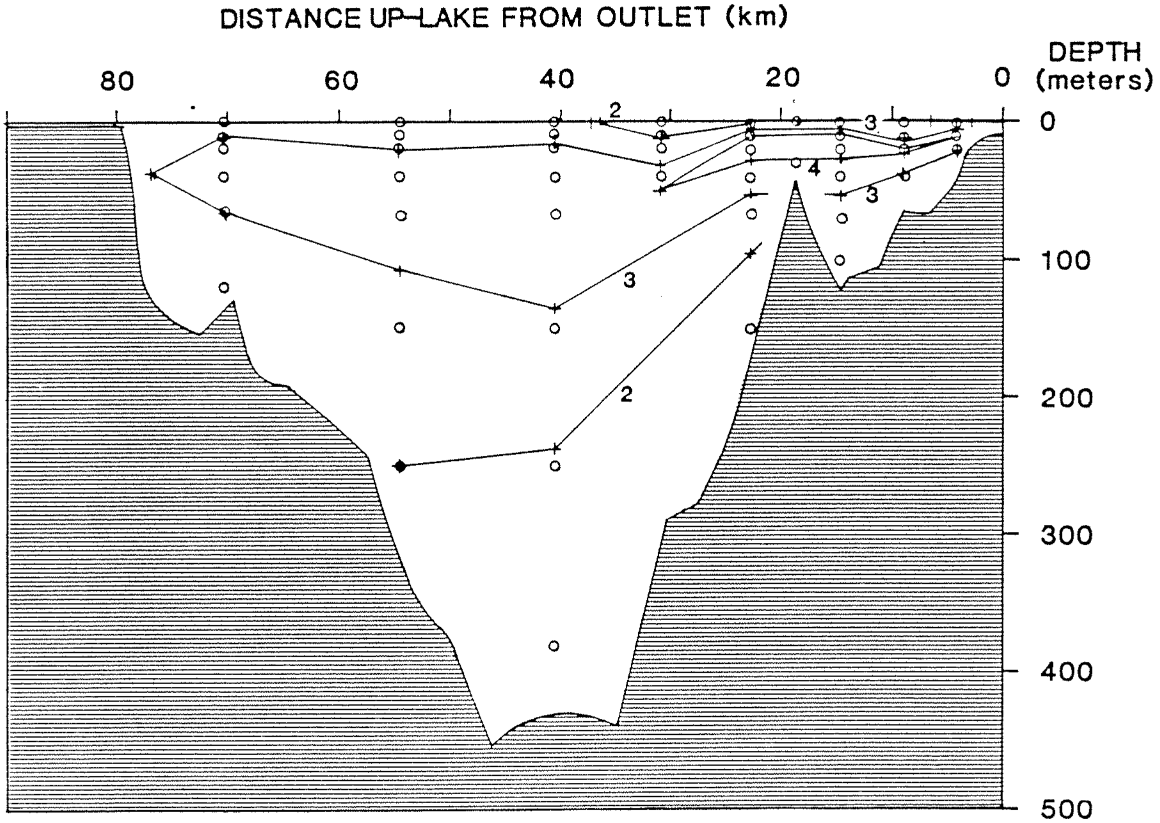
	AREAL EXPORT RATE (kg/km^2-yr; mean ± s.e.)	
	Phosphorus	Nitrogen
NATURAL AREAS[a]:		
Soluble Reactive	1 ± 1	4 ± 4
Total	2 ± 1	6 ± 4
AGRICULTURAL AREAS[b]:		
Soluble Reactive	34 ± 18	2,000 ± 1,400
Total	38 ± 18	2,100 ± 1,400
URBAN RUNOFF[c]:		
Soluble Reactive	31 ± 31	130 ± 110
Total	95 ± 99	210 ± 180
SEPTIC SYSTEMS[d]:		
Total Soluble	68 ± 57	550 ± 380

a.) Natural drainages represented by First Creek and Mitchell Creek.
b.) Agricultural drainages represented by USBR Drains No. 6, 8, and 11 (apple orchard areas).
c.) Urban/suburban runoff areas represented by the two largest storm drainages within the City of Chelan.
d.) Septic system loadings calculated based on a dwelling density of 1/acre, 2.4 persons/dwelling, and measured septic systems loadings and soil removals; see Section 4.5 of this report.

Based on the nitrogen mass balances, approximately 58 ± 9 percent of the total input to Lake Chelan was lost or retained in the lake (Table 5.10). The remaining load was discharged through the lake outlet. The somewhat lower apparent retention of nitrogen (relative to P) may reflect the greater demand and incorporation of P into algal cells (see below), and subsequent sedimentation. In addition, soluble P has a much greater affinity for particles than soluble N and, therefore, would be more susceptible to sedimentation.

5.5 Nutrients - In-lake Distributions

As stated previously, no significant ($P > 0.05$; ANOVA) seasonal variations in TP concentrationa were observed at any of the lake stations. However, significant ($P < 0.05$) spatial variations were encountered within the lake, and are depicted in Figure 5.21. The lowest TP concentrations (1 - 2 ug/L) typically occurred at greatest depth in the Lucerne Basin. Conversely, the highest levels of TP (4 - 5 ug/L) were consistently observed at depths of 10 and 20 m at Stations 4 (km 15) and 5 (km 23).



Contours in ug P/L

Figure 5.21

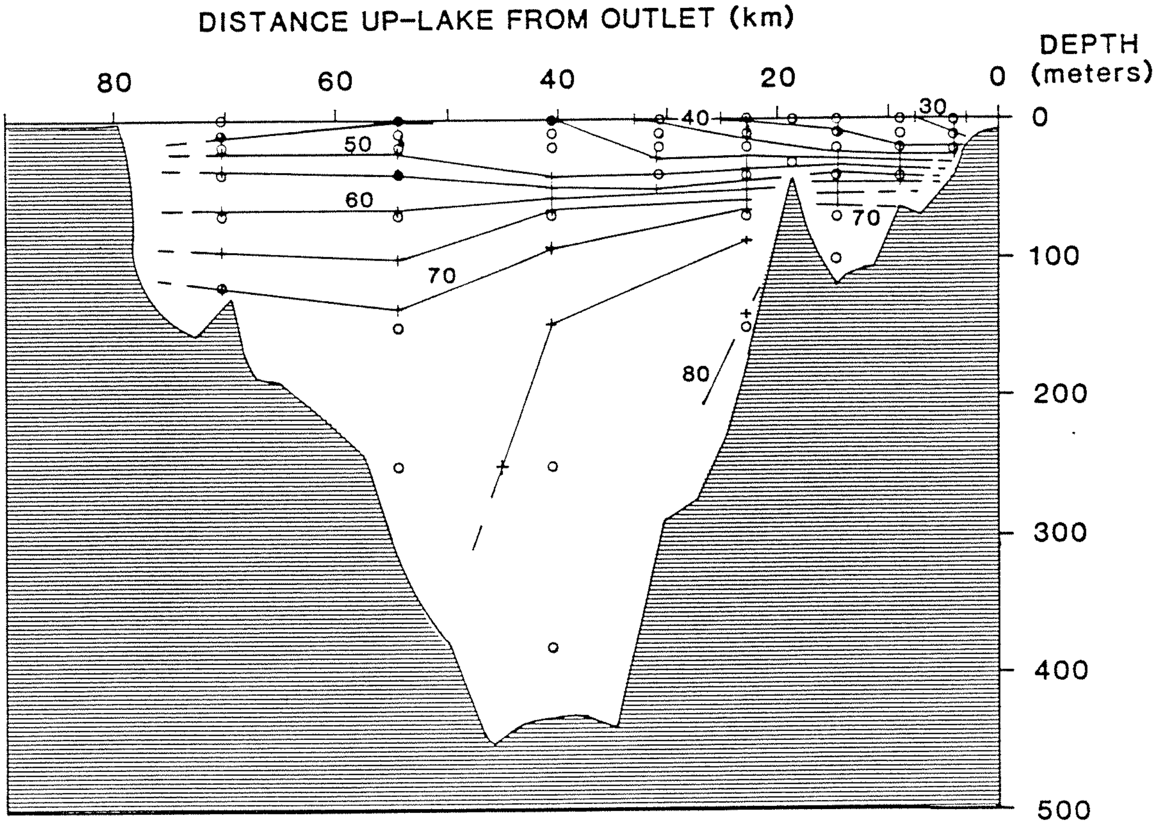
LAKE CHELAN AVERAGE TOTAL PHOSPHOROUS LONGITUDINAL PROFILE APRIL TO SEPTEMBER, 1987

These locations coincided with a zone of relatively intense longitudinal mixing, which was identified from specific conductance and current meter data (see Section 5.2 above). This area also received a considerable TP input from adjacent orchard areas (e.g. Stink Creek and Agricultural Drains 6 - 8). Apparently, relatively large inputs of phosphorus to the vicinity of km 15 to 23 were mixed into this lake reach and did not readily disperse into adjacent segments of the lake. Such an apparent separation of lake segments is consistent with the conceptual model of lake mixing discussed previously, and has important consequences regarding the lake's response to nutrient inputs.

No significant ($P > 0.05$; ANOVA) seasonal or spatial variations in SRP, TN, or NH_4 concentration were observed in the lake over the study period. However, NO_2+NO_3 concentrations varied considerably both temporally and spatially. The highest concentrations of this nutrient (70 - 80 ugN/L) were observed during the winter months at all surface stations, and at depth during the spring-summer stratification period (Figure 5.22). The lowest NO_2+NO_3-N concentrations (20 - 30 ug/L) were encountered near the lake outlet toward the end of the stratification season (i.e. August - September, 1987). These variations are indicative of the seasonal uptake of this algal nutrient within the lake, and the progressive decline in concentration as the water circulates down-lake. Like the TP data discussed above, these patterns are consistent with the "river-run" conceptual circulation model of Lake Chelan during the spring-summer stratification season.

The ratios of nitrogen to phosphorus in lake waters are generally reliable indicators of which nutrient may be more limiting to algal growth (Healey and Hendzel, 1980; Forsberg, 1980). Although N and P requirements of algae are known to vary, in general N:P ratios exceeding roughly 7:1 to 15:1 (by wt.) indicate that phosphorus is the more limiting nutrient. Figure 5.23 presents a summary of temporal changes in SRP and TSIN concentrations within epilimnetic waters of the Lucerne and Wapato Basins. The ambient TSIN:SRP always exceeded 20:1 (by wt.) in these samples, which is suggestive of phosphorus limitation. Observed TN:TP ratios within the lake epilimnion also support a conclusion of phosphorus limitation, since spring-summer ratios averaged 34:1 (± 3:1) in the Lucerne Basin, and 30:1 (± 3:1) in the Wapato Basin. Measured N:P ratios in particulate matter (including algae) obtained from these epilimnetic samples were similarly high and above the 15:1 upper threshold range. All information considered, phosphorus appears to be the principal nutrient presently limiting algal growth in Lake Chelan.

Seasonal depletion of TSIN in epilimnetic waters appeared to be rather extensive during the growing season, which contrasted with the comparatively stable nature of SRP (Figure 5.23). This phenomenon appears to be typical of P-limited ultraoligotrophic lakes, and likely results from different rates at which each nutrient is recycled within the epilimnion (Hendrey and Welch, 1974; Richey et al., 1981). However, TSIN:SRP ratios were generally maintained above 15:1 (by wt.) within the lake, and nitrogen limitation of algal growth is therefore unlikely.



Contours in ug N/L

Figure 5.22

LAKE CHELAN AVERAGE
NITRATE + NITRITE LOGITUDINAL PROFILE
APRIL TO SEPTEMBER, 1987

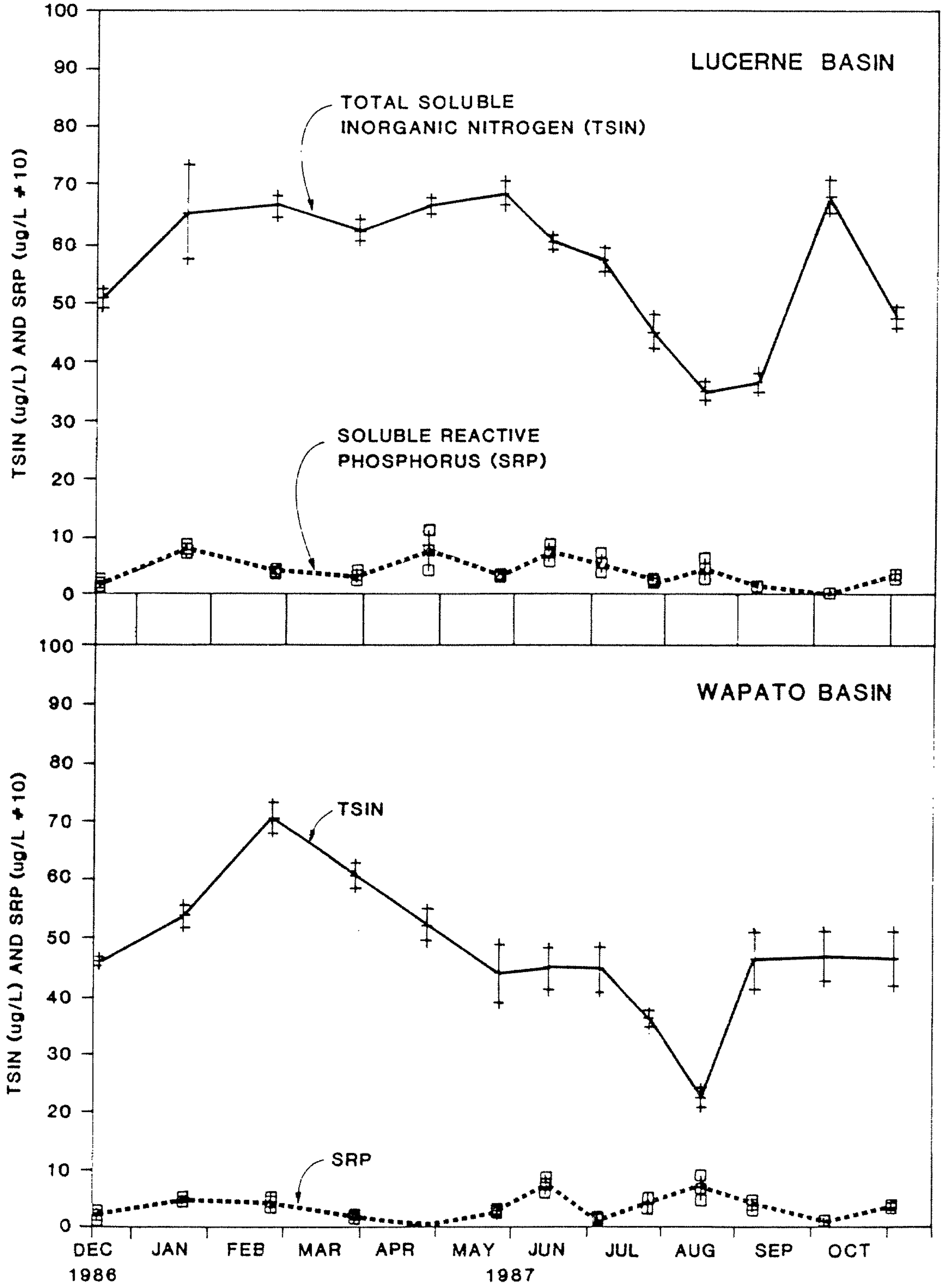


Figure 5.23

TEMPORAL VARIATION IN
EPILIMNETIC SRP AND TSIN LEVELS
LUCERNE AND WAPATO BASINS
(Mean +/- Std. Err.)

5.6 Open-water Trophic Response

In addition to nutrient concentrations, one of the principal factors which often controls algal growth in a deep lake such a Chelan is available light. In general, photosynthesis during the spring-summer months does not occur at depths where the ambient light intensity is less than approximately one percent of incident (Wetzel, 1975). This approximate lower boundary of the euphotic zone occurs at roughly 40 to 50 m (150 ft) throughout the lake, based on an average measured light extinction of 0.10 ± 0.01 m^{-1} (Table 5.7). Because the estimated euphotic zone depth generally corresponded with the location of the thermocline in both the Lucerne and Wapato Basins, algal photosynthesis was likely confined to epilimnetic and upper metalimnetic regions of Lake Chelan.

For net algal photosynthesis and growth to occur, total algal respiration in the mixed layer must be less than total (gross) photosynthesis. Net growth likely occurs in both basins throughout the spring-summer stratification period, since light levels were sufficiently high throughout the epilimnion (0 to 40 m) to allow photosynthesis to easily exceed respiration. However, during the winter months of relatively deep vertical mixing and reduced incident light intensity, light limitation of algal production within the upper mixed layer of Lake Chelan could occur. This seasonal limitation may have been restricted to the deeper Lucerne Basin (mean depth = 180 m), because with the low light extinction, mixing to a relatively great depth may be necessary to limit growth. Within the shallower Wapato Basin (mean depth = 43 m), ambient light levels in the upper mixed layer were always at least 10 percent of incident, and may have been adequate to support algal production, even during winter.

The existing biomass of planktonic algae within Lake Chelan was evaluated with measurements of chl a and phytoplankton cell volume (biovolume). Samples for chl a were collected from the surface and at depths of 10 and 20 m within the euphotic zone at all lake stations. Samples for biovolume were obtained from the surface only at four selected stations (2, 4, 6, and 8). Although preliminary LANDSAT imagery suggested that chl a varied longitudinally in surficial waters, no such differences were observed during the study period. Temporal variations in epilimnetic chl a were also minimal, and all data appeared to cluster around an average value of 0.66 ± 0.03 ug/L (Figure 5.24; Table 5.7). Like the other trophic status indicators discussed above, chl a concentrations measured during the study period were indicative of oligotrophic conditions (OECD, 1982).

In contrast to the chl a data, biovolume levels varied markedly both temporally and spatially across the lake (Figure 5.25). During the winter and early spring months, surface water biovolumes were generally low, but approximately two times higher in the Wapato Basin than at Lucerne Basin sites. This may have been due to the greater light availability which results from a shallower mixed depth in Wapato Basin. Although both basins initially supported phytoplankton "blooms" of approximately 100 mm^3/m^3

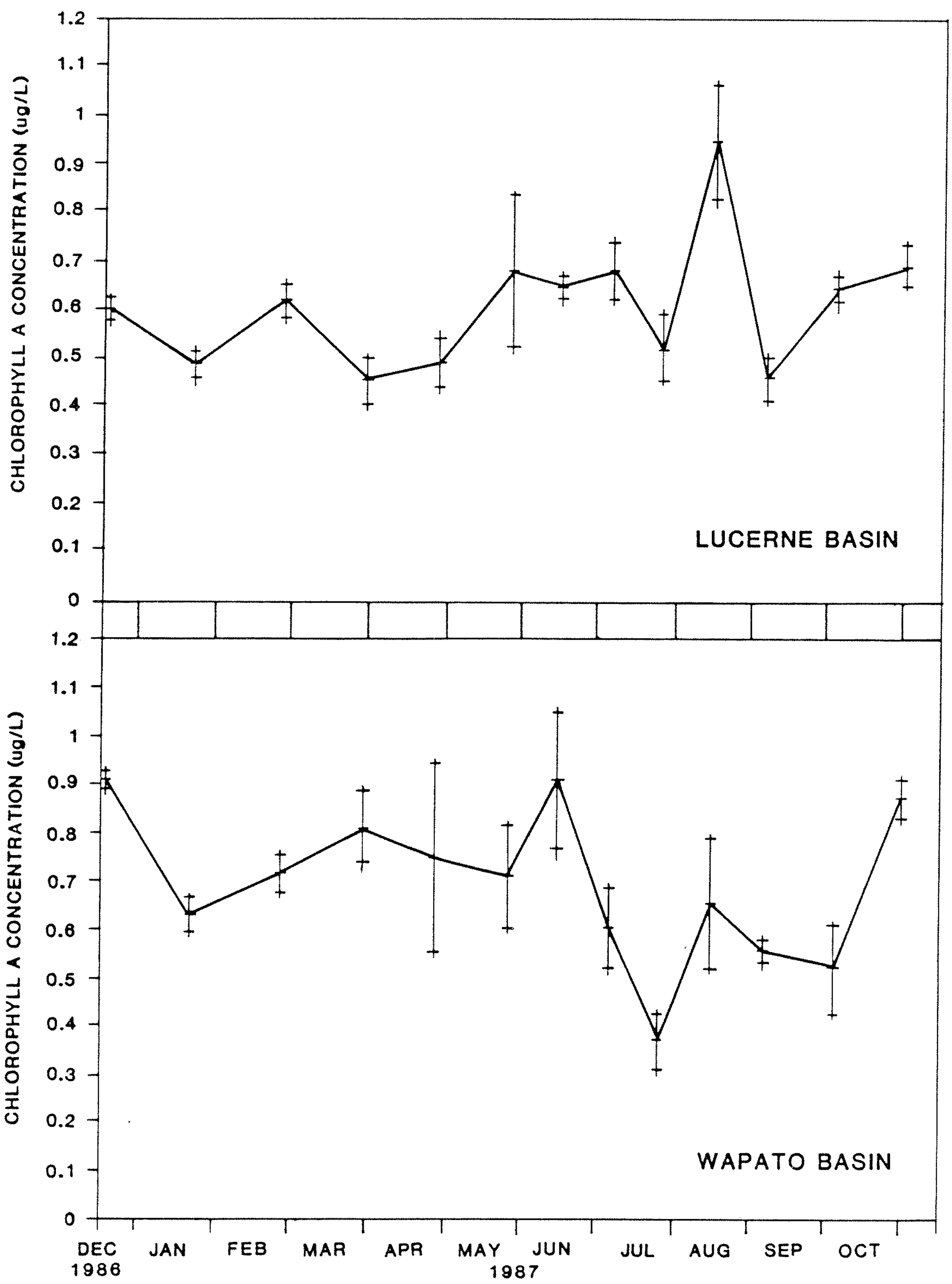


Figure 5.24

TEMPORAL VARIATION IN
EPLIMINETIC CHLOROPHYLL A LEVELS
LUCERNE AND WAPATO BASINS
(Mean +/- Std. Err.)

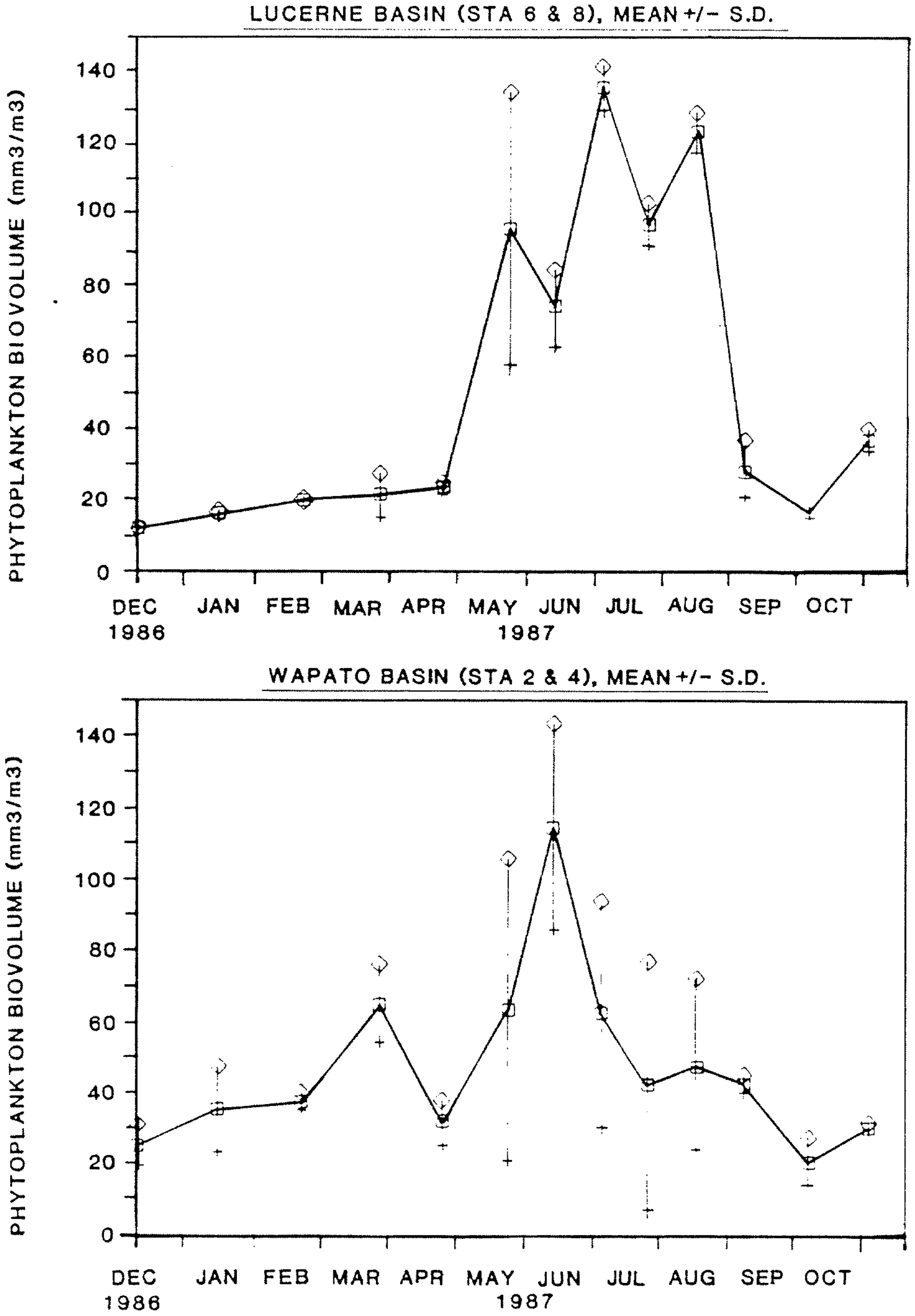


Figure 5.25

TEMPORAL VARIATION IN SURFICIAL PHYTOPLANKTON CELL VOLUME LUCERN AND WAPATO BASINS (Mean -/- Std. Err.)

during the late spring, these elevated biomass levels were only maintained throughout the summer months within the Lucerne Basin. Throughout much of the summer, surface biovolume levels were greatest at Station 8 (km 70), and progressively declined to lowest values at Station 2 (km 4).

At all stations and during all sampling events, the phytoplankton assembledge was dominated by several species of the diatom Cyclotella. Other important components of the plankton included Rhizosolenia, Cryptomonas, Rhodomonas, and Dinobryon. Nearly all of the phytoplankton were within the nanoplankton range (2 to 20 um). The only blue-green genus observed in the samples was Synechococcus, which is a ubiquitous picoplankter (ca. 1 um diameter). In general, both the dominant algal genera and biovolume data are characteristic of oligotrophic lake systems (Wetzel, 1975; Sweet, 1987).

The contrasting behavior of chl a and biovolume observed within Lake Chelan is not unusual in lake systems, and is often the result of physiological changes which occur in phytoplankton in response to varying environmental factors such as nutrient supply (Nicholls and Dillon, 1975; Bannister, 1979; Healey and Hendzel, 1980). These changes are often represented in the ratio of chla to cell carbon, which was calculated from the cell volume data based on Strathmann (1969).

A plot of seasonal changes in the chl a:carbon ratio is presented in Figure 5.26. The Lucerne Basin data reveal the rather classic pattern of high chl a:carbon ratios during winter, which gradually decline to much lower ratios in summer. This decline is likely the result of progressive reductions in available P supplies from moderate (2%) to severe (1%) deficiency conditions (Healey and Hendzel, 1980), although ambient levels of SRP were generally too low throughout the year (< 1 ug/L) to reliably quantify availability. Chl a:carbon ratios were notably more variable in the Wapato Basin than in the Lucerne Basin, which may relate to the more variable conditions in a river-run system.

The observed responses of chl a and biovolume within Lake Chelan appear to be the result of several phenomena, including the following:

- Light limitation due to greater mixing depth contributes to a stronger seasonal variation of algal growth in the Lucerne Basin;
- Greater stratification and less vertical and longitudinal mixing during the spring-summer months within the Wapato Basin result in nutrient depletion over a longer time period within that basin;
- More pronounced vertical mixing rates in the Lucerne Basin, resulting in a greater nutrient supply to epilimnetic waters during the stratification season, may contribute to the higher sustained biovolume in that basin;

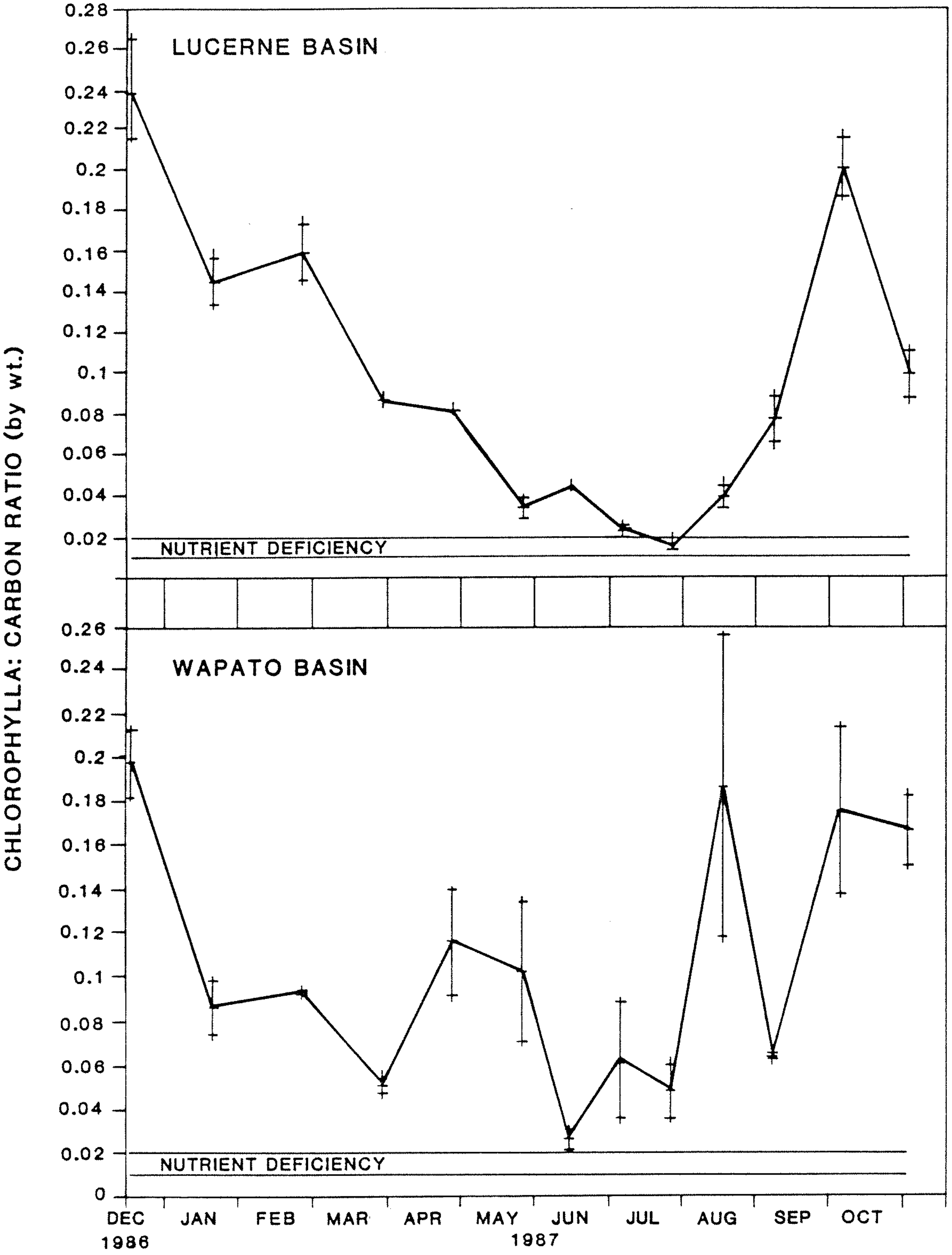


Figure 5.26

TEMPORAL VARIATION IN
CHLOROPHYLL A TO CELL CARBON RATIOS
LUCERNE AND WAPATO BASINS
(Mean +/- Std. Err.)

- The epilimnetic region of the Lucerne Basin is larger and less variable than that of the Wapato Basin, which may contribute to less temporal variation in biomass parameters.

In addition to assessments of phytoplankton biomass characteristics, a limited investigation of photosynthetic activity was conducted. ^{14}C assimilation experiments were performed on three occasions from May to September, 1987 at two stations each in the Lucerne and Wapato Basins. Similar to the chl a data, the results of these experiments did not reveal any significant ($P > 0.10$) temporal or spatial variation in productivity rates, and all data appeared to cluster around an average areal productivity of 10 ± 1 mg C/m^2-hr. ^{14}C productivity appeared to be more correlated with chl a than with biovolume. Consistency with the chl a data is reasonable since chl a, not biovolume, is the active ingredient in photosynthesis.

A profile of net productivity, averaged for the three dates, is presented in Figure 5.27. Relative light intensities are also presented for comparison. The profile illustrates the characteristic surface inhibition of activity due to photoinhibition (Wetzel, 1975). Below a maximum rate of photosynthesis at depths of 5 to 10 m, rates declined in nearly direct proportion with light. Similar ^{14}C productivity rates and depth profile characteristics were previously reported within the Stehekin area by Funk et al. (1987). Assuming an 8 ± 2 month growing season, and an average photoperiod of 12 hrs/day, annual production within Lake Chelan may average 30 ± 9 gm C/m^2-yr.

5.7 Dissolved Oxygen

Dissolved oxygen (DO) is a sensitive indicator of lake eutrophication, and is often the variable of greatest significance to cold water fish production. In stratified lakes, DO is usually saturated, or supersaturated in the epilimnion due to reaeration from the atmosphere and net photosynthesis. In the usually unlighted hypolimnion, water column and sediment respiration, in the absence of photosynthesis, depletes DO. The rate of depletion per unit area is referred to as the areal hypolimnetic oxygen deficit rate (AHOD), and has been shown to be related to P loading, net productivity, temperature, and hypolimnetic depth (Cornett and Rigler, 1979; Welch and Perkins, 1979).

In comparison with many other northern temperate lakes, the concentrations of dissolved oxygen (DO) within Lake Chelan varied little over the study period, and generally ranged only from 10 to 11 mg/L. Highest concentrations (to approximately 15 % above saturation) were observed within shallow epilimnetic waters during the stratification season, likely as a result of algal photosynthesis (Figure 5.28).

The lowest DO concentrations were encountered within hypolimnetic waters of the Wapato Basin (70 - 100 m) during the autumn and early winter period, and reached a minimum concentration of 9.6 mg/L (75% saturation) (Figures 5.28 and 5.29). The progressive decline in DO levels within bottom waters of the Wapato Basin (range = 2 mg/L) was equivalent to an

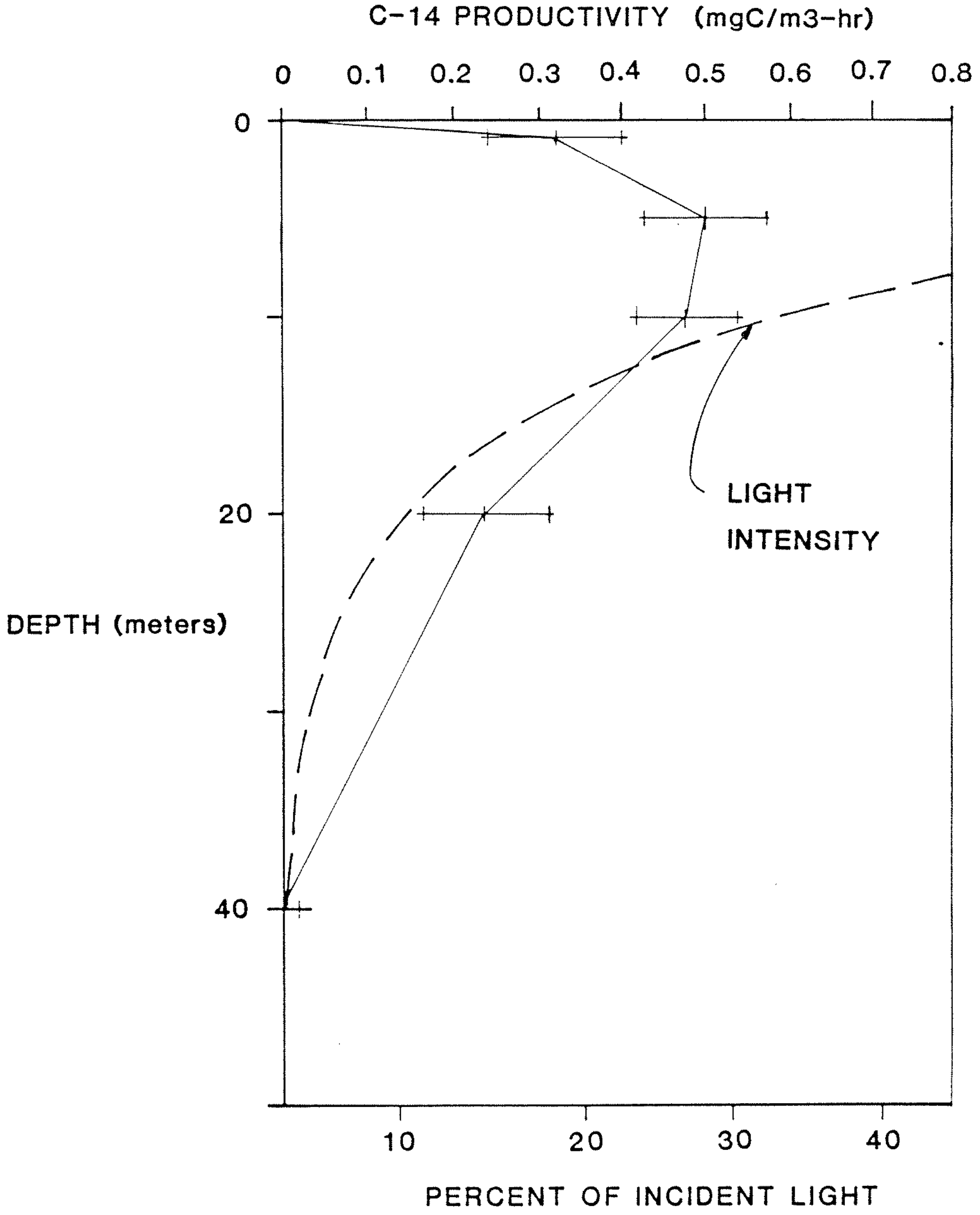


Figure 5.27

AVERAGE SUMMER DEPTH VARIATION
OF CARBON-14 PRODUCTION,
(Mean +/- Std. Err.)

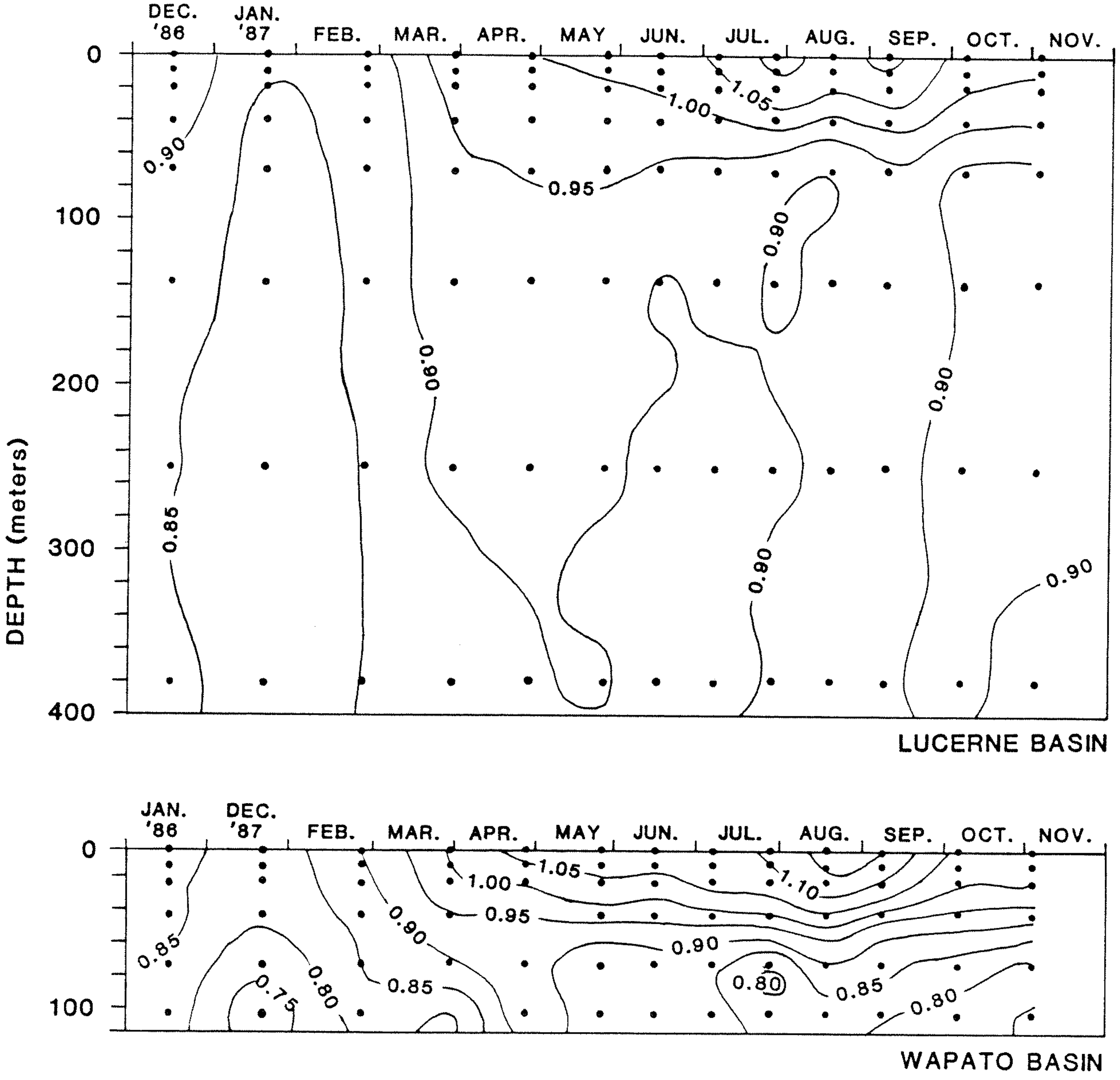


Figure 5.28

CONTOURS OF DISSOLVED OXYGEN SATURATION IN THE LUCERNE AND WAPATO WATER BASINS (CONTOUR INTERVAL = 5% SATURATION)

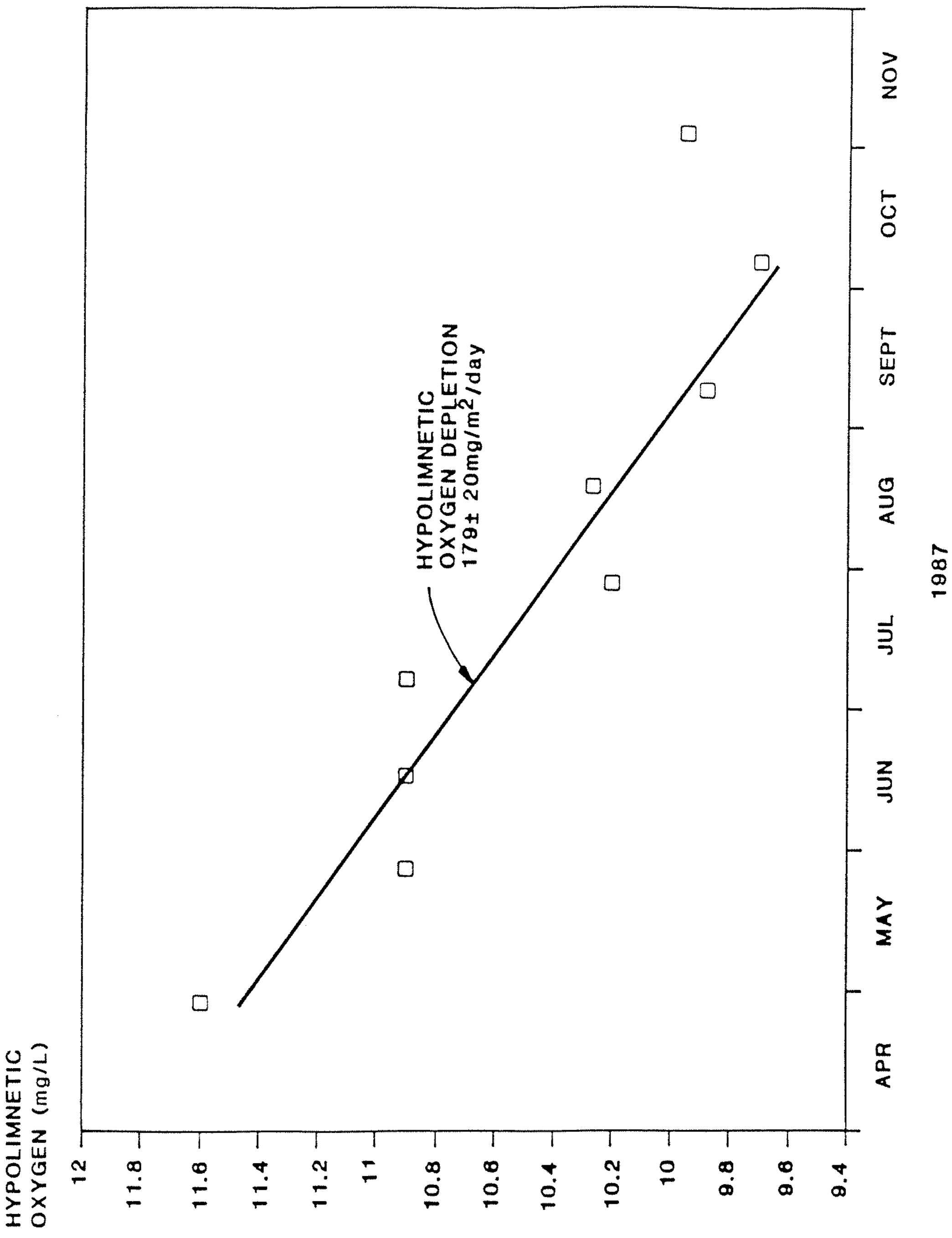


Figure 5.29

DEPLETION OF HYPOLIMNETIC OXYGEN
IN THE WAPATO BASIN, (STATION 4-100)
APRIL TO NOVEMBER, 1987

AHOD of 179 ± 20 mg/m^2-day. This calculated AHOD appears largely attributable to the sedimentation and subsequent decomposition of algal materials within these waters, based on the similarity of observed and predicted values (predictions based on Cornett and Rigler, 1979 model). No discernable DO depletion was observed within the Lucerne Basin. The apparent lack of depletion may have been due to a "dilution" of respiration in the very large hypolimnetic volume of the Lucerne Basin. Depletion is also undetectable in similarly deep Lake Tahoe (Goldman, 1981).

The calculated AHOD for the Wapato Basin (179 ± 20 mg/m^2-day), is less than the 250 mg/m^2-day threshold between oligotrophy and eutrophy suggested by Mortimer (1942). Although the AHOD for the Wapato Basin could be significant; from the standpoint of fish production, DO levels were always maintained within an optimal range (i.e. > 9 mg/L), due to the rather large volume of the hypolimnion.

5.8 Nearshore Periphyton Accumulation

Attached algae, or "periphyton", have been shown to be a useful biological indicator of nutrient enrichment in lakes (Stockner and Armstrong 1971; Collins and Weber 1978; Shortreed et al. 1984; Loeb 1986; Loeb et al. 1986). Increased levels of periphyton biomass have been measured in lakes receiving experimental nutrient additions (i.e., Mathisen 1972; Ennis 1975; Shortreed et al. 1984) and in the littoral areas of Lake Tahoe adjacent to urban development (Goldman and deAmezaga 1975; Loeb 1986). Although periphyton often contribute the majority of the littoral zone production (Hargrave 1969; Loeb et al. 1983), periphyton communities have received little attention in most limnological studies. Because the littoral zone serves as the interface between the surrounding watershed and the main body of the lake, changes in periphyton characteristics may be used as a sensitive, early indicator of pollutant inputs.

The objective of this study was to characterize periphyton abundance, composition, and spatial distribution relative to nutrient inputs or land-use activities in the Lake Chelan basin during the summer of 1987. This investigation was restricted to epilithic periphyton in the shallow eulittoral ('splash zone'), which in most lakes comprises the area between the water's edge and a depth of approximately 1 meter (3 ft). Periphyton in the eulittoral zone may be expected to respond rapidly to nutrient enrichment arising from diffuse watershed sources. In addition, the eulittoral zone is the most visible and actively used area of the lake where water quality problems may be readily perceived by the public. The nuisance potential of periphyton in Lake Chelan was evaluated based on the spatial distribution and coverage by dense algal assemblages and on comparisons with periphyton standing crops in other lakes.

As discussed previously in Section 3, periphyton samples were collected from five primary sampling locations in nearshore (0.5 m depth) areas adjacent to First Creek, Mitchell Creek, Greens Landing, Purtteman Gulch, and Knapp Coulee. At each site, samples were collected along transects at distances of 2 m, 10 m, 50 m, and occasionally 220 m on both sides of the midpoint of the inflowing stream channel. Periphyton samples were also collected from the lake outlet. Sampling occurred during May, July, and September of 1987. All samples (186 total) were analyzed for chl<u>a</u> content, and selected samples were analyzed for TOC, TP, TN, biovolume, and species composition.

Tributary and mid-lake SRP and TSIN concentrations were determined during each survey, and specific conductance measurements were performed along several radial transect paths from each tributary. Nutrient concentrations along the transect paths and at the periphyton sampling locations were estimated using conductance as a tracer constituent. This relationship between specific conductance and soluble nutrient concentrations in the nearshore regions assumes relatively little quantitative nutrient uptake occurs as the tributary plume disperses into the lake. Given the relatively high dispersion coefficients calculated for the nearshore areas (100 - 1,000 m^2/sec; based on conductance data; Fischer et al., 1979), and thus the rapid mixing rates, this assumption appears reasonable.

Periphyton biomass (as chl <u>a</u>) exhibited considerable temporal and spatial variations over the summer (May - September) sampling period. Levels were significantly lower ($P < 0.05$; ANOVA) during the July sampling than in May and September, possibly as result of weather variations. Relatively high winds occurred in the basin over the several days preceding the July sampling, and may have resulted in a significant scouring loss of biomass.

Average periphyton chl <u>a</u> levels over the summer period at each station are presented in Figure 5.30. Relatively low periphyton levels (1 - 10 mg chl <u>a</u>/m^2) were generally characteristic of the 50 m and 220 m stations at each tributary site, except perhaps at the Greens Landing 50 m (east) station where chl <u>a</u> levels exceeded 50 mg/m^2 on May 26. Similarly low levels (4 - 10 mg/m^2) were also observed within the lake outlet channel. Higher levels of periphyton chl <u>a</u> were generally found at the 2 m and 10 m stations adjacent to the tributaries, and a maximum level of 240 mg/m^2 was observed at the Greens Landing 2 m station during the May sampling. The lower range of chl <u>a</u> values (i.e. 1 -10 mg/m^2) were comparable to levels reported on natural substrata in background areas of other temperate oligotrophic lakes (Schindler et al., 1973; Loeb and Reuter, 1981; Bjork-Ramberg, 1984; Loeb, 1986). Periphyton chl <u>a</u> above this range (esp. > 50 mg/m^2), is typically associated with local enrichment (Loeb, 1986).

Periphyton biovolume levels correlated highly ($P \leq 0.01$; regression) with the chl <u>a</u> data, and ranged from less than 0.05 mm^3/cm^2 to 10 mm^3/cm^2. Diatoms (esp. <u>Gomphonema</u> and <u>Melosira</u>) and filamentous green algae (<u>Ulothrix</u>, <u>Mougeotia</u>, <u>Cladophora</u>, and <u>Oedogonium</u>) dominated the algal community of Lake Chelan periphyton. Blue-green algae (<u>Phormidium</u> and <u>Oscillatoria</u>) were also observed at all stations examined, but generally comprised less than ten (10) percent of the algal community (by volume).

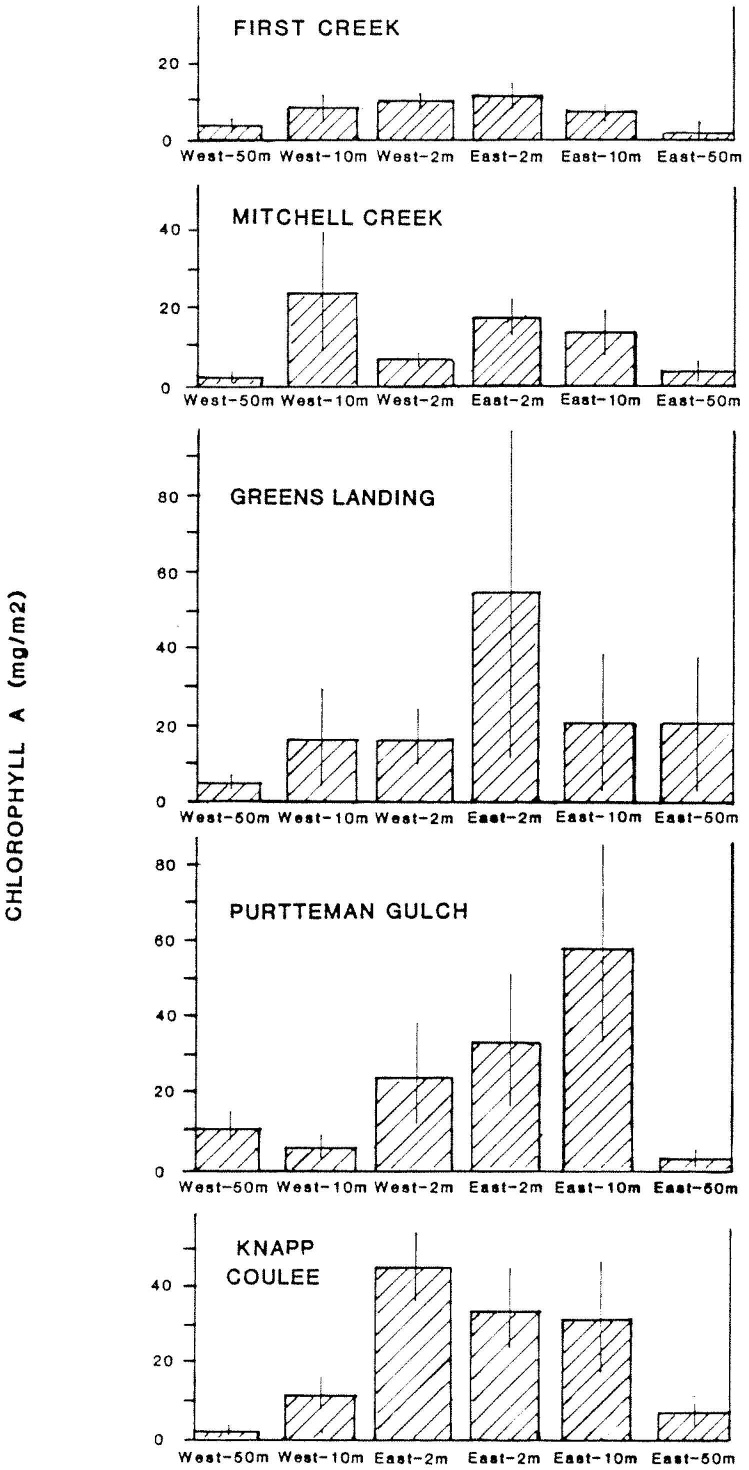


Figure 5.30

LONGSHORE PERIPHYTON BIOMASS
NEAR SELECTED CREEK INLETS
(Mean +/-1Std. Dev.)

Unlike the main body of Lake Chelan, where P is clearly the principal limiting nutrient, assessments of nutrient limitation characteristics of the eulittoral periphyton community suggested that both N and P were important determinants of periphyton growth. For example, the ratio of TSIN to SRP calculated for nearshore areas of the tributary sites averaged about 20 to 40:1 near First Creek, Knapp Coulee, Purtteman Gulch, and in the lake outlet (May -September data). Near Mitchell Creek and Greens Landing, however, the ambient N:P ratios were generally below 5:1 (late spring ratios near Greens Landing were approximately 10 - 15:1). TSIN:SRP ratios above approximately 15:1 are often indicative of P limitation, while ratios below about 7:1 suggest N limitation (Forsberg, 1980). Based on these data, therefore, periphyton communities at some sites within the lake would be expected to exhibit P limitation, while others may be more controlled by N inputs. The rather large variation in N:P ratios in tributaries of the lower basin appears to be related to different land use characteristics of the drainages (see Table 5.11).

In order to provide a more direct determination of the potentially limiting nutrient to periphyton growth, levels of C, N, and P were measured in selected tissue samples collected from the nearshore areas. Both a rigorous acid digestion and a more biologically specific ultraviolet (UV) procedure were employed to assess P levels (Bothwell, 1985). The "true" P content within periphyton is probably intermediate between these two methods. Based on the acid digestion for P, all periphyton tissue would be characterized as N-deficient, since observed N:P ratios were all less than 7:1 (range: 0.3 - 6:1; see Appendix I). However, the results of the UV digestion method resulted in tissue N:P ratios some 2 to 24 times greater than those ratios obtained using acid digestion, with P limitation suggested at some sites and N limitation at others.

Although the large variability between P methods prevented a detailed assessment of the nutrient content of periphyton tissue, these data do confirm the importance of N as a potentially limiting nutrient. This result is also consistent with the low ambient TSIN:SRP ratios in waters at some of the sampling sites. The importance of P as a limiting nutrient could not be confirmed by the tissue nutrient data, although its control of periphyton growth is suspected in many areas on the basis of high ambient water TSIN:SRP ratios.

As a further test of the relationship between nutrient supplies and periphyton growth, and in order to develop a possible management framework for periphyton control, periphyton chl a accumulation at each sampling station was regressed against the predicted ambient nutrient concentration. Because of the suspected importance of both N and P as determinants of growth, the data were divided into two groups prior to analysis. Ambient TSIN:SRP ratios exceeding 15:1 were assumed to represent P limitation, while ratios below 7:1 were assumed to indicate N limitation. Periphyton samples collected in areas with intermediate nutrient ratios were not included in the regressions. Predicted TSIN and

SRP water concentrations associated with each periphyton sample were calculated using the specific conductance tracer data discussed above.

Overall, a highly significant ($P < 0.001$; log-log regression analysis) relationship was observed between the predicted ambient SRP concentration and periphyton chl a within nearshore areas of Lake Chelan (Figure 5.31). The regression equation calculated from these data is as follows:

$$LOG_{10}(\text{chl } \underline{a}; \text{mg/m}^2) = 0.88 + 0.50 \times LOG_{10}(\text{SRP; ug/L})$$

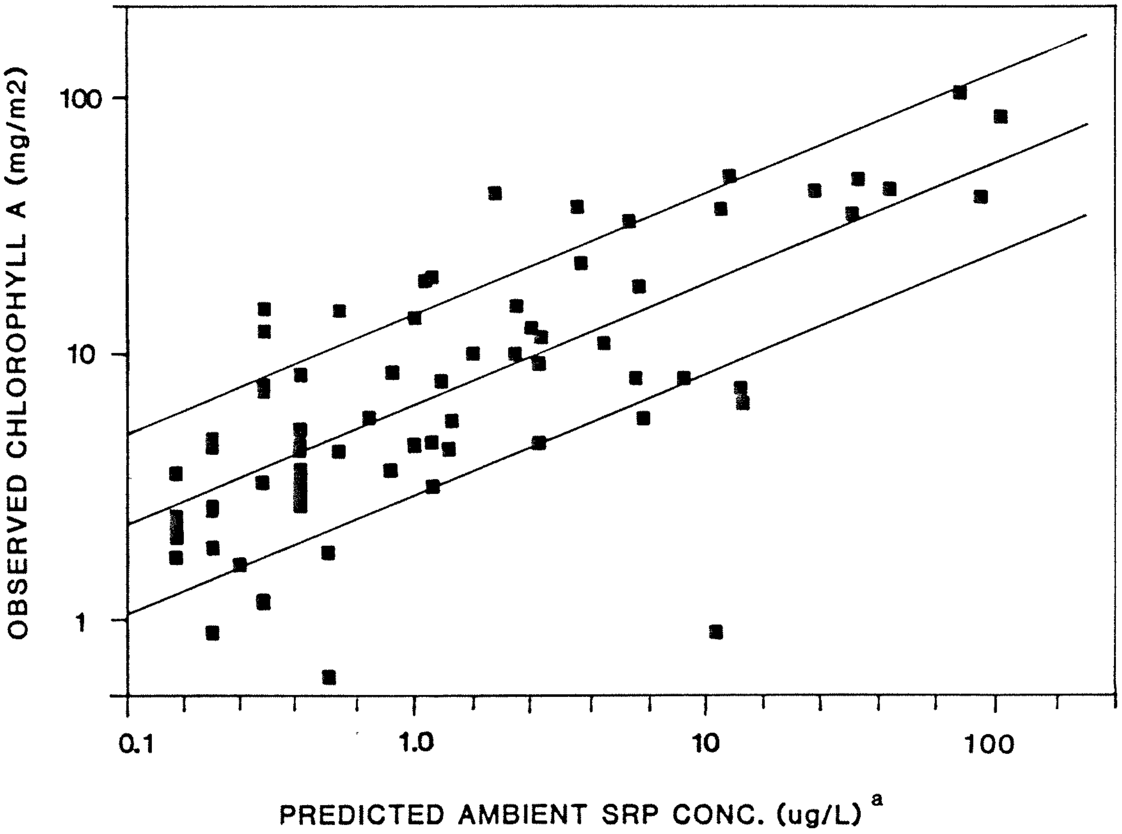
The prediction uncertainty of this formulation was approximately ± 37 percent. Over the range of SRP levels encountered (0.2 to 100 ug/L), periphyton chl a increased approximately 10 to 50-fold, ranging from an average of 3 ± 1 mg/m^2 at the lowest SRP concentrations (generally away from tributary inputs) to 74 ± 27 mg/m^2 in high SRP areas (immediately adjacent to input streams). These data support the hypothesis that P supplies exert at least partial control over periphyton accumulations.

A significant relationship was not observed ($P > 0.10$) between chl a and TSIN levels, possibly because relatively few samples (less than 25 percent of the total) were collected in areas with low ambient TSIN:SRP ratios.

In order to examine whether the rate of local mixing may have enhanced the effect of P on periphyton growth (by controlling possible local supply rates), nearshore dispersion coefficients were calculated based on conductance profile data (Fischer et al., 1979). However, over an estimated range of approximately 100 - 1,000 m^2/sec, no significant ($P > 0.20$; multiple regression analysis) relationship between chl a and mixing intensity was observed. The only other factor identified besides nutrients (i.e. SRP) which appeared to control periphyton accumulation was the availability of suitable substrate (i.e. rocks). Grazing by invertebrates (i.e. snails and caddisfly larvae) may also have been important.

Considerable controversy exists in the definition of a "nuisance" periphyton level in freshwater systems. Based on experimental observations and results of a literature survey (Horner et al. 1983), hypothesized that filamentous periphytic algal biomass greater than 100-150 mg chl a/m^2 constitutes a nuisance condition in streams. This hypothesis was tested further in western Washington and Swedish streams by investigating the correlation between biomass and measurements of conditions which represent an ecological and aesthetic nuisance (Welch et al. 1988). Indices of water quality (i.e., dissolved oxygen concentrations and benthic invertebrate abundance/diversity) were apparently unaffected by periphyton biomass in these streams, where biomass levels averaged less than 170 mg chl a/m^2. However, biomass in the range of 100-150 mg chl a/m^2 were associated with dense filamentous coverage and were judged to have an adverse effect aesthetically.

The applicability of the proposed nuisance level to lakes is supported by observations in Lake Tahoe. Enhanced growth of attached algae in Lake



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a. SRP PREDICTED USING SPECIFIC
CONDUCTANCE TRACER DATA (SEE TEXT).

Figure 5.31

PERIPHYTON BIOMASS VERSUS
AMBIENT SRP ALL LAKE STATIONS
MAY-SEPTEMBER, 1987
(Mean +/- Std. Err.)

Tahoe was one of the early indicators of accelerated eutrophication. High levels (100-150 mg chl *a*/m^2) have been measured adjacent to areas in the watershed which were disturbed (i.e., developed) relative to chl *a* levels (<10 - 20 mg/m^2) adjacent to undisturbed areas (Loeb 1986; Loeb et al. 1986). Goldman and Byron (1987) describe nuisance conditions, adjacent to developed areas in Lake Tahoe, caused by the detachment of dying algal mats that float to the surface in late spring.

In Lake Chelan, periphyton chl *a* was elevated (50 - 240 mg/m^2) within the vicinity of several nutrient-rich inflowing tributaries, and appeared to be at least partially the result of SRP discharges. Some areas were characterized by dense filamentous growths and associated odors, which were considered objectionable to several local residents. The spatial extent of these growths, however, appeared to be generally limited to within approximately 50 meters (150 ft) of the tributaries. Most areas of Lake Chelan were characterized by low chl *a* levels comparable to those measured in other ultraoligotrophic temperate lakes. Elevated periphyton biomass may be an early indicator of nutrient enrichment arising from watershed activities.

5.9 Bacterial Quality

The bacterial quality of lake surface waters and tributaries within the Lake Chelan Basin was primarily assessed by examining the presence of various pathogen indicator groups, including fecal streptococcus (FS), fecal coliform (FC), and total coliform (TC) bacteria. Limited sampling in relative "hot spot" areas was also conducted for the potentially pathogenic enterococci group. All of the indicator groups examined are major microbiological components of the feces of warm-blooded animals, and are correlated with the presence of pathogenic organisms in source materials (Geldereich, 1976). However, upon release into the environment, pathogen and indicator species often decay at different rates, resulting in a progressively poorer correlation between groups as the time since discharge increases. The coliform groups tend to decay at very rapid rates within surface water environments (approx. 1.0/day), while streptococcus bacteria decline considerably slower (approx. 0.1/day)(Zison et al., 1978; EPA, 1986). Pathogenic organisms and viral groups generally appear to decay at intermediate rates.

Because of the likely importance of decay as a major controlling parameter of pathogenic conditions within Lake Chelan, the more persistent FS bacterial group was selected as the principal indicator parameter for this study. A smaller number of FC and TC determinations were also performed for comparison with existing regulatory standards. All sampling was conducted at the lake (and tributary) surface. The collected data approximated a log-normal (X + 1) distribution, and all data summaries reported herein were based on this assumed distribution.

A summary of seasonal abundance and variations of bacterial parameters within the two basins of Lake Chelan is presented in Table 5.7. The lowest concentrations of all bacterial groups occurred during the fall/winter period at stations within the Lucerne Basin, with an estimated geometric mean FS concentration of approximately 0.1/100 ml. Coliform bacteria were rarely detected within the Lucerne Basin, particularly during the winter months. The rather low coliform densities observed during this study within open water stations of the Lucerne Basin are consistent with historical data (NPS, unpublished data).

Peak concentrations of all three indicators occurred near the lake outlet. On average, the levels of all bacterial indicators were highest during the thermally stratified period (April to September), although similarly elevated concentrations were observed year-round at the outlet. A seasonal summary of FS levels along the longitudinal axis of Lake Chelan is presented in Figure 5.32, and reveals a progressive downlake increase in surficial lake concentrations. The most significant ($P < 0.01$) increase in FS levels occurred near the lake outlet, as geometric mean concentrations increased approximately three-fold over the first 4 km (6 mi) of the lake. Although these data are indicative of a significant bacterial source near the City of Chelan, elevated FS concentrations at the lake outlet may also be related to local hydrodynamic characteristics. Specifically, the "river-run" behavior of this relatively shallow lake segment (see Section 5.2) minimizes the opportunity for both mixing and bacterial decay, and may simply increase the susceptibility of this area to bacterial inputs. Potential source contributions are discussed below.

An annual summary of bacterial data collected near the lake outlet is presented in Table 5.12. The fecal and total coliform data collected at the lake outlet during the 1986/1987 study period were not significantly different ($P > 0.10$) from long-term (1967 to 1986) average levels computed from historical data (based on over 200 determinations available from Ecology, EPA, USGS, and Chelan County). Although the available data are well within compliance with state standards and federal criteria for water contact recreational use (e.g. geom. mean FC < 50/100ml; EPA, 1986; Ecology, 1987), these samples did not meet existing drinking water standards (i.e. TC < 1/100 ml). Major water supply withdrawals for the City of Chelan presently occur within the outlet vicinity. Although drinking water is chlorinated prior to distribution, concerns over the sanitary quality of lake water supplies nevertheless remain (e.g., Chelan-Douglas Health District, 1981).

Similar to the chemical parameters discussed above, tributary data were collected during this study to assess the magnitude of principal FS sources to Lake Chelan. These loading data are summarized in Table 5.13. In general, the geometric mean areal export rates of FS were similar for most of the watersheds monitored throughout the Chelan Basin, which suggests a relatively consistent natural source. However, stormwater runoff to the Wapato Basin exhibited comparatively high concentrations and export rates of FS, and represented about 40 percent of the estimated lake inputs. Most of this input entered Lake Chelan during the winter months. Similarly high bacterial loadings are frequently reported in stormwater runoff (Pitt, 1983), and have generally been attributed to small animal sources and soil erosion within developed areas. A

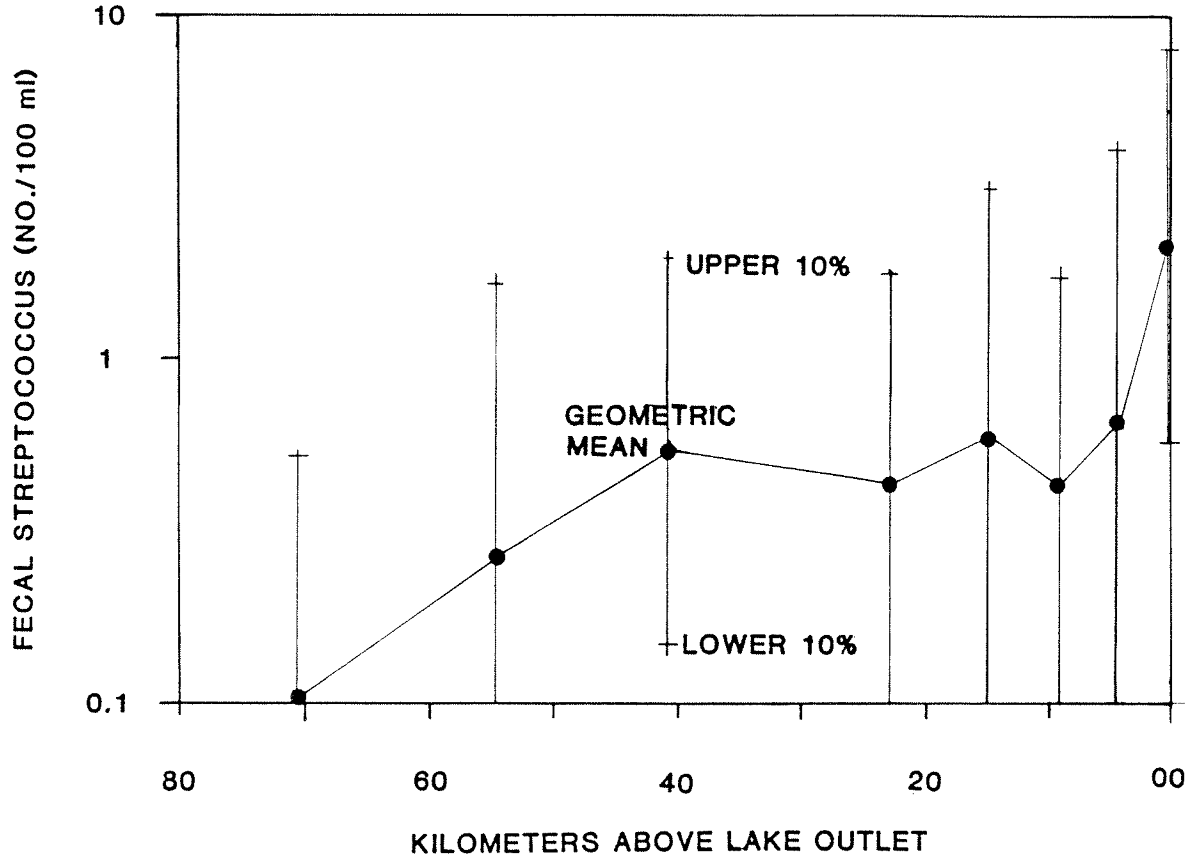

Figure 5.32

LONGITUDINAL VARIATION OF FECAL STREPTOCOCCUS CONCENTRATION SURFICIAL LAKE SAMPLES; APRIL TO SEPTEMBER, 1987

TABLE 5.12

SUMMARY OF BACTERIAL QUALITY NEAR THE LAKE OUTLET
December 1987 to November 1988

PARAMETER	Geometric Mean (No./100 ml)	Upper 10% (No./100 ml)	Detection Frequency
Fecal Streptococcus	3.7	9.0	24/35
Fecal Coliform	3.0	5.8	14/28
Total Coliform	5.4	20.	22/28
Enterococci	<1.	<1.	0/10

relatively large urban/suburban source of FS is also consistent with the observed winter increase in FS near the lake outlet, since much of the developed area and stormwater flow within the basin occurs within this area, and during the winter season.

The annual FS mass balances suggest an approximate parity between measured inputs and outputs in the lake (Table 5.13). However, since in-lake decay is likely to be a major component of the lake mass balance for this non-conservative parameter, additional sources of FS are therefore implicated. Such other undocumented sources may have included septic tank effluent, sewer overflows, recreational boater inputs, and possibly waterfowl. Based on detailed observations of a variety of septic systems throughout the Wapato Basin, this potential FS source appears to be minor (see Section 4.5). Occasional overflows along the eastern lakeshore sanitary sewer conveyance pipelines (force mains) were reported during the study period, primarily as a result of pump failures. The magnitude of these potentially significant FS contributions, however, could not be estimated.

The potential fecal contributions from recreational boaters was specifically addressed during this study by monitoring FS concentrations before, during, and after two major recreational weekends (Memorial Day and July Fourth holidays). Samples were collected daily from 8 open water and nearshore stations within and adjacent to the Wapato Basin. However, no significant ($P > 0.10$; ANOVA) differences between holiday and non-holiday FS concentrations were observed at any station during these major use events. Based on these data, therefore, FS (and other associated parameter) inputs from recreational use activities appeared to be minor. The apparently minor boating input may reflect the preponderance of smaller craft without on-board sanitary facilities. Considerably greater fecal discharges have been reported from larger vessels within the Puget Sound area (Patmont and Pelletier, 1988).

TABLE 5.13. SUMMARY OF FECAL STREPTOCOCCUS CONCENTRATION AND LOADING DATA

	Concentration (#/100ml)			ANNUAL ORGANISM LOAD	AREAL LOAD (geom. mean)
	Geom. Mean	Upper 10%	(n)	(geom. mean; bill/yr)	(bill/km2/yr)
LUCERNE TRIBUTARIES					
Stehekin River	1.	3.	(12)	6,457 +/- 990	7.8 +/- 1.2
Railroad Creek	4.	25.	(13)	4,320 +/- 994	25.7 +/- 5.9
Misc. Lucerne	9.	68.	(26)	11,645 +/- 4,362	10.8 +/- 4.0
Mitchell Ck.	68.	410.	(13)	1,255 +/- 313	38.2 +/- 9.5
Greens Landing	43.	460.	(7)	388 +/- 194	25.0 +/- 12.5
WAPATO TRIBUTARIES					
First Ck.	29.	330.	(13)	931 +/- 303	19.2 +/- 6.3
Purtteman Gulch	240.	530.	(4)	2,700 +/- 213	170.9 +/- 13.5
Knapp Coulee	460.	6,500.	(3)	230 +/- 154	31.7 +/- 21.2
Total Meas. Wapato				3,861 +/- 401	54.0 +/- 5.6
Misc. Wapato				5,452 +/- 4,047	54.0 +/- 40.1
AGRICULTURAL DRAINS					
USBR Dr. No. 6	7.	82.	(13)	21 +/- 8	10.6 +/- 4.0
USBR Dr. No. 8	79.	400.	(12)	178 +/- 90	164.1 +/- 83.1
URBAN DRAINS					
Urban Dr. 1	1,700.	8,800.	(6)	1,746 +/- 952	2,407 +/- 1,313
Urban Dr. 2	1,500.	2,000.	(3)	1,031 +/- 512	1,422 +/- 706
Total Meas. Urban Drains	1,600.	6,400.	(9)	3,856 +/- 1,081	2,809 +/- 788
Misc. Urban Drains *				20,008 +/- 5,964	2,809 +/- 837
TOTAL LUCERNE BASIN INPUTS				24,065 +/- 4,597	
TOTAL WAPATO BASIN INPUTS				33,177 +/- 7,299	
TOTAL LAKE INPUTS				57,242 +/- 8,626	
CHELAN OUTFLOW	4	9	(35)	58,714 +/- 9,884	
IN-LAKE RETENTION/LOSS				-3 +/- 23 percent	

5.10 Trace Metals

Water

Although available historical data on trace metal content in Lake Chelan (available primarily from USGS records, R.W.Beck, 1983, and Funk et al., 1987) indicate generally low concentrations relative to other regional waters, a number of existing and potential source contributions are nevertheless present within the basin. These sources include abandoned mine tailings within the Holden (Railroad Creek) area (that yield primarily iron (Fe) and zinc (Zn); Anderson and Benjamin, 1982), agricultural drainage (primarily arsenic (As)), and urban/suburban runoff (primarily Fe, lead (Pb), and Zn; Galvin and Moore, 1982).

In order to assess general source contributions and transport characteristics of trace metals within the lake, concentrations of As, Fe, and Zn were determined in selected lake and tributary samples. These three metals were selected not only because of potential anthropogenic inputs, but also because they differ markedly in terms of particulate affinity and thus potential in-lake transport (Stumm and Morgan, 1981; Murray, 1987). In general, Zn exhibits a high degree of solid adsorption in aquatic systems, while As is relatively mobile within the aqueous phase. Fe exhibits intermediate adsorptive properties.

The observed in-lake concentrations of total recoverable As, Fe, and Zn exhibited very little temporal or spatial variations over the study period, and averaged 0.22 ± 0.01 ug/L, 3.6 ± 1.4 ug/L, and 2.0 ± 0.1 ug/L, respectively. The only discernable variation in metals was observed in the Fe data, as in-lake levels peaked (6 - 12 ug/L) in lake surface waters during the spring, probably as a result of runoff inputs (see below). The observed in-lake concentrations were well below all applicable aquatic life water quality criteria and drinking water standards (EPA, 1986).

Summaries of the tributary As data are presented in Table 5.14. Concentrations of As were similarly low in the three Lucerne Basin watersheds monitored (i.e. Stehekin River, Railroad Creek, and Mitchell Creek), and exhibited an average concentration at these sites of 0.32 ± 0.06 ug/L. Concentrations in these tributaries were only slightly elevated relative to lake levels. As concentrations were somewhat higher in urban runoff samples, averaging approximately 1.3 ± 1.0 ug/L.

Measured concentrations of As were greatly elevated in agricultural drainage samples, and exhibited an average concentration of 13 ± 8 ug/L, or approximately 40 times greater than local background. The source of this arsenic increase may be related to the use of arsenicals (e.g lead-arsenic) as pesticides in orcharding activities.

The orchard drain samples periodically exceeded the proposed maximum contaminant level for total As in drinking water of 30 ug/L (EPA, 1988). Although there is no domestic consumptive use of these return flows,

TABLE 5.14. SUMMARY OF ARSENIC, IRON, AND ZINC CONCENTRATION AND LOADING DATA

	Concentration (ug/L)			ANNUAL LOAD	AREAL LOAD
	Mean	Std. Dev.	(n)	(kg/year)	(kg/km2-year)
ARSENIC:					
MEASURED TRIBUTARIES					
Stehekin River	0.41 +/-	0.18	(5)	611.2 +/- 80.7	0.74 +/- 0.10
Railroad Creek	0.46 +/-	0.38	(5)	121.8 +/- 27.3	0.73 +/- 0.16
Mitchell Ck.	0.10 +/-	0.03	(3)	0.3 +/- 0.1	0.01 +/- 0.00
USBR Dr. No. 6	13.23 +/-	8.44	(5)	7.5 +/- 3.9	3.70 +/- 1.91
Urban Dr. 1	1.35 +/-	0.97	(4)	0.1 +/- 0.1	0.18 +/- 0.14
ESTIMATED INPUTS					
Misc. Tributaries	0.36 +/-	0.28		108.1 +/- 61.3	
Misc. AG Drains				4.0 +/- 2.1	3.70 +/- 1.91
Misc. Urban Drains				2.2 +/- 1.7	0.18 +/- 0.14
TOTAL LAKE INPUTS				855.2 +/- 105.1	
CHELAN OUTFLOW	0.20 +/-	0.03	(5)	378.7 +/- 30.8	
IN-LAKE RETENTION/LOSS				56 +/- 7 percent	
IRON:					
MEASURED TRIBUTARIES					
Stehekin River	98.7 +/-	89.8	(5)	159,974 +/- 27,680	192 +/- 33
Railroad Creek	976.4 +/-	1,320.1	(5)	309,765 +/- 136,346	1,846 +/- 812
Mitchell Ck.	51.9 +/-	44.5	(4)	202 +/- 106	6 +/- 3
USBR Dr. No. 6	56.0 +/-	119.3	(6)	11 +/- 10	6 +/- 5
Urban Dr. 1	6,428.0 +/-	6,737.4	(4)	1,718 +/- 1,013	2,369 +/- 1,397
ESTIMATED INPUTS					
Misc. Tributaries	77.9 +/-	73.4		23,659 +/- 17,646	
Misc. AG Drains				6 +/- 5	6 +/- 5
Misc. Urban Drains				29,574 +/- 17,438	2,369 +/- 1,397
TOTAL LAKE INPUTS				524,908 +/- 141,326	
CHELAN OUTFLOW	6.0 +/-	3.3	(5)	11,102 +/- 2,799	
IN-LAKE RETENTION/LOSS				98 +/- 1 percent	
ZINC:					
MEASURED TRIBUTARIES					
Stehekin River	1.0 +/-	0.4	(5)	1,639 +/- 204	2 +/- 0
Railroad Creek	70.2 +/-	69.5	(5)	18,703 +/- 8,156	111 +/- 49
Mitchell Ck.	9.3 +/-	5.6	(3)	30 +/- 18	1 +/- 1
USBR Dr. No. 6	6.3 +/-	12.2	(5)	1 +/- 1	1 +/- 1
Urban Dr. 1	284.9 +/-	165.7	(4)	62 +/- 33	85 +/- 46
ESTIMATED INPUTS					
Misc. Tributaries				1,943 +/- 1,062	1 +/- 1
Misc. AG Drains				1 +/- 1	1 +/- 1
Misc. Urban Drains				1,059 +/- 575	85 +/- 46
TOTAL LAKE INPUTS				23,438 +/- 8,247	
CHELAN OUTFLOW	1.6 +/-	0.2	(5)	2,507 +/- 184	
IN-LAKE RETENTION/LOSS				89 +/- 4 percent	

there is limited use of groundwater adjacent to some of the orchard areas within the Lower Chelan Basin. Because general water quality characteristics of groundwaters in these orchard areas are similar in many respects to the return flow drainage (compare Tables 4.5, 5.9, and 5.11), a similarly elevated As concentration is anticipated in groundwaters within agricultural regions of the basin. Several drain samples approached the tentative aquatic life criteria for As of 48 ug/L (EPA, 1986).

Mass loading of As from each tributary was calculated as the product of the measured or assumed flow-weighted average concentration and annual discharge (see Table 5.1). The mass loading associated with the agricultural (and other anthropogenic) inputs of As to Lake Chelan appeared to be rather minor, representing only about 1 percent of the total lake input (Table 5.14). Based on preliminary lake mass balances, approximately 56 ± 7 percent of the total lake input of As appears to have been retained within lake sediments. This rather low retention (compared with the other two metals; see below) is consistent with the relatively mobile behavior of As in aquatic systems (Callahan et al., 1979).

Concentrations of Fe were relatively similar between the Stehekin River, Mitchell Creek, and agricultural drainages (average = 120 ± 50 ug/L), and likely reflect a somewhat consistent natural condition (Table 5.14). However, Fe concentrations were considerably greater within Railroad Creek and urban runoff samples, which exhibited flow-weighted averages of 1,600 ± 800 ug/L and 11,000 ± 6,000 ug/L, respectively. Fe levels within these two drainages were highly correlated ($P < 0.01$) with suspended solids concentrations, and most of the Fe exported from these catchments was likely attached to particulate materials. Preliminary mass balances of Fe within Lake Chelan suggest that approximately 98 ± 1 percent of the total lake input was retained within lake sediments.

Concentrations of Zn were also relatively similar between the Stehekin River, Mitchell Creek, and agricultural drainages, and the average concentrations of Zn within these catchments ranged from approximately 1 to 10 ug/L (Table 5.14). Measured concentrations of Zn in Railroad Creek and in urban runoff were much greater than the apparent background condition, and exhibited average Zn concentrations of 70 ± 69 ug/L and 280 ± 170 ug/L, respectively. If present in a bioavailable form, these Zn levels may produce chronic and possibly even acute effects to aquatic life, since Zn concentrations as low as 47 ug/L may inhibit the growth of some sensitive aquatic species (EPA, 1986). Relative to the existing secondary drinking water standard of 5,000 ug/L, however, the observed Zn concentrations are not considered harmful to humans.

Watershed export rates of Zn from Railroad Creek and urban runoff areas were approximately 25 to 50 times greater than the three reference drainages (Table 5.14). Much of the Zn loading from Railroad Creek and (especially) urban runoff appeared to be associated with particulate materials, based on TSS correlations. A preliminary input-output mass balance of Zn suggests that Railroad Creek inputs represented more than 80 percent of the total lake loading of this trace metal. Although the great majority (88 ± 5 percent) of the total input appears to have been retained within the lake sediments, this anthropogenic zinc input is nonetheless significant.

The existing Zn load enters Railroad Creek via leachate produced from an extensive (area = 0.35 km^2 [85 acres]; depth = 15 - 30 m [50 - 100 ft]) mine tailing area adjacent to the community of Holden Village, approximately 15 km (10 mi) upstream from Lake Chelan (Cunningham and Pine, 1968; Anderson and Benjamin, 1982). Creek waters downstream of the tailings have been reported to be toxic to both algae and macroinvertebrate species, primarily because of high ambient levels of Zn. Based on these toxicity data, and considering that Zn concentrations at the mouth of Railroad Creek periodically exceeded criteria for the protection of aquatic life (see above), it is considered likely that a localized (but presently undocumented) zone of toxicity also exists within adjacent nearshore areas of Lake Chelan. However, this hypothesized impact area within the lake is believed to be rather limited, since ambient Zn concentrations in offshore areas of Lake Chelan (observed range: 1.3 - 2.9 ug/L) were well below reported toxic levels (EPA, 1986).

Sediments

Concentrations of twelve (12) selected trace metals (including As, Fe, and Zn) were determined in sediment samples collected adjacent to different land use activities within the Lucerne and Wapato Basins (Table 5.15). Results from a sediment sample collected previously from the lake outlet by Ecology are also presented (Hopkins, et al., 1985). The highest sediment concentrations of all metals except lead (Pb) generally occurred in samples collected from the deep, central areas of both basins. The generally higher deep-water concentrations, compared to those at shallower depths, may be attributable to the phenomenon of focusing, by which finer-grained sediments are continually redistributed to depth. Deeper sediments were represented by finer-grained materials which are typically associated with a somewhat higher metal concentration (Dexter et al., 1983).

In general, the concentrations of trace metals measured in the Lake Chelan sediment samples were comparable to levels reported in soils and sediments from throughout the Pacific Northwest (dry wt. basis; Dexter et al., 1983; Harper-Owes, 1986). However, the most appropriate approximation of "natural" sediment concentrations within the lake is likely to be represented by the deep sediment core sample obtained from the Wapato Basin (Station 4; Table 5.15). Based on ^{210}Pb dating, the sediment section obtained 30 to 50 cm (12 - 20 in) below the sediment surface at this station was likely deposited between approximately the years 1880 and 1920, prior to most development (Figure 2.2). Comparisons of trace metal concentrations in surficial sediments collected throughout the lake with these reference levels suggests that metal elevations (i.e. > 2-fold increases) may have occurred for arsenic, cadmium, copper, lead,

TABLE 5.15. SUMMARY OF SELECTED CHEMICAL PROPERTIES OF LAKE CHELAN SEDIMENTS

		NOVEMBER 4-5, 1986					
PARAMETER	1984 0-15 cm WDOE OUTLET 5-10 m	0-5 cm AT CHELAN URBAN DRAIN 1 7 m	0-5 cm AT CHELAN URBAN DRAIN 2 5 m	0-5 cm LAKE CHELAN STA. 1 7 m	0-5 cm AT MANSON URBAN DRAIN 7 m	0-5 cm AT ORCHARD DRAIN 8 7 m	0-5 cm OFFSHORE ORCHARD DRAIN 8 77 m
APPROX. DEPOSITION DATE							
CONVENTIONALS:							
Total Solids (%)	-	59.9	41.4	64.2	40.5	65.2	31.4
Sand (% dry wt.)	97.0	99.0	88.3	97.5	14.0	99.5	1.6
Silt (% dry wt.)	0.0	0.7	7.5	1.8	79.8	0.3	76.8
Clay (% dry wt.)	3.0	0.3	4.2	0.7	6.2	0.2	21.6
TOC (mg/kg dry wt.)	8,000	3,040	2,030	3,060	13,100	11,400	15,200
TN (mg/kg dry wt.)	-	670	390	470	1,280	1,060	1,550
TP (mg/kg dry wt.)	-	600	730	400	760	360	770
METALS (mg/kg dry wt.):							
Arsenic	1.7	1.3	2.5	2.5	2.4	1.1	4.5
Beryllium	-	0.2	0.3	0.2	0.2	0.1 U	0.5
Cadmium	1.6	0.2	0.3	0.2	0.7	0.2	0.3
Chromium	6.6	14.0	16.0	8.0	17.0	5.0	26.0
Copper	19.3	17.0	23.0	8.0	22.0	4.0	30.0
Iron							
Lead	13.3	14.0	17.0	6.0	83.0	6.0	21.0
Mercury	0.02	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	-	10.0	12.0	9.0	10.0	4.0	18.0
Selenium	-	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5
Silver	-	0.4	0.6	0.3	0.4	0.2	0.6
Zinc	124.5	92.0	99.0	78.0	170.0	46.0	100.0
PESTICIDES (ug/kg dry wt.):							
4,4'-DDE	32	13	5	47	40	55	16
4,4'-DDD	53	15	5	50	64	287	19
4,4'-DDT	10	8	5	73	69	58	16
TOTAL-DDT	95	37	14	170	173	400	51
TOTAL-DDT:TOC (ppm)	12	12	7	55	13	35	3
POLYNUCLEAR AROMATICS (ug/kg dry wt.):							
Benzo(a)anthracene	34	50	72 U	31 U	74 U	31 U	127 U
Benzo(b)fluoranthene	10 U	67	72 U	31 U	74 U	31 U	127 U
Benzo(k)fluoranthene	50 U	50	72 U	31 U	74 U	31 U	127 U
Benzo(ghi)perylene	10 U	50	72 U	31 U	74 U	31 U	127 U
Benzo(a)pyrene	10 U	83	72 U	31 U	74 U	31 U	127 U
Chrysene	47	83	72 U	31 U	74 U	31 U	127 U
Fluoranthene	5 U	200	72	31 U	74 U	31 U	127 U
Naphthalene	16	33 U	72 U	31 U	74 U	31 U	127 U
Phenanthrene	50	33 U	72 U	31 U	74 U	31 U	127 U
Pyrene	59	83	72 U	31 U	74 U	31 U	127 U

TABLE 5.15, CONTINUED

	NOVEMBER 4-5, 1986						JULY 6, 1987	
PARAMETER	0-5 cm NEAR ORCHARD DRAIN 6 6 m	0-5 cm OFFSHORE ORCHARD DRAIN 6 80 m	0-5 cm LAKE CHELAN STA. 4 124 m	30-50 cm LAKE CHELAN STA. 4 124 m	0-5 cm AT SAFETY HARBOR 2 m	0-5 cm LAKE CHELAN STA. 6a 451 m	0-5 cm LAKE CHELAN STA. 7a 170 m	50-60 cm LAKE CHELAN STA. 7a 170 m
APPROX DEPOSITION DATE			1976-86	1880-1920			1976-86	1930-50
CONVENTIONALS:								
Total Solids (%)	74.2	30.6	25.0	33.0	72.2	39.5	29.8	98.0
Sand (% dry wt.)	100.0	3.4	1.8	6.3	100.0	93.3		
Silt (% dry wt.)	0.1 U	74.4	77.4	80.2	0.1 U	0.2		
Clay (% dry wt.)	0.1 U	22.2	20.8	13.5	0.1 U	6.5		
TOC (mg/kg dry wt.)	4,250	15,800	14,100	-	1,350	13,200		
TN (mg/kg dry wt.)	600	1,900	1,540	-	270	1,830		
TP (mg/kg dry wt.)	440	880	1,100	800	300	1,000	1,100	1,200
METALS (mg/kg dry wt.)								
Arsenic	0.5 U	7.2	9.8	7.4	0.5 U	7.0	30.0	38.0
Beryllium	0.1 U	0.5	0.5	0.5	0.1	0.4		
Cadmium	0.1	0.6	0.9	0.3	0.2	0.5		
Chromium	6.0	28.0	25.0	17.0	3.0	32.0		
Copper	5.0	35.0	53.0	22.0	3.0	25.0		
Iron			17,000	16,000		17,000	35,000	35,000
Lead	2.0	28.0	26.0	8.0	2.0	9.0		
Mercury	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U		
Nickel	5.0	18.0	16.0	12.0	3.0	13.0		
Selenium	0.6	0.5 U	0.5 U	0.7	0.5 U	0.5 U		
Silver	0.3	0.8	1.0	0.7	0.3	0.7		
Zinc	34.0	130.0	200.0	71.0	32.0	100.0	240.0	250.0
PESTICIDES (ug/kg dry wt.):								
4,4'-DDE	1	203	120	-	1 U	8		
4,4'-DDD	1 U	389	108	-	1 U	3		
4,4'-DDT	1 U	108	44	-	1 U	3 U		
TOTAL-DDT	1	699	272	-	3 U	11		
TOTAL-DDT:TOC (ppm)	1 U	44	19	-	2 U	1		
POLYNUCLEAR AROMATICS (ug/kg dry wt.):								
Benzo(a)anthracene	27 U	131 U	360	-	28 U	76 U		
Benzo(b)fluoranthene	27 U	131 U	520	-	28 U	76 U		
Benzo(k)fluoranthene	27 U	131 U	280	-	28 U	76 U		
Benzo(ghi)perylene	27 U	131 U	200 U	-	28 U	76 U		
Benzo(a)pyrene	27 U	196	400	-	28 U	76 U		
Chrysene	32	131 U	640	-	28 U	76 U		
Fluoranthene	27 U	131 U	1,440	-	28 U	76 U		
Naphthalene	27 U	131 U	200 U	-	28 U	76 U		
Phenanthrene	27 U	131 U	520	-	28 U	76 U		
Pyrene	27 U	131 U	920	-	28 U	76 U		

Table 5.16. Summary of selected fish tissue residue concentrations in Lake Chelan in September 1987. Values expressed in terms of fresh, wet fish tissue. T-DDT = DDD + DDE + DDT.

SPECIES	KOKANEE	KOKANEE	CHINOOK	RAINBOW TROUT	BURBOT	BURBOT	SQUAWFISH	SQUAWFISH	SQUAWFISH	SQUAWFISH	SUCKER	SUCKER	SUCKER	SUCKER
LOCATION	Lower Wapato	Upper Lucerne	Upper Lucerne	Upper Lucerne	Upper Wapato	Upper Lucerne	Lower Wapato	Upper Wapato	Upper Lucerne	Upper Lucerne	Lower Wapato	Upper Wapato	Upper Wapato	Upper Lucerne
METALS (mg/kg wet)														
Arsenic	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
Cadmium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Copper	2.40	1.70	1.00	0.66	0.46	< 0.3	0.49	0.34	2.10	0.66	0.58	0.70	0.56	1.10
Lead	< 0.1	< 0.1	< 0.1	< 0.1	0.15	< 0.1	< 0.1	0.14	0.23	< 0.1	0.15	0.33	0.18	< 0.1
Mercury	< 0.05	< 0.05	< 0.05	< 0.05	0.12	0.21	0.062	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Selenium	0.37	0.32	0.21	0.28	0.24	0.27	0.29	0.16	0.21	0.34	0.28	0.28	0.48	0.25
Zinc	19	56	5	6	6	4	18	15	21	17	17	25	21	22
PESTICIDES (ug/kg wet)														
4,4'-DDE	630	260	2800	780	440	59	3200	3600	1400	1100	290	820	650	370
4,4'-DDD	93	36	190	30	18	2	160	150	80	61	39	77	89	81
4,4'-DDT	50	25	110	5	20	< 1.6	3	< 1.6	< 1.6	< 1.6	13	110	95	24
T-DDT	773	321	3100	815	487	61	3363	3750	1480	1161	342	1007	834	475
Endrin	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6

and zinc. However, all five (5) apparent metal increases were within a factor of ten of the reference values.

Consistent with the mass loading data discussed above, the highest Zn concentrations within surficial (0 - 5 cm) sediments of Lake Chelan were observed in the Lucerne Basin offshore from Railroad Creek (between Stations 7 and 8; Table 5.15). Similar Zn concentrations were also observed in underlying sediments (50 - 60 cm; estimated 1930 to 1950 deposition) collected from this location. Based on these data, it appears that Zn loading to Lake Chelan over the period 1930 to 1950 (based on approximate ^{210}Pb dating) may have been relatively similar to existing conditions. Because little reduction in Zn loading has apparently occurred over the past 30 to 60 years, since local mining activities ceased, this input will probably continue for some time into the future.

Pb exhibited the highest sediment concentration (83 mg/kg) in a nearshore sample collected adjacent to Manson (Table 5.15). The occurrence of elevated Pb in this sample could represent either an agricultural or urban-related input, since this metal has been used in local orcharding activities (i.e. Pb-As; see above) and is also a common constituent in urban runoff (Galvin and Moore, 1982). However, because of the low levels of combustion products in this sample, which would generally be associated with urban runoff (see below), an agricultural source is considered most likely. Further sampling would be required to determine both the source and possible significance of the apparent lead input.

Fish Tissue

During previous monitoring activities and also as a component of this investigation, Ecology collected samples of fish tissue from Lake Chelan for a variety of metal and organic determinations (Hopkins et al., 1985). During this recent (1987) effort, fourteen (14) samples comprised of six (6) fish species were collected from the lake. The species included northern squawfish (*Ptychocheilus oregonensis*), largescale suckers (*Catastomus macrocheilus*), burbot (*Lota lota*), kokanee salmon (*Oncorhynchus nerka*), chinook salmon (*Oncorhynchus tshawytscha*), and rainbow trout (*Salmo gairdneri*). Fish samples were collected from three sites in the lake near possible sources of metals and organics. Collection sites included the Lucerne Basin near the mouth of Railroad Creek, the upper Wapato Basin near Manson, and the lower Wapato Basin near Chelan.

Residues of seven (7) metals analyzed in these fish tissue samples are summarized in Table 5.16. Concentrations of arsenic and cadmium were not detected (< 0.15 and 0.25 mg/kg wet wt., respectively) in any of the fish samples. Quantifiable residues of lead and mercury were detected in less than half of the samples analyzed (< 0.10 and 0.05 mg/kg, respectively). Copper, selenium, and zinc residues were quantifiable in nearly all samples.

In order to assess whether metal residues may vary with location, species differences, or tissue type (e.g. fillets vs. whole fish), the data were analyzed using analysis of variance (ANOVA) techniques (Sokal and Rohlf, 1969). No significant (P > 0.05) differences were detected for any of these variables, largely because of the rather small sample sizes involved. However, the data do reveal a slight increase in copper and zinc concentrations near Railroad Creek, and slightly higher lead levels in the Wapato Basin. These general trends mirror the water and sediment results discussed earlier. Another possible trend concerned zinc concentrations, which were generally lower in fillets than in whole fish. This may reflect the documented affinity of zinc in bones, internal organs, and fish skin (Phillips and Russo, 1978; Schmitt and Finger, 1987). Additional data would be required, however, to reliably document these possible spatial and tissue differences.

The metal residues observed during the 1987 study were generally similar to previously reported data from Lake Chelan (Hopkins et al., 1985; Funk et al., 1987). These values are also similar to residues reported in other areas of Washington and also throughout the U.S. (Lowe et al., 1985; Johnson et al., 1986). No significant (P > 0.10) differences are apparent between metal residues in Lake Chelan fish and the regional or national averages.

All of the tissue residues for all metals except mercury were well within human health and environmental guidelines set by the U.S. Food and Drug Administration (FDA), the National Academy of Science (NAS), the International Joint Commission (IJC) Great Lakes Committee, the EPA, and various researchers (Finch, 1973; EPA, 1980; Nriagu and Simmons, 1984; Eisler, 1987). The maximum measured mercury concentration of 0.21 mg/kg wet wt. in a burbot sample exceeded the 0.1 mg/kg level recommended for the protection of predatory birds and animals, and approached the 0.25 mg/kg criterion recommended for expectant mothers (Eisler, 1987). The presence of mercury in this species may be related to its specific feeding habits, since it typically consumes deep-water benthos (Phillips and Russo, 1978). However, mercury was generally undetectable in sediments collected from Lake Chelan (Table 5.15). Furthermore, mercury residues in Lake Chelan fish were very similar to the national average (national geom. mean = 0.11 mg/kg) and its significance within the lake thus appears limited.

5.11 Pesticide Residues

A variety of pesticide compounds, including DDT, have historically been applied to orchard lands adjacent to Lake Chelan. Because of strong sediment adsorption and bioaccumulation properties, the highest concentrations of many of these substances occur in sediment and tissue matrices (Callahan et al., 1979; EPA, 1980; Eadie and Robbins, 1987). Very low (and rarely detectable; < 0.02 ug/L) concentrations of target pesticides have been reported in water samples collected from Lake Chelan (R.W.Beck, 1983; Funk et al., 1987; similarly low water concentrations are predicted based on sediment and tissue data - see below and EPA, 1980). Furthermore, the greatest human health and environmental risk associated with pesticides such as DDT are associated with biotic accumulation (EPA, 1980). Accordingly, sediments and fish tissues were targeted during this investigation to assess existing pesticide residues.

Sediments

Of the 23 pesticide and herbicide compounds which have been analyzed in sediment samples collected from Lake Chelan, only DDT and its associated products DDD and DDE have been reported at quantifiable levels (greater than 0.1 - 1.0 ug/kg). A summary of sediment data collected during this investigation, and historical data available for these compounds, is presented in Table 5.15. Spatial variations in the total DDT concentration (T-DDT; 4,4′-DDT + 4,4′-DDD + 4,4′-DDE) among the surficial sediment samples are also depicted in Figure 5.33. T-DDT concentrations reported in these lake sediments have ranged from less than 0.1 ug/kg (dry wt) near Stehekin (Funk et al., 1987), to approximately 700 ug/kg (dry wt) observed during this study adjacent to agricultural drains near Manson. The relatively toxic 4,4′-DDT compound generally represented 15 to 35 percent of the T-DDT concentration.

Although the highest T-DDT levels in surficial lake sediments occurred in areas closest to agricultural use areas, a rather large spatial variation in these data is nevertheless apparent (Table 5.15; Figure 5.33). Much of this observed variation in bulk sediment concentrations, however, is attributable to differences in the physical and chemical composition of lake sediments, particularly relative to their potential to adsorb DDT compounds. A better measure of the relative concentration of total DDT in these sediments is expressed in the ratio of T-DDT to total organic carbon (TOC), since sediment TOC content is known to largely control the degree of sediment DDT adsorption (Callahan, et al., 1979). The constituent:TOC ratio of highly non-polar substances such as DDT more accurately reflects equilibrium chemical conditions operable within lake systems (Eisenreich, 1987).

As expected, the T-DDT:TOC ratio of surficial sediments varied considerably less than the bulk T-DDT concentration, and consistently averaged 20 ± 6 mg/kg TOC throughout the Wapato Basin (Table 5.15). The corresponding T-DDT:TOC ratio within the upper Lucerne Basin (40 to 80 km uplake from the outlet) was much lower at approximately 1 ± 1 mg/kg TOC. These data suggest that DDT residues are dispersed relatively evenly throughout the Wapato Basin, but have not yet been transported to a substantial degree to more uplake regions. Apparently, DDT inputs to Lake Chelan have remained relatively close to the original source areas.

Fish Tissue

The fourteen (14) fish tissue samples described earlier were analyzed for twenty-two (22) pesticides and seven (7) PCB congeners (see Section 5.10 and Appendix D). However, only 4,4′-DDT and its metabolites (4,4′-DDD and 4,4′-DDE) and endrin were detected in any of the samples. These data are summarized in Table 5.16. No other DDT metabolites were detected.

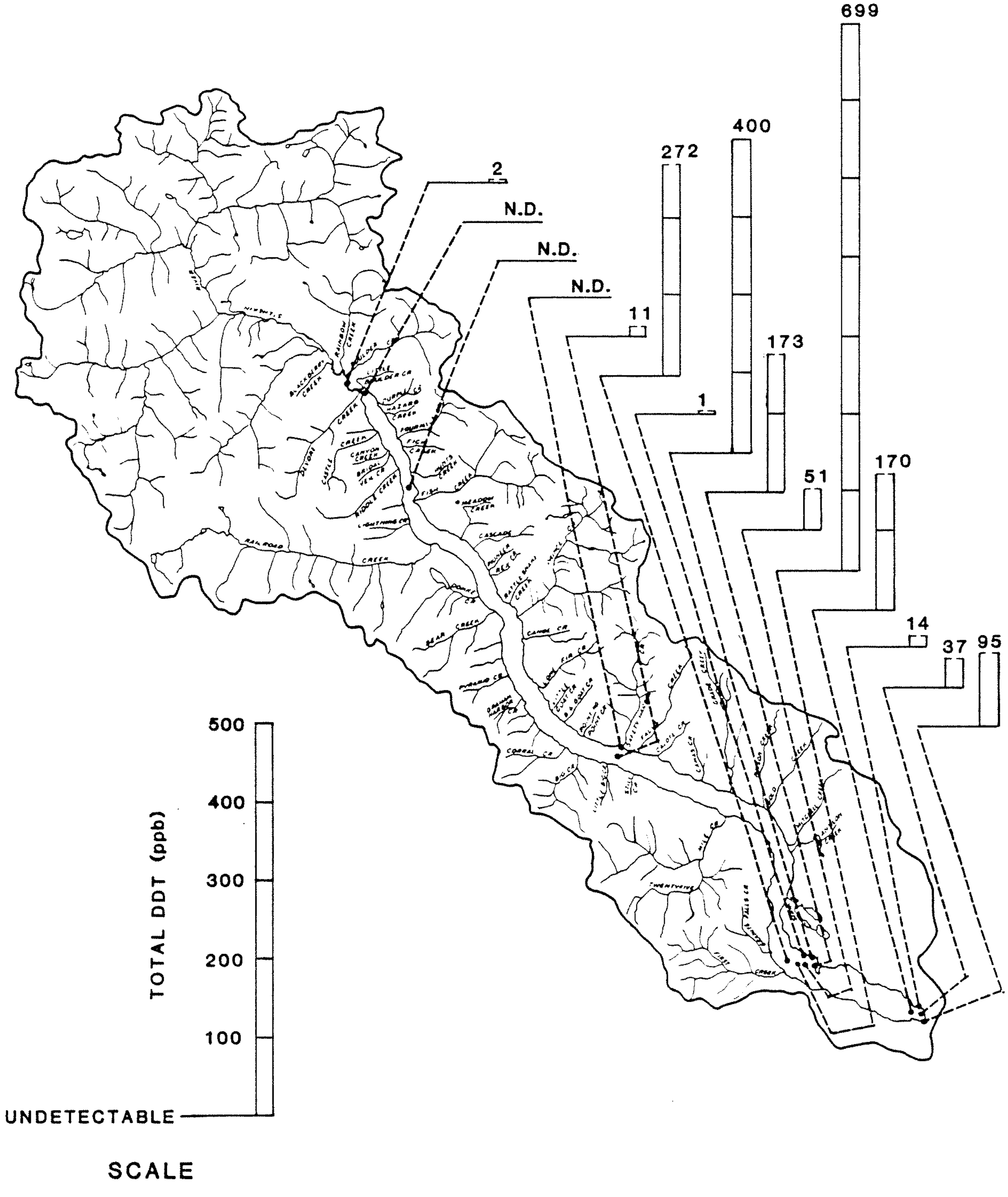

Figure 5.33

TOTAL DDT IN LAKE CHELAN SURFICIAL SEDIMENT SAMPLES

Endrin was detected in only a single sample at a concentration of approximately 5 ug/kg wet weight.

T-DDT concentrations in fish tissue ranged from 61 to 3,750 ug/kg wet weight, and averaged 1,300 ± 300 ug/kg (Table 5.16). These concentrations are similar to values reported previously for the Lake Chelan outlet (460 - 4,470 ug/kg; Hopkins et al., 1985), but are substantially higher than concentrations previously reported near Stehekin (< 1 ug/kg; Funk et al., 1987). Different analytical methodologies may partly explain the lower Stehekin-area T-DDT residue levels reported by Funk et al. (see Appendix D for analytical protocols used in this study).

DDE (4,4′ isomer) was the predominant DDT metabolite present in all samples, and typically accounted for 75 to 95 percent of the T-DDT residue concentration (Table 5.16). This contrasts somewhat with the sediment data, where 4,4′-DDT represented only 20 to 40 percent of the T-DDT (Table 5.17). These results are consistent with the presence of more metabolized forms of DDT within fish tissue, relative to possible sediment sources. Similar conditions have been reported in other lake environments (Kent and Johnson, 1979).

Similar to the metal residue data discussed in Section 5.10, possible differences in T-DDT residue concentrations relating to location, species, tissue type, size, and lipid content were assessed using ANOVA techniques. The results of this analysis revealed marginally significant ($P < 0.10$) positive correlations of T-DDT with both fish length and percent lipids. Location, species, and tissue differences appeared to have only a minor influence on residue concentrations. These results are generally consistent with the migratory behavior of fish in lake environments, and suggest that fish of a given size and lipid content may typically contain similar T-DDT residues. The correlation of T-DDT with lipid content has been observed in a variety of other investigations, and is attributed to the relatively high solubility of DDT in fatty tissue (EPA, 1980). The correlation of T-DDT with fish length may indicate a biomagnification effect, since some of the larger fish samples (e.g. chinook salmon and squawfish) are believed to be primary predators in Lake Chelan (Whitney and Wydoski, 1979). Larger piscivorous fish are also typically slower to depurate T-DDT following cessation of inputs (Armstrong, 1981; DeVault et al., 1985). Additional data would be required, however, to reliably evaluate these conditions.

The geometric mean (and also median) concentration of T-DDT measured in samples of edible fish tissue collected from Lake Chelan since 1982 is approximately 1,000 ug/kg wet weight (based on 22 samples; excluding Funk et al., 1979). This concentration is approximately three (3) times greater than the nationwide geometric mean fish T-DDT value during 1980-81 of 290 ug/kg (Schmitt et al., 1985). The Lake Chelan tissue concentrations, however, are similar to values reported for similar species in the lower Yakima, middle Columbia, and Okanogan River Basins over the 1980-85 period (geom. mean = 1,000 ug/kg; Hopkins et al., 1985;

Johnson et al., 1986). All of these drainages support extensive orcharding activities which historically have utilized DDT pesticides. Much lower, and frequently undetectable, T-DDT concentrations have been reported for drainages with little or no agricultural activities.

Based on the observed probability distribution of T-DDT residues in edible fish tissue collected from Lake Chelan, no samples exceeded the current FDA action level of 5,000 ug/kg wet weight for human consumption. Approximately 50 percent of the fish samples exceeded the IJC recommendation for the protection of wildlife (based on egg shell thinning of predator birds) of 1,000 ug/kg.

DDT is a suspected human carcinogen. The relative risk of ingesting DDT associated with fish obtained from Lake Chelan can be estimated using a simplified cancer risk model and parameters developed by EPA (1986b). Using this model, the lifetime cancer risk to those who consume the average Lake Chelan fish (T-DDT = 1,400 ug/kg) at an extreme rate of 165 grams/day (0.4 lbs/day; the upper 99.9 % national consumption rate; Finch, 1973) is approximately 1×10^{-3}, or 1:1,000. For comparison, the lifetime cancer risk for an average smoker is 8×10^{-2}, or 1:12 (Crouch and Wilson, 1984). Proportionally lower cancer risks are anticipated for lower fish consumption rates (average = 6.5 gms/day; corresponding risk = 4×10^{-5}). By these measures, existing T-DDT residues in Lake Chelan may constitute a potential human health and environmental concern, although similar conditions likely exist in a variety of other drainages in the region (see above).

Pesticide use and manufacture of DDT in the U.S. was banned in 1972, and most lake systems have exhibited steady declines in T-DDT residues in fish tissue since that time (DeVault et al., 1985; Eadie and Robbins, 1987). Historical data on T-DDT residues in Lake Chelan fish tissues available for the 1982-87 period do not reveal any significant ($P > 0.10$) decline in tissue concentrations over this period, although the data are too limited to reliably detect such a temporal trend. T-DDT residues in Lake Chelan are expected to decline at some as yet undetermined rate.

5.12 Other Organics

In addition to trace metals and pesticides, sediment samples collected from Lake Chelan were analyzed for a list of 76 extractable organic compounds, selected from EPA's Hazardous Substances List (Appendix J; GC/MS methods). Of this list of compounds, only 13 were present at levels which exceeded detection limits (1 - 50 ug/kg). Three of these identified compounds, bis(2-ethylhexyl) phthalate, di-n-octyl phthalate, and benzoic acid, are common laboratory contaminants, and the reported values may not represent valid analytical determinations. Results for the remaining 10 "significant" compounds, which all fall under the category of polynuclear aromatic hydrocarbons (PAHs), are summarized in Table 5.15.

Most of the PAHs detected in the surficial sediment samples are relatively high molecular weight compounds which can be formed during combustion activities (e.g. fires, engine exhaust; Callahan, et al., 1979). Some of these compounds, such as benzo(a)pyrene, are also potent animal and human carcinogens (EPA, 1986b). The highest observed total PAH concentration (5,080 ug/kg dry wt) was observed at the deepest location within the Wapato Basin (Station 4; Table 5.15). Significant PAH levels (with a similar PAH:TOC ratio) were also observed near the lake outlet adjacent to a major stormwater outfall serving the City of Chelan. No PAH compounds were detected within the Lucerne Basin.

These data suggest that PAH sources to Lake Chelan are rather diffuse, and likely include a variety of urban/suburban, agricultural, and possibly other land use contributions. The significance of the existing PAH residues has not been determined. However, the measured concentrations were generally at least ten times lower than apparent toxic effect thresholds for sensitive aquatic animals observed in the Puget Sound estuarine environment (Tetra Tech, 1986). Assuming that a correspondence in toxic thresholds exists between these different environments, sediment PAH toxicity is not anticipated within Lake Chelan. Considerably more data would be required, however, to reliably evaluate potential sediment toxicity.

As a final component of the Lake Chelan limnological investigations, the potential trihalomethane (PTHM) production of lake waters was examined. Potentially toxic and carcinogenic THM compounds, most notably chloroform, are often produced as a byproduct when water supplies are chlorinated for disinfection purposes (EPA, 1986b). PTHM content can be increased substantially by eutrophication (Cooke et al., in press). Based on the results of eight PTHM determinations performed over four sampling dates in 1987, lake waters exhibited a very consistent PTHM value of 38 ± 2 ug/L. Nearly all the THM production was attributable to chloroform. No temporal or spatial variations were observed, and all reported concentrations were well above distilled water control values.

The existing primary drinking water standard for THM compounds is 100 ug/L (EPA, 1986b), and considerably above the PTHM values reported above for Lake Chelan. However, because of the potentially carcinogenic properties of chloroform, a considerably lower concentration (approximately 2 ug/L) has been recommended by EPA as a water quality criterion. The apparent between these values primarily reflects the presence of moderate THM concentrations (2 - 100 ug/L) in many water supplies in the U.S., and the documented benefit of chlorination for disinfection purposes.

While the observed PTHM values reported above are considered possible outcomes of chlorination of Lake Chelan water containing THM precursors, it should be noted that the test conditions employed were expected to produce near <u>maximum</u> values. For example, residual chlorine dosage levels applied (and maintained) to the samples ranged from 2 to 3 mg/L, which is greater than typical local water supply doses of 0.5 to 1 mg/L. Holding times (1 week) and temperatures (20 ^{0}C) also tended to be extreme. Ambient THM concentrations determined randomly in samples collected from local distribution systems measured 0 to 5 ug/L, and were considerably lower than PTHM values of 35 to 40 ug/L. Under most conditions, therefore, THM production resulting from lake water chlorination is likely to be minimal.

CHAPTER 6

Discussion

6.0 DISCUSSION

Previous sections of this report have presented the rationale, methodology, and findings of hydrogeologic and limnologic investigations performed within the Lake Chelan Basin. These studies provide both a detailed baseline assessment of water quality conditions within the lake, and a basis to assess possible changes in lake quality resulting from future land use and management activities. This section presents a general overview of pertinent limnological features identified in the lake system, compares Lake Chelan with other similar lakes, and discusses possible management objectives within the basin. The section concludes with a discussion of several hypothetical development and management scenarios.

6.1 Limnology of Lake Chelan

Physical

Lake Chelan can be divided into two distinct morphometric basins which occur on either side of a prominent sill and lake constriction. The larger Lucerne Basin contains over 92 percent of the total lake volume and exhibits a maximum depth of 453 meters (1,486 ft). Tributary inputs to the Lucerne Basin originate predominantly in forested headwater areas of the Cascade Mountains, and include considerable glacial sources. The average residence time of water within the Lucerne Basin is approximately 10 years.

The smaller Wapato Basin exhibits a maximum depth of 122 meters (400 ft), and receives most of its water input from the Lucerne Basin. In the absence of significant interbasin mixing, the average bulk water residence time within the Wapato Basin would be approximately 0.8 years. 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.

During the spring and summer months, both basins of the lake develop a pronounced vertical stratification in response to seasonal warming, and exhibit a thermocline depth of approximately 25 to 40 meters (80 - 130 ft). Surface temperatures during the summer months are considerably warmer within the Wapato Basin than in the Lucerne Basin (see Plate 1). Winter temperatures are also cooler within the Wapato Basin, due to the smaller volume (and thus less heat content) of this lake basin. Because of the great depth of the lake and relatively strong circulation currents, ice cover of the lake is limited to very localized nearshore areas. 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 somewhat isolated throughout the year. Full circulation is likely to occur every few years.

Because of the elongated shape of the lake and rather strong winds which act on the lake surface, a large internal seiche develops seasonally within the Lucerne Basin. The principal mode of this seiche has a period of approximately 2 to 3 days, and is capable of alternately raising and lowering the thermocline by 30 to 40 meters (100 - 130 ft) throughout the summer period. Other seiche and associated wind-related water movements also develop within the lake, and result in a rather complex circulation regime. Currents associated with these seiche movements are most pronounced at the sill, where velocities at depth (i.e. 30 m) regularly approach 30 cm/s (0.7 mph). The alternating seiche currents result in the nearly complete mixing of waters some 5 km (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.

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 period. For example, reduced longitudinal mixing occurs seasonally within the lake reach between km 23 and km 31 (near Twentyfive Mile Creek; Table 5.6). During the summer months, this region of the lake functions as a partial hydrodynamic barrier to uplake mixing. Consistent with the reduced longitudinal mixing, surface temperatures vary widely within this lake area (Plate 1).

Reduced longitudinal mixing also occurs over the lower 15 km (9 mi) of the lake (Table 5.6). This lower lake reach functions much like a river during the summer stratification months, with epilimnetic circulation during these periods occurring almost solely in the direction of the lake outlet. The very different circulatory and mixing regimes observed between regions of the lake are at least partially explainable in terms of different seiche characteristics. The different mixing properties result in regions of the lake having different sensitivities to pollutant inputs. These are discussed in more detail below.

Trophic Status

The principal limiting nutrient to algal growth in open water areas of Lake Chelan is P. This conclusion was based on the rather high N:P ratios observed in the water column (greater than 15:1 in soluble reactive, particulate, and total nutrient pools), low ambient SRP levels (mean = 0.4 ug/L), and previous algal bioassay data (EPA, 1977). Supplies of N may co-limit phytoplankton growth only during the late summer/early fall period, and may also be important determinants of nearshore periphyton biomass in some areas. Supplies of P to the lake, however, appear to generally control pelagic and nearshore algal productivity and resultant water quality characteristics.

The concentration of TP within Lake Chelan averaged 3.2 ± 0.2 ug/L over the study period, which is well below reported levels in most other lakes throughout the Northwest. TP concentrations tended to be highest (4 - 5 ug/L) at shallow depths near the sill and lowest (1 - 2 ug/L) at greatest depths within the lake. Overall, TP concentrations during summer stratification were elevated ($P < 0.01$) within epilimnetic waters of the Lower Chelan Basin (3.9 ± 0.2 ug/L; km 0 - 27) compared to more uplake areas (3.0 ± 0.2 ug/L; km 27 - 81). The presence of elevated TP concentrations within the Lower Basin is most likely the result of local TP inputs, largely from agricultural sources near Manson. Relative to the generally accepted ultraoligotrophic threshold TP value of 4.5 ug/L (OECD, 1982), all areas of Lake Chelan can be classified as extremely nutrient-poor and unproductive (Table 6.1).

In addition to the lake TP concentration, other indicators of trophic status also characterize pelagic waters of Lake Chelan as ultraoligotrophic. For example, the average chl a concentration within lake surface waters of 0.66 ± 0.03 ug/L was below the ultraoligotrophic threshold of 1.0 ug/L (OECD, 1982; Table 6.1). Similarly, algal biovolume and annual ^{14}C productivity values were generally indicative of ultraoligotrophic conditions. The phytoplankton assembledge was dominated by the centrate diatom Cyclotella, which also appears to be characteristic of very unproductive waters (Stockner, 1971; Goldman, 1981; Sweet, 1987).

Lake transparency (as measured with a Secchi disk) averaged 13 ± 1 meters (44 ft), which is slightly below the ultraoligotrophic threshold of 14 meters (46 ft) and not consistent with other criteria (i.e., transparency would be expected to be greater; Table 6.1). However, glacial silts suspended in the water column also contribute to lake turbidity, and this trophic status classification parameter thus may not be directly applicable to Lake Chelan. All information considered, Lake Chelan is easily classified as ultraoligotrophic. Fish production is similarly quite low (Brown, 1984).

No substantial differences in trophic status were observed between different areas of the lake, although the Lucerne Basin tended to support a somewhat greater ($P < 0.10$) phytoplankton biomass during summer months. The elevated biomass condition may have been the result of larger and more steady nutrient supply rates to epilimnetic regions of the upper basin, although this difference was not reflected in TP concentration increases (Table 6.2). During summer, vertical turbulence is greater in the Upper Basin, largely due to highly energetic seiche movements and other wind-related currents characteristic of this area. Such turbulence could provide more entrainment of P from depth to permit the larger, more sustained biomass observed in the uplake areas. Additionally, the greater vertical turbulence may reduce phytoplankton sinking rates in the Upper Basin, relative to those of the Lower Basin, and result in higher sustained biomass levels (Welch, 1980). The greater biomass condition of the Upper Basin could also conceivably be caused by a lower rate of grazing by herbivorous zooplankton, though this biological process was not evaluated during this study.

In contrast to the biomass data, no spatial differences ($P > 0.10$) were observed in chl a concentrations (Table 6.2). Furthermore, net productivity of the phytoplankton during the summer months tended to be slightly higher in the Lower Basin relative to the Upper Basin, although

TABLE 6.1

SUMMARY OF BOUNDARY VALUES FOR LAKE CLASSIFICATION

TROPHIC CLASSIFICATION (a)	ANNUAL MEAN TP (ug/L)	SUMMER TSIN:SRP (by wt.)	ANNUAL MEAN CHL A (ug/L)	SUMMER MEAN BIOVOLUME (mm3/m3)	ANNUAL PRODUCTIVITY (gmC/m2-yr)	ANNUAL MEAN SECCHI DISK (m)
ULTRA-OLIGOTROPHIC THRESHOLD	4.5	-	1.0	-	20.	14.
OLIGOTROPHIC (max. liklihood)	8.0	-	1.7	-	-	9.9
OLIGO-MESOTROPHIC THRESHOLD	14.	-	3.2	1,500.	100.	6.6
MESOTROPHIC (max. liklihood)	27.	-	4.7	-	-	4.2
MESO-EUTROPHIC THRESHOLD	48.	-	7.1	5,000.	400.	3.1
EUTROPHIC (max. liklihood)	84.	-	14.	-	-	2.4
EU-HYPERTROPHIC THRESHOLD	150.	-	24.	20,000.	-	1.8
REGIONAL ULTRA-OLIGOTROPHIC LAKES (b):						
CRATER LAKE (OR; $\bar{z}$ = 325 m)	15.	<0.1:1	0.3	124.	62.	29.
LAKE TAHOE (CA/NV; $\bar{z}$ = 313 m)	4.5	2:1	-	200.	118.	24.
GREAT CENTRAL (BC; $\bar{z}$ = 212 m)	1.9	30:1	1.0	1,500.	17.	12.
LAKE CHELAN (WA; $\bar{z}$ = 144 m)	3.2	130:1	0.7	74.	30.	13.

a) Based on Wetzel (1977), OECD (1982), and UNESCO (in press)

b) Adapted from Holm-Hansen et al. (1976), Stockner and Shortreed (1985), Larson et al. (1987), and Byron and Goldman (1988)

TABLE 6.2 SUMMARY OF SELECTED WATER QUALITY CHARACTERISTICS OF LAKE CHELAN, APR-SEP, 1987

PARAMETER (units)	MODEL NOTATION (see text)	UPPER CHELAN BASIN (km 27 - 81) (mean +/- s.e.)	LOWER CHELAN BASIN (km 0 - 27) (mean +/- s.e.)
LAKE SURFACE AREA (km2)	A	81.5 +/- 0.8	53.3 +/- 0.5
EPILIMNETIC DEPTH (m)		34.7 +/- 2.7	30.4 +/- 2.9
ADVECTIVE OUTFLOW (m3/sec)	Q	42.8 +/- 2.2	41.5 +/- 2.0
LONGITUDINAL DIFFUSION (m3/sec)	E'	92.6 +/- 69.4	92.6 +/- 69.4
VERTICAL DIFFUSION (m3/sec)	E"	93.0 +/- 44.9	22.2 +/- 7.0
TOTAL DISCHARGE (m3/sec)		228.4 +/- 82.7	156.4 +/- 69.8
EPILIMNETIC RESIDENCE TIME (months)		4.4 +/- 1.7	3.3 +/- 1.5
DIRECT TP INPUT (kgP/d)	W	57.3 +/- 10.3	6.9 +/- 2.0
ADVECTIVE TP INPUT (kgP/d)		0.0 +/- 0.0	11.1 +/- 0.8
LONGITUDINAL TP DIFFUSION (kgP/d)		7.2 +/- 5.8	-7.2 +/- 5.8
VERTICAL TP DIFFUSION (kgP/d)		1.6 +/- 2.7	-1.0 +/- 1.2
TOTAL TP INPUT TO EPILIM. (kgP/d)		66.1 +/- 12.1	18.1 +/- 2.5
VOLUMETRIC TP INPUT (ugP/L-d)		0.023 +/- 0.004	0.011 +/- 0.002
EPILIMNETIC AVERAGES:			
TOTAL PHOSPHORUS (ug/L)	P_e	3.0 +/- 0.2	3.9 +/- 0.2
CHLOROPHYLL A (ug/L)		0.7 +/- 0.0	0.7 +/- 0.0
BIOVOLUME (mm3/m3)		81.8 +/- 11.1	58.8 +/- 8.8
BIOCARBON (ugC/L)		15.7 +/- 2.5	10.9 +/- 2.1
C-14 PRODUCTIVITY (mgC/m2-d)		104.4 +/- 20.4	147.6 +/- 26.4
HYPOLIMNETIC TP (ug/L)	P_h	3.2 +/- 0.3	3.4 +/- 0.5
APPARENT GROWTH RATE (/day) (a)		0.19 +/- 0.04	0.45 +/- 0.08
CHL A:CARBON RATIO (by wt.)		0.05 +/- 0.01	0.09 +/- 0.02
PHOSPHORUS UPTAKE (ugP/L-d) (b)		0.073 +/- 0.023	0.119 +/- 0.036
APPARENT P RECYCLE RATIO (c)		3.1 +/- 1.2	10.6 +/- 3.6

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a. Apparent phytoplankton growth rate calculated as C-14 productivity divided by biocarbon, normalized for epilimnetic depth.

b. Phosphorus uptake rate calculated based on C-14 productivity, and assuming a C:P stoichiometry of 41 +/- 10:1 (Redfield, 1958), normalized for epilimnetic depth.

c. Apparent phosphorus recycle ratio calculated as phosphorus uptake divided by total phosphorus supply.

this difference was also not significant ($P > 0.10$). However, these data suggest that the phytoplankton growth rate in the Lower Basin was approximately 2 to 3 times greater than that of the Upper Basin, and this difference appeared significant ($P < 0.05$). The faster phytoplankton growth rate calculated for the Lower Chelan Basin is also consistent with the higher chl a:carbon ratio ($P < 0.10$) measured in this area. The chl a:carbon ratio is strongly correlated with growth rate in laboratory studies (Bannister, 1974). The more rapid growth rate of phytoplankton in the Lower Chelan Basin is also consistent with the elevated TP concentration.

The different trophic status measures observed between the Upper and Lower Basins of Lake Chelan (i.e. greater TP and growth rate in the Lower Basin vs. greater biomass in the Upper Basin vs. equivalent chl a) may be due to a variety of limnologic factors. These factors include the greater hydrodynamic activity of the uplake area, which may increase nutrient recycling and decrease phytoplankton sinking rates. The greater biomass condition of the Upper Basin may also be related to possible biological differences (e.g., grazing rates). Other investigators have also noted different response characteristics of various trophic state indicators, particularly in ultraoligotrophic lakes (LeBrasseur, et al. 1978; Stockner and Shortreed, 1985; Byron and Goldman, 1988). The Lake Chelan trophic status data is consistent with these other studies. Comparison of Lake Chelan with other similar lakes is discussed in Section 6.2.

Although the overall trophic status of open water regions was relatively similar across the lake, different areas of Lake Chelan nevertheless varied in their sensitivity to inputs. For example, the hypolimnetic volume of the Wapato Basin is much smaller than that of the Lucerne Basin, and would be expected to be more sensitive to the decomposition of sinking organic material such as algae. Consistent with this hypothesis, significant seasonal DO depletions of approximately 2 mg/L were observed at depth within the Wapato Basin, while those in corresponding regions of the Lucerne Basin were negligible. Although DO levels throughout Lake Chelan presently exceed 9 mg/L and are within the optimal range for fish growth, possible future nutrient enrichment may result in more critical DO depletions within deep areas of the Wapato Basin. Depletion of DO in the Wapato Basin may be one of the first recognizable pelagic changes which could result from possible future nutrient enrichment of Lake Chelan.

As stated above, the lower 15 km (9 mi) of the lake exhibits reduced longitudinal mixing during summer stratification, and flow patterns become more uniformly directed towards the lake outlet at more downlake locations. This reduced longitudinal mixing results in progressive reductions in water residence time within the lake as the outlet is approached. For pollutants such as pathogens which decay over time, inputs to the lake at more downlake locations may result in a greater water quality response (i.e., less decay) than a similar input discharged to a more uplake region. The observed elevation of coliform and streptococcus bacteria near the lake outlet area appears to be at least partially a result of this spatial sensitivity. Bacterial levels near the lake outlet exceed recommended levels for water supply, but are well within limits established for recreational uses.

Besides the pelagic quality characteristics discussed above, a considerable concern exists regarding nearshore water quality conditions. Many local residences 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 (CDHD, 1981). In addition, nutrient-rich tributary inputs entering the Lower Chelan Basin result in a 10 to 50-fold increase in periphyton biomass accumulations in the shallow eulittoral zone, relative to more undisturbed areas. Much of this increase is attributable to P inputs from upland watershed sources. Both the composition and biomass of periphyton adjacent to some of the more enriched streams exceed general nuisance thresholds, and may result in local impairment of nearshore quality conditions. The extent of these nearshore "impact" areas, however, appears limited to a combined shoreline length of less than 100 m (300 ft) adjacent to tributary discharges (based on LANDSAT analysis and Figure 5.30). In addition to their role in determining littoral quality, periphyton characteristics may also be useful as sensitive, early indicators of nutrient inputs which could affect the main body of Lake Chelan.

The existing TP loading to Lake Chelan is equivalent to an input per unit of lake surface area of 139 ± 18 mg/m^2-yr. As expected, this value is far less than Vollenweider's (1976) "critical" mesotrophic TP loading calculated for Lake Chelan of approximately 700 mg/m^2-yr, and again reveals the low nutrient supply condition of the lake. Rather than a guideline for management, however, the comparison of these TP loading values simply illustrates why Lake Chelan as a whole is in a state of ultraoligotrophy.

Approximately 75 to 90 percent of the current TP input to Lake Chelan is derived from natural sources within the basin, including undeveloped forested areas and direct lake precipitation. Of the roughly 17 ± 7 percent of the lake TP input attributable to anthropogenic inputs, approximately half (i.e. 8 ± 4 % of the total) is due to agricultural inputs, primarily from orchard activities. Agricultural inputs of TN represented an even larger component of the lake total (14 ± 8 %). The <u>potential</u> agricultural inputs of N and P within the basin are considerably greater than this total, but are partially attenuated within the enriched Dry/Roses/Wapato Lake system prior to discharge into Lake Chelan (Dion et. al., 1976; and this study). Agricultural inputs appear to represent a major component of nearshore inputs and associated periphyton accumulations.

Stormwater runoff inputs which enter the Wapato Basin primarily during the winter months are also a significant component of the lake TP input, representing roughly 6 ± 6 percent of the lake total. However, most of the stormwater TP (and other constituent) inputs are in a particulate form, and appear to settle within a short distance of the outfall discharges. Although the mass loading represented by stormwater inputs is rather high, the seasonal nature and suspected low bioavailability of these discharges partially minimizes their potential importance to lake quality. Furthermore, much of the existing stormwater loading discharges to the lake near its outlet, and may not readily circulate to more uplake locations.

Septic system inputs of TP represent approximately 3 ± 2 percent of the effective lake total. In contrast to stormwater inputs, nearly all of the TP load attributable to septic system sources is bioavailable, and enters the lake at a rather constant rate throughout the year from many diffuse sources. Although these inputs are small relative to lake totals, they do represent a significant component of nearshore supplies, and thus may influence periphyton biomass accumulations. Most of the septic TP input is attributable to systems installed in areas with a relatively shallow (i.e., less than 3 m; 10 ft) depth to water beneath the drainfield trench. Future septic system TP inputs could be controlled by regulating the location and/or design of new systems (see below).

Toxicants

A more limited study of selected toxicant residues within water, sediment, and fish tissue of Lake Chelan was performed during this investigation. The largest inputs of metals to Lake Chelan are derived from an abandoned tailings pile and mine portal located near Holden Village, and adjacent to Railroad Creek. Existing discharges of zinc from the area represent more than 80 percent of the total lake input of this metal, and may result in localized aquatic life toxicity within the Railroad Creek discharge area. Metals discharges from the tailings area are not likely to be reduced in the near future, because leaching appears to be occurring at a uniform rate.

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

Groundwater and surface water drainage from agricultural areas of the Lower Chelan Basin exhibit concentrations of nitrate and arsenic which periodically exceed existing and proposed drinking water standards, respectively. These observed exceedances are apparently the result of previous fertilizer and pesticide 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 adjacent to the drain outfalls, although these inputs appear to diffuse rapidly to acceptable levels within a short distance of the outfalls (R.W. Beck 1983; and this study).

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 metabolites in surficial sediments of the lake were approximately twenty times higher in the Wapato Basin than in the Lucerne Basin, and likely 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 between fish species. DDT residue concentrations in Lake Chelan fish are similar to other regional waters. None of the fish sampled exceeded the FDA action level of 5,000 ug/kg wet weight. Individuals who consistently consume large quantities of fish (0.4 lbs per day) from the lake may increase their lifetime risk of contracting cancer by as much as 1:1,000. Wildlife may also be at risk from DDT exposure.

6.2 Comparisons With Other Ultraoligotrophic Lakes

Before discussing possible management strategies, a comparison of the water quality of Lake Chelan with that of three similar ultraoligotrophic lakes would be useful (Table 6.1). Unlike the P limited condition in Lake Chelan, N is the limiting nutrient in Crater Lake (Oregon) and Lake Tahoe (California). As a result, their P concentrations are higher and N concentrations are lower than those in Lake Chelan. TSIN is undetectable in the upper 140 m of Crater Lake and its N:P ratio is even much less than that in Lake Tahoe. Lake Tahoe has experienced a significant increase in its N supply rate over the past 30 years, largely as a result of anthropogenic increases in atmospheric deposition and watershed export. Great Central Lake (British Columbia) is P limited.

The clarity of Lake Tahoe and Crater Lake is much greater than that in Lake Chelan, by a factor of 2 or more (Table 6.1). The reason for this appears to be related to the greater input of glacier flour to Lake Chelan. Great Central Lake also exhibits a relatively low transparency, although much of this lower clarity is due to the presence of light-attenuating humic acid compounds. The greater non-algal turbidity probably explains why Lake Chelan, with twice the chl a content as Crater Lake, has only one half the productivity. Without glacier flour, there would be a greater photic zone in which photosynthesis would occur. Even with no change in the maximum rate of productivity, which is controlled by low P content, integral productivity (over a unit surface area) would be greater.

Both biovolume and productivity in Lake Tahoe are greater than in Lake Chelan. However, the past two decades or more have shown a dramatic increase in productivity of Lake Tahoe (Goldman, 1981). The first measurement in 1959 of 40 g C/m2-yr was similar to the current estimate of 30 g C/m2-yr in Lake Chelan. However, increased input of N from atmospheric deposition and transport from watershed development has caused almost a tripling in phytoplankton productivity (40 to 118 gC/m2-yr from 1959 to 1986; Byron and Goldman, 1988). Biovolume has increased as well, from 83 mm3/m3 in 1969 to the current 200 mm3/m3. That increase in productivity and biovolume has occurred without a detectable increase in nutrient content. A similar result of greater increases in productivity and biomass than nutrient content was also reported in lake fertilization experiments conducted at Great Central Lake (LeBrasseur, et al. 1978; Stockner and Shortreed, 1985).

Associated with the phytoplankton increase in Lake Tahoe has been a loss of clarity at the rate of about 0.45 meters/yr (1.5 ft/yr; Goldman and Byron, 1986). A decrease in the clarity of Crater Lake has also been reported by Larson (1984), in spite of being subjected to limited development in the very small National Park watershed. The extreme sensitivity of transparency within these two ultraoligotrophic lakes to nutrient inputs is largely a result of low abiotic turbidity. A reduced sensitivity would be expected in Lake Chelan.

There has also been a dramatic change in the species composition of the phytoplankton in Lake Tahoe. Small flagellates, such a Cryptomonas, now dominate, where diatoms, such as Fragillaria crotonensis and Cyclotella ocellata, dominated in the 1960s (Goldman, 1981). The A/C ratio (Araphidinae/Centrales), determined from diatom remains in sediments, has increased about eight fold with an abrupt change occurring about 1963 (Goldman, 1985). The loss of the centrate diatoms (Centrales), such as Cyclotella, in favor of planktonic pennate species (Araphidinae), such as Fragillaria, was developed as an index of eutrophication (Stockner, 1972). By comparison, Lake Chelan phytoplankton are dominated by Cyclotella, but small flagellates (Cryptomonas and Rhodomonas) are also important components. Planktonic A/C ratios are quite low in Lake Chelan, and similar to earlier years in Lake Tahoe.

Periphyton biomass is another important indicator of eutrophication in Lake Tahoe that is also showing signs of enrichment in Lake Chelan. Periphyton biomass in the nearshore regions of Lake Tahoe, adjacent to disturbed areas, has increased markedly in the past two decades. Biomass levels around 100 - 150 mg chl a/m2, which have been suggested to represent a nuisance threshold (Welch et al., 1988), are typical in disturbed areas, while levels of less than 10 - 20 mg chl a/m2 occur in undisturbed areas (Loeb, 1986; Loeb et al., 1986). The same background levels also occurred in Lake Chelan, while levels greater than 50 mg chl a/m2 were found near sources of enrichment. Moreover, the data have shown a significant dependence of periphyton biomass on SRP content in the nearshore area. While slight increases in nutrient loading to Lake Chelan may not result in noticeable increases in pelagic productivity, the greater availability to periphyton make that community an early indicator of change.

One of the principal uses of Lake Chelan is recreational fishing. Previous studies of the lake fishery have revealed very low fisheries productivity (Brown, 1984). Although in theory this productivity can be increased through nutrient additions, in practice such nutrient increases have met with limited success. Ultraoligotrophic Great Central Lake on Vancouver Island, for example, has received periodic nutrient additions over the past 10 years in an effort to increase fisheries production (primarily for sockeye salmon fry; Hyatt and Stockner, 1985). TP additions to this lake represented an approximate 50 percent increase over natural conditions. Although the fertilization has increased total fisheries production, sticklebacks and other less valuable species have represented the bulk of the production increase, with little benefit to the salmonid resource. In this lake, as in many others throughout the Northwest, elevated temperatures within epilimnetic waters during the summer growing season largely preclude foraging in these areas by salmonids and minimizes the benefit of nutrient additions. Since many physical factors such as depth, light penetration, and temperature are similar between Lake Chelan and Great Central Lake, similar fishery production responses to nutrient increases would be expected in Chelan. Although a careful program of eutrophication could potentially increase the principal kokanee and chinook recreational fishery in Lake Chelan, based on this information, such a scheme may have limited value, and may not be desirable when other uses of the lake are considered.

6.3 Management Goals

Existing uses of Lake Chelan include water supply, water contact recreation, recreational fishing, and aesthetic enjoyment. Large tracts of National Park lands within upper areas of the basin also represent important beneficial uses of the lake and nearshore environment. These uses are at least partially dependent upon the maintenance of near-pristine conditions. A principal objective of future management efforts within the lake basin, therefore, will be to protect all characteristic beneficial uses, as much as is reasonably possible, from water quality degradation.

Lake Chelan represents a very unique resource in Washington. Besides being the longest and deepest natural lake in the state, its nearly pristine qualities are responsible for much of the allure of the area. Through past and current regulatory and funding actions, Ecology has striven to preserve the excellent water quality of the lake. The maintenance of near-pristine water quality conditions into the future was also a primary purpose behind Ecology's funding of this study.

Knowledge of the effect of nutrient inputs from human development is critical to foster responsible growth. Data presented previously in this report provide a rather extensive technical base which allows the effects of such development to be evaluated. Use of this information, in turn, can lead to responsible planning and management of the lake basin.

Ecology has stated that the overall management goal for Lake Chelan is the preservation of its existing near-pristine water quality conditions (J. Hodgson, Ecology, personal communication, 1988). It is understood that growth will occur, however, significant change from its current near-pristine condition is not considered acceptable. This general management goal forms the basis for more specific management objectives and actions discussed below.

The existing condition of Lake Chelan as it pertains to nutrient and aesthetic qualities is represented in its trophic classification.

Although trophic descriptions have no absolute meaning, they are generally used by most lake investigators and managers either to denote the nutrient "status" of a waterbody, or to describe the effects of nutrients on a range of water quality conditions within that waterbody (OECD, 1982). As discussed above, chemical and biological data for Lake Chelan easily classify pelagic regions of the lake as ultraoligotrophic, or among the most unproductive and pristine of northern temperate lakes throughout the world.

A primary management goal for Lake Chelan, therefore, is to maintain the existing ultraoligotrophic condition within pelagic areas of the lake, in order to prevent likely shifts in the plankton community (e.g. as in Lake Tahoe) and associated water quality changes. 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 to only allow future development within the basin to a level which has a low risk of altering the existing ultraoligotrophic status of the lake. The "acceptable" level of risk of trophic degradation, based on previous regulatory policies and accepted scientific measures of certainty, was assumed for this assessment to be five (5) percent.

Phosphorus has been identified as the principal nutrient which controls algal growth in Lake Chelan, and the in-lake TP concentration is also widely recognized as the master variable which defines trophic status in most freshwater (OECD, 1982). Accordingly, maintenance of ultraoligotrophic status is likely to be dependent upon keeping in-lake TP concentrations below the ultraoligotrophic threshold value of 4.5 ug/L (Table 6.1). In the context of the probabilistic management goal stated above, additional development within the Lake Chelan basin is considered acceptable only if there is less than a five (5) percent chance that such development will cause in-lake TP concentrations to exceed 4.5 ug/L. Therefore, there is a 95 percent chance that the resulting average TP concentration will be less than 4.5 ug/l. Such an "acceptable" TP increase would minimize biological changes and also prevent significant DO depletions in the Wapato Basin (based on Section 5.0 data and Cornett and Rigler, 1979). Achievement of such a management goal is also likely to minimize the production of THM precursor compounds and degradation of the nearshore environment both of which affect the suitability of the drinking water supply.

Given existing and projected land uses within the drainage basin, nearly all of the potential future development and associated TP loading is likely to occur within the watershed of the Lower Chelan Basin. Seasonal average epilimnetic TP concentrations are also currently higher in this area of the lake (3.9 ± 0.2 ug/L over the 1987 stratification season) than at more up-lake locations. Epilimnetic TP concentrations decreased to more uniform values throughout the lake during winter mixing. Based on this information, the summer stratification season within epilimnetic waters of the Lower Chelan Basin was identified as being most susceptible to additional development-related inputs. Seasonal evaluations of nutrient dynamics within this area of the lake formed the basis of assessments of "acceptable" development conditions.

The general mass balance differential equation which describes phosphorus transport to and from epilimnetic waters may be expressed as (Chapra and Reckhow, 1983):

$$V_l(\partial P_{l,e}/\partial t) = W_{l,d} + Q_u P_{u,e} - Q_l P_{l,e} - vA_l P_{l,e}$$
$$+ E'(P_{u,e}-P_{l,e}) + E''(P_{l,h}-P_{l,e})$$

where:
V = Volume (m^3)
∂ = indicates "Change In"
t = Time (sec)
P = TP Concentration (ug/L)
W = TP Loading Rate (mg/sec)
Q = Discharge Rate (m^3/sec)
v = TP Settling Velocity (m/sec)
A = Surface Area (m^2)
E'= Bulk Longitudinal Diffusion Rate (m^3/sec)
E''= Bulk Vertical Diffusion Rate (m^3/sec)

and subscripts denote:
l = Lower Chelan Basin (km 0 - 27)
u = Upper Chelan Basin (km (27 - 81)
e = epilimnion
h = hypolimnion
d = direct inputs (e.g. tributaries)

The mass balance model is also depicted graphically in Figure 6.1. The diffusive mass transport terms (i.e. E′ and E") may either be positive or negative depending on the direction of the concentration gradient. For example, if the Lower Chelan Basin epilimnetic TP concentration is higher than that of the Upper Chelan Basin (i.e. $P_{l,e} > P_{u,e}$), longitudinal diffusive TP transport will occur from the Lower Basin toward the Upper Basin.

Based on the hydrodynamic data summarized in Table 6.2, the seasonal average residence time of water within the epilimnion of the Lower Chelan Basin is approximately 3.2 ± 1.5 months. Over the April to September stratification season, therefore, this area of the lake may approach a steady-state condition where lake concentrations are nearly in equilibrium with input conditions.In addition to the steady-state assumption, the mass balance differential can be further simplified in order to evaluate the effect of small increases in direct TP loading on the in-lake TP concentration. For example, with small additional TP inputs related to increases in W_d, it may be assumed that $P_{u,e}$ and $P_{l,h}$ (the Upper Basin epilimnetic TP and Lower Basin hypolimnetic TP concentrations, respectively) will vary little from existing conditions. This scenario is consistent with the general conservative management goals outlined above,

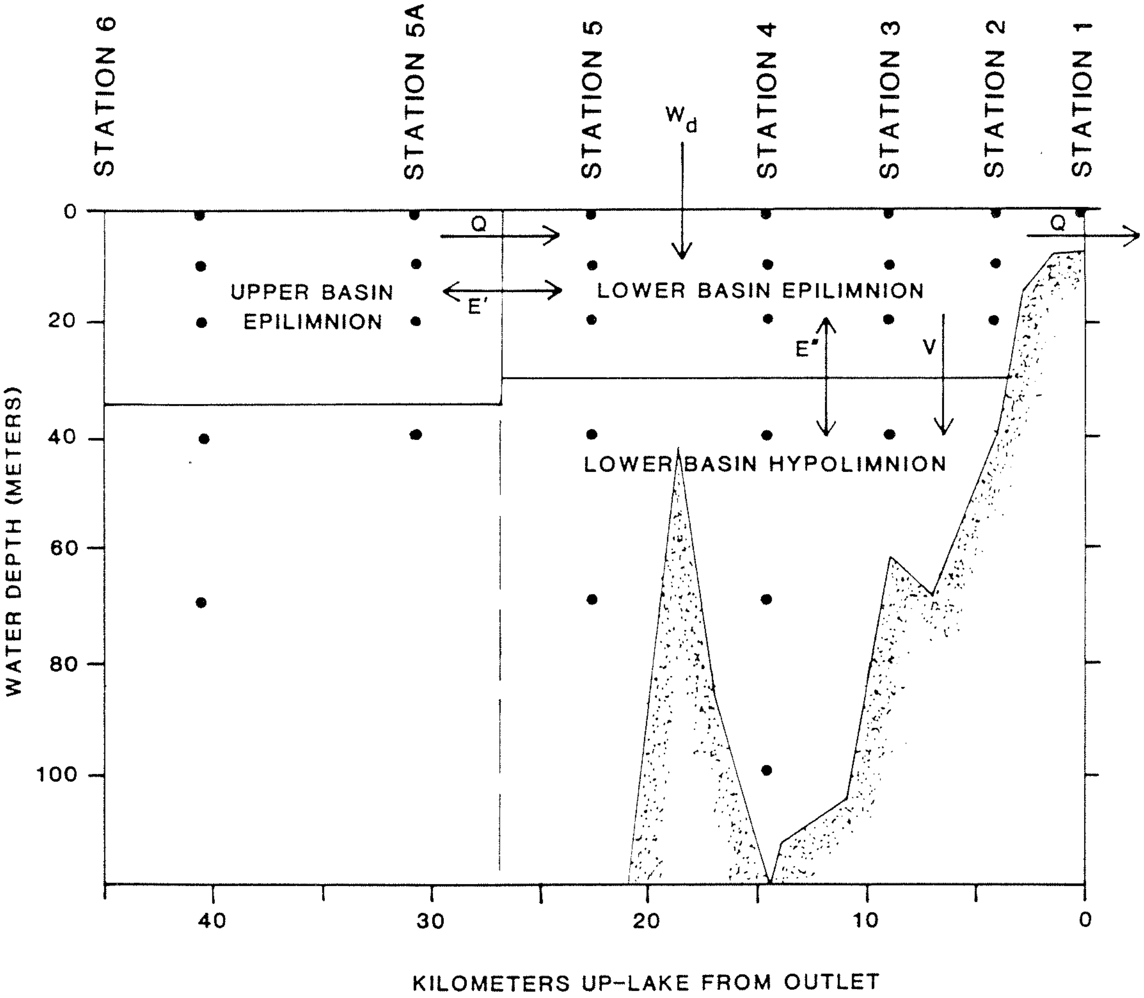


Figure 6.1

CONCEPTUAL MODEL OF
SEASONAL PHOSPHORUS DYNAMICS
IN THE LOWER CHELAN BASIN

with the result that the steady-state solution may be expressed as (Chapra and Reckhow, 1983):

$$P_{l,e} = \frac{W_d + Q_{u,e}P_{u,e} + E'P_{u,e} + E''P_{l,h}}{Q_l + E' + E'' + vA_l}$$

This formulation is equivalent to the quotient of gross TP loading to the epilimnion divided by a characteristic constant of proportionality:

$$P_{l,e} = W_T/k_l$$

where: $W_T = W_d + Q_{u,e}P_{u,e} + E'P_{u,e} + E''P_{l,h}$

$k_l = (Q_l + E' + E'' + vA_l)$

The constant of proportionality (k_l) reflects the combined epilimnetic characteristics of dilution, diffusion, and sedimentation. By definition, E' and E'' are both non-negative values, even though uncertainties in the calculation of these diffusion rates based on tracer data are rather large (Table 6.2). For the purposes of performing uncertainty propagation calculations (see below), the minimum values of both E' and E'' were therefore assumed to equal zero.

The steady-state phosphorus mass balance formulation discussed above was applied to Lake Chelan for the purpose of evaluating the additional direct TP loading which would result in attainment of a given in-lake TP concentration. The formulation can be rearranged to yield the following:

$$W_d' = (W_T)(P_c/P_{l,e} - 1)$$

where: W_d' = Additional Direct TP Loading to the Lower Basin

P_c = 4.5 ug/L (evaluated at the 5 percent risk level)

Given the above formulation and parameter values as summarized in Table 6.2, the calculated additional direct TP loading (i.e. W_d') which would result in a seasonal epilimnetic TP concentration of 4.5 ug/L is 7.3 ± 4.1 kgP/day. The 5 percent risk value, which generally corresponds with the stated Ecology policy goal, was calculated using Monte Carlo analysis techniques at 0.5 kgP/day (Shannon, 1975). For comparison, the existing direct TP loading to the Lower Chelan Basin averages 6.9 ± 2.0 kgP/day over the summer period. The calculated threshold loading increase will be discussed further in Section 6.4 in relation to possible development scenarios. Nearshore effects of additional loading increases will also be addressed.

6.4 Development Scenarios

In order to relate the threshold TP loading increases discussed above to possible land use changes within the basin, several development scenarios were evaluated. For purposes of discussion, only residential developments utilizing septic systems are considered in these projections. Residential septic systems were considered far more amenable to management than other important land uses (e.g., orchards), and are more closely tied to population forecasts available for the basin (J. Vodopich, Chelan County, written communication, 1988). TP loadings associated with other residential activities (e.g., increased stormwater runoff) were also evaluated.

Two potential management scenarios were considered. The first assumed that no additional regulations would be implemented to control P inputs from septic systems. The overall soil removal of P from these systems was assumed to be equivalent to the average of all systems monitored during this study of 90 ± 8 percent (Table 4.6). The second management scenario assumed the adoption of more stringent septic system siting and design criteria, so that overall P removal within the basin would be increased. These two scenarios are discussed below.

6.4.1 No Additional Regulations

Without the adoption of additional regulations, septic system and stormwater TP loadings associated with each future development unit (e.g., each single-family residence) are likely to be similar to existing conditions. Unit loadings measured during this study, therefore, should be similar to future conditions under such a scenario. The validity of this assumption is supported in part by the observation that all seven (7) septic systems which exhibited definable attenuation properties appeared to generally conform with existing septic system regulations, even though some of these systems were installed prior to the adoption of such requirements.

The unit TP loadings associated with septic system and stormwater discharges from residential developments are summarized in Table 6.3. The existing unit septic system loading of 0.75 ± 0.63 kgP/day-1,000 dwellings was based on results summarized in Tables 4.6 and 4.7, assuming an average 2.4 individuals per dwelling. No seasonal changes in TP loadings to the lake from septic systems are likely, given the rather slow groundwater flow rates (approx. 5 - 100 m/yr; Appendix E) and corresponding long travel times to Lake Chelan.

TABLE 6.3
SUMMARY OF UNIT DEVELOPMENT P LOADINGS

SOURCE	Phosphorus Loading (kgP/day-1,000 dwellings)
Septic Systems:	
Existing Regulations	0.75 ± 0.63
Enhanced Regulations	0.08 ± 0.06
Stormwater Inputs	0.10 ± 0.10

Unit stormwater discharges were based on results summarized in Table 5.11, and further assuming that the "effective" input may be represented by measured SRP loadings from urban catchments within the City of Chelan. The rate of P input during the summer was assumed (conservatively) to be similar to the average annual rate, in order to account for miscellaneous P inputs associated with residential activities (e.g., yard fertilization). The dwelling density within the stormwater catchments monitored in this study was approximately 9 ± 4 per hectare (4 homes/acre). Compared to septic system contributions, unit stormwater P loadings were relatively minor (Table 6.3).

Based on a combined unit P input of 0.85 ± 0.64 kgP/day-1,000 dwellings from residential developments utilizing septic systems, the number of additional dwellings which could be assimilated within the Lower Chelan Basin without causing a change in lake trophic classification can be estimated. For the stated five percent "acceptable" risk level, approximately 500 additional dwellings (1,200 residents) using septic systems could be assimilated within the Lower Basin (based on Monte Carlo probabilistic analysis). Given current population trends (Figure 2.2), this additional development could conceivably occur within roughly 20 to 60 years, depending upon development pressures and how many new dwellings will connect to the regional sewer system.

On average, the addition of 500 new dwelling units with septic systems would result in an increased seasonal TP loading to the lake of approximately 0.44 ± 0.33 kgP/day. This calculated value corresponds to an increase in seasonal tributary loadings (W_d - atmospheric inputs) in the Lower Chelan Basin of roughly 15 ± 13 percent over existing conditions. Based on the observed relationship between available P inputs and periphyton (Figure 5.31), this additional watershed loading could effect an increase in nearshore periphyton biomass of approximately 8 ± 8 percent. Since the present extent of nuisance periphyton conditions is rather limited, such an increase may not be perceptible. Ecology believes that this minor increase in periphyton biomass is acceptable, and that additional management controls (beyond those stated above) to further minimize changes in the nearshore periphyton community are unnecessary.

6.4.2 Enhanced Septic System Regulations

The discussion presented above identified septic system discharges of P as the primary nutrient source attributable to residential development. Furthermore, systems installed in areas with a relatively shallow water table condition were found to contribute the bulk of the total septic system TP loading to Lake Chelan. Implementation of additional regulations designed to increase the effective thickness of the unsaturated soil zone which underlies the septic system drainfield may result in large improvements in overall P removal efficiency, and therefore reduced future loading related to development in the Lake Chelan Basin.

Before more stringent septic system regulations could be adopted, Chelan-Douglas Health District officials must first designate the Lake Chelan drainage basin as a "Geologically Sensitive Area" pursuant to RCW 70.05.060 and WAC 248-96-025. Under such a declaration, the health officer is given the authority to require additional reasonable standards as are necessary to prevent water pollution. Given Ecology's pristine water quality goal for Lake Chelan, and the possibility that this goal may not be met if future development continues without additional controls, designation of the basin as "geologically sensitive" is believed to be appropriate.

The general criteria which may be used to formulate an enhanced septic system regulation may include a minimum thickness of unsaturated soil between the bottom of the drainfield trench and the seasonal high water table. Preliminary infiltration and flow analyses of the drainfield area may also be necessary to properly evaluate potential mounding of groundwater beneath the drainfield (see Figures 4.5 through 4.8). These mounding evaluations, in turn, may necessitate the collection of site-specific groundwater flow information (e.g., water table fluctuations, grain size distributions, and hydraulic conductivity data), in addition to standard percolation tests. More specific testing and analysis activities associated with the recommended regulation are described in Subsection 6.4.3 below.

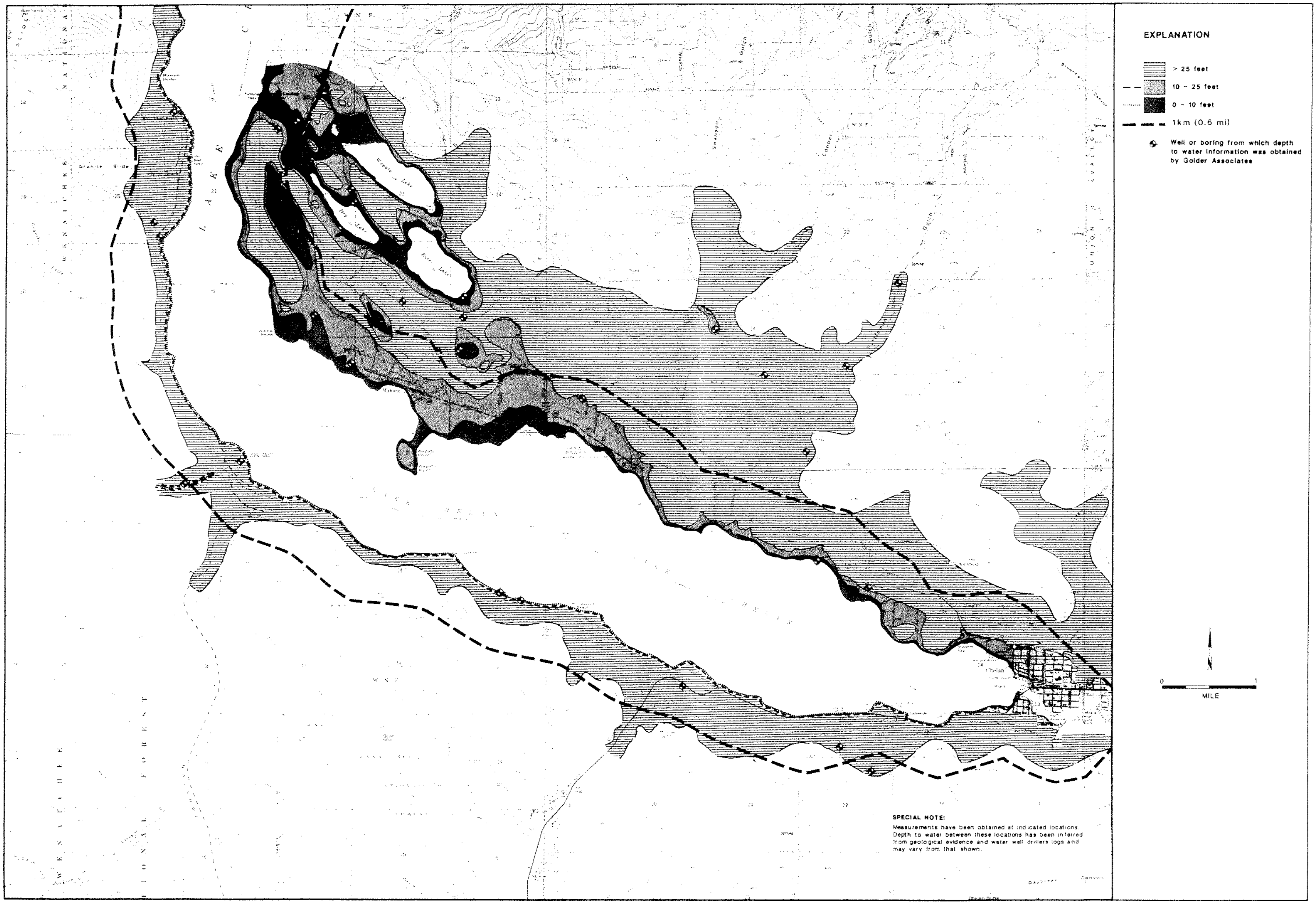
Under equilibrium operating conditions (i.e., with mounding effects included), the minimum thickness of the unsaturated zone from the bottom of the drainfield trench to the water surface should be approximately 3 meters (10 ft) to ensure high overall P removals. Based on data collected during this investigation, systems operating with an unsaturated thickness of less than roughly 3 meters exhibited a tendency towards decreased P removal efficiency. Other investigators have observed a similar relationship of decreased nutrient removal as the unsaturated thickness declines (Taylor and Kuniski, 1974; Dillon and Kirchener, 1975; Cogger, 1988). The importance attributed to the unsaturated zone in determining P removal has also led to the requirement for a similar unsaturated zone thickness beneath larger wastewater drainfield systems (e.g., Hensel et al., 1984). The expected overall P removal efficiency for systems with more than a 3 meter unsaturated zone, based on data summarized in Table 4.6, is approximately 99 ± 1 percent. The off-site septic system P transport associated with such systems is roughly ten times lower than the existing average condition.

As discussed above, achievement of an unsaturated zone thickness of greater than 3 meters is partially dependent upon site-specific soil conditions and septic system design factors which determine groundwater mounding. These conditions are difficult to anticipate and are appropriately handled by the Health District on a case-by-case basis using evaluation methods as outlined below. However, there are some areas of the Lower Chelan Basin where the ambient (i.e., without mounding) thickness of the unsaturated zone is less than 3 meters. In these areas, which are depicted in Figure 6.2, it may be quite difficult to achieve the 3 meter thickness criterion using a natural soil drainfield. Septic systems installed in these areas are not expected to perform as well as in other areas. Considering the stated water quality goals for Lake Chelan and the likelihood of continued basin development, these areas may be generally regarded as unsuitable for future conventional septic system installations.

Another important hydrogeologic factor which may influence performance characteristics of septic systems is the depth to limiting layer. For the purpose of this analysis, the limiting layer is defined as the first aquitard or relatively impermeable layer which would restrict vertical groundwater flow and therefore promote the development of saturated soil conditions. These limiting layers locally include bedrock, lacustrine deposits (e.g., silts and clays), and glacial till. Based on the regional mapping presented in Figure 6.3, a large area of the Lower Chelan Basin may generally exhibit a limiting layer at relatively shallow depth. Most of these limiting layers, however, do not presently support saturated groundwater conditions, primarily because of the rather limited existing recharge (see Sections 4.2 and 5.1). Wastewater infiltration, however, could lead to the development of localized saturated conditions beneath the drainfield.

The generalized distribution of the depth to limiting layer, as presented in Figure 6.3, should be interpreted with some caution, since considerable variability of this parameter was observed over rather short distances. This variability is due in part to the complex surficial geologic conditions which characterize the basin (Figure 4.1). Because of this variability, in areas which exhibit the potential for a relatively shallow depth to limiting layer, site-specific sampling and groundwater mounding evaluations are likely to be necessary to ensure achievement of a 3 meter unsaturated soil thickness. These efforts are described in Section 6.4.3 below.

Based on an assumed 99 ± 1 percent overall septic system removal efficiency with an enhanced regulation, the unit P input from future septic systems is expected to average 0.08 ± 0.06 kgP/day-1,000 dwellings (Table 6.3). Given estimated stormwater loadings as summarized above, the number of additional dwellings which could be assimilated within the Lower Chelan Basin without causing a change in lake trophic classification was estimated. For the stated five percent "acceptable"



SPECIAL NOTE:
Measurements have been obtained at indicated locations. Depth to water between these locations has been inferred from geological evidence and water well drillers logs and may vary from that shown.

Figure 6.2

DEPTH TO WATER

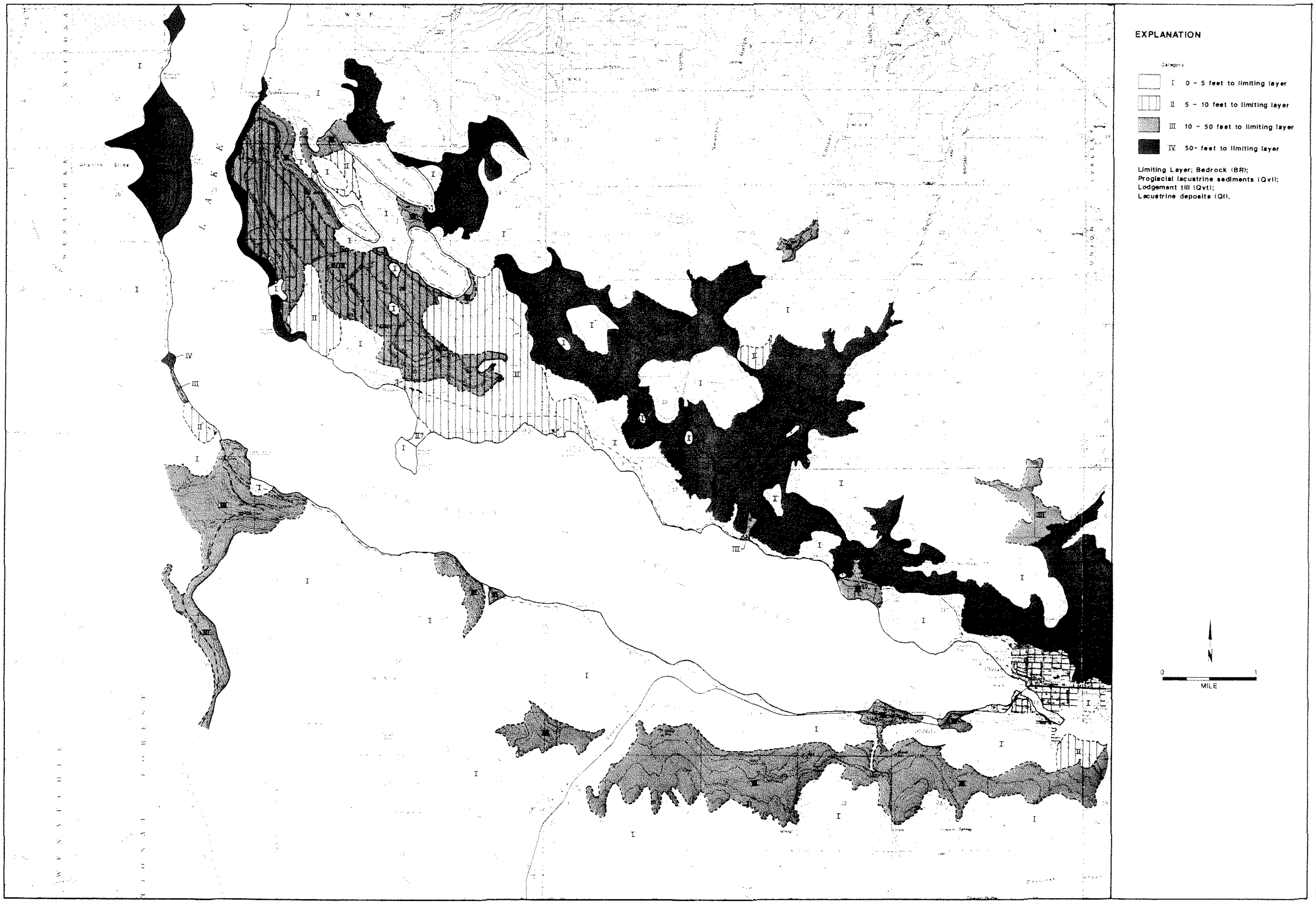


Figure 6.3

DEPTH TO LIMITING LAYER

risk level, approximately 2,600 additional dwellings (6,200 residents) using septic systems could be assimilated within the Lower Basin (based on Monte Carlo probabilistic analysis). Based on these analyses, implementation of an enhanced septic system regulation may result in an approximate 5-fold increase in the number of developments which could be assimilated. This estimated future septic system development capacity also corresponds to an approximate 200 percent increase in the number of septic systems currently being utilized within the basin. Given current population trends (Figure 2.2), this "saturation development" level is unlikely to occur within the near future.

6.4.3 Recommended Regulatory Approach

The recommended evaluation and design criteria for new residential septic systems within the Chelan Basin includes siting, testing, and analysis components. Each of these elements are outlined below.

Siting: 1) Proposed systems which lie within areas characterized by an estimated ambient depth to water of less than 8 meters (25 ft) or a distance to Lake Chelan of less than 1 km (0.6 mi.) (based on Figure 6.2) shall be required to perform additional testing and analysis as outlined below. The 1 km distance criterion addresses the general distribution of potentially unsuitable soils within the basin, and takes into account attenuation likely to occur over extended travel distances.

2) No proposed systems shall be installed within 30 meters (100 ft) of the extreme high water boundary of Lake Chelan or any perennial or seasonal surface water feature which may discharge to Lake Chelan.

Testing: 1) All proposed systems shall meet existing variable head percolation test (perc test) requirements;

2) For each candidate site which meets the perc test criteria, a soil boring shall be obtained to a minimum depth of 5 meters (16 ft) below the bottom of the proposed drainfield trench (deeper borings may be necessary in specific situations to assure compliance with a 3 meter unsaturated zone);

3) Borings shall be advanced during the June to September period when the water table is highest;

4) Continuous soil samples (e.g., every 2.5 ft using a standard split-spoon sampler) shall be collected to a minimum depth of 5 meters, classified and logged by a qualified geologist or engineer, and analyzed (individually) for grain size distribution by a qualified laboratory;

5) Boring logs describing the soil profile, the estimated depth of the seasonally high water table (if encountered), and all grain size data shall be submitted with the septic system permit application.

Analysis: 1) All proposed systems shall conform with existing general treatment and hydraulic loading criteria (e.g., EPA, 1980a);

2) Generally, no septic systems shall be permitted in areas where more than 50 percent of the soil materials encountered over the unsaturated zone are represented by gravels, cobbles, or rocks (i.e., material which does not pass a No. 4 sieve);

3) The hydraulic conductivity of each individual soil sample analyzed above shall be estimated by a qualified geologist or engineer using grain size relationships as outlined in Freeze and Cherry (1979);

4) Using the minimum hydraulic conductivity value obtained throughout the 5 meter soil boring, the potential groundwater mound beneath the drainfield during the design flow condition shall be evaluated by a qualified engineer or geologist using appropriate modelling procedures (e.g., Freeze and Cherry, 1979; Hensel et al., 1984);

5) For all septic systems, the minimum depth from the bottom of the drainfield trench to the top of the estimated seasonally high groundwater mound must exceed 3 meters (10 ft).

The recommended testing and analysis procedures summarized above for residential septic systems in the Chelan Basin are similar in many respects to existing requirements for larger community drainfield systems in other areas (Siegrist et al., 1986). Because of this overlap, and also because the proposed procedures are not difficult to perform, the professional expertise needed to properly design and evaluate septic systems for the Chelan Basin should not be difficult to obtain. These activities, however, will increase the total design cost for future residential septic systems.

Although control of septic system sources of nutrients is recommended as an important major component of a Lake Chelan protection program, longer-term basin planning efforts should also include management of other non-point sources such as urban and agricultural runoff. Such efforts could include a variety of management activities by public health, public works, and agricultural entities to control potential nutrient, pathogen, and hazardous waste emissions. These management activities could include the following:

o Decreased and/or more controlled use of nutrients and pesticides in both agricultural and residential areas, primarily to reduce the possibility of <u>excessive</u> use of these materials beyond those necessary to maintain high yields;

- Increased use of permeable surfaces in urban areas to improve subsurface stormwater infiltration and associated pollutant attenuation; and

- Increased public awareness of the relationship of land and water use activities to water quality characteristics of Lake Chelan.

The previous discussion of possible development scenarios within the Lake Chelan drainage basin assumed that the existing sewage collection and treatment system continues to function in a manner similar to the present condition. However, future sewer needs will undoubtedly change as development progresses. Along with the recommendations discussed above, modification of the sewer system should be considered as a possible management option to minimize degradation of Lake Chelan.

6.5 Alternative Water Supply Intakes

A variety of existing drinking water purveyors currently obtain water from Lake Chelan in areas requiring treatment prior to consumption. The area of most concern is near the lake outlet by Chelan, where surface waters contain elevated FS, FC, and TC concentrations which regularly exceed potable water standards (Table 5.12; Figure 5.32), and particularly during the summer months. No other water quality deficiencies besides potential pathogen conditions were identified related to consumptive uses.

Hydrodynamic data suggest that the upper 30 meters (100 ft) of the Wapato Basin is well mixed, and likely exhibit similar water quality characteristics. Within this relatively shallow depth range and especially near possible pathogen sources near Chelan, waters are likely to be at relatively high risk of pathogen contamination. Depths below 30 to 40 meters, however, are more isolated from surface inputs, and appear to be largely supplied by deep water inputs from the Lucerne Basin (Figure 5.18). Accordingly, optimal sites for water supply intakes in the Wapato Basin are located at depths greater than approximately 30 to 40 meters. These deeper zones also have little risk of deep water anoxia and associated water quality degradation, particularly if Ecology's stated water quality objectives for Lake Chelan are achieved (see Section 6.3).

In order to reach a water depth of 40 meters, the principal existing intake which supplies the City of Chelan would need to extended approximately 4.0 kilometers (2.5 mi) uplake. However, prior to recommending such an extension, the costs and effectiveness of alternative methods of improving the quality of the water supply should be evaluated (e.g., filtration). Currently, water filtration is required for all surface water systems, and this requirement may be applied to the Chelan system regardless of the intake location. However, EPA and DSHS are currently evaluating criteria for possible exemption from the filtration requirement (e.g., from a deep Lake Chelan intake), with decisions expected by the spring of 1989 (T. Justus, DSHS, personal communication). These upcoming EPA and DSHS decisions may substantially affect an optimal course of action for the Chelan water system.

CHAPTER 7

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APPENDIX A

Monitoring Well Construction Details

RECORD OF BOREHOLE CH-1

Figure
Page 1 of 1

LOCATION: See Figure (Sather property, drain 8)
DATUM: Land surface elev. 1165'
DATE: 11/19/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

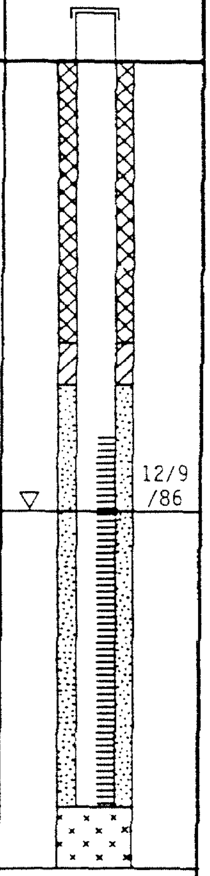
SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Dense, dark brown, sandy SILT, damp	ML			
5.3	Dense, tan SILT, damp	ML	1	DO	9 14 24
8.0	Dense to very dense, light brown, stratified SILT, silty SAND, sandy SILT, occasional pebbles, wet	SM	2	DO	14 27 50/.4
13.0	Very dense, light brown, medium to coarse SAND, little to some silt, wet	SW	3	DO	32 31 28
18.0	Very dense, tan, fine SAND, trace silt, wet	SP	4	DO	8 18 41
21.5	End of borehole at 21.5 feet				

DEPTH, FT.

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-2

Figure
Page 1 of 1

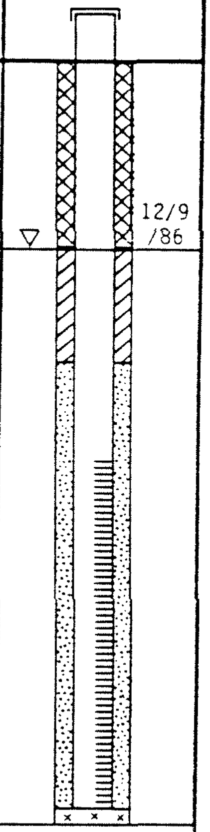
LOCATION: See Figure (Simmonds property, drain 6)
DATUM: Land surface elev. 1235'
DATE: 11/19/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES			
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Compact, light olive-gray, fine to coarse SAND, trace to little silt, wet	SW				
			1	DO	2 5 12	5
8.0	Very dense, light olive-gray to gray, fine to coarse SAND, trace to little silt, occasional gravel, wet	SW	2	DO	6 22 50	10
			3	DO	19 17 52	15
			4	DO	50/.5	20
20.5	End of borehole at 20.5 feet					
						25
						30

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 8"
Well diameter: 2"
Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-3

Figure
Page 1 of 1

LOCATION: See Figure (Morris property)
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.

DATUM: Land surface elev. 1230'

DATE: 11/20/86
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
	Very dense, brown, SAND and GRAVEL/COBBLES, dry	GW				5		No installation
6.0	End of borehole at 6.0 feet Refusal					10 15 20 25 30		

REMARKS: Boring diameter: 8"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-4

Figure
Page 1 of 1

LOCATION: See Figure (McClellan property, drain 11)
DATUM: Land surface elev. 1172.76'
DATE: 11/20/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

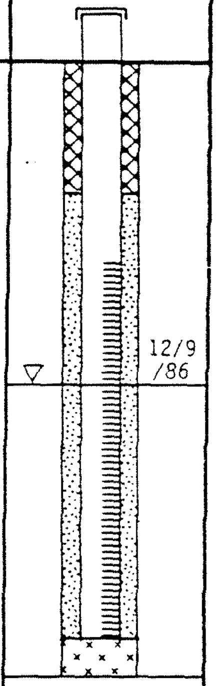
SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Loose, brown to light olive-gray, fine to coarse SAND and SILT, wet	SW	1	DO	3 3 3
			2	DO	5 4 0
15.5	Stiff, light olive-gray, clayey SILT, wet	ML	3	DO	7 3 7
16.5	End of borehole at 16.5 feet				

DEPTH, FT.: 5, 10, 15, 20, 25, 30

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

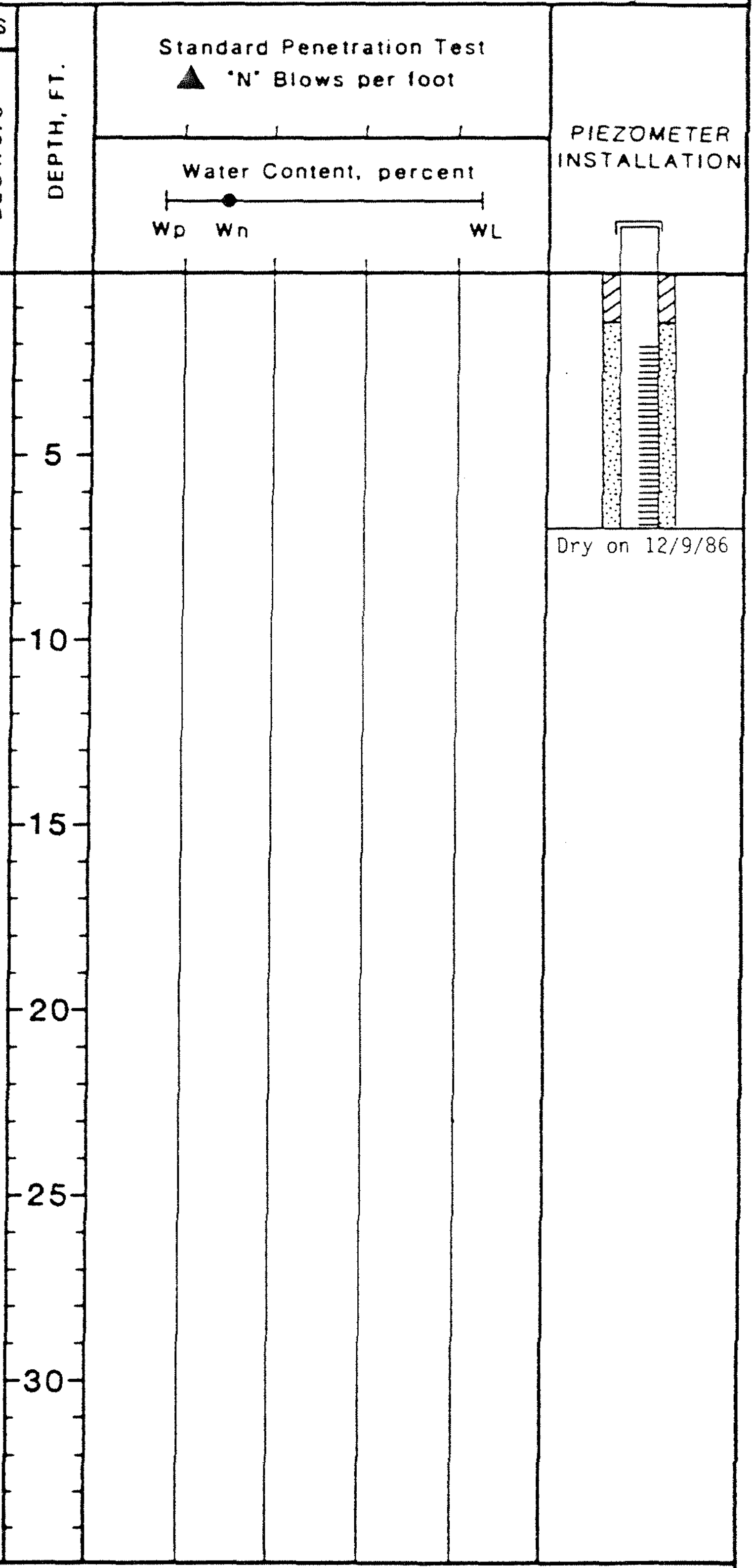
LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-5

Figure
Page 1 of 1

LOCATION: See Figure (Goodwin property, downgradient)
DATUM: Land surface elev. 1280'
DATE: 11/20/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Dark brown, silty SAND,damp	SM			
4.0	Tan, gravelly SAND, moist	SP			
7.0	End of borehole at 7.0 feet Refusal - bedrock?				



Dry on 12/9/86

REMARKS: Boring diameter: 8"
Well diameter: 2"
Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

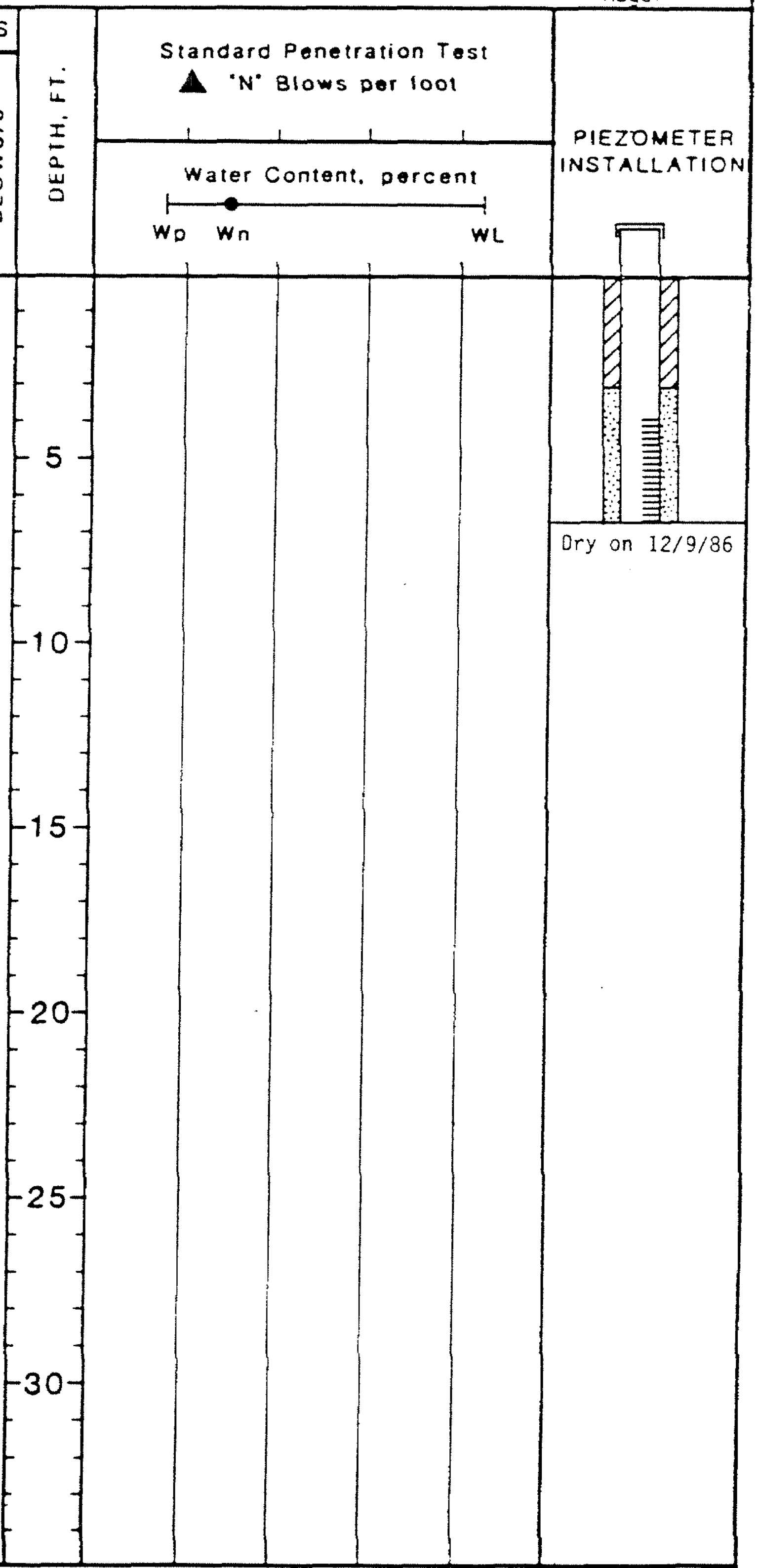
LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-6

Figure
Page 1 of 1

LOCATION: See Figure (Goodwin property, upgradient) DATUM: Land surface elev. 1280'
DATE: 11/20/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Dark brown, silty, fine to coarse SAND	SM			
3.1	Tan, gravelly silty SAND	SP			
6.7	End of borehole at 6.7 feet Refusal-Bedrock				



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-7

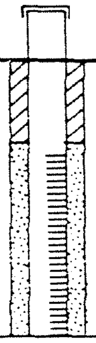
Figure
Page 1 of 1

LOCATION: See Figure (Goodwin property, downgradient)
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
DATUM: Land surface elev. 1190'
DATE: 11/20/86
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES				
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	PIEZOMETER INSTALLATION
0.0	Greenish brown, silty fine to coarse SAND, dry	SM					
5.5	Light greenish gray, thinly bedded, fine sandy SILT, damp	ML	1	DO	6 5 50/.1	5	
6.5	Sandy GRAVEL, little cobbles, damp	GW					
7.5	End of borehole at 7.5 feet Refusal						Dry on 12/9/86
						10	
						15	
						20	
						25	
						30	

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Estimated from 7.5 min. topographic map.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

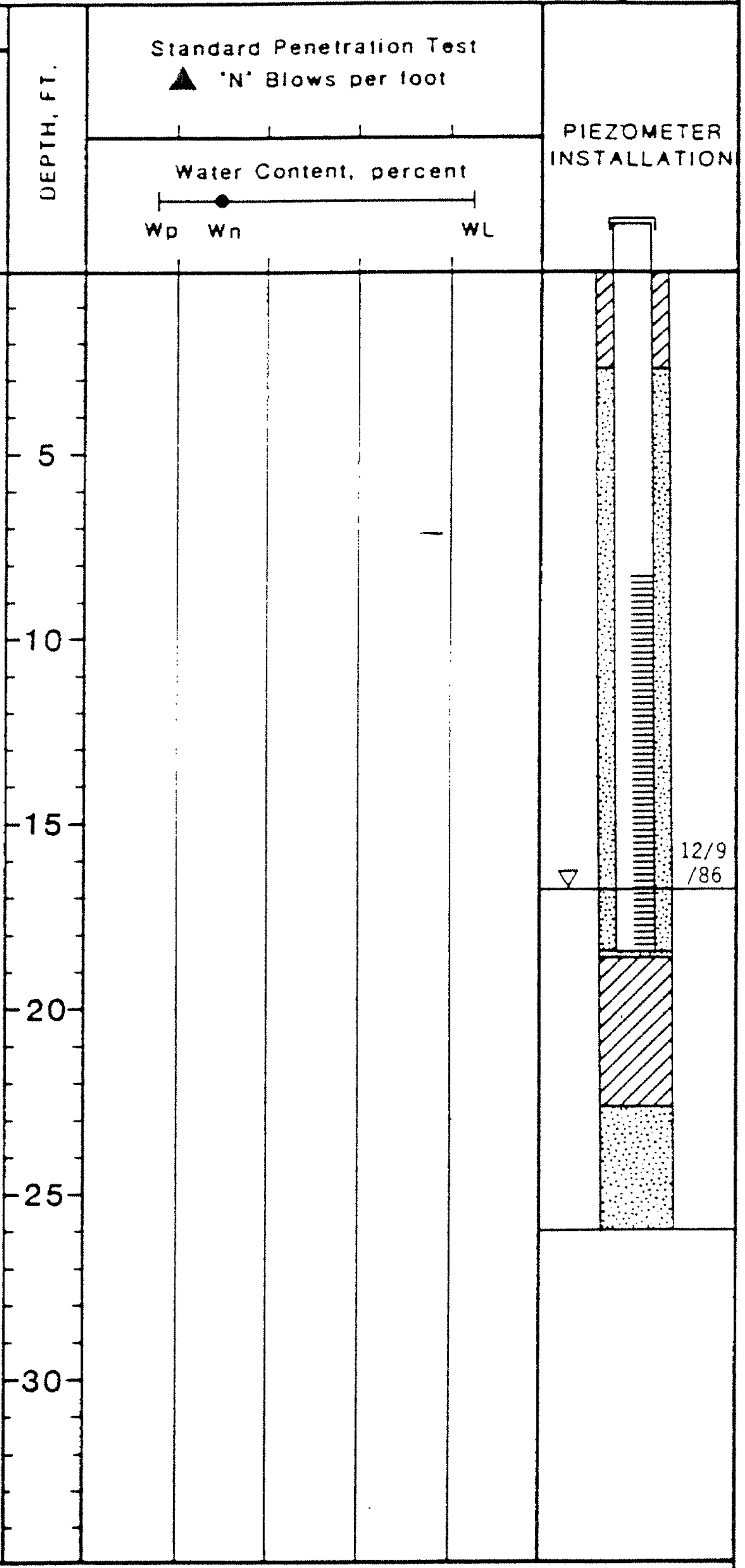
JOB# 863-1123-003

RECORD OF BOREHOLE CH-8

Figure
Page 1 of 1

LOCATION: See Figure (Lutz property, downgradient)
DATUM: Land surface elev. 1115.03'
DATE: 11/20/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6'
0.0	Very dense, brown, coarse sandy GRAVEL to GRAVEL and coarse SAND, trace to little silt, damp	SP	1	DO	16 33 30
			2	DO	15 33 44
			3	DO	50/.1
14.0	Dense, greenish brown, silty fine SAND, wet	SM	4	DO	23 19 18
21.0	Very dense, light greenish gray, fine to medium SAND, little to some silt, trace gravel, damp to moist	SW	5	DO	19 20/0
26.0	End of borehole at 26.0 feet Refusal				



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

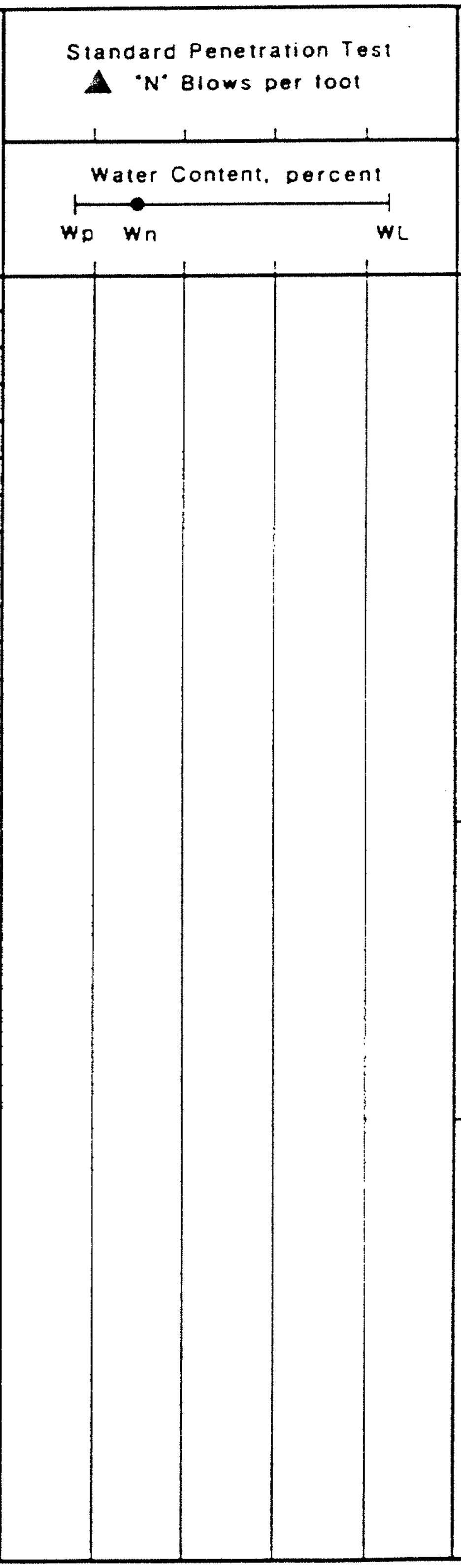
LAKE CHELAN
JOB# 863-1123-003

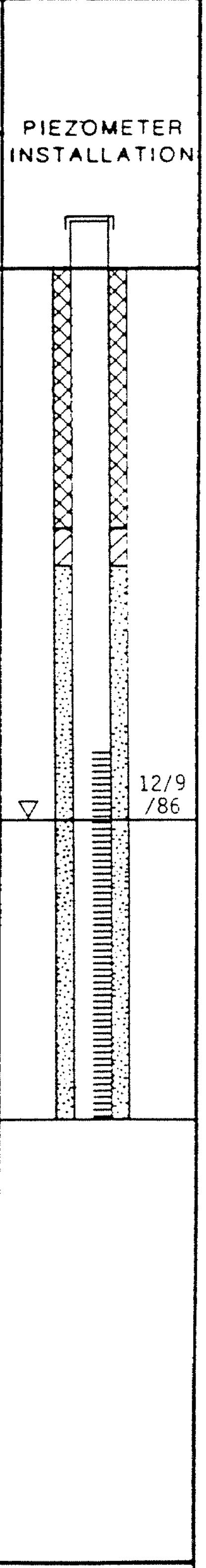
RECORD OF BOREHOLE CH-9

Figure
Page 1 of 1

LOCATION: See Figure (Lutz property, upgradient)
DATUM: Land surface elev. 1118.84'
DATE: 11/21/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES			
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Very dense, brown to gray,gravelly fine to coarse SAND, little to some silt, damp	SW				
			1	DO	25 50 50/.4	5
			2	DO	15 52 50/.4	10
11.0	Very dense, gray to greenish gray, medium to coarse SAND, little to some gravel, little silt, moist to damp	SP				
			3	DO	16 50/.5	15
			4	DC	50/.3	20
23.0	End of borehole at 23.0 feet Refusal					25
						30





REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-10

Figure
Page 1 of 1

LOCATION: See Figure (Venneberg property, downgradient)

DATUM: Land surface elev. 1105.59'

DATE: 11/22/86

SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.

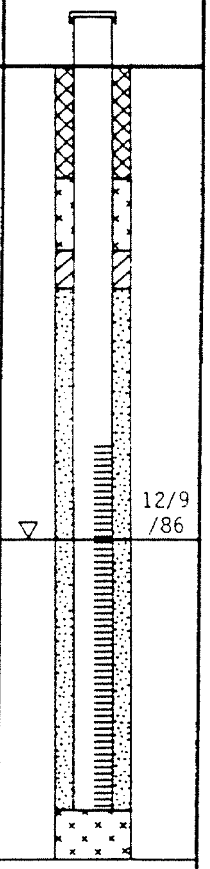
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES			
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Compact, brown to gray, fine to coarse SAND, trace to little gravel, becoming silty 20 to 20.5 feet, damp to wet	SW				
			1	DO	3 7 7	5
			2	DO	5 7 8	10
			3	DO	3 2 15	15
20.5	Hard, greenish gray SILT to sandy SILT, damp	ML	4	DO	17 50 50/.3	20
21.3	End of borehole at 21.3 feet					
						25
						30

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-11

Figure
Page 1 of 1

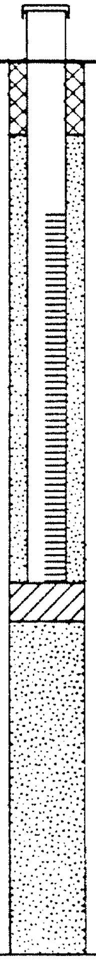
LOCATION: See Figure (Morris property, upgradient)
DATUM: Land surface elev. 1245'
DATE: 11/23/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES			
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Compact, cark brown, silty SAND, dry	SM	1	DO	5 6 15	
3.5	Compact, tan, sandy SILT, dry	ML				5
5.5	Compact, olive gray, SILT to clayey SILT, moist	ML	2	DC	5 7 8	10
11.0	Loose, orange brown, silty, fine SAND to fine sandy SILT, wet	SM	3	DO	2 3 5	
13.5	Loose, light olive brown, SILT trace sand, trace clay, wet	ML				15
16.0	Compact, tan, fine to medium SAND, dry	SP	4	DO	5 9 11	20
			5	DO	3 5 7	
24.0	End of borehole at 24.0 feet					25 30

Standard Penetration Test
▲ "N" Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



Dry on 12/9/86

REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

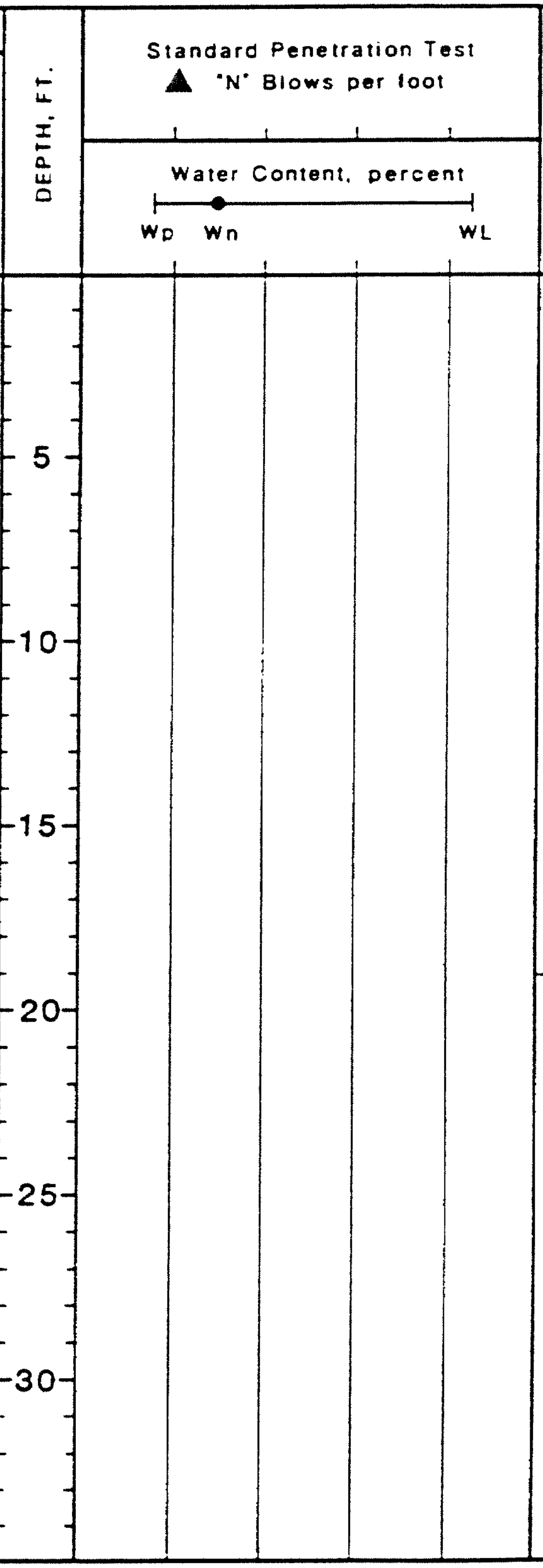
LAKE CHELAN
JOB # 863-1123-003

RECORD OF BOREHOLE CH-12

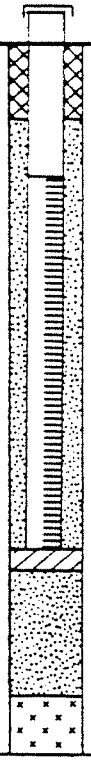
Figure
Page 1 of 1

LOCATION: See Figure (Morris property, downgradient)
DATUM: Land surface elev. 1245'
DATE: 11/23/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Very stiff, tan, clayey SILT, damp	ML	1	DO	12 12 15
5.5	Compact, light olive gray, fine sandy SILT, wet	ML	2	DO	5 5 5
11.0	Compact, light gray, thinly bedded, fine to medium SAND and sandy SILT, moist to wet	SM	3	DO	3 5 7
16.0	Compact, light gray, fine to medium SAND, dry	SP	4	DO	4 5 7
19.0	End of Borehole at 19.0 ft				



PIEZOMETER INSTALLATION



Dry on 12/9/86

REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level. Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-13

Figure
Page 1 of 1

LOCATION: See Figure (Wollborg property)
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
DATUM: Land surface elev. 1400'
DATE: 11/23/86
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot / Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Compact, dark brown to gray silty SAND and GRAVEL, dry	GM	1	DO	1 9 10	5 10		No installation
12.0	End of Borehole at 12.0 ft. Refusal					15 20 25 30		

REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-14

Figure
Page 1 of 1

LOCATION: See Figure (Wollborg property)
DATUM: Land surface elev. 1400'
DATE: 11/23/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Loose, brown to gray silty SAND and GRAVEL, dry	GM	1	DO	4 3 7			No installation
						5		
6.0	End of Borehole at 6.0 ft. Refusal							
						10		
						15		
						20		
						25		
						30		

REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-15

Figure
Page 1 of 1

LOCATION: See Figure (Allison property, upgradient)

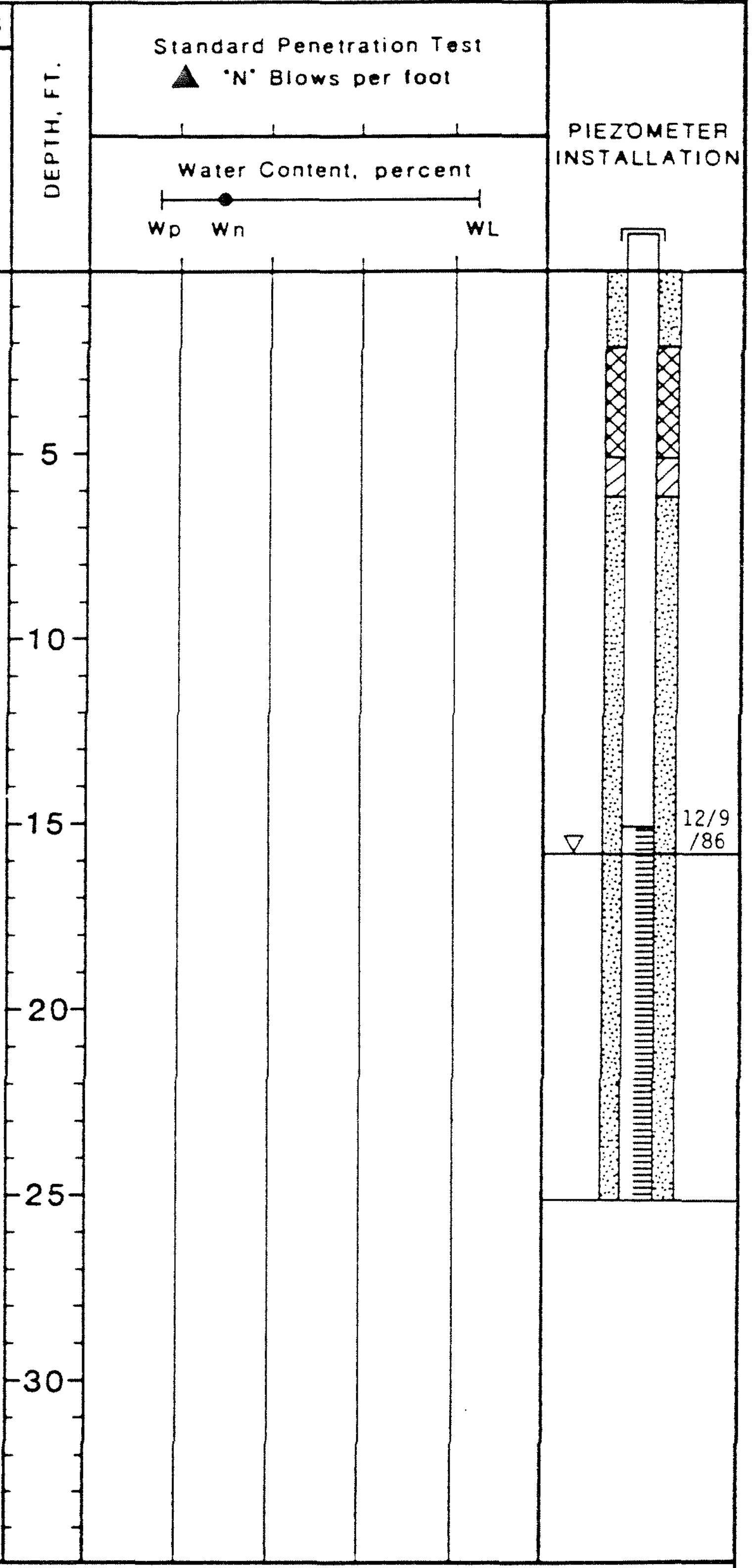
DATUM: Land surface elev. 1215'

DATE: 11/23/86

SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.

BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Stiff to very stiff, light greenish gray, thinly bedded silty CLAY to clayey SILT damp	CL	1	DO	7 9 14
			2	DO	3 6 7
11.0	Compact, brown, fine to medium SAND, dry to damp	SP	3	DO	4 5 8
16.0	Stiff, grayish brown, clayey SILT to silty CLAY, wet	ML	4	DO	3 3 7
25.0	End of Borehole at 25.0 ft.				



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-16

Figure

Page 1 of 1

LOCATION: See Figure (Allison property, downgradient)

SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.

DATUM: Land surface elev. 1203.70'

DATE: 11/24/86

BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES			
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Stiff to very stiff, olive brown clayey SILT, dry to damp	ML	1	DO	5 5 7	5
			2	DO	7 8 12	10
11.0	Compact, brown, fine to medium SAND, dry to damp	SP	3	DO	5 9 10	15
16.0	Stiff to very stiff, olive gray to brown, thinly bedded fine sandy SILT to clayey SILT, wet	ML	4	DO	3 5 4	20
			5	DO	3 7 10	
24.0	End of Borehole at 24.0 ft.					25
						30

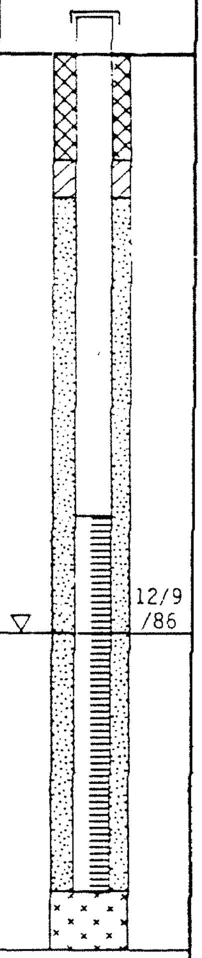
Standard Penetration Test

▲ 'N' Blows per foot

Water Content, percent

Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-17

Figure
Page 1 of 2

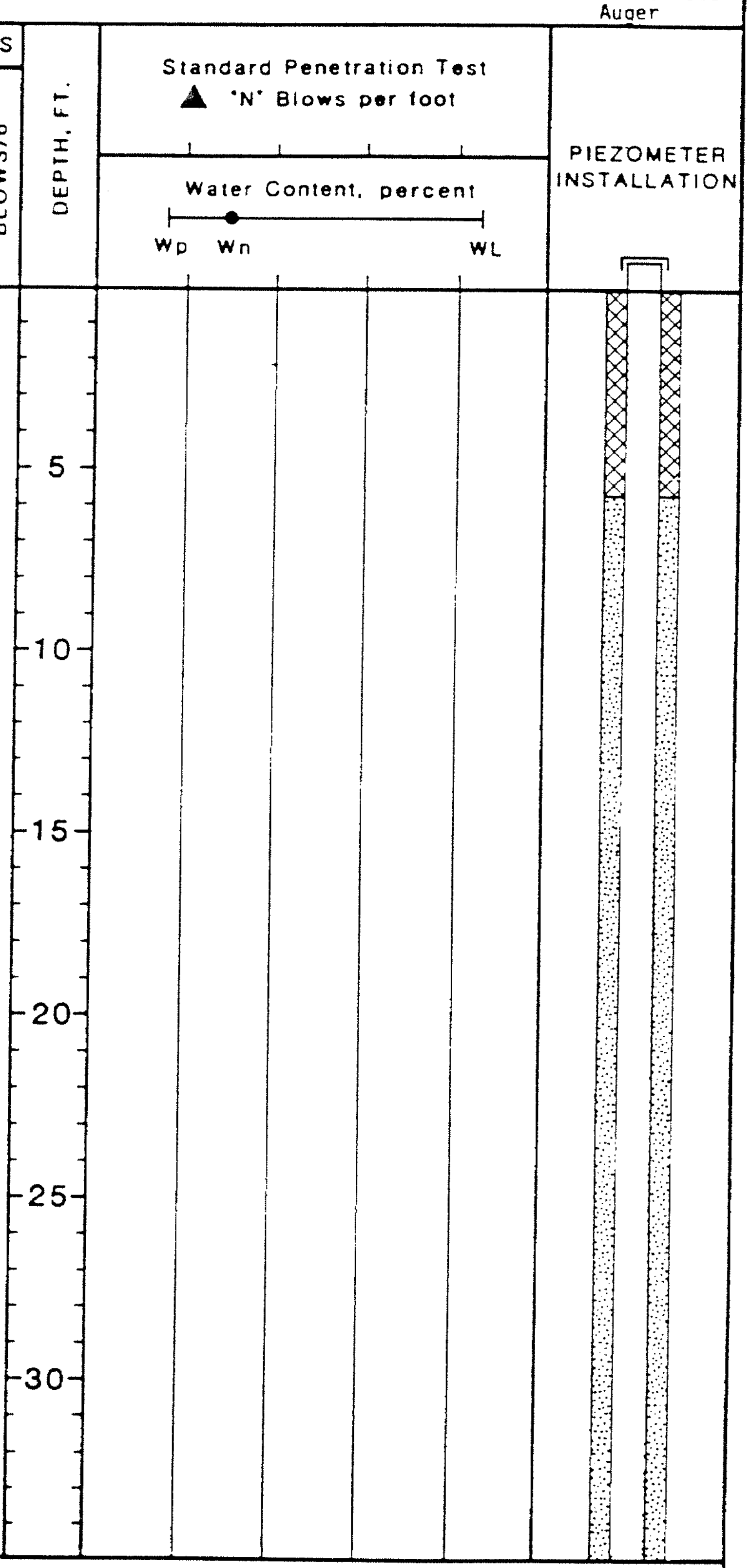
LOCATION: See Figure (Morris property, downgradient)
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
DATUM: Land surface elev. 1245'
DATE: 11/24/86
BORING METHOD: Hollow Stem Auger

SOIL PROFILE

ELEVN / DEPTH	DESCRIPTION	USCS CLASS
0.0	Loose, tan, SILT, dry	ML
6.0	Compact, brown, thinly bedded, sandy SILT to silty fine SAND, moist to wet	ML
13.0	Compact, to dense, tan, fine to medium SAND, dry	SP
35.0		

SAMPLES

NUMBER	TYPE	BLOWS/6"
1	DO	5 6 4
2	DO	4 6 5
3	DO	4 5 7
4	DO	3 6 10
5	DO	3 5 10
6	DO	7 14 14
7	DO	5 7 11



REMARKS: Boring diameter: 8"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

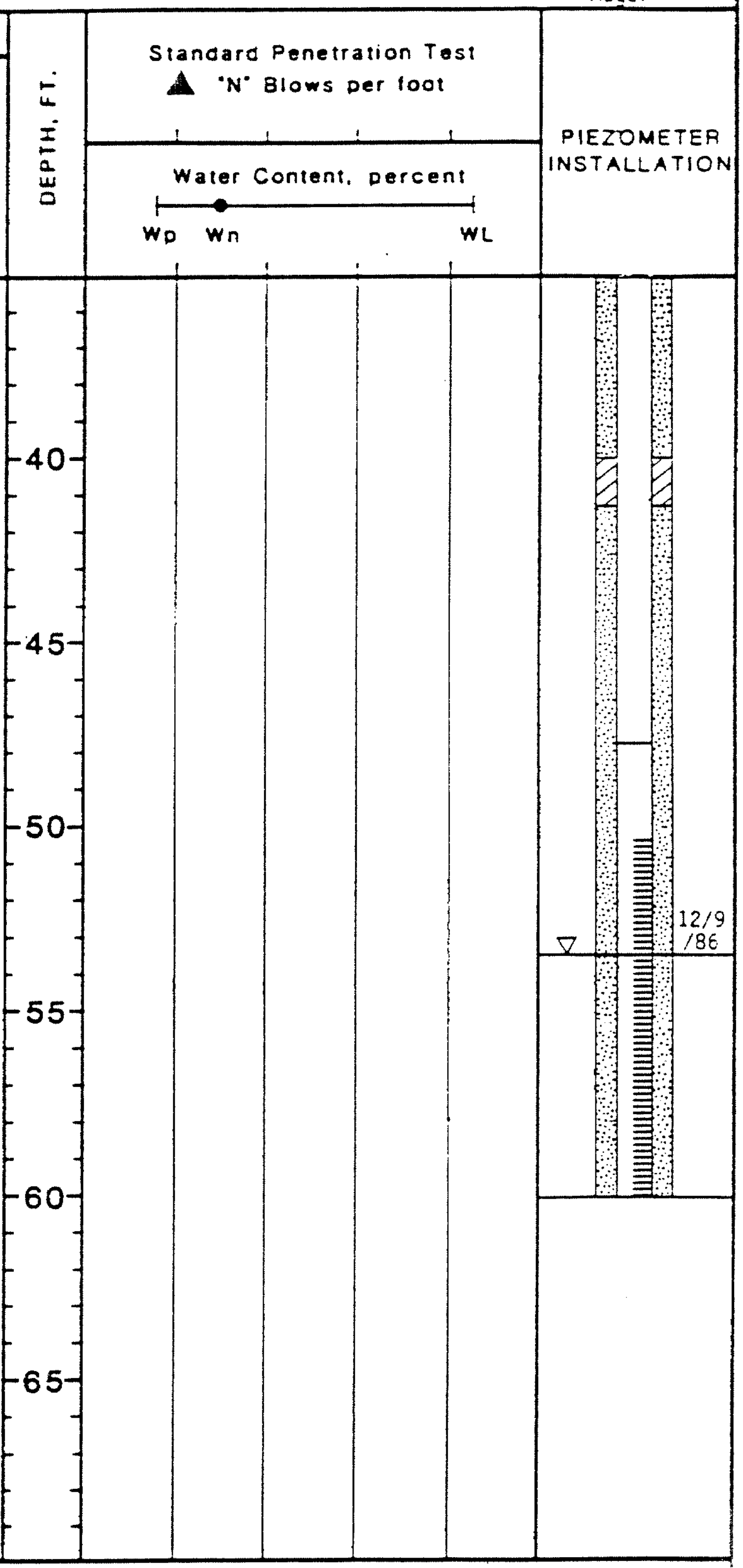
LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-17(cont.)

Figure
Page 2 of 2

LOCATION: See Figure
DATUM:
DATE: 11/24/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
35.0	Compact, to dense, tan, fine to medium SAND, becomming damp to moist at 40.0 ft.	SP			
			8	DO	5 13 24
			9	DO	7 16 21
			10	DO	5 19 23
51.0	Stiff, green brown, clayey SILT to silty CLAY, wet	ML	11	DO	2 4 9
60.0	End of Borehole at 60.0 ft.				



REMARKS:

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

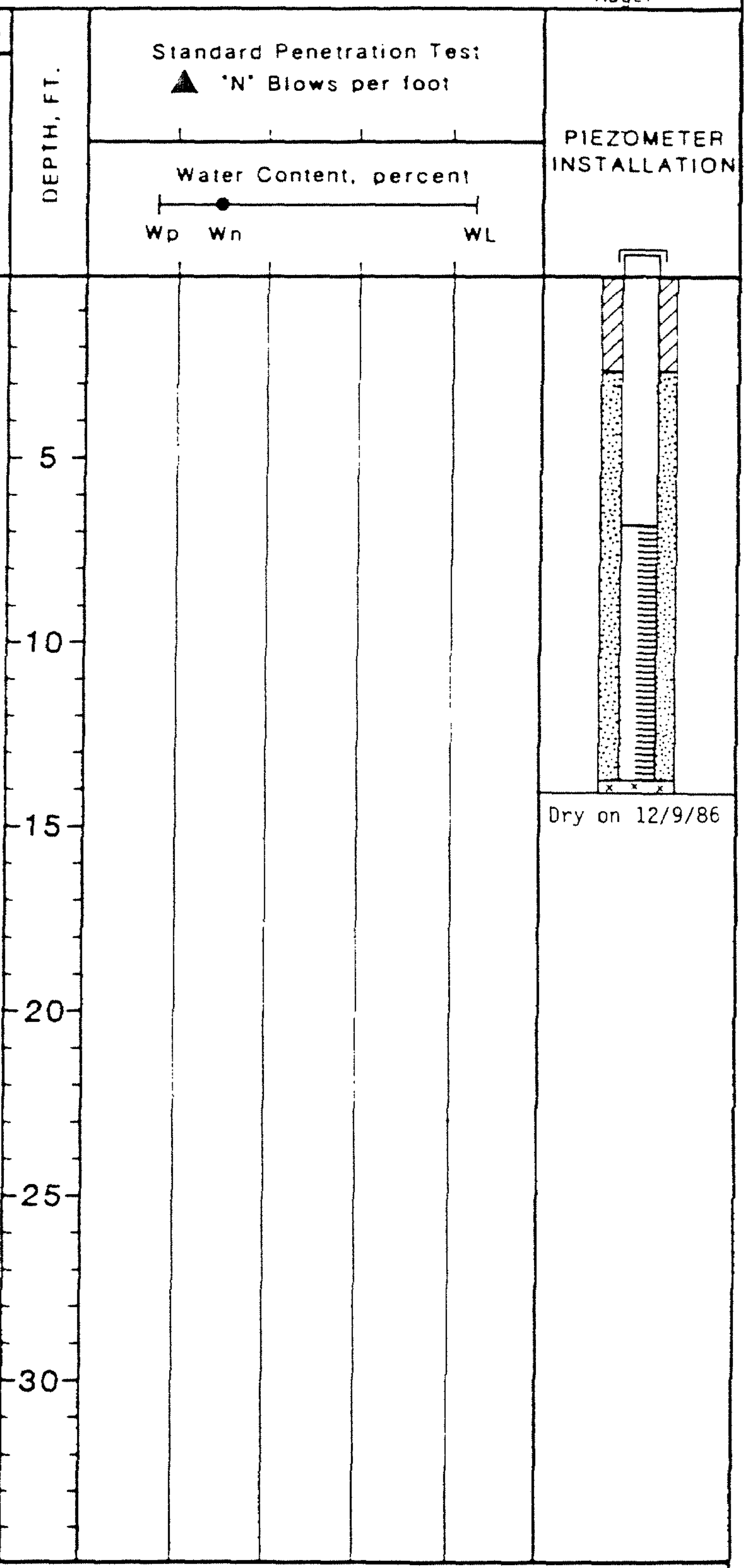
LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-18

Figure
Page 1 of 1

LOCATION: See Figure (Rockney property, downgradient)
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
DATUM: Land surface elev. 1410'
DATE: 11/25/86
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Compact, dark brown, silty SAND, damp	SM			
3.0	Very dense, gray, silty SAND and GRAVEL, moist to wet	GM	1	DO	33 50/.3
			2	DC	40 50 50
14.0	End of borehole at 13.6 feet Refusal				



REMARKS: Boring diameter: 8"
Well diameter: 2"
Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-19

Figure
Page 1 of 2

LOCATION: See Figure
(Morris property)

DATUM: Land surface
elev. 1230'

DATE: 12/15/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Dense to very dense, brown gravelly SAND to SAND and GRAVEL, trace silt, occasional cobbles, dry	GP						No installation
						5		
			1	CS				
						10		
			2	CS				
						15		
			3	CS				
						20		
						25		
			4	CS				
						30		
			5	CS				

REMARKS: Boring diameter: 6"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-19 (cont.)

Figure
Page 2 of 2

LOCATION: See Figure

DATUM:

DATE: 12/15/86
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES					
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ "N" Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
35.0	Dense to very dense, brown gravelly SAND to SAND and GRAVEL, trace silt, occasional cobbles, dry	GP	6 7 8	CS CS CS		40 45 50		No installation
52.0	End of borehole at 52.0 feet					55 60 65		

* REMARKS:

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-20

Figure
Page 1 of 1

LOCATION: See Figure
(Collins property, downgradient)

DATUM: Land surface
elev. 1168.17'

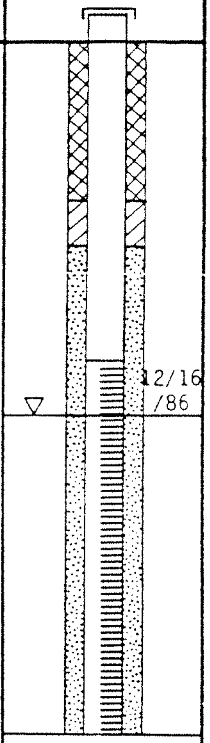
DATE: 12/16/86
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES			
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Brown, clayey SILT, wet	ML				5 10
15.0	Brown, gravelly SAND, wet	SP				15
18.4	End of borehole at 18.4 feet					20 25 30

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-21

Figure
Page 1 of 1

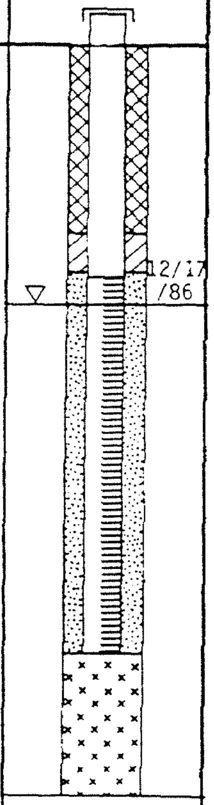
LOCATION: See Figure
(Goodwin property, downgradient)

DATUM: Land surface
elev. 1171.57'

DATE: 12/17/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES					
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Brown, clayey SILT to silty CLAY, wet							
		ML				5		
						10		
						15		
16.0	Brown, medium SAND, wet	SP						
20.0	End of borehole at 20.0 feet					20		
						25		
						30		



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH- 22

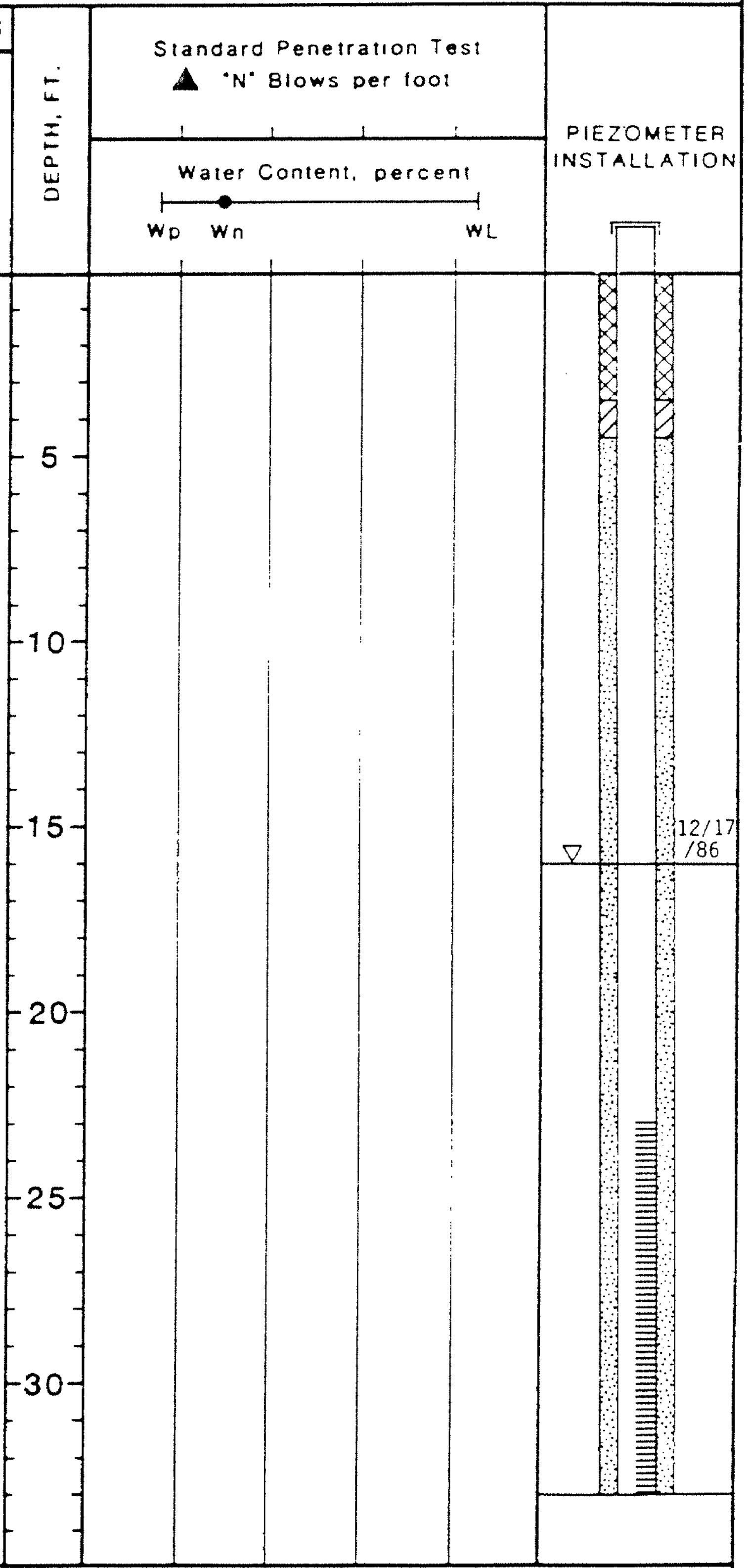
Figure
Page 1 of 1

LOCATION: See Figure
(Collins property, upgradient)

DATUM: Land surface
elev. 1202.45'

DATE: 12/17/86
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES		
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Tan, brown, silty CLAY, damp	CL			
6.0	Brown, sandy, cobbly GRAVEL, damp	GW	1	CS	
24.0	Yellowish brown silty SAND, moist to wet	SM	2	CS	
33.0	End of borehole at 33.0 feet				



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-23

Figure
Page 1 of 1

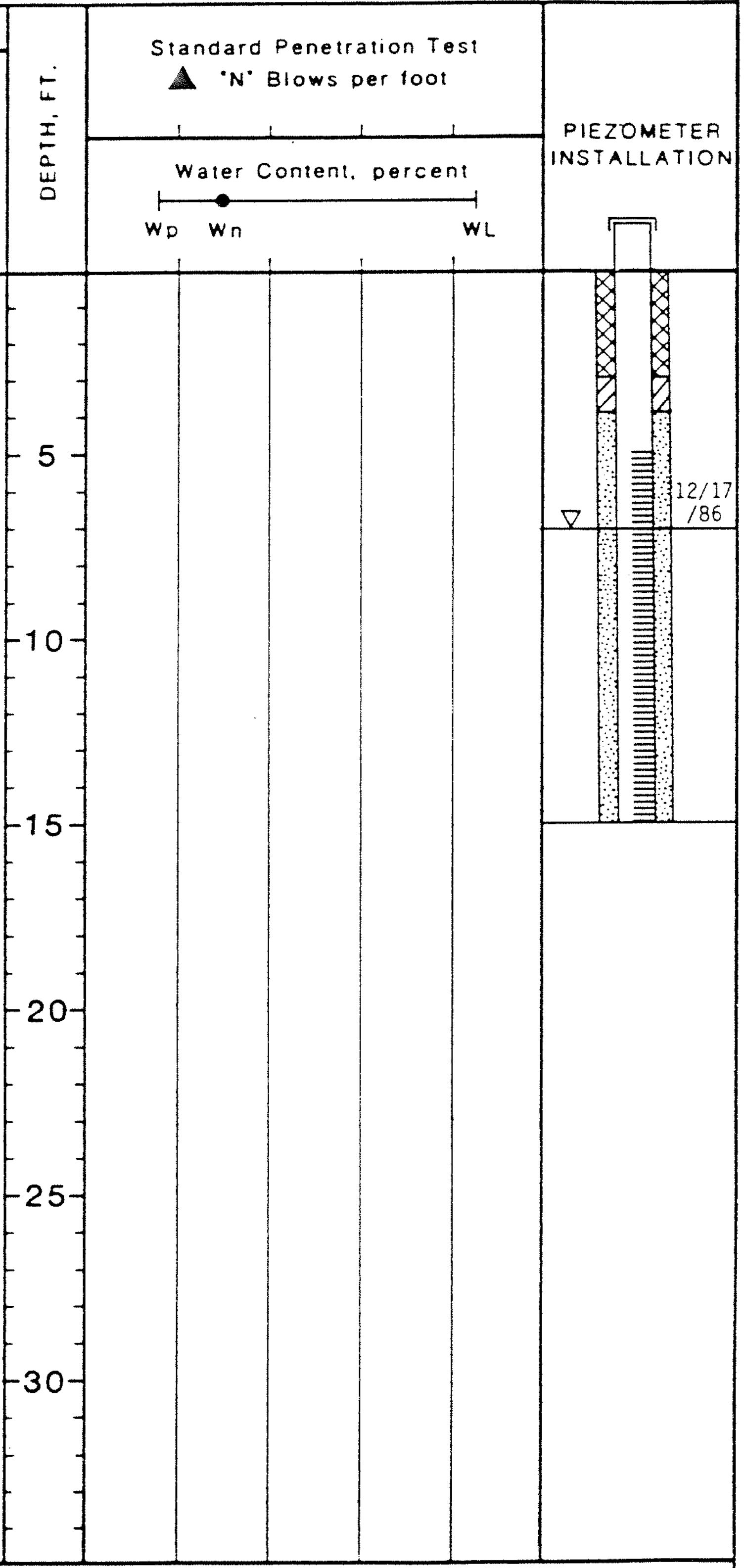
LOCATION: See Figure
(Pickens property, downgradient)

DATUM: Land surface
elev. 1165'

DATE: 12/17/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Very soft, olive brown, coarse, sandy clayey SILT, wet	ML			
			1	CS	
15.0	End of borehole at 15.0 feet				



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-24

Figure
Page 1 of 1

LOCATION: See Figure
(McClellan property, downgradient)

DATUM: Land surface
elev. 1172.80'

DATE: 12/18/86

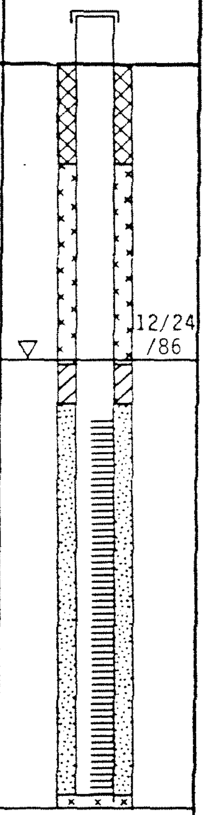
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES				
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Brown, medium to coarse SAND and SILT, damp to moist.	SW				
			1	CS		
16.0	Dense, brown, gravelly medium to coarse SAND, trace silt, moist to wet	SW				
20.0	End of borehole at 20.0 feet					

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-25

Figure
Page 1 of 2

LOCATION: See Figure
(Wollborg property)

DATUM: Land surface
elev. 1400'

DATE: 12/18/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Tan, silty SAND, dry	SM						No installation
4.0	Brown SAND and GRAVEL with boulders/cobbles, dry	GW				5 10 15		
18.0	Brown, stratified medium SAND, trace to little silt, gravel, and cobbles, dry	SP				20 25 30		

REMARKS: Boring diameter: 6"

Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN

JOB# 863-1123-003

RECORD OF BOREHOLE CH-25 (cont.)

Figure
Page 2 of 2

LOCATION: See Figure
DATUM:
DATE: 12/18/86
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES					
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
35.0	Brown, stratified medium SAND, trace to little silt and gravel and cobbles Damp at 35.0 feet							No installation
40.0	End of borehole at 40.0 feet					40		
						45		
						50		
						55		
						60		
						65		

REMARKS:

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-26

Figure
Page 1 of 2

LOCATION: See Figure
(Lake Chelan State Park, downgradient)

DATUM: Land surface elev. 1165'

DATE: 12/18/86
BORING METHOD: Air Rotary

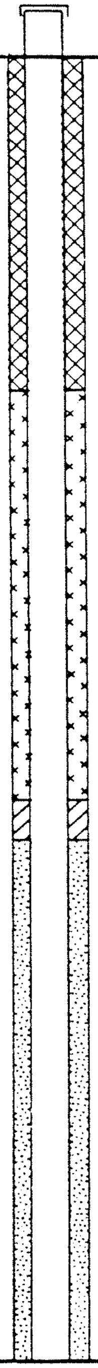
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
0.0	Brown silty SAND, dry	SM			
3.0	Orangish brown, gravelly fine to coarse SAND, dry	SW			
			1	CS	

DEPTH, FT.: 5, 10, 15, 20, 25, 30

Standard Penetration Test
▲ "N" Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 6"
Well diameter: 2"
Land surface elevation in feet above mean sea level.
Obtained by altimeter survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-26 (cont.)

Figure
Page 2 of 2

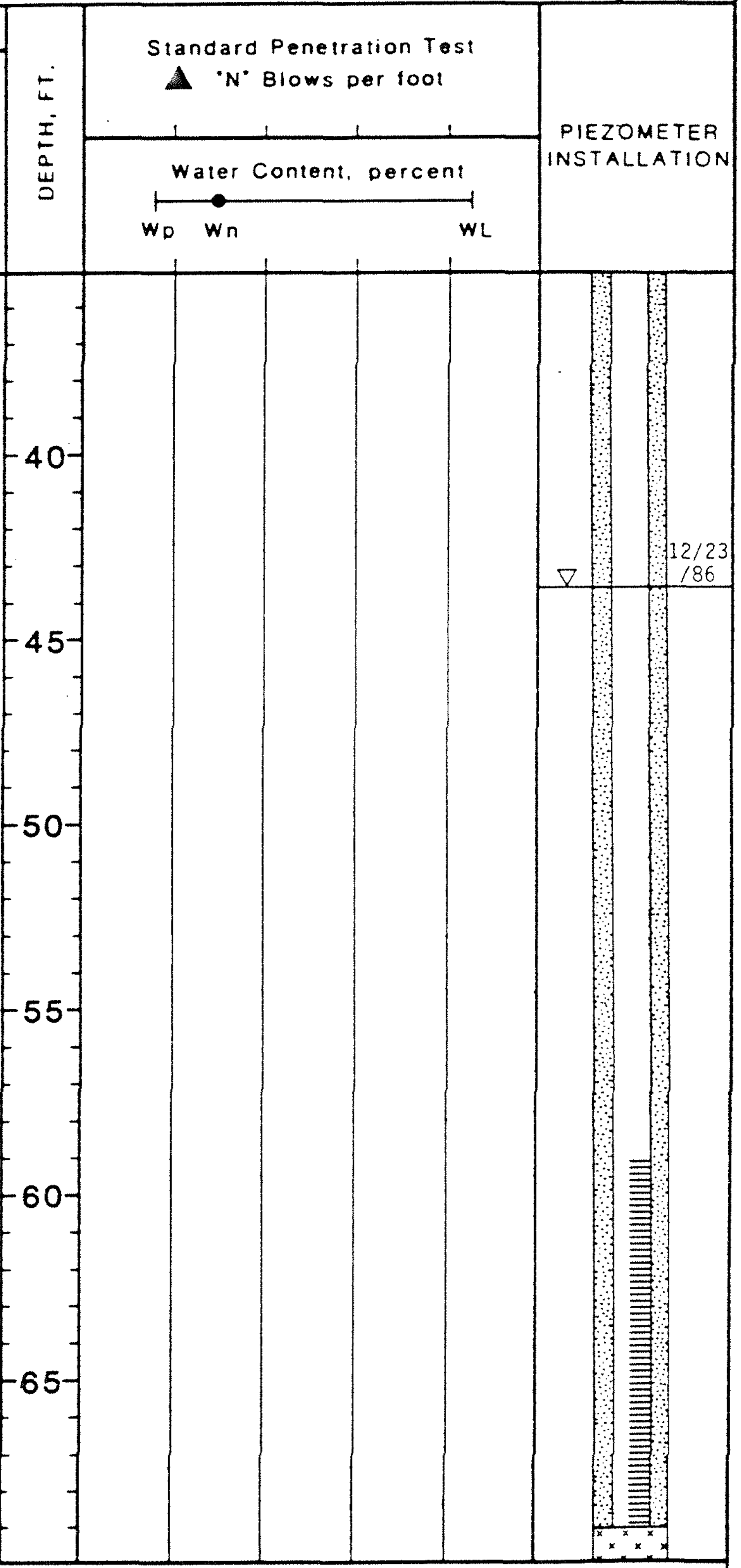
LOCATION: See Figure

DATUM:

DATE: 12/18/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
35.0	Orangish brown, gravelly fine to coarse SAND, dry	SW	2	CS	
50.0	Orangish brown, fine to coarse SAND, damp	SW	3	CS	
56.0	Olive brown, sandy, clayey SILT, moist to wet	ML	4	CS	
60.0	Brown, silty SAND to sandy SILT, trace to little gravel, wet (Till?)	SM	5	CS	
70.0	End of borehole at 70.0 feet				



REMARKS:

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-27

Figure
Page 1 of 1

LOCATION: See Figure (Lutz property, downgradient)

DATUM: Land surface elev. 1115.64'

DATE: 12/22/86

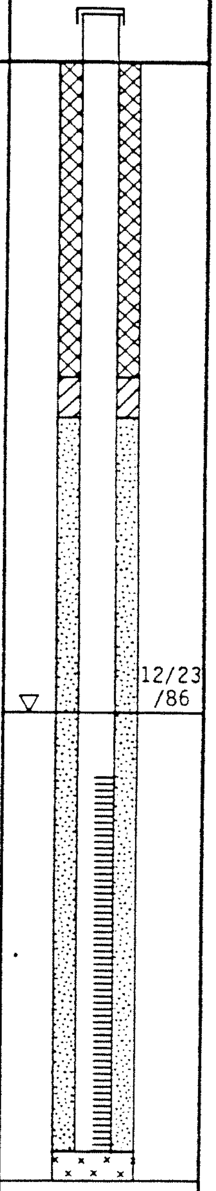
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES			
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.
0.0	Very dense, brown, coarse sandy GRAVEL to GRAVEL and coarse SAND, trace to little silt, damp	SP				5 10
14.0	Dense, greenish brown, silty fine SAND, wet	SM				15 20
21.0	Very dense, light greenish gray, fine to medium SAND, little to some silt, trace gravel, damp to moist (Till?)	SW				25
30.0	End of borehole at 30.0 feet					30

Standard Penetration Test
▲ 'N' Blows per foot

Water Content, percent
Wp Wn WL

PIEZOMETER INSTALLATION



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level. Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-28

Figure
Page 1 of 2

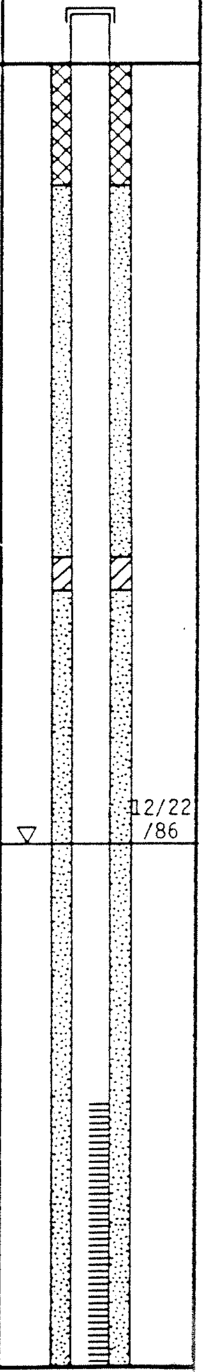
LOCATION: See Figure (Cove Marina, downgradient)

DATUM: Land surface elev. 1111.55'

DATE: 12/22/86

BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES				Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.		
	Very dense, brownish gray, silty gravelly SAND and SILT, some cobbles, dry	GM				5 10		
			1	CS		15		
	Damp below 18'					20		
25.0	Dense, brown SAND, little to some silt, little gravel, wet	GM				25		
			2	CS		30		



REMARKS: Boring diameter: 6"
Well diameter: 2"

Land surface elevation in feet above mean sea level. Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

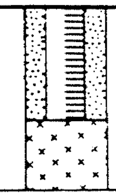
Golder Associates

LAKE CHELAN
JOB# 863-1123-003

RECORD OF BOREHOLE CH-28 (cont.)

Figure
Page 2 of 2

LOCATION: See Figure (Cove Marina, downgradient)
DATUM:
DATE: 12/22/86
BORING METHOD: Air Rotary

SOIL PROFILE			SAMPLES				Standard Penetration Test ▲ 'N' Blows per foot / Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.		
	Dense, brown SAND, little to some silt, little gravel, wet	GM						
40.0	End of borehole at 40.0 feet					40		
						45		
						50		
						55		
						60		
						65		

REMARKS: Boring diameter: 6"
Well diameter: 2"

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB # 863-1123-003

RECORD OF BOREHOLE CH-29

Figure
Page 1 of 1

LOCATION: **See Figure** (Cove Marina)
DATUM: Land surface elev. approx. 1112'
DATE: 11/22/86
SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN.
BORING METHOD: Hollow Stem Auger

SOIL PROFILE			SAMPLES					
ELEVN DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"	DEPTH, FT.	Standard Penetration Test ▲ 'N' Blows per foot Water Content, percent Wp Wn WL	PIEZOMETER INSTALLATION
0.0	Very dense, brown GRAVEL and COBBLES, little sand, dry	GW						No installation
			1		25/.2	5		
	End of Borehole at 6.0 feet Refusal							
						10		
						15		
						20		
						25		
						30		

REMARKS: Boring diameter: 8"

Land surface elevation in feet above mean sea level.
Obtained by optical level survey.

VERTICAL SCALE:
1 IN. TO 5 FT.

Golder Associates

LAKE CHELAN
JOB# 863-1123-003

APPENDIX B

Pump Test and Slug Test Summaries

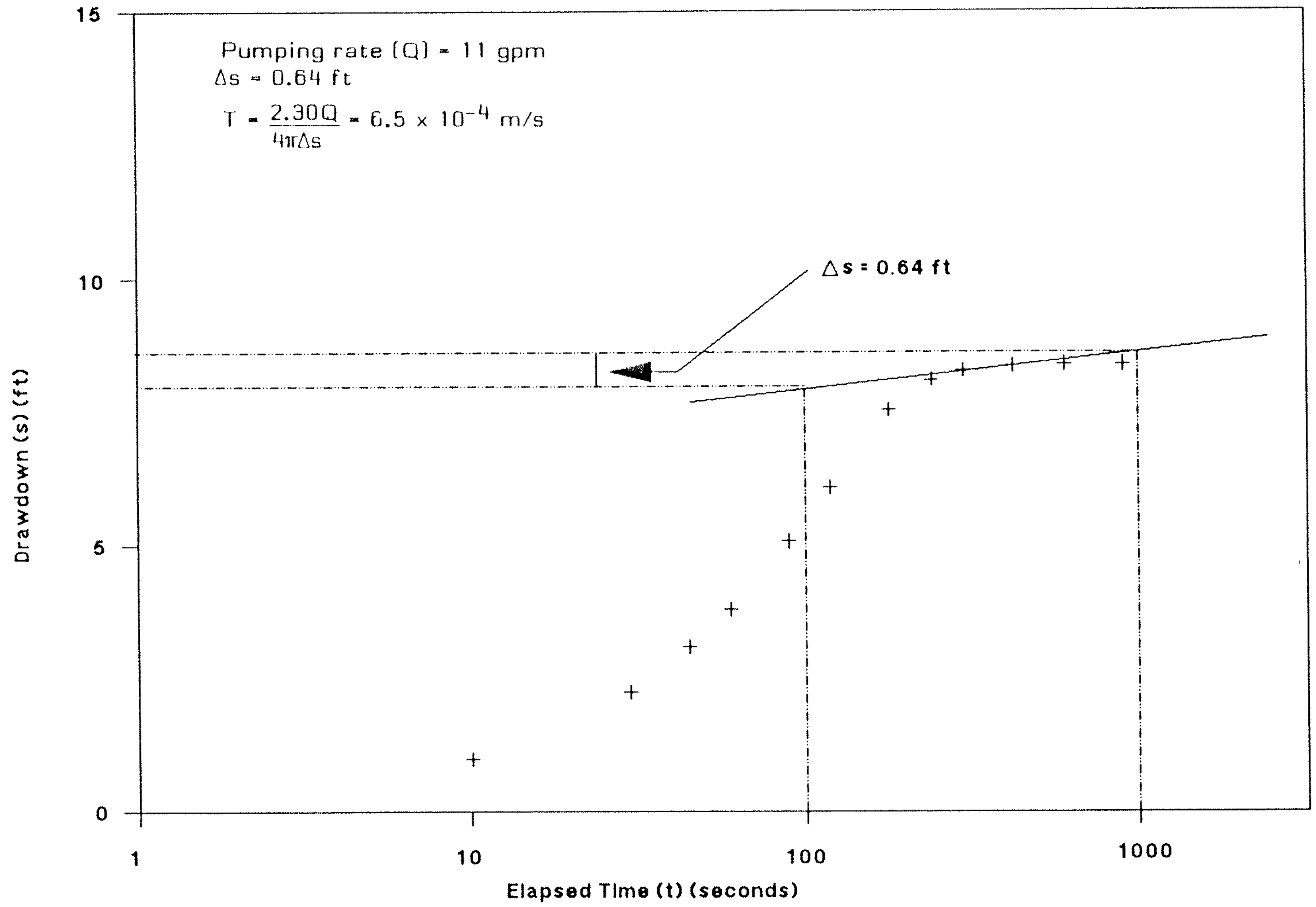
TABLE 1-3

PUMP TEST SUMMARY

Well	Pumping Rate Q (gpm)	Well Diameter (in)	Test Length (min)	Time After Which Casing Effect Negligeable (min)	Estimated Saturated Thickness (ft)	Drawdown Data		Recovery Data		
						Transmissivity	Hydraulic Conductivity	Transmissivity	Hydraulic Conductivity	
						m^2/s	m/s	m^2/s	m/s	Lithology
Risley	18	10	15.2	2	23	$1.4x10^{-3}$	$2x10^{-4}$	$2.0x10^{-3}$	$3x10^{-4}$	Silt/Sand and Gravel
Kelley	10	6	40	1	27	$7.0x10^{-4}$	$9x10^{-5}$	$6.7x10^{-4}$	$8x10^{-5}$	Silt and Gravel
Clapp	11	8	15.5	3	27	$6.5x10^{-4}$	$8x10^{-5}$	$1.3x10^{-3}$	$2x10^{-4}$	Sand and Gravel
Lesmeister	19	6	16.5	10	118	---	---	$1.6x10^{-5}$	$4x10^{-7}$	Bedrock
Pickens	11	36	16	--	1	---	---	---	---	Sandy Clayey Silt

Note:

1. Saturated thickness estimated from well log data.
2. Casing storage effects in Pickens well throughout the test - No analysis possible.
3. Casing storage effects in Lesmeisters' well up to 10 minutes. Insufficient drawdown data for analysis.
4. Lithology from drillers logs or from soils mapping.



Casing storage affects first 3 minutes of data.

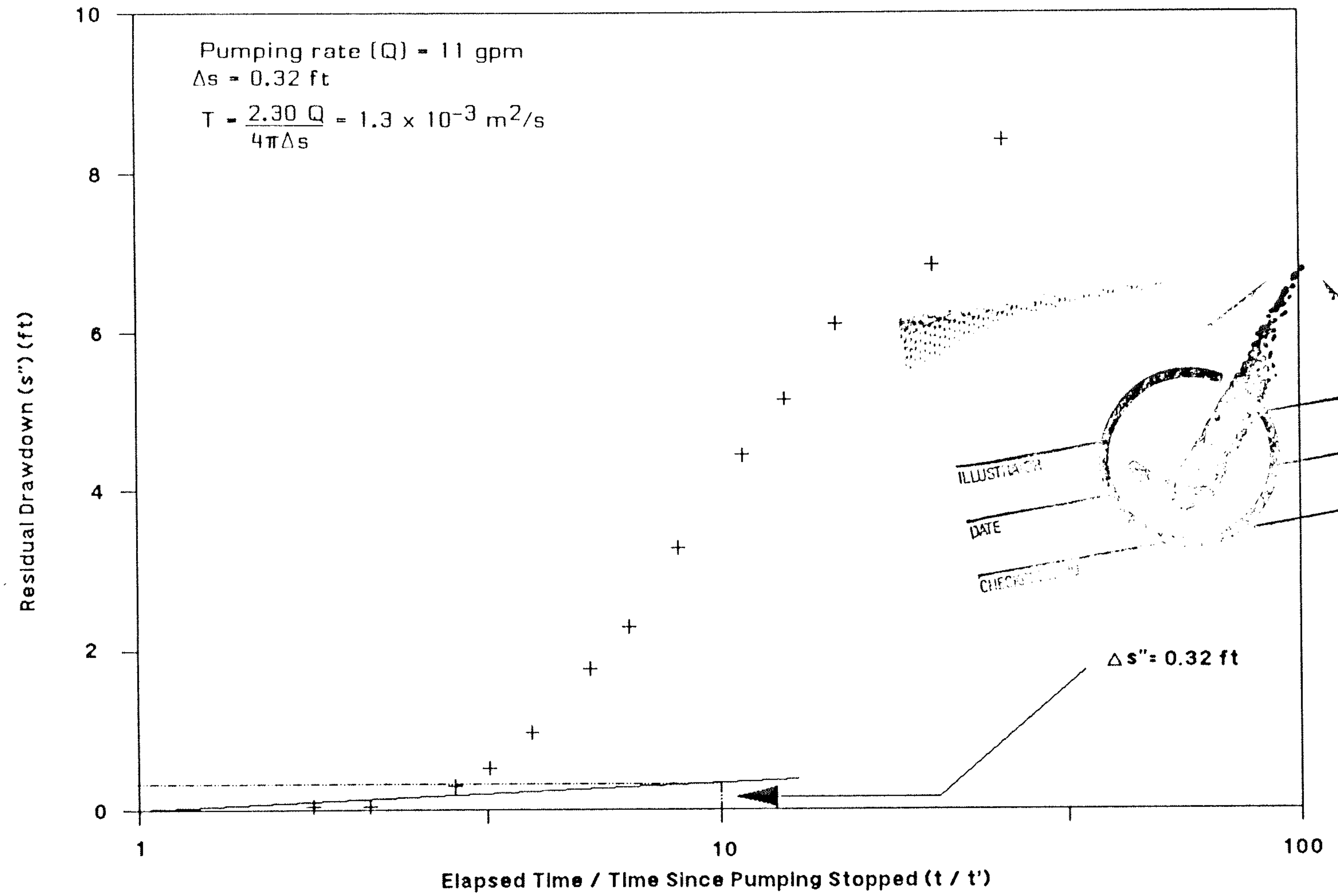
CLAPP

PUMP TEST (Drawdown Portion)

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8373 DATE DRAWN CB APPROVED MD

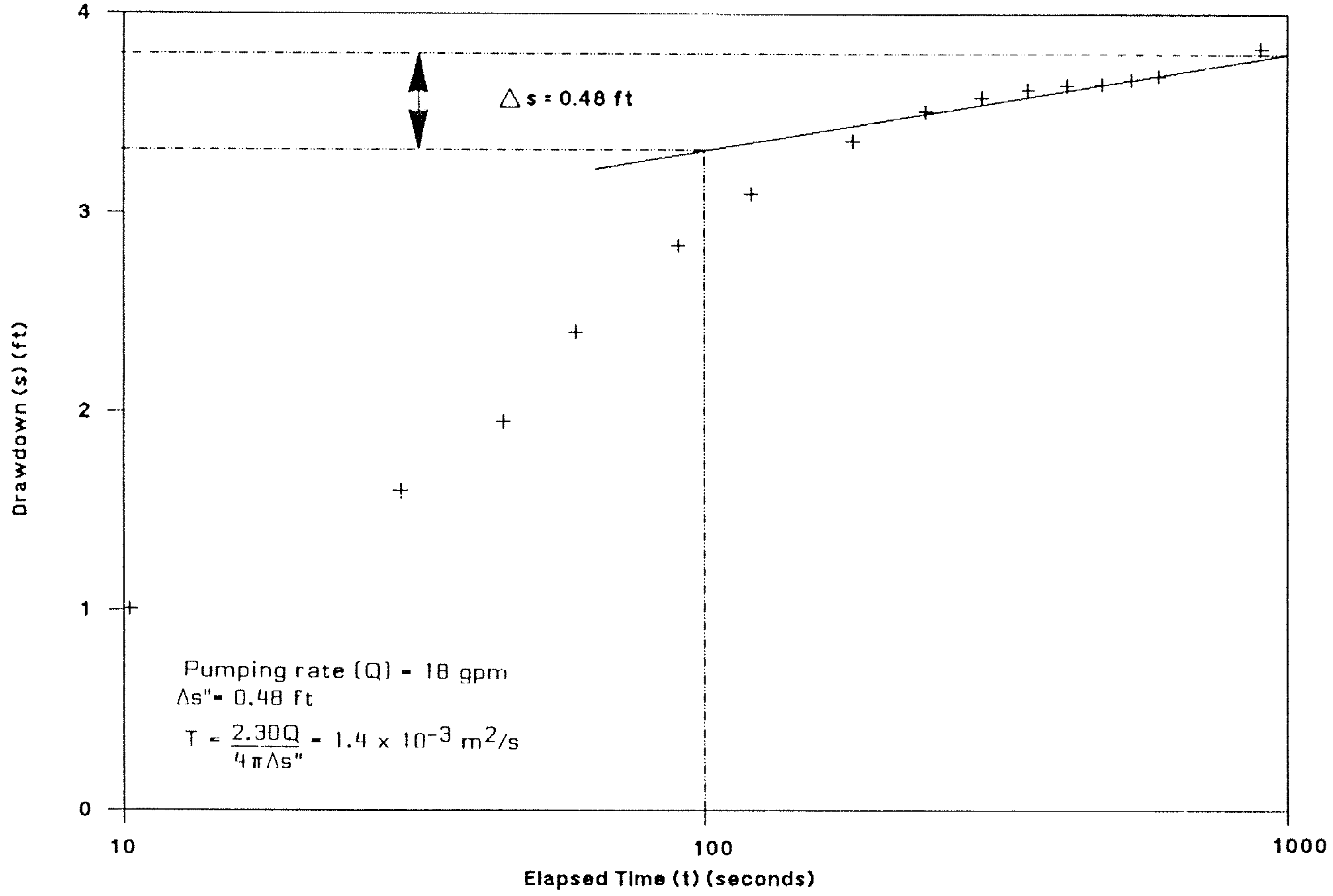
Golder Associates



CLAPP
PUMP TEST (Recovery Portion)
LAKE CHELAN

Golder Associates

PROJECT NO 863-1123-003 DWG NO 8369 DATE DRAWN CB APPROVED MD



Pumping rate (Q) = 18 gpm

$\Delta s'' = 0.48$ ft

$T = \frac{2.30Q}{4\pi\Delta s''} = 1.4 \times 10^{-3}\ m^2/s$

Casing storage affects first 2 minutes of data.

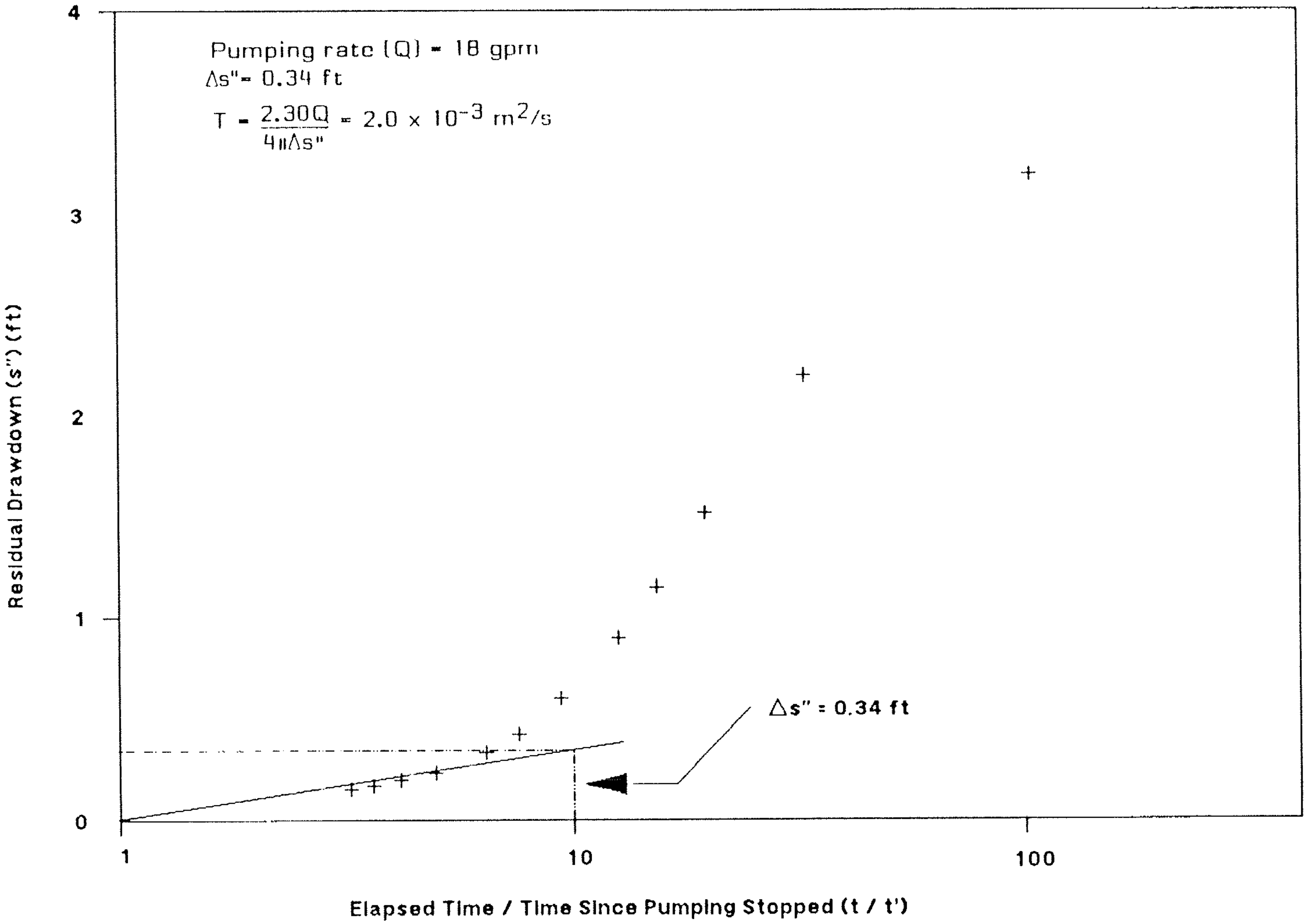
RISLEY

PUMP TEST (Drawdown Portion)

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8371 DATE DRAWN CB APPROVED MD

Golder Associates



Pumping rate (Q) = 18 gpm
$\Delta s'' = 0.34$ ft
$T = \frac{2.30Q}{4\pi \Delta s''} = 2.0 \times 10^{-3}\ m^2/s$

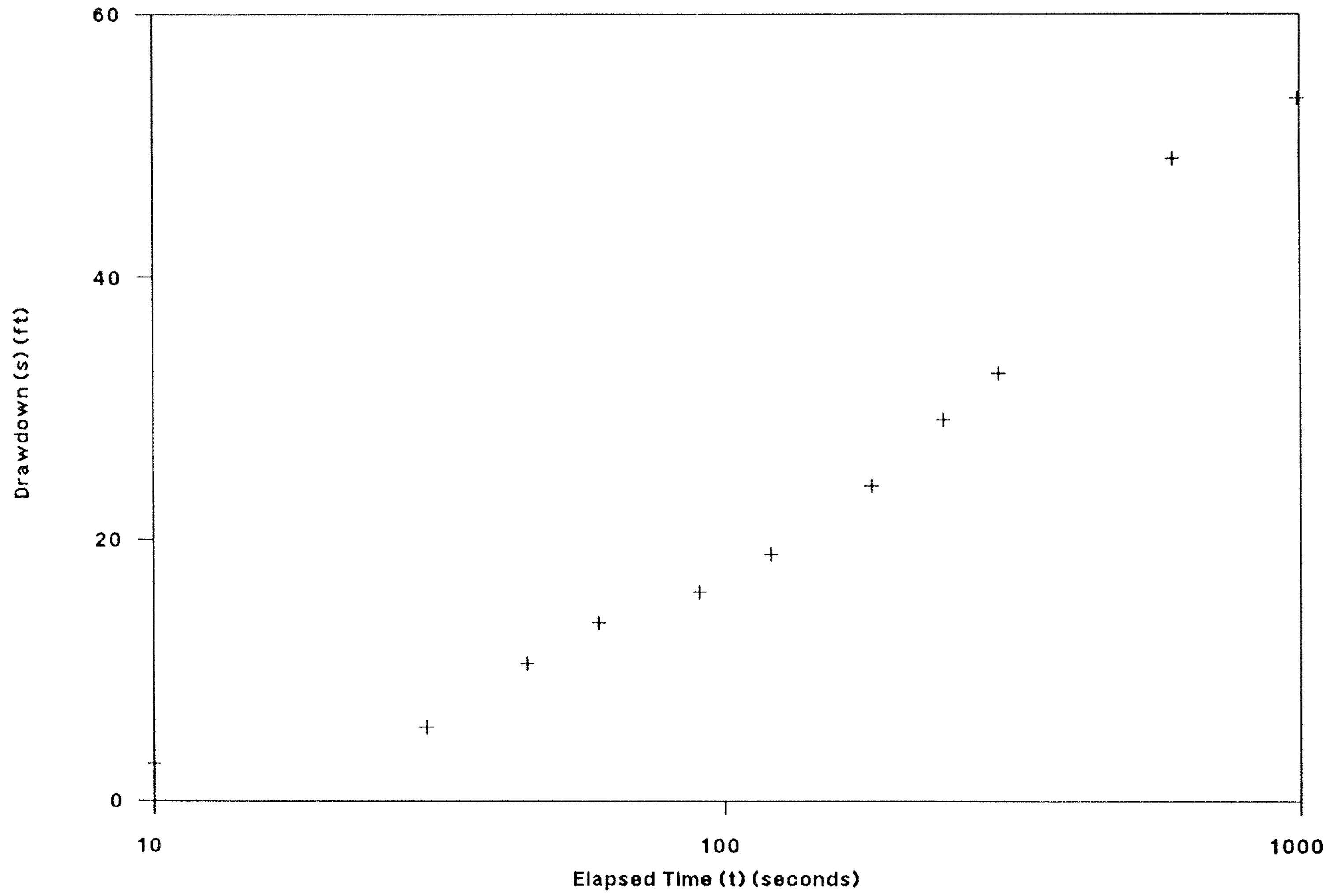
RISLEY

PUMP TEST (Recovery Portion)

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8367 DATE DRAWN CB APPROVED MD

Golder Associates



Casing storage affects first 10 minutes of data.

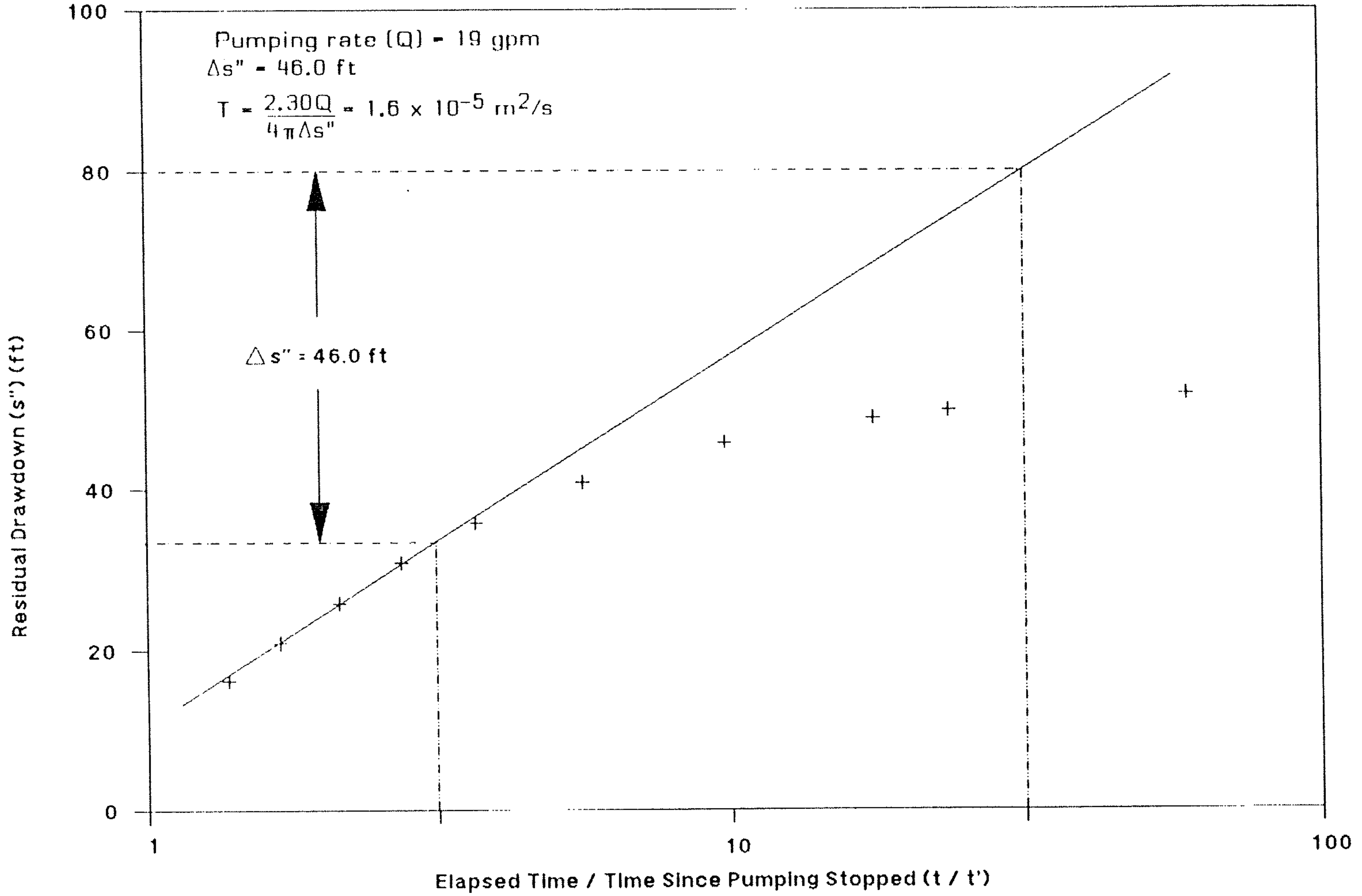
LESMEISTER

PUMP TEST (Drawdown Portion)

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8374 DATE DRAWN CB APPROVED MD

Golder Associates



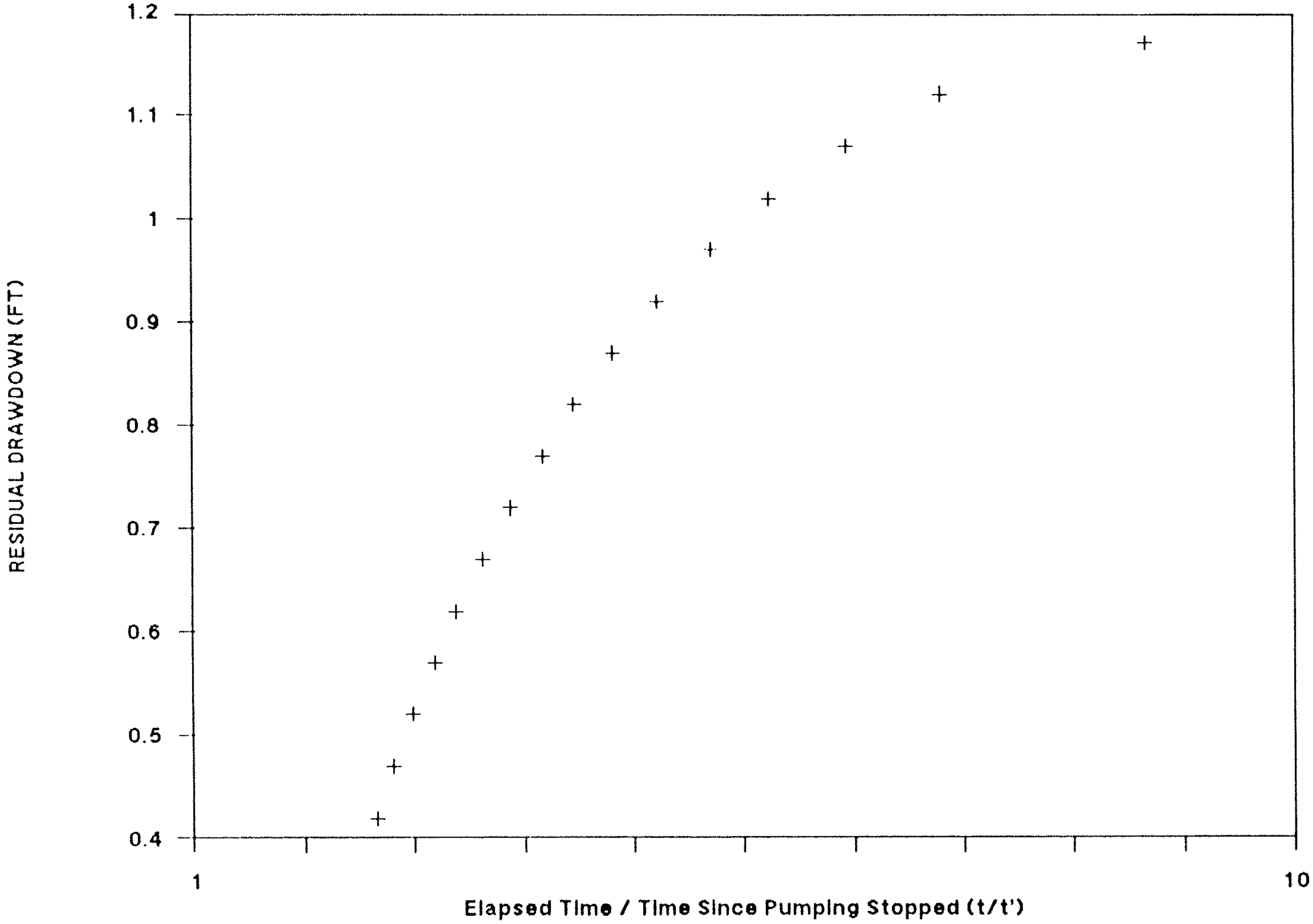
LESMEISTER

PUMP TEST (Recovery Portion)

LAKE CHELAN

Golder Associates

PROJECT NO 863-1123-003 DWG NO 8370 DATE DRAWN CB APPROVED MD



PICKENS

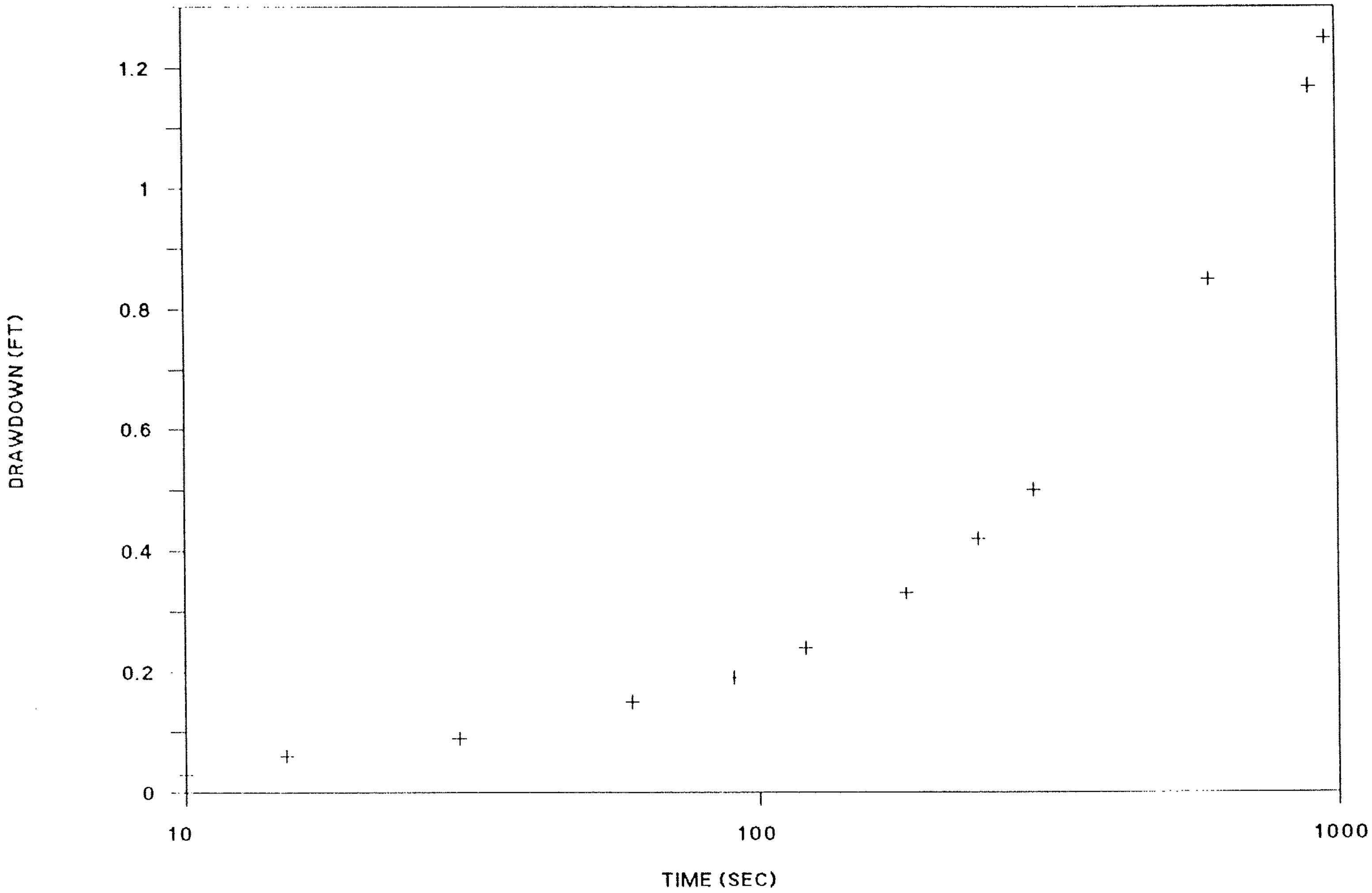
DOMESTIC PUMP TEST

(Recovery Portion)

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8366 DATE DRAWN CB APPROVED MD

Golder Associates

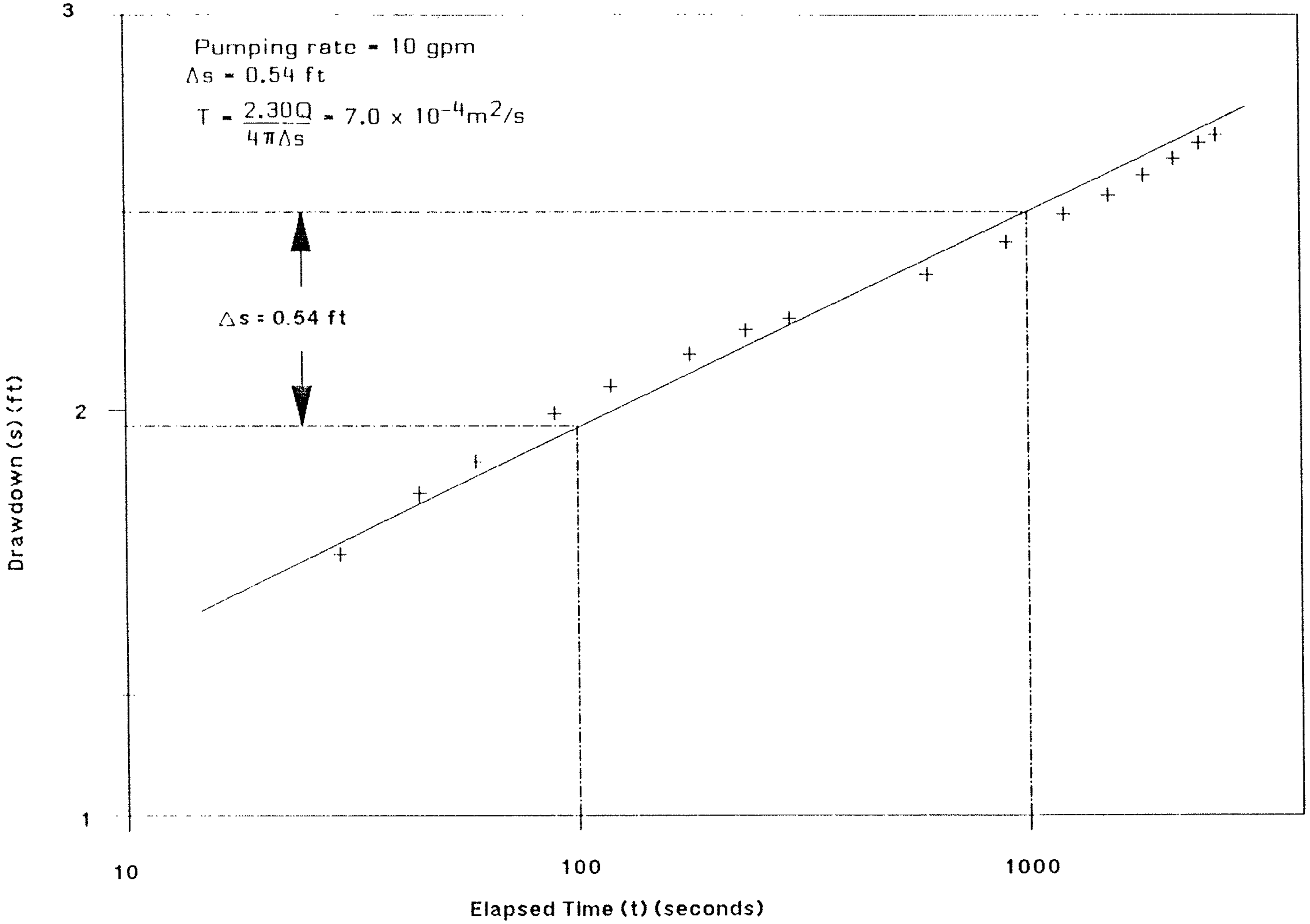


Casing storage affects entire test.

PICKENS
DOMESTIC PUMP TEST
(Drawdown portion)
LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8365 DATE DRAWN CB APPROVED MD

Golder Associates



Casing storage affects first minute of data.

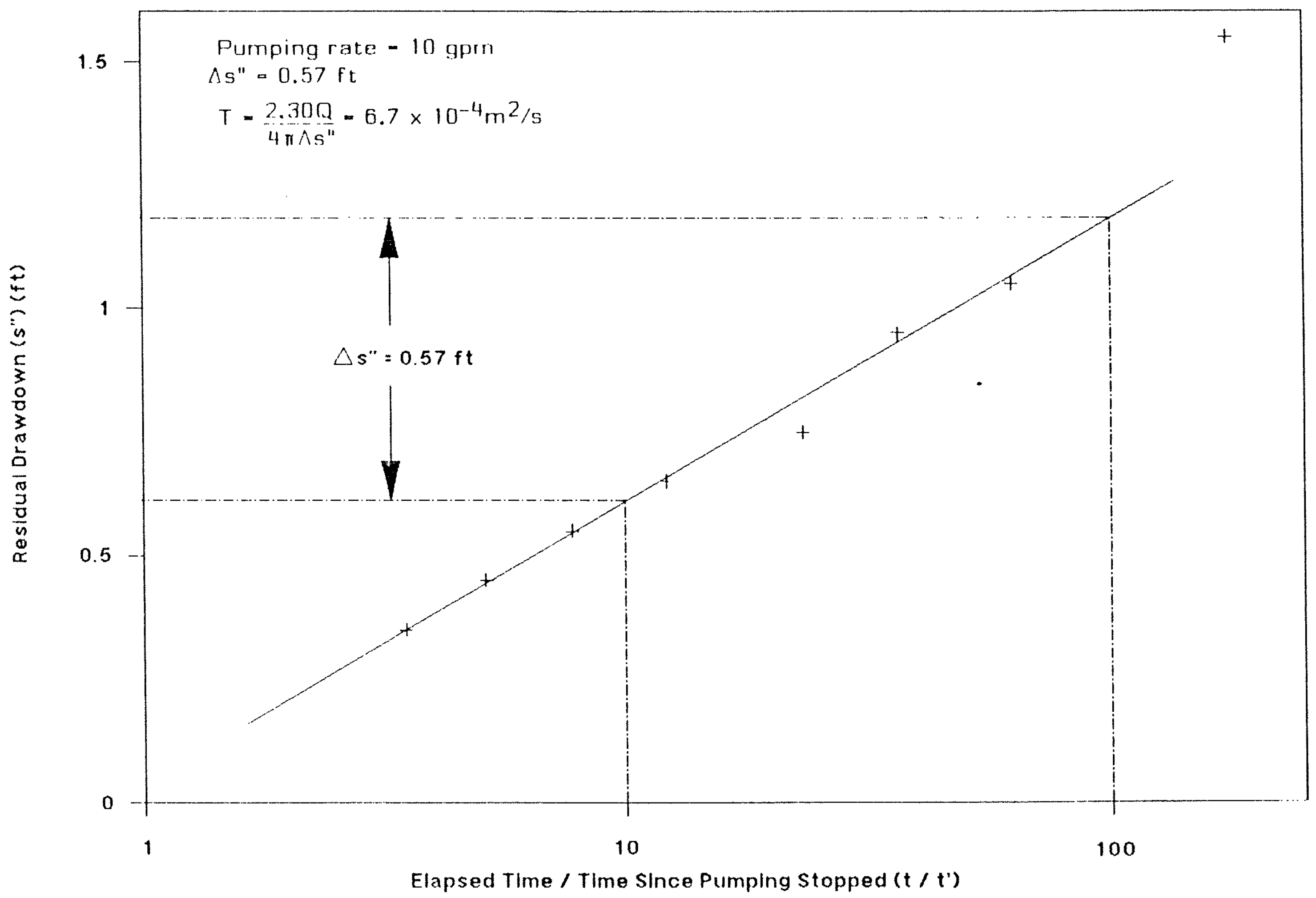
KELLY

PUMP TEST (Drawdown Portion)

LAKE CHELAN

Golder Associates

PROJECT NO 863-1123-003 DWG NO 8372 DATE DRAWN CB APPROVED MD



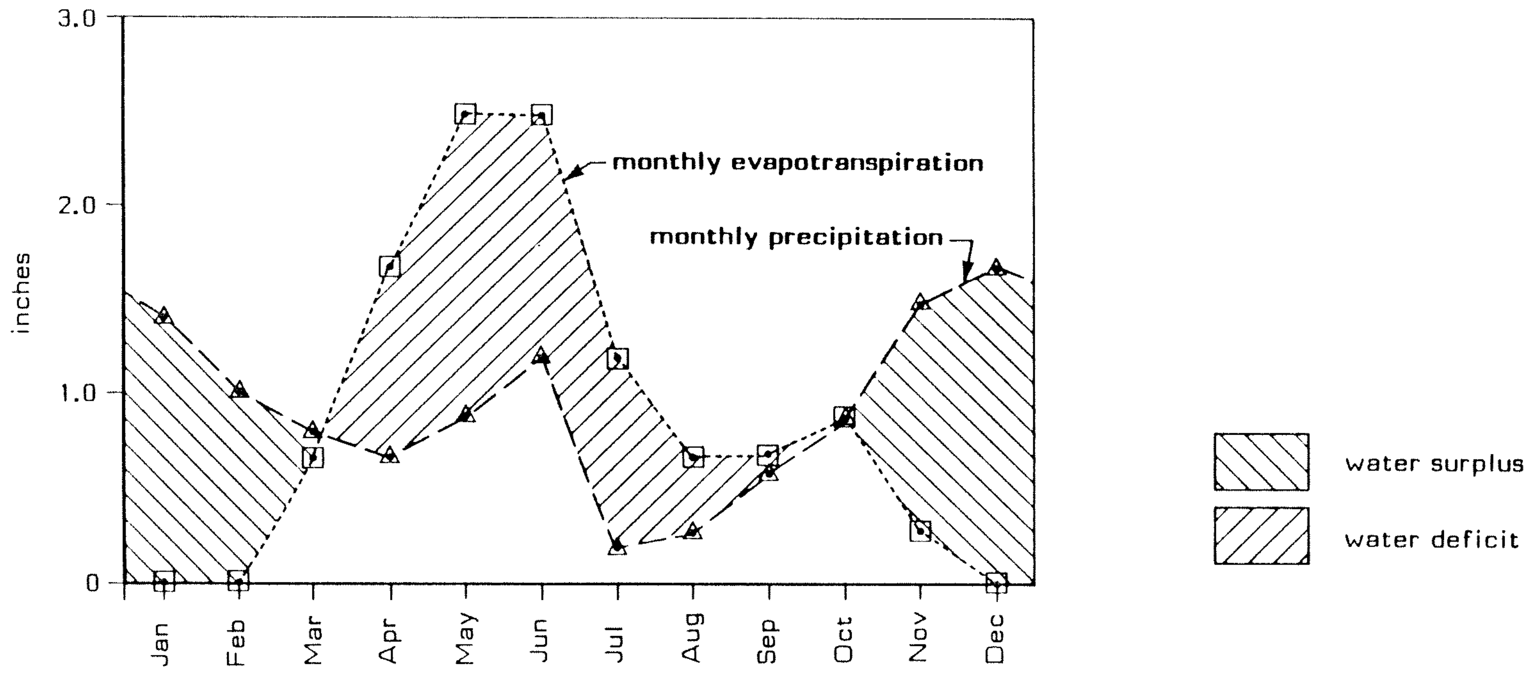
KELLY

PUMP TEST (Recovery Portion)

LAKE CHELAN

Golder Associates

PROJECT NO 863-1123-003 DWG NO 8368 DATE DRAWN CB APPROVED MD



Monthly average evapotranspiration
and precipitation 1931-1960

Data from Donaldson and Ruscha, 1975

MONTHLY AVERAGE PRECIPITATION AND EVAPOTRANSPIRATION AMOUNTS, CHELAN, WA

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8571 DATE DRAWN CB APPROVED DB

Golder Associates

TABLE 1-4

SLUG TEST DETAILS

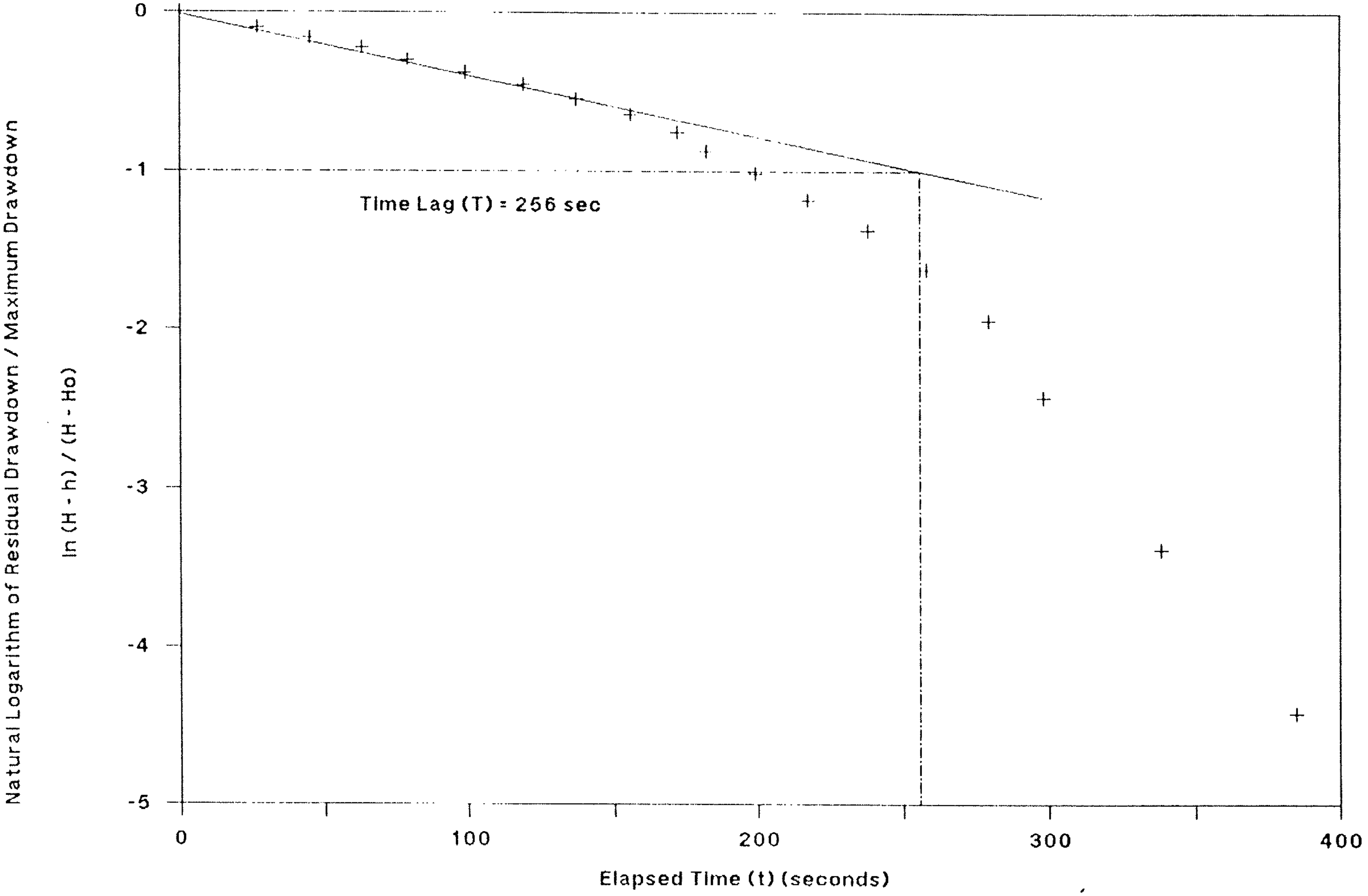
Well	Standpipe Radius r(in)[a]	Saturated Gravel Pack Length L(ft)	Gravel Pack Radius R(ft)	Time Lag To (sec)	Hydraulic Conductivity(K)[c] (m/sec)	Soil Type
McClellan(Up)CH-4	2.35	7.3	0.08	223	1.6×10^{-5}	Sand and Silt
Venneberg(Dn)CH-10	2.35	7.0	0.08	470	7.9×10^{-6}	Sand
Allison(Up)CH-15	2.35	10.0	0.33	232	8.6×10^{-6}	Clayey Silt/ Sand
Sather(Ag)CH-1	2.35	10.0	0.08	128	2.2×10^{-5}	Sandy Silt to Sand
Pickins(Dn)CH-23	1.84	9.3	0.25	14[b]	1.0×10^{-4}	Sandy Clayey Silt
				41[b]	3.5×10^{-5}	Sandy Clayey Silt
Simmonds(Ag)CH-2	2.35	10.0	0.08	165	1.7×10^{-5}	Sand
Collins(Dn)CH-22	1.84	12.0	0.25	256	4.5×10^{-6}	Sandy Gravel/ Silty Sand

Notes:

[a] Because all or most of recovery in each well occurred within the screened and gravel packed intervals "r" is taken to be the effective radius of the 2-inch diameter well and the surrounding gravel pack (assumed to have a porosity of 30%).

[b] These values represent maximum and minimum case time lags from the time-drawdown data of this well.

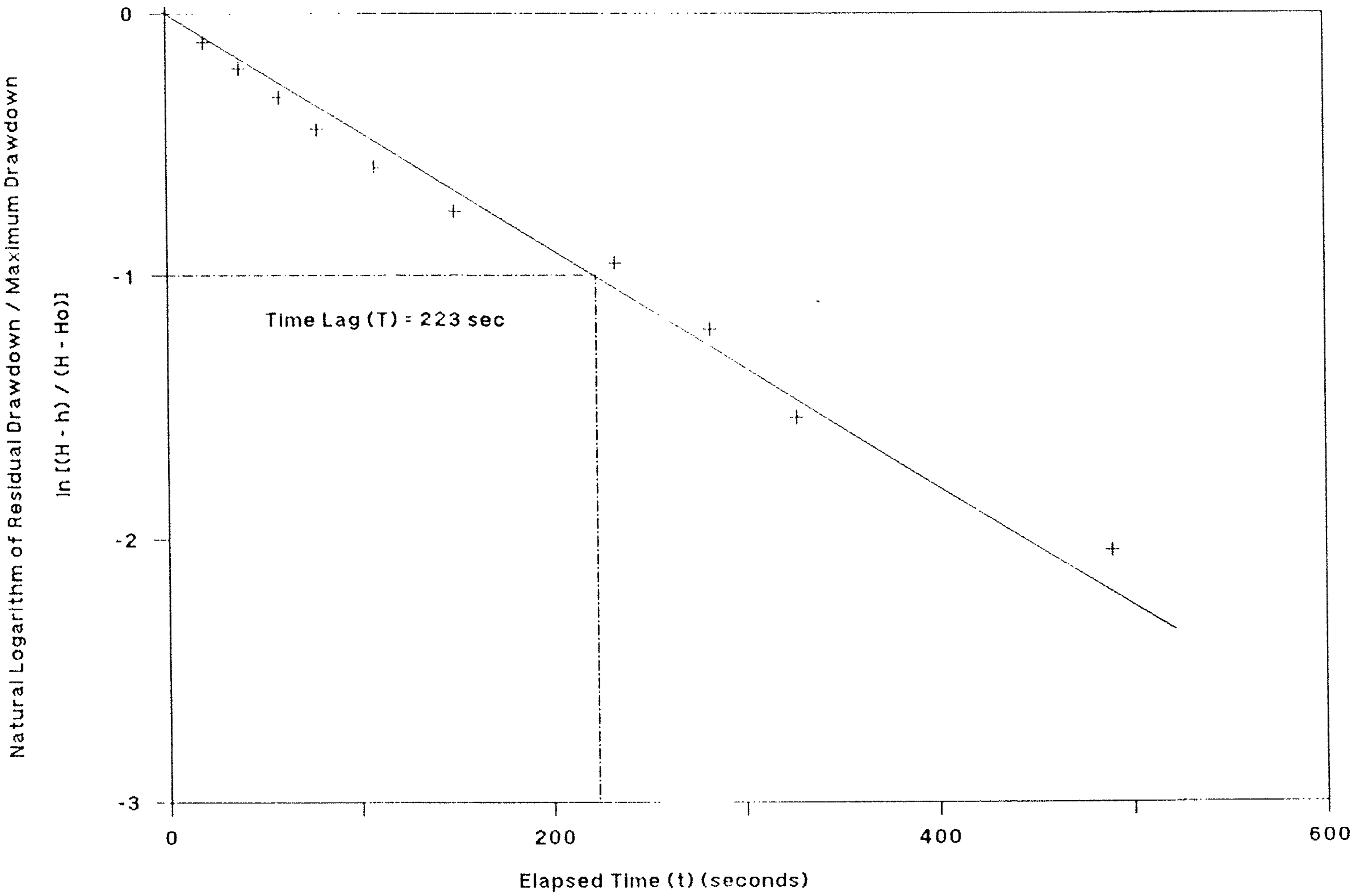
[c] $K = \frac{r^2 \ln (L/R)}{2LT_o}$



COLLINS, DN
SLUG TEST CH-20
LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8381 DATE DRAWN CB APPROVED MD

Golder Associates



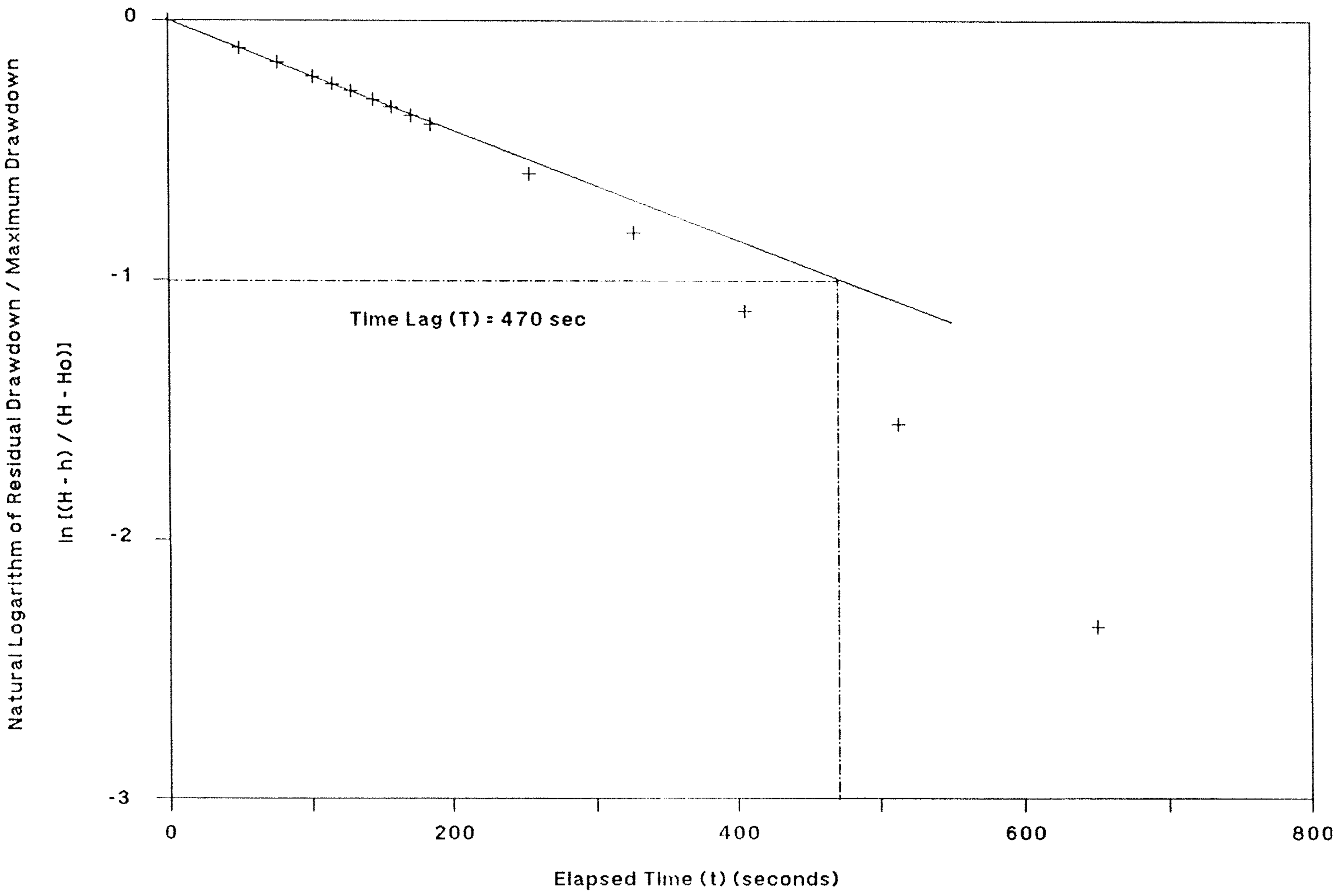
McCLELLAN, UP

SLUG TEST, CH-4

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8376 DATE DRAWN CB APPROVED MD

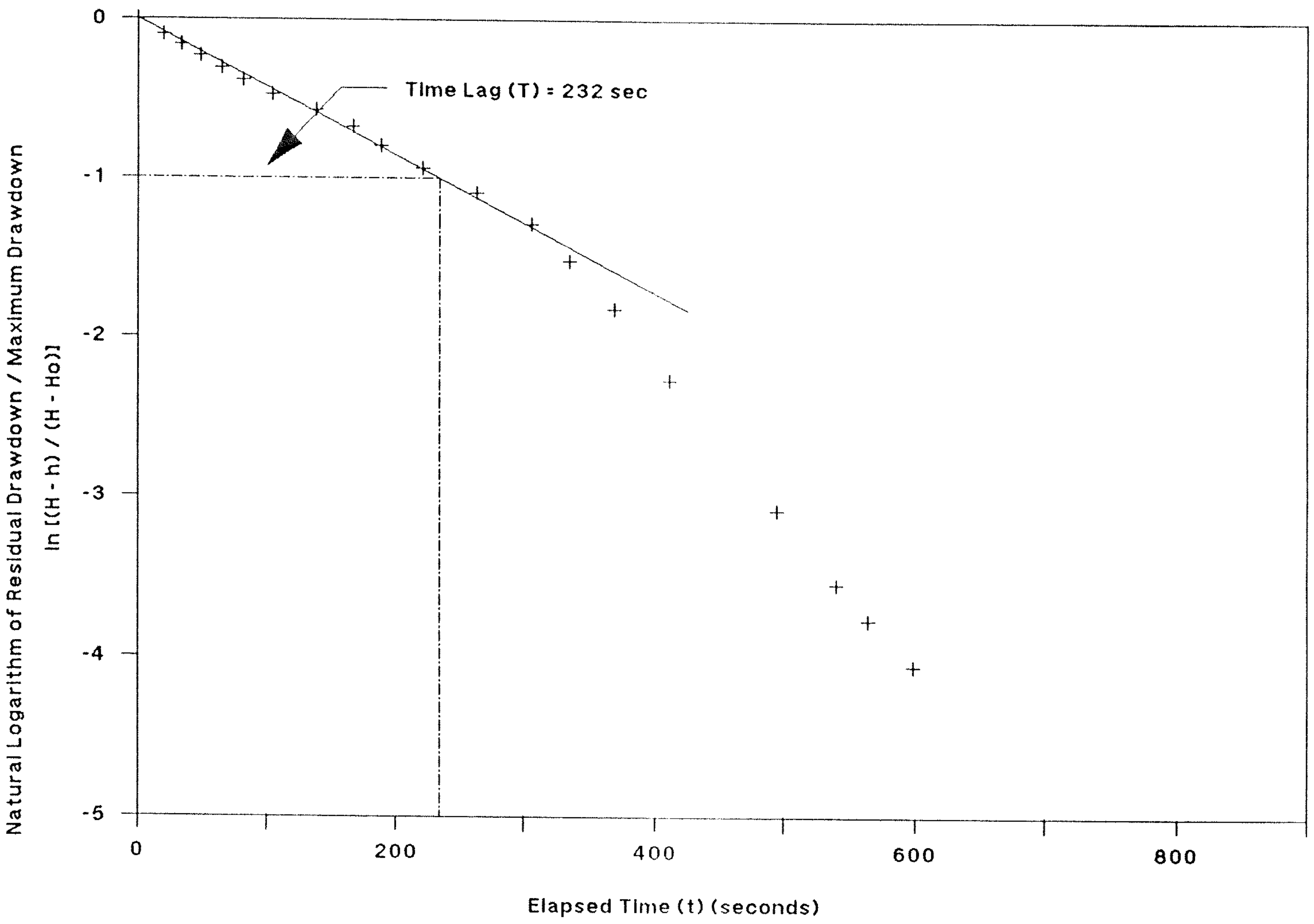
Golder Associates



VENNENBERG
SLUG TEST, CH-10
LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8375 DATE DRAWN CB APPROVED MD

Golder Associates

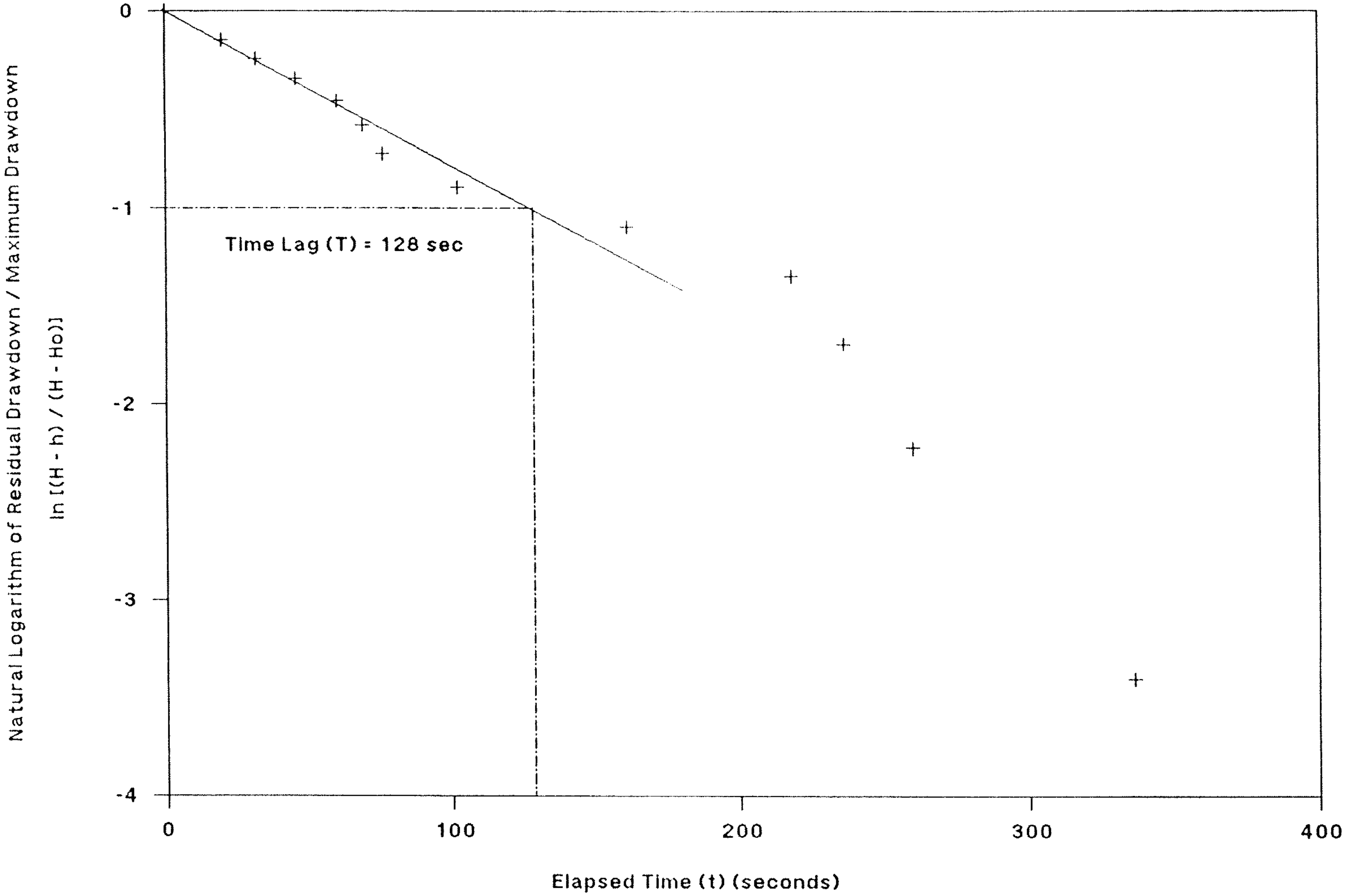


ALLISON, UP
SLUG TEST, CH-15

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8377 DATE DRAWN CB APPROVED MD

Golder Associates



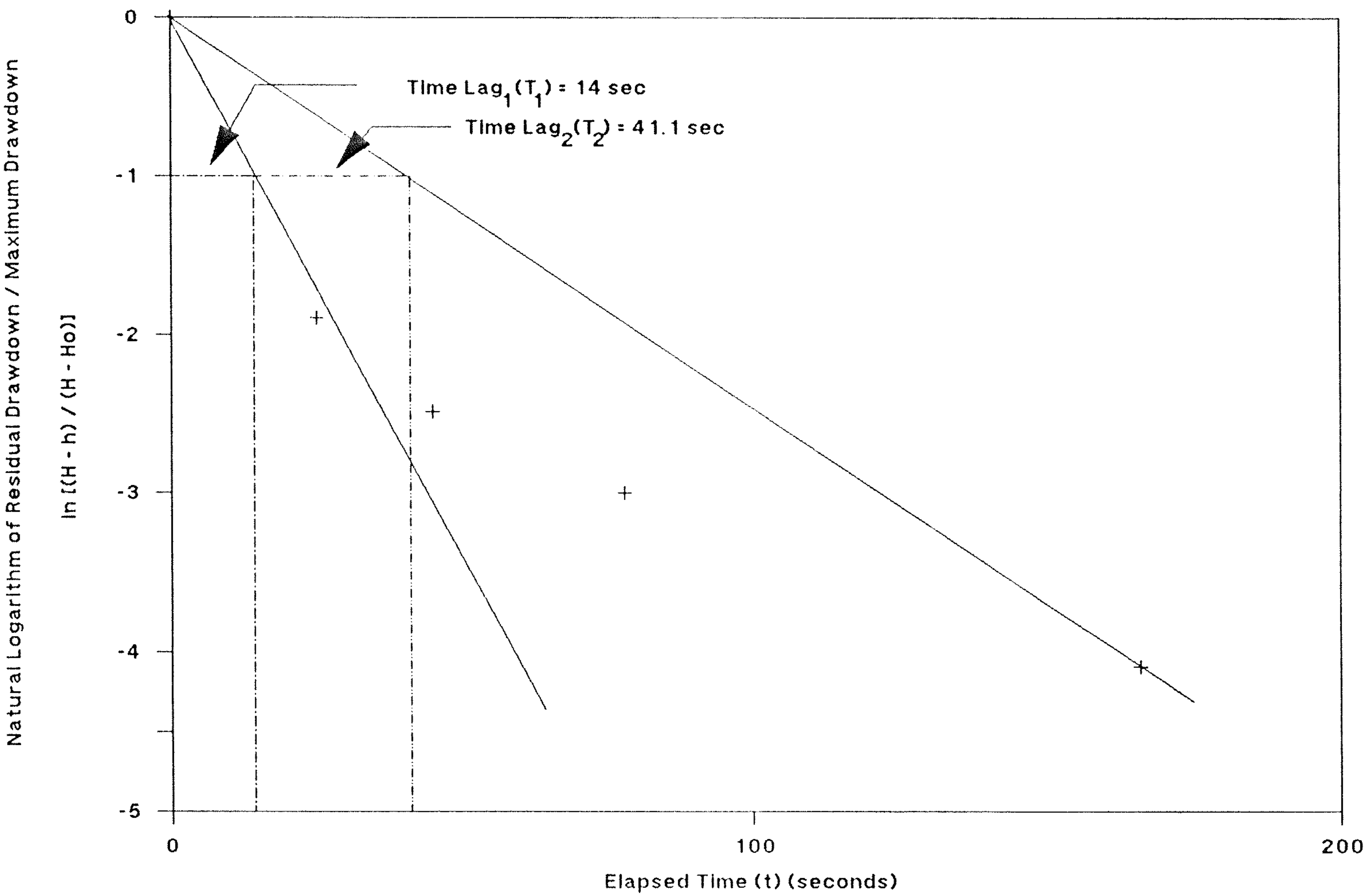
SATHER

SLUG TEST, CH-1

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8378 DATE DRAWN CB APPROVED MD

Golder Associates



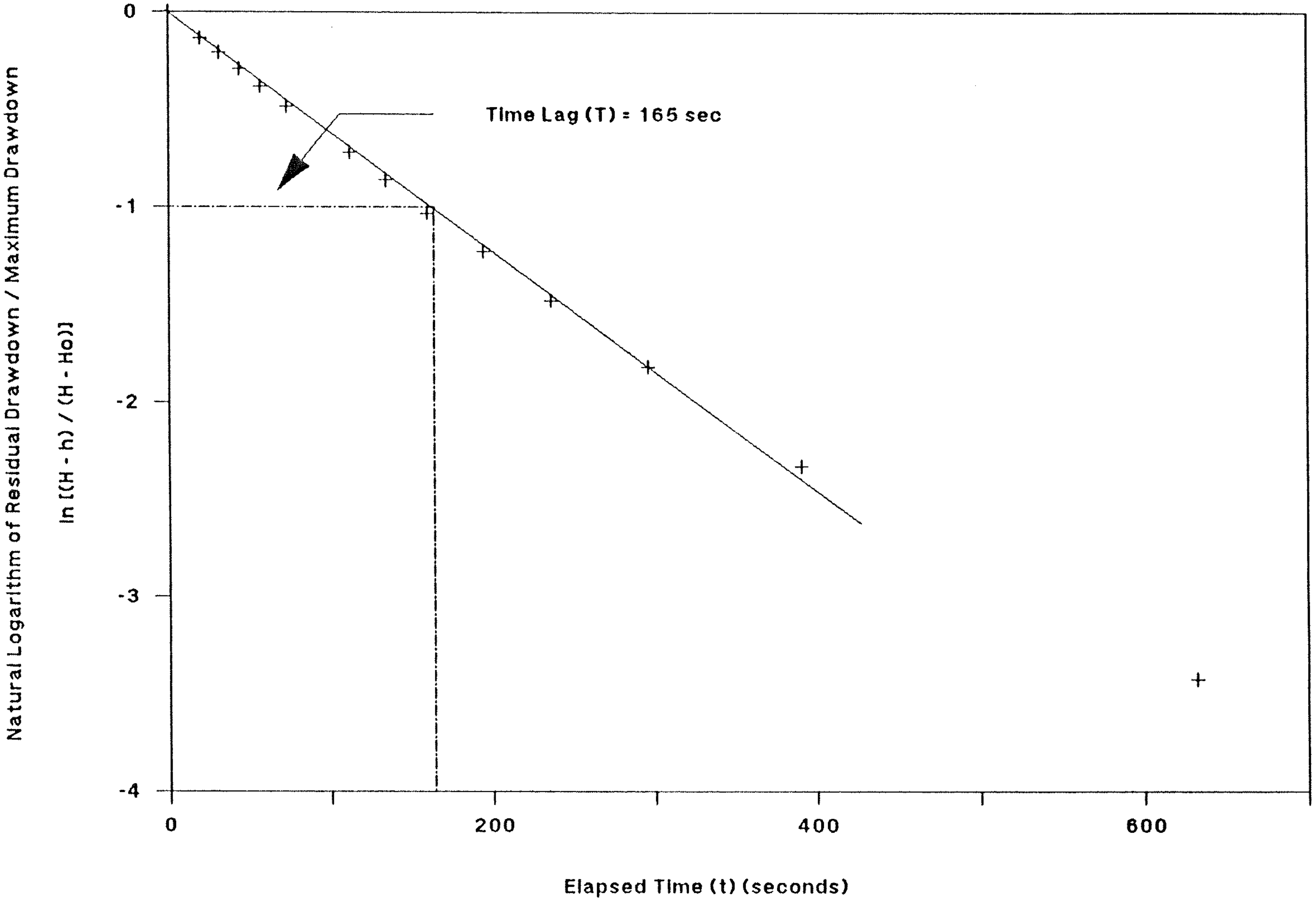
PICKENS

SLUG TEST, CH-23

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8379 DATE DRAWN CB APPROVED MD

Golder Associates



SIMMONDS

SLUG TEST, CH-2

LAKE CHELAN

PROJECT NO 863-1123-003 DWG NO 8380 DATE DRAWN CB APPROVED MD

Golder Associates

APPENDIX C

Grain Size Distributions

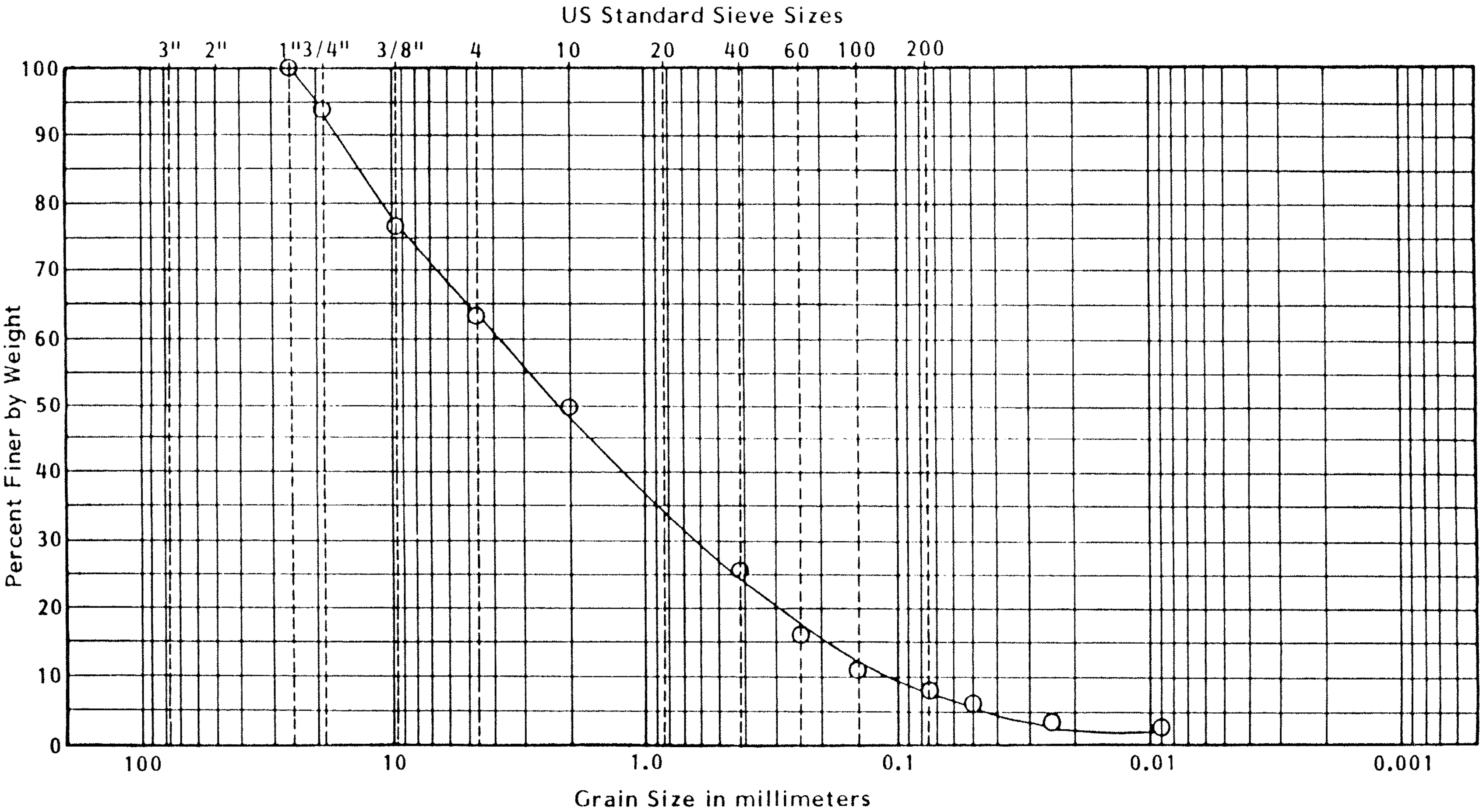
Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/26/87 Tested by JGJ Approved by

Figure

GRAIN SIZE DISTRIBUTION

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-26 C-2 "State Park"	20.0' - 25.0'	-	-	-	-	Brown, fine, gravelly, SAND, little silt

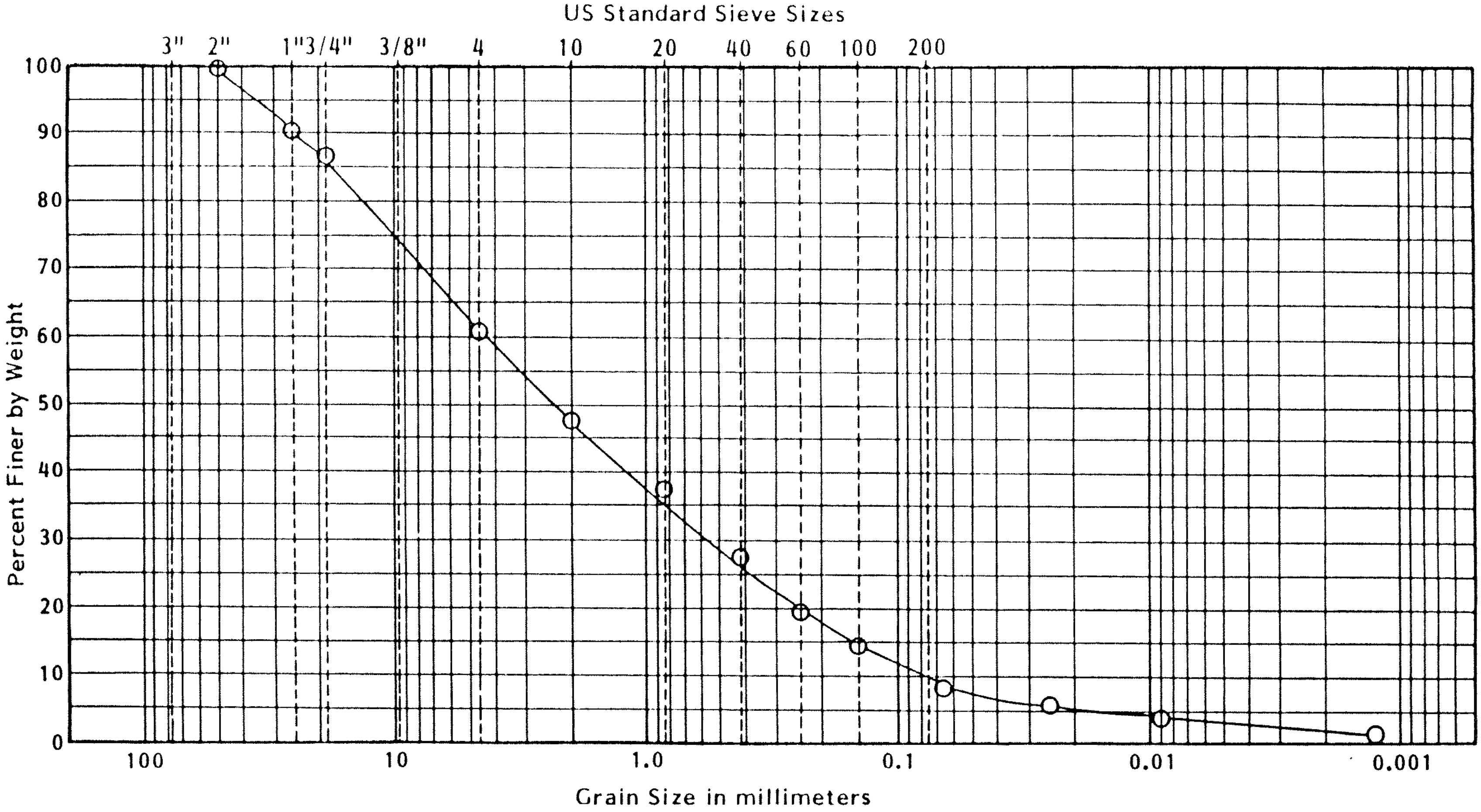
Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/26/87 Tested by JGJ Approved by ______

Figure

GRAIN SIZE DISTRIBUTION

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

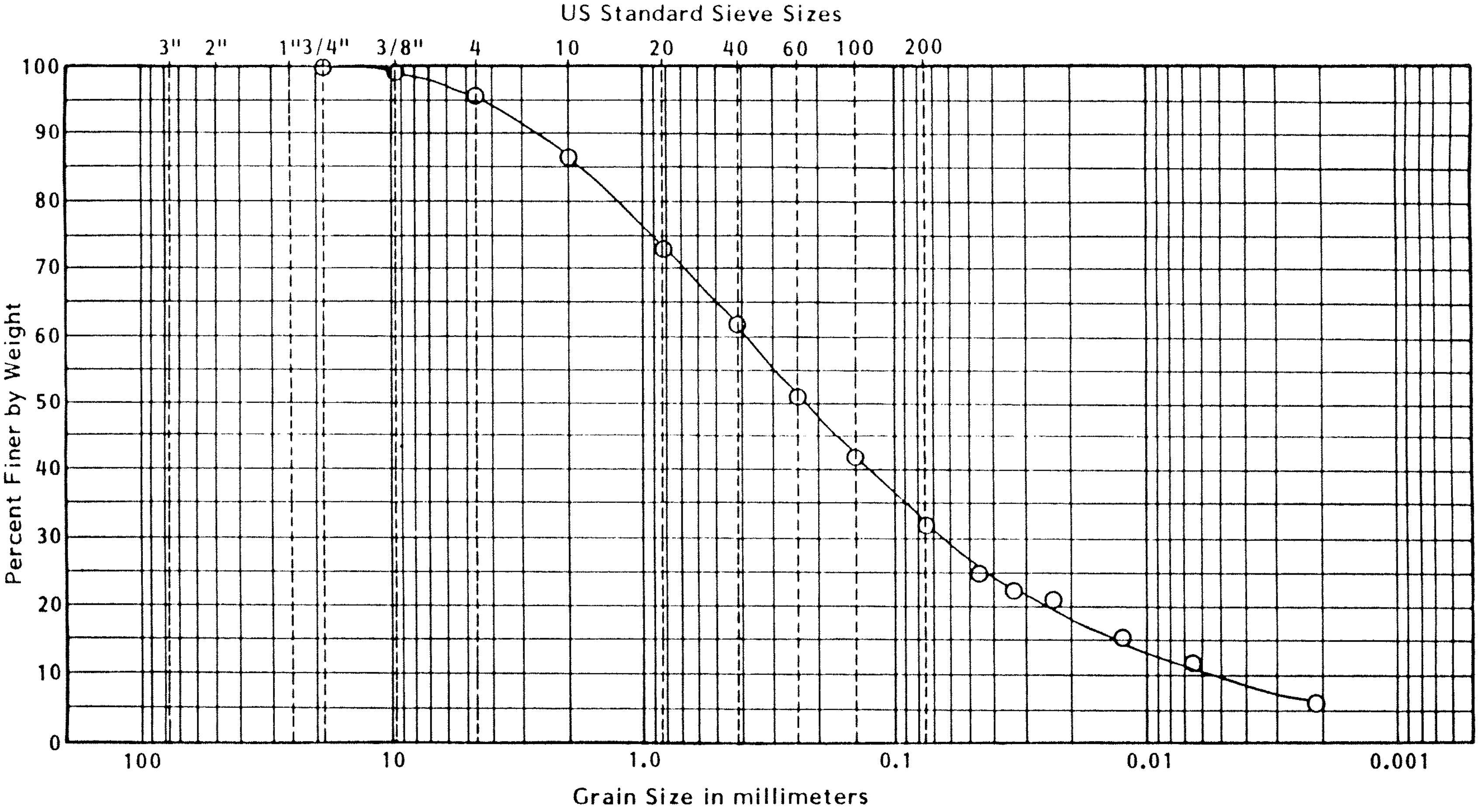
Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-8 S-1 "Lutz, DN (Shallow)"	5.0 - 6.5'	-	-	-	-	Light brown, fine, GRAVEL and fine to coarse, SAND, little silt

Project Harper-Owes/Monitor/Chelan
Project No. 863-1123-003 Date 10/26/87 Tested by JGJ Approved by

Figure

GRAIN SIZE DISTRIBUTION

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-28 C-1 "Cove, DN"	11' - 14'	-	-	-	-	Brown, fine to coarse, SAND and SILT Trace fine gravel

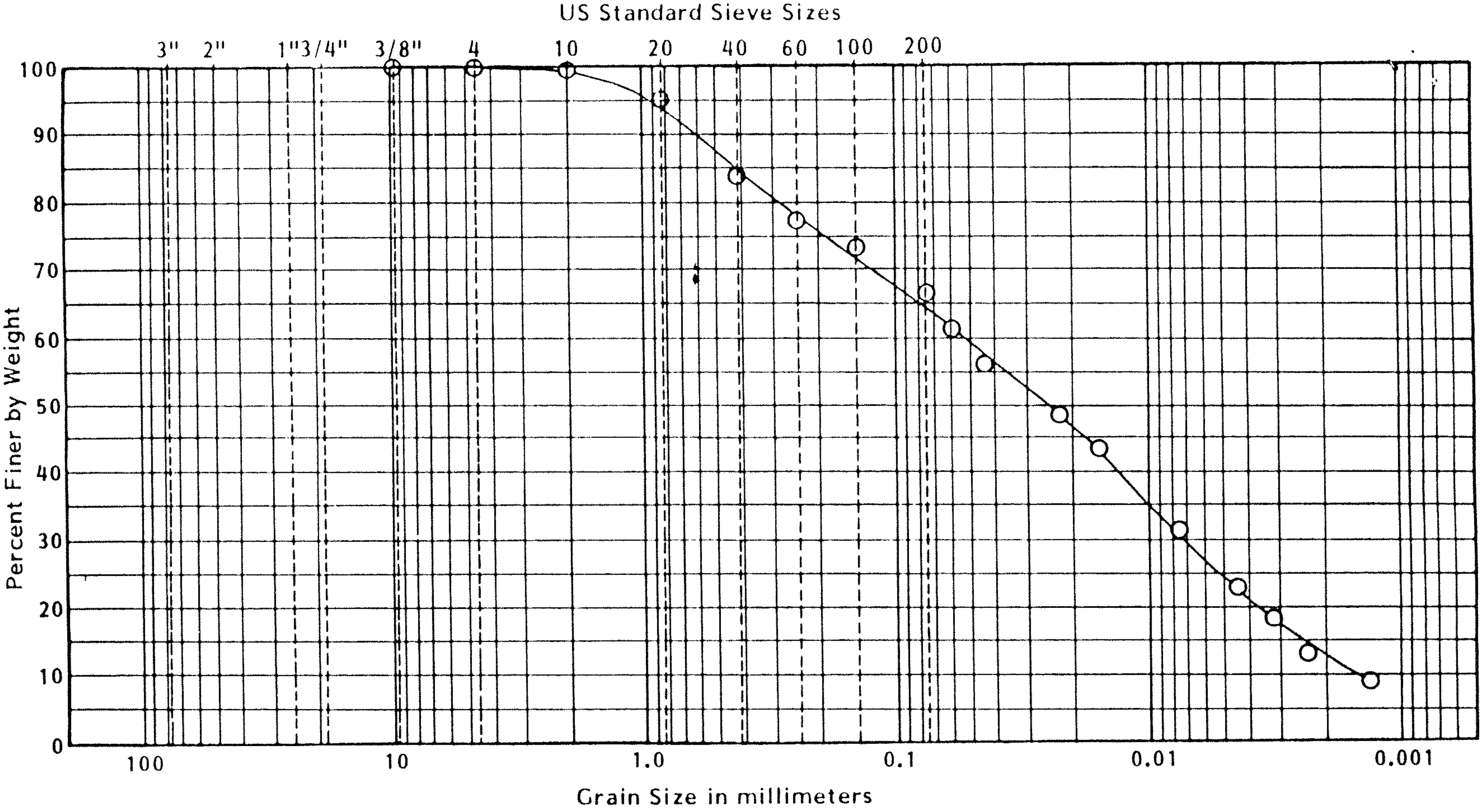
Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/27/87 Tested by JGJ Approved by

Figure

GRAIN SIZE DISTRIBUTION

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-23 C-1 "Pickens, DN"	6.0' - 9.0'	-	-	-	-	Brown, sandy, SILT

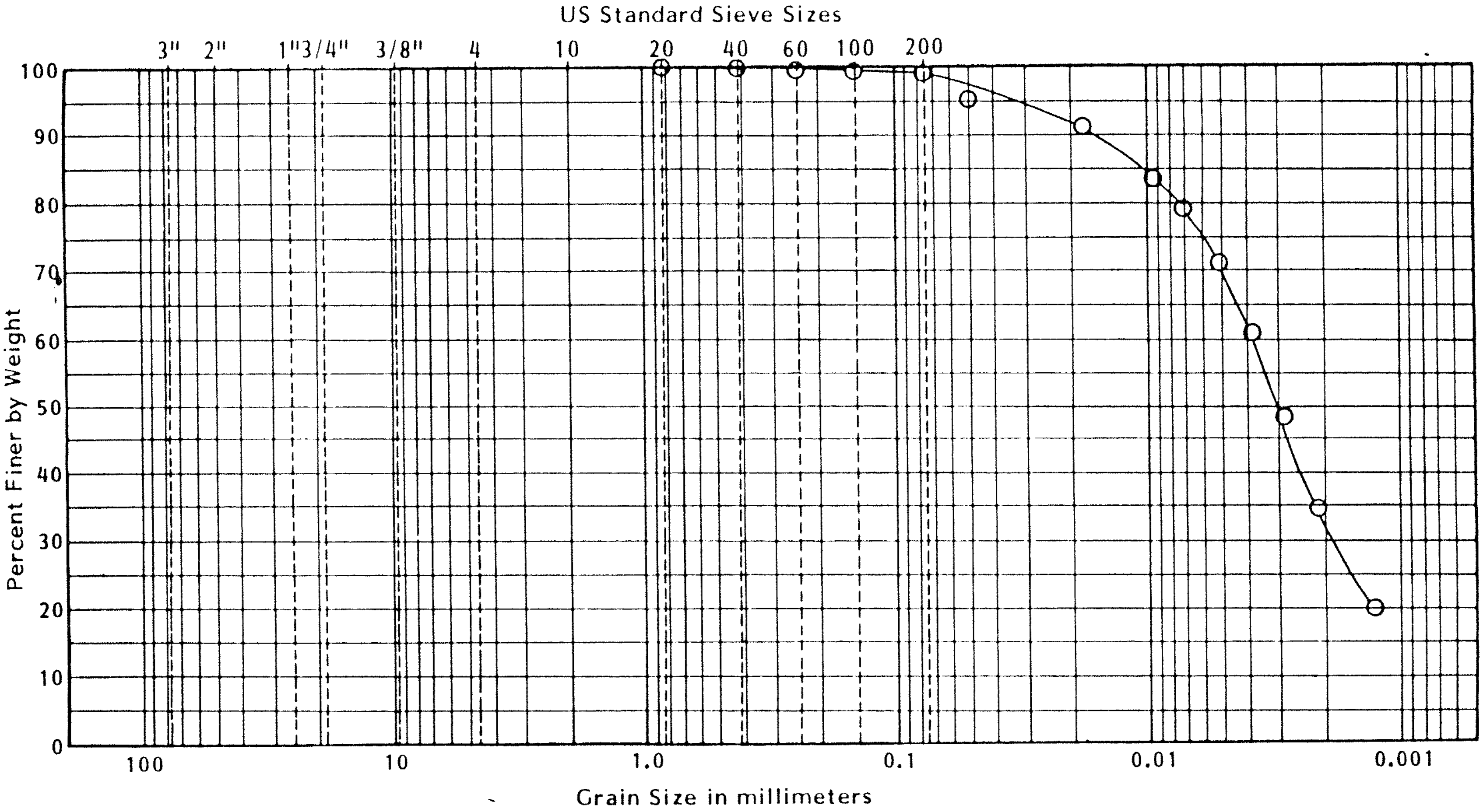
Figure

GRAIN SIZE DISTRIBUTION

Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/27/87 Tested by JGJ Approved by

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-15 S-2 "Allison, UP"	7.5' - 9.0'	-	-	-	-	Brown, clayey, SILT

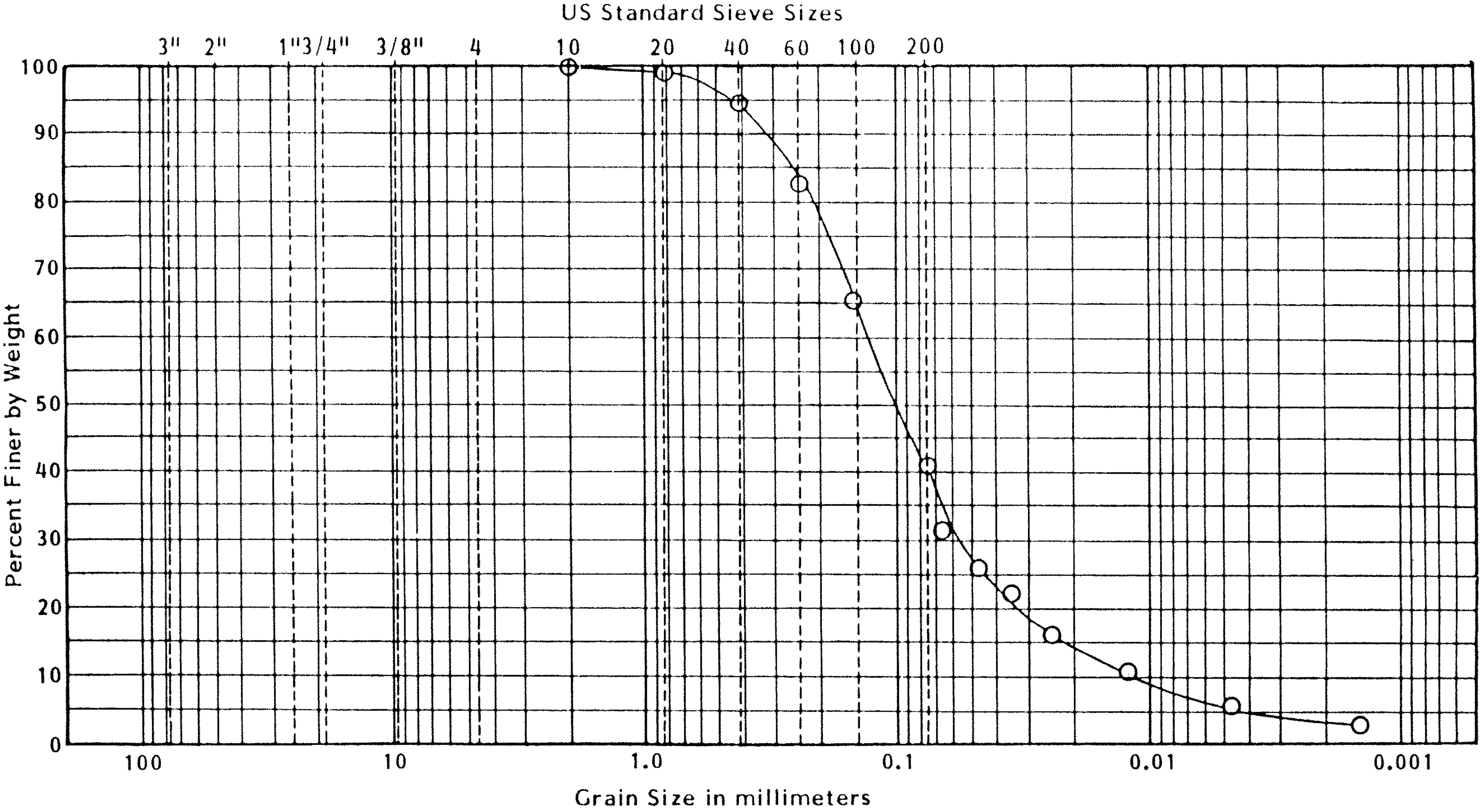
Figure

GRAIN SIZE DISTRIBUTION

Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/26/87 Tested by JGJ Approved by

Golder Associates



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-4 S-2 "McClellan, UP"	10.0' - 11.5'	-	-	-	-	Brown, fine, SAND and SILT

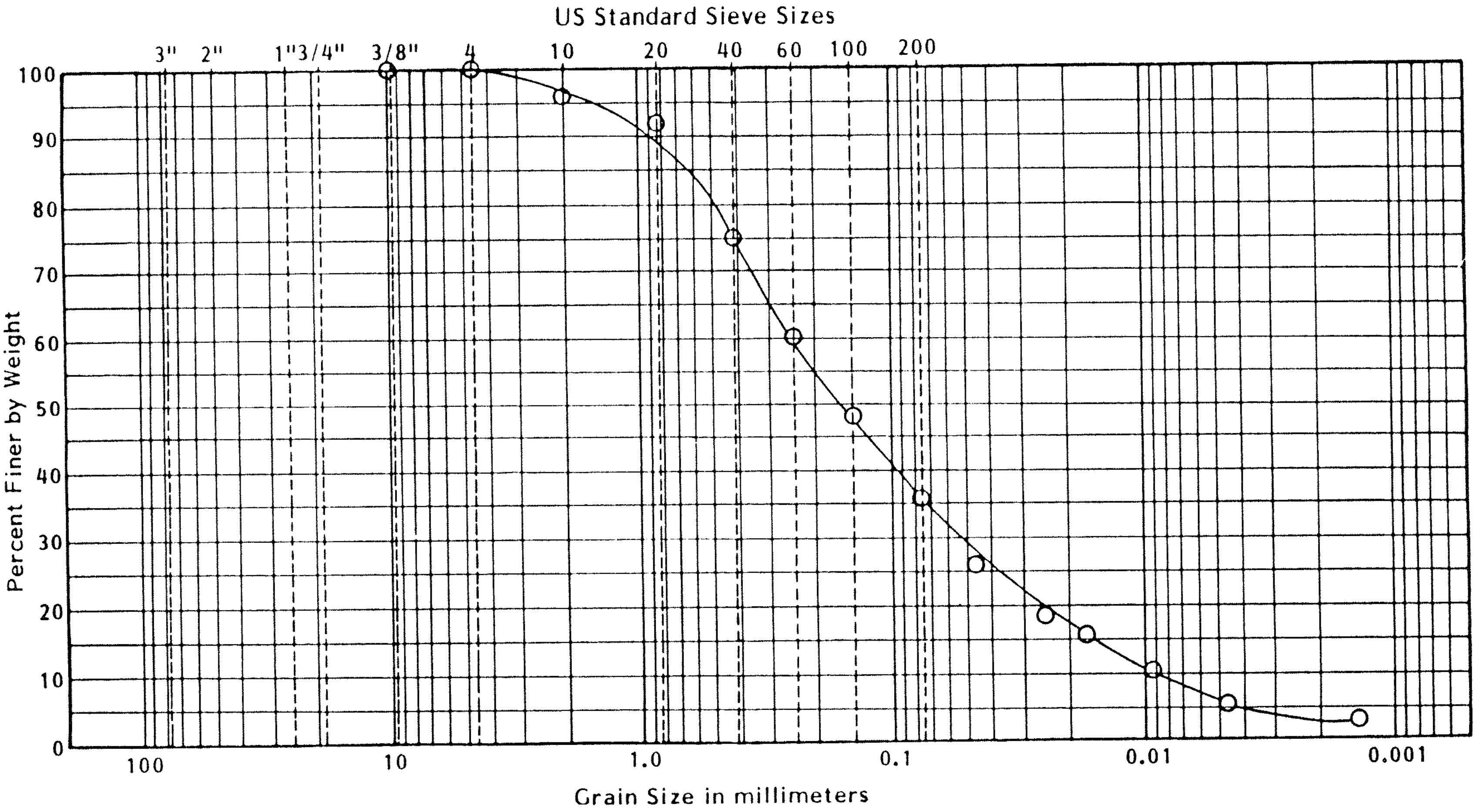
Project Harper-Owes/Monitor/Chelan

Project No. 863-1123-003 Date 10/27/87 Tested by JGJ Approved by

Golder Associates

Figure

GRAIN SIZE DISTRIBUTION



Cobbles	Gravel		Sand			Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

Boring No.	Elev. or Depth	W_n	W_L	W_p	I_p	Description or Classification
CH-4 S-1 "McClellan, UP"	5.0' - 6.5'	-	-	-	-	Brown, silty, medium to fine, SAND

APPENDIX D

Fish Tissue Sampling and Analysis Procedures

Description of fish caught in Lake Chelan and used for pesticide and metals analysis, September, 1967.

Location	Fish Species	Genus/ species	Number in Sample	Weight (grams)	Length (cm)	Sex	Catch Method	Sample Type *	:	Sample No.	% Lipid Fraction	% Solids Fraction	Mean sample weight	Mean sample length
Lower Wapato	Kokanee	Oncorhynchus nerka	1	342	34	Male	gill net	whole	:	418382	3.5	18	342	34
Lower Wapato	Squawfish	Ptychocheilus oregonensis	3	541	39	?	gill net	whole	:	418384	3.4	24	885	44
				793	43	Female	gill net	whole	:					
				1320	51	Female	gill net	whole	:					
Lower Wapato	Sucker	Catostomus macrocheilus	2	280	30	Male	gill net	whole	:	418390	4.2	23	384	33
				488	36	Female	gill net	whole	:					
Upper Wapato	Burbot	Lota lota	2	790	51	Female	set line	edible	:	418381	0.5	17	830	53
				870	54	Male	set line	edible	:					
Upper Wapato	Squawfish	Ptychocheilus oregonensis	3	550	38	?	gill net	whole	:	418393	3.5	23	590	39
				740	43	Female	gill net	whole	:					
				480	36	Male	gill net	whole	:					
Upper Wapato	Sucker	Catostomus macrocheilus	3	740	41	Female	gill net	whole	:	418391	5.3	24	653	39
				540	38	Male	gill net	whole	:					
				680	39	Male	gill net	whole	:					
Upper Wapato	Sucker	Catostomus macrocheilus	3	710	38	Female	gill net	whole	:	418392	8.0	23	587	36
				700	38	Female	gill net	whole	:					
				350	31	?	gill net	whole	:					
Upper Lucerne	Chinook	Oncorhynchus tshawytscha	1	4120	70	Male	gill net	fillet	:	418385	3.3	23	4120	70
Upper Lucerne	Kokanee	Oncorhynchus nerka	1	330	31	Male	gill net	whole	:	418380	1.0	17	330	31
Upper Lucerne	Burbot	Lota lota	3	530	45	Female	set line	edible	:	418383	0.4	17	513	44
				480	42	Female	set line	edible	:					
				530	45	Female	set line	edible	:					
Upper Lucerne	Rbw. Trout	Salmo gairdneri	2	2360	59	Male	hook & lin	fillet	:	418387	3.2	22	1715	55
				1070	50	Female	hook & lin	fillet	:					
Upper Lucerne	Squawfish	Ptychocheilus oregonensis	3	408	36	?	gill net	whole	:	418386	4.9	25	595	38
				893	42	Female	gill net	whole	:					
				484	36	?	gill net	whole	:					
Upper Lucerne	Squawfish	Ptychocheilus oregonensis	3	484	35	?	gill net	whole	:	418388	3.6	22	547	38
				659	42	?	gill net	whole	:					
				499	36	?	gill net	whole	:					
Upper Lucerne	Sucker	Catostomus macrocheilus	3	540	40	Female	gill net	whole	:	418389	5.0	23	556	37
				440	34	Male	gill net	whole	:					
				587	37	Male	gill net	whole	:					

* Fillet is without skin, edible is with skin intact, whole is the entire fish.

Description of Lake Chelan fish collection sites, September 14-17, 1985.

Name of Site	Date	Gear	Description
Lower Wapato near the City of Chelan	9/14	gill net	Off breakwater of moorage next to city park
	9/15	gill net	Off bullhead, west of business area on south shore
Upper Wapato near Manson	9/14	gill net	Off agricultural return drain just east of Willow Pt.
	9/14	set line	Off agricultural return drain just east of Willow Pt.
	9/14	set line	Approx. one-fourth mile west of Wapato Pt.
	9/15	trolling	Manson Bay from Wapato Pt. to Willow Pt.
Lower Lucerne at 25 Mile Cr.	9/15	set line	Two lines set west of the creek
Upper Lucerne near Railroad Cr.	9/16	gill net	Approx. 50' south and north of the mouth of the creek
	9/16	set line	Approx. 150' & 250' north of the creek
	9/16	trolling	South shore between Railroad Cr. and Lightning Cr.
	9/17	trolling	North shore opposite Railroad Cr.

Methods used to analyze Lake Chelan fish tissue samples for pesticides, PCBs, & metals.
All analyses performed at the Enseco/California Analytical Laboratories.

COMPOUND/METAL	Method I.D.	Method Description	Reference
Aldrin	8080	Solvent-flush injection GC-EC or HS	USEPA, 1986*
Dieldrin	CNFRL/EPA 608+	Influent-split,dual column GC-EC++	Johnson, Norton, & Yake, 1986
alpha-BHC	CNFRL/EPA 608	"	"
beta-BHC	CNFRL/EPA 608	"	"
delta-BHC	CNFRL/EPA 608	"	"
gamma-BHC (Lindane)	CNFRL/EPA 608	"	"
Chlordane	CNFRL/EPA 608	"	"
o,p-DDD	CNFRL/EPA 608	"	"
o,p-DDE	CNFRL/EPA 608	"	"
o,p-DDT	CNFRL/EPA 608	"	"
p,p'-DDD	CNFRL/EPA 608	"	"
p,p'-DDE	CNFRL/EPA 608	"	"
p,p'-DDT	CNFRL/EPA 608	"	"
Heptachlor	CNFRL/EPA 608	"	"
Heptachlor epoxide	CNFRL/EPA 608	"	"
Endosulfan I	CNFRL/EPA 608	"	"
Endosulfan II	CNFRL/EPA 608	"	"
Endosulfan sulfate	8080	Solvent-flush injection GC-EC or HS	USEPA, 1986
Endrin	CNFRL/EPA 608	Influent-split,dual column GC-EC	Johnson, Norton, & Yake, 1986
Endrin ketone	8080	Solvent-flush injection GC-EC or HS	USEPA, 1986
Methoxychlor	CNFRL/EPA 608	Influent-split,dual column GC-EC	Johnson, Norton, & Yake, 1986
Toxaphene	CNFRL/EPA 608	"	Johnson, Norton, & Yake, 1986
PCB (Arochlor)-1016	8080	Solvent-flush injection GC-EC or HS	USEPA, 1986
PCB (Arochlor)-1221	8080	"	USEPA, 1986
PCB (Arochlor)-1232	8080	"	USEPA, 1986
PCB (Arochlor)-1242	CNFRL/EPA 608	Influent-split,dual column GC-EC	
PCB (Arochlor)-1248	CNFRL/EPA 608	"	
PCB (Arochlor)-1254	CNFRL/EPA 608	"	
PCB (Arochlor)-1260	CNFRL/EPA 608	"	
Arsenic	7060	Atomic Absorption,Furnace Technique	USEPA, 1986
Cadmium	6010	ICP** Atomic Emission Spectroscopy	USEPA, 1986
Copper	6010	ICP** Atomic Emission Spectroscopy	USEPA, 1986
Lead	7421	Atomic Absorption,Furnace Technique	USEPA, 1986
Mercury	7471	Manual Cold-Vapor Technique	USEPA, 1986
Selenium	7740	Atomic Absorption,Furnace Technique	USEPA, 1986
Zinc	6010	ICP** Atomic Emission Spectroscopy	USEPA, 1986

\+ Columbia National Fish Research Laboratory Method with USEPA Method 608 chromatography protocol.

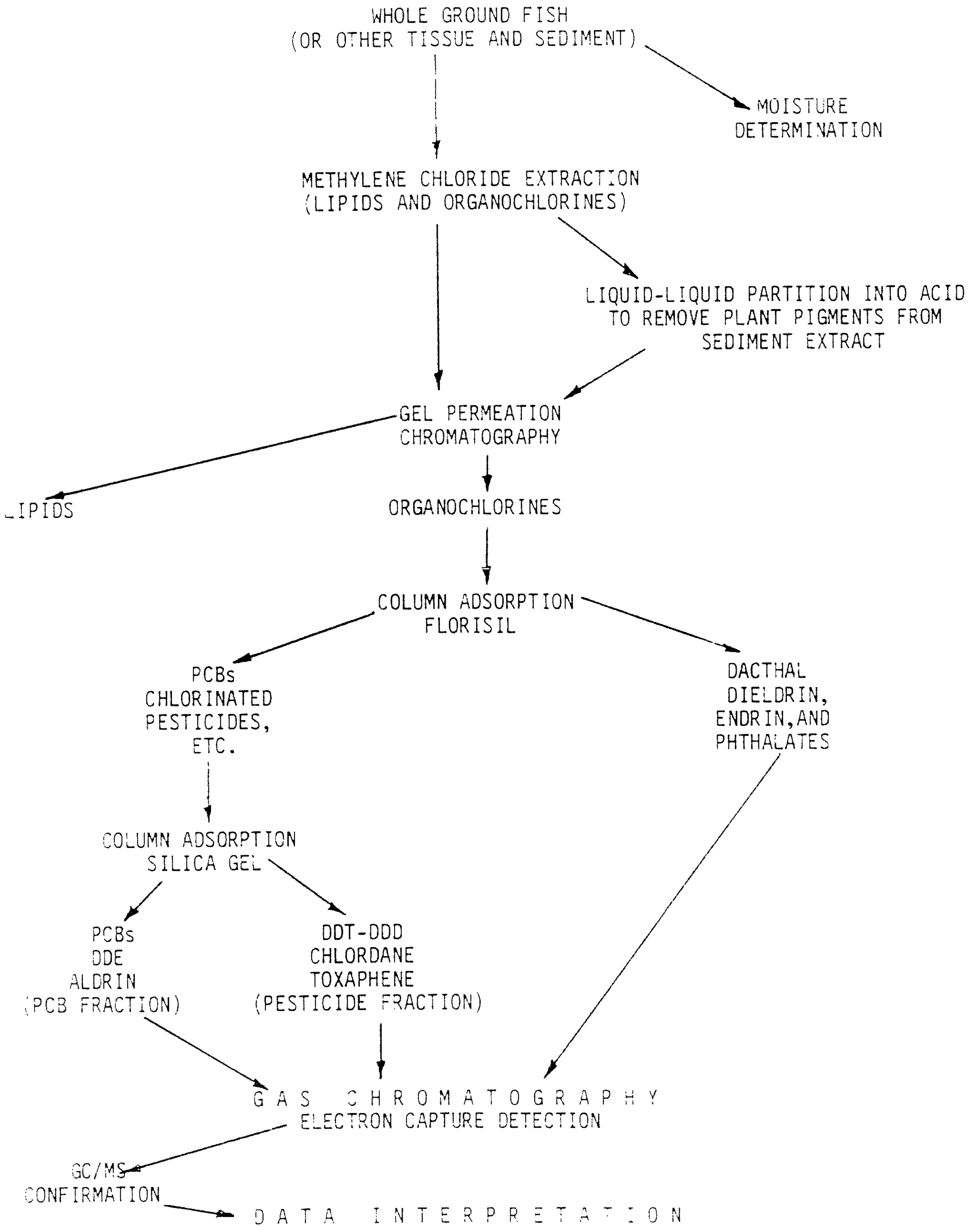
++ Gas chromatography with Electron Capture or Halogen Specific detectors.

* USEPA, 1986: Test Methods for Evaluating Solid Waste, SW-846, Nov. 1986.

** Inductively Coupled Plasma

Method blank. and spiked sample information provided by Enesco/California Analytical Laboratories for the Lake Chelan fish tissue samples. Organics in ug/kg. metals in mg/kg. NA= not applicable. ND= not detected

COMPOUND/METAL	Method Blank	Sample Value	Spike Concen.	Average % Recovery
Aldrin	<8	NA	20	72
Dieldrin	16	NA	50	86
alpha-BHC	<8			
beta-BHC	<8			
delta-BHC	<8			
gamma-BHC (Lindane)	<8	NA	20	58
Chlordane	<80			
o,p-DDD	<16			
o,p-DDE	<16			
o,p-DDT	<16			
p,p'-DDD	<16			
p,p'-DDE	<16			
p,p'-DDT	<16		50	132
Heptachlor	<8	NA	20	56
Heptachlor epoxide	<8			
Endosulfan I	<8			
Endosulfan II	<16			
Endosulfan sulfate	<16			
Endrin	<16	NA	50	42
Endrin ketone	<16			
Methoxychlor	<80			
Toxaphene	<160			
PCB (Arochlor)-1016	<80			
PCB (Arochlor)-1221	<80			
PCB (Arochlor)-1232	<80			
PCB (Arochlor)-1242	<80			
PCB (Arochlor)-1248	<80			
PCB (Arochlor)-1254	<160	ND	1000	85
PCB (Arochlor)-1260	<160			
Arsenic	<0.15	ND	2.0	48
Cadmium	<0.25	ND	2.5	102
Copper	<0.3	1.0	12.5	78
Lead	<0.1	ND	1.0	96
Mercury	<0.05	ND	0.3	46
Selenium	<0.1	0.2	0.3	76
Zinc	<0.5	5.3	25.0	88


WHOLE GROUND FISH
(OR OTHER TISSUE AND SEDIMENT)
MOISTURE DETERMINATION
METHYLENE CHLORIDE EXTRACTION
(LIPIDS AND ORGANOCHLORINES)
LIQUID-LIQUID PARTITION INTO ACID TO REMOVE PLANT PIGMENTS FROM SEDIMENT EXTRACT
GEL PERMEATION CHROMATOGRAPHY
LIPIDS
ORGANOCHLORINES
COLUMN ADSORPTION FLORISIL
PCBs CHLORINATED PESTICIDES, ETC.
DACTHAL DIELDRIN, ENDRIN, AND PHTHALATES
COLUMN ADSORPTION SILICA GEL
PCBs DDE ALDRIN (PCB FRACTION)
DDT-DDD CHLORDANE TOXAPHENE (PESTICIDE FRACTION)
GAS CHROMATOGRAPHY
ELECTRON CAPTURE DETECTION
GC/MS CONFIRMATION
DATA INTERPRETATION

APPENDIX E

Septic System Monitoring Sites: Physical Conditions

APPENDIX E

SEPTIC SYSTEM MONITORING SITES: PHYSICAL CONDITIONS

Site 1 - Cove Marina

One downgradient monitoring well was installed at the Cove Marina. The boring encountered silty gravelly sand to a depth of 13 meters (40 ft). Groundwater was encountered below 6 meters (20 ft). The well, Cove (Dn)-CH-28, was located about 13 meters (40 ft) from a drainfield servicing a small washroom (Figure E.1). The well was also downgradient of a larger drainfield servicing the small motel at the Marina. The soil conditions at the site are silty gravelly sands of fluvial origin and are similar to much of the sands and gravels observed on the North Shore. A grain size distribution typical of the material is presented in Appendix C. The depth to water at the site varied between about 3.6 and 7.6 meters (12 and 25 ft) below ground surface over the study period. Some of the observed variation may have been due to lake level influences (see Section 4.2). The hydraulic conductivity of the silty gravelly sands was estimated at about 1×10^{-5} m/s based on grain size data. The general direction of groundwater flow at the site is northwards towards Lake Chelan.

The upgradient well for the site was Kelly's domestic well. This well is located about 1.5 km (1 mi) north of the Marina, but is probably typical of ground water quality upgradient of the Marina because of its location in similar materials. The Kelly well is located above most of the development at Shrine Beach. The well is reportedly 34 meters (112 ft) deep and is open at the bottom in gravel and silt. The static water level was approximately 27.5 meters (90 ft) below ground surface. The hydraulic conductivity of the gravel and silt was estimated at about 1×10^{-4} m/s based on the results of the pump test performed on this well (see Appendix B).

Groundwater mounding calculations were performed in order to evaluate the impact of wastewater disposal at the Cove Marina on local groundwater levels. Based on the dimensions of the drainfield, and assuming an average wastewater flow from the washroom of about 0.5 m^3/d (135 gpd), and aquifer parameters as shown on Table 4.3, it was estimated that the groundwater level would increase by less than 0.3 meters (1 ft) under the drainfield. The high hydraulic conductivity also results in a rapid seepage velocity (4 m/day) for the wastewater to flow vertically through the unsaturated zone to the water table. A conceptual model of groundwater conditions within the vicinity of the drainfield is depicted in Figure 4.5.

Site 2 - Lake Chelan State Park

One downgradient monitoring well was installed at the State Park (Figure E.2). The well, State Park (Dn)-CH-26, is located about 13 meters (40 ft) downgradient of the drainfield servicing approximately 17 camping spaces and the park residences. The park is used year round but most use takes place during summer. The soil conditions at the site consist of about 17 meters (56 ft) of gravelly fine to coarse sands overlying clayey silts and

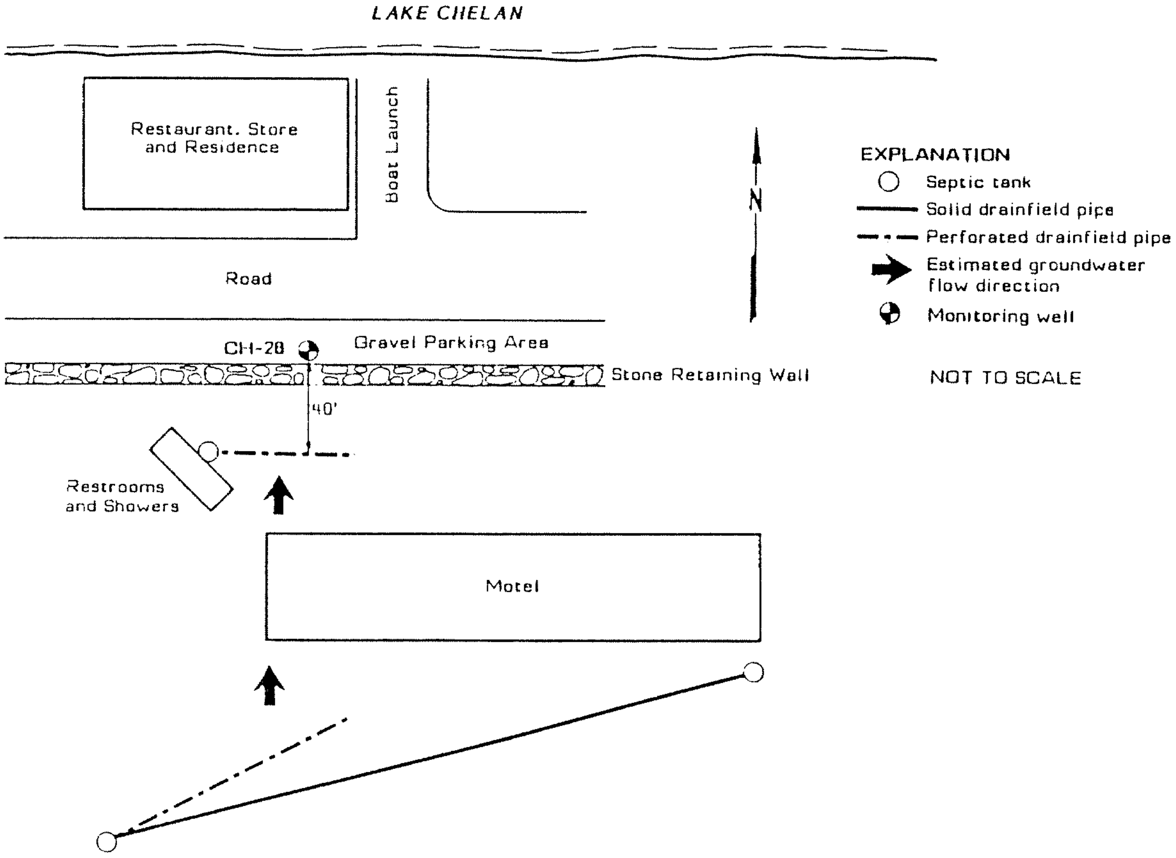


Figure E.1

SITE 1
COVE MARINA

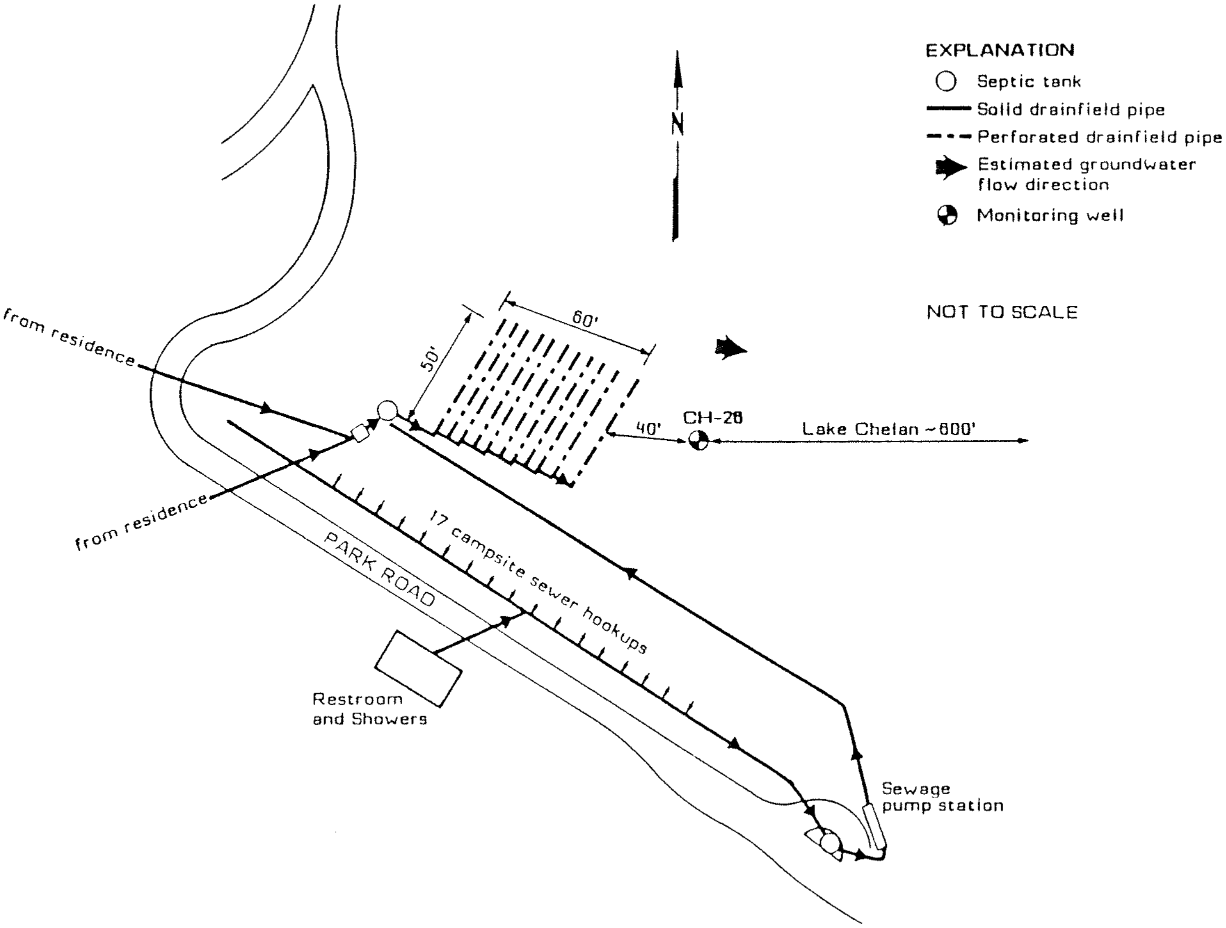


Figure E.2

SITE 2
CHELAN STATE PARK

silty sands. The sands and gravels are of fluvial origin (Figure 5.1) and are similar to the glacial fluvial sands and gravels which cover much of the Chelan area. A grain size distribution typical of the soils is presented in Appendix C. The groundwater level at the site varied from about 11 to 14.6 meters (36 to 48 ft) below ground surface during the year. The hydraulic conductivity of the gravelly sand was estimated at about 1 x 10^{-4} m/s based on grain size data. The general direction of groundwater flow at the site was eastward to Lake Chelan.

Groundwater quality characteristics upgradient of the State Park was assumed to be represented by the Tucker domestic supply, located about 1.5 km (1 mi) west of the State Park in the First Creek valley floor. The Tucker well is about 4 meters (12 ft) deep and is completed in fluvial deposits near the valley bottom. Local springs and seeps were also directed into the well.

Based on reported drainfield dimensions, estimated aquifer parameters and a wastewater loading of 5.1 m^3/d (1350 gpd), it was estimated that the groundwater level under the State Park drainfield would increase by about 0.3 meters (Figure 4.5). The seepage rate for wastewater to move vertically through the unsaturated zone to the water table was estimated at about 40 m/day.

Site 3 - Lutz, 3050 South Shore

Three monitoring wells (CH-8, CH-9, and CH-27) were installed on the Lutz property within 8 meters (25 ft) of the drainfield location (Figure E.3). The first monitoring well (CH-8) was installed approximately 4 meters (12 ft) north and downgradient of the drainfield to a depth of approximately 5.6 meters (18.5 ft). Surficial soils at this site consisted of sands and gravels with some silt to a depth of about 3.3 to 4.3 meters (11 to 14 ft), grading into finer silty sand materials below those depths (see Appendix C).

The second well (CH-9) was installed approximately 8 meters (25 ft) south of the drainfield to a depth of 7.0 meters (23 ft). Silty sand materials were generally encountered throughout the boring. Although the well was initially intended to serve as an upgradient monitoring site, subsequent evaluations of groundwater flow characteristics within the site vicinity (see below) suggested that the well could potentially receive wastewater inputs from the adjacent drainfield. Water quality characteristics of groundwater obtained from this well also suggested the presence of significant wastewater inputs (see Section 4.4).

Following installation in December 1986, water levels within the first two wells declined, and it soon became apparent that well CH-8 would not function as a groundwater monitoring site throughout the year. Accordingly, a third well (CH-27) was installed immediately adjacent to CH-8, and completed at a depth of 8.8 meters (29 ft) in silty sands to fine to medium sands. Over the course of the study (December 1986 to November 1987), water levels within all on-site wells varied from 4 to 5.5 meters (13 to 18 ft) below ground level, possibly as a result of lake level fluctuations.

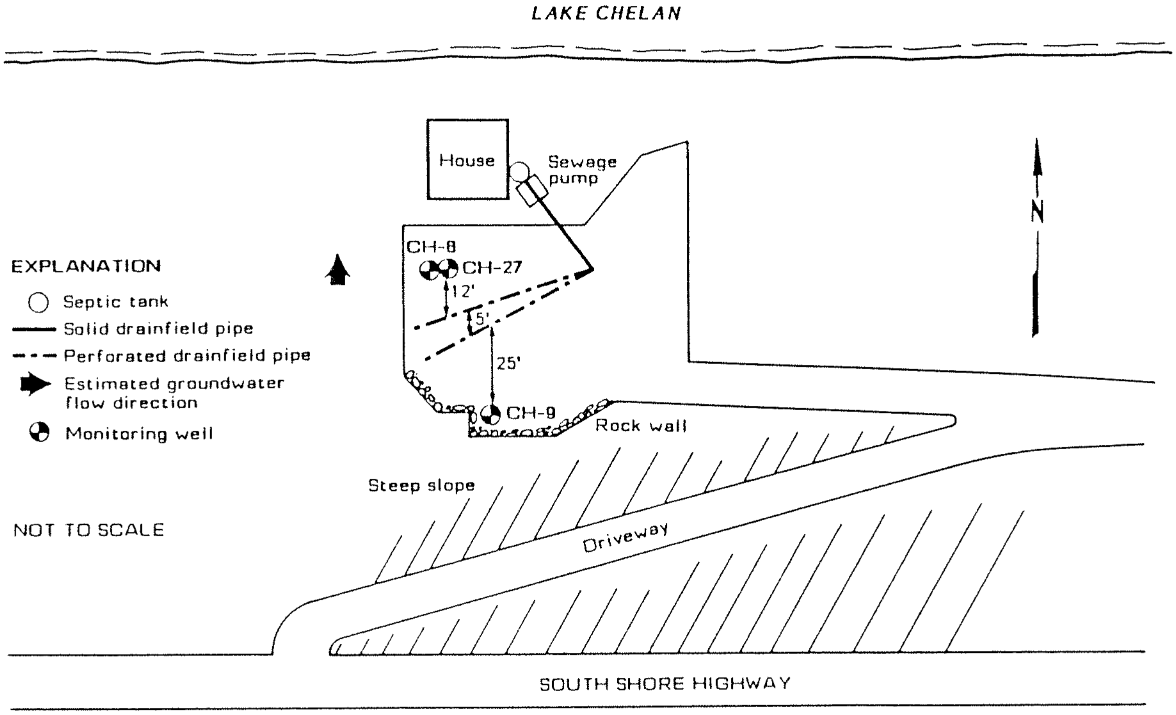


Figure E.3

SITE 4
LUTZ

Regional information suggested that the general groundwater flow direction within the site vicinity was northerly towards Lake Chelan. This general flow direction was confirmed with on-site water level data. Based on grain sized data from the near surface gravel and sands with some silt, the hydraulic conductivity of these soils was estimated at approximately 1 x 10^{-6} m/s. The hydraulic conductivity of the underlying silty fine sands is likely to be similar to the overlying soils.

Vertical seepage of wastewaters to the underlying water table likely occurs at a rate of about 0.4 m/day. Based on reported drainfield dimensions, estimated aquifer properties, and an assumed wastewater loading of approximately 0.68 m^3/day (180 gpd), a local groundwater mound of about 1 meter (3 ft) could develop at the Lutz site (Figure 4.6). The local mounding effects could be sufficiently large to have created a local reversal of groundwater flow, with wastewater flow towards well CH-9. Based on the geologic conditions, it is also possible that discrete, less permeable silty horizons present with the gravel and sands could temporarily divert wastewater flow horizontally rather than vertically in the unsaturated zone. This could result in localized thin perched zones in the unsaturated zone with downward seepage over a larger area, possibly towards well CH-9.

All information considered, the intended upgradient character of well CH-9 appears to be questionable, and this monitoring site may have received wastewater inputs. For the purposes of this report, well CH-9 is denoted the Lutz-A well, and well CH-27 is represented as Lutz-B. Well CH-8 was not sampled for water quality determinations.

Groundwater quality characteristics upgradient of the Lutz site were assumed to be represented by the Kelly domestic well discussed above, because of similar geologic and land use characteristics of the two upgradient watersheds. The somewhat closer Tucker domestic well may only be representative of conditions within the relatively large First Creek basin, and was therefore not considered as a suitable upgradient site.

Site 4 - Venneberg, 3272 South Shore

One downgradient monitoring well was installed at the Venneberg site. The well was located about 6.4 meters (21 ft) downgradient of the drainfield serving the single-family residence (Figure E.4). The well is located about 15 meters (50 ft) from Lake Chelan. The soil conditions at the site are fine to coarse sands of fluvial origin to a depth of about 6 meters (20 ft). These coarse materials are underlain by less permeable silts. The groundwater level at the site varied from about 0.6 to 5.5 meters (2 to 18 ft) below ground surface, probably in response to fluctuating water levels in Lake Chelan. Since the drainfield is located on a bench about 2 meters (6 ft) above the monitoring well elevation, the depth to water under the drainfield likely varies from about 2.6 to 7.5 meters (8.5 to 24.6 ft) below ground during the year. The local groundwater flow direction is likely northwards towards Lake Chelan. A rising head permeability test was carried out in the well which indicated a horizontal hydraulic conductivity for the sand of about 1 x 10^{-5} m/s.

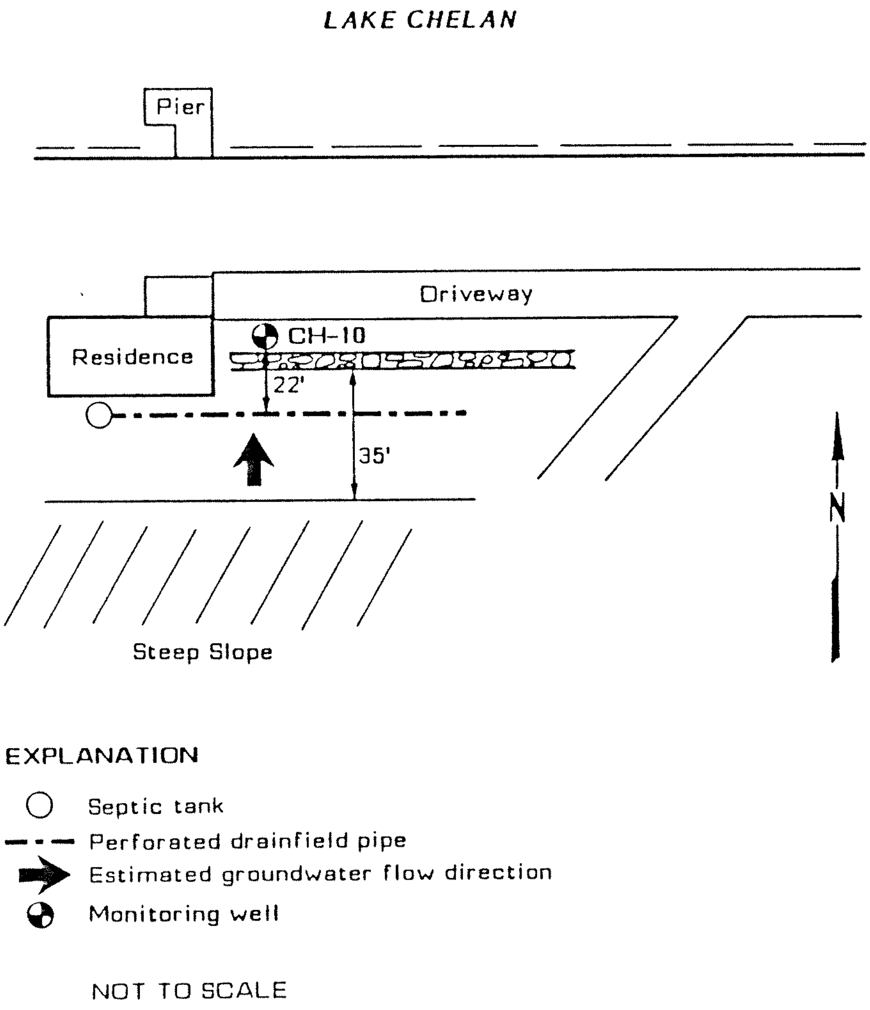


Figure E.4
SITE 3
VENNENBERG

Based on reported drainfield dimensions, estimated aquifer parameters and assumed wastewater loadings, it was estimated that the groundwater level under the drainfield could be increased by less than 0.3 meters (1 ft) as a result of wastewater disposal (Figure 4.5). The seepage rate for wastewater to flow vertically from the drainfield to the water table was estimated at about 4 m/day. Groundwater quality characteristics upgradient of the Venneberg site were assumed to be represented by the Kelly domestic well as previously discussed.

Site 5 - Allison, 1251 Swartout, Manson

Two monitoring wells were installed at the Allison site. The downgradient monitoring well, Allison (Dn) CH-16 was located about 7.6 meters (25 ft) downgradient of the drainfield serving a single family residence (Figure E.5). The well is 7.3 meters (24 ft) deep and is completed in fine to medium sand from 3.3 to 4.9 meters (11 to 16 ft) and sandy silt to clayey silt from 4.9 to 7.6 meters (16 to 25 ft). The surficial materials encountered at the site to a depth of 3.3 meters (11 ft) were clayey silts to silty clay. A grain-size distribution of these surficial soils is presented in Appendix C. The water level in the well was about 6.5 meters (15 ft) below ground surface throughout the year (i.e., within the lower 0.3 meters (1 ft) of the sand).

The upgradient monitoring well, Allison (Up) CH-15 was located about 15 meters (50 ft) east of the drainfield and was completed to a depth of 7.6 meters (25 ft) in fine to medium sand and clayey silt to silty clay. The water level in this well varied between about 4.3 to 5.2 meters (14 and 17 ft) below ground surface. A rising head permeability test was carried out in this well indicating a horizontal hydraulic conductivity of about 1 x 10^{-5} m/s for the screened zone. Since the well is screened across a fine to medium sand (relatively high permeability) and a clayey silt to silty clay (relatively low permeability), it is likely that the hydraulic conductivity is that of the sand rather than the clayey silt (see Appendix A). Based on the grain size distribution of the surficial clayey silt, the hydraulic conductivity of the clayey silt soils was estimated at approximately 1 x 10^{-7} m/s.

The non-homogeneous geology at the site (clayey silts overlying sands) is responsible for a complex subsurface flow system. The relatively permeable sands act as an underdrain for the overlying less permeable silty clay. Because of their relatively low permeability, wastewater entering the surficial silty clays may not seep rapidly downward maintaining an unsaturated zone under the drainfield. Instead, the surficial soils could become saturated, because they drain slowly downward to the more permeable sands. This is typical of "perched" conditions. Because the sand is much more permeable (i.e., 100 times or greater) than the clayey silt, there is less opportunity for hydraulic head build up within the sand as a result of wastewater seepage from the overlying silty clay. A thin saturated zone develops at the base of the sand and an unsaturated zone (about 0.9 to 1.2 meters [3 or 4 ft] thick) exists between the water level in the sand and the base of the silty clay.

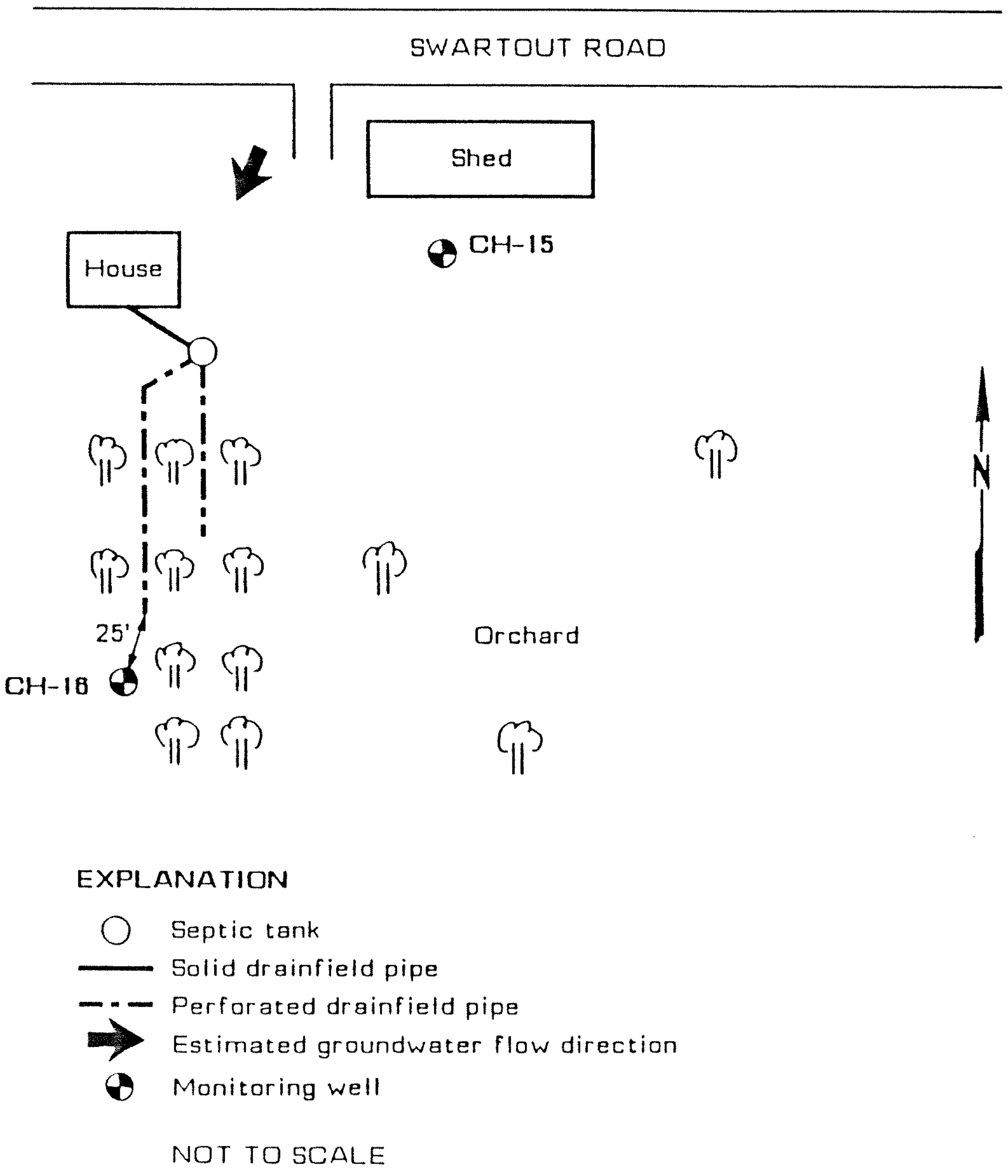


Figure E.5

SITE 5
ALLISON

Based on the reported drainfield dimensions, estimated hydraulic conductivity for the silty clay and assured wastewater loading, it was estimated that near saturated conditions possibly leading to effluent surfacing could develop in the silty clay. There was, however, a strong downward gradient from the silty clay to the underlying sand where there is a greater capacity to transmit wastewater. The higher permeability within the sand minimizes groundwater mounding within that unit, and is able to transmit the wastewater downgradient with only a slight (less than 0.3 meters [1 ft]) increase in hydraulic head. Unsaturated conditions are thus maintained within the upper 0.9 to 1.2 meters (3 to 4 ft) of the sand. A conceptual model of groundwater conditions at Site 5 is presented in Figure 4.7.

Sites 6 and 13, Morris, 87 Roses Ave, Manson

Three monitoring wells were installed at this site to monitor two drainfields (Figure E.6). One drainfield was monitored by up and downgradient monitoring wells; Morris (Up) CH-11 and Morris (Dn) CH-12, respectively. These wells are both about 4.3 meters (14 ft) deep and were designed to monitor a sandy silt to clayey silt perched zone detected during drilling between about 2 and 5 meters (6 and 16 ft) below ground surface. Both wells, however, were dry during all sampling periods.

The second drainfield at this location is monitored by one downgradient monitoring well, Morris (Dn) CH-17. This well is located about 24.4 meters (80 ft) downgradient of the drainfield which serves the single family residence (Figure E.6). The well is 18.3 meters (60 ft) deep and was completed in fine to medium sand and clayey silt to silty clay underlying the shallow perched zone. The water level in the well was about 15.9 to 16.8 meters (52 to 55 ft) below ground level and appeared to be representative of the regional groundwater level at this location.

The upgradient well utilized for this location was Allison's domestic well at 1142 Green Avenue in Manson. This well is located about 30 meters (100 ft) upgradient of the drainfield and is a shallow large diameter well which was originally used for irrigation purposes. The well is no longer used. The depth to water in this well was about 1.5 meters (5 ft) below ground surface.

This site is similar to the previously discussed Site 5. The surficial soils are of much lower permeability than the deeper soils and as a result, there is the potential for developing a saturated to partially saturated perched zone underlying the drainfields. This perched zone then drains slowly downward to a more permeable zone where there is little opportunity for hydraulic head build-up.

Site 7 - McClellan, Roses Lake Manson

Two monitoring wells were installed at the McClellan site (Figure E.7). The downgradient monitoring well, McClellan (Dn) CH-24, was located about 10.7 meters (35 ft) from the drainfield servicing the single family residence. The well is about 6 meters (20 ft) deep and was completed in a

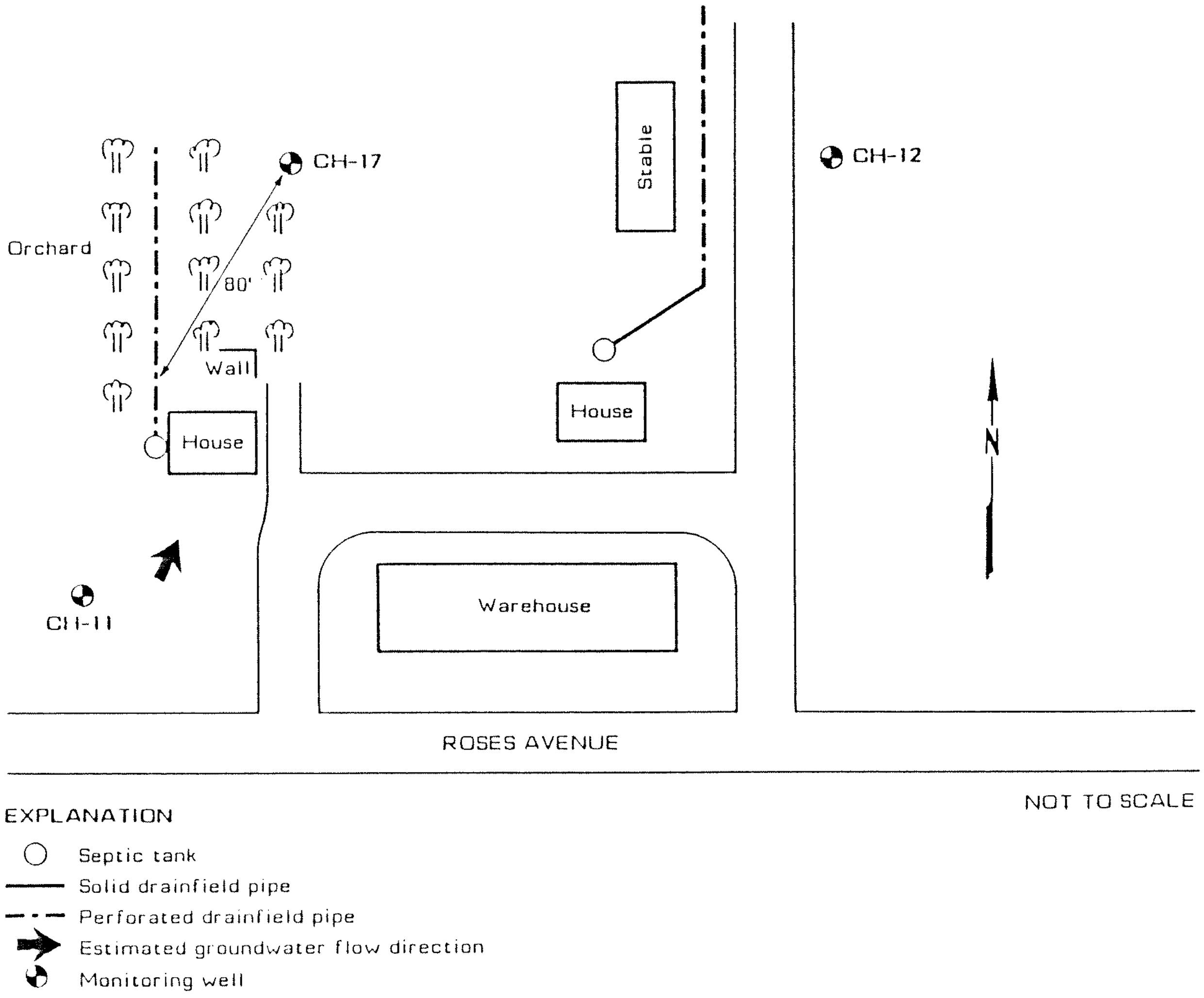


Figure E.6

SITES 6 AND 13
MORRIS

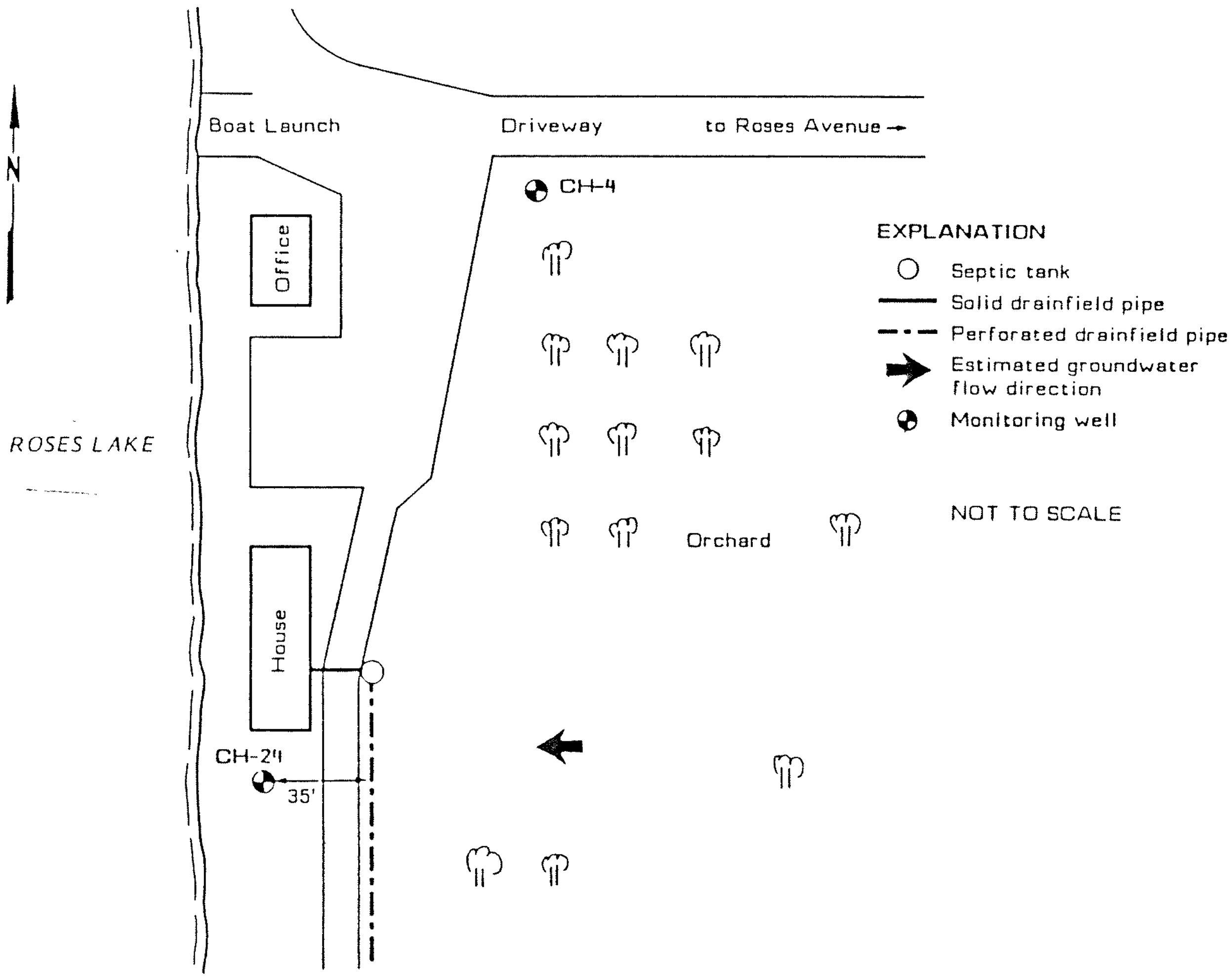


Figure E.7

SITE 7
McCLELLAN

silty sand to sand of fluvial and possibly lacustrine origin. The water level in the well was about 3 meters (9 ft) below ground level.

The upgradient well is McClellan (Up) CH-4 which is located about 60 meters (200 ft) north of the drainfield. This well also serves to monitor groundwater quality near the mouth of USBR Drain No. 11. The well was completed in a silty fine to coarse sand to silt and sand. The water level in the well was about 2.4 meters (8 ft) below ground surface. A rising head permeability test was carried out in this well indicating a horizontal hydraulic conductivity of about 1 x 10^{-5} m/s. Grain size data from soil samples five to ten feet below the surface indicated that the hydraulic conductivity of these soils may be about 1 x 10^{-6} m/s or less. Because of the fluvial and/or lacustrine depositional environment and the development of horizontal bedding with interbedded sands and silts, it is likely that the vertical (cross bed) hydraulic conductivity is less than the horizontal (between bed) hydraulic conductivity. Under these conditions, it is not unlikely to find the vertical hydraulic conductivity one or two orders of magnitude (i.e., 10 to 100 times) lower than the horizontal hydraulic conductivity. Therefore, vertical hydraulic conductivities in the soils below the drainfield could be less than 1 x 10^{-6} m/s, whereas horizontal hydraulic conductivities could be about 1 x 10^{-5} m/s.

This site is also somewhat similar to the previously discussed Site 5, although it appears that the soils are interbedded sands and silts rather than distinct units. Because of the interbedded nature of the soils, there would be a tendency for infiltrating wastewater to flow horizontally within the fine sand zones and vertically across the siltier interbeds. There is a potential for developing saturated perched conditions immediately beneath the drainfield based on the hydraulic conductivity of the siltier zones, however, there is likely an unsaturated zone beneath the shallow perched zone which could transmit these wastewaters. The potential for groundwater mounding in the relatively higher permeability sandy zones below the perched zone is minimal based on the assumed hydraulic parameters and wastewater loading rates.

Sites 8 & 9 - Goodwin/Collins Dry Lake Rd. Manson

Three monitoring wells were installed at this site to monitor two drainfields each serving single family residences (Figure E.8). One upgradient well, Collins (Up) (CH-22), serves as the background well for both systems. This well is 10 meters (33 ft) deep and is completed in sandy gravel and silty sand. Water level in the upgradient well varied between 4.3 to 5.2 meters (14 and 17 ft) below ground surface.

The two downgradient monitoring wells are Collins (Dn) CH-20 and Goodwin (Dn) CH-21. Collins (Dn) is located about 6 meters (20 ft) downgradient from one of the drainfields (Figure E.8). The borehole encountered 4.6 meters (15 ft) of clayey silt overlying gravelly sand to a depth of about 5.5 meters (18 ft). The well is screened across both materials. The water level was about 1.5 meters (5 ft) below ground level. The results of a rising head permeability test indicated a horizontal hydraulic conductivity of about 5 x 10^{-6} m/s for the local soils. Since this well

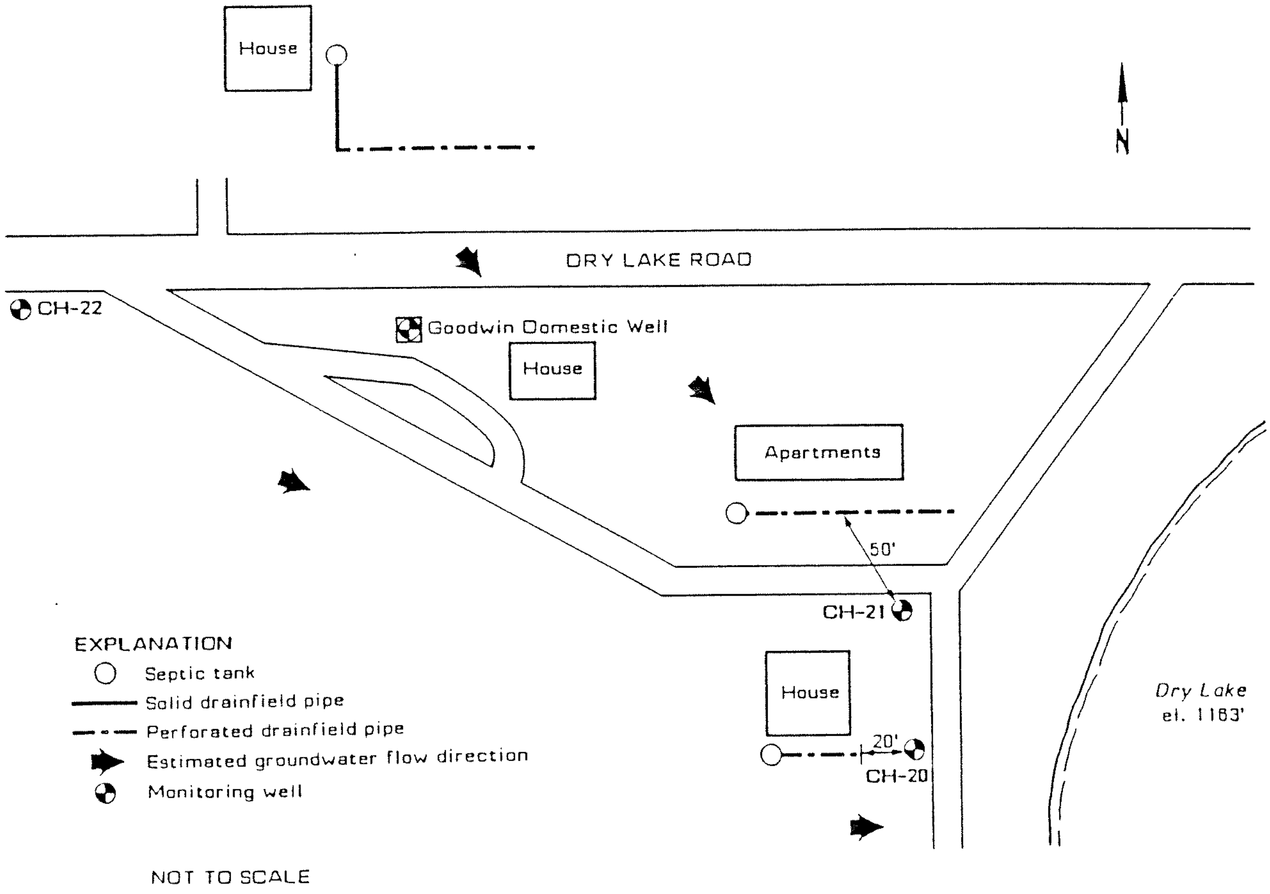


Figure E.8

SITES 8 AND 9
GOODWIN/COLLINS

was completed both in relatively low permeability clayey silt and relatively higher permeability gravelly sand, the testing is more likely representative of the sand rather than the clayey silt. Based on grain size data in similar soil types (e.g., Pickens (Dn) or Allison (Up), the hydraulic conductivity of the clayey silt which occurs from surface to a depth of 4.6 meters (15 ft) is probably 1 x 10^{-7} m/s or less.

Goodwin (Dn) (CH-21) is located about 15 meters (50 ft) downgradient from the second drainfield at the site and is completed in a clayey silt and sand at a depth of 6 meters (20 ft)(Figure E.8). The borehole encountered 4.9 meters (16 ft) of clayey silt overlying 1.2 meters (4 ft) of sand. The water level in the well was about 2.4 meters (8 ft) below ground surface. The hydraulic conductivity of the near surface clayey silt to silty clay was estimated at approximately 1 x 10^{-7} m/s or less.

These two septic systems are in similar conditions to that previously discussed at Site 5, although it appears that there is not an unsaturated zone below the upper low permeability clayey silt soils. The low permeability surface soils result in the development of saturated conditions below the drainfield as shown on Figure 4.8. Because of the groundwater mounding, there is a downward potential to the more permeable sand zone and this likely represents the major discharge horizon for the effluent towards Dry Lake.

Site 10 - Pickens, 220 Greens Landing, Manson

One downgradient monitoring well was installed at the Pickens site. The well, Pickens (Dn) CH-23, is located about 15 meters (50 ft) downgradient of the drainfield which serves the single family residence (Figure E.9). The well is 4.6 meters (15 ft) deep and appears to have been completed in fluvial deposits of laminated sands and silts/clays. The water level was about 1.8 to 2 meters (6 to 7 ft) below ground level. A rising head permeability test was performed on this well to estimate hydraulic conductivity of the screened materials. Based on the test, the horizontal hydraulic conductivity was estimated at between 3 x 10^{-5} and 1 x 10^{-4} m/s. Since these deposits were interbedded sands and silts, it is likely that the hydraulic conductivity values are more representative of the higher permeability sandy interbeds rather than the lower permeability silts and clays. Grain size data indicates a probable hydraulic conductivity for the silts and clays of 1 x 10^{-7} m/sec or less. Similar to the McClellan site discussed above, it is probable that the horizontal hydraulic conductivity of the soils is much greater (10 to 100 times) than the vertical hydraulic conductivity because of the depositional environment. High hydraulic conductivities are expected in the sandy interbeds while lower hydraulic conductivities are expected across the silty and clayey interbeds.

The upgradient well for this site is Pickens domestic well. This is an abandoned shallow well which previously served the residence. The well is about 24 meters (80 ft) upgradient of the drainfield and is about 2.4 meters (8 ft) deep.

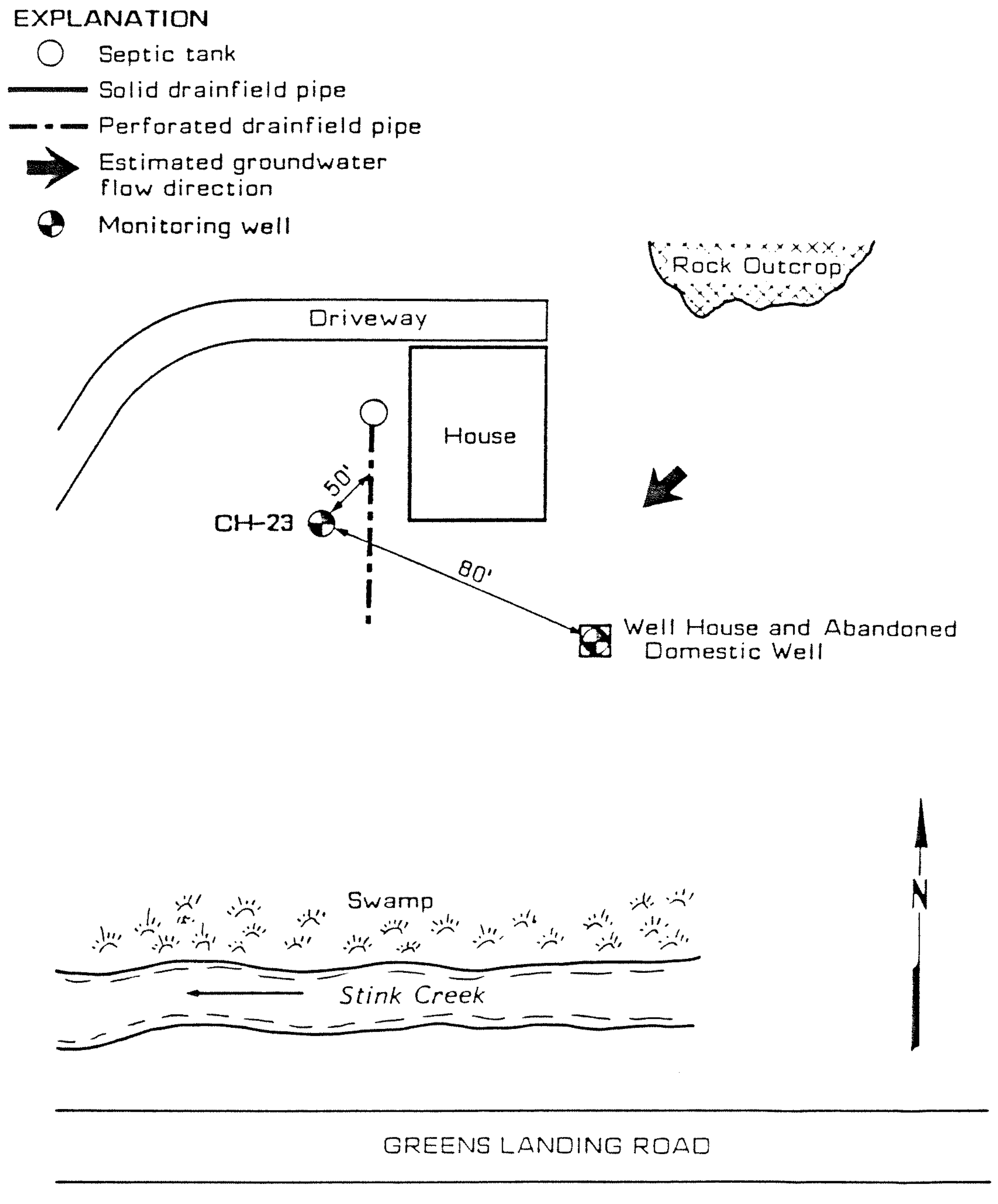


Figure E.9

SITE 10 PICKENS

This site is again similar lithologically to Site 5 and Sites 8 and 9 being underlain by interbedded clays, silts and sands. Conceptual models of possible wastewater flow conditions at the Pickens site are shown on Figures 4.7 and 4.8. Based on the hydraulic conductivity of the clayey silt to silty clay, it is probable that saturated conditions could exist immediately under and possibly within the drainfield. This could, however, be a shallow perched zone if the sand zones are sufficiently permeable and continuous to provide underdrainage to this perched zone.

Site 11 - Willows Park, Chelan Hills Maintenance Association

A monitoring well ("Willows" well) was previously installed at this site by the Chelan Hills Maintenance Association to monitor water quality downgradient of a number of septic systems within one of the subdivisions of Chelan Hills (see Figure 3.1 for location). The well is approximately 12 meters (40 ft) deep and appears to be completed in lacustrine deposits of silt, clay, and sand based on the geologic mapping. The water level in the well fluctuated between 3.5 to 8.5 meters (11 to 28 ft) below ground level largely in response to water level changes in Lake Chelan. The Willows well was sampled three times during the project.

Upgradient groundwater quality characteristics were assumed to be represented by the Clapp and Risley domestic wells. The Clapp well is located about 5 km (3 mi) north of the Willows well in Purtteman Gulch, and is screened in sands and gravels. The Risley well is located about 9 km (5.5 mi) north of the Willows well in Cooper Gulch. The well is 11.6 meters (38 ft) deep and was completed in silts, sands and gravels. Although these wells are some distance from the Willows well, they are completed in similar geologic materials and within similar land use areas of the Willows region and are thus considered reasonable indicators of upgradient water quality.

Site 12 - Lake Chelan Condominiums, Chelan

Like the Willows well discussed above, the "Condos" well was installed previously by the Chelan Hills Maintenance Association to monitor groundwater quality downgradient from the western portions of the Chelan Hills Development (see Figure 3.1 for locations). The well is 34 meters (110 ft) deep and is apparently completed in sands and gravels of a glacial/fluvial origin. The water level in the well was approximately 20 meters (60 ft) below ground surface. The well was sampled two times during the project. Upgradient water quality conditions were assumed to be represented by the Clapp and Risley domestic wells.

Site 14 - Goodwin, 4845 Wapato Lake Rd., Manson

Two monitoring wells were installed at this site to monitor the drainfield servicing the single family residence (Figure 3.1). The upgradient well, Goodwin CH-6, and downgradient well, Goodwin CH-5, are both about 2 meters (7 ft) deep where the drilling encountered refusal. These wells were completed in silty to gravelly sand probably overlying bedrock. Both wells were dry during the study.

Site 15 - Rockney, Banks and Chase Ave, Manson

One downgradient monitoring well was installed at this site (Figure 3.1). The well is located about 6 meters (20 ft) from the drainfield which serves the single family residence. The well is about 4.3 meters (14 ft) deep and completed in silty sand and gravel probably overlying bedrock. The well was dry during the study.

APPENDIX F

Summary of Chemical Data

Lake Chelan database documentation: explanation of field names and data qualifiers for the LAKE database.

FIELD NAME	PARAMETER	UNITS
DATE	Date	--
STA	Station	--
DEP	Depth	meters
TEMP	Temperature	degrees C
PH	pH	SU
DO	Dissolved Oxygen	mg/L
DO_SAT	Diss. Oxygen Saturation	percent
SECCHI	Secchi Disk Depth	meters
EXTINCT	Light Extinction Coefficient	1/meter
FS	Fecal Streptococci	#/100mL
FC	Fecal Coliform	#/100mL
TC	Total Coliform	#/100mL
COND	Specific Conductance	umho/cm @ 25C
TSS	Total Suspended Solids	mg/L
TURB	Turbidity	NTU
ALK	Alkalinity	mg CaCO3 /L
SRP	Soluble Reactive P	ug P /L
TP	Total P	ug P /L
TSP	Total Soluble P	ug P /L
NH3N	Ammonia N	ug N /L
NO23N	Nitrite+Nitrate N	ug N /L
TUVN	Total N (UV)	ug N /L
TSUVN	Total Soluble N (UV)	ug N /L
CHLA	Chlorophyll a (Phaeo Corrected)	ug/L
PHAEO	Phaeophytin	ug/L

MISSING DATA CODE: -999

DATA QUALIFIERS:

J = Estimated value: value not accurate
U = Analyzed but not detected. The number reported is the detection limit.
P = Greater than (>).

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEC
16-Dec-86	1	0	7.0	7.0	10.4	89%	5 P	-999	1	2	7	55.6	-999	-999.0	16.2	-0.1 J	1.6	-999.0	6.7	41.6	-999.0	-999.0	0.9	0.2
16-Dec-86	2	0	8.0	7.0	9.9	87%	9.8	-999	2	2 U	8	55.2	-999	-999.0	18.7	-0.1 J	2.6	0.6 J	7.0	39.8	42.4 J	26.2 J	1.0	0.2
16-Dec-86	2	10	8.0	6.9	9.9	86%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	-0.0 J	4.9	-999.0	5.3	40.0	70.6 J	-999.0	0.9	0.4
16-Dec-86	2	20	8.1	7.3	9.8	86%	-999	-999	-999	-999	-999	54.6	-999	-999.0	-999.0	0.7	3.4	-999.0	5.1	43.5	66.3 J	-999.0	0.8	0.7
16-Dec-86	3	0	8.3	7.0	9.8	86%	11	-999	1 U	-999	-999	53.7	-999	-999.0	20.0	0.4	2.0	-999.0	3.2 J	42.3	65.6 J	-999.0	0.9	0.1
16-Dec-86	3	10	8.2	7.1	10.2	90%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.8	2.5	-999.0	20.2	20.7	52.7 J	-999.0	1.0	0.4
16-Dec-86	3	20	8.3	7.2	9.0	79%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.5	5.3	-999.0	7.4	39.8	32.3 J	-999.0	-999.0	-999.0
16-Dec-86	3	40	7.6	7.1	10.0	87%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.6	4.0	-999.0	20.2	48.9	59.5 J	-999.0	-999.0	-999.0
16-Dec-86	4	0	8.3	7.0	9.6	85%	14.6	-999	380	2 U	8	54.5	-999	-999.0	19.8	0.3 J	1.1 J	0.6 J	-3.9 J	46.1	60.4 J	30.2 J	-999.0	-999.0
16-Dec-86	4	10	8.3	6.8	10.5	93%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.2 J	4.0	-999.0	-4.9 J	51.0	63.2 J	-999.0	0.9	0.4
16-Dec-86	4	20	8.3	6.9	10.1	89%	-999	-999	-999	-999	-999	54.9	-999	-999.0	-999.0	0.2 J	13.4	-999.0	-1.4 J	47.5	113.4	-999.0	1.0	0.5
16-Dec-86	4	40	7.8	6.9	10.2	89%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.3 J	2.8	-999.0	3.8 J	65.7	64.8 J	-999.0	-999.0	-999.0
16-Dec-86	4	70	4.9	6.9	10.3	83%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.2 J	6.1	-999.0	8.2	93.6	176.0	-999.0	-999.0	-999.0
16-Dec-86	4	100	4.3	6.8	10.4	83%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.0 J	6.3	-999.0	14.4	62.2	173.0	-999.0	-999.0	-999.0
16-Dec-86	4T	0	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	4T	30	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	5	0	8.7	7.4	10.6	94%	14.6	-999	2	-999	-999	53.8	-999	-999.0	18.5	-0.0 J	1.1 J	-999.0	29.1	39.4	28.1 J	-999.0	0.7	0.3
16-Dec-86	5	10	8.6	7.4	10.6	94%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.3 J	2.0	-999.0	2.1 J	46.0	61.1 J	-999.0	0.8	0.4
16-Dec-86	5	20	8.7	7.4	10.5	93%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.2 J	9.2	-999.0	11.7	44.2	68.1 J	-999.0	0.8	0.4
16-Dec-86	5	40	8.6	7.2	10.5	93%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.2 J	2.6	-999.0	2.7 J	44.9	27.2 J	-999.0	-999.0	-999.0
16-Dec-86	5	70	7.5	7.2	10.6	92%	-999	-999	-999	-999	-999	54.2	-999	-999.0	-999.0	0.3 J	3.0	-999.0	10.5	69.9	59.6 J	-999.0	-999.0	-999.0
16-Dec-86	5	150	5.9	7.1	10.8	90%	-999	-999	-999	-999	-999	54.4	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	5A	0	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	5A	10	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	5A	20	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	5A	40	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Dec-86	6	0	8.9	7.3	10.6	95%	14	-999	2	2 U	2 U	53.8	-999	-999.0	20.8	0.4	1.4	-999.0	-4.4 J	50.3	51.9 J	-999.0	0.6	-999.0
16-Dec-86	6	10	8.7	7.2	10.5	94%	-999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.0	1.8	-999.0	-5.4 J	53.1	172.0	-999.0	0.6	-999.0
16-Dec-86	6	20	8.7	7.2	10.5	94%	-999	-999	-999	-999	-999	54.4	-999	-999.0	-999.0	0.3 J	11.1	-999.0	1.2 J	45.2	77.4 J	-999.0	0.7	-999.0
16-Dec-86	6	40	8.7	7.3	10.4	93%	-999	-999	-999	-999	-999	53.8	-999	-999.0	-999.0	0.5	2.0	-999.0	15.5	48.2	66.4 J	-999.0	-999.0	-999.0
16-Dec-86	6	70	6.8	7.1	10.6	90%	-999	-999	-999	-999	-999	53.8	-999	-999.0	-999.0	0.9	3.7	-999.0	10.1	85.3	80.9	-999.0	-999.0	-999.0
16-Dec-86	6	150	5.9	7.1	10.8	90%	-999	-999	-999	-999	-999	54.6	-999	-999.0	-999.0	0.7	2.0	-999.0	9.0	82.0	102.0	-999.0	-999.0	-999.0
16-Dec-86	6	250	5.6	7.1	10.7	88%	-999	-999	-999	-999	-999	54.4	-999	-999.0	-999.0	0.7	4.9	-999.0	9.5	78.8	93.5	-999.0	-999.0	-999.0
16-Dec-86	6	380	5.5	7.2	10.7	88%	-999	-999	-999	-999	-999	53.7	-999	-999.0	-999.0	0.6	8.2	-999.0	5.5	90.7	65.6 J	-999.0	-999.0	-999.0
16-Dec-86	7	0	8.4	7.3	10.3	91%	16.5	-999	1 U	-999	-999	53.4	-999	-999.0	21.0	0.3 J	2.0	-999.0	-5.4 J	58.8	21.1 J	-999.0	0.7	0.0
16-Dec-86	7	10	8.5	7.3	10.4	92%	-999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.4	6.1	-999.0	-2.4 J	55.3	61.2 J	-999.0	0.6	0.0
16-Dec-86	7	20	8.6	7.3	10.4	92%	-999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.4	2.2	-999.0	-1.4 J	54.5	49.7 J	-999.0	0.6	0.0
16-Dec-86	7	40	8.6	7.3	10.1	90%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.2 J	3.9	-999.0	2.9 J	52.6	61.9 J	-999.0	-999.0	-999.0
16-Dec-86	7	70	6.9	7.1	10.3	88%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.3 J	2.3	-999.0	7.0	86.3	73.0 J	-999.0	-999.0	-999.0
16-Dec-86	7	150	5.9	7.2	10.5	87%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.9	3.7	-999.0	8.2	84.5	125.0	-999.0	-999.0	-999.0
16-Dec-86	7	250	5.6	7.3	10.1	83%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	1.0	5.6	-999.0	17.5	89.1	14.5 J	-999.0	-999.0	-999.0
16-Dec-86	8	0	8.3	7.4	10.6	93%	13.7	-999	1 U	-999	-999	53.8	-999	-999.0	19.0	0.0 J	2.3	1.6	5.1	50.5	79.0	57.1 J	0.5	0.0
16-Dec-86	8	10	8.3	7.4	10.4	92%	-999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.5	1.8	-999.0	6.7	49.5	61.2 J	-999.0	0.6	0.0
16-Dec-86	8	20	8.4	7.3	10.1	89%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.0	4.9	-999.0	9.8	42.6	45.9 J	-999.0	0.6	0.0
16-Dec-86	8	40	8.4	7.2	10.3	91%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.0	1.8	-999.0	16.3	49.5	61.1 J	-999.0	-999.0	-999.0
16-Dec-86	8	70	6.6	6.9	10.3	87%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.0	1.8	-999.0	22.5	81.9	99.7	-999.0	-999.0	-999.0
16-Dec-86	8	120	6.1	7.3	10.5	88%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.6	5.1	-999.0	-2.4 J	61.6	68.5 J	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
20-Jan-87	1	0	4.5	7.5	10.4	83%	-999	-999	11	2	2	54.8	-999	0.5	21.4	0.4	0.6 J	-999.0	0.2 J	85.0	105.3	-999.0	-999.0	-999.0
20-Jan-87	2	0	5.1	7.5	9.9	80%	10.8	0.084	1 U	2 U	2	52.7	-999	0.6	18.6	0.5	1.4	-0.1 J	1.8 J	48.3	78.7	47.5 J	-999.0	-999.0
20-Jan-87	2	10	5.2	7.5	10.2	83%	-999	-999	-999	-999	-999	54.5	-999	0.5	-999.0	0.4	0.8 J	-999.0	2.4 J	53.6	73.1 J	-999.0	0.6	0.4
20-Jan-87	2	20	5.2	7.5	10.3	84%	-999	-999	-999	-999	-999	52.5	-999	0.8	-999.0	0.4 J	2.4	-999.0	0.6 J	43.2	81.0	-999.0	0.7	0.6
20-Jan-87	3	0	5.8	7.2	9.8	81%	12.7	0.129	1 U	-999	-999	53.7	-999	0.3	18.9	0.4	1.0 J	-999.0	3.6 J	49.3	54.3 J	-999.0	-999.0	-999.0
20-Jan-87	3	10	5.8	7.6	9.5	79%	-999	-999	-999	-999	-999	53.2	-999	1.0	-999.0	0.5	5.5	-999.0	-0.5 J	76.9	59.0 J	-999.0	0.8	0.7
20-Jan-87	3	20	5.8	7.5	9.5	79%	-999	-999	-999	-999	-999	51.7	-999	0.6	-999.0	0.5	1.0 J	-999.0	3.5 J	48.9	128.5	-999.0	0.8	0.5
20-Jan-87	3	40	5.7	7.5	9.8	80%	-999	-999	-999	-999	-999	52.3	-999	0.2	-999.0	1.1	2.6	-999.0	8.2	46.9	67.0 J	-999.0	-999.0	-999.0
20-Jan-87	4	0	5.9	7.3	10.0	83%	12.6	0.113	1 U	2 U	2 U	53.1	0.1 J	0.4	19.5	0.4	1.3	0.8 J	-0.3 J	54.4	42.7 J	45.5 J	0.5	0.4
20-Jan-87	4	10	6.0	7.3	9.7	80%	-999	-999	-999	-999	-999	52.7	-999	0.5	-999.0	0.6	2.2	-999.0	0.3 J	58.1	82.6	-999.0	0.8	0.5
20-Jan-87	4	20	6.0	7.3	9.6	80%	-999	-999	-999	-999	-999	53.0	-999	0.7	-999.0	0.6	-999.0	-999.0	1.1 J	58.5	-999.0	-999.0	0.7	0.4
20-Jan-87	4	40	6.0	7.3	9.7	80%	-999	-999	-999	-999	-999	52.7	-999	0.2	-999.0	0.6	4.9	-999.0	1.7 J	53.7	35.4 J	-999.0	-999.0	-999.0
20-Jan-87	4	70	4.8	7.1	9.5	76%	-999	-999	-999	-999	-999	53.1	-999	0.3	-999.0	0.8	1.9	-999.0	2.3 J	90.2	99.5	-999.0	-999.0	-999.0
20-Jan-87	4	100	4.3	7.0	9.0	72%	-999	-999	-999	-999	-999	54.1	-999	0.3	-999.0	1.1	4.2	-999.0	3.1 J	108.5	127.8	-999.0	-999.0	-999.0
20-Jan-87	4T	0	6.4	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	4T	30	6.5	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	5	0	6.5	7.2	10.4	88%	15.7	0.132	1 U	-999	-999	51.6	-999	0.4	18.6	0.6	1.5	-999.0	4.8	99.6	70.3 J	-999.0	0.4	0.3
20-Jan-87	5	10	6.6	7.3	10.0	84%	-999	-999	-999	-999	-999	51.4	-999	1.3	-999.0	0.9	6.6	-999.0	2.3 J	64.4	98.6	-999.0	0.7	0.5
20-Jan-87	5	20	6.6	7.3	10.0	85%	-999	-999	-999	-999	-999	51.3	-999	0.3	-999.0	1.1	1.3	-999.0	1.3 J	55.5	69.3 J	-999.0	0.7	0.5
20-Jan-87	5	40	6.7	7.3	9.8	83%	-999	-999	-999	-999	-999	52.4	-999	0.4	-999.0	0.6	7.5	-999.0	4.6 J	53.3	17.2 J	-999.0	-999.0	-999.0
20-Jan-87	5	70	6.7	7.3	9.8	83%	-999	-999	-999	-999	-999	52.1	-999	0.3	-999.0	1.0	1.7	-999.0	2.6 J	86.6	103.9	-999.0	-999.0	-999.0
20-Jan-87	5	150	5.9	7.2	10.0	83%	-999	-999	-999	-999	-999	51.6	-999	0.2	-999.0	1.2	7.8	-999.0	-0.2 J	75.1	154.5	-999.0	-999.0	-999.0
20-Jan-87	5A	0	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	5A	10	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	5A	20	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	5A	40	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
20-Jan-87	6	0	6.5	7.5	10.0	84%	15.1	0.1	1 U	2 U	2 U	52.0	-999	0.2	18.8	0.9	4.6	-999.0	-0.5 J	57.3	82.5	-999.0	0.4	0.3
20-Jan-87	6	10	6.6	7.5	10.0	84%	-999	-999	-999	-999	-999	52.1	-999	0.2	-999.0	0.9	1.5	-999.0	2.4 J	109.7	151.4	-999.0	0.4	0.3
20-Jan-87	6	20	6.7	7.5	9.8	82%	-999	-999	-999	-999	-999	51.2	-999	0.9	-999.0	1.2	4.0	-999.0	1.5 J	51.0	83.3	-999.0	0.5	0.5
20-Jan-87	6	40	6.6	7.5	9.9	83%	-999	-999	-999	-999	-999	51.2	-999	0.4	-999.0	1.0	3.9	-999.0	3.9 J	-999.0	79.0	-999.0	-999.0	-999.0
20-Jan-87	6	70	6.7	7.4	10.0	84%	-999	-999	-999	-999	-999	51.0	-999	0.3	-999.0	0.8	2.2	-999.0	1.0 J	48.4	47.9 J	-999.0	-999.0	-999.0
20-Jan-87	6	150	5.9	7.3	9.7	80%	-999	-999	-999	-999	-999	51.3	-999	0.3	-999.0	1.1	4.0	-999.0	4.9	85.4	96.3	-999.0	-999.0	-999.0
20-Jan-87	6	250	5.6	7.3	9.7	80%	-999	-999	-999	-999	-999	52.0	-999	0.2	-999.0	1.1	4.6	-999.0	-0.2 J	75.3	94.0	-999.0	-999.0	-999.0
20-Jan-87	6	380	5.5	-999.0	9.7	80%	-999	-999	-999	-999	-999	51.6	-999	0.1	-999.0	1.3	4.9	-999.0	-1.2 J	79.0	63.8 J	-999.0	-999.0	-999.0
20-Jan-87	7	0	6.5	7.3	10.3	87%	14.2	0.103	1 U	-999	-999	52.5	0.1 J	0.2	18.1	0.5	1.0 J	-0.1 J	-0.1 J	64.4	83.3	74.9 J	0.4	0.4
20-Jan-87	7	10	6.6	7.5	9.9	83%	-999	-999	-999	-999	-999	51.7	-999	0.3	-999.0	0.8	4.0	-999.0	0.0 J	79.0	131.8	-999.0	0.5	0.4
20-Jan-87	7	20	6.6	7.5	9.9	84%	-999	-999	-999	-999	-999	52.0	-999	0.4	-999.0	0.5	1.3	-999.0	0.4 J	66.0	119.1	-999.0	0.5	0.4
20-Jan-87	7	40	6.6	7.4	9.8	83%	-999	-999	-999	-999	-999	51.4	-999	0.5	-999.0	0.5	0.8 J	-999.0	1.1 J	58.7	81.0	-999.0	-999.0	-999.0
20-Jan-87	7	70	6.6	7.5	9.8	83%	-999	-999	-999	-999	-999	52.1	-999	0.7	-999.0	0.5	4.0	-999.0	-1.3 J	58.2	65.4 J	-999.0	-999.0	-999.0
20-Jan-87	7	150	5.9	7.4	9.8	81%	-999	-999	-999	-999	-999	52.0	-999	0.3	-999.0	0.6	0.6 J	-999.0	0.8 J	69.6	7.1 J	-999.0	-999.0	-999.0
20-Jan-87	7	250	5.6	7.4	9.7	80%	-999	-999	-999	-999	-999	52.4	-999	0.3	-999.0	0.6	4.6	-999.0	2.1 J	99.3	74.9 J	-999.0	-999.0	-999.0
20-Jan-87	8	0	6.5	7.8	10.6	89%	16.3	0.114	1 U	2 U	2 U	51.0	-999	0.4	18.1	0.4	1.3	0.4 J	-1.3 J	63.9	93.7	270.4	0.5	0.3
20-Jan-87	8	10	6.6	7.3	10.3	87%	-999	-999	-999	-999	-999	51.6	-999	0.3	-999.0	0.7	0.6 J	-999.0	1.7 J	53.6	73.4 J	-999.0	0.5	0.5
20-Jan-87	8	20	6.6	7.3	10.2	86%	-999	-999	-999	-999	-999	51.0	-999	0.4	-999.0	0.6	0.8 J	-999.0	-0.9 J	54.4	60.6 J	-999.0	0.6	0.3
20-Jan-87	8	40	6.6	7.3	10.2	86%	-999	-999	-999	-999	-999	51.4	-999	0.3	-999.0	0.5	2.6	-999.0	1.4 J	54.1	82.1	-999.0	-999.0	-999.0
20-Jan-87	8	70	6.6	7.3	10.0	84%	-999	-999	-999	-999	-999	51.2	-999	0.3	-999.0	0.5	0.4 J	-999.0	-0.5 J	256.6	49.1 J	-999.0	-999.0	-999.0
20-Jan-87	8	120	5.9	7.3	10.1	84%	-999	-999	-999	-999	-999	50.5	-999	0.3	-999.0	0.5	2.4	-999.0	3.6 J	91.2	113.2	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
25-Feb-87	1	0	4.7	7.7	11.2	90%	-999	-999	1 U	2 U	2 U	54.1	0.2	0.3	19.5	0.7	2.3	-999.0	14.2	54.0	176.0	-999.0	0.9	0.5
25-Feb-87	2	0	5.4	7.7	11.1	91%	12.1	0.098	1 U	2 U	2 U	54.9	-999	0.4	18.8	0.5	1.4	0.4 J	6.9	58.6	54.1 J	91.1	0.7	0.4
25-Feb-87	2	10	5.4	7.7	11.1	91%	-999	-999	-999	-999	-999	53.1	-999	-999.0	-999.0	0.7	3.2	-999.0	11.8	56.8	62.6 J	-999.0	0.9	0.6
25-Feb-87	2	20	5.5	7.7	10.8	89%	-999	-999	-999	-999	-999	53.1	-999	-999.0	-999.0	0.8	14.2	-999.0	9.8	69.0	84.2	-999.0	0.6	0.5
25-Feb-87	3	0	5.6	7.4	11.2	92%	17	0.09	1 U	-999	-999	55.2	-999	0.2	19.3	0.4	0.8 J	-999.0	20.6	58.6	67.8 J	-999.0	0.8	0.3
25-Feb-87	3	10	5.5	7.2	11.4	94%	-999	-999	-999	-999	-999	53.2	-999	-999.0	-999.0	0.3 J	1.4	-999.0	7.2	57.3	55.7 J	-999.0	0.8	0.4
25-Feb-87	3	20	5.5	7.2	11.2	92%	-999	-999	-999	-999	-999	53.5	-999	-999.0	-999.0	1.1	4.8	-999.0	4.4 J	60.0	87.3	-999.0	0.8	0.4
25-Feb-87	3	40	5.1	7.2	10.7	87%	-999	-999	-999	-999	-999	53.7	-999	-999.0	-999.0	1.4	3.0	-999.0	15.7	57.4	101.0	-999.0	-999.0	-999.0
25-Feb-87	4	0	5.5	7.1	10.5	86%	19.2	0.147	1 U	2 U	2 U	54.2	-999	0.3	19.4	0.1 J	1.4	1.4	17.7	63.0	52.3 J	56.8 J	0.6	0.3
25-Feb-87	4	10	5.5	7.1	10.6	87%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.1 J	3.2	-999.0	2.5 J	63.9	58.0 J	-999.0	0.7	0.6
25-Feb-87	4	20	5.3	7.0	10.7	87%	-999	-999	-999	-999	-999	53.8	-999	-999.0	-999.0	0.3 J	4.6	-999.0	0.0 J	62.6	68.9 J	-999.0	0.8	0.6
25-Feb-87	4	40	5.1	7.0	10.4	85%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.3 J	1.1 J	-999.0	-0.5 J	63.1	93.2	-999.0	-999.0	-999.0
25-Feb-87	4	70	5.0	7.1	10.6	86%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.4	6.1	-999.0	5.1	62.6	94.5	-999.0	-999.0	-999.0
25-Feb-87	4	100	4.4	7.2	10.3	82%	-999	-999	-999	-999	-999	54.2	-999	-999.0	-999.0	0.3 J	1.9	-999.0	0.0 J	75.8	80.0	-999.0	-999.0	-999.0
25-Feb-87	4T	0	6.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	4T	30	5.1	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	5	0	6.1	7.0	10.8	90%	18.3	0.175	1 U	-999	-999	53.9	-999	0.2	19.3	0.3 J	1.4	-999.0	32.4	68.8	58.4 J	-999.0	0.5	0.4
25-Feb-87	5	10	6.1	6.9	10.5	87%	-999	-999	-999	-999	-999	53.5	-999	-999.0	-999.0	0.4	1.4	-999.0	10.3	83.2	59.4 J	-999.0	0.6	0.4
25-Feb-87	5	20	6.1	6.9	10.5	87%	-999	-999	-999	-999	-999	53.5	-999	-999.0	-999.0	0.3 J	1.7	-999.0	3.6 J	66.3	76.7 J	-999.0	0.7	0.4
25-Feb-87	5	40	6.1	6.7	10.4	87%	-999	-999	-999	-999	-999	52.7	-999	-999.0	-999.0	0.3 J	2.6	-999.0	1.0 J	65.4	60.1 J	-999.0	-999.0	-999.0
25-Feb-87	5	70	6.1	6.7	10.5	87%	-999	-999	-999	-999	-999	52.6	-999	-999.0	-999.0	0.3 J	3.0	-999.0	-0.5 J	70.3	98.8	-999.0	-999.0	-999.0
25-Feb-87	5	150	5.9	6.8	10.5	87%	-999	-999	-999	-999	-999	52.8	-999	-999.0	-999.0	0.4	3.7	-999.0	4.0 J	69.8	67.2 J	-999.0	-999.0	-999.0
25-Feb-87	5A	0	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	5A	10	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	5A	20	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	5A	40	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
25-Feb-87	6	0	6.2	6.8	10.6	89%	19	0.098	1 U	2 U	2 U	53.1	-999	0.4	19.3	0.5	2.8	0.2 J	3.5 J	67.8	60.1 J	76.4 J	0.5	0.0
25-Feb-87	6	10	6.1	6.9	10.5	88%	-999	-999	-999	-999	-999	53.1	-999	-999.0	-999.0	0.1 J	0.8 J	-999.0	4.0 J	66.1	60.9 J	-999.0	0.5	0.0
25-Feb-87	6	20	6.1	6.7	10.6	88%	-999	-999	-999	-999	-999	53.2	-999	-999.0	-999.0	0.5	5.0	-999.0	4.4 J	67.4	118.6	-999.0	0.6	0.0
25-Feb-87	6	40	6.1	6.4	10.7	89%	-999	-999	-999	-999	-999	53.0	-999	-999.0	-999.0	0.5	2.3	-999.0	-0.9 J	69.8	56.9 J	-999.0	-999.0	-999.0
25-Feb-87	6	70	6.1	6.8	10.5	88%	-999	-999	-999	-999	-999	53.0	-999	-999.0	-999.0	0.5	2.1	-999.0	-1.9 J	66.6	140.2	-999.0	-999.0	-999.0
25-Feb-87	6	150	6.0	6.9	10.6	88%	-999	-999	-999	-999	-999	53.1	-999	-999.0	-999.0	0.4	1.0 J	-999.0	-0.5 J	70.1	54.4 J	-999.0	-999.0	-999.0
25-Feb-87	6	250	5.6	6.9	10.7	88%	-999	-999	-999	-999	-999	53.0	-999	-999.0	-999.0	0.5	1.0 J	-999.0	3.5 J	66.9	73.7 J	-999.0	-999.0	-999.0
25-Feb-87	6	380	5.5	6.9	10.4	85%	-999	-999	-999	-999	-999	53.1	-999	-999.0	-999.0	1.1	1.0 J	-999.0	-0.9 J	72.8	76.4 J	-999.0	-999.0	-999.0
25-Feb-87	7	0	6.3	6.3	10.1	85%	18	0.114	1 U	-999	-999	53.2	-999	0.5	18.4	0.3 J	0.4 J	0.6 J	4.9	61.7	79.7	86.5	0.5	0.0
25-Feb-87	7	10	6.1	6.4	10.2	85%	-999	-999	-999	-999	-999	52.6	-999	-999.0	-999.0	1.0	0.6 J	-999.0	6.4	67.4	73.6 J	-999.0	0.5	0.0
25-Feb-87	7	20	6.1	6.4	10.0	83%	-999	-999	-999	-999	-999	52.6	-999	-999.0	-999.0	0.4	0.8 J	-999.0	5.9	67.1	88.9	-999.0	0.5	0.0
25-Feb-87	7	40	6.1	6.5	10.2	85%	-999	-999	-999	-999	-999	52.8	-999	-999.0	-999.0	0.3 J	1.0 J	-999.0	8.4	67.8	67.2 J	-999.0	-999.0	-999.0
25-Feb-87	7	70	6.1	6.7	10.2	85%	-999	-999	-999	-999	-999	52.7	-999	-999.0	-999.0	0.4	0.8 J	-999.0	8.4	68.3	85.8	-999.0	-999.0	-999.0
25-Feb-87	7	150	5.8	6.7	10.1	84%	-999	-999	-999	-999	-999	53.0	-999	-999.0	-999.0	0.7	1.7	-999.0	-1.4 J	83.8	65.2 J	-999.0	-999.0	-999.0
25-Feb-87	7	250	5.7	6.8	10.0	82%	-999	-999	-999	-999	-999	52.7	-999	-999.0	-999.0	0.7	0.4 J	-999.0	-4.4 J	85.1	70.5 J	-999.0	-999.0	-999.0
25-Feb-87	8	0	6.3	6.9	10.4	87%	17.2	0.13	1 U	2 U	2 U	53.1	-999	0.2	19.4	0.5	0.8 J	-0.5 J	-1.9 J	64.7	69.5 J	67.3 J	0.7	0.0
25-Feb-87	8	10	6.1	6.9	10.0	83%	-999	-999	-999	-999	-999	52.6	-999	-999.0	-999.0	0.4	1.2 J	-999.0	-2.4 J	62.2	64.5 J	-999.0	0.7	0.0
25-Feb-87	8	20	6.1	6.7	10.3	86%	-999	-999	-999	-999	-999	52.4	-999	-999.0	-999.0	0.4	0.8 J	-999.0	-2.4 J	64.7	92.2	-999.0	0.7	0.0
25-Feb-87	8	40	6.1	6.6	10.4	87%	-999	-999	-999	-999	-999	52.6	-999	-999.0	-999.0	0.3 J	1.2 J	-999.0	0.0 J	62.7	64.1 J	-999.0	-999.0	-999.0
25-Feb-87	8	70	6.1	6.6	10.2	85%	-999	-999	-999	-999	-999	52.3	-999	-999.0	-999.0	0.5	1.2 J	-999.0	-2.9 J	62.2	64.1 J	-999.0	-999.0	-999.0
25-Feb-87	8	120	6.0	6.7	10.4	86%	-999	-999	-999	-999	-999	52.4	-999	-999.0	-999.0	0.7	0.8 J	-999.0	-5.4 J	62.2	71.3 J	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
30-Mar-87	1	0	7.9	7.7	11.4	100%	3.3 P	-999	1 U	2 U	2 U	54.8	0.2	0.3	19.8	0.0	1.7	-999.0	12.1	49.9	81.6	-999.0	0.6	0.1
30-Mar-87	2	0	7.7	7.9	11.3	98%	13	0.028	1 U	2 U	2 U	55.3	-999	0.5	19.9	-0.1 J	1.1 J	0.7 J	16.4	51.0	54.4 J	71.4 J	0.6	0.2
30-Mar-87	2	10	7.3	7.9	11.9	102%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.2 J	5.3	-999.0	13.9	53.1	75.0 J	-999.0	1.1	0.1
30-Mar-87	2	20	6.6	7.9	12.0	101%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.0	1.6	999.0	6.7	45.9	95.0	-999.0	1.0	0.5
30-Mar-87	3	0	7.4	7.9	11.9	102%	12	0.053	1 U	-999	-999	55.6	0.1 J	0.4	19.5	-0.1 J	1.3	-999.0	13.3	52.5	56.9 J	-999.0	0.7	0.1
30-Mar-87	3	10	6.9	7.9	12.0	102%	-999	-999	-999	-999	-999	55.4	-999	-999.0	-999.0	0.0	1.7	-999.0	7.9	53.9	63.9 J	-999.0	-999.0	-999.0
30-Mar-87	3	20	6.7	7.9	11.9	100%	-999	-999	-999	-999	-999	55.3	-999	-999.0	-999.0	0.3 J	4.0	-999.0	0.6 J	56.9	51.8 J	999.0	1.0	0.2
30-Mar-87	3	40	5.4	7.6	11.2	92%	-999	-999	-999	-999	-999	55.3	-999	-999.0	-999.0	0.6	1.3	999.0	7.3	59.6	63.6 J	-999.0	-999.0	-999.0
30-Mar-87	4	0	7.2	7.8	11.9	102%	15	0.045	1 U	2 U	2 U	54.1	-999	0.4	19.2	0.3 J	1.3	0.2 J	3.6 J	56.3	102.0	64.6 J	0.6	0.1
30-Mar-87	4	10	6.7	7.8	11.7	99%	999	-999	-999	-999	-999	54.8	-999	-999.0	-999.0	0.2 J	4.5	-999.0	1.1 J	59.2	108.0	-999.0	0.8	0.2
30-Mar-87	4	20	6.4	7.7	11.7	98%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.2 J	4.9	-999.0	-4.2 J	59.7	82.5	-999.0	0.7	0.3
30-Mar-87	4	40	5.5	7.7	11.5	95%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.0	1.9	-999.0	-999.0	46.5	44.9 J	-999.0	-999.0	-999.0
30-Mar-87	4	70	5.0	7.5	11.2	90%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.5	3.8	-999.0	15.1	65.9	74.2 J	-999.0	-999.0	-999.0
30-Mar-87	4	100	4.6	7.3	9.9	79%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.2 J	1.9	-999.0	7.3	97.8	114.0	-999.0	999.0	999.0
30-Mar-87	4T	0	7.2	-999.0	-999.0	-99900%	14.5	0.025	-999	-999	-999	55.9	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	4T	30	6.3	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	5	0	7.2	7.5	11.7	100%	14.5	0.054	1 U	-999	-999	54.1	-999	0.4	19.4	0.3 J	1.3	-999.0	19.4	58.4	65.9 J	-999.0	0.4	0.2
30-Mar-87	5	10	6.6	7.6	11.5	98%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	0.5	2.3	-999.0	12.1	57.3	70.1 J	-999.0	0.7	0.1
30-Mar-87	5	20	6.4	7.4	11.4	96%	-999	-999	-999	-999	-999	55.3	-999	-999.0	-999.0	0.5	5.7	-999.0	5.5	63.4	61.2 J	-999.0	0.8	0.3
30-Mar-87	5	40	6.3	7.4	11.4	96%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.8	2.6	-999.0	-0.6 J	63.3	58.9 J	999.0	-999.0	999.0
30-Mar-87	5	70	6.3	7.4	11.4	95%	-999	-999	-999	-999	-999	54.4	999	-999.0	-999.0	0.8	2.6	-999.0	0.6 J	57.9	65.3 J	-999.0	-999.0	-999.0
30-Mar-87	5	150	5.9	7.5	11.4	95%	-999	-999	-999	-999	-999	54.8	-999	-999.0	-999.0	1.0	2.8	-999.0	3.6 J	58.7	70.6 J	-999.0	-999.0	-999.0
30-Mar-87	5A	0	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	5A	10	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	5A	20	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	5A	40	-999.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
30-Mar-87	6	0	6.7	7.5	11.7	99%	19.5	0.06	1 U	2 U	2 U	54.4	0.4	0.4	19.0	0.5	1.9	0.7 J	-1.8 J	66.6	145.0	68.5 J	0.5	0.2
30-Mar-87	6	10	6.4	7.5	11.5	97%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.3 J	1.3	-999.0	-2.4 J	56.7	69.8 J	-999.0	0.5	0.2
30-Mar-87	6	20	6.2	7.5	11.5	97%	-999	-999	-999	-999	-999	54.2	-999	-999.0	-999.0	0.1 J	8.5	-999.0	-2.6 J	63.2	57.2 J	-999.0	0.7	0.3
30-Mar-87	6	40	6.1	7.5	11.5	96%	-999	-999	-999	-999	-999	54.1	-999	999.0	-999.0	0.2 J	4.2	-999.0	10.9	65.6	67.0 J	-999.0	-999.0	-999.0
30-Mar-87	6	70	6.1	7.5	11.3	95%	999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.0	3.6	-999.0	-2.4 J	50.0	70.6 J	-999.0	-999.0	-999.0
30-Mar-87	6	150	6.0	7.5	11.2	93%	-999	-999	-999	-999	-999	53.9	-999	-999.0	-999.0	0.2 J	3.0	-999.0	9.7	71.6	94.8	-999.0	-999.0	-999.0
30-Mar-87	6	250	5.7	7.3	10.9	90%	-999	-999	-999	-999	-999	54.8	-999	-999.0	999.0	0.5	4.5	-999.0	-3.0 J	81.3	70.3 J	-999.0	-999.0	-999.0
30-Mar-87	6	380	5.6	7.3	10.8	89%	-999	-999	999	999	-999	54.8	-999	-999.0	-999.0	0.3 J	2.6	-999.0	8.5	79.3	83.4	-999.0	-999.0	-999.0
30-Mar-87	7	0	6.9	7.5	11.5	98%	21.5	0.073	1 U	-999	-999	57.5	-999	0.2	18.5	0.2 J	0.9 J	-999.0	10.3	65.6	93.3	-999.0	0.4	0.1
30-Mar-87	7	10	6.4	7.2	11.5	97%	-999	-999	-999	-999	-999	54.7	-999	-999.0	-999.0	0.2 J	3.8	-999.0	13.9	65.6	66.3 J	-999.0	0.5	0.3
30-Mar-87	7	20	6.3	7.3	11.5	97%	-999	-999	-999	999	-999	54.4	-999	-999.0	-999.0	0.2 J	3.6	-999.0	7.9	64.5	96.2	-999.0	-999.0	-999.0
30-Mar-87	7	40	6.1	7.2	11.3	95%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.2 J	2.4	-999.0	7.9	64.8	70.5 J	-999.0	-999.0	999.0
30-Mar-87	7	70	6.1	7.2	11.3	94%	-999	-999	-999	-999	-999	54.2	-999	-999.0	-999.0	0.3 J	1.3	999.0	2.5 J	66.6	78.6	-999.0	-999.0	-999.0
30-Mar-87	7	150	5.9	7.2	11.4	95%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.2 J	2.5	-999.0	10.9	70.1	48.4 J	-999.0	-999.0	-999.0
30-Mar-87	7	250	5.9	7.4	11.3	94%	-999	-999	-999	-999	-999	54.8	-999	-999.0	-999.0	0.3 J	1.7	-999.0	9.1	70.2	67.3 J	-999.0	-999.0	-999.0
30-Mar-87	8	0	7.1	7.1	11.5	99%	20	0.072	1 U	-999	-999	55.4	-999	0.3	18.7	0.8	1.3	0.4 J	-1.8 J	66.2	64.3 J	86.3	0.2 J	0.1
30-Mar-87	8	10	6.4	7.0	11.3	95%	-999	-999	-999	-999	-999	54.7	-999	-999.0	-999.0	0.2 J	2.6	-999.0	-2.4 J	60.3	70.6 J	-999.0	0.4	0.2
30-Mar-87	8	20	6.3	7.0	11.4	96%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.2 J	1.5	-999.0	2.4 J	68.2	70.8 J	-999.0	0.4	0.2
30-Mar-87	8	40	6.1	7.1	11.3	95%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.2 J	1.3	-999.0	3.6 J	70.5	68.3 J	-999.0	-999.0	-999.0
30-Mar-87	8	70	6.0	7.1	11.0	92%	-999	-999	-999	999	-999	54.5	-999	-999.0	-999.0	0.2 J	1.9	-999.0	10.9	72.2	62.6 J	-999.0	-999.0	-999.0
30-Mar-87	8	120	5.9	7.1	11.0	91%	-999	-999	-999	-999	-999	54.8	-999	-999.0	-999.0	0.3 J	1.7	-999.0	5.5	74.4	68.0 J	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAED
28-Apr-87	1	0	14.3	7.7	11.0	111%	-999	-999	6	2	13	60.9	0.1 J	0.3	20.8	-0.1 J	3.6	-999.0	1.0 J	-999.0	103.6	-999.0	0.2 J	0.2
28-Apr-87	2	0	13.1	7.7	11.2	111%	12.5	0.126	1 U	2 U	2 U	61.0	-999	0.5	20.5	-0.1 J	3.6	1.8	-1.3 J	48.2	72.4 J	62.2 J	0.5	0.2
28-Apr-87	2	10	11.2	7.7	11.6	110%	-999	-999	-999	-999	-999	61.0	-999	-999.0	-999.0	-0.1 J	4.0	-999.0	3.3 J	45.5	140.0	-999.0	1.7	0.5
28-Apr-87	2	20	8.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	4.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
28-Apr-87	3	0	11.4	7.7	11.4	109%	11	0.138	1 U	2 U	2 U	60.4	-999	0.4	19.8	-0.3 J	4.2	-999.0	0.0 J	43.7	89.0	-999.0	0.5	0.1
28-Apr-87	3	10	10.1	7.7	11.4	105%	-999	-999	-999	-999	-999	61.3	-999	-999.0	-999.0	-0.1 J	4.2	-999.0	3.9 J	47.0	189.0	-999.0	0.1 J	0.1
28-Apr-87	3	20	7.9	7.7	11.9	103%	-999	-999	-999	-999	-999	59.5	-999	-999.0	-999.0	0.0	6.0	-999.0	16.3	53.6	145.0	-999.0	0.9	0.4
28-Apr-87	3	40	5.8	7.4	11.4	94%	-999	-999	-999	-999	-999	59.9	-999	-999.0	-999.0	0.1 J	4.8	-999.0	5.9	70.7	173.0	-999.0	-999.0	-999.0
28-Apr-87	4	0	11.9	7.6	11.0	106%	13.5	0.141	1 U	2 U	2 U	60.2	-999	0.5	19.8	0.0	3.2	1.2 J	5.2	55.3	194.0	120.0	0.8	0.5
28-Apr-87	4	10	9.6	7.6	11.2	102%	-999	-999	-999	-999	-999	59.7	-999	-999.0	-999.0	-0.1 J	6.8	-999.0	4.6 J	280.0	130.0	-999.0	1.1	0.5
28-Apr-87	4	20	7.8	7.6	11.0	95%	-999	-999	-999	-999	-999	59.3	-999	-999.0	-999.0	0.0	4.6	-999.0	46.3	225.0	92.3	-999.0	0.5	0.3
28-Apr-87	4	40	5.8	7.5	11.4	94%	-999	-999	-999	-999	-999	59.9	-999	-999.0	-999.0	-0.1 J	4.4	-999.0	1.6 J	61.4	84.5	-999.0	-999.0	-999.0
28-Apr-87	4	70	5.0	7.4	11.3	92%	-999	-999	-999	-999	-999	59.8	-999	-999.0	-999.0	0.1 J	6.4	-999.0	11.1	63.3	148.5	-999.0	-999.0	-999.0
28-Apr-87	4	100	4.8	7.5	11.6	94%	-999	-999	-999	-999	-999	59.7	-999	-999.0	-999.0	0.1 J	4.0	-999.0	6.2	-999.0	227.0	-999.0	-999.0	-999.0
28-Apr-87	4T	0	10.2	-999.0	-999.0	-99900%	15.5	0.123	-999	-999	-999	58.7	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
28-Apr-87	4T	30	7.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
28-Apr-87	5	0	9.4	7.5	11.4	103%	18	0.099	1 U	2 U	2 U	57.9	-999	0.3	19.4	-0.1 J	2.8	-999.0	6.9	35.3	96.9	-999.0	0.3	0.2
28-Apr-87	5	10	8.9	7.6	11.0	98%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.6	4.8	-999.0	2.3 J	45.2	173.0	-999.0	0.3	0.3
28-Apr-87	5	20	8.3	7.6	11.2	99%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	0.0	3.4	-999.0	1.2 J	63.7	76.3 J	-999.0	0.3	0.5
28-Apr-87	5	40	7.1	7.6	11.4	98%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.0	4.0	-999.0	4.2 J	57.8	214.0	-999.0	-999.0	-999.0
28-Apr-87	5	70	6.8	7.5	11.4	97%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.1 J	4.6	-999.0	8.2	98.8	204.0	-999.0	-999.0	-999.0
28-Apr-87	5	150	5.9	7.5	11.2	93%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.0	3.0	-999.0	1.0 J	65.2	134.0	-999.0	-999.0	-999.0
28-Apr-87	5A	0	8.8	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	55.3	-999	-999.0	-999.0	0.3 J	1.8	-999.0	1.0 J	57.6	76.9 J	-999.0	-999.0	-999.0
28-Apr-87	5A	10	8.2	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.1 J	3.0	-999.0	4.2 J	54.3	54.2 J	-999.0	0.2 J	0.2
28-Apr-87	5A	20	7.7	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.0	5.0	-999.0	1.3 J	60.7	58.5 J	-999.0	0.5	0.2
28-Apr-87	5A	40	7.2	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.0	4.2	-999.0	5.2	61.2	69.8 J	-999.0	0.7	0.8
28-Apr-87	6	0	8.2	7.6	11.2	99%	17.5	0.062	1 U	2 U	2 U	58.0	-999	0.4	18.5	-0.1 J	3.6	1.6	0.3 J	63.0	100.0	104.0	0.3	0.3
28-Apr-87	6	10	7.6	7.6	11.4	99%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	2.0	4.0	-999.0	2.9 J	68.1	107.0	-999.0	0.4	0.3
28-Apr-87	6	20	7.2	7.5	11.2	96%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	2.0	4.8	-999.0	18.9	121.0	212.7	-999.0	0.6	0.4
28-Apr-87	6	40	7.0	7.5	11.4	97%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.1 J	5.8	-999.0	6.2	64.1	219.0	-999.0	-999.0	-999.0
28-Apr-87	6	70	6.8	7.5	11.4	97%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.3 J	5.0	-999.0	4.9	64.4	166.0	-999.0	-999.0	-999.0
28-Apr-87	6	150	5.9	7.4	11.0	91%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.1 J	3.8	-999.0	0.3 J	75.4	155.0	-999.0	-999.0	-999.0
28-Apr-87	6	250	5.7	7.3	10.8	89%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.1 J	4.2	-999.0	0.7 J	77.8	50.4 J	-999.0	-999.0	-999.0
28-Apr-87	6	380	5.6	7.3	10.9	90%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.0 J	4.0	-999.0	0.0 J	-999.0	157.0	-999.0	-999.0	-999.0
28-Apr-87	7	0	8.3	7.5	11.2	99%	19	0.108	1 U	2 U	2 U	57.9	-999	0.4	18.8	-0.1 J	2.4	-999.0	5.9	62.9	106.0	-999.0	0.5	0.3
28-Apr-87	7	10	7.4	7.5	11.0	95%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.0	4.4	-999.0	12.4	65.4	135.0	-999.0	0.6	0.6
28-Apr-87	7	20	6.9	7.5	11.2	95%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.0	4.0	-999.0	3.6 J	66.5	62.2 J	-999.0	0.7	0.6
28-Apr-87	7	40	6.8	7.5	11.2	95%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	1.5	3.4	-999.0	1.6 J	43.8	68.0 J	-999.0	-999.0	-999.0
28-Apr-87	7	70	6.6	7.5	11.2	94%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.0	3.6	-999.0	5.1	67.9	61.1 J	-999.0	-999.0	-999.0
28-Apr-87	7	150	6.1	7.5	11.0	91%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.0	6.6	-999.0	0.2 J	63.2	93.1	-999.0	-999.0	-999.0
28-Apr-87	7	250	5.7	7.5	11.0	90%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	-0.1 J	4.2	-999.0	0.0 J	69.1	77.1 J	-999.0	-999.0	-999.0
28-Apr-87	8	0	8.3	7.5	11.4	101%	15.5	0.087	1 U	2 U	2 U	57.8	-999	0.5	19.1	0.0	4.0	0.6 J	0.0 J	66.6	179.0	86.2	0.4	0.3
28-Apr-87	8	10	7.9	7.5	11.4	100%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.6	3.5	-999.0	0.3 J	63.1	87.7	-999.0	0.5	0.3
28-Apr-87	8	20	6.8	7.5	11.4	97%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	0.1 J	2.8	-999.0	-1.6 J	69.7	165.0	-999.0	0.7	0.5
28-Apr-87	8	40	6.6	7.4	11.2	95%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.0	2.4	-999.0	-0.3 J	69.1	387.0	-999.0	-999.0	-999.0
28-Apr-87	8	70	6.3	7.4	11.2	94%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	0.0	4.2	-999.0	1.6 J	72.6	498.0	-999.0	-999.0	-999.0
28-Apr-87	8	120	5.9	7.4	11.2	93%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	-0.1 J	3.0	-999.0	-0.3 J	39.8	62.2 J	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
27-May-87	1	0	16.4	7.7	9.8	105%	-999	-999	10	2	4	60.9	0.1 J	0.4	19.7	0.4	1.7	-999.0	13.3	31.4	70.6 J	-999.0	0.5	0.3
27-May-87	2	0	16.1	7.8	10.0	106%	8.5	0.133	19	2 U	2 U	60.7	0.1 J	0.3	20.0	0.4	1.7	1.3	-0.8 J	26.6	201.0	106.0	0.8	0.4
27-May-87	2	10	13.8	7.9	11.0	110%	-999	-999	-999	-999	-999	59.7	-999	-999.0	-999.0	0.2 J	3.6	-999.0	0.6 J	24.4	53.3 J	-999.0	0.7	0.2
27-May-87	2	20	9.4	7.9	11.4	103%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.4	3.8	-999.0	4.1 J	46.2	142.0	-999.0	0.7	0.5
27-May-87	3	0	16.0	7.9	10.1	107%	7.5	0.141	3	-999	-999	60.7	-999	0.3	20.0	0.2 J	2.3	-999.0	17.9	33.1	85.2	-999.0	0.7	0.2
27-May-87	3	10	13.9	7.9	10.9	110%	-999	-999	-999	-999	-999	59.6	-999	-999.0	-999.0	0.4	2.2	-999.0	8.2	40.3	162.0	-999.0	-999.0	-999.0
27-May-87	3	20	10.5	7.9	11.4	106%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.6	6.3	-999.0	7.3	48.3	120.0	-999.0	0.6	0.3
27-May-87	3	40	7.3	7.6	11.6	100%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	0.4	3.2	-999.0	9.4	47.6	80.2	-999.0	-999.0	-999.0
27-May-87	4	0	14.0	7.7	10.7	108%	10.5	0.118	1 U	2 U	4	59.3	-999	0.3	19.3	0.2 J	2.6	1.5	9.4	45.3	51.9 J	23.7 J	1.2	0.3
27-May-87	4	10	13.8	7.8	11.0	110%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.2 J	3.4	-999.0	8.3	47.2	72.4 J	-999.0	0.4	0.3
27-May-87	4	20	10.1	7.8	11.4	105%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.2 J	3.6	-999.0	5.9	44.7	96.3	-999.0	0.4	0.4
27-May-87	4	40	6.9	7.7	11.4	97%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.5	2.1	-999.0	5.9	61.8	205.0	-999.0	-999.0	-999.0
27-May-87	4	70	5.1	7.4	10.2	83%	-999	-999	-999	-999	-999	59.1	-999	-999.0	-999.0	0.2 J	3.4	-999.0	3.0 J	86.5	76.0 J	-999.0	-999.0	-999.0
27-May-87	4	100	4.9	7.4	10.9	88%	-999	-999	-999	-999	-999	59.1	-999	-999.0	-999.0	0.2 J	3.0	-999.0	6.2	68.9	130.0	-999.0	-999.0	-999.0
27-May-87	4T	0	13.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	59.4	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
27-May-87	4T	30	9.4	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
27-May-87	5	0	12.1	7.7	11.1	107%	12.5	0.105	1 U	-999	-999	58.4	-999	0.2	19.2	0.2 J	1.8	-999.0	17.5	53.2	108.7	-999.0	1.5	0.7
27-May-87	5	10	11.7	7.7	10.8	103%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.2 J	2.1	-999.0	7.5	51.9	195.0	-999.0	0.6	0.5
27-May-87	5	20	11.5	7.7	11.0	105%	-999	-999	-999	-999	-999	58.4	-999	-999.0	-999.0	0.4	3.0	-999.0	9.4	47.3	70.6 J	-999.0	0.7	0.4
27-May-87	5	40	10.6	7.7	11.1	103%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.4	2.1	-999.0	17.9	54.9	60.2 J	-999.0	-999.0	-999.0
27-May-87	5	70	7.3	7.6	11.4	98%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.4	2.2	-999.0	15.8	68.7	80.0	-999.0	-999.0	-999.0
27-May-87	5	150	6.2	7.6	11.5	96%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.2 J	1.5	-999.0	12.9	67.4	165.0	-999.0	-999.0	-999.0
27-May-87	5A	0	10.4	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.2 J	2.5	-999.0	12.2	51.3	61.1 J	-999.0	0.6	0.4
27-May-87	5A	10	10.2	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.3 J	2.8	-999.0	11.4	54.6	52.5 J	-999.0	0.6	0.5
27-May-87	5A	20	10.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.2 J	2.8	-999.0	12.2	57.4	55.9 J	-999.0	0.7	0.4
27-May-87	5A	40	9.2	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.2 J	2.8	-999.0	7.3	58.5	180.0	-999.0	-999.0	-999.0
27-May-87	6	0	10.0	7.6	10.7	98%	13	0.084	2	2 U	2 U	57.5	0.1 J	0.3	18.3	0.2 J	2.2	1.1 J	1.3 J	57.2	181.0	20.4 J	0.6	0.4
27-May-87	6	10	9.0	7.6	11.3	101%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	0.4	4.4	-999.0	-1.5 J	68.9	102.0	-999.0	0.7	0.6
27-May-87	6	20	8.9	7.6	10.7	95%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.2 J	3.8	-999.0	1.3 J	66.2	105.0	-999.0	0.9	0.8
27-May-87	6	40	8.0	7.6	11.3	99%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.4	3.8	-999.0	1.3 J	56.8	143.0	-999.0	-999.0	-999.0
27-May-87	6	70	6.4	7.4	11.4	96%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.2 J	3.6	-999.0	-999.0	-999.0	93.6	-999.0	-999.0	-999.0
27-May-87	6	150	6.0	7.4	10.8	89%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.4	2.4	-999.0	2.0 J	71.0	94.5	-999.0	-999.0	-999.0
27-May-87	6	250	5.7	7.3	10.9	90%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.2 J	4.2	-999.0	3.7 J	81.6	184.0	-999.0	-999.0	-999.0
27-May-87	6	380	5.6	7.3	11.0	91%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.2 J	2.4	-999.0	6.6	76.4	98.9	-999.0	-999.0	-999.0
27-May-87	7	0	10.5	7.6	11.2	104%	12.5	0.134	1 U	-999	-999	57.2	-999	0.2	18.3	0.4	2.8	-999.0	3.4 J	56.9	74.1 J	-999.0	0.5	0.3
27-May-87	7	10	9.3	7.4	10.9	98%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.2 J	2.8	-999.0	4.8	75.6	168.0	-999.0	0.2 J	0.2
27-May-87	7	20	8.4	7.3	10.9	96%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.4	3.8	-999.0	4.8	78.0	106.0	-999.0	0.2 J	0.2
27-May-87	7	40	7.4	7.3	11.3	97%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	0.2 J	3.2	-999.0	4.5 J	80.6	198.0	-999.0	-999.0	-999.0
27-May-87	7	70	6.4	7.4	11.3	95%	-999	-999	-999	-999	-999	56.5	-999	-999.0	-999.0	0.2 J	1.5	-999.0	3.7 J	69.0	126.0	-999.0	-999.0	-999.0
27-May-87	7	150	6.0	7.5	11.5	96%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.2 J	6.1	-999.0	6.6	60.4	178.0	-999.0	-999.0	-999.0
27-May-87	7	250	5.7	7.6	11.2	92%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.2 J	4.7	-999.0	11.9	60.4	135.0	-999.0	-999.0	-999.0
27-May-87	8	0	9.2	7.6	11.1	100%	9	0.132	1 U	-999	-999	56.3	-999	0.4	18.3	0.4	2.2	2.1	8.3	63.5	84.1	101.0	0.5	0.2
27-May-87	8	10	9.0	7.5	10.9	98%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.2 J	3.2	-999.0	9.0	58.9	126.0	-999.0	-999.0	-999.0
27-May-87	8	20	8.1	7.5	11.1	97%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.4	4.2	-999.0	10.8	66.2	78.3	-999.0	1.4	1.0
27-May-87	8	40	7.4	7.5	11.2	96%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.2 J	3.0	-999.0	13.6	55.5	90.0	-999.0	-999.0	-999.0
27-May-87	8	70	6.5	7.5	11.2	94%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	0.4	3.6	-999.0	9.0	67.8	161.0	-999.0	-999.0	-999.0
27-May-87	8	120	5.9	7.5	11.1	92%	-999	-999	-999	-999	-999	55.0	-999	-999.0	-999.0	0.2 J	3.0	-999.0	9.4	86.0	115.3	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
16-Jun-87	1	0	18.1	7.8	10.0	111%	7.5	-999	1 U	2 U	2	60.9	0.1 J	0.3	20.3	0.7	4.6	-999.0	4.7 J	27.7	180.0	-999.0	0.3	0.1
16-Jun-87	2	0	18.8	7.8	10.0	112%	7.2	0.126	2	2	13	60.9	-999	0.4	19.9	1.3	1.6	1.8	4.3 J	27.0	146.0	0.0 J	0.4	0.3
16-Jun-87	2	10	13.5	7.9	10.3	102%	-999	-999	-999	-999	-999	60.6	-999	-999.0	-999.0	1.2	3.8	-999.0	2.9 J	55.4	46.2 J	-999.0	0.9	0.3
16-Jun-87	2	20	11.2	7.9	11.0	104%	-999	-999	-999	-999	-999	59.6	-999	-999.0	-999.0	0.7	1.8	-999.0	1.9 J	42.9	108.0	-999.0	0.9	0.3
16-Jun-87	3	0	17.4	7.9	9.9	108%	7	0.061	1 U	-999	-999	60.7	-999	0.4	20.0	0.7	3.6	-999.0	2.9 J	39.9	140.0	-999.0	0.8	0.2
16-Jun-87	3	10	14.0	8.0	10.7	108%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	0.4	3.2	-999.0	3.8 J	363.0	184.0	-999.0	0.8	-0.0 J
16-Jun-87	3	20	11.7	7.9	11.0	105%	-999	-999	-999	-999	-999	58.7	-999	-999.0	-999.0	0.5	5.2	-999.0	2.9 J	38.6	122.0	-999.0	1.4	0.4
16-Jun-87	3	40	8.9	7.6	11.1	99%	-999	-999	-999	-999	-999	58.4	-999	-999.0	-999.0	0.2 J	2.5	-999.0	3.8 J	46.5	124.0	-999.0	-999.0	-999.0
16-Jun-87	4	0	14.9	7.7	10.0	103%	10.5	0.107	1	2 U	8	59.1	-999	0.3	19.4	0.4	2.0	2.4	5.7	39.2	82.0	24.6 J	0.7	0.3
16-Jun-87	4	10	13.7	7.8	10.5	105%	-999	-999	-999	-999	-999	58.5	-999	-999.0	-999.0	0.4	3.0	-999.0	1.9 J	40.9	317.0	-999.0	1.7	-0.3 J
16-Jun-87	4	20	11.9	7.7	10.5	101%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.2 J	3.8	-999.0	2.9 J	177.0	-999.0	-999.0	0.8	0.2
16-Jun-87	4	40	7.0	7.4	10.9	93%	-999	-999	-999	-999	-999	58.7	-999	-999.0	-999.0	0.2 J	1.4	-999.0	2.9 J	55.6	28.4 J	-999.0	-999.0	-999.0
16-Jun-87	4	70	5.3	7.8	10.8	88%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.7	12.0	-999.0	4.7 J	40.9	105.0	-999.0	-999.0	-999.0
16-Jun-87	4	100	5.0	7.4	10.9	88%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	0.2 J	2.4	-999.0	2.4 J	67.3	113.0	-999.0	-999.0	-999.0
16-Jun-87	4T	0	16.3	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Jun-87	4T	30	12.1	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
16-Jun-87	5	0	14.1	7.6	10.4	105%	10	0.121	2	-999	-999	58.6	-999	0.3	19.0	0.4	1.5	-999.0	3.8 J	89.5	71.1 J	-999.0	0.8	0.1
16-Jun-87	5	10	13.1	7.7	10.1	100%	-999	-999	-999	-999	-999	59.5	-999	-999.0	-999.0	0.8	3.6	-999.0	4.7 J	48.2	97.8	-999.0	1.2	0.1
16-Jun-87	5	20	12.6	7.6	10.6	103%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.4	2.6	-999.0	4.7 J	44.5	51.0 J	-999.0	0.9	0.2
16-Jun-87	5	40	12.1	7.7	10.6	102%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	-0.3 J	1.8	-999.0	7.1	47.0	65.9 J	-999.0	-999.0	-999.0
16-Jun-87	5	70	9.5	7.6	11.1	101%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.2 J	1.2 J	-999.0	10.9	169.0	20.3 J	-999.0	-999.0	-999.0
16-Jun-87	5	150	6.3	7.4	10.9	91%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	0.5	0.2 J	-999.0	0.5 J	80.5	102.0	-999.0	-999.0	-999.0
16-Jun-87	5A	0	11.4	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.2 J	1.0 J	-999.0	1.4 J	55.1	132.0	-999.0	1.7	0.9
16-Jun-87	5A	10	11.3	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.5	1.4	-999.0	1.4 J	46.7	375.0	-999.0	1.9	1.0
16-Jun-87	5A	20	11.1	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	-0.1 J	3.0	-999.0	4.3 J	53.3	85.9	-999.0	1.8	0.7
16-Jun-87	5A	40	10.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.4	0.6 J	-999.0	1.0 J	52.8	114.0	-999.0	-999.0	-999.0
16-Jun-87	6	0	10.6	7.6	10.9	102%	10.4	0.066	1	2 U	2 U	56.2	-999	0.3	18.4	1.0	1.0 J	1.2 J	1.9 J	60.4	39.9 J	17.8 J	0.7	0.2
16-Jun-87	6	10	10.6	7.5	10.9	102%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.4	1.0 J	-999.0	5.5	52.8	129.0	-999.0	0.7	0.4
16-Jun-87	6	20	10.5	7.6	10.9	101%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.4	0.8 J	-999.0	3.3 J	56.6	91.0	-999.0	0.7	0.4
16-Jun-87	6	40	10.1	7.6	10.9	100%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.4	1.0 J	-999.0	5.2	56.4	62.7 J	-999.0	-999.0	-999.0
16-Jun-87	6	70	7.4	7.5	11.0	95%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.2 J	1.6	-999.0	7.1	66.1	66.0 J	-999.0	-999.0	-999.0
16-Jun-87	6	150	6.1	7.4	10.8	90%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.2 J	0.6 J	-999.0	1.4 J	66.7	138.3	-999.0	-999.0	-999.0
16-Jun-87	6	250	5.8	7.4	10.8	89%	-999	-999	-999	-999	-999	58.3	-999	-999.0	-999.0	0.0	0.8 J	-999.0	-0.4 J	77.7	293.0	-999.0	-999.0	-999.0
16-Jun-87	6	380	5.6	7.3	10.7	88%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	0.7	0.4 J	-999.0	-0.9 J	83.5	124.0	-999.0	-999.0	-999.0
16-Jun-87	7	0	10.7	7.6	10.9	102%	10	0.148	4	-999	-999	53.9	-999	0.3	17.3	0.7	-0.2 J	-999.0	0.5 J	61.1	64.4 J	-999.0	0.4	0.3
16-Jun-87	7	10	10.3	7.6	10.8	100%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.8	1.4	-999.0	7.1	57.7	116.0	-999.0	0.7	0.3
16-Jun-87	7	20	10.0	7.6	10.8	99%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.0	0.6 J	-999.0	3.8 J	54.4	78.4	-999.0	0.8	0.6
16-Jun-87	7	40	7.5	7.5	11.0	95%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.7	2.4	-999.0	3.8 J	73.9	134.2	-999.0	-999.0	-999.0
16-Jun-87	7	70	6.4	7.4	10.9	92%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.7	3.2	-999.0	9.5	77.5	66.5 J	-999.0	-999.0	-999.0
16-Jun-87	7	150	5.9	7.3	10.7	89%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.4	3.0	-999.0	7.1	75.5	39.1 J	-999.0	-999.0	-999.0
16-Jun-87	7	250	5.7	7.3	10.6	87%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.5	3.8	-999.0	2.9 J	79.1	61.9 J	-999.0	-999.0	-999.0
16-Jun-87	8	0	9.9	7.5	10.9	100%	6.2	0.149	1	-999	-999	53.5	-999	0.4	17.4	1.5	2.2	3.0	2.9 J	53.4	116.0	71.3 J	0.5	0.3
16-Jun-87	8	10	9.7	7.4	10.9	99%	-999	-999	-999	-999	-999	51.3	-999	-999.0	-999.0	0.4 J	4.9	-999.0	3.7 J	57.1	61.4 J	-999.0	0.7	0.3
16-Jun-87	8	20	9.3	7.5	10.7	97%	-999	-999	-999	-999	-999	52.3	-999	-999.0	-999.0	0.5	3.6	-999.0	6.2	58.6	96.4	-999.0	0.6	0.3
16-Jun-87	8	40	7.2	7.4	10.9	93%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.5	2.2	-999.0	7.6	79.5	76.6 J	-999.0	-999.0	-999.0
16-Jun-87	8	70	6.4	7.3	10.5	88%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.8	5.0	-999.0	3.3 J	123.0	117.0	-999.0	-999.0	-999.0
16-Jun-87	8	120	6.1	7.3	10.4	86%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.5	3.6	-999.0	1.0 J	78.5	52.7 J	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TOVN	TSOVN	CHLA	PHAEO
07-Jul-87	1	0	20.0	7.6	9.2	105%	-999	-999	1 U	1.8 U	2	59.4	0.1 J	0.4	20.0	0.1 J	2.2	-999.0	15.1	21.4	72.4 J	-999.0	0.3	0.2
07-Jul-87	2	0	19.7	7.8	9.2	105%	10	-999	1 U	1.8 U	1.8 U	59.5	0.3	0.4	20.0	0.1 J	1.8	0.0 J	6.4	27.6	256.0	119.0	999.0	-999.0
07-Jul-87	2	10	16.8	8.0	10.1	108%	-999	-999	-999	-999	-999	58.0	-999	-999.0	19.6	0.0	8.5	-999.0	5.9	24.4	32.2 J	-999.0	0.6	0.3
07-Jul-87	2	20	14.4	8.0	10.8	110%	-999	-999	-999	999	-999	57.9	-999	-999.0	19.1	0.2 J	3.2	-999.0	8.9	31.1	83.2	-999.0	0.9	0.4
07-Jul 87	3	0	19.3	7.8	9.4	106%	11.5	0.075	1 U	-999	-999	60.1	-999	0.4	19.9	0.1 J	2.0	-999.0	22.7	30.4	53.4 J	-999.0	0.4	0.3
07-Jul-87	3	10	16.6	7.8	10.1	108%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.1 J	1.8	-999.0	15.8	35.6	116.0	-999.0	1.0	0.4
07-Jul-87	3	20	14.4	8.0	11.0	112%	-999	-999	999	-999	-999	57.8	-999	-999.0	-999.0	0.1 J	3.2	-999.0	8.6	28.8	122.0	-999.0	0.8	0.3
07-Jul-87	3	40	8.2	7.5	10.8	95%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.1 J	2.8	-999.0	6.1	64.2	91.2	-999.0	-999.0	-999.0
07-Jul-87	4	0	18.7	7.6	9.5	107%	10.5	0.13	1	-999	-999	59.2	-999	0.3	19.4	0.2 J	1.6	0.0 J	24.5	25.2	64.2 J	46.6 J	0.1 J	1.2
07-Jul-87	4	10	16.5	7.7	9.6	104%	-999	-999	-999	-999	-999	57.9	-999	-999.0	19.1	0.1 J	4.2	-999.0	24.9	33.2	44.4 J	-999.0	0.7	0.1
07-Jul-87	4	20	13.6	7.7	10.6	106%	-999	-999	-999	-999	-999	57.7	-999	-999.0	19.1	0.1 J	4.4	-999.0	17.3	36.8	152.0	-999.0	0.8	0.3
07-Jul-87	4	40	8.6	7.4	11.1	99%	-999	-999	-999	-999	-999	57.8	-999	-999.0	19.0	0.1 J	2.0	-999.0	0.6 J	54.5	112.0	-999.0	999.0	-999.0
07-Jul-87	4	70	5.5	6.8	10.4	85%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	0.1 J	2.8	-999.0	6.4	79.6	93.1	-999.0	-999.0	-999.0
07-Jul-87	4	100	5.0	7.0	10.9	88%	-999	-999	-999	-999	-999	58.9	-999	-999.0	-999.0	0.2 J	1.6	-999.0	16.2	49.2	65.5 J	-999.0	-999.0	-999.0
07-Jul 87	4T	0	18.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
07-Jul-87	4T	30	11.6	-999.0	-999.0	99900%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
07-Jul-87	5	0	18.0	7.6	9.5	104%	11	0.118	1	-999	-999	58.7	-999	0.4	19.2	0.2 J	1.6	-999.0	5.7	34.4	92.2	-999.0	0.5	0.2
07-Jul-87	5	10	15.5	7.6	9.6	100%	-999	-999	-999	-999	-999	58.7	-999	-999.0	19.9	0.2 J	11.1	-999.0	8.6	28.7	158.0	-999.0	0.8	0.4
07-Jul-87	5	20	14.3	7.7	10.0	101%	-999	-999	-999	-999	-999	57.5	-999	-999.0	19.0	0.6	3.4	-999.0	8.9	35.3	103.0	-999.0	1.0	0.4
07-Jul-87	5	40	9.1	7.7	10.6	95%	-999	-999	-999	-999	-999	56.6	-999	-999.0	18.1	0.1 J	2.0	-999.0	-0.1 J	45.9	98.1	-999.0	-999.0	-999.0
07-Jul-87	5	70	6.7	7.4	10.9	92%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	-0.1 J	1.6	-999.0	8.6	70.2	68.9 J	-999.0	-999.0	-999.0
07-Jul-87	5	150	6.1	7.3	10.9	91%	-999	-999	-999	-999	-999	57.2	-999	-999.0	-999.0	0.1 J	1.0 J	-999.0	7.9	87.6	89.5	-999.0	-999.0	-999.0
07-Jul-87	5A	0	15.2	7.4	10.2	106%	10	0.11	-999	-999	-999	56.4	-999	-999.0	-999.0	0.1 J	1.6	-999.0	4.2 J	38.0	60.8 J	-999.0	1.1	0.1
07-Jul-87	5A	10	15.0	7.6	10.1	104%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	0.3 J	1.6	-999.0	16.2	40.4	49.2 J	-999.0	0.9	0.2
07-Jul-87	5A	20	14.1	7.5	10.2	103%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.2 J	2.1	-999.0	6.1	42.9	63.6 J	-999.0	0.5	0.2
07-Jul-87	5A	40	9.2	-999.0	11.2	101%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.1 J	1.4	-999.0	12.2	60.4	98.1	-999.0	-999.0	-999.0
07-Jul-87	6	0	14.0	7.7	10.2	103%	10.5	0.113	1 U	1.8 U	1.6 U	55.4	0.1 J	0.3	18.2	0.1 J	1.8	-0.2 J	7.1	43.3	100.0	91.5	0.8	0.2
07-Jul-87	6	10	13.8	7.7	10.6	107%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.1 J	2.0	-999.0	7.5	51.4	67.7 J	-999.0	0.8	0.3
07-Jul-87	6	20	13.3	7.7	10.4	103%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.6	2.6	-999.0	8.2	46.7	351.0	-999.0	0.8	0.4
07-Jul-87	6	40	8.8	7.5	11.0	98%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.1 J	1.8	-999.0	23.4	61.6	107.0	-999.0	-999.0	-999.0
07-Jul-87	6	70	6.8	7.3	11.2	95%	999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.3 J	2.0	-999.0	5.0	71.1	156.0	-999.0	-999.0	-999.0
07-Jul-87	6	150	6.0	7.4	11.1	92%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.3 J	1.0 J	-999.0	5.0	74.1	94.9	-999.0	-999.0	-999.0
07-Jul-87	6	250	5.7	7.3	10.8	89%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.1 J	2.0	-999.0	25.6	78.7	225.0	-999.0	999.0	-999.0
07-Jul-87	6	380	5.7	6.6	10.9	90%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	0.5 J	0.6 J	-999.0	12.2	78.8	119.0	-999.0	-999.0	-999.0
07-Jul-87	7	0	13.8	7.6	11.2	113%	11.4	0.94	1 U	-999	-999	54.7	-999	0.4	17.8	0.0	1.0 J	-999.0	10.4	39.8	52.5 J	-999.0	0.4	0.2
07-Jul-87	7	10	13.4	7.6	10.6	106%	-999	-999	-999	-999	-999	54.9	-999	-999.0	19.7	0.1 J	2.4	-999.0	5.0	40.9	37.8 J	999.0	0.6	0.3
07-Jul-87	7	20	12.3	7.6	10.8	105%	-999	-999	-999	-999	-999	55.9	-999	-999.0	18.1	0.2 J	2.6	-999.0	10.8	50.5	163.0	-999.0	0.7	0.4
07-Jul-87	7	40	9.4	7.5	11.0	100%	-999	-999	-999	-999	-999	54.8	-999	-999.0	17.9	0.3 J	1.0 J	-999.0	14.4	58.7	35.9 J	-999.0	-999.0	-999.0
07-Jul-87	7	70	6.8	7.3	11.2	95%	-999	-999	999	-999	-999	56.1	-999	-999.0	-999.0	0.2 J	2.2	-999.0	17.3	73.5	80.5	-999.0	-999.0	-999.0
07-Jul-87	7	150	6.1	7.3	11.0	92%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.1 J	2.2	-999.0	6.4	80.6	12.4 J	-999.0	999.0	-999.0
07-Jul-87	7	250	5.7	7.3	11.0	91%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.2 J	2.0	-999.0	22.7	108.0	116.0	-999.0	-999.0	-999.0
07-Jul-87	8	0	13.3	7.7	10.8	107%	10.7	0.115	1 U	-999	-999	53.7	-999	0.4	17.4	0.6	0.6 J	0.2 J	-999.0	40.6	32.0 J	56.1 J	0.4	0.3
07-Jul-87	8	10	12.7	7.6	10.6	104%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	1.5	2.8	-999.0	14.0	48.0	62.9 J	-999.0	0.5	0.2
07-Jul-87	8	20	11.3	7.6	10.9	103%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.3 J	3.2	-999.0	15.8	49.8	214.0	-999.0	0.8	0.3
07-Jul-87	8	40	10.5	7.5	10.9	101%	-999	-999	-999	-999	-999	54.2	-999	-999.0	-999.0	0.3 J	0.8 J	-999.0	16.2	54.7	110.0	-999.0	-999.0	-999.0
07-Jul-87	8	70	6.8	7.5	10.8	92%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.2 J	2.8	-999.0	11.1	51.0	100.0	-999.0	-999.0	-999.0
07-Jul-87	8	120	6.2	7.4	10.9	91%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.2 J	1.4	999.0	17.3	72.1	166.0	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
28-Jul-87	1	0	20.8	7.4	9.6	112%	-999	-999	1	1.8 U	2	59.0	1.3	0.4	19.7	0.5	2.1	-999.0	8.0	32.0	23.2 J	-999.0	0.3	0.2
28-Jul-87	2	0	21.0	7.6	9.5	111%	11.5	0.091	1 U	1.8 U	1.8 U	59.4	-999	0.3	20.0	6.5	2.1	1.2 J	1.5 J	30.3	172.0	47.6 J	-999.0	-999.0
28-Jul-87	2	10	17.8	7.7	9.6	105%	-999	-999	-999	-999	-999	59.5	-999	-999.0	-999.0	0.5	10.0	-999.0	8.3	24.0	77.2 J	-999.0	0.2 J	0.2
28-Jul-87	2	20	14.2	8.0	10.3	105%	-999	-999	-999	-999	-999	59.1	-999	-999.0	-999.0	0.9	2.7	-999.0	1.8 J	31.0	108.0	-999.0	0.5	0.2
28-Jul-87	3	0	20.0	7.8	9.8	113%	10.5	0.087	2	-999	-999	58.0	-999	0.5	19.7	0.8	2.1	-999.0	7.3	29.6	123.0	-999.0	0.2	0.1
28-Jul-87	3	10	17.9	7.9	10.2	112%	-999	-999	-999	-999	-999	59.7	-999	-999.0	-999.0	0.4	2.7	-999.0	5.9	25.1	86.3	-999.0	0.3	0.1
28-Jul-87	3	20	14.1	7.9	10.9	110%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.4	3.8	-999.0	17.5	33.4	279.0	-999.0	0.5	0.4
28-Jul-87	3	40	9.1	7.5	11.4	102%	-999	-999	-999	-999	-999	58.7	-999	-999.0	-999.0	0.7	2.8	-999.0	19.9	51.1	118.9	-999.0	-999.0	-999.0
28-Jul-87	4	0	20.4	7.8	9.6	111%	12.5	0.095	11	1.8 U	1.8 U	59.8	-999	0.4	19.6	0.3 J	1.8	6.3	14.1	27.8	27.2 J	0.0 J	0.2	0.1
28-Jul-87	4	10	17.3	7.9	10.1	109%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.1 J	8.4	-999.0	12.1	26.3	121.0	-999.0	0.4	0.1
28-Jul-87	4	20	14.2	7.9	10.8	110%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.1 J	6.3	-999.0	5.9	31.6	106.0	-999.0	0.6	0.2
28-Jul-87	4	40	8.5	7.5	11.0	98%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.1 J	2.1	-999.0	16.0	55.3	96.7	-999.0	-999.0	-999.0
28-Jul-87	4	70	5.6	7.8	9.4	77%	-999	-999	-999	-999	-999	59.7	-999	-999.0	-999.0	0.1 J	9.6	-999.0	14.5	-999.0	113.0	-999.0	-999.0	-999.0
28-Jul-87	4	100	5.1	7.7	10.2	83%	-999	-959	-999	-999	-999	59.4	-999	-999.0	-999.0	0.2 J	1.9	-999.0	27.1	46.1	46.7 J	-999.0	-999.0	-999.0
28-Jul-87	4T	0	19.8	-999.0	-999.0	-99900%	12.5	0.103	-999	-999	-999	59.7	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
28-Jul-87	4T	30	12.1	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
28-Jul-87	5	0	18.8	7.8	10.0	112%	12.5	0.097	1	-999	-999	58.8	-999	0.4	19.4	0.1 J	2.1	-999.0	26.1	21.8	46.8 J	-999.0	0.3	0.2
28-Jul-87	5	10	17.0	7.9	10.3	111%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.5	4.0	-999.0	3.5 J	26.6	172.0	-999.0	0.3	0.5
28-Jul-87	5	20	15.3	7.8	10.9	113%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	0.8	3.2	-999.0	-999.0	61.9	89.4	-999.0	0.7	0.4
28-Jul-87	5	40	8.7	7.5	11.4	102%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.4	2.9	-999.0	9.7	53.7	111.0	-999.0	-999.0	-999.0
28-Jul-87	5	70	6.7	7.8	10.0	85%	-999	-999	-999	-999	-999	59.1	-999	-999.0	-999.0	0.3 J	8.3	-999.0	9.3	24.6	272.0	-999.0	-999.0	-999.0
28-Jul-87	5	150	6.1	7.4	10.2	85%	-999	-999	-999	-999	-999	58.4	-999	-999.0	-999.0	0.4	2.5	-999.0	3.5 J	87.6	121.0	-999.0	-999.0	-999.0
28-Jul-87	5A	0	18.3	-999.0	-999.0	-99900%	11.5	0.103	-999	-999	-999	58.5	-999	-999.0	-999.0	0.1 J	2.3	-999.0	11.1	33.5	143.0	-999.0	0.3	0.1
28-Jul-87	5A	10	15.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.3 J	1.8	-999.0	41.1	38.4	93.5	-999.0	0.5	0.2
28-Jul-87	5A	20	14.3	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.3 J	1.9	-999.0	7.6	37.1	97.6	-999.0	0.4	0.1
28-Jul-87	5A	40	10.1	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.3 J	2.2	-999.0	10.0	44.8	89.4	-999.0	-999.0	-999.0
28-Jul-87	6	0	17.0	7.8	10.4	112%	12.5	0.096	1 U	1.8 U	1.8 U	57.3	-999	0.4	17.5	0.1 J	2.1	1.2 J	3.2 J	35.8	95.7	69.8 J	0.2 J	0.1
28-Jul-87	6	10	15.9	7.8	10.4	110%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.3 J	1.8	-999.0	2.5 J	38.4	91.8	-999.0	0.5	0.1
28-Jul-87	6	20	14.4	7.8	10.6	108%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.1 J	6.3	-999.0	3.2 J	36.1	174.0	-999.0	0.8	0.2
28-Jul-87	6	40	10.1	7.6	10.8	100%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.1 J	5.4	-999.0	8.7	60.2	76.1 J	-999.0	-999.0	-999.0
28-Jul-87	6	70	7.0	7.5	11.2	95%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.1 J	4.3	-999.0	-0.9 J	76.2	124.0	-999.0	-999.0	-999.0
28-Jul-87	6	150	6.1	7.4	11.2	93%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.3 J	1.6	-999.0	0.1 J	81.7	129.0	-999.0	-999.0	-999.0
28-Jul-87	6	250	5.8	7.3	11.2	93%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	0.3 J	2.1	-999.0	6.9	74.6	314.0	-999.0	-999.0	-999.0
28-Jul-87	6	380	5.7	7.4	10.9	90%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	2.7	1.2 J	-999.0	0.5 J	86.8	147.0	-999.0	-999.0	-999.0
28-Jul-87	7	0	16.5	7.7	10.3	110%	12.5	0.099	1 U	-999	-999	57.4	-999	0.3	19.4	0.2 J	5.4	-999.0	11.4	37.2	179.0	-999.0	0.4	0.2
28-Jul-87	7	10	15.0	7.8	10.8	112%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.1 J	2.9	-999.0	42.8	41.7	109.0	-999.0	0.6	0.3
28-Jul-87	7	20	13.0	7.8	10.9	108%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.5	3.0	-999.0	14.1	39.7	130.0	-999.0	0.9	0.4
28-Jul-87	7	40	10.0	7.5	11.2	103%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.3 J	4.0	-999.0	45.9	59.8	124.0	-999.0	-999.0	-999.0
28-Jul-87	7	70	6.8	7.4	11.4	97%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.4	2.3	-999.0	11.1	78.1	170.0	-999.0	-999.0	-999.0
28-Jul-87	7	150	6.1	7.8	10.4	87%	-999	-999	-999	-959	-999	56.9	-999	-999.0	-999.0	0.4	9.3	-999.0	16.5	35.6	228.0	-999.0	-999.0	-999.0
28-Jul-87	7	250	5.8	7.4	10.2	84%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.3 J	1.9	-999.0	5.6	80.2	153.0	-999.0	-999.0	-999.0
28-Jul-87	8	0	17.2	7.8	10.5	114%	11.5	0.103	1 U	-999	-999	55.8	-999	0.4	18.1	0.3 J	3.0	2.1	31.2	25.4	102.0	101.5	0.4	0.2
28-Jul-87	8	10	14.8	7.8	10.5	108%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.1 J	2.7	-999.0	9.3	28.8	104.0	-999.0	0.6	-0.3 J
28-Jul-87	8	20	13.5	7.8	11.0	110%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.3 J	5.6	-999.0	17.5	37.9	65.4 J	-999.0	0.6	0.3
28-Jul-87	8	40	10.5	7.5	11.2	104%	-999	-999	-999	-999	-999	54.1	-999	-999.0	-999.0	0.1 J	3.8	-999.0	13.4	45.6	366.5	-999.0	-999.0	-999.0
28-Jul-87	8	70	6.8	7.8	10.7	91%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.1 J	5.8	-999.0	19.3	37.7	201.0	-999.0	-999.0	-999.0
28-Jul-87	8	120	6.3	7.4	11.0	92%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.1 J	2.5	-999.0	13.8	68.9	85.0	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
18-Aug-87	1	0	21.0	-999.0	-999.0	-99900%	7.5	-999	2	2	30	60.4	-999	0.6	19.0	0.2 J	2.1	-999.0	11.3	9.4 J	23.9 J	-999.0	1.0	0.5
18-Aug-87	2	0	20.5	8.0	10.0	116%	8.75	0.009	1 U	2 U	300	61.9	-999	0.4	19.7	3.5	1.9	0.9 J	7.7	11.7	71.9 J	88.6	-999.0	-999.0
18-Aug-87	2	10	19.1	8.0	10.8	121%	-999	-999	-999	-999	-999	61.8	-999	-999.0	-999.0	0.7	2.4	-999.0	2.8 J	17.3	45.9 J	-999.0	1.1	0.3
18-Aug-87	2	20	17.5	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
18-Aug-87	3	0	19.9	7.9	10.4	119%	9.75	0.017	1 U	-999	-999	59.4	-999	0.4	18.4	0.9	1.7	-999.0	7.3	24.8	53.5 J	-999.0	0.8	-0.1 J
18-Aug-87	3	10	19.3	8.0	10.5	119%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	1.2	2.0	-999.0	6.4	14.7	71.2 J	-999.0	0.6	0.3
18-Aug-87	3	20	17.5	7.9	10.8	117%	-999	-999	-999	-999	-999	58.5	-999	-999.0	-999.0	2.8	3.9	-999.0	7.0	23.4	72.9 J	-999.0	0.8	0.5
18-Aug-87	3	40	9.8	7.6	11.8	107%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.1 J	2.1	-999.0	17.7	43.1	78.7	-999.0	-999.0	-999.0
18-Aug-87	4	0	19.5	8.1	10.0	113%	10.5	0.02	1 U	-999	-999	58.5	-999	0.4	18.2	0.2 J	1.5	-999.0	7.0	10.2	29.6 J	40.8 J	0.6	0.2
18-Aug-87	4	10	19.1	8.0	10.1	114%	-999	-999	-999	-999	-999	57.2	-999	-999.0	-999.0	0.2 J	3.0	-999.0	7.0	19.2	33.0 J	-999.0	0.5	0.2
18-Aug-87	4	20	17.8	7.9	10.3	113%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	1.5	3.2	-999.0	6.1	22.8	51.8 J	-999.0	0.7	0.4
18-Aug-87	4	40	9.3	7.6	11.3	102%	-999	-999	-999	-999	-999	58.4	-999	-999.0	-999.0	0.4	2.6	-999.0	10.1	47.5	75.7 J	-999.0	-999.0	-999.0
18-Aug-87	4	70	5.5	7.4	11.0	90%	-999	-999	-999	-999	-999	58.9	-999	-999.0	-999.0	0.9	3.4	-999.0	4.3 J	80.7	82.6	-999.0	-999.0	-999.0
18-Aug-87	4	100	5.1	7.2	10.3	83%	-999	-999	-999	-999	-999	59.6	-999	-999.0	-999.0	0.2 J	2.6	-999.0	5.1	92.5	95.2	-999.0	-999.0	-999.0
18-Aug-87	4T	0	19.4	-999.0	-999.0	-99900%	12.5	0.017	-999	-999	-999	58.9	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
18-Aug-87	4T	30	10.8	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
18-Aug-87	5	0	18.9	7.8	10.0	112%	13.5	0.031	1 U	-999	-999	58.2	-999	0.4	18.7	0.2 J	1.7	-999.0	10.7	23.9	97.2	-999.0	0.6	0.3
18-Aug-87	5	10	18.1	7.9	9.9	109%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.1 J	3.0	-999.0	4.6 J	23.0	73.9 J	-999.0	0.6	0.3
18-Aug-87	5	20	16.8	7.9	10.0	107%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.2 J	4.1	-999.0	5.2	24.6	202.0	-999.0	0.8	0.4
18-Aug-87	5	40	8.8	7.6	10.9	98%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	0.1 J	2.2	-999.0	8.0	59.2	73.0 J	-999.0	-999.0	-999.0
18-Aug-87	5	70	6.6	7.8	9.7	82%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.2 J	9.0	-999.0	4.6 J	21.3	15.8 J	-999.0	-999.0	-999.0
18-Aug-87	5	150	6.2	7.6	11.0	92%	-999	-999	-999	-999	-999	57.2	-999	-999.0	-999.0	0.1 J	1.7	-999.0	2.5 J	73.3	96.1	-999.0	-999.0	-999.0
18-Aug-87	5A	0	17.9	-999.0	-999.0	-99900%	12.75	0.003	-999	-999	-999	57.7	-999	0.6	17.7	0.2 J	1.5	-999.0	4.6 J	20.8	55.4 J	-999.0	0.5	0.3
18-Aug-87	5A	10	16.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.5	1.9	-999.0	4.0 J	21.9	95.2	-999.0	0.6	0.4
18-Aug-87	5A	20	16.6	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.1 J	2.2	-999.0	4.3 J	21.6	165.0	-999.0	0.6	0.3
18-Aug-87	5A	40	8.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.1 J	2.1	-999.0	7.0	29.8	47.7 J	-999.0	-999.0	-999.0
18-Aug-87	6	0	16.4	7.8	10.2	109%	11	0.026	1 U	2 U	4	56.2	-999	0.4	17.9	0.1 J	1.5	0.8 J	7.7	32.2	40.4 J	75.7 J	0.6	0.3
18-Aug-87	6	10	16.2	7.8	10.3	109%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	1.4	2.2	-999.0	4.3 J	31.3	21.3 J	-999.0	0.6	0.4
18-Aug-87	6	20	16.0	7.8	10.2	108%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.1 J	3.7	-999.0	4.3 J	30.3	159.0	-999.0	0.7	0.4
18-Aug-87	6	40	9.7	7.8	10.3	94%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.1 J	4.3	-999.0	4.6 J	26.2	91.2	-999.0	-999.0	-999.0
18-Aug-87	6	70	6.8	7.5	11.2	95%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.1 J	5.8	-999.0	12.8	64.6	156.0	-999.0	-999.0	-999.0
18-Aug-87	6	150	6.1	7.4	11.1	93%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.4	1.9	-999.0	3.1 J	80.2	120.3	-999.0	-999.0	-999.0
18-Aug-87	6	250	5.8	7.4	11.8	97%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.5	3.7	-999.0	3.1 J	71.2	42.2 J	-999.0	-999.0	-999.0
18-Aug-87	6	380	5.7	7.4	11.3	93%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.4	2.2	-999.0	4.6 J	65.5	85.9	-999.0	-999.0	-999.0
18-Aug-87	7	0	15.8	7.8	10.0	105%	11	0.038	1 U	-999	-999	55.3	-999	0.4	17.7	0.9	2.4	-999.0	3.1 J	32.5	33.0 J	-999.0	0.8	0.4
18-Aug-87	7	10	15.5	7.9	10.1	105%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.5	2.8	-999.0	6.7	26.9	53.5 J	-999.0	0.7	0.4
18-Aug-87	7	20	15.2	7.9	10.1	105%	-999	-999	-999	-999	-999	55.4	-999	-999.0	-999.0	1.1	2.6	-999.0	6.4	27.4	60.9 J	-999.0	1.1	0.7
18-Aug-87	7	40	9.9	7.8	10.3	94%	-999	-999	-999	-999	-999	55.7	-999	-999.0	-999.0	0.5	5.2	-999.0	8.9	34.8	48.5 J	-999.0	-999.0	-999.0
18-Aug-87	7	70	7.1	7.5	10.4	89%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.1 J	1.9	-999.0	-999.0	65.8	108.0	-999.0	-999.0	-999.0
18-Aug-87	7	150	6.1	7.7	10.5	88%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.1 J	6.7	-999.0	4.9	27.1	60.9 J	-999.0	-999.0	-999.0
18-Aug-87	7	250	5.8	7.7	10.4	86%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.4	1.9	-999.0	9.2	28.0	78.0	-999.0	-999.0	-999.0
18-Aug-87	8	0	15.3	7.8	10.0	104%	9	0.067	1 U	-999	-999	54.7	-999	0.5	16.6	0.1 J	2.1	2.2	4.9	22.2	34.9 J	48.9 J	1.2	-0.4 J
18-Aug-87	8	10	14.6	7.8	10.1	103%	-999	-999	-999	-999	-999	54.6	-999	-999.0	-999.0	0.8	5.2	-999.0	5.2	27.1	62.1 J	-999.0	1.0	0.5
18-Aug-87	8	20	13.8	7.7	10.4	105%	-999	-999	-999	-999	-999	54.4	-999	-999.0	-999.0	0.1 J	5.2	-999.0	9.8	29.2	240.0	-999.0	1.5	0.8
18-Aug-87	8	40	12.5	7.6	10.5	102%	-999	-999	-999	-999	-999	53.6	-999	-999.0	-999.0	0.2 J	2.8	-999.0	17.4	32.1	104.0	-999.0	-999.0	-999.0
18-Aug-87	8	70	8.1	7.7	10.6	93%	-999	-999	-999	-999	-999	54.6	-999	-999.0	-999.0	0.1 J	6.5	-999.0	7.3	30.8	62.1 J	-999.0	-999.0	-999.0
18-Aug-87	8	120	6.3	7.5	11.0	93%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.1 J	1.9	-999.0	6.1	59.0	101.0	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
08-Sep-87	1	0	20.4	8.0	10.1	117%	-999	-999	1 U	1.8 U	1.8 U	58.7	0.1 J	0.5	17.5	0.2 J	2.2	-999.0	14.1	11.2	96.2	-999.0	0.5	0.2
08-Sep-87	2	0	20.8	8.0	9.9	115%	9.5	0.007	1 U	1.8 U	7.8	58.8	-999	0.4	18.4	0.5	2.0	1.4	32.7	11.7	57.4 J	100.0	0.5	0.2
08-Sep-87	2	10	18.5	8.1	10.6	118%	-999	-999	-999	-999	-999	57.8	-999	-999.0	17.5	0.1 J	6.6	-999.0	46.1	19.6	67.0 J	-999.0	0.5	0.2
08-Sep-87	2	20	16.3	8.1	11.0	117%	-999	-999	-999	-999	-999	56.9	-999	-999.0	17.1	0.8	3.0	-999.0	35.8	24.8	106.0	-999.0	0.6	0.4
08-Sep-87	3	0	20.5	8.0	9.9	115%	10	0.018	1 U	-999	-999	58.9	-999	0.6	18.1	0.6	1.8	-999.0	35.8	17.1	82.2	-999.0	0.6	0.0
08-Sep-87	3	10	18.7	8.2	10.6	118%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	1.5	2.2	-999.0	31.7	26.0	90.3	-999.0	0.6	0.3
08-Sep-87	3	20	16.7	8.1	10.9	117%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.2 J	4.2	-999.0	38.6	19.4	78.4	-999.0	1.0	0.6
08-Sep-87	3	40	9.8	7.6	9.9	91%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.2 J	2.2	-999.0	15.2	60.9	93.7	-999.0	-999.0	-999.0
08-Sep-87	4	0	20.0	7.9	9.9	113%	11.5	0.027	1 U	-999	-999	59.0	-999	0.4	17.8	0.2 J	2.0	1.0 J	16.2	13.2	166.0	0.0	0.5	0.2
08-Sep-87	4	10	18.8	8.0	9.9	111%	-999	-999	-999	-999	-999	58.0	-999	-999.0	17.5	0.2 J	6.6	-999.0	19.3	16.1	91.2	-999.0	0.6	0.3
08-Sep-87	4	20	16.5	8.0	10.5	112%	-999	-999	-999	-999	-999	57.0	-999	-999.0	17.4	0.4	3.0	-999.0	15.5	25.0	116.0	-999.0	0.6	0.4
08-Sep-87	4	40	9.2	-999.0	10.5	95%	-999	-999	-999	-999	-999	57.8	-999	-999.0	17.4	0.2 J	2.0	-999.0	22.1	63.9	193.0	-999.0	-999.0	-999.0
08-Sep-87	4	70	5.7	7.5	10.6	87%	-999	-999	-999	-999	-999	58.3	-999	-999.0	-999.0	0.4	2.4	-999.0	10.4	91.6	136.0	-999.0	-999.0	-999.0
08-Sep-87	4	100	5.1	7.3	9.9	80%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.4	2.0	-999.0	16.5	108.0	207.0	-999.0	-999.0	-999.0
08-Sep-87	4T	0	20.0	-999.0	-999.0	-99900%	12	0.031	-999	-999	-999	59.7	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
08-Sep-87	4T	30	12.9	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
08-Sep-87	5	0	19.0	7.7	9.8	111%	11.5	0.031	1 U	-999	-999	58.3	-999	0.4	17.4	0.1 J	2.6	-999.0	23.4	12.8	51.7 J	-999.0	0.4	0.3
08-Sep-87	5	10	18.5	7.9	9.9	111%	-999	-999	-999	-999	-999	58.2	-999	-999.0	-999.0	0.1 J	12.3	-999.0	14.8	11.1	165.0	-999.0	0.5	0.3
08-Sep-87	5	20	17.1	7.9	10.2	110%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.2 J	3.2	-999.0	21.7	16.2	115.0	-999.0	0.1 J	0.1
08-Sep-87	5	40	11.6	7.7	11.1	107%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.1 J	3.0	-999.0	22.4	45.8	87.0	-999.0	-999.0	-999.0
08-Sep-87	5	70	7.6	7.6	10.7	93%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	1.1	3.4	-999.0	13.4	146.0	98.5	-999.0	-999.0	-999.0
08-Sep-87	5	150	6.2	7.5	10.8	91%	-999	-999	-999	-999	-999	58.1	-999	-999.0	-999.0	0.1 J	2.4	-999.0	10.4	104.0	56.2 J	-999.0	-999.0	-999.0
08-Sep-87	5A	0	20.0	7.6	9.8	113%	11.5	0.034	-999	-999	-999	58.3	-999	0.7	17.8	0.1 J	9.0	-999.0	14.1	15.4	66.9 J	-999.0	0.2 J	0.1
08-Sep-87	5A	10	19.2	7.8	9.8	111%	-999	-999	-999	-999	-999	57.9	-999	-999.0	18.0	0.1 J	1.6	-999.0	15.9	16.8	65.9 J	-999.0	0.5	0.3
08-Sep-87	5A	20	17.4	7.9	10.2	110%	-999	-999	-999	-999	-999	56.6	-999	-999.0	17.5	0.1 J	4.1	-999.0	14.8	17.2	82.2	-999.0	0.7	0.4
08-Sep-87	5A	40	12.5	7.7	10.8	105%	-999	-999	-999	-999	-999	55.1	-999	-999.0	22.7	0.1 J	2.2	-999.0	19.0	45.4	79.6	-999.0	-999.0	-999.0
08-Sep-87	6	0	18.1	7.8	9.9	110%	12	0.039	2	-999	-999	57.4	0.1 J	0.7	17.3	0.1 J	2.6	1.4	15.9	23.3	62.0 J	72.9 J	0.4	0.1
08-Sep-87	6	10	17.6	7.8	9.9	109%	-999	-999	-999	-999	-999	57.2	-999	-999.0	-999.0	0.1 J	2.4	-999.0	12.4	21.3	96.6	-999.0	0.3	0.2
08-Sep-87	6	20	16.7	7.9	10.3	111%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.1 J	2.2	-999.0	14.5	26.6	126.5	-999.0	0.6	0.3
08-Sep-87	6	40	10.8	7.9	10.2	96%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.4	3.2	-999.0	22.7	22.1	83.2	-999.0	-999.0	-999.0
08-Sep-87	6	70	7.1	7.6	11.1	95%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.3 J	2.8	-999.0	14.7	64.8	115.0	-999.0	-999.0	-999.0
08-Sep-87	6	150	6.1	7.5	11.0	92%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.1 J	1.2 J	-999.0	8.2	77.4	73.8 J	-999.0	-999.0	-999.0
08-Sep-87	6	250	5.8	7.5	11.0	91%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.2 J	2.4	-999.0	9.7	74.6	114.0	-999.0	-999.0	-999.0
08-Sep-87	6	380	5.7	7.5	11.0	91%	-999	-999	-999	-999	-999	57.2	-999	-999.0	-999.0	0.2 J	1.5	-999.0	11.7	74.0	172.3	-999.0	-999.0	-999.0
08-Sep-87	7	0	17.9	7.7	10.1	111%	13	0.037	1 U	-999	-999	56.6	-999	0.7	16.9	0.1 J	2.0	-999.0	13.8	20.7	46.6 J	-999.0	0.4	0.3
08-Sep-87	7	10	17.2	7.8	10.2	111%	-999	-999	-999	-999	-999	55.9	-999	-999.0	17.3	0.1 J	2.4	-999.0	15.5	24.7	92.0	-999.0	0.3	0.1
08-Sep-87	7	20	15.9	7.8	10.2	108%	-999	-999	-999	-999	-999	55.9	-999	-999.0	17.1	0.1 J	4.2	-999.0	11.4	24.3	80.2	-999.0	0.3	0.0
08-Sep-87	7	40	10.1	7.8	10.6	98%	-999	-999	-999	-999	-999	54.6	-999	-999.0	16.6	0.2 J	4.2	-999.0	23.8	35.8	82.8	-999.0	-999.0	-999.0
08-Sep-87	7	70	6.8	7.6	11.0	94%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.2 J	2.0	-999.0	14.8	71.4	120.0	-999.0	-999.0	-999.0
08-Sep-87	7	150	6.1	7.5	11.3	94%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.2 J	3.0	-999.0	17.6	83.2	55.6 J	-999.0	-999.0	-999.0
08-Sep-87	7	250	5.7	7.5	11.4	94%	-999	-999	-999	-999	-999	15.0	-999	-999.0	-999.0	0.2 J	1.4	-999.0	12.8	78.1	117.0	-999.0	-999.0	-999.0
08-Sep-87	8	0	17.8	7.6	10.6	116%	9.5	0.027	1 U	-999	-999	55.2	-999	0.6	16.5	0.2 J	3.2	2.4	14.8	15.0	42.2 J	70.7 J	0.4	0.3
08-Sep-87	8	10	17.2	7.7	10.3	111%	-999	-999	-999	-999	-999	55.7	-999	-999.0	-999.0	0.1 J	2.6	-999.0	9.0	24.6	74.3 J	-999.0	0.4	0.4
08-Sep-87	8	20	16.2	7.8	10.8	115%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.1 J	3.2	-999.0	14.8	25.7	45.7 J	-999.0	0.6	0.4
08-Sep-87	8	40	9.4	7.6	11.3	102%	-999	-999	-999	-999	-999	55.1	-999	-999.0	-999.0	0.2 J	2.4	-999.0	18.3	59.2	63.6 J	-999.0	-999.0	-999.0
08-Sep-87	8	70	6.8	7.5	11.4	96%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	0.2 J	2.6	-999.0	10.0	103.0	138.0	-999.0	-999.0	-999.0
08-Sep-87	8	120	6.2	7.4	11.4	95%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.4	2.0	-999.0	12.1	82.3	86.8	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAED
06-Oct-87	1	0	17.4	-999.0	-999.0	-99900%	-999	-999	1 U	2 U	2	60.9	-999	0.3	19.4	0.1 J	5.0	-999.0	88.7	41.6	65.0 J	-999.0	0.5	0.1
06-Oct-87	2	0	17.5	7.9	9.4	102%	-999	-999	1 U	2 U	23	60.5	-999	0.4	24.5	0.1 J	2.4	1.4	33.5	12.2	66.4 J	155.0	0.5	0.1
06-Oct-87	2	10	17.5	7.9	9.4	103%	-999	-999	-999	-999	-999	56.7	-999	-999.0	-999.0	0.1 J	2.4	-999.0	48.0	15.2	104.0	-999.0	0.0	0.0
06-Oct-87	2	20	16.0	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	0.6	0.2
06-Oct-87	3	0	17.5	7.8	9.9	108%	-999	-999	1 U	-999	-999	60.7	-999	0.2	18.9	0.1 J	2.5	-999.0	59.6	8.0 J	124.7	-999.0	0.6	0.2
06-Oct-87	3	10	17.5	7.8	9.4	102%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.1 J	2.2	-999.0	27.7	7.2 J	130.0	-999.0	0.6	0.2
06-Oct-87	3	20	16.1	7.7	9.6	102%	-999	-999	-999	-999	-999	55.4	-999	-999.0	-999.0	0.1 J	5.9	-999.0	26.3	22.4	88.5	-999.0	0.9	0.3
06-Oct-87	3	40	9.4	7.6	10.2	92%	-999	-999	-999	-999	-999	60.2	-999	-999.0	-999.0	-0.1 J	7.8	-999.0	11.7	70.9	126.0	-999.0	-999.0	-999.0
06-Oct-87	4	0	17.4	7.7	9.4	102%	-999	-999	1 U	2 U	2	59.9	-999	0.3	19.4	0.1 J	2.6	2.4	27.7	13.1	18.2 J	51.2 J	0.6	0.1
06-Oct-87	4	10	17.2	7.7	9.4	102%	-999	-999	-999	-999	-999	56.7	-999	-999.0	-999.0	0.1 J	13.0	-999.0	24.8	11.6	67.6 J	-999.0	0.6	0.1
06-Oct-87	4	20	16.1	7.8	9.5	101%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.1 J	4.1	-999.0	61.1	116.0	65.9 J	-999.0	0.8	0.2
06-Oct-87	4	40	9.6	7.6	10.4	95%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	-0.1 J	3.1	-999.0	29.2	78.4	166.0	-999.0	-999.0	-999.0
06-Oct-87	4	70	5.6	7.4	10.0	82%	-999	-999	-999	-999	-999	60.6	-999	-999.0	-999.0	0.1 J	3.7	-999.0	23.4	100.0	165.0	-999.0	-999.0	-999.0
06-Oct-87	4	100	5.1	7.2	9.7	79%	-999	-999	-999	-999	-999	60.6	-999	-999.0	-999.0	-0.1 J	2.6	-999.0	26.3	109.0	122.0	-999.0	-999.0	-999.0
06-Oct-87	4T	0	17.4	-999.0	-999.0	-99900%	16	-999	-999	-999	-999	57.9	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
06-Oct-87	4T	30	15.5	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
06-Oct-87	5	0	17.0	7.6	9.4	102%	14	-999	1 U	-999	-999	57.9	-999	0.2	18.9	0.1 J	2.8	-999.0	29.2	13.0	40.2 J	-999.0	0.7	0.2
06-Oct-87	5	10	17.0	7.8	9.4	101%	-999	-999	-999	-999	-999	56.7	-999	-999.0	-999.0	-0.1 J	11.7	-999.0	42.2	15.8	108.0	-999.0	0.6	0.2
06-Oct-87	5	20	16.8	7.7	9.4	101%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	0.1 J	7.8	-999.0	29.2	8.7 J	81.2	-999.0	0.8	0.2
06-Oct-87	5	40	11.6	7.5	10.1	96%	-999	-999	-999	-999	-999	58.6	-999	-999.0	-999.0	0.1 J	2.4	-999.0	44.4	43.9	88.0	-999.0	-999.0	-999.0
06-Oct-87	5	70	6.9	7.5	10.2	87%	-999	-999	-999	-999	-999	58.7	-999	-999.0	-999.0	-0.1 J	2.9	-999.0	42.2	48.5	114.0	-999.0	-999.0	-999.0
06-Oct-87	5	150	6.2	7.5	11.0	92%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	0.1 J	2.4	-999.0	34.3	77.9	132.0	-999.0	-999.0	-999.0
06-Oct-87	5A	0	16.5	7.8	9.4	100%	13	-999	-999	-999	-999	-999.0	-999	0.4	12.3	0.1 J	3.6	-999.0	33.5	12.8	48.3 J	-999.0	0.8	0.2
06-Oct-87	5A	10	16.4	7.9	9.4	100%	-999	-999	-999	-999	-999	59.8	-999	-999.0	-999.0	-0.1 J	2.6	-999.0	43.7	16.7	60.8 J	-999.0	0.8	0.3
06-Oct-87	5A	20	16.3	7.7	9.5	101%	-999	-999	-999	-999	-999	58.3	-999	-999.0	-999.0	0.1 J	2.4	-999.0	40.8	12.2	60.2 J	-999.0	1.2	-0.7 J
06-Oct-87	5A	40	11.8	7.7	10.3	99%	-999	-999	-999	-999	-999	55.0	-999	-999.0	-999.0	0.1 J	2.9	-999.0	52.4	49.3	133.0	-999.0	-999.0	-999.0
06-Oct-87	6	0	16.1	7.8	9.5	101%	12.5	-999	1 U	2 U	2 U	58.0	-999	0.3	17.9	-0.1 J	2.6	2.0	53.8	17.2	48.2 J	124.0	0.6	0.2
06-Oct-87	6	10	16.0	7.8	9.5	100%	-999	-999	-999	-999	-999	62.8	-999	-999.0	-999.0	-0.1 J	2.4	-999.0	58.2	17.2	59.9 J	-999.0	0.6	0.3
06-Oct-87	6	20	16.0	7.8	9.4	99%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	-0.1 J	3.5	-999.0	35.0	17.3	95.6	-999.0	0.7	0.2
06-Oct-87	6	40	11.4	7.8	9.5	90%	-999	-999	-999	-999	-999	58.4	-999	-999.0	-999.0	2.5	8.0	-999.0	52.4	14.5	63.3 J	-999.0	-999.0	-999.0
06-Oct-87	6	70	6.9	7.7	10.2	87%	-999	-999	-999	-999	-999	59.4	-999	-999.0	-999.0	2.2	4.3	-999.0	48.0	46.3	90.1	-999.0	-999.0	-999.0
06-Oct-87	6	150	6.1	7.5	10.8	90%	-999	-999	-999	-999	-999	58.8	-999	-999.0	-999.0	3.1	1.8	-999.0	50.9	75.2	116.0	-999.0	-999.0	-999.0
06-Oct-87	6	250	5.8	7.4	10.7	88%	-999	-999	-999	-999	-999	58.3	-999	-999.0	-999.0	0.1 J	3.1	-999.0	26.3	77.5	114.0	-999.0	-999.0	-999.0
06-Oct-87	6	380	5.7	7.4	10.7	88%	-999	-999	-999	-999	-999	59.1	-999	-999.0	-999.0	3.6	2.4	-999.0	33.5	79.2	110.0	-999.0	-999.0	-999.0
06-Oct-87	7	0	15.5	7.4	9.4	98%	14	-999	1 U	-999	-999	55.3	-999	0.3	18.4	7.9	2.2	-999.0	130.9	20.8	167.0	-999.0	0.6	0.2
06-Oct-87	7	10	15.4	7.7	9.4	98%	-999	-999	-999	-999	-999	54.5	-999	-999.0	-999.0	0.1 J	5.0	-999.0	61.1	19.2	90.5	-999.0	0.5	0.2
06-Oct-87	7	20	15.3	7.7	9.4	98%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.1 J	7.1	-999.0	48.0	22.7	80.3	-999.0	0.6	0.2
06-Oct-87	7	40	10.6	7.7	9.5	89%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	1.7	3.3	-999.0	90.1	23.9	23.0 J	-999.0	-999.0	-999.0
06-Oct-87	7	70	6.9	7.5	10.3	88%	-999	-999	-999	-999	-999	57.6	-999	-999.0	-999.0	2.8	2.2	-999.0	58.2	72.7	125.0	-999.0	-999.0	-999.0
06-Oct-87	7	150	6.0	7.4	10.4	87%	-999	-999	-999	-999	-999	59.0	-999	-999.0	-999.0	0.1 J	2.8	-999.0	33.5	77.8	133.0	-999.0	-999.0	-999.0
06-Oct-87	7	250	5.8	7.4	10.4	86%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	3.6	2.2	-999.0	46.6	82.7	117.0	-999.0	-999.0	-999.0
06-Oct-87	8	0	15.6	7.9	10.7	112%	11.5	-999	1 U	-999	-999	61.1	-999	0.3	18.4	0.1 J	2.8	2.0	49.5	21.8	56.3 J	101.0	0.5	0.1
06-Oct-87	8	10	15.2	7.8	10.2	106%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	-0.1 J	3.9	-999.0	48.0	21.5	264.0	-999.0	0.6	0.2
06-Oct-87	8	20	15.0	7.8	10.2	105%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.1 J	5.0	-999.0	45.1	23.8	73.6 J	-999.0	0.8	0.2
06-Oct-87	8	40	11.0	7.5	10.8	102%	-999	-999	-999	-999	-999	56.9	-999	-999.0	-999.0	0.4	3.1	-999.0	98.8	54.6	105.0	-999.0	-999.0	-999.0
06-Oct-87	8	70	7.5	7.4	10.7	92%	-999	-999	-999	-999	-999	57.5	-999	-999.0	-999.0	0.1 J	4.3	-999.0	35.0	26.2	144.0	-999.0	-999.0	-999.0
06-Oct-87	8	120	6.4	7.3	10.7	90%	-999	-999	-999	-999	-999	58.0	-999	-999.0	-999.0	0.1 J	2.8	-999.0	45.1	85.8	160.0	-999.0	-999.0	-999.0

DATE	STA	DEP	TEMP	PH	DO	DO_SAT	SECCHI	EXTINCT	FS	FC	TC	COND	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CHLA	PHAEO
03-Nov-87	1	0	13.8	7.0	10.1	101%	-999	-999	1 U	2	8	58.4	0.6	-999.0	18.9	0.2 J	2.8	-999.0	19.2	14.2	98.2	-999.0	0.5	0.6
03-Nov-87	2	0	14.2	7.1	9.9	100%	-999	-999	1 U	2 U	4	57.6	0.4	-999.0	17.4	0.3 J	4.5	3.0	20.0	20.6	65.9	88.5	0.8	0.4
03-Nov-87	2	10	14.2	7.2	9.8	99%	-999	-999	-999	-999	-999	59.2	-999	-999.0	-999.0	0.2 J	2.8	-999.0	19.6	22.9	75.9 J	-999.0	0.7	0.4
03-Nov-87	2	20	14.3	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	-999.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	0.8	0.3
03-Nov-87	3	0	14.2	7.2	9.9	101%	-999	-999	1 U	-999	-999	57.3	-999	-999.0	17.4	0.3 J	2.1	-999.0	21.2	29.3	118.0	-999.0	1.0	0.4
03-Nov-87	3	10	14.3	7.3	10.1	102%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.3 J	2.6	-999.0	17.5	21.0	114.0	-999.0	0.9	0.5
03-Nov-87	3	20	14.3	7.3	10.0	102%	-999	-999	-999	-999	-999	57.1	-999	-999.0	-999.0	0.3 J	2.1	-999.0	18.4	18.9	92.1	-999.0	1.1	0.4
03-Nov-87	3	40	9.4	7.3	10.0	91%	-999	-999	-999	-999	-999	57.3	-999	-999.0	-999.0	0.2 J	3.7	-999.0	11.8	96.6	118.0	-999.0	-999.0	-999.0
03-Nov-87	4	0	14.3	7.3	10.1	103%	-999	-999	1 U	2 U	17	57.2	-999	-999.0	17.4	0.3 J	2.2	1.5	21.2	24.1	62.1 J	98.0	1.1	0.4
03-Nov-87	4	10	14.3	7.3	10.2	104%	-999	-999	-999	-999	-999	57.8	-999	-999.0	-999.0	0.5	8.6	-999.0	17.1	16.8	109.0	-999.0	0.8	0.4
03-Nov-87	4	20	14.4	7.4	10.2	104%	-999	-999	-999	-999	-999	57.4	-999	-999.0	-999.0	0.3 J	4.9	-999.0	38.4	30.5	188.0	-999.0	0.9	0.5
03-Nov-87	4	40	9.2	7.4	10.1	91%	-999	-999	-999	-999	-999	56.7	-999	-999.0	-999.0	0.2 J	2.6	-999.0	18.0	81.5	135.0	-999.0	-999.0	-999.0
03-Nov-87	4	70	5.5	7.3	9.5	78%	-999	-999	-999	-999	-999	59.3	-999	-999.0	-999.0	0.3 J	3.0	-999.0	15.5	106.0	134.0	-999.0	-999.0	-999.0
03-Nov-87	4	100	5.1	7.3	10.0	81%	-999	-999	-999	-999	-999	55.6	-999	-999.0	-999.0	0.3 J	3.5	-999.0	9.0	104.0	94.6	-999.0	-999.0	-999.0
03-Nov-87	4T	0	14.4	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	57.0	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
03-Nov-87	4T	30	13.7	-999.0	-999.0	-99900%	-999	-999	-999	-999	-999	55.7	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
03-Nov-87	5	0	14.3	7.3	10.0	101%	14	-999	1 U	-999	-999	56.5	-999	-999.0	17.4	0.3 J	2.1	-999.0	13.9	22.2	82.2	-999.0	0.9	0.5
03-Nov-87	5	10	14.3	7.4	9.9	100%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.3 J	5.0	-999.0	10.2	14.5	88.6	-999.0	0.7	0.5
03-Nov-87	5	20	14.3	7.4	9.9	101%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.3 J	3.7	-999.0	18.0	18.2	82.2	-999.0	0.8	0.5
03-Nov-87	5	40	12.9	7.5	9.9	98%	-999	-999	-999	-999	-999	56.5	-999	-999.0	-999.0	0.3 J	1.9	-999.0	17.1	17.7	99.0	-999.0	-999.0	-999.0
03-Nov-87	5	70	7.4	7.4	10.2	88%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.3 J	2.4	-999.0	10.6	77.6	64.5 J	-999.0	-999.0	-999.0
03-Nov-87	5	150	6.2	7.4	10.5	88%	-999	-999	-999	-999	-999	56.7	-999	-999.0	-999.0	0.2 J	1.3	-999.0	16.3	39.6	150.0	-999.0	-999.0	-999.0
03-Nov-87	5A	0	14.2	7.4	9.6	97%	12	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.3 J	2.4	-999.0	14.3	18.4	27.1 J	-999.0	0.5	0.4
03-Nov-87	5A	10	14.2	7.5	9.7	98%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.2 J	1.7	-999.0	20.4	17.4	28.9 J	-999.0	0.9	0.1
03-Nov-87	5A	20	14.2	7.5	9.5	96%	-999	-999	-999	-999	-999	56.3	-999	-999.0	-999.0	0.3 J	2.2	-999.0	22.5	13.7	120.2	-999.0	0.6	0.5
03-Nov-87	5A	40	12.3	7.5	9.7	94%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.2 J	2.1	-999.0	13.5	49.1	58.1 J	-999.0	-999.0	-999.0
03-Nov-87	6	0	14.0	7.5	10.0	101%	14.5	-999	1 U	-999	-999	56.4	0.4	-999.0	17.4	0.6	2.1	1.3	24.9	19.1	88.6	92.1	0.6	0.3
03-Nov-87	6	10	14.0	7.5	9.8	99%	-999	-999	-999	-999	-999	55.9	-999	-999.0	-999.0	0.3 J	2.1	-999.0	20.8	19.1	43.5 J	-999.0	0.6	0.4
03-Nov-87	6	20	13.9	7.6	9.8	99%	-999	-999	-999	-999	-999	56.0	-999	-999.0	-999.0	0.2 J	2.6	-999.0	27.4	22.2	84.3	-999.0	0.5	0.3
03-Nov-87	6	40	11.0	7.6	9.7	91%	-999	-999	-999	-999	-999	56.2	-999	-999.0	-999.0	0.3 J	2.5	-999.0	16.3	19.9	81.4	-999.0	-999.0	-999.0
03-Nov-87	6	70	7.2	7.6	10.0	85%	-999	-999	-999	-999	-999	55.2	-999	-999.0	-999.0	0.4 J	2.1	-999.0	11.4	70.0	152.0	-999.0	-999.0	-999.0
03-Nov-87	6	150	6.1	7.5	10.7	89%	-999	-999	-999	-999	-999	57.7	-999	-999.0	-999.0	0.3 J	1.1 J	-999.0	13.5	45.5	82.7	-999.0	-999.0	-999.0
03-Nov-87	6	250	5.8	7.5	10.4	86%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.3 J	1.7	-999.0	14.7	83.5	127.0	-999.0	-999.0	-999.0
03-Nov-87	6	380	5.7	7.4	11.2	93%	-999	-999	-999	-999	-999	56.4	-999	-999.0	-999.0	0.2 J	1.1 J	-959.0	10.6	85.1	69.1 J	-999.0	-999.0	-999.0
03-Nov-87	7	0	13.9	7.7	10.5	106%	14.5	-999	1 U	-999	-999	55.4	-999	-999.0	16.9	0.3 J	1.9	-999.0	26.9	22.9	57.2 J	-999.0	0.3	0.2
03-Nov-87	7	10	13.6	7.7	10.5	105%	-999	-999	-999	-999	-999	55.8	-999	-999.0	-999.0	0.3 J	2.8	-999.0	25.7	26.1	162.0	-999.0	0.8	0.4
03-Nov-87	7	20	13.6	7.7	10.4	104%	-999	-999	-999	-999	-999	55.7	-999	-999.0	-999.0	0.3 J	4.1	-999.0	19.2	20.3	39.9 J	-999.0	0.6	0.3
03-Nov-87	7	40	9.6	7.7	10.4	94%	-999	-999	-999	-999	-999	55.7	-999	-999.0	-999.0	0.2 J	2.1	-999.0	28.2	25.2	101.0	-999.0	-999.0	-999.0
03-Nov-87	7	70	6.8	7.6	11.1	94%	-999	-999	-999	-999	-999	54.9	-999	-999.0	-999.0	0.3 J	1.9	-999.0	17.5	76.2	130.0	-999.0	-999.0	-999.0
03-Nov-87	7	150	6.1	7.6	10.8	90%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.3 J	1.7	-999.0	14.7	93.4	165.0	-999.0	-999.0	-999.0
03-Nov-87	7	250	5.9	7.5	10.9	90%	-999	-999	-999	-999	-999	56.6	-999	-999.0	-999.0	0.3 J	0.9 J	-999.0	12.2	91.0	143.0	-999.0	-999.0	-999.0
03-Nov-87	8	0	13.5	7.5	10.1	101%	12	-999	1 U	-999	-999	56.2	-999	-999.0	16.9	0.2 J	2.1	1.5	21.6	25.3	50.8 J	41.7 J	0.8	0.4
03-Nov-87	8	10	13.4	7.6	10.1	101%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.3 J	5.2	-999.0	25.6	26.6	77.3 J	-999.0	0.8	0.4
03-Nov-87	8	20	13.4	7.6	10.2	101%	-999	-999	-999	-999	-999	56.1	-999	-999.0	-999.0	0.2 J	4.5	-999.0	26.1	25.8	43.5 J	-999.0	0.8	0.4
03-Nov-87	8	40	10.4	7.6	10.2	94%	-999	-999	-999	-999	-999	55.3	-999	-999.0	-999.0	0.2 J	1.9	-999.0	25.3	25.5	39.0 J	-999.0	-999.0	-999.0
03-Nov-87	8	70	6.9	7.6	10.2	87%	-999	-999	-999	-999	-999	55.5	-999	-999.0	-999.0	0.2 J	2.9	-999.0	14.3	54.6	124.3	-999.0	-999.0	-999.0
03-Nov-87	8	120	6.4	7.5	10.7	90%	-999	-999	-999	-999	-999	56.8	-999	-999.0	-999.0	0.2 J	6.5	-999.0	16.3	92.2	156.0	-999.0	-999.0	-999.0

Lake Chelan database documentation: explanation of field names and data qualifiers for the TRIBS database.

FIELD NAME	PARAMETER	UNITS
STA	Station	--
DATE	Date	--
FLOW	Discharge	cfs
TEMP	Temperature	degrees C
PH	pH	SU
DO	Dissolved Oxygen	mg/L
F_COND	Specific Conductance (Field)	umho/cm @ 25C
L_COND	Specific Conductance (Lab)	umho/cm @ 25C
FS	Fecal Streptococci	#/100mL
FC	Fecal Coliform	#/100mL
TC	Total Coliform	#/100mL
TSS	Total Suspended Solids	mg/L
TURB	Turbidity	NTU
ALK	Alkalinity	mg CaCO3 /L
SRP	Soluble Reactive P	ug P /L
TP	Total P	ug P /L
TSP	Total Soluble P	ug P /L
NH3N	Ammonia N	ug N /L
NO23N	Nitrite+Nitrate N	ug N /L
TUVN	Total N (UV)	ug N /L
TSUVN	Total Soluble N (UV)	ug N /L
CL	Chloride	mg/L

MISSING DATA CODE: -999

DATA QUALIFIERS:

J = Estimated value: value not accurate
U = Analyzed but not detected. The number reported is the detection limit.
P = Greater than (>).

STN	TYPE	DATE	FLOW	TEMP	PH	DO	F_COND	L_COND	FS	FC	TC	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CL
AG-06	AG	15-Dec-86	0.099	9.7	-999.0	-999.0	420	484.0	1 U	-999	-999	-999	-999.0	166.7	113.1	85.2	-999.0	15.5	7937	-999	-999	-999.0
AG-06	AG	19-Jan-87	0.21	8.5	7.4	11.1	434	467.0	1 U	-999	-999	0.2	0.4	180.5	141.2	121.5	-999.0	3.9	7354	7682	-999	-999.0
AG-06	AG	24-Feb-87	0.2	7.9	7.1	11.2	457	528.2	2	8	2 U	0.4	0.5	-999.0	168.6	157.5	-999.0	10.3	7613	7734	-999	-999.0
AG-06	AG	30-Mar-87	0.24	8.1	7.0	11.3	461	539.4	140	-999	-999	0.3	-999.0	-999.0	170.7	205.2	-999.0	30.3	7450	9164	-999	-999.0
AG-06	AG	27-Apr-87	0.29	11.0	7.5	10.5	404	519.7	1 U	2 U	50	-999	-999.0	174.7	109.9	176.8	-999.0	10.4	7917	8280	-999	-999.0
DOE#8	AG	15-Apr-86	0.3	-999.0	-999.0	-999.0	400	-999.0	-999	3 U	-999	-999	-999.0	-999.0	-999.0	240.0	-999.0	10.0	9500	-999	-999	-999.0
AG-06	AG	26-May-87	0.2 J	-999.0	-999.0	-999.0	-999	432.3	8	-999	-999	0.4	-999.0	-999.0	141.1	152.9 J	-999.0	4.8	8504	8550	-999	-999.0
AG-06	AG	15-Jun-87	1.2	11.4	7.1	11.0	338	429.2	26	2 U	240	-999	-999.0	-999.0	168.5	179.2	-999.0	3.8	8526	6043	-999	-999.0
AG-06	AG	06-Jul-87	0.71	12.7	7.1	9.5	342	430.0	18	-999	-999	-0.1	-999.0	-999.0	130.3	159.1	-999.0	4.5	7385	9092	-999	-999.0
AG-06	AG	27-Jul-87	0.29	13.0	7.0	10.0	335	443.9	7	-999	-999	-999	-999.0	-999.0	-999.0	184.3	172.1	0.8	6347	7906	6405	4.9
AG-06	AG	17-Aug-87	1.6	13.7	7.0	9.0	329	412.5	5	2 U	30	-999	-999.0	-999.0	180.3	192.1	-999.0	3.1	4890	-999	-999	-999.0
AG-06	AG	09-Sep-87	0.34	15.0	6.8	9.1	299	418.5	110	2 U	220	0.28	-999.0	-999.0	182.3	198.4	-999.0	19.0	5872	7333	-999	-999.0
AG-06	AG	05-Oct-87	0.4 J	13.5	7.0	9.0	-999	431.7	57	-999	-999	-999	-999.0	-999.0	192.4	208.1	-999.0	19.0	6027	7207	-999	-999.0
AG-06	AG	02-Nov-87	0.16 J	12.5	7.1	10.4	355	351.4	6	2 U	33	0.8	-999.0	-999.0	369.8	360.1	-999.0	15.1	5956	7434	-999	2.0
AG-06 WS	AG	26-May-87	-999	11.1	-999.0	-999.0	366	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	146.4	-999.0	-999.0	-999	7609	-999	-999.0
AG-08	AG	15-Dec-86	0.082 J	8.7	-999.0	-999.0	-999	553.5	6	-999	-999	-999	-999.0	186.2	86.1	41.2	-999.0	17.1	8086	-999	-999	-999.0
AG-08	AG	19-Jan-87	0.16	7.1	7.4	10.4	498	526.8	47	-999	-999	-999	0.7	190.5	113.6	83.9	-999.0	1.2	7089	7689	-999	-999.0
AG-08	AG	24-Feb-87	0.4	7.5	7.2	7.5	556	599.1	118	-999	-999	-999	0.4	203.1	126.2	112.1	-999.0	18.2	9163	8632	-999	-999.0
AG-08	AG	30-Mar-87	0.19	9.1	7.1	10.0	501	595.7	900	-999	-999	-999	-999.0	-999.0	118.4	133.9	-999.0	20.6	9177	6563	-999	-999.0
AG-08	AG	27-Apr-87	0.12	11.0	7.3	10.1	478	597.4	28	-999	-999	-999	-999.0	-999.0	94.4	111.9	-999.0	1.6	8684	7362	-999	-999.0
AG-08	AG	15-Jun-87	0.24	14.1	7.3	9.6	-999	538.5	130	-999	-999	-999	-999.0	-999.0	102.6	110.5	-999.0	3.3	9301	7132	-999	-999.0
AG-08	AG	06-Jul-87	0.591 J	12.3	7.3	-999.0	452	550.7	172	-999	-999	-999	-999.0	-999.0	103.3	120.5	-999.0	11.8	7704	9654	-999	-999.0
AG-08	AG	27-Jul-87	0.242 J	13.8	7.1	9.8	458	557.3	29	-999	-999	-999	-999.0	-999.0	212.7	139.2	-999.0	3.9	7012	8309	-999	-999.0
AG-08	AG	17-Aug-87	1.333 J	15.0	7.1	8.6	476	566.8	25	-999	-999	-999	-999.0	-999.0	120.1	120.4	-999.0	-999.0	-999	9293	-999	-999.0
AG-08	AG	09-Sep-87	0.283 J	16.2	7.1	8.8	386	550.2	280	-999	-999	-999	-999.0	-999.0	77.3	107.5	-999.0	18.3	7996	9383	-999	-999.0
AG-08	AG	05-Oct-87	0.333 J	14.5	7.1	7.0	-999	533.8	103	-999	-999	-999	-999.0	-999.0	121.9	121.6	-999.0	23.4	7812	9111	-999	-999.0
AG-08	AG	02-Nov-87	0.133 J	13.0	7.1	10.2	453	528.0	150	-999	-999	-999	-999.0	-999.0	111.8	234.4	-999.0	23.7	7598	9182	-999	-999.0
AG-11	AG	15-Dec-86	0.063	9.8	-999.0	-999.0	445	515.2	9	-999	-999	-999	-999.0	190.0	189.1	198.9	-999.0	17.5	6427	15571	-999	-999.0
AG-11	AG	19-Jan-87	0.037	8.1	7.4	10.8	446	511.5	14	-999	-999	-999	7.7	209.0	422.2	406.7	-999.0	5.6	7007	6921	-999	-999.0
AG-11	AG	24-Feb-87	0.072	7.0	6.8	10.1	517	594.9	52	-999	-999	-999	0.7	-999.0	189.8	246.6	-999.0	22.6	7514	7413	-999	-999.0
AG-11	AG	30-Mar-87	0.08	7.8	6.5	10.3	450	607.6	840	-999	-999	-999	-999.0	-999.0	216.9	248.1	-999.0	49.7	8588	8607	-999	-999.0
AG-11	AG	27-Apr-87	0.039	9.2	7.1	9.6	470	572.8	96	-999	-999	-999	-999.0	-999.0	247.4	302.9	-999.0	1.0	7915	7809	-999	-999.0
AG-11	AG	15-Jun-87	0.098	12.1	7.0	10.2	441	548.1	590	-999	-999	-999	-999.0	-999.0	262.0	262.7	-999.0	3.8	9987	6270	-999	-999.0
AG-11	AG	06-Jul-87	0.08	-999.0	-999.0	-999.0	-999	518.6	380	-999	-999	-999	-999.0	-999.0	218.0	251.7	-999.0	13.7	7172	8057	-999	-999.0
AG-11	AG	27-Jul-87	0.06	14.1	6.8	8.8	410	519.2	868	-999	-999	-999	-999.0	-999.0	-999.0	285.4	-999.0	-0.2	7214	8511	-999	-999.0
AG-11	AG	17-Aug-87	0.31	15.0	6.8	8.2	408	528.6	86	-999	-999	-999	-999.0	-999.0	300.0	316.9	-999.0	4.0	5280	6200	-999	-999.0
AG-11	AG	09-Sep-87	0.17	15.1	6.7	7.6	408	577.3	1200 J	-999	-999	-999	-999.0	-999.0	387.4	438.0	-999.0	23.4	9027	9942	-999	-999.0
AG-11	AG	05-Oct-87	0.14	14.8	7.0	7.9	-999	390.8	310	-999	-999	-999	-999.0	-999.0	343.6	353.0	-999.0	326.2	6075	7296	-999	-999.0
AG-11	AG	02-Nov-87	-999	13.0	7.1	10.8	535	483.0	400	-999	-999	-999	-999.0	-999.0	730.4	653.1	-999.0	205.8	5837	6810	-999	-999.0
First	FI	15-Dec-86	0.84	4.0	-999.0	-999.0	127	140.5	5	-999	-999	-999	-999.0	58.0	3.9	6.5	-999.0	20.2	87	109	-999	-999.0
First	FI	19-Jan-87	2.3	1.9	7.1	12.0	125	133.9	1 U	-999	-999	-999	1.5	61.0	14.1	7.5	-999.0	-0.6 J	83	101	-999	-999.0
First	FI	24-Feb-87	3.4	3.5	7.6	11.3	124	141.4	3	-999	-999	1.4	0.9	-999.0	2.3	9.1	-999.0	1.5 J	77	102	-999	-999.0
First	FI	30-Mar-87	1.1	7.9	7.3	11.8	120	141.4	5	-999	-999	-999	-999.0	-999.0	0.2 J	7.2	-999.0	35.1	111	110	-999	-999.0
First	FI	27-Apr-87	4.9	9.4	8.1	9.6	113	131.1	34	-999	-999	-999	-999.0	-999.0	0.4	17.4	-999.0	8.2	32	92	-999	-999.0
DOE#4	FI	15-Apr-86	5.63	-999.0	-999.0	-999.0	100	-999.0	-999	3 U	-999	-999	-999.0	-999.0	-999.0	350.0	-999.0	10.0	40	-999	-999	-999.0
First	FI	26-May-87	13.2	10.0	7.5	11.8	104	124.5	44	-999	-999	-999	-999.0	-999.0	1.3	12.6	-999.0	4.8	31	54 J	-999	-999.0
First	FI	15-Jun-87	7.6	11.0	7.9	10.6	96	120.2	48	-999	-999	-999	-999.0	-999.0	1.2	9.6	-999.0	3.8 J	21	39 J	-999	-999.0
First	FI	06-Jul-87	5.5	10.8	7.6	10.0	103	121.7	136	-999	-999	-999	-999.0	-999.0	1.0	9.3	-999.0	9.3	52	70 J	-999	-999.0
First	FI	27-Jul-87	3.4	11.0	7.1	9.3	109	127.0	268	-999	-999	-999	-999.0	-999.0	3.4	10.4	-999.0	4.6 J	92	101	-999	-999.0
First	FI	17-Aug-87	6.2	11.1	7.8	10.4	106	129.8	105	-999	-999	-999	-999.0	-999.0	2.4	15.5	-999.0	7.3	67	130	-999	-999.0
First	FI	07-Sep-87	3.4	12.0	6.8	9.2	105	135.6	524	-999	-999	-999	-999.0	-999.0	2.6	13.5	-999.0	26.2	-999	120	-999	-999.0
First	FI	05-Oct-87	3.5	9.2	7.7	11.0	-999	127.7	79	-999	-999	-999	-999.0	-999.0	3.0	11.7	-999.0	59.6	116	146	-999	-999.0
First	FI	02-Nov-87	3.2	8.2	7.3	11.8	278	104.8	26	-999	-999	-999	-999.0	-999.0	0.2 J	7.5	-999.0	5.3	66	162	-999	-999.0

STA	TYPE	DATE	FLOW	TEMP	PH	DO	F_COND	L_COND	FS	FC	TC	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CL
Mitchell	MI	16-Dec-86	4.1	2.1	8.2	12.0	297	340.6	5	-999	-999	-999	-999.0	130.8	10.0	14.3	-999.0	3.6 J	13	64 J	-999	-999.0
Mitchell	MI	20-Jan-87	1.0	-0.5	8.2	12.1	302	311.4	86	-999	-999	-999	1.1	130.9	14.2	13.0	-999.0	-0.2 J	43	69 J	-999	-999.0
Mitchell	MI	25-Feb-87	0.78	-0.5	8.1	13.0	302	355.8	100	-999	-999	-999	1.1	-999.0	13.4	18.0	-999.0	-1.9 J	26	41 J	-999	-999.0
Mitchell	MI	31-Mar-87	2.0	6.0	8.3	11.5	281	326.0	350	-999	-999	2.4	-999.0	-999.0	10.7	17.1	-999.0	-1.2 J	8 J	8 J	-999	-999.0
Mitchell	MI	28-Apr-87	4.6	11.1	8.2	9.4	230	281.5	40	-999	-999	-999	-999.0	-999.0	8.2	37.2	-999.0	3.6 J	2 J	53 J	-999	-999.0
Mitchell	MI	27-May-87	4.5	12.1	8.4	10.6	255	312.0	180	-999	-999	1.8	-999.0	-999.0	9.0	28.1	-999.0	-23.4	4 J	94	-999	-999.0
Mitchell	MI	16-Jun-87	4.9	12.0	8.6	10.2	216	297.3	530	-999	-999	-999	-999.0	-999.0	7.4	27.5	-999.0	-0.4 J	5 J	39 J	-999	-999.0
Mitchell	MI	06-Jul-87	1.8	10.4	8.2	9.9	273	278.4	236	-999	-999	0.9	-999.0	-999.0	7.2	14.6	-999.0	8.6	21	44 J	-999	-999.0
Mitchell	MI	28-Jul-87	2.4	15.5	8.5	10.8	258	327.1	102	-999	-999	-999	-999.0	-999.0	7.3	18.7	16.2	8.0	5 J	35 J	134	-999.0
Mitchell	MI	18-Aug-87	1.7	11.9	8.4	11.2	276	337.8	40	240	300	-999	-999.0	-999.0	5.0	9.5	-999.0	7.7	5 J	36 J	-999	-999.0
Mitchell	MI	07-Sep-87	1.3	13.8	8.5	10.3	252	342.1	40	-999	-999	-999	-999.0	-999.0	7.1	14.7	-999.0	16.5	5 J	48 J	-999	-999.0
Mitchell	MI	06-Oct-87	2.3	9.5	8.3	11.0	-999	339.1	70	-999	-999	0.66	-999.0	-999.0	10.6	23.8	-999.0	36.4	5 J	69 J	-999	-999.0
Mitchell	MI	03-Nov-87	0.95	12.0	7.5	10.7	253	315.8	4	2 U	49	0.8	-999.0	-999.0	7.8	11.0	-999.0	10.6	5 J	30 J	-999	-999.0
Knapp	KN	27-Apr-87	0.042	12.3	8.2	9.3	553	672.7	28	-999	-999	-999	-999.0	-999.0	114.5	216.0	-999.0	24.8	4066	4542	-999	-999.0
DOE#3	KN	15-Apr-86	0.03	-999.0	-999.0	-999.0	550	-999.0	-999	43	-999	-999	-999.0	-999.0	-999.0	390.0	-999.0	20.0	5200	-999	-999	-999.0
Knapp	KN	26-May-87	0.077	7.8	-999.0	-999.0	636	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	197.1	-999.0	-999.0	-999	4130	-999	-999.0
Knapp	KN	15-Jun-87	0.033	14.0	8.3	9.2	506	644.1	2000 P	-999	-999	-999	-999.0	-999.0	163.5	232.9	-999.0	74.1	5437	3984	-999	-999.0
Knapp	KN	06-Jul-87	0.14	12.4	-999.0	-999.0	593	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	224.2	-999.0	-999.0	-999	4917	-999	-999.0
Knapp	KN	07-Sep-87	0.13	13.9	8.3	15.0	501	691.3	848	-999	-999	-999	-999.0	-999.0	182.3	240.5	-999.0	10.4	3905	4247	-999	-999.0
Purtteman	PU	27-Apr-87	1.1	14.7	8.8	10.1	497	600.9	100	-999	-999	-999	-999.0	-999.0	120.7	184.2	-999.0	11.7	-999	4018	-999	-999.0
DOE#18	PU	16-Apr-86	0.66	-999.0	-999.0	-999.0	600	-999.0	-999	1 U	-999	-999	-999.0	-999.0	-999.0	100.0	-999.0	10.0	3000	-999	-999	-999.0
Purtteman	PU	26-May-87	1.0	-999.0	-999.0	-999.0	-999	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	176.2	-999.0	-999.0	-999	4276	-999	-999.0
Purtteman	PU	15-Jun-87	0.93	14.5	8.6	9.5	457	600.6	200	-999	-999	-999	-999.0	-999.0	135.5	164.3	-999.0	16.1	5557	5822	-999	-999.0
Purtteman	PU	06-Jul-87	0.92	14.2	8.3	9.3	506	608.4	520	-999	-999	-999	-999.0	-999.0	160.9	193.0	-999.0	27.8	1887	4595	-999	-999.0
Purtteman	PU	07-Sep-87	0.93	15.4	8.2	9.2	454	620.0	328	-999	-999	-999	-999.0	-999.0	190.8	199.7	-999.0	36.1	3700	4858	-999	-999.0
Stink	MSC	30-Mar-87	1.4	8.6	8.2	13.6	617	730.6	21	-999	-999	-999	-999.0	-999.0	4.3	34.0	-999.0	52.1	350	893	-999	-999.0
Wapato Lake	MSC	30-Mar-87	1.6	8.1	8.2	16.8	422	503.9	1 U	-999	-999	-999	-999.0	-999.0	29.6	80.4	-999.0	33.9	2 J	211	-999	-999.0
Stink	MSC	27-Apr-87	0.29	21.0	8.4	12.2	660	-999.0	84	30	110	-999	-999.0	-999.0	12.1	46.7	-999.0	-999.0	194	878	-999	-999.0
Wapato Lake	MSC	27-Apr-87	1.4	16.8	8.5	13.6	427	-999.0	1 U	-999	-999	-999	-999.0	-999.0	22.9	89.8	-999.0	6.5	5 J	428	-999	-999.0
DOE#6	MSC	15-Apr-86	1.5	-999.0	-999.0	-999.0	400	-999.0	-999	43	-999	-999	-999.0	-999.0	-999.0	90.0	-999.0	20.0	10	-999	-999	-999.0
DOE#7	MSC	15-Apr-86	1.5	-999.0	-999.0	-999.0	600	-999.0	-999	23	-999	-999	-999.0	-999.0	-999.0	70.0	-999.0	20.0	290	-999	-999	-999.0
Wapoto Lake	MSC	26-May-87	0.46 J	-999.0	-999.0	-999.0	-999	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	108.7	-999.0	-999.0	-999	-999	-999	-999.0
Stink	MSC	26-May-87	0.44	-999.0	-999.0	-999.0	-999	-999.0	2000 P	-999	-999	-999	-999.0	-999.0	-999.0	101.5	-999.0	-999.0	-999	708	-999	-999.0
Greens Landing	MSC	26-May-87	0.9 J	16.2	-999.0	-999.0	528	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999	-999	-999	-999.0
Stink	MSC	15-Jun-87	0.13	23.2	8.3	11.2	715	796.6	380	-999	-999	-999	-999.0	-999.0	4.6	37.6	-999.0	7.6	5 J	984	-999	-999.0
Wapato Lake	MSC	15-Jun-87	0.46	21.5	8.7	12.0	377	503.2	21	-999	-999	-999	-999.0	-999.0	68.2	108.7	-999.0	8.0	5 J	565	-999	-999.0
Greens Landing	MSC	06-Jul-87	0.486 J	16.0	8.2	9.4	368	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999.0	142.2	-999.0	-999.0	-999	1348	-999	-999.0
Wapato Lake	MSC	06-Jul-87	0.43	22.7	7.5	6.8	441	527.1	4	-999	-999	-999	-999.0	-999.0	91.1	144.8	-999.0	12.4	5 J	512	-999	-999.0
Stink	MSC	06-Jul-87	0.056	-999.0	-999.0	-999.0	-999	863.8	160	-999	-999	-999	-999.0	-999.0	2.1	25.4	-999.0	15.2	5 J	742	-999	-999.0
Wapato Lake	MSC	27-Jul-87	0.1	26.5	8.3	14.0	438	-999.0	4	-999	-999	-999	-999.0	-999.0	46.6	112.8	-999.0	15.2	5 J	259	-999	-999.0
Greens Landing	MSC	07-Sep-87	0.05	20.0	8.4	9.7	354	480.3	132	-999	-999	-999	-999.0	-999.0	41.6	54.9	-999.0	31.0	162	-999	-999	-999.0
25 Mile	RND	16-Dec-86	5.5	2.1	8.1	12.7	187	177.4	4	-999	-999	-999	-999.0	62.5	2.3	4.9	-999.0	-2.4 J	10	4 J	-999	-999.0
Canoe	RND	16-Dec-86	0.18	3.9	7.9	12.1	147	164.6	1	-999	-999	-999	-999.0	67.1	0.4	1.8	-999.0	5.5	15	15 J	-999	-999.0
Granite Falls	RND	20-Jan-87	0.1	0.1	7.0	13.0	158	169.6	23	-999	-999	-999	1.1	79.6	17.1	20.1	-999.0	1.7 J	2 J	9 J	-999	-999.0
Purple	RND	20-Jan-87	0.02	4.0	6.6	10.6	37	35.2	2	-999	-999	-999	0.3	15.2	1.6	4.0	-999.0	-0.6 J	3 J	111	-999	-999.0
Coyote	RND	25-Feb-87	0.33	3.0	7.8	11.6	121	133.3	1 U	-999	-999	-999	1.2	-999.0	10.2	16.2	-999.0	-2.4 J	22	89	-999	-999.0
Deep Harbor	RND	25-Feb-87	1.4	0.9	7.6	11.6	135	140.8	3	-999	-999	-999	1.1	-999.0	2.4	5.9	-999.0	-3.9 J	83	52 J	-999	-999.0
Little	RND	31-Mar-87	4.0	4.9	7.5	11.9	55	59.4	13	-999	-999	-999	-999.0	-999.0	0.0 J	2.3	-999.0	13.9	22	50 J	-999	-999.0
Cascade	RND	31-Mar-87	2.8	6.5	8.0	11.3	118	134.7	55	-999	-999	-999	-999.0	-999.0	0.0 J	1.7	-999.0	12.1	5 J	59 J	-999	-999.0

STA	TYPE	DATE	FLOW	TEMP	PH	DO	F_COND	L_COND	FS	FC	TC	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CL
Prince	RND	28-Apr-87	136	9.0	7.6	9.8	36	43.2	2	-999	-999	2.4	-999.0	-999.0	0.1 J	9.6	-999.0	0.7 J	29	116	-999	-999.0
Pioneer	RND	28-Apr-87	0.571	11.0	8.0	9.6	115	139.9	1 U	-999	-999	-999	-999.0	-999.0	1.5	12.8	-999.0	-999.0	5 J	104	-999	-999.0
Poison	RND	27-May-87	6.6	10.3	7.6	14.6	83	93.8	12	-999	-999	2.2	-999.0	-999.0	7.7	15.1	-999.0	4.8	5 J	47 J	-999	-999.0
4 Mile	RND	27-May-87	35	11.0	7.8	-999.0	-999	40.3	13	-999	-999	-999	-999.0	-999.0	0.8	5.3	-999.0	4.5 J	5 J	142	-999	-999.0
Canyon	RND	16-Jun-87	2.6	8.2	7.2	10.2	29	33.0	2	-999	-999	0.3	-999.0	-999.0	0.7	2.4	-999.0	4.7 J	5 J	39 J	-999	-999.0
Hazard	RND	16-Jun-87	0.44	10.0	7.8	9.8	88	105.8	28	-999	-999	-999	-999.0	-999.0	1.5	3.2	-999.0	4.3 J	4 J	39 J	-999	-999.0
Safety Harbor	RND	07-Jul-87	9.4	12.8	7.7	9.8	59	66.2	12	-999	-999	-999	-999.0	-999.0	2.9	4.4	-999.0	14.0	5 J	128	-999	-999.0
Devore	RND	07-Jul-87	24	11.9	7.3	10.2	44	52.1	1	-999	-999	-999	-999.0	-999.0	0.2 J	1.2 J	-999.0	6.8	10	46 J	-999	-999.0
Rex	RND	07-Jul-87	0.1	14.1	7.9	9.9	160	148.9	7	-999	-999	0.1 J	-999.0	-999.0	2.2	3.6	-999.0	8.9	5 J	35 J	-999	-999.0
Grade	RND	28-Jul-87	3.8	14.8	7.7	11.2	87	109.9	128	-999	-999	2.7	-999.0	-999.0	9.0	12.6	-999.0	-0.9 J	7 J	39 J	-999	-999.0
Little Big	RND	18-Aug-87	0.49	11.0	8.1	9.8	177	214.5	14	-999	-999	-999	-999.0	-999.0	1.8	4.3	-999.0	4.9	5 J	21 J	-999	-999.0
Domke	RND	18-Aug-87	3.8	15.0	7.8	9.3	-999	54.3	59	-999	-999	0.8	-999.0	-999.0	0.8	4.3	-999.0	9.2	13	39 J	-999	-999.0
Fish	RND	08-Sep-87	2.7	15.0	8.0	9.2	74	93.0	24	-999	-999	0.1 J	-999.0	-999.0	0.2 J	3.6	-999.0	14.1	5 J	21 J	-999	-999.0
Falls	RND	08-Sep-87	1.1	14.3	8.0	9.2	60	78.0	37	-999	-999	-999	-999.0	-999.0	6.8	9.9	-999.0	15.5	5 J	101	-999	-999.0
Lightning	RND	06-Oct-87	2.4	9.6	7.7	10.8	-999	-999.0	75	-999	-999	-999	-999.0	-999.0	1.2	12.8	-999.0	32.1	18	81	-999	-999.0
Bear	RND	06-Oct-87	6.3	8.3	7.5	10.3	-999	-999.0	32	-999	-999	-999	-999.0	-999.0	0.1 J	4.6	-999.0	45.1	29	61 J	-999	-999.0
Riddle	RND	03-Nov-87	2.8	8.0	7.3	11.1	67	-999.0	14	-999	-999	-999	-999.0	-999.0	0.5	1.9	-999.0	11.4	5 J	43 J	-999	-999.0
Pyramid	RND	03-Nov-87	1.0	11.0	8.2	10.2	48	-999.0	34	-999	-999	-999	-999.0	-999.0	0.3 J	1.9	-999.0	19.2	29	124	-999	-999.0
Railroad	RR	16-Dec-86	75	-999.0	7.2	12.2	-999	97.8	1	-999	-999	-999	-999.0	20.3	0.5	1.1 J	-999.0	8.6	90	115	-999	-999.0
Railroad	RR	20-Jan-87	71.9	-0.8	-999.0	-999.0	-999	101.5	1	-999	-999	0.2	1.3	19.8	0.9	2.4	-999.0	-0.7 J	147	82	-999	-999.0
Railroad	RR	25-Feb-87	31.9	0.0	7.2	11.5	107	113.6	1 U	-999	-999	1	4.9	-999.0	0.5	1.0 J	-999.0	-3.9 J	93	75 J	-999	-999.0
Railroad	RR	31-Mar-87	99.6	5.0	6.7	12.1	-999	107.4	1 U	-999	-999	0.4	-999.0	-999.0	1.0	0.9 J	-999.0	0.6 J	81	66 J	-999	-999.0
Railroad	RR	28-Apr-87	442	8.3	7.4	9.6	54	60.5	1 U	-999	-999	21.8	-999.0	-999.0	0.1 J	7.0	-999.0	0.7 J	157	318	-999	-999.0
Railroad	RR	26-May-87	537	-999.0	-999.0	-999.0	-999	45.7	2	-999	-999	1.2	-999.0	-999.0	0.2 J	6.7	-999.0	14.7	66	102	-999	-999.0
Railroad	RR	16-Jun-87	532	9.3	7.0	9.8	33	39.5	10	8	140	2.2	-999.0	-999.0	1.0	6.4	-999.0	3.3 J	43	61 J	-999	-999.0
Railroad	RR	07-Jul-87	269	14.0	7.5	10.4	41	49.0	4	-999	-999	0.1 J	-999.0	-999.0	0.2 J	3.0	-999.0	7.5	30	156	-999	-999.0
Railroad	RR	28-Jul-87	209	15.2	-999.0	-999.0	41	51.6	4	-999	-999	1.2	-999.0	-999.0	0.4	2.5	-999.0	0.5 J	31	108	-999	-999.0
Railroad	RR	18-Aug-87	123	11.5	7.7	9.7	58	66.7	17	-999	-999	0.4	-999.0	-999.0	0.2 J	2.8	-999.0	5.2	42	65 J	-999	-999.0
Railroad	RR	08-Sep-87	128	13.0	7.8	10.2	51	59.2	21	-999	-999	0.98	-999.0	-999.0	0.2 J	3.6	-999.0	19.0	34	60 J	-999	-999.0
Railroad	RR	06-Oct-87	73.6	8.0	7.4	11.2	-999	88.9	25	2 U	23	0.52	-999.0	-999.0	0.1 J	2.2	-999.0	33.5	48	57 J	-999	-999.0
Railroad	RR	03-Nov-87	46.5	6.5	7.4	11.6	88	105.4	34	-999	-999	0.4	-999.0	-999.0	0.5	1.3 J	-999.0	13.0	32	101	-999	-999.0
Stehekin	ST	16-Dec-86	319	2.0	7.2	12.2	62	63.0	2	-999	-999	-999	-999.0	21.5	0.4	2.6	-999.0	14.8	7 J	73 J	-999	-999.0
Stehekin	ST	20-Jan-87	230	0.0	7.3	11.8	75	62.5	1	-999	-999	0.1 J	1.0	22.1	1.0	2.8	-999.0	1.3 J	154	111	-999	-999.0
Stehekin	ST	25-Feb-87	240	1.4	7.1	11.7	60	61.6	1 U	2 U	7	0.6	0.3	-999.0	0.5	0.8 J	-999.0	-2.9 J	79	137	-999	-999.0
Stehekin	ST	31-Mar-87	594	7.2	7.6	11.3	58	63.6	-999	-999	-999	0.3	-999.0	-999.0	0.2 J	3.4	-999.0	1.2 J	71	78	-999	-999.0
Stehekin	ST	27-Apr-87	4030	5.0	7.5	10.2	-999	51.0	1 U	-999	-999	3.5	-999.0	-999.0	0.0 J	7.0	-999.0	-0.6 J	106	168	-999	-999.0
Stehekin	ST	26-May-87	3440	-999.0	-999.0	-999.0	-999	39.1	1 U	-999	-999	2.8	-999.0	-999.0	0.4	7.8	-999.0	10.1	74	174	-999	-999.0
Stehekin	ST	16-Jun-87	3040	7.3	7.1	10.3	35	38.8	4	4	7	3.7	-999.0	-999.0	0.8	5.8	-999.0	2.4 J	36	75 J	-999	-999.0
Stehekin	ST	07-Jul-87	1660	9.9	7.2	13.2	35	43.3	1 U	-999	-999	0.3	-999.0	-999.0	0.3 J	3.6	-999.0	0.3 J	32	39 J	-999	-999.0
Stehekin	ST	28-Jul-87	1250	13.0	-999.0	-999.0	35	43.6	2	1.8 U	4.5	5	-999.0	-999.0	0.4	6.5	-999.0	7.3	26	25 J	-999	-999.0
Stehekin	ST	18-Aug-87	640	13.2	7.6	9.6	45	50.7	2	-999	-999	5.2	-999.0	-999.0	0.4	7.5	-999.0	7.0	34	37 J	-999	-999.0
Stehekin	ST	08-Sep-87	668	8.0	7.7	9.9	44	46.2	4	-999	-999	11.4	-999.0	-999.0	0.5	12.5	-999.0	19.6	26	39 J	-999	-999.0
Stehekin	ST	06-Oct-87	350	9.8	7.3	10.4	-999	52.7	1 U	2 U	8	1.48	-999.0	-999.0	0.3 J	4.6	-999.0	55.3	28	68 J	-999	-999.0
Stehekin	ST	03-Nov-87	174	8.0	7.4	10.7	50	62.2	1 U	-999	-999	1.2	-999.0	-999.0	0.3 J	3.0	-999.0	15.9	11	34 J	-999	-999.0
URB-1	URB	15-Dec-86	0.07	5.1	-999.0	-999.0	758	797.7	4900	-999	-999	-999	-999.0	32.9	1.7	341.8	-999.0	149.0	447	-999	-999	-999.0
URB-1	URB	28-Jan-87	2.1	0.9	7.5	15.0	580	-999.0	2400	-999	-999	1349	-999.0	-999.0	-999.0	1573.6	-999.0	615.6	-999	2831	-999	-999.0
URB-1	URB	30-Jan-87	1.8	-999.0	-999.0	-999.0	-999	-999.0	2000	900	-999	-999	-999.0	-999.0	-999.0	557.2	-999.0	-999.0	-999	1253	-999	-999.0
URB-1	URB	31-Jan-87	0.9	-999.0	-999.0	-999.0	-999	-999.0	-999	70	-999	-999	-999.0	-999.0	-999.0	894.5	-999.0	-999.0	-999	1263	-999	-999.0
URB-1	URB	01-Feb-87	1.4	-999.0	-999.0	-999.0	-999	-999.0	-999	50	-999	1826	-999.0	-999.0	-999.0	1320.6	-999.0	-999.0	-999	2085	-999	-999.0
URB-1	URB	24-Feb-87	0.002	2.0	7.0	10.6	71	65.2	99	7	300	53.3	59.0	23.4	84.9	232.5	-999.0	170.7	167	477	-999	-999.0
URB-1	URB	29-Apr-87	0.2	13.5	6.8	8.5	110	134.8	2200	-999	-999	300.9	-999.0	-999.0	123.8	1033.6	-999.0	1144.1	1024	3691	-999	-999.0

STA	TYPE	DATE	FLOW	TEMP	PH	DO	F_COND	L_COND	FS	FC	TC	TSS	TURB	ALK	SRP	TP	TSP	NH3N	NO23N	TUVN	TSUVN	CL
URB-1	URB	16-Jun-87	0.38	17.4	6.9	9.6	37	45.4	2000 P	1600 P	1600 P	26.2	-999.0	-999.0	147.0	131.8	-999.0	300.0	221	970	-999	-999.0
URB-2	URB	15-Dec-86	0.001	5.0	-999.0	-999.0	1170	1410.8	1800	-999	-999	-999	-999.0	49.6	4.9	202.9	-999.0	254.0	48	-999	-999	-999.0
URB-2	URB	28-Jan-87	0.20	2.1	7.6	13.8	942	-999.0	1100	-999	-999	1268	-999.0	-999.0	-999.0	507.3	-999.0	154.3	-999	1889	-999	-999.0
URB-2	URB	30-Jan-87	0.2	-999.0	-999.0	-999.0	-999	-999.0	1800	900	-999	-999	-999.0	-999.0	-999.0	574.4	-999.0	-999.0	-999	1200	-999	-999.0
URB-2	URB	31-Jan-87	0.1	-999.0	-999.0	-999.0	-999	-999.0	-999	30	-999	1154	-999.0	-999.0	-999.0	582.2	-999.0	-999.0	-999	1977	-999	-999.0
URB-2	URB	01-Feb-87	0.15	-999.0	-999.0	-999.0	-999	-999.0	-999	4	-999	1832	-999.0	-999.0	-999.0	35.8	-999.0	-999.0	-999	1020	-999	-999.0
URB-3	URB	15-Dec-86	0.08	10.7	-999.0	-999.0	87	102.6	4	-999	-999	-999	-999.0	23.0	3.5	7.5	-999.0	42.6	51	-999	-999	-999.0
URB-3	URB	19-Jan-87	0.050	8.0	7.4	11.1	68	63.2	1 U	-999	-999	-999	3.8	20.0	2.6	5.9	-999.0	1.5 J	65	3535	-999	-999.0
URB-3	URB	28-Jan-87	1.9	4.9	7.1	13.0	1290	-999.0	740	-999	-999	237	-999.0	-999.0	-999.0	477.6	-999.0	97.5	-999	3535	-999	-999.0
URB-3	URB	24-Feb-87	0.14	4.9	7.3	9.3	97	77.7	2	-999	-999	-999	8.9	29.1	12.2	18.4	-999.0	21.1	-999	202	-999	-999.0

Lake Chelan database documentation: explanation of field names and data qualifiers for the GRNDWAT database.

FIELD NAME	PARAMETER	UNITS
STA	Station	--
DATE	Date	--
BH#	Project Borehole Number (MW only)	--
TYPE	Station type: DOM=domestic well, MW=monitoring well, SPR=spring, QA=QA sample	--
USE	Station use: BKG=Background, RES=septic system, BR=bedrock AG=Agricultural, REP=QA replicate, BLK=QA blank	--
GR	Gradient with respect to septic system: U=upgradient, D=downgrad	--
V	Number of casing volumes purged prior to sampling	--
ELEV	Elevation at Well Head	ft MSL
D_TO_W	Depth to Water	ft
SWL	Static Water Elevation	ft MSL
T_DEG	Temperature	degrees C
F_COND	Specific Conductance (Field)	umho/cm @ 25C
PH	pH	SU
EH	Eh	mV (Pt Std)
DO	Dissolved Oxygen	mg/L
FS	Fecal Streptococci	#/100mL
FC	Fecal Coliform	#/100mL
TC	Total Coliform	#/100mL
L_COND	Specific Conductance (Lab)	umho/cm @ 25C
TURB	Turbidity	NTU
ALK	Alkalinity	mg CaCO3 /L
SRP	Soluble Reactive P	ug P /L
TP	Total P	ug P /L
NH3N	Ammonia N	ug N /L
NO23N	Nitrite+Nitrate N	ug N /L
TN	Total N (UV)	ug N /L
CL	Chloride	mg/L

MISSING DATA CODE: -999

DATA QUALIFIERS:

J = Estimated value; value not accurate
U = Analyzed but not detected. The number reported is the detection limit.
P = Greater than (>).

STA	DATE	BH#	TYPE	USE	GR	V	ELEV	D_TO_W	SWL	T_DEG	F_COND	PH	EH	DO	FS P	FC P	TC P	L_COND	TURB	ALK	SRP	TP	NH3N	NO23N	TN	CL
KELLY	1/87		DOM	BKG	U		1200.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	2.1	-999.0	-999	17.8	-999.0	-999	2677.0	1.9
COVE	1/87	CH-28	MW	RES	D		1112.45	-999.00	-999.00	10.0	570	6.8	306	-999.0	1U	-999	-999	-999	2.5	-999.0	-999	9.8	-999.0	-999	6718.0	7.4
TUCKER	1/87		SPR	RES	U		1700.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	2U	2U	-999	4.9	-999.0	-999	11.4	-999.0	-999	5.5J	1.4
STATE PARK	1/87	CH-26	MW	RES	D		1165.00	-999.00	-999.00	7.0	500	6.2	-999	-999.0	2U	-999	-999	-999	250.0	-999.0	-999	28.2	-999.0	-999	1838.0	5.8
REED	1/87		DOM	BKG			2155.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	1.0	-999.0	-999	5.5	-999.0	-999	37.8J	-0.6J
LUTZ-UP	1/87	CH-9	MW	RES	U		1118.74	15.78	1102.96	9.1	470	7.7	-999	8.1	1U	-999	-999	-999	131.0	-999.0	-999	29.2	-999.0	-999	1154.0	10.6
VENNEBERG	1/87	CH-10	MW	RES	D		1106.39	18.41	1073.63	10.0	570	7.4	-999	8.3	1U	-999	-999	-999	60.0	-999.0	-999	9.8	-999.0	-999	417.0	-0.4J
LUTZ-DN	1/87	CH-27	MW	RES	D		1115.54	18.08	1097.46	8.0	293	7.5	-999	6.0	1U	-999	-999	-999	29.0	-999.0	-999	21.1	-999.0	-999	363.0	5.4
CLAPP	1/87		DOM	BKG			2275.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	4.4	-999.0	-999	181.4	-999.0	-999	1378.0	2.5
ALLISON-UP	1/87	CH-15	MW	RES	U		1215.00	17.17	1197.83	9.0	830	6.8	-999	7.1	1U	-999	-999	-999	470.0	-999.0	-999	127.3	-999.0	-999	391.0	4.6
ALLISON-DN	1/87	CH-16	MW	RES	D	1	1203.50	14.70	1188.80	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	178.0	-999.0	-999	-999.0	-999.0	-999	-999.0	-999.0
ALLISON-DN	1/87	CH-16	MW	RES	D	3	1203.50	14.70	1188.80	10.8	660	6.8	-999	6.8	1U	-999	-999	-999	19.8	-999.0	-999	110.1	-999.0	-999	11208.0	3.7
RISLEY	1/87		DOM	BKG			2665.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	1.4	-999.0	-999	54.1	-999.0	-999	191.9	2.0
LESMEISTER	1/87		DOM	BR			1990.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	0.7	-999.0	-999	7.2	-999.0	-999	4392.0	0.9
ALLISON-DOM	1/87		DOM	RES	U		1350.00	-999.00	-999.00	7.5	765	7.6	271	-999.0	4	-999	-999	-999	26.0	-999.0	-999	169.4	-999.0	-999	15926.0	0.0
MORRIS	1/87	CH-17	MW	RES	D		1245.00	54.14	1190.86	7.4	800	6.8	-999	9.1	130	-999	-999	-999	420.0	-999.0	-999	63.2	-999.0	-999	6916.0	0.6
McCLELLAN-UP	1/87	CH-4	MW	AG	U		1172.56	7.67	1164.89	9.9	790	7.1	-999	7.5	1U	-999	-999	-999	52.0	-999.0	-999	199.5	-999.0	-999	12015.0	3.4
McCLELLAN-DN	1/87	CH-24	MW	RES	D	1	1173.60	8.75	1164.85	-999.0	-999	-999.0	-999	-999.0	370	-999	-999	-999	225.0	-999.0	-999	-999.0	-999.0	-999	-999.0	-999.0
McCLELLAN-DN	1/87	CH-24	MW	RES	D	3	1173.60	8.75	1164.85	9.0	1300	7.3	-999	6.4	5	2U	4	-999	39.0	-999.0	-999	661.0	-999.0	-999	10986.0	3.3
COLLINS-UP	1/87	CH-22	MW	RES	U		1202.45	17.35	1185.10	12.0	460	7.5	263	-999.0	1U	-999	-999	-999	3.9	-999.0	-999	43.4	-999.0	-999	12258.0	-0.3J
GOODWIN-DN	1/87	CH-21	MW	RES	D	1	1171.37	7.92	1163.45	-999.0	-999	-999.0	-999	-999.0	1	-999	-999	-999	26.0	-999.0	-999	-999.0	-999.0	-999	-999.0	-999.0
GOODWIN-DN	1/87	CH-21	MW	RES	D	3	1171.37	7.92	1163.45	13.2	450	7.5	-999	6.2	1U	2U	2U	-999	1.8	-999.0	-999	7.9	-999.0	-999	8585.0	3.0
GOODWIN-DN	1/87	CH-21	QA01	REP	D	3	1171.37	7.92	1163.45	13.2	450	7.5	-999	6.2	1U	-999	-999	-999	2.4	-999.0	-999	102.0	-999.0	-999	6034.0	1.8
COLLINS-DN	1/87	CH-20	MW	RES	D	1	1168.17	4.84	1163.33	-999.0	-999	-999.0	-999	-999.0	8	-999	-999	-999	395.0	-999.0	-999	-999.0	-999.0	-999	-999.0	-999.0
COLLINS-DN	1/87	CH-20	MW	RES	D	3	1168.17	4.84	1163.33	8.8	970	7.1	-999	6.7	1U	2U	11	-999	1.8	-999.0	-999	648.0	-999.0	-999	5354.0	30.0
COLLINS-DN	1/87	CH-20	QA02	REP	D	3	1168.17	4.84	1163.33	8.8	970	7.1	-999	6.7	1U	-999	-999	-999	2.4	-999.0	-999	639.9	-999.0	-999	4112.0	31.0
PICKENS-UP	1/87		DOM	RES	U		1165.87	-999.00	-999.00	8.5	721	7.2	276	-999.0	5	-999	-999	-999	116.0	-999.0	-999	38.2	-999.0	-999	4337.0	2.4
PICKENS-DN	1/87	CH-23	MW	RES	D		1165.00	6.15	1158.85	11.0	720	7.4	273	-999.0	1U	-999	-999	-999	420.0	-999.0	-999	3193.0	-999.0	-999	7170.0	5.5
SIMMONDS	1/87	CH-2	MW	AG			1235.00	6.09	1228.91	6.5	1400	6.8	-999	3.3	1U	-999	-999	-999	13.6	-999.0	-999	14.0	-999.0	-999	3399.0	3.2
SATHER	1/87	CH-1	MW	AG		1	1165.00	11.78	1153.22	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	-999	87.0	-999.0	-999	-999.0	-999.0	-999	-999.0	-999.0
SATHER	1/87	CH-1	MW	AG		3	1165.00	11.78	1153.22	10.0	441	6.9	-999	8.6	1U	-999	-999	-999	4.8	-999.0	-999	47.0	-999.0	-999	9606.0	4.0
BLANK	1/87		QA03	BLK			-999.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999	-1.1J	-999.0	-999	32.9J	-999.0
BLANK	1/87		QA04	BLK			-999.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999.0	-999.0	-999	-1.4J	-999.0	-999	77.8J	-999.0
KELLY	4/87		DOM	BKG	U		1200.00	-999.00	-999.00	12.7	330	7.5	-999	13.5	1U	-999	-999	-999	2.1	-999.0	-999	18.5	8.2	1550	1313.0	2.2
COVE	4/87	CH-28	MW	RES	D		1112.45	26.04	1084.91	16.0	345	7.2	-999	6.8	1U	2U	2U	-999	1.3	241.1	-999	10.2	0.0J	2319	2287.0	2.1
TUCKER	4/87		SPR	RES	U		1700.00	-999.00	-999.00	10.9	130	7.3	-999	8.7	1U	-999	-999	-999	4.0	-999.0	-999	16.4	22.8	0J	56.1J	-3.3J
STATE PARK	4/87	CH-26	MW	RES	D		1165.00	48.20	1116.80	17.0	371	7.7	-999	3.2	10U	-999	-999	-999	14.7	-999.0	-999	50.9	5.9	285	1319.0	0.2
REED	4/87		DOM	BKG			2155.00	-999.00	-999.00	7.0	110	6.8	-999	12.6	1U	-999	-999	-999	4.5	51.6	-999	8.4	59.3	45	79.2	-3.1J
LUTZ-UP	4/87	CH-9	MW	RES	U		1118.74	14.47	1104.27	14.0	300	7.1	-999	7.2	1U	-999	-999	-999	136.8	169.3	-999	55.5	50.2	3252	1154.0	14.5
VENNEBERG	4/87	CH-10	MW	RES	D		1106.39	8.35	1083.69	13.0	470	6.9	-999	7.9	1U	2U	2U	-999	104.2	-999.0	-999	33.8	9.5	421	604.0	0.8
LUTZ-DN	4/87	CH-27	MW	RES	D		1115.54	17.27	1098.27	14.0	308	7.5	-999	6.1	1U	2U	2U	-999	14.9	-999.0	-999	32.6	64.2	1436	2431.0	5.1
CLAPP	4/87		DOM	BKG			2275.00	-999.00	-999.00	13.0	500	7.5	-999	7.7	4	-999	-999	-999	0.3	242.0	-999	253.9	91.6	1540	1698.0	1.8
ALLISON-UP	4/87	CH-15	MW	RES	U		1215.00	15.25	1199.75	13.0	510	7.0	-999	8.4	72	-999	-999	-999	121.1	-999.0	-999	230.7	-1.0J	21018	20079.0	2.9
ALLISON-DN	4/87	CH-16	MW	RES	D		1203.50	15.04	1188.46	13.0	480	7.1	-999	6.2	1U	-999	-999	-999	10.7	-999.0	-999	151.1	57.7	13518	12651.0	4.1
RISLEY	4/87		DOM	BKG			2665.00	-999.00	-999.00	8.7	680	7.0	-999	6.6	3	-999	-999	-999	5.2	230.7	-999	92.5	-0.6J	214	212.0	2.4
SPRING-01	4/87		SPR	BKG	U		-999.00	-999.00	-999.00	13.0	315	7.0	-999	8.6	2U	-999	-999	-999	-999.0	-999.0	-999	96.0	1.0J	800	717.0	0.5
LESMEISTER	4/87		DOM	BR			1990.00	-999.00	-999.00	12.1	620	7.7	-999	7.3	2	-999	-999	-999	0.5	-999.0	-999	13.6	25.4	8586	8536.5	1.9
ALLISON-DOM	4/87		DOM	RES	U		1350.00	5.70	1344.30	13.0	485	7.4	-999	10.5	1U	-999	-999	-999	23.2	-999.0	-999	230.7	19.9	20878	24027.5	-2.4J
MORRIS	4/87	CH-17	MW	RES	D		1245.00	55.38	1189.62	14.0	365	6.7	-999	8.0	1U	-999	-999	-999	13.7	-999.0	-999	199.0	5.2	8533	5575.0	1.1
McCLELLAN-UP	4/87	CH-4	MW	AG	U		1172.56	7.80	1164.76	13.0	450	7.6	-999	6.3	1U	-999	-999	-999	61.1	-999.0	-999	251.5	52.2	7537	9744.0	1.0
McCLELLAN-DN	4/87	CH-24	MW	RES	D		1173.60	8.94	1164.66	13.0	435	7.7	-999	8.2	1U	-999	-999	-999	21.1	-999.0	-999	1245.1	80.2	10716	9481.0	3.4
COLLINS-UP	4/87	CH-22	MW	RES	U		1202.45	15.75	1186.70	15.0	340	6.9	-999	6.0	1U	-999	-999	-999	34.7	-999.0	-999	50.6	25.1	9926	4713.0	1.8
GOODWIN-DN	4/87	CH-21	MW	RES	D		1171.37	7.92	1163.45	14.0	355	7.5	-999	6.2	1U	2U	17	-999	4.9	191.0	-999	120.5	70.7	7741.5	9176.0	2.3
GOODWIN-DN	4/87	CH-21	QA01	REP	D		1171.37	7.92	1163.45	14.0	355	7.5	-999	6.2	4	-999	-999	-999	3.4	-999.0	-999	121.7	0.7J	7338	6998.0	2.9
COLLINS-DN	4/87	CH-20	MW	RES	D		1168.17	4.79	1163.38	12.0	650	7.7	-999	4.4	1U	2U	95	-999	91.6	384.5	-999	676.0	53.8	4405	4471.0	23.9
COLLINS-DN	4/87	CH-20	QA02	REP	D		1168.17	4.79	1163.38	12.0	650	7.7	-999	4.4	2	-999	-999	-999	87.4	-999.0	-999	634.6	51.5	4057	4761.0	22.3
PICKENS-UP	4/87		DOM	RES	U		1165.87	-999.00	-999.00	10.0	470	7.0	-999	6.4	70	-999	-999	-999	4.3	-999.0	-999	66.2	55.7	3382	5240.0	1.8
PICKENS-DN	4/87	CH-23	MW	RES	D		1165.00	6.10	1158.90	12.0	480	6.8	-999	3.0	1U	12	1600P	-999	152.6	326.6	-999	4020.2	308.0	3111	3298.0	16.6
SIMMONDS	4/87	CH-2	MW	AG			1235.00	6.09	1228.91	11.0	429	7.1	-999	5.8	4	-999	-999	-999	17.9	-999.0	-999	37.8	19.2	2599	1494.0	1.7
SATHER	4/87	CH-1	MW	AG			1165.00	11.33	1153.67	14.0	430	7.1	-999	7.8	2	-999	-999	-999	84.2	-999.0	-999	111.2	55.7	14957	13402.0	5.2
WILLOWS	4/87		MW	RES	D		1085.51	19.05	1066.46	13.0	325	7.7	-999	2.2	90	-999	-999	-999	0.0	-999.0	-999	208.6	32.6	10.4	274.0	1.8
PICKENS-SEPTAGE	4/87		SEW	RES			-999.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	40000P	1600P	1600P	-999	-999.0	-999.0	-999	15160.6	101151.0	0J	51151.0	21.4
BLANK	4/87		QA03	BLK			-999.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	0.3	-999.0	-999	1.5	57.0	0J	57.4J	-3.1J
BLANK	4/87		QA04	BLK			-999.00	-999.00	-999.00	-999.0	-999	-999.0	-999	-999.0	- 999	-999	-999	-999	2.5	-999.0	-999	1.1J	56.1	0J	60.1J	-3.3J

STA	DATE	BH#	TYPE	USE	GR V	ELEV	D_TO_W	SWL	T_DEG	F_COND	PH	EH	DO	FS P	FC P	TC P	L_COND	TURB	ALK	SRP	TP	NH3N	NO23N	TN	CL
KELLY	7/87		DOM	BKG	U	1200	-999	-999.00	12.5	370	7.4	-999	15.8	1U	1.8U	1.8U	-999	-999	194.4	11.1	19.3	-0.8J	1554	1580	-1.9J
COVE	7/87	CH-28	MW	RES	D	1112.45	12.9	1098.05	14.0	540	6.8	-999	5.0	1U	-999	-999	-999	-999	-999	-999.0	12.9	-999.0	-999	19585	8.8
TUCKER	7/87		SPR	RES	U	1700	-999	-999.00	11.5	130	7.2	-999	10.2	32	-999	-999	-999	-999	-999	-999.0	15.0	-999.0	-999	0J	-3.2J
STATE PARK	7/87	CH-26	MW	RES	D	1165	36.82	1128.18	12.0	440	6.2	-999	1.8	1	-999	-999	-999	-999	-999	-999.0	41.8	-999.0	-999	1092	-1.3J
REED	7/87		DOM	BKG		2155	-999	-999.00	8.0	96	7.1	-999	12.5	1U	-999	-999	-999	-999	45.6	5.4	10.1	7.7	37.2	33.4J	-2.2J
LUTZ-UP	8/87	CH-9	MW	RES	U	1118.74	11.46	1107.28	15.0	200	6.9	-999	4.8	1U	1.8U	1.8U	522.6	-999	164.4	37.7	61.6	18.3	2172	2308	20.4
VENNEBERG	8/87	CH-10	MW	RES	D	1106.39	2.02	1090.02	13.0	480	6.5	-999	6.4	1U	-999	-999	790.1	-999	-999	-999.0	437.9	-999.0	-999	1710	3.7
LUTZ-DN	8/87	CH-27	MW	RES	D	1115.54	13.52	1102.02	15.0	330	7.1	-999	1.6	1U	-999	-999	521.6	-999	-999	-999.0	46.0	-999.0	-999	1202	8.4
CLAPP	7/87		DOM	BKG		2275	-999	-999.00	10.6	480	7.2	-999	8.8	1U	1.8U	1.8U	-999	-999	229.6	222.6	231.8	1.1J	1247	1489	0.9
ALLISON-UP	7/87	CH-15	MW	RES	U	1215	14.85	1200.15	17.5	700	6.9	-999	7.8	22	-999	-999	-999	-999	-999	-999.0	164.8	-999.0	-999	15649	6.9
ALLISON-DN	7/87	CH-16	MW	RES	D	1203.5	14.5	1189.00	17.0	710	6.6	-999	2.9	1U	-999	-999	-999	-999	-999	-999.0	147.8	-999.0	-999	14533	2.4
RISLEY	7/87		DOM	BKG		2665	-999	-999.00	8.5	480	7.1	-999	8.6	1U	-999	-999	-999	-999	238.5	69.2	74.7	0.4J	292	357	-0.2J
LESMEISTER	7/87		DOM	BR		1990	-999	-999.00	12.9	550	6.1	-999	9.5	1U	-999	-999	-999	-999	-999	-999.0	18.4	-999.0	-999	9844	3.3
ALLISON-DOM	7/87		DOM	RES	U	1350	5.34	1344.66	12.0	740	7.1	-999	7.8	80	-999	-999	-999	-999	-999	-999.0	218.4	-999.0	-999	19072	6.1
MORRIS	7/87	CH-17	MW	RES	D	1245	52.05	1192.95	14.1	690	6.5	-999	8.0	6	-999	-999	-999	-999	-999	-999.0	153.9	-999.0	-999	9145	2.7
McCLELLAN-UP	7/87	CH-4	MW	AG	U	1172.56	8.01	1164.55	15.3	750	7.5	-999	6.5	1U	-999	-999	-999	-999	-999	-999.0	234.3	-999.0	-999	8096	5.4
McCLELLAN-DN	7/87	CH-24	MW	RES	D	1173.60	9.12	1164.48	14.9	640	7.5	-999	6.9	3	1.8U	1.8U	-999	-999	347.6	894.5	866.7	8.0	9484	10896	5.6
COLLINS-UP	7/87	CH-22	MW	RES	U	1202.45	14.37	1188.08	15.5	500	6.7	-999	5.7	1U	-999	-999	-999	-999	-999	-999.0	85.7	-999.0	-999	11738	5.5
GOODWIN-DN	7/87	CH-21	MW	RES	D	1171.37	8.23	1163.14	15.5	480	7.1	-999	5.5	1U	-999	-999	-999	-999	-999	106.4	112.4	1.1J	-999	9145	2.0
GOODWIN-DN	7/87	CH-21	QA01	REP	D	1171.37	8.23	1163.14	15.5	480	7.1	-999	5.5	2	-999	-999	-999	-999	184.9	82.8	111.5	5.2	8184	9088	3.1
COLLINS-DN	7/87	CH-20	MW	RES	D	1168.17	5.17	1163.00	17.9	830	7.3	-999	6.4	1U	1.8U	1.8U	-999	-999	262.1	642.7	769.3	0.4J	5481	6826	15.0
COLLINS-DN	7/87	CH-20	QA02	REP	D	1168.17	5.17	1163.00	17.9	830	7.3	-999	6.4	1U	-999	-999	-999	-999	346.3	827.4	763.2	8.9	5023	6461	15.1
PICKENS-DN	8/87	CH-23	MW	RES	D	1165	7.56	1157.44	16.5	1600	6.9	-999	1.3	1U	540	18U	873.7	-999	314.3	1805.1	2954.2	531.0	2497	3666	17.9
SIMMONDS	8/87	CH-2	MW	AG		1235	6.09	1228.91	15.0	480	7.1	-999	2.4	1U	-999	-999	908.3	-999	-999	-999.0	33.1	-999.0	-999	2038	14.0
SATHER	8/87	CH-1	MW	AG		1165	12.13	1152.87	14.0	320	7.0	-999	5.7	1U	-999	-999	611.7	-999	-999	-999.0	102.7	-999.0	-999	15967	13.7
WILLOWS	8/87		MW	RES	D	1085.51	-999	-999.00	12.5	320	7.1	-999	1.4	6	-999	-999	-999	-999	-999	-999.0	79.7	-999.0	-999	242	4.2
CONDOS	8/87		MW	RES		1160	55.54	1104.46	15.0	490	7.2	-999	7.6	7	-999	-999	755.6	-999	-999	-999.0	226.8	-999.0	-999	10385	12.7
PICKENS-SEPTAGE	7/87		SEW	RES		-999	-999	-999.00	-999.0	-999	6.6	-200	-999.0	7200000	160000000	17000000	-999	-999	790	18280.1	25162.2	215314.0	10.2	195958	42.4
COVE-SEPTAGE	7/87		SEW	RES		-999	-999	-999.00	-999.0	-999	6.7	100	-999.0	210000	-999	-999	-999	-999	123.5	2490.3	3901.6	28411.0	7J	19585	5.7
ST PARK-SEPTAGE	7/87		SEW	RES		-999	-999	-999.00	-999.0	-999	7.2	-222	-999.0	470000	-999	-999	-999	-999	495	15795.4	15082.9	236101.0	11.7	141104	56.4
CHELAN STP	7/87		SEW	RES		-999	-999	-999.00	23.8	-999	7.4	-50	-999.0	2100000	130000000	33000000	-999	-999	161.8	5230.2	8274.4	-999.0	0J	55202	17.8
LUTZ-SEPTAGE	7/87		SEW	RES		-999	-999	-999.00	-999.0	-999	6.4	-204	-999.0	550	-999	-999	-999	-999	124.4	10490.1	10119.4	31246.1	0J	22520	18.5
BLANK	7/87		QA03	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	2.2	-0.6	3.1	43.9	0J	10.2J	-1.2J
BLANK	7/87		QA04	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	2.2	-0.4	2.2	54.0	0J	3.1J	-0.6J
BLANK	8/87		QA05	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	3.8	-999	0.8	5.4	5.2	28.6	0J	0J	0.4
KELLY	11/87		DOM	BKG	U	1200	-999	-999.00	12.8	380	7.3	-999	8.8	1U	2U	2U	-999	-999	184	14.2	15.7	16.2	1633	1906	4.0
COVE	11/87	CH-28	MW	RES	D	1112.45	-999	-999.00	16.0	235	6.9	-999	4.6	1U	-999	-999	-999	-999	-999	-999.0	132.5	-999.0	-999	3651	12.5
TUCKER	11/87		SPR	RES	U	1700	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	-999	-999.0	10.9	-999.0	-999	15.8J	0.9
STATE PARK	11/87	CH-26	MW	RES	D	1165	41.6	1123.40	11.0	-999	7.2	-999	2.2	4	-999	-999	330	-999	-999	-999.0	872.5	-999.0	-999	3464	3.3
REED	11/87		DOM	BKG		2155	-999	-999.00	7.0	90	7.1	-999	12.0	1U	-999	-999	-999	-999	43	4.0	6.8	17.7	31.1	48.3J	-0.4J
LUTZ-UP	11/87	CH-9	MW	RES	U	1118.74	15.2	1103.54	16.0	-999	7.7	-999	4.0	2	8	2U	350	-999	161	50.3	59.4	22.0	1870	2828	17.5
VENNEBERG	11/87	CH-10	MW	RES	D	1106.39	12.12	1079.92	12.0	-999	6.8	-999	2.9	1U	-999	-999	320	-999	-999	-999.0	30.8	-999.0	-999	7306	2.0
LUTZ-DN	11/87	CH-27	MW	RES	D	1115.54	16.71	1098.83	17.0	-999	7.3	-999	4.0	1U	-999	-999	340	-999	-999	-999.0	42.4	-999.0	-999	1081	6.6
CLAPP	11/87		DOM	BKG		2275	-999	-999.00	9.9	480	7.2	-999	9.8	1U	2U	23	-999	-999	228	231.9	69.2	11.2	1347	1198	4.7
ALLISON-UP	11/87	CH-15	MW	RES	U	1215	13.81	1201.19	12.8	850	7.0	-999	8.3	1U	-999	-999	-999	-999	-999	-999.0	141.7	-999.0	-999	27821	4.1
ALLISON-DN	11/87	CH-16	MW	RES	D	1203.5	14.08	1189.42	15.5	710	7.0	-999	3.8	4	-999	-999	-999	-999	-999	-999.0	151.2	-999.0	-999	15343	5.5
RISLEY	11/87		DOM	BKG		2665	-999	-999.00	9.6	480	7.2	-999	8.9	4	-999	-999	-999	-999	234	70.2	13.6	10.0	510	624	4.1
LESMEISTER	11/87		DOM	BR		1990	-999	-999.00	12.0	600	7.1	-999	8.4	1U	-999	-999	-999	-999	-999	-999.0	10.9	-999.0	-999	12205	2.9
ALLISON-DOM	11/87		DOM	RES	U	1350	7.5	1342.50	12.0	-999	7.3	-999	5.0	180	-999	-999	-999	-999	-999	-999.0	238.3	-999.0	-999	28485	2.6
MORRIS	11/87	CH-17	MW	RES	D	1245	48.26	1196.74	11.2	790	7.3	-999	9.6	-999	-999	-999	-999	-999	-999	-999.0	164.3	-999.0	-999	17957	4.0
McCLELLAN-UP	11/87	CH-4	MW	AG	U	1172.56	7.88	1164.68	14.3	630	7.3	-999	5.1	1U	-999	-999	-999	-999	-999	-999.0	263.8	-999.0	-999	9795	5.9
McCLELLAN-DN	11/87	CH-24	MW	RES	D	1173.6	8.93	1164.67	14.0	650	7.5	-999	4.8	1U	2U	2U	-999	-999	266	655.1	894.0	9.6	10747	12816	3.1
COLLINS-UP	11/87	CH-22	MW	RES	U	1202.45	15.35	1187.10	14.0	-999	6.8	-999	4.0	1U	-999	-999	430	-999	-999	-999.0	71.3	-999.0	-999	12667	3.4
GOODWIN-DN	11/87	CH-21	MW	RES	D	1171.37	8.5	1162.87	15.0	-999	6.9	-999	4.8	1U	-999	-999	380	-999	-999	-999.0	120.3	-999.0	-999	7060	7.7
COLLINS-DN	11/87	CH-20	MW	RES	D	1168.17	4.8	1163.37	15.0	-999	7.1	-999	3.5	1U	23	2U	660	-999	334	251.1	281.1	14.2	9229	11828	14.3
PICKENS-UP	11/87		DOM	RES	U	1165.87	7.15	1158.72	-999.0	-999	-999.0	-999	-999.0	1U	-999	-999	610	-999	-999	-999.0	65.0	-999.0	-999	2898	7.2
PICKENS-UP	11/87		QA01	REP	U	1165.87	7.15	1158.72	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	-999	49.0	56.6	15.8	2505	3021	6.3
PICKENS-DN	11/87	CH-23	MW	RES	D	1165	6.35	1158.65	15.0	-999	7.2	-999	6.6	4	50	2U	630	-999	339	3151.1	2957.2	570.7	1797	2467	18.2
PICKENS-DN	11/87	CH-23	QA02	REP	D	1165	6.35	1158.65	15.0	-999	7.2	-999	6.6	2	-999	-999	-999	-999	-999	1330.9	2967.6	254.3	1661	2485	17.7
SIMMONDS	11/87	CH-2	MW	AG		1235	5.95	1229.05	12.0	770	7.2	175	1.0	1U	-999	-999	-999	-999	-999	-999.0	32.0	-999.0	-999	2499	13.3
SATHER	11/87	CH-1	MW	AG		1165	13.55	1151.45	14.0	560	7.1	-999	5.1	2	-999	-999	-999	-999	-999	-999.0	95.3	-999.0	-999	13573	14.1
WILLOWS	11/87		MW	RES	D	1085.51	-999	3307.51	12.0	-999	7.1	-999	2.0	10	-999	-999	360	-999	-999	-999.0	42.1	-999.0	-999	205	4.4
CONDOS	11/87		MW	RES	D	1160	56.85	1103.15	14.0	-999	7.2	-999	6.5	40	-999	-999	530	-999	-999	-999.0	123.9	-999.0	-999	14063	11.5
CHELAN STP	11/87		SEW	RES		-999	-999	-999.00	17.5	460	7.7	-999	3.3	200000P	16000000P	16000000P	-999	-999	-999	4117.4	5941.9	48190.4	30	41215	14.9
BLANK	11/87		QA03	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	-999	7.4	8.3	54.7	0J	44.6J	0.1
BLANK	11/87		QA04	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	-999	-999.0	0.8J	-999.0	-999	29.8J	0.6
BLANK	11/87		QA05	BLK		-999	-999	-999.00	-999.0	-999	-999.0	-999	-999.0	-999	-999	-999	-999	-999	-999	-999.0	0.2J	-999.0	-999	69.7J	0.8

P-THM results for Lake Chelan water samples.

Date	Station	P-Trichloro-methane (ug/L)	P-Chloro-dibromo-methane (ug/L)	P-Bromo-dichloro-methane (ug/L)	P-Tribromo methane (ug/L)
30-Mar-87	2-0	34	1 u	1	5 u
	6-0	43	1 u	2	5 u
27-May-87	2-0	38	1 u	2	5 u
	6-0	34	1 u	1 u	5 u
28-Jul-87	2-0	35	1 u	3	5 u
	6-0	35	1 u	3	5 u
06-Oct-87	2-0	37	1 u	1 u	5 u
	6-0	30	2	1 u	5 u

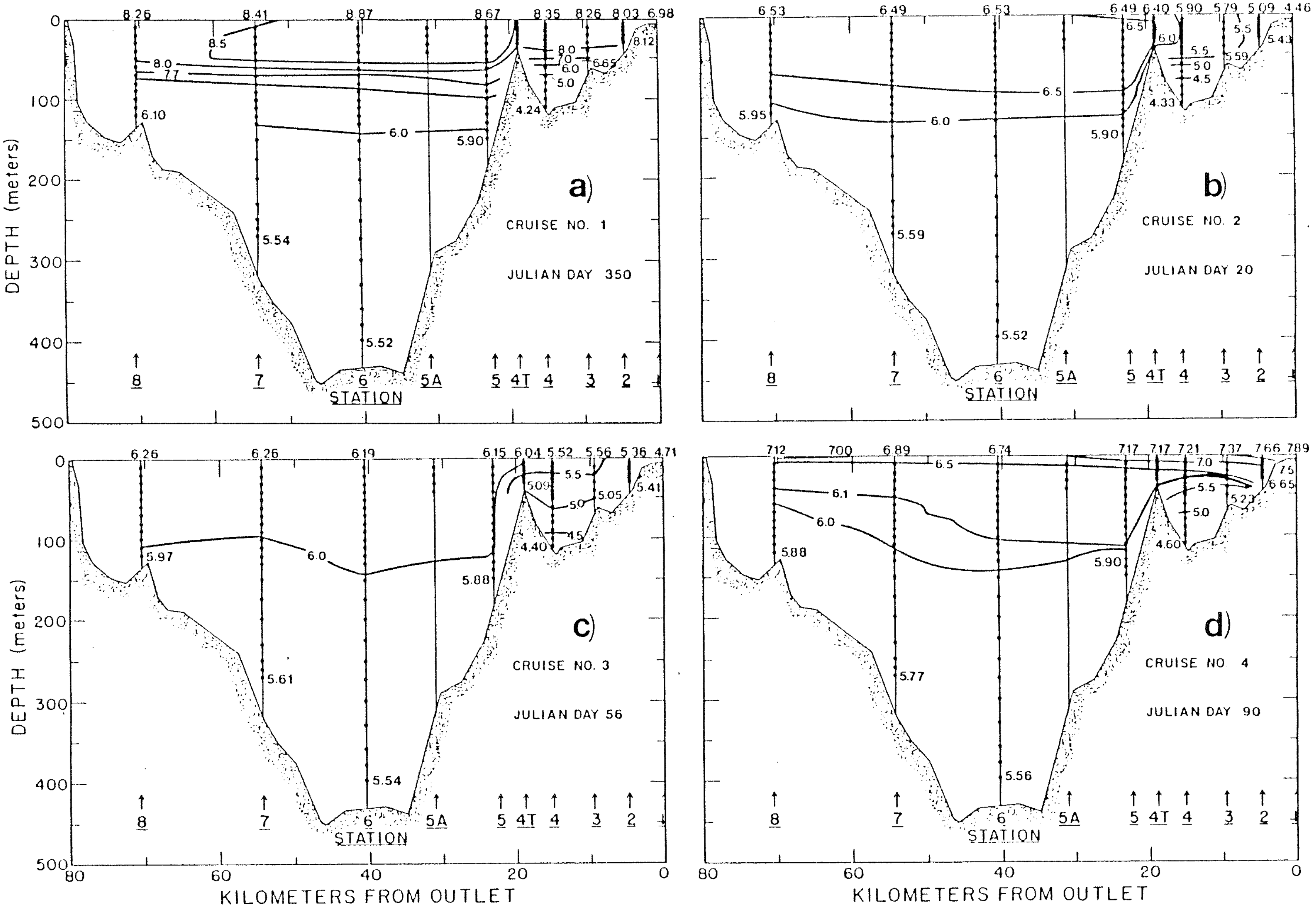
"u" indicates that the compound was analysed but not detected.
The number given is the detection limit.

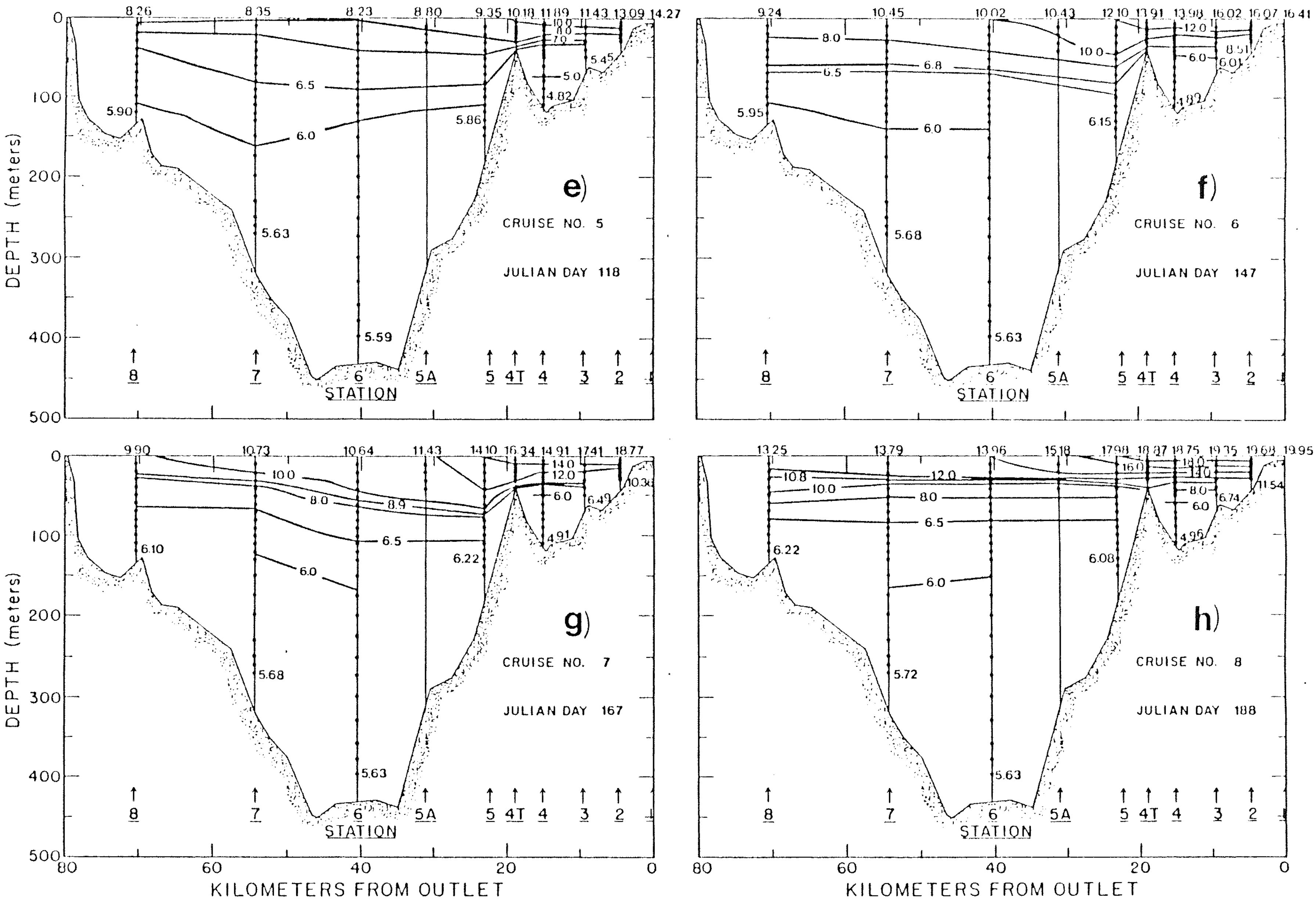
SUMMARY OF DETAILED CHEMICAL ANALYSES FOR SELECTED GROUNDWATERS AND TRIBUTARIES

SITE	SAMPLING DATE	pH	HCO3 (mg/L)	F (mg/L)	Ca (mg/L)	Fe (ug/L)	Al (ug/L)	TSP (ug/L)
AG-6	Apr-87	7.5	213	0.40	125	10	26	177
AG-6	Jul-87	7.0	220	0.04	19	< 3	-	172
CLAPP	Apr-87	7.5	295	0.16	91	< 3	1	253
CLAPP	Jul-87	7.2	280	0.28	144	< 3	-	232
COLLINS-DN	Jul-87	7.3	320	0.64	118	< 3	-	769
COLLINS-UP	Apr-87	6.9	469	0.60	77	< 3	3	49
COVE	Apr-87	7.2	294	0.57	133	< 3	4	9
GOODWIN-DN	Apr-87	7.5	233	0.28	105	< 3	6	120
GOODWIN-DN	Jul-87	7.1	226	0.35	103	< 3	-	112
KELLY	Jul-87	7.4	237	2.03	159	< 3	-	19
LUTZ-A	Apr-87	7.1	207	0.12	106	-	15	54
LUTZ-A	Jul-87	6.9	201	0.43	103	< 3	-	62
McCLELLAN-DN	Jul-87	7.5	424	0.42	108	-	-	867
MITCHELL CK	Jul-87	8.5	159	0.26	82	< 3	-	19
PICKENS-DN	Apr-87	6.8	398	0.89	156	< 3	7	4,019
PICKENS-DN	Jul-87	6.9	383	0.55	61	< 3	-	2,954
REED	Apr-87	6.8	63	0.23	33	-	3	7
REED	Jul-87	7.1	56	0.27	27	< 3	-	10
RISLEY	Apr-87	7.0	281	0.15	136	-	186	91
RISLEY	Jul-87	7.1	291	0.20	137	< 3	-	75
CHELAN-STP	Jul-87	7.4	197	1.20	44	301	-	8,274
COVE-SEP	Jul-87	6.7	151	0.13	66	28,940	-	3,902
LUTZ-SEP	Jul-87	6.4	152	0.64	37	347	-	10,119
PICKENS-SEP	Jul-87	6.6	964	4.98	35	4,443	-	25,162
ST.PARK-SEP	Jul-87	7.2	604	0.97	43	308	-	15,083

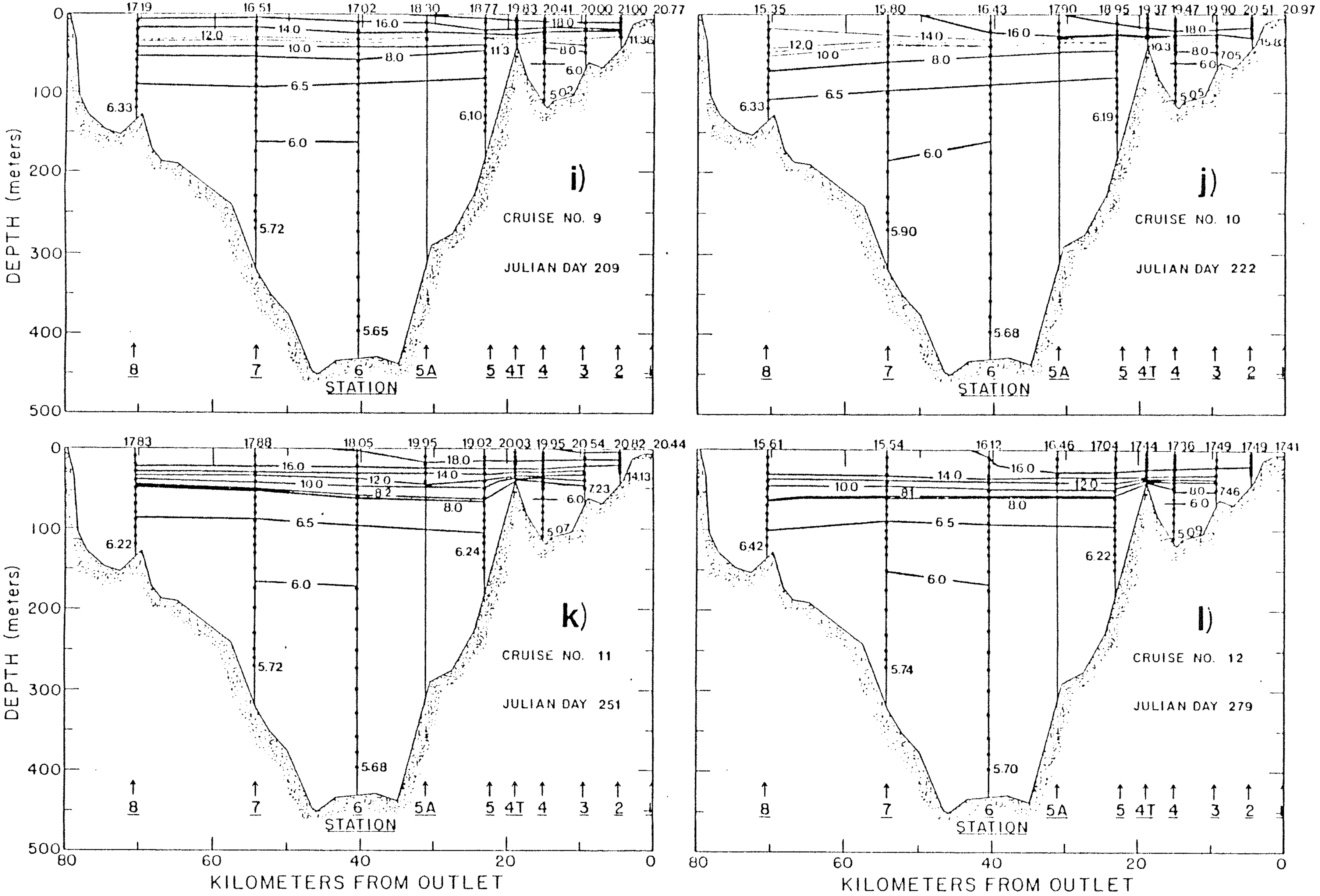
APPENDIX G

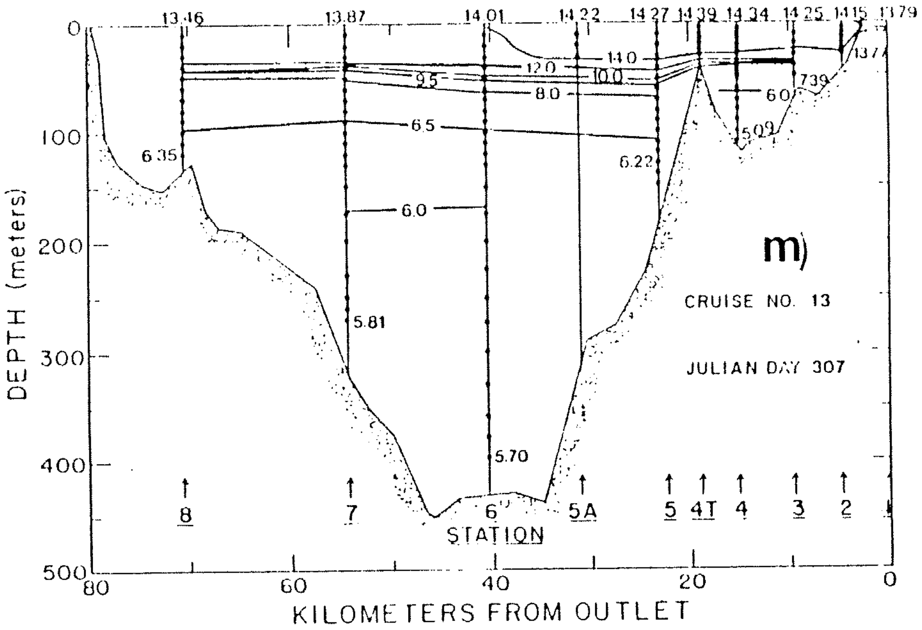
Longitudinal Temperature Profiles During Each Lake Survey


a)
CRUISE NO. 1
JULIAN DAY 350
8.26
8.41
8.87
8.67
8.35
8.26
8.03
6.98
8.5
8.0
7.7
8.0
7.0
6.0
5.0
6.65
8.12
6.10
6.0
5.90
4.24
5.54
5.52
b)
CRUISE NO. 2
JULIAN DAY 20
6.53
6.49
6.53
6.49
6.40
5.90
5.79
5.09
4.46
6.5
6.0
5.5
5.5
5.0
4.5
5.59
5.43
6.5
5.95
6.0
5.90
4.33
5.59
5.52
c)
CRUISE NO. 3
JULIAN DAY 56
6.26
6.26
6.19
6.15
6.04
5.52
5.56
5.36
4.71
5.5
5.09
5.0
5.05
5.41
4.5
4.40
5.97
6.0
5.88
5.61
5.54
d)
CRUISE NO. 4
JULIAN DAY 90
7.12
7.00
6.89
6.74
7.17
7.17
7.21
7.37
7.66
7.89
6.5
7.0
7.5
6.65
5.5
5.23
5.0
6.1
6.0
5.88
5.90
4.60
5.77
5.56
DEPTH (meters)
0
100
200
300
400
500
8
7
6
5A
5
4T
4
3
2
STATION
80
60
40
20
0
KILOMETERS FROM OUTLET



DEPTH (meters)
KILOMETERS FROM OUTLET
STATION
8
7
6
5A
5
4T
4
3
2
e)
CRUISE NO. 5
JULIAN DAY 118
8.26 8.35 8.23 8.80 9.35 10.18 11.89 11.43 13.09 14.27
10.0
8.0
7.0
6.5
6.0
5.0
5.90
5.86
5.63
5.59
5.45
4.82
f)
CRUISE NO. 6
JULIAN DAY 147
9.24 10.45 10.02 10.43 12.10 13.91 13.98 16.02 16.07 16.41
8.0
6.8
6.5
6.0
10.0
12.0
5.95
6.15
5.68
5.63
8.51
6.01
4.89
g)
CRUISE NO. 7
JULIAN DAY 167
9.90 10.73 10.64 11.43 14.10 16.34 14.91 17.41 18.77
10.0
8.0
8.9
6.5
6.0
14.0
12.0
6.10
6.22
5.68
5.63
6.49
10.36
4.91
h)
CRUISE NO. 8
JULIAN DAY 188
13.25 13.79 13.96 15.18 17.98 18.87 18.75 19.35 19.68 19.95
10.8
12.0
10.0
8.0
6.5
6.0
16.0
18.0
14.0
6.22
6.08
5.72
5.63
6.74
11.54
4.96
0
100
200
300
400
500
80
60
40
20
0


i)
CRUISE NO. 9
JULIAN DAY 209
j)
CRUISE NO. 10
JULIAN DAY 222
k)
CRUISE NO. 11
JULIAN DAY 251
l)
CRUISE NO. 12
JULIAN DAY 279
DEPTH (meters)
0
100
200
300
400
500
80
60
40
20
0
KILOMETERS FROM OUTLET
STATION
8
7
6
5A
5
4T
4
3
2
18.0
16.0
14.0
12.0
10.0
8.0
6.5
6.0
17.19
16.51
17.02
18.30
18.77
19.83
20.41
20.00
21.00
20.77
6.33
5.72
5.65
6.10
11.3
11.36
5.02
15.35
15.80
16.43
17.90
18.95
19.37
19.47
19.90
20.51
20.97
5.90
5.68
6.19
10.3
7.05
15.8
5.05
17.83
17.88
18.05
19.95
19.02
20.03
19.95
20.54
20.82
20.44
6.22
6.24
5.68
7.23
14.13
5.07
8.2
15.61
15.54
16.12
16.46
17.04
17.14
17.36
17.49
17.19
17.41
6.42
5.74
5.70
6.22
8.1
7.46
5.09


m)
CRUISE NO. 13
JULIAN DAY 307
DEPTH (meters)
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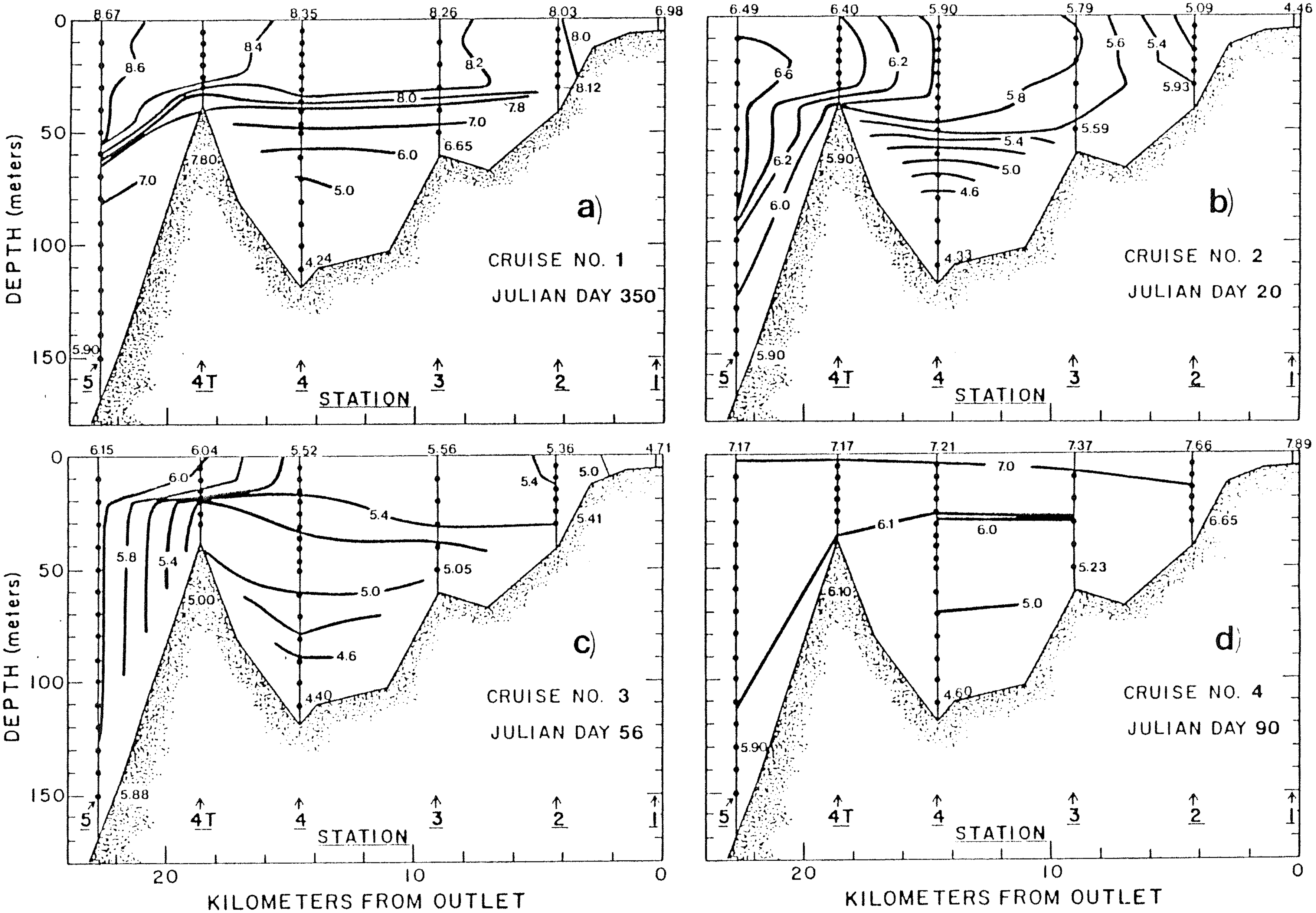
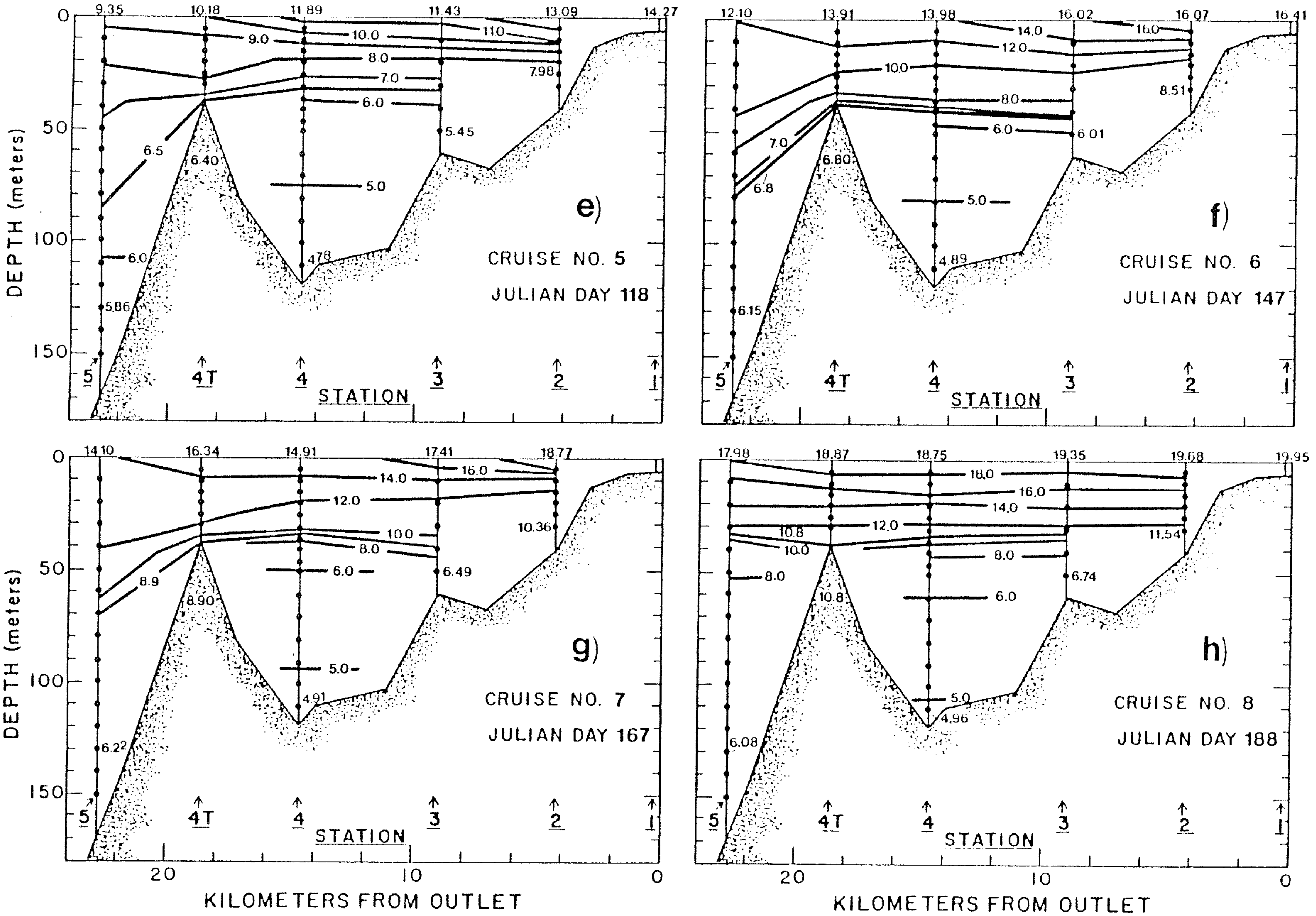
100
200
300
400
500
KILOMETERS FROM OUTLET
80
60
40
20
0
STATION
8
7
6
5A
5
4T
4
3
2
13.46
13.87
14.01
14.22
14.27
14.39
14.34
14.25
14.15
13.79
14.0
12.0
10.0
9.5
8.0
6.5
6.0
6.35
6.22
5.81
5.70
7.39
6.0
5.09
13.77


a)
CRUISE NO. 1
JULIAN DAY 350
8.67
8.35
8.26
8.03
6.98
8.6
8.4
8.2
8.0
8.12
8.0
7.8
7.0
6.0
6.65
7.80
7.0
5.0
4.24
5.90
b)
CRUISE NO. 2
JULIAN DAY 20
6.49
6.40
5.90
5.79
5.09
4.46
6.6
6.2
5.8
5.6
5.4
5.93
5.59
5.4
5.0
4.6
5.90
6.2
6.0
4.33
5.90
c)
CRUISE NO. 3
JULIAN DAY 56
6.15
6.04
5.52
5.56
5.36
4.71
6.0
5.4
5.0
5.41
5.4
5.8
5.4
5.05
5.00
5.0
4.6
4.40
5.88
d)
CRUISE NO. 4
JULIAN DAY 90
7.17
7.17
7.21
7.37
7.66
7.89
7.0
6.65
6.1
6.0
5.23
6.10
5.0
4.60
5.90
DEPTH (meters)
0
50
100
150
5
4T
4
3
2
1
STATION
20
10
0
KILOMETERS FROM OUTLET



e)
CRUISE NO. 5
JULIAN DAY 118
9.35
10.18
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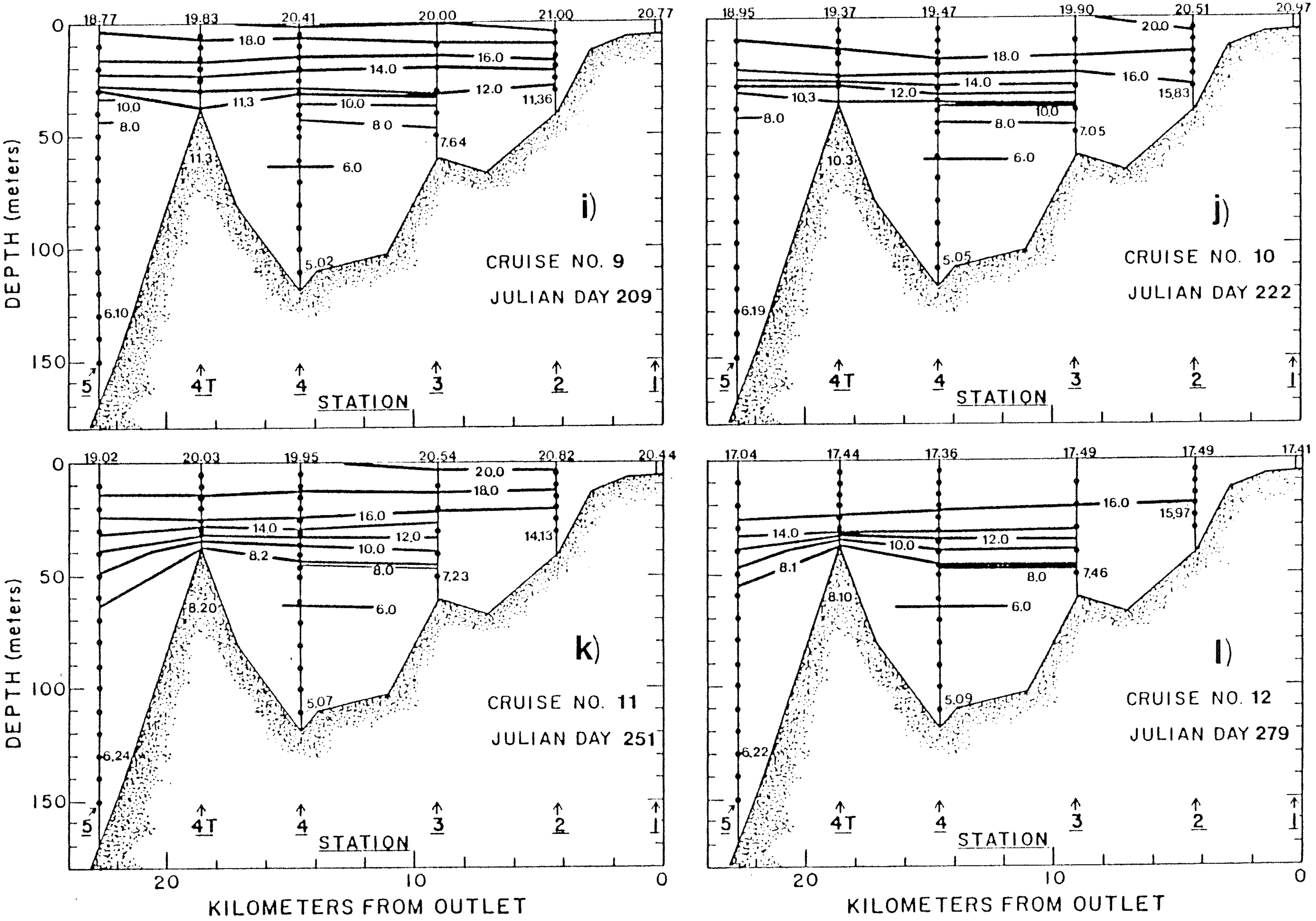
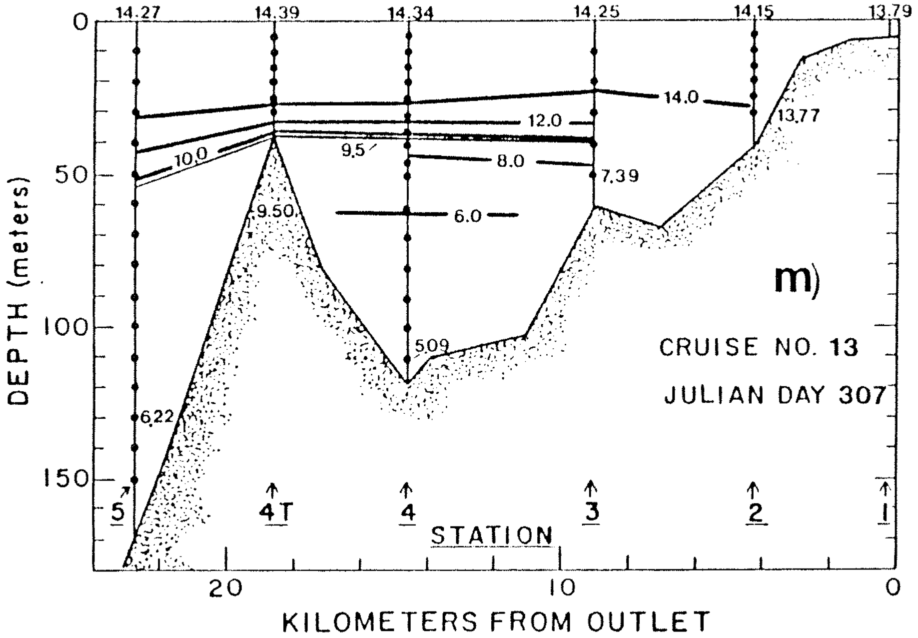
11.43
13.09
14.27
9.0
10.0
11.0
8.0
7.0
6.0
7.98
5.45
6.5
6.40
5.0
6.0
4.78
5.86
f)
CRUISE NO. 6
JULIAN DAY 147
12.10
13.91
13.98
16.02
16.07
16.41
14.0
16.0
12.0
10.0
8.0
8.51
7.0
6.80
6.0
6.01
6.8
5.0
4.89
6.15
g)
CRUISE NO. 7
JULIAN DAY 167
14.10
16.34
14.91
17.41
18.77
16.0
14.0
12.0
10.36
10.0
8.0
6.49
8.9
8.90
6.0
5.0
4.91
6.22
h)
CRUISE NO. 8
JULIAN DAY 188
17.98
18.87
18.75
19.35
19.68
19.95
18.0
16.0
14.0
12.0
10.8
10.0
11.54
8.0
6.74
6.0
10.8
5.0
4.96
6.08
DEPTH (meters)
0
50
100
150
5
4T
4
3
2
1
STATION
20
10
0
KILOMETERS FROM OUTLET



DEPTH (meters)
0
50
100
150
KILOMETERS FROM OUTLET
20
10
0
STATION
5
4T
4
3
2
1
i)
CRUISE NO. 9
JULIAN DAY 209
18.77
19.83
20.41
20.00
21.00
20.77
18.0
16.0
14.0
12.0
10.0
11.3
10.0
8.0
8.0
11.36
7.64
11.3
6.0
5.02
6.10
j)
CRUISE NO. 10
JULIAN DAY 222
18.95
19.37
19.47
19.90
20.51
20.97
20.0
18.0
16.0
14.0
12.0
10.3
10.0
15.83
8.0
8.0
7.05
6.0
10.3
5.05
6.19
k)
CRUISE NO. 11
JULIAN DAY 251
19.02
20.03
19.95
20.54
20.82
20.44
20.0
18.0
16.0
14.0
12.0
10.0
8.2
8.0
14.13
7.23
8.20
6.0
5.07
6.24
l)
CRUISE NO. 12
JULIAN DAY 279
17.04
17.44
17.36
17.49
17.49
17.41
16.0
15.97
14.0
12.0
10.0
8.1
8.0
7.46
8.10
6.0
5.09
6.22


14.27
14.39
14.34
14.25
14.15
13.79
0
50
100
150
DEPTH (meters)
14.0
12.0
10.0
9.5
8.0
6.0
13.77
7.39
9.50
5.09
6.22
m)
CRUISE NO. 13
JULIAN DAY 307
5
4T
4
3
2
1
STATION
20
10
0
KILOMETERS FROM OUTLET

APPENDIX H

Phytoplanton Data

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2 - 0

SAMPLE DATE: 86-12-16

TOTAL DENSITY (#/ml): 297

TOTAL BIOVOLUME (cu.uM/ml): 31004

DIVERSITY INDEX: 1.81

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	192	64.7	11290	36.4
2	Cyclotella ocellata	59	19.8	7354	23.7
3	Synedra rumpens	10	3.4	1432	4.6
4	Rhodomonas minuta	8	2.6	153	0.5
5	Asterionella formosa	5	1.7	7878	25.4
6	Navicula minima	3	0.9	113	0.4
7	Cosmarium sp.	3	0.9	537	1.7
8	Quadrigula closterioides	3	0.9	61	0.2
9	Crucigenia quadrata	3	0.9	217	0.7
10	Melosira distans	3	0.9	1519	4.9
11	Achnanthes minutissima	3	0.9	128	0.4
12	Chromulina like	3	0.9	26	0.1
13	Rhizosolenia eriensis	3	0.9	243	0.8
14	Rhodomonas sp.	3	0.9	51	0.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4 - 0

SAMPLE DATE: 86-12-16

TOTAL DENSITY (#/ml): 239

TOTAL BIOVOLUME (cu.uM/ml): 19816

DIVERSITY INDEX: 1.89

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	141	59.3	7932	40.0
2	Cyclotella ocellata	53	22.2	6627	33.4
3	Synedra rumpens	11	4.6	2474	12.5
4	Rhizosolenia eriensis	9	3.7	839	4.2
5	Rhodomonas minuta	7	2.8	133	0.7
6	Gloeocystis sp.	7	2.8	398	2.0
7	Ankistrodesmus falcatus	4	1.9	110	0.6
8	Chromulina like	2	0.9	22	0.1
9	Fragilaria pinnata	2	0.9	133	0.7
10	Cryptomonas erosa	2	0.9	1149	5.8

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6 - 0

SAMPLE DATE: 86-12-16

TOTAL DENSITY (#/ml): 110

TOTAL BIOVOLUME (cu.uM/ml): 10866

DIVERSITY INDEX: 2.82

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	42	38.1	2299	21.2
2	Cyclotella ocellata	25	23.0	3159	29.1
3	Synedra rumpens	10	8.8	1633	15.0
4	Rhizosolenia eriensis	8	7.1	827	7.6
5	Gloeocystis sp.	5	4.4	277	2.5
6	Quadrigula closterioides	4	3.5	124	1.1
7	Rhodomonas minuta	4	3.5	78	0.7
8	Dinobryon sertularia	3	2.7	350	3.2
9	Chlamydomonas-like	3	2.7	948	8.7
10	Crucigenia crucifera	2	1.8	413	3.8
11	Chromulina like	1	0.9	10	0.1
12	Achnanthes flexella	1	0.9	471	4.3
13	Achnanthes minutissima	1	0.9	49	0.4
14	Ankistrodesmus falcatus	1	0.9	24	0.2
15	Cosmarium sp.	1	0.9	204	1.9

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8 - 0

SAMPLE DATE: 86-12-16

TOTAL DENSITY (#/ml): 167

TOTAL BIOVOLUME (cu.uM/ml): 13778

DIVERSITY INDEX: 2.06

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	92	55.0	5051	36.7
2	Cyclotella ocellata	35	21.1	4401	31.9
3	Synedra rumpens	12	7.3	1714	12.4
4	Rhizosolenia eriensis	9	5.5	873	6.3
5	Dinobryon sertularia	6	3.7	735	5.3
6	Gloeocystis sp.	5	2.8	115	0.8
7	Achnanthes minutissima	3	1.8	153	1.1
8	Ankistrodesmus falcatus	2	0.9	38	0.3
9	Oocystis pusilla	2	0.9	661	4.8
10	Quadrigula closterioides	2	0.9	37	0.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2 - 0

SAMPLE DATE: 87-01-20

TOTAL DENSITY (#/ml): 339

TOTAL BIOVOLUME (cu.uM/ml): 47370

DIVERSITY INDEX: 2.31

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	197	58.1	17905	37.8
2	Cyclotella ocellata	55	16.2	7649	16.1
3	Rhodomonas minuta	20	6.0	406	0.9
4	Rhizosolenia eriensis	12	3.4	1378	2.9
5	Fragilaria construens	9	2.6	2925	6.2
6	Chlamydomonas-like	6	1.7	1886	4.0
7	Synedra rumpens	6	1.7	812	1.7
8	Gloeocystis sp.	6	1.7	348	0.7
9	Cymbella angustata	3	0.9	566	1.2
10	Tabellaria fenestrata	3	0.9	6964	14.7
11	Melosira distans	3	0.9	1149	2.4
12	Mallomonas sp.	3	0.9	1103	2.3
13	Achnanthes flexella	3	0.9	1407	3.0
14	Cryptomonas erosa	3	0.9	1509	3.2
15	Cosmarium sp.	3	0.9	609	1.3
16	Navicula pseudoscutiformis	3	0.9	508	1.1
17	Cocconeis disculus	3	0.9	218	0.5
18	Chromulina like	3	0.9	29	0.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4 - 0

SAMPLE DATE: 87-01-20

TOTAL DENSITY (#/ml): 217

TOTAL BIOVOLUME (cu.uM/ml): 23098

DIVERSITY INDEX: 2.38

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	109	50.4	10777	46.7
2	Cyclotella ocellata	38	17.4	4718	20.4
3	Rhizosolenia eriensis	23	10.4	2517	10.9
4	Rhodomonas minuta	17	7.8	340	1.5
5	Chrysochromulina-like	9	4.3	189	0.8
6	Synedra rumpens	4	1.7	528	2.3
7	Gloeocystis sp.	4	1.7	198	0.9
8	Dinobryon sertularia	2	0.9	226	1.0
9	Cryptomonas erosa	2	0.9	981	4.2
10	Asterionella formosa	2	0.9	1661	7.2
11	Ankistrodesmus falcatus	2	0.9	142	0.6
12	Chromulina like	2	0.9	19	0.1
13	Navicula minima	2	0.9	83	0.4
14	Mallomonas sp.	2	0.9	717	3.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6 - 0

SAMPLE DATE: 87-01-20

TOTAL DENSITY (#/ml): 139

TOTAL BIOVOLUME (cu.uM/ml): 17473

DIVERSITY INDEX: 2.94

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	41	29.4	3241	18.6
2	Cyclotella ocellata	33	23.9	4655	26.6
3	Rhizosolenia eriensis	24	17.4	2424	13.9
4	Rhodomonas minuta	10	7.3	205	1.2
5	Ankistrodesmus falcatus	9	6.4	224	1.3
6	Synedra rumpens	4	2.8	537	3.1
7	Chrysochromulina-like	3	1.8	51	0.3
8	Unident. chrysophyte	3	1.8	256	1.5
9	Cryptomonas erosa	3	1.8	1330	7.6
10	Melosira distans	1	0.9	253	1.4
11	Cosmarium sp.	1	0.9	269	1.5
12	Crucigenia crucifera	1	0.9	109	0.6
13	Gloeocystis sp.	1	0.9	58	0.3
14	Chromulina like	1	0.9	13	0.1
15	Fragilaria construens	1	0.9	286	1.6
16	Ochromonas sp.	1	0.9	109	0.6
17	Gymnodinium sp.	1	0.9	3453	19.8

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8 - 0

SAMPLE DATE: 87-01-20

TOTAL DENSITY (#/ml): 138

TOTAL BIOVOLUME (cu.uM/ml): 14171

DIVERSITY INDEX: 2.21

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	77	55.4	7843	55.3
2	Rhizosolenia eriensis	22	15.8	2331	16.4
3	Cyclotella ocellata	12	8.9	1540	10.9
4	Rhodomonas minuta	7	5.0	137	1.0
5	Chromulina like	5	4.0	55	0.4
6	Synedra rumpens	4	3.0	575	4.1
7	Ankistrodesmus falcatus	4	3.0	205	1.4
8	Dinobryon sertularia	3	2.0	329	2.3
9	Cryptomonas erosa	1	1.0	712	5.0
10	Cymbella cesatii	1	1.0	253	1.8
11	Sphaerocystis schroeteri	1	1.0	192	1.4

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2 - 0

SAMPLE DATE: 87-02-25

TOTAL DENSITY (#/ml): 293

TOTAL BIOVOLUME (cu.uM/ml): 39802

DIVERSITY INDEX: 2.30

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	156	53.1	12403	31.2
2	Cyclotella ocellata	70	23.9	9098	22.9
3	Rhizosolenia eriensis	10	3.5	985	2.5
4	Unident. green alga	8	2.7	6217	15.6
5	Gloeocystis sp.	8	2.7	467	1.2
6	Dinobryon sertularia	8	2.7	2491	6.3
7	Ankistrodesmus falcatus	5	1.8	324	0.8
8	Quadrigula closterioides	5	1.8	187	0.5
9	Synedra rumpens	5	1.8	726	1.8
10	Rhodomonas minuta	3	0.9	52	0.1
11	Amphora perpusilla	3	0.9	430	1.1
12	Cymbella microcephala	3	0.9	137	0.3
13	Cosmarium sp.	3	0.9	1089	2.7
14	Anomoeoneis sp.	3	0.9	415	1.0
15	Asterionella formosa	3	0.9	4562	11.5
16	Crucigenia crucifera	3	0.9	220	0.6

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4 - 0

SAMPLE DATE: 87-02-25

TOTAL DENSITY (#/ml): 232

TOTAL BIOVOLUME (cu.uM/ml): 34721

DIVERSITY INDEX: 2.45

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	82	35.5	7433	21.4
2	Cyclotella ocellata	70	30.0	9762	28.1
3	Rhizosolenia eriensis	42	18.2	4617	13.3
4	Synedra rumpens	13	5.5	2077	6.0
5	Asterionella formosa	4	1.8	6508	18.7
6	Dinobryon sertularia	2	0.9	1268	3.7
7	Achnanthes minutissima	2	0.9	106	0.3
8	Navicula capitata	2	0.9	1014	2.9
9	Cymbella minuta	2	0.9	782	2.3
10	Quadrigula closterioides	2	0.9	51	0.1
11	Cosmarium sp.	2	0.9	444	1.3
12	Fragilaria pinnata	2	0.9	127	0.4
13	Elakatothrix gelatinosa	2	0.9	89	0.3
14	Gloeocystis sp.	2	0.9	127	0.4
15	Navicula sp.	2	0.9	317	0.9

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 7 - 0

SAMPLE DATE: 87-02-25

TOTAL DENSITY (#/ml): 186

TOTAL BIOVOLUME (cu.uM/ml): 19916

DIVERSITY INDEX: 2.09

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhizosolenia eriensis	88	47.3	9353	47.0
2	Cyclotella stelligera	56	30.0	4664	23.4
3	Cyclotella ocellata	20	10.9	2536	12.7
4	Synedra rumpens	7	3.6	947	4.8
5	Ankistrodesmus falcatus	3	1.8	85	0.4
6	Nitzschia capitellata	2	0.9	609	3.1
7	Surirella angusta	2	0.9	583	2.9
8	Crucigenia crucifera	2	0.9	144	0.7
9	Nitzschia sp.	2	0.9	203	1.0
10	Achnanthes minutissima	2	0.9	85	0.4
11	Oocystis sp.	2	0.9	254	1.3
12	Navicula pupula	2	0.9	456	2.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8 - 0

SAMPLE DATE: 87-02-25

TOTAL DENSITY (#/ml): 169

TOTAL BIOVOLUME (cu.uM/ml): 19588

DIVERSITY INDEX: 2.09

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	72	42.9	7360	37.6
2	Rhizosolenia eriensis	65	38.4	6587	33.6
3	Synedra rumpens	11	6.3	1477	7.5
4	Cyclotella ocellata	5	2.7	565	2.9
5	Ankistrodesmus falcatus	3	1.8	75	0.4
6	Asterionella formosa	2	0.9	1326	6.8
7	Gloeocystis ampla	2	0.9	289	1.5
8	Dinobryon sertularia	2	0.9	543	2.8
9	Cosmarium sp.	2	0.9	316	1.6
10	Chromulina like	2	0.9	15	0.1
11	Melosira distans	2	0.9	298	1.5
12	Quadrigula closterioides	2	0.9	72	0.4
13	Nitzschia acicularis	2	0.9	422	2.2
14	Anomoeoneis sp.	2	0.9	241	1.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Union, I - 0

SAMPLE DATE: 87-03-31

TOTAL DENSITY (#/ml): 578

TOTAL BIOVOLUME (cu.uM/ml): 75644

DIVERSITY INDEX: 1.76

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	369	63.8	41386	54.7
2	Dinobryon sertularia	120	20.7	20385	26.9
3	Cyclotella ocellata	35	6.0	4362	5.8
4	Rhizosolenia eriensis	10	1.7	947	1.3
5	Navicula sp.	5	0.9	748	1.0
6	Ankistrodesmus falcatus	5	0.9	125	0.2
7	Pinnularia sp.	5	0.9	1994	2.6
8	Synedra rumpens	5	0.9	698	0.9
9	Cosmarium sp.	5	0.9	1047	1.4
10	Fragilaria pinnata	5	0.9	299	0.4
11	Cocconeis placentula	5	0.9	2296	3.0
12	Nitzschia paleacea	5	0.9	488	0.6
13	Navicula pseudoscutiformis	5	0.9	872	1.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4 - 0

SAMPLE DATE: 87-03-31

TOTAL DENSITY (#/ml): 438

TOTAL BIOVOLUME (cu.uM/ml): 53450

DIVERSITY INDEX: 2.14

	SPECIES	DENSITY	PCT	BIOVUL	PCT
1	Cyclotella stelligera	217	49.6	26648	49.9
2	[illegible]	107	24.3	13704	25.6
3	Cyclotella ocellata	61	13.9	7624	14.3
4	Rhizosolenia eriensis	12	2.7	1448	2.7
5	Rhodomonas minuta	8	1.8	152	0.3
6	[illegible] cascadensis	4	0.9	[illegible]	[illegible]
7	Synedra rumpens	4	0.9	[illegible]	1.0
8	Fragilaria construens	4	0.9	[illegible]	[illegible]
9	Nitzschia dissipata	4	0.9	[illegible]	[illegible]
10	Fragilaria pinnata	4	0.9	[illegible]	[illegible]
11	Ankistrodesmus falcatus	4	0.9	[illegible]	0.2
12	Sphaerocystis schroeteri	4	0.9	534	1.0
13	Cosmarium sp.	4	0.9	800	1.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, [illegible] - 4

SAMPLE DATE: 87-03-31

TOTAL DENSITY (#/ml): 218

TOTAL BIOVOLUME (cu.um/ml): 28024

DIVERSITY INDEX: 2.04

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	108	49.5	11547	41.2
2	Rhizosolenia eriensis	46	21.1	4554	16.3
3	Cyclotella ocellata	44	20.2	5511	19.7
4	Synedra rumpens	4	1.8	561	2.0
5	Rhodomonas minuta	4	1.8	80	0.3
6	Ankistrodesmus falcatus	2	0.9	56	0.2
7	Synedra radians	2	0.9	721	2.6
8	Cyclotella comta	2	0.9	4549	16.2
9	Chrysochromulina-like	2	0.9	40	0.1
10	Dinobryon sertularia	2	0.9	240	0.9
11	Elakatothrix gelatinosa	2	0.9	168	0.6

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 5 - 0

SAMPLE DATE: 87-06-21

TOTAL DENSITY (#/ml): 127

TOTAL BIOVOLUME (cu.uM/ml): 14549

DIVERSITY INDEX: 2.50

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	48	38.1	5024	34.5
2	Rhizosolenia eriensis	28	22.0	2759	19.0
3	Cyclotella ocellata	26	20.3	3222	22.1
4	Synedra rumpens	10	7.6	1356	9.3
5	Rhodomonas minuta	3	2.5	64	0.4
6	Amphora perpusilla	2	1.7	357	2.5
7	Ankistrodesmus falcatus	2	1.7	54	0.4
8	Synedra radians	1	0.8	776	5.3
9	Oocystis pusilla	1	0.8	232	1.6
10	Achnanthes minutissima	1	0.8	54	0.4
11	Dinobryon sertularia	1	0.8	129	0.9
12	Navicula decussis	1	0.8	206	1.4
13	Scenedesmus denticulatus	1	0.8	193	1.3
14	Nitzschia sp.	1	0.8	129	0.9

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2 - v

SAMPLE DATE: 87-04-28

TOTAL DENSITY (#/ml): 358

TOTAL BIOVOLUME (cu.uM/ml): 36698

DIVERSITY INDEX: 1.59

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	213	59.5	12179	33.2
2	Cyclotella ocellata	111	31.0	13886	37.8
3	Achnanthes exigua	6	1.7	691	1.9
4	Fragilaria construens	6	1.7	4838	13.2
5	Cymbella microcephala	3	0.9	164	0.4
6	Kephyrion-like	3	0.9	216	0.6
7	Synedra rumpens	3	0.9	432	1.2
8	Oocystis lacustris	3	0.9	3802	10.4
9	Ankistrodesmus falcatus	3	0.9	77	0.2
10	Achnanthes minutissima	3	0.9	154	0.4
11	Elakatothrix gelatinosa	3	0.9	259	0.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4 - 9

SAMPLE DATE: 87-04-28

TOTAL DENSITY (#/ml): 278

TOTAL BIOVOLUME (cu.uM/ml): 24415

DIVERSITY INDEX: 1.60

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	153	55.0	8905	36.5
2	Cyclotella ocellata	97	35.0	12150	49.8
3	Cosmarium sp.	9	3.3	1944	8.0
4	Ankistrodesmus falcatus	5	1.7	116	0.5
5	Fragilaria pinnata	5	1.7	278	1.1
6	Synedra rumpens	2	0.8	324	1.3
7	Kephyrion-like	2	0.8	162	0.7
8	Dictyosphaerium ehrenbergianum	2	0.8	278	1.1
9	Fragilaria construens	2	0.8	259	1.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6 - 9

SAMPLE DATE: 87-04-28

TOTAL DENSITY (#/ml): 184

TOTAL BIOVOLUME (cu.um/ml): 21005

DIVERSITY INDEX: 2.06

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	89	48.4	5477	26.1
2	Cyclotella ocellata	54	29.5	6781	32.3
3	Dinobryon sertularia	15	8.2	4340	20.7
4	Synedra radians	6	3.3	2170	10.3
5	Elakatothrix gelatinosa	6	3.3	506	2.4
6	Synedra rumpens	5	2.5	633	3.0
7	Cosmarium sp.	5	2.5	949	4.5
8	Ankistrodesmus falcatus	3	1.6	75	0.4
9	Achnanthes hauckiana	2	0.8	72	0.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6 - 0

SAMPLE DATE: 87-04-28

TOTAL DENSITY (#/ml): 173

TOTAL BIOVOLUME (cu.uM/ml): 25559

DIVERSITY INDEX: 2.51

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	60	34.5	4112	16.1
2	Cyclotella ocellata	55	31.9	6916	27.1
3	Rhizosolenia eriensis	27	15.5	2992	11.7
4	Synedra rumpens	7	4.0	1256	4.9
5	Synedra radians	6	3.4	2153	8.4
6	Ankistrodesmus falcatus	3	1.7	75	0.3
7	Achnanthes minutissima	3	1.7	150	0.6
8	Fragilaria pinnata	1	0.9	179	0.7
9	Fragilaria construens	1	0.9	2177	8.5
10	Hannaea arcus	1	0.9	2617	10.2
11	Rhodomonas minuta	1	0.9	30	0.1
12	Asterionella formosa	1	0.9	1974	7.7
13	Navicula cryptocephala	1	0.9	277	1.1
14	Unident. pennate diatom	1	0.9	526	2.0
15	Crucigenia crucifera	1	0.9	127	0.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0

SAMPLE DATE: 87-05-27

TOTAL DENSITY (#/ml): 1046

TOTAL BIOVOLUME (cu.uM/ml): 109396

DIVERSITY INDEX: 1.19

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	657	62.8	36149	33.0
2	Cyclotella ocellata	352	33.6	45291	41.4
3	Cryptomonas erosa	9	0.9	4814	4.4
4	Achnanthes minutissima	9	0.9	463	0.4
5	Achnanthes lanceolata	9	0.9	1666	1.5
6	Cyclotella comta	9	0.9	21014	19.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-05-27

TOTAL DENSITY (#/ml): 791

TOTAL BIOVOLUME (cu.uM/ml): 71654

DIVERSITY INDEX: 1.34

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	375	47.4	21445	29.9
2	Cyclotella ocellata	375	47.4	46864	65.4
3	Ankistrodesmus falcatus	21	2.6	693	1.0
4	Dinobryon sertularia	7	0.9	833	1.2
5	Navicula sp.	7	0.9	1041	1.5
6	Fragilaria construens	7	0.9	778	1.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-05-27

TOTAL DENSITY (#/ml): 882

TOTAL BIOVOLUME (cu.uM/ml): 134278

DIVERSITY INDEX: 1.73

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	424	48.0	23293	17.3
2	Cyclotella ocellata	354	40.2	45146	33.6
3	Dinobryon sertularia	35	3.9	4166	3.1
4	Ankistrodesmus falcatus	21	2.4	521	0.4
5	Cosmarium sp.	7	0.8	1458	1.1
6	Stephanodiscus astraea	7	0.8	55834	41.6
7	Cymbella cesatii	7	0.8	1284	1.0
8	Achnanthes minutissima	7	0.8	347	0.3
9	Rhizosolenia eriensis	7	0.8	660	0.5
10	Fragilaria leptostauron	7	0.8	1277	1.0
11	Elakatothrix gelatinosa	7	0.8	292	0.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-05-27

TOTAL DENSITY (#/ml): 615

TOTAL BIOVOLUME (cu.uM/ml): 56995

DIVERSITY INDEX: 1.86

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	263	42.7	14738	25.9
2	Cyclotella ocellata	257	41.9	32181	56.5
3	Rhizosolenia eriensis	32	5.1	3504	6.1
4	Dinobryon sertularia	26	4.3	3152	5.5
5	Rhodomonas minuta	11	1.7	210	0.4
6	Synedra rumpens	5	0.9	736	1.3
7	Achnanthes linearis	5	0.9	694	1.2
8	Elakatothrix gelatinosa	5	0.9	441	0.8
9	Kephyrion-like	5	0.9	368	0.6
10	Cymbella cesatii	5	0.9	972	1.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0

SAMPLE DATE: 87-06-16

TOTAL DENSITY (#/ml): 1137

TOTAL BIOVOLUME (cu.uM/ml): 141113

DIVERSITY INDEX: 1.41

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	680	59.8	37422	26.5
2	Cyclotella ocellata	379	33.3	49754	35.3
3	Achnanthes minutissima	19	1.7	972	0.7
4	Cyclotella comta	19	1.7	44129	31.3
5	Ankistrodesmus falcatus	10	0.9	243	0.2
6	Chrysochromulina-like	10	0.9	194	0.1
7	Navicula decussis	10	0.9	1866	1.3
8	Fragilaria construens	10	0.9	6532	4.6

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-06-16

TOTAL DENSITY (#/ml): 1220

TOTAL BIOVOLUME (cu.uM/ml): 126738

DIVERSITY INDEX: 1.36

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	648	53.1	35640	28.1
2	Cyclotella ocellata	508	41.6	63450	50.1
3	Ankistrodesmus falcatus	22	1.8	540	0.4
4	Elakatothrix gelatinosa	11	0.9	907	0.7
5	Fragilaria construens venter	11	0.9	518	0.4
6	Oocystis pusilla	11	0.9	1166	0.9
7	Cyclotella comta	11	0.9	24516	19.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-06-16

TOTAL DENSITY (#/ml): 636

TOTAL BIOVOLUME (cu.uM/ml): 83997

DIVERSITY INDEX: 2.07

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	273	43.0	34834	41.5
2	Cyclotella stelligera	231	36.4	12715	15.1
3	Elakatothrix gelatinosa	42	6.6	3531	4.2
4	Dinobryon sertularia	26	4.1	3152	3.8
5	Rhizosolenia eriensis	21	3.3	1997	2.4
6	Rhodomonas minuta	16	2.5	315	0.4
7	Cyclotella comta	11	1.7	23853	28.4
8	Cryptomonas erosa	5	0.8	2732	3.3
9	Synedra rumpens	5	0.8	736	0.9
10	Ankistrodesmus falcatus	5	0.8	131	0.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-06-16

TOTAL DENSITY (#/ml): 619

TOTAL BIOVOLUME (cu.uM/ml): 61968

DIVERSITY INDEX: 1.99

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	286	46.3	35811	57.8
2	Cyclotella stelligera	220	35.5	12099	19.5
3	Rhizosolenia eriensis	36	5.8	3402	5.5
4	Dinobryon sertularia	26	4.1	3069	5.0
5	Elakatothrix gelatinosa	15	2.5	1289	2.1
6	Achnanthes linearis	10	1.7	1351	2.2
7	Navicula decussis	5	0.8	982	1.6
8	Cryptomonas erosa	5	0.8	2660	4.3
9	Achnanthes minutissima	5	0.8	256	0.4
10	Ankistrodesmus falcatus	5	0.8	128	0.2
11	Scenedesmus denticulatus	5	0.8	921	1.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0

SAMPLE DATE: 87-07-07

TOTAL DENSITY (#/ml): 265

TOTAL BIOVOLUME (cu.uM/ml): 26152

DIVERSITY INDEX: 1.68

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	131	49.6	7214	27.6
2	Cyclotella ocellata	105	39.8	13438	51.4
3	Elakatothrix gelatinosa	7	2.7	1378	5.3
4	Fragilaria construens	5	1.8	1049	4.0
5	Oocystis pusilla	5	1.8	759	2.9
6	Cymbella microcephala	2	0.9	124	0.5
7	Achnanthes minutissima	2	0.9	117	0.4
8	Fragilaria pinnata	2	0.9	843	3.2
9	Ankistrodesmus falcatus	2	0.9	59	0.2
10	Unident. dinoflagellate	2	0.9	1171	4.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-07-07

TOTAL DENSITY (#/ml): 431

TOTAL BIOVOLUME (cu.uM/ml): 52771

DIVERSITY INDEX: 1.30

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	219	50.8	27393	51.9
2	Cyclotella stelligera	194	45.1	10692	20.3
3	Cyclotella comta	4	0.8	8023	15.2
4	Anomoeoneis sp.	4	0.8	566	1.1
5	Unident. green alga	4	0.8	4241	8.0
6	Ankistrodesmus falcatus	4	0.8	88	0.2
7	Unident. dinoflagellate	4	0.8	1767	3.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-07-07

TOTAL DENSITY (#/ml): 1422

TOTAL BIOVOLUME (cu.uM/ml): 140478

DIVERSITY INDEX: 1.36

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	826	58.1	103275	73.5
2	Cyclotella stelligera	510	35.9	28067	20.0
3	Rhizosolenia eriensis	24	1.7	2309	1.6
4	Dinobryon sertularia	24	1.7	4374	3.1
5	Synedra rumpens	12	0.9	1701	1.2
6	Rhodomonas minuta	12	0.9	243	0.2
7	Elakatothrix gelatinosa	12	0.9	510	0.4

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-07-07

TOTAL DENSITY (#/ml): 1225

TOTAL BIOVOLUME (cu.uM/ml): 128664

DIVERSITY INDEX: 1.35

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	807	65.9	100845	78.4
2	Cyclotella stelligera	311	25.4	17107	13.3
3	Rhizosolenia eriensis	68	5.6	6464	5.0
4	Oocystis pusilla	10	0.8	1050	0.8
5	Dinobryon sertularia	10	0.8	1166	0.9
6	Achnanthes lewisiana	10	0.8	1215	0.9
7	Elakatothrix gelatinosa	10	0.8	816	0.6

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                PHYTOPLANKTON SAMPLE ANALYSIS

                       SAMPLE: Lake Chelan, 2-0

                  SAMPLE DATE: 87-07-28

           TOTAL DENSITY (#/ml): 128

     TOTAL BIOVOLUME (cu.uM/ml): 16254

              DIVERSITY INDEX: 1.80

    SPECIES                          DENSITY    PCT     BIOVOL    PCT
--  ------------------------------   -------   ----    -------   ----
 1  Cyclotella ocellata                   81   63.6      10186   62.7
 2  Cyclotella stelligera                 27   20.9       1738   10.7
 3  Oocystis pusilla                       5    3.6        377    2.3
 4  Cryptomonas sp.                        3    2.7       1397    8.6
 5  Sphaerocystis schroeteri               2    1.8        244    1.5
 6  Fragilaria construens                  1    0.9        261    1.6
 7  Navicula minima                        1    0.9         51    0.3
 8  Amphora ovalis                         1    0.9        673    4.1
 9  Achnanthes lanceolata                  1    0.9        210    1.3
10  Navicula pseudoscutiformis             1    0.9        204    1.3
11  Elakatothrix gelatinosa                1    0.9         98    0.6
12  Crucigenia crucifera                   1    0.9         99    0.6
13  Oocystis lacustris                     1    0.9        717    4.4
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PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-07-28

TOTAL DENSITY (#/ml): 147

TOTAL BIOVOLUME (cu.uM/ml): 15725

DIVERSITY INDEX: 1.83

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	82	55.8	10417	66.2
2	Cyclotella stelligera	39	26.9	2321	14.8
3	Oocystis pusilla	13	8.7	835	5.3
4	Rhodomonas minuta	3	1.9	56	0.4
5	Fragilaria construens	3	1.9	473	3.0
6	Elakatothrix gelatinosa	1	1.0	118	0.8
7	Kephyrion obliquum	1	1.0	204	1.3
8	Navicula decussis	1	1.0	270	1.7
9	Cosmarium sp.	1	1.0	296	1.9
10	Cryptomonas erosa	1	1.0	733	4.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-07-28

TOTAL DENSITY (#/ml): 795

TOTAL BIOVOLUME (cu.uM/ml): 90396

DIVERSITY INDEX: 0.73

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	660	83.0	82473	91.2
2	Cyclotella stelligera	124	15.6	6804	7.5
3	Rhizosolenia eriensis	12	1.5	1119	1.2

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                    PHYTOPLANKTON SAMPLE ANALYSIS

                              SAMPLE: Lake Chelan, 8-0

                         SAMPLE DATE: 87-07-28

                 TOTAL DENSITY (#/ml): 838

          TOTAL BIOVOLUME (cu.uM/ml): 102151

                     DIVERSITY INDEX: 0.72

     SPECIES                                DENSITY    PCT     BIOVOL    PCT
--   ------------------------------         -------   ----    -------   ----
 1   Cyclotella ocellata                        729   87.0      91125   89.2
 2   Cyclotella stelligera                       85   10.1       4678    4.6
 3   Achnanthes minutissima                       6    0.7        304    0.3
 4   Rhodomonas minuta                            6    0.7        122    0.1
 5   Rhizosolenia eriensis                        6    0.7        577    0.6
 6   Asterionella formosa                         6    0.7       5346    5.2
```

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0
SAMPLE DATE: 87-08-18
TOTAL DENSITY (#/ml): 224
TOTAL BIOVOLUME (cu.uM/ml): 17165
DIVERSITY INDEX: 1.63

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	157	70.1	8623	50.2
2	Cyclotella ocellata	38	16.8	4703	27.4
3	Fragilaria pinnata	6	2.8	628	3.7
4	Rhizosolenia eriensis	2	0.9	199	1.2
5	Navicula pseudoscutiformis	2	0.9	366	2.1
6	Nitzschia sinuata	2	0.9	523	3.0
7	Achnanthes minutissima	2	0.9	105	0.6
8	Synedra rumpens	2	0.9	293	1.7
9	Rhodomonas minuta	2	0.9	42	0.2
10	Unident. green alga	2	0.9	314	1.8
11	Navicula pupula	2	0.9	564	3.3
12	Amphora perpusilla	2	0.9	347	2.0
13	Kephyrion-like	2	0.9	146	0.9
14	Navicula sp.	2	0.9	314	1.8

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-08-18

TOTAL DENSITY (#/ml): 233

TOTAL BIOVOLUME (cu.uM/ml): 46030

DIVERSITY INDEX: 1.78

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	106	45.6	5843	12.7
2	Cyclotella ocellata	99	42.7	12433	27.0
3	Fragilaria construens venter	5	1.9	868	1.9
4	Navicula pupula	5	1.9	1221	2.7
5	Oocystis pusilla	2	1.0	488	1.1
6	Amphora perpusilla	2	1.0	750	1.6
7	Ceratium hirundinella	2	1.0	22153	48.1
8	Cocconeis placentula	2	1.0	1040	2.3
9	Kephyrion-like	2	1.0	158	0.3
10	Dinobryon sertularia	2	1.0	271	0.6
11	Rhodomonas minuta	2	1.0	45	0.1
12	Fragilaria construens	2	1.0	760	1.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0
SAMPLE DATE: 87-08-18
TOTAL DENSITY (#/ml): 948
TOTAL BIOVOLUME (cu.uM/ml): 116316
DIVERSITY INDEX: 1.17

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	729	76.9	91125	78.3
2	Cyclotella stelligera	154	16.2	8465	7.3
3	Ankistrodesmus falcatus	16	1.7	810	0.7
4	Rhodomonas minuta	8	0.9	162	0.1
5	Rhizosolenia eriensis	8	0.9	770	0.7
6	Achnanthes minutissima	8	0.9	405	0.3
7	Asterionella formosa	8	0.9	10692	9.2
8	Dinobryon sertularia	8	0.9	972	0.8
9	Synedra radians	8	0.9	2916	2.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-08-18

TOTAL DENSITY (#/ml): 945

TOTAL BIOVOLUME (cu.uM/ml): 127951

DIVERSITY INDEX: 0.93

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	795	84.1	99409	77.7
2	Cyclotella stelligera	80	8.4	4374	3.4
3	Rhodomonas minuta	27	2.8	530	0.4
4	Rhizosolenia eriensis	27	2.8	2518	2.0
5	Dinobryon sertularia	9	0.9	1060	0.8
6	Cyclotella comta	9	0.9	20059	15.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0

SAMPLE DATE: 87-09-08

TOTAL DENSITY (#/ml): 267

TOTAL BIOVOLUME (cu.uM/ml): 44106

DIVERSITY INDEX: 1.10

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	224	84.1	34050	77.2
2	Cyclotella ocellata	15	5.6	1869	4.2
3	Rhizosolenia eriensis	5	1.9	474	1.1
4	Oocystis lacustris	5	1.9	3838	8.7
5	Fragilaria construens	2	0.9	1396	3.2
6	Anomoeoneis sp.	2	0.9	399	0.9
7	Ankistrodesmus falcatus	2	0.9	62	0.1
8	Achnanthes minutissima	2	0.9	125	0.3
9	Fragilaria construens venter	2	0.9	120	0.3
10	Cryptomonas erosa	2	0.9	1296	2.9
11	Navicula decussis	2	0.9	479	1.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-09-08

TOTAL DENSITY (#/ml): 208

TOTAL BIOVOLUME (cu.uM/ml): 38575

DIVERSITY INDEX: 1.96

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	130	62.6	23927	62.0
2	Cyclotella ocellata	35	16.8	4374	11.3
3	Rhodomonas minuta	14	6.5	272	0.7
4	Rhizosolenia eriensis	6	2.8	554	1.4
5	Ankistrodesmus falcatus	4	1.9	97	0.3
6	Fragilaria construens	4	1.9	871	2.3
7	Elakatothrix gelatinosa	4	1.9	327	0.8
8	Fragilaria leptostauron	2	0.9	358	0.9
9	Achnanthes exigua	2	0.9	218	0.6
10	Oocystis pusilla	2	0.9	420	1.1
11	Oocystis lacustris	2	0.9	2395	6.2
12	Cyclotella comta	2	0.9	4413	11.4
13	Scenedesmus denticulatus	2	0.9	350	0.9

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-09-08

TOTAL DENSITY (#/ml): 265

TOTAL BIOVOLUME (cu.uM/ml): 35880

DIVERSITY INDEX: 1.07

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	206	77.6	25729	71.7
2	Cyclotella stelligera	41	15.5	5796	16.2
3	Rhizosolenia eriensis	11	4.3	1086	3.0
4	Asterionella formosa	2	0.9	3019	8.4
5	Ankistrodesmus falcatus	2	0.9	57	0.2
6	Elakatothrix gelatinosa	2	0.9	192	0.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-09-08

TOTAL DENSITY (#/ml): 160

TOTAL BIOVOLUME (cu.uM/ml): 19462

DIVERSITY INDEX: 1.03

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	129	80.4	16081	82.6
2	Cyclotella stelligera	20	12.5	2047	10.5
3	Rhizosolenia eriensis	6	3.6	543	2.8
4	Elakatothrix gelatinosa	3	1.8	240	1.2
5	Unident. desmid	1	0.9	236	1.2
6	Asterionella formosa	1	0.9	314	1.6

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0

SAMPLE DATE: 87-10-06

TOTAL DENSITY (#/ml): 59

TOTAL BIOVOLUME (cu.uM/ml): 26006

DIVERSITY INDEX: 3.08

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	21.4	36.3	5563	21.4
2	Cyclotella ocellata	11.0	18.7	1625	6.2
3	Cyclotella comta	7.1	12.1	16181	62.2
4	Rhodomonas minuta	3.9	6.6	78	0.3
5	Cryptomonas sp.	2.6	4.4	1037	4.0
6	Unident. cryptophyte	1.9	3.3	49	0.2
7	Navicula decussis	1.3	2.2	249	1.0
8	Fragilaria pinnata	1.3	2.2	78	0.3
9	Ankistrodesmus falcatus	1.3	2.2	32	0.1
10	Achnanthes minutissima	1.3	2.2	65	0.2
11	Elakatothrix gelatinosa	1.3	2.2	109	0.4
12	Oocystis pusilla	0.6	1.1	280	1.1
13	Fragilaria construens	0.6	1.1	73	0.3
14	Fragilaria construens venter	0.6	1.1	93	0.4
15	Unident. green alga	0.6	1.1	97	0.4
16	Navicula sp.	0.6	1.1	97	0.4
17	Gomphonema gracile	0.6	1.1	159	0.6
18	Asterionella formosa	0.6	1.1	143	0.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0

SAMPLE DATE: 87-10-06

TOTAL DENSITY (#/ml): 64

TOTAL BIOVOLUME (cu.uM/ml): 12461

DIVERSITY INDEX: 2.74

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	20.8	32.3	416	3.3
2	Cyclotella stelligera	14.7	22.9	2693	21.6
3	Cyclotella ocellata	12.7	19.8	1592	12.8
4	Cryptomonas sp.	4.0	6.3	1609	12.9
5	Unident. cryptophyte	2.7	4.2	67	0.5
6	Cyclotella comta	2.0	3.1	4565	36.6
7	Rhizosolenia eriensis	2.0	3.1	191	1.5
8	Oocystis pusilla	1.3	2.1	434	3.5
9	Dinobryon bavaricum	1.3	2.1	161	1.3
10	Navicula anglica	0.7	1.0	241	1.9
11	Mallomonas sp.	0.7	1.0	255	2.0
12	Elakatothrix gelatinosa	0.7	1.0	56	0.5
13	Navicula pupula	0.7	1.0	181	1.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-10-06

TOTAL DENSITY (#/ml): 96

TOTAL BIOVOLUME (cu.uM/ml): 14578

DIVERSITY INDEX: 2.42

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	43.6	45.5	6429	44.1
2	Rhodomonas minuta	17.4	18.2	349	2.4
3	Cyclotella stelligera	12.2	12.7	2061	14.1
4	Rhizosolenia eriensis	9.6	10.0	911	6.2
5	Elakatothrix gelatinosa	5.2	5.5	587	4.0
6	Asterionella formosa	1.7	1.8	767	5.3
7	Cryptomonas erosa	1.7	1.8	907	6.2
8	Amphora perpusilla	0.9	0.9	145	1.0
9	Cryptomonas sp.	0.9	0.9	349	2.4
10	Unident. cryptophyte	0.9	0.9	22	0.1
11	Cyclotella comta	0.9	0.9	1979	13.6
12	Ochromonas sp.	0.9	0.9	74	0.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-10-06

TOTAL DENSITY (#/ml): 82

TOTAL BIOVOLUME (cu.uM/ml): 15970

DIVERSITY INDEX: 2.56

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella ocellata	41.0	50.0	6311	39.5
2	Rhodomonas minuta	12.4	15.1	248	1.6
3	Cyclotella stelligera	8.5	10.4	1195	7.5
4	Rhizosolenia eriensis	6.2	7.5	589	3.7
5	Cryptomonas sp.	1.5	1.9	620	3.9
6	Dinobryon sertularia	1.5	1.9	279	1.7
7	Cryptomonas erosa	1.5	1.9	805	5.0
8	Asterionella formosa	1.5	1.9	341	2.1
9	Oocystis pusilla	1.5	1.9	418	2.6
10	Crucigenia crucifera	1.5	1.9	658	4.1
11	Oocystis lacustris	0.8	0.9	477	3.0
12	Gymnodinium sp.	0.8	0.9	2091	13.1
13	Elakatothrix gelatinosa	0.8	0.9	130	0.8
14	Chroococcus minimus	0.8	0.9	11	0.1
15	Cyclotella comta	0.8	0.9	1758	11.0
16	Achnanthes minutissima	0.8	0.9	39	0.2

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 2-0
SAMPLE DATE: 87-11-03
TOTAL DENSITY (#/ml): 96
TOTAL BIOVOLUME (cu.uM/ml): 29749
DIVERSITY INDEX: 3.49

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	32.9	34.3	657	2.2
2	Dinobryon sertularia	14.6	15.2	2190	7.4
3	Cryptomonas erosa	6.4	6.7	3322	11.2
4	Cyclotella comta	6.4	6.7	14502	48.7
5	Cyclotella ocellata	4.6	4.8	799	2.7
6	Cryptomonas sp.	4.6	4.8	1825	6.1
7	Unident. cryptophyte	3.7	3.8	91	0.3
8	Chroomonas sp.	3.7	3.8	237	0.8
9	Cyclotella stelligera	2.7	2.9	351	1.2
10	Westella linearis	2.7	2.9	383	1.3
11	Amphora perpusilla	0.9	1.0	152	0.5
12	Navicula minima	0.9	1.0	40	0.1
13	Cymbella lunata	0.9	1.0	785	2.6
14	Rhizosolenia eriensis	0.9	1.0	87	0.3
15	Tabellaria fenestrata	0.9	1.0	2190	7.4
16	Chroococcus minimus	0.9	1.0	26	0.1
17	Navicula muralis	0.9	1.0	41	0.1
18	Fragilaria pinnata	0.9	1.0	383	1.3
19	Elakatothrix gelatinosa	0.9	1.0	153	0.5
20	Nitzschia sp.	0.9	1.0	110	0.4
21	Achnanthes clevei	0.9	1.0	137	0.5
22	Chlamydomonas sp.	0.9	1.0	297	1.0
23	Oocystis lacustris	0.9	1.0	562	1.9
24	Fragilaria construens venter	0.9	1.0	350	1.2
25	Ochromonas sp.	0.9	1.0	78	0.3

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 4-0
SAMPLE DATE: 87-11-03
TOTAL DENSITY (#/ml): 74
TOTAL BIOVOLUME (cu.uM/ml): 27949
DIVERSITY INDEX: 3.54

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	19.0	25.7	381	1.4
2	Dinobryon sertularia	7.5	10.1	1220	4.4
3	Cryptomonas sp.	7.5	10.1	2991	10.7
4	Cyclotella comta	6.8	9.2	15430	55.2
5	Cyclotella ocellata	6.1	8.3	1277	4.6
6	Rhizosolenia eriensis	5.4	7.3	646	2.3
7	Cyclotella stelligera	5.4	7.3	1008	3.6
8	Cryptomonas erosa	4.1	5.5	2121	7.6
9	Unident. cryptophyte	2.7	3.7	68	0.2
10	Synedra rumpens	1.4	1.8	285	1.0
11	Mallomonas sp.	1.4	1.8	517	1.8
12	Unident. dinoflagellate	1.4	1.8	680	2.4
13	Chrysochromulina sp.	1.4	1.8	27	0.1
14	Elakatothrix gelatinosa	0.7	0.9	228	0.8
15	Navicula sp.	0.7	0.9	102	0.4
16	Fragilaria construens	0.7	0.9	228	0.8
17	Ochromonas sp.	0.7	0.9	58	0.2
18	Oocystis pusilla	0.7	0.9	294	1.1
19	Eunotia incisa	0.7	0.9	389	1.4

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 6-0

SAMPLE DATE: 87-11-03

TOTAL DENSITY (#/ml): 115

TOTAL BIOVOLUME (cu.uM/ml): 39251

DIVERSITY INDEX: 2.70

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	54	47.5	1089	2.8
2	Cryptomonas erosa	13	11.0	6571	16.7
3	Rhizosolenia eriensis	10	8.5	1016	2.6
4	Cyclotella ocellata	9	7.6	1706	4.3
5	Cyclotella comta	7	5.9	22086	56.3
6	Dinobryon sertularia	6	5.1	931	2.4
7	Cyclotella stelligera	4	3.4	1176	3.0
8	Chrysochromulina sp.	4	3.4	78	0.2
9	Cryptomonas sp.	3	2.5	1166	3.0
10	Elakatothrix gelatinosa	2	1.7	122	0.3
11	Synedra radians	1	0.8	350	0.9
12	Chlamydomonas sp.	1	0.8	316	0.8
13	Gymnodinium sp.	1	0.8	2624	6.7
14	Chromulina sp.	1	0.8	19	0.0

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Lake Chelan, 8-0

SAMPLE DATE: 87-11-03

TOTAL DENSITY (#/ml): 83

TOTAL BIOVOLUME (cu.uM/ml): 33135

DIVERSITY INDEX: 2.83

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	32.0	38.4	641	1.9
2	Cryptomonas erosa	19.4	23.2	10070	30.4
3	Cyclotella comta	8.2	9.8	18598	56.1
4	Rhizosolenia eriensis	6.0	7.1	566	1.7
5	Cyclotella ocellata	3.7	4.5	559	1.7
6	Elakatothrix gelatinosa	3.0	3.6	219	0.7
7	Mallomonas sp.	1.5	1.8	566	1.7
8	Synedra radians	1.5	1.8	536	1.6
9	Ankistrodesmus falcatus	1.5	1.8	74	0.2
10	Chrysochromulina sp.	1.5	1.8	30	0.1
11	Cryptomonas sp.	0.7	0.9	298	0.9
12	Nitzschia palea	0.7	0.9	134	0.4
13	Achnanthes linearis	0.7	0.9	98	0.3
14	Melosira distans	0.7	0.9	295	0.9
15	Ochromonas sp.	0.7	0.9	63	0.2
16	Gomphonema sp.	0.7	0.9	298	0.9
17	Anomoeoneis vitrea	0.7	0.9	89	0.3

APPENDIX

Summary of Periphyton Data

Appendix B. Periphyton cell content of chl a, TOC, TN and TP.

Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
5/26/87					
Chelan Outlet	1	7.1	NA	NA	NA
	2	10.0	NA	NA	NA
Mitchell Creek	2 m W-1	7.5	NA	NA	NA
	2 m W-2	4.9	NA	NA	NA
	10 m W-1	11.3	210	21.0	10.0
	10 m W-2	18.0	NA	NA	NA
	50 m W-1	3.6	51.6	7.6	6.3
	50 m W-2	3.4	NA	NA	NA
	2 m E-1	12.4	NA	NA	NA
	2 m E-2	8.0	NA	NA	NA
	10 m E-1	22.2	NA	NA	NA
	10 m E-2	25.9	NA	NA	NA
	50 m E-1	7.9	NA	NA	NA
	50 m E-1R	7.5	NA	NA	NA
	50 m E-2	9.6	NA	NA	NA
Greens Landing	2 m W-1	27.8	NA	NA	NA
	2 m W-2	18.0	NA	NA	NA
	10 m W-1	29.3	NA	NA	NA
	10 m W-2	54.7	NA	NA	NA
	220 m W-1	8.3	NA	NA	NA
	220 m W-2	9.9	NA	NA	NA
	2 m E-1	62.7	NA	NA	NA
	2 m E-2	241.2	NA	NA	NA
	2 m E-2R	191.4	NA	NA	NA
	10 m E-1	57.8	174	27.9	23.8
	10 m E-2	54.7	NA	NA	NA
	50 m E-1	67.5	NA	NA	NA
	50 m E-2	44.8	NA	NA	NA
Purtteman G.	2 m W-1	16.3	NA	NA	NA
	2m W-2	8.0	NA	NA	NA
	10 m W-1	1.0	NA	NA	NA
	10 m W-2	0.8	NA	NA	NA
	50 m W-1	6.0	NA	NA	NA
	50 m W-2	9.2	NA	NA	NA
	2 m E-1	0.6	NA	NA	NA
	2 m E-2	--	NA	NA	NA
	10 m E-1	41.8	244	29.4	79.6
	10 m E-2	33.0	NA	NA	NA

	A	B	C	D	E	F
49	Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
50						
51		50 m E-1	7.0	NA	NA	NA
52		50 m E-2	3.4	NA	NA	NA
53						
54	First Creek	2 m W-1	7.8	NA	NA	NA
55		2 m W-2	10.9	NA	NA	NA
56		10 m W-1	5.2	NA	NA	NA
57		10 m W-2	4.8	NA	NA	NA
58		50 m W-1	2.6	NA	NA	NA
59		50 m W-2	4.5	NA	NA	NA
60		2 m E-1	8.4	NA	NA	NA
61		2 m E-1R	7.1	NA	NA	NA
62		2 m E-2	5.1	NA	NA	NA
63		10 m E-1	7.7	418	29.9	16.9
64		10 m E-2	5.6	NA	NA	NA
65		50 m E-1	1.3	89.4	8.0	4.1
66		50 m E-2	1.0	NA	NA	NA
67						
68	Knapp Coulee	2 m W-1	20.3	NA	NA	NA
69		2 m W-2	36.2	NA	NA	NA
70		10 m W-1	17.2	NA	NA	NA
71		10 m W-2	19.3	NA	NA	NA
72		50 m W-1	--	NA	NA	NA
73		50 m W-2	--	NA	NA	NA
74		2 m E-1	65.2	NA	NA	NA
75		2 m E-1R	62.7	NA	NA	NA
76		2 m E-2	30.1	NA	NA	NA
77		10 m E-1	16.6	296	40.6	15.5
78		10 m E-2	20.9	NA	NA	NA
79		50 m E-1	13.5	NA	NA	NA
80		50 m E-2	15.9	NA	NA	NA
81						
82	7/6/87					
83						
84	Chelan Outlet	1	2.3	NA	NA	NA
85		1R	5.3	NA	NA	NA
86		2	7.7	NA	NA	NA
87						
88	Mitchell Creek	2 m W-1	--	NA	NA	NA
89		2 m W-2	9.0	NA	NA	NA
90		10 m W-1	2.7	68.7	6.4	7.9
91		10 m W-1R	2.7	NA	NA	NA
92		10 m W-2	--	NA	NA	NA
93		50 m W-1	0.2	78.8	4.9	4.7
94		50 m W-1R	1.4	NA	NA	NA
95		50 m W-2	0.2	NA	NA	NA
96		50 m W-2R	0.4	NA	NA	NA

	A	B	C	D	E	F
97	Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
98						
99		2 m E-1	22.0	NA	NA	NA
100		2 m E-2	16.1	NA	NA	NA
101		2 m E-2R	15.4	NA	NA	NA
102		10 m E-1	5.3	NA	NA	NA
103		10 m E-2	4.5	NA	NA	NA
104		10 m E-2R	4.7	NA	NA	NA
105		50 m E-1	1.9	NA	NA	NA
106		50 m E-2	2.4	NA	NA	NA
107		50 m E-2R	1.3	NA	NA	NA
108						
109	Greens Landing	2 m W-1	3.3	NA	NA	NA
110		2 m W-2	0.6	NA	NA	NA
111		10 m W-1	4.7	NA	NA	NA
112		10 m W-2	1.0	NA	NA	NA
113		220 W-1	6.4	NA	NA	NA
114		220 W-2	1.6	NA	NA	NA
115		2 m E-1	1.2	NA	NA	NA
116		2 m E-2	8.0	NA	NA	NA
117		10 m E-1	0.8	147	17.5	2.9
118		10 m E-2	--	NA	NA	NA
119		50 m E-1	3.4	NA	NA	NA
120		50 m E-2	2.1	NA	NA	NA
121						
122	Purtteman G.	2 m W-1	7.3	NA	NA	NA
123		2 m W-1R	6.9	NA	NA	NA
124		2 m W-2	9.6	NA	NA	NA
125		2 m W-2R	11.3	NA	NA	NA
126		10 m W-1	8.6	NA	NA	NA
127		10 m W-1R	9.4	NA	NA	NA
128		10 m W-2	9.9	NA	NA	NA
129		10 m W-2R	10.7	NA	NA	NA
130		50 m W-1	6.4	NA	NA	NA
131		50 m W-1R	4.7	NA	NA	NA
132		50 m W-2	6.4	NA	NA	NA
133		50 m W-2R	4.3	NA	NA	NA
134		2 m E-1	34.1	NA	NA	NA
135		2 m E-1R	32.2	NA	NA	NA
136		2 m E-2	47.2	NA	NA	NA
137		2 m E-2R	42.9	NA	NA	NA
138		10 m E-1	25.2	167	20.2	35.9
139		10 m E-2	33.0	NA	NA	NA
140		10 m E-2R	32.3	NA	NA	NA
141		50 m E-1	1.3	NA	NA	NA
142		50 m E-1R	1.6	NA	NA	NA
143		50 m E-2	0.2	NA	NA	NA
144		50 m E-2R	0.4	NA	NA	NA

	A	B	C	D	E	F
145	Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
146						
147	First Creek	2 m W-1	13.4	NA	NA	NA
148		2 m W-2	6.8	NA	NA	NA
149		10 m W-1	4.3	NA	NA	NA
150		10 m W-2	3.8	NA	NA	NA
151		50 m W-1	1.9	NA	NA	NA
152		50 m W-2	2.9	NA	NA	NA
153		2 m E-1	10.7	NA	NA	NA
154		2 m E-2	23.2	NA	NA	NA
155		10 m E-1	6.0	247	16.9	25.4
156		10 m E-2	4.3	NA	NA	NA
157		50 m E-1	1.9	91.2	10.9	10.5
158		50 m E-2	2.4	NA	NA	NA
159						
160	Knapp Coulee	2 m W-1	52.5	NA	NA	NA
161		2 m W-2	43.7	NA	NA	NA
162		10 m W-1	9.3	NA	NA	NA
163		10 m W-2	3.9	NA	NA	NA
164		50 m W-1	2.6	NA	NA	NA
165		50 m W-2	2.6	NA	NA	NA
166		2 m E-1	13.5	NA	NA	NA
167		2 m E-2	13.3	NA	NA	NA
168		10 m E-1	17.7	118	10.8	25.4
169		10 m E-2	17.6	NA	NA	NA
170		50 m E-1	1.3	NA	NA	NA
171		50 m E-2	2.3	NA	NA	NA
172						
173	9/7/87					
174						
175	Chelan Outlet	1	5.9	NA	NA	NA
176		1R	4.8	NA	NA	NA
177		2	4.8	NA	NA	NA
178		2R	4.8	NA	NA	NA
179						
180	Mitchell Creek	2 m W-1	1.6	NA	NA	NA
181		2 m W-2	9.6	NA	NA	NA
182		10 m W-1	92.6	1335	111.2	23.5
183		10 m W-1R	72.0	NA	NA	NA
184		10 m W-2	27.0	NA	NA	NA
185		50 m W-1	0.9	45.6	5.3	16.5
186		50 m W-2	0.9	NA	NA	NA
187		2 m E-1	16.7	NA	NA	NA
188		2 m E-1R	14.8	NA	NA	NA
189		2 m E-2	32.7	NA	NA	NA
190		10 m E-1	16.9	NA	NA	NA
191		10 m E-2	11.6	NA	NA	NA
192		50 m E-1	2.0	NA	NA	NA

	A	B	C	D	E	F
193	Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
194						
195		50 m E-2	--	NA	NA	NA
196						
197	Greens Landing	2 m W-1	26.8	NA	NA	NA
198		2 m W-2	23.2	NA	NA	NA
199		10 m W-1	5.5	NA	NA	NA
200		10 m W-2	4.3	NA	NA	NA
201		220 m W-1	2.7	NA	NA	NA
202		220 m W-2	3.1	NA	NA	NA
203		2 m E-1	21.5	NA	NA	NA
204		2 m E-2	18.0	NA	NA	NA
205		10 m E-1	4.0	107	14.4	2.8
206		10 m E-2	6.6	NA	NA	NA
207		50 m E-1	2.9	NA	NA	NA
208		50 m E-2	4.5	NA	NA	NA
209						
210	Purtteman G.	2 m W-1	54.5	NA	NA	NA
211		2 m W-2	50.4	NA	NA	NA
212		10 m W-1	6.3	NA	NA	NA
213		10 m W-2	5.6	NA	NA	NA
214		50 m W-1	12.1	NA	NA	NA
215		50 m W-2	23.2	NA	NA	NA
216		2 m E-1	33.9	NA	NA	NA
217		2 m E-2	89.2	NA	NA	NA
218		10 m E-1	88.8	565	102.7	68.4
219		10 m E-2	132.1	NA	NA	NA
220		50 m E-1	7.3	NA	NA	NA
221		50 m E-2	2.4	NA	NA	NA
222						
223	First Creek	2 m W-1	15.0	NA	NA	NA
224		2 m W-2	5.9	NA	NA	NA
225		2 m W-2R	8.8	NA	NA	NA
226		10 m W-1	13.4	NA	NA	NA
227		10 m W-2	17.6	NA	NA	NA
228		50 m W-1	3.2	NA	NA	NA
229		50 m W-2	5.0	NA	NA	NA
230		2 m E-1	13.9	NA	NA	NA
231		2 m E-2	10.5	NA	NA	NA
232		10 m E-1	17.1	259	22.9	6.8
233		10 m E-2	7.1	NA	NA	NA
234		50 m E-1	3.0	74.9	12.2	2.1
235		50 m E-2	3.4	NA	NA	NA
236						
237	Knapp Coulee	2 m W-1	69.7	NA	NA	NA
238		2 m W-2	53.6	NA	NA	NA
239		10 m W-1	13.1	NA	NA	NA
240		10 m W-2	6.0	NA	NA	NA

	A	B	C	D	E	F
241	Station	Sampling Site	Chl a (mg/m2)	TOC (ug/cm2)	TN (ug/cm2)	TP (ug/cm2)
242						
243		50 m W-1	4.8	NA	NA	NA
244		50 m W-2	2.3	NA	NA	NA
245		2 m E-1	16.9	NA	NA	NA
246		2 m E-2	72.4	NA	NA	NA
247		10 m E-1	82.5	588	67.4	21.4
248		10 m E-1R	NA	578	67.4	NA
249		10 m E-2	44.5	NA	NA	NA
250		50 m E-1	10.7	NA	NA	NA
251		50 m E-1R	8.8	NA	NA	NA
252		50 m E-2	10.0	NA	NA	NA
253						
254						
255	R Analytical replicate					
256						
257	-- Sample lost during analysis					
258						
259	NA Not authorized for analysis					

APPENDIX J

Sediment Data

Laucks
Testing Laboratories, Inc.
940 South Harney St. Seattle, Washington 98108 (206)767-5060

Chemistry, Microbiology, and Technical Services

Certificate

CLIENT: Harper Owes
1110 3rd Ave., Suite 610
Seattle, WA 98101
ATTN: Clay Patmont

LABORATORY NO: 99745

DATE: Dec. 16, 1986

REPORT ON: SOILS

SAMPLE IDENTIFICATION: Submitted 11/6/86 and identified as shown below:

1) LC-1 11/7 1530 grab stainless med van veen
2) LC-2 11/7 1545 grab stainless med van veen
3) LC-3 11/7 1600 grab stainless med van veen
4) LC-4 11/7 1640 grab stainless med van veen
5) LC-5 11/7 1650 grab stainless med van veen
6) LC-6 11/7 1700 grab stainless med van veen
7) LC-7 11/5 0940 grab stainless med van veen
8) LC-8 11/5 0955 grab stainless med van veen
9) LC-9 11/5 1005 grab stainless med van veen
10) LC-10 11/5 1050 comp 30-50 cm piston care comp
11) LC-11 11/5 grab 30-50 cm piston care comp
12) LC-12 11/5 grab 30-50 cm piston care comp

TESTS PERFORMED AND RESULTS:

Samples were analyzed for priority pollutants in accordance with Test Methods for Evaluating Solid Waste, (SW-846), U.S.E.P.A., 1982, Methods organics), 8270 (semi-volatile extractables), 8080 (pesticides and PCB's), 6010 and the 7000 series (metals analysis).

Harper Owes

LABORATORY NO: 99745

Inorganics

	1	2	3	4	5
Total Solids, %	59.9	41.4	64.2	40.5	65.2
	parts per million (mg/kg) dry basis				
Arsenic	1.3	2.5	2.5	2.4	1.1
Beryllium	0.2	0.3	0.2	0.2	L/0.1
Cadmium	0.2	0.3	0.2	0.7	0.2
Chromium	14.	16.	8.	17.	5.
Copper	17.	23.	8.	22.	4.
Lead	14.	17.	6.	83.	6.
Mercury	L/0.1	L/0.1	L/0.1	L/0.1	L/0.1
Nickel	10.	12.	9.	10.	4.
Selenium	L/0.5	L/0.5	L/0.5	L/0.5	L/0.5
Silver	0.4	0.6	0.3	0.4	0.2
Zinc	92.	99.	78.	170.	46.
Total Phosphorus	600.	730.	400.	760.	360.

	6	7	8	9	10
Total Solids, %	31.4	74.2	30.6	25.0	33.0
	parts per million (mg/kg) dry basis				
Arsenic	4.5	L/0.5	7.2	9.8	7.4
Beryllium	0.5	L/0.1	0.5	0.5	0.5
Cadmium	0.3	0.1	0.6	0.9	0.3

Harper Owes

LABORATORY NO: 99745

	6	7	8	9	10
	parts per million (mg/kg) dry basis				
Chromium	26.	6.	28.	25.	17.
Copper	30.	5.	35.	53.	22.
Lead	21.	2.	28.	26.	8.
Mercury	L/0.1	L/0.1	L/0.1	L/0.1	L/0.1
Nickel	18.	5.	18.	16.	12.
Selenium	0.5	0.6	L/0.5	L/0.5	0.7
Silver	0.6	0.3	0.8	1.0	0.7
Zinc	100.	34.	130.	200.	71.
Total Phosphorus	770.	440.	880.	1100.	800.

	11	12	Lab Blank
Total Solids, %	72.2	39.5	---
	parts per million (mg/kg) dry basis		
Arsenic	L/0.5	7.0	L/0.5
Beryllium	0.1	0.4	L/0.1
Cadmium	0.2	0.5	L/0.1
Chromium	3.	32.	L/1.
Copper	3.	25.	L/1.
Lead	2.	9.	L/1.
Mercury	L/0.1	L/0.1	L/0.1
Nickel	3.	13.	L/2.
Selenium	L/0.5	L/0.5	L/0.5
Silver	0.3	0.7	L/0.1
Zinc	32.	100.	1.
Total Phosphorus	300.	1000.	L/50.

Harper Owes

LABORATORY NO: 99745

Extractables (by GC/MS)

	parts per billion (ug/kg)				
	1	2	3	4	5
N-nitrosodimethylamine	L/20.	L/30.	L/20.	L/30.	L/20.
Bis(2-chloroethyl)ether	L/20.	L/30.	L/20.	L/30.	L/20.
2-Chlorophenol	L/20.	L/30.	L/20.	L/30.	L/20.
Phenol	L/20.	L/30.	L/20.	L/30.	L/20.
1,3-Dichlorobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
1,4-Dichlorobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
1,2-Dichlorobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
Bis(2-chloroisopropyl)ether	L/20.	L/30.	L/20.	L/30.	L/20.
Hexachloroethane	L/20.	L/30.	L/20.	L/30.	L/20.
N-nitroso-di-n-propylamine	L/20.	L/30.	L/20.	L/30.	L/20.
Nitrobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
Isophorone	L/20.	L/30.	L/20.	L/30.	L/20.
2-Nitrophenol	L/20.	L/30.	L/20.	L/30.	L/20.
2,4-Dimethylphenol	L/20.	L/30.	L/20.	L/30.	L/20.
Bis(2-chloroethoxy)methane	L/20.	L/30.	L/20.	L/30.	L/20.
2,4-Dichlorophenol	L/20.	L/30.	L/20.	L/30.	L/20.
1,2,4-Trichlorobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
Naphthalene	L/20.	L/30.	L/20.	L/30.	L/20.
Hexachlorobutadiene	L/20.	L/30.	L/20.	L/30.	L/20.
4-Chloro-m-cresol	L/20.	L/30.	L/20.	L/30.	L/20.
Hexachlorocyclopentadiene	L/20.	L/30.	L/20.	L/30.	L/20.
2,4,6-Trichlorophenol	L/20.	L/30.	L/20.	L/30.	L/20.
2-Chloronaphthalene	L/20.	L/30.	L/20.	L/30.	L/20.
Acenaphthylene	L/20.	L/30.	L/20.	L/30.	L/20.
Dimethylphthalate	L/20.	L/30.	L/20.	L/30.	L/20.
2,6-Dinitrotoluene	L/20.	L/30.	L/20.	L/30.	L/20.
Acenaphthene	L/20.	L/30.	L/20.	L/30.	L/20.
2,4-Dinitrophenol	L/20.	L/30.	L/20.	L/30.	L/20.
2,4-Dinitrotoluene	L/20.	L/30.	L/20.	L/30.	L/20.
4-Nitrophenol	L/20.	L/30.	L/20.	L/30.	L/20.
Fluorene	L/20.	L/30.	L/20.	L/30.	L/20.
4-Chlorophenyl phenyl ether	L/20.	L/30.	L/20.	L/30.	L/20.

Harper Owes

LABORATORY NO: 99745

parts per billion (ug/kg)

	1	2	3	4	5
Diethylphthalate	L/20.	L/30.	L/20.	L/30.	L/20.
4,6-Dinitro-o-cresol	L/20.	L/30.	L/20.	L/30.	L/20.
1,2-Diphenylhydrazine	L/20.	L/30.	L/20.	L/30.	L/20.
4-Bromophenyl phenyl ether	L/20.	L/30.	L/20.	L/30.	L/20.
Hexachlorobenzene	L/20.	L/30.	L/20.	L/30.	L/20.
Pentachlorophenol	L/20.	L/30.	L/20.	L/30.	L/20.
Phenanthrene	L/20.	L/30.	L/20.	L/30.	L/20.
Anthracene	L/20.	L/30.	L/20.	L/30.	L/20.
Dibutylphthalate	L/20.	L/30.	L/20.	L/30.	L/20.
Fluoranthene	120.	30.	L/20.	L/30.	L/20.
Pyrene	50.	L/30.	L/20.	L/30.	L/20.
Benzidine	L/20.	L/30.	L/20.	L/30.	L/20.
Butyl benzyl phthalate	L/20.	L/30.	L/20.	L/30.	L/20.
Benzo(a)anthracene	30.	L/30.	L/20.	L/30.	L/20.
Chrysene	50.	L/30.	L/20.	L/30.	L/20.
3,3'-Dichlorobenzidine	L/20.	L/30.	L/20.	L/30.	L/20.
Bis(2-ethylhexyl)phthalate	370.	950.	1000.	740.	530.
N-nitrosodiphenylamine	L/20.	L/30.	L/20.	L/30.	L/20.
Di-n-octyl phthalate	30.	L/30.	20.	40.	L/20.
Benzo(b)fluoranthene	40.	L/30.	L/20.	L/30.	L/20.
Benzo(k)fluoranthene	30.	L/30.	L/20.	L/30.	L/20.
Benzo(a)pyrene	50.	L/30.	L/20.	L/30.	L/20.
Indeno(1,2,3-cd)pyrene	L/20.	L/30.	L/20.	L/30.	L/20.
Dibenzo(ah)anthracene	L/20.	L/30.	L/20.	L/30.	L/20.
Benzo(ghi)perylene	30.	L/30.	L/20.	L/30.	L/20.
*Aniline	L/20.	L/30.	L/20.	L/30.	L/20.
*Benzoic Acid	L/20.	350.	210.	540.	500.
*Benzyl Alcohol	L/20.	L/30.	L/20.	L/30.	L/20.
*4-Chloroaniline	L/20.	L/30.	L/20.	L/30.	L/20.
*Dibenzofuran	L/20.	L/30.	L/20.	L/30.	L/20.
*2-Methylnaphthalene	L/20.	L/30.	L/20.	L/30.	L/20.

Harper Owes

LABORATORY NO: 99745

	parts per billion (ug/kg)				
	6	7	8	9	11
4-Chloro-m-cresol	L/40.	L/20.	L/40.	L/50.	L/20.
Hexachlorocyclopentadiene	L/40.	L/20.	L/40.	L/50.	L/20.
2,4,6-Trichlorophenol	L/40.	L/20.	L/40.	L/50.	L/20.
2-Chloronaphthalene	L/40.	L/20.	L/40.	L/50.	L/20.
Acenaphthylene	L/40.	L/20.	L/40.	L/50.	L/20.
Dimethylphthalate	L/40.	L/20.	L/40.	L/50.	L/20.
2,6-Dinitrotoluene	L/40.	L/20.	L/40.	L/50.	L/20.
Acenaphthene	L/40.	L/20.	L/40.	L/50.	L/20.
2,4-Dinitrophenol	L/40.	L/20.	L/40.	L/50.	L/20.
2,4-Dinitrotoluene	L/40.	L/20.	L/40.	L/50.	L/20.
4-Nitrophenol	L/40.	L/20.	L/40.	L/50.	L/20.
Fluorene	L/40.	L/20.	L/40.	L/50.	L/20.
4-Chlorophenyl phenyl ether	L/40.	L/20.	L/40.	L/50.	L/20.
Diethylphthalate	L/40.	L/20.	L/40.	L/50.	L/20.
4,6-Dinitro-o-cresol	L/40.	L/20.	L/40.	L/50.	L/20.
1,2-Diphenylhydrazine	L/40.	L/20.	L/40.	L/50.	L/20.
4-Bromophenyl phenyl ether	L/40.	L/20.	L/40.	L/50.	L/20.
Hexachlorobenzene	L/40.	L/20.	L/40.	L/50.	L/20.
Pentachlorophenol	L/40.	L/20.	L/40.	L/50.	L/20.
Phenanthrene	L/40.	L/20.	L/40.	130.	L/20.
Anthracene	L/40.	L/20.	L/40.	L/50.	L/20.
Dibutylphthalate	L/40.	L/20.	L/40.	L/50.	L/20.
Fluoranthene	L/40.	L/20.	L/40.	360.	L/20.
Pyrene	L/40.	L/20.	L/40.	230.	L/20.
Benzidine	L/40.	L/20.	L/40.	L/50.	L/20.
Butyl benzyl phthalate	L/40.	L/20.	L/40.	L/50.	L/20.
Benzo(a)anthracene	L/40.	L/20.	L/40.	90.	L/20.
Chrysene	L/40.	24.	L/40.	160.	L/20.
3,3'-Dichlorobenzidine	L/40.	L/20.	L/40.	L/50.	L/20.
Bis(2-ethylhexyl)phthalate	790.	380.	770.	900.	410.
N-nitrosodiphenylamine	L/40.	L/20.	L/40.	L/50.	L/20.

Harper Owes

LABORATORY NO: 99745

parts per billion (ug/kg)

	12	Lab Blank
Bis(2-chloroisopropyl)ether	L/30.	L/50.
Hexachloroethane	L/30.	L/50.
N-nitroso-di-n-propylamine	L/30.	L/50.
Nitrobenzene	L/30.	L/50.
Isophorone	L/30.	L/50.
2-Nitrophenol	L/30.	L/50.
2,4-Dimethylphenol	L/30.	L/50.
Bis(2-chloroethoxy)methane	L/30.	L/50.
2,4-Dichlorophenol	L/30.	L/50.
1,2,4-Trichlorobenzene	L/30.	L/50.
Naphthalene	L/30.	L/50.
Hexachlorobutadiene	L/30.	L/50.
4-Chloro-m-cresol	L/30.	L/50.
Hexachlorocyclopentadiene	L/30.	L/50.
2,4,6-Trichlorophenol	L/30.	L/50.
2-Chloronaphthalene	L/30.	L/50.
Acenaphthylene	L/30.	L/50.
Dimethylphthalate	L/30.	L/50.
2,6-Dinitrotoluene	L/30.	L/50.
Acenaphthene	L/30.	L/50.
2,4-Dinitrophenol	L/30.	L/50.
2,4-Dinitrotoluene	L/30.	L/50.
4-Nitrophenol	L/30.	L/50.
Fluorene	L/30.	L/50.
4-Chlorophenyl phenyl ether	L/30.	L/50.
Diethylphthalate	L/30.	L/50.
4,6-Dinitro-o-cresol	L/30.	L/50.
1,2-Diphenylhydrazine	L/30.	L/50.
4-Bromophenyl phenyl ether	L/30.	L/50.
Hexachlorobenzene	L/30.	L/50.
Pentachlorophenol	L/30.	L/50.

Harper Owes

LABORATORY NO: 99745

parts per billion (ug/kg)

	12	Lab Blank
Phenanthrene	L/30.	L/50.
Anthracene	L/30.	L/50.
Dibutylphthalate	L/30.	L/50.
Fluoranthene	L/30.	L/50.
Pyrene	L/30.	L/50.
Benzidine	L/30.	L/50.
Butyl benzyl phthalate	L/30.	L/50.
Benzo(a)anthracene	L/30.	L/50.
Chrysene	L/30.	L/50.
3,3'-Dichlorobenzidine	L/30.	L/50.
Bis(2-ethylhexyl)phthalate	610.	120.
N-nitrosodiphenylamine	L/30.	L/50.
Di-n-octyl phthalate	50.	L/50.
Benzo(b)fluoranthene	L/30.	L/50.
Benzo(k)fluoranthene	L/30.	L/50.
Benzo(a)pyrene	L/30.	L/50.
Indeno(1,2,3-cd)pyrene	L/30.	L/50.
Dibenzo(ah)anthracene	L/30.	L/50.
Benzo(ghi)perylene	L/30.	L/50.
*Aniline	L/30.	L/50.
*Benzoic Acid	510.	L/50.
*Benzyl Alcohol	L/30.	L/50.
*4-Chloroaniline	L/30.	L/50.
*Dibenzofuran	L/30.	L/50.
*2-Methylnaphthalene	L/30.	L/50.
*2-Methylphenol	L/30.	L/50.
*4-Methylphenol	L/30.	L/50.
*2-Nitroaniline	L/30.	L/50.
*3-Nitroaniline	L/30.	L/50.
*4-Nitroaniline	L/30.	L/50.
*2,4,5-Trichlorophenol	L/30.	L/50.

LABORATORY NO: 99745

Harper Owes

	parts per billion (ug/kg)				
	6	7	8	9	11
alpha-BHC	L/1.	L/1.	L/1.	L/1.	L/1.
beta-BHC	L/1.	L/1.	L/1.	L/1.	L/1.
delta-BHC	L/1.	L/1.	L/1.	L/1.	L/1.
gamma-BHC (lindane)	L/1.	L/1.	L/1.	L/1.	L/1.
heptachlor	L/1.	L/1.	L/1.	L/1.	L/1.
aldrin	L/1.	L/1.	L/1.	L/1.	L/1.
heptachlor epoxide	L/1.	L/1.	L/1.	L/1.	L/1.
dieldrin	L/1.	L/1.	L/1.	L/1.	L/1.
4,4'-DDE	5.	1.	62.	30.	L/1.
4,4'-DDD	6.	L/1.	119.	27.	L/1.
endosulfan sulfate	L/1.	L/1.	L/1.	L/1.	L/1.
4,4'-DDT	5.	L/1.	33.	11.	L/1.
chlordane	L/1.	L/1.	L/1.	L/1.	L/1.
alpha endosulfan	L/1.	L/1.	L/1.	L/1.	L/1.
beta endosulfan	L/1.	L/1.	L/1.	L/1.	L/1.
endrin	L/1.	L/1.	L/1.	L/1.	L/1.
endrin aldehyde	L/1.	L/1.	L/1.	L/1.	L/1.
toxaphene	L/50.	L/50.	L/50.	L/50.	L/50.
PCB 1016	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1221	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1232	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1242	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1248	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1254	L/20.	L/20.	L/20.	L/20.	L/20.
PCB 1260	L/20.	L/20.	L/20.	L/20.	L/20.
Methoxychlor	L/2.	L/2.	L/2.	L/2.	L/2.
Endrin Ketone	L/1.	L/1.	L/1.	L/1.	L/1.

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PAGE: 14

Harper Owes

LABORATORY NO: 99745

Key

L/ indicates "less than"
* indicates additional compounds from the EPA's Hazardous Substances List.

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

J. M. Owens

JMO:dr

Harper Owes

LABORATORY NO: 99745

APPENDIX A

Matrix Spike/Matrix Spike Duplicate Report

		parts per million (mg/kg)*				mg/kg*			QC Limits	
Samp #	Analyte	Spike Added	Sample Result	MS Result	% Rec	MSD Result	% Rec	RPD	RPD	Rec
4	Arsenic	25.	2.4	19.	68.	19.	65.	5.	#	#
4	Selenium	2.5	L/0.5	2.3	84.	2.3	84.	0.	#	#
8	Silver	10.	0.8	10.	96.	11.	103.	7.0	#	#
8	Beryllium	2.5	0.5	2.6	84.	2.6	84.	0.	8.	61-113
8	Cadmium	2.5	0.6	2.6	82.	2.6	81.	1.2	26.	65-124
8	Chromium	25.	28.	50.	90.	51.	93.	3.3	10.	76-123
8	Copper	50.	35.	79.	88.	80.	89.	1.1	11.	80-118
8	Lead	50.	28.	69.	83.	70.	85.	2.4	40.	66-135
8	Nickel	25.	18.	35.	69.**	34.	64.**	7.5	21.	75-128
8	Zinc	100.	130.	220.	89.	220.	93.	4.4	24.	67-121
8	Phosphorus	1000.	880.	1800.	93.	1800.	94.	1.1	#	#
5	Mercury	0.5	L/0.1	0.5	100.	0.5	100.	0.	#	#
		parts per billion (ug/kg)				ug/kg				
11	Lindane	12.6	0.	8.8	69.8	10.4	82.5	16.7	50.	46-127
11	Heptachlor	12.6	0.	6.6	52.4	7.8	61.9	16.6	31.	35-130
11	Aldrin	12.6	0.	6.9	54.8	8.0	63.5	14.7	43.	34-132
11	Dieldrin	31.4	0.	26.2	83.4	28.9	92.0	9.8	38.	31-134
11	Endrin	31.4	0.	25.1	79.9	29.1	92.7	14.8	45.	42-139
11	DDT	31.4	0.2	25.0	79.6	23.1	73.6	7.8	50.	23-134

* reported on the dry basis
\# no control limits established

** Persistently poor surrogate and spike recoveries signal a laboratory problem and the need for re-extraction and re-analysis. However, occasional outliers are regarded as anomolies and, in this case, re-analysis was not deemed necessary because other indicators were in control.

Harper Owes

LABORATORY NO: 99745

APPENDIX B

Surrogate Recovery Quality Control Report

Listed below are surrogate (chemically similar) compounds utilized in the analysis of organic compounds. The surrogates are added to every sample prior to extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The control limits represent the 95% confidence interval established in our laboratory through repetitive analysis of these sample types.

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
		parts per billion (ug/kg)			
Lab Blank	Isodrin	100.	40.1	40.1	10-113
1	Isodrin	100.	29.3	29.3	10-113
2	Isodrin	100.	35.4	35.4	10-113
3	Isodrin	100.	21.7	21.7	10-113
4	Isodrin	100.	29.9	29.9	10-113
5	Isodrin	100.	33.8	33.8	10-113
6	Isodrin	100.	15.4	15.4	10-113
7	Isodrin	100.	25.6	25.6	10-113
8	Isodrin	100.	22.0	22.0	10-113
9	Isodrin	100.	25.8	25.8	10-113
11	Isodrin	100.	19.8	19.8	10-113
11 MS	Isodrin	100.	31.4	31.4	10-113
11 MSD	Isodrin	100.	39.8	39.8	10-113
12	Isodrin	100.	30.6	30.6	10-113

Harper Owes

LABORATORY NO: 99745

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
		parts per billion (ug/kg)			
Lab Blank	Dibutylchlorendate	200.	110.	55.	18-123
1	Dibutylchlorendate	200.	93.	46.5	18-123
2	Dibutylchlorendate	200.	102.	51.	18-123
3	Dibutylchlorendate	200.	84.5	42.2	18-123
4	Dibutylchlorendate	200.	81.4	40.7	18-123
5	Dibutylchlorendate	200.	98.0	49.0	18-123
6	Dibutylchlorendate	200.	71.8	35.8	18-123
7	Dibutylchlorendate	200.	66.2	33.1	18-123
8	Dibutylchlorendate	200.	67.9	34.0	18-123
9	Dibutylchlorendate	200.	83.3	41.5	18-123
11	Dibutylchlorendate	200.	71.2	35.6	18-123
11 MS	Dibutylchlorendate	200.	86.4	43.2	18-123
11 MSD	Dibutylchlorendate	200.	110.	55.	18-123
12	Dibutylchlorendate	200.	84.6	42.3	18-123

Harper

LABORATORY NO: 99745

APPENDIX

Matrix Spike/Duplicate Spike Quality Control

Reported below are the results of additional QC compounds utilized in the analysis of organic compounds. Compounds of interest are spiked into two additional sample aliquots prior to extraction and/or analysis to monitor for matrix effects, sample processing errors, and to calculate percent recoveries of compunds of interest and relative error in the analysis. The control limits represent the 95% confidence interval established in the laboratory through repetitive analysis of these sample types.

Sample 11

	ug/kg				ug/kg				
Compound	Conc Spike	Conc Samp	Conc MS	% REC	Conc MSD	% REC	RPD	RPD Limit	REC Limit
1,2,4-Trichlorobenzene	1570.	0.	1157.	73.7	1236.	78.7	-7.	23	38-107
Acenaphthene	1570.	0.	1366.	87.0	1336.	85.1	2.	19	31-137
2,4-Dinitrotoluene	1570.	0.	1418.	90.3	1167.	74.3	19.	47	28-89
Pyrene	1570.	0.	978.	62.3	798.	50.8	10.	36	35-142
N-Nitrosodipropylamine	1570.	0.	1678.	106.9	1697.	108.1	-1.	38	41-126
1,4-Dichlorobenzene	1570.	0.	1297.	82.6	1397.	89.0	-8.	27	28-104
Pentachlorophenol	3140.	0.	848.	27.0	942.	30.0	-11.	47	17-109
Phenol	3140.	0.	2704.	86.1	2619.	83.4	3.	35	26-90
2-Chlorophenol	3140.	0.	2324.	74.0	2474.	78.8	-6.	50	25-102
P-Chloro-m-cresol	3140.	0.	3288.	104.7	2826.	90.0	15.	33	26-103
4-Nitrophenol	3140.	0.	3140.	100.0	2157.	68.7	37.	50	11-114

Conc = Concentration
Samp = Sample
MS = Matrix Spike

MSD = Matrix Spike Duplicate
REC = Recovery
RPD = Relative Percent Difference

11/20/1986

Surrogate Recovery Quality Control Report

Listed below are the surrogate (chemically similar) compounds utilized in analysis of organic compounds. The surrogates are added to every sample prior to extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The contol limits are established in our laboratory through repetitive analysis of these sample types.

Job No.: 99745
Client: HARPER OWES
Matrix: Soil Units: ug/kg
Analysis: AB/N s by GC/MS

==

Compound: 2-Fluorophenol Limits: 25 - 121

Sample ID	Recovery	Comment
1	64.2	
2	73.5	
3	50.8	
4	65.4	
5	60.0	
6	68.1	
7	69.3	
8	64.4	
9	54.1	
11	76.8	
12	67.3	
BLK	73.9	
MS11	79.2	
MSD11	75.3	

Compound: d5-Phenol Limits: 24 - 113

Sample ID	Recovery	Comment
1	75.2	
2	88.4	
3	67.5	
4	91.4	
5	83.0	
6	89.0	
7	92.4	
8	83.8	
9	73.7	
11	96.9	
12	92.1	
BLK	92.8	
MS11	112.6	
MSD11	85.4	

Compound: 2-Bromophenol Limits: -

Sample ID	Recovery	Comment
1	66.5	
2	69.2	
3	53.6	
4	71.9	

```
                    6            71.4
                    7            73.7
                    8            68.7
                    9            57.6
                   11            78.1
                   12            76.6
                  BLK            77.1
                 MS11            89.0
                MSD11            77.4

Compound: d5-Nitrobenzene    Limits: 23 - 120
               Sample ID    Recovery    Comment

                    1            54.0
                    2            63.8
                    3            42.8
                    4            57.8
                    5            48.8
                    6            59.6
                    7            54.6
                    8            57.4
                    9            44.2
                   11            63.8
                   12            58.0
                  BLK            64.6
                 MS11            68.6
                MSD11            65.0

Compound: 2-Fluorobiphenyl    Limits: 30 - 115
               Sample ID    Recovery    Comment

                    1            73.4
                    2            72.8
                    3            54.0
                    4           106.4
                    5            72.6
                    6            79.0
                    7            70.8
                    8            76.0
                    9            62.0
                   11            82.6
                   12            86.2
                  BLK            77.0
                 MS11            93.6
                MSD11            80.4

Compound: d10-Azobenzene    Limits: -
               Sample ID    Recovery    Comment

                    1            66.8
                    2            91.6
                    3            68.2
                    4            80.4
                    5            85.4
                    6            84.0
                    7            77.0
                    8            71.2
                    9            62.4
                   12            82.8
                  BLK            76.8
                 MS11            85.2
                MSD11            79.6
                   11            86.6

Compound: 2,4,6-Tribromophenol    Limits: 19 - 122
```

1	69.0
2	68.2
3	43.2
4	63.6
5	60.2
6	58.9
7	44.2
8	56.7
9	45.2
12	77.0
BLK	62.6
MS11	61.8
MSD11	66.1
11	46.8

Compound: d14-p-Terphenyl   Limits: 18 - 137

Sample ID	Recovery	Comment
1	49.2	
2	69.2	
3	48.6	
4	54.8	
5	62.4	
6	63.8	
7	57.8	
8	61.0	
9	47.4	
12	72.2	
BLK	57.4	
MS11	63.2	
MSD11	47.4	
11	65.4	

^{210}Pb Activity

Core Interval	dpm/g Dry Wt.	% Water
W1 + W2-0002	16.37	84.7
W1 + W2-0204	14.26	77.5
W1 + W2-0406	12.93	75.1
W1 + W2-0608	-----	71.1
W1 + W2-08-10	-----	69.4
W1 40-50	1.33	64.9

Wet Weights of Sediment Samples in Plastic Bags

Core Interval	Wet Weight
W1 0002	22.50
W1 0204	26.88
W1 0406	20.65
W1 0608	22.13
W1 0810	19.04
W1 4050	119.42
W2 0002	15.48
W2 0204	18.70
W2 0406	23.72
W2 0608	24.21
W2 0810	27.40

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Chemistry, Microbiology, and Technical Services

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CLIENT: Harper Owes
1110 - 3rd Avenue, Suite 610
Seattle, WA 98101
ATTN: Greg Pelletier

LABORATORY NO. 6993

DATE: December 17, 1987

REPORT ON: SEDIMENT

SAMPLE IDENTIFICATION: Submitted 11/18/87 and identified as shown below:

1) 20-5060
2) 21-0005
3) LC-9 11/05/87
4) LC-12 11/05/87

TESTS PERFORMED AND RESULTS:

	1	2	3	4	Lab Blank
Total Solids, %	98.0	29.8	30.6	36.8	---
	parts per million (mg/kg), dry basis				
Iron	35,000.	35,000.	17,000.	17,000.	8.
Arsenic	38.	30.	---	---	<0.5
Zinc	250.	240.	---	---	4.
Phosphorus	1,200.	1,100.	---	---	<100.

Key

< indicates "less than"

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

JMO:emt

Laucks
Testing Laboratories, Inc.
940 South Harney St., Seattle, Washington 98108 (206)767-5060

Chemistry, Microbiology, and Technical Services

Certificate

CLIENT: Harper Owes
1110 - 3rd Avenue, Suite 610
Seattle, WA 98101
ATTN: Greg Pelletier

LABORATORY NO. 7034

DATE: December 4, 1987

PO# 99745

REPORT ON: SOIL

SAMPLE IDENTIFICATION: Submitted 11/20/87 and identified as shown below:

WI-3040

TESTS PERFORMED AND RESULTS:

Total Solids, % ---------------------- 30.6

<u>parts per million (mg/kg), dry basis</u>

Iron ---------------------------------- 16,000.

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

JMO:emt

Harper Owes

LABORATORY NO. 1473

APPENDIX

Replicate Quality Control Report

		%			
Sample #	Analyte	Replicate 1	Replicate 2	Relative Error, %	Control Limit
3	Total Solids	68.7	70.2	2.2	
11	Sand	100.	100.	0.	
11	Silt	L/0.1	L/0.1	0.	
11	Clay	L/0.1	L/0.1	0.	

ORGANIC CARBON AND NITROGEN
ANALYSIS RESULTS 12/16/86

RESULTS: mg/gr

(SAMPLE)	(N)	(C)
1	0.64	2.92
1-D	0.70	3.16
2	0.39	2.03
3	0.47	3.06
4	1.28	13.1
5	1.06	11.4
6	1.55	15.2
7	0.60	4.25
8	1.90	15.8
9	1.54	14.1
11	0.27	1.35
12	1.83	13.2
METHOD BLK	<5 ug	<10 ug
BCSS-1	----	21.7
ACTUAL VALUE	----	21.9
NBS 1645	0.83	----
ACTUAL VALUE	0.79	----

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