WASHINGTON STATE DEPARTMENT OF ECOLOGY

# USBR Columbia River Pump Exchange Project

# Potential Water Quality Impacts on the Lower Yakima River

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

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# Potential Water Quality Impacts on the Lower Yakima River

*by*
*Jim Carroll and Joe Joy*

Environmental Assessment Program
Olympia, Washington 98504-7710

In contractual arrangements with:
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# Table of Contents


Page

List of Figures ... ii

List of Tables ... iii

Acknowledgements ... iv

Abstract ... v

Introduction ... 1
- Project Description ... 1
- Project Goals ... 5
- Background Information ... 7

Methods ... 11
- Study Design ... 11
- Data Quality Objectives and Analytical Procedures ... 19
- Sampling and Quality Control Procedures ... 19
- Data Assessment Procedures ... 21

Results and Discussion ... 23
- Field Studies Results ... 23
- QUAL2E Model Structure and Approach ... 24
- QUAL2E Model Calibration and Confirmation ... 29
- QUAL2E Model Results of USBR Pump Exchange Scenarios ... 49

References ... 63

Appendices

A. Laboratory and field results.
B. Quality assurance and quality control: Field duplicate analyses.
C. QUAL2E input files for calibration and confirmation model runs.
D. QUAL2E input files for operation change model runs.
E. Hydrolab datalogger survey data.
F. Key to box plots.

# List of Figures

Page

Figure 1. Area map of the Lower Yakima River Basin with land use and hydrology....... 3

Figure 2. Detail of Prosser to Chandler Return reach and Wanawish Dam diversion....... 6

Figure 3. Median daily flows by month for the Yakima River at Prosser and Kiona...... 13

Figure 4. Median daily flows by month for the Chandler and Kennewick canals........... 14

Figure 5. Major constituent interactions in the QUAL2E model.................................... 25

Figure 6. Time-concentration plots of dye cloud passage past RM 43.0 and RM 36.0 of the Yakima River. ......................................................................... 34

Figure 7. Calibration and confirmation of QUAL2E for prediction of temperature, DO, nd BOD in the lower Yakima River during September 1999 and July 2000 ........................................................................................... 42

Figure 8. Calibration and confirmation of QUAL2E for prediction of chlorophyll *a* and phosphorus in the lower Yakima River during September 1999 and July 2000 ........................................................................................... 44

Figure 9. Calibration and confirmation of QUAL2E for prediction of nitrogen forms in the lower Yakima River during September 1999 and July 2000 ................. 46

Figure 10. Calibration and confirmation of QUAL2E for prediction of chloride and TSS in the lower Yakima River during September 1999 and July 2000 ........ 48

Figure 11. Results of QUAL2E simulations of temperature, DO, and BOD for operational-change scenarios compared to current conditions ....................... 57

Figure 12. Results of QUAL2E simulations of chlorophyll *a*, organic-P, and dissolved-P for operational-change scenarios compared to current conditions........................................................................................... 58

Figure 13. Results of QUAL2E simulations of organic-N, ammonia-N, and nitrate-N for operational-change scenarios compared to current conditions.................. 59

Figure 14. Results of QUAL2E simulations of TSS and chloride for operational-change scenarios compared to current conditions.......................................... 60

# List of Tables


Page

Table 1. Class A (excellent) characteristic uses, freshwater quality criteria, and special conditions for the lower Yakima River and tributaries .......................... 6

Table 2. Lower Yakima River basin waterbodies identified in the 1998 303(d) list as not meeting water quality standards.......................................................... 10

Table 3. River, tributary, and point source sampling sites for the USBR modeling project ........................................................................................................ 15

Table 4. Site locations and parameters for the USBR modeling project - September 28-29, 1999 Ecology survey.......................................................... 16

Table 5. Site locations and parameters for the USBR modeling project - July 25-26, 2000 Ecology survey .................................................................... 17

Table 6. Summary of parameters, methods, reporting limits, and targets for precision and bias ........................................................................................ 20

Table 7. Comparison of data collected at site YAK-6 during the September 1999 and July 2000 surveys to long-term monitoring data collected by Ecology at site 36A090 during July through September (1980-2000) ........................... 23

Table 8. Schematic of QUAL2E reaches and hydraulics coefficients ............................ 26

Table 9. Flow balance for calibration and validation of QUAL2E................................ 30

Table 10. Summary of measurements used for calibration and confirmation of the QUAL2E model of the lower Yakima River ................................................. 36

Table 11. QUAL2E data type 1A: global algae, nitrogen, phosphorus, and light parameters for calibration of July 2000 conditions and confirmation of September 1999 conditions ........................................................................ 37

Table 12. QUAL2E data types 6, 6A, and 6B: BOD, algae, nitrogen, phosphorus, and TSS reach-level parameters for calibration of July 2000 conditions and confirmation of September 1999 conditions............................................ 38

Table 13. 5-day BOD conversion to UBOD data used in QUAL2E modeling ............. 38

Table 14. Overall performance of calibration and confirmation models using root mean square error (RMSE) and coefficient variation (CV) with comparison to overall observed field RMSE and CV..................................... 41

Table 15. Comparison of calibrated and confirmed model flows to current and operational-change scenario model simulation flows..................................... 50

Table 16. Mean and maximum water quality changes predicted by QUAL2E model for operational-change scenarios .................................................................... 52

Table 17. Summary of greatest mean and maximum change within a reach predicted by QUAL2E model by parameter ................................................................. 53

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# Abstract

The Washington State Department of Ecology used the steady-state QUAL2E model to evaluate potential water quality changes from proposed operational changes by the U.S. Bureau of Reclamation (USBR) at the Chandler Canal and Columbia Canal diversions. The study area for this modeling project encompassed the lower 47 miles of the Yakima River, downstream of Prosser. The proposed operational changes are part of the USBR Columbia River Pump Exchange Project. Two synoptic surveys were conducted by Ecology, in September 1999 and July 2000, to assess water quality characteristics during the summer low-flow season. The water quality data from these surveys were used to calibrate and confirm the QUAL2E model.

Poor upstream water quality was concluded to be the foremost determinant of water quality conditions in the last 47 miles of the lower Yakima River evaluated in this study. Changes in operational flows at Chandler Canal cannot overcome the water quality degradation occurring upstream. The QUAL2E model mainly predicted some dilution effects on water quality parameters due to increased water volumes associated with the operational changes. Reduced settling of chlorophyll *a* and total suspended solids was also predicted due to increased velocities of flows. These effects were especially apparent in the Prosser Dam to Chandler Return reach. The proposed operational change at Columbia Canal diversion is predicted to have no noticeable impact on water quality conditions downstream of that diversion.

Compared to current conditions, the operational changes were predicted to decrease mean daily water temperatures by less than a 0.5°F in any reach and dissolved oxygen (DO) concentrations by less than 0.1 mg/L within any reach. Chlorophyll *a* levels throughout the study area were predicted to increase slightly from current conditions with each operational-change scenario. The Washington State temperature and DO criteria would continue to be violated because of elevated water temperatures and algae/periphyton productivity. Upstream boundary conditions would determine both the temperature and productivity regimes within the whole study area.

# Introduction

## Project Description

The U.S. Bureau of Reclamation (USBR) has proposed several changes in water management in the lower Yakima River to more effectively meet the needs of irrigators and fisheries. The Columbia River Pump Exchange Project is one of these changes that may be beneficial to fisheries habitat and water quality in the lower Yakima River while improving service to irrigators. Figure 1 shows the portion of the lower Yakima River that pertains to the project proposal.

The focus of the Columbia River Pump Exchange Project is to move, wholly or partially, water removed from the Yakima River at the Kennewick Irrigation District (KID) and Columbia Irrigation District (CID) diversions. The diversions would be moved from the mainstem Yakima River to a pump station installed in the Columbia River near Kennewick. The exchange of water taken from the Columbia River would be equivalent to the water left in the Yakima River.

The current diversion of water for KID begins at Prosser Dam located at river mile (RM) 47.0, near the city of Prosser (Figure 1). Prosser Dam diverts that water into the Chandler Canal. Normally the canal capacity is about 1300 cubic feet per second (cfs). This can vary from 1100 to 1500 cfs, depending on the condition of the canal. The canal operates year-round except for a maintenance period in October and November. The canal water travels 11 miles downstream, paralleling the mainstem Yakima, to the Chandler Power and Pumping Plant at RM 35.8 (Figure 2). At this point, up to 749 cfs is used to deliver water to the KID. Up to 416 cfs of canal water turns hydraulic pumps that move up to 333 cfs of canal water under the river, up the opposite bank, and into the KID irrigation canal. A ratio of 1.25 cfs to 1 cfs pump water to KID water is required to deliver water to the KID canal water from Chandler. The water (up to 416 cfs) that was used to turn the hydraulic pumps is returned to the river below the power plant. The balance of the water in Chandler Canal is sent through electrical turbines at the power plant, and is returned to the river below the plant.

In some previous years, nearly all water was diverted out of the Yakima River between Prosser Dam and Chandler Return. In 1994 federal Public Law 103-434 was signed as the result of the Yakima River Basin Water Enhancement Project bill. To protect fisheries and water resources, Public Law 103-434 establishes minimum target flows over Prosser Dam of 300 cfs, and states that actual flows may not be less than the target flow by 50 cfs. In high water years, the target flow is increased (e.g., 1999 had a target of about 600 cfs). Target flows vary from 300 to 600 cfs based on the water supply estimate for the basin in a given year.

By moving the KID irrigation diversion to the Columbia River pump station at Kennewick, up to 749 cfs usually diverted from the Yakima River to the Chandler Canal could be allowed to flow over the Prosser Dam. Again, this includes water that turns the hydraulic pumps (up to 416 cfs) and water delivered to the KID canal (up to 333 cfs), for a maximum net increase of 749 cfs to

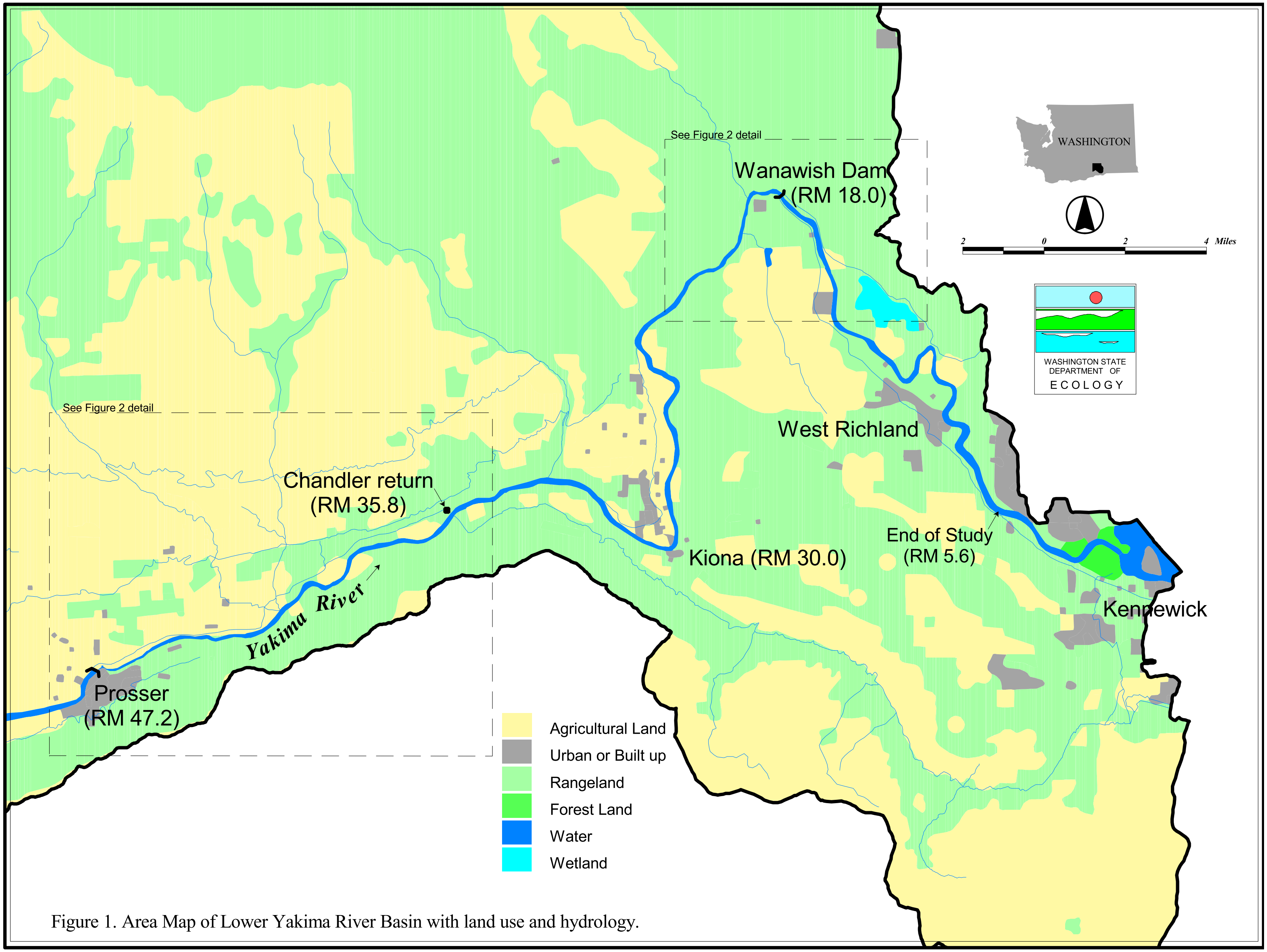



Figure 1. Area Map of Lower Yakima River Basin with land use and hydrology.

spill over the Prosser Dam into the 11-mile mainstem reach. Partial exchange conditions are also being considered that would still use pumps to deliver some water to KID through the Chandler system.

Another part of the proposed project is for the CID diversion to be included in the KID pump station routing. CID's current diversion of approximately 160 cfs is at Wanawish Dam (formerly Horn Rapids Dam) at RM 18.0, approximately 29 miles below Prosser (Figure 2). Wanawish Dam would continue to be used and maintained, diverting approximately 30 cfs to local irrigators. The remaining irrigation needs would be supplied by the KID pump exchange project. This change in diversion could add approximately 130 cfs to the last 18 miles of the river.

The USBR is interested in comparing water quality effects of the proposed operational changes in the lower Yakima River through mathematical modeling. The Washington State Department of Ecology (Ecology) Environmental Assessment Program, by contractual agreement with the USBR, has developed a model to evaluate the possible water quality changes in the lower Yakima. This technical study describes a modeling project that provides the USBR with the water quality information it needs to select the best operational options for the Columbia River Pump Exchange Project.

## Project Goals

The purpose of this modeling project was to assess the possible effects of the water management operational changes on water quality in the lower Yakima River. The Columbia River Pump Exchange Project offers one or more water management options on water routing from Prosser Dam to the mouth of the Yakima, especially at Chandler Canal and Wanawish Dam. This water quality modeling project is part of a larger effort by USBR to assess the effect of the Columbia River Pump Exchange Project on aquatic habitat and fish populations in the lower Yakima River.

This modeling project included the following major tasks:

- Collect historical water quality and flow data for model calibration and to determine critical river periods, locations, and average water quality conditions.
- Collect additional field data for model calibration and verification.
- Construct a water quality model with flexible and accurate hydrological routing, and with a large number of water quality parameters.
- Compare results from the calibrated model to current conditions and to various combinations of water management activities.
- Compare results from the water quality model to previous SNTEMP temperature modeling results (Payne and Monk, 1999).

This water quality assessment used a mathematical model that was calibrated to hydrologic and water quality conditions in the lower Yakima River. Using independent data sets, the model was confirmed or verified over a range of critical conditions. After the model was calibrated and its

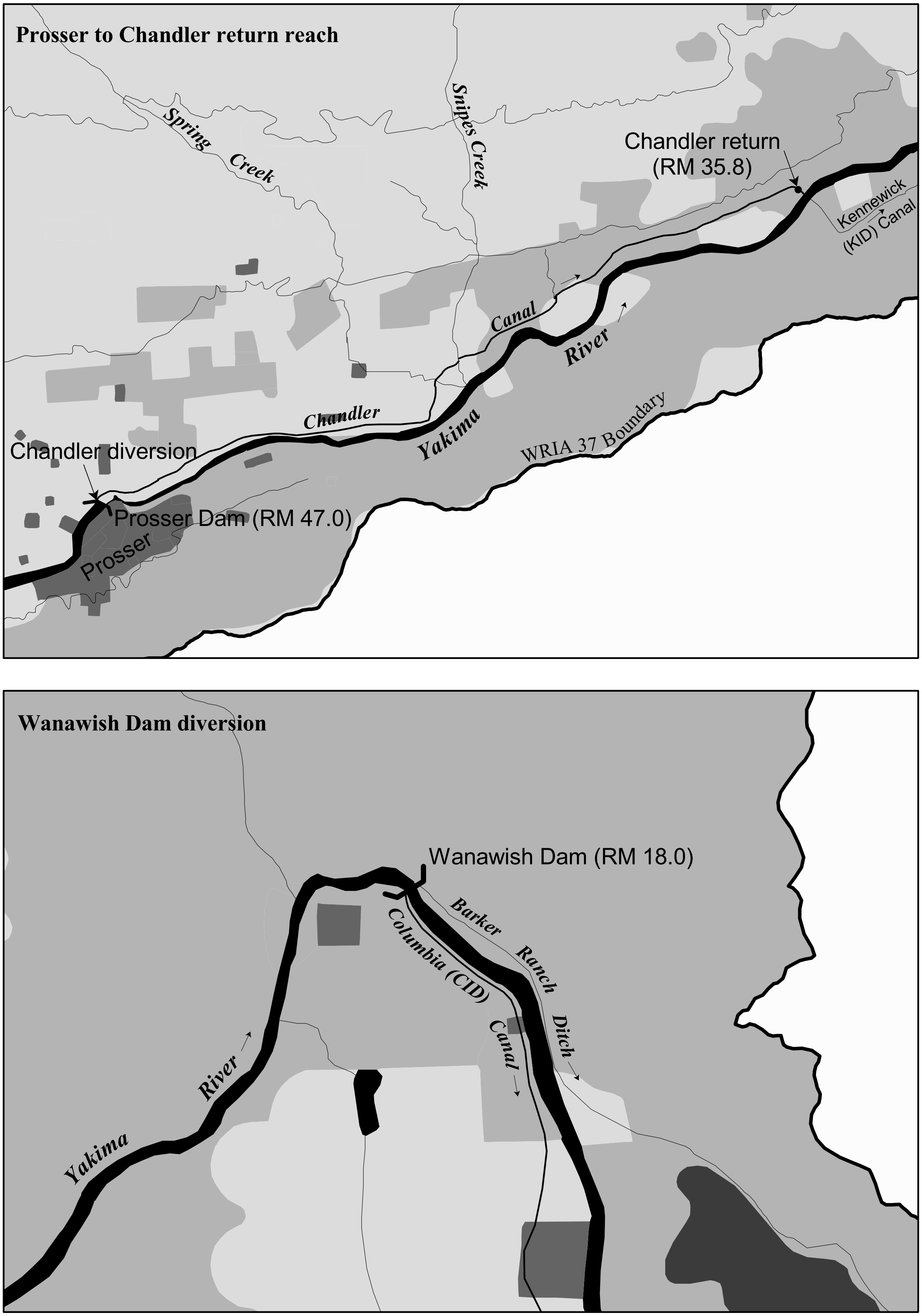



Figure 2. Detail of Prosser to Chandler return reach and Wanawish Dam diversion.

range of accuracy known, several water management scenarios were simulated. The water quality parameters of concern included total suspended solids (TSS), turbidity, dissolved oxygen (DO), temperature, pH, nutrients, biochemical oxygen demand (BOD), and selected pesticides.

Several of these parameters have direct interactions, or have complex biological components that require simulation (e.g., nutrient and periphyton or phytoplankton interaction). Because of their expense and the extended laboratory analysis time needed, pesticide and metals analyses were not collected for this project. Organochlorine pesticide data were inferred from historical sample collections, and correlations were established to TSS (Joy and Patterson, 1997). Turbidity was also not directly modeled, but a previously developed regression relationship between TSS, a model parameter, and turbidity for the lower Yakima was employed (Joy and Patterson, 1997). Since pH simulation functions are generally not available in water quality models, pH response to the changes in water management could only be inferred from the changes observed in DO simulation output.

# Background Information

The lower Yakima River basin contains approximately 3,300 square miles ($mi^2$) in south-central Washington. The 47-mile portion of the lower Yakima River (i.e., from Prosser to the mouth of the Yakima) pertaining to this project study area routes the remainder of the water in the Yakima River to the Columbia River. All of the study area is located in Benton County. The lower Yakima River basin is one of the most intensely irrigated areas in the United States. A vast and complex irrigation network has served to make the lower Yakima River basin one of the leading producers of tree and vine fruit as well as other diverse agricultural products. The USBR manages the reservoirs and water delivery network that supplies most of the water for this production. The USBR also manages the system for flood control, power generation, and fisheries.

Most of the major irrigation return drains and large municipal and industrial dischargers have returned excess water or effluent to the Yakima River above Prosser. The water quality of the Yakima River at Prosser (i.e., water entering the project study area) represents the net result of most water quality impacts to the river for all of the Yakima River basin. Further impacts to the water quality of the Yakima River below Prosser are minimal in comparison to upriver impacts. They include three smaller tributaries/return drains (Snipes Creek, Spring Creek, and Corral Creek) and subsurface groundwater flow that discharge water to the river channel. There are also four permitted dischargers to the Yakima River below Prosser:

- City of Prosser Wastewater Treatment Plant (WWTP) (RM 46.6)
- Treetop (Seneca Foods) (RM 45.2)
- Benton City WWTP (RM 28.6)
- City of West Richland WWTP (RM 9.8)

KID return water is returned to the mainstem Yakima via the Amon Wasteway at RM 2.1 (within the area where the river level is affected by the McNary Pond backwater from the Columbia River) or directly to the Columbia River. All return water for the CID is returned to the Columbia River.

The lower Yakima River and tributaries below Prosser fall into the Washington State Class A water quality classification (Table 1). The Yakima River state classification carries a special maximum temperature criterion of 21°C. The Yakima River from the mouth to RM 80.4, and both Snipes and Spring creeks, are not meeting state water quality standards. Water quality monitoring by Ecology, the U.S. Geological Survey (USGS), and others over several years have documented poor water quality conditions in the lower Yakima River and its tributaries. As a result, the lower Yakima River has been placed on Washington State's 303(d) List (Ecology, 2000) as required by the federal Clean Water Act for several parameters (Table 2). Water quality criteria violations include pesticides, PCBs, temperature, fecal coliform bacteria, pH, DO, and turbidity. Inadequate instream flows that cause beneficial-use losses have also been listed for some reaches (e.g., inadequate flows that reduce fish habitat and thus reduce the beneficial fisheries use of the lower Yakima). Wastes from some agricultural practices, irrigation return drains, municipal and industrial treatment plant effluents, run-off from poorly managed forest and range practices, and urban run-off have been identified as pollutant sources. Again, pollutant sources generally originate upstream (above Prosser) of this project study area.

Table 1. Class A (excellent) characteristic uses, freshwater quality criteria, and special conditions for the lower Yakima River and tributaries (WAC 173-201A).

| | |
|---|---|
| **General Characteristics**<br>Shall meet or exceed the requirements for all or substantially all uses. | |
| **Characteristic Uses**<br>Shall include, but not be limited to the following: Water Supply (domestic, industrial, agricultural); Stock Watering; Fish and Shellfish: Salmonid and Other fish migration, rearing, spawning, and harvesting, Crustaceans and Other shellfish rearing, spawning, and harvesting; Wildlife Habitat; Recreation (primary contact, sport fishing, boating, and aesthetic enjoyment); Commerce and Navigation. | |
| **Water Quality Criteria** | |
| Fecal Coliform | Shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean exceeding 200 colonies/100 mL |
| Dissolved Oxygen | Shall exceed 8 mg/L |
| Total Dissolved Gas | Shall not exceed 110% of saturation at any point of sample collection. |
| Temperature (special condition for lower Yakima River only) | Shall not exceed 21.0°C.due to human activities. When natural conditions exceed 21°C., no increase allowed which raises receiving water temperature greater than 0.3°C; nor increases at any time shall exceed $t=34/(T+9)$ |
| Temperature | Shall not exceed 18.0°C.due to human activities. When natural conditions exceed 18°C., no increase allowed which raises receiving water temperature greater than 0.3°C; nor increases at any time shall exceed $t=28/(T+7)$ |
| pH | Shall be within the range of 6.5 to 8.5 with a human-caused variation within a range of less than 0.5 units |
| Turbidity | Shall not exceed 5 NTU over background when the turbidity is 50 NTU or less, or have more than a 10% turbidity increase when background is more than 50 NTU. |
| Toxic, radioactive, or deleterious materials | Concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health as determined by the department. |
| Aesthetic Values | Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste. |

Table 2. Lower Yakima River basin waterbodies identified in the 1998 303(d) list as not meeting water quality standards (Ecology, 2000).

| **Waterbody Number** | **Name** | **Media** | **Parameter Exceeding Standards** |
|---|---|---|---|
| WA-37-1010 | Yakima River from mouth to Toppenish Creek (rm 80.4) | Water | Temperature, pH, fecal coliform, dissolved oxygen, [DDT, 4-4'-DDE, 4-4'-DDD (human health only)], endosulfan, dieldrin, turbidity, silver, arsenic, mercury |
| WA-37-1010 | same | Tissue | Dieldrin, DDT, 4-4'-DDE, PCB-1254, PCB-1260 |
| WA-37-1010 | same | Habitat | Instream flow |
| WA-37-1012 | Snipes Creek | Water | Dissolved oxygen, temperature |
| WA-37-1014 | Spring Creek | Water | Temperature |

# Methods

## Study Design

The project objectives were met through a combination of historical data review, field sampling, and development and analysis of the QUAL2E water quality model.

### Data Review

Physical channel, water quality, and climate data are necessary to construct a mathematical model that accurately simulates hydrology and water quality characteristics. Historical and current data were available from several government agencies and technical literature. A data search from several agencies and sources was conducted. The goal was to have enough water quality and physical data at several sites in each of the following three reaches during the critical period to calibrate and verify a water quality model:

- Prosser Dam to Chandler Power Return
- Chandler Power Return to Wanawish (formerly Horn Rapids) Dam
- Wanawish Dam to the Columbia River

Channel cross sections were available from past instream flow incremental method assessments. Rating curves and other physical data were available through the USGS and the USBR. USGS gaging station data from the Yakima River at Kiona station and discharge data from the following USBR Hydromet stations were used: Yakima River at Prosser, Chandler Canal, and Kennewick Irrigation District Canal. Physical data were estimated from maps, aerial photographs, discharge data, and by using mathematical formulae.

Water quality monitoring has been conducted at sites within the three reaches by several agencies. Data are more numerous at a few sites in the upper two reaches than for the lowest reach. The most extensive water quality data have been collected by several agencies at Benton City/Kiona (RM 29.9). Data from periodic sampling of tributary and mainstem sites in the Prosser to Chandler reach, and at West Richland in the Wanawish to Columbia reach, were located from sources within Ecology.

### Field Studies

Historical data did not provide complete data sets for model calibration or confirmation. Therefore, field data collection was necessary. A reconnaissance survey was conducted in September 1999 in order to identify specific sampling locations and evaluate the logistical requirements of the surveys. Ecology staff conducted two field synoptic surveys to collect water quality data for the study. The sampling dates were as follows:

- September 27-30, 1999
- July 24-28, 2000

Both sampling dates were chosen to represent the time of critical water quality conditions in the lower Yakima River, which is during the seasonal low-flow period from July to September. Figure 3 presents box plots of the median daily flows by month for the Yakima River at Prosser (RM 45.8) and at Kiona (RM 30.0). The USBR has identified two periods of critical biological concern. The first period is the spring out-migration of salmon that occurs from February through June. The second is the late summer aquatic food chain production period that occurs from July through September. The latter period also coincides with the summer low-flow period when Public Law 103-434 target flows usually come into play. Changes in parameters relative to aquatic life toxicity or habitat limitations are of greatest interest during the summer low-flows when the greatest water quality changes are expected. Because the lowest assimilative capacity occurs during July, August, and September, both surveys were scheduled during that time to ensure sufficient data for confirmation of model predictions for this critical low-flow period.

Another reason for focusing on the July through September period is that this also is within the period of operation of the KID and CID irrigation seasons. Figure 4 presents box plots of median daily flows by month for the Chandler Canal and KID Canal. While the Chandler Canal is in operation nearly all year (except part of October and November for maintenance), the KID Canal operates generally from April through September. This project specifically evaluates the partial or whole removal of the KID diversion from the Yakima River in exchange for pumped Columbia River water, and as the KID water right is a seasonal diversion (i.e., generally April through September), it defines the period of evaluation. The Chandler Canal remains in operation the rest of the year (i.e., outside of the KID irrigation season) for generation of power at the Chandler Power Plant.

The July 2000 survey data set was used to calibrate the water quality model and the September 1999 survey data collection was used to verify or confirm the water quality model performance. Each sampling event included two days of sampling at 10 stations along the mainstem dispersed between the three reaches. The sampling sites are presented in Table 3, and schedules for field measurements and sample collection for laboratory analysis are presented in Tables 4 and 5. Samples were collected by boat and from bridges and bank-sides, depending on access. The following point sources and tributaries also were sampled: Prosser WWTP, West Richland WWTP, Treetop/Seneca Foods, Snipes and Spring Creek, Chandler Return, and Corral Creek. Benton City WWTP was not discharging during the surveys, so it was not sampled.

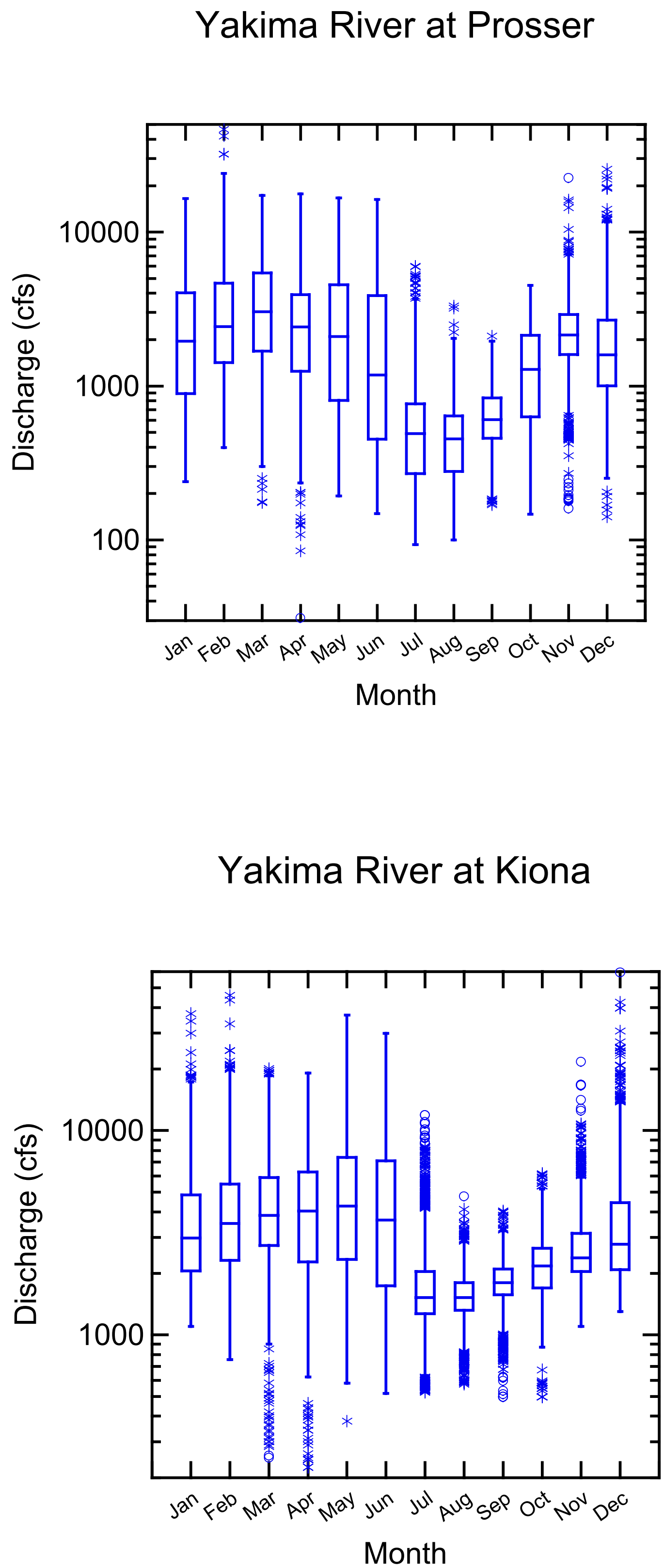
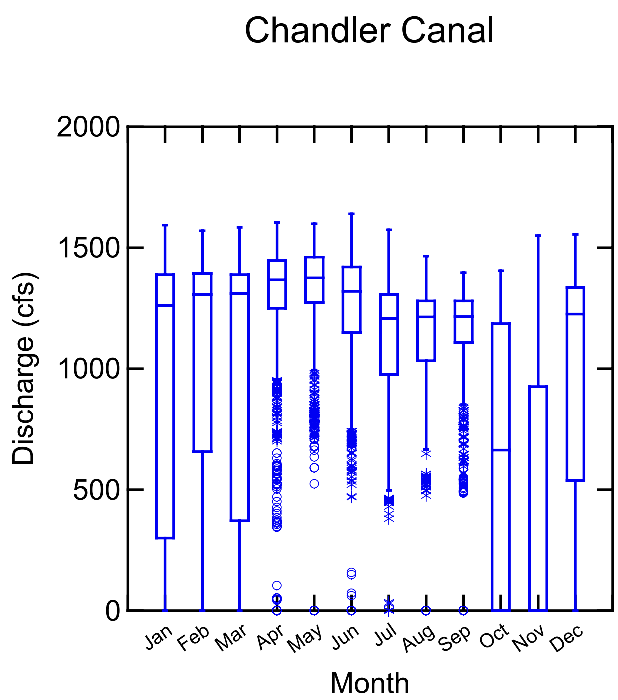



Figure 3. Median daily flows by month for the Yakima River at Prosser (RM 45.8) for 1980-99, and Kiona (RM 30.0) for 1933-99. Key to box plots is in Appendix F.



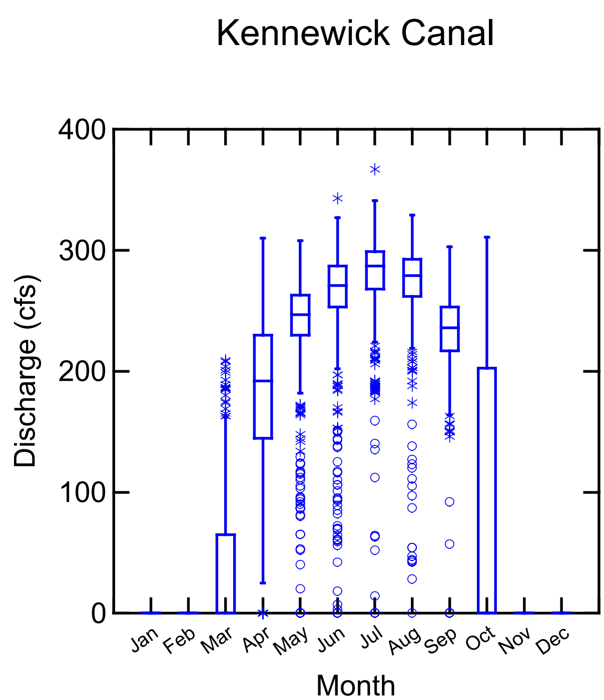




Figure 4. Median daily flows by month for the Chandler and Kennewick canals, 1960-99. Key to box plots is in Appendix F.

Table 3. River, tributary, and point source sampling sites for the USBR modeling project.

| River mile | Site name | # | Location |
|---|---|---|---|
| 47.1 | BRCHANUP | 1 | Above Prosser Dam |
| 46.6 | BRPROSWW | 2 | Prosser WWTP |
| 45.8 | BRBLPROS | 3 | Below Prosser WWTP |
| 45.2 | BRTREETO | 4 | Twin City Foods |
| 41.8 | YAK-17 | 5 | Spring Creek |
| 41.8 | YAK-19 | 6 | Snipes Creek |
| 36.0 | BRABCHAN | 7 | Above Chandler Return |
| 35.8 | BRCHANRE | 8 | Chandler Return |
| 34.0 | BRBLCHAN | 9 | Below Chandler Return |
| 33.5 | BRCORRAL | 10 | Corral Creek |
| 29.6 | YAK-6 | 12 | Kiona bridge |
| 27.0 | BRBLBENT | 13 | Below Kiona |
| 18.8 | BRABWANA | 14 | Above Wanawish Dam |
| 16.2 | BRBLWANA | 16 | Below Wanawish Dam |
| 12.8 | BRTWINBR | 17 | Twin Bridges |
| 9.8 | BRWRICHW | 19 | West Richland WWTP |
| 8.4 | YAK-7 | 15 | Van Geisen bridge |
| 5.6 | BRHWY182 | 20 | Above Hwy 182 |

Table 4. Site locations and parameters for the USBR modeling project: September 28-29, 1999 Ecology survey.

| Site Location | Site Name | # | RM | Type | Field | Turb | TSS | Alka | Hard | Cl | Chl a | TOC | OPO4 | TPN | Nut. 5 | BOD | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pool above Prosser | BRCHANUP | 1 | 47.1 | Mainstem | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Prosser WWTP | BRPROSWW | 2 | 46.6 | Effluent | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 |
| Yakima below Prosser | BRBLPROS | 3 | 45.8 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | | 1 |
| Twin City Foods IWTP | BRTREETO | 4 | 45.2 | Effluent | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 |
| Spring Creek | YAK-17 | 5 | 41.8 | Tributary | 1 | 1 | 1 | | | 1 | | | 1 | 1 | 1 | | 1 |
| Snipes Creek | YAK-19 | 6 | 41.8 | Tributary | 1 | 1 | 1 | | | 1 | | | 1 | 1 | 1 | | 1 |
| Yakima above Chandler | BRABCHAN | 7 | 36.0 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Chandler Return | BRCHANRE | 8 | 35.8 | Tributary | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| Below Chandler Return | BRBLCHAN | 9 | 34.0 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Corral Creek | BRCORRAL | 10 | 33.5 | Tributary | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 |
| West Richland WWTP | BRWRICHW | 19 | 9.8 | Effluent | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 |
| Yakima at Kiona | YAK-6 | 12 | 29.6 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Below Kiona | BRBLBENT | 13 | 27.0 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | | 1 |
| Above Wanawish Dam | BRABWANA | 14 | 18.8 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| QA | | | | | | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | | 3 |
| **Day 1 Totals** | | | | | 16 | 18 | 18 | 11 | 11 | 18 | 11 | 11 | 11 | 11 | 18 | 5 | 19 |
| Above Wanawish Dam | BRABWANA | 14 | 18.8 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Prosser WWTP | BRPROSWW | 2 | 45.8 | Effluent | 1 | 2 | 2 | | | 2 | | | | 1 | 2 | 1 | 1 |
| Twin City Foods | BRTREETO | 4 | 45.2 | Effluent | 1 | 2 | 2 | | | 2 | | | | 1 | 2 | 1 | 1 |
| Below Wanawish Dam | BRBLWANA | 16 | 16.2 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Twin Bridges | BRTWINBR | 17 | 12.8 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | | 1 |
| West Richland WWTP | BRWRICHW | 19 | 9.8 | Effluent | 2 | 2 | 2 | | | 2 | | | | 1 | 2 | 1 | 1 |
| Van Geisen Bridge | YAK-7 | 15 | 8.4 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Hwy 182 Bridge | BRHWY182 | 20 | 5.6 | Mainstem | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 |
| QA | | | | | | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 3 |
| **Day 2 Totals** | | | | | 9 | 13 | 13 | 6 | 6 | 13 | 6 | 6 | 4 | 7 | 13 | 5 | 11 |
| **Two-Day Totals** | | | | | 25 | 31 | 31 | 17 | 17 | 31 | 17 | 17 | 15 | 18 | 31 | 10 | 30 |

Field Parameters: pH, DO, temperature, conductivity

Lab Parameters: Turbidity (Turb), total suspended solids (TSS), alkalinity (Alka), hardness (Hard), chloride (Cl), chlorophyll a (Chl a), total organic carbon (TOC), ortho-phosphate (OPO4), total persulfate nitrogen (TPN), total phosphorus, ammonia, nitrate, nitrite (Nut. 5), biochemical oxygen demand (BOD), fecal coliform (FC)

Effluent samples will be collected from an ISCO 24-hour composite sampler

Table 5. Site locations and parameters for the USBR modeling project: July 25-26, 2000 Ecology survey.

| Site Location | Station Nm | # | RM | Type | Field | Turb | TSS | Alka | Hard | Cl | Chl a | TOC | DOC | OPO4 | TPN | Nut. 5 | BOD | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pool above Prosser(AM) | BRCHANUP | 1 | 47.1 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Chandler Return(AM) | BRCHANRE | 8 | 35.8 | Trib | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Prosser WWTP (grab) | BRPROSWW | 2 | 46.6 | Effluent | 1 | 1 | 1 | | | 1 | | | | | | 1 | | 1 |
| Yakima below Prosser WWTP | BRBLPROS | 3 | 45.8 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | | 1 |
| Spring Creek | YAK-17 | 5 | 41.8 | Trib | 1 | 1 | 1 | | | 1 | | | | 1 | 1 | 1 | | 1 |
| Snipes Creek | YAK-19 | 6 | 41.8 | Trib | 1 | 1 | 1 | | | 1 | | | | 1 | 1 | 1 | | 1 |
| Chandler Return(PM) | BRCHANRE | 8 | 35.8 | Trib | 1 | 1 | 1 | 1 | | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Corral Creek | BRCORRAL | 10 | 33.5 | Trib | 1 | 1 | 1 | | | 1 | | | | | 1 | 1 | | 1 |
| Pool above Prosser(PM) | BRCHANUP | 1 | 47.1 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Yakima above Chandler (PM) | BRABCHAN | 7 | 36.0 | MS | 1 | 1 | 1 | 1 | | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| QA1(Pool above Prosser) | BRCHANUP | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Yakima above Chandler (AM) | BRABCHAN | 7 | 36.0 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Below Chandler Return | BRBLCHAN | 9 | 34.0 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Yakima at Kiona | YAK-6 | 12 | 29.6 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Below Kiona | BRBLBENT | 13 | 27.0 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | | 1 |
| Above Wanawish Dam (PM) | BRABWANA | 14 | 18.8 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| QA2 (Yakima at Kiona) | YAK-6 | 12 | | | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Day 1 Totals** | | | | | 15 | 17 | 17 | 13 | 10 | 17 | 13 | 7 | 7 | 13 | 16 | 17 | 7 | 17 |
| Above Wanawish Dam (AM) | BRABWANA | 14 | 18.8 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Van Geisen Bridge (AM) | YAK-7 | 15 | 8.4 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Prosser WWTP(grab) | BRPROSWW | 2 | 45.8 | Effluent | 1 | 1 | 1 | | | 1 | | | | | 1 | 1 | | 1 |
| Prosser WWTP (composite) | BRPROSWW | 2 | 45.8 | Effluent | | 1 | 1 | | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 |
| QA3 (Above Wanawish Dam) | BRABWANA | 14 | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | |
| Below Wanawish Dam | BRBLWANA | 16 | 16.2 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Twin Bridges | BRTWINBR | 17 | 12.8 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Van Geisen Bridge (PM) | YAK-7 | 15 | 8.4 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Hwy 182 Bridge | BRHWY182 | 20 | 5.6 | MS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| QA4 (Hwy 182) | BRHWY182 | 20 | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 |
| **Day 2 Totals** | | | | | 7 | 10 | 10 | 8 | 8 | 10 | 8 | 3 | 3 | 8 | 10 | 10 | 4 | 9 |
| **Two-Day Totals** | | | | | 22 | 27 | 27 | 21 | 18 | 27 | 21 | 10 | 10 | 21 | 26 | 27 | 11 | 26 |

Field Parameters: pH, DO, temperature, conductivity

Lab Parameters: Turbidity (Turb), total suspended solids (TSS), alkalinity (Alka), hardness (Hard), chloride (Cl), chlorophyll a (Chl a), total organic carbon (TOC), dissolved organic carbon (DOC), ortho-phosphate (OPO4), total persulfate nitrogen (TPN), total phosphorus, ammonia, nitrate, nitrite (Nut. 5), biochemical oxygen demand (BOD), fecal coliform (FC)

Effluent samples will be collected from an ISCO 24-hour composite sampler

During each survey, water column data were collected at each river station using a Hydrolab® Surveyor II. These field measurements included dissolved oxygen, pH, conductivity, and temperature. Additionally, at five stations (RM 47.1, 36.0, 30.0, 18.4, and 8.4 (5.6 in July 2000)), *in situ* data loggers (Datasonde 3) were placed for at least 48 hours to record dissolved oxygen, pH, conductivity, and temperature (Appendix B). These data were used to assess diel changes in the parameters measured. During the synoptic surveys, grab samples were collected once to twice a day for two days from the river and tributary stations. Effluent grab and composite samples were collected from the WWTPs and Treetop during one or both of the synoptic surveys.

Vertical profiles of light extinction were measured at two stations (RM 29.6 and 14.4). Photosynthetic production and respiration were estimated using diurnal data as in Thomann and Mueller (1987). A time of travel dye study was performed July 27-28, 2000 in the Prosser to Chandler Return reach to validate velocity and dispersion estimates in the river for the model. The dye study was performed using Rhodamine WT dye in accordance with protocols outlined in Wilson (1968) and Hubbard et al. (1982).

Ecology's Stream Hydrology Unit made instantaneous discharge measurements at three sites on the Yakima River on July 25 and 26, 2000 to help assess groundwater inflow and outflow reaches throughout the project area. Discharge measurements were made by boat, by wading, or from bridges in accordance with the mid-section method of stream flow measurement used by the USGS and outlined in WAS (1993).

To simulate water temperature, climate data input was required by the model for performing the energy balance for heat transfer across the air-water interface. Climate data were obtained through the Washington State University Irrigated Agricultural Research and Experiment Station (IAREC) near Prosser. Mean hourly air temperature, dew point temperature, solar radiation, wind speed and relative humidity during the field studies were recorded at Public Agricultural Weather System network station #720, four miles north of Prosser, at the IAREC headquarters. Using the measured hourly air and dew point temperatures for station #720, hourly wet bulb temperature was calculated on the humidity calculator available on-line at http://members.nbci.com/snowball3/js/humcalc.html.

Climate data were also made available through the Hanford Meteorological Station (HMS) operated by the Pacific Northwest National Laboratory for the U.S. Department of Energy at the Hanford Site. HMS maintains a web site at http://terrassa.pnl.gov:2080/HMS/hms.html. Mean hourly air temperature (including dry bulb, wet bulb, dew point temperatures), relative humidity, barometric pressure, wind speed, solar radiation, and percent sky cover were recorded during the field studies at the HMS station headquarters, about 20 miles north of Benton City on the Hanford Site.

## Data Analysis and Modeling

All project data were entered in Microsoft Excel spreadsheets or retained in text files. Data analysis included evaluation of data distribution characteristics and, as necessary, appropriate distribution transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) were made using SYSTAT/SYGRAPH8, EXCEL, or WQHYDRO (Aroner, 1994) computer software.

The project required a model capable of simulating the transport and fate of several water quality constituents. In addition, the model needed to be flexible enough to easily change hydrologic routing. A steady-state model appeared to be adequate to simulate the scenarios of interest to USBR. The QUAL2E model (USEPA, 1987) fulfilled all the needs required in this project.

QUAL2E is a one-dimensional, steady-state numerical model capable of simulating a variety of conservative and non-conservative water quality parameters (Brown and Barnwell, 1987). The model has been supported and expanded by the U.S. Environmental Protection Agency (USEPA) through its Center for Exposure Assessment Modeling.

The model has been widely used to assess multiple point source impacts on well-mixed river systems, and its usefulness is well documented. Ecology has used QUAL2E for total maximum daily load (TMDL) assessments in several large and complex basins including the Snoqualmie River (Joy, 1993), the Puyallup River (Pelletier, 1993), and the Colville River (Pelletier, 1997). Ecology staff also used QUAL2E in the Timber, Fish, and Wildlife temperature model assessment (Sullivan et al., 1990).

Model calibration and validation procedures were based on recommendations by USEPA (1987 and 1991), Thomann and Mueller (1987), and Chapra (1997).

## Data Quality Objectives and Analytical Procedures

The Manchester Laboratory (MEL, 1994) publishes lower reporting limits for the analytical methods they perform. These lower reporting limit values were deemed satisfactory to meet the data quality objectives for this project. Field measurements and laboratory analyses are listed in Table 6, including the methods, corresponding lower reporting limits, and target precision and target bias acceptable range.

## Sampling and Quality Control Procedures

Replicate samples were collected to assess total variation for field sampling and laboratory analysis and thereby provide an estimate of total precision. At least 10% of the total number of laboratory samples and field measurements collected per parameter were replicated.

All water samples for laboratory analysis were collected in pre-cleaned containers supplied by the Manchester Environmental Laboratory (MEL), except dissolved organic carbon and ortho-phosphorus, which were collected in a syringe and filtered into a pre-cleaned container. The syringe was rinsed with ambient water at each sampling site three times before filtering. All samples for laboratory analysis were preserved as specified by MEL (MEL, 1994) and delivered to MEL within 24 hours of collection. Laboratory analyses listed in Table 6 were performed in accordance with MEL (1994).

Table 6. Summary of parameters, methods, reporting limits, and targets for precision and bias.

| Parameter | Lower Reporting Limit | Target Precision RSD (relative std. deviation) or acceptable range | Target Bias | Method[a] |
|---|---|---|---|---|
| **Field Measurements** | | | | |
| Velocity | NA | ± 0.05 f/s | NA | Current Meter |
| Temperature (Temp) | NA | ± 0.36 °F | NA | Alcohol Thermometer |
| pH | NA | ± 0.1 pH units | NA | Field Meter/Electrode |
| Dissolved Oxygen (DO) | NA | ± 0.06 mg/L | NA | Winkler Titration |
| Specific Conductivity (Cond) | NA | ± 20 umhos/cm | NA | Conductivity Bridge |
| Light Attenuation | 0.0014 uW/cm$^2$ | <15% RSD | <10% | Irradiameter |
| **General Chemistry** | | | | |
| Specific Conductance | 1 umhos/cm | <10% RSD | <10% | SM16 2510 |
| Ammonia nitrogen (NH3) | 0.01 mg/L | <10% RSD | <20% | EPA 350.1 |
| Nitrate + nitrite nitrogen (NO2-3) | 0.01 mg/L | <10% RSD | <10% | EPA 353.2 |
| Total persulfate nitrogen (TPN) | 0.01 mg/L | <10% RSD | <10% | SM 4500 NO3-F (Mod) |
| Orthophosphate (Ortho-P) | 0.005 mg/L | <10% RSD | <20% | EPA 365.3 |
| Total phosphorus (TP) | 0.010 mg/L | <10% RSD | <15% | EPA 365.3 |
| Chloride (Cl) | 0.1 mg/L | <10% RSD | <10% | EPA 300.0 |
| Total Organic Carbon (TOC) | 1.0 mg/L | <10% RSD | <15% | EPA 415.1 |
| Dissolved Organic Carbon[b] (DOC) | 1.0 mg/L | <10% RSD | <15% | EPA 415.1 |
| 5-day BOD[c] (BOD5) | 4 mg/L | <15% RSD | NA | EPA 405.1 |
| Phytoplankton ID/Biovolume | NA | NA | NA | SM18 10200F; Sweet, 1987 |
| Fecal Coliforms (Membrane Filter) | 1 col./100 ml | <25% RSD | <10% | SM16 909C |
| Total Suspended Solids (TSS) | 1 mg/L | <15% RSD | <10% | EPA 160.2 |
| Turbidity | 1 NTU | <10% RSD | <10% | EPA 180.1 |

[a] SM = Standard methods for the examination of water and wastewater. 20th edition (1998). American Public Health Association, American Water Works Association, and Water Environmental Federation. Washington, D.C.

[b] Filter in field with Whatman PURADISC™ 0.45 um pore size syringe filter.

[c] Use uncensored data for readings below 4 mg/L.

Field sampling and measurement protocols followed those specified in WAS (1993) for temperature (alcohol thermometer), pH (Orion Model 250A meter and Triode$^{TM}$ pH electrode), conductivity (Beckman Model RB-5 and YSI 33), dissolved oxygen (Winkler titration), streamflow (Marsh-McBirney 201 & 2000), and *in situ* temperature, dissolved oxygen, pH, and specific conductance (Hydrolab® multi-parameter meters). All meters were pre-calibrated and post-calibrated per manufacturers' instructions.

Effluent samples from the point sources listed in Table 3 were collected in pre-cleaned ISCO 24-hour composite samplers. Effluent sampling was conducted according to standard operating procedures for Class II inspections by Ecology as documented in Glenn (1994).

## Data Assessment Procedures

Laboratory data reduction, review, and reporting followed procedures outlined in MEL's Lab Users Manual (MEL, 1994). All water quality data were entered into Ecology's Environmental Information Management (EIM) system. Data were verified, and 100% of data entry was reviewed for errors.

# Results and Discussion

## Field Studies Results

Laboratory and field results from the September 1999 and July 2000 surveys are located in Appendix A. Ecology has maintained a long-term monitoring site on the Yakima River at Kiona (37A090) where data have been collected monthly since 1967 (Ecology, 2000). A summary of data collected July through September from 1980 to 2000 is presented in Table 7. Comparing the Class A criteria in Table 1 to the summarized values in Table 7, one can see that pH, temperature, dissolved oxygen, and fecal coliform criteria are not always met. These data have been partially responsible for some of the 303(d) listings in Table 2.

Table 7. Comparison of data collected at site YAK-6 (Yakima River at Kiona) during the September 1999 (one sample) and July 2000 (two samples) surveys to long-term monitoring data collected by Ecology at site 36A090 (Kiona) during July through September (1980 – 2000).

| Parameter | September 1999 | July 2000 | | Yakima at Kiona | | |
|---|---|---|---|---|---|---|
| | | 1155* | 1215* | med** | min | max |
| Fecal coliform (cfu/100 mL) | 55 | 26 | 11 | 55 | 1 | 290 |
| Nitrate+Nitrite – N (mg/L) | 1.08 | 0.993 | 0.972 | 1.06 | <0.01 | 1.61 |
| Ammonia – N (mg/L) | 0.038 | <0.01 | <0.01 | 0.02 | <0.01 | 0.08 |
| Total Nitrogen – N (mg/L) | 1.24 | 1.2 | 1.19 | 1.4 | 0.3 | 2.0 |
| Orthophosphate – P (mg/L) | 0.067 | 0.11 | 0.11 | 0.07 | <0.01 | 0.12 |
| Total Phosphorus – P (mg/L) | 0.126 | 0.13 | 0.13 | 0.12 | <0.02 | 0.25 |
| Total Suspended Solids (mg/L) | 11 | 15 | 15 | 23 | 1 | 86 |
| Turbidity (NTU) | 6.8 | 6.4 | 6.9 | 8 | 1.5 | 32 |
| Temperature (°C)*** | 14.0 (12.8 – 15.2) | 23.8 (22.1-25.7) | | 20.6 | 13.6 | 25.4 |
| pH (s.u.)*** | 8.0 (7.8 – 8.3) | 8.3 (7.9 – 8.7) | | 8.3 | 7.6 | 8.8 |
| Sp. Conductivity (umhos/cm)*** | 233 (230 – 237) | 224 (222 – 226) | | 267 | 138 | 325 |
| Dissolved oxygen (mg/L)*** | 10.6 (9.9 – 11.7) | 9.2 (7.5 – 11.2) | | 9.8 | 7.1 | 11.6 |

* Time of sample collection
** Median
*** Survey diel data mean and range reported for these parameters

Water quality results collected from the Yakima River at Kiona (YAK- 6) during the September 1999 and July 2000 surveys also are summarized in Table 7. All the survey data fell within the range of July-September values reported for the Ecology long-term database. Data collected during the July 2000 survey were near the long-term median values, with pH, temperature, and minimum DO values in violation of Class A criteria. Data collected during the September 1999 survey had similar nutrient, TSS, fecal coliform, and turbidity results as the July 2000 survey, however, higher DO and lower pH and temperature values resulted in no violations of any of the applicable Class A criteria.

## Quality Assurance/ Quality Control

All samples were received by MEL in good condition, and all analyses were performed within established EPA holding times. Laboratory quality control results were all within acceptable limits. Appendix B contains the results of the field duplicate analyses.

# QUAL2E Model Structure and Approach

QUAL2E was calibrated to model the lower Yakima River between RM 47.2 (above Prosser diversion) and RM 5.6 (Figure 1). Model input was provided to simulate water temperature, DO, BOD, chloride, TSS, nitrogen (N) in the forms of organic-N, ammonia-N, nitrate-N, phosphorus (P) in the forms of organic-P, dissolved P, and chlorophyll a at steady-state conditions. The modeling concluded at RM 5.6 (near Highway 182 bridge) because of the possible influence of backwater conditions up the mouth of the Yakima River from the McNary Dam pool on the Columbia River. Backwater conditions were outside the scope of this study to evaluate. QUAL2E major constituent interactions are shown in Figure 5.

The study portion of the Yakima River was divided in 14 reaches for QUAL2E modeling. A schematic of reaches and loading sources is presented in Table 8 using model notation documented in USEPA (1987). Each reach was divided into 0.2-mile long computational elements, which were assumed to have uniform steady-state conditions.

The model was calibrated using data collected during the July 25-26, 2000 field synoptic survey. Calibration was accomplished by adjustment of model coefficients during successive or iterative model runs, until optimum goodness of fit between predicted model results and observed field values was achieved. Goodness of fit was measured using the root-mean-square-error (RMSE), a commonly used measure of model variability (Reckhow et al., 1986), based on the difference between model predictions and observed values. After an optimum calibration was achieved for the July data, the model was applied to the September 28-29, 1999 survey data for confirmation of model performance at a different set of conditions. Only observed inputs and climatological inputs were changed for the model confirmation run. After calibration and confirmation, the model was run to test for water quality changes based on the operational-change scenarios proposed by the USBR.

Printouts of the QUAL2E input files used in the calibration and confirmation simulations are presented in Appendix C. Printouts for the QUAL2E input files for the operational change model runs are presented in Appendix D.

As mentioned earlier, the list of water quality parameters of concern includes TSS, turbidity, DO, temperature, pH, nutrients, BOD, and selected pesticides. Daily average concentrations or values for most of these parameters were resolved with the QUAL2E model. Turbidity could not be directly modeled in QUAL2E, so a regression relationship between TSS (a model parameter) and turbidity for the lower Yakima was used (Joy and Patterson, 1997).

# QUAL2EU SCHEMATIC

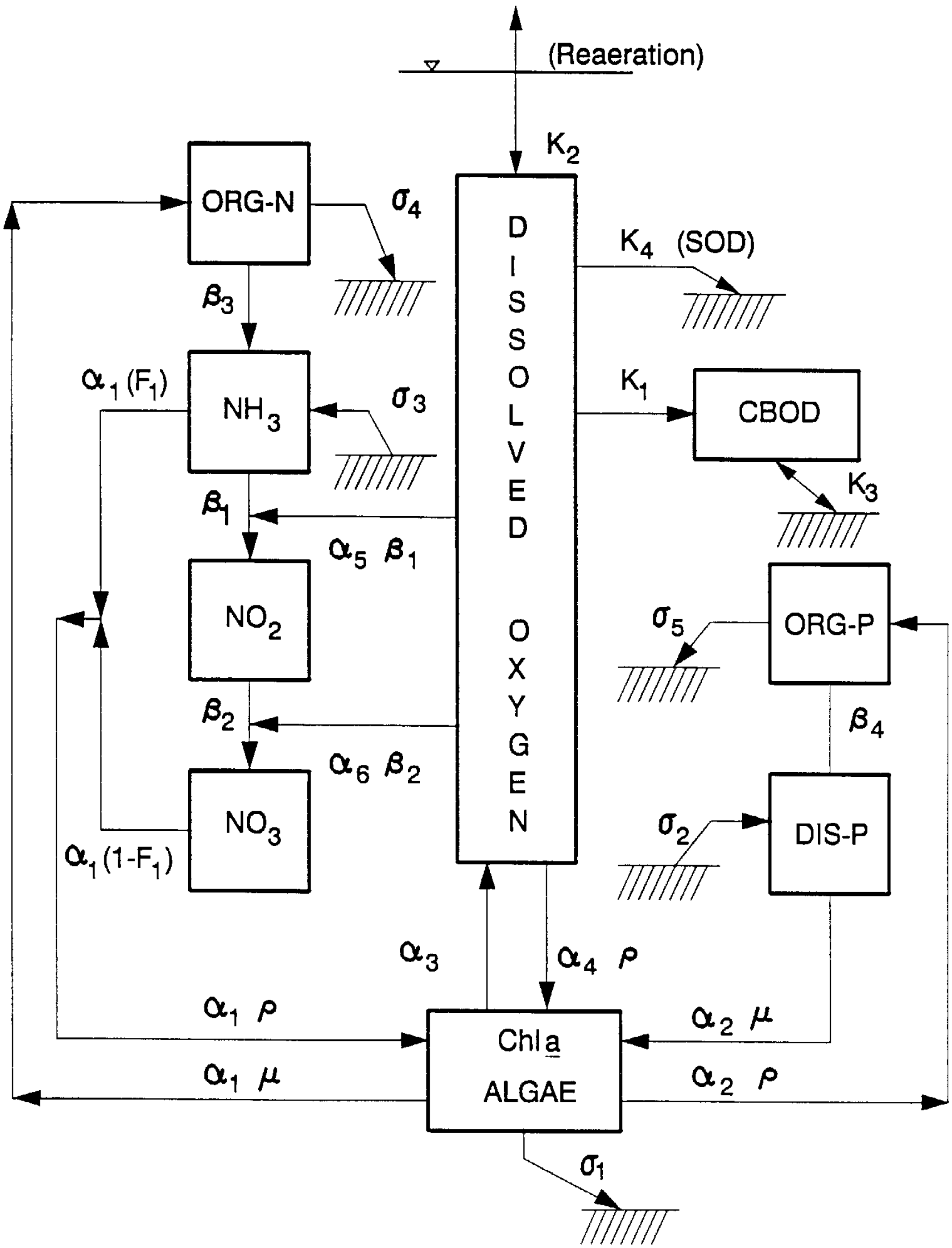



Figure 5. Major constituent interactions in the QUAL2E model.

Table 8. Schematic of QUAL2E reaches and hydraulics coefficients.

| Upstream River Mile (mile) | Downstream River Mile (mile) | Ecology Mainstem Sampling Station | Ecology Tributary Sampling Station | *QUAL2E Reaches, Elements, and PointLoads* Reach Number | Element Number | Reach Element Number | Data Type 4 Flag | Pointload Number | *QUAL2E Hydraulics Coefficients* V = aQ^b and D = cQ^d for Q in cfs, V in fps, and D in ft *a* | *b* | *c* | *d* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47.2 | 47.0 | Above Prosser Dam (47.1) | | 1 | 1 | 1 | 1 | | 0.00023 | 1 | 5 | 0 |
| 47.0 | 46.8 | Prosser Dam (47.0) | | 2 | 2 | 1 | 2 | | 0.0186 | 0.589 | 0.304 | 0.338 |
| 46.8 | 46.6 | | | 2 | 3 | 2 | 2 | | | | | |
| 46.6 | 46.4 | | Prosser POTW (46.6) | 2 | 4 | 3 | 6 | 1 | | | | |
| 46.4 | 46.2 | | | 2 | 5 | 4 | 2 | | | | | |
| 46.2 | 46.0 | | | 2 | 6 | 5 | 2 | | | | | |
| 46.0 | 45.8 | Yakima blw Prosser (45.8) | | 2 | 7 | 6 | 2 | | | | | |
| 45.8 | 45.6 | | | 3 | 8 | 1 | 2 | | 0.0186 | 0.589 | 0.304 | 0.338 |
| 45.6 | 45.4 | | | 3 | 9 | 2 | 2 | | | | | |
| 45.4 | 45.2 | | | 3 | 10 | 3 | 2 | | | | | |
| 45.2 | 45.0 | | Seneca Foods (45.2) | 3 | 11 | 4 | 6 | 2 | | | | |
| 45.0 | 44.8 | | | 3 | 12 | 5 | 2 | | | | | |
| 44.8 | 44.6 | | | 3 | 13 | 6 | 2 | | | | | |
| 44.6 | 44.4 | | | 3 | 14 | 7 | 2 | | | | | |
| 44.4 | 44.2 | | | 3 | 15 | 8 | 2 | | | | | |
| 44.2 | 44.0 | | | 3 | 16 | 9 | 2 | | | | | |
| 44.0 | 43.8 | | | 3 | 17 | 10 | 2 | | | | | |
| 43.8 | 43.6 | | | 3 | 18 | 11 | 2 | | | | | |
| 43.6 | 43.4 | | | 3 | 19 | 12 | 2 | | | | | |
| 43.4 | 43.2 | | | 3 | 20 | 13 | 2 | | | | | |
| 43.2 | 43.0 | | | 3 | 21 | 14 | 2 | | | | | |
| 43.0 | 42.8 | | | 3 | 22 | 15 | 2 | | | | | |
| 42.8 | 42.6 | | | 3 | 23 | 16 | 2 | | | | | |
| 42.6 | 42.4 | | | 3 | 24 | 17 | 2 | | | | | |
| 42.4 | 42.2 | | | 3 | 25 | 18 | 2 | | | | | |
| 42.2 | 42.0 | | | 3 | 26 | 19 | 2 | | | | | |
| 42.0 | 41.8 | | | 3 | 27 | 20 | 2 | | | | | |
| 41.8 | 41.6 | | Snipes/Spring Ck (41.8) | 4 | 28 | 1 | 6 | 3 | 0.0186 | 0.589 | 0.304 | 0.338 |
| 41.6 | 41.4 | | | 4 | 29 | 2 | 2 | | | | | |
| 41.4 | 41.2 | | | 4 | 30 | 3 | 2 | | | | | |
| 41.2 | 41.0 | | | 4 | 31 | 4 | 2 | | | | | |
| 41.0 | 40.8 | | | 4 | 32 | 5 | 2 | | | | | |
| 40.8 | 40.6 | | | 4 | 33 | 6 | 2 | | | | | |
| 40.6 | 40.4 | | | 4 | 34 | 7 | 2 | | | | | |
| 40.4 | 40.2 | | | 4 | 35 | 8 | 2 | | | | | |
| 40.2 | 40.0 | | | 4 | 36 | 9 | 2 | | | | | |
| 40.0 | 39.8 | | | 4 | 37 | 10 | 2 | | | | | |
| 39.8 | 39.6 | | | 4 | 38 | 11 | 2 | | | | | |
| 39.6 | 39.4 | | | 4 | 39 | 12 | 2 | | | | | |
| 39.4 | 39.2 | | | 4 | 40 | 13 | 2 | | | | | |
| 39.2 | 39.0 | | | 4 | 41 | 14 | 2 | | | | | |
| 39.0 | 38.8 | | | 4 | 42 | 15 | 2 | | | | | |
| 38.8 | 38.6 | | | 4 | 43 | 16 | 2 | | | | | |
| 38.6 | 38.4 | | | 4 | 44 | 17 | 2 | | | | | |
| 38.4 | 38.2 | | | 4 | 45 | 18 | 2 | | | | | |
| 38.2 | 38.0 | | | 4 | 46 | 19 | 2 | | | | | |
| 38.0 | 37.8 | | | 4 | 47 | 20 | 2 | | | | | |
| 37.8 | 37.6 | | | 5 | 48 | 1 | 2 | | 0.0186 | 0.589 | 0.304 | 0.338 |
| 37.6 | 37.4 | | | 5 | 49 | 2 | 2 | | | | | |
| 37.4 | 37.2 | | | 5 | 50 | 3 | 2 | | | | | |
| 37.2 | 37.0 | | | 5 | 51 | 4 | 2 | | | | | |
| 37.0 | 36.8 | | | 5 | 52 | 5 | 2 | | | | | |
| 36.8 | 36.6 | | | 5 | 53 | 6 | 2 | | | | | |
| 36.6 | 36.4 | | | 5 | 54 | 7 | 2 | | | | | |
| 36.4 | 36.2 | | | 5 | 55 | 8 | 2 | | | | | |
| 36.2 | 36.0 | Yakima ab Chandler (36.0) | | 5 | 56 | 9 | 2 | | | | | |
| 36.0 | 35.8 | | | 6 | 57 | 1 | 2 | | 0.0186 | 0.589 | 0.304 | 0.338 |
| 35.8 | 35.6 | | Chandler return (35.8) | 6 | 58 | 2 | 6 | | | | | |
| 35.6 | 35.4 | | | 6 | 59 | 3 | 2 | | | | | |
| 35.4 | 35.2 | | | 6 | 60 | 4 | 2 | | | | | |
| 35.2 | 35.0 | | | 6 | 61 | 5 | 2 | | | | | |
| 35.0 | 34.8 | | | 6 | 62 | 6 | 2 | | | | | |
| 34.8 | 34.6 | | | 6 | 63 | 7 | 2 | | | | | |
| 34.6 | 34.4 | | | 6 | 64 | 8 | 2 | | | | | |
| 34.4 | 34.2 | | Swiss Corral Ck (34.3) | 6 | 65 | 9 | 2 | | | | | |
| 34.2 | 34.0 | Yakima blw Chandler (34.0) | | 6 | 66 | 10 | 2 | | | | | |
| 34.0 | 33.8 | | | 6 | 67 | 11 | 2 | | | | | |
| 33.8 | 33.6 | | | 6 | 68 | 12 | 2 | | | | | |
| 33.6 | 33.4 | | Corral Ck (33.5) | 7 | 69 | 1 | 6 | 4 | 0.0481 | 0.493 | 0.214 | 0.390 |
| 33.4 | 33.2 | | | 7 | 70 | 2 | 2 | | | | | |

Table 8.  Schematic of QUAL2E reaches and hydraulics coefficients.

| Upstream River Mile | Downstream River Mile | Ecology Mainstem Sampling Station | Ecology Tributary Sampling Station | *QUAL2E Reaches, Elements, and PointLoads* Reach Number | Element Number | Reach Element Number | Data Type 4 Flag | Pointload Number | *QUAL2E Hydraulics Coefficients* V = aQ^b and D = cQ^d for Q in cfs, V in fps, and D in ft *a* | *b* | *c* | *d* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mile) | (mile) | | | | | | | | | | | |
| 33.2 | 33.0 | | | 7 | 71 | 3 | 2 | | | | | |
| 33.0 | 32.8 | | | 7 | 72 | 4 | 2 | | | | | |
| 32.8 | 32.6 | | | 7 | 73 | 5 | 2 | | | | | |
| 32.6 | 32.4 | | | 7 | 74 | 6 | 2 | | | | | |
| 32.4 | 32.2 | | | 7 | 75 | 7 | 2 | | | | | |
| 32.2 | 32.0 | | | 7 | 76 | 8 | 2 | | | | | |
| 32.0 | 31.8 | | | 7 | 77 | 9 | 2 | | | | | |
| 31.8 | 31.6 | | | 7 | 78 | 10 | 2 | | | | | |
| 31.6 | 31.4 | | | 7 | 79 | 11 | 2 | | | | | |
| 31.4 | 31.2 | | | 7 | 80 | 12 | 2 | | | | | |
| 31.2 | 31.0 | | | 7 | 81 | 13 | 2 | | | | | |
| 31.0 | 30.8 | | | 7 | 82 | 14 | 2 | | | | | |
| 30.8 | 30.6 | | | 7 | 83 | 15 | 2 | | | | | |
| 30.6 | 30.4 | | | 7 | 84 | 16 | 2 | | | | | |
| 30.4 | 30.2 | | | 7 | 85 | 17 | 2 | | | | | |
| 30.2 | 30.0 | | | 7 | 86 | 18 | 2 | | | | | |
| 30.0 | 29.8 | | | 7 | 87 | 19 | 2 | | | | | |
| 29.8 | 29.6 | Yakima at Kiona (29.6) | | 7 | 88 | 20 | 2 | | | | | |
| 29.6 | 29.4 | | | 8 | 89 | 1 | 2 | | 0.0312 | 0.512 | 0.192 | 0.371 |
| 29.4 | 29.2 | | | 8 | 90 | 2 | 2 | | | | | |
| 29.2 | 29.0 | | | 8 | 91 | 3 | 2 | | | | | |
| 29.0 | 28.8 | | | 8 | 92 | 4 | 2 | | | | | |
| 28.8 | 28.6 | | Benton City POTW(28.6) | 8 | 93 | 5 | 2 | | | | | |
| 28.6 | 28.4 | | | 8 | 94 | 6 | 2 | | | | | |
| 28.4 | 28.2 | | | 8 | 95 | 7 | 2 | | | | | |
| 28.2 | 28.0 | | | 8 | 96 | 8 | 2 | | | | | |
| 28.0 | 27.8 | | Kiona Irrigation Pump | 8 | 97 | 9 | 7 | | | | | |
| 27.8 | 27.6 | | | 8 | 98 | 10 | 2 | | | | | |
| 27.6 | 27.4 | | | 8 | 99 | 11 | 2 | | | | | |
| 27.4 | 27.2 | | | 8 | 100 | 12 | 2 | | | | | |
| 27.2 | 27.0 | Yakima blw Kiona (27.0) | | 8 | 101 | 13 | 2 | | | | | |
| 27.0 | 26.8 | (Sept. survey) | | 8 | 102 | 14 | 2 | | | | | |
| 26.8 | 26.6 | | | 9 | 103 | 1 | 2 | | 0.0188 | 0.614 | 0.245 | 0.342 |
| 26.6 | 26.4 | | | 9 | 104 | 2 | 2 | | | | | |
| 26.4 | 26.2 | | | 9 | 105 | 3 | 2 | | | | | |
| 26.2 | 26.0 | | | 9 | 106 | 4 | 2 | | | | | |
| 26.0 | 25.8 | | | 9 | 107 | 5 | 2 | | | | | |
| 25.8 | 25.6 | | | 9 | 108 | 6 | 2 | | | | | |
| 25.6 | 25.4 | | | 9 | 109 | 7 | 2 | | | | | |
| 25.4 | 25.2 | | | 9 | 110 | 8 | 2 | | | | | |
| 25.2 | 25.0 | Yakima blw Kiona (25.0) | | 9 | 111 | 9 | 2 | | | | | |
| 25.0 | 24.8 | (July survey) | | 9 | 112 | 10 | 2 | | | | | |
| 24.8 | 24.6 | | | 9 | 113 | 11 | 2 | | | | | |
| 24.6 | 24.4 | | | 9 | 114 | 12 | 2 | | | | | |
| 24.4 | 24.2 | | | 9 | 115 | 13 | 2 | | | | | |
| 24.2 | 24.0 | | | 9 | 116 | 14 | 2 | | | | | |
| 24.0 | 23.8 | | | 9 | 117 | 15 | 2 | | | | | |
| 23.8 | 23.6 | | | 9 | 118 | 16 | 2 | | | | | |
| 23.6 | 23.4 | | | 9 | 119 | 17 | 2 | | | | | |
| 23.4 | 23.2 | | | 9 | 120 | 18 | 2 | | | | | |
| 23.2 | 23.0 | | | 9 | 121 | 19 | 2 | | | | | |
| 23.0 | 22.8 | | | 9 | 122 | 20 | 2 | | | | | |
| 22.8 | 22.6 | | | 10 | 123 | 1 | 2 | | 0.0183 | 0.608 | 0.240 | 0.348 |
| 22.6 | 22.4 | | | 10 | 124 | 2 | 2 | | | | | |
| 22.4 | 22.2 | | | 10 | 125 | 3 | 2 | | | | | |
| 22.2 | 22.0 | | | 10 | 126 | 4 | 2 | | | | | |
| 22.0 | 21.8 | | | 10 | 127 | 5 | 2 | | | | | |
| 21.8 | 21.6 | | | 10 | 128 | 6 | 2 | | | | | |
| 21.6 | 21.4 | | | 10 | 129 | 7 | 2 | | | | | |
| 21.4 | 21.2 | | | 10 | 130 | 8 | 2 | | | | | |
| 21.2 | 21.0 | | | 10 | 131 | 9 | 2 | | | | | |
| 21.0 | 20.8 | | | 10 | 132 | 10 | 2 | | | | | |
| 20.8 | 20.6 | | | 10 | 133 | 11 | 2 | | | | | |
| 20.6 | 20.4 | | | 10 | 134 | 12 | 2 | | | | | |
| 20.4 | 20.2 | | | 10 | 135 | 13 | 2 | | | | | |
| 20.2 | 20.0 | | | 10 | 136 | 14 | 2 | | | | | |
| 20.0 | 19.8 | | | 10 | 137 | 15 | 2 | | | | | |
| 19.8 | 19.6 | | | 10 | 138 | 16 | 2 | | | | | |
| 19.6 | 19.4 | | | 10 | 139 | 17 | 2 | | | | | |
| 19.4 | 19.2 | | | 10 | 140 | 18 | 2 | | | | | |

Table 8. Schematic of QUAL2E reaches and hydraulics coefficients.

| Upstream River Mile | Downstream River Mile | Ecology Mainstem Sampling Station | Ecology Tributary Sampling Station | *QUAL2E Reaches, Elements, and PointLoads* | | | | | *QUAL2E Hydraulics Coefficients* V = aQ^b and D = cQ^d for Q in cfs, V in fps, and D in ft | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mile) | (mile) | | | Reach Number | Element Number | Reach Element Number | Data Type 4 Flag | Pointload Number | *a* | *b* | *c* | *d* |
| 19.2 | 19.0 | | | 10 | 141 | 19 | 2 | | | | | |
| 19.0 | 18.8 | Yakima ab Wanawish (18.8) | | 10 | 142 | 20 | 2 | | | | | |
| 18.8 | 18.6 | | | 11 | 143 | 1 | 2 | | 0.0350 | 0.532 | 0.236 | 0.350 |
| 18.6 | 18.4 | | | 11 | 144 | 2 | 2 | | | | | |
| 18.4 | 18.2 | | | 11 | 145 | 3 | 2 | | | | | |
| 18.2 | 18.0 | | | 11 | 146 | 4 | 2 | | | | | |
| 18.0 | 17.8 | Wanawish Dam | CID diversion+ | 11 | 147 | 5 | 7 | | | | | |
| 17.8 | 17.6 | | Barker Ranch diversion | 11 | 148 | 6 | 2 | | | | | |
| 17.6 | 17.4 | | | 11 | 149 | 7 | 2 | | | | | |
| 17.4 | 17.2 | | | 11 | 150 | 8 | 2 | | | | | |
| 17.2 | 17.0 | | | 11 | 151 | 9 | 2 | | | | | |
| 17.0 | 16.8 | | | 11 | 152 | 10 | 2 | | | | | |
| 16.8 | 16.6 | | | 11 | 153 | 11 | 2 | | | | | |
| 16.6 | 16.4 | | | 11 | 154 | 12 | 2 | | | | | |
| 16.4 | 16.2 | Yakima blw Wanawish (16.2) | | 11 | 155 | 13 | 2 | | | | | |
| 16.2 | 16.0 | | | 12 | 156 | 1 | 2 | | 0.0167 | 0.629 | 0.369 | 0.298 |
| 16.0 | 15.8 | | | 12 | 157 | 2 | 2 | | | | | |
| 15.8 | 15.6 | | | 12 | 158 | 3 | 2 | | | | | |
| 15.6 | 15.4 | | | 12 | 159 | 4 | 2 | | | | | |
| 15.4 | 15.2 | | | 12 | 160 | 5 | 2 | | | | | |
| 15.2 | 15.0 | | | 12 | 161 | 6 | 2 | | | | | |
| 15.0 | 14.8 | | | 12 | 162 | 7 | 2 | | | | | |
| 14.8 | 14.6 | | | 12 | 163 | 8 | 2 | | | | | |
| 14.6 | 14.4 | | | 12 | 164 | 9 | 2 | | | | | |
| 14.4 | 14.2 | | | 12 | 165 | 10 | 2 | | | | | |
| 14.2 | 14.0 | | | 12 | 166 | 11 | 2 | | | | | |
| 14.0 | 13.8 | | | 12 | 167 | 12 | 2 | | | | | |
| 13.8 | 13.6 | | | 12 | 168 | 13 | 2 | | | | | |
| 13.6 | 13.4 | | | 12 | 169 | 14 | 2 | | | | | |
| 13.4 | 13.2 | | | 12 | 170 | 15 | 2 | | | | | |
| 13.2 | 13.0 | | | 12 | 171 | 16 | 2 | | | | | |
| 13.0 | 12.8 | Yakima @ Twin Br. (12.8) | | 12 | 172 | 17 | 2 | | | | | |
| 12.8 | 12.6 | | | 12 | 173 | 18 | 2 | | | | | |
| 12.6 | 12.4 | | | 12 | 174 | 19 | 2 | | | | | |
| 12.4 | 12.2 | | | 13 | 175 | 1 | 2 | | 0.0111 | 0.663 | 0.526 | 0.275 |
| 12.2 | 12.0 | | | 13 | 176 | 2 | 2 | | | | | |
| 12.0 | 11.8 | | | 13 | 177 | 3 | 2 | | | | | |
| 11.8 | 11.6 | | | 13 | 178 | 4 | 2 | | | | | |
| 11.6 | 11.4 | | | 13 | 179 | 5 | 2 | | | | | |
| 11.4 | 11.2 | | | 13 | 180 | 6 | 2 | | | | | |
| 11.2 | 11.0 | | | 13 | 181 | 7 | 2 | | | | | |
| 11.0 | 10.8 | | | 13 | 182 | 8 | 2 | | | | | |
| 10.8 | 10.6 | | | 13 | 183 | 9 | 2 | | | | | |
| 10.6 | 10.4 | | | 13 | 184 | 10 | 2 | | | | | |
| 10.4 | 10.2 | | | 13 | 185 | 11 | 2 | | | | | |
| 10.2 | 10.0 | | | 13 | 186 | 12 | 2 | | | | | |
| 10.0 | 9.8 | | W. Richland POTW (9.8) | 13 | 187 | 13 | 6 | 5 | | | | |
| 9.8 | 9.6 | | | 13 | 188 | 14 | 2 | | | | | |
| 9.6 | 9.4 | | | 13 | 189 | 15 | 2 | | | | | |
| 9.4 | 9.2 | | | 13 | 190 | 16 | 2 | | | | | |
| 9.2 | 9.0 | | | 13 | 191 | 17 | 2 | | | | | |
| 9.0 | 8.8 | | | 13 | 192 | 18 | 2 | | | | | |
| 8.8 | 8.6 | | | 13 | 193 | 19 | 2 | | | | | |
| 8.6 | 8.4 | Yakima @ Van Geisen (8.4) | | 13 | 194 | 20 | 2 | | | | | |
| 8.4 | 8.2 | | | 14 | 195 | 1 | 2 | | 0.0161 | 0.631 | 0.419 | 0.291 |
| 8.2 | 8.0 | | | 14 | 196 | 2 | 2 | | | | | |
| 8.0 | 7.8 | | | 14 | 197 | 3 | 2 | | | | | |
| 7.8 | 7.6 | | | 14 | 198 | 4 | 2 | | | | | |
| 7.6 | 7.4 | | | 14 | 199 | 5 | 2 | | | | | |
| 7.4 | 7.2 | | | 14 | 200 | 6 | 2 | | | | | |
| 7.2 | 7.0 | | | 14 | 201 | 7 | 2 | | | | | |
| 7.0 | 6.8 | | | 14 | 202 | 8 | 2 | | | | | |
| 6.8 | 6.6 | | | 14 | 203 | 9 | 2 | | | | | |
| 6.6 | 6.4 | | | 14 | 204 | 10 | 2 | | | | | |
| 6.4 | 6.2 | | | 14 | 205 | 11 | 2 | | | | | |
| 6.2 | 6.0 | | | 14 | 206 | 12 | 2 | | | | | |
| 6.0 | 5.8 | | | 14 | 207 | 13 | 2 | | | | | |
| 5.8 | 5.6 | Yakima @ hwy 182 (5.6) | | 14 | 208 | 14 | 2 | | | | | |

The USBR requested simulations of the following operational-change scenarios. Both specific water quality changes within a reach and the residual downstream effects were evaluated for each scenario modeled.

In the Prosser Dam to Chandler Power Return and downstream through the project area:

- Current conditions
- Chandler partial diversion of Kennewick Irrigation District (KID) with powerhouse in operation
- Chandler full diversion of KID with powerhouse in operation
- Chandler without diversion or powerhouse operation (Chandler off)

In the Wanawish Dam to Columbia River reach:

- No exchange at Columbia Canal (existing diversion conditions)
- Exchange at Columbia Canal (reduced diversion)

Changes in parameters relative to aquatic life toxicity or habitat limitations are of greatest interest. Washington State water quality standards, USEPA guidelines, and literature research recommendations for the parameters of interest were compared to simulation results.

The following sections explain the selection of model parameters during calibration, verification, and simulation model runs.

# QUAL2E Model Calibration and Confirmation

## Fixed Model Inputs

### Hydrology

The Ecology surveys provide snapshots of the critical water quality period for the lower Yakima River at two flow regimes. Initial condition flows for the Yakima River at Prosser for the September 1999 and July 2000 surveys were 628 and 980 cfs, respectively. Flows for the Yakima River at Kiona for the September 1999 and July 2000 surveys were 1537 cfs and 2340 cfs, respectively. Based on historical flow records, mean flows for July and September are 795 cfs and 694 cfs, respectively, for Prosser; and 1984 cfs and 1847 cfs, respectively, for Kiona. The July 2000 survey experienced flows below average (approximately 80% of average) and the September 1999 survey experienced flows slightly higher than average (approximately 125-140% of average). Comparison of the QUAL2E model fit to data collected during both surveys tested the validity of the model over a range of conditions present in the summer season.

Flow balances were developed for the average condition observed during each survey (Table 9). Increasing and decreasing irrigation demands and other water control demands and returns resulted in flows increasing or decreasing slightly over the survey periods. The daily mean flows

Table 9. Flow balance for calibration and validation of QUAL2E.

| | | | | | September 28-29, 1999 | | | | July 25-26, 2000 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upstream RM (mile) | Dnstream RM (mile) | Reach Number | Ecology/SCCD Mainstem Sampling Station | Ecology Tributary Sampling Station | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) |
| 47.2 | 47.0 | 1 | Above Prosser Dam (47.1) | | 980 | | 0.0 | 980.0 | 561 | | 0.0 | 561.0 |
| 47.0 | 46.8 | 2 | Prosser Dam (47.0) | | | | | 982.3 | | | | 562.8 |
| 46.8 | 46.6 | | | | | | | 984.6 | | | | 564.5 |
| 46.6 | 46.4 | | | Prosser POTW (46.6) | | 1.0 | | 987.9 | | 1.2 | | 567.5 |
| 46.4 | 46.2 | | | | | | | 990.2 | | | | 569.2 |
| 46.2 | 46.0 | | | | | | | 992.5 | | | | 571.0 |
| 46.0 | 45.8 | | Yakima blw Prosser (45.8) | | | | 13.8 | 994.8 | | | 10.6 | 572.8 |
| 45.8 | 45.6 | 3 | | | | | | 997.1 | | | | 574.5 |
| 45.6 | 45.4 | | | | | | | 999.4 | | | | 576.3 |
| 45.4 | 45.2 | | | | | | | 1001.7 | | | | 578.0 |
| 45.2 | 45.0 | | | Seneca Foods (45.2) | | 0.1 | | 1004.1 | | 0.1 | | 579.9 |
| 45.0 | 44.8 | | | | | | | 1006.4 | | | | 581.7 |
| 44.8 | 44.6 | | | | | | | 1008.7 | | | | 583.4 |
| 44.6 | 44.4 | | | | | | | 1011.0 | | | | 585.2 |
| 44.4 | 44.2 | | | | | | | 1013.3 | | | | 587.0 |
| 44.2 | 44.0 | | | | | | | 1015.6 | | | | 588.7 |
| 44.0 | 43.8 | | | | | | | 1017.9 | | | | 590.5 |
| 43.8 | 43.6 | | | | | | | 1020.2 | | | | 592.3 |
| 43.6 | 43.4 | | | | | | | 1022.5 | | | | 594.0 |
| 43.4 | 43.2 | | | | | | | 1024.8 | | | | 595.8 |
| 43.2 | 43.0 | | | | | | | 1027.1 | | | | 597.5 |
| 43.0 | 42.8 | | | | | | | 1029.4 | | | | 599.3 |
| 42.8 | 42.6 | | | | | | | 1031.7 | | | | 601.1 |
| 42.6 | 42.4 | | | | | | | 1034.0 | | | | 602.8 |
| 42.4 | 42.2 | | | | | | | 1036.3 | | | | 604.6 |
| 42.2 | 42.0 | | | | | | | 1038.6 | | | | 606.4 |
| 42.0 | 41.8 | | | | | | 46.0 | 1040.9 | | | 35.2 | 608.1 |
| 41.8 | 41.6 | 4 | | Snipes/Spring Ck (41.8) | | 109.9 | | 1153.1 | | 67.0 | | 676.9 |
| 41.6 | 41.4 | | | | | | | 1155.4 | | | | 678.6 |
| 41.4 | 41.2 | | | | | | | 1157.7 | | | | 680.4 |
| 41.2 | 41.0 | | | | | | | 1160.0 | | | | 682.2 |
| 41.0 | 40.8 | | | | | | | 1162.4 | | | | 683.9 |
| 40.8 | 40.6 | | | | | | | 1164.7 | | | | 685.7 |
| 40.6 | 40.4 | | | | | | | 1167.0 | | | | 687.5 |
| 40.4 | 40.2 | | | | | | | 1169.3 | | | | 689.2 |
| 40.2 | 40.0 | | | | | | | 1171.6 | | | | 691.0 |
| 40.0 | 39.8 | | | | | | | 1173.9 | | | | 692.7 |
| 39.8 | 39.6 | | | | | | | 1176.2 | | | | 694.5 |
| 39.6 | 39.4 | | | | | | | 1178.5 | | | | 696.3 |
| 39.4 | 39.2 | | | | | | | 1180.8 | | | | 698.0 |
| 39.2 | 39.0 | | | | | | | 1183.1 | | | | 699.8 |
| 39.0 | 38.8 | | | | | | | 1185.4 | | | | 701.6 |
| 38.8 | 38.6 | | | | | | | 1187.7 | | | | 703.3 |
| 38.6 | 38.4 | | | | | | | 1190.0 | | | | 705.1 |
| 38.4 | 38.2 | | | | | | | 1192.3 | | | | 706.8 |
| 38.2 | 38.0 | | | | | | | 1194.6 | | | | 708.6 |
| 38.0 | 37.8 | | | | | | 46.0 | 1196.9 | | | 35.2 | 710.4 |
| 37.8 | 37.6 | 5 | | | | | | 1199.2 | | | | 712.1 |
| 37.6 | 37.4 | | | | | | | 1201.5 | | | | 713.9 |
| 37.4 | 37.2 | | | | | | | 1203.8 | | | | 715.7 |
| 37.2 | 37.0 | | | | | | | 1206.1 | | | | 717.4 |
| 37.0 | 36.8 | | | | | | | 1208.4 | | | | 719.2 |
| 36.8 | 36.6 | | | | | | | 1210.7 | | | | 720.9 |
| 36.6 | 36.4 | | | | | | | 1213.0 | | | | 722.7 |
| 36.4 | 36.2 | | | | | | | 1215.3 | | | | 724.5 |
| 36.2 | 36.0 | | Yakima ab Chandler (36.0) | | | | 20.7 | 1217.6 | | | 15.9 | 726.2 |
| 36.0 | 35.8 | 6 | | | | | | 1219.9 | 728 | | | 728.0 |
| 35.8 | 35.6 | | | Chandler return (35.8) | | 1030.0 | | 2252.2 | | 716.0 | | 1446.6 |
| 35.6 | 35.4 | | | | | | | 2254.5 | | | | 1449.2 |
| 35.4 | 35.2 | | | | | | | 2256.8 | | | | 1451.7 |
| 35.2 | 35.0 | | | | | | | 2259.1 | | | | 1454.3 |
| 35.0 | 34.8 | | | | | | | 2261.4 | | | | 1456.9 |
| 34.8 | 34.6 | | | | | | | 2263.7 | | | | 1459.5 |
| 34.6 | 34.4 | | | | | | | 2266.0 | | | | 1462.1 |
| 34.4 | 34.2 | | | Swiss Corral Ck (34.3) | | | | 2268.3 | | | | 1464.7 |
| 34.2 | 34.0 | | Yakima blw Chandler (34.0) | | | | | 2270.6 | | | | 1467.2 |
| 34.0 | 33.8 | | | | | | | 2272.9 | | | | 1469.8 |
| 33.8 | 33.6 | | | | | | 27.6 | 2275.2 | | | 11.0 | 1472.4 |
| 33.6 | 33.4 | 7 | | Corral Ck (33.5) | | 18.8 | | 2296.3 | | 13.0 | | 1488.0 |
| 33.4 | 33.2 | | | | | | | 2298.6 | | | | 1490.5 |

Table 9. Flow balance for calibration and validation of QUAL2E.

| | | | | | September 28-29, 1999 | | | | July 25-26, 2000 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upstream RM (mile) | Dnstream RM (mile) | Reach Number | Ecology/SCCD Mainstem Sampling Station | Ecology Tributary Sampling Station | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) |
| 33.2 | 33.0 | | | | | | | 2300.9 | | | | 1493.1 |
| 33.0 | 32.8 | | | | | | | 2303.2 | | | | 1495.7 |
| 32.8 | 32.6 | | | | | | | 2305.5 | | | | 1498.3 |
| 32.6 | 32.4 | | | | | | | 2307.8 | | | | 1500.9 |
| 32.4 | 32.2 | | | | | | | 2310.1 | | | | 1503.4 |
| 32.2 | 32.0 | | | | | | | 2312.4 | | | | 1506.0 |
| 32.0 | 31.8 | | | | | | | 2314.7 | | | | 1508.6 |
| 31.8 | 31.6 | | | | | | | 2317.0 | | | | 1511.2 |
| 31.6 | 31.4 | | | | | | | 2319.3 | | | | 1513.8 |
| 31.4 | 31.2 | | | | | | | 2321.6 | | | | 1516.3 |
| 31.2 | 31.0 | | | | | | | 2323.9 | | | | 1518.9 |
| 31.0 | 30.8 | | | | | | | 2326.2 | | | | 1521.5 |
| 30.8 | 30.6 | | | | | | | 2328.5 | | | | 1524.1 |
| 30.6 | 30.4 | | | | | | | 2330.8 | | | | 1526.7 |
| 30.4 | 30.2 | | | | | | | 2333.1 | | | | 1529.3 |
| 30.2 | 30.0 | | | | | | | 2335.4 | | | | 1531.8 |
| 30.0 | 29.8 | | | | | | | 2337.7 | | | | 1534.4 |
| 29.8 | 29.6 | | Yakima at Kiona (29.6) | | 2340 | | 46.0 | 2340.0 | 1537 | | 18.4 | 1537.0 |
| 29.6 | 29.4 | 8 | | | | | | 2336.9 | | | | 1533.9 |
| 29.4 | 29.2 | | | | | | | 2333.8 | | | | 1530.8 |
| 29.2 | 29.0 | | | | | | | 2330.7 | | | | 1527.7 |
| 29.0 | 28.8 | | | | | | | 2327.6 | | | | 1524.6 |
| 28.8 | 28.6 | | | Benton City POTW(28.6) | | | | 2324.5 | | | | 1521.5 |
| 28.6 | 28.4 | | | | | | | 2321.4 | | | | 1518.4 |
| 28.4 | 28.2 | | | | | | | 2318.4 | | | | 1515.4 |
| 28.2 | 28.0 | | | | | | | 2315.3 | | | | 1512.3 |
| 28.0 | 27.8 | | | Kiona Irrigation Pump | | -17.8 | | 2294.3 | | -20.0 | | 1489.2 |
| 27.8 | 27.6 | | | | | | | 2291.2 | | | | 1486.1 |
| 27.6 | 27.4 | | | | | | | 2288.2 | | | | 1483.0 |
| 27.4 | 27.2 | | | | | | | 2285.1 | | | | 1479.9 |
| 27.2 | 27.0 | | Yakima blw Kiona (27.0) | | | | | 2282.0 | | | | 1476.8 |
| 27.0 | 26.8 | | (Sept. survey) | | | | -43.3 | 2278.9 | | | -43.3 | 1473.7 |
| 26.8 | 26.6 | 9 | | | | | | 2275.8 | | | | 1470.6 |
| 26.6 | 26.4 | | | | | | | 2272.7 | | | | 1467.5 |
| 26.4 | 26.2 | | | | | | | 2269.6 | | | | 1464.4 |
| 26.2 | 26.0 | | | | | | | 2266.5 | | | | 1461.3 |
| 26.0 | 25.8 | | | | | | | 2263.4 | | | | 1458.2 |
| 25.8 | 25.6 | | | | | | | 2260.3 | | | | 1455.1 |
| 25.6 | 25.4 | | | | | | | 2257.2 | | | | 1452.1 |
| 25.4 | 25.2 | | | | | | | 2254.1 | | | | 1449.0 |
| 25.2 | 25.0 | | Yakima blw Kiona (25.0) | | | | | 2251.0 | | | | 1445.9 |
| 25.0 | 24.8 | | (July survey) | | | | | 2247.9 | | | | 1442.8 |
| 24.8 | 24.6 | | | | | | | 2244.8 | | | | 1439.7 |
| 24.6 | 24.4 | | | | | | | 2241.7 | | | | 1436.6 |
| 24.4 | 24.2 | | | | | | | 2238.6 | | | | 1433.5 |
| 24.2 | 24.0 | | | | | | | 2235.5 | | | | 1430.4 |
| 24.0 | 23.8 | | | | | | | 2232.5 | | | | 1427.3 |
| 23.8 | 23.6 | | | | | | | 2229.4 | | | | 1424.2 |
| 23.6 | 23.4 | | | | | | | 2226.3 | | | | 1421.1 |
| 23.4 | 23.2 | | | | | | | 2223.2 | | | | 1418.0 |
| 23.2 | 23.0 | | | | | | | 2220.1 | | | | 1414.9 |
| 23.0 | 22.8 | | | | | | -61.9 | 2217.0 | | | -61.9 | 1411.9 |
| 22.8 | 22.6 | 10 | | | | | | 2213.9 | | | | 1408.8 |
| 22.6 | 22.4 | | | | | | | 2210.8 | | | | 1405.7 |
| 22.4 | 22.2 | | | | | | | 2207.7 | | | | 1402.6 |
| 22.2 | 22.0 | | | | | | | 2204.6 | | | | 1399.5 |
| 22.0 | 21.8 | | | | | | | 2201.5 | | | | 1396.4 |
| 21.8 | 21.6 | | | | | | | 2198.4 | | | | 1393.3 |
| 21.6 | 21.4 | | | | | | | 2195.3 | | | | 1390.2 |
| 21.4 | 21.2 | | | | | | | 2192.2 | | | | 1387.1 |
| 21.2 | 21.0 | | | | | | | 2189.1 | | | | 1384.0 |
| 21.0 | 20.8 | | | | | | | 2186.0 | | | | 1380.9 |
| 20.8 | 20.6 | | | | | | | 2182.9 | | | | 1377.8 |
| 20.6 | 20.4 | | | | | | | 2179.8 | | | | 1374.7 |
| 20.4 | 20.2 | | | | | | | 2176.7 | | | | 1371.6 |
| 20.2 | 20.0 | | | | | | | 2173.6 | | | | 1368.6 |
| 20.0 | 19.8 | | | | | | | 2170.6 | | | | 1365.5 |
| 19.8 | 19.6 | | | | | | | 2167.5 | | | | 1362.4 |
| 19.6 | 19.4 | | | | | | | 2164.4 | | | | 1359.3 |
| 19.4 | 19.2 | | | | | | | 2161.3 | | | | 1356.2 |

Table 9. Flow balance for calibration and validation of QUAL2E.

| | | | | | September 28-29, 1999 | | | | July 25-26, 2000 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upstream RM (mile) | Dnstream RM (mile) | Reach Number | Ecology/SCCD Mainstem Sampling Station | Ecology Tributary Sampling Station | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) | Measured Mainstem Flow (cfs) | Measured Tributary Flow (cfs) | Pro-rated Incremental Inflow/ Outflow for reach (cfs) | Calculated Element Outflow (cfs) |
| 19.2 | 19.0 | | | | | | | 2158.2 | | | | 1353.1 |
| 19.0 | 18.8 | | Yakima ab Wanawish (18.8) | | | | -61.9 | 2155.1 | 1350 | | -61.9 | 1350.0 |
| 18.8 | 18.6 | 11 | | | | | | 2155.8 | | | | 1350.4 |
| 18.6 | 18.4 | | | | | | | 2156.5 | | | | 1350.9 |
| 18.4 | 18.2 | | | | | | | 2157.2 | | | | 1351.3 |
| 18.2 | 18.0 | | | | | | | 2157.9 | | | | 1351.8 |
| 18.0 | 17.8 | | Wanawish Dam | CID diversion+ | | -160.0 | | 1998.7 | | -194.0 | | 1158.2 |
| 17.8 | 17.6 | | | Barker Ranch diversion | | -40.0 | | 1959.4 | | -40.0 | | 1118.6 |
| 17.6 | 17.4 | | | | | | | 1960.1 | | | | 1119.1 |
| 17.4 | 17.2 | | | | | | | 1960.8 | | | | 1119.5 |
| 17.2 | 17.0 | | | | | | | 1961.5 | | | | 1119.9 |
| 17.0 | 16.8 | | | | | | | 1962.2 | | | | 1120.4 |
| 16.8 | 16.6 | | | | | | | 1962.9 | | | | 1120.8 |
| 16.6 | 16.4 | | | | | | | 1963.7 | | | | 1121.3 |
| 16.4 | 16.2 | | Yakima blw Wanawish (16.2) | | | | 9.3 | 1964.4 | | | 5.7 | 1121.7 |
| 16.2 | 16.0 | 12 | | | | | | 1965.1 | | | | 1122.1 |
| 16.0 | 15.8 | | | | | | | 1965.8 | | | | 1122.6 |
| 15.8 | 15.6 | | | | | | | 1966.5 | | | | 1123.0 |
| 15.6 | 15.4 | | | | | | | 1967.2 | | | | 1123.5 |
| 15.4 | 15.2 | | | | | | | 1967.9 | | | | 1123.9 |
| 15.2 | 15.0 | | | | | | | 1968.6 | | | | 1124.3 |
| 15.0 | 14.8 | | | | | | | 1969.3 | | | | 1124.8 |
| 14.8 | 14.6 | | | | | | | 1970.1 | | | | 1125.2 |
| 14.6 | 14.4 | | | | | | | 1970.8 | | | | 1125.6 |
| 14.4 | 14.2 | | | | | | | 1971.5 | | | | 1126.1 |
| 14.2 | 14.0 | | | | | | | 1972.2 | | | | 1126.5 |
| 14.0 | 13.8 | | | | | | | 1972.9 | | | | 1127.0 |
| 13.8 | 13.6 | | | | | | | 1973.6 | | | | 1127.4 |
| 13.6 | 13.4 | | | | | | | 1974.3 | | | | 1127.8 |
| 13.4 | 13.2 | | | | | | | 1975.0 | | | | 1128.3 |
| 13.2 | 13.0 | | | | | | | 1975.7 | | | | 1128.7 |
| 13.0 | 12.8 | | Yakima @ Twin Br. (12.8) | | | | | 1976.5 | | | | 1129.2 |
| 12.8 | 12.6 | | | | | | | 1977.2 | | | | 1129.6 |
| 12.6 | 12.4 | | | | | | 13.5 | 1977.9 | | | 8.3 | 1130.0 |
| 12.4 | 12.2 | 13 | | | | | | 1978.6 | | | | 1130.5 |
| 12.2 | 12.0 | | | | | | | 1979.3 | | | | 1130.9 |
| 12.0 | 11.8 | | | | | | | 1980.0 | | | | 1131.3 |
| 11.8 | 11.6 | | | | | | | 1980.8 | | | | 1131.8 |
| 11.6 | 11.4 | | | | | | | 1981.5 | | | | 1132.2 |
| 11.4 | 11.2 | | | | | | | 1982.2 | | | | 1132.7 |
| 11.2 | 11.0 | | | | | | | 1982.9 | | | | 1133.1 |
| 11.0 | 10.8 | | | | | | | 1983.6 | | | | 1133.5 |
| 10.8 | 10.6 | | | | | | | 1984.4 | | | | 1134.0 |
| 10.6 | 10.4 | | | | | | | 1985.1 | | | | 1134.4 |
| 10.4 | 10.2 | | | | | | | 1985.8 | | | | 1134.9 |
| 10.2 | 10.0 | | | | | | | 1986.5 | | | | 1135.3 |
| 10.0 | 9.8 | | | W. Richland POTW (9.8) | | 0.6 | | 1987.8 | | 0.6 | | 1136.3 |
| 9.8 | 9.6 | | | | | | | 1988.6 | | | | 1136.8 |
| 9.6 | 9.4 | | | | | | | 1989.3 | | | | 1137.2 |
| 9.4 | 9.2 | | | | | | | 1990.0 | | | | 1137.6 |
| 9.2 | 9.0 | | | | | | | 1990.7 | | | | 1138.1 |
| 9.0 | 8.8 | | | | | | | 1991.4 | | | | 1138.5 |
| 8.8 | 8.6 | | | | | | | 1992.2 | | | | 1139.0 |
| 8.6 | 8.4 | | Yakima @ Van Geisen (8.4) | | | | 14.4 | 1992.9 | | | 8.8 | 1139.4 |
| 8.4 | 8.2 | 14 | | | | | | 1993.6 | | | | 1139.8 |
| 8.2 | 8.0 | | | | | | | 1994.3 | | | | 1140.3 |
| 8.0 | 7.8 | | | | | | | 1995.0 | | | | 1140.7 |
| 7.8 | 7.6 | | | | | | | 1995.7 | | | | 1141.2 |
| 7.6 | 7.4 | | | | | | | 1996.4 | | | | 1141.6 |
| 7.4 | 7.2 | | | | | | | 1997.2 | | | | 1142.0 |
| 7.2 | 7.0 | | | | | | | 1997.9 | | | | 1142.5 |
| 7.0 | 6.8 | | | | | | | 1998.6 | | | | 1142.9 |
| 6.8 | 6.6 | | | | | | | 1999.3 | | | | 1143.3 |
| 6.6 | 6.4 | | | | | | | 2000.0 | | | | 1143.8 |
| 6.4 | 6.2 | | | | | | | 2000.7 | | | | 1144.2 |
| 6.2 | 6.0 | | | | | | | 2001.4 | | | | 1144.7 |
| 6.0 | 5.8 | | | | | | | 2002.2 | | | | 1145.1 |
| 5.8 | 5.6 | | Yakima @ hwy 182 (5.6) | | | | 10.0 | 2002.9 | 1145.54 | | 6.1 | 1145.5 |

for the survey dates were used as initial condition flows in the model. Residual inflows and outflows in the study area were calculated from differences in the mass balance of discharge quantities and chloride concentrations between flow measurement stations. These were entered into the QUAL2E model as pro-rated or distributed incremental inflows or outflows. Higher error was associated to these inflows and outflows besides the normal 10% variability due to flow measurement error, particularly below the Kiona USGS gaging station where there were no continuous flow gaging stations or flow records. The inability of the USBR to maintain (under control flow) a constant flow during the two surveys also contributed to possible error in the estimates.

The placement of estimated residual inflows and outflows below Kiona (RM 30.0) obtained from flow measurements taken during the July 2000 survey were used for the September 1999 survey, since there were no flow measurements made below Kiona for the latter survey. The September inflows below Kiona were increased over July 2000 since there was approximately a 63% increase in measured inflows for the Prosser to Kiona reach for the September 1999 survey compared to the July 2000 survey.

**Flow Components**

QUAL2E uses flow-exponent equations to functionally represent the hydraulic routing of the river. The flow-exponent equations relating velocity (V in ft/sec), depth (D in ft), and width (W in ft) with flow (Q in cfs) are written as follows (McCutcheon, 1989):

$$V = a\,Q^{b} \qquad D = c\,Q^{d} \qquad W = eQ^{f} \qquad \text{(equation 1)}$$

A time-of-travel dye study was conducted on July 27-28, 2000 on the Prosser (RM 47.0) to Chandler Return (RM 36.0) reach of the Yakima River. Figure 6 presents the time-concentration curves from the dye cloud as it passed two monitoring stations at RM 43.0 and RM 36.0. An average reach velocity of 0.83 ft/sec was calculated based on the time passage of the peak concentrations equaling a time-of-travel of approximately 11 hours for the Prosser to Chandler reach at that flow. Using the measured velocity, flow, and width, the flow-exponent equations were resolved for the Prosser to Chandler reach. Channel cross sections available from past instream flow incremental method assessments, rating curves, and other physical data available through the USGS and the USBR were used to estimate the flow-exponent and coefficients for the remaining reaches. Table 8 includes the flow exponents and coefficients used in all the reaches for the QUAL2E model.

**Climatology**

The QUAL2E model employs an internal temperature subroutine to simulate instream water temperature. Local climatological data supplied by the user drives this subroutine. When daily mean climate data are supplied, QUAL2E performs an energy balance for heat transfer across the air-water interface and outputs a mean daily temperature. QUAL2E can also be used in a dynamic mode that calculates a diurnal temperature range, using 3-hour interval climate data, during the otherwise steady-state model conditions. Both modes were attempted in a pre-modeling exercise and compared to the continuous temperature records measured by the

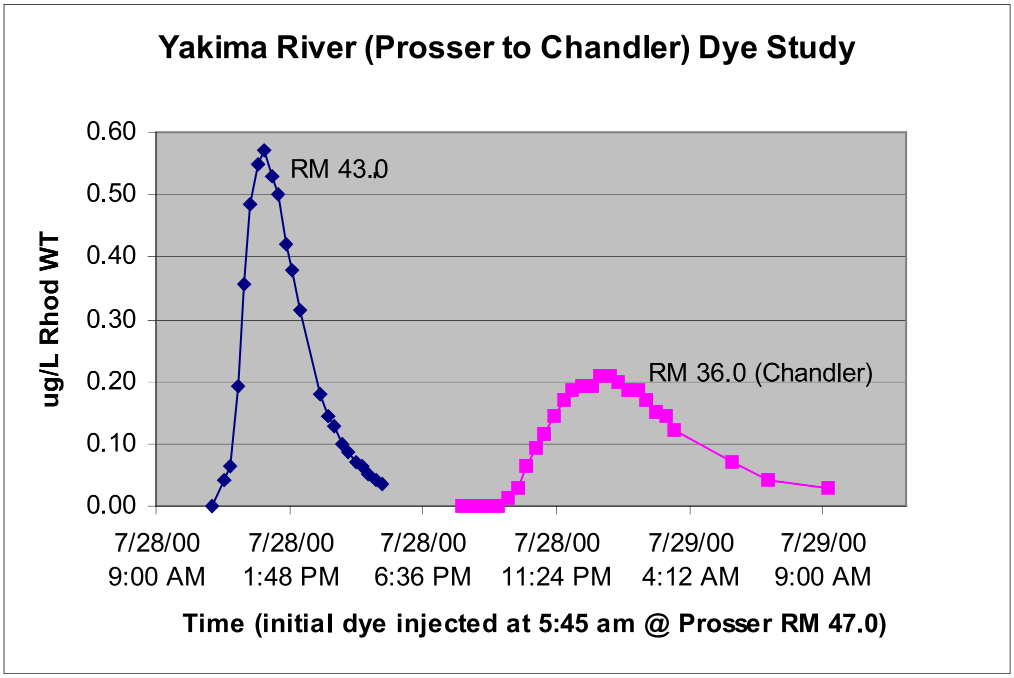



Figure 6. Time-concentration plots of dye cloud passage past RM 43.0 and RM 36.0 of the Yakima River.

Hydrolab dataloggers during the two surveys (Appendix E). During initial calibration, the diurnal mode continuously calculated an attenuated diurnal temperature range compared to the measured field data, a result substantiated by an earlier finding using QUAL2E for temperature modeling (Sullivan et al., 1990). Therefore the diurnal mode was not employed for the rest of the modeling project, and only a mean daily temperature was simulated.

The local climatological data used for steady-state temperature simulation (only a daily mean temperature output) were the daily mean fraction of cloud cover, dry bulb and wet bulb temperatures, barometric (atmospheric) pressure, and wind speed. A dust attenuation coefficient from the literature was also supplied. Calibration was best achieved by using the dry bulb temperature, calculated wet bulb temperature, and the wind speed from the Public Agricultural Weather System station #720. The fraction of cloud cover recorded at HMS (Hanford Meteorological Station) and the barometric pressure recorded at the HMS remote station #18 (West Richland airport) were also used. A single value was specified for each of the required temperature simulation inputs, and QUAL2E applied these values to all of the reaches.

**Water Quality Inputs and Groundwater Characteristics**

The water quality of the residual inflows (i.e., groundwater) affects the instream water quality of the Yakima River. Incremental groundwater inflows occur throughout the Prosser (RM 47.2) to Kiona (RM 30.0) reach, and from Wanawish Dam (RM 18.8) to the last downstream monitoring station at RM 5.6. The groundwater quality characteristics are influenced by seepage from the surrounding irrigated agricultural regions.

The temperature of incoming groundwater was estimated to equal the long-term, mean air temperature of the region (Theurer et al., 1984). HMS supplied a regional long-term mean air temperature from 1945-99 of 53.4° F. Using this temperature, the DO concentration was approximated to be 10.6 mg/L, mid-range of the 6 to 12 mg/L concentrations typically found in recently recharged groundwater (Matthess, 1982). Nutrient and chloride concentrations were selected from ranges found in Benton County well waters sampled less than 100 feet from the surface and published in the USGS Water-Supply Bulletin #53 (USGS, 1985) and from water quality characteristics reported for Snipes and Spring creeks at baseflow conditions by the Sunnyside and Roza Irrigation District.

All other initial condition source and point source water quality inputs were taken from data collected in the field during the two surveys. Table 10 summarizes the water quality inputs used in the QUAL2E models to define the initial condition, point sources, and groundwater quality characteristics.

## Calibrated Model Inputs

Tables 11 and 12 show the calibration coefficients and parameters selected to fit the observed conditions during the July 2000 survey. The July coefficients were also applied to the simulation of the September 1999 survey data to test the performance of the QUAL2E model, or to confirm its ability to accurately simulate the river under other conditions.

### Coefficients for Temperature Calibration

Temperature correction factors are used in QUAL2E since most processes are modeled using model coefficients that are temperature dependent. Temperature correction factors used in the modeling were commonly accepted values from the scientific literature (USEPA, 1985, 1987, and 1991) or model default values. September and scenario run inputs were not changed from initially selected values for the July survey.

### Coefficients for Dissolved Oxygen Calibration

Various options for the calculation of atmospheric reaeration rates are available for use in the QUAL2E model. Using the guidance of USEPA (1985, 1991), the O'Conner and Dobbins option (QUAL2E option 3) was considered to be the most representative of conditions in the lower Yakima River, based on velocity and depth during low-flow conditions. Reaeration in reach 1 (Prosser Dam) was estimated to be 0.2 $day^{-1}$.

For the July 2000 survey, calibrated levels of net oxygen production by phytoplankton alone were not sufficient to model the supersaturated DO conditions observed. Periphyton (attached algae) net oxygen production was estimated during model calibration to achieve the best prediction of DO profiles. Net oxygen production by periphyton was estimated as the difference between total net oxygen production related to plant productivity as measured by ranges in diurnal DO (Thomann and Mueller, 1987) and predicted phytoplankton net oxygen production as calculated by the QUAL2E model. Oxygen production by periphyton was found to be increasingly significant

Table 10. Summary of input data used for the calibration and confirmation of the QUAL2E model of the lower Yakima River.

| Station Name | QUAL2E Pointload | Flow | Temp | DO | BOD | Chloride | Total Suspended Solids | Chlorophyll a | Organic Nitrogen | Ammonia-N | Nitrite-Nitrate | Organic Phosphorus | Dissolved Phophorus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | # | cfs | degrees F | mg/L | mg/L | mg/L | mg/L | ug/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| **July 25-26, 2000 (Calibration data)** | | | | | | | | | | | | | |
| RM 47.2 Headwaters | | 628 | 74.06 | 9.67 | 2.39 | 5.06 | 23 | 16.3 | 0.177 | 0.010 | 1.006 | 0.035 | 0.050 |
| Incremetal Inflow | | | 53.4 | 10.6 | 1.5 | 11.5 | 31 | | 0.400 | 0.030 | 1.675 | 0.046 | 0.065 |
| PROSSER WWTP | 1 | 1.18 | 78.8 | 9.2 | 11.7 | 85.2 | 11 | | 1.265 | 0.046 | 0.299 | | 2.540 |
| SENECA (TREETOP) | 2 | 0.12 | 83.3 | 7.2 | 16.1 | 18.9 | 1 | | 0.202 | 0.077 | 0.014 | 0.138 | |
| SNIPES/SPRING CREEKS | 3 | 67 | 70.3 | 8.7 | 2 | 5.49 | 23 | 3.9 | 0.169 | 0.010 | 0.763 | 0.026 | 0.052 |
| CHANDLER RETURN | 4 | 716 | 75.2 | 9.67 | 1.9 | 4.99 | 17 | 19.3 | 0.203 | 0.010 | 0.948 | 0.028 | 0.078 |
| CORRAL CREEK | 5 | 13 | 65.7 | 9.1 | 2 | 4.63 | 25 | 3.9 | 0.150 | 0.010 | 1.050 | 0.026 | 0.052 |
| WEST RICHLAND WWTP | 8 | 0.6 | 64.4 | 4.19 | 1.39 | 145 | 11 | | | 0.046 | 25.000 | 3.920 | |
| **Sept 28-29, 1999 (Confirmation data)** | | | | | | | | | | | | | |
| RM 47.2 Headwaters | | 980 | 57 | 10.34 | 1 | 5.16 | 16 | 3.9 | 0.159 | 0.041 | 1.040 | 0.057 | 0.054 |
| Incremetal Inflow | | | 53.4 | 10.6 | 1.5 | 11.5 | 31 | | 0.400 | 0.030 | 1.675 | 0.046 | 0.065 |
| PROSSER WWTP | 1 | 1 | 67.5 | 8.3 | 8.78 | 86.7 | 11 | | 1.265 | 0.046 | 0.299 | | 2.540 |
| SENECA (TREETOP) | 2 | 0.12 | 83.3 | 7.2 | 16.1 | 18.9 | 1 | | 0.202 | 0.077 | 0.014 | 0.138 | |
| SNIPES/SPRING CREEKS | 3 | 109.9 | 57.4 | 10.5 | 2 | 5.11 | 44 | 3.9 | 0.162 | 0.038 | 0.663 | 0.081 | 0.040 |
| CHANDLER RETURN | 4 | 1030 | 58.6 | 10.3 | 1 | 5.24 | 12 | 3.9 | 0.110 | 0.040 | 1.070 | 0.056 | 0.057 |
| CORRAL CREEK | 5 | 18.8 | 57.4 | 8.4 | 2 | 5.2 | 37 | 3.9 | 0.139 | 0.031 | 1.040 | 0.106 | |
| WEST RICHLAND WWTP | 8 | 0.6 | 64.4 | 4.19 | 1.39 | 145 | 11 | | | 0.046 | 25.000 | 3.920 | |

Table 11. QUAL2E data type 1A: global algae, nitrogen, phosphorus, and light parameters for calibration of July 2000 conditions and confirmation of September 1999 conditions.

| QUAL2E Coefficient | Description | Units | Value Used |
|---|---|---|---|
| $\alpha_5$ | $O_2$ uptake per $NH_3$ oxidized | mg O/mg N | 3.43 |
| $\alpha_6$ | $O_2$ uptake per $NO_2$ oxidized | mg O/mg N | 1.14 |
| $\alpha_3$ | $O_2$ production per unit algae | mg O/mg A | 1.6 |
| $\alpha_4$ | $O_2$ respiration per unit algae | mg O/mg A | 2.0 |
| $\alpha_1$ | N content of algae | mg N/mg A | 0.08 |
| $\alpha_2$ | P content of algae | mg P/mg A | 0.011 |
| $\mu_{max}$ | algal maximum growth rate | $day^{-1}$ | 2.30 |
| $\rho$ | algal respiration rate | $day^{-1}$ | 0.12 |
| $K_N$ | N half-saturation concentration | mg N /L | 0.03 |
| $K_P$ | P half-saturation concentration | mg P /L | 0.005 |
| $\lambda_1$ | linear algal light extinction | $(ft^{-1})$/(ug/L chl *a*) | 0.0027 |
| $\lambda_2$ | non-linear algal light extinction | $(ft^{-1})/(\text{ug/L chl } a)^{0.666}$ | 0.0165 |
| LFNOPT | light function option | -- | 3 |
| $K_L$ | light saturation coefficient | $BTU/ft^2/min$ | 0.5125 |
| LAVOPT | daily averaging option for light | -- | 3 |
| AFACT | light averaging factor | dimensionless | 1.0 |
| TFACT | algal/temp solar rad. factor | dimensionless | 0.45 |
| LGROPT | algal growth limitation option | -- | 2 |
| F or $P_N$ | algal preference for ammonia | dimensionless | 0.9 |
| KNITRF | nitrification inhibition constant | $day^{-1}$ | 0.6 |

downstream of Kiona as evidenced by greater diurnal swings and unaccounted supersaturation of instream DO. Periphyton net oxygen production was entered into the QUAL2E model as negative sediment oxygen demand (Table 12).

**Coefficients for BOD Calibration**

QUAL2E simulates UBOD assuming first-order kinetics and a decay rate that can be specified by the user for each reach. A decay rate coefficient commonly used in literature is –0.23 $day^{-1}$ (USEPA, 1985 and 1987). QUAL2E recommends simulating UBOD (USEPA, 1987), although there are provisions for simulating 5-day BOD. The survey data for September 1999 and July 2000 included only 5-day BOD determinations due to the exorbitant cost of UBOD determinations. Generally a multiplier is used to convert 5-day BOD values to UBOD values. The multiplier is calculated from a conversion equation dependent on the decay rate coefficient (USEPA 1987). For this model a multiplier of 1.46 is used in conjunction with the –0.23 day-1 decay rate coefficient to simulate UBOD. Table 13 presents the 5-day BOD and UBOD data used in the modeling.

Table 12. QUAL2E data types 6, 6A, and 6B: BOD, algae, nitrogen, phosphorus, and TSS reach-level parameters for calibration of July 2000 conditions and confirmation of September 1999 conditions.

| QUAL2E Coefficient | Description | Units | Value Used |
|---|---|---|---|
| $K_1$ | BOD decay rate constant | $day^{-1}$ | 0.23 |
| $K_3$ | BOD settling rate | $day^{-1}$ | (-0.26 – -0.66) |
| $K_4$ | sediment oxygen demand (SOD) | $g/ft^2$ – day | (-0.00 – -0.18) |
| $K_2$ | reaeration rate constant | $day^{-1}$ | QUAL2E Option 3 |
| $\beta_3$ | hydrolysis of organic N to $NH_3$ rate constant | $day^{-1}$ | 0.1 |
| $\sigma_4$ | organic N settling rate | $day^{-1}$ | (-3.6 – 1.0) |
| $\beta_1$ | biological oxidation of $NH_3$ to $NO_2$ rate constant | $day^{-1}$ | 1.2 |
| $\sigma_3$ | benthos source rate for $NH_3$ | $mg/ft^2$ – day | (0.0 – 1.0) |
| $\beta_2$ | biological oxidation of $NO_2$ to $NO_3$ rate constant | $day^{-1}$ | 3 |
| $\beta_4$ | organic P decay rate | $day^{-1}$ | 0.1 |
| $\sigma_2$ | benthos source rate for dissolved-P | $mg/ft^2$ – day | (0.0 – 7.0) |
| $\alpha_0$ | ratio of chlorophyll *a* / algae | ug chl *a* / mg A | 10 |
| $\sigma_1$ | algal settling rate | feet/day | (0.5 – 6.00) |
| $\lambda_0$ | non-algal light extinction | $ft^{-1}$ | 0.26 |
| $\sigma_6$ | TSS settling rate | $day^{-1}$ | (0.0 – 0.8) |

Table 13. 5-day BOD conversion to UBOD data used in QUAL2E modeling.

| | BOD(5-Day) (mg/L)[1] | | UBOD (mg/L)[2] | |
|---|---|---|---|---|
| RM / Point Source | Sept 1999 Survey | July 2000 Survey | Sept 1999 Survey | July 2000 Survey |
| 47.2 | 0.68 | 1.63 | 1.00 | 2.39 |
| 36.0 | 0.77 | 1.50 | 1.12 | 2.20 |
| 29.6 | - | 1.50 | - | 2.20 |
| 27.0 | 0.70 | - | 1.02 | - |
| 18.8 | - | 1.40 | - | 2.05 |
| 16.4 | 1.01 | 1.40 | 1.48 | 2.05 |
| 5.8 | 1.53 | 1.80 | 2.23 | 2.63 |
| Prosser WWTP | 6.00 | 8.00 | 8.78 | 11.71 |
| Treetop | 11.00 | - | 16.10 | - |
| Chandler Return | - | 1.30 | - | 1.90 |
| West Richland WWTP | 0.95 | - | 1.39 | - |

1) if less than detection limit of 4 mg/L, BOD(5-Day) values are estimates based on final day-5 readings

2) UBOD calculated from BOD(5-Day) using a multiplier of 1.46 and a decay rate of -0.23 $day^{-1}$

All 5-day BOD concentration results for the river samples were below detection limit for both the September 1999 and July 2000 surveys. They are recorded as such in the data appendix (Appendix A) with the appropriate qualifiers. However, in order to provide a more accurate simulation of the first-order deoxygenation reaction, estimates of the below-detection, 5-day BOD concentrations were used in the model. These values were the final laboratory bench readings on day-5 and are considered only estimates, because they were below the detection limit.

**Coefficients for Algae and Nutrient Calibrations**

Global kinetic coefficients, parameters, and model options for algae and nutrient simulations listed in Table 11 were selected as typical mid-range values or recommended options summarized by USEPA (1991). These selections were not varied from initially selected recommended values for calibration, with the exception of the light function option (LFNOPT) and the corresponding light saturation coefficient (KL). The light function mathematically relates photosynthesis and light. The elevated light intensities during the July 2000 survey required the use of the Steel's Equation option (QUAL2E option 3), because it was the only option with a photoinhibition expression for high-light intensity. Both of the other options grossly over-estimated chlorophyll a concentrations, because they assumed photosynthetic activity continued at a maximum rate. Using option 3, KL was calibrated within a suggested range (USEPA, 1985) to achieve the best fit to the observed chlorophyll a data.

In addition, reach-level coefficients were applied to achieve the best fit to the observed field data. These are the oxidation, decay, and settling rates that govern the transformation and fate of nitrogen and phosphorus as simulated in the QUAL2E model. Table 12 presents the values or range of values applied at the reach-level for each of the nutrients. All reach-level coefficients were within the range of values recommended (USEPA, 1991)

**Coefficients for TSS Calibration**

TSS was modeled in QUAL2E as an arbitrary non-conservative constituent. The QUAL2E first-order decay mechanism for a non-conservative constituent was not used for TSS, though reach-specific settling rate coefficients were used to achieve the best fit to the observed TSS survey data.

## Comparison of Observed and Simulated Water Quality

QUAL2E was calibrated to the July 2000 data because it represented better critical conditions and greater dynamic processes than the September 1999 data. The September 1999 survey took place the last week of September when water and air temperatures were cooler and available light for productivity had attenuated compared to the hot, summer conditions of the July 2000 survey. Water quality measurements in July 2000 were also more representative of the average July to September water quality conditions (Table 7). The calibrated QUAL2E model was confirmed with the September 1999 data set.

The results of the QUAL2E model simulations for calibration and confirmation were compared to observed values collected by Ecology during the surveys. The uncertainty of the model prediction was estimated by the root-mean-square-error (RMSE), a measure of the difference between the model prediction and the measured daily average value. Table 14 presents the overall RMSE performance of the calibration and confirmation simulations for each constituent and compares these to the overall RMSE based on sample duplicates collected in the field. A presentation and discussion of each of the constituents modeled in the QUAL2E calibration and confirmation step follows.

**Temperature**

Results of the QUAL2E simulations for calibration and confirmation are compared with mean water temperatures observed by Ecology during September 1999 and July 2000 in Figure 7. The QUAL2E model had an overall RMSE for temperature of 0.40° F and 0.39° F for the calibration and confirmation model runs, respectively, approaching the field precision limit of 0.36° F. Model performance was slightly better for the confirmation data set from September 1999 compared with the July 2000 calibration results. Variability during the summer is influenced by wider diurnal temperature ranges.

The model inputs for temperature include initial condition, tributary, and groundwater inflow temperatures, as well as local climatology. These were treated as fixed inputs and were not changed from initial entries. No other coefficients were changed as initially entered. The calibrated model of the July 2000 survey data underpredicted the temperatures in the Prosser to Chandler reach, evidently due to the over-cooling effects of the modeled groundwater inflows in this reach. Since the groundwater inflow temperature was estimated from the mean annual air temperature and not directly measured, there may be some annual variation in groundwater temperatures with warmer temperatures expected in the summer season. The rest of the calibrated model accurately tracked a gradual increase in mean daily water temperature to the end of the study area. The model was confirmed with the September 1999 data set, which accurately predicted field conditions except for the slight cooling observed at the Wanawish Dam monitoring site.

**DO and BOD**

Results of the QUAL2E simulations for calibration and confirmation are compared with mean DO and BOD observed by Ecology during September 1999 and July 2000 in Figure 7. The QUAL2E model had an overall RMSE for DO of 0.08 mg/L and 0.17 mg/L for the calibration and confirmation model runs, respectively. These are higher than the 0.06 mg/L field-precision limit. Mean DO values from the September 1999 survey were above the 100% saturation point. The mean DO values from the July 2000 survey were above the 110% saturation point, in violation of the Class A 110% saturation criterion. Very elevated water temperatures reduced the saturation point concentration in July, while algae and benthic productivity caused wide diurnal ranges and elevated DO means during both surveys.

Table 14. Overall performance of calibration and confirmation models using root mean square error (RMSE) and coefficient variation (CV) with comparison to overall observed field RMSE and CV.

| Parameter | Units | RMSE of Observed Field Duplicates[2] | CV% of Observed Field RMSE | RMSE of calibration model (July 2000)[1] | CV% of calibration model RMSE (July 2000)[1] | RMSE of confirmation model (Sept 1999) | CV% of confirmation model RMSE (Sept 1999) |
|---|---|---|---|---|---|---|---|
| Temperature | degrees F | 0.36 | - | 0.40 | 0.5% | 0.39 | 0.7% |
| DO | mg/L | 0.06 | - | 0.08 | 0.9% | 0.17 | 1.8% |
| BOD | mg/L | - | - | 0.09 | 3.9% | 0.39 | 28.4% |
| Chlorophyll a[1] | ug/L | 1.00 | 9.33% | 0.6 | 4.9% | 2.2 | 52.4% |
| Organic P | mg/L | 0.004 | 3.02% | 0.008 | 29.1% | 0.004 | 6.7% |
| Dissolved P | mg/L | 0.003 | 3.19% | 0.009 | 9.1% | 0.005 | 8.0% |
| Organic-N | mg/L | 0.015 | 1.26% | 0.010 | 4.7% | 0.047 | 36.5% |
| Ammonia-N | mg/L | 0.003 | 13.27% | 0.003 | 21.0% | 0.008 | 20.2% |
| Nitrate-N | mg/L | 0.012 | 1.29% | 0.039 | 4.1% | 0.060 | 5.7% |
| Chloride | mg/L | 0.04 | 0.74% | 0.05 | 0.9% | 0.14 | 2.5% |
| TSS[1] | mg/L | 0.7 | 2.80% | 1.6 | 10.6% | 1.9 | 15.2% |
| Turbidity | NTU | 0.6 | 7.51% | 0.8 | 11.3% | 0.6 | 10.0% |

[1] RM 18.8 station chlorophyll a and TSS data from July 2000 not included in field variability RMSE and CV% or in the calibrated model RMSE and CV%.
[2] RMSE calculated from July 2000 and September 1999 survey duplicate data, except temperature and DO which are field precision limits.

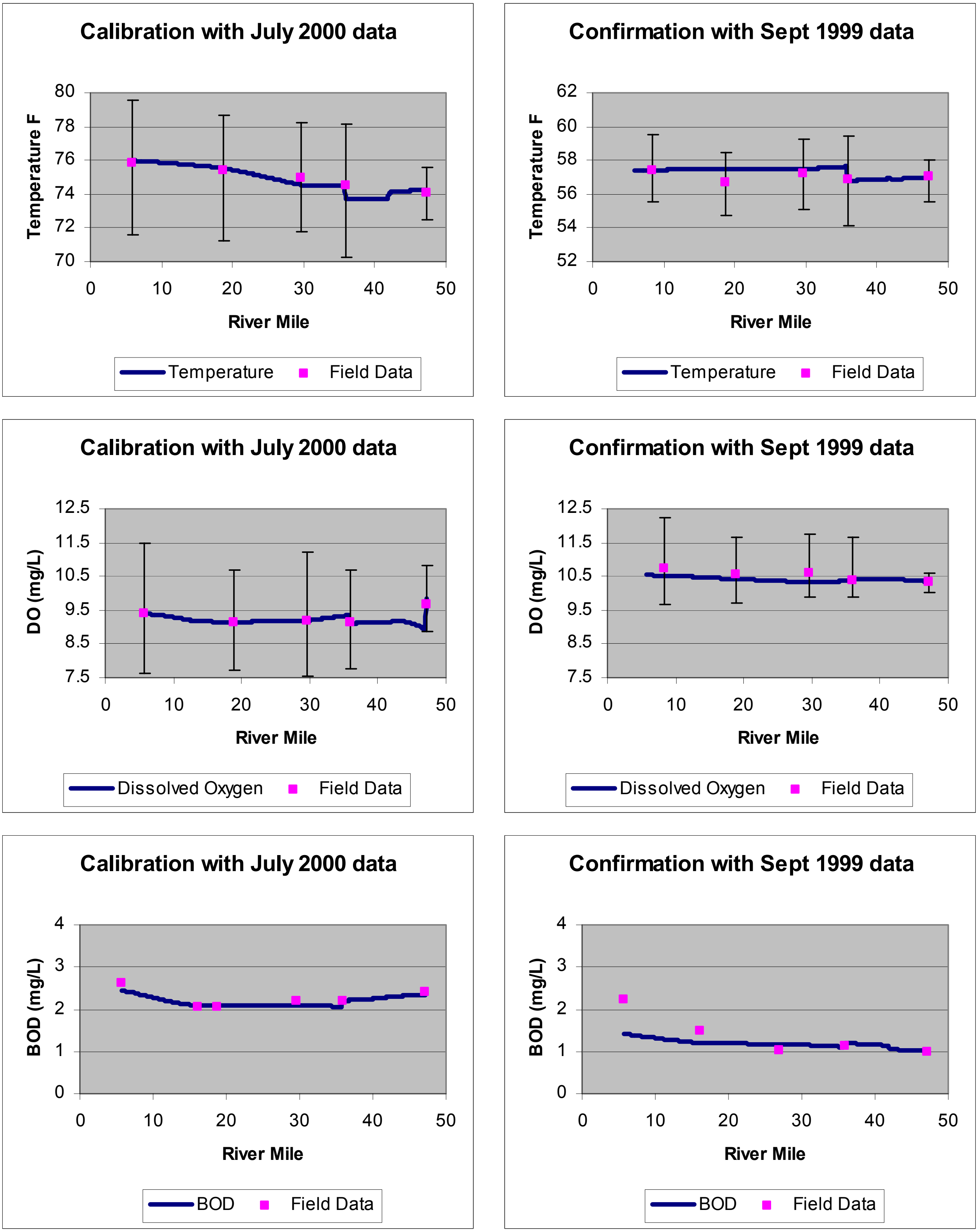



Figure 7. Calibration and confirmation of QUAL2E for prediction of temperature, DO, and BOD in the lower Yakima River during September 1999 and July 2000 (vertical lines are observed means and ranges).

During both surveys, over-saturated and elevated instream DO entering the initial condition reach dominated DO conditions through the entire study area. DO levels remained relatively constant and were maintained en route through the study area by the net oxygen production of algae and periphyton.

QUAL2E had an overall estimated RMSE for BOD of 0.09 mg/L and 0.39 mg/L for the calibration and confirmation model runs, respectively. Again, these are estimates because all river BOD values collected during the surveys were below detection limit and would not allow accurate quantification of variability. BOD levels appear to remain relatively constant from initial conditions throughout most of the study area, though both surveys appeared to have a slight trend for the BOD concentration to increase below the Twin Bridges monitoring site in the lower 5 to 10 miles of the study area. This increase still resulted in values below the reported detection limit for BOD and, therefore, remains inconclusive.

**Algae**

Chlorophyll a is used as a measurement of water column algae in the Yakima River system. Results of the QUAL2E simulations for calibration and confirmation are compared with chlorophyll a observed during the September 1999 and July 2000 surveys in Figure 8. The QUAL2E model had an overall RMSE for chlorophyll a of 0.6 ug/L and 2.2 ug/L for the calibration and confirmation model runs, respectively. The calibration RMSE was below the variability of 1.0 ug/L for the duplicate pair data. The confirmation model run underpredicted the September 1999 chlorophyll a data in all reaches. Several explanations exist for this underprediction.

The July 2000 survey occurred during the summer with warm air, warm water temperatures, and abundant light; while the September 1999 survey occurred at the end of summer with cool air, cool water temperatures, and declining light. With plenty of available nutrients, light, and warm temperatures, algae growth would be expected to be high. Particularly, the July 2000 survey conditions would be expected to have continued accelerated growth of algae if not for the photoinhibition that limits growth. A light function with photoinhibition was used in the QUAL2E model to calibrate algae growth in the July 2000 data, but this may have caused underestimated algae growth for the September 1999 data. Some researchers have found the photoinhibition light function to be inaccurate below the inhibition threshold (USEPA, 1985).

Additionally, the settling terms used in the calibrated model generally followed flow velocity patterns. Higher settling terms were evidenced in the lower velocity (de-watered) Prosser to Chandler reach, the Horn Rapids reach below Wanawish Dam, as well as the low-velocity reach behind Wanawish Dam. Lower settling terms were used in faster moving, flow-through reaches such as those at the lower end of the river. The September 1999 chlorophyll *a* field data suggest that there is very little algal settling in the system during the September flow condition. When all the reach-level settling terms used in the July calibrated model are reduced 75%, the model has a RMSE for chlorophyll *a* of 0.5 ug/L for the September data.

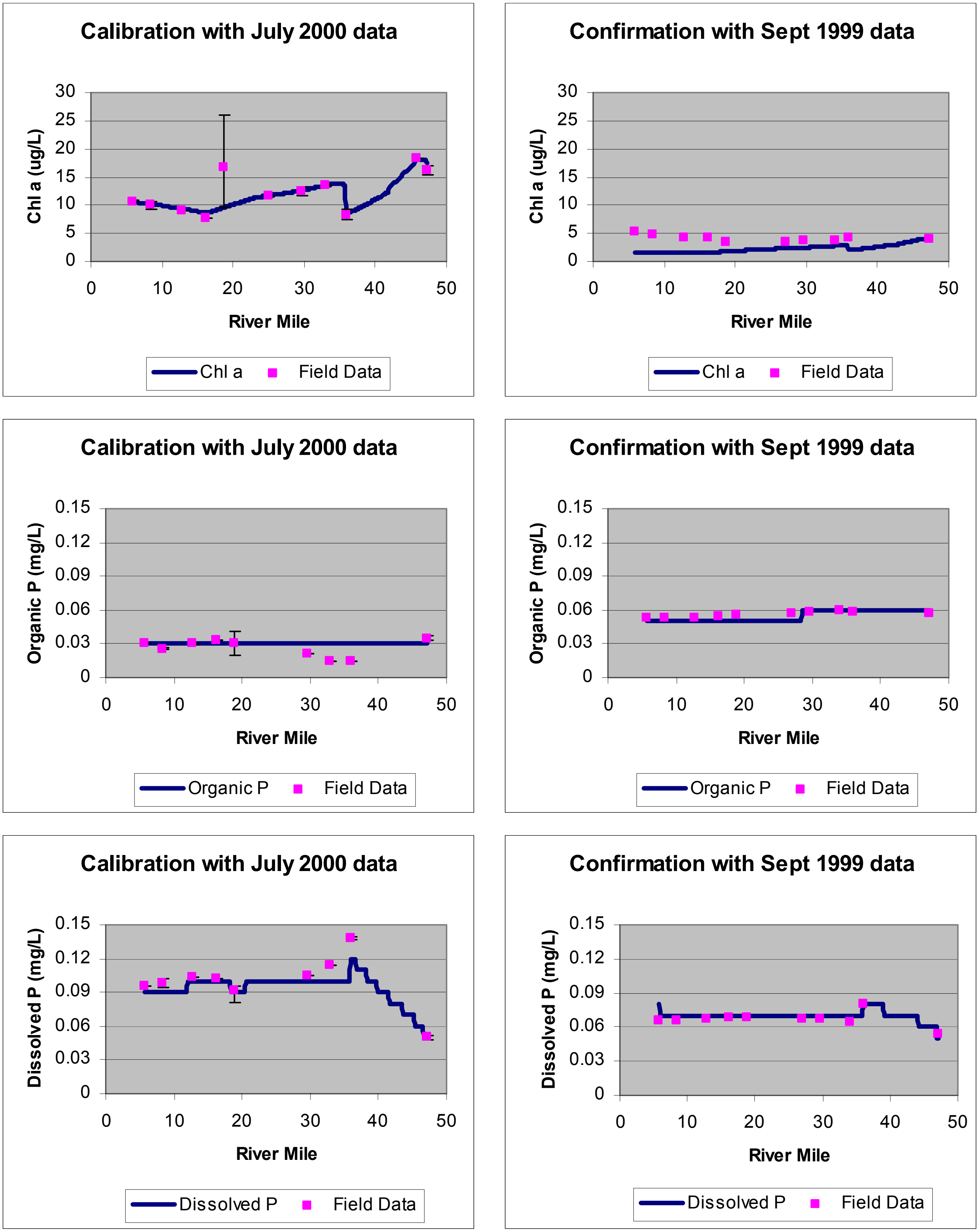



Figure 8. Calibration and confirmation of QUAL2E for prediction of chlorophyll a and phosphorus in the lower Yakima River during September 1999 and July 2000 (vertical lines are observed means and ranges).

To summarize, during the July-September season, algae in the lower 47-miles of the Yakima River mostly originate from upstream sources and flow through the study area to the mouth with slightly higher settling rates in low-velocity reaches. Algae growth and productivity in the lower Yakima during this season, while high, seem to be limited by light inhibition of the algae types present.

**Nutrients**

Results of the QUAL2E simulations for calibration and confirmation are compared with mean nutrient concentrations observed during September 1999 and July 2000 in Figures 8 and 9. The QUAL2E model had an overall RMSE for the organic and dissolved forms of phosphorus of less than 0.009 mg/L and less than 0.005 mg/L for the calibration and confirmation model runs, respectively. Field duplicates for phosphorus forms displayed variability slightly less than this.

Organic phosphorus levels remained relatively stable throughout the study area compared to the initial conditions in both surveys, except for a slight decrease in the Prosser to Kiona reach during the July 2000 survey. The phosphorus-pool was dominated by dissolved-P during both surveys, but particularly during the July 2000 survey. Both surveys exhibited an increase in dissolved-P in the Prosser to Chandler reach, and then a declining and subsequent leveling of concentrations throughout the rest of the study area. Concentrations throughout the study area always remained above initial condition concentrations. Again, this pattern was most pronounced in the July 2000 survey.

The increases of dissolved-P in the Prosser to Chandler reach might have one or several explanations:

- There could be a transformation of phosphorus forms taking place. Algae settling in this reach could be a rich organic-P source which could then be converting into the dissolved inorganic state. There was a drop in organic-P and chlorophyll *a* levels in the water column of the Prosser to Chandler reach during the July 2000 survey concurrent with increased dissolved-P levels. This was not evident in the September 1999 survey, though, that still had an increase in dissolved-P in the Prosser to Chandler reach.
- Sediment release of phosphorus in aerobic waters is possible with increases of pH above 8.0 (Bostrom et al., 1982). The Prosser to Chandler reach appears to be a seasonal settling reach for chlorophyll *a* and TSS (see TSS discussion below) with a diurnal pH range from 7.6 to 8.5 during the July and September surveys (Appendix E).
- This is a reach with a net groundwater inflow, and elevated dissolved-P levels of the entering groundwater could be affecting the reach. Another section of net groundwater inflows at the end of the study area does not show a rise in dissolved-P levels, but this may be accounted for by the increased dilution afforded by increased downstream flows compared to the de-watered Prosser to Chandler reach.

The QUAL2E model was calibrated to the increased dissolved-P levels in the Prosser to Chandler reach using benthic source rate terms for dissolved-P in this reach. It adequately predicted the increase for both the calibration and the confirmation simulation model runs.

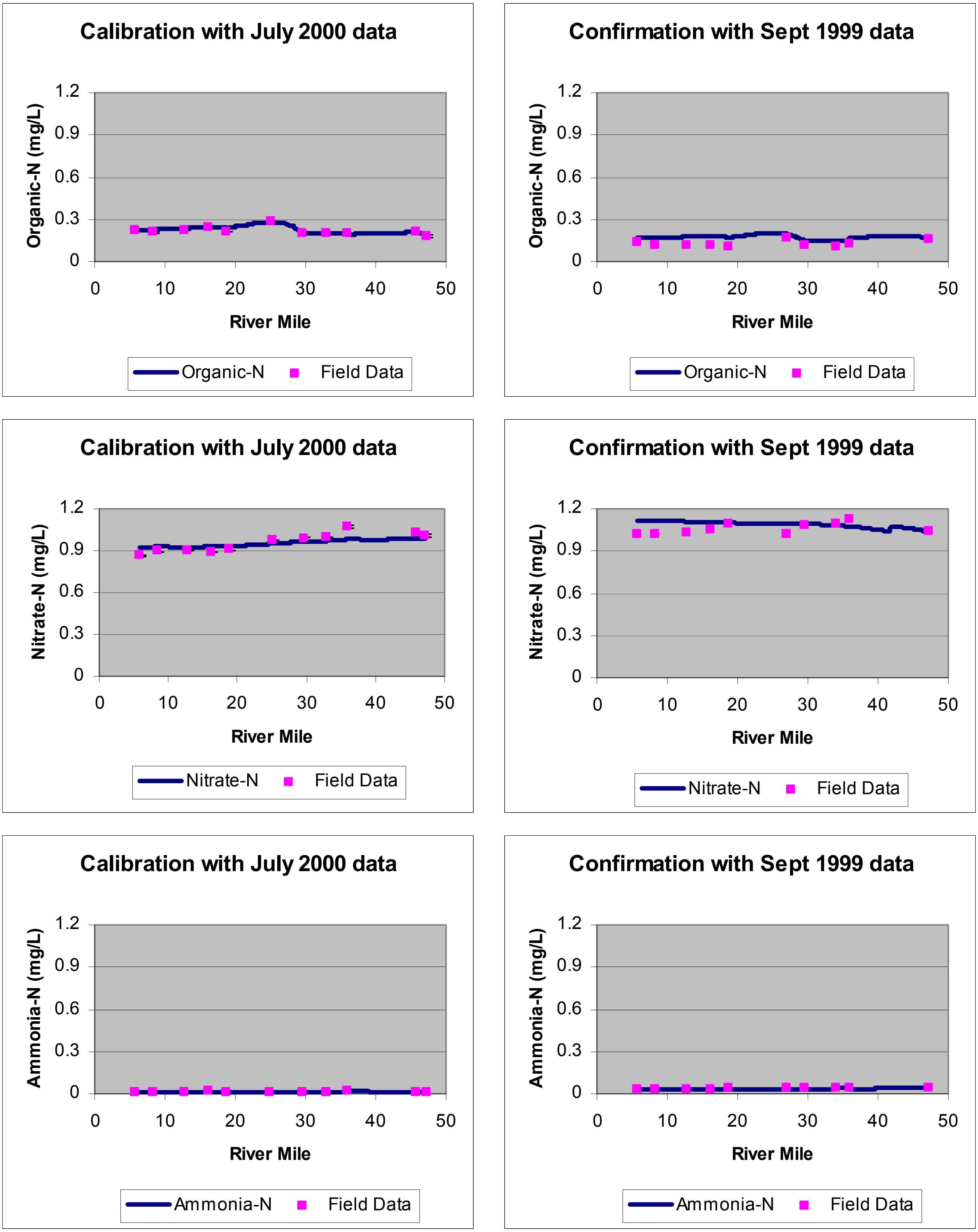



Figure 9. Calibration and confirmation of QUAL2E for prediction of nitrogen forms in the lower Yakima River during September 1999 and July 2000.

The QUAL2E model had an overall RMSE for organic-N of 0.010 mg/L and 0.047 mg/L for the calibration and confirmation model runs, respectively. Field duplicates for organic-N displayed variability comparable to the calibration model run, but less than the confirmation model run. The QUAL2E model had an overall RMSE for the nitrate-N of 0.039 mg/L and 0.060 mg/L for the calibration and confirmation model runs, respectively. Field duplicates for nitrate-N had a lower variability. The QUAL2E model had an overall RMSE for ammonia-N of 0.003 mg/L and 0.008 mg/L for the calibration and confirmation model runs, respectively. The water column was nearly devoid of ammonia during the July 2000 survey with most determinations being below the detection limit of 0.010 mg/L. September 1999 values hovered just above the detection limit.

The nitrogen pool was dominated by nitrate for both the September 1999 and July 2000 surveys. Field measurements of nitrate-N included nitrite-N. Nitrite-N was forcefully converted to nitrate-N in the QUAL2E model by using the highest rate constant for the oxidation of nitrite-N to nitrate-N from the recommended range (USEPA, 1991). In general, the levels of all forms of nitrogen remained constant throughout the study area and approximately equal to the initial conditions at the headwaters. Slight sinks and rises were probably due to the transformation of forms within the water column from algae uptake and decomposition.

**Solids and Turbidity**

TSS results of the QUAL2E simulations for calibration and confirmation are compared with TSS observed by Ecology during September 1999 and July 2000 in Figure 10. The QUAL2E model had an overall RMSE for TSS of 1.6 mg/L and 1.9 mg/L for the calibration and confirmation model runs, respectively. TSS was modeled in QUAL2E as an arbitrary non-conservative constituent. Settling rate coefficients used in the Prosser to Chandler reach and above and below Wanawish Dam correspond to hydraulic velocity drops. The de-watered Prosser to Chandler reach has lower velocities due to diverted water, and appears to have a seasonal storage of sediment during the low-flow season. Likewise, Horn Rapids below Wanawish Dam is a wide and shallow rapid made up of many riffles and pools at low flow, with velocity gradient drops that seasonally collect and trap sediment. The slower moving water directly behind Wanawish Dam also acts as a sediment depositional area.

Both the September 1999 and July 2000 surveys had lower TSS concentrations at Kiona compared to the historical median for that time period (Figure 7). This may be due to implementation of the recent suspended sediment TMDL for the Yakima River (Joy and Patterson, 1997). In general, the suspended sediment load to the last 47 miles of the Yakima River during July-September seems to originate from upstream sources and flow through the study area with some seasonal sedimentation in lower velocity reaches.

Turbidity was not directly modeled in QUAL2E, but a regression equation between observed TSS and turbidity data can be used to predict the turbidity levels in the study area. Joy and Patterson (1997) found a strong correlation between TSS and turbidity values in the lower Yakima River during the April to October irrigation season. Similarly, the river site TSS and turbidity results from the two surveys had a fairly strong correlation ($r^2 = 0.856$). The RMSE for

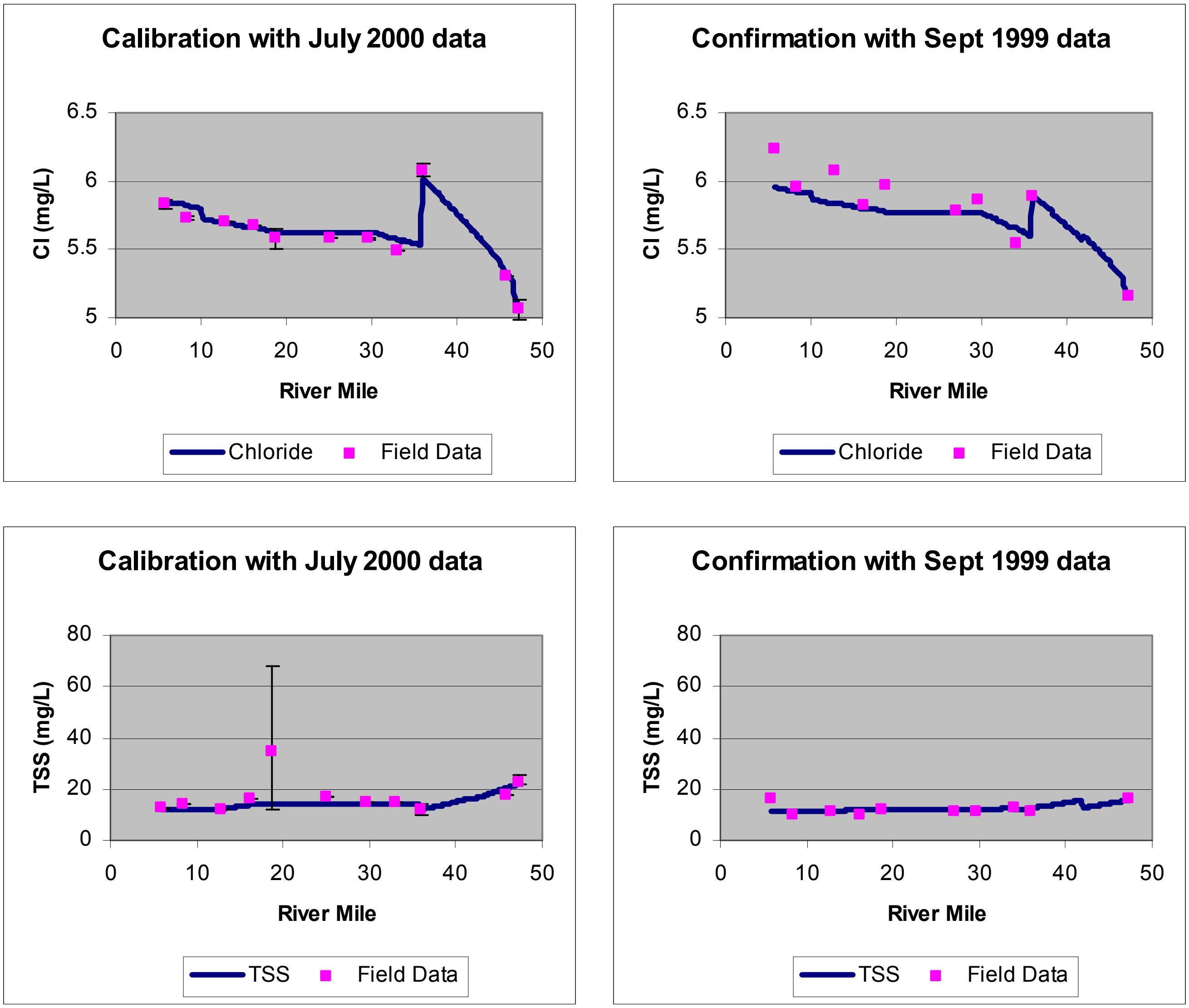



Figure 10. Calibration and confirmation of QUAL2E for prediction of chloride and TSS in the lower Yakima River during September 1999 and July 2000 (vertical lines are observed means and ranges).

the predicted turbidity based on the regression and turbidities observed during the studies was 1.0 NTU. The QUAL2E model had an overall RMSE for turbidity of 0.8 NTU and 0.6 NTU for the calibration and confirmation model runs, respectively. These are similar to the RMSE of 0.6 NTU for the duplicate turbidity samples collected during the surveys. Turbidity patterns in the study area during the two surveys followed those of TSS described above and were generally lower than reported historical values.

**Chloride**

Chloride was modeled in QUAL2E as an arbitrary conservative constituent. Field measurements and simulation of chloride were used as a conservative tracer through the study area. Results of the QUAL2E simulations for calibration and confirmation are compared with chloride observed by Ecology during September 1999 and July 2000 in Figure 10. The QUAL2E model had an overall RMSE for chloride of 0.05 mg/L and 0.14 mg/L for the calibration and confirmation model runs, respectively, slightly higher than the overall observed field variability for chloride. The good agreement between predicted and observed values reflects an accurately balanced hydraulic model, since all hydraulic and chloride inputs were measured (except estimated groundwater chloride concentrations). In particular, the groundwater inflow patterns match well with the chloride data. Increases in chloride concentrations between Prosser (RM 47.2) and Chandler (RM 36.0) reflect the groundwater chloride contributions in this partially de-watered reach of the mainstem.

## QUAL2E Model Results of USBR Pump Exchange Scenarios

The following is a list of operational-change scenarios the USBR asked to have simulated, and the corresponding scenario labels referred to in the rest of this report.

In the Prosser Dam to Chandler Power Return, and downstream through the project area:

- Current July to September conditions (current conditions)
- Chandler partial diversion of Kennewick Irrigation District (KID) with powerhouse in operation (Scenario 1)
- Chandler full diversion of KID with powerhouse in operation (Scenario 2)
- Chandler without diversion or powerhouse operation - Chandler off (Scenario 3)

In the Wanawish Dam to Columbia River reach:

- Current July to September conditions (current conditions)
- Columbia Irrigation District (CID) canal diversion shut off

Table 15 presents the flow regimes used for the Prosser Dam and Chandler Canal operational-change scenarios (Scenario 1-3). The flow regime of the current baseline condition was based on historical averages calculated from available flow records. The operational change of eliminating the CID canal diversion at Wanawish Dam was modeled, but simulations produced no noticeable changes in water quality conditions downstream of the diversion and are, therefore, not discussed further in this report.

Table 15. Comparison of calibrated and confirmed model flows to current and operational-change scenario model flows.

| Station | Calibrated model July 2000 flow (cfs) | Confirmed model Sept 1999 flow (cfs) | Current flow[1] (cfs) (no change) | Scenario 1 flow (cfs) (partial KID removal) | Scenario 2 flow (cfs) (full KID removal) | Scenario 3 flow (cfs) (Chandler off) |
|---|---|---|---|---|---|---|
| Yakima River at Prosser | 628 | 980 | 655 | 1071 | 1251 | 1775 |
| Chandler Canal (diversion) | 1050 | 1275 | 1120 | 704 | 524 | 0 |
| Chandler Return (total) | 716 | 1030 | 855 | 624 | 524 | 0 |
| Chandler Return (power) | 299 | 724 | 524 | 524 | 524 | 0 |
| Chandler Return (pumps)[2] | 418 | 306 | 331 | 100 | 0 | 0 |
| KID (Kennewick) Canal | 334 | 245 | 265 | 80 | 0 | 0 |
| Yakima River below Chandler [3] | 1344 | 2010 | 1510 | 1695 | 1775 | 1775 |
| Within model range of flows?[3] | | | | | | |
| Prosser to Chandler reach | (628 - 980 cfs) | | yes | no (but close) | no | no |
| Chandler to mouth reach | (1344 - 2010 cfs) | | yes | yes | yes | yes |

[1] Current flows based on means of July through September historical records:
- Prosser (1980-99 record)
- Chandler and KID canals (1960-99 record)
- Chandler Return flows based on calculation of other flows
- Yakima below Chandler calculated as sum Prosser and Chandler Return flow

[2] Based on ratio of 1.25 cfs to 1 cfs ratio turbine pump water to irrigation water (per Ben Golemon, Chandler Power Plant)

[3] Sum of Prosser and Chandler Return flows (excludes additions of groundwater, tributaries, and point sources from Prosser to mouth)

Operational-change scenarios were simulated in QUAL2E and compared to a current baseline condition to measure the mechanistic changes in water quality expected from the operational change. The QUAL2E model calibrated to the July 2000 survey had flow conditions very similar to a current condition and was therefore used as the baseline model to compare with the operational-change scenarios. Climate data, groundwater inflows/characteristics, and upstream water quality conditions for the July 2000 calibrated model were also considered to be representative of current conditions.

The calibrated QUAL2E model spanned a range of operational flows from 628 to 980 cfs in the Prosser to Chandler reach, and from 1344 to 2010 cfs in the remaining portion of the study area (Table 15). All operational-change scenario flows for the study area below Chandler fell within the reliability of the model. Scenario 1 with 1071 cfs in the Prosser to Chandler reach was slightly higher than the model upper-end calibration flow of 980 cfs. The other two, Scenario 2 and 3, had flows 1.3 and 1.8 times higher than the calibrated model flows for the Prosser to Chandler reach. This somewhat reduces the predictive capabilities of the QUAL2E model for these scenarios, but the scenario results should still be indicative of general water quality changes in that reach.

Table 16 summarizes the results of the scenario model simulations where mean and maximum water quality changes within specific reaches and for the entire study area are presented. Table 17 summarizes the greatest potential change in water quality for each parameter by specific reach. Following is an evaluation and discussion of each constituent simulated under Scenario 1-3 conditions. When significant change is predicted, both specific water quality change within a reach and the residual downstream effect are evaluated for each constituent modeled.

## Temperature

Temperature results of the QUAL2E simulations for the operational-change scenarios compared with a current temperature condition are presented in Figure 11. Scenario 3 is predicted to exert the greatest change in the mean daily temperature through the study area, but less than a 0.5°F decrease in any reach. This corroborates another water temperature modeling effort that has been recently completed. The SNTEMP model of the Prosser Dam to Chandler Return reach was constructed in 1998 (Payne and Monk, 1999). Water temperature data were collected in 1995 and 1997 at points within the reach and used for model calibration. The model was used to simulate some of the same diversion changes proposed by USBR. The results of the simulation indicated only a 1°C decrease in mean daily temperature at Chandler Power Return, regardless of how much water was allowed over Prosser Dam (Payne and Monk, 1999). Essentially, the temperature of the water entering the study area from upstream (i.e., the headwater or boundary condition) is the most influencing factor in the resulting instream temperature downstream.

The Yakima River has a special temperature criterion of 69.8°F (21°C). All of the July 2000 survey temperature data were in violation of this criterion (Figure 7). Even the lowest temperatures in the diel temperature swing exceeded the temperature criterion. The highest temperatures during the survey neared 80°F at RM 5.6. None of the proposed operational

Table 16. Mean and maximum water quality changes predicted by QUAL2E model for operational-change scenarios.

| | | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | mean change | max change | mean change | max change | mean change | max change |
| RM 47.2 - RM 5.6 (entire study reach) | | | | | | | |
| TEMP | ($^oF$) | -0.12 | -0.25 | -0.17 | -0.32 | -0.31 | -0.51 |
| CL | (mg/L) | -0.14 | -0.34 | -0.16 | -0.42 | -0.17 | -0.56 |
| DO | (mg/L) | 0.05 | 0.12 | 0.05 | 0.14 | 0.01 | 0.14 |
| BOD | (mg/L) | 0.07 | 0.09 | 0.09 | 0.12 | 0.20 | 0.26 |
| ORG N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | -0.02 | -0.03 |
| NH3N | (mg/L) | 0.00 | -0.01 | 0.00 | -0.01 | 0.00 | -0.01 |
| NO3N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | 0.00 | -0.02 |
| ORG P | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DISS P | (mg/L) | -0.01 | -0.03 | -0.02 | -0.03 | -0.02 | -0.04 |
| TSS | (mg/L) | 1.16 | 2.26 | 1.51 | 2.87 | 2.36 | 4.15 |
| CHLA | (ug/L) | 1.58 | 3.35 | 1.87 | 4.17 | 1.84 | 5.70 |
| RM 47.2 - RM 36.0 (Prosser to Chandler reach) | | | | | | | |
| TEMP | ($^oF$) | 0.06 | -0.08 | 0.07 | -0.10 | 0.09 | -0.13 |
| CL | (mg/L) | -0.22 | -0.34 | -0.26 | -0.42 | -0.35 | -0.56 |
| DO | (mg/L) | 0.00 | 0.12 | 0.00 | 0.14 | -0.03 | 0.14 |
| BOD | (mg/L) | 0.04 | 0.07 | 0.05 | 0.08 | 0.07 | 0.11 |
| ORG N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | -0.01 | -0.02 |
| NH3N | (mg/L) | 0.00 | -0.01 | 0.00 | -0.01 | 0.00 | -0.01 |
| NO3N | (mg/L) | 0.00 | -0.01 | 0.00 | -0.02 | 0.00 | -0.02 |
| ORG P | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DISS P | (mg/L) | -0.01 | -0.03 | -0.02 | -0.03 | -0.02 | -0.04 |
| TSS | (mg/L) | 1.61 | 2.26 | 2.02 | 2.87 | 2.84 | 4.15 |
| CHLA | (ug/L) | 1.67 | 3.35 | 2.05 | 4.17 | 2.71 | 5.70 |
| RM 36.0 - RM 18.0 (Chandler to Wanawish Dam reach) | | | | | | | |
| TEMP | ($^oF$) | -0.15 | -0.24 | -0.22 | -0.32 | -0.46 | -0.51 |
| CL | (mg/L) | -0.10 | -0.11 | -0.12 | -0.12 | -0.10 | -0.10 |
| DO | (mg/L) | 0.06 | 0.09 | 0.06 | 0.10 | 0.00 | 0.07 |
| BOD | (mg/L) | 0.08 | 0.09 | 0.12 | 0.12 | 0.25 | 0.26 |
| ORG N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | -0.02 | -0.03 |
| NH3N | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NO3N | (mg/L) | -0.01 | -0.01 | -0.01 | -0.01 | 0.00 | 0.00 |
| ORG P | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DISS P | (mg/L) | -0.01 | -0.02 | -0.02 | -0.02 | -0.02 | -0.03 |
| TSS | (mg/L) | 0.93 | 0.94 | 1.24 | 1.26 | 2.13 | 2.16 |
| CHLA | (ug/L) | 1.24 | 1.75 | 1.45 | 2.06 | 1.19 | 1.78 |
| RM 18.0 - RM 5.6 (Wanawish Dam to end of study reach) | | | | | | | |
| TEMP | ($^oF$) | -0.24 | -0.25 | -0.31 | -0.32 | -0.48 | -0.50 |
| CL | (mg/L) | -0.13 | -0.15 | -0.14 | -0.18 | -0.13 | -0.16 |
| DO | (mg/L) | 0.08 | 0.09 | 0.09 | 0.10 | 0.06 | 0.07 |
| BOD | (mg/L) | 0.07 | 0.09 | 0.10 | 0.12 | 0.24 | 0.26 |
| ORG N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | -0.02 | -0.03 |
| NH3N | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NO3N | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | 0.00 | -0.01 |
| ORG P | (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DISS P | (mg/L) | -0.01 | -0.02 | -0.01 | -0.02 | -0.02 | -0.03 |
| TSS | (mg/L) | 1.08 | 1.15 | 1.42 | 1.50 | 2.23 | 2.28 |
| CHLA | (ug/L) | 1.97 | 2.14 | 2.31 | 2.49 | 1.97 | 2.08 |

Table 17. Summary of greatest mean and maximum change within a reach predicted by QUAL2E model by parameter.

| | | Greatest mean change within reach | Greatest maximum change within reach | Scenario with greatest potential mean change |
|---|---|---|---|---|
| TEMP ($^oF$) | RM 47.2 - RM 5.6 | -0.31 | -0.51 | 3 |
| | RM 47.2 - RM 36.0 | 0.09 | -0.13 | 3 |
| | RM 36.0 - RM 18.0 | -0.46 | -0.51 | 3 |
| | RM 18.0 - RM 5.6 | -0.48 | -0.50 | 3 |
| DO (mg/L) | RM 47.2 - RM 5.6 | 0.05 | 0.14 | 2 |
| | RM 47.2 - RM 36.0 | -0.03 | 0.14 | 3 |
| | RM 36.0 - RM 18.0 | 0.06 | 0.10 | 2 |
| | RM 18.0 - RM 5.6 | 0.09 | 0.10 | 2 |
| BOD (mg/L) | RM 47.2 - RM 5.6 | 0.20 | 0.26 | 3 |
| | RM 47.2 - RM 36.0 | 0.07 | 0.11 | 3 |
| | RM 36.0 - RM 18.0 | 0.25 | 0.26 | 3 |
| | RM 18.0 - RM 5.6 | 0.24 | 0.26 | 3 |
| CHLa (ug/L) | RM 47.2 - RM 5.6 | 1.87 | 5.70 | 3 |
| | RM 47.2 - RM 36.0 | 2.71 | 5.70 | 3 |
| | RM 36.0 - RM 18.0 | 1.45 | 2.06 | 2 |
| | RM 18.0 - RM 5.6 | 2.31 | 2.49 | 2 |
| ORG P (mg/L) | all reaches | no change[1] | no change | |
| DISS P (mg/L) | RM 47.2 - RM 5.6 | -0.02 | -0.04 | 3 |
| | RM 47.2 - RM 36.0 | -0.02 | -0.04 | 3 |
| | RM 36.0 - RM 18.0 | -0.02 | -0.03 | 3 |
| | RM 18.0 - RM 5.6 | -0.02 | -0.03 | 3 |
| ORG N (mg/L) | RM 47.2 - RM 5.6 | -0.02 | -0.03 | 3 |
| | RM 47.2 - RM 36.0 | -0.01 | -0.02 | 3 |
| | RM 36.0 - RM 18.0 | -0.02 | -0.03 | 3 |
| | RM 18.0 - RM 5.6 | -0.02 | -0.03 | 3 |
| NH3 N (mg/L) | RM 47.2 - RM 5.6 | no change | -0.01 | |
| | RM 47.2 - RM 36.0 | no change | -0.01 | |
| | RM 36.0 - RM 18.0 | no change | no change | |
| | RM 18.0 - RM 5.6 | no change | no change | |
| NO3 N (mg/L) | RM 47.2 - RM 5.6 | -0.01 | -0.02 | 2 |
| | RM 47.2 - RM 36.0 | no change | -0.02 | |
| | RM 36.0 - RM 18.0 | -0.01 | -0.01 | 2 |
| | RM 18.0 - RM 5.6 | -0.01 | -0.02 | 2 |
| TSS (mg/L) | RM 47.2 - RM 5.6 | 2.4 | 4.2 | 3 |
| | RM 47.2 - RM 36.0 | 2.8 | 4.2 | 3 |
| | RM 36.0 - RM 18.0 | 2.1 | 2.2 | 3 |
| | RM 18.0 - RM 5.6 | 2.2 | 2.3 | 3 |

[1] no change means below QUAL2E model resolution of +/- 0.01

changes is predicted to entirely remedy these temperature violations during the summer season, but the changes will not increase downstream temperatures. A decrease in upstream water temperature appears to be the only way to significantly decrease the instream water temperature within the study area.

## Dissolved Oxygen and Algae

Results of the QUAL2E simulations for operational-change scenarios in comparison with a current DO condition and chlorophyll a are presented in Figure 11 and 12. Very little change in mean DO concentrations is predicted to occur. The changes in DO within any reach are predicted to be less than 0.1 mg/L. Supersatuated levels of DO, in excess of the 110% criterion, are still predicted to occur due to the elevated water temperatures, and algae and periphyton productivity. Upstream boundary conditions would determine the temperature, chlorophyll a, and nutrient regimes within the whole study area; therefore, the instream DO also would be dependent on the upstream conditions.

Results of the QUAL2E simulations for operational-change scenarios in comparison with current algae (as chlorophyll *a*) conditions are presented in Figure 12. Chlorophyll *a* levels throughout the study area are predicted to increase from current conditions with each operational-change scenario. This seems mainly due to the reduced settling in the Prosser to Chandler reach. Chlorophyll *a* concentrations are still predicted to decline in comparison to upstream boundary conditions, but generally a flow-through situation with slight losses is predicted to occur. Again, the limiting factor for algae growth seems to be photoinhibition of growth, as water temperatures and nutrients are not limiting.

The Prosser to Chandler reach is predicted to experience the greatest change in algae levels because of reduced settling of algae entering the study area from upstream. In Scenario 3, mean chlorophyll *a* levels in the Prosser to Chandler reach are predicted to increase from 13.1 ug/L to 15.8 ug/L. The flows for all the operational-change scenarios in the Prosser to Chandler reach are higher than the September 1999 survey flows where chlorophyll *a* levels were underpredicted. The settling rates used in the model could result in an underprediction of chlorophyll *a* for the operational-change scenarios; however, algae levels are likely to be no more than the incoming levels of algae at the upstream boundary. In all cases, the study area would remain an enriched system predominately influenced by upstream boundary conditions.

During the July 2000 survey, daily minimum DO concentrations at all four datalogger sites spanning the study area dropped below the 8 mg/L Class A criterion (Appendix E). Diel ranges of DO at the four sites were from 2.9 to 3.9 mg/L over a 24-hour period. The differences between the minimum and mean DO were from 1.37 to 1.79 mg/L. Since QUAL2E only reports a mean daily DO concentration, a Class A criterion violation would be likely unless the model predicted a mean DO concentration change of at least 0.24 mg/L to 0.54 mg/L higher than current conditions. In all reaches, DO violations are still predicted to occur under all scenarios because of the wide diel range.

## Nutrients

Results of the QUAL2E simulations for operational-change scenarios in comparison with current nutrient conditions are presented in Figures 12 and 13. Little to no change is expected from the proposed operational-change scenarios to the nitrogen and phosphorus pools, with the exception of dissolved-P. Dissolved-P levels would benefit from the dilution effects of increased flows, especially in the Prosser to Chandler reach. All three operational-change scenarios, with their proposed increased flows, reduced the amount of dissolved-P level increases seen in the Prosser to Chandler reach compared to current conditions.

Overall, the greatest decrease in dissolved-P would be expected from Scenario 3 where there would be a 23% reduction in mean concentrations in the Prosser to Chandler reach and a 21% reduction through the whole study area. While this is a significant reduction, the levels of dissolved-P and all other forms of nitrogen and phosphorus coming into the study area from upstream/headwater sources are high enough that no significant reduction to primary productivity would occur.

## Solids

Results of the QUAL2E simulations for operational-change scenarios in comparison with a current TSS condition are presented in Figure 14. Similar to the chlorophyll *a* results, TSS levels in the water column are predicted to increase as a result of the operational-change scenarios, most prominently in the Prosser to Chandler reach, due to a decrease in settling. Once again, with increased flows, a more flow-through mechanism is expected to dominate within the study area. There are essentially no sources of TSS in the study area. Almost all the TSS enters as upstream TSS and is either transported through or settles and deposits along the river bottom where it probably stays until it is scoured by higher flows in the winter season.

Qualitatively, the reduced settling of TSS predicted by the operational-change scenario simulations may suggest less fish habitat degradation, particularly in the Prosser to Chandler reach. There may be a small reduction in pesticide toxicity in the sediments associated with the reduced TSS settling. The predicted changes in TSS are too small to infer a measurable change in DDT concentrations using a regression of TSS and DDT previously established (Joy and Patterson, 1997).

## pH

The QUAL2E model does not simulate pH. Ecology survey data and the reviewed historical data document pH violations during the summer (July-September), showing values sometimes ranging in excess of the 8.5 water quality criterion upper limit. Generally, this was the result of the diel range of pH values as shown by the datalogger data in Appendix E in which elevated pH values above 8.5 occur during mid-day in conjunction with photosynthetic utilization of carbon dioxide with resulting increase in pH. As discussed above, the operational-change scenarios are not predicted to reduce productivity in the study area and may, in fact, increase it slightly. Therefore, pH violations are likely to continue throughout the study area.

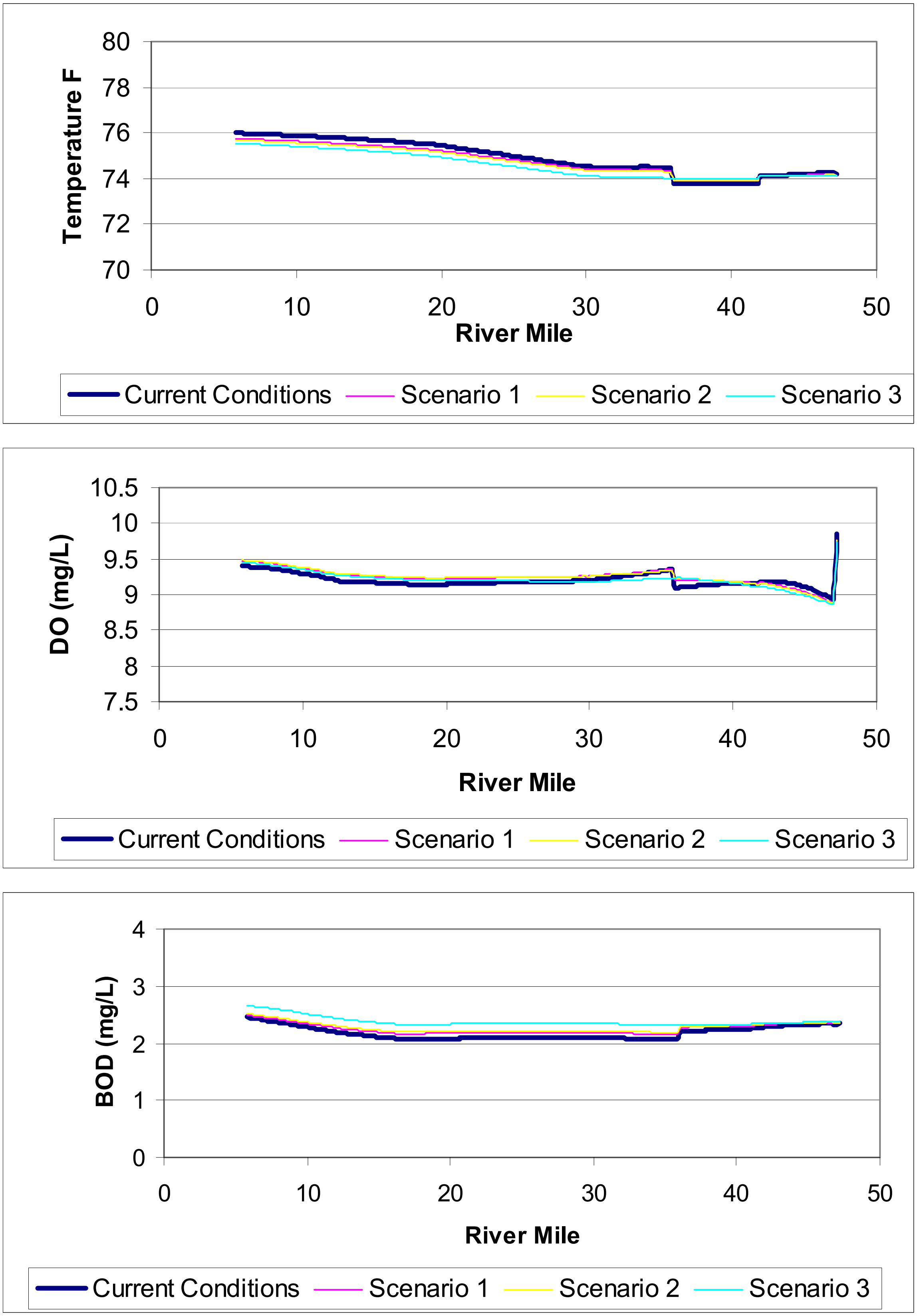



Figure 11. Results of QUAL2E simulations of temperature, DO, and BOD for operational-change scenarios compared to current conditions.

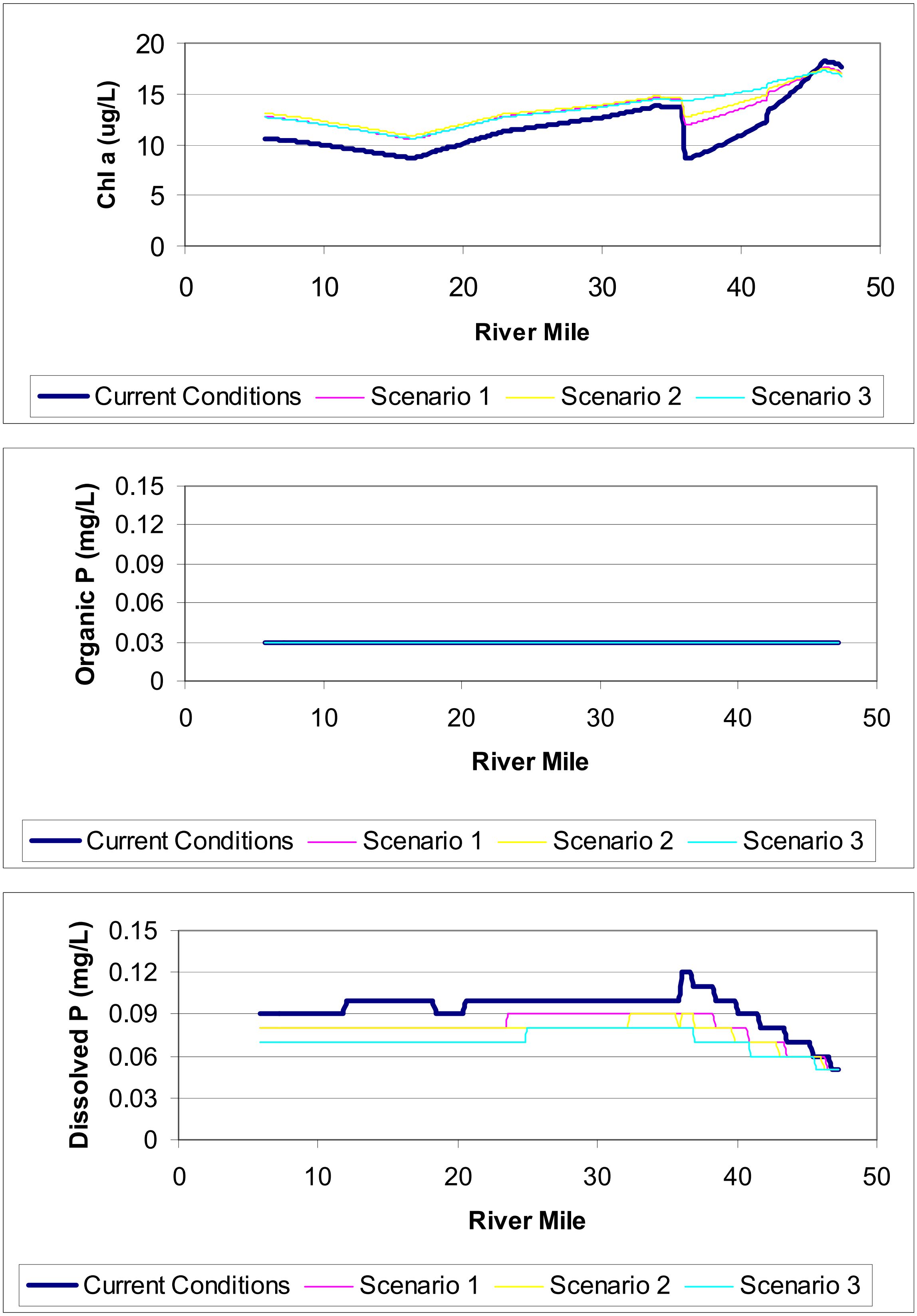



Figure 12. Results of QUAL2E simulations of chlorophyll a, organic P, and dissolved P for operational-change scenarios compared to current conditions.

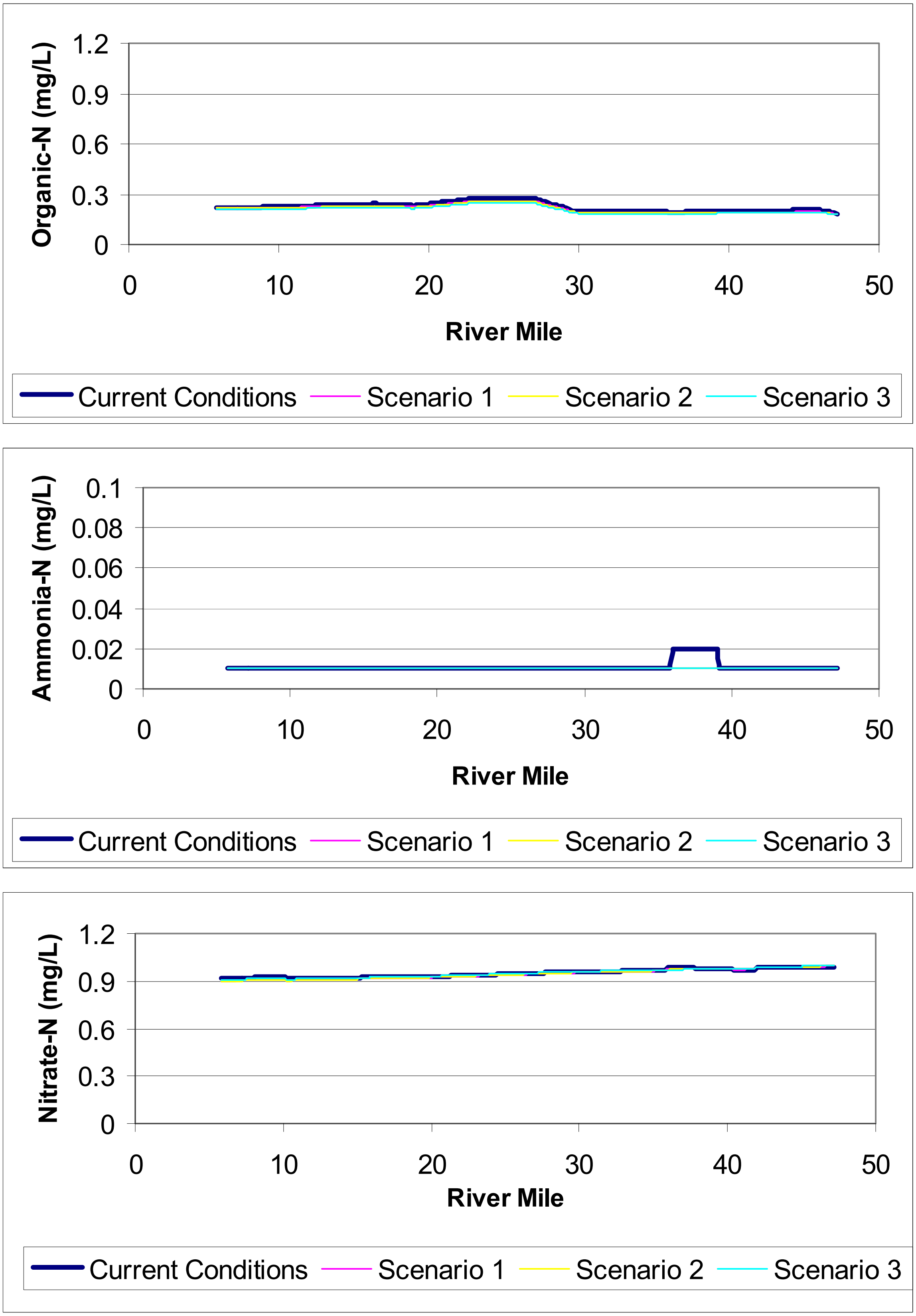
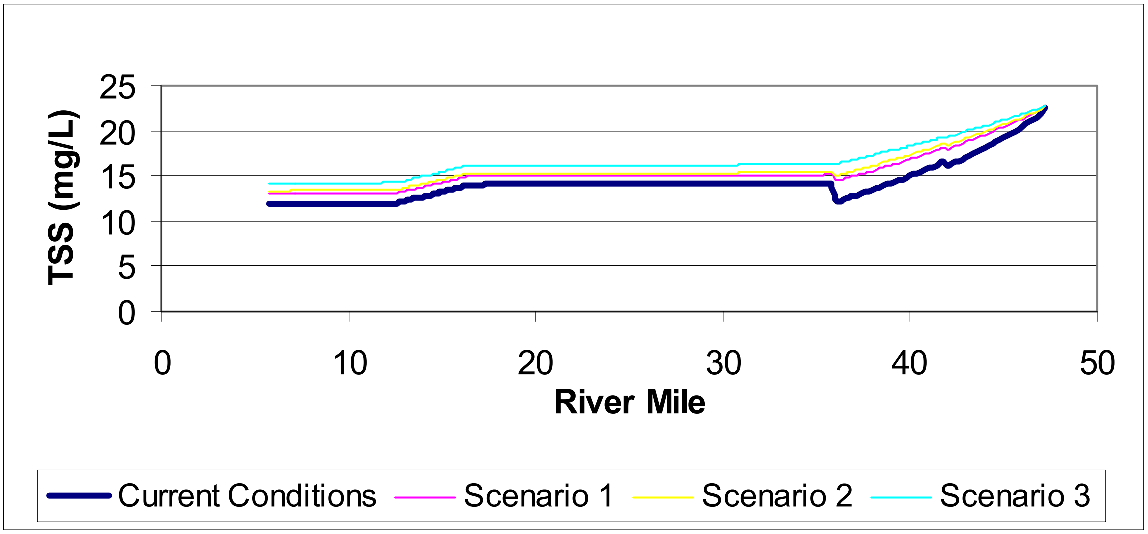



Figure 13. Results of QUAL2E simulations of organic-N, ammonia-N, and nitrate-N for operational-change scenarios compared to current conditions.



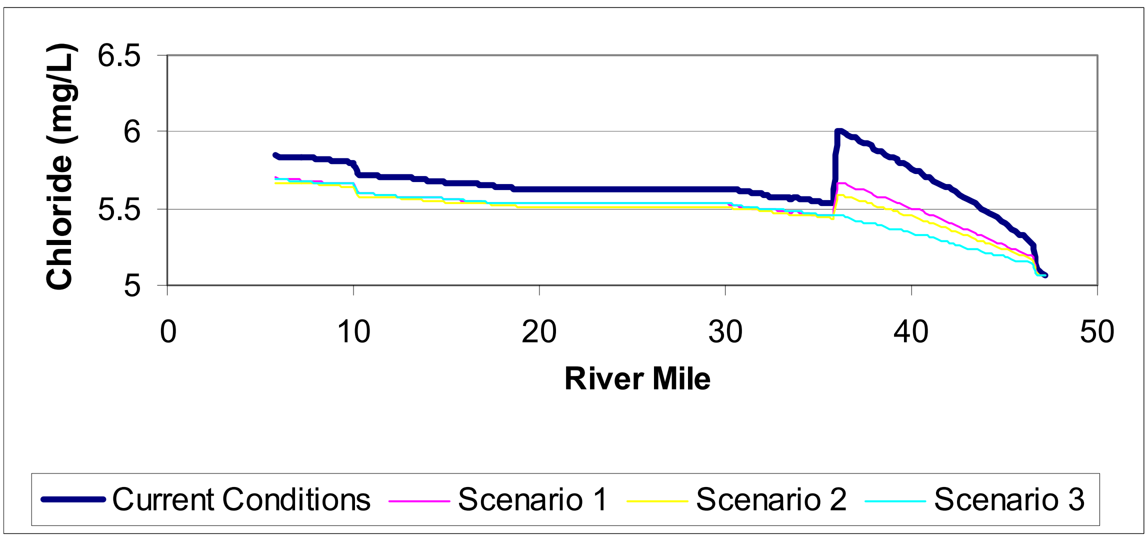




Figure 14. Results of QUAL2E simulations of TSS and chloride for operational-change scenarios compared to current conditions.

# Conclusions

A steady-state model, QUAL2E, was used to evaluate potential changes of temperature, DO, BOD, chlorophyll *a*, nutrients, and TSS from proposed operational changes by the USBR at the Chandler Canal and Columbia Canal diversions. The proposed operational changes are part of the USBR Columbia River Pump Exchange Project. The study area for this modeling project encompasses the Yakima River from Prosser (RM 47.2) to RM 5.6 near the Highway 182 bridge. Two synoptic surveys were conducted by Ecology, in September 1999 and July 2000, to assess water quality characteristics during the low-flow, critical season of concern. The water quality data from these surveys were used to calibrate and confirm the QUAL2E model.

- The Ecology survey data compared well with historical water quality and flow data. The July 2000 survey data were representative of average water quality conditions, so the QUAL2E model calibrated to the July 2000 data was used as a current condition to compare operational changes.

- The QUAL2E model of the lower Yakima predicted minimal change in water quality due to the proposed operational changes. Poor upstream water quality is the foremost determinant of water quality conditions in the last 47 miles of the lower Yakima River evaluated in this study. Changes in operational flows at Prosser Dam cannot overcome the water quality degradation occurring upstream.

- The proposed operational change at Wanawish Dam is predicted to have no noticeable impact on water quality conditions downstream of the Columbia Irrigation District diversion.

- Operational-change scenario simulations mainly predict dilution effects on water quality parameters due to increased water volumes associated with the operational changes. Reduced settling of chlorophyll *a* and TSS also is predicted due to increased velocities of flows. These effects were especially apparent in the Prosser Dam to Chandler Return reach.

- Mean daily water temperatures were predicted to decrease less than a 0.5°F in any reach. The Washington State temperature criterion would continue to be violated because of the elevated temperature of water entering the study area during the warmest months of the year.

- DO concentrations are predicted to change by less than 0.1 mg/L within any reach. In all reaches, DO violations below the 8 mg/L Class A criterion and above the 110% saturation criterion are predicted to occur, due to the elevated water temperatures and algae/periphyton productivity. Upstream boundary conditions would determine both the temperature and productivity regimes within the whole study area; therefore, the in-stream DO also would be dependent on the upstream conditions.

- Chlorophyll *a* levels throughout the study area are predicted to increase slightly from current conditions with each operational-change scenario. This seems mainly due to the reduced settling in the Prosser to Chandler reach. Chlorophyll *a* concentrations are predicted to decline in comparison to upstream boundary conditions, but a flow-through situation with slight losses is likely. In all cases, the study area would remain an enriched system predominately influenced by upstream boundary conditions.

# References


APHA et al., 1985. Standard Methods for the Examination of Water and Wastewater. Sixteenth edition. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington D.C.

Aroner, E., 1994. WQHYDRO: Water Quality/Hydrology Graphics/Analysis System. April 1994. P.O. Box 18149, Portland, OR.

Bostrom, B., M. Jansson, and C. Forsberg, 1982. Phosphorus release from lake sediments. Arch. Hydrobiol. Beih. Ergebn. Limnol., 18: 5-59, Stuttgart, November 1982.

Brown, L. and T. Barnwell, Jr., 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual. EPA/600/3-87/007. U.S. Environmental Protection Agency, ORD, Athens, GA.

Glenn, N, 1994. Quality Assurance Project Plan for Basin Class II Inspections. Environmental Assessments Program, Washington State Department of Ecology, Olympia, WA.

Hubbard, E., F. Kilpatrick, L. Martens, and J. Wilson, Jr., 1982. Measurement of Time of Travel and Dispersion in Streams by Dye Tracing. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Chapter A9, Book 3; Applications of Hydraulics. U.S. Government Printing Office, Washington D.C.

Joy, J., 1993. Snoqualmie River Total Maximum Daily Load Study. Publication 94-e25. Washington State Department of Ecology, Olympia, WA.

Joy, J., and B. Patterson, 1997. A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River. Publication 97-321. Washington State Department of Ecology, Olympia, WA.

Mathess, G., 1982. The Properties of Groundwater. Publishers John Wiley & Sons, Inc., New York, NY.

MEL, 1994. Manchester Environmental Laboratory Lab Users Manual. Washington State Department of Ecology, Manchester, WA.

Monk, P., 1999. Personal communication**.** Thomas R. Payne & Associates, Yakima, WA.

Payne, Thomas R. & Associates, and Monk, P., 1999. Yakima River Water Temperature Model: Prosser Diversion to Chandler Powerhouse (1998 Supplement); Report to the Yakima River Basin Defense Coalition, Yakima, WA.

Pelletier, G., 1993. Puyallup River Total Maximum Daily Load for Biochemical Oxygen Demand, Ammonia, and Residual Chlorine. Publication 96-326. Washington State Department of Ecology, Olympia, WA.

Pelletier, G., 1997. Colville River Water Quality: Pollutant Loading Capacity and Recommendations for Total Maximum Daily Loads. Publication 96-349. Washington State Department of Ecology, Olympia, WA.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, and P. Knudsen, 1990. Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington. TFW-WQ3-90-006. Washington State Department of Natural Resources, Olympia, WA.

Theurer, F.D., K.A. Voos, and W. J. Miller, 1984. Instream water temperature model. Instream Flow Information Paper 16. U.S. Fish Wildl. Serv. FWS/OBS-84/15.

Thomann, R.V. and J.A. Mueller, 1987. Principles of Surface Water Modeling and Control. Harper and Row Publishers, Inc. New York, NY.

USEPA, 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA/600/3-85/040. U.S. Environmental Protection Agency, Athens, GA.

USEPA, 1987. The Enhanced Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and users manual. EPA/600/3-87/007. U.S. Environmental Protection Agency.

USEPA, 1991. Instruction materials for the workshop on The Stream Water Quality and Uncertainty Model: QUAL2EU. July 24-28, 1991. U.S. Environmental Protection Agency, Athens, GA.

USGS, 1985. Water in the Lower Yakima River Basin, Washington. Water-Supply Bulletin 53, U.S. Geological Society.

WAS, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA.

Wilson, Jr., J.F., 1968. Fluorometric Procedures for Dye Tracing. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Chapter A12, Book 3; Applications of Hydraulics. U.S. Government Printing Office, Washington D.C.

# Appendices

# Appendix A

# Laboratory and field results

Appendix A. Laboratory data summary of Ecology field surveys for the Lower Yakima River modeling project.

| Sample ID | Station Name | Station # | Date | SampleTime | Ammonia-N | BOD | Chloride | Chlorophyll a | Conductivity | DOC | Fecal Coliform | Hardness | Nitrite-Nitrate | Dissolved Phophorus | Total Phosphorus | Alkalinity | TOC | Total Persulfate Nitrogen | Total Suspended Solids | Turbidity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mg/L | mg/L | mg/L | ug/L | umhos/cm | mg/L | #/100mL | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU |
| 00308180 | BRCHANUP | 1 | 25-Jul-00 | 9:30:00 AM | 0.010 U | 4 U | 5.13 | 16.5 | | 1.7 | 130 | 101 | 1.020 | 0.052 | 0.087 | 106 | 2.6 | 1.2 | 26 | 10.0 |
| 00308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.010 U | 4 U | 5.05 | 16.9 | | 2.0 | 120 | 103 | 1.000 | 0.050 | 0.087 | 106 | 2.2 | 1.2 | 22 | 9.9 |
| 00308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.010 U | 4 U | 4.99 | 15.5 | | 1.9 | 100 | 102 | 0.998 | 0.048 | 0.081 | 104 | 2.1 | 1.18 | 22 | 11.0 |
| 00308202 | BRPROSWW | 2 | 26-Jul-00 | 10:35:00 AM | 0.523 | 8 | 85.2 | | | 8.6 | | | 1.310 | | 7.490 | | 11.4 | 3.28 | 11 | 5.2 |
| 00308183 | BRBLPROS | 3 | 25-Jul-00 | 2:40:00 PM | 0.010 U | | 5.3 | 18.4 | | | 200 | 101 | 1.030 | | 0.103 | 107 | | 1.25 | 18 | 6.8 |
| 00308184 | YAK-17 | 5 | 25-Jul-00 | 12:40:00 PM | 0.010 U | | 4.33 | | | | 260 | | 0.740 | 0.037 | 0.076 | | | 0.913 | 32 | 10.0 |
| 00308185 | YAK-19 | 6 | 25-Jul-00 | 12:15:00 PM | 0.010 U | | 7.33 | | | | 420 | | 0.799 | 0.044 | 0.082 J | | | 0.987 | 8 | 3.0 |
| 00308190 | BRABCHAN | 7 | 25-Jul-00 | 3:25:00 PM | 0.017 | | 6.12 | 7.5 | | | 14 | | 1.080 | 0.139 | 0.153 | 111 | | 1.3 | 10 | 4.7 |
| 00308192 | BRABCHAN | 7 | 25-Jul-00 | 9:00:00 AM | 0.024 | | 6.03 | 9.2 | | | 51 | 105 | 1.060 | 0.137 | 0.151 | 108 | | 1.29 | 14 | 6.3 |
| 00308181 | BRCHANRE | 8 | 25-Jul-00 | 11:00:00 AM | 0.010 U | 4 U | 5.04 | 17.9 | | 1.6 | 57 | 92.6 | 0.963 | 0.091 | 0.117 | 102 | 1.9 | 1.17 | 16 | 7.0 |
| 00308186 | BRCHANRE | 8 | 25-Jul-00 | 3:40:00 PM | 0.010 U | | 4.93 | 20.7 | | | 40 | | 0.932 | 0.065 | 0.095 | 102 | | 1.15 | 17 | 8.5 |
| 00308193 | BRBLCHAN | 9 | 25-Jul-00 | 10:25:00 AM | 0.010 U | | 5.49 | 13.6 | | | 37 | 101 | 0.997 | 0.114 | 0.128 | 105 | | 1.21 | 15 | 6.7 |
| 00308187 | BRCORRAL | 10 | 25-Jul-00 | 11:45:00 AM | 0.010 U | | 4.63 | | | | 100 | | 1.050 | | 0.070 | | | 1.21 | 25 | 7.0 |
| 00308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 0.010 U | 4 U | 5.57 | 11.6 | | 1.8 | 26 | 102 | 0.993 | 0.105 | 0.126 | 106 | 1.9 | 1.2 | 15 | 6.4 |
| 00308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 0.010 U | 4 U | 5.58 | 13.3 | | 1.8 | 11 | 104 | 0.972 | 0.105 | 0.125 | 106 | 1.9 | 1.19 | 15 | 6.9 |
| 00308195 | BRBLBENT | 13 | 25-Jul-00 | 2:00:00 PM | 0.011 | | 5.59 | 11.8 | | | 31 | 102 | 0.980 | | 0.118 | 106 | | 1.28 | 17 | 7.2 |
| 00308196 | BRABWANA | 14 | 25-Jul-00 | 3:45:00 PM | 0.010 U | 4 U | 5.5 | 14.3 | | 1.7 | 34 | 103 | 0.915 | 0.081 | 0.101 | 105 | 2.0 | 1.12 | 12 | 5.1 |
| 00308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.010 | | 5.65 | 9.6 | | | 53 | 102 | 0.921 | 0.095 | 0.136 | 106 | | 1.14 | 68 | 6.4 |
| 00308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.016 | | 5.59 | 25.9 | | | | 103 | 0.902 | 0.096 | 0.129 | 106 | | 1.16 | 25 | 6.6 |
| 00308199 | YAK-7 | 15 | 26-Jul-00 | 9:26:00 AM | 0.010 U | | 5.74 | 9.3 | | | 27 | 101 | 0.917 | 0.094 | 0.118 | 107 | | 1.14 | 14 | 6.2 |
| 00308207 | YAK-7 | 15 | 26-Jul-00 | 2:30:00 PM | 0.010 U | | 5.72 | 10.7 | | | 18 | 101 | 0.884 | 0.101 | 0.127 | 107 | | 1.11 | 14 | 6.0 |
| 00308205 | BRBLWANA | 16 | 26-Jul-00 | 10:00:00 AM | 0.018 | 4 U | 5.68 | 7.6 | | 2.0 | 20 | 102 | 0.885 | 0.102 | 0.135 | 106 | 2.1 | 1.15 | 16 | 6.5 |
| 00308206 | BRTWINBR | 17 | 26-Jul-00 | 10:48:00 AM | 0.010 U | | 5.71 | 9.0 | | | 25 | 101 | 0.902 | 0.103 | 0.133 | 107 | | 1.14 | 12 | 6.0 |
| 00308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.010 U | 4 U | 5.86 | 10.5 | | 2.0 | 23 | 99.4 | 0.872 | 0.096 | 0.126 | 107 | 2.3 | 1.09 | 13 | 5.4 |
| 00308209 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.010 U | | 5.8 | 10.9 | | | 15 | 93.8 | 0.860 | 0.096 | 0.127 | 107 | | 1.1 | 12 | 5.5 |
| 99398280 | BRCHANUP | 1 | 28-Sep-99 | 12:50:00 PM | 0.041 | 4 U | 5.2 | 3.9 | 230 | 1.7 | 63 | 90.3 | 1.040 | 0.054 | 0.111 | 95.4 | 1.6 | 1.24 | 16 | 5.8 |
| 99398281 | BRPROSWW | 2 | 28-Sep-99 | 10:26:00 AM | 0.283 | | 86.5 | | 999 | | 230 | | 0.230 | | 0.300 | | | 1.64 | 13 | 6.7 |
| 99398299 | BRPROSWW | 2 | 29-Sep-99 | 12:10:00 PM | 0.089 | | 98.5 | | 1050 | | | | 0.307 | | 2.250 | | | 1.64 | 9 | 6.1 |
| 99398300 | BRPROSWW | 2 | 29-Sep-99 | 12:00:00 AM | 0.046 | 6 | 86.7 | | 1010 | 6.8 | | | 0.299 | | 2.540 | | 9.5 | 1.61 | 11 | 7.3 |
| 99398282 | BRBLPROS | 3 | 28-Sep-99 | 1:30:00 PM | 0.041 | | 6.0 | 3.7 | 242 | 1.7 | 120 | 90.1 | 1.100 | 0.083 | 0.150 | 99.7 | 1.6 | 1.27 | 12 | 6.2 |
| 99398283 | BRTREETO | 4 | 28-Sep-99 | 12:00:00 PM | 0.029 | | 17.4 | | 483 | | 1 | | 0.010 U | | 0.113 | | | 0.19 | 5 | 3.3 |
| 99398301 | BRTREETO | 4 | 29-Sep-99 | 1:10:00 PM | 0.079 | | 14.1 | | 442 | | 40 | | 0.015 | | 0.138 | | | 0.33 | 8 | 1.0 |
| 99398302 | BRTREETO | 4 | 29-Sep-99 | 12:00:00 AM | 0.077 | 11 | 18.9 | | 486 | 6.6 | | | 0.014 | | 0.138 | | 7.0 | 0.29 | 1 | 0.7 |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 0.035 | | 5.6 | | 214 | | 250 | | 0.862 | | 0.145 | | | 1.05 | 60 | 17.0 |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 0.040 | | 5.6 | | 214 | | 220 | | 0.865 | | 0.147 | | | 1.07 | 59 | 16.0 |
| 99398285 | YAK-19 | 6 | 28-Sep-99 | 2:20:00 PM | 0.039 | | 4.5 | | 198 | | 74 | | 0.406 | | 0.089 | | | 0.61 | 24 | 9.1 |
| 99398286 | BRABCHAN | 7 | 28-Sep-99 | 10:00:00 AM | 0.044 | 4 U | 5.9 | 4.3 | 243 | 1.6 | 190 | 93.4 | 1.130 | 0.080 | 0.138 | 100.0 | 1.7 | 1.30 | 11 | 6.0 |
| 99398287 | BRCHANRE | 8 | 28-Sep-99 | 2:50:00 PM | 0.040 | | 5.2 | | 231 | 1.6 | 23 | 86.3 | 1.070 | 0.057 | 0.113 | 95.4 | 1.7 | 1.22 | 12 | 7.4 |
| 99398297 | BRCHANRE | 8 | 28-Sep-99 | 2:55:00 PM | | | | | | | 28 | | | | | | | | | |
| 99398288 | BRBLCHAN | 9 | 28-Sep-99 | 12:15:00 PM | 0.042 | | 5.5 | 3.7 | 236 | 1.5 | 54 | 97.5 | 1.090 | 0.065 | 0.125 | 98.3 | 1.6 | 1.24 | 13 | 6.8 |
| 99398289 | BRCORRAL | 10 | 28-Sep-99 | 3:05:00 PM | 0.031 | | 5.2 | | 292 | | 31 | | 1.040 | | 0.106 | | | 1.21 | 37 | 8.0 |
| 99398291 | YAK-6 | 12 | 28-Sep-99 | 2:30:00 PM | 0.038 | | 5.9 | 3.7 | 239 | 1.7 | 55 | | 1.080 | 0.067 | 0.126 | 99.5 | 1.7 | 1.24 | 11 | 6.8 |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 0.039 | 4 U | 5.8 | 3.3 | 240 | 1.7 | 43 | 95.0 | 1.020 | 0.067 | 0.124 | 99.1 | 1.8 | 1.23 | 11 | 6.2 |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 0.040 | | 5.8 | 3.5 | 240 | 1.6 | 26 | 91.1 | 1.030 | 0.070 | 0.123 | 98.9 | 1.7 | 1.24 | 11 | 6.5 |
| 99398293 | BRABWANA | 14 | 28-Sep-99 | 6:45:00 PM | 0.041 | | 6.0 | 3.4 | 242 | 1.5 | 3 | 96.3 | 1.090 | 0.068 | 0.124 | 100.0 | 1.8 | 1.24 | 12 | 6.1 |
| 99398298 | BRABWANA | 14 | 29-Sep-99 | 9:35:00 AM | 0.046 | | 5.9 | 3.3 | 240 | 1.6 | 24 | 90.8 | 1.050 | 0.068 | 0.116 | 99.2 | 1.8 | 1.23 | 11 | 6.5 |
| 99398294 | YAK-7 | 15 | 28-Sep-99 | 4:20:00 PM | 0.037 | | 6.0 | | 242 | | 14 | | 1.090 | | 0.119 | | | 1.20 | 12 | 4.6 |
| 99398308 | YAK-7 | 15 | 29-Sep-99 | 2:00:00 PM | 0.031 | | 6.0 | 4.8 | 239 | 1.6 | 6 | 88.7 | 1.020 | 0.066 | 0.119 | 100.0 | 1.8 | 1.17 | 10 | 6.3 |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 0.037 | 4 U | 5.8 | 4.2 | 240 | 1.8 | 14 | 89.8 | 1.050 | 0.068 | 0.122 | 99.1 | 1.8 | 1.20 | 10 | 6.4 |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 0.037 | | 5.8 | 4.0 | 239 | 1.6 | 9 | 93.5 | 1.050 | 0.069 | 0.120 | 99.1 | 1.7 | 1.20 | 11 | 6.8 |
| 99398304 | BRTWINBR | 17 | 29-Sep-99 | 11:45:00 AM | 0.037 | | 6.1 | 4.2 | 241 | 1.8 | 6 | 87.1 | 1.030 | | 0.120 | 99.8 | 1.7 | 1.18 | 11 | 6.6 |
| 99398306 | BRWRICHW | 19 | 29-Sep-99 | 10:58:00 AM | 0.090 | | 150.0 | | 1030 | | 6 | | 24.400 | | 3.630 | | | 23.10 | 50 | 1.9 |
| 99398307 | BRWRICHW | 19 | 29-Sep-99 | 12:00:00 AM | 0.046 | 4 U | | | | 4.4 | | | 25.000 | | 3.920 | | 4.9 | 23.30 | | |
| 99398311 | BRWRICHW | 19 | 29-Sep-99 | 5:35:00 PM | | | 145.0 | | 1020 | | 4 | | | | | | | | 6 | 2.6 |
| 99398309 | BRHWY182 | 20 | 29-Sep-99 | 3:45:00 PM | 0.036 | 4 U | 6.2 | 5.4 | 244 | 1.6 | 11 | 101.0 | 1.020 | 0.066 | 0.119 | 100.0 | 1.9 | 1.19 | 16 | 7.0 |

U = below detection limit J = estimated

**Lower Yakima Field Data Collected 09/27-30/1999**

| R.M. | station | stn name | date | time | temp | do | wink | comment | cond | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 47.2 | 1 | BRCHANUP | 9/27/99 | 1335 | | | 10.45 | | | |
| 36.0 | 7 | BRABCHAN | 9/27/99 | 1442 | | | 11.67 | | | |
| 29.8 | 12 | YAK-6 | 9/27/99 | 1540 | | | 11.41 | | | |
| 8.6 | 15 | YAK-7 | 9/27/99 | 1701 | | | 11.99 | | | |
| 18.8 | 14 | BRABWANA | 9/27/99 | 1808 | | | 11.57 | | | |
| 47.2 | 1 | BRCHANUP | 9/28/99 | 1250 | 14.1 | | 10.2 | | 250 | |
| 46.6 | 2 | BRPROSWW | 9/28/99 | 1026 | 19.6 | | | | 975 | |
| 45.8 | 3 | BRBLPROS | 9/28/99 | 1330 | 14.4 | | 10.76 | | 250 | |
| 45.2 | 4 | BRTREETO | 9/28/99 | 1200 | 15.8 | | | | | |
| 41.8 | 5 | YAK-17 | 9/28/99 | 1400 | 14.3 | | 10.4 | | 225 | |
| 41.6 | 6 | YAK-19 | 9/28/99 | 1420 | 13.8 | | 10.71 | | 205 | |
| 36.0 | 7 | BRABCHAN | 9/28/99 | 1000 | 12.58 | 10.56 | 10.4 | read @0930 | 244 | 8.02 |
| 35.8 | 8 | BRCHANRE | 9/28/99 | 1450 | 14.8 | | 10.3 | | 190 | |
| 35.0 | | | 9/28/99 | 1117 | 12.86 | 11.01 | | | 242 | 8.13 |
| 34.0 | 9 | BRBLCHAN | 9/28/99 | 1211 | 13.52 | 10.61 | 11.05 | | 235 | 8.12 |
| 33.5 | 10 | BRCORRAL | 9/28/99 | 1505 | 14.1 | | 10.2 | | | |
| 33.0 | | | 9/28/99 | 1254 | 13.62 | 11.2 | | | 237 | 8.19 |
| 31.0 | | | 9/28/99 | 1343 | 14.05 | 11.48 | | | 240 | 8.19 |
| 29.8 | 12 | YAK-6 | 9/28/99 | 1438 | 14.56 | 11.58 | 11.72 | | 242 | 8.26 |
| 29.0 | | | 9/28/99 | 1525 | 14.45 | 11.53 | | | 240 | 8.23 |
| 27.0 | 13 | BRBLBENT | 9/28/99 | 1648 | 14.66 | 11.51 | 11.77 | 12.02 (dup) | 241 | 8.3 |
| 22.0 | | | 9/28/99 | 1758 | 14.75 | 11.36 | | | 242 | 8.3 |
| 18.8 | 14 | BRABWANA | 9/28/99 | 1858 | 14.76 | 11.24 | 11.41 | | 244 | 8.37 |
| 8.6 | 15 | YAK-7 | 9/28/99 | 1620 | 15.4 | | 12.27 | | 250 | |
| 18.8 | 14 | BRABWANA | 9/29/99 | 935 | 13 | | 10.3 | | 220 | |
| 16.2 | 16 | BRBLWANA | 9/29/99 | 1001 | 12.86 | 10.49 | 10.4 | 10.45 (dup) 10 min. | 239 | 8.2 |
| 14.4 | | | 9/29/99 | 1106 | 13.19 | 11.27 | | | 239 | 8.25 |
| 12.8 | 17 | BRTWINBR | 9/29/99 | 1155 | 13.42 | 11.33 | 11.18 | 10 min earlier | 240 | 8.27 |
| 9.8 | | | 9/29/99 | 1320 | 13.69 | 11.33 | | | 240 | 8.24 |
| 9.6 | 19 | BRWRICHW | 9/29/99 | 1058 | 18 | | 4.19 | | 1100 | |
| 8.6 | 15 | YAK-7 | 9/29/99 | 1421 | 14.07 | 11.66 | 11.61 | | 240 | 8.36 |
| 5.6 | 20 | BRHWY182 | 9/29/99 | 1600 | 14.6 | 11.9 | 12.02 | | 245 | 8.36 |
| 46.6 | 2 | BRPROSWW | 9/29/99 | 1210 | 19.8 | | 8.3 | | 1100 | |
| 46.6 | 2 | BRPROSWW | 9/29/99 | 24hr | 4 | | | | | |
| 45.2 | 4 | BRTREETO | 9/29/99 | 1310 | 28.5 | | | | 500 | |
| 45.2 | 4 | BRTREETO | 9/29/99 | 24hr | 11.6 | | | | 500 | |
| 9.6 | 19 | BRWRICHW | 9/29/99 | 6hr | | | | | | |
| 47.2 | 1 | BRCHANUP | 9/29/99 | 1334 | 14.2 | | 10.2 | | | |
| 47.2 | 1 | BRCHANUP | 9/30/99 | 850 | 14.4 | | 9.85 | | | |
| 47.0 | | | 9/30/99 | 918 | 13.5 | | 10.56 | | | |
| 36.0 | 7 | BRABCHAN | 9/30/99 | 1005 | 13.3 | | 10.5 | | | |
| 29.8 | 12 | YAK-6 | 9/30/99 | 1045 | 13.8 | | 10.61 | | | |
| 18.8 | 14 | BRABWANA | 9/30/99 | 1131 | 13.6 | | 10.35 | | | |
| 8.6 | 15 | YAK-7 | 9/30/99 | 1220 | 14.6 | | 10.96 | | | |

Lower Yakima Field Data Collected 07/25-26/2000

| R.M. | station | stn name | date | time | temp | do | wink | comment | cond | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 47.2 | 1 | BRCHANUP | 7/25/00 | 930 | 22.80 | | 9.3 | | 261 | 8.36 |
| 36.0 | 7 | BRABCHAN | 7/25/00 | 1525 | 25.40 | | 10.7 | | 285 | 8.64 |
| 29.8 | 12 | YAK-6 | 7/25/00 | 1155 | 23.93 | | 9.3 | | 243 | 8.40 |
| 47.2 | 1 | BRCHANUP | 7/25/00 | 1345 | 24.00 | | 10.3 | | 251 | 8.50 |
| 45.8 | 3 | BRBLPROS | 7/25/00 | 1440 | 24.40 | | 9.6 | | 260 | 8.52 |
| 41.8 | 5 | YAK-17 | 7/25/00 | 1240 | 21.50 | | | | 215 | 8.31 |
| 41.6 | 6 | YAK-19 | 7/25/00 | 1215 | 20.90 | | 8.7 | | 280 | 8.01 |
| 36.0 | 7 | BRABCHAN | 7/25/00 | 900 | 22.09 | | 7.9 | | 250 | 8.18 |
| 35.8 | 8 | BRCHANRE | 7/25/00 | 1100 | 23.50 | | 10.2 | | 251 | 8.37 |
| 35.8 | 8 | BRCHANRE | 7/25/00 | 1540 | 24.50 | | 10.8 | | 258 | 8.66 |
| 34.0 | 9 | BRBLCHAN | 7/25/00 | 1025 | 23.07 | | 8.7 | | 242 | 8.33 |
| 33.5 | 10 | BRCORRAL | 7/25/00 | 1145 | 18.70 | | 9.1 | | 358 | 8.18 |
| 27.0 | 13 | BRBLBENT | 7/25/00 | 1400 | 24.84 | | 9.3 | | 244 | 8.42 |
| 18.8 | 14 | BRABWANA | 7/25/00 | 1548 | 25.36 | | 9.7 | | 241 | 8.59 |
| 18.8 | 14 | BRABWANA | 7/26/00 | 920 | 21.60 | | 8.2 | | 268 | 8.46 |
| 16.2 | 16 | BRBLWANA | 7/26/00 | 1000 | 22.74 | | | | 244 | 8.43 |
| 47.2 | 1 | BRCHANUP | 7/26/00 | 1020 | 22.20 | | 9.5 | | 270 | 8.36 |
| 12.8 | 17 | BRTWINBR | 7/26/00 | 1048 | 23.28 | | 9.1 | | 246 | 8.94 |
| 8.6 | 15 | YAK-7 | 7/26/00 | 926 | 22.63 | | 7.9 | | 247 | 8.30 |
| 5.6 | 20 | BRHWY182 | 7/26/00 | 1430 | 25.30 | | 10.0 | | 270 | 8.75 |
| 46.6 | 2 | BRPROSWW | 7/26/00 | 24hr | 26.00 | 9.2 | | | 1000 | 7.70 |
| 45.8 | 3 | BRBLPROS | 7/26/00 | 1110 | 22.50 | | 9.4 | | 270 | 8.40 |
| 5.6 | 20 | BRHWY182 | 7/26/00 | 900 | | | 8.6 | | | |
| 36.0 | 7 | BRABCHAN | 7/26/00 | 1150 | 23.10 | | 9.7 | | 275 | 8.42 |
| 29.8 | 12 | YAK-6 | 7/26/00 | 1215 | 24.10 | | 9.9 | | 265 | 8.53 |
| 8.6 | 15 | YAK-7 | 7/26/00 | 1430 | 24.92 | | 9.7 | | 244 | 8.51 |

# Appendix B

# Quality assurance and quality control: Field duplicate analyses

LOWER YAKIMA LAB QA/QC DATA - p.1

| SampleId | Stn. Id | Stn. | SampleDate | SampleTime | Ammonia | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.01 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.01 | 0.01 | 0.00000 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 0.01 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 0.01 | 0.01 | 0.00000 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.01 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.016 | 0.013 | 0.00424 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.01 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.01 | 0.01 | 0.00000 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 0.04 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 0.035 | 0.0375 | 0.00354 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 0.039 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 0.04 | 0.0395 | 0.00071 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 0.037 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 0.037 | 0.037 | 0.00000 | | | |
| | | | | | | 0.022 | | 9.38% | 0.00 | 13.27% |

| SampleId | Stn. Id | Stn. | SampleDate | SampleTime | Chloride | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 5.05 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 4.99 | 5.02 | 0.04243 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 5.57 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 5.58 | 5.575 | 0.00707 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 5.65 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 5.59 | 5.62 | 0.04243 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 5.86 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 5.8 | 5.83 | 0.04243 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 5.62 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 5.61 | 5.615 | 0.00707 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 5.78 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 5.81 | 5.795 | 0.02121 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 5.82 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 5.81 | 5.815 | 0.00707 | | | |
| | | | | | | 5.61 | | 0.52% | 0.04 | 0.74% |

| SampleId | Stn. Id | Stn. | SampleDate | SampleTime | Nitrite-Nitrate | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 1 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.998 | 0.999 | 0.00141 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 0.993 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 0.972 | 0.9825 | 0.01485 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.921 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.902 | 0.9115 | 0.01344 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.872 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.86 | 0.866 | 0.00849 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 0.865 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 0.862 | 0.8635 | 0.00212 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 1.02 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 1.03 | 1.025 | 0.00707 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 1.05 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 1.05 | 1.05 | 0.00000 | | | |
| | | | | | | 0.957 | | 0.91% | 0.01 | 1.29% |

| SampleId | Stn. Id | Stn. | SampleDate | SampleTime | TP | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.087 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.081 | 0.084 | 0.00424 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 0.126 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 0.125 | 0.1255 | 0.00071 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.136 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.129 | 0.1325 | 0.00495 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.126 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.127 | 0.1265 | 0.00071 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 0.147 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 0.145 | 0.146 | 0.00141 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 0.124 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 0.123 | 0.1235 | 0.00071 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 0.122 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 0.12 | 0.121 | 0.00141 | | | |
| | | | | | | 0.12 | | 2.13% | 0.00 | 3.02% |

LOWER YAKIMA LAB QA/QC DATA - p.2

| SampleId | Stn. Id | Stn. Na | SampleDate | SampleTime | TPN | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 1.2 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 1.18 | 1.19 | 0.01414 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 1.2 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 1.19 | 1.195 | 0.00707 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 1.14 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 1.16 | 1.15 | 0.01414 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 1.09 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 1.1 | 1.095 | 0.00707 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 1.07 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 1.05 | 1.06 | 0.01414 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 1.23 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 1.24 | 1.235 | 0.00707 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 1.2 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 1.2 | 1.2 | 0.00000 | | | |
| | | | | | | 1.16 | | 0.89% | 0.01 | 1.26% |

| SampleId | Stn. Id | Stn. Na | SampleDate | SampleTime | TSS | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 22 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 22 | 22 | 0.00000 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 15 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 15 | 15 | 0.00000 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 25 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 68 | 46.5 | 30.40559 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 12 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 13 | 12.5 | 0.70711 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 59 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 60 | 59.5 | 0.70711 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 11 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 11 | 11 | 0.00000 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 10 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 11 | 10.5 | 0.70711 | | | |
| | | | | | | 25.29 | | 1.98% | 0.71 | 2.80% |

| SampleId | Stn. Id | Stn. Na | SampleDate | SampleTime | Turbidity | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 9.9 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 11 | 10.45 | 0.77782 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 6.4 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 6.9 | 6.65 | 0.35355 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 6.4 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 6.6 | 6.5 | 0.14142 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 5.4 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 5.5 | 5.45 | 0.07071 | | | |
| 99398296 | YAK-17 | 5 | 28-Sep-99 | 2:05:00 PM | 16 | | | | | |
| 99398284 | YAK-17 | 5 | 28-Sep-99 | 2:00:00 PM | 17 | 16.5 | 0.70711 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 6.2 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 6.5 | 6.35 | 0.21213 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 6.4 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 6.8 | 6.6 | 0.28284 | | | |
| | | | | | | 8.36 | | 5.31% | 0.63 | 7.51% |

| SampleId | Stn. Id | Stn. Na | SampleDate | SampleTime | Chlorophyll | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 16.9 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 15.5 | 16.2 | 0.98995 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 11.6 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 13.3 | 12.45 | 1.20208 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 9.6 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 25.9 | 17.75 | 11.52584 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 10.5 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 10.9 | 10.7 | 0.28284 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 3.32 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 3.47 | 3.395 | 0.10607 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 4.15 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 4.03 | 4.09 | 0.08485 | | | |
| | | | | | | 10.76 | | 6.60% | 1.00 | 9.33% |

| SampleId | Stn. Id | Stn. Na | SampleDate | SampleTime | Ortho-P | Mean | S.D. | RSD CV% | RMSE | RMSE CV% |
|---|---|---|---|---|---|---|---|---|---|---|
| 308189 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.05 | | | | | |
| 308191 | BRCHANUP | 1 | 25-Jul-00 | 1:45:00 PM | 0.048 | 0.049 | 0.00141 | | | |
| 308194 | YAK-6 | 12 | 25-Jul-00 | 11:55:00 AM | 0.105 | | | | | |
| 308197 | YAK-6 | 12 | 25-Jul-00 | 12:15:00 PM | 0.105 | 0.105 | 0.00000 | | | |
| 308198 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.095 | | | | | |
| 308204 | BRABWANA | 14 | 26-Jul-00 | 9:20:00 AM | 0.096 | 0.0955 | 0.00071 | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.101 | | | | | |
| 308208 | BRHWY182 | 20 | 26-Jul-00 | 2:30:00 PM | 0.096 | 0.0985 | 0.00354 | | | |
| 99398292 | BRBLBENT | 13 | 28-Sep-99 | 4:30:00 PM | 0.067 | | | | | |
| 99398295 | BRBLBENT | 13 | 28-Sep-99 | 4:45:00 PM | 0.07 | 0.0685 | 0.00212 | | | |
| 99398303 | BRBLWANA | 16 | 29-Sep-99 | 9:30:00 AM | 0.068 | | | | | |
| 99398310 | BRBLWANA | 16 | 29-Sep-99 | 9:45:00 AM | 0.069 | 0.0685 | 0.00071 | | | |
| | | | | | | 0.081 | | 2.26% | 0.00 | 3.19% |

# Appendix C

## QUAL2E input files for calibration and confirmation model runs

```
TITLE01             LOWER YAKIMA WATER QUALITY MODEL-CALIBRATION
TITLE02             PRE-CALIBRATED MODEL RM 47.2 TO RM 5.6; JULY 2000
TITLE03  YES        CONSERVATIVE MINERAL I       CL    MG/L
TITLE04   NO        CONSERVATIVE MINERAL II
TITLE05   NO        CONSERVATIVE MINERAL III
TITLE06  YES        TEMPERATURE
TITLE07  YES        BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        ALGAE AS CHL-A IN UG/L
TITLE09  YES        PHOSPHORUS CYCLE AS P IN MG/L
TITLE10               (ORGANIC-P, DISSOLVED-P)
TITLE11  YES        NITROGEN CYCLE AS N IN MG/L
TITLE12               (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13  YES        DISSOLVED OXYGEN IN MG/L
TITLE14   NO        FECAL COLIFORMS IN NO./100 ML
TITLE15  YES        ARBITRARY NON-CONSERVATIVE  TSS    MG/L
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=   0.00000         5D-ULT BOD CONV K COEF  =   0.00000
INPUT METRIC (YES=1)    =   0.00000         OUTPUT METRIC (YES=1)   =   0.00000
NUMBER OF REACHES       =  14.00000         NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000         NUMBER OF POINT LOADS   =   8.00000
TIME STEP (HOURS)       =                   LNTH  COMP  ELEMENT (DX)=   0.20000
MAXIMUM ITERATIONS      =  100.0000         TIME INC. FOR RPT2 (HRS)=
LATITUDE OF BASIN (DEG) =   46.2500         LONGITUDE OF BASIN (DEG)=   119.500
STANDARD MERIDIAN (DEG) =  120.0000         DAY OF YEAR START TIME  =   206.000
EVAP. COEFF. (AE)       =   0.00068         EVAP. COEFF. (BE)       =   0.00027
ELEV. OF BASIN (ELEV)   = 461.00000         DUST ATTENUATION COEF.  = 0.1000000
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)= 3.4300  O UPTAKE BY NO2 OXID(MG O/MG N)= 1.1400
O PROD  BY ALGAE (MG O/MG A)   = 1.6000  O UPTAKE BY ALGAE (MG O/MG A)  = 2.0000
N CONTENT OF ALGAE (MG N/MG A) = 0.0800  P CONTENT OF ALGAE (MG P/MG A) = 0.0110
ALG MAX SPEC GROWTH RATE(1/DAY)= 2.3000  ALGAE RESPIRATION RATE (1/DAY) = 0.1200
N HALF SATURATION CONST (MG/L) = 0.0300  P HALF SATURATION CONST  (MG/L)= 0.0050
LIN ALG EXCO (1/FT)/(UGCHLA/L) = 0.0027  NLINCO (1/FT)/(UGCHLA/L)**(2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) = 3.0000  LIGHT SAT'N COEFF (BTU/FT2/MIN)= 0.5125
DAILY AVERAGING OPTION (LAVOPT)=      3  LIGHT AVERAGING FACTOR (AFACT) = 1.0000
NUMBER OF DAYLIGHT HOURS (DLH) = 00.000  TOTAL DAILY SOLR RAD (BTU/FT2) = 0000.0
ALGY GROWTH CALC OPTION(LGROPT)= 2.0000  ALGAL PREF FOR NH3-N (PREFN)   = 0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)= 0.4500  NITRIFICATION INHIBITION COEF  = 0.6000
ENDATA1A
THETA    BOD SETT    1.000
THETA    SOD RATE    1.080
THETA    ORGN SET    1.000
THETA    NH3 DECA    1.080
THETA    PORG SET    1.000
THETA    ALG GROW    1.066
THETA    ALG SETT    1.000
ENDATA1B
STREAM REACH      1.RCH= PROSSER DAM       FROM         47.2    TO          47.0
STREAM REACH      2.RCH= PROSSER-BLWPROS   FROM         47.0    TO          45.8
STREAM REACH      3.RCH= BLWPROS-SNIPES    FROM         45.8    TO          41.8
STREAM REACH      4.RCH= SNIPES-BLWSNIPE   FROM         41.8    TO          37.8
STREAM REACH      5.RCH= BLWSNIPE-CHANDL   FROM         37.8    TO          36.0
STREAM REACH      6.RCH= CHANDL-CORRAL     FROM         36.0    TO          33.6
STREAM REACH      7.RCH= CORRAL-KIONA      FROM         33.6    TO          29.6
STREAM REACH      8.RCH= KIONA-BLWKIONA    FROM         29.6    TO          26.8
STREAM REACH      9.RCH= BLWKIONA-YAKIMA   FROM         26.8    TO          22.8
STREAM REACH     10.RCH= YAKIMA-ABWANAWI   FROM         22.8    TO          18.8
STREAM REACH     11.RCH= ABWANIW-BLWWANA   FROM         18.8    TO          16.2
STREAM REACH     12.RCH= BLWWANA-TWINBR    FROM         16.2    TO          12.4
STREAM REACH     13.RCH= TWINBR-VANGEISE   FROM         12.4    TO           8.4
STREAM REACH     14.RCH= VANGEISE-HWY182   FROM          8.4    TO           5.6
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         1           1
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FLAG FIELD RCH=   2.        6           2 2 6 2 2 2
FLAG FIELD RCH=   3.       20           2 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   4.       20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.        9           2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6.       12           2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   7.       20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   8.       14           2 2 2 2 2 2 2 2 7 2 2 2 2 2 2
FLAG FIELD RCH=   9.       20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  10.       20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.       13           2 2 2 2 7 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.       19           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  13.       20           2 2 2 2 2 2 2 2 2 2 2 2 6 2 2 2 2 2 2 2
FLAG FIELD RCH=  14.       14           2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=   1.             0.00023       1.0       5.0       0.0       0.03
HYDRAULICS RCH=   2.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   3.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   4.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   5.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   6.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   7.       140    0.0481     0.493     0.214     0.390       0.03
HYDRAULICS RCH=   8.       140    0.0312     0.552     0.192     0.371       0.03
HYDRAULICS RCH=   9.       140    0.0188     0.614     0.245     0.342       0.03
HYDRAULICS RCH=  10.       140    0.0183     0.608     0.240     0.348       0.03
HYDRAULICS RCH=  11.       140    0.0350     0.532     0.236     0.350       0.03
HYDRAULICS RCH=  12.       140    0.0167     0.629     0.369     0.298       0.03
HYDRAULICS RCH=  13.       140    0.0111     0.663     0.526     0.275       0.03
HYDRAULICS RCH=  14.       140    0.0161     0.631     0.419     0.291       0.03
ENDATA5
TEMP/LCD   RCH=   1.     461.00    0.1  0.000    72.2  60.23  29.38    7.0
ENDATA5A
REACT COEF RCH=   1.   0.230    0.00   -0.05   1      0.2
REACT COEF RCH=   2.   0.230   -0.26   -0.05   3
REACT COEF RCH=   3.   0.230   -0.26   -0.05   3
REACT COEF RCH=   4.   0.230   -0.26   -0.05   3
REACT COEF RCH=   5.   0.230   -0.26   -0.05   3
REACT COEF RCH=   6.   0.230   -0.36   -0.00   3
REACT COEF RCH=   7.   0.230   -0.36   -0.00   3
REACT COEF RCH=   8.   0.230   -0.26   -0.11   3
REACT COEF RCH=   9.   0.230   -0.26   -0.11   3
REACT COEF RCH=  10.   0.230   -0.26   -0.11   3
REACT COEF RCH=  11.   0.230   -0.26   -0.15   3
REACT COEF RCH=  12.   0.230   -0.56   -0.15   3
REACT COEF RCH=  13.   0.230   -0.66   -0.15   3
REACT COEF RCH=  14.   0.230   -0.66   -0.18   3
ENDATA6
N AND P COEF   RCH=   1.   0.10  0.000   1.20   1.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   2.   0.10  -1.00   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   3.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   4.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   5.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   6.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=   7.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   1.00
N AND P COEF   RCH=   8.   0.10  -3.60   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   9.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  10.   0.10  1.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  11.   0.10  -0.50   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=  12.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  13.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  14.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
ENDATA6A
ALG/OTHER COEF RCH=   1.    10.   0.50   0.26                 0.20
ALG/OTHER COEF RCH=   2.    10.   1.50   0.26                 0.60
ALG/OTHER COEF RCH=   3.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   4.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   5.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   6.    10.   3.20   0.26                 0.00
ALG/OTHER COEF RCH=   7.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=   8.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=   9.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=  10.    10.   6.00   0.26                 0.00
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ALG/OTHER COEF RCH=  11.     10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  12.     10.   1.50   0.26                 0.80
ALG/OTHER COEF RCH=  13.     10.   2.50   0.26                 0.00
ALG/OTHER COEF RCH=  14.     10.   2.50   0.26                 0.00
ENDATA6B
INITIAL COND-1 RCH=   1.   74.1
INITIAL COND-1 RCH=   2.   74.1
INITIAL COND-1 RCH=   3.   74.1
INITIAL COND-1 RCH=   4.   74.1
INITIAL COND-1 RCH=   5.   74.1
INITIAL COND-1 RCH=   6.   74.1
INITIAL COND-1 RCH=   7.   74.1
INITIAL COND-1 RCH=   8.   74.1
INITIAL COND-1 RCH=   9.   74.1
INITIAL COND-1 RCH=  10.   74.1
INITIAL COND-1 RCH=  11.   74.1
INITIAL COND-1 RCH=  12.   74.1
INITIAL COND-1 RCH=  13.   74.1
INITIAL COND-1 RCH=  14.   74.1
ENDATA7
INITIAL COND-2 RCH=   1.
INITIAL COND-2 RCH=   2.
INITIAL COND-2 RCH=   3.
INITIAL COND-2 RCH=   4.
INITIAL COND-2 RCH=   5.
INITIAL COND-2 RCH=   6.
INITIAL COND-2 RCH=   7.
INITIAL COND-2 RCH=   8.
INITIAL COND-2 RCH=   9.
INITIAL COND-2 RCH=  10.
INITIAL COND-2 RCH=  11.
INITIAL COND-2 RCH=  12.
INITIAL COND-2 RCH=  13.
INITIAL COND-2 RCH=  14.
ENDATA7A
INCR INFLOW-1  RCH=   1.     0.
INCR INFLOW-1  RCH=   2.   10.6   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   3.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   4.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   5.   15.9   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   6.   11.0   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   7.   18.4   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   8.  -43.3
INCR INFLOW-1  RCH=   9.  -61.9
INCR INFLOW-1  RCH=  10.  -61.9
INCR INFLOW-1  RCH=  11.    5.7   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  12.    8.3   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  13.    8.8   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  14.    6.1   53.4  10.6   1.5  11.5                      31
ENDATA8
INCR INFLOW-2  RCH=   1.
INCR INFLOW-2  RCH=   2.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   3.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   4.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   5.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   6.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   7.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   8.
INCR INFLOW-2  RCH=   9.
INCR INFLOW-2  RCH=  10.
INCR INFLOW-2  RCH=  11.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  12.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  13.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  14.         0.400  0.030  0.012  1.675  0.046  0.065
ENDATA8A
ENDATA9
HEADWTR-1 HDW=   1.  RM 47.2            628. 74.06  9.67  2.39  5.06
ENDATA10
HEADWTR-2  HDW=   1.    23   117  16.3 0.177 0.010 0.000 1.006 0.035 0.050
ENDATA10A
POINTLD-1 PTL=   1. PROSSER             1.18  78.8   9.2  11.7  85.2
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POINTLD-1 PTL=   2. SENECA              0.12  83.3   7.2  16.1  18.9
POINTLD-1 PTL=   3. SNIPES              67.0  70.3   8.7   2.0  5.49
POINTLD-1 PTL=   4. CHANDLER             716  75.2  9.67  1.90  4.99
POINTLD-1 PTL=   5. CORRAL              13.0  65.7   9.1   2.0  4.63
POINTLD-1 PTL=   6. KIONADIST          -20.0
POINTLD-1 PTL=   7. CID                 -234
POINTLD-1 PTL=   8. WRICHLAND            0.6  64.4  4.19  1.39  145.
ENDATA11
POINTLD-2  PTL=   1.    11   230       1.265 0.046 0.000 0.299 0.000 2.540
POINTLD-2  PTL=   2.     1    40       0.202 0.077 0.000 0.014 0.138 0.000
POINTLD-2  PTL=   3.    23   322  3.92 0.169 0.010 0.000 0.763 0.026 0.052
POINTLD-2  PTL=   4.  16.5    49  19.3 0.203 0.010 0.000 0.948 0.028 0.078
POINTLD-2  PTL=   5.    25   100  3.92 0.150 0.010 0.000 1.050 0.026 0.052
POINTLD-2  PTL=   6.
POINTLD-2  PTL=   7.
POINTLD-2  PTL=   8.    11     5       0.000 0.046 0.000  25.0  3.92 0.000
ENDATA11A
DAM DATA       DAM=   1.    2.    1.  1.60  1.05  1.00    6.
DAM DATA       DAM=   2.   11.    5.  1.60  1.05  1.00    4.
ENDATA12
ENDATA13
ENDATA13A
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TITLE01               LOWER YAKIMA WATER QUALITY MODEL-CONFIRMATION
TITLE02               PRE-CALIBRATED MODEL RM 47.2 TO RM 5.6; SEPT 1999
TITLE03  YES         CONSERVATIVE MINERAL I       CL    MG/L
TITLE04   NO         CONSERVATIVE MINERAL II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06  YES         TEMPERATURE
TITLE07  YES         BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P, DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORMS IN NO./100 ML
TITLE15  YES         ARBITRARY NON-CONSERVATIVE  TSS    MG/L
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=   0.00000         5D-ULT BOD CONV K COEF  =    0.00000
INPUT METRIC (YES=1)    =   0.00000         OUTPUT METRIC (YES=1)   =    0.00000
NUMBER OF REACHES       =  14.00000         NUMBER OF JUNCTIONS     =    0.00000
NUM OF HEADWATERS       =   1.00000         NUMBER OF POINT LOADS   =    8.00000
TIME STEP (HOURS)       =                   LNTH  COMP  ELEMENT (DX)=    0.20000
MAXIMUM ITERATIONS      =  100.0000         TIME INC. FOR RPT2 (HRS)=
LATITUDE OF BASIN (DEG) =   46.2500         LONGITUDE OF BASIN (DEG)=    119.500
STANDARD MERIDIAN (DEG) =  120.0000         DAY OF YEAR START TIME  =    271.000
EVAP. COEFF. (AE)       =   0.00068         EVAP. COEFF. (BE)       =    0.00027
ELEV. OF BASIN (ELEV)   =  461.0000         DUST ATTENUATION COEF.  =    0.10000
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)= 3.4300  O UPTAKE BY NO2 OXID(MG O/MG N)= 1.1400
O PROD  BY ALGAE (MG O/MG A)   = 1.6000  O UPTAKE BY ALGAE (MG O/MG A)  = 2.0000
N CONTENT OF ALGAE (MG N/MG A) = 0.0800  P CONTENT OF ALGAE (MG P/MG A) = 0.0110
ALG MAX SPEC GROWTH RATE(1/DAY)= 2.3000  ALGAE RESPIRATION RATE (1/DAY) = 0.1200
N HALF SATURATION CONST (MG/L) = 0.0300  P HALF SATURATION CONST  (MG/L)= 0.0050
LIN ALG EXCO (1/FT)/(UGCHLA/L) = 0.0027  NLINCO (1/FT)/(UGCHLA/L)**(2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) = 3.0000  LIGHT SAT'N COEFF (BTU/FT2/MIN)= 0.5125
DAILY AVERAGING OPTION (LAVOPT)=      3  LIGHT AVERAGING FACTOR (AFACT) = 1.0000
NUMBER OF DAYLIGHT HOURS (DLH) =         TOTAL DAILY SOLR RAD (BTU/FT2) =
ALGY GROWTH CALC OPTION(LGROPT)= 2.0000  ALGAL PREF FOR NH3-N (PREFN)   = 0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)= 0.4500  NITRIFICATION INHIBITION COEF  = 0.6000
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ENDATA1A
THETA    BOD SETT    1.000
THETA    SOD RATE    1.080
THETA    ORGN SET    1.000
THETA    NH3 DECA    1.080
THETA    PORG SET    1.000
THETA    ALG GROW    1.066
THETA    ALG SETT    1.000
ENDATA1B
STREAM REACH      1.RCH= PROSSER DAM       FROM         47.2    TO          47.0
STREAM REACH      2.RCH= PROSSER-BLWPROS   FROM         47.0    TO          45.8
STREAM REACH      3.RCH= BLWPROS-SNIPES    FROM         45.8    TO          41.8
STREAM REACH      4.RCH= SNIPES-BLWSNIPE   FROM         41.8    TO          37.8
STREAM REACH      5.RCH= BLWSNIPE-CHANDL   FROM         37.8    TO          36.0
STREAM REACH      6.RCH= CHANDL-CORRAL     FROM         36.0    TO          33.6
STREAM REACH      7.RCH= CORRAL-KIONA      FROM         33.6    TO          29.6
STREAM REACH      8.RCH= KIONA-BLWKIONA    FROM         29.6    TO          26.8
STREAM REACH      9.RCH= BLWKIONA-YAKIMA   FROM         26.8    TO          22.8
STREAM REACH     10.RCH= YAKIMA-ABWANAWI   FROM         22.8    TO          18.8
STREAM REACH     11.RCH= ABWANIW-BLWWANA   FROM         18.8    TO          16.2
STREAM REACH     12.RCH= BLWWANA-TWINBR    FROM         16.2    TO          12.4
STREAM REACH     13.RCH= TWINBR-VANGEISE   FROM         12.4    TO           8.4
STREAM REACH     14.RCH= VANGEISE-HWY182   FROM          8.4    TO           5.6
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         1           1
FLAG FIELD RCH=   2.         6           2 2 6 2 2 2
FLAG FIELD RCH=   3.        20           2 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   4.        20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.         9           2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6.        12           2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   7.        20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   8.        14           2 2 2 2 2 2 2 2 7 2 2 2 2 2
FLAG FIELD RCH=   9.        20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  10.        20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.        13           2 2 2 2 7 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.        19           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  13.        20           2 2 2 2 2 2 2 2 2 2 2 2 6 2 2 2 2 2 2 2
FLAG FIELD RCH=  14.        14           2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=   1.             0.00023       1.0       5.0       0.0       0.03
HYDRAULICS RCH=   2.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   3.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   4.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   5.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   6.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   7.       140    0.0481     0.493     0.214     0.390       0.03
HYDRAULICS RCH=   8.       140    0.0312     0.552     0.192     0.371       0.03
HYDRAULICS RCH=   9.       140    0.0188     0.614     0.245     0.342       0.03
HYDRAULICS RCH=  10.       140    0.0183     0.608     0.240     0.348       0.03
HYDRAULICS RCH=  11.       140    0.0350     0.532     0.236     0.350       0.03
HYDRAULICS RCH=  12.       140    0.0167     0.629     0.369     0.298       0.03
HYDRAULICS RCH=  13.       140    0.0111     0.663     0.526     0.275       0.03
HYDRAULICS RCH=  14.       140    0.0161     0.631     0.419     0.291       0.03
ENDATA5
TEMP/LCD   RCH=   1.     461.00    0.1  0.000  48.25  42.31  29.90   2.46
ENDATA5A
REACT COEF RCH=   1.   0.230    0.00   -0.05   1     0.2
REACT COEF RCH=   2.   0.230   -0.26   -0.05   3
REACT COEF RCH=   3.   0.230   -0.26   -0.05   3
REACT COEF RCH=   4.   0.230   -0.26   -0.05   3
REACT COEF RCH=   5.   0.230   -0.26   -0.05   3
REACT COEF RCH=   6.   0.230   -0.36   -0.00   3
REACT COEF RCH=   7.   0.230   -0.36   -0.00   3
REACT COEF RCH=   8.   0.230   -0.26   -0.11   3
REACT COEF RCH=   9.   0.230   -0.26   -0.11   3
REACT COEF RCH=  10.   0.230   -0.26   -0.11   3
REACT COEF RCH=  11.   0.230   -0.26   -0.15   3
REACT COEF RCH=  12.   0.230   -0.56   -0.15   3
REACT COEF RCH=  13.   0.230   -0.66   -0.15   3
REACT COEF RCH=  14.   0.230   -0.66   -0.18   3
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ENDATA6
N AND P COEF   RCH=   1.   0.10  0.000   1.20   1.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   2.   0.10  -1.00   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   3.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   4.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   5.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   6.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=   7.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   1.00
N AND P COEF   RCH=   8.   0.10  -3.60   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   9.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  10.   0.10  1.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  11.   0.10  -0.50   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=  12.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  13.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  14.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
ENDATA6A
ALG/OTHER COEF RCH=   1.    10.   0.50   0.26                 0.20
ALG/OTHER COEF RCH=   2.    10.   1.50   0.26                 0.60
ALG/OTHER COEF RCH=   3.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   4.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   5.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   6.    10.   3.20   0.26                 0.00
ALG/OTHER COEF RCH=   7.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=   8.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=   9.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=  10.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  11.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  12.    10.   1.50   0.26                 0.80
ALG/OTHER COEF RCH=  13.    10.   2.50   0.26                 0.00
ALG/OTHER COEF RCH=  14.    10.   2.50   0.26                 0.00
ENDATA6B
INITIAL COND-1 RCH=   1.   57.6
INITIAL COND-1 RCH=   2.   57.6
INITIAL COND-1 RCH=   3.   57.6
INITIAL COND-1 RCH=   4.   57.6
INITIAL COND-1 RCH=   5.   57.6
INITIAL COND-1 RCH=   6.   57.6
INITIAL COND-1 RCH=   7.   57.6
INITIAL COND-1 RCH=   8.   57.6
INITIAL COND-1 RCH=   9.   57.6
INITIAL COND-1 RCH=  10.   57.6
INITIAL COND-1 RCH=  11.   57.6
INITIAL COND-1 RCH=  12.   57.6
INITIAL COND-1 RCH=  13.   57.6
INITIAL COND-1 RCH=  14.   57.6
ENDATA7
INITIAL COND-2 RCH=   1.
INITIAL COND-2 RCH=   2.
INITIAL COND-2 RCH=   3.
INITIAL COND-2 RCH=   4.
INITIAL COND-2 RCH=   5.
INITIAL COND-2 RCH=   6.
INITIAL COND-2 RCH=   7.
INITIAL COND-2 RCH=   8.
INITIAL COND-2 RCH=   9.
INITIAL COND-2 RCH=  10.
INITIAL COND-2 RCH=  11.
INITIAL COND-2 RCH=  12.
INITIAL COND-2 RCH=  13.
INITIAL COND-2 RCH=  14.
ENDATA7A
INCR INFLOW-1  RCH=   1.
INCR INFLOW-1  RCH=   2.   13.8   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   3.   46.0   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   4.   46.0   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   5.   20.7   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   6.   27.6   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   7.   46.0   53.4  10.6   1.5  11.5                        31
INCR INFLOW-1  RCH=   8.  -43.9
INCR INFLOW-1  RCH=   9.  -62.7
INCR INFLOW-1  RCH=  10.  -62.7
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INCR INFLOW-1  RCH=  11.    9.3   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  12.   13.5   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  13.   14.4   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  14.   10.0   53.4  10.6   1.5  11.5                      31
ENDATA8
INCR INFLOW-2  RCH=   1.
INCR INFLOW-2  RCH=   2.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   3.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   4.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   5.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   6.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   7.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   8.
INCR INFLOW-2  RCH=   9.
INCR INFLOW-2  RCH=  10.
INCR INFLOW-2  RCH=  11.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  12.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  13.        0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  14.        0.400  0.030  0.012  1.675  0.046  0.065
ENDATA8A
ENDATA9
HEADWTR-1 HDW=   1.  RM 47.2            980.  57.0 10.34  1.00  5.16
ENDATA10
HEADWTR-2  HDW=   1.     16   63.  3.92 0.159 0.041 0.000 1.040 0.057 0.054
ENDATA10A
POINTLD-1 PTL=   1. PROSSER             1.00  67.5   8.3  8.78  86.7
POINTLD-1 PTL=   2. SENECA              0.12  83.3   7.2  16.1  18.9
POINTLD-1 PTL=   3. SNIPES             109.9  57.4  10.5   2.0  5.11
POINTLD-1 PTL=   4. CHANDLER            1030  58.6  10.3  1.00  5.24
POINTLD-1 PTL=   5. CORRAL              18.8  57.4   8.4   2.0  5.20
POINTLD-1 PTL=   6. KIONADIST          -17.8
POINTLD-1 PTL=   7. CID                 -200
POINTLD-1 PTL=   8. WRICHLAND            0.6  64.4  4.19  1.39  145.
ENDATA11
POINTLD-2  PTL=   1.     11   230       1.265 0.046 0.000 0.299 0.000 2.540
POINTLD-2  PTL=   2.      1    40       0.202 0.077 0.000 0.014 0.138 0.000
POINTLD-2  PTL=   3.     44   165  3.92 0.162 0.038 0.000 0.663 0.081 0.040
POINTLD-2  PTL=   4.     12    26  3.92 0.110 0.040 0.000 1.070 0.056 0.057
POINTLD-2  PTL=   5.     37    31  3.92 0.139 0.031 0.000 1.040 0.106 0.000
POINTLD-2  PTL=   6.
POINTLD-2  PTL=   7.
POINTLD-2  PTL=   8.     11     5       0.000 0.046 0.000  25.0  3.92 0.000
ENDATA11A
DAM DATA       DAM=   1.    2.    1.  1.60  1.05  1.00    6.
DAM DATA       DAM=   2.   11.    5.  1.60  1.05  1.00    4.
ENDATA12
ENDATA13
ENDATA13A
```

# Appendix D

## QUAL2E input files for operation change model runs

```
TITLE01             LOWER YAKIMA WATER QUALITY MODEL- Q=1071 cfs
TITLE02             PRE-CALIBRATED MODEL RM 47.2 TO RM 5.6;
TITLE03  YES        CONSERVATIVE MINERAL I       CL    MG/L
TITLE04   NO        CONSERVATIVE MINERAL II
TITLE05   NO        CONSERVATIVE MINERAL III
TITLE06  YES        TEMPERATURE
TITLE07  YES        BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        ALGAE AS CHL-A IN UG/L
TITLE09  YES        PHOSPHORUS CYCLE AS P IN MG/L
TITLE10               (ORGANIC-P, DISSOLVED-P)
TITLE11  YES        NITROGEN CYCLE AS N IN MG/L
TITLE12               (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13  YES        DISSOLVED OXYGEN IN MG/L
TITLE14   NO        FECAL COLIFORMS IN NO./100 ML
TITLE15  YES        ARBITRARY NON-CONSERVATIVE  TSS    MG/L
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=   0.00000         5D-ULT BOD CONV K COEF  =   0.00000
INPUT METRIC (YES=1)    =   0.00000         OUTPUT METRIC (YES=1)   =   0.00000
NUMBER OF REACHES       =  14.00000         NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000         NUMBER OF POINT LOADS   =   8.00000
TIME STEP (HOURS)       =                   LNTH  COMP  ELEMENT (DX)=   0.20000
MAXIMUM ITERATIONS      =  100.0000         TIME INC. FOR RPT2 (HRS)=
LATITUDE OF BASIN (DEG) =   46.2500         LONGITUDE OF BASIN (DEG)=   119.500
STANDARD MERIDIAN (DEG) =  120.0000         DAY OF YEAR START TIME  =   206.000
EVAP. COEFF. (AE)       =   0.00068         EVAP. COEFF. (BE)       =   0.00027
ELEV. OF BASIN (ELEV)   = 461.00000         DUST ATTENUATION COEF.  = 0.1000000
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)= 3.4300  O UPTAKE BY NO2 OXID(MG O/MG N)= 1.1400
O PROD  BY ALGAE (MG O/MG A)   = 1.6000  O UPTAKE BY ALGAE (MG O/MG A)  = 2.0000
N CONTENT OF ALGAE (MG N/MG A) = 0.0800  P CONTENT OF ALGAE (MG P/MG A) = 0.0110
ALG MAX SPEC GROWTH RATE(1/DAY)= 2.3000  ALGAE RESPIRATION RATE (1/DAY) = 0.1200
N HALF SATURATION CONST (MG/L) = 0.0300  P HALF SATURATION CONST  (MG/L)= 0.0050
LIN ALG EXCO (1/FT)/(UGCHLA/L) = 0.0027  NLINCO (1/FT)/(UGCHLA/L)**(2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) = 3.0000  LIGHT SAT'N COEFF (BTU/FT2/MIN)= 0.5125
DAILY AVERAGING OPTION (LAVOPT)=      3  LIGHT AVERAGING FACTOR (AFACT) = 1.0000
NUMBER OF DAYLIGHT HOURS (DLH) = 00.000  TOTAL DAILY SOLR RAD (BTU/FT2) = 0000.0
ALGY GROWTH CALC OPTION(LGROPT)= 2.0000  ALGAL PREF FOR NH3-N (PREFN)   = 0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)= 0.4500  NITRIFICATION INHIBITION COEF  = 0.6000
ENDATA1A
THETA    BOD SETT    1.000
THETA    SOD RATE    1.080
THETA    ORGN SET    1.000
THETA    NH3 DECA    1.080
THETA    PORG SET    1.000
THETA    ALG GROW    1.066
THETA    ALG SETT    1.000
ENDATA1B
STREAM REACH      1.RCH= PROSSER DAM       FROM         47.2    TO          47.0
STREAM REACH      2.RCH= PROSSER-BLWPROS   FROM         47.0    TO          45.8
STREAM REACH      3.RCH= BLWPROS-SNIPES    FROM         45.8    TO          41.8
STREAM REACH      4.RCH= SNIPES-BLWSNIPE   FROM         41.8    TO          37.8
STREAM REACH      5.RCH= BLWSNIPE-CHANDL   FROM         37.8    TO          36.0
STREAM REACH      6.RCH= CHANDL-CORRAL     FROM         36.0    TO          33.6
STREAM REACH      7.RCH= CORRAL-KIONA      FROM         33.6    TO          29.6
STREAM REACH      8.RCH= KIONA-BLWKIONA    FROM         29.6    TO          26.8
STREAM REACH      9.RCH= BLWKIONA-YAKIMA   FROM         26.8    TO          22.8
STREAM REACH     10.RCH= YAKIMA-ABWANAWI   FROM         22.8    TO          18.8
STREAM REACH     11.RCH= ABWANIW-BLWWANA   FROM         18.8    TO          16.2
STREAM REACH     12.RCH= BLWWANA-TWINBR    FROM         16.2    TO          12.4
STREAM REACH     13.RCH= TWINBR-VANGEISE   FROM         12.4    TO           8.4
STREAM REACH     14.RCH= VANGEISE-HWY182   FROM          8.4    TO           5.6
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         1          1
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FLAG FIELD RCH=   2.        6          2 2 6 2 2 2
FLAG FIELD RCH=   3.       20          2 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   4.       20          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.        9          2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6.       12          2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   7.       20          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   8.       14          2 2 2 2 2 2 2 2 7 2 2 2 2 2
FLAG FIELD RCH=   9.       20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  10.       20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.       13          2 2 2 2 7 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.       19          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  13.       20          2 2 2 2 2 2 2 2 2 2 2 2 2 6 2 2 2 2 2 2
FLAG FIELD RCH=  14.       14          2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=   1.            0.00023      1.0       5.0       0.0        0.03
HYDRAULICS RCH=   2.       140   0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   3.       140   0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   4.       140   0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   5.       140   0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   6.       140   0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   7.       140   0.0481     0.493     0.214     0.390       0.03
HYDRAULICS RCH=   8.       140   0.0312     0.552     0.192     0.371       0.03
HYDRAULICS RCH=   9.       140   0.0188     0.614     0.245     0.342       0.03
HYDRAULICS RCH=  10.       140   0.0183     0.608     0.240     0.348       0.03
HYDRAULICS RCH=  11.       140   0.0350     0.532     0.236     0.350       0.03
HYDRAULICS RCH=  12.       140   0.0167     0.629     0.369     0.298       0.03
HYDRAULICS RCH=  13.       140   0.0111     0.663     0.526     0.275       0.03
HYDRAULICS RCH=  14.       140   0.0161     0.631     0.419     0.291       0.03
ENDATA5
TEMP/LCD   RCH=   1.     461.00    0.1  0.000    72.2  60.23  29.38    7.0
ENDATA5A
REACT COEF RCH=   1.   0.230    0.00   -0.05   1     0.2
REACT COEF RCH=   2.   0.230   -0.26   -0.05   3
REACT COEF RCH=   3.   0.230   -0.26   -0.05   3
REACT COEF RCH=   4.   0.230   -0.26   -0.05   3
REACT COEF RCH=   5.   0.230   -0.26   -0.05   3
REACT COEF RCH=   6.   0.230   -0.36   -0.00   3
REACT COEF RCH=   7.   0.230   -0.36   -0.00   3
REACT COEF RCH=   8.   0.230   -0.26   -0.11   3
REACT COEF RCH=   9.   0.230   -0.26   -0.11   3
REACT COEF RCH=  10.   0.230   -0.26   -0.11   3
REACT COEF RCH=  11.   0.230   -0.26   -0.15   3
REACT COEF RCH=  12.   0.230   -0.56   -0.15   3
REACT COEF RCH=  13.   0.230   -0.66   -0.15   3
REACT COEF RCH=  14.   0.230   -0.66   -0.18   3
ENDATA6
N AND P COEF   RCH=   1.   0.10  0.000   1.20   1.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   2.   0.10  -1.00   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   3.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   4.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   5.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   6.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=   7.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   1.00
N AND P COEF   RCH=   8.   0.10  -3.60   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   9.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  10.   0.10  1.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  11.   0.10  -0.50   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=  12.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  13.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  14.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
ENDATA6A
ALG/OTHER COEF RCH=   1.    10.   0.50   0.26                 0.20
ALG/OTHER COEF RCH=   2.    10.   1.50   0.26                 0.60
ALG/OTHER COEF RCH=   3.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   4.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   5.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   6.    10.   3.20   0.26                 0.00
ALG/OTHER COEF RCH=   7.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=   8.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=   9.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=  10.    10.   6.00   0.26                 0.00
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ALG/OTHER COEF RCH=  11.    10.   6.00   0.26                0.00
ALG/OTHER COEF RCH=  12.    10.   1.50   0.26                0.80
ALG/OTHER COEF RCH=  13.    10.   2.50   0.26                0.00
ALG/OTHER COEF RCH=  14.    10.   2.50   0.26                0.00
ENDATA6B
INITIAL COND-1 RCH=   1.   74.1
INITIAL COND-1 RCH=   2.   74.1
INITIAL COND-1 RCH=   3.   74.1
INITIAL COND-1 RCH=   4.   74.1
INITIAL COND-1 RCH=   5.   74.1
INITIAL COND-1 RCH=   6.   74.1
INITIAL COND-1 RCH=   7.   74.1
INITIAL COND-1 RCH=   8.   74.1
INITIAL COND-1 RCH=   9.   74.1
INITIAL COND-1 RCH=  10.   74.1
INITIAL COND-1 RCH=  11.   74.1
INITIAL COND-1 RCH=  12.   74.1
INITIAL COND-1 RCH=  13.   74.1
INITIAL COND-1 RCH=  14.   74.1
ENDATA7
INITIAL COND-2 RCH=   1.
INITIAL COND-2 RCH=   2.
INITIAL COND-2 RCH=   3.
INITIAL COND-2 RCH=   4.
INITIAL COND-2 RCH=   5.
INITIAL COND-2 RCH=   6.
INITIAL COND-2 RCH=   7.
INITIAL COND-2 RCH=   8.
INITIAL COND-2 RCH=   9.
INITIAL COND-2 RCH=  10.
INITIAL COND-2 RCH=  11.
INITIAL COND-2 RCH=  12.
INITIAL COND-2 RCH=  13.
INITIAL COND-2 RCH=  14.
ENDATA7A
INCR INFLOW-1  RCH=   1.     0.
INCR INFLOW-1  RCH=   2.   10.6   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   3.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   4.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   5.   15.9   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   6.   11.0   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   7.   18.4   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   8.  -43.3
INCR INFLOW-1  RCH=   9.  -61.9
INCR INFLOW-1  RCH=  10.  -61.9
INCR INFLOW-1  RCH=  11.    5.7   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  12.    8.3   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  13.    8.8   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  14.    6.1   53.4  10.6   1.5  11.5                      31
ENDATA8
INCR INFLOW-2  RCH=   1.
INCR INFLOW-2  RCH=   2.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   3.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   4.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   5.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   6.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   7.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   8.
INCR INFLOW-2  RCH=   9.
INCR INFLOW-2  RCH=  10.
INCR INFLOW-2  RCH=  11.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  12.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  13.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  14.         0.400  0.030  0.012  1.675  0.046  0.065
ENDATA8A
ENDATA9
HEADWTR-1 HDW=   1.  RM 47.2           1071. 74.06  9.67  2.39  5.06
ENDATA10
HEADWTR-2  HDW=   1.    23   117  16.3 0.177 0.010 0.000 1.006 0.035 0.050
ENDATA10A
POINTLD-1 PTL=   1. PROSSER             1.18  78.8   9.2  11.7  85.2
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POINTLD-1 PTL=   2. SENECA              0.12  83.3   7.2  16.1  18.9
POINTLD-1 PTL=   3. SNIPES              67.0  70.3   8.7   2.0  5.49
POINTLD-1 PTL=   4. CHANDLER            624.  75.2  9.67  1.90  4.99
POINTLD-1 PTL=   5. CORRAL              13.0  65.7   9.1   2.0  4.63
POINTLD-1 PTL=   6. KIONADIST          -20.0
POINTLD-1 PTL=   7. CID                -234
POINTLD-1 PTL=   8. WRICHLAND            0.6  64.4  4.19  1.39  145.
ENDATA11
POINTLD-2  PTL=   1.    11   230       1.265 0.046 0.000 0.299 0.000 2.540
POINTLD-2  PTL=   2.     1    40       0.202 0.077 0.000 0.014 0.138 0.000
POINTLD-2  PTL=   3.    23   322  3.92 0.169 0.010 0.000 0.763 0.026 0.052
POINTLD-2  PTL=   4.  16.5    49  19.3 0.203 0.010 0.000 0.948 0.028 0.078
POINTLD-2  PTL=   5.    25   100  3.92 0.150 0.010 0.000 1.050 0.026 0.052
POINTLD-2  PTL=   6.
POINTLD-2  PTL=   7.
POINTLD-2  PTL=   8.    11     5       0.000 0.046 0.000  25.0  3.92 0.000
ENDATA11A
DAM DATA       DAM=   1.    2.    1.  1.60  1.05  1.00    6.
DAM DATA       DAM=   2.   11.    5.  1.60  1.05  1.00    4.
ENDATA12
ENDATA13
ENDATA13A


TITLE01              LOWER YAKIMA WATER QUALITY MODEL- Q= 1251 cfs
TITLE02              PRE-CALIBRATED MODEL RM 47.2 TO RM 5.6;
TITLE03  YES         CONSERVATIVE MINERAL I       CL    MG/L
TITLE04   NO         CONSERVATIVE MINERAL II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06  YES         TEMPERATURE
TITLE07  YES         BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P, DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORMS IN NO./100 ML
TITLE15  YES         ARBITRARY NON-CONSERVATIVE  TSS    MG/L
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=   0.00000          5D-ULT BOD CONV K COEF  =   0.00000
INPUT METRIC (YES=1)    =   0.00000          OUTPUT METRIC (YES=1)   =   0.00000
NUMBER OF REACHES       =  14.00000          NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000          NUMBER OF POINT LOADS   =   8.00000
TIME STEP (HOURS)       =                    LNTH  COMP  ELEMENT (DX)=   0.20000
MAXIMUM ITERATIONS      =  100.0000          TIME INC. FOR RPT2 (HRS)=
LATITUDE OF BASIN (DEG) =   46.2500          LONGITUDE OF BASIN (DEG)=   119.500
STANDARD MERIDIAN (DEG) =  120.0000          DAY OF YEAR START TIME  =   206.000
EVAP. COEFF. (AE)       =   0.00068          EVAP. COEFF. (BE)       =   0.00027
ELEV. OF BASIN (ELEV)   = 461.00000          DUST ATTENUATION COEF.  = 0.1000000
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)= 3.4300  O UPTAKE BY NO2 OXID(MG O/MG N)= 1.1400
O PROD  BY ALGAE (MG O/MG A)   = 1.6000  O UPTAKE BY ALGAE (MG O/MG A)  = 2.0000
N CONTENT OF ALGAE (MG N/MG A) = 0.0800  P CONTENT OF ALGAE (MG P/MG A) = 0.0110
ALG MAX SPEC GROWTH RATE(1/DAY)= 2.3000  ALGAE RESPIRATION RATE (1/DAY) = 0.1200
N HALF SATURATION CONST (MG/L) = 0.0300  P HALF SATURATION CONST  (MG/L)= 0.0050
LIN ALG EXCO (1/FT)/(UGCHLA/L) = 0.0027  NLINCO (1/FT)/(UGCHLA/L)**(2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) = 3.0000  LIGHT SAT'N COEFF (BTU/FT2/MIN)= 0.5125
DAILY AVERAGING OPTION (LAVOPT)=      3  LIGHT AVERAGING FACTOR (AFACT) = 1.0000
NUMBER OF DAYLIGHT HOURS (DLH) = 00.000  TOTAL DAILY SOLR RAD (BTU/FT2) = 0000.0
ALGY GROWTH CALC OPTION(LGROPT)= 2.0000  ALGAL PREF FOR NH3-N (PREFN)   = 0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)= 0.4500  NITRIFICATION INHIBITION COEF  = 0.6000
ENDATA1A
THETA    BOD SETT    1.000
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THETA    SOD RATE    1.080
THETA    ORGN SET    1.000
THETA    NH3 DECA    1.080
THETA    PORG SET    1.000
THETA    ALG GROW    1.066
THETA    ALG SETT    1.000
ENDATA1B
STREAM REACH      1.RCH= PROSSER DAM       FROM          47.2    TO          47.0
STREAM REACH      2.RCH= PROSSER-BLWPROS   FROM          47.0    TO          45.8
STREAM REACH      3.RCH= BLWPROS-SNIPES    FROM          45.8    TO          41.8
STREAM REACH      4.RCH= SNIPES-BLWSNIPE   FROM          41.8    TO          37.8
STREAM REACH      5.RCH= BLWSNIPE-CHANDL   FROM          37.8    TO          36.0
STREAM REACH      6.RCH= CHANDL-CORRAL     FROM          36.0    TO          33.6
STREAM REACH      7.RCH= CORRAL-KIONA      FROM          33.6    TO          29.6
STREAM REACH      8.RCH= KIONA-BLWKIONA    FROM          29.6    TO          26.8
STREAM REACH      9.RCH= BLWKIONA-YAKIMA   FROM          26.8    TO          22.8
STREAM REACH     10.RCH= YAKIMA-ABWANAWI   FROM          22.8    TO          18.8
STREAM REACH     11.RCH= ABWANIW-BLWWANA   FROM          18.8    TO          16.2
STREAM REACH     12.RCH= BLWWANA-TWINBR    FROM          16.2    TO          12.4
STREAM REACH     13.RCH= TWINBR-VANGEISE   FROM          12.4    TO           8.4
STREAM REACH     14.RCH= VANGEISE-HWY182   FROM           8.4    TO           5.6
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         1           1
FLAG FIELD RCH=   2.         6           2 2 6 2 2 2
FLAG FIELD RCH=   3.        20           2 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   4.        20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.         9           2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6.        12           2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   7.        20           6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   8.        14           2 2 2 2 2 2 2 2 7 2 2 2 2 2
FLAG FIELD RCH=   9.        20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  10.        20           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.        13           2 2 2 2 7 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.        19           2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  13.        20           2 2 2 2 2 2 2 2 2 2 2 2 6 2 2 2 2 2 2 2
FLAG FIELD RCH=  14.        14           2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=   1.             0.00023       1.0       5.0       0.0       0.03
HYDRAULICS RCH=   2.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   3.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   4.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   5.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   6.       140    0.0186     0.589     0.304     0.338       0.03
HYDRAULICS RCH=   7.       140    0.0481     0.493     0.214     0.390       0.03
HYDRAULICS RCH=   8.       140    0.0312     0.552     0.192     0.371       0.03
HYDRAULICS RCH=   9.       140    0.0188     0.614     0.245     0.342       0.03
HYDRAULICS RCH=  10.       140    0.0183     0.608     0.240     0.348       0.03
HYDRAULICS RCH=  11.       140    0.0350     0.532     0.236     0.350       0.03
HYDRAULICS RCH=  12.       140    0.0167     0.629     0.369     0.298       0.03
HYDRAULICS RCH=  13.       140    0.0111     0.663     0.526     0.275       0.03
HYDRAULICS RCH=  14.       140    0.0161     0.631     0.419     0.291       0.03
ENDATA5
TEMP/LCD   RCH=   1.     461.00    0.1  0.000   72.2  60.23  29.38   7.0
ENDATA5A
REACT COEF RCH=   1.   0.230    0.00   -0.05   1     0.2
REACT COEF RCH=   2.   0.230   -0.26   -0.05   3
REACT COEF RCH=   3.   0.230   -0.26   -0.05   3
REACT COEF RCH=   4.   0.230   -0.26   -0.05   3
REACT COEF RCH=   5.   0.230   -0.26   -0.05   3
REACT COEF RCH=   6.   0.230   -0.36   -0.00   3
REACT COEF RCH=   7.   0.230   -0.36   -0.00   3
REACT COEF RCH=   8.   0.230   -0.26   -0.11   3
REACT COEF RCH=   9.   0.230   -0.26   -0.11   3
REACT COEF RCH=  10.   0.230   -0.26   -0.11   3
REACT COEF RCH=  11.   0.230   -0.26   -0.15   3
REACT COEF RCH=  12.   0.230   -0.56   -0.15   3
REACT COEF RCH=  13.   0.230   -0.66   -0.15   3
REACT COEF RCH=  14.   0.230   -0.66   -0.18   3
ENDATA6
N AND P COEF   RCH=   1.   0.10  0.000   1.20   1.00   3.00   0.10   0.00   0.00
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N AND P COEF   RCH=   2.   0.10  -1.00   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   3.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   4.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   5.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   6.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=   7.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   1.00
N AND P COEF   RCH=   8.   0.10  -3.60   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   9.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  10.   0.10  1.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  11.   0.10  -0.50   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=  12.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  13.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  14.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
ENDATA6A
ALG/OTHER COEF RCH=   1.    10.   0.50   0.26                 0.20
ALG/OTHER COEF RCH=   2.    10.   1.50   0.26                 0.60
ALG/OTHER COEF RCH=   3.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   4.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   5.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   6.    10.   3.20   0.26                 0.00
ALG/OTHER COEF RCH=   7.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=   8.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=   9.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=  10.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  11.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  12.    10.   1.50   0.26                 0.80
ALG/OTHER COEF RCH=  13.    10.   2.50   0.26                 0.00
ALG/OTHER COEF RCH=  14.    10.   2.50   0.26                 0.00
ENDATA6B
INITIAL COND-1 RCH=   1.   74.1
INITIAL COND-1 RCH=   2.   74.1
INITIAL COND-1 RCH=   3.   74.1
INITIAL COND-1 RCH=   4.   74.1
INITIAL COND-1 RCH=   5.   74.1
INITIAL COND-1 RCH=   6.   74.1
INITIAL COND-1 RCH=   7.   74.1
INITIAL COND-1 RCH=   8.   74.1
INITIAL COND-1 RCH=   9.   74.1
INITIAL COND-1 RCH=  10.   74.1
INITIAL COND-1 RCH=  11.   74.1
INITIAL COND-1 RCH=  12.   74.1
INITIAL COND-1 RCH=  13.   74.1
INITIAL COND-1 RCH=  14.   74.1
ENDATA7
INITIAL COND-2 RCH=   1.
INITIAL COND-2 RCH=   2.
INITIAL COND-2 RCH=   3.
INITIAL COND-2 RCH=   4.
INITIAL COND-2 RCH=   5.
INITIAL COND-2 RCH=   6.
INITIAL COND-2 RCH=   7.
INITIAL COND-2 RCH=   8.
INITIAL COND-2 RCH=   9.
INITIAL COND-2 RCH=  10.
INITIAL COND-2 RCH=  11.
INITIAL COND-2 RCH=  12.
INITIAL COND-2 RCH=  13.
INITIAL COND-2 RCH=  14.
ENDATA7A
INCR INFLOW-1  RCH=   1.     0.
INCR INFLOW-1  RCH=   2.   10.6   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   3.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   4.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   5.   15.9   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   6.   11.0   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   7.   18.4   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   8.  -43.3
INCR INFLOW-1  RCH=   9.  -61.9
INCR INFLOW-1  RCH=  10.  -61.9
INCR INFLOW-1  RCH=  11.    5.7   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  12.    8.3   53.4  10.6   1.5  11.5                      31
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INCR INFLOW-1  RCH=  13.    8.8   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  14.    6.1   53.4  10.6   1.5  11.5                      31
ENDATA8
INCR INFLOW-2  RCH=   1.
INCR INFLOW-2  RCH=   2.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   3.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   4.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   5.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   6.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   7.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   8.
INCR INFLOW-2  RCH=   9.
INCR INFLOW-2  RCH=  10.
INCR INFLOW-2  RCH=  11.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  12.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  13.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  14.         0.400  0.030  0.012  1.675  0.046  0.065
ENDATA8A
ENDATA9
HEADWTR-1 HDW=   1.  RM 47.2           1251. 74.06  9.67  2.39  5.06
ENDATA10
HEADWTR-2  HDW=   1.    23   117  16.3 0.177 0.010 0.000 1.006 0.035 0.050
ENDATA10A
POINTLD-1 PTL=   1. PROSSER             1.18  78.8   9.2  11.7  85.2
POINTLD-1 PTL=   2. SENECA              0.12  83.3   7.2  16.1  18.9
POINTLD-1 PTL=   3. SNIPES              67.0  70.3   8.7   2.0  5.49
POINTLD-1 PTL=   4. CHANDLER            524.  75.2  9.67  1.90  4.99
POINTLD-1 PTL=   5. CORRAL              13.0  65.7   9.1   2.0  4.63
POINTLD-1 PTL=   6. KIONADIST          -20.0
POINTLD-1 PTL=   7. CID                -234
POINTLD-1 PTL=   8. WRICHLAND            0.6  64.4  4.19  1.39  145.
ENDATA11
POINTLD-2  PTL=   1.    11   230       1.265 0.046 0.000 0.299 0.000 2.540
POINTLD-2  PTL=   2.     1    40       0.202 0.077 0.000 0.014 0.138 0.000
POINTLD-2  PTL=   3.    23   322  3.92 0.169 0.010 0.000 0.763 0.026 0.052
POINTLD-2  PTL=   4.  16.5    49  19.3 0.203 0.010 0.000 0.948 0.028 0.078
POINTLD-2  PTL=   5.    25   100  3.92 0.150 0.010 0.000 1.050 0.026 0.052
POINTLD-2  PTL=   6.
POINTLD-2  PTL=   7.
POINTLD-2  PTL=   8.    11     5       0.000 0.046 0.000  25.0  3.92 0.000
ENDATA11A
DAM DATA       DAM=   1.    2.    1.  1.60  1.05  1.00    6.
DAM DATA       DAM=   2.   11.    5.  1.60  1.05  1.00    4.
ENDATA12
ENDATA13
ENDATA13A


TITLE01               LOWER YAKIMA WATER QUALITY MODEL- Q= 1775 cfs
TITLE02               PRE-CALIBRATED MODEL RM 47.2 TO RM 5.6;
TITLE03  YES          CONSERVATIVE MINERAL I       CL    MG/L
TITLE04   NO          CONSERVATIVE MINERAL II
TITLE05   NO          CONSERVATIVE MINERAL III
TITLE06  YES          TEMPERATURE
TITLE07  YES          BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES          ALGAE AS CHL-A IN UG/L
TITLE09  YES          PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                 (ORGANIC-P, DISSOLVED-P)
TITLE11  YES          NITROGEN CYCLE AS N IN MG/L
TITLE12                 (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13  YES          DISSOLVED OXYGEN IN MG/L
TITLE14   NO          FECAL COLIFORMS IN NO./100 ML
TITLE15  YES          ARBITRARY NON-CONSERVATIVE  TSS    MG/L
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
PRINT SOLAR/LCD DATA
NO PLOT DO AND BOD
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FIXED DNSTM COND (YES=1)=   0.00000         5D-ULT BOD CONV K COEF  =   0.00000
INPUT METRIC (YES=1)    =   0.00000         OUTPUT METRIC (YES=1)   =   0.00000
NUMBER OF REACHES       =  14.00000         NUMBER OF JUNCTIONS     =   0.00000
NUM OF HEADWATERS       =   1.00000         NUMBER OF POINT LOADS   =   8.00000
TIME STEP (HOURS)       =                   LNTH  COMP  ELEMENT (DX)=   0.20000
MAXIMUM ITERATIONS      =  100.0000         TIME INC. FOR RPT2 (HRS)=
LATITUDE OF BASIN (DEG) =   46.2500         LONGITUDE OF BASIN (DEG)=   119.500
STANDARD MERIDIAN (DEG) =  120.0000         DAY OF YEAR START TIME  =   206.000
EVAP. COEFF. (AE)       =   0.00068         EVAP. COEFF. (BE)       =   0.00027
ELEV. OF BASIN (ELEV)   = 461.00000         DUST ATTENUATION COEF.  = 0.1000000
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)= 3.4300  O UPTAKE BY NO2 OXID(MG O/MG N)= 1.1400
O PROD  BY ALGAE (MG O/MG A)   = 1.6000  O UPTAKE BY ALGAE (MG O/MG A)  = 2.0000
N CONTENT OF ALGAE (MG N/MG A) = 0.0800  P CONTENT OF ALGAE (MG P/MG A) = 0.0110
ALG MAX SPEC GROWTH RATE(1/DAY)= 2.3000  ALGAE RESPIRATION RATE (1/DAY) = 0.1200
N HALF SATURATION CONST (MG/L) = 0.0300  P HALF SATURATION CONST  (MG/L)= 0.0050
LIN ALG EXCO (1/FT)/(UGCHLA/L) = 0.0027  NLINCO (1/FT)/(UGCHLA/L)**(2/3)= 0.0165
LIGHT FUNCTION OPTION (LFNOPT) = 3.0000  LIGHT SAT'N COEFF (BTU/FT2/MIN)= 0.5125
DAILY AVERAGING OPTION (LAVOPT)=      3  LIGHT AVERAGING FACTOR (AFACT) = 1.0000
NUMBER OF DAYLIGHT HOURS (DLH) = 00.000  TOTAL DAILY SOLR RAD (BTU/FT2) = 0000.0
ALGY GROWTH CALC OPTION(LGROPT)= 2.0000  ALGAL PREF FOR NH3-N (PREFN)   = 0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)= 0.4500  NITRIFICATION INHIBITION COEF  = 0.6000
ENDATA1A
THETA    BOD SETT    1.000
THETA    SOD RATE    1.080
THETA    ORGN SET    1.000
THETA    NH3 DECA    1.080
THETA    PORG SET    1.000
THETA    ALG GROW    1.066
THETA    ALG SETT    1.000
ENDATA1B
STREAM REACH      1.RCH= PROSSER DAM       FROM         47.2    TO          47.0
STREAM REACH      2.RCH= PROSSER-BLWPROS   FROM         47.0    TO          45.8
STREAM REACH      3.RCH= BLWPROS-SNIPES    FROM         45.8    TO          41.8
STREAM REACH      4.RCH= SNIPES-BLWSNIPE   FROM         41.8    TO          37.8
STREAM REACH      5.RCH= BLWSNIPE-CHANDL   FROM         37.8    TO          36.0
STREAM REACH      6.RCH= CHANDL-CORRAL     FROM         36.0    TO          33.6
STREAM REACH      7.RCH= CORRAL-KIONA      FROM         33.6    TO          29.6
STREAM REACH      8.RCH= KIONA-BLWKIONA    FROM         29.6    TO          26.8
STREAM REACH      9.RCH= BLWKIONA-YAKIMA   FROM         26.8    TO          22.8
STREAM REACH     10.RCH= YAKIMA-ABWANAWI   FROM         22.8    TO          18.8
STREAM REACH     11.RCH= ABWANIW-BLWWANA   FROM         18.8    TO          16.2
STREAM REACH     12.RCH= BLWWANA-TWINBR    FROM         16.2    TO          12.4
STREAM REACH     13.RCH= TWINBR-VANGEISE   FROM         12.4    TO           8.4
STREAM REACH     14.RCH= VANGEISE-HWY182   FROM          8.4    TO           5.6
ENDATA2
ENDATA3
FLAG FIELD RCH=   1.         1          1
FLAG FIELD RCH=   2.         6          2 2 6 2 2 2
FLAG FIELD RCH=   3.        20          2 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   4.        20          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   5.         9          2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   6.        12          2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   7.        20          6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=   8.        14          2 2 2 2 2 2 2 2 7 2 2 2 2 2
FLAG FIELD RCH=   9.        20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  10.        20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  11.        13          2 2 2 2 7 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  12.        19          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  13.        20          2 2 2 2 2 2 2 2 2 2 2 2 2 2 6 2 2 2 2 2 2
FLAG FIELD RCH=  14.        14          2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=   1.             0.00023      1.0       5.0       0.0       0.03
HYDRAULICS RCH=   2.       140    0.0186     0.589     0.304     0.338      0.03
HYDRAULICS RCH=   3.       140    0.0186     0.589     0.304     0.338      0.03
HYDRAULICS RCH=   4.       140    0.0186     0.589     0.304     0.338      0.03
HYDRAULICS RCH=   5.       140    0.0186     0.589     0.304     0.338      0.03
HYDRAULICS RCH=   6.       140    0.0186     0.589     0.304     0.338      0.03
HYDRAULICS RCH=   7.       140    0.0481     0.493     0.214     0.390      0.03
HYDRAULICS RCH=   8.       140    0.0312     0.552     0.192     0.371      0.03
HYDRAULICS RCH=   9.       140    0.0188     0.614     0.245     0.342      0.03
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HYDRAULICS RCH=  10.       140    0.0183     0.608     0.240     0.348       0.03
HYDRAULICS RCH=  11.       140    0.0350     0.532     0.236     0.350       0.03
HYDRAULICS RCH=  12.       140    0.0167     0.629     0.369     0.298       0.03
HYDRAULICS RCH=  13.       140    0.0111     0.663     0.526     0.275       0.03
HYDRAULICS RCH=  14.       140    0.0161     0.631     0.419     0.291       0.03
ENDATA5
TEMP/LCD   RCH=   1.     461.00    0.1  0.000   72.2  60.23  29.38   7.0
ENDATA5A
REACT COEF RCH=   1.   0.230    0.00   -0.05   1     0.2
REACT COEF RCH=   2.   0.230   -0.26   -0.05   3
REACT COEF RCH=   3.   0.230   -0.26   -0.05   3
REACT COEF RCH=   4.   0.230   -0.26   -0.05   3
REACT COEF RCH=   5.   0.230   -0.26   -0.05   3
REACT COEF RCH=   6.   0.230   -0.36   -0.00   3
REACT COEF RCH=   7.   0.230   -0.36   -0.00   3
REACT COEF RCH=   8.   0.230   -0.26   -0.11   3
REACT COEF RCH=   9.   0.230   -0.26   -0.11   3
REACT COEF RCH=  10.   0.230   -0.26   -0.11   3
REACT COEF RCH=  11.   0.230   -0.26   -0.15   3
REACT COEF RCH=  12.   0.230   -0.56   -0.15   3
REACT COEF RCH=  13.   0.230   -0.66   -0.15   3
REACT COEF RCH=  14.   0.230   -0.66   -0.18   3
ENDATA6
N AND P COEF   RCH=   1.   0.10  0.000   1.20   1.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   2.   0.10  -1.00   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   3.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   6.00
N AND P COEF   RCH=   4.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   5.   0.10  0.200   1.20   1.00   3.00   0.10   0.00   7.00
N AND P COEF   RCH=   6.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=   7.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   1.00
N AND P COEF   RCH=   8.   0.10  -3.60   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=   9.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  10.   0.10  1.000   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  11.   0.10  -0.50   1.20   0.00   3.00   0.10   0.00   2.00
N AND P COEF   RCH=  12.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  13.   0.10  0.200   1.20   0.00   3.00   0.10   0.00   0.00
N AND P COEF   RCH=  14.   0.10  0.000   1.20   0.00   3.00   0.10   0.00   0.00
ENDATA6A
ALG/OTHER COEF RCH=   1.    10.   0.50   0.26                 0.20
ALG/OTHER COEF RCH=   2.    10.   1.50   0.26                 0.60
ALG/OTHER COEF RCH=   3.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   4.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   5.    10.   5.20   0.26                 0.60
ALG/OTHER COEF RCH=   6.    10.   3.20   0.26                 0.00
ALG/OTHER COEF RCH=   7.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=   8.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=   9.    10.   4.40   0.26                 0.00
ALG/OTHER COEF RCH=  10.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  11.    10.   6.00   0.26                 0.00
ALG/OTHER COEF RCH=  12.    10.   1.50   0.26                 0.80
ALG/OTHER COEF RCH=  13.    10.   2.50   0.26                 0.00
ALG/OTHER COEF RCH=  14.    10.   2.50   0.26                 0.00
ENDATA6B
INITIAL COND-1 RCH=   1.   74.1
INITIAL COND-1 RCH=   2.   74.1
INITIAL COND-1 RCH=   3.   74.1
INITIAL COND-1 RCH=   4.   74.1
INITIAL COND-1 RCH=   5.   74.1
INITIAL COND-1 RCH=   6.   74.1
INITIAL COND-1 RCH=   7.   74.1
INITIAL COND-1 RCH=   8.   74.1
INITIAL COND-1 RCH=   9.   74.1
INITIAL COND-1 RCH=  10.   74.1
INITIAL COND-1 RCH=  11.   74.1
INITIAL COND-1 RCH=  12.   74.1
INITIAL COND-1 RCH=  13.   74.1
INITIAL COND-1 RCH=  14.   74.1
ENDATA7
INITIAL COND-2 RCH=   1.
INITIAL COND-2 RCH=   2.
INITIAL COND-2 RCH=   3.
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INITIAL COND-2 RCH=   4.
INITIAL COND-2 RCH=   5.
INITIAL COND-2 RCH=   6.
INITIAL COND-2 RCH=   7.
INITIAL COND-2 RCH=   8.
INITIAL COND-2 RCH=   9.
INITIAL COND-2 RCH=  10.
INITIAL COND-2 RCH=  11.
INITIAL COND-2 RCH=  12.
INITIAL COND-2 RCH=  13.
INITIAL COND-2 RCH=  14.
ENDATA7A
INCR INFLOW-1  RCH=   1.     0.
INCR INFLOW-1  RCH=   2.   10.6   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   3.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   4.   35.2   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   5.   15.9   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   6.   11.0   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   7.   18.4   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=   8.  -43.3
INCR INFLOW-1  RCH=   9.  -61.9
INCR INFLOW-1  RCH=  10.  -61.9
INCR INFLOW-1  RCH=  11.    5.7   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  12.    8.3   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  13.    8.8   53.4  10.6   1.5  11.5                      31
INCR INFLOW-1  RCH=  14.    6.1   53.4  10.6   1.5  11.5                      31
ENDATA8
INCR INFLOW-2  RCH=   1.
INCR INFLOW-2  RCH=   2.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   3.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   4.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   5.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   6.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   7.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=   8.
INCR INFLOW-2  RCH=   9.
INCR INFLOW-2  RCH=  10.
INCR INFLOW-2  RCH=  11.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  12.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  13.         0.400  0.030  0.012  1.675  0.046  0.065
INCR INFLOW-2  RCH=  14.         0.400  0.030  0.012  1.675  0.046  0.065
ENDATA8A
ENDATA9
HEADWTR-1 HDW=   1.  RM 47.2          1775. 74.06  9.67  2.39  5.06
ENDATA10
HEADWTR-2  HDW=   1.    23   117  16.3 0.177 0.010 0.000 1.006 0.035 0.050
ENDATA10A
POINTLD-1 PTL=   1. PROSSER            1.18  78.8   9.2  11.7  85.2
POINTLD-1 PTL=   2. SENECA             0.12  83.3   7.2  16.1  18.9
POINTLD-1 PTL=   3. SNIPES             67.0  70.3   8.7   2.0  5.49
POINTLD-1 PTL=   4. CHANDLER              0  75.2  9.67  1.90  4.99
POINTLD-1 PTL=   5. CORRAL             13.0  65.7   9.1   2.0  4.63
POINTLD-1 PTL=   6. KIONADIST         -20.0
POINTLD-1 PTL=   7. CID                -234
POINTLD-1 PTL=   8. WRICHLAND           0.6  64.4  4.19  1.39  145.
ENDATA11
POINTLD-2  PTL=   1.    11   230       1.265 0.046 0.000 0.299 0.000 2.540
POINTLD-2  PTL=   2.     1    40       0.202 0.077 0.000 0.014 0.138 0.000
POINTLD-2  PTL=   3.    23   322  3.92 0.169 0.010 0.000 0.763 0.026 0.052
POINTLD-2  PTL=   4.  16.5    49  19.3 0.203 0.010 0.000 0.948 0.028 0.078
POINTLD-2  PTL=   5.    25   100  3.92 0.150 0.010 0.000 1.050 0.026 0.052
POINTLD-2  PTL=   6.
POINTLD-2  PTL=   7.
POINTLD-2  PTL=   8.    11     5       0.000 0.046 0.000  25.0  3.92 0.000
ENDATA11A
DAM DATA       DAM=   1.    2.    1.  1.60  1.05  1.00    6.
DAM DATA       DAM=   2.   11.    5.  1.60  1.05  1.00    4.
ENDATA12
ENDATA13
ENDATA13A
```
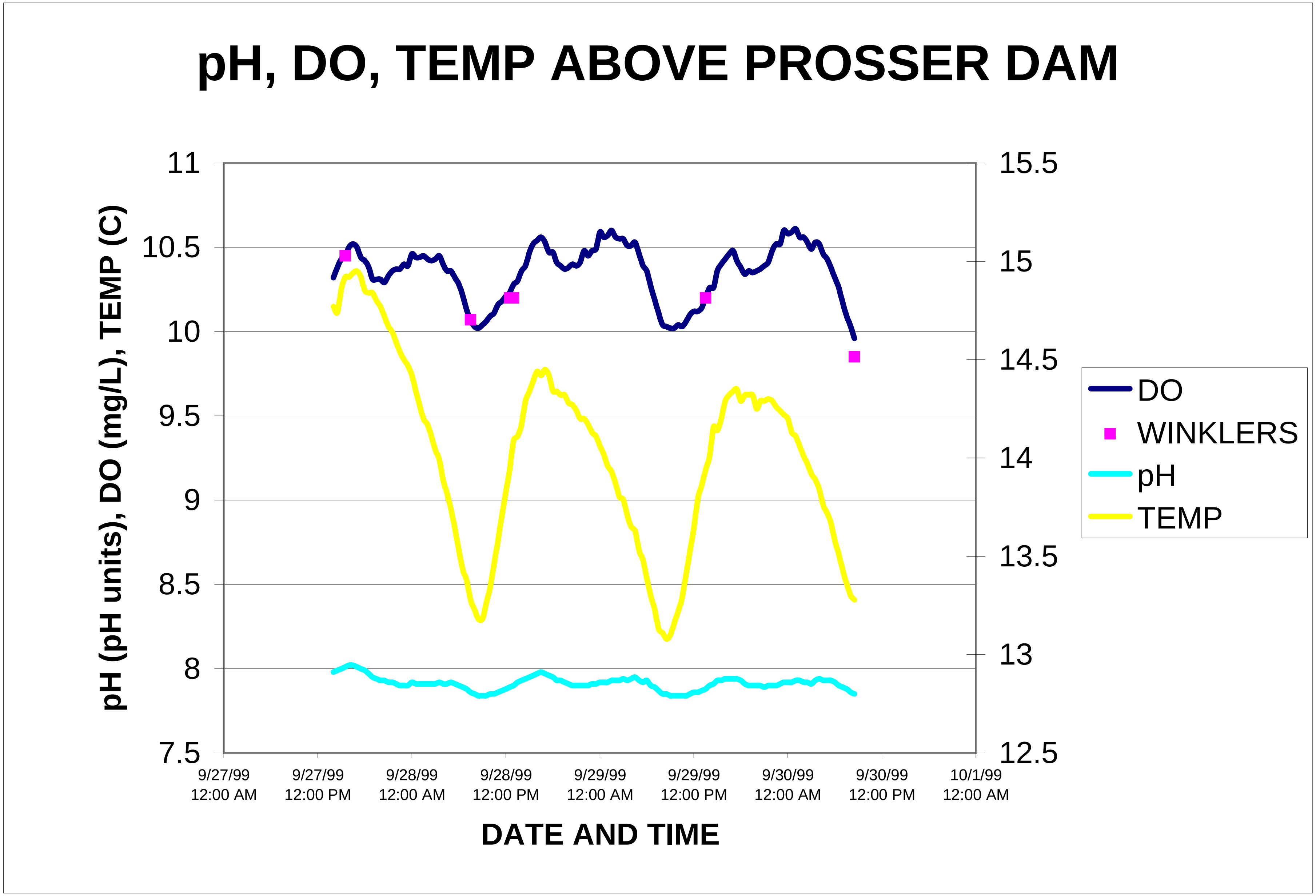
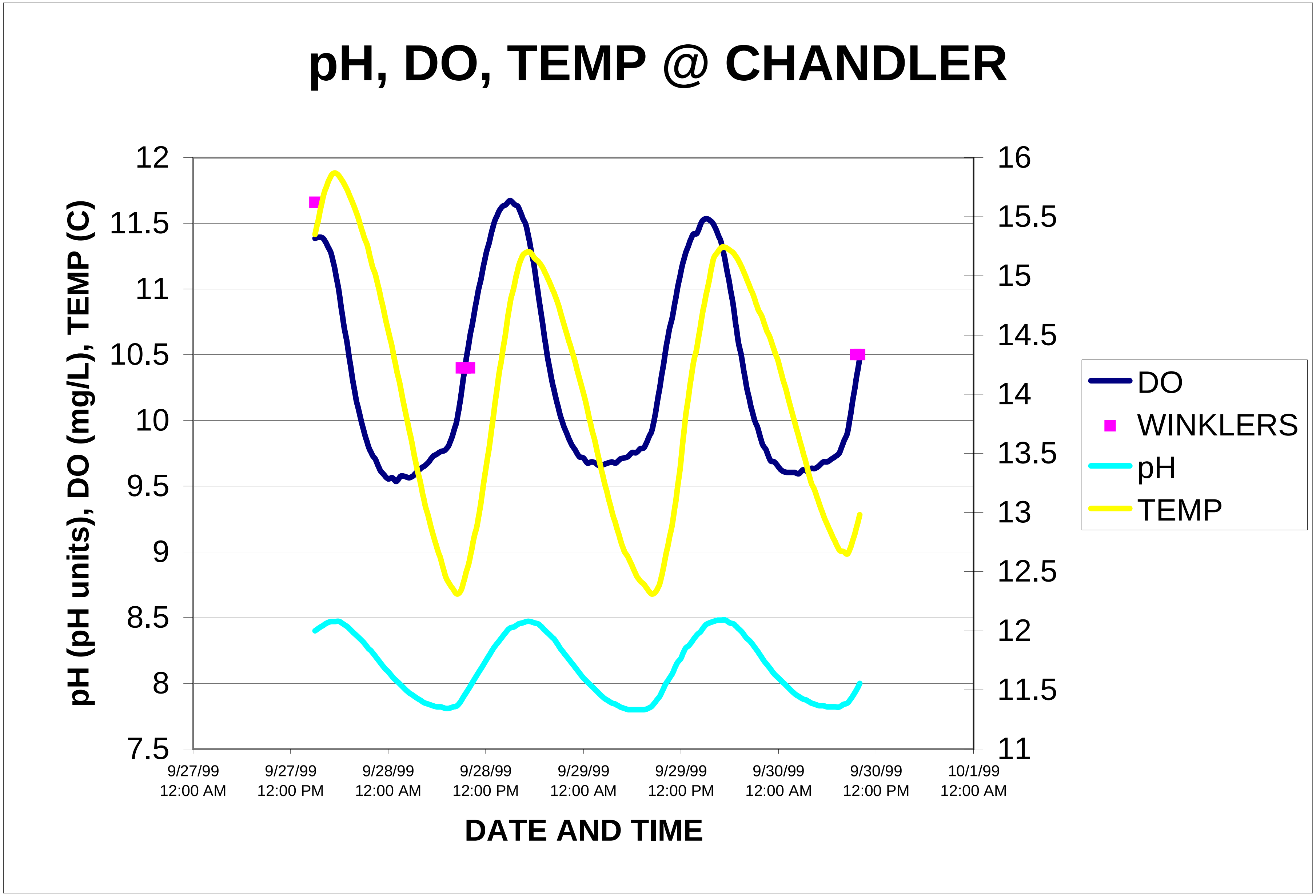
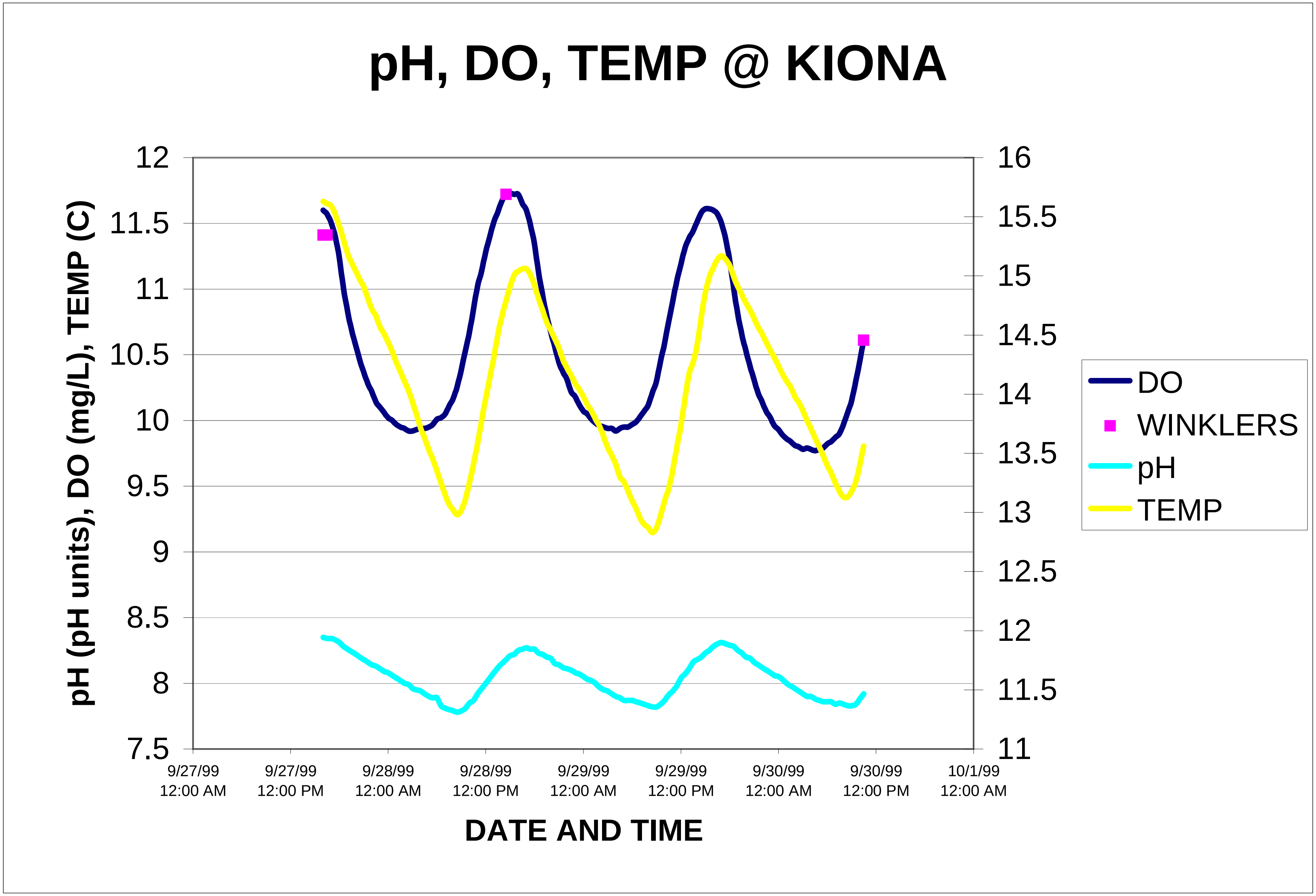

# Appendix E

# Hydrolab datalogger survey data

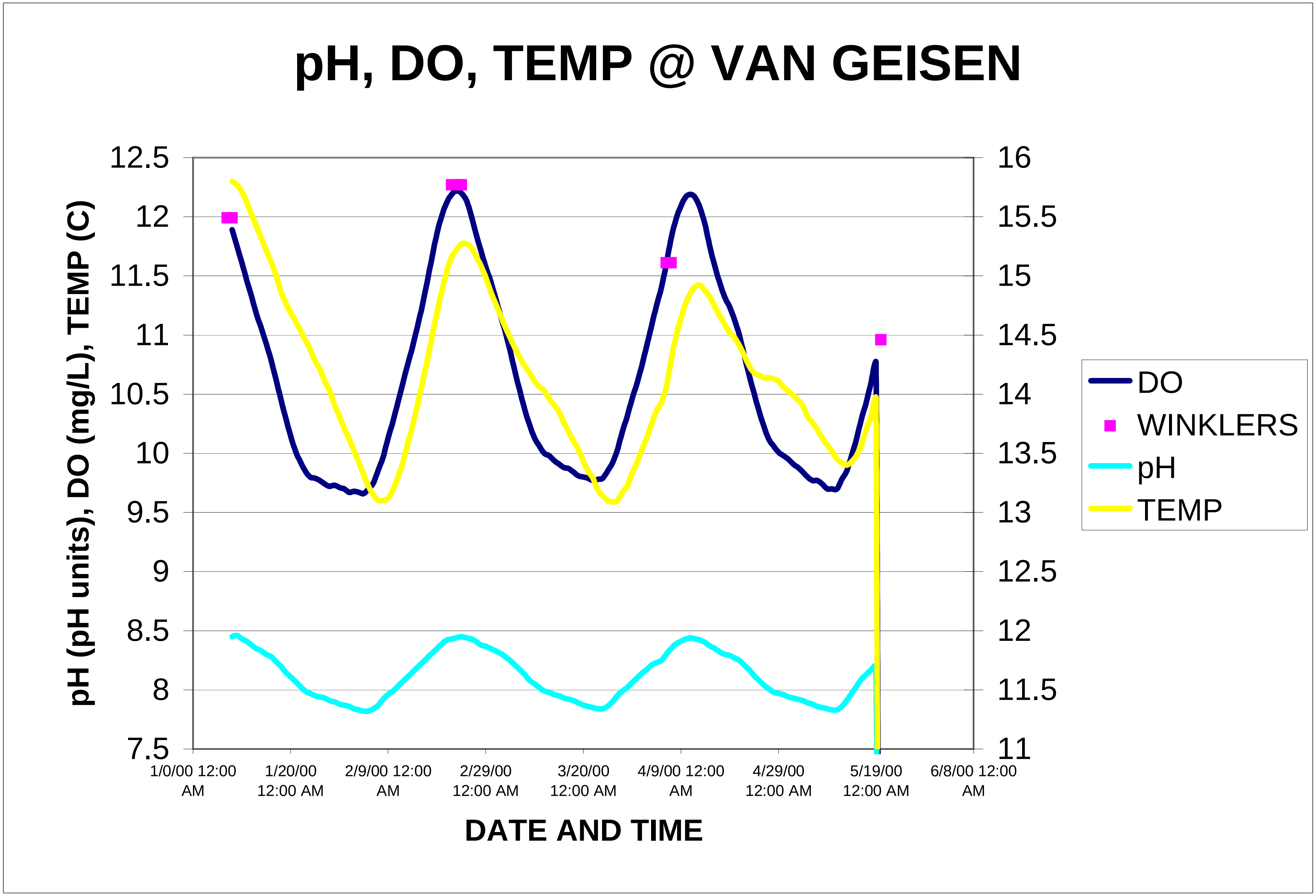


pH, DO, TEMP ABOVE PROSSER DAM
pH (pH units), DO (mg/L), TEMP (C)
11
10.5
10
9.5
9
8.5
8
7.5
15.5
15
14.5
14
13.5
13
12.5
9/27/99 12:00 AM
9/27/99 12:00 PM
9/28/99 12:00 AM
9/28/99 12:00 PM
9/29/99 12:00 AM
9/29/99 12:00 PM
9/30/99 12:00 AM
9/30/99 12:00 PM
10/1/99 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

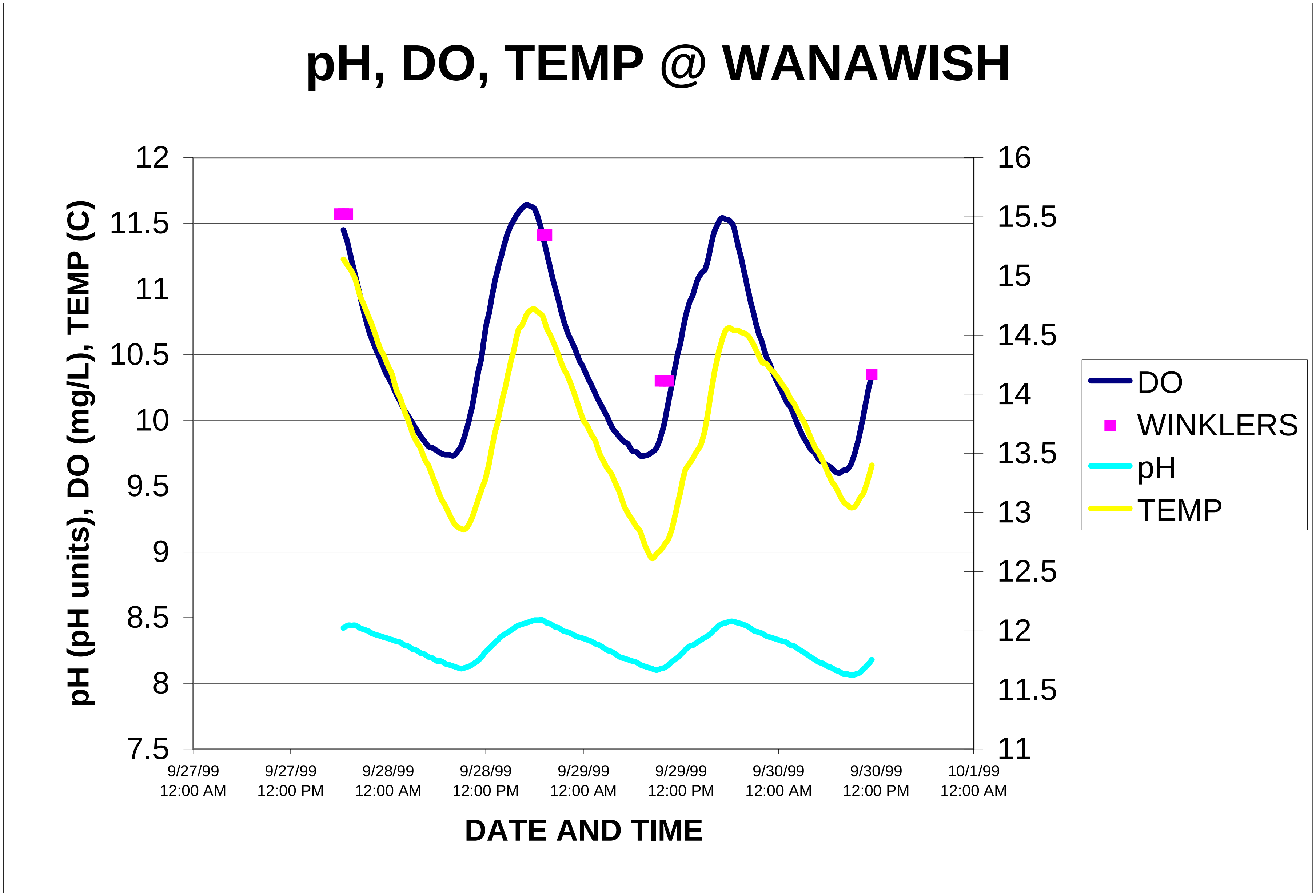

pH, DO, TEMP @ CHANDLER
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
9/27/99 12:00 AM
9/27/99 12:00 PM
9/28/99 12:00 AM
9/28/99 12:00 PM
9/29/99 12:00 AM
9/29/99 12:00 PM
9/30/99 12:00 AM
9/30/99 12:00 PM
10/1/99 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP



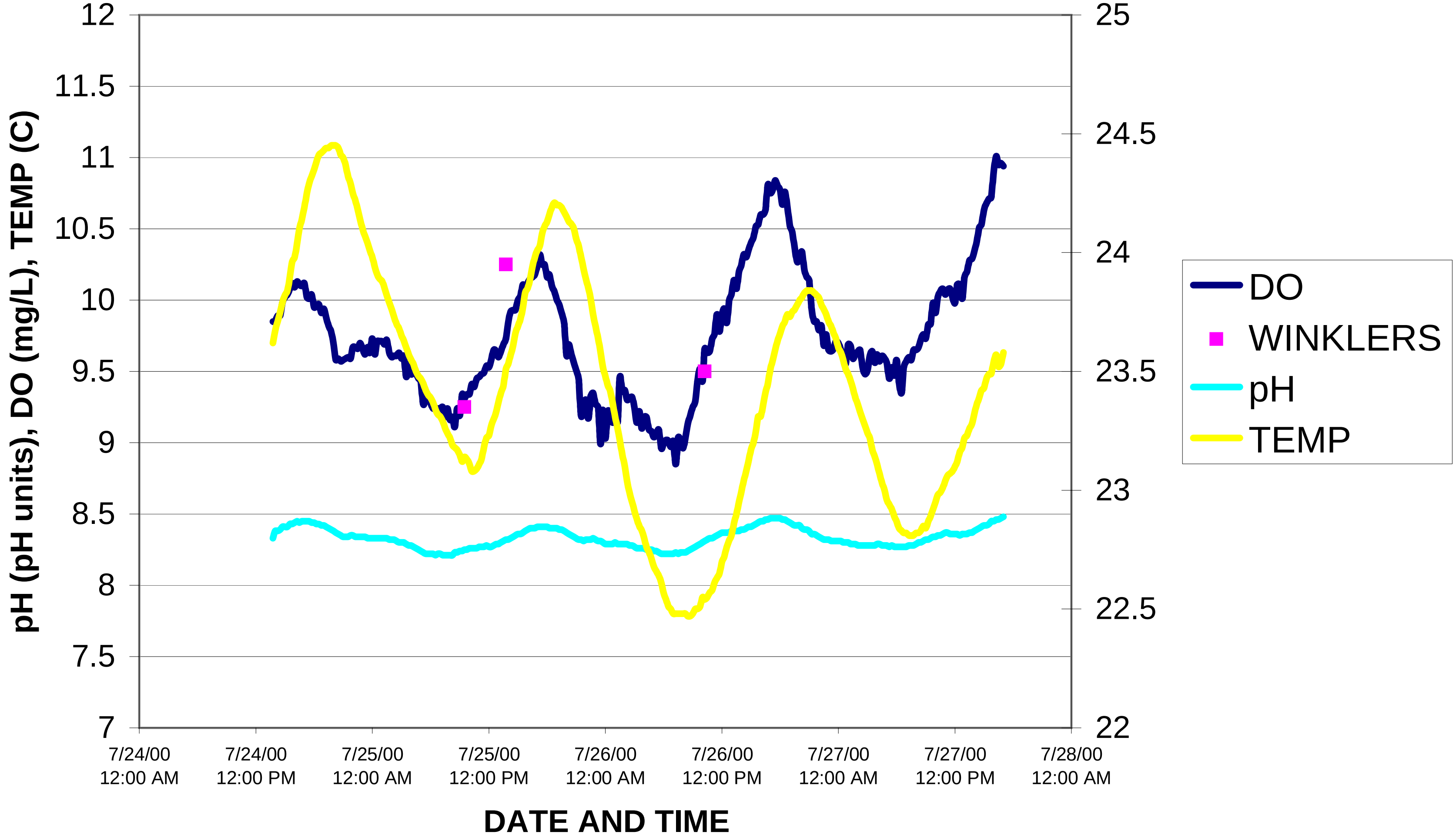
pH, DO, TEMP @ KIONA
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
9/27/99 12:00 AM
9/27/99 12:00 PM
9/28/99 12:00 AM
9/28/99 12:00 PM
9/29/99 12:00 AM
9/29/99 12:00 PM
9/30/99 12:00 AM
9/30/99 12:00 PM
10/1/99 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

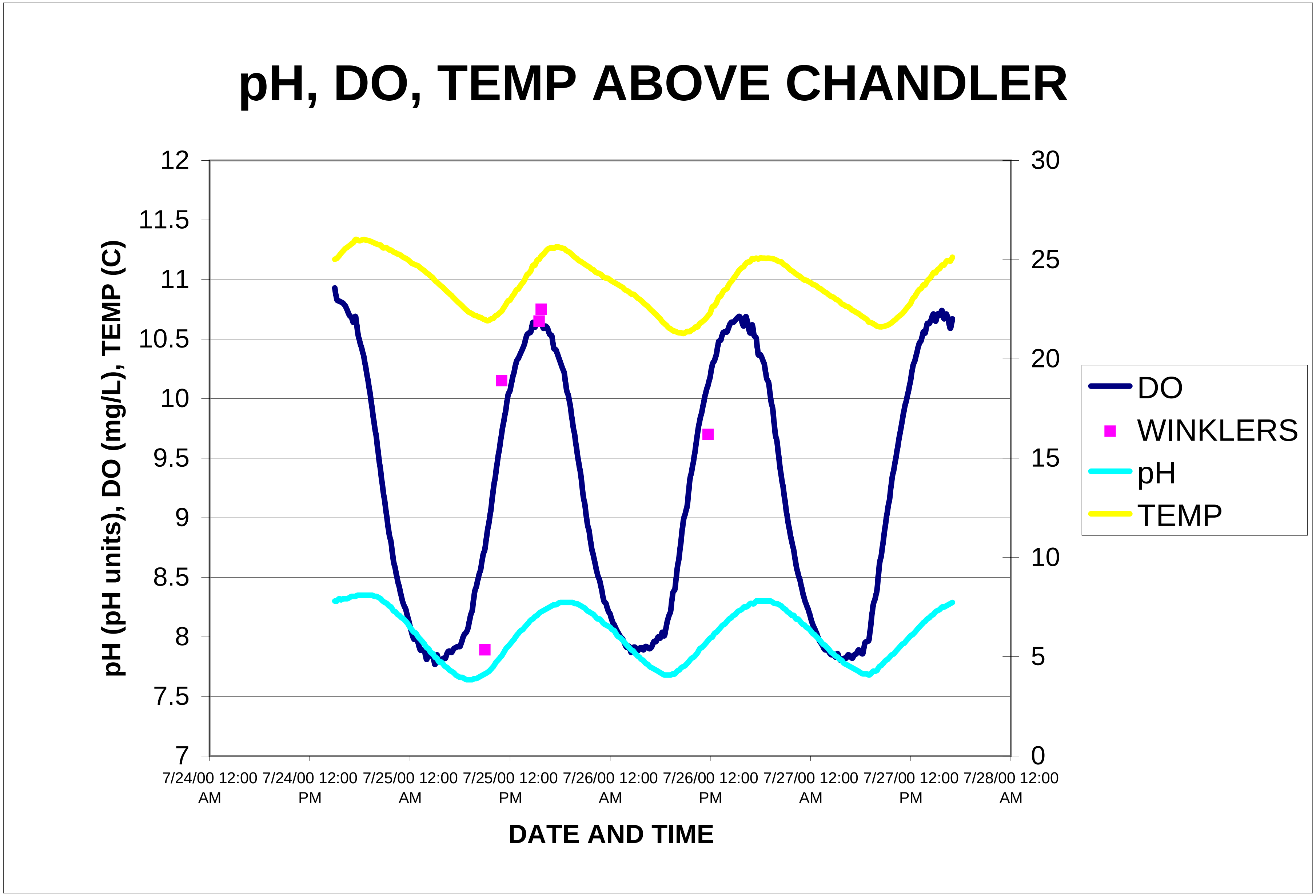


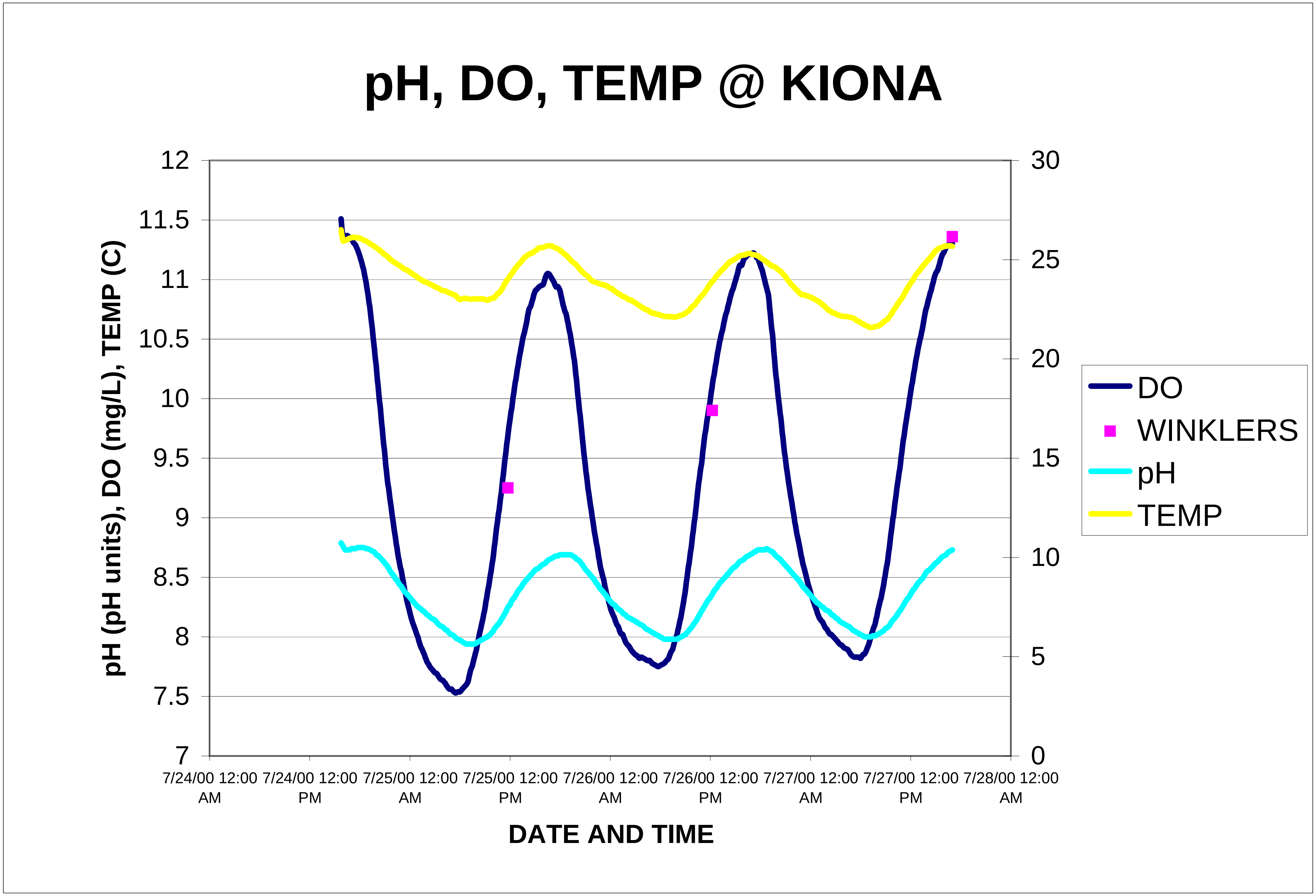
pH, DO, TEMP @ VAN GEISEN
pH (pH units), DO (mg/L), TEMP (C)
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
1/0/00 12:00 AM
1/20/00 12:00 AM
2/9/00 12:00 AM
2/29/00 12:00 AM
3/20/00 12:00 AM
4/9/00 12:00 AM
4/29/00 12:00 AM
5/19/00 12:00 AM
6/8/00 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

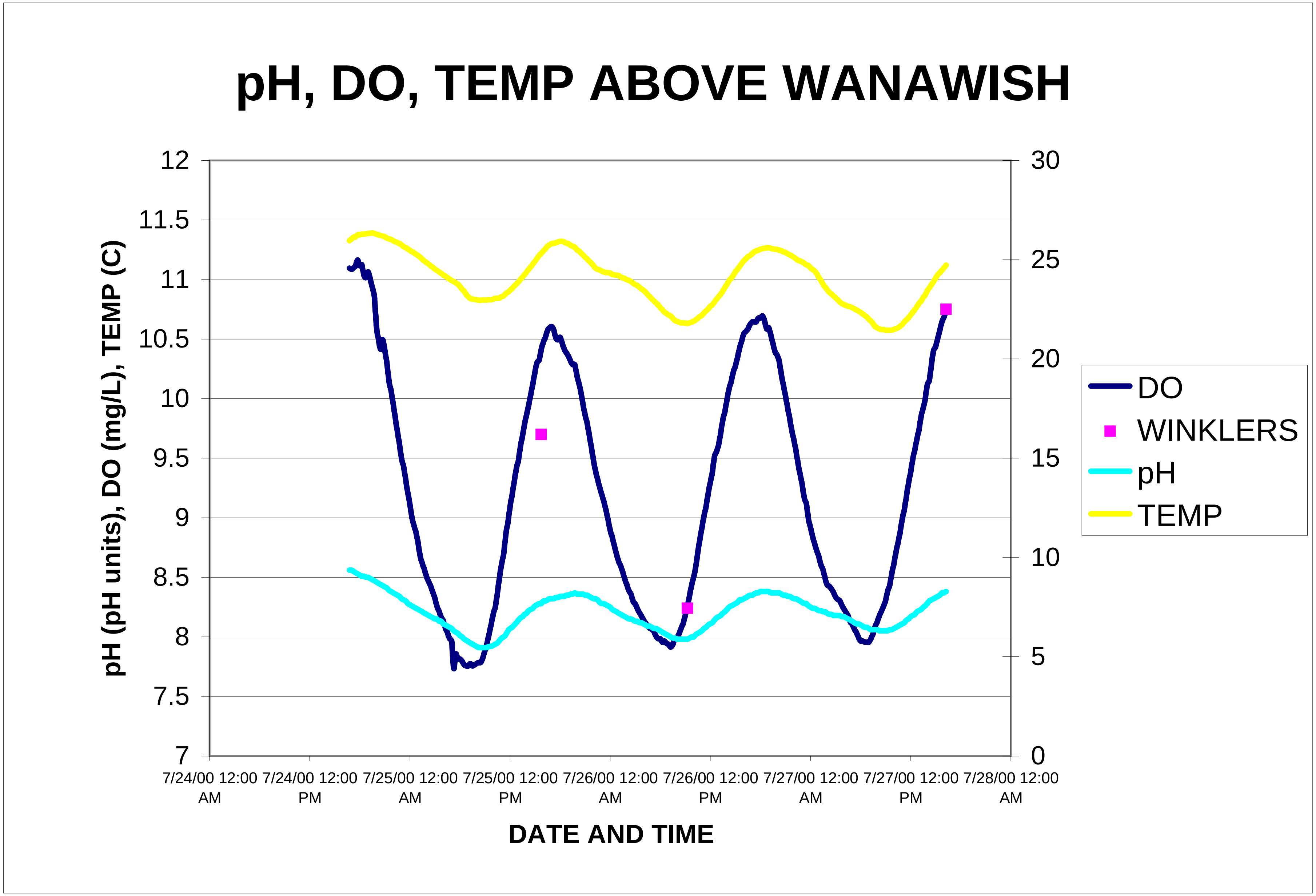

pH, DO, TEMP @ WANAWISH
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
9/27/99 12:00 AM
9/27/99 12:00 PM
9/28/99 12:00 AM
9/28/99 12:00 PM
9/29/99 12:00 AM
9/29/99 12:00 PM
9/30/99 12:00 AM
9/30/99 12:00 PM
10/1/99 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

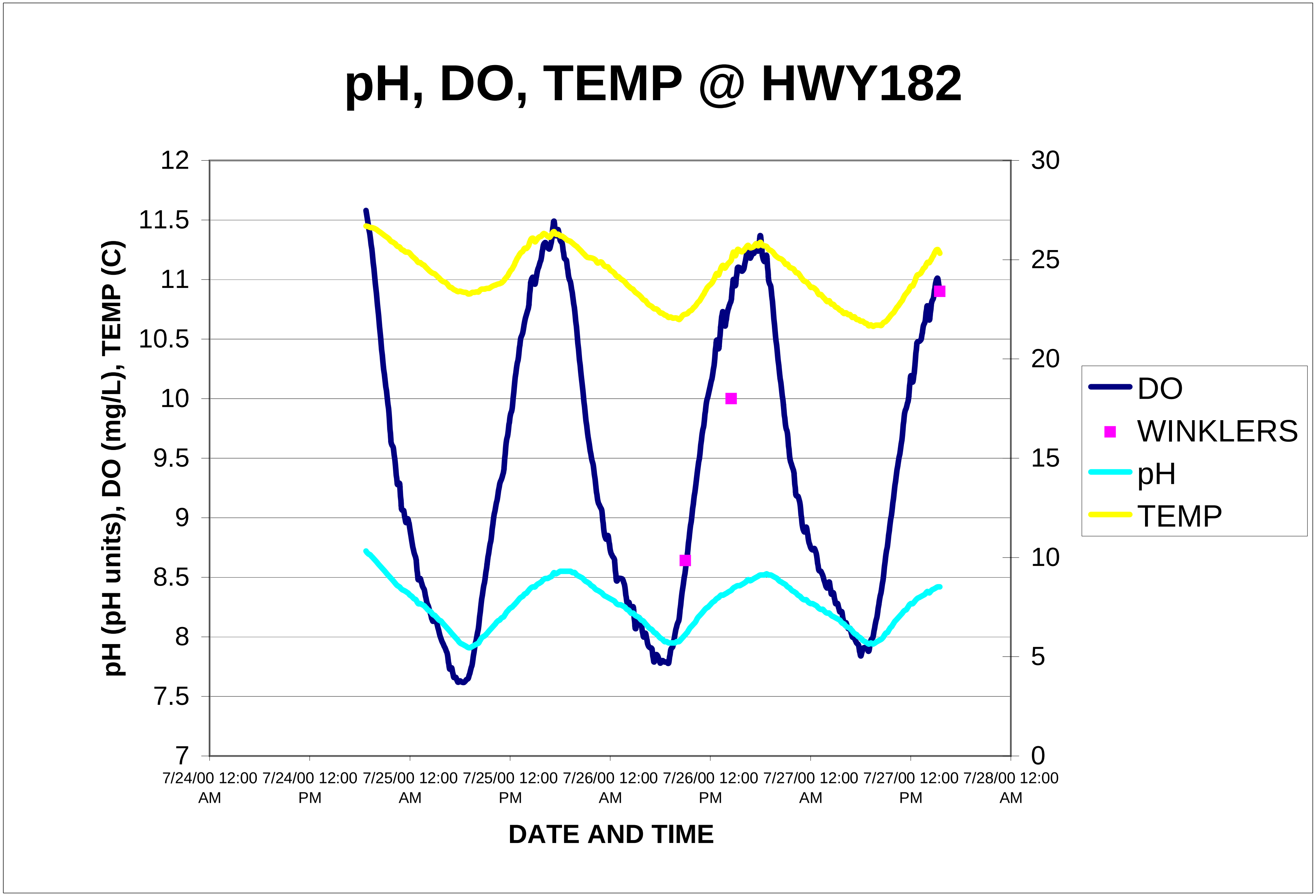
# pH, DO, TEMP @ PROSSER




pH, DO, TEMP ABOVE CHANDLER
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
30
25
20
15
10
5
0
7/24/00 12:00 AM
7/24/00 12:00 PM
7/25/00 12:00 AM
7/25/00 12:00 PM
7/26/00 12:00 AM
7/26/00 12:00 PM
7/27/00 12:00 AM
7/27/00 12:00 PM
7/28/00 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

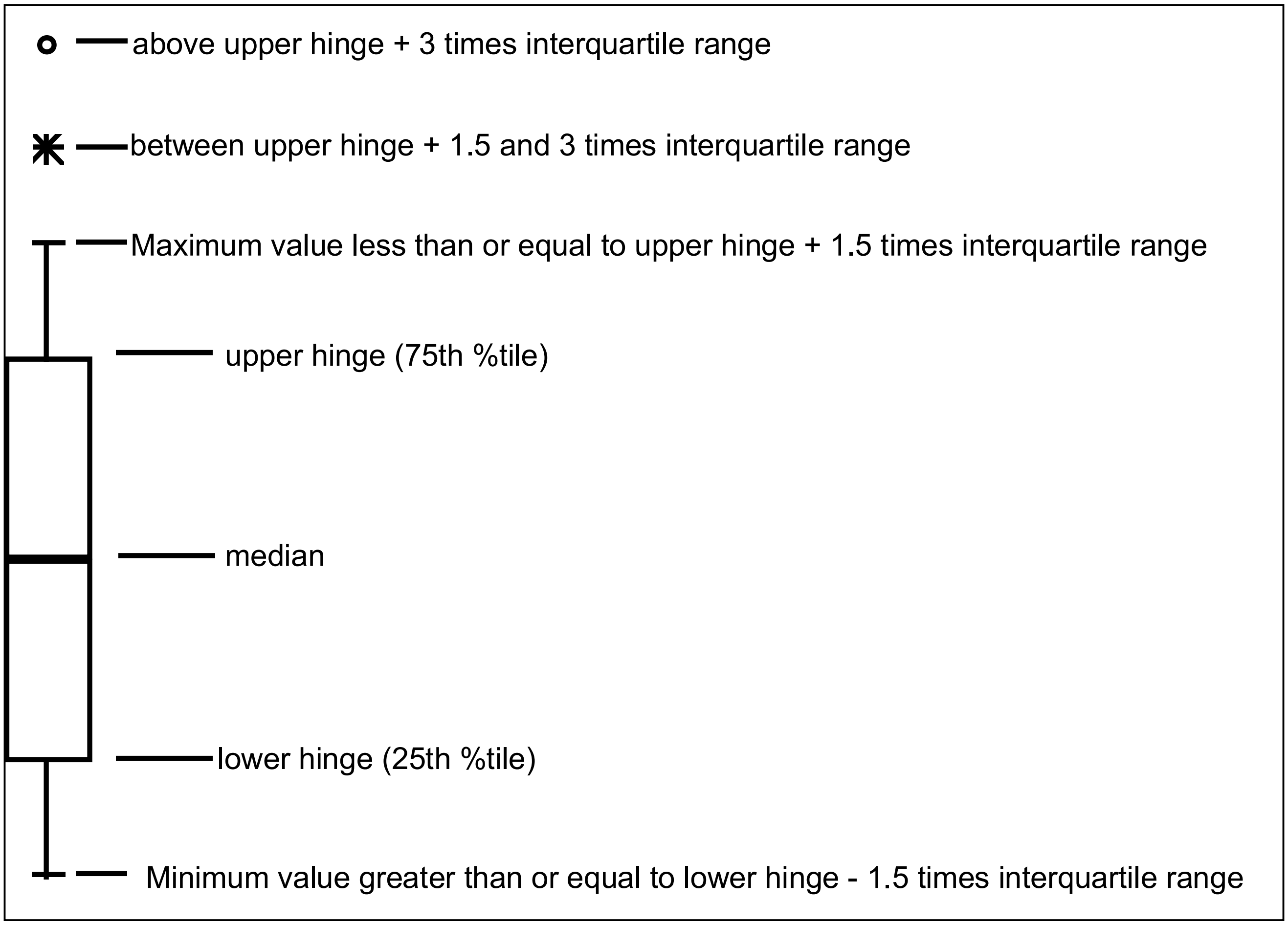

pH, DO, TEMP @ KIONA
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
30
25
20
15
10
5
0
7/24/00 12:00 AM
7/24/00 12:00 PM
7/25/00 12:00 AM
7/25/00 12:00 PM
7/26/00 12:00 AM
7/26/00 12:00 PM
7/27/00 12:00 AM
7/27/00 12:00 PM
7/28/00 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP


pH, DO, TEMP ABOVE WANAWISH
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
30
25
20
15
10
5
0
7/24/00 12:00 AM
7/24/00 12:00 PM
7/25/00 12:00 AM
7/25/00 12:00 PM
7/26/00 12:00 AM
7/26/00 12:00 PM
7/27/00 12:00 AM
7/27/00 12:00 PM
7/28/00 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP


pH, DO, TEMP @ HWY182
pH (pH units), DO (mg/L), TEMP (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
30
25
20
15
10
5
0
7/24/00 12:00 AM
7/24/00 12:00 PM
7/25/00 12:00 AM
7/25/00 12:00 PM
7/26/00 12:00 AM
7/26/00 12:00 PM
7/27/00 12:00 AM
7/27/00 12:00 PM
7/28/00 12:00 AM
DATE AND TIME
DO
WINKLERS
pH
TEMP

# Appendix F

## Key to box plots


above upper hinge + 3 times interquartile range
between upper hinge + 1.5 and 3 times interquartile range
Maximum value less than or equal to upper hinge + 1.5 times interquartile range
upper hinge (75th %tile)
median
lower hinge (25th %tile)
Minimum value greater than or equal to lower hinge - 1.5 times interquartile range