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# Historical Data Sources and Water Quality Problems in the Chehalis River Basin

First Interim Report
for the
Chehalis River TMDL Study

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ABSTRACT

Water quality problems have been identified in the Chehalis River Basin of Southwest Washington for at least 30 years. The Water Quality Program of the Washington State Department of Ecology (Ecology) has requested a review of historical data, with the object of identifying needs for additional study; and, if appropriate, establishing the Total Maximum Daily Load (TMDL) of pollutants contributing to water quality problems.

The Chehalis River displays the hydrologic characteristics typical of Western Washington rivers with minimal snowmelt input. Critical low flows occur in late summer, and high flows are associated with intense rainfall. Ambient data show long-term and widespread problems with low dissolved oxygen and high water temperatures during summer low flows, and elevated bacteria counts and turbidity during winter high flows. Certain metals appear to exceed chronic toxicity criteria, although data quality problems limit the certainty of that observation. Many special studies have been conducted in the Chehalis River system. These studies have examined sediment loading, oxygen problems in the mainstem Chehalis River between Centralia and Chehalis; water quality problems in the Black River; and problems on smaller tributaries, including Hanaford, Dillenbaugh, Salzer, and Wildcat Creeks.

The review of historical data supports the development of a TMDL for bacteria and dissolved oxygen. A special study and Basin action plan is recommended to improve Chehalis River system water temperatures. Needs are identified for additional study of turbidity, toxicity, metals, local water quality problems on small tributaries, and near-field compliance of permitted dischargers with the Washington State Water Quality Standards.

# INTRODUCTION

Since at least the 1960's, the Chehalis River system has earned the attention of the Washington State Department of Ecology (Ecology) and its predecessor agencies because of impaired water quality. In 1990, Ecology listed four Chehalis River segments, three segments of the Newaukum River, two segments of the Wynoochee River, and three other tributaries - Salzer, Dillenbaugh, and Wildcat Creeks - as Water Quality Limited (WQL) (Ecology, 1990). The WQL designation indicates that pollutant sources have limited the water body's ability to support beneficial uses, such as recreation, fisheries, and water supply.

These water quality problems have resulted in Ecology's decision to conduct water quality studies of the Chehalis River system. The goal of these studies is to prevent the degradation of water quality in the river system by establishing the Total Maximum Daily Load (TMDL) of pollutants.

The TMDL process was established by the Federal Clean Water Act. After a TMDL is developed for any particular pollutant, the TMDL is allocated among several categories: wasteload allocations to point sources; load allocations to nonpoint sources; and allocations to background sources, future growth, and scientific uncertainty. This process is described in more detail elsewhere (Ecology, 1991b).

This report serves as a background review for the Chehalis River TMDL study of ambient data and historical special studies. Based on this report, Ecology will prioritize identified problems and recommend control strategies and areas for further study. The TMDL process will be applied to the most significant problems identified.

Except for routine ambient monitoring, a detailed data analysis will not be presented in this report. The studies and databases referenced can be examined separately for a detailed understanding of their contents. Specific facilities, spills, complaints, and local problems will only be noted where they contribute significantly to a widespread water quality problem. Also, this report includes only the portion of the Chehalis River from the mouth of the Wynoochee River upstream, since the tidally influenced area downstream has been examined extensively in other studies. A thorough search for all pertinent information was attempted, but given the constraints of time and the availability of documents, it is likely that information exists that was not discovered or discussed in this report.

# BACKGROUND

The Chehalis River Basin covers an area of 2,114 square miles in Western Washington (Figure 1). It includes Eastern Grays Harbor County, Southeastern Mason County, Southeastern Thurston County, Northeastern Lewis County, and small portions of Jefferson, Pacific, and Cowlitz Counties. The cities of Centralia and Chehalis lie in the center of the Basin, Olympia is near its northern edge, and Aberdeen near the mouth. The Chehalis Reservation (Chehalis

Confederated Tribes) is located west of Rochester, and the fishing interests of the Quinault Tribe extend up the Chehalis River from Grays Harbor.

The Chehalis drains into Grays Harbor at Aberdeen. The larger tributaries of the Chehalis River include the Wynoochee River, Satsop River, Black River, Skookumchuck River, Newaukum River, and South Fork Chehalis River. Headwaters lie in the Olympic Mountains to the north, in the Willapa Hills to the southeast, and a western spur of the Cascades to the east. Montesano is considered the upstream boundary of tidal influence.

Land use in the basin encompasses a wide range of activities. Timber harvesting is widespread in the higher elevations of the basin. Dairy, poultry, hay, row crops, and other agriculture are common in the valleys. Several private aquaculture facilities are located in the Grand Mound/Rochester area. Industrial development is mostly limited to the Chehalis/Centralia area and to the coal mine/power plant site south of Bucoda, with isolated facilities in various other locations. The largest urban areas are the twin cities of Centralia and Chehalis. However, Southwest Thurston County is undergoing rapid development along the I-5 corridor and around Black Lake, which may ultimately include a satellite international airport near Littlerock, as was recently proposed.

## AMBIENT MONITORING DATA

Ambient monitoring stations exist at several locations in the Chehalis River Basin. The U.S. Geological Survey (USGS) has measured flow at 33 different locations in the Basin since 1910. USGS currently measures flow on the Chehalis River at Doty (River Mile [RM] 101.8), Grand Mound (RM 59.9), and Porter (RM 33.3), and on several of the tributaries, including the Newaukum, Skookumchuck, Satsop and Wynoochee Rivers (Williams and Pearson, 1985). USGS also monitors water quality at the Porter station. Flow and water quality data are published annually by USGS (the reference cited is the most recent of these). Data are also available from the STORE environmental database.

Historically, the Ecology Ambient Monitoring Section has collected data at several water quality stations on the Chehalis River, including stations at Dryad (RM 97.9), Centralia (67.5), Porter (RM 33.3), and Montesano (RM 13.2) (Ecology, 1991a). Data also exist for the Newaukum, Skookumchuck, Black, and Satsop Rivers. Porter and Dryad are currently monitored monthly each year. The other stations either were monitored in previous years and have been discontinued, or are currently monitored monthly one year out of three.

The "WQHYDRO" environmental data presentation/analysis package (Aroner, 1991) was used for the statistical analyses and graphical displays of data used in this report. A brief explanation of the "box-and-whiskers" statistical plots shown in the figures is provided here. The dashed line in the center represents the median value of the data. The top and bottom of the box represents the 75th and 25th percentile. Therefore, the box encompasses the middle 50% of the data points. The vertical "whiskers" represent the range of the data.

**Hydrologic Characteristics**

The Chehalis Basin experiences rainfall patterns that are typical of Western Washington. Spatially, rainfall averages over 150 inches per year in the Satsop and Wynoochee headwaters, over 100 inches in the mainstem headwaters, and over 80 inches per year in the Newaukum and Skookumchuck headwaters. Mean annual rainfall of 45 to 50 inches falls on the center of the Basin from Chehalis to Olympia. The pattern of rainfall is illustrated in Figure 2, which was originally published in Glancy (1971).

Seasonally, rainfall follows the pattern for the maritime northwest. Maximum monthly rainfall occurs in November through March. July and August are the months of lowest rainfall. These patterns are illustrated by Figure 3, which shows monthly precipitation at Centralia. November rainfall averages almost 8 inches, and occasionally reaches 12 inches. July rainfall averages less than 1 inch, and rarely exceeds 2 inches.

The Chehalis River Basin is not glacially fed, although snowmelt flows make a minor contribution to flows in the upper Skookumchuck and Newaukum River watersheds. In general, the flow regimes follow the classic pattern of groundwater recharge/release and excess rainfall overland flow. The response of the watershed to normal rainfall is typically a function of soil saturation, land use, topography, channel characteristics, the pattern and timing of rain cells, and other factors. Intense sustained rainfall may result in heavy flooding, as was experienced in January and November of 1990. Critical low flows occur in the summer, when flow is sustained by groundwater baseflow. Typically, low rainfall years correspond to low flow years.

The seasonal pattern of Chehalis River discharge can be seen in Figures 4 and 5, which show monthly flows recorded by the USGS from 1977 through 1988 at the Grand Mound and Porter stations, respectively. Maximum flows occur in December through March, and critical low flows occur in August. Monthly low flows range from 150 to 250 cubic feet per second (cfs) at Grand Mound, and from 200 to 500 cfs at Porter. Peak flows have been measured at over 20,000 cfs at Grand Mound, and at over 30,000 cfs at Porter. Flows during the January 1990 flood were the highest on record, and were estimated at over 60,000 cfs at Grand Mound and Porter.

Critical low flows are defined by the seven-day low flow which recurs once ever ten years on the average (7Q10). The 7Q10 flows for the Chehalis River and tributaries are shown in Table 1. Since the Wynoochee and Skookumchuck Rivers are controlled by reservoir release, 7Q10 flows are not specified for those rivers. More study would be needed to define critical low flow in that situation, since the 7Q10 may not be the appropriate estimation method.

Table 1. Critical Low Flows for Chehalis River and Tributaries. (7Q10 using log-Pierson III analysis)

| Station | ID# | Period of Record | Flow (cfs) |
|---|---|---|---|
| Chehalis at Doty | 12020000 | 1941-1979 | 21.4 |
| Chehalis nr Grand Mound | 12027500 | 1930-1979 | 114.4 |
| Chehalis at Porter | 12031000 | 1953-1979 | 198.3 |
| So Fk Chehalis nr Boistfort | 12020900 | 1967-1979 | 0.7 |
| Newaukum nr Chehalis | 12025000 | 1930-1979 | 21.5 |
| Satsop near Satsop | 12035000 | 1930-1979 | 204.0 |

**Conductivity**

Conductivity, also called specific conductance, is an indirect measure of the amount of dissolved solids in the water. Conductivity in the Chehalis River is shown in Figure 6. The four stations represented are Dryad (RM 97.9), Centralia (RM 67.5), Porter (RM 33.3), and Montesano (RM 13.2) .

On the average, conductivity is highest at Centralia, and lowest in the headwaters near Dryad. Conductivity decreases downstream and is lower in winter, probably as a result of dilution at higher flows. Spikes in conductivity at Montesano indicate tidally influenced seawater intrusion. The data indicate that the highest concentration of dissolved constituents observed in the river are found in the summer at the Centralia station.

**Temperature**

> "Temperature shall not exceed 18.0°C (freshwater) ... due to human activities."
> WAC 173-201-045(2)(c)(iv)

Figure 7 shows the distribution of recorded temperatures from June through September at the four Chehalis River monitoring stations. The water quality criterion of 18°C is also indicated. Water temperature exceeds the criterion for more than 25% of the samples at all stations during this season, and for more than 50% of samples at the Centralia station.

The seasonal pattern of temperature is illustrated in Figure 8 with data from the Centralia station. Exceedances occurred every year during the summer months, with the worst problems observed in July. The stations at Doty, Porter, and Montesano all show a similar pattern of exceedances, although slightly less extreme than the Centralia station data.

**Dissolved Oxygen**

> "Freshwater - dissolved oxygen shall exceed 8.0 mg/L."
> WAC 173-201-045(2)(c)(ii)(A)
>
> "Chehalis River from Scammon Creek (RM 65.8) to Newaukum River (RM 75.2). Special condition - dissolved oxygen shall exceed 5.0 mg/L from June 1 to September 15. For the remainder of the year, the dissolved oxygen shall meet Class A criteria." WAC 173-201-080(8)

Dissolved oxygen (D.O.) measurements at the four Ecology Chehalis River ambient stations during June through September are shown in Figure 9. Dissolved oxygen levels less than criteria have been observed at Centralia and Porter. A graph of D.O. values at Centralia plotted by month (Figure 10) shows that excursions below the criteria have occurred from April to October. Dissolved oxygen at Porter is shown in Figure 11. Dissolved oxygen levels have dropped below criteria in at least 2 of the last 13 years, typically in July and August. Examination of USGS ambient D.O. data at the Porter station increases that frequency to 5 excursions below the criteria in 20 years.

Dissolved oxygen is influenced by a number of factors including temperature; the discharge of pollutants that exert Biochemical Oxygen Demand (BOD); and oxygen use by plant, animal, and microbial respiration. High temperatures in the river reduce the saturated dissolved oxygen concentration. In addition, numerous studies have identified BOD loading and "eutrophication," or enhanced plant and algae growth, as probable causes of D.O. problems in the Chehalis River. These studies are described in a separate section of this report.

**pH**

> "pH shall be within the range of 6.5 to 8.5 (freshwater) ... "
> WAC 173-201-045(2)(c)(v)

Figure 12 shows pH for all months at the four Chehalis monitoring stations monitored by Ecology. Over a 13 year period, Dryad and Centralia have experienced excursions outside the criteria once and twice, respectively. Examination of pH measured by USGS at Porter shows 3 excursions during 20 years. The seasonal pattern of pH is consistent, with high values in summer and low values in winter.

High and low pH values in the Chehalis system, if not caused by natural processes, are likely associated with other pollution problems, such as nonpoint organic sources in the winter and eutrophication in the summer. Control of those sources through other indicators (turbidity, bacteria, D.O.) would probably improve pH compliance. Also, the excursions are rare, and other studies have not revealed a wide-spread problem. Therefore, a specific effort to address pH problems is not a high priority at this time.

## Turbidity

> "Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU." WAC 173-201-045(2)(c)(vi)

Figure 13 shows seasonal turbidity at the four Chehalis River ambient monitoring stations. The line marked "WQ Standard" indicates the 50 NTU level. Although it is difficult to interpret the regulations in the context of these graphs, one can observe that the range of turbidity spans several orders of magnitude. Since the vertical scale is logarithmic, the magnitude of the peak values at all stations as compared to the upper range of the quartiles would indicate that elevated turbidity is occurring that may warrant some concern. In addition, turbidity during the November through April period in comparison to the May through October period has a higher median value at stations downstream of Dryad, and a higher peak value at all stations.

This analysis indicates that elevated turbidity is occurring in the wet season. The magnitude of some turbidity values raises concerns that land uses are causing violations of water quality standards. However, more study is needed to determine how background levels should be defined for the system, the conditions that result in turbidity exceedances, and the locations where exceedances are a problem.

## Fecal Coliform Bacteria

> "Freshwater - fecal coliform organisms shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10 percent of samples exceeding 200 organisms/100 mL." WAC 173-201-045(2)(c)(i)(A)

Fecal coliform levels at the four Chehalis River ambient monitoring stations are shown in Figure 14. Comparison of the two seasons show that median and upper quartile values are higher in wet season at the stations downstream of Dryad.

Figures 15 through 18 demonstrate bacteria standard compliance using a calendar year time frame for four mainstem sites. If the figure indicates that the 90th percentile for a particular year exceeds the criterion of 200 organisms/100 mL, then more than 10% of the samples exceeded the criterion, which violates the water quality standard. For both Montesano and Centralia, the 10-percentile standard was violated almost every year. Dryad and Porter also have several years with exceedances, although fewer than Montesano and Centralia. The calendar year geometric mean, shown in the bottom plots, was exceeded in two years at Montesano and one at Centralia.

This analysis indicates that violations of fecal coliform standards are a significant problem throughout the Chehalis Basin. The highest values are observed in the wet season, which would indicate contaminated stormwater runoff as a probable source.

## Ammonia

Ammonia water quality standards are dependent on ambient pH and temperature. Therefore, measurements of these two parameters must be made at the time of ammonia sample collection in order to evaluate compliance with the standards.

A review of ambient ammonia data was conducted, including calculations of the criteria for conditions at the time of sampling. No violations of ammonia standards were observed during ambient monitoring of mainstem Chehalis River stations. Figure 19 illustrates this analysis.

## Metals

Water quality criteria for several metals are specified in state regulation. The criteria will not be summarized here, for reasons discussed below, except to note that most metals criteria are calculated from the hardness of the ambient water. Hardness in the Chehalis averages 25 mg/L as $CaCO_3$, and this value was used for criteria calculations.

Water samples have been collected and analyzed for metals from the Chehalis River at Porter by USGS from 1960 to 1982, and from the Black River at Moon Road by Ecology during 1990 and 91. Unfortunately, this data is mostly of poor quality, and therefore should only be discussed in general terms. Although USGS data indicate that certain metals may have occurred at levels in the Chehalis River that exceed water quality criteria, it is now uncertain that a problem truly exists. This is because the USGS recently withdrew their support for the metals data after they discovered sample collection problems that were biasing the data upwards (Pendergast, 1992). Data for the Black River indicate the occurrence of the same metals, but at lower levels. A few metals occasionally exceed their chronic criteria, but the data are "qualified" as being of poor quality.

Due to data quality concerns, no conclusions can be drawn as to whether violations of metals criteria occur in the Chehalis system. Further study is needed to confirm the presence and levels of metals. If metals are occurring at critical levels, then the source of the metals should be evaluated. Industrial sources have been documented in the past, and urban stormwater is also a likely source. It is also possible that natural background levels are elevated.

## Flow-Quality Relationships

Table 2 lists the results of a Kendall correlation analysis for most ambient monitoring parameters versus river discharge for five sampling sites. Kendall's coefficient of concordance ("tau") is a nonparametric alternative to the parametric Pearson product correlation coefficient. The test is based on the relative rank of the data, so that extreme values and non-normal distributions of data have little effect on the test outcome.

The correlations found in the data and discussed in this section do not necessarily result from cause-effect relationships. Two parameters may correlate because they correlate to a third parameter, such as seasonal meteorological conditions. The correlations should be taken as indicators or clues of relationships, but not as absolute proof.

Table 2. Kendall tau correlation between daily river discharge and ambient water quality parameters. Chehalis ambient monitoring stations, 1978-1990.

| | Water Quality Station | | | | |
|---|---|---|---|---|---|
| Parameter | Dryad (RM 97.9) | Centralia (RM 67.5) | Porter (RM 33.3) | Montesano (RM 13.15) | Satsop R. (RM 2.3) |
| Temperature | (-) | (-) | (-) | (-) | (-) |
| Conductance | (-) | (-) | (-) | (-) | (-) |
| pH | (-) | (-) | (-) | (-) | (-) |
| TSS | (+) | (+) | (+) | (+) | (+) |
| Turbidity | (+) | (+) | (+) | (+) | (+) |
| Fec. Coli. | o | (+) | (+) | (+) | (-) |
| Diss. Oxygen | (+) | (+) | (+) | (+) | (+) |
| $NO_2NO_3$ | (+) | (+) | (+) | (+) | (+) |
| $NH_3$-N | o | (-) | (+) | (+) | (+) |
| TP | o | (-) | - | + | (+) |
| OP-Diss. | o | (-) | (-) | o | o |

(+) 99% significant positive correlation
(-) 99% significant negative correlation
\+ 90% significant positive correlation
\- 90% significant negative correlation
o Not significant (less than 90%)
ND No data

Temperature, conductance, and pH show a negative correlation with discharge at all stations at the 99% significance level. The negative correlation implies that the higher the discharge, the lower the value of the parameter. The temperature correlation reflects the typical inverse relationship of high summer temperatures associated with low flows and low winter temperatures associated with higher winter streamflows. Conductance may reflect a dilution relationship between concentration and discharge. If ionic constituents are primarily contributed by point sources and groundwater, higher flows mean greater dilution. A lower pH associated with high flows may reflect a number of conditions, including the leaching of organic acids or aquatic plant respiration in the absence of photosynthesis. A high pH at low flows may reflect the effects of aquatic plant photosynthesis or reduced dilution during summer low flows.

Turbidity and suspended solids show a 99% significant positive correlation with flow at all stations. This generally suggests erosion and scouring. Higher flows are associated with higher erosion rates and overland transport of particulates. In addition, higher flows may result in the resuspension and transport of streambed sediments.

Centralia, Porter, and Montesano all show positive correlations between fecal coliforms and discharge, significant at the 99% level. This may indicate that nonpoint sources associated with rainfall events dominate instream bacteria concentrations. Curiously, the Satsop River shows a significant negative correlation, which is difficult to explain.

Dissolved oxygen shows a significant positive correlation with discharge. High discharge occurs in winter months when water temperatures are low and the saturation concentration of oxygen is high. Conversely, high summer water temperatures result in lower saturation concentrations. Also, low oxygen levels at low flows may reflect less dilution of oxygen-demanding substances, lower reaeration rates, and greater rates of respiration at higher temperatures by the ambient biota.

Nutrients show a mixed pattern of both positive and negative correlations. Nitrate/nitrite concentrations increase significantly with increasing flow at the 99% level. Ammonia and total phosphorus also show a significant positive correlation with discharge at the Montesano and Satsop River stations. Possible reasons for these relationships include the leaching of the highly soluble nitrate ion from saturated soils during the wet season, wet weather transport of nutrients associated with solids, or reduced algal uptake during periods of high flow and low productivity. At Centralia, ammonia, total phosphorus, and ortho-phosphorus all show a negative correlation to discharge, significant at the 99% level. This may be a result of point source discharges providing most of the loading of those parameters on this stretch of the river, and concentrations decreasing with increasing flow due to dilution.

**Trend Analysis**

Ambient monitoring data for the mainstem Chehalis River stations were analyzed for trends over time. A Seasonal Kendall Test was used for the trend analysis, and the data set was adjusted to remove variation due to flow and time of sampling.

Most stations for most parameters showed no significant trend. Flow showed a downward trend at Montesano and Centralia (Grand Mound minus Skookumchuck flows). An upward trend in total phosphorus and conductivity was observed at the Centralia, Porter, and Montesano stations. Ammonia and fecal coliform showed a downward trend at most stations.

The downward trend in flow could be a reflection of either short-term climatic trends, or of increased consumptive use of the water resource. The downward trend in ammonia and fecal coliform reflects a statewide trend, which may represent improvements in pollutant treatment and control. The conductivity trend shows a very small increase over time, and is probably not worthy of any concern. The upward trend in phosphorus goes against a statewide downward trend. This trend shows a steady increase in phosphorus in the Chehalis River over the last ten years of about 2 ppb per year. Increased phosphorus loading to the Chehalis River system from municipal, industrial, and agricultural sources is a possibility. The upward trend in conductivity and phosphorus may also be affected by the downward trend in flow through decreased dilution.

It must be noted here that the difficulty in interpreting trends is that, as with correlations or regressions, the cause of a trend cannot always be determined and the true cause of the trend may be an unknown factor such as changes in sampling method. Also, ammonia and phosphorus levels are often close to or less than the level of detection, which decreases the certainty that a trend truly exists.

## SPECIAL STUDIES

### Sediment Loading

Sediment loading in the Chehalis River during water years 1962-65 was studied by Glancy (1971). The focus of that study was the sediment yield of the basin and the source of sediments. The study found that almost three-quarters of the sediment load in the basin came from the Satsop and Wynoochee Rivers (43.8% and 30.6% respectively). Only one-quarter (24.2%) of the sediment load originated above Porter.

Of the tributaries above Porter, the Chehalis River above Doty, the South Fork Chehalis River, and the Newaukum River had the highest sediment yield. The Skookumchuck and Black Rivers had relatively low sediment yield. In general, subbasins with high rainfall and steep slopes had the greatest sediment yield. Changes in subbasin sediment transport were largely attributed to changes in channel characteristics and land use due to human activities.

### Water Quality Basin Planning

R.W. Beck and Associates (1975) completed the Sewage Drainage Basin Plan (SDBP) for the upper Chehalis River Basin. This report is a comprehensive study of water quality problems, their sources, and potential solutions in the basin.

Problems with turbidity, dissolved oxygen, and temperature were observed at that time at roughly the same magnitude as observed in the most recent ambient data. The probable sources of turbidity, color, bacteria, and nutrients were identified as storm and farm run-off sources. Low D.O. is attributed to nutrient enrichment problems and to treatment plant effluent. Solar heating is suggested as the cause of temperature violations.

The SDBP identifies a number of suspected causes of water quality problems. The main purpose of the study was to identify future needs for sewer and treatment plant development. However, other sources were identified, including areas with failing septic tanks, historical landfills, poor animal waste management, forest practices, and specific permitted and non-permitted industrial facilities, including wood products, meat packing, and food processing.

Ecology (1975) issued the 303(e) report for the Chehalis River Basin as an addendum to the SDBP. The report reiterates material in the SDBP and summarizes basin-wide ambient monitoring and studies for 1971 through 1973. A graphical synopsis of water quality problems in the Chehalis Basin is provided.

In the 303(e) report, high temperatures were documented on the Wynoochee, Newaukum, and mainstem Chehalis Rivers. Bacteria problems were identified in Wildcat Creek, the Newaukum River, and the mainstem Chehalis River. High turbidities were observed in the Newaukum and mainstem Chehalis Rivers during the wet season. Concerns were raised about the potential for problems in the Wynoochee River if the dam cut river flow. Wildcat Creek was noted for its problems with the McCleary WTP discharge, and the possibility of algal blooms in the Chehalis River were identified.

Battelle (1974) ran a water quality model of the Chehalis River and Grays Harbor. Although almost the entire effort was devoted to Grays Harbor, Battelle attempted to model the Chehalis from the Newaukum River to Porter with a one-dimensional eutrophication model. Unfortunately, because no new data were collected and existing data was scarce, the model was never calibrated or verified. Review of the model documentation shows that little effort was spent on verifying the accuracy of the model inputs and structure. Results do not reflect the water quality conditions found by other studies. Therefore, the report provides little information and makes no recommendations.

**Dillenbaugh Creek**

Dillenbaugh Creek was the subject of an intensive survey by Ecology in 1986 (Crawford, 1987a). Earlier surveys had observed D.O. levels below water quality criteria (Johnson and Prescott, 1982; Joy, 1984). The object of the 1986 survey was to investigate point and nonpoint sources of pollution, including NPDES permitted dischargers.

A wide variety of sources were found to be causing violations of fecal coliform, dissolved oxygen, and temperature water quality criteria in Dillenbaugh Creek. Farming activities, including a dairy feedlot, were considered the primary cause of low oxygen. Failing septic systems were identified as the major source of bacterial contamination. Industries in the Chehalis Industrial Park were contributing to violations of temperature standards. An urban storm sewer was found to be the source of several contaminated discharges. A 10-acre woodwaste landfill was also suspected of impacting the creek. The Southwest Regional Office of Ecology (SWRO) took follow-up action on a number of the documented sources.

**Salzer Creek**

Salzer Creek has been the object of several water quality investigations. On October 1979, low oxygen was observed in the Chehalis River at Mellen Street, which prompted an investigation of the cause (Houck, 1980). The source of the problem was identified as the failure of a food processing wastewater pipe, which caused a spill to Salzer Creek. The wastewater was being land-applied by the National Fruit Canning Company on fields bordering Salzer Creek. Follow-up by SWRO resulted in the installation of an alarm system to provide notification of pipeline failure. (National Frozen Foods, the successor company, currently holds a Washington State Discharge Permit to land apply food processing waste near Salzer Creek.)

Surveys after the spill continued to document low dissolved oxygen in Salzer Creek (Johnson and Prescott, 1982; Joy, 1984). In 1986, Ecology conducted a survey of Salzer Creek to identify point and nonpoint sources in the drainage and their impacts on water quality in the creek (Crawford, 1987b). Problems were discovered with very low dissolved oxygen and high fecal coliform levels. Farm animal management practices were identified as the predominant cause of these problems. Leachate from the Centralia landfill was identified as an apparent pollution problem. The Southwest Washington Fairgrounds were also considered a potential threat to degrade the creek with contaminated stormwater runoff. SWRO took action to correct some of the identified problems. The Centralia Landfill is undergoing corrective action as a federal Superfund site.

**Mainstem Near Chehalis/Centralia**

The stretch of the Chehalis River from the Newaukum River downstream to the Skookumchuck (RM 75.2 to RM 66.9) is probably the most heavily studied area in the Chehalis Basin. Problems with low dissolved oxygen in the river have been identified for at least 25 years. This stretch will be called the "Centralia reach" in this report.

McCall (1970) reported on sampling of the Centralia reach in 1969, where he observed extremely low oxygen and high bacteria levels. He mentions that stratification and low oxygen problems were observed in 1967. In 1970, improvements to the Chehalis Wastewater Treatment Plant (WTP) had resulted in higher surface oxygen levels and relatively low bacteria counts. However, the deepest points sampled in three different areas in August 1970 were anoxic.

In September 1972, Devitt (1972) repeated sampling at the same stations in the Centralia reach as in 1970. Oxygen levels were between 5 and 7.5 mg/L at all depths and stations, which meets the standards for that stretch. However, river temperatures were relatively cool, and no stratification was observed. Devitt commented that stratification and algal activity were factors that complicated the interpretation of D.O. data on that stretch of the river. However, the conclusion was reached that changes in the municipal treatment plants had improved the river, although problems still remained.

In addition, Devitt made the following observation regarding the aesthetics of this stretch of the river:

> "Automobiles which have been used to rip rap the river banks to retard erosion are unsightly, but they are obvious mostly to the limited numbers of boaters who use this section of river. Garbage has been dumped at some areas. Cows still have free access to the river.
>
> The improved water quality, of course, improved the general esthetics of the river but the general area is still somewhat of an eyesore."

It is interesting to note that automobile rip-rap and cows with free access could still be observed in 1991.

In his report on the Salzer Creek spill investigation, Houck (1980) noted several points regarding conditions in the river itself. A travel time of 6.4 days was estimated from the Chehalis WTP to the Mellen Street bridge for conditions at the time of the spill. Decreases in oxygen between Salzer Creek and the Mellen Street bridge were attributed to "a large bacterial bloom and/or sediment oxygen demand." Houck recommended further study of the relative importance of BOD, nutrients, and sediment oxygen demand (SOD).

As a consequence of the 1979 spill, a comprehensive study was undertaken of the Centralia reach that included evaluation of conditions in the river and compliance sampling (Class II) inspections of the Chehalis and Centralia WTPs. Yake's (1980) inspection report on the Chehalis WTP included an indepth evaluation of receiving water conditions and the impact of the plant discharge. Samples were taken from the river at the Mellen Street bridge as well as from plant effluent. A number of observations and findings were made:

1. The Centralia reach is deep, slow, and stratified, and algal photosynthesis is the process that dominates oxygen dynamics. Algal activity is indicated by elevated chlorophyll *a* levels near the surface relative to deeper samples, and by diurnal fluctuations of dissolved oxygen from supersaturated to depressed levels.

2. The growth of algae in this stretch of the river is controlled by the level of inorganic nitrogen (nitrate+nitrite+ammonia) in the water.

3. The Chehalis WTP raises the level of nitrogen in the river by two to six times the level upstream of the plant.

4. The impact of BOD, both carbonaceous (CBOD) and nitrogenous (NBOD), does not appear to adequately account for low oxygen levels. More likely, inorganic nitrogen inputs have a far more significant impact on D.O. through the effect of algal growth and respiration. The effect of algal decay below the euphotic zone on D.O. levels could not be determined from the data.

5. The Chehalis WTP appears to be capable of nitrification (ammonia to nitrate) and denitrification (nitrate to nitrogen gas). Nitrogen reduction in the treatment system was observed, but plant operators were not intentionally managing the plant for nitrogen removal, and it is not clear how the reductions could be maintained on an on-going basis. Effluent quality would be improved and impacts on the river reduced if nitrification-denitrification could be continually and effectively accomplished.

Johnson and Prescott (1982) conducted four field investigations of the Centralia reach during the summer of 1980. Seventeen stations were sampled at several depths on July 15, July 30, August 5, and September 16 of that year. Stratification was observed, which reached a maximum during the July 30 sampling. The maximum temperature gradient was 4.5°C from surface to bottom at the station upstream of the Mellen Street bridge, and the river D.O. concentration was less than 1.0 mg/L at a depth of 4 meters. On August 5, the gradients were somewhat less severe and anoxic layers were deeper, but nonetheless four stations showed temperature gradients of at least 2.0°C with D.O. levels of less than 2.0 mg/L near the bottom.

In summarizing their conclusions, Johnson and Prescott made a number of other observations. Surface D.O. was not a problem, and no diurnal variation was observed. Water temperatures were sometimes high enough to pose a threat to salmonids. Nitrogen was the limiting parameter for algal growth during late July and August. They close with the following observation:

> "It appears to us that the fluctuations in physical/chemical parameters we observed in this sluggish reach of the Chehalis River are typical of many eutrophic Western Washington lakes -- except that nitrogen rather than phosphorus was limiting."

In September 1981, Clark (1981) sampled oxygen and temperature at five sites in the Chehalis River, three in the Chehalis reach and two downstream of the Skookumchuck. Oxygen levels were all above 8 mg/L and temperatures were 15.0°C or less. However, the percent saturation of D.O. was between 80 and 90 percent.

In the summer of 1982, the U.S. Fish and Wildlife Service conducted a survey of spring chinook salmon habitat, which included temperature and oxygen monitoring at four sites on the Chehalis River and at the mouths of the Newaukum and Skookumchuck Rivers (Hiss, 1983). Measurements were made on six dates from July through September. Again, stratification was found in August at the two stations in the Centralia reach, with high surface temperatures and low bottom D.O.

Temperatures in the Chehalis River were between 16°C and 20°C in July and August, and as high as 16°C in the Skookumchuck River and 19°C in the Newaukum River. The report points out that the observed temperatures are higher than the safe temperature for salmonid egg development (14°C). These temperatures also approach the critical level for adult salmon survival (23°C), and since measurements were made in the morning, river temperatures may actually exceed the critical level.

In July through October 1982, Ecology conducted a survey of the Centralia reach (Joy, 1984). This survey included flow measurements, an estimate of time of travel, field measurements of water quality parameters, and laboratory analysis of water samples. The survey results were used to simulate Chehalis River conditions with a one-dimensional steady-state dissolved oxygen computer model.

Several observations were made as a result of Joy's 1982 survey:

1. Estimated river velocities in the Centralia reach were between 0.04 and 0.10 feet per second fps) at low flow. The estimated time for a volume of water to travel the 7 miles from the Chehalis WTP to the Mellen Street bridge was 5 to 7 days at flows in the range of 73 to 112 cfs.

2. Patterns of high surface temperatures and stratified pools with extremely low oxygen at the bottom reinforced previous survey findings. Oxygen levels less than the standard of 5.0 mg/L were found in deeper layers at up to seven locations in late August. Surface oxygen was depressed below the standard of 8.0 at several locations after September 15.

3. SOD was considered to be significant in several locations, and estimates of the SOD rate were made. Suspected sources of organic sediments were the Chehalis WTP, Salzer Creek, and settled plankton cells.

4. $BOD_5$ concentrations in Salzer Creek ranged from 33 to 110 mg/L, which compares to Chehalis WTP discharges of 40 to 70 mg/L and Centralia WTP discharges of 16 to 30 mg/L.

5. Algal production was indicated by supersaturated D.O., elevated pH and chlorophyll *a*, and low inorganic nitrogen near the surface.

6. Nitrogen was again estimated to be the limiting nutrient in the Chehalis River as far downstream as the Independence bridge. Above the Chehalis WTP, neither phosphorus nor nitrogen could be identified as limiting. On the average, the source of inorganic nitrogen loading in the Centralia reach was two-thirds from the Chehalis WTP and one-third from upstream background sources.

7. In the area of the Centralia reach just below Salzer Creek, inorganic nitrogen levels were lower and organic nitrogen levels higher relative to upstream, without corresponding increases in chlorophyll *a* and oxygen. Joy suspected that, in this area, heterotrophic bacterial activity might be more prevalent than planktonic photosynthesis. This would be understandable, considering the large BOD loads discharged from Salzer Creek during this survey.

Using the survey results, Joy ran several computer model simulations of dissolved oxygen in the Centralia reach. The model incorporated multiple rates and parameters, including stream reaeration, BOD decay, nitrification, temperature, initial D.O., point source and instream CLOD and NBOD, SOD, algal respiration and photosynthetic oxygen production. The model simulated non-stratified conditions well, but did not predict stratified conditions.

In one simulation, the conditions of the October 1979 Salzer Creek spill were evaluated, including the effect of Chehalis WTP and upstream sources. Upstream sources alone reduced D.O. by 1.1 mg/L in the Centralia reach, but not below the 8.0 mg/L standard. The Chehalis WTP reduced the D.O. by an additional 1.1 mg/L to less than 8.0 mg/L. Under these conditions, the model showed that the addition of the high-strength pollutants spilled into Salzer Creek depleted D.O. in the river to near zero, as was observed during the spill.

Joy then ran several simulations of 7Q10 conditions as one-dimensional non-stratified flow. His analysis concluded that either relatively poor upstream water quality conditions (quantified as 6 mg/L BOD and 0.15 mg/L $NH_3$-N in the model) or poor Chehalis WTP effluent quality (105 mg/L BOD, 20 mg/L $NH_3$-N) could drive down instream D.O. to close to 5 mg/L. The combination of the two conditions were likely to cause violations of the 5 mg/L D.O. standard.

In conclusion, Joy identifies algal growth dynamics, the quantification of benthic oxygen demand, and oxygen depletion under stratified conditions as areas that his work did not address and that deserve further study.

To evaluate a proposed increase in the Darigold NPDES permitted discharge, Joy (1987) ran additional simulations of the Chehalis and evaluated the nutrient balance at the discharge location. No significant reduction in D.O. was found from the proposed increase in CLOD and NBOD loading in the Darigold discharge. Total inorganic nitrogen loading was estimated to increase by about 5 percent. His analysis did not consider the effects of nutrient discharges on D.O. through the stimulation of algal growth.

**Hanaford Creek**

Sampling was conducted in the Hanaford Creek watershed in 1970 and 1971 to assess baseline conditions and, based on the impacts of initial operations at the mine site, assess the potential future effects of the coal mine/power plant project (McCall, 1971). Elevated turbidity, conductivity, and iron were observed due to construction. Mercury was also detected from the coal piles, but the quality of data is suspect. Data were reported for twice monthly sampling over a year at seven stations in the Hanaford Creek system. Six of seven stations reported oxygen levels below 8.0 mg/L, and the station at the mouth of South Hanaford Creek reported oxygen at 4.0 or less from June to September 1970. Temperatures at three stations exceeded 18.0°C on at least one occasion.

**Mainstem below the Skookumchuck**

Thurston County conducted low flow sampling and analysis of the Chehalis River near Grand Mound in the late summer and fall of 1989 (TCEH, 1989). This work was conducted as part of a preliminary study for the proposed Grand Mound wastewater treatment plant. Samples were analyzed for oxygen, conductivity, temperature, pH, nutrients, BOD, TSS, and fecal coliforms.

All parameters measured by Thurston County met water quality standards. The exception was temperature in late August 1989, which was between 18°C and 19°C at two stations. Also, a D.O. of 8.2 mg/L and pH of 8.4 were measured at the Prather Road bridge, which are barely within the standards. Nitrate/nitrite tended to increase in the downstream direction, while total phosphorus tended to decrease. Total phosphorus was in the range of 0.1 to 0.2 mg/L for most samples.

As part of the Satsop Power Plant Project, the Washington Public Power Supply System (WPPSS) implemented a construction water quality monitoring program from 1977 to 1982 (Stanley, 1983). A preoperational water quality monitoring program was also developed, to be implemented at least one year prior to fuel load. Because the project has been indefinitely postponed, the preoperational studies are presumed to have not been conducted.

The stretch of the Chehalis monitored by WPPSS includes four mainstem stations and two tributary creeks and extends from the South Elma bridge (RM 23.9) to near Montesano (RM 13.5). The 1981 report (Envirosphere Company, 1982) indicates that dissolved oxygen, temperature, and turbidity met water quality standards, except during the summer when temperatures in the Chehalis River exceeded 18°C.

**Black River**

The Black River had not been the subject of extensive study prior to 1989. During the period of August 6 or 7, 1989, a large fish kill occurred on the Black River (Ecology, 1989). A wide variety of species were found dead in the vicinity of the Moon Road bridge. The kill appeared to progress downstream, where hundreds of dead adult chinook salmon were found in the Chehalis River near Oakville on and after August 11.

As the extent of the fish kill became apparent, water quality sampling was conducted in the Black River to determine whether ambient conditions were a factor in the kill. Toxic materials, although suspected, were not detected in significant amounts. Temperatures in the lower river (below river mile 10) were found to be between 18 and 20°C at the surface. Dissolved oxygen measurements between 6 and 8 mg/L were widespread, and several deeper samples showed D.O. between 1 and 4 mg/L.

These conditions were documented over a week after the kill, and the ambient conditions at the time of the kill are not known. However, the low oxygen and high temperatures probably represented stressed environmental conditions, which would have left the river susceptible to damage from any additional adverse changes in river conditions, such as the discharge of a toxic or oxygen-demanding pollutant, or the termination of a significant source of relatively cool tributary flow.

Surveys conducted subsequent to the fish kill found that stretches of the river supported dense growths of aquatic macrophytes. Increases in D.O. from morning to midday indicated that significant productivity was occurring. Nutrient levels increased in a downstream direction. Total phosphorus levels in the lower river were in excess of 0.1 mg/L, EPA's desired goal for the prevention of nuisance plant growth in rivers. The ratio of total inorganic nitrogen to orthophosphorus in the upper river suggested nitrogen and phosphorus limitations in alternating locations, but in the lower river phosphorus-limited conditions were strongly indicated.

As a result of the 1989 fish kill, a water quality screening study was conducted on the Black River (Dickes, 1990). The study was a cooperative effort between the Chehalis Confederated Tribes (CCT) and Ecology. Samples were taken at three stations on seven dates from November 1989 through June 1990.

The screening study found that the dissolved oxygen criterion of 8 mg/L was violated in November, December, and June. During March, April and May, pH values were below the standard of 6.5. Fecal coliform exceedances were detected during wet weather months. TSS and turbidity levels were high during a storm event in January. Although data quality was poor, lead and copper appeared to exceed chronic water quality criteria. Further investigation was recommended to include flow measurements; a low flow study of D.O.; a wet weather evaluation of fecal coliforms, TSS, and turbidity; and continued monitoring for metals.

Another effort that developed as a result of the 1989 fish kill was the Black River Watch (BRW) Cooperative Monitoring Project (TCEH, 1991). Private aquaculture facilities and local residents worked cooperatively under the guidance and support of the Thurston County Office of Water Quality to conduct water quality monitoring on the Black River. The CCT, Thurston County Department of Health, and Ecology all provided additional support. Six stations were sampled weekly from mid-July through October 1990, and monthly through March 1991. In addition, a bioassessment was conducted in May 1991.

Temperature in the Black River reached a high of 23.5°C in August. Three stations (Canoe Club, Swecker's Dock, and Johnson's Dock) showed thermal stratification from July through September. Dissolved oxygen near the bottom of the stratified areas ranged from 0.5 to 5 mg/L at the Canoe Club station, and between 4 and 7 mg/L at Swecker's and Johnson's Docks. Dissolved oxygen all stations fell below the standard of 8 mg/L on several of the sampling events.

Fecal coliforms violated criteria at all stations sampled by the BRW, except for the upstream station at 110th street. Particularly high values were measured on October 22, 1990. A follow-up survey traced the high bacteria counts to the area just upstream of Mima Creek.

The BRW bioassessment found that the Moon Road and Howanut Road bridge sites showed a higher diversity and more sensitive population of aquatic insect taxa. Other stations tended to have low diversity and taxa tolerant of organic pollution. Low water velocity, uniform flow, and heavy siltation were cited as the most significant factors affecting macroinvertebrate diversity, with low oxygen and high temperatures mentioned as additional considerations.

**Wildcat Creek**

Wildcat Creek is tributary to the Chehalis River via Cloquallum Creek, and is the receiving water for the McCleary wastewater treatment plant. A number of special studies and investigations have been conducted on this creek from 1969 through 1987 (Melville, 1969; Devitt, 1973; Musgrove, 1977; Kendra, 1987). Because of the extensive work on this creek, the studies will not be discussed in detail.

Elimination of discharges from the Simpson Door plant and an upgrade of the McCleary WTP have eliminated most of the problems observed in previous studies. Kendra found most problems to be corrected or improving, except that he noted that Wildcat Creek "may be considered water quality-limited due to excessive inputs of nitrogen and phosphorus... the eutrophication issue should be addressed in depth prior to future WTP expansion."

**Toxicity and Toxic Materials**

A number of sites contaminated with toxic compounds in the Chehalis Basin are known to have had an impact on surface waters. These include the Centralia Landfill near Salzer Creek (Springer, 1988), the Lewis County PUD/Ross Electric Coal Creek site (Norton, 1986), and the American Crossarm and Conduit site near Dillenbaugh Creek (Yake, 1987). Other sites have been investigated in the past as possible sources of contamination. The Ecology Toxic Cleanup Program maintains a list of all known contaminated sites as part of the requirements of the Model Toxics Control Act (MTCA). Site cleanups and the control of contaminants may be pursued either under the federal Superfund Program or under MTCA.

Michaud (1989) conducted a bioassay study in the mainstem Chehalis River, Satsop River, and Humptulips River. The object of the study was to determine whether the Chehalis River, which has poor salmon returns, shows significant toxicity as compared to the Humptulips River, which has good salmon returns. The study used a *Ceriodaphnia* reproduction and survival test. From February 1987 to February 1988, samples were collected on four dates from three stations on the Humptulips River, and on three dates from one station on the Satsop River and four stations on the Chehalis River.

Significant toxicity was found in the Humptulips River in February 1987, and in the Chehalis River at Dryad (RM 98.3) and in the Satsop River (RM 2.2) during sampling in September 1987. No chemical analysis was conducted and no source of toxicity was identified. The three watersheds above the stations where toxicity was found have largely agricultural and silvicultural land uses, which led Michaud to speculate that forest or farm chemicals may have been a cause. The toxicity that was found is a cause of concern, and more study is needed to confirm that a recurring problem exists and to identify the source of toxicity.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis of the studies discussed above, a number of on-going, widespread water quality problems can be identified in the Chehalis River Basin. These problems are summarized below, in order of priority, with recommendations for action included.

1. Low dissolved oxygen has been identified as a significant problem in many areas of the Chehalis system during dry weather low flows. The Centralia reach and the Black River in particular exhibit characteristics more typical of a stratified eutrophic lake. In addition, low oxygen has been observed as far downstream as Porter. Salzer, Dillenbaugh, Hanaford, and Wildcat Creeks have historically had site-specific problems, although the problems have likely been improved at some locations.

   Studies to date have looked at a number of causes of low D.O. in the Chehalis system. BOD loading from the Chehalis WTP and spills of food processing wastewater into Salzer Creek have historically been identified as the cause of low oxygen in the Centralia reach. The quality of the water entering the Centralia reach from upstream also has a strong influence on D.O. levels. Specific sources have not been identified above the Chehalis WTP.

   Studies of the Centralia reach and the Black River have provided evidence that nutrient enrichment and SOD may also significantly contribute to D.O. problems. Both of these stretches have exhibited significant variation between morning and midday D.O. levels, which indicates the existence of highly productive conditions. Elevated chlorophyll *a* levels in the surface waters of the Centralia reach confirm the productivity of the system. Data indicate that the Centralia reach is nitrogen limited, most likely because of the high loading of phosphorus introduced by the Chehalis WTP. The Black River and the Chehalis below the Skookumchuck both have been shown to be phosphorus limited with concentrations above the EPA guideline of 0.1 mg/L.

   Despite the apparent productivity, surface waters often remain depressed below saturation, and bottom waters in areas that stratify exhibit severely depressed D.O. levels and even anoxic conditions. This situation indicates that an oxygen demand is being exhibited by sediments and benthic debris.

The effects of nutrient enrichment and the influence of SOD on D.O. in the Chehalis system have not been closely examined by previous studies. Productivity enhanced by nutrient inputs could impair D.O. levels through the respiration and decay of algal and macrophyte biomass. This could occur both during the night and morning hours when respiration is not offset by photosynthesis; at the end of the growing season when the plant community dies off; and by the oxygen demand of benthic deposits of settled algal cells and macrophyte detritus. It is also possible that nutrient inputs, by increasing photosynthetic algal production, are enhancing the fisheries resource through increased oxygen levels and food availability.

The source of SOD may be from instream plant production, as discussed above. It may also be caused by inputs to the river from external sources, such as pollutant sources high in settleable solids or natural vegetative detritus. The level of SOD, location of areas with significant levels of SOD, and the source of SOD have not been determined by previous studies.

The special water quality study currently underway to examine the causes of low D.O. in the Black and Chehalis Rivers is supported by this report. The water quality study will result in the establishment of a TMDL for specific pollutants in specific areas for the control of dissolved oxygen in the Chehalis River Basin. The TMDL will include the Centralia reach, the Black River, and other tributaries or headwaters where significant loading or local problems are discovered. The TMDL will address eutrophication, algal and macrophyte growth, and the role of nutrients in enhancing growth; stratification effects; benthic oxygen demand; and any other factors found significant by the water quality study.

Until the water quality study and TMDL analysis is completed, some interim measures may be appropriate for new projects that may have an impact on dissolved oxygen in the Chehalis River system. All new project proposals that represent potential significant concentrated sources of nutrients or BOD to affected receiving waters (such as dense residential development, commercial and industrial sites, and concentrated livestock operations) should include as part of the SEPA process, or other equivalent environmental assessment, an analysis of the project's potential to increase nutrient or BOD loading to receiving waters, including an estimation of probable pollutant loading levels, and possible alternatives to control or eliminate the input of nutrients or BOD from the project.

2. Fecal coliform bacteria have been identified as a widespread wet weather problem. Excessive levels of bacteria associated with rainfall events occur in the Black River and in the Chehalis River above Montesano and above Centralia.

   A TMDL for fecal coliform bacteria is recommended for wet weather conditions in the Chehalis and Black Rivers. However, several steps are needed prior to the establishment of a TMDL:

- The findings of this report support the need for a screening study to better characterize the sources of bacteria. This study was conducted in the January and March 1991, and the results are presented in a separate document.

- Since EPA has not provided guidance for, nor conducted a bacteria TMDL, the methodology must be developed. To this purpose, EPA has provided partial funding of a bacteria TMDL through a federal 319 grant. Based on the screening study, the Black River was identified as a subbasin with the worst bacteria levels, and has been selected for development of the methodology for a bacteria TMDL under the grant.

Based on the results of the Black River study, a fecal coliform TMDL will be established for the Black River, and may be extended to other areas of the Chehalis River system with demonstrated bacteria problems.

3. Temperature in excess of 18°C has been observed throughout the Chehalis River system in most years. Since human activities have had a significant impact on the environment of the Chehalis Basin for over a century, it is difficult to say whether the elevated temperatures that have been observed represent "natural" conditions in the river. However, studies have found that human activities, such as the removal of riparian shade trees, can elevate river water temperatures (TFW, 1990). Fisheries experts have identified high temperatures as one of the water quality problems that are restricting the effort to restore anadromous salmonid fisheries in the Chehalis Basin (Hiss, 1982; Hiss, 1983). Therefore, it is likely that human activities are impairing the beneficial uses of the Chehalis River, by causing changes in the environment that result in elevated river water temperatures. Some effort to improve summertime river temperatures is needed.

   Temperature controls have been engineered into the Skookumchuck Dam, and are under study for the Wynoochee Dam (Martin, 1990). However, except for dam projects, temperature problems in the Chehalis River Basin have not been studied in detail. More work is needed to determine the level of effort and regulatory action needed to improve river temperatures throughout the basin.

   The Timber, Fish, and Wildlife program has been examining the impact of logging practices on water temperature. A study of models for predicting temperature (TFW, 1990) stated that:

   > "Although many characteristics were shown to correlate with stream temperature, two factors were of such overwhelming importance that they could be used to reliably predict temperature sensitivity--shading and elevation (which probably indicates air temperature regime). A simple graphic model (the temperature "screen") based on these characteristics correctly identified the temperature category according to water quality criteria of 89% of the sites."

It is likely that increased riparian shading could lead to river water temperature reductions. To test this, an inventory of riparian shading could be developed and applied to a model to predict changes in summer water temperatures based on riparian shade enhancement. If the modeling indicates that improvements in temperatures could be achieved, a program could be developed to protect, improve, and restore riparian shade trees in the basin.

A special study of basin-wide temperature and riparian shading is recommended, which may include an inventory of riparian shading and modeling of temperature. The temperature study could be a cooperative effort between the fisheries resource agencies, Ecology, and local agencies and interest groups such as county conservation districts, the CCT, and the Quinault Tribe. Some initial work toward this end may be possible under the Chehalis Fisheries Restoration Act administered by U.S. Fish and Wildlife Service. The decision to initiate and coordinate this study must be made by the Water Quality Program (WQP) at Ecology or by another resource agency.

4. Turbidity data indicate high levels with wet season runoff. Whether the levels represent "natural" conditions or violations of criteria due to human land uses, cannot be determined. It is possible that because of the association of suspended solids with phosphorus and bacteria transport, study of those issues may result in controls or improvements in turbidity problems. If other water quality studies do not trigger adequate turbidity controls, a study of turbidity in the basin may be appropriate. It is recommended that ambient turbidity data be reviewed after the D.O. and bacteria TMDLs in the basin are complete, to determine if additional study and control efforts are warranted.

5. A bioassay study of the Chehalis River basin found toxicity in several locations. These results are troubling, since they are apparent violations of the Water Quality Standards. To evaluate whether a toxicity problem exists in the Chehalis Basin, a more comprehensive study is needed. This study would evaluate both acute and chronic toxicity in several locations in the basin at different seasons. If toxicity is found, initial work could be done to identify the source of toxicity. The decision to undertake this project should be made by the WQP, in consideration of its priority with respect to other toxicity problems in the state. The WQP may also wish to request a screening for toxicity as part of the bacteria and D.O. TMDLs.

6. Metals data have indicated the potential for violations of criteria in the Chehalis River system. However, the quality of the data has been poor, and the coverage limited. A screening study would be necessary to survey selected metals throughout the basin, to establish whether areas of the river are truly water quality limited for selected metals, to determine what the sources of the metals are, and to evaluate what controls are needed for both point and nonpoint sources. A TMDL is not recommended at this time, but may be appropriate if the screening study confirms water quality limited conditions. The decision to undertake a screening study should be made by the WQP. The metals study could be incorporated in a toxicity study as described above. The WQP may also wish to request a screening for metals as part of the ongoing bacteria and D.O. TMDLs.

7. Although some permitted point source dischargers in the Chehalis River Basin have been examined for their contributions to D.O. and bacteria problems downstream in the receiving water, most dischargers have not been evaluated for "near-field" effects. This includes an analysis of mixing zone characteristics and compliance with metals, chlorine, ammonia, and whole effluent toxicity water quality standards in the vicinity of the plant discharge. The WQP should decide about the need for this work, which could performed as part of a basin-wide metals or toxicity study.

8. Several of the creeks that are tributary to the Chehalis River have been identified as having significant water quality problems of their own. Specifically, Dillenbaugh Creek, Salzer Creek, Hanaford Creek, and Wildcat Creek have been studied in the past, and other creeks may be identified during future surveys. Dissolved oxygen and fecal coliform problems in these creeks may be addressed under the TMDL recommended above. Water quality problems on tributary creeks not addressed in TMDL studies may deserve further study, such as toxics in Dillenbaugh Creek, or mining impacts on Hanaford Creek. The WQP should make the decision to undertake these additional studies.

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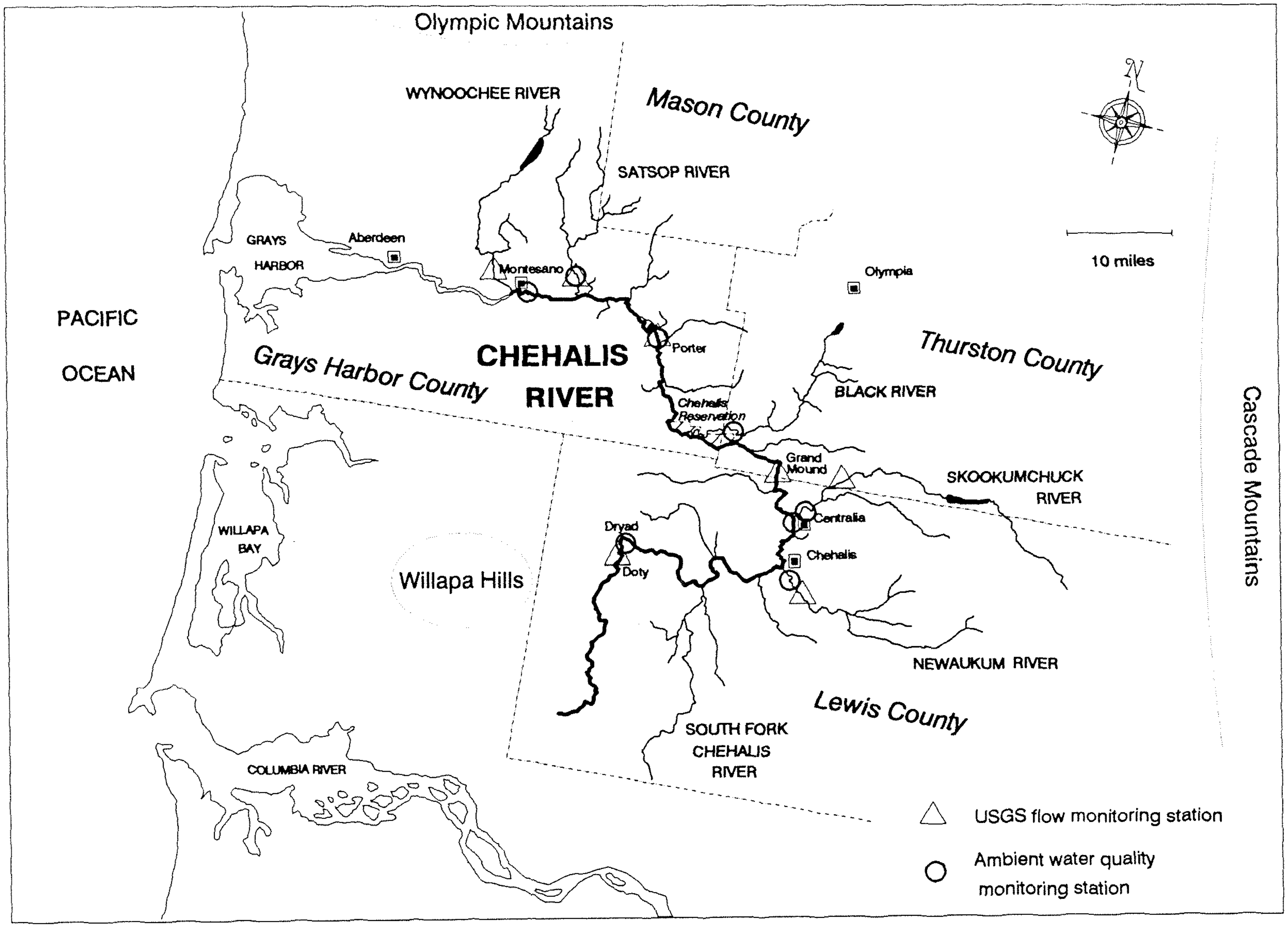
FIGURES




# Figure 1. Chehalis River System

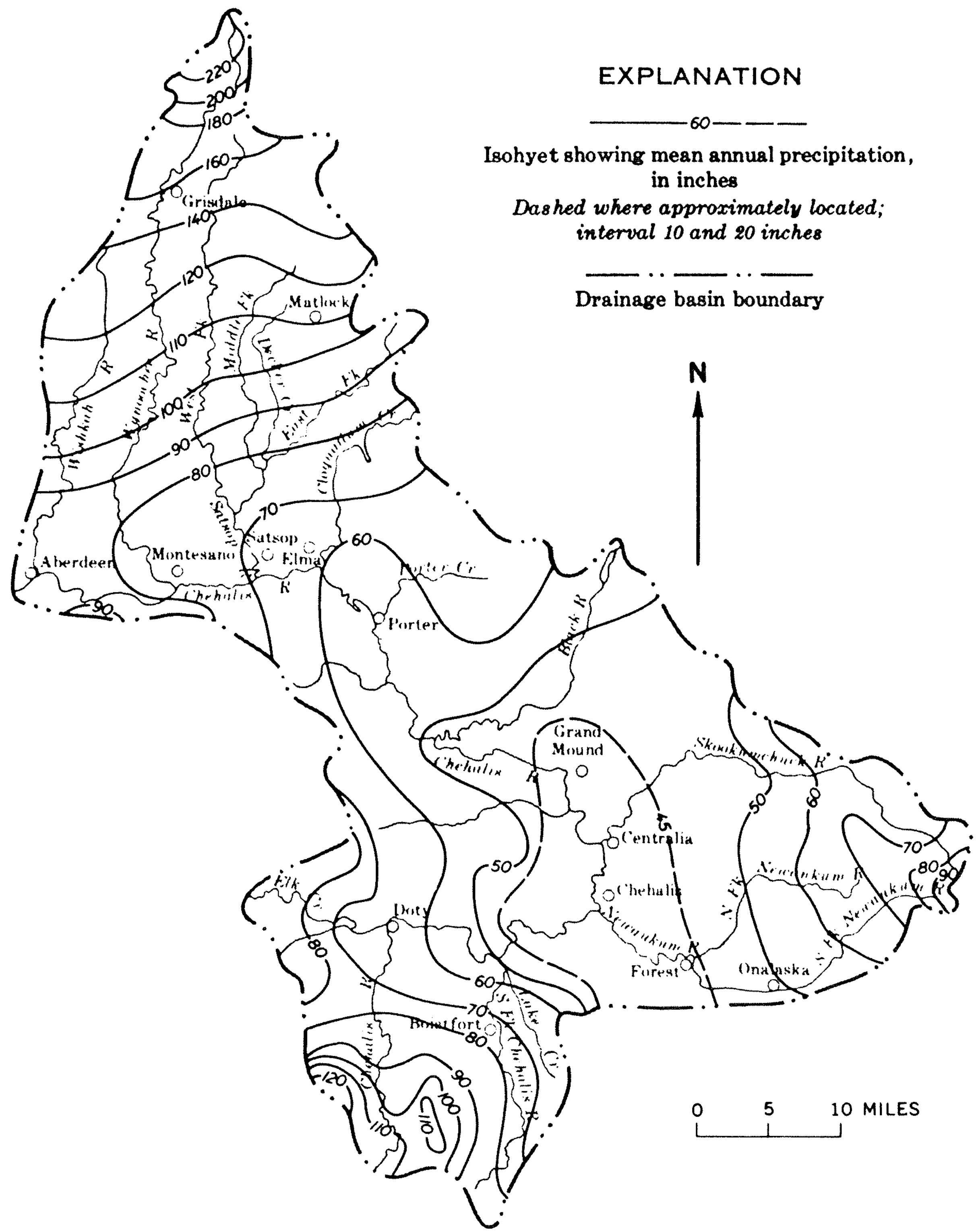



FIGURE 2. Areal distribution of mean annual precipitation, Chehalis River basin. Prepared by U.S. Weather Bureau, using adjusted climatological data (1930-57) and values derived by correlation with physiographic factors. Published by U.S. Soil Conservation Service (1965).

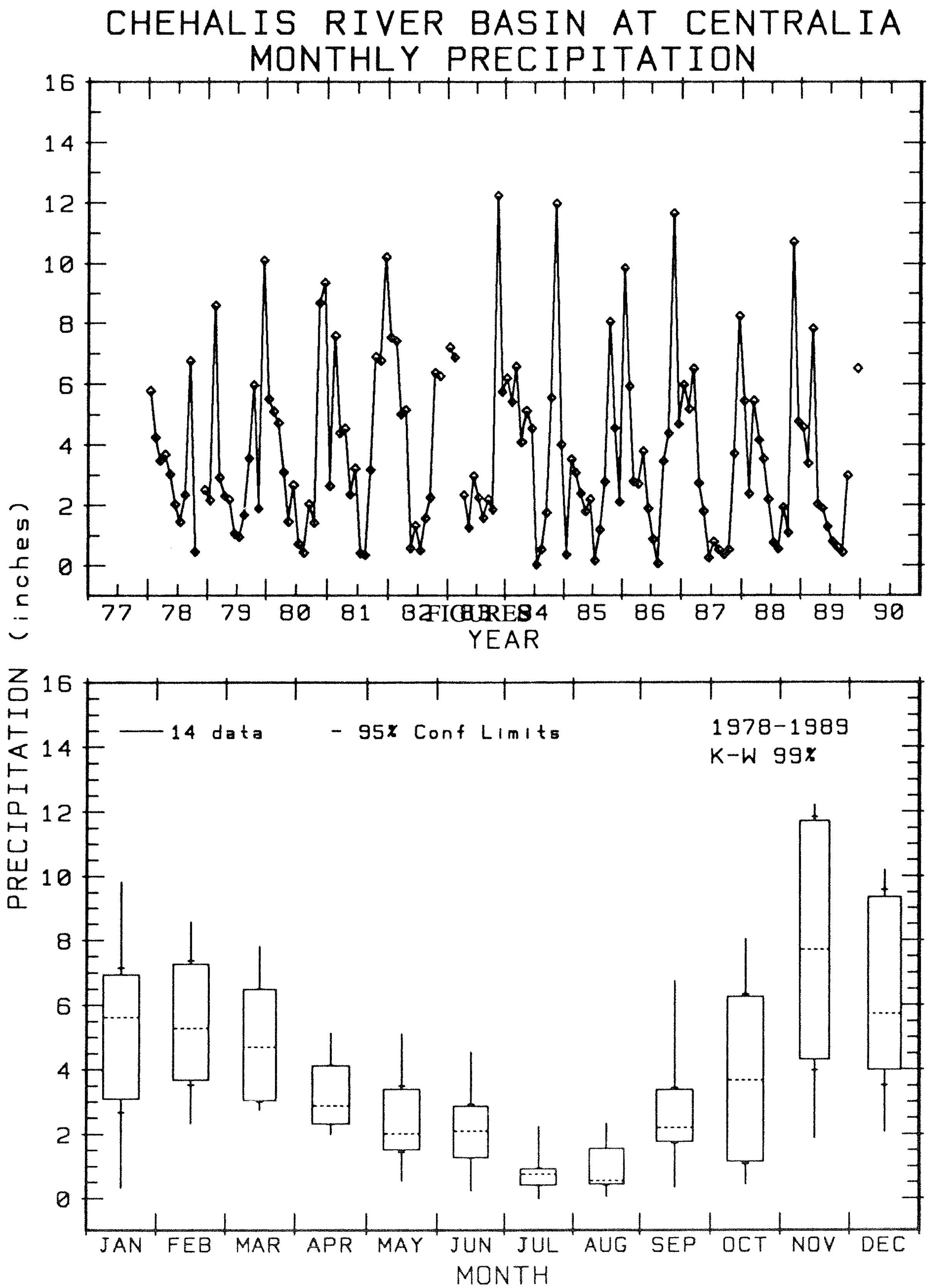
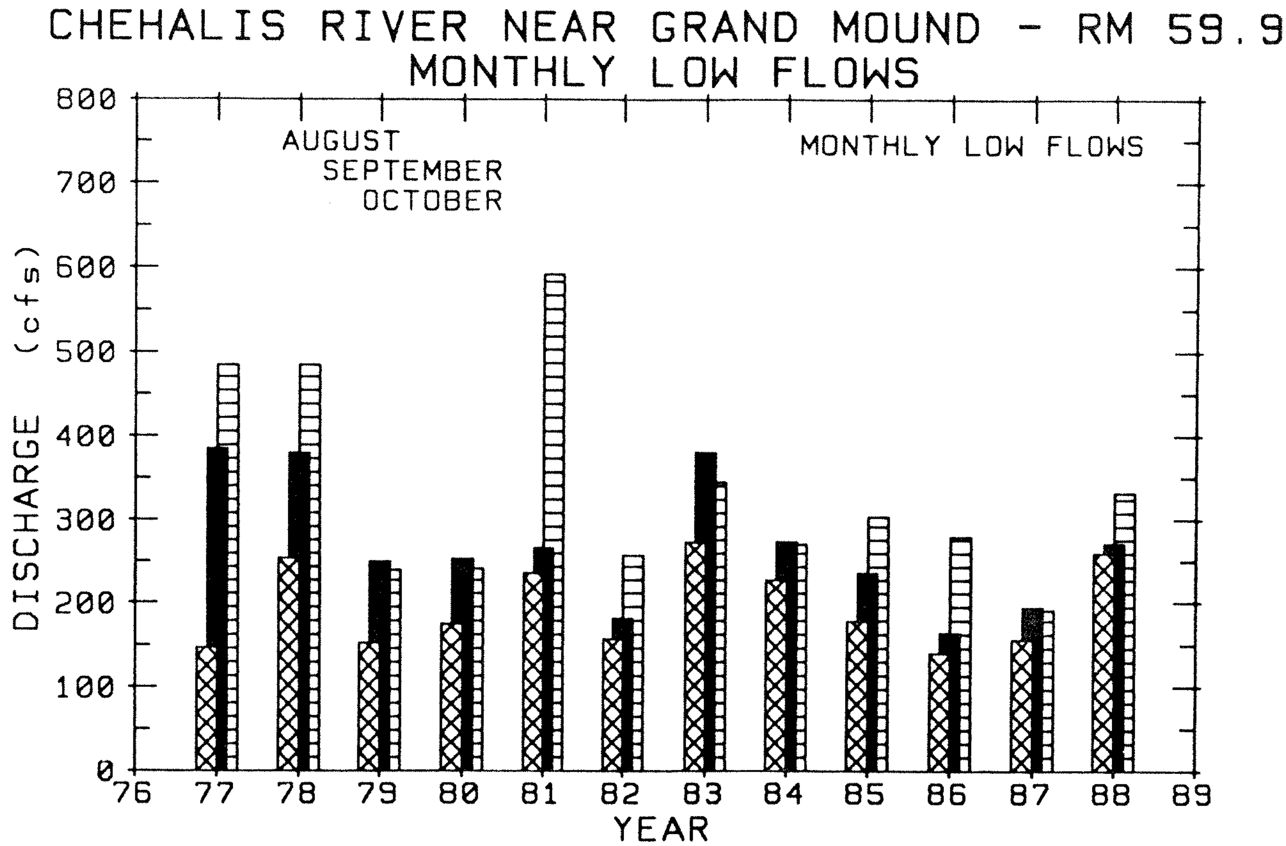

CHEHALIS RIVER BASIN AT CENTRALIA
MONTHLY PRECIPITATION
PRECIPITATION (inches)
16
14
12
10
8
6
4
2
0
77
78
79
80
81
82
84
85
86
87
88
89
90
YEAR
14 data
- 95% Conf Limits
1978-1989
K-W 99%
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 3


CHEHALIS RIVER NEAR GRAND MOUND - RM 59.9
MONTHLY LOW FLOWS
AUGUST
SEPTEMBER
OCTOBER
MONTHLY LOW FLOWS
DISCHARGE (cfs)
800
700
600
500
400
300
200
100
0
76
77
78
79
80
81
82
83
84
85
86
87
88
89
YEAR

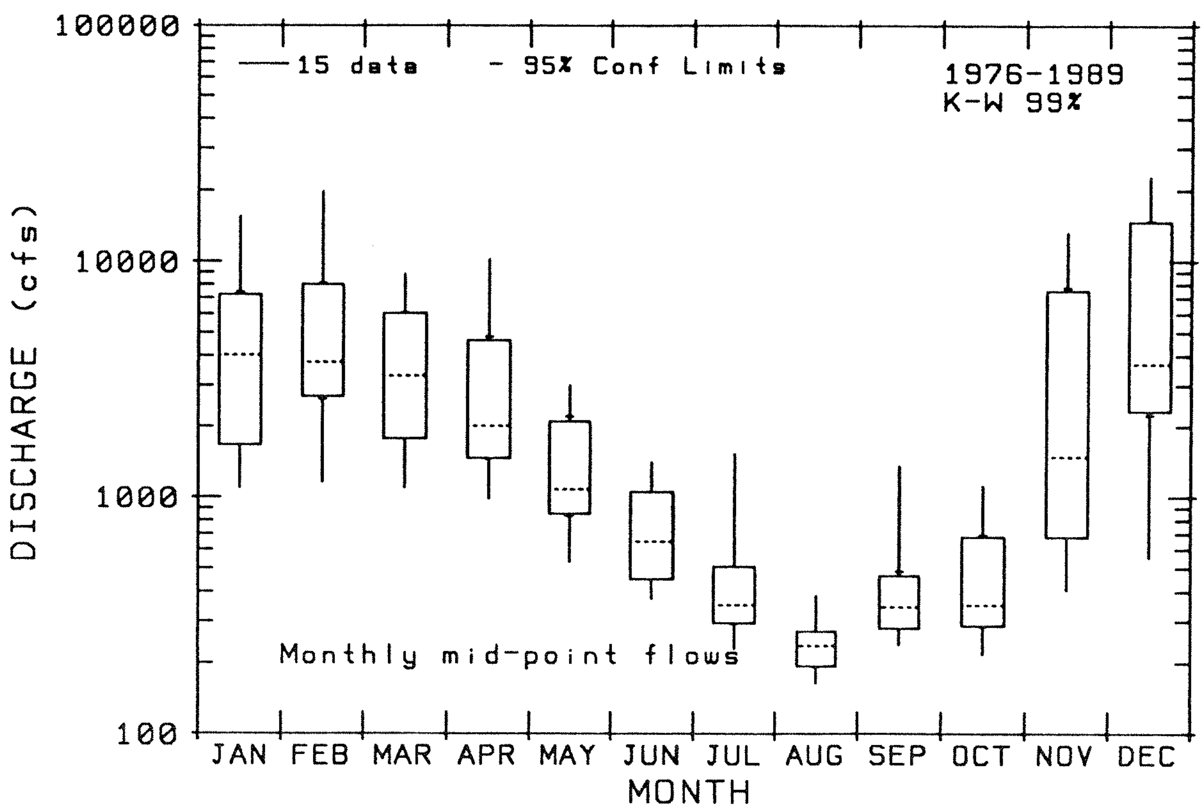

15 data
- 95% Conf Limits
1976-1989
K-W 99%
DISCHARGE (cfs)
100000
10000
1000
100
Monthly mid-point flows
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 4

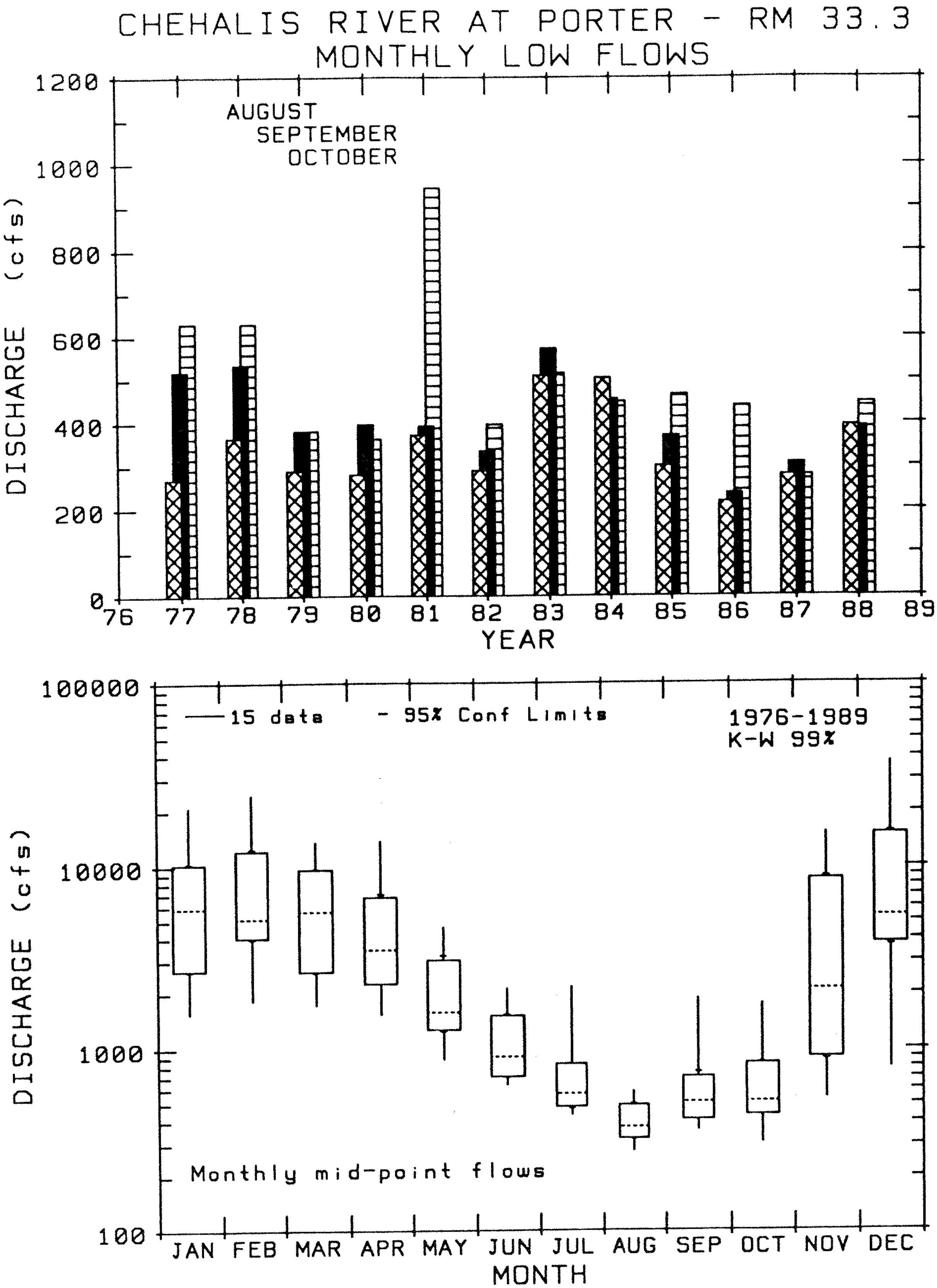
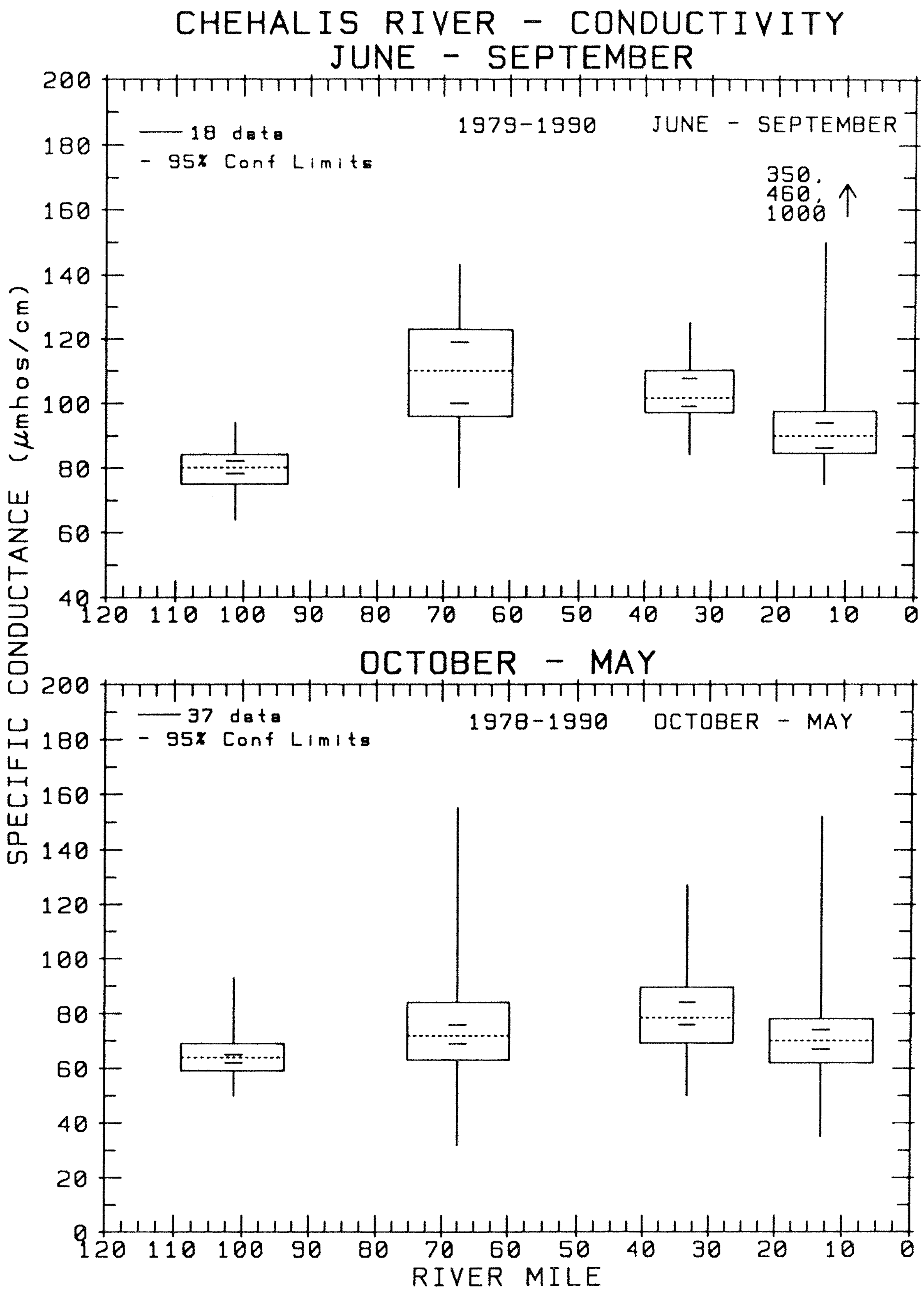

CHEHALIS RIVER AT PORTER - RM 33.3
MONTHLY LOW FLOWS
AUGUST
SEPTEMBER
OCTOBER
DISCHARGE (cfs)
1200
1000
800
600
400
200
0
76 77 78 79 80 81 82 83 84 85 86 87 88 89
YEAR
100000
10000
1000
100
15 data
- 95% Conf Limits
1976-1989
K-W 99%
DISCHARGE (cfs)
Monthly mid-point flows
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

Figure 5



CHEHALIS RIVER - CONDUCTIVITY
JUNE - SEPTEMBER
18 data
- 95% Conf Limits
1979-1990 JUNE - SEPTEMBER
350, 460, 1000
SPECIFIC CONDUCTANCE (μmhos/cm)
200 180 160 140 120 100 80 60 40
120 110 100 90 80 70 60 50 40 30 20 10 0
OCTOBER - MAY
37 data
- 95% Conf Limits
1978-1990 OCTOBER - MAY
200 180 160 140 120 100 80 60 40 20 0
120 110 100 90 80 70 60 50 40 30 20 10 0
RIVER MILE


Figure 6

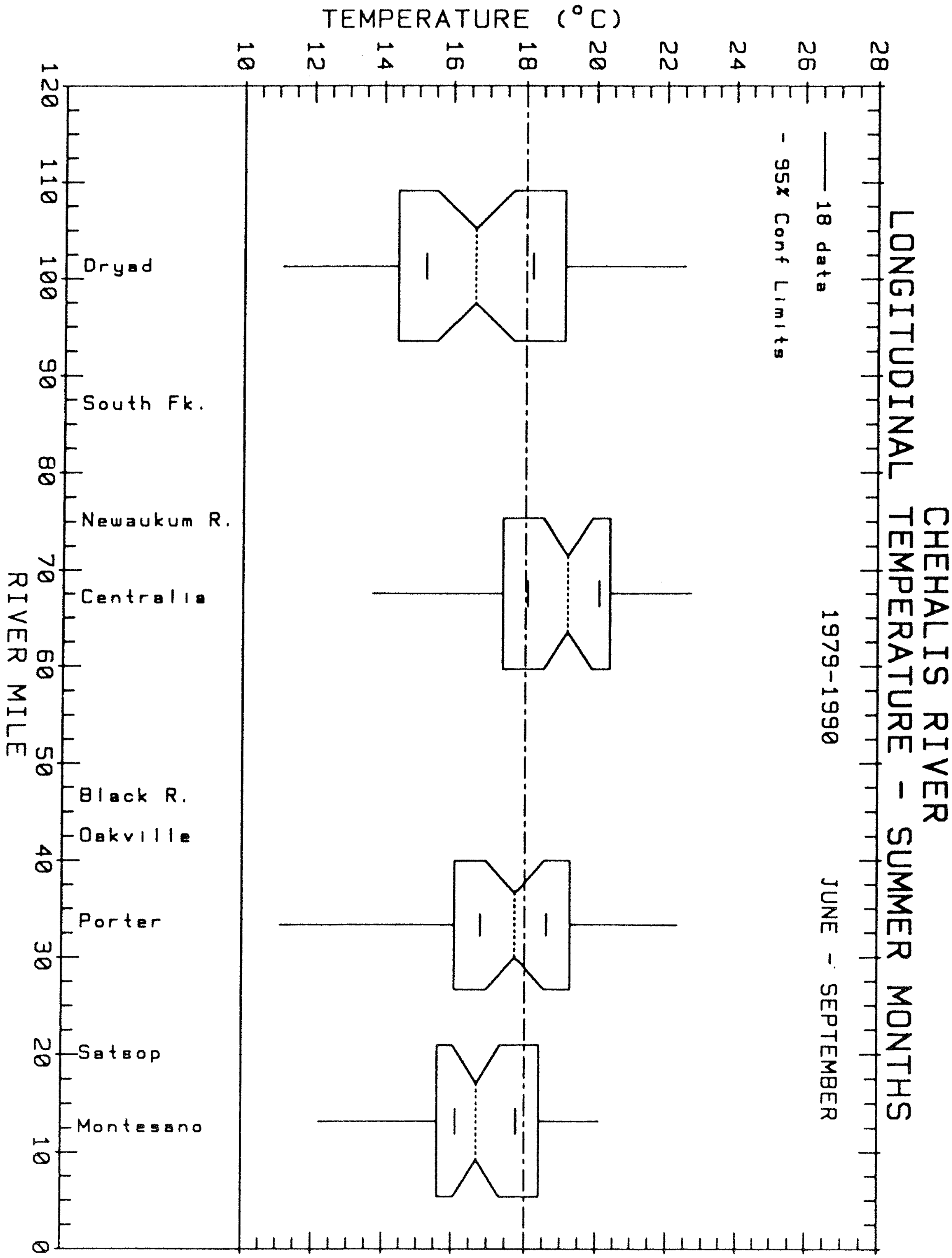

CHEHALIS RIVER
LONGITUDINAL TEMPERATURE - SUMMER MONTHS
1979-1990
JUNE - SEPTEMBER
—— 18 data
- 95% Conf Limits
TEMPERATURE (°C)
10
12
14
16
18
20
22
24
26
28
RIVER MILE
120
110
100
90
80
70
60
50
40
30
20
10
0
Dryad
South Fk.
Newaukum R.
Centralia
Black R.
Oakville
Porter
Satsop
Montesano

Figure 7

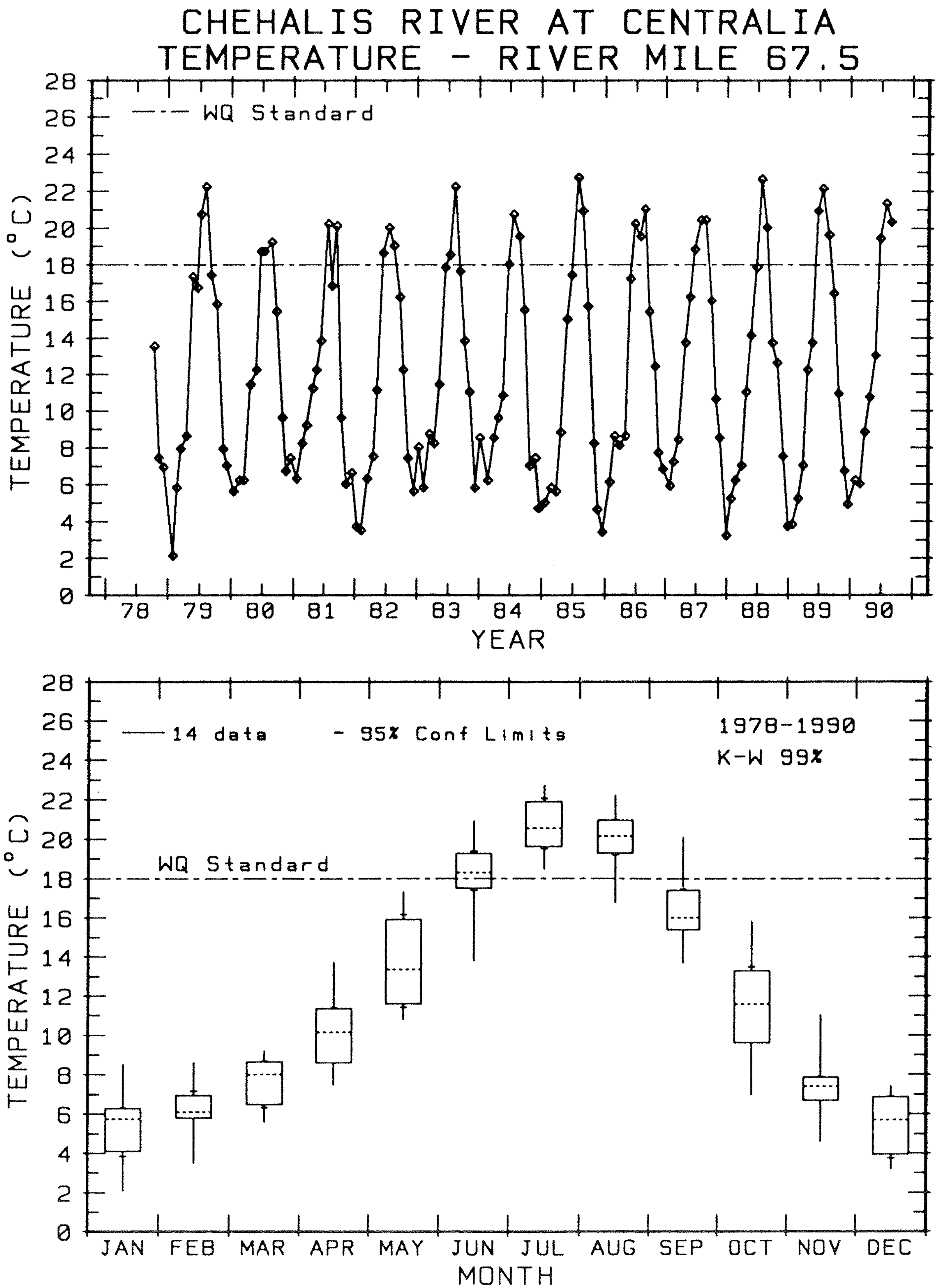
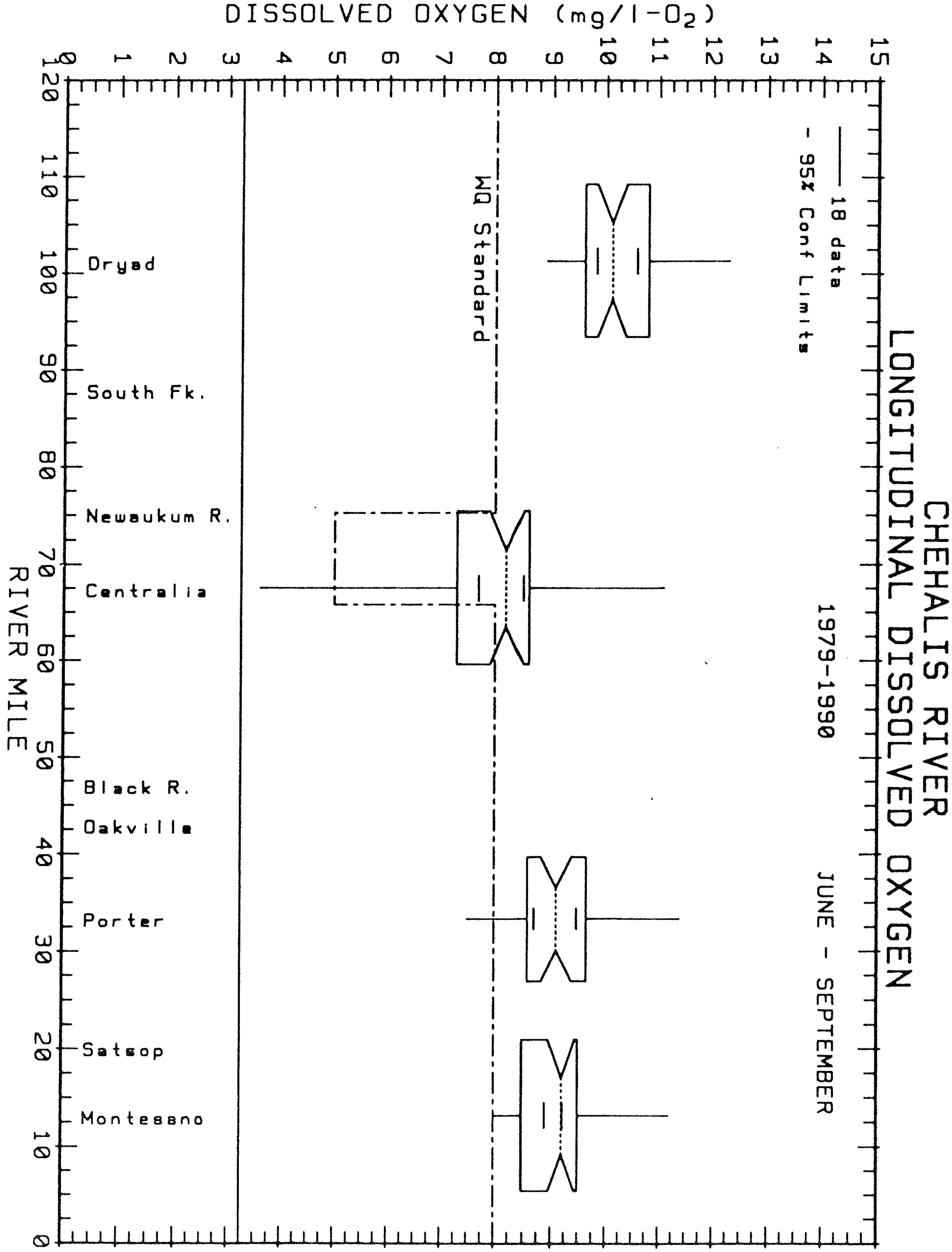

CHEHALIS RIVER AT CENTRALIA
TEMPERATURE - RIVER MILE 67.5
WQ Standard
TEMPERATURE (°C)
78 79 80 81 82 83 84 85 86 87 88 89 90
YEAR
14 data
- 95% Conf Limits
1978-1990
K-W 99%
WQ Standard
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

Figure 8



CHEHALIS RIVER
LONGITUDINAL DISSOLVED OXYGEN
1979-1990
JUNE - SEPTEMBER
18 data
95% Conf Limits
WQ Standard
DISSOLVED OXYGEN (mg/l-O2)
RIVER MILE
Dryad
South Fk.
Newaukum R.
Centralia
Black R.
Oakville
Porter
Satsop
Montesano


Figure 9

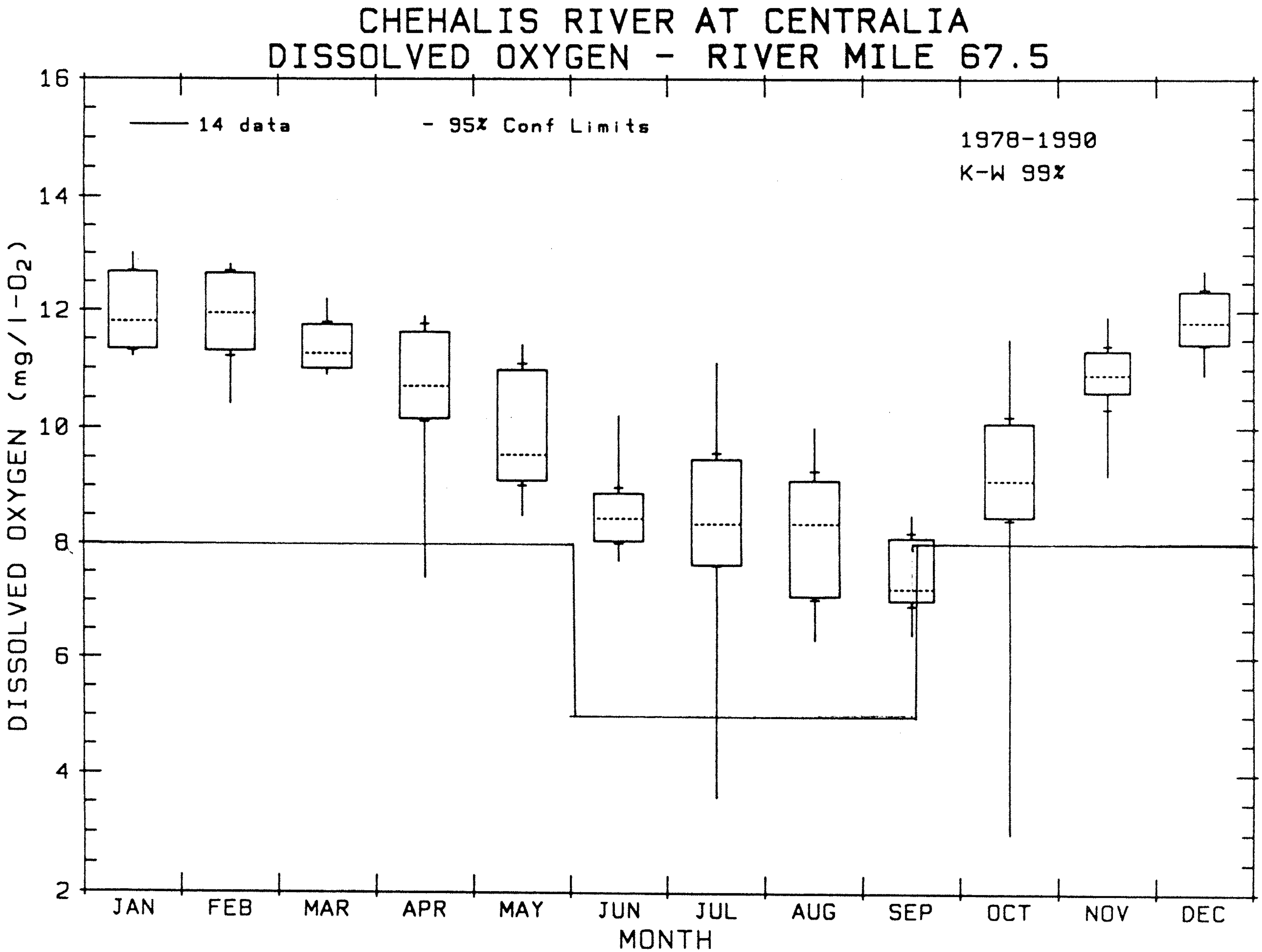

CHEHALIS RIVER AT CENTRALIA
DISSOLVED OXYGEN - RIVER MILE 67.5
14 data
- 95% Conf Limits
1978-1990
K-W 99%
DISSOLVED OXYGEN (mg/l-O2)
16
14
12
10
8
6
4
2
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Figure 10

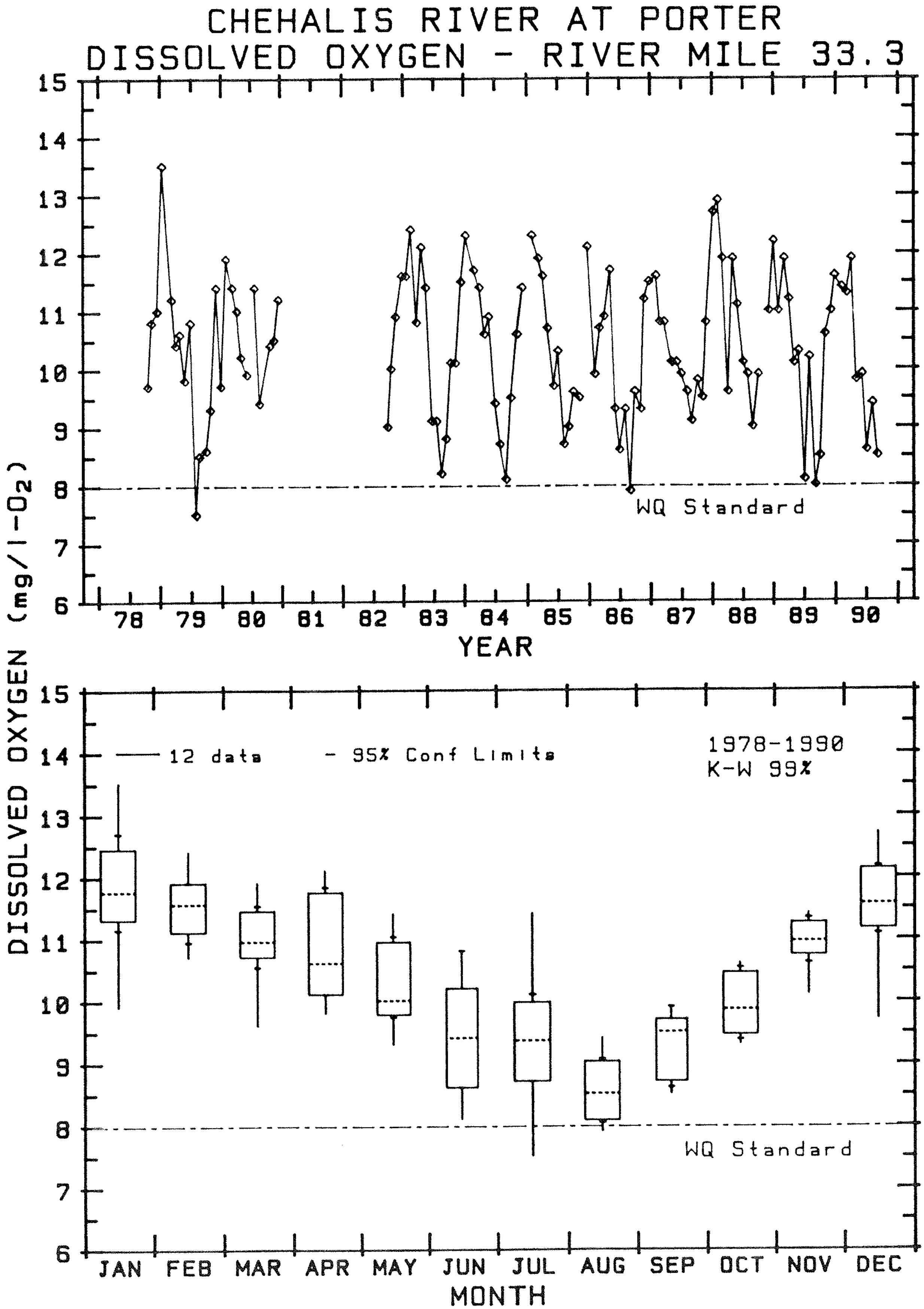

CHEHALIS RIVER AT PORTER
DISSOLVED OXYGEN - RIVER MILE 33.3
DISSOLVED OXYGEN (mg/l-O2)
15
14
13
12
11
10
9
8
7
6
WQ Standard
78 79 80 81 82 83 84 85 86 87 88 89 90
YEAR
12 data
- 95% Conf Limits
1978-1990
K-W 99%
WQ Standard
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

Figure 11

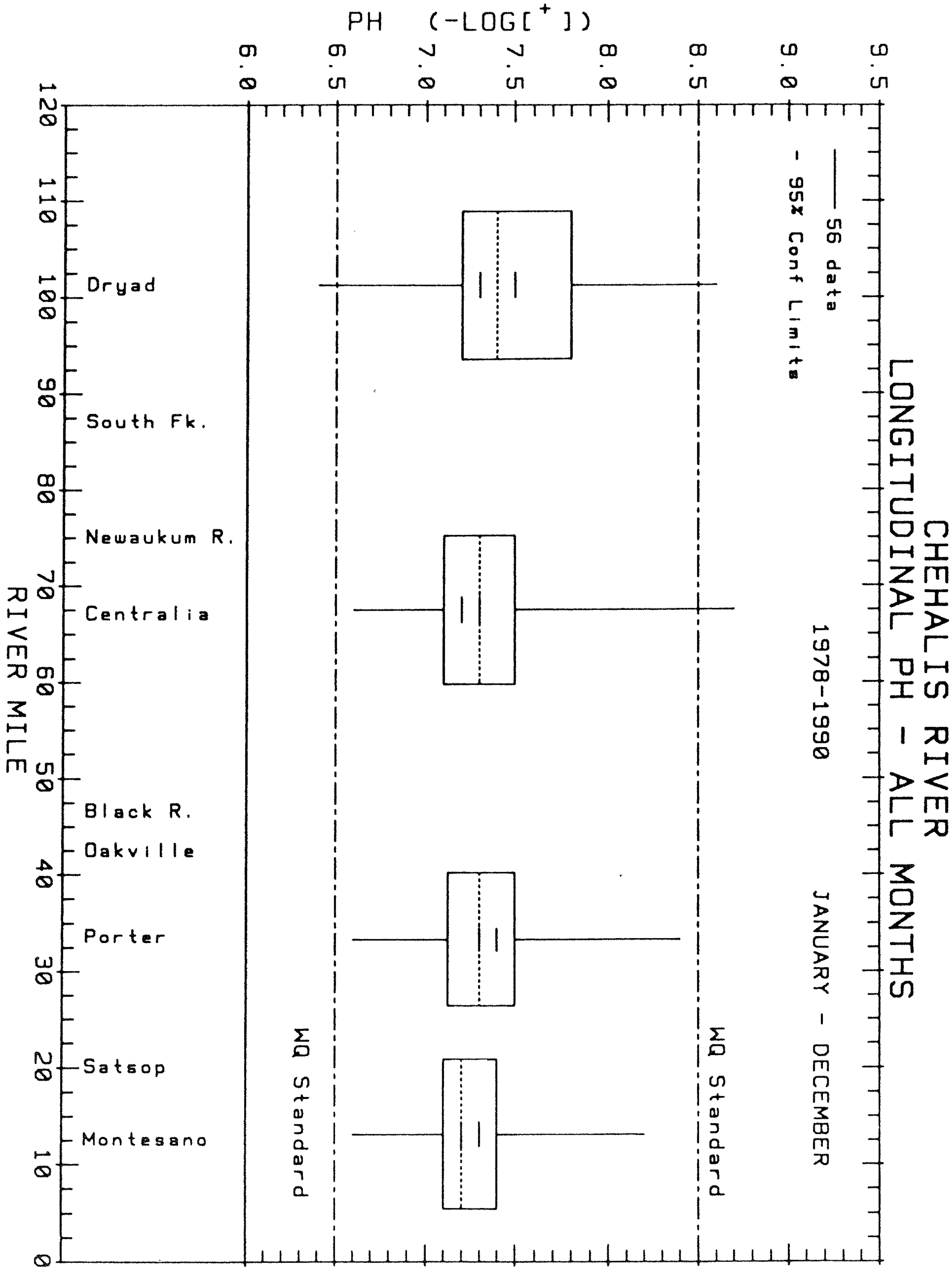

CHEHALIS RIVER
LONGITUDINAL PH - ALL MONTHS
1978-1990
JANUARY - DECEMBER
56 data
- 95% Conf Limits
PH (-LOG[+])
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
WQ Standard
WQ Standard
Dryad
South Fk.
Newaukum R.
Centralia
Black R.
Oakville
Porter
Satsop
Montesano
120
110
100
90
80
70
60
50
40
30
20
10
0
RIVER MILE

Figure 12

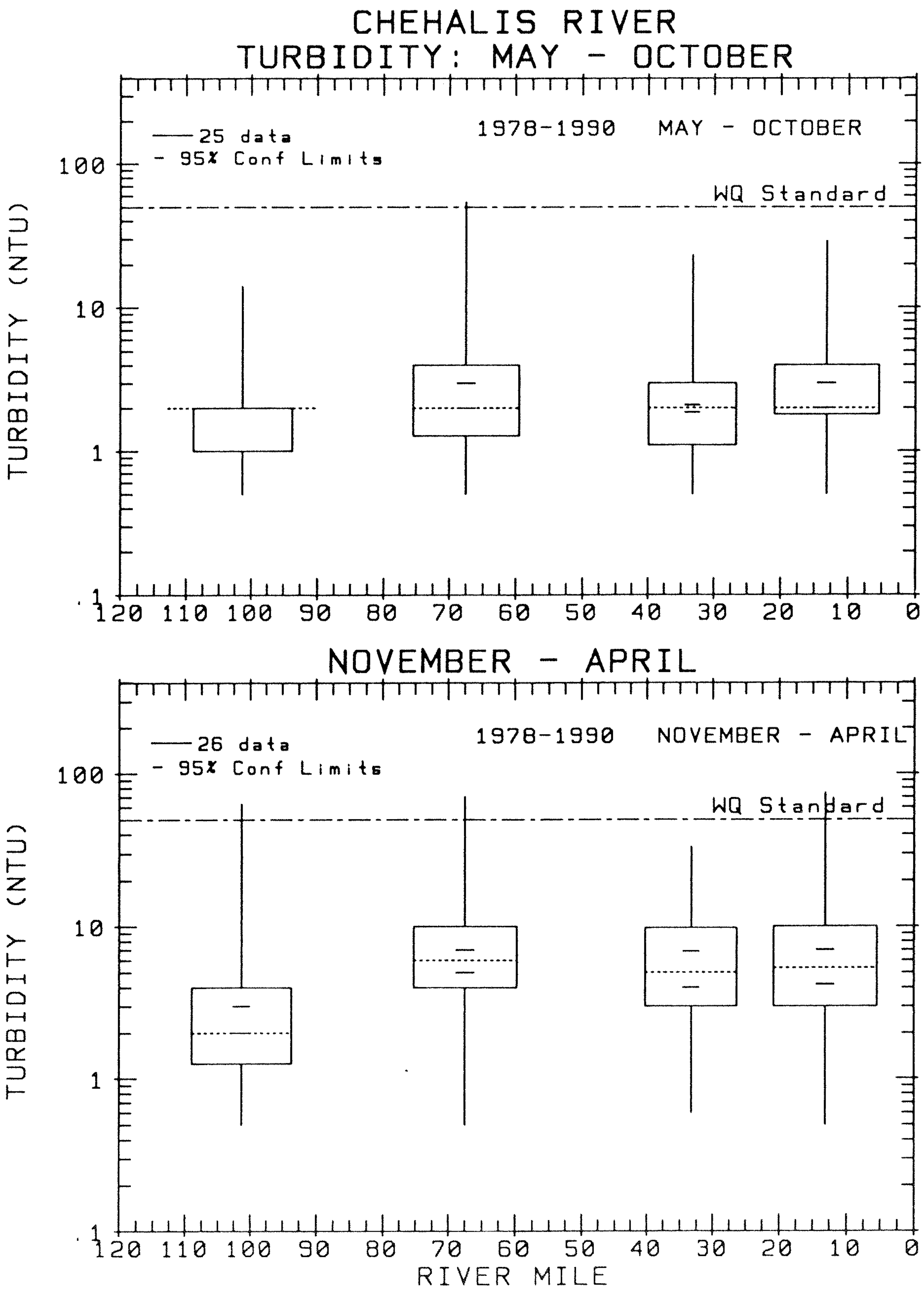

CHEHALIS RIVER
TURBIDITY: MAY - OCTOBER
25 data
- 95% Conf Limits
1978-1990 MAY - OCTOBER
WQ Standard
TURBIDITY (NTU)
100
10
1
.1
120 110 100 90 80 70 60 50 40 30 20 10 0
NOVEMBER - APRIL
26 data
- 95% Conf Limits
1978-1990 NOVEMBER - APRIL
WQ Standard
TURBIDITY (NTU)
100
10
1
.1
120 110 100 90 80 70 60 50 40 30 20 10 0
RIVER MILE

Figure 13

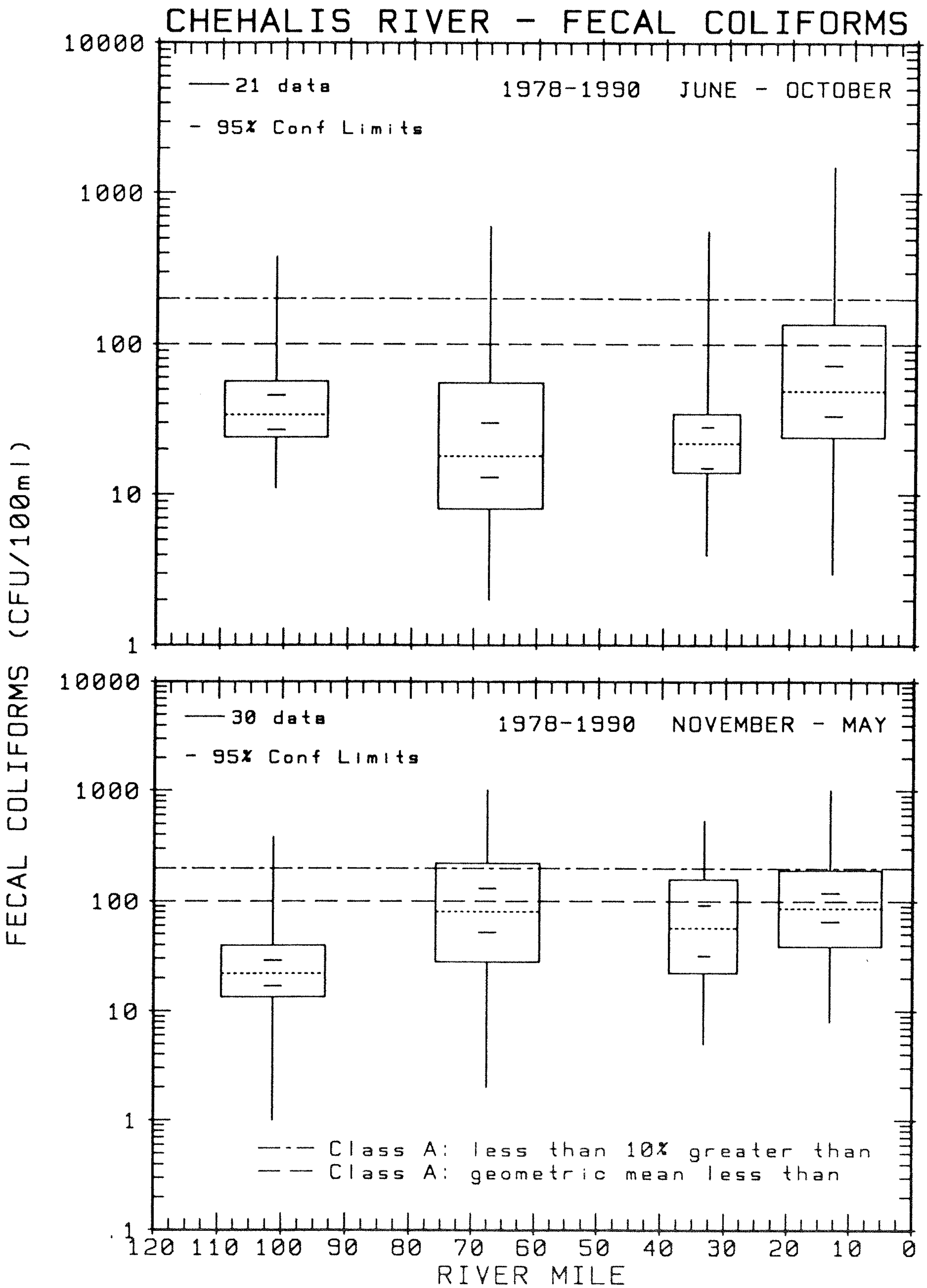
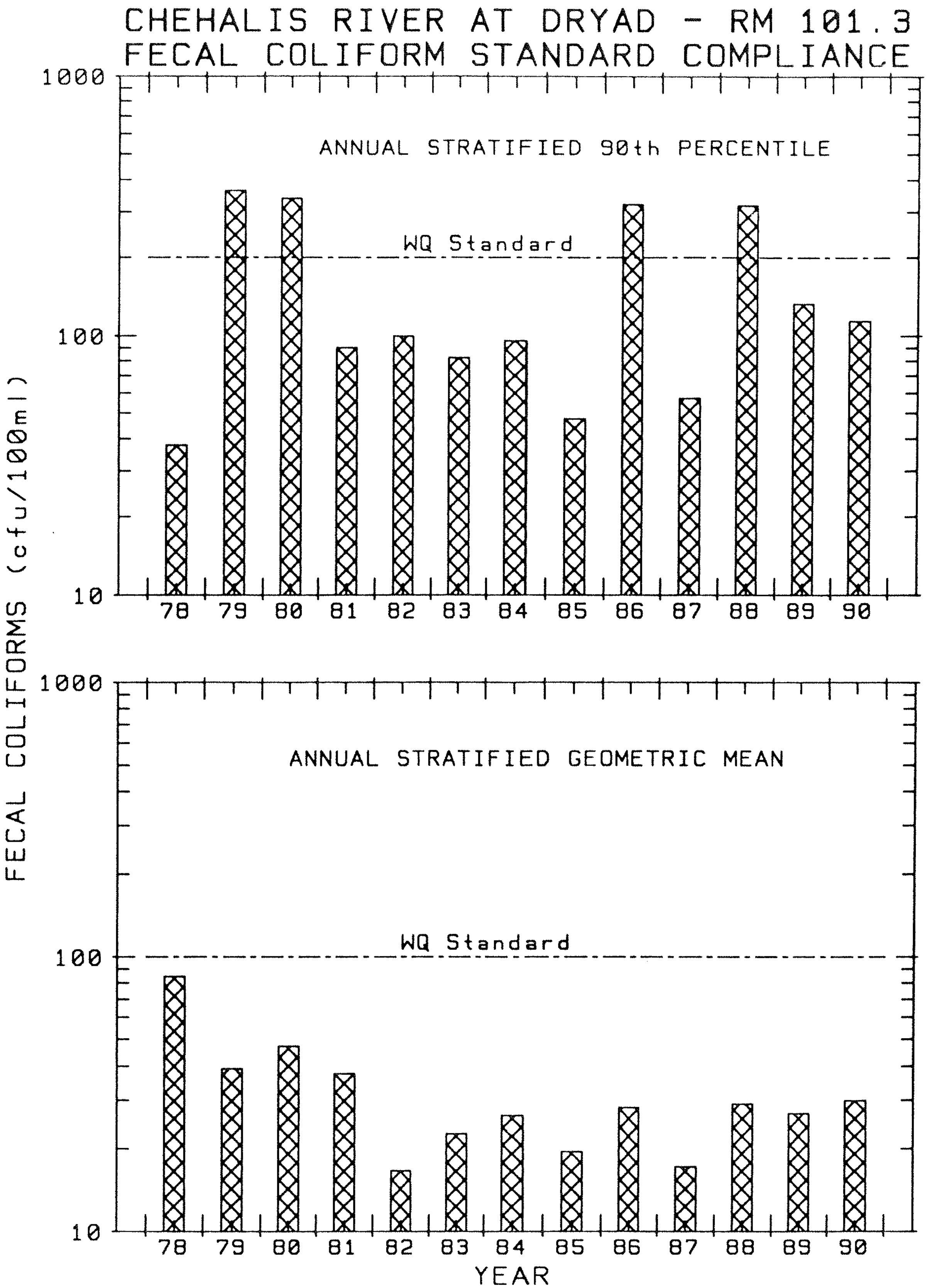

CHEHALIS RIVER - FECAL COLIFORMS
21 data
95% Conf Limits
1978-1990 JUNE - OCTOBER
30 data
95% Conf Limits
1978-1990 NOVEMBER - MAY
Class A: less than 10% greater than
Class A: geometric mean less than
FECAL COLIFORMS (CFU/100ml)
10000
1000
100
10
1
120 110 100 90 80 70 60 50 40 30 20 10 0
RIVER MILE

Figure 14



CHEHALIS RIVER AT DRYAD - RM 101.3
FECAL COLIFORM STANDARD COMPLIANCE
ANNUAL STRATIFIED 90th PERCENTILE
WQ Standard
1000
100
10
78 79 80 81 82 83 84 85 86 87 88 89 90
FECAL COLIFORMS (cfu/100ml)
ANNUAL STRATIFIED GEOMETRIC MEAN
WQ Standard
1000
100
10
78 79 80 81 82 83 84 85 86 87 88 89 90
YEAR


Figure 15

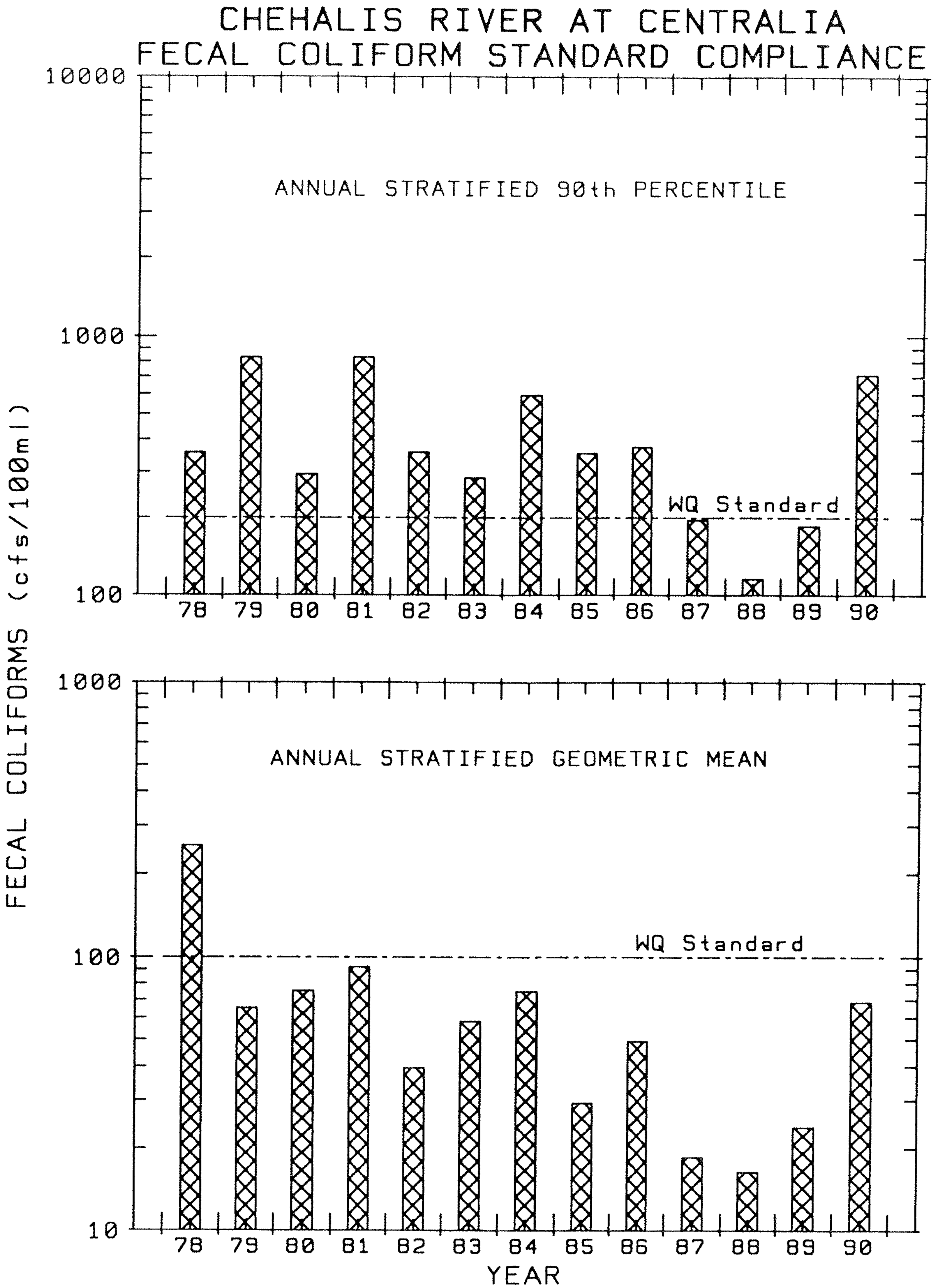

CHEHALIS RIVER AT CENTRALIA
FECAL COLIFORM STANDARD COMPLIANCE
ANNUAL STRATIFIED 90th PERCENTILE
WQ Standard
10000
1000
100
78 79 80 81 82 83 84 85 86 87 88 89 90
FECAL COLIFORMS (cfs/100ml)
ANNUAL STRATIFIED GEOMETRIC MEAN
WQ Standard
1000
100
10
78 79 80 81 82 83 84 85 86 87 88 89 90
YEAR

Figure 16

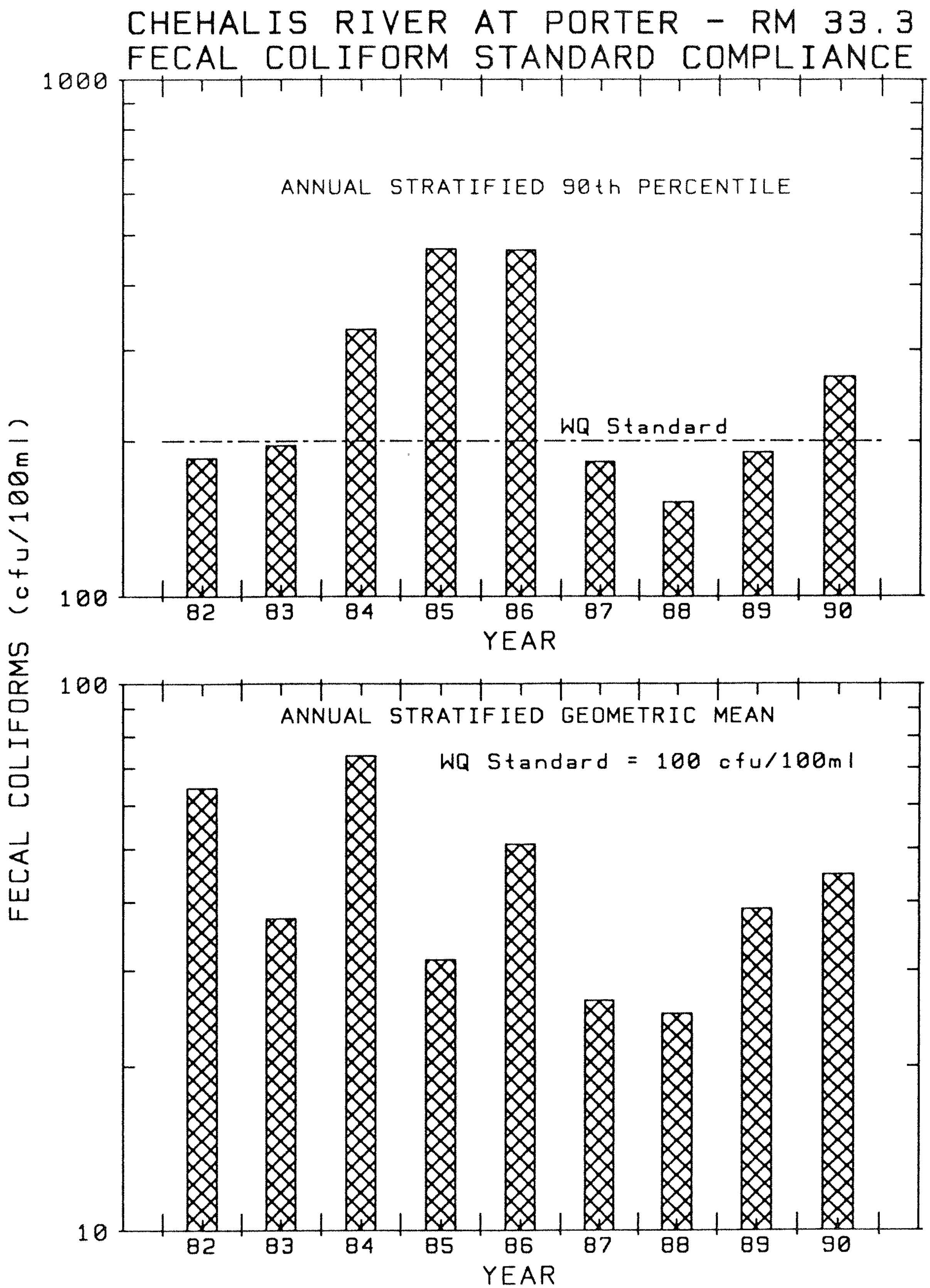
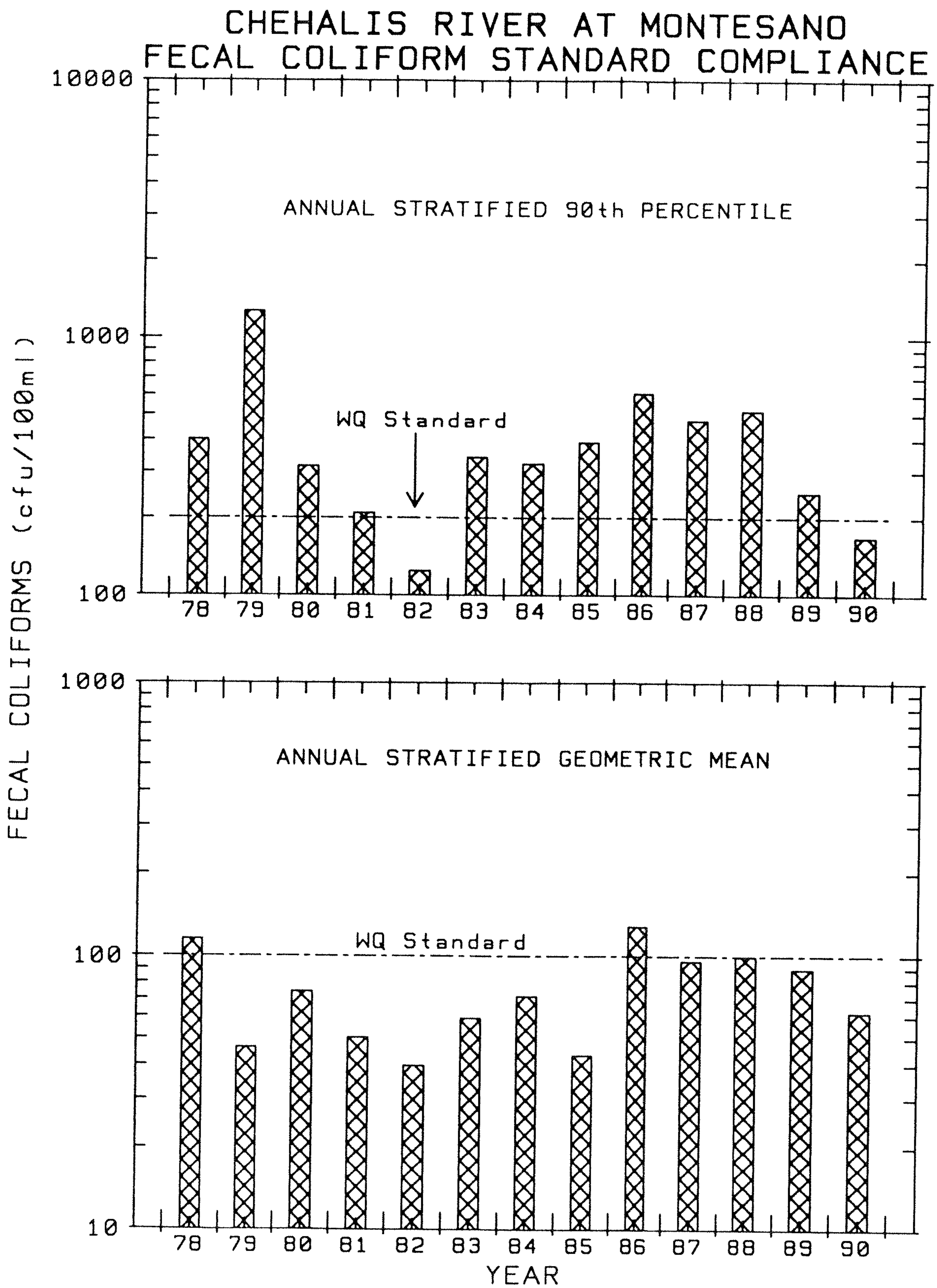
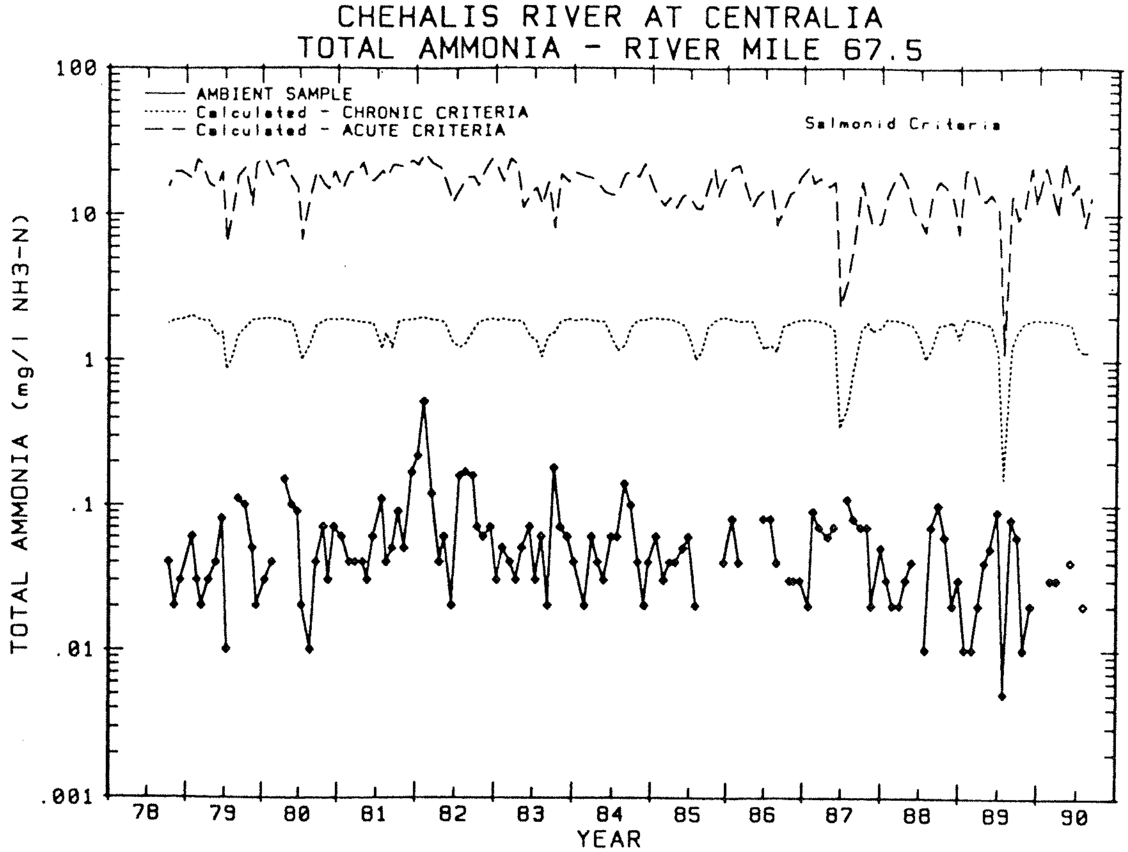

CHEHALIS RIVER AT PORTER - RM 33.3
FECAL COLIFORM STANDARD COMPLIANCE
1000
ANNUAL STRATIFIED 90th PERCENTILE
WQ Standard
100
82
83
84
85
86
87
88
89
90
YEAR
FECAL COLIFORMS (cfu/100ml)
100
ANNUAL STRATIFIED GEOMETRIC MEAN
WQ Standard = 100 cfu/100ml
10
82
83
84
85
86
87
88
89
90
YEAR

Figure 17



CHEHALIS RIVER AT MONTESANO
FECAL COLIFORM STANDARD COMPLIANCE
10000
1000
100
ANNUAL STRATIFIED 90th PERCENTILE
WQ Standard
78 79 80 81 82 83 84 85 86 87 88 89 90
FECAL COLIFORMS (cfu/100ml)
1000
100
10
ANNUAL STRATIFIED GEOMETRIC MEAN
WQ Standard
78 79 80 81 82 83 84 85 86 87 88 89 90
YEAR


Figure 18


CHEHALIS RIVER AT CENTRALIA
TOTAL AMMONIA - RIVER MILE 67.5
AMBIENT SAMPLE
Calculated - CHRONIC CRITERIA
Calculated - ACUTE CRITERIA
Salmonid Criteria
TOTAL AMMONIA (mg/l NH3-N)
100
10
1
.1
.01
.001
78
79
80
81
82
83
84
85
86
87
88
89
90
YEAR

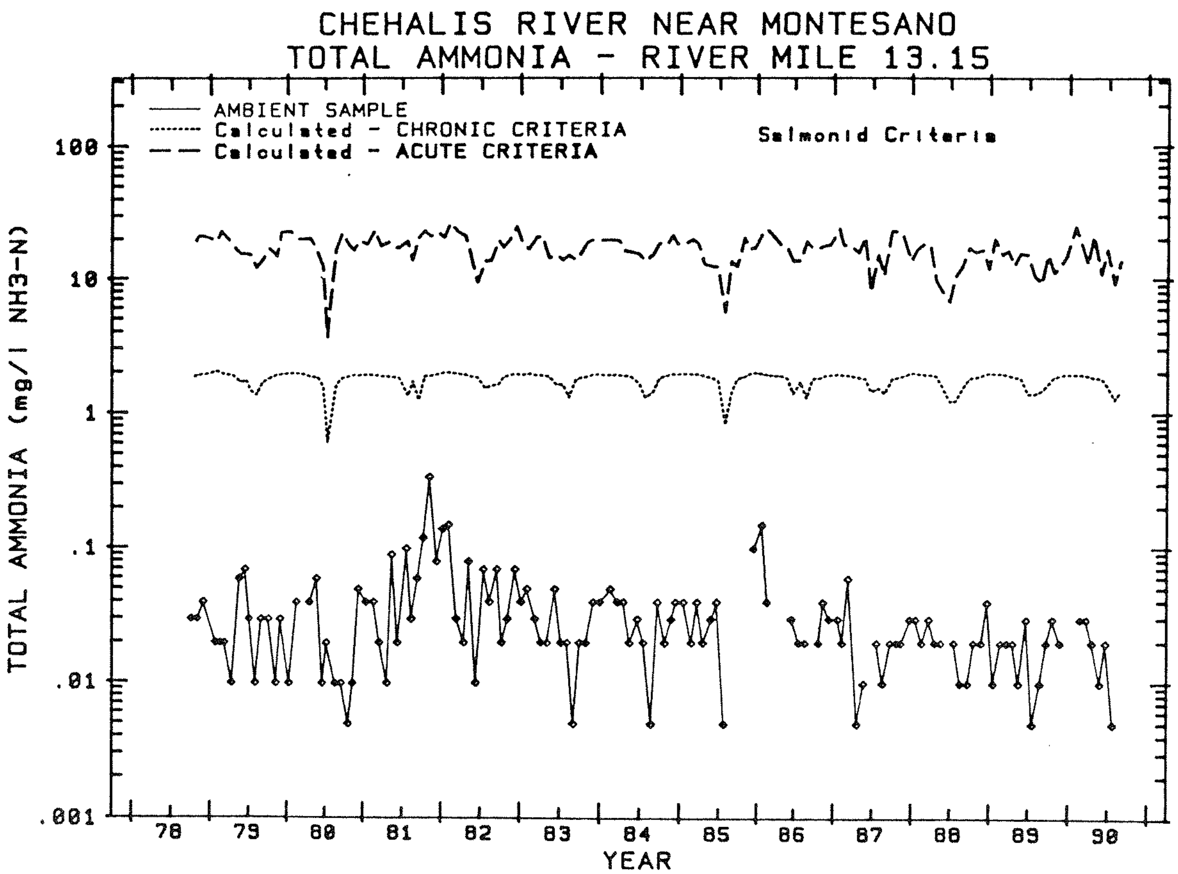

CHEHALIS RIVER NEAR MONTESANO
TOTAL AMMONIA - RIVER MILE 13.15
AMBIENT SAMPLE
Calculated - CHRONIC CRITERIA
Calculated - ACUTE CRITERIA
Salmonid Criteria
TOTAL AMMONIA (mg/l NH3-N)
100
10
1
.1
.01
.001
78
79
80
81
82
83
84
85
86
87
88
89
90
YEAR

Figure 19