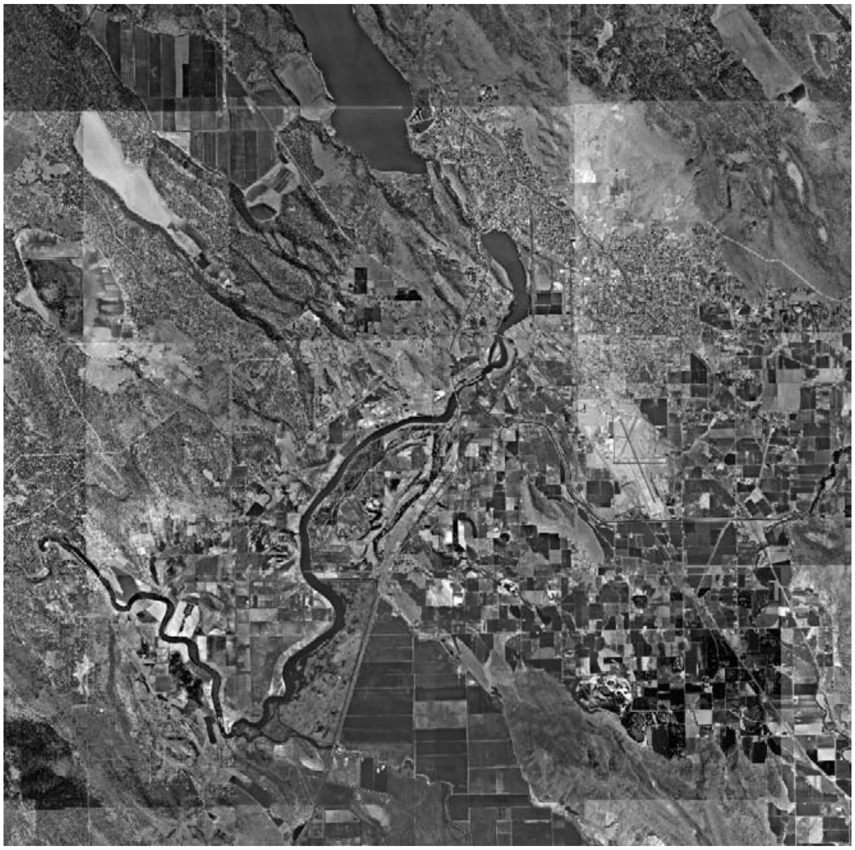
Characterization of Organic Matter Fate and Transport in the Klamath River below Link Dam to Assess Treatment/Reduction Potential



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Executive Summary

Objectives and Tasks

The principal objective of this project was to characterize the quantity and composition of organic matter originating from Upper Klamath Lake and that within Keno Reservoir to assess options for reducing detrimental water quality impacts of this material on Keno Reservoir and downstream Klamath River reaches. Keno Reservoir is located at the terminus of Link River in Klamath Falls, with headwaters approximately 1.2 miles below Link Dam (Upper Klamath Lake). The approximately 20 mile long reservoir is broad and shallow, with depths typically less than 5 meters and widths ranging from several hundred feet wide to several thousand feet. With the exception of the regions in the vicinity of Klamath Falls, much of the shoreline is dominated by agricultural lands, with the exception of Keno, where the river enters the Cascade Range.

Recent studies assessing flow and water quality in the Klamath River support earlier work that the water quality conditions in Upper Klamath Lake have a significant impact on downstream river reaches during summer periods – particularly Lake Ewauna and Keno Reservoir – and impacts may extend considerably farther downstream (PacifiCorp, 2005). Of primary concern is organic matter (living and dead) imparting a considerable oxygen-demanding load on the system, with its concomitant nutrient load. Currently, releases from the hyper-eutrophic Upper Klamath Lake convey this load via Link River to the impoundment behind Keno Dam. In addition to the Upper Klamath Lake releases, municipal, industrial, and agricultural flows enter the river in the Keno Reservoir reach. During summer periods a significant portion of the Lake Ewauna to Keno Dam reach experiences widespread, persistent anoxia, which limits assimilative capacity of the river and may further degrade water quality conditions. Although conditions are generally acceptable through May or early June, by August dissolved oxygen concentrations fall to less than 1.0 mg/l for much of the reservoir depth and length from River Mile (RM) 250 downstream. The result is extreme water quality impairment from an aquatic ecosystem perspective.

One desirable attribute of treatment wetlands is that the necessary facilities could be implemented in just a few years. Given the long time span necessary to provide recovery of hypereutrophic UKL conditions (decades to centuries), solutions that could be implemented in a matter of years are appealing.

The project consisted of two primary tasks: (1) to quantify the spatial and temporal character and distribution of organic matter and associated water quality constituents in the reach between Link Dam and Keno Dam, and (2) use this information to assess the feasibility of improving the water quality in this reach using treatment wetlands. A subsequent phase of the project would include design and implement a pilot treatment wetland and monitoring program to assess large scale application.

Project Elements

To quantify and characterize organic matter and associated constituent conditions and assess the potential to treat and/or reduce these loads in reaches below Link Dam, several inter-related tasks were completed, including:

- monitoring program design
- monitoring and laboratory oversight
- data management
- data analysis to identify potential for treatment wetlands
- reporting

The monitoring program design was developed with assistance from Dr. George Tchobanoglous, Professor Emeritus, University of California, Davis, input from U.S. Bureau of Reclamation (Klamath Area Office and MP-170 Sacramento), U.S. Fish and Wildlife, U.S. Geological Survey, as well as Basic Laboratory and others. Monitoring occurred on nine dates during the 2005 season between May 3 and October 18. Samples were collected at six sites distributed form Link Dam to Keno Dam: Link Dam, Lake Ewauna, Miller Island, below the Klamath Straits Drain, within the Drain, and Keno Dam. Twenty three individual types of physical, chemical, and biological constituents were sampled or assessed at various frequencies. A unique element of the monitoring program was the collection of a suite of filtered and unfiltered biochemical oxygen demand samples to identify the particulate and dissolved fractions of material that were present in water. BOD_5 samples were filtered at 10 microns, 1.0 micron, and 0.45 microns. The 0.45 micron filter size was selected to distinguish between dissolved and particulate material, while the 1.0 micron filter size was to screen material at the colloidal level. The 10 micron filter was included to provide additional detail in the particulate range. A wide range of other parameters were collected to provide insight into system processes in this complex system, including temperature, dissolved oxygen, pH, conductivity, total suspended solids, light extinction properties, chemical oxygen demand, nutrients, algae, and zooplankton.

The physical process of collecting field samples and observations was completed in cooperation with U.S. Bureau of Reclamation. Primary laboratory oversight was carried out by Watercourse; however, Reclamation was consulted on several occasions regarding laboratory performance. All project laboratory and field data were reviewed and entered into electronic format. Laboratory analyses and field data were used in determination of the potential use of the treatment wetlands. Dr. George Tchobanoglous was consulted throughout the design and implementation of the project. Dr. Bob Gearhart provided review of the wetlands calculations.

Wetland Design Calculations

Free Water Surface Wetlands

Upon completion of the field data collection, wetland design calculations were carried out. These calculations provide a theoretical basis for wetland design are intended to identify the potential for wetlands treatment to mitigating water quality conditions that primarily emanate from Upper Klamath Lake. As such, the calculations do not produce final design parameters and specification. Appropriate lands, infrastructure, potential costs, and other features would be required prior to implementing wetlands for treatment. A pilot project is strongly recommended.

Free water surface (FWS) wetlands are those that most closely resemble natural wetlands in both appearance and function. In assessing the feasibility of treatment using wetlands, a FWS wetland was the primary type considered for determining the viability of wetland treatment of organic matter. Free water surface wetlands can remove between 60 to 80 % of BOD_5 and 50 to 90% of total suspended solids (TSS), which includes organic matter, depending on design criteria, influent characteristics, influent concentrations of BOD_5 and TSS, and operation of the wetland and have been used in a variety of locations with success.

The concept assessed herein presumes wetlands could be located adjacent to the Klamath River in the Keno Reservoir reach (although wetlands could also be located in areas away from the river) to reduce the organic load originating from Upper Klamath Lake. Benefits realized within the Keno Reservoir reach would also be translated to downstream river reaches. Although a FWS wetland would also provide potential wildlife habitat, these wetlands would be actively managed for treatment. While it is not practical to define a typical FWS wetland flow rate and area without representative, site specific data, existing FWS wetlands can provide valuable guidance on possible flows, sizes, and treatment effectiveness.

Calculations

Fundamental to the design of a FWS treatment wetland is determining the design BOD (BOD_{design}). BOD_{design} is the BOD_5 concentration used to determine the required detention time for the FWS wetland. The detention time is the amount of time water is required to remain in the wetland to achieve the desired reduction of BOD_5 concentration. BOD_{design} takes into consideration the variability of the BOD_5 in the wetland influent water, as well as the natural processes within the wetland that contribute to additional BOD_5 in the effluent water of the wetland, the desired effluent BOD_5 concentration, and the probability that the effluent BOD_5 will not exceed its desired value.
Once the detention time is calculated, the organic loading rate for the wetland can be determined. The organic loading rate should not exceed a maximum acceptable rate for a FWS wetland, or the wetland efficiency may decreases. Assuming an overall water depth for the wetland, an aspect ratio for the wetland dimensions (e.g., length:width), and the calculated detention time, the area, length and width of the wetland can be calculated.

A wetland design based on global average BOD_5 values (all sites for the entire season – May through October) would on average reduce BOD_5 by 26 percent and requires 1,054 acres of wetland area. However, during periods of high BOD in influent waters, this wetland area would be incapable of processing the assumed 25 percent of river flow and diversions to the wetland would have to be reduced to less than half – a considerable reduction in overall treatment capacity during a critical water quality period. A more conservative wetland area based on maximum annual observed BOD_5 (all sites for the entire season) would on average reduce BOD_5 by 82 percent and require 2,192 acres of wetland area. However, if May was not included in the period average (i.e., calculations based on June through October average conditions), a wetland on the order of 1,400 acres would be sufficient. A flow rate of 25 percent of monthly average in flow to Keno Reservoir was used as a baseline for system design. Subsequently, wetland acreage was calculated based on a coefficient of reliability of 99 percent, a depth of 1.5 feet, and a residence time of 4 days (see Table below).

Further, field data suggest that removal percentage varies along the reservoir with increasing distance from Link Dam. Wetlands closer to Link Dam (Link Dam to approximately Miller Island) would be relatively more efficient than those located closer to Keno. The Klamath Straits Drain experienced low BOD_5 conditions throughout the season and wetlands treatment for organic matter removal would most likely prove modest.

Sensitivity analysis varying wetland depth, plant void ration, and internal plant decay BOD suggest that wetland parameter design selection can appreciably affect required wetland area while still maintaining BOD loading rates well under the maximum 100 lb BOD/ac-day. These findings indicate that design modification could provide valuable flexibility in locating wetlands where BOD_5 loads are high and/or potential wetland acreage is limited.

Wetland areas for maximum seasonal BOD5 loads based on monthly flows and a hydraulic residence time of 4 days.

Month	Q_{in}, cfs	Q_{out}, cfs	Q_{avg}, cfs	Q_{avg}, MGD	Wetland Area, acres	Wetland Depth, ft	Hydraulic Residence Time, days
May	622	497	560	362	2960	1.5	4.00
June	291	233	262	169	1384	1.5	4.00
July	269	215	242	157	1282	1.5	4.00
August	268	215	241	156	1277	1.5	4.00
September	243	195	219	141	1158	1.5	4.00
October	242	194	218	141	1152	1.5	4.00
Entire Period	323	259	291	188	1538	1.5	4.00

Conclusions and Recommendations

Conclusions

Through detailed field monitoring, specific data were collected to complete preliminary estimates of wetlands treatment, reliability, and reduction of organic matter as represented by BOD. Filtered and unfiltered samples illustrated the range of BOD present in the Link Dam to Keno Dam reach, with most material being particulate matter – useful information in wetland design consideration. Associated sampling further characterized the broad range of physical, chemical, and biological water quality conditions present in the system. Quality assurance provided valuable field data validation measures in this complex system.

Theoretical calculations indicate that different BOD influent values for a FWS wetland can effect wetland design conditions. Because BOD values differ considerably throughout length of Keno reservoir, the placement of the wetlands may play a role in overall treatment effectiveness. The reduction of BOD in the wetland water is largely dependent on the influent BOD, the desired BOD effluent, depth, flow rate, wetland size, and desired level of reliability. Increasing the depth of the wetland is acceptable as long as the organic load is less than 100 lb BOD /ac-day, but increasing the organic load means that there may be a higher frequency of maintenance in the wetland to remove organic matter. Planning for worst case conditions (e.g., seasonal maximum measured BOD) versus average conditions (e.g., average seasonal BOD) changes the wetland design considerably. Worst case conditions represent a more conservative, and generally more prudent, approach to design.

Based on field data, preliminary calculations indicate that wetlands treatment may be a viable option for notably reducing organic loads from Upper Klamath Lake. Treating 25 percent of typical summer flows would require approximately 1,400 acres of wetlands, and scaling this up to 100 percent of river flows would translate to approximately 5,600 acres of wetlands. Although an appreciable area, such wetland acreage is not unheard of: Kadlec and Knight (1996) identify wetlands of several thousand acres treating several hundred cubic feet per second. Thus there is appreciable potential that wetlands treatment below Link Dam could provide considerable benefit to the water quality of Keno Reservoir and downstream Klamath River reaches.

There are remaining issues that require further assessment with regard to the ultimate efficacy of such wetlands, including local climate, effective size and location, assessment of soil and groundwater conditions, earthwork, infrastructure required, etc. As noted previous, a pilot project is highly recommended to test some of the basic assumptions identified herein as well as others required for comprehensive testing and implementation of wetlands. Such work could be completed in concert with non-technical concerns including, but not limited to, land availability and cost, operations and maintenance, ownership/responsibility, overall economic considerations, water rights (losses associated with wetlands), questions of wildlife use (e.g., endangered species), and other topics of interest.

Also, some regulatory framework may play an important role in the utilization of wetlands to improve water quality – an avenue that has recently been discussed in the basin, but without a definite framework in place. Receiving water standards and issues associated with discharge will need to be addressed.

Finally, the water quality processes within Keno Reservoir are complex and the water quality response of treatment wetlands is not completely understood at this time. Overall, there are many processes and issues surrounding implementation of wetlands treatment. However, the potential to provide considerable benefit in a short time frame, given the level of impairment at Upper Klamath Lake inflows into the Klamath River, suggest that further study is warranted.

Recommendations

Based on the findings of the field work and associated analysis, several recommendations have been identified. These recommendations are not prioritized, nor have costs been associated with the various activities.

- *Continued field monitoring*: Reclamation currently maintains a suite of water quality probes and collects other physical data within Keno Reservoir and, in cooperation with other agencies and entities, monitors conditions around Upper Klamath lake. It is recommended that these programs be maintained to construct a continuous and long record of conditions in the project area. Definition of system variability will be invaluable if wetlands treatment systems are deemed an acceptable and appropriate means of addressing current and/or future water quality problems. Should wetlands be implemented, monitoring to assess the efficacy of such systems will be required.
- *Characterization of organic matter*: Continue monitoring organic matter via BOD, COD, TOC, and other appropriate measures. These programs may include baseline studies, as well as specific studies (e.g., characterizing small temporal or spatial conditions). Filtered and unfiltered samples can lend considerable insight into the particulate, dissolved, labile, and refractory nature of organic matter – a critical and unique attribute of this system.
- *Wetlands pilot project*: consider implementing a pilot project to assess organic matter removal potential of treatment wetlands with a small scale project adjacent to the Klamath River or in neighboring areas. Such projects would be invaluable investigations not only into the ability of wetlands to process organic matter, but also to determine the best methods to implement, maintain, and operate such a system.
- *Assess potential implications of wetlands on Keno Reservoir water quality*: Using field data and/or analytical and numerical tools (models), explore the impacts of variable levels of treatment (in space and time) on Keno Reservoir. Improving water quality in Keno Reservoir could lead to a host of beneficial water quality responses including greater assimilative capacity under continuous aerobic conditions (versus the current seasonal, widespread, and persistent anoxia). However, the response of the system is largely unknown and prior to considering large scale wetlands, a water quality impacts assessment should be completed.
- *Regulatory implications*: Exploring the regulatory implications of wetlands treatment from water quality to aquatic system species and other wildlife (e.g., waterfowl), as well as legal repercussions should be completed.

Acknowledgements

The authors acknowledge the cooperation and support of Rich Piaskowski (U.S. Bureau of Reclamation) for project management. Jason Cameron (U.S. Bureau of Reclamation) for oversight of the field monitoring program. Jessica Asbill, Damion Ciotti, Stephani Painter, and Travis Kern (U.S. Bureau of Reclamation) for field sample and data collection. Dr. George Tchobanoglous (University of California, Davis) for sharing his expertise and providing guidance in sampling specific to wetlands treatment systems, as well as peer review. Dr. Robert Gearhart (California State University, Humboldt) for his critical review of wetland treatment design calculations. Watercourse would also like to acknowledge the proposal review by U.S. Fish and Wildlife Service and U.S. Geological Survey, which provided valuable guidance, feedback, and encouragement on aspects of the study design, locations, and desired outcomes. Finally, Watercourse acknowledges the sponsorship and financial support of the project by the U.S. Bureau of Reclamation, Klamath Basin Area Office.

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1. Introduction

1.1. Project Purpose

The principal objective of this project was to characterize the quantity and composition of organic matter originating from Upper Klamath Lake and that within Keno Reservoir and to assess options to reduce the detrimental water quality impacts of this material on Keno Reservoir and downstream Klamath River reaches. The project consisted of two primary tasks: (1) to quantify the spatial and temporal character and distribution of organic matter and associated water quality constituents in the reach between Link Dam and Keno Dam, and (2) use this information to assess the feasibility of improving the water quality in this reach using treatment wetlands. A subsequent phase of the project would include design and implement a pilot treatment wetland and monitoring program to assess large scale application.

Although significant past and current efforts to improve Upper Klamath Lake water quality are valuable aspects of restoration in the upper basin, the timeline for potential recovery of Upper Klamath Lake is decades at best and perhaps longer due to the internal nutrient loading within in the lake, the large supply of natural sources of phosphorous, and the difficulty controlling diffuse (non-point) anthropogenic sources (NAS 2004). The approach assessed herein, while not a panacea, does provide the prospect to decrease the loads of organic matter borne out of Upper Klamath Lake in downstream reaches, potentially providing improvements in water quality in a relatively short period of time.

1.2. Report Organization

This report is largely a data and technical report. The project area and background are presented in Chapter 2, with a more comprehensive project description provided in Chapter 3. The monitoring program design, sampling periods and frequency, quality assurance, and laboratory information is outlined in Chapter 4. Chapter 5 includes a brief summary of the field data collected during the 2005 field season as well as associated data from other agencies (e.g., flow data). There was a wide array of data collected that was not pertinent to wetland calculations, but was included largely in response to requests of initial reviewers of the proposal. Biochemical oxygen demand is discussed in detail therein because it is an important element of the wetland design calculations. Chapter 6 includes the methodology and calculation of wetland design parameters based on field data from the project area. Summary and conclusions are presented in Chapter 7. Several appendices are included to provide supporting data, calculation, tabulated and graphical summaries, quality assurance plans and standard operating procedures, as well as other information.

1.3. Acknowledgements

Watercourse Engineering acknowledges the cooperation and support of Rich Piaskowski (U.S. Bureau of Reclamation) for project management. Jason Cameron (U.S. Bureau of Reclamation) for oversight of the field monitoring program. Jessica Asbill, Damion

Ciotti, Stephani Painter, and Travis Kern (U.S. Bureau of Reclamation) for field sample and data collection. Dr. George Tchobanoglous (University of California, Davis) for sharing his expertise and providing guidance in sampling specific to wetlands treatment systems, as well as peer review. Dr. Robert Gearhart (California State University, Humboldt) for his critical review of wetland treatment design calculations. Watercourse would also like to acknowledge the proposal review by U.S. Fish and Wildlife Service and U.S. Geological Survey, which provided valuable guidance, feedback, and encouragement on aspects of the study design, locations, and desired outcomes. Finally, Watercourse acknowledges the sponsorship and financial support of the project by the U.S. Bureau of Reclamation, Klamath Basin Area Office.

2. Project Area and Background

Keno Reservoir, owned and operated by PacifiCorp, is located at the terminus of Link River in Klamath Falls, with headwaters approximately 1.2 miles below Link Dam (Figure 1). The approximately 20 mile long reservoir, with maximum depth of approximately 7 meters, but typically reservoir depths are less than 5 meters. The reservoir varies in width from several hundred feet wide to over approximately 0.75 miles wide in the Lake Ewauna region. Due to a relatively stable water surface elevation, herbaceous vegetation occupies the immediate margins of the lake with bulrush (*Scirpus* spp.) and cattail (*Typha latifolia*) the dominant forms. In the vicinity of Klamath Falls municipal and industrial lands border the river and local topography confines the channel to some degree. Along the eastern shore of the reservoir from approximately Highway 97 to the Klamath Straits Drains, extensive wetlands border the river associated with Miller Island Wildlife Refuge and a private hunting club. The wildlife refuge lands are managed distinct from the river, i.e., they are separated by a levee/dike system. The hunting club wetlands are directly connected to the reservoir and little management of these wetlands is apparent. Much of the remaining shoreline is dominated by agricultural lands, with the exception of Keno, where the river enters the Cascade Range.

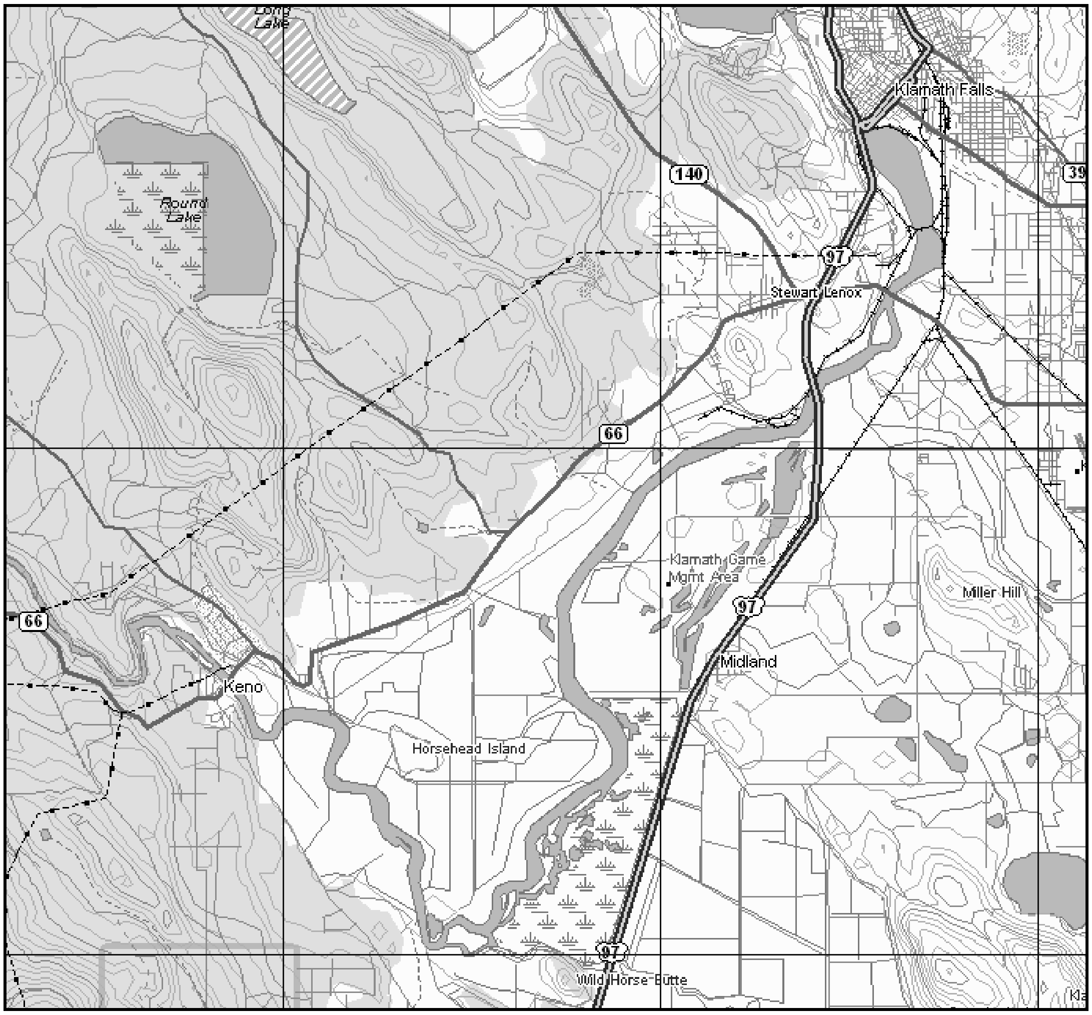

Figure 1. Project area

There are no hydropower production facilities at the downstream dam of Keno Reservoir. The current dam was completed in 1967, but California and Oregon Power Company (Copco) had previously constructed a dam at this site in 1930 to create a backwater, reduce velocities, and thus reduce erosion potential on dikes and levees adjacent to the river. In 1968, Pacific Power and Light (the successor of Copco and predecessor of PacifiCorp) and United States Bureau of Reclamation (USBR) entered into a contract to operate Keno Dam to maintain Keno Reservoir between elevations 4085.0 and 4086.5 ft msl whenever USBR is diverting to the federal irrigation project. Notwithstanding, PacifiCorp seeks to maintain Keno Reservoir at elevation 4085.4 ± 0.1 feet from October 1 to May 15 and 4085.5 ± 0.1 feet from May 16 to September 30. These elevations are suited to irrigation pump depths and also allow for gravity flow from Keno Reservoir onto Oregon Department of Fish and Wildlife Miller Island Wildlife Refuge. To maintain such narrow limits given the various inflows and outflows from Keno reservoir operations are managed 24 hours per day 7-days per week. The reservoir is drawn down approximately 2 feet every one or two years for two or three days in April or May to allow irrigators to clean intakes and maintain pumps. (PacifiCorp, 2002).

Waters enter Keno Reservoir via Link River, a 1.2 mile river reach between Link Dam at Upper Klamath Lake (UKL) and the reservoir headwaters. Thus, Upper Klamath Lake forms the primary source of the Klamath River, which subsequently flows through southern Oregon and northern California into the Pacific Ocean. Upper Klamath Lake has a surface area of approximately 121 square miles, an average depth of approximately 8 feet (NAS, 2004), and length of 22 miles. The residence time is approximately 6 months (NAS, 2004), but varies from year to year due to inter-annual variability of hydrologic conditions, as well as impoundment, regulation, and stream diversion. The lake receives inflow primarily from the Williamson and Wood Rivers.

Bortleson and Fretwell (1993) suggest that UKL has probably been naturally eutrophic since before settlement of the basin by non-Native Americans. A eutrophic lake is defined as having both high levels of nutrients and primary production (Horne and Goldman, 1994). During the 20th century Upper Klamath Lake has become hypereutrophic, which means that its nutrient levels have become high enough to cause annual, extensive, nuisance-level algae blooms that result in degraded water quality. Further, hypereutrophication is the final stage of eutrophication and is usually termed irreversible, i.e., the control of external nutrient sources become an ineffective management strategy because sufficient nutrients are available from internal sources (e.g., sediment) within the lake to promote appreciable primary production. Detailed descriptions of water quality conditions are described in a myriad of published reports, and generally summarized by NAS (2004). Although a large amount of research has been focused on the lake itself, study of the impacts of Upper Klamath Lake water quality conditions on downstream river reaches, e.g., Keno Reservoir, has been considerably less extensive.

In 1953, a study was conducted by State of Oregon et al (1955) to explain the problems associated with the primary production at Upper Klamath Lake and downstream effects. The decomposition of the lake’s algae blooms, which are composed predominantly of the blue-green algae *Aphanizomenon flos-aquae*,

> [r]educed [sic] the dissolved oxygen content of the Klamath River at Keno to a minimum of 0.4 parts per million (Parts per million are equivalent to milligrams per liter), far below the minimum to sustain fish life. During the periods when these low dissolved oxygen levels were recorded near Keno, researchers found that the waters flowing out of Upper Klamath Lake upstream “were almost always supersaturated with dissolved oxygen.” In order for these high dissolved oxygen levels to be depleted to the very low levels recorded near Keno, researchers estimated that the Klamath River would have to contain a level of pollution equal to the raw sewage produced by a population of more than 240,000 persons.

In August 1957, Oregon and California entered into the Klamath River Basin Compact. The compact includes provisions relating to water quality. The Klamath River Basin Commission funded several studies over the following decades, including Oregon State

Sanitary Authority (OSSA, 1964), Federal Water Pollution Control Administration (1968), U.S. Bureau of Reclamation (1971), Army Corps of Engineers (Corps, 1977, 1982), (Bortleson and Fretwell, 1993), ODEQ (2002), and NAS (2004).

Recent studies assessing flow and water quality in the Klamath River support earlier studies that the water quality conditions in Upper Klamath Lake have a significant impact on downstream river reaches during summer periods – particularly Lake Ewauna and Keno Reservoir – and impacts may extend considerably farther downstream (PacifiCorp, 2005). Of primary concern is organic matter (living and dead) imparting a considerable oxygen-demanding load on the system, with its concomitant nutrient load. Currently, releases from the hyper-eutrophic Upper Klamath Lake convey this load via Link River to the impoundment behind Keno Dam. In addition to the Upper Klamath Lake releases, municipal, industrial, and agricultural flows enter the river in the Keno Reservoir reach. During summer periods a significant portion of the Lake Ewauna to Keno Dam reach experiences widespread, persistent anoxia, which limits assimilative capacity of the river and may further degrade water quality conditions. Vertical and longitudinal distributions of dissolved oxygen for Keno Reservoir from Link River to Keno Dam representative periods in June and August, 2001 are presented in Figure 2. Although conditions are generally acceptable through May or early June, by August dissolved oxygen concentrations fall to less than 1.0 mg/l for much of the reservoir depth and length from River Mile (RM) 250 downstream. The result is extreme water quality impairment from an aquatic ecosystem perspective. Further, 5-day biochemical oxygen demand (BOD_5) concentrations in excess of 50 mg/l have been reported in the Link Dam to Keno Dam river reach, with typical concentrations between 10 and 30 mg/l during summer periods (U.S. Bureau of Reclamation data). By contrast natural river systems typically have BOD_5 values less than 3 mg/l (EPA, 1997). These conditions are hypothesized to occur due to large quantities of organic matter originating in Upper Klamath Lake and exceeding the assimilative capacity of the Link River and Keno Reservoir reaches.

Based on these water quality impairments, an investigative study was designed to examine the potential to reduce organic matter and its associated oxygen demand within Keno Reservoir through constructed wetlands. Constructed wetlands can reduce soluble organic matter through several mechanisms, including sedimentation, filtration, adsorption, and biological conversion (EPA, 2000). Of particular importance in wetland design is particle size distribution. Generally, dissolved constituents are defined as those that pass a 0.45 micron filter, while particulate matter is assumed larger than 0.45 microns APHA, 1995). However, colloidal materials are defined on a slightly difference scale, with the cutoff between colloidal and dissolved material at 1.0 micron (EPA, 2000; G. Tchobanoglous pers. comm.). Characterizing the spatial and temporal distribution of organic matter through filtered and unfiltered samples was an integral aspect of the proposed work.

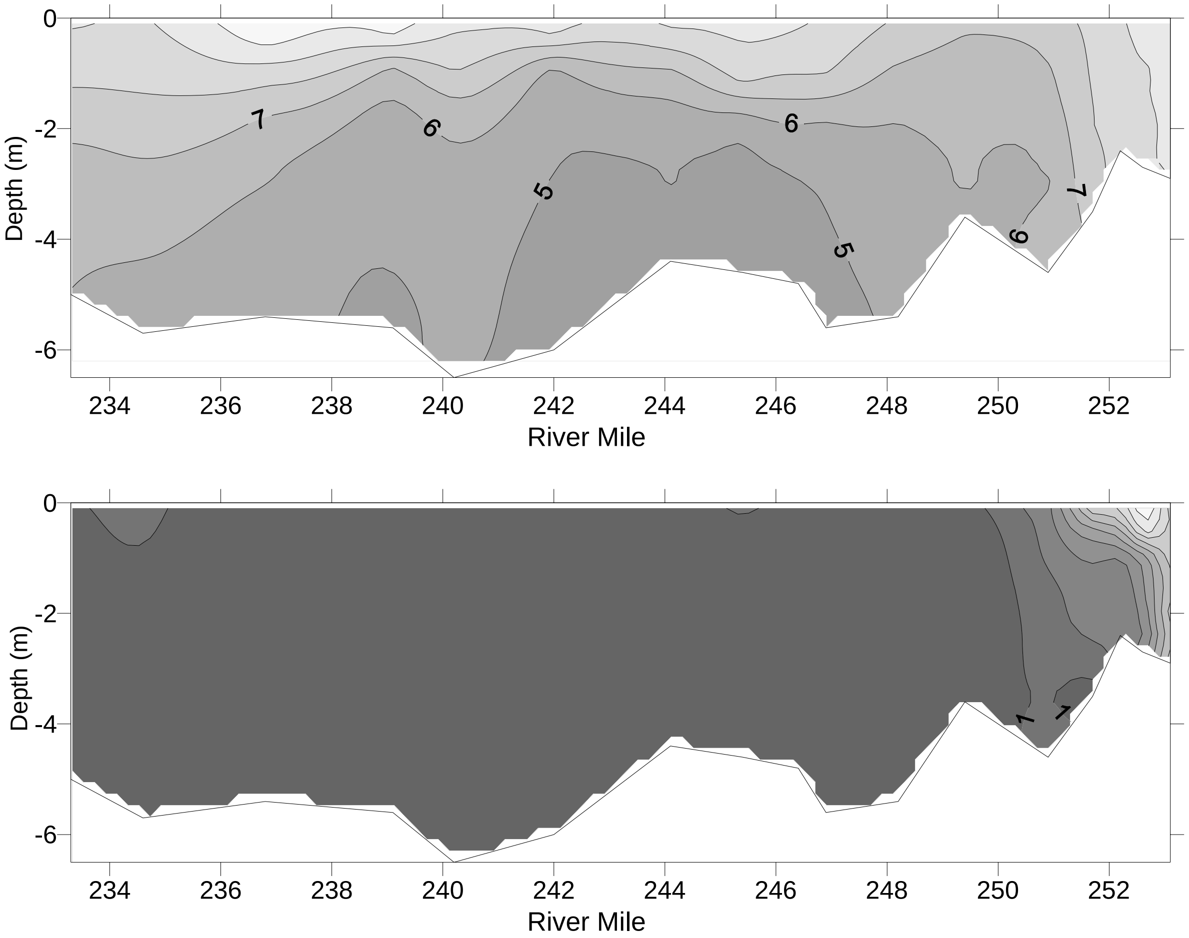

Figure 2. Measured dissolved oxygen concentrations in Keno Reservoir from Link River (≈RM 253) to Keno Dam (≈RM 233): June 15-18, 2001 (top) and August 13-14, 2001 (bottom) [source: U.S. Bureau of Reclamation Klamath Area Office]

3. Project Description

To quantify and characterize organic matter and associated constituent conditions and assess the potential to treat and/or reduce these loads in reaches below Link Dam, several inter-related tasks were completed, including:

- monitoring program design
- monitoring and laboratory oversight
- data management
- data analysis to identify potential for treatment wetlands
- reporting

Each of these tasks is briefly described below.

Monitoring Program Design:

The monitoring program design was developed with assistance from Dr. Tchobanoglous, Professor Emeritus, University of California, Davis, input from U.S. Bureau of Reclamation (Klamath Area Office and MP-170 Sacramento), U.S. Fish and Wildlife, U.S. Geological Survey, as well as Basic Laboratory and various vendors. The selected sampling parameters, locations, frequencies, and impetus for each parameter are discussed in subsequent sections of this report. An important aspect of the program was adaptability – the modification of techniques in response to actual field conditions provided more useful project data.

Monitoring

The physical process of collecting field samples and observations was completed in cooperation with U.S. Bureau of Reclamation. Reclamation was in charge of managing water quality probe data and most other physical observations and grab samples were collected and submitted to predetermined laboratories for analysis. Watercourse, with input from Reclamation, provided laboratory oversight throughout the project.

Data Management

All project laboratory and field data were reviewed and entered into electronic format. These data, and any associated documentation, are included as a project deliverable.

Data Analysis and Wetlands Treatment Potential

The laboratory analyses and field data were used in the determination of the potential use of the treatment wetlands. Ideally, sufficient data and analysis are available to identify a pilot level treatment facility (future work), as well as identify additional monitoring needs (e.g., spatially and temporally for the various constituents).

Reporting

The project tasks identified above are presented in detail within this project report. Although not included in the original scope of work, an important addition to the project was the incorporation of peer review. The monitoring program, QAQC, Standard Operation Procedures, and draft report was provided to the peer review panel for review.

Dr. George Tchobanoglous was consulted throughout the design and implementation of the project. Dr. Bob Gearhart provided review of the wetlands calculations.

4. Monitoring Program Design

Monitoring program design included identification of sampling period, parameters, frequency, field methods, level of quality assurance, and laboratory and analytical services.

4.1. Sampling Period, Locations, and Parameters

The program focused on late spring through early fall periods when water quality conditions were most problematic – May through October. Selected parameters were sampled once per month in May, September, and October, and twice per month June through August (Table 1) when conditions change more rapidly based on previous monitoring.

Table 1. Klamath River 2005 sampling schedule

May 3, 2005	August 9, 2005
June 7, 2005	August 23, 2005
June 28, 2005	September 20, 2005
July 12, 2005	October 18, 2005
July 26, 2005	

To assess spatial and temporal variability in water quality conditions and identification of associated treatment potential, a variety of sampling locations were required. Specific location and motivation for selected sites include:

- Link Dam: characterize primary inflow water quality conditions (releases from Upper Klamath Lake)
- Klamath Straits Drain (KSD): characterize return flow water quality conditions
- Klamath River at Highway 97: characterize potential changes in water quality conditions from upstream locations
- Klamath River at Miller Island: characterize potential changes in water quality conditions from upstream locations
- Klamath River below Klamath Straits Drain: characterize potential changes in water quality conditions from upstream locations
- Klamath River at Keno: characterize potential changes in water quality conditions from upstream locations and conditions near the terminus of the impoundment

These sites are presented in Table 2 with corresponding river mile and shown in Figure 3, and monitoring program parameters including the purpose of collection are presented in Table 3.

Table 2. Sampling locations for Project

Site Number	Sampling Location	River Mile
1	Link Dam	253.1
2	Klamath River at Highway 97	249.1
3	Klamath River at Miller Island	245.6
4	Klamath River below Klamath Straits Drain (KRS12)	239.0
5	Klamath River at Keno	234.9
6	Klamath Straits Drain (KSD)	240.5*

* River mile where the KSD enters the Klamath River. The actual sampling spot is approximately 300 meters below Highway 97.

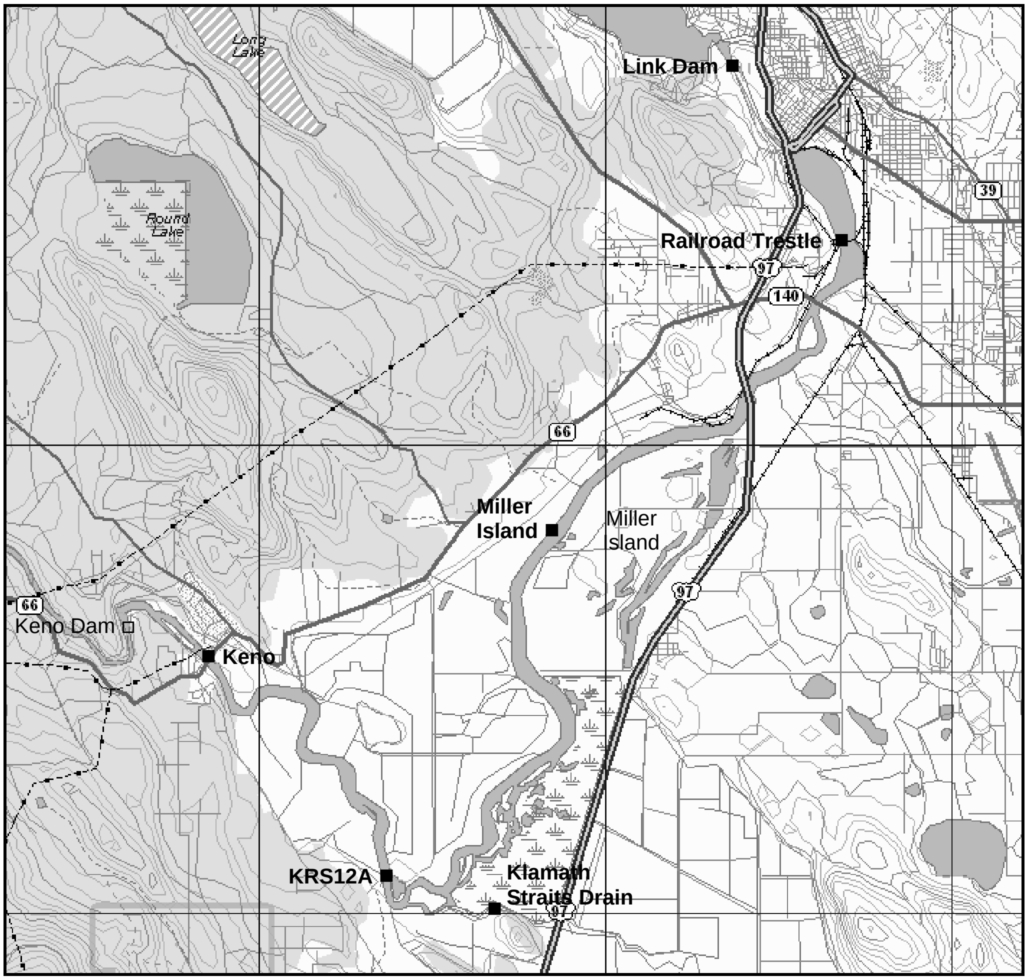

Figure 3. Project area and monitoring sites

Table 3. Project monitoring constituents

Parameter	Parameter Name	Purpose
Organic and Particulate Matter		
BOD_5	Biochemical oxygen demand, 5 day	Characterize biochemical oxygen demand on the water from biologically available organic matter. Coupled with COD, this information assists in estimation of labile and refractory fractions of organic matter.
BOD_5, filtered	Biochemical oxygen demand of filtered water, 5 day	Characterize the dissolved fraction of biochemical oxygen demand from dissolved biologically available organic matter in the water. Coupled with COD, assists in estimation of labile and refractory, as well as particulate and dissolved fractions of organic matter (10, 1, 0.45 μm)
BOD_{10}	Biochemical oxygen demand, 10 day	An additional BOD sample to provide insight to ultimate BOD
BOD_{10}, filtered	Biochemical oxygen demand of filtered water, 10 day	An additional BOD sample to provide insight to ultimate BOD. The filtered sample assists in identifying particulate and dissolved fractions
COD	Carbonaceous oxygen demand	Characterize the ultimate oxygen demand on the water from all carbon in the water. Along with BOD, assists in estimation of labile and refractory fractions of organic matter.
COD, filtered	Carbonaceous oxygen demand of filtered water	Characterize the ultimate oxygen demand on the water from dissolved carbon in the water. Along with BOD, assists in estimation of labile and refractory, as well as particulate and dissolved fractions of organic matter.
TOC	Total organic carbon	Characterize total organic carbon content of the water.
TSS	Total Suspended Solids	Determine total amount of particulate matter in water.
Algae		
Algae species	-	Characterize spatial and temporal aspect of the algal community.
Chlor-a	Chlorophyll-a	Characterize spatial and temporal algae concentration (biomass) in water.
Phaeophyton	-	Characterize spatial and temporal amount of organic matter in the water that is comprised of dead algae
Zooplankton	-	Characterize spatial and temporal aspects of zooplankton community (two sites: KR near Railroad Bridge and near Keno - monthly)
Nutrients (availability affect primary production (algae))		
NH4	Ammonia	Characterize inorganic (bioavailable) nutrient concentrations and potential oxygen demand associated with nitrification in water
NO2+NO3	Nitrate / Nitrite	Characterize inorganic (bioavailable) nutrient concentrations in water
TKN	Total Kjedal Nitrogen	Characterize inorganic (ammonia) and organic nutrient concentrations in water
TP	Total Phosphorus	Characterize inorganic (orthophosphate) and organic nutrient concentrations in water
PO4	Phosphate	Characterize inorganic (bioavailable) nutrient concentrations in water
Physical Parameters		
Tw	Water Temperature	Characterize temperature conditions governing physical, chemical, and biological processes
DO	Dissolved Oxygen	Characterize dissolved oxygen conditions governing physical, chemical, and biological processes
pH	-	Characterize hydrogen ion concentration and acid-base status, potential for unionized ammonia toxicity.
EC	Electrical Conductivity	Identify ionic character of the water.
Secchi Depth		Provides information on light penetration for primary production
PAR	Photosynthetic available radiation	Provides information on light penetration for primary production

4.2. Field Methods and Quality Assurance

A critical aspect of the project was the implementation of a quality assurance project plan (QAPP) for laboratory oversight and processing of quality assurance samples and associated analysis. Coupled with the QAPP was the development of standard operating procedures (SOP) for field sampling, and sample preparation and handling were developed.

4.2.1. Quality Assurance Project Plan (QAPP)

External quality assurance (QA) samples provide a means to assess precision and bias in sample, and provide an opportunity to validate data collected in the field and subsequently analyzed in a laboratory. The methods of data validation, including the percent of external QA samples to regular samples, the types of external QA samples to employ, and the formula for calculating data validation are included in the QAPP. External QA samples for each constituent of the study were not available (e.g., chlorophyll a, phaeophyton and physical parameters collected with water quality probes). External QA samples were provided for the nutrients, biological oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC). The QAPP is presented in Appendix A: Quality Assurance Project Plan (QAPP).

4.2.2. Standard Operating Procedures (SOP)

The Standard Operating Procedure (SOP) provided explicit instructions for field preparation, in-field sampling, and protocols for sample handling after sampling. The SOP also provided instructions for collecting the different types of samples, including grab samples, sieved samples, and quality assurance (QA) samples. Detailed sample preservation procedures were included, and the SOP provided instructions for recording field information, equipment and supply lists, and contact information for personnel and laboratories involved in the project. The SOP is presented in Appendix B: Standard Operating Procedure (SOP).

An important component of the sampling program focused on filtered and unfiltered biochemical oxygen demand (BOD) samples to identify the fractions of material that were present in water. BOD samples were filtered at 10 microns, 1.0 micron, and 0.45 microns (Tchobanoglous et al, 2000). The 0.45 micron filter size was selected to distinguish between dissolved and particulate material, while the 1.0 micron filter size was to screen material at the colloidal level. The 10 micron filter was included to provide additional detail in the particulate range. The procedure for using the inline filters to create the sieved BOD samples was changed as the sampling season progressed as the initial inline filters used were not practical for field sampling and new filters were identified and employed.

The filtered sampling regime was initially implemented using Whatman, Inc. Nuclepore® Track-Etch™ membrane filters (the membrane filters are employed using a filter holder assembly and a peristaltic pump) and initially included an additional sample filtered through a 0.1 micron size membrane filter. However, the quality of the water did not allow field staff to filter samples in a timely fashion except at the 10 micron level.

The 1.0 micron membrane filter rate was about one liter per 30 minutes. No water could be passed through the 0.1 micron membrane filter.

Thus, for the May 3rd and June 7th sampling efforts, BOD samples were filtered at the 10 micron level using the membrane filters and at the 0.45 micron level using Waterra FHT high efficiency, extra capacity in-line filters. Prefiltering was attempted to improve performance: (a) the 10 micron membrane filter was used to pre-filter for the 1 micron membrane filter; and (b) the high capacity 0.45 micron filter was used to pre-filter for the 0.1 micron membrane filter. Neither approach improved sampling efficiency – as reduced filtering time or the number of membrane filters required to process the 1.0 micron sample. (The 10 micron filtered sample at the Klamath Straits drain used up to 10 or more membrane filters)

Therefore, high capacity filters at the 1.0 and 10 micron size were acquired to improve sampling efficiency (1.0 micron: Millipore disposable groundwater filter capsule; 10 micron: Whatman, Inc, Polydisc™ HD 50 ml in-line disc filter), and were used throughout the remainder of the study. The high capacity Waterra FHT 0.45 micron filter was used to capture the 0.45 micron filtered samples for the remainder of the study. The 0.1 micron filtered samples were dropped from the study. The SOP for the program, including filtering protocol, is presented in Appendix B: Standard Operating Procedure (SOP).

4.3. Laboratory/Analytical Contractors

The primary laboratory for analytical water column samples was Basic Laboratory, Inc. in Redding, California. The organic carbon samples were processed by BSK Analytical Laboratories in Fresno, California through an arrangement with Basic Laboratory. Phytoplankton speciation, chlorophyll a, and phaeophyton analysis was contracted to Aquatic Analysts in White Salmon, Washington. Limited zooplankton analysis was also added to the program and was processed by ZP Taxonomics.

5. Field Data

Several types of data were collected and/or collated, including hydrologic information; physical, chemical, and biological data; and meteorological observations. The various data sets are addressed described below, with specific attention given to the BOD sampling.

Watercourse provided a field technician to assist Reclamation in field preparation, sample collection, and sample delivery to appropriate analytical services. Reclamation provided additional field support including physical measurements (e.g., water quality probe observations), assistance with grab sampling as needed, as well as boat transportation to individual sites within Keno Reservoir and access to Link Dam. All data are included electronically as part of this report.

5.1. Hydrologic Information

Hydrologic data were obtained from Reclamation, PacifiCorp and U.S. Geological Survey (USGS) for the calendar year 2005 at seven locations in the study area (Table 4). These data represent inflows, outflows, and intermediate locations within the study area.

Table 4. Hydrologic information

Name	Hydrologic Data Type	Owner
Link Dam	Flow	Reclamation
East Side and West Side Powerhouse	Flow	PacifiCorp
Link River near Klamath Falls (11507500*)	Flow	USGS
Keno Reservoir	Stage	PacifiCorp
Lost River Diversion Channel	Flow	Reclamation
North Canal	Flow	Reclamation
ADY Canal	Flow	Reclamation
KSD	Flow	Reclamation
Klamath River below Keno Dam (11509500*)	Flow	USGS

*USGS gage number

During the study period reservoir stage varied less than 0.5 feet, and although not strictly within Reclamations request of PacifiCorp the stage was generally consistent with the intention to hold reservoir elevations stable (Figure 4). Daily mean flow measured at Link River near Klamath Falls ranged from 469 cfs to 3450 cfs, with an average flow of 1293 cfs. Flow conditions during the study period for all locations are depicted graphically in Appendix C: Flow Data.

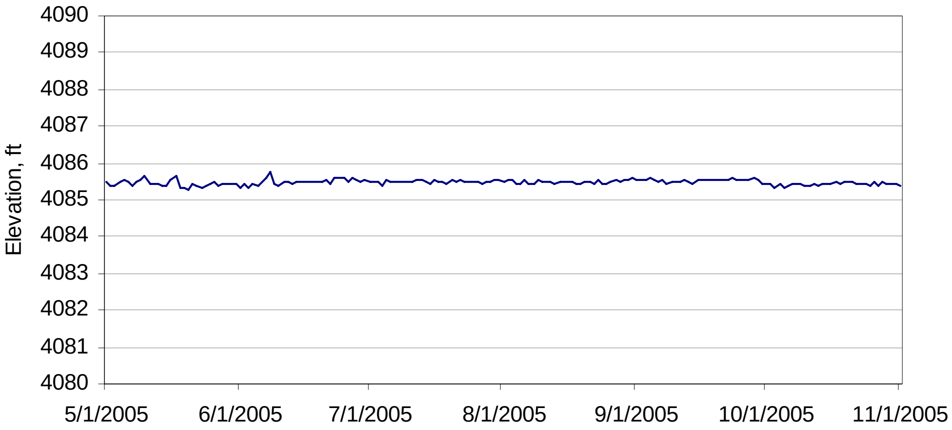

Figure 4. Keno Reservoir water surface elevation (PacifiCorp)

5.2. Physical Water Quality Data

Physical data including water temperature, specific conductivity, dissolved oxygen, and pH were measured at each site at several depths throughout the study period (TDS and ORP data were available for certain dates and locations, but are not included herein) with a Datasonde DS-3 water quality probe. Light extinction measurements were completed and extinction coefficients estimated. In addition, air temperature, wind speed and direction, turbidity, and Secchi depth were measured at each site once per visit, except turbidity which was sampled three times at each site to provide an average. Brief descriptions of the physical characteristics of the reservoir as interpreted from field data are included. This discussion is not intended to be comprehensive, but rather to summarize the basic conditions present in 2005. All physical data is presented in Appendix D: Physical Data, with the exception of light extinction information, which is presented in Appendix E: Light Extinction Information.

Temperature

Keno Reservoir was largely isothermal in the spring with temperatures ranging from 14.5 to 16°C. As spring transitioned to summer, water temperatures generally increased to a maximum of over 25°C. During this period the reservoir exhibited weak, intermittent stratification. By October, the temperature fell to below 11°C. Reservoir thermal characteristics were largely reflective of meteorological conditions with water temperatures typically at or near equilibrium temperature[1].

Electrical Conductivity

Electrical conductivity typically exhibited a longitudinal gradient through Keno Reservoir. The upstream reaches of the reservoir generally had conductivity less than 150 μS/cm, reflecting conditions in Upper Klamath Lake. With increasing distance downstream, conductivity reached as high as 300 μS/cm in the vicinity of Keno – presumably in response to elevated conductivity in return flow. Conductivity was generally was in the range of 150 to over 200 μS/cm within the reservoir. Temporally, spring period conductivity was highest near Keno when there was a larger difference between Lake Ewauna and Keno Dam. In the summer, there was a smaller difference between the values recorded at Lake Ewauna and Keno.

Dissolved Oxygen (DO)

Dissolved oxygen varied widely through the study period with minimum values near zero and the maximum values in excess of 12 mg/l. In early spring dissolved oxygen concentrations were fairly uniform ranging from 7 to 8 mg/l (bottom waters were less than 3 mg/l near Keno in May). In June some recovery was evident, with the entire reservoir in excess of 8 mg/l. However, by July, the reservoir experienced severe anoxia (DO < 2.0 mg/l) in near bottom waters from RM 248 to RM 235. The inflow from Link River was on the order of 8 mg/l. By late July dissolved oxygen concentrations were less than 2 mg/l from near surface to the bed from RM 252 to RM 235 – roughly 95 percent of the reservoir. There was a strong longitudinal gradient at the head of the reservoir near the Link River inflow, with dissolved oxygen concentrations diminishing from approximately 7 mg/l in Link River to less than 2 mg/l within approximately one mile downstream. Little vertical variation was evident. Poor dissolved oxygen conditions persisted in the reservoir through October 18th (the last sampling date), at which time dissolved oxygen concentrations were less than 2 mg/l from RM 250 to RM 238.

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[1] Equilibrium temperature is the water temperature at which the sum of all heat fluxes through the water surface is zero (Bogan et al, 2003)

pH

pH ranged from 6.6 to 9.8 during the field season. In May, the reservoir pH ranged from approximately 7 to 8, but by June, pH had risen throughout the reservoir to above 8.5 and in some locations (near Keno) above 9. Consistent with severe anoxia in midsummer, pH values fell to below 8 (and as low as 7) for much of the reservoir on August 9, 2005. Throughout the remainder of the year, the reservoir exhibited a persistent longitudinal gradient from Lake Ewauna to Keno that ranged from a high (upstream) of over 9 to a low (downstream) between pH 7 and 8.

Turbidity

As with other parameters, turbidity varied spatially and temporally throughout the study site. With the exception of the Railroad Bridge and Miller Island sites, which exhibited large seasonal variations, turbidity generally decreased in the downstream direction.

Total Suspended Solids (TSS)

The minimum TSS concentration was 2 mg/l and the maximum was 21 mg/l. There was no apparent longitudinal pattern to the TSS concentrations. However, spring had lower concentrations, which increased to a maximum in early summer. After early summer, the TSS decreased for the remainder of the study throughout the reservoir.

Total Dissolved Solids (TDS)

TDS was collected from May through July. The minimum TDS concentration was 74 mg/l at Link Dam and the maximum was 538 mg/l at the KSD site. TDS generally increased in the downstream direction, with a notable change below the KSD – which was consistently higher in TDS concentration than the water in Keno Reservoir.

Light Extinction

To estimate the light extinction properties within the Keno Reservoir reach, photosynthetically active radiation (PAR) measurements were collected at multiple depths. Measurement of PAR (400-700 nm) was accomplished using either the LI-192 Underwater Quantum Sensor. Over the length of the study period light extinction properties, as represented by calculated light extinction coefficients, varied spatially and temporally (Table 5). Light extinction coefficients were highly variable in the upper reaches of the reservoir (0.4048 to 1.583/ft), at the Link Dam and Railroad Bridge sites, reflecting proximity to Upper Klamath Lake. Sites in the lower half of the reservoir, Keno Dam and KRS12A indicate overall lower values and more modest variability (0.4299 to 0.7073/ft). The Miller Island site appears to represent a transition with variability intermediate between the upper and lower reservoir areas (0.4998 to 1.059/ft). The KSD light extinction coefficients were consistently in the range of approximately 0.8 to 1.0/ft.

Table 5. Calculated light extinction coefficients: Keno Reservoir and environs: 2006

Site	River Mile	Light Extinction Coefficients, 1/ft								
		5/3/05	**6/7/05**	**6/28/05**	**7/12/05**	**7/26/05**	**8/9/05**	**8/23/05**	**9/20/05**	**10/18/05**
Link Dam	253.1	0.5771	0.6171	0.5600	1.503	1.034	1.050	1.099	N/A	N/A
Klamath River at Railroad Bridge	251.7	0.4048	0.4361	1.065	1.189	0.8056	1.005	1.583	1.191	0.7213
Klamath River at Miller Island	245.6	N/A	0.5470	0.8451	0.5876	0.4998	0.8632	0.8472	1.059	0.5656
KRS12A	239.0	0.7073	0.5628	0.5357	0.4299	0.6862	0.7065	0.6270	0.4984	0.5189
Klamath River at Keno	234.9	0.5763	0.6133	0.5997	0.4449	0.6477	0.7054	0.5386	0.5351	0.5370
KSD	240.5	0.8000	0.7845	1.083	1.146	0.9510	1.086	0.7983	0.9978	0.8491

For time of measurement, see tabulated data in Appendix E: Light Extinction Information

Secchi Disk

Secchi disk readings generally corresponded to light extinction coefficients, with lower readings in the upper reaches than in the lower reservoir and the Miller Island site as an intermediate point (Table 6). However, the relationship is not particularly robust for all sites (Figure 5), but some locations were highly correlated (Railroad Bridge, KRS12A, and Keno). Exploring non-linear relationships (logarithmic, exponential, and power functions) yielded modest improvement. Overall, there are multiple factors which may explain some of the differences between light extinction and Secchi disk including disturbance of the water column with the Secchi disk under extreme algae conditions; differences among the two methods in assessing light penetration with regard to dissolved and particulate matter (e.g., gilvin (Kirk,1996); and different operators interpreting Secchi disk differently.

Table 6. Secchi disk: Keno Reservoir and environs: 2006

Site	River Mile	Secchi Depth (ft)								
		5/3/05	**6/7/05**	**6/28/05**	**7/12/05**	**7/26/05**	**8/9/05**	**8/23/05**	**9/20/05**	**10/18/05**
Link Dam	253.1	4.3	3.3	1.8	2.1	1.1	2.5	2.0	1.8	2.8
Klamath River at Railroad Bridge	251.7	4.9	3.3	2.1	1.5	2.5	2.6	1.3	1.8	2.6
Klamath River at Miller Island	245.6	3.1	3.1	2.0	2.8	2.8	3.0	3.0	2.1	4.6
KRS12A	239.0	3.3	3.4	3.6	6.4	2.3	2.8	4.1	5.6	5.6
Klamath River at Keno	234.9	3.6	4.1	3.6	7.5	2.3	2.6	6.1	5.9	4.8
KSD	240.5	1.8	1.8	1.5	3.0	2.5	1.6	3.6	2.1	2.6

For time of measurement, see tabulated data in Appendix D: Physical Data

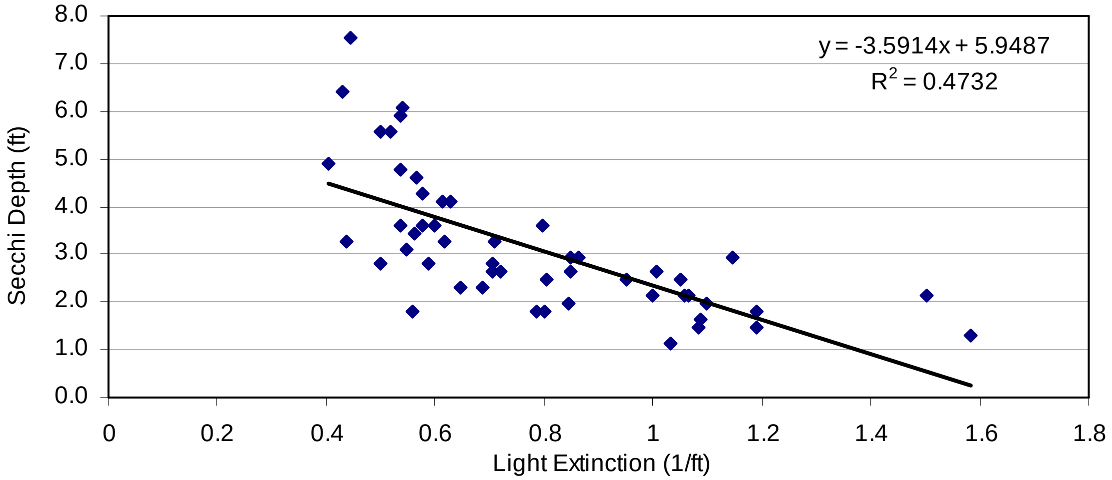

Figure 5. Secchi disk versus light extinction coefficient, all sites in the study area 2006

5.3. Biological Data

5.3.1. Algal Data

Field methods, field data, and estimates of light extinction coefficients are discussed. Sample bottles were also collected for determining the concentrations of chlorophyll-a and phaeophyton results. Data and graphs of algae information (chlorophyll a, phaeophyton, and species data) are presented in Appendix G: Algal Data

Chlorophyll-a and Phaeophyton

The minimum concentration of chlorophyll-a was 1.0 μm/l, and the maximum concentration was 359 μm/l. The minimum concentration of phaeophyton was 0.2 μm/l and the maximum was 39 μm/l. Spring experienced low concentrations of chlorophyll-a, but concentrations increased to a relative maximum in early summer (June 28, 2005). Chlorophyll-a concentration then decreased and increased again to have a second maximum in late summer (August 23, 2005). Chlorophyll-a concentrations then decreased to approximately the same levels as spring. The Link Dam and Railroad Bridge sites showed extremely high chlorophyll-a concentration on August 23, 2005, and the Railroad Bridge site still had high concentrations on September 20, 2005. Phaeophyton concentrations followed the same pattern as chlorophyll-a concentrations, with lower concentrations, except on August 9, 2005, when phaeophyton concentrations exceeded chlorophyll-a concentrations below the Railroad Bridge site, and on October 18, 2005, when phaeophyton concentrations exceeded chlorophyll-a concentrations at all sites.

Species

Over 100 species of algae were identified in Keno Reservoir during the 2005 field season. Examination of cell density through the season indicates that the reservoir is dominated by chrysophytes, cryptophytes, diatoms, and green algae in the spring with blue green species largely absent (May 3, 2005). By late spring, blue green algae species are most abundant, a position these species maintain through the summer. Dominant blue green species include *Aphanizomenon* and *Anabaena*. In the fall (October 18, 2005), cryptophytes and diatom abundance begins to approach blue green algae densities, but overall algal populations are markedly lower than summer time highs. A complete species listing and algal density by group and location throughout the sampling period are depicted graphically in the appendix.

5.3.2. Zooplankton

Although not originally included in the project scope, zooplankton sampling was completed at two sites to augment the monitoring program. Vertical tows were completed with a 15 cm diameter (length 50 cm), 80 micron plankton net at the Railroad Trestle and Keno sites. Allan Vogel of ZP Taxonomics provided guidance on collection, preservation, and transportation of the samples and processed them for species composition. These observations, although limited in number shed additional light on the trophic structure of Keno Reservoir as well as upstream waters. Species collected were typical of mesotrophic and eutrophic systems. Abundance as well as scarcity of species reflected temperature conditions, as well as overall water quality impairment (e.g., low dissolved oxygen, high levels of nutrients, and appreciable organic matter).

A detailed and practical summary of species presence and general conditions of zooplankton populations in Keno Reservoir is provided in Appendix H: An Assessment of the Zooplankton Species Composition from Keno Reservoir

5.4. Chemical Data

Chemical data, collected via grab samples each site, included ammonia, nitrate-nitrite, TKN, total phosphorus, orthophosphate, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), chemical oxygen demand (COD) (both filtered and unfiltered), and BOD samples filtered to various sizes and tested to either 5 days or 10 days). Brief descriptions of the chemical characteristics of the reservoir as interpreted from field data are included. This discussion is not intended to be comprehensive, but rather to summarize the basic conditions present in 2005. The exception is BOD data, which are discussed in greater detail at the end of this section. Data are presented in Appendix F: BOD, Nutrient, and Other Data

Total Kjeldahl Nitrogen (TKN)

TKN concentrations ranged from 0.7 mg/l and the maximum was 4.8 mg/l, but the average for each site was similar at approximately 2.3 mg/l. Spring and fall concentrations of TKN were similar, but summer experienced higher concentrations in general. The distribution of TKN throughout the reservoir for each site during the season is shown in Figure 6.

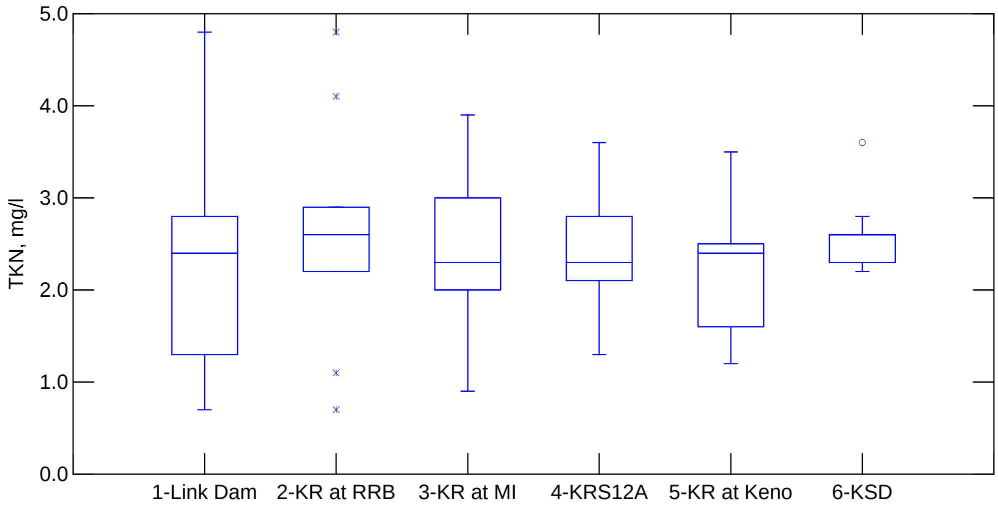

Figure 6. Box and whisker plots of TKN, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

Ammonia

The minimum ammonia concentration ranged dramatically the study area during the summer of 2005 - from 0.10 mg/l to 2.15 mg/l. Ammonia concentrations increased steadily with distance from Link Dam (average concentration 0.2 mg/l) to Miller Island (0.85 mg/l) to Keno Dam (over 1.0 mg/l). The KSD averaged 0.85 mg/l. Ammonia concentrations were generally lower in spring and highest in summer, with elevated levels from Miller Island downstream to Keno well over 1 mg/l for the September and October sampling dates. The distribution of ammonia throughout the reservoir for each site during the season is shown in Figure 6.

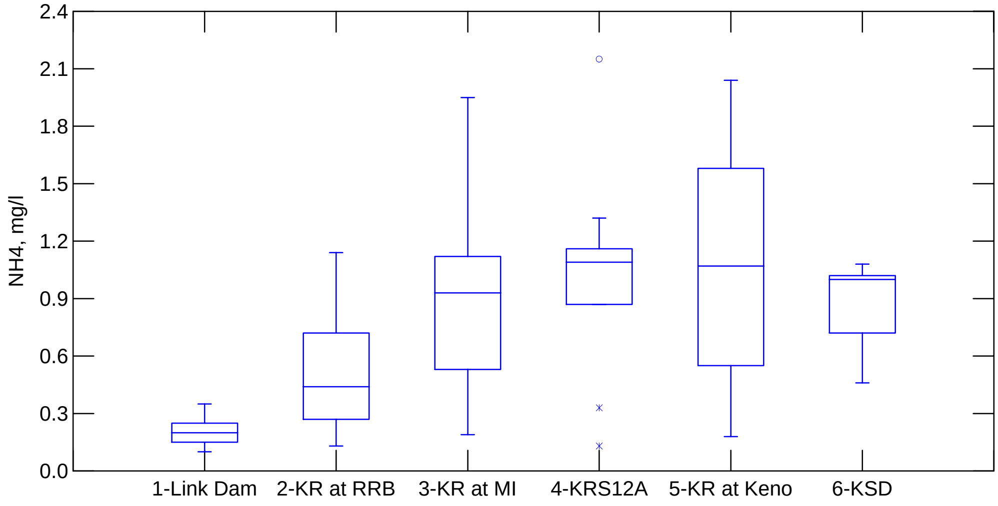

Figure 7. Box and whisker plots of ammonia, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

Nitrate plus Nitrite

Nitrate plus nitrite concentrations ranged from 0.02 mg/l to 0.10 mg/l at all sites except the KSD where concentrations ranged from 0.07 to 0.61 mg/l. Nitrate plus nitrite concentrations, with the exception of the KSD varied little, but several sites recorded non-detected amounts. The distribution of nitrate plus nitrite throughout the reservoir for each site during the season is shown in Figure 6.

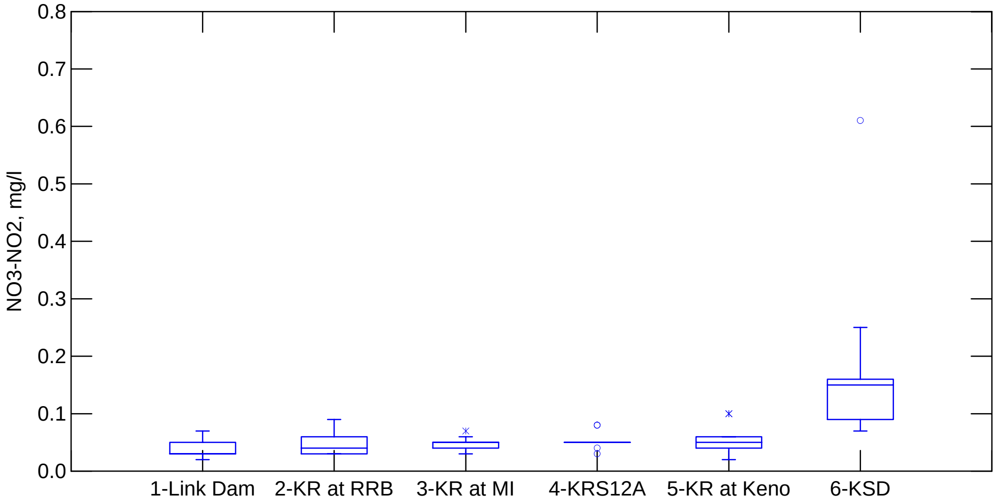

Figure 8. Box and whisker plots of nitrate plus nitrite, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

Phosphorus (TP and OPO4)

Total phosphorus (TP) concentration ranged from 0.03 mg/l to 0.34 mg/l in reservoir and river sites, with a range of 0.18 to 0.63 mg/l in the KSD. Average concentration increased in the downstream direction, increasing from 0.14 mg/l at Link Dam to 0.21 mg/l at Keno. Generally summer concentrations were higher than spring, with concentrations decreasing only slightly into fall.

Orthophosphate concentration ranged from 0.01 mg/l to 0.27 mg/l in reservoir and river sites, with a range of 0.11 to 0.49 mg/l in the KSD. Average concentration increased in the downstream direction, increasing from 0.04 mg/l at Link Dam to 0.13 mg/l at Keno. Generally summer concentrations were higher than spring, with concentrations decreasing in the fall. The distribution of total phosphorous and orthophosphate throughout the reservoir for each site during the season is shown in Figure 6 and Figure 10.

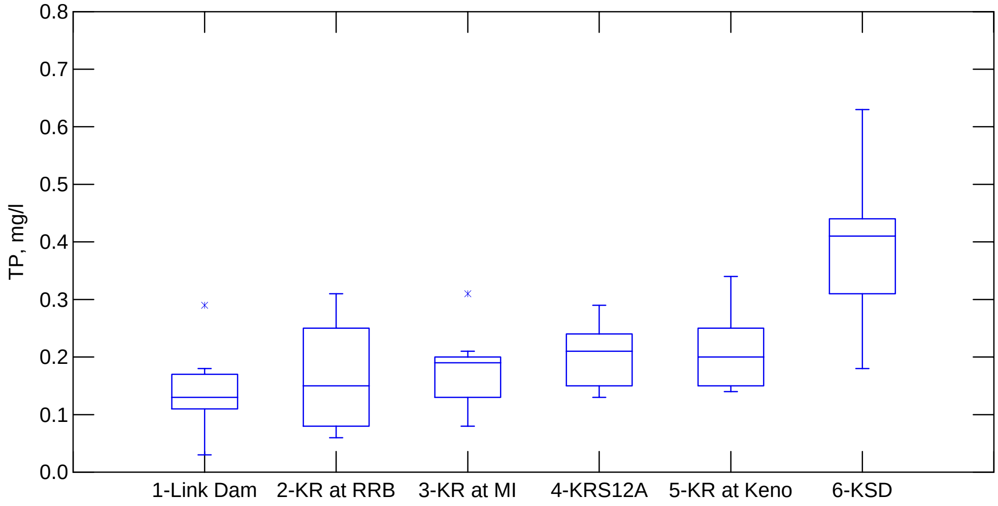

Figure 9. Box and whisker plots of total phosphorous, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

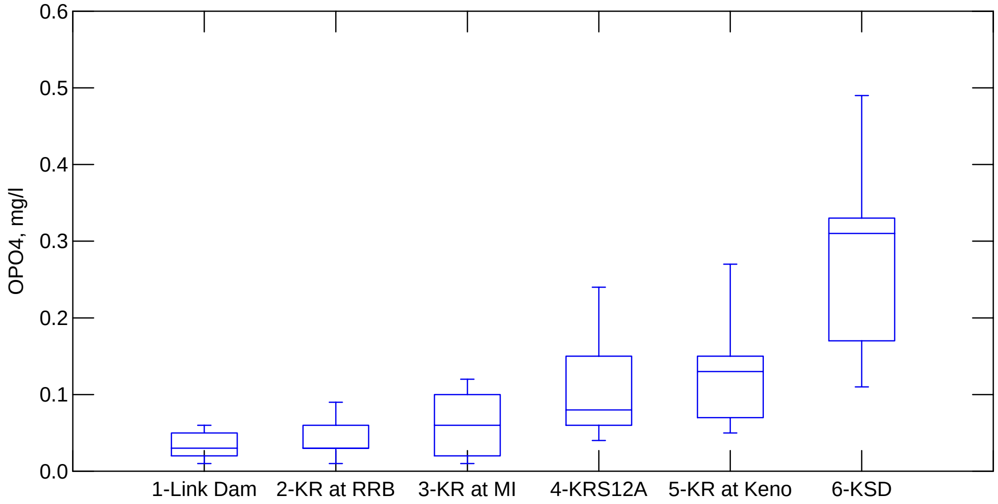

Figure 10. Box and whisker plots of orthophosphate, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

Chemical Oxygen Demand (COD)

COD concentrations ranged from non-detect to 70 mg/l. The highest overall values were found in the KSD, where the average was 51.3 mg/l and the concentrations ranged from 32 to 70 mg/l. In the reservoir and river reaches the average COD was similar at Link Dam and the Railroad Bridge at approximately 40 mg/l, but decreased to just over 30 mg/l for the remainder of the reservoir. There was a notable seasonal component to COD, with highest values in summer and lower concentrations in spring and fall. KSD was consistently higher than the other locations throughout the year.

Filtered COD values were about 50 percent of unfiltered samples for the Link Dam and Railroad Bridge sites (approximately 20 mg/l), but at the other downstream sites, the dissolved fraction of COD was higher, on the order of 70 to 90 percent of unfiltered samples (22.8 to 25.0 mg/l). In the KSD the dissolved fraction was notably higher –

nearly 95 percent of the unfiltered sample (48.6 mg/l). There was a seasonal component to filtered COD, with highest values in summer and lower concentrations in spring and fall. Exceptions include Link Dam and Railroad Bridge sites where concentrations continued to increase throughout the sampling period. KSD was consistently higher than the other locations throughout the year. The distribution of total phosphorous and orthophosphate throughout the reservoir for each site during the season is shown in Figure 6 and Figure 10.

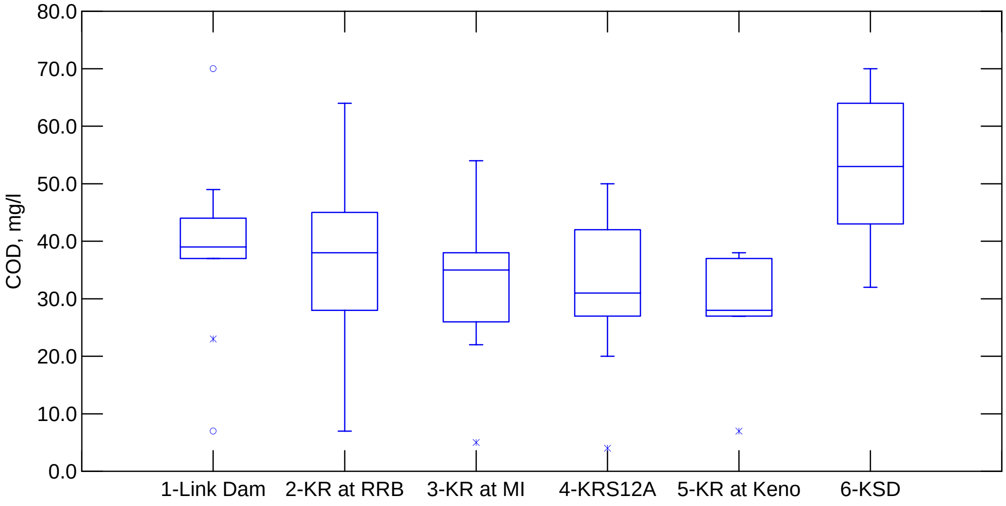

Figure 11. Box and whisker plots of COD, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

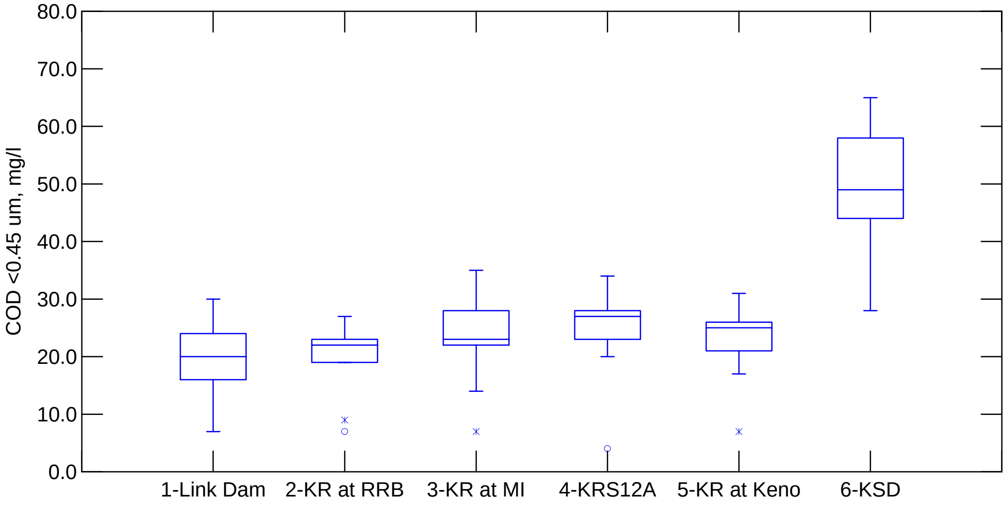

Figure 12. Box and whisker plots of Cod filtered (0.45 micron), Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

Organic Carbon (TOC)

The minimum total organic carbon (TOC) concentration was 5.2 mg/l and the maximum TOC concentration was 32 mg/l. Most of the organic carbon was dissolved. In spring, the concentrations were lower, but as the study progressed, TOC concentrations increased until the last sampling session of October 18, 2005 when the concentrations decreased back to spring levels. There did not appear to be any longitudinal pattern in the reservoir.

The distribution of total organic carbon throughout the reservoir for each site during the season is shown in Figure 6.

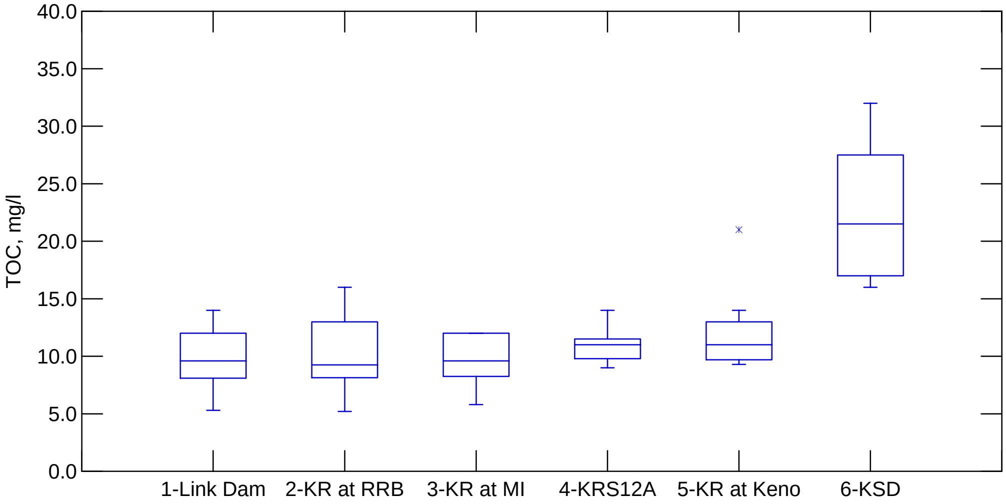

Figure 13. Box and whisker plots of total organic carbon, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

5.4.1. BOD data

Several different types of BOD samples were collected, including unfiltered BOD_5, unfiltered BOD_{10}, and filtered samples of both BOD_5 and BOD_{10} using different size filters. BOD_5 is the typical BOD laboratory test for waste water or other discharge assessment, wherein field samples are tested for 5 days. BOD_{10} is a variation of the BOD_5 test which allows the test to continue for 10 days, to provide increased insight and estimate of $BOD_{ultimate}$, the amount of oxygen used to degrade all organic matter in the water. BOD_{10} was collected, both as unfiltered and filtered at less than 0.45 microns samples from one site. From all sites, BOD_5 was collected as (a) unfiltered, (b) filtered at less than10 microns, (c) filtered less than1.0 microns and (d) filtered at less than 0.45 microns.

BOD5 concentrations generally decreased with distance from the Railroad Trestle site downstream (Figure 14). Concentrations were higher at the Railroad Trestle site than at Link Dam. This is presumed to be due to multiple factors, including but not limited to:

- Higher overall oxygen concentrations in samples at Link Dam. Upper Klamath Lake at Link Dam dissolved oxygen concentrations are generally higher than those at the Railroad Trestle site, which may be close to zero. The available oxygen in the Link Dam samples may oxidize some of the organic matter prior to initiation of the BOD test in the laboratory, thus reducing BOD numbers.
- Resuspension of settled organic matter in Lake Ewauna. Lake Ewauna is a broad, shallow body of water between Link River and the Railroad Trestle. Afternoon winds are common during spring through fall periods in the Klamath Falls area. Settled organic matter may be resuspended, thus acting as a source of oxidizable material to water column samples (particularly when dissolved oxygen conditions are low in Lake Ewauna).

- External inputs with large BOD loads. Two municipal sewage treatment plants discharge into Lake Ewauna. These inputs, as well as non-point source loading may elevate BOD levels.
- Other unquantified loads

Filtered and unfiltered BOD_5 data, presented as infrequent time series in Figure 15 through Figure 21, suggest that most BOD_5 was associated with larger particle fractions; however, exceptions occur where smaller particles made up a larger portion of the total BOD concentration (e.g. July 27, 2005 data). Occasionally BOD values of a filtered sample exceeded that of a corresponding unfiltered sample. These occurrences illustrate the uncertainty inherent in the BOD measurement, as does the reporting limit of 3 mg/l for BOD. Although limited filtered samples were collected on some dates, when all types of BOD_5 samples were collected, additional calculations were performed to determine the amount of BOD_5 present in the four particle size ranges: larger than 10 microns, between 10 and 1 microns, between 1 and 0.45 microns and smaller than 0.45 microns. The BOD_5 associated with the different particle size ranges are presented by site (upstream to downstream with KSD as the last site) in Figure 22 through Figure 26.

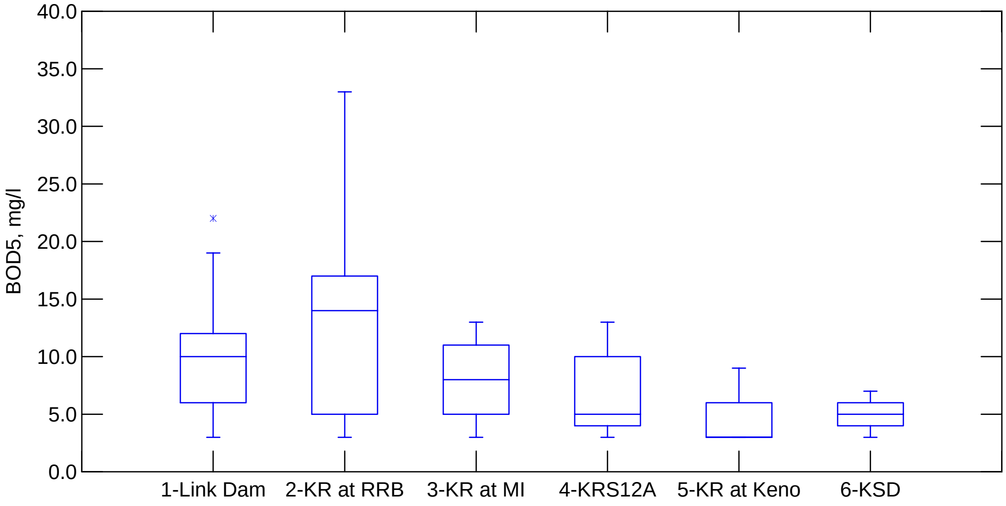

Figure 14. Box and whisker plot of BOD_5 concentrations, Keno Reservoir (and the Klamath Straits Drain), May through October, 2005

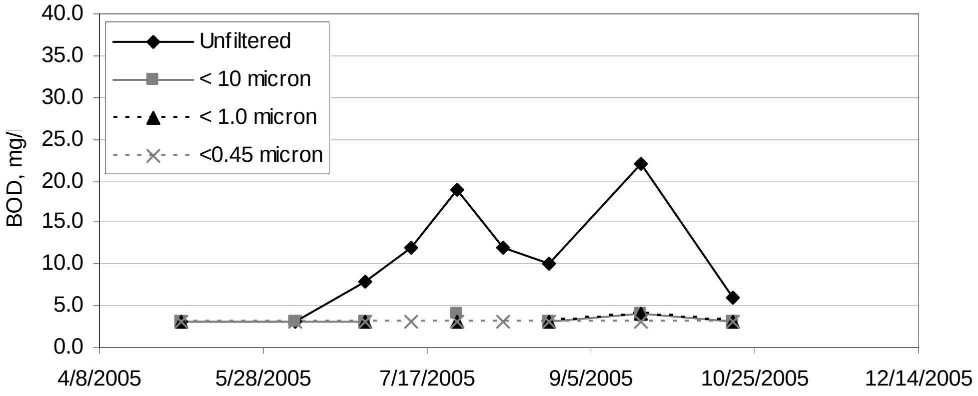

Figure 15. BOD$_5$ concentrations at Link Dam

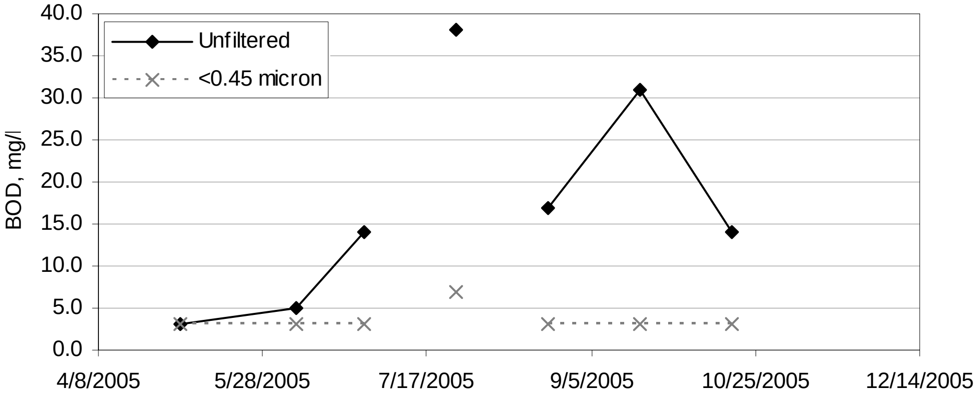

Figure 16. BOD$_{10}$ concentrations at Link Dam

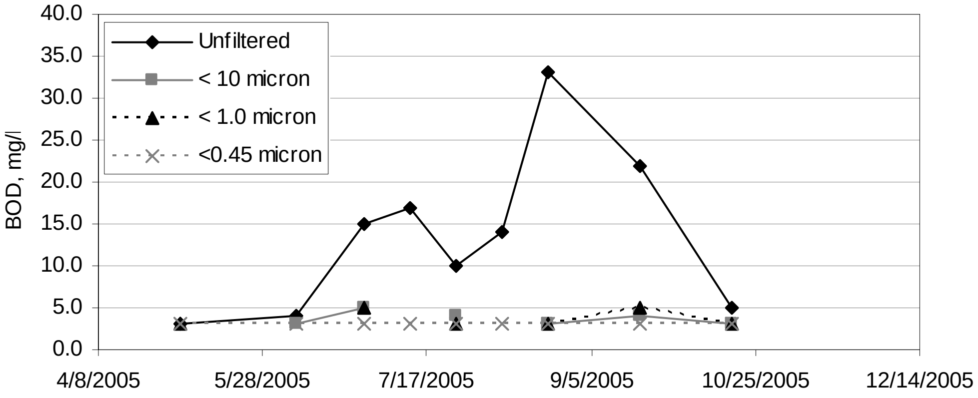

Figure 17. BOD$_5$ concentrations at Klamath River at the Railroad Bridge

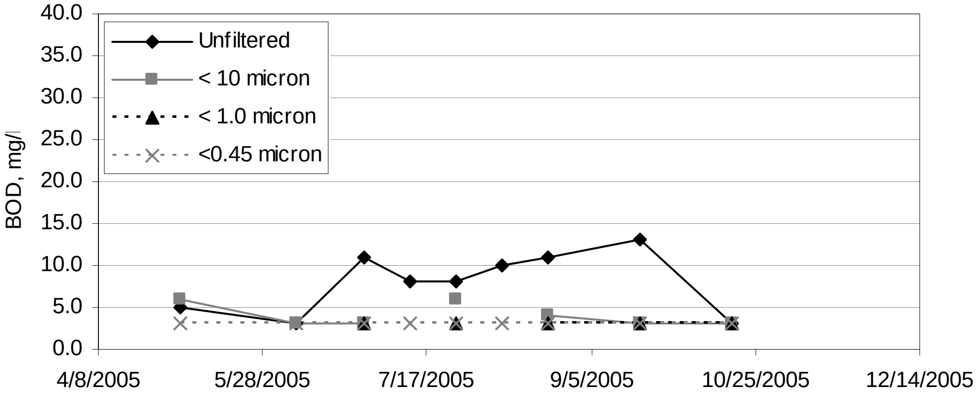

Figure 18. BOD_5 concentrations at Klamath River at Miller Island

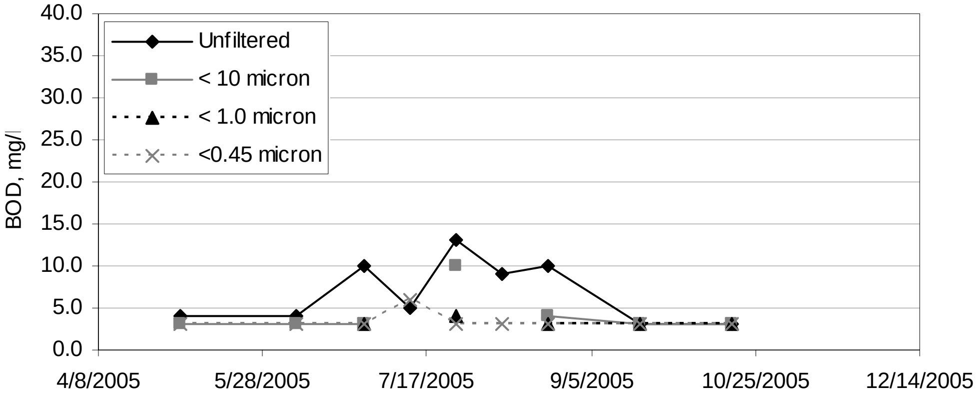

Figure 19. BOD_5 concentrations at Klamath River at site KRS12A

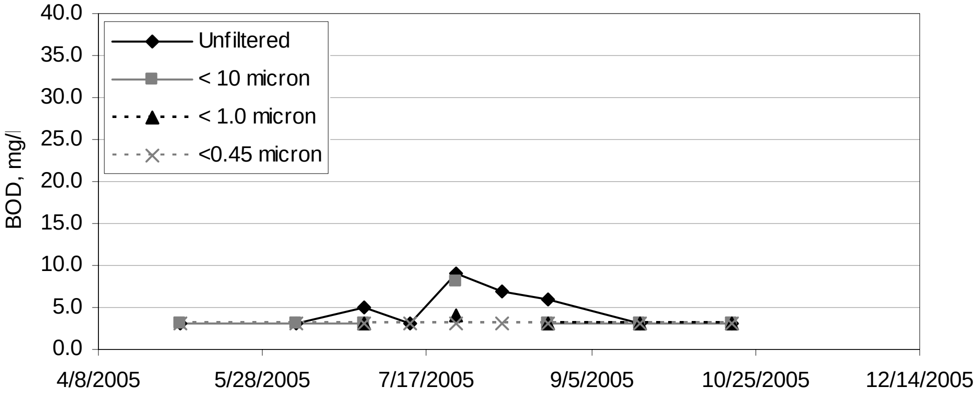

Figure 20. BOD_5 concentrations at Klamath River near Keno Dam

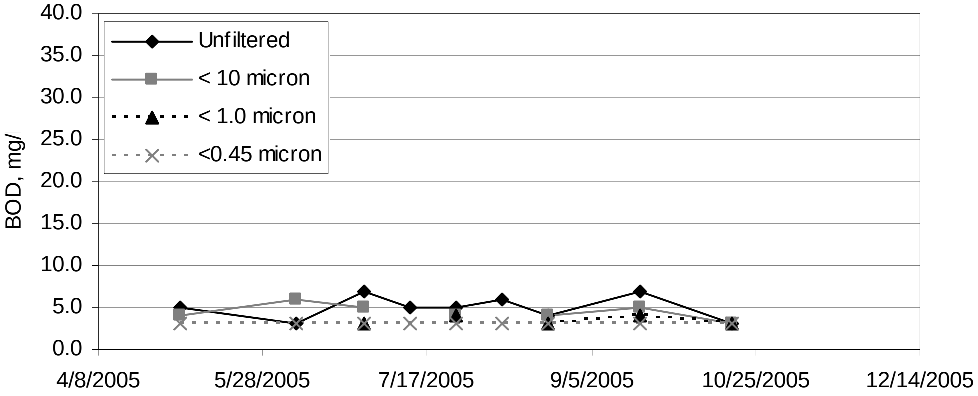

Figure 21. BOD$_5$ concentrations at KSD

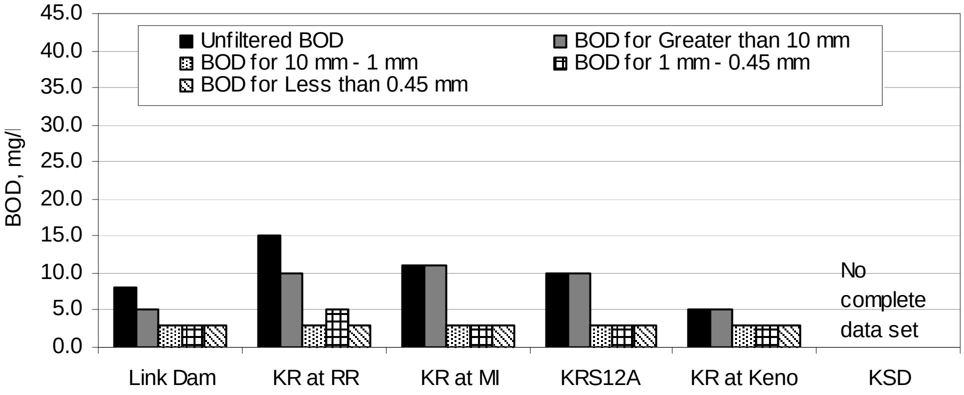

Figure 22. BOD$_5$ associated with different particle size ranges – 6/28/2005

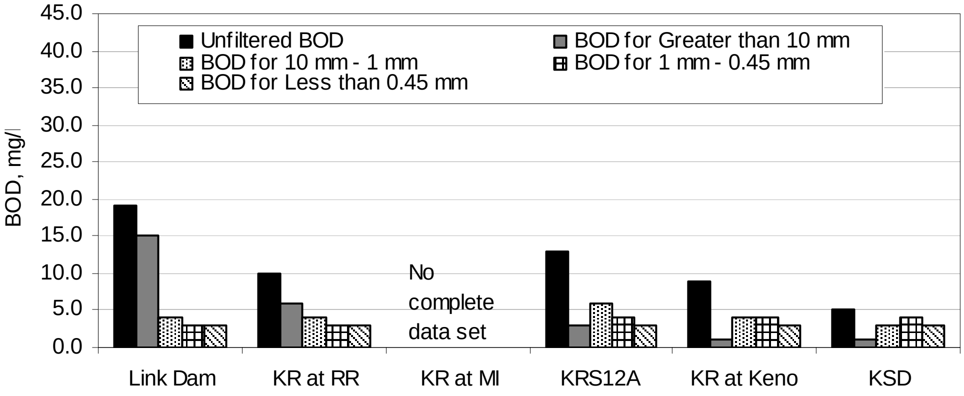

Figure 23. BOD$_5$ associated with different particle size ranges – 7/26/2005

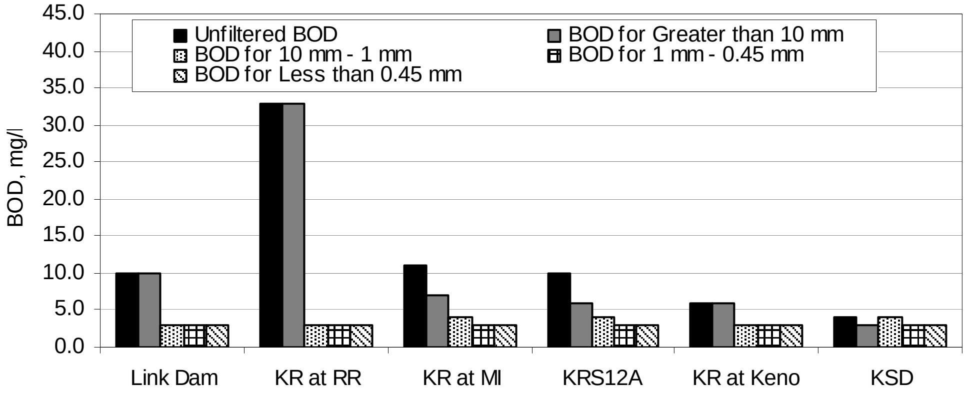

Figure 24. BOD$_5$ associated with different particle size ranges – 8/23/2005

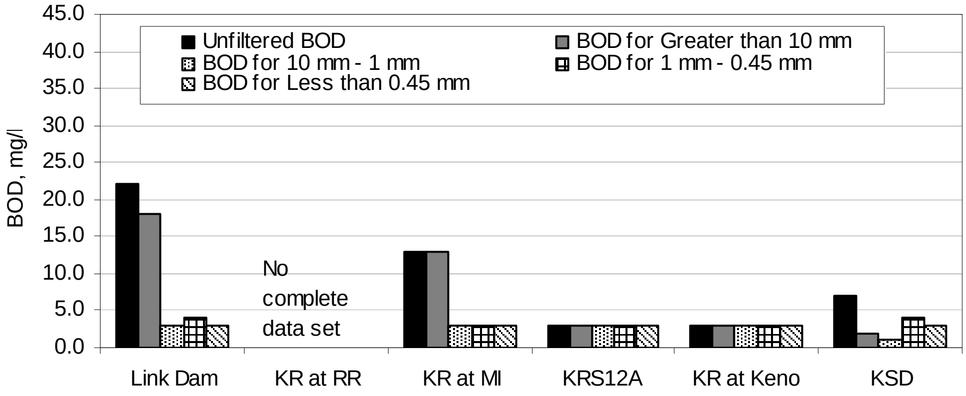

Figure 25. BOD$_5$ associated with different particle size ranges – 9/20/2005

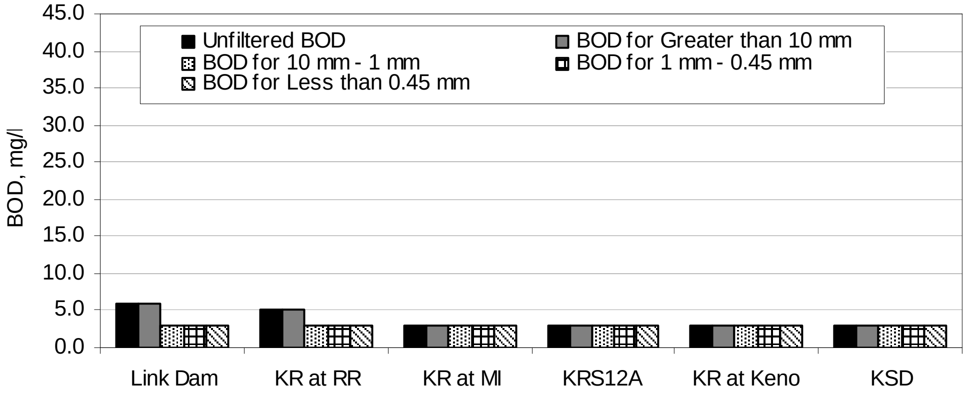

Figure 26. BOD$_5$ associated with different particle size ranges – 10/18/2005

Data Statistics for BOD Data

The BOD_5 data, while varying temporally and spatially throughout the system, showed higher concentrations in upstream reaches of the reservoir, and was associated mostly with larger particle fractions. The data also suggest seasonal BOD_5 fluctuations, with higher values during the summer. Therefore, the unfiltered BOD_5 data was determined to be most representative for designing the FWS wetland (See Section 6, below). Statistics for unfiltered BOD_5 were calculated and are presented in Table 7.

Table 7. Unfiltered BOD_5 statistics for the Klamath River below Link Dam May through August 2005.

BOD_5 Statistics	All Data	Link Dam	KR at RR Bridge	KR at MI	KRS12A	KR near Keno Dam	KSD
N of cases	54	9	9	9	9	9	9
Minimum	3	3	3	3	3	3	3
Maximum	33	22	33	13	9	13	7
Median	6	10	14	8	3	5	5
Mean	8.111	10.556	13.667	8	4.667	6.778	5
Std. Error	0.818	2.199	3.232	1.213	0.745	1.245	0.5
Standard Dev	6.015	6.598	9.695	3.64	2.236	3.734	1.5
Variance	36.176	43.528	94	13.25	5	13.944	2.25
Skewness(G1)	1.922	0.634	0.887	-0.3	1.054	0.501	0
Kurtosis(G2)	4.817	-0.438	0.647	-1.316	-0.029	-1.437	-1.079

5.5. Data Validation

Data validation of laboratory analysis was carried out through the use of external quality assurance (QA) samples. External QA samples are additional samples included with the field samples for laboratory analysis which have known quantities of constituents; however, the laboratory is unaware of the samples (blind). External quality assurance provides a means of assessing laboratory performance and a means to validate field data. External quality assurance samples (QA samples) were included with the production samples, or non-QA samples, at a rate if 10% for spikes and duplicates and 5% for blanks per sampling session during the entire sampling period, as per the Quality Assurance Project Plan (QAPP) adopted by Watercourse and the USBR. Overall results were good with a completeness of 89 percent, and few reanalysis required. BOD was an exception, but performance was overall acceptable. A detailed summary of the data validation process and results is included in Appendix I: Quality Assurance Summary. Information on quality assurance processes for water quality probes is maintained by USBR in the Klamath Area Office.

6. Wetland Calculation Design and Analysis

Once the initial data was collected, the characterization of the organic matter content was determined using the ratios of labile to refractory, and dissolved to particulate. Also, the appropriate BOD was assigned to each particle size range. The temporal characterization of organic matter in the river was determined. Once the organic matter had been characterized, estimates of the time and distance for settling of the particulate matter, as well as estimates of the time and distance on other wetland chemical reactions that would occur were calculated. These estimates, as well as the general characterization of the water quality in the river, were used to determine an estimated removal efficiency using an idealized FWS wetland. Wetland treatment feasibility was based on a comparison of the estimated removal efficiency and acceptable removal efficiency.

6.6. Background

6.6.1. Organic Matter

The source, type, and fate of organic matter is an integral part of all aquatic ecosystems, effecting, among other factors, the basic net productivity of the system. Organic matter consists of organic carbon, nitrogen, phosphorus, oxygen, hydrogen, and sulfur that is either produced within the aquatic ecosystem (autochthonous) or is derived from a source outside the ecosystem (allochthonous) (Kalff, 2002; Wetzel, 2000). Organic matter is often categorized as particulate organic matter (POM); dissolved organic matter (DOM); labile organic matter (LOM); and refractory organic matter (ROM). Particulate organic matter may consist of coarse particulate organic matter (CPOM), suspended particles greater than 1 mm in size; fine particulate organic matter (FPOM), particles between 1 mm and 0.45 µm in diameter (Webster 1979); and ultra fine particulate organic matter (UPOM) which is less typically less than 0.45 µm and often described as dissolved organic matter (DOM).

Labile and refractory fractions of organic matter characterize the relative ease with which material is broken down or changed by biological, chemical and/or physical processes. LOM can be quickly broken down or changed by biological, chemical and/or physical processes (and is thus readily utilized by organisms) (Kaplan and Newbold, 2003). ROM is resistant to change in its structure; the decay rate of RDOM is around two orders of magnitude greater than LDOM (Cole and Wells, 2002).

Along the course of a river system, the relative magnitudes of the various partitions of organic matter vary. Particulate organic matter generally decreases with increasing stream order. This is partially due to the exploitation of organic matter resource by the biological community – there is a gradual reduction in particle size as well as a decrease in organic content due to instream processing by individual organisms and settling. Downstream reaches thus experience a reduction in the amount or fraction of organic matter that is easily metabolized (e.g. a decrease in the labile to refractory ratio) (Minshall 1983).

Another aspect of organic matter is that concentration and flow (and/or velocity) are generally positively correlated. As flows increase small, fine particles are entrained/suspensed and transported downstream. High concentrations of organic matter often occur during high flow rates, whether or not the discharge is related to precipitation directly or indirectly. Seasonal differences occur as well. For example, an early winter storm may produce much more particulate organic matter than a similar or stronger storm late in the winter season due to seasonal storage of organic matter in the watershed. When flows are low, fine particles may settle out to the bed of the stream, only to be resuspended later during larger flows and transported further down the reach (Webster 1979).

These attributes of organic matter – particulate or dissolved, labile or refractory forms; as well as relationships of transport and suspension/settling – are aspects of wetland design.

6.6.2. Free Water Surface Wetlands (FWS)

There are many types of treatment wetlands. However, free water surface (FWS) wetlands are those that most closely resemble natural wetlands in both appearance and function. In assessing the feasibility of treatment using wetlands, a FWS wetland was the primary type considered for determining the viability of wetland treatment of organic matter. FWS wetlands typically consist of channels or basins with a natural or constructed impermeable barrier to prevent loss from seepage. Plants in the FWS serve multiple purposes, including:

- Stems and submerged leaves serve as substrate for the growth of attach bacteria.
- Leaves above the water provide shade reducing the potential for algal growth
- Oxygen transported from the leaves down to the root zone supports plant growth and may also provide a source of oxygen for bacteria

Open water areas in FWS wetlands are important because the major source of oxygen is surface reaeration fro the atmosphere and attached algae (Crites and Tchobanoglous, 1998).

Free water surface wetlands can remove between 60 to 80 % of BOD_5 and 50 to 90% of total suspended solids (TSS), which includes organic matter, depending on design criteria, influent characteristics, influent concentrations of BOD_5 and TSS, and operation of the wetland (Crites and Tchobanoglous, 1998). Such wetlands have been used in a variety of locations with success. The concept assessed herein are wetlands that could be located adjacent to the Klamath River in the Keno Reservoir reach (although wetlands could also be located in areas away from the river) to reduce the organic load originating from Upper Klamath Lake, as well as other inputs. Benefits realized within the Keno Reservoir reach would also be translated to downstream river reaches. Although a FWS wetland would also provide potential wildlife habitat, these wetlands would be actively managed for treatment. Ideally, the flow through an individual FWS wetland is similar to plug flow, i.e., moving through the system as a series of discrete volumes. Water is introduced into a FWS wetland at an upstream end and passes through the system to a discharge point at a downstream location. More complex systems allow for recirculation of treated water to the head of the system to help further reduce concentrations of organic matter and to provide more dissolved oxygen at the inlet point to allow for aerobic bacterial interactions to take place. While it is not practical to define a typical FWS wetland flow rate and area without representative, site specific data, existing FWS wetlands can provide valuable guidance on possible flows, sizes, and treatment effectiveness.

Locating wetlands adjacent to the river margins minimized conveyance to and from the wetlands system and minimizes the space allocated to treatment wetlands. Further, locating the wetlands along the riverbank could be designed to accept agricultural and storm water runoff, potentially reducing the water quality impacts these point and non-point return flows have on the river. Also, a FWS wetland may also provide potential wildlife habitat; however, because these wetlands would be actively managed (careful timing of management actions must be considered to avoid adversely affecting wildlife activities). One of the most desirable attributes of a treatment wetland is that the necessary facilities could be implemented in just a few years. Given the long time span necessary to provide recovery of hypereutrophic UKL conditions (decades to centuries), solutions that could be implemented in a matter of years are appealing. Finally, treatment wetlands can be tested at a pilot level to determine appropriate design parameters and removal efficiencies. This information is then used to design full-scale projects. It is not recommended that any managed wetland project be implemented without first completing a pilot project.

Costs associated with FWS wetlands include land acquisition, infrastructure, vegetation purchase and planting, and maintenance (including vegetation replanting vegetation harvesting, dredging, sludge and plant material removal). Further, a FWS wetland may not appreciably reduce the nutrient levels in the Klamath River. If the BOD and TSS were to be significantly reduced in the river, the increased available oxygen and the increase of water clarity theoretically would lead to increased algae concentrations or allow rooted aquatic vegetation to colonize shallow areas of the channel (this can be an indicator of increased assimilative capacity – a benefit). Also, it is possible that any BOD removal achieved within the wetland could be overshadowed by the BOD generated by the wetland itself – resulting from plant decay and sludge accumulation – but this is not envisioned in this application because the source water contains elevated levels of BOD.

Basic construction of a FWS wetland would utilize the existing soils, to the degree feasible, in the area and create a series of basins. The size and number of basins would depend on flow rate and the desired residence time of the water in the wetland. (The desired residence time depends of the influent concentrations of BOD and TSS and the desired effluent concentrations of BOD and TSS). Using natural materials would minimize maintenance (e.g. replacement of plastic linings). The necessary diversion works (pumping, piping, and plumbing) would be constructed to feed the wetlands. Ideally, if the basins were constructed correctly, there would be no need to have a pumping system in place as each basin would be at a lower elevation than the previous; however, water would still need to be diverted from the Klamath River and because there is little head difference between the inlet and the outlet of the potential wetlands additional pumping may be required. Also, the natural settling process of the materials used to construct the basins might disrupt natural flow from one basin to another. The wetland would be easier to manage and maintain if a pumping system were used which allowed for rerouting of water to take a basin “offline” for repair, cleaning or to allow for recirculation. Systems should be designed such that short-term interruption in power would not adversely impact the plant community through lack of water supply.

Construction of the wetland would also include vegetation planning. Emergent plants such as cattails, bulrush, reeds, and arrowhead are usually used in FWS wetlands, but other plants native to the area can be utilized as well. Spacing, the time of year to plant, and other considerations such as ideal temperature and pH vary per plant species. Another aspect of the wetland design may include mitigation measures against mosquito breeding, such as ensuring a minimum velocity, using mosquito fish, or using chemical deterrents.

6.7. Calculating wetland design

6.7.1. Overview

The method of FWS treatment wetland design described herein is typically used in treating wastewater effluent. Nonetheless, the level of impairment, and water quality conditions identified through field monitoring (outlined above), allow similar principles to be applied. Specifically, the design method herein can provide an estimate of the efficiency of treatment that would be provided by a FWS treatment wetland for the Klamath River between Link Dam and Keno Dam.

Fundamental to the design of a FWS treatment wetland is determining the design BOD (BOD_{design}). BOD_{design} is the BOD_5 concentration used to determine the required detention time for the FWS wetland. The detention time is the amount of time water is required to remain in the wetland to achieve the desired reduction of BOD_5 concentration. BOD_{design} takes into consideration the variability of the BOD_5 in the wetland influent water, as well as the natural processes within the wetland that contribute to additional BOD_5 in the effluent water of the wetland, the desired effluent BOD_5 concentration, and the probability that the effluent BOD_5 will not exceed its desired value.

Once the detention time is calculated, the organic loading rate for the wetland can be determined. It is important that the organic loading rate not exceed the maximum acceptable rate for a FWS wetland, or the wetland efficiency decreases. Assuming an overall water depth for the wetland, an aspect ratio for the wetland dimensions and the calculated detention time, the area, length and width of the wetland can be calculated. For this system, the wetland is being considered to treat the seasonal extreme BOD_5 concentrations. The basic steps in FWS wetland include

- Design BOD (including a desired level of reliability)
- Detention time
- Organic loading rate
- Wetland area (width and length)

and are shown schematically in Figure 27, wherein assumptions are shown in italics and decision points are in bold.

To assess a variety of conditions, several sets of wetland design calculations were performed. The average and maximum BOD_5 (33 mg/l and 8.1 mg/l, respectively) were used to determine approximate a representative range of wetland sizes and specifications. Also, wetland design calculations were performed using the maximum BOD_5 data and statistics at each of the six sampling sites to determine if there may be different design criteria based on different longitudinal water quality characteristics in Keno Reservoir. All design scenarios are presented in Table 8.

Table 8. Wetland design scenarios

	Scenario							
Parameter	1	2	3	4	5	6	7	8
BOD data	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD influent type	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
Influent BOD, mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0

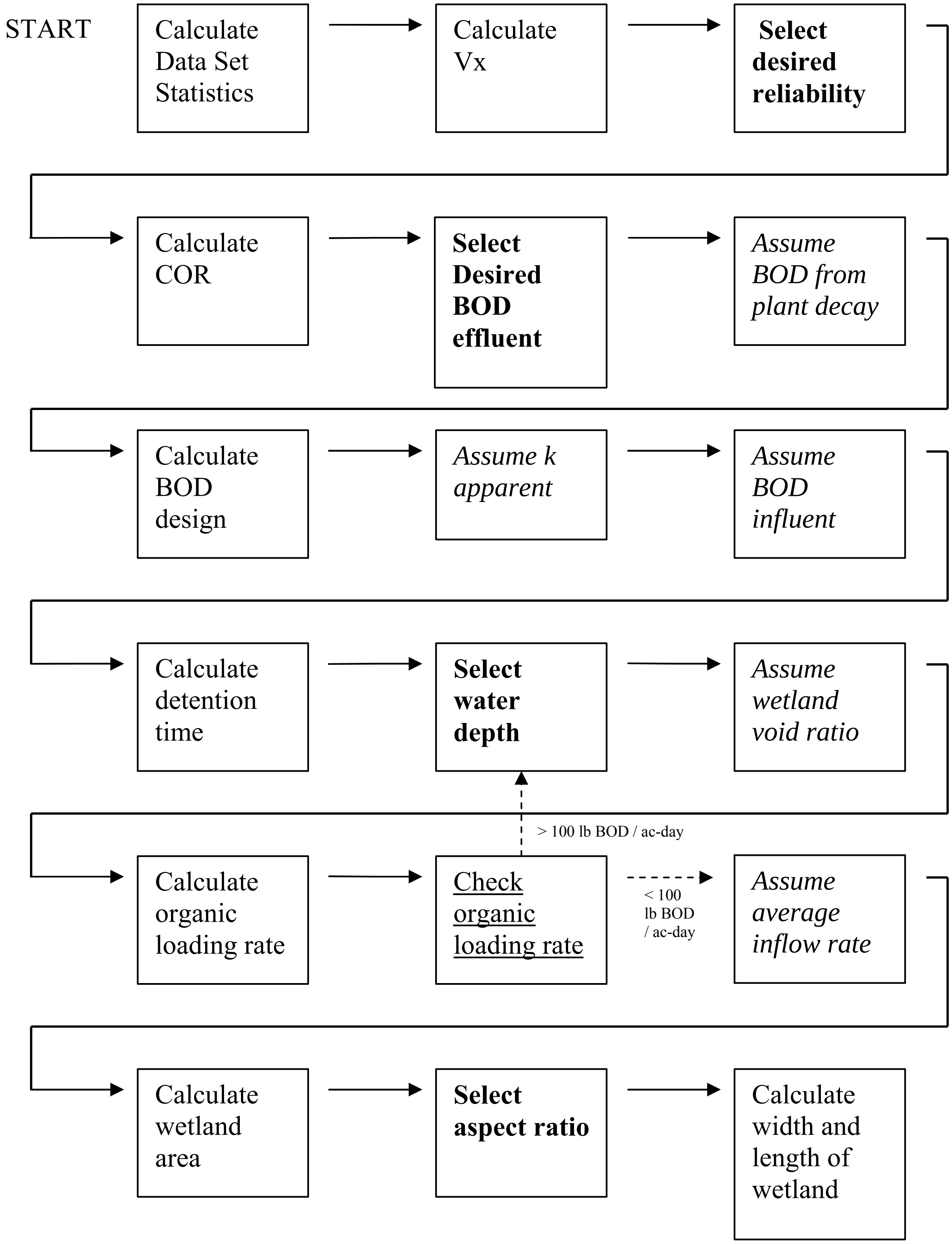

Figure 27. Outline of FWS wetland design steps

6.7.2. Design BOD

Design BOD represents the desired BOD in the effluent from the FWS wetland. Design parameters may also included TSS, total nitrogen and total phosphorous; however, the intent of this project was the reduction in organic matter, and thus BOD was the parameter of interest.

The BOD $_{\text{design}}$ was calculated as a function of influent BOD and a coefficient of reliability using equation (1), wherein influent BOD was calculated as the difference between effluent BOD and that BOD produced naturally from within the wetland (equation (2)).

$$\mathrm{BOD}_{\mathrm{design}} = \mathrm{COR} \times \mathrm{BOD}_{\mathrm{RIW}} \tag{1}$$

$$\mathrm{BOD}_{\mathrm{RIW}} = \mathrm{BOD}_{\mathrm{EFF}} - \mathrm{BOD}_{\mathrm{PD}} \tag{2}$$

Where:

COR = coefficient of reliability

$\mathrm{BOD}_{\mathrm{RIW}}$ = influent BOD_5 to constructed wetland, mg/l

$\mathrm{BOD}_{\mathrm{EFF}}$ = effluent BOD_5 from constructed wetland, mg/l

$\mathrm{BOD}_{\mathrm{PD}}$ = BOD_5 resulting from plant decay, mg/l

$\mathrm{BOD}_{\mathrm{PD}}$ was assumed to be 3 mg/l. This was less than the recommended 5 mg/l in Crites and Tchobanoglous (1998) because the desired $\mathrm{BOD}_{\mathrm{EFF}}$ was set to 6 mg/l, and using $\mathrm{BOD}_{\mathrm{PD}}$ equals 5 mg/l would produce a $\mathrm{BOD}_{\mathrm{RIW}}$ of 1 mg/l and a BOD $_{\text{design}}$ of less than 1 mg/l, which is not measurable in the field using conventional BOD analysis. During peer review a $\mathrm{BOD}_{\mathrm{PD}}$ of 3 mg/l was identified as an acceptable value for the calculations.

Crites and Tchobanoglous (1998) identify a coefficient of reliability as "the probability of adequate performance for at least a specified period of time under specified conditions." Monitoring program design provided sufficient field data to determine the necessary information (e.g., coefficient of variation, standard deviation, mean) to apply the coefficient of reliability method, which is calculated using equations (3) and (4).

$$\mathrm{COR} = \left(\mathrm{V_x}^2 + 1\right)^{1/2} * \exp\left(-\,\mathrm{Z}_{1-\alpha}\left(\ln\left(\mathrm{V_x}^2 + 1\right)\right)^{1/2}\right) \tag{3}$$

$$\mathrm{V_x} = \sigma_{\mathrm{x}} / \mathrm{m_x} \tag{4}$$

Where:

COR = coefficient of reliability

V_x = coefficient of variation

$Z_{1-\alpha}$ = number of standard deviations away from mean of a normal distribution for a cumulative probability of occurrence, $1-\alpha$. (See Table 9)

$1-\alpha$ = cumulative probability of occurrence (reliability level)

σ_x = standard deviation of BOD_5 data

m_x = mean of BOD_5 data

Table 9. Values of standardized normal distribution

Cumulative Probability $1\text{-}\alpha$	Percentile $Z_{1-\alpha}$
99.9	3.090
99	2.326
98	2.054
95	1.645
92	1.405
90	1.282
80	0.842
70	0.525
60	0.253
50	0

Niku et al. (1979) as cited in Crites and Tchobanoglous (1998)

6.7.3. Detention time

The FWS wetland detention time for removal of BOD_5 was calculated using equation (5).

$$t = \frac{\left(\ln \frac{C}{C_o}\right)}{k_{apparent}} \qquad (5)$$

Where:

t = detention time for BOD removal, days

C = BOD $_{design}$, mg/l

C_o = influent BOD_5 concentration, mg/l

$k_{apparent}$[2] = empirical temperature-corrected apparent BOD_5 removal-rate constant, 0.678 d^{-1}

For Scenario 1, wherein maximum BOD_5 concentration was assumed 33 mg/l, the standardized normal distribution, $Z_{1-\alpha}$ was 3.090 for a cumulative probability of 99.9, resulting in a COR of 0.737 and a BOD $_{design}$ of 2.21 mg/l. Subsequently, detention time for BOD removal was calculated to be 3.99 days where BOD_{EFF} would not exceed 6 mg/l.

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[2] Settling and processing is not uniformly distributed throughout a wetland, e.g., larger particles usually settle in the first sections of a wetland. The BOD removal rate, $k_{apparent}$, which was used in the wetland design is an "empirical *apparent overall removal rate* coefficient, and, in most cases, may not have any physical meaning" (Tchobanoglous 2000). While there is evidence that the actual removal rates in a wetland change as removal occurs and that the BOD removal rates are zero order and not dependent on BOD concentration (Tchobanoglous et al, 2000), calculation of actual $k_{apparent}$ would not be practical on a theoretical basis. A "retarded rate coefficient" as presented in Tchobanoglous et al (2000) and Crites and Tchobanoglous (1998) could be calculated as a better approximation of removal rate, but requires a coefficient of retardation, which is a relatively undocumented value. Crites and Tchobanoglous (1998) presents one value of a coefficient of retardation of 0.5 in an example problem, but provides no explanation as to why that value was chosen, or an acceptable range of values.

If the actual sizes and densities of the particles associated with BOD were known, an estimate of the settling time could be calculated for each particle size, assuming a specific flow rate. However, particle size and density were not collected during the 2005 field sampling. If a pilot project is implemented, apparent BOD removal rates can be more appropriately investigated

To assess the impacts of various levels of reliability, detention time for Scenario 1 was calculated for a range of cumulative probabilities. As identified in Table 10, calculated detention times varied from 3.53 days to 3.99 days for cumulative probabilities of 50 and 99.9 percent, respectively. Because the higher cumulative probability produced more consistent BOD_5 concentrations in the wetland effluent with little difference in detention time, a cumulative probability of 99.9 was used in the calculations for BOD_{design}.

Table 10. Detention time for different cumulative probabilities of occurrence – Scenario 1

$1-\alpha$	$Z_{1-\alpha}$	COR	BOD_{EFF}	BOD_{RIW}	BOD_{Design}	BOD_{INF}	t, days
99.9	3.090	0.737	6	3	2.21	33	3.99
99	2.326	0.795	6	3	2.39	33	3.87
98	2.054	0.817	6	3	2.45	33	3.83
95	1.645	0.852	6	3	2.56	33	3.77
92	1.405	0.873	6	3	2.62	33	3.74
90	1.282	0.883	6	3	2.65	33	3.72
80	0.842	0.923	6	3	2.77	33	3.65
70	0.525	0.953	6	3	2.86	33	3.61
60	0.253	0.980	6	3	2.94	33	3.57
50	0	1.005	6	3	3.02	33	3.53

6.7.4. Organic loading rate

The organic loading rate of the FWS wetland with the detention time, influent BOD_5 and effluent BOD_5 specified above was calculated to determine if it was below the recommended maximum allowable organic loading rate of 100 lb BOD/ac-day (Crites and Tchobanoglous, 1998). Above the recommended maximum, a wetland may not maintain aerobic conditions near the water surface and treatment efficiency may drop and odor problems could result. The organic loading rate was calculated using equation (6).

$$L_{org} = \frac{(C)(d_w)(\eta)(F_1)}{(t \times F_2)} \tag{6}$$

Where:

L_{org} = organic loading rate, lb BOD/ac-day
C = influent BOD_5 concentration, mg/l
d_w = depth of flow, ft
η = plant based void ratio, 0.65 to 0.75 typically
F_1 = conversion factor, 8.34 lb / [MG-mg/l)]
F_2 = conversion factor, 3.07 ac-ft/MG
t = detention time, day

The organic loading rate was calculated for a range of depths (shown in Table 11 for Scenario 1). A depth of 1.5 feet was chosen for the wetland for each scenario. At this depth, the organic loading rate of the wetland was 23.61 lb BOD/ac-day for Scenario 1, well below the recommended maximum rate of 100 lb BOD/ac-day.

6.7.5. Wetland area and width

Once the detention time and depth were determined, FWS wetland area was calculated using equation (7).

$$A = \frac{(Q_{ave})(t)(3.07)}{(d_w \times \eta)} \tag{7}$$

Where:

A = area of wetland, acres
Q_{avg} = average daily flow through wetland, Mgal /day
t = detention time, day
d_w = depth of flow, ft
η = plant based void ratio, 0.65 to 0.75 typically

Q_{avg} was calculated using equation (8). Q_{in} was assumed to be 25 percent of the average flow at USGS gage 11507500, Link River at Klamath Falls, OR, calculated from May through October 2005. Also, it was assumed that Q_{out} would equal 80 percent of Q_{in} (20 percent loss rate) to account for losses due to evaporation, evapo-transpiration, and seepage.

$$Q_{avg} = \frac{(Q_{in} + Q_{out})}{2} \tag{8}$$

Where:

Q_{avg} = average daily flow through the wetland, MGD
Q_{in} = inflow into wetland, MGD
Q_{out} = outflow from wetland, MGD

The average flow at the USGS gage from May through October 2005 was 1,292 cfs (835 MGD). Assuming that only 25% of the river flow is diverted into the wetland, Q_{in} was 323 cfs (209 MGD) and Q_{avg} was 291 cfs (188 MGD). The wetland area was 2,192 acres at a water depth of 1.5 feet for Scenario 1.

The width of the wetland was calculated using equation (9).

$$w = \left(\frac{A}{R_A}\right)^{1/2} \tag{9}$$

Where:

w = width of FWS wetland, ft
A = area of FWS wetland, ft^2
R_A = aspect ratio, length/width, typically 2:1 or 4:1

The width of the wetland was 0.9 miles, using an aspect ratio of 4:1, and the length of the wetland, calculated as A/w, was 3.7 miles for Scenario 1.

Table 11. Organic loading rates, areas and widths for different flow depths for Scenario 1: maximum seasonal BOD loads

Depth, ft	η	L_{org}	A, acres	A, ft^2	R_A	w, mile	l, mile
0.25	0.7	3.93	13,149	572,787,660	4	2.3	9.1
0.5	0.7	7.87	6,575	286,393,830	4	1.6	6.4
0.75	0.7	11.80	4,383	190,929,220	4	1.3	5.2
1	0.7	15.74	3,287	143,196,915	4	1.1	4.5
1.25	0.7	19.67	2,630	114,557,532	4	1.0	4.1
1.5	0.7	23.61	2,192	95,464,610	4	0.9	3.7
1.75	0.7	27.54	1,878	81,826,809	4	0.9	3.4
2	0.7	31.47	1,644	71,598,458	4	0.8	3.2

6.8. *Water Balance*

A monthly water balance was performed to determine the hydraulic residence time of the wetland, as designed above, under different flow rates. The average monthly flow for the period May through October 2005 was used as Q_{in}. Q_{out} was based on the assumed 20% loss rate within the wetland. Q_{avg} was calculated as in Equation (8) as before. Hydraulic residence times are presented in Table 12 for Scenario 1. Note that the hydraulic residence time for the entire period is longer than the detention time (3.99 days, see Table 10) required to achieve the desired effluent BOD except May, when Q_{in} was 622 cfs. Wetland areas required for a hydraulic residence time of 4 days for each month as well as the period average are shown in Table 13.

Table 12. Monthly hydraulic residence times for Scenario 1: maximum seasonal BOD loads

Month	Q_{in}, cfs	Q_{out}, cfs	Q_{avg}, cfs	Q_{avg}, MGD	Wetland Area, acres	Wetland Depth, ft	Hydraulic Residence Time, days
May	622	497	560	362	2,192	1.5	2.96
June	291	233	262	169	2,192	1.5	6.33
July	269	215	242	157	2,192	1.5	6.84
August	268	215	241	156	2,192	1.5	6.87
September	243	195	219	141	2,192	1.5	7.57
October	242	194	218	141	2,192	1.5	7.61
Entire Period	323	259	291	188	2,192	1.5	5.70

Table 13. Monthly wetland areas for Scenario 1: maximum seasonal BOD loads and hydraulic residence time of 4 days.

Month	Q_{in}, cfs	Q_{out}, cfs	Q_{avg}, cfs	Q_{avg}, MGD	Wetland Area, acres	Wetland Depth, ft	Hydraulic Residence Time, days
May	622	497	560	362	2960	1.5	4.00
June	291	233	262	169	1384	1.5	4.00
July	269	215	242	157	1282	1.5	4.00
August	268	215	241	156	1277	1.5	4.00
September	243	195	219	141	1158	1.5	4.00
October	242	194	218	141	1152	1.5	4.00
Entire Period	323	259	291	188	1538	1.5	4.00

Wetland acreages presented in Table 13 suggest that an area of approximately 1,400 acres would be sufficient for the months of June through October, while processing 25 percent of the river in May would require over twice this area. Because May is a less problematic month, a lower flow rate could be used and the smaller wetland area employed. The wetland acreage required for treating larger flow regimes from the Klamath River (e.g., in excess of 25 percent of the base flow) can be estimated by directly scaling the values in Table 12 and Table 13, e.g., to process 50 percent of the river flow for the entire period would require wetland areas twice as a large, or to process the entire river flow the wetland area would be four times as large.

6.9. Sensitivity Analysis

To examine the effect of selected assumed values for the design parameters, the wetland depth, the plant void ratio and the BOD from internal plant decay were varied to assess impact on wetland design calculations. The resulting detention times, wetland areas, and organic loads associated with various assumptions for each of the eight scenarios are presented. Recall the scenarios, presented in Table 8, include scenario 1 where the maximum seasonal BOD values based on data from all sites are applied, scenario 2 where the average seasonal BOD values based on data from all sites are applied, and scenarios 3 through 8 represent the maximum BOD values from each of the six individual sites between Link Dam and Keno. Wetland calculations outlined herein utilized spatial and temporal variability in monitoring design to allow determination of treatment wetland requirements based on local conditions (e.g., longitudinally along Keno Reservoir or in the Klamath Straits Drain). Summary tables of the sensitivity analysis results are presented in Appendix J:. Presented in Figure 28, Figure 29 and Figure 30 are the baseline calculation detention times, wetland areas and organic loads, for comparison of the sensitivity analysis.

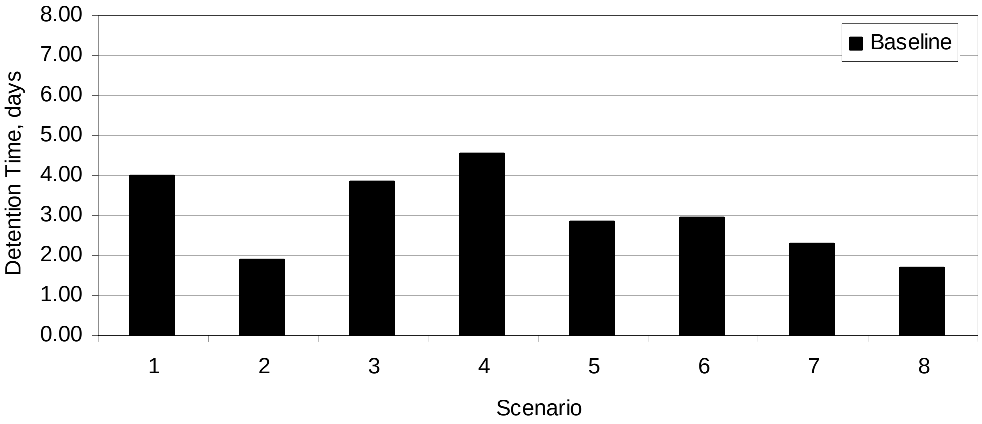

Figure 28. Detention time for baseline conditions: depth of 1.5 ft, plant void ratio of 70% and plant decay BOD of 3 mg/l.

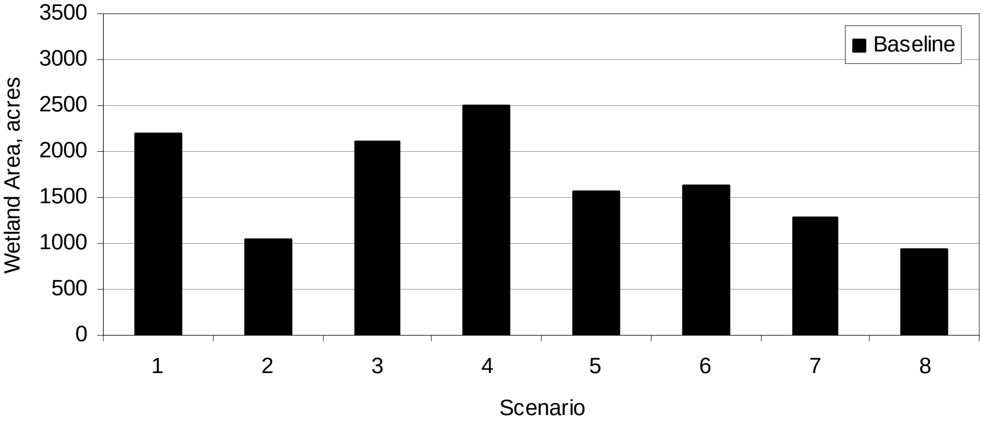

Figure 29. Wetland area for baseline conditions: depth of 1.5 ft, plant void ratio of 70% and plant decay BOD of 3 mg/l.

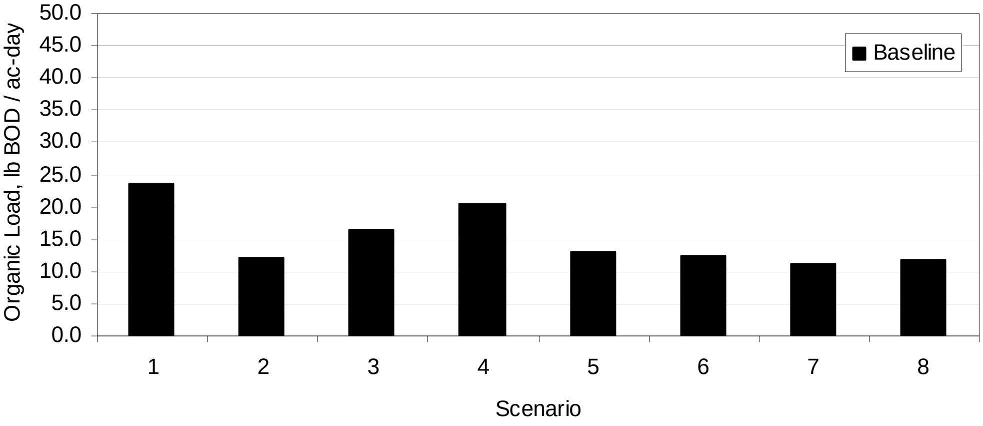

Figure 30. Organic load for baseline conditions: depth of 1.5 ft, plant void ratio of 70% and plant decay BOD of 3 mg/l.

Wetland Depth

Wetland calculations were repeated for 2.5 and 3.0 foot depths in addition to the previous assumption of 1.5 feet. Varying the depth did not change the calculated detention time of the wetland (Figure 31) for this analysis because increasing depth was assumed to decrease the wetland area (Figure 32), resulting in an increase in the organic loading rate (Figure 33). Although the organic load doubled in the 3 foot deep wetland versus the 1.5 foot deep wetland, the load remained well under the recommended maximum of 100 lb BOD/ac-day. These findings suggest that the wetland area can be reduced 50 percent by employing a 3 foot deep wetland versus a 1.5 foot deep wetland.

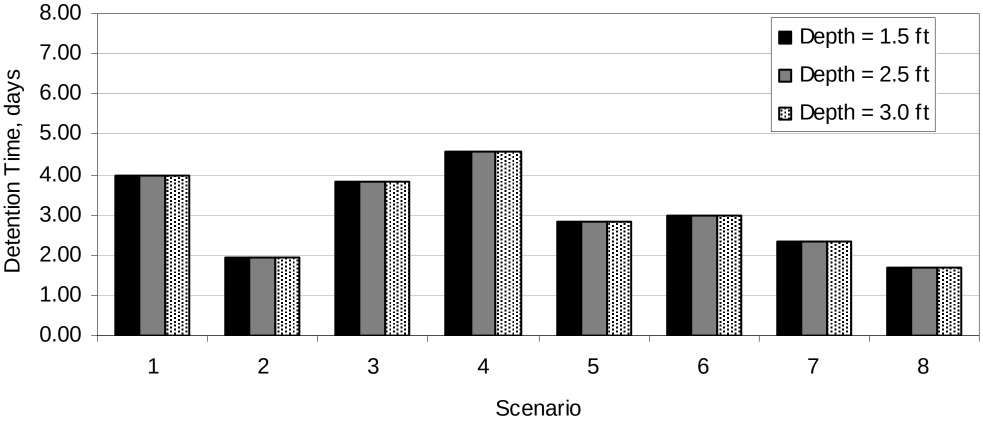

Figure 31. Calculated detention time in the wetland based on different depths

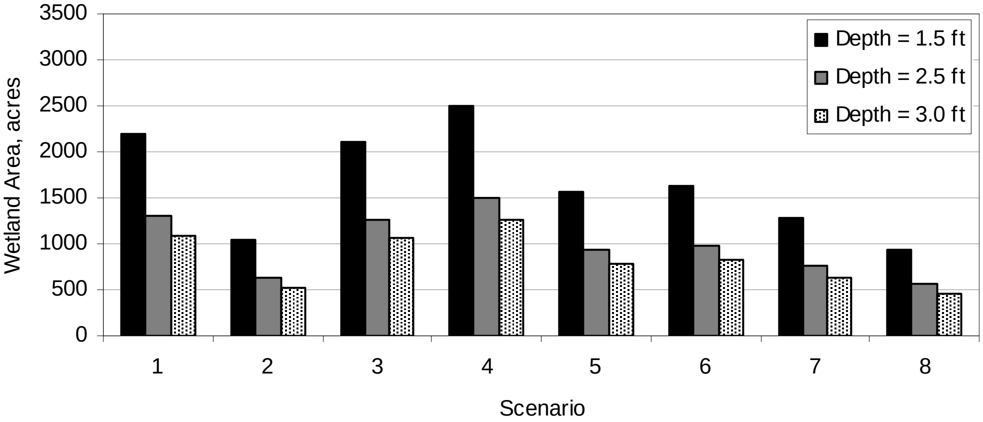

Figure 32. Calculated wetland area in the wetland based on different depths

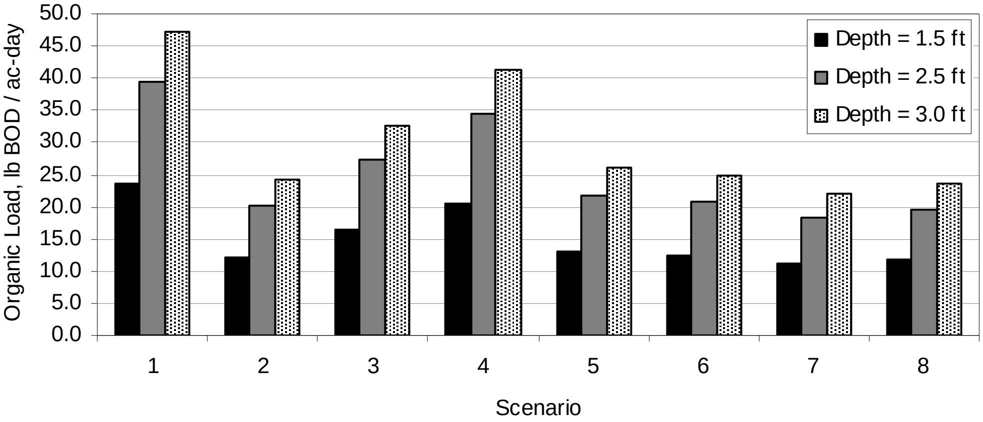

Figure 33. Calculated organic load rate in the wetland based on different depths

Plant Void Ratio

Wetland design was calculated for a plant void ratio of 60 percent and 80 percent, in addition to the initial assumption of 70 percent. Increasing or decreasing the plant void ratio also did not affect the detention time of the wetland (Figure 33). However, increasing the void ratio decreased the wetland area (Figure 35) and increased the organic loading rate (Figure 36). Decreasing the void ratio to 70 percent increased wetland area and decreased the organic loading rate, while increasing the void ratio to 80 percent resulted in the inverse. The organic loading rate remained well under the recommended maximum of 100 lb BOD/ac-day. Because plant void ratio may vary through time in treatment wetlands for various reasons (e.g., increases or decreases in plant cover due to colonization, die back), this range of void ratios identifies the range of wetland

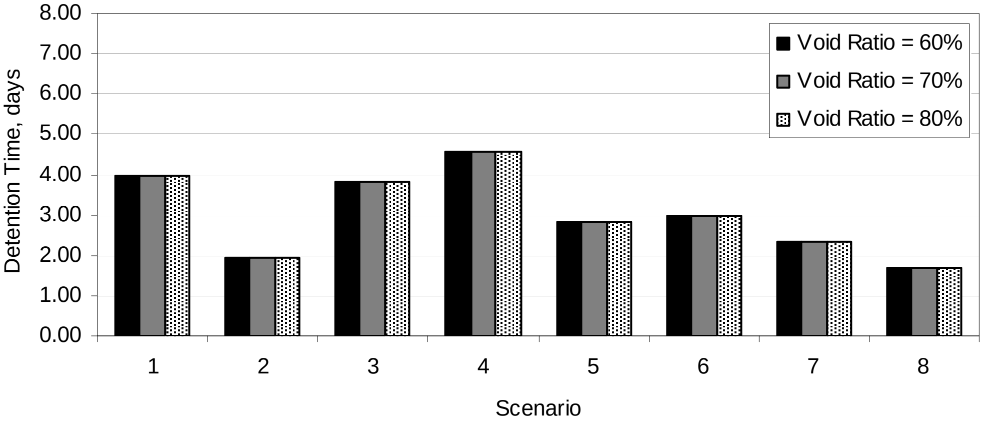

Figure 34. Calculated detention time in the wetland based on different plant void ratios

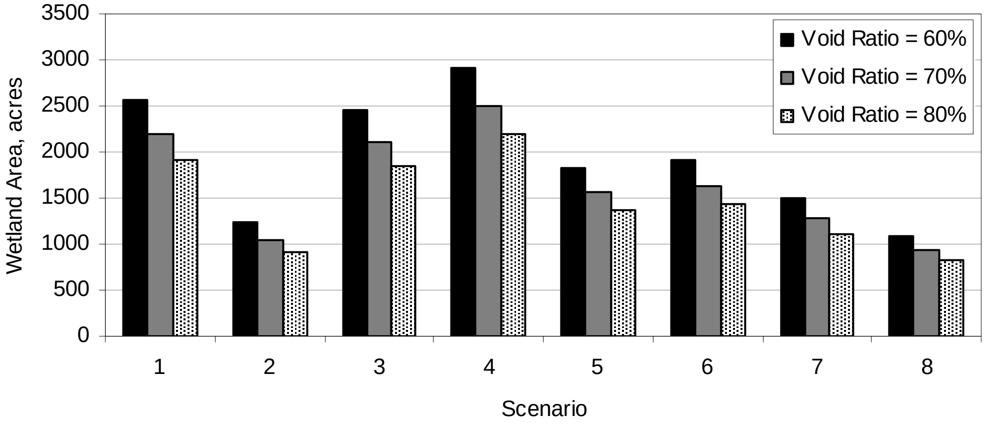

Figure 35. Calculated wetland area in the wetland based on different plant void ratios

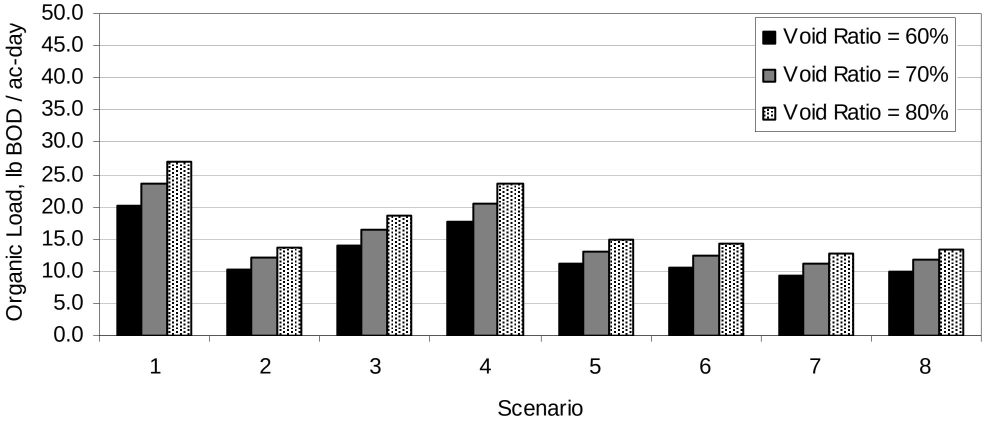

Figure 36. Calculated organic load rate in the wetland based on different plant void ratios

Internal Plant Decay BOD

Wetland design was calculated for internal plant decay BOD of 1.0 mg/l, 3.0 mg/l and 5.0 mg/l. Increasing BOD due to the internal plant decay of the wetland increased the required detention time in the wetland and increased the wetland area. Also, increasing the BOD due to internal plant decay decreased the organic load of the wetland.

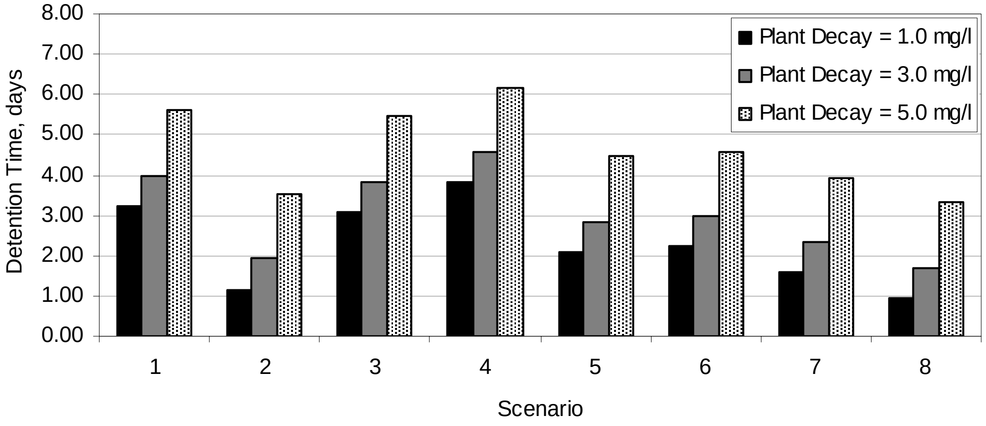

Figure 37. Calculated detention time in the wetland based on different internal plant decay BOD

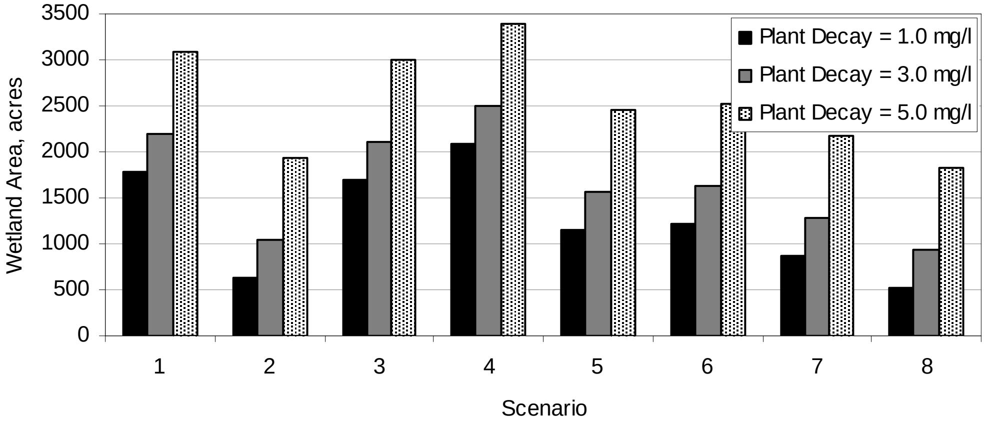

Figure 38. Calculated wetland area in the wetland based on different internal plant decay BOD

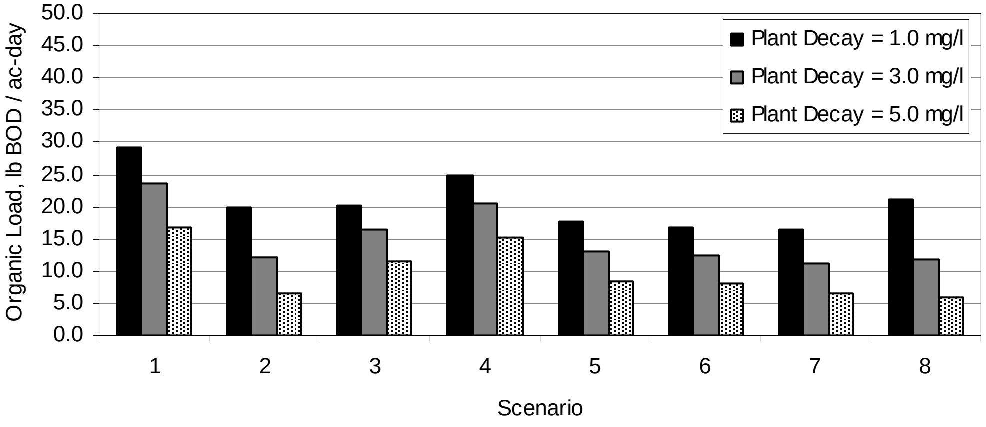

Figure 39. Calculated organic load rate in the wetland based on different internal plant decay BOD

6.10. Summary

The initial assumptions and calculated values used to in design the FWS wetland for each scenario are presented in Table 14**Error! Reference source not found.**. The associated percent reduction of BOD_5 for each scenario is presented in Table 15. A wetland design based on global average BOD_5 values (all sites for the entire season) would on average reduce BOD_5 by 26 percent and requires 1,054 acres of wetland area. However, during periods of high BOD in influent waters, this wetland area would be incapable of processing the assumed 25 percent of river flow and diversions to the wetland would have to be reduced to less than half – a considerable reduction in overall treatment capacity during a critical water quality period. A more conservative wetland area based on maximum annual observed BOD_5 (all sites for the entire season) would on average reduce BOD_5 by 82 percent and require 2,192 acres of wetland area. However, if May was not included in the period average a wetland on the order of 1,400 acres would be sufficient (and May may not be a reliable month to employ wetlands due to late cool weather conditions). Further, field data suggest that removal percentage varies along the reservoir with increasing distance from Link Dam. Wetlands closer to Link Dam (Link Dam to approximately Miller Island) would be relatively more efficient than those located closer to Keno. The Klamath Straits Drain experienced low BOD_5 conditions throughout the season and wetlands treatment for organic matter removal would most likely prove modest.

Sensitivity analysis varying wetland depth, plant void ration, and internal plant decay BOD suggest that wetland parameter design selection can appreciably affect required wetland area while still maintaining BOD loading rates well under the maximum 100 lb BOD/ac-day. These findings indicate that design modification could provide valuable flexibility in locating wetlands where BOD_5 loads are high and/or potential wetland acreage is limited.

Table 14. Summary of wetland parameters and calculations for each scenario

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD_5 data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD_5 inflow assumed	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD_5-ave	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD_5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD_5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD_5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD_5	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD_5	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD_5	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD_5	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.93	0.64	0.91	0.99	0.78	0.80	0.71	0.60
Wetland length	Calculated	mile	3.70	2.57	3.63	3.96	3.12	3.19	2.83	2.41

Table 15. BOD_5 reduction, required detention time and area for each scenario

		Scenario							
Parameter	Units	1	2	3	4	5	6	7	8
BOD_5 data	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD_5 inflow assumed	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD_5 reduction	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD_5 reduction	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	acres	2192	1054	2114	2506	1557	1631	1278	933

7. Summary and Conclusions

7.1. Summary

7.1.1. Objectives and Tasks

The principal objective of this project was to characterize the quantity and composition of organic matter originating from Upper Klamath Lake and that within Keno Reservoir to assess options for reducing detrimental water quality impacts of this material on Keno Reservoir and downstream Klamath River reaches. Keno Reservoir is located at the terminus of Link River in Klamath Falls, with headwaters approximately 1.2 miles below Link Dam (Upper Klamath Lake). The approximately 20 mile long reservoir is broad and shallow, with depths typically less than 5 meters and widths ranging from several hundred feet wide to several thousand feet. With the exception of the regions in the vicinity of Klamath Falls, much of the shoreline is dominated by agricultural lands, with the exception of Keno, where the river enters the Cascade Range.

Recent studies assessing flow and water quality in the Klamath River support earlier work that the water quality conditions in Upper Klamath Lake have a significant impact on downstream river reaches during summer periods – particularly Lake Ewauna and Keno Reservoir – and impacts may extend considerably farther downstream (PacifiCorp, 2005). Of primary concern is organic matter (living and dead) imparting a considerable oxygen-demanding load on the system, with its concomitant nutrient load. Currently, releases from the hyper-eutrophic Upper Klamath Lake convey this load via Link River to the impoundment behind Keno Dam. In addition to the Upper Klamath Lake releases, municipal, industrial, and agricultural flows enter the river in the Keno Reservoir reach. During summer periods a significant portion of the Lake Ewauna to Keno Dam reach experiences widespread, persistent anoxia, which limits assimilative capacity of the river and may further degrade water quality conditions. Although conditions are generally acceptable through May or early June, by August dissolved oxygen concentrations fall to less than 1.0 mg/l for much of the reservoir depth and length from River Mile (RM) 250 downstream. The result is extreme water quality impairment from an aquatic ecosystem perspective.

One desirable attribute of treatment wetlands is that the necessary facilities could be implemented in just a few years. Given the long time span necessary to provide recovery of hypereutrophic UKL conditions (decades to centuries), solutions that could be implemented in a matter of years are appealing.

The project consisted of two primary tasks: (1) to quantify the spatial and temporal character and distribution of organic matter and associated water quality constituents in the reach between Link Dam and Keno Dam, and (2) use this information to assess the feasibility of improving the water quality in this reach using treatment wetlands. A subsequent phase of the project would include design and implement a pilot treatment wetland and monitoring program to assess large scale application.

7.1.2. Project Elements

To quantify and characterize organic matter and associated constituent conditions and assess the potential to treat and/or reduce these loads in reaches below Link Dam, several inter-related tasks were completed, including:

- monitoring program design
- monitoring and laboratory oversight
- data management
- data analysis to identify potential for treatment wetlands
- reporting

The monitoring program design was developed with assistance from Dr. George Tchobanoglous, Professor Emeritus, University of California, Davis, input from U.S. Bureau of Reclamation (Klamath Area Office and MP-170 Sacramento), U.S. Fish and Wildlife, U.S. Geological Survey, as well as Basic Laboratory and others. Monitoring occurred on nine dates during the 2005 season between May 3 and October 18. Samples were collected at six sites distributed form Link Dam to Keno Dam: Link Dam, Lake Ewauna, Miller Island, below the Klamath Straits Drain, within the Drain, and Keno Dam. Twenty three individual types of physical, chemical, and biological constituents were sampled or assessed at various frequencies. A unique element of the monitoring program was the collection of a suite of filtered and unfiltered biochemical oxygen demand samples to identify the particulate and dissolved fractions of material that were present in water. BOD_5 samples were filtered at 10 microns, 1.0 micron, and 0.45 microns. The 0.45 micron filter size was selected to distinguish between dissolved and particulate material, while the 1.0 micron filter size was to screen material at the colloidal level. The 10 micron filter was included to provide additional detail in the particulate range. A wide range of other parameters were collected to provide insight into system processes in this complex system, including temperature, dissolved oxygen, pH, conductivity, total suspended solids, light extinction properties, chemical oxygen demand, nutrients, algae, and zooplankton.

The physical process of collecting field samples and observations was completed in cooperation with U.S. Bureau of Reclamation. Primary laboratory oversight was carried out by Watercourse; however, Reclamation was consulted on several occasions regarding laboratory performance. All project laboratory and field data were reviewed and entered into electronic format. Laboratory analyses and field data were used in determination of the potential use of the treatment wetlands. Dr. George Tchobanoglous was consulted throughout the design and implementation of the project. Dr. Bob Gearhart provided review of the wetlands calculations.

7.1.3. Wetland Design Calculations

Free Water Surface Wetlands

Upon completion of the field data collection, wetland design calculations were carried out. These calculations provide a theoretical basis for wetland design are intended to identify the potential for wetlands treatment to mitigating water quality conditions that primarily emanate from Upper Klamath Lake. As such, the calculations do not produce final design parameters and specification. Appropriate lands, infrastructure, potential costs, and other features would be required prior to implementing wetlands for treatment. A pilot project is strongly recommended.

Free water surface (FWS) wetlands are those that most closely resemble natural wetlands in both appearance and function. In assessing the feasibility of treatment using wetlands, a FWS wetland was the primary type considered for determining the viability of wetland treatment of organic matter. Free water surface wetlands can remove between 60 to 80 % of BOD_5 and 50 to 90% of total suspended solids (TSS), which includes organic matter, depending on design criteria, influent characteristics, influent concentrations of BOD_5 and TSS, and operation of the wetland and have been used in a variety of locations with success.

The concept assessed herein presumes wetlands could be located adjacent to the Klamath River in the Keno Reservoir reach (although wetlands could also be located in areas away from the river) to reduce the organic load originating from Upper Klamath Lake. Benefits realized within the Keno Reservoir reach would also be translated to downstream river reaches. Although a FWS wetland would also provide potential wildlife habitat, these wetlands would be actively managed for treatment. While it is not practical to define a typical FWS wetland flow rate and area without representative, site specific data, existing FWS wetlands can provide valuable guidance on possible flows, sizes, and treatment effectiveness.

Calculations

Fundamental to the design of a FWS treatment wetland is determining the design BOD (BOD_{design}). BOD_{design} is the BOD_5 concentration used to determine the required detention time for the FWS wetland. The detention time is the amount of time water is required to remain in the wetland to achieve the desired reduction of BOD_5 concentration. BOD_{design} takes into consideration the variability of the BOD_5 in the wetland influent water, as well as the natural processes within the wetland that contribute to additional BOD_5 in the effluent water of the wetland, the desired effluent BOD_5 concentration, and the probability that the effluent BOD_5 will not exceed its desired value.
Once the detention time is calculated, the organic loading rate for the wetland can be determined. The organic loading rate should not exceed a maximum acceptable rate for a FWS wetland, or the wetland efficiency may decreases. Assuming an overall water depth for the wetland, an aspect ratio for the wetland dimensions (e.g., length:width), and the calculated detention time, the area, length and width of the wetland can be calculated.

A wetland design based on global average BOD_5 values (all sites for the entire season – May through October) would on average reduce BOD_5 by 26 percent and requires 1,054 acres of wetland area. However, during periods of high BOD in influent waters, this wetland area would be incapable of processing the assumed 25 percent of river flow and diversions to the wetland would have to be reduced to less than half – a considerable reduction in overall treatment capacity during a critical water quality period. A more conservative wetland area based on maximum annual observed BOD_5 (all sites for the entire season) would on average reduce BOD_5 by 82 percent and require 2,192 acres of wetland area. However, if May was not included in the period average (i.e., calculations based on June through October average conditions), a wetland on the order of 1,400 acres would be sufficient. A flow rate of 25 percent of monthly average in flow to Keno Reservoir was used as a baseline for system design. Subsequently, wetland acreage was calculated based on a coefficient of reliability of 99 percent, a depth of 1.5 feet, and a residence time of 4 days (Table 16).

Further, field data suggest that removal percentage varies along the reservoir with increasing distance from Link Dam. Wetlands closer to Link Dam (Link Dam to approximately Miller Island) would be relatively more efficient than those located closer to Keno. The Klamath Straits Drain experienced low BOD_5 conditions throughout the season and wetlands treatment for organic matter removal would most likely prove modest.

Sensitivity analysis varying wetland depth, plant void ration, and internal plant decay BOD suggest that wetland parameter design selection can appreciably affect required wetland area while still maintaining BOD loading rates well under the maximum 100 lb BOD/ac-day. These findings indicate that design modification could provide valuable flexibility in locating wetlands where BOD_5 loads are high and/or potential wetland acreage is limited.

Table 16. Wetland areas for maximum seasonal BOD5 loads based on monthly flows and a hydraulic residence time of 4 days.

Month	Q_{in}, cfs	Q_{out}, cfs	Q_{avg}, cfs	Q_{avg}, MGD	Wetland Area, acres	Wetland Depth, ft	Hydraulic Residence Time, days
May	622	497	560	362	2960	1.5	4.00
June	291	233	262	169	1384	1.5	4.00
July	269	215	242	157	1282	1.5	4.00
August	268	215	241	156	1277	1.5	4.00
September	243	195	219	141	1158	1.5	4.00
October	242	194	218	141	1152	1.5	4.00
Entire Period	323	259	291	188	1538	1.5	4.00

7.2. Conclusions and Recommendations

7.2.1. Conclusions

Through detailed field monitoring, specific data were collected to complete preliminary estimates of wetlands treatment, reliability, and reduction of organic matter as represented by BOD. Filtered and unfiltered samples illustrated the range of BOD present in the Link Dam to Keno Dam reach, with most material being particulate matter – useful information in wetland design consideration. Associated sampling further characterized the broad range of physical, chemical, and biological water quality conditions present in the system. Quality assurance provided valuable field data validation measures in this complex system.

Theoretical calculations indicate that different BOD influent values for a FWS wetland can effect wetland design conditions. Because BOD values differ considerably throughout length of Keno reservoir, the placement of the wetlands may play a role in overall treatment effectiveness. The reduction of BOD in the wetland water is largely dependent on the influent BOD, the desired BOD effluent, depth, flow rate, wetland size, and desired level of reliability. Increasing the depth of the wetland is acceptable as long as the organic load is less than 100 lb BOD /ac-day, but increasing the organic load means that there may be a higher frequency of maintenance in the wetland to remove organic matter. Planning for worst case conditions (e.g., seasonal maximum measured BOD) versus average conditions (e.g., average seasonal BOD) changes the wetland design considerably. Worst case conditions represent a more conservative, and generally more prudent, approach to design.

Based on field data, preliminary calculations indicate that wetlands treatment may be a viable option for notably reducing organic loads from Upper Klamath Lake. Treating 25 percent of typical summer flows would require approximately 1,400 acres of wetlands, and scaling this up to 100 percent of river flows would translate to approximately 5,600 acres of wetlands. Although an appreciable area, such wetland acreage is not unheard of: Kadlec and Knight (1996) identify wetlands of several thousand acres treating several hundred cubic feet per second. Thus there is appreciable potential that wetlands treatment below Link Dam could provide considerable benefit to the water quality of Keno Reservoir and downstream Klamath River reaches.

There are remaining issues that require further assessment with regard to the ultimate efficacy of such wetlands, including local climate, effective size and location, assessment of soil and groundwater conditions, earthwork, infrastructure required, etc. As noted previous, a pilot project is highly recommended to test some of the basic assumptions identified herein as well as others required for comprehensive testing and implementation of wetlands. Such work could be completed in concert with non-technical concerns including, but not limited to, land availability and cost, operations and maintenance, ownership/responsibility, overall economic considerations, water rights (losses associated with wetlands), questions of wildlife use (e.g., endangered species), and other topics of interest.

Also, some regulatory framework may play an important role in the utilization of wetlands to improve water quality – an avenue that has recently been discussed in the basin, but without a definite framework in place. Receiving water standards and issues associated with discharge will need to be addressed.

Finally, the water quality processes within Keno Reservoir are complex and the water quality response of treatment wetlands is not completely understood at this time. Overall, there are many processes and issues surrounding implementation of wetlands treatment. However, the potential to provide considerable benefit in a short time frame, given the level of impairment at Upper Klamath Lake inflows into the Klamath River, suggest that further study is warranted.

7.2.2. Recommendations

Based on the findings of the field work and associated analysis, several recommendations have been identified. These recommendations are not prioritized, nor have costs been associated with the various activities.

- *Continued field monitoring*: Reclamation currently maintains a suite of water quality probes and collects other physical data within Keno Reservoir and, in cooperation with other agencies and entities, monitors conditions around Upper Klamath lake. It is recommended that these programs be maintained to construct a continuous and long record of conditions in the project area. Definition of system variability will be invaluable if wetlands treatment systems are deemed an acceptable and appropriate means of addressing current and/or future water quality problems. Should wetlands be implemented, monitoring to assess the efficacy of such systems will be required.
- *Characterization of organic matter*: Continue monitoring organic matter via BOD, COD, TOC, and other appropriate measures. These programs may include baseline studies, as well as specific studies (e.g., characterizing small temporal or spatial conditions). Filtered and unfiltered samples can lend considerable insight into the particulate, dissolved, labile, and refractory nature of organic matter – a critical and unique attribute of this system.
- *Wetlands pilot project*: consider implementing a pilot project to assess organic matter removal potential of treatment wetlands with a small scale project adjacent to the Klamath River or in neighboring areas. Such projects would be invaluable investigations not only into the ability of wetlands to process organic matter, but also to determine the best methods to implement, maintain, and operate such a system.
- *Assess potential implications of wetlands on Keno Reservoir water quality*: Using field data and/or analytical and numerical tools (models), explore the impacts of variable levels of treatment (in space and time) on Keno Reservoir. Improving water quality in Keno Reservoir could lead to a host of beneficial water quality responses including greater assimilative capacity under continuous aerobic conditions (versus the current seasonal, widespread, and persistent anoxia). However, the response of the system is largely unknown and prior to considering large scale wetlands, a water quality impacts assessment should be completed.
- *Regulatory implications*: Exploring the regulatory implications of wetlands treatment from water quality to aquatic system species and other wildlife (e.g., waterfowl), as well as legal repercussions should be completed.

7.3. Concluding Comment

The relationship between Upper Klamath Lake and downstream river and reservoir reaches is a complex and challenging problem. There is along history of work in this region of the Klamath River basin, and a large part of the impetus and foundation for this work relied on the efforts of those who worked in this arena over the last several decades. Although progress may be modest, with ongoing development of new information, techniques, and ideas, advancement in this important area of water quality will continue.

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9. Appendix

9.1. Appendix A: Quality Assurance Project Plan (QAPP)

July 18, 2005

1. Project/Task Organization

The Keno Wetland Water Quality Monitoring Program (KWWQMP) is being operated out of the Klamath Basin Area Office (KBAO) of the Bureau of Reclamation (Reclamation). Reclamation and Watercourse are jointly working to complete field operations, sampling, and monitoring in the Keno Wetland project area, from Link Dam to Keno Dam. Watercourse Engineering, Inc. is providing planning and Quality Assurance (QA) support.

2. Problem Definition/Background

Monitoring is being completed to assess the potential for treatment wetlands to improve water quality conditions in the Keno Reservoir reach through removal of organic matter and its associated oxygen demand. To determine the feasibility of water quality improvement through use of wetlands, more information about the organic matter distribution, the BOD associated with different particle sizes and the general water quality of the system needs to be collected. The purpose of this project is to collect the necessary data.

3. Project/Task Description

Sample Sites and Sub-programs:

The KWWQMP will sample from six sites located from Link Dam through Keno Reservoir. Multiple sampling sub-programs are included within this program:

- Grab samples every four weeks (Grab) – with assistance from Reclamation
- Instantaneous acquisition of physical parameters with multi-probe instrumentation (Probe) – managed by Reclamation
- Continuous acquisition of physical parameters with deployment of multi-probe instrumentation (Sonde) – managed by Reclamation
- Algae studies that include chlorophyll-a and phaeophyton concentrations as well as algal speciation (Algae) – with assistance from Reclamation

Presented in Table 18 are site locations and sampling sub-programs.

4. Data Quality Objectives for Measurement Data

Project Objectives:

The purpose of this program is to gather baseline water quality information as well as detailed organic matter and BOD information for assessment of the feasibility of using treatment wetland in this area to improve water quality in the upper Klamath River.

Scope of Work:

This program is scheduled to run from May through October 2005. Chemical, biological, and physical parameters affecting the water quality for aquatic life in the river will be measured.

Data Assessment:

External Double blind samples will be employed during the KWWQMP. The QA protocol that will be followed is the QA Standard Operating Procedure (SOP) supplied by the MP-Reclamation Environmental Monitoring Branch (EMB) in Sacramento. Reanalysis will be done on all samples that fall outside of the accuracy or precision limits shown in Table 17. The quality control sample data provided by the Basic will also be examined to determine if those data are also within the acceptable limits.

Table 17. Data Quality Objectives (from MP-Reclamation EMB SOP for QA, 2000)

Parameters	Reporting Limit (mg/L)	Accuracy (% Recovery)	Precision (% RPD)	Completeness (%)	Corrective Actions
Ammonia	0.06 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Nitrate + Nitrite as N	0.16 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Total Kjeldahl Nitrogen	0.20 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Orthophosphate	0.03 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Total Phosphorus	0.05 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Biological Oxygen Demand (5-day)	3.0 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Total Organic Carbon	0.20 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch
Chemical Oxygen Demand	7.0 mg/L	80%-120%	[>5x RL] = 0%-20% [≤ 5x RL] difference within ± RL	90%	Re-analyze sample and if not confirmed Re-analyze the batch

RL = Reporting Limit [ ] = If concentration of determination is....

Table 18. Sample Sites and Associated Water Quality Sub-programs

Site #	Agency	Location	Grab	Probe	Sonde	Algae
1	USBR	Link Dam	x	x	x	X
2	USBR	Klamath River at Railroad Bridge	x	x	x	X
3	USBR	Klamath River at Miller Island	x	x	x	X
4	USBR	Klamath River at Keno	x	x	x	X
5	USBR	KRS12A	x	x	x	X
6	USBR	KSD	x	x	x	x

5. Sampling Design (Experimental Design)

This program is divided into 4 different sub-programs; each designed to provide an overall assessment of the Keno Reservoir water quality as it may relate, directly or indirectly, to a potential treatment wetlands (assessment of the reservoir trophic status and limnology are likewise important).

- Continuous Deployment of Water Quality Probes (Sonde): Physical parameters are measured hourly via multi-probe units (sondes) deployed at the sites from May through October 2005 (see Table 19). Parameters include temperature, dissolved oxygen, pH, specific conductance, and oxidation reduction potential (redox). Sondes are exchanged each week, and transported to the KBAO, where they are downloaded, cleaned, calibrated, and readied for field deployment the following week. The KBAO SOP is used for the calibration, usage, post-calibration, and maintenance of the deployed units.

- Instantaneous Acquisition of Physical Parameters (Probe): Physical parameters are measured on site every four weeks with multi-probe instrumentation at the sites in May, September, and October 2005, and every two weeks in June through August 2005. Parameters include temperature, dissolved oxygen, pH, specific conductance, and/or redox. Measurements are obtained at a convenient location or near the grab sample site.

- Grab Samples (Grab): Water quality grab samples are collected every four weeks from May, September and October 2005, and every two weeks in June through August, 2005 Presented in Table 19 is the list of water quality constituents that will be collected. All constituents will be collected every four weeks in May, September, and October 2005. However, during June through August 2005 sieved BOD will only be collected every four weeks, while the other constituents will be collected every two weeks.

- Algae Study: Algae samples will be collected at each site along with the grab samples. Constituents include chlorophyll-a and phaeophyton concentrations, and algal speciation.

Table 19. Study parameters collected during the KWWQMP

#	Parameter	Parameter Name	Use
Organic and Particulate Matter			
1	Sieved BOD_5	-	Provides detailed data on the BOD associated with different sized particles suspended in the water.
2	BOD_5	Biochemical oxygen demand, 5 day	Estimates the biochemical oxygen demand on the water from biologically available organic matter in the water. Along with COD, assists in estimation of labile and refractory fractions of organic matter.
3	BOD_5, filtered	Biochemical oxygen demand of filtered water, 5 day	Estimates the ultimate oxygen demand on the water from dissolved biologically available organic matter in the water. Along with COD, assists in estimation of labile and refractory fractions of organic matter.
4	BOD_{10}	Biochemical oxygen demand, 10 day	Provides an additional estimate of the refractory nature of the organic matter.
5	BOD_{10}, filtered	Biochemical oxygen demand of filtered water, 10 day	Provides an additional estimate of the refractory nature of the dissolved organic matter.
6	COD	Carbonaceous oxygen demand	Estimates the ultimate oxygen demand on the water from all carbon in the water. Along with BOD, assists in estimation of labile and refractory fractions of organic matter.
7	COD, filtered	Carbonaceous oxygen demand of filtered water	Estimates the ultimate oxygen demand on the water from dissolved carbon in the water. Along with BOD, assists in estimation of labile and refractory fractions of organic matter.
8	TOC	Total organic carbon	Required to estimate particulate organic carbon (POC), which helps estimate the fraction of organic matter that is particulate.
9	TSS	Total Suspended Solids	Provides a total amount of particulate matter in water.
Algae			
10	Algae species	-	Provides data on type of algal community.
11	Chlor-a	Chlorophyll-a	Provides an estimate of algae concentration in water.
12	Phaeophyton	-	Provides an estimate of the amount of organic matter in the water that is comprised of dead algae
Nutrients			
13	NH4	Ammonia	Provides data about nutrient concentrations in water
14	NO2+NO3	Nitrate / Nitrite	Provides data about nutrient concentrations in water
15	TKN	Total Kjedahl Nitrogen	Provides data about nutrient concentrations in water
16	TP	Total Phosphorus	Provides data about nutrient concentrations in water
17	PO4	Phosphate	Provides data about nutrient concentrations in water
Physical Parameters			
18	Tw	Water Temperature	Provides physical data about water
19	DO	Dissolved Oxygen	Provides physical data about water
20	pH	-	Provides physical data about water
21	EC	Electrical Conductivity	Provides physical data about water

6. Sampling Method Requirements

For field sampling protocol, the “Standard Operating Procedure for Water Quality Grab Sampling” (SOP) is used. This document is included as appendix A.

All water samples will be collected using the grab-sample method. Samples will be collected using a clean sample bottle, churn splitter, Van Dorn sampler, or a peristaltic pump, as appropriate to the site. The SOP instructs how the monitoring and sampling will be performed and associated procedures for documenting the field activities. A multi-probe instrument will be used to measure the physical parameters (pH, specific conductance, dissolved oxygen, and water temperature) of the environmental water.

7. Sample Handling and Custody Requirements

Water samples will be collected in high-density polyethylene (HDPE) bottles and preserved according to EPA, Standard Methods, or other approved analytical methodology. Samples collected in the field will be labeled with:

- sample identification
- preservatives used
- constituent analyses required
- date and time sampled
- samplers initials

Sample volume is based on analytical requirements and is listed in Table 21. After collection, samples are kept in coolers on ice until delivered to the laboratory. All samples collected in the field require a Chain Of Custody (COC) and field data sheet. The COC and field data sheet will clearly document all the samples collected during that sampling period, associated sample identification numbers, and the date and time of collection for each sample. The field data sheet **must** be completed in the field while sampling. The COC may be completed at the end of the day when sampling is finished. The COC sheet is placed in a zip-lock bag and is shipped in the ice chest with the samples. A custody seal is attached across the opening of the ice chest by the field sampler. A commercial package carrier will transport the ice chests. The original COC sheet will be kept on file at the laboratory and the other copy returned to the KBAO or Watercourse Engineering, Inc.

8. Analytical Method Requirements

The analytical methods used by Basic for this project are shown in Table 20.

Table 20. Analytical Methods of Basic Laboratories for 2005 Keno Reservoir field study

Constituent	Analytical Method	Method Detection Limit, mg/l	Reporting Limit, mg/l
Ammonia, NH_4	EPA 350.1	0.03	0.06
Biological Oxygen Demand, BOD (5-day)	Standard Methods 5210	3.00	3.00
Chemical Oxygen Demand, COD	Standard Methods 5220	3.00	7.00
Nitrate, NO_3	EPA 353.2	0.05	0.16
Ortho-Phosphate, OPO_4	EPA 4500P-E	0.01	0.03
Total Kjeldahl Nitrogen, TKN	EPA 351.2	0.10	0.20
Total Phosphorus, TP	EPA 4500P	0.02	0.05
Total Suspended Solids, TSS	Standard Methods 2540D	2.00	6.00
Total Organic Carbon, TOC	Standard Methods 5310C	0.03	0.20

9. Sample Bottle Requirements

The size of high-density polyethylene (HDPE) bottles required is listed in Table 3 for each constituent. All bottles are rinsed three times with the environmental water prior to filling with sample. Any filtration required will be done from the churn splitter in the field. All acid preservation is completed at the sampling site immediately after sample collection. If sample bottles are pre-preserved the triple rinse with environmental water is omitted. A permanent waterproof-ink marker is used to write information about the sample on the bottle's label.

Table 21. Sample Bottles requirements, preservatives and hold times

Constituents	Bottle Type	Filtered	Preservation
Carbonaceous Oxygen Demand, COD	125 ml HDPE	No	4^{o}C, 2 ml H_2SO_4
Total Organic Carbon, TOC	250 ml Amber Glass	No	4^{o}C, 1 ml H_2SO_4
Biological Oxygen Demand, BOD_5	1,000 ml HDPE	No	4^{o}C
Biological Oxygen Demand – 10 day, BOD_{10}	1,000 ml HDPE	No	4^{o}C
Ammonia, NH_4; Nitrate-Nitrite, NO_3-NO_2 Total Kjeldahl Nitrogen, TKN; Total Phosphorus, TP	1,000 ml HDPE	No	4^{o}C, 2 ml H_2SO_4
Orthophosphate, OPO_4	500 ml HDPE	No	4^{o}C
Total Suspended Solids, TSS	500 ml HDPE	No	4^{o}C
Filtered Carbonaceous Oxygen Demand, $COD_{filtered}$	1,000 ml HDPE	Yes	4^{o}C
Filtered Biological Oxygen Demand, $BOD_{5\text{-filtered}}$	1,000 ml HDPE	Yes	4vC
Filtered Biological Oxygen Demand – 10 day, $BOD_{10\text{-filtered}}$	1,000 ml HDPE	No	4^{o}C
Sieved <10 um Biological Oxygen Demand, $BOD_{5\text{-sieved} <10}$	1,000 ml HDPE	Yes	4^{o}C
Sieved <1.0 um Biological Oxygen Demand, $BOD_{5\text{-sieved} <1.0}$	1,000 ml HDPE	Yes	4^{o}C
Sieved <0.1 um Biological Oxygen Demand, $BOD_{5\text{-sieved} <0.1}$	1,000 ml HDPE	Yes	4^{o}C
Zooplankton	250 ml	No	25 percent Isopropyl alcohol
Chlorophyll a, Phaeophyton	250 ml, Dark HDPE	No	4^{o}C, Then Freeze
Algae Speciation	250 ml HDPE	No	4^{o}C, 5ml Lugol

10. Quality Control Requirements

The QA samples that will accompany the regular samples include a blank, a duplicate, a spike or a reference solution sample. The Basic Laboratory will be running all constituent analysis while employing internal QC samples. Specifics of the laboratory QC protocols can be found in their laboratory procedures documents.

11. Instrument Calibration and Calibration Frequency

The laboratory performs instrument calibrations following the procedures and frequencies stated in the analytical methods for each parameter.

The handheld multi-probe instruments will be calibrated before it is to be used in the field. The calibrations will follow the KBAO Calibration Protocol (appendix C). Field personnel will record multi-probe instrument calibrations on calibration sheets, which will be filed at the field office where the calibration is performed. Any other field probes used for this monitoring effort shall be calibrated prior to use in the field following factory specifications and procedures.

12. Data Review, Validation and Verification Requirements

KBAO and Watercourse Engineering, Inc. will review and verify all data generated from this program.

The laboratory's QC check samples must meet certain levels of acceptability when analyzed with the production samples. These levels of acceptability are set at certain limits found in the methods. Part of the data verification process involves checking these laboratory QC check sample results to ensure they are within acceptable ranges. If a laboratory QC check for a sample fails to demonstrate an acceptable result, the anomaly must be explained with a footnote or included in the case narrative section of the data report. In order to ensure data quality, QA personnel will assess laboratory data packages to determine if all samples were analyzed within the holding times.

13. Review and Verification Methods

When the KWWQMP incorporates external QA check samples into a batch of production samples submitted to a laboratory, the laboratory must meet certain standards of acceptance on these QA check samples for the data to be approved as reliable. For this project, the standards of acceptability (from MP-Reclamation EMB SOP for QA, 2000) for the external QA check samples are:

Duplicates:	For values > 5X Reporting Limit, %RPD ≤ 20% For values ≤ 5X Reporting Limit, values may vary ± Reporting Limit
Spikes:	Recovery: 80%-120% Limit does not apply when sample value exceeds spike concentration by ≥ 5 times
Reference Materials:	Recovery: 80%-120% of certified value for values ≥ 20X Reporting Limit For values < 20X Reporting Limit, recovery should be ± 2X Reporting Limit from the certified value
Blanks:	Blank concentration should be less than 10% of lowest sample concentration or less than or equal to two times the reporting limit.

Reclamation uses the following equations to validate data:

Relative percent difference: A statistic for evaluating the precision of a duplicate set. For duplicate results X1 and X2:

$$RPD=((X1-X2)/((X1+X2)/2))x100$$

Completeness: The amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal operations. It is usually expressed as a percentage:

$$\%\ completeness = V/n \times 100$$

where: V= number of measurements judged valid
n = total number of measurements

Percent recovery: A measure of accuracy determined from comparison of a reported spike value to its true spike concentration:

% Rec. =((observed conc.-sample conc.)/(true spike conc.)) x 100

Accuracy: Accuracy is a measure of the bias inherent in a system or the degree of agreement of a measurement with an accepted reference or true value. It is most frequently expressed as percent recovery.

Precision: A measurement of mutual agreement (or variability) among individual measurements of the same property, usually under prescribed similar conditions. Precision is usually expressed in terms of relative percent difference, but can be expressed in terms of range.

Range: The difference between the largest and smallest numbers in a set of numbers.

All data entered into tables by KBAO are subjected to a thorough secondary review before being released to clients.

14. Reconciliation with Data Quality Objectives (DQO)

After each sampling event, calculations, and determinations for precision, completeness and accuracy will be made immediately and corrective actions implemented if needed. If data quality indicators do not meet the project's specifications, data may be discarded and re-sampling may occur. The cause of failure will be evaluated. If the cause is due to equipment failure, calibration/maintenance techniques will be reassessed and improved. If the problem is determined to be a sampling error, team members will be retrained. If the problem is laboratory related, the laboratory program manager will be contacted and corrective actions implemented. Any limitations on data use will be detailed in both interim and final reports and other documentation as needed.

This QAPP will be revised if DQO failure occurs while following protocol. Revisions will be submitted to the review team, including the quality assurance group and technical advisors for approval.

9.2. *Appendix B: Standard Operating Procedure (SOP)*

July 18, 2005

1. Prior to leaving the office

- Gather sampling equipment - see Equipment & Supplies List in Table 23.
- Inspect all sampling equipment for damage, dirt, etc.
- Pack a cell phone and telephone number directory
- Check equipment batteries, replace if expired and carry extras

- Verify that all handheld instruments have been recently calibrated by checking the calibration log.
- Pack field notebook, extra paper, SOP, QAPP, Chain Of Custody (COC) sheets, and shipping addresses (should be in QAPP or SOP)
- Check bottles needed for sampling - see Grab Sample List in Table 22.
- Affix labels to appropriate bottles or pack appropriate labels.
- Prepare Blank samples and reference solution bottles (If applicable)
- Get Ice (Blue Ice or crushed ice)

2. At the sampling site

- Fill in the labels on the bottles
- Collect all necessary samples - see the appropriate Quality Assurance Project Plan for a constituent/bottle list for the project
- Filter and preserve samples as needed - see Grab Sample List in Table 22.
- Store samples in a cooler on ice and cover with ice
- Fill out field notebook and field log (field log and field notebook are the same for Reclamation.) and COC sheet(s)

3. After sampling

- Package coolers for shipping (fill out shipping label, affix cooler seal). Place COC in plastic bag in cooler before sealing.
- Ship the samples at the end of each day of sampling or drop off at lab (arrange for after hours drop-off if necessary)
- Post-calibration of equipment
- Clean and store field equipment
- Copy pages from field notebook and store in a secure location in the office after sampling session.
- Copy field notebook, field log and COC and send to appropriate parties.

4. Grab Sampling

The sample bottle or churn splitter is used to collect a water grab sample. Care is exercised not to disturb sediment while sampling. Avoid surface debris when collecting samples. The sample bottle and/or churn splitter is rinsed with environmental water three times. If bottles are pre-preserved, rinsing with environmental water is not appropriate. Prior to collecting the sample and water is run through the pour spout of the churn splitter during each rinse. Do not disturb the location where sample is to be taken with discarded rinse water. The preferred method of collecting whole (unfiltered) samples is to dip the sample bottle with the mouth pointed up-stream in the current. Filtered and Quality Assurance (QA) samples must be collected in a churn splitter (see description below). If used, the churn splitter is cleaned at each site after sample collection by 1) carefully inspecting and removing any foreign material, 2) rinsing the exterior, and 3) rinsing the interior three times with De-Ionized (DI) water. Allow DI water to run through the pour spout during each rinse.

See Table 22 for a list of constituents, appropriate bottles, filtration, and sample preservation information.

5. Van Dorn Sampler

The Van Dorn sampler is used to collect samples from a site where it is not possible to directly fill the sample bottles or churn splitter, such as reservoir sampling from a bridge. Rinse the Van Dorn sampler with environmental water three times prior to the collection of sample water. The

Van Dorn sampler is lowered, the trigger mechanism activated, and then raised to the surface. The water is then poured from the Van Dorn sampler into the churn splitter. The Van Dorn sampler is cleaned at each site after sample collection by 1) carefully inspecting and removing any foreign material, 2) rinsing the exterior, and 3) rinsing the interior three times with DI water.

Samples may also be collected using a peristaltic pump. The pump fitted with tubing, and the tubing is lowered to the desired sampling depth. The pump is run until 5 tube volumes have been pumped. The sample bottles are then filled sequentially as the pump continues to operate. For QA samples (regular, duplicate, and spikes) the pump is used to fill the churn splitter. Sample bottles are filled from the churn splitter as described below. The pump is rinsed with distilled water between sample locations. At the end of the sampling period the pump and tubing are rinsed with distilled water followed by a dilute chlorine bleach solution.

6. Churn Splitter

The churn splitter allows different sub-sample volumes to be obtained from the composite sample while still maintaining the same basic chemical and physical properties of the original sample. The volume of the churn splitter limits the volume of sample that can be divided. Suspended inorganic sediments coarser than 62 micrometers (um) cannot be split. Samples may be taken from a plastic (Nalgene^{TM}) churn splitter for analysis of all other dissolved and suspended inorganic constituents.

Sub-samples totaling 10 liters may be withdrawn from the 14-liter churn. The 4 liters remaining in the 14-liter churn should not be used for unfiltered sub-samples because they will not be representative. However, the sample water remaining in the churn splitter may be used for filtered sub-samples for the determination of dissolved constituents.

Table 22. Grab Sample List

Constituents	Bottle Type	Filtered	Preservation
Carbonaceous Oxygen Demand, COD	125 ml HDPE	No	$4^{o}C$, 2 ml H_2SO_4
Total Organic Carbon, TOC	250 ml Amber Glass	No	$4^{o}C$, 1 ml H_2SO_4
Biological Oxygen Demand, BOD_5	1,000 ml HDPE	No	$4^{o}C$
Biological Oxygen Demand – 10 day, BOD_{10}	1,000 ml HDPE	No	$4^{o}C$
Ammonia, NH_4; Nitrate-Nitrite, NO_3-NO_2 Total Kjeldahl Nitrogen, TKN; Total Phosphorus, TP	1,000 ml HDPE	No	$4^{o}C$, 2 ml H_2SO_4
Orthophosphate, OPO_4	500 ml HDPE	No	$4^{o}C$
Total Suspended Solids, TSS	500 ml HDPE	No	$4^{o}C$
Filtered Carbonaceous Oxygen Demand, $COD_{filtered}$	1,000 ml HDPE	Yes	$4^{o}C$
Filtered Biological Oxygen Demand, $BOD_{5\text{-}filtered}$	1,000 ml HDPE	Yes	4vC
Filtered Biological Oxygen Demand – 10 day, $BOD_{10\text{-}filtered}$	1,000 ml HDPE	No	$4^{o}C$
Sieved <10 um Biological Oxygen Demand, $BOD_{5\text{-}sieved <10}$	1,000 ml HDPE	Yes	$4^{o}C$
Sieved <1.0 um Biological Oxygen Demand, $BOD_{5\text{-}sieved <1.0}$	1,000 ml HDPE	Yes	$4^{o}C$
Sieved <0.1 um Biological Oxygen Demand, $BOD_{5\text{-}sieved <0.1}$	1,000 ml HDPE	Yes	$4^{o}C$
Zooplankton	250 ml	No	25 percent Isopropyl alcohol
Chlorophyll a, Phaeophyton	250 ml, Dark HDPE	No	$4^{o}C$, Then Freeze
Algae Speciation	250 ml HDPE	No	$4^{o}C$, 5ml Lugol

The procedure for cleaning and use of the churn splitter is as follows:

A. Watercourse will clean the churn splitter between sampling events. After removing any foreign material from the churn splitter with a nylon brush, soap & water, the churn splitter is rinsed three times with DI water.
B. Rinse the churn splitter with DI water three times. Drain DI water from the spout during each rinse. The churn splitter is now ready for field use.
C. The churn splitter is rinsed with environmental water three times in the field at each sample site prior to sample water collection. Drain environmental water through pour spout during each rinse.
D. Fill out the labels on all sub-sample containers. Set aside the filtered sample bottles (at the QA site there are multiple bottles to be filtered) that will contain filtered environmental water. These samples will be filtered from the remaining environmental water in the churn splitter after the other unfiltered samples have been collected. The remaining bottles (unfiltered sample bottles) are rinsed three times with environmental water after the churn splitter has been rinsed and filled. Only rinse the bottles that will contain water collected at the current site. The churn splitter is rinsed three times with DI water after each site.
E. If QA samples are not collected at a site, then approximately 6 liters of environmental water is required at each site. Fill the churn splitter so as to have enough water for all samples. The last 4 liters of sample in churn cannot be used for non-filtered samples. It

is important to sufficiently fill the churn splitter to have adequate water supply for all samples.

F. For QA samples, the churn splitter may have to be filled more than once to collect all the required samples. Duplicate and triplicate (spike or reference) samples are collected at the QA site. Three sample bottles (regular, duplicate, and spike) are filled from the same churn splitter volume for most of the constituents. All three bottles for these constituents must be collected from the same churn splitter volume. Triplicate (spike) samples are collected for nutrients. The field sampler adds a spike solution to a known volume of environmental water for these constituents. For some of the constituents, only two sample bottles (regular and duplicate samples) of environmental water are filled from the same churn splitter of water and the third is filled with a reference solution. A third bottle of environmental water is not collected for BOD and COD triplicate (spike/reference) samples. A reference solution of known concentration is poured into the spike/reference bottle by the sampler for this constituent. Specific preparation of QA samples is discussed in the "Sample Quality Control and Quality Assurance" section of this SOP.

G. It is sometimes necessary to composite water into the churn splitter from a sampling devise. A Van Dorn sampler can be used for this. Where a Van Dorn sampler cannot be used, a sample bottle is used over and over to fill the churn splitter. Swirl the water in sample bottle prior to pouring into the churn splitter in order to minimize the amount of suspended material lost in transferring from the bottle to the churn splitter. As stated in the Grab Sampling section above, it is preferred to collect unfiltered environmental water directly into a sample bottle. QA samples (regular, duplicate, and triplicate) must be dispensed from a single churn splitter volume.

H. Churn the sample at a uniform rate of about 9 inches per second (in/s). The churning disc should touch the bottom of the tank on every stroke and the stroke length should be as long as possible without breaking the water surface. If the churning rate is significantly greater than 9 in/s or if the churning disc breaks the water surface, excessive air is introduced into the sample and may change the dissolved gases, bicarbonate, pH, and other characteristics of the sample. On the other hand, inadequate stirring may result in non-representative sub-samples.

I. After churning the sample in the splitter for at least 10 strokes to assure uniform dispersion of the suspended material, begin the withdrawal of sub-samples. As sub-samples are withdrawn and the volume of sample in the churn decreases, maintain the churning rate of about 9 in/s. If a break in churning is necessary, the stirring rate must be reestablished (i.e., 10 strokes) before withdrawals are continued.

J. While operating the churn, withdraw an adequate volume of sample water to field rinse bottles for unfiltered sub samples. Rinse each bottle three times with sample water.

K. Withdraw sub-samples for unfiltered samples first. The first sub-sample withdrawn should be the largest sub-sample required (usually 1 liter of sample).

L. After all the required unfiltered sub-samples have been withdrawn, the environmental water remaining in the churn may be filtered for sub-samples required for dissolved constituents. Remember to field rinse bottles three times with **filtered** sample water prior to filling. Procedures for filtering and preserving samples are described later.

M. After all filtered sub-samples have been withdrawn, empty the churn splitter and clean the mixing tank, lid, and churning disc three times with DI water. Allow the DI water to run through the pour spout during each rinse.

7. Filtering Water Samples

Water samples are filtered using a peristaltic pump and 0.45um inline filter. The inlet tube to the pump is rinsed with environmental water then placed in the churn splitter. An inline filter is attached to the exit tube of the pump. About 500-ml of environmental water is pumped through filter before any sample water is collected. This water should not be used to rinse sample bottles. Rinse all filtered sample bottles three times with the filtered environmental water. Continue filtering until all filtered samples have been collected. After using the pump at a sample site, discard the inline filter and pump about a 500-ml of DI water through the tubing. Rinse the outside of the inlet and outlet tubing with DI water.

If the peristaltic pump fails or is unusable for any reason, samples can be filtered with a filter syringe. The filter syringe is used as follows: Disassemble a clean 100-ml filter syringe. Rinse the inside of syringe with environmental water three times. Place a new 0.45um disc style filter on the end of the syringe. Fill the filter syringe with environmental water. Push 10-15 ml of environmental water through the filter before any sample water is collected. Filter approximately half of the water in the syringe into the sample bottle and rinse. Shake sample bottle and discard water. Rinse the sample bottle three times with the filtered environmental water. Fill the sample bottle with filtered water using the syringe-filter procedure. Refill the syringe if more sample water is needed and the filter has not clogged. If filter is clogged, attach a new filter, rinse as stated above, and continue.

8. Sieved BOD samples

Three sieved BOD samples will be taken at each site during most site visits. The water will be filtered on site using inline filters such as the Whatman Polydisc filters and the peristaltic pump. The inline filter will have environmental water run through it prior to filling the sample bottle so that the filter has been rinsed. It is possible that more than one filter will be needed to fill each sample bottle. If that is the case, the new filter will be rinsed with environmental water before the sample is continued to be collected.

9. Water Sample Preservation

Physical preservation techniques are used for all samples and include cooling and keeping the samples out of the sunlight. Some of the water samples are also preserved with acid to prevent degradation of constituents before they are analyzed. Specific requirements for the field preservation of the samples are listed in the Grab Sample List (Table 22). All samples will be preserved immediately at the collection site.

Nutrients

Ammonia, Nitrate-Nitrite, TKN and Total Phosphorus require H_2SO_4 and have a hold time of 28 days. The sample is also chilled to 4^oC in the field.

Algae

The chlorophyll-a and phaeophyton samples require $MgCO_3$ preservative and are chilled to 4^oC in the field. Algae speciation samples require Lugol's iodine preservative. However, they do not require chilling.

COD and TOC

The COD and TOC samples require H2SO4 preservative and have a hold time of 7 days. These samples are chilled to 4^oC in the field.

Other Samples

No acid preservation is used for orthophosphate, TSS or BOD. Orthophosphate and BOD samples have a 48-hour hold time. The samples are also chilled to 4^oC in the field.

If in doubt about any sample, it is best to keep it chilled and out of the sunlight.

Dispensing Acid from Ampule for preserving samples
Rubber, latex or vinyl gloves and safety glasses are worn to prevent acid from contacting hands or eyes while preserving samples. If acid is present in ***the*** neck of the ampule, gently tap until all of the acid is in the body of the ampule. Place the provided ampule "breaker" over the ampule, point away from face, and apply steady pressure until the ampule snaps at the prescored line. Hold the ampule upside down over the sample bottle between the thumb and index finger of one hand. With the other index finger, lightly tap the bottom of the ampule until all of the acid is dispensed. Properly discard the empty acid ampules.

If sample bottles are pre-preserved, no additional acidifaction is necessary. However, pre-preserved sample bottles should not be rinsed with environmental water prior to sample collection.

10. Sample Handling and Transportation

Sample handling and transportation vary depending upon the analysis requested, sample preservation requirements, and the distance to the laboratory. However, once preserved, some samples will remain stable for long periods of time. All samples for KBAO projects will be shipped overnight delivery on the day they are collected.
All water samples will be shipped in a cooler or ice chest. This provides protection, insulation, and containment in case of breakage or spillage. When shipping samples that require chilling, pack adequate quantities of frozen blue ice or crushed ice with the samples. Seal the ice chests securely with duct or packing tape to ensure they do not accidentally open.

11. Sample Quality Control and Quality Assurance

Objective
Quality control of samples during collection, transportation and processing is an integral part of a sampling program. Quality control procedures are implemented to assess potential sampling and analytical bias.

Techniques
Production Samples
A production sample is a sample taken at a site where no QA samples are collected. A production sample has the abbreviation of "P".

Regular Samples
A regular sample is the production sample at the QA site and has associated QA samples. A regular sample has the abbreviation of "R".

Duplicate Samples
A split sample is a portion or sub-sample of a total sample. The duplicate sample has an identical water matrix as the regular sample. This sample is used to determine analytical precision within a laboratory. A duplicate sample has the abbreviation of "D".

Triplicate Samples (Field Spikes and Reference Solutions)

These are reference solutions used to fill the sample bottles or chemical solutions (spikes) that are added to specified volumes of environmental water. A graduated cylinder is used to measure the volume of environmental water used for the "spiked" samples. All of the triplicate sulfide nutrient and trace metal samples are "spiked". Rinse the graduated cylinder three times with sample water. Using the graduated cylinder, measure out the appropriate volume of sample water (total triplicate sample volume – volume of spike = volume of environmental water). Pour approximately half of the sample water from the graduated cylinder into the sample bottle. Add the "spike" solution to the sample bottle. DO NOT add the spike to the graduated cylinder. Rinse the inside of the "spike" container with sample water from the graduated cylinder and add to the sample bottle. Pour the remaining half of the sample water from the graduated cylinder into the sample bottle. A reference solution is used for the BOD, COD and TOC triplicate sample. In this case the triplicate (reference solution) is not mixed with environmental water, instead the reference solution is used to fill the entire sample bottle. A triplicate sample has the abbreviation of "S".

Blanks

A blank sample is used to test laboratory analysis and ensure the bottles are not contaminated. Blank sample bottles are rinsed three times with DI water. The sample bottles are then filled with DI water and corresponding preservatives are added. The blank should be prepared in the lab/office to avoid field contamination and carried in the field while sampling. A blank sample has the abbreviation of "B".

Rinseate Blanks

A rinseate blank tests the field crew techniques and sampling equipment for contamination. After the sampling equipment has been cleaned with DI water at the last sampling site, the rinseate blank is collected. Rinseate blanks are prepared by pouring DI water into the sample collection equipment (Van Dorn, etc). Wet all internal surfaces. The rinseate water is then collected into the churn splitter. The sample bottles are rinsed three times with the rinseate water before sample collection. Fill the sample bottles with rinseate water. Filter rinseate water for filtered constituents using a peristaltic pump and filter. Preservation is added to samples requiring it. A rinseate blank has the abbreviation of "RB."

12. Standards

Standards or reference materials are used for equipment that requires calibration. Use of reference standards is an integral component of quality control. Both field and laboratory equipment must be periodically calibrated to assure the instruments accuracy. Laboratories should calibrate equipment as required by the analysis method. The field equipment, such as handheld multi-parameter probe units, requires regular calibration. The manufacturer's instructions for calibrating these units shall be followed.

13. Sample Identification

Unique sample identification (ID) numbers are used for samples collected at different sites. The same number is used for all sample bottles collected at a given site on a given day. A letter prefix associated to the specific sampling project precedes the sample ID number. These sample identification numbers are pre-selected by Watercourse Engineering. For samples that are field filtered, "filtered" is added to the sample ID on the bottle.

14. Field Notebooks

A bound field notebook is used to document collection of a sample, sample ID number, field observations, and other pertinent information necessary to reconstruct the sample collection processes. All entries are made in permanent waterproof ink. Any corrections made to the field notebooks are lined out, initialed, and dated. The person who collected the sample signs the field notebook. Field personnel will carry the field notebook during sampling. Past physical measurements and observations can be compared to current conditions. The field crew will make copies of the field notebook once they have returned to the office. Making copies will minimize the amount of data lost in the event the field notebook gets lost or damaged.

Field notebooks include:

- Sample Identification Information (including Field ID)
- Field Measurements (Water temp., pH, DO, etc)
- Equipment Information (serial number, model number, manufacturer, etc.)
- Sample Types (P, R, D, S, B, RB)
- Sample Collection (what analysis/constituents requested, etc.)
- Sample Preservation Information
- Date and Time of Collection
- Weather Conditions
- Comments

Field notebooks provide a convenient system for tracking the monitoring and analysis requests for each site in a particular project. Further, the field ID provides the cross-reference to laboratory results and sampling locations. The field crew keeps the field notebooks on file when the program is complete.

15. Chain of Custody

A COC accompanies all samples to record possession and transportation of samples. Field identification number, sample type, requested analysis, date of collection, and time of collection as well as other information is recorded on the COC. COC's are completed with permanent ink. Any corrections made to the COC's are lined out, initialed, and dated. All samples are kept in a secured area accessible only to authorized personnel during sample collection and transport. Upon completion of the field collection of the samples, the COC sheet accompanies the samples to the lab. COC sheets are also legally binding and act as a work order for the laboratory. It is critical that the field identification numbers are properly recorded on the field notebook and COC forms. Sample collectors, individuals transferring samples, and those receiving samples, all sign the COC. The COC forms are in triplicate and field personnel should remove only the field copy (pink sheet).

16. Calibration Log

A bound calibration logbook is used to store calibration information for equipment requiring calibration. Calibration information for the handheld multi-parameter probe units will be recorded in a bound calibration logbook. When instruments are calibrated in the field, all appropriate calibration information is recorded in the field notebook

17. Ringed Field Binder

A ringed binder is used to store information pertinent to a sampling project. The binder can be used to store a copy of the SOP, Quality Assurance Project Plan, level one clean-bottle certificates, acid purity certificates, certificates for in-line filters, COC sheets, copy of field notebook, and other pertinent information.

18. Security Shipping Seals

When shipping samples a security seal is attached across the lid and side of the ice chests. The seal is signed and dated by the sampling personnel. The seal is attached so that it must be broken when the container is opened.

Table 23. Equipment and supplies list

Equipment and Supplies	Personal Supplies
▪ Field notebook	▪ Drinking water / food
▪ Field datasheets	▪ Leather gloves
▪ Clipboard	▪ Sunglasses
▪ Chain Of Custody form	▪ Hat
▪ Zip-lock bag for COC form	▪ Extra socks
▪ “Sharpie” felt tip pens	▪ Sun block
▪ Ball point pens	▪ Anti-bacterial hand gel
▪ Van Dorn sampler with rope	
▪ Churn splitter	
▪ Peristaltic pump and in-line filters	
▪ Prepared bottles and labels	
▪ Extra sample bottles	
▪ Extra bottle labels	
▪ Sulfuric acid ampules	
▪ Nitric acid ampules	
▪ Waste container for broken acid ampules	
▪ Rubber, latex, or vinyl gloves	
▪ Safety glasses	
▪ Spikes	
▪ Graduated cylinder	
▪ 10 gallons DI water	
▪ Squeeze bottle for DI water	
▪ Data sonde units, spare batteries and cables	
▪ Bucket for data sondes	
▪ Turbidity meter	
▪ Ice chests	
▪ Ice packs (Blue ice)	
▪ Packing tape	
▪ UPS overnight shipping forms	
▪ Rope	
▪ Waders (Waders may be knee, hip, or chest)	
▪ Cell phone and telephone numbers	
▪ Knife/scissors	
▪ Maps	
▪ Paper towels	
▪ Camera and film	
▪ GPS unit	
▪ Extra batteries	
▪ Tools	
▪ Syringe filters (back-up filters)	

19. Contact Information

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JWSWEET@aol.com

Zooplankton SOP for Keno Reservoir

Zooplankton monitoring was included on a limited basis during the 2005 field season. Outlined herein is a zooplankton protocol developed in cooperation with Allan Vogel.

1. Information included in field book and, as noted, on bottles:
    a. Location (bottle)
    b. Date/time of sampling (bottle)
    c. Vertical distance of tow (bottle)
    d. Number of tows (bottle)
    e. Mesh size (80 micron)
    f. Net diameter (15 cm diameter)
    g. Record any current/circulation and wind
2. Preserve in 20-25% by final volume Isopropyl alcohol:
    a. NOTE: Always use 150 mL of sample no matter which strength and volume of isopropyl alcohol you use.
    b. Pre-preserve clean 250mL plastic bottles with
        - 50mL/each of 90% isopropyl alcohol (this can be purchased at any drug store)
        - 75mL/each of 70% isopropyl alcohol (this can be purchased at any drug store)
3. Sampling
    a. Ensure the cap is on the bottom of the collection cup tightly and that the net is free from twists, tangles and debris.
    b. Lower the net straight over the side of the boat until it is approximately 1 meter off the bottom; DO NOT let the net hit the bottom as you will compromise the sample and possibly damage the net. (If you do haul it back up, thoroughly rinse with deionized (DI) water, and inspect to see if the net is salvageable).
    c. Let the net "settle" into an upright, fully open position prior to raising.
    d. Make a note of how far the net is lowered (via the half-meter markings on rope).
    e. Pull the rope and net very, very slowly and steadily back to the surface (finger over finger, inch by inch). Pulling too fast creates a backwash and you lose your sample.
    f. Wash down the net with DI water and transfer the contents of the collection cup into a marked 250mL bottle. Add DI water until the sample volume reaches 150mL.
    g. Pour the 150mL of sample into one of the pre-preserved bottles (final volume equals 200mL). Make sure the bottle is completely labeled.
4. Equipment
    a. Zooplankton net (store in plastic bag to prevent tearing or catching on other equipment, and to maintain a clean net)
    b. Rope with 0.5 meter markings to lower net
    c. Labeled sample bottles
    d. Squirt bottle to clean net
    e. DI water
5. Allan Vogel's Contact info:

    Allan Hayes Vogel, Ph.D.
    ZP's Taxonomic Services
    P.O. Box 18646 Salem, OR 97304
    llvogel@teleport.com (503) 390 4684

9.3. Appendix C: Flow Data (Graphical)

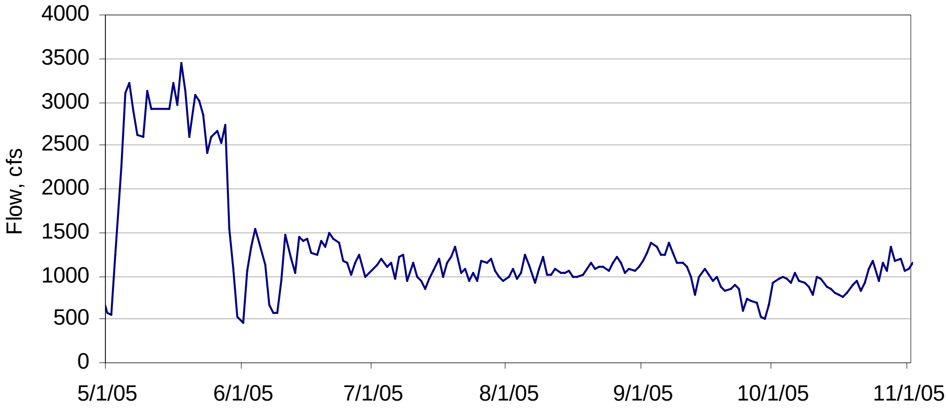


Figure 40. Daily mean flow measured at Link Dam - USGS 11507500

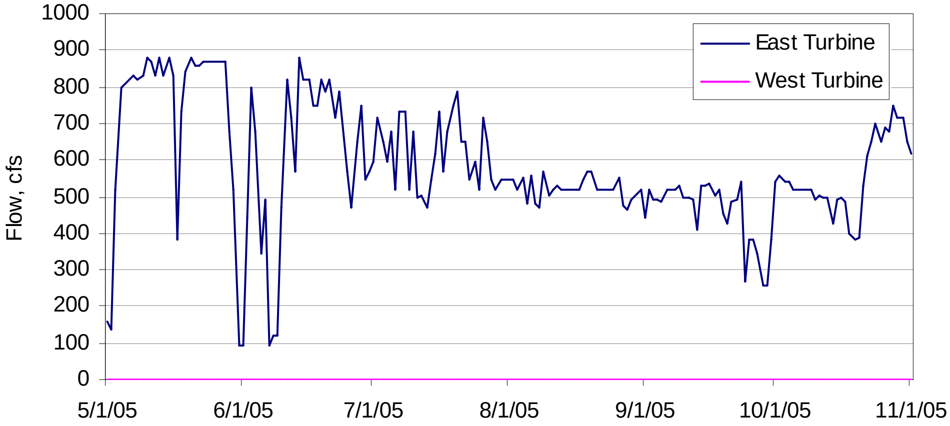


Figure 41. East Turbine and West Turbine flows (PacifiCorp). Note: West Turbine flow is zero for entire study period

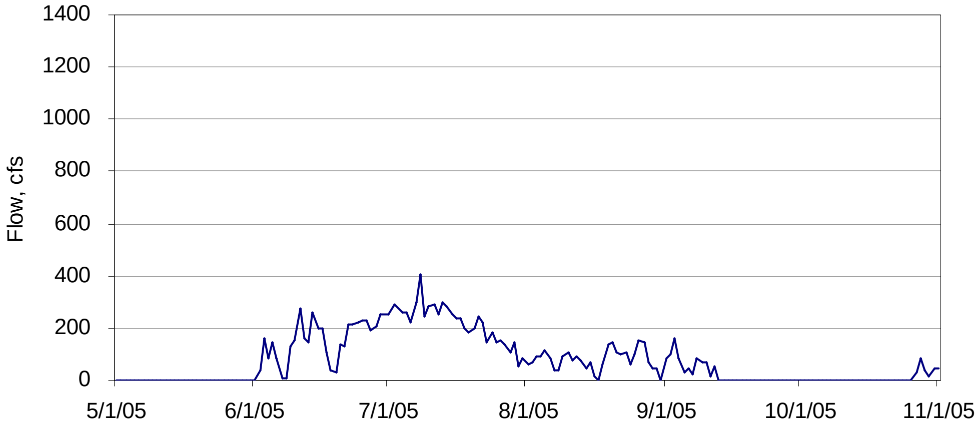


Figure 42. Klamath River flow into Lost River (USBR).

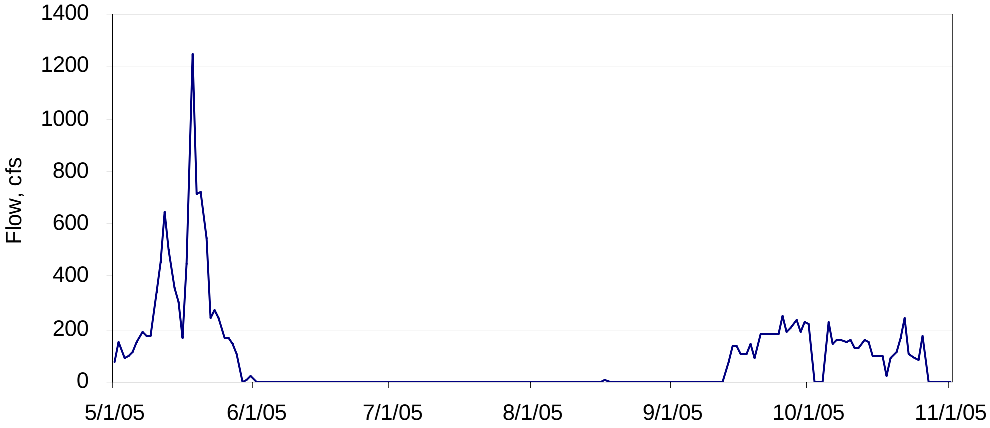


Figure 43. Lost River flow into Klamath River (USBR).

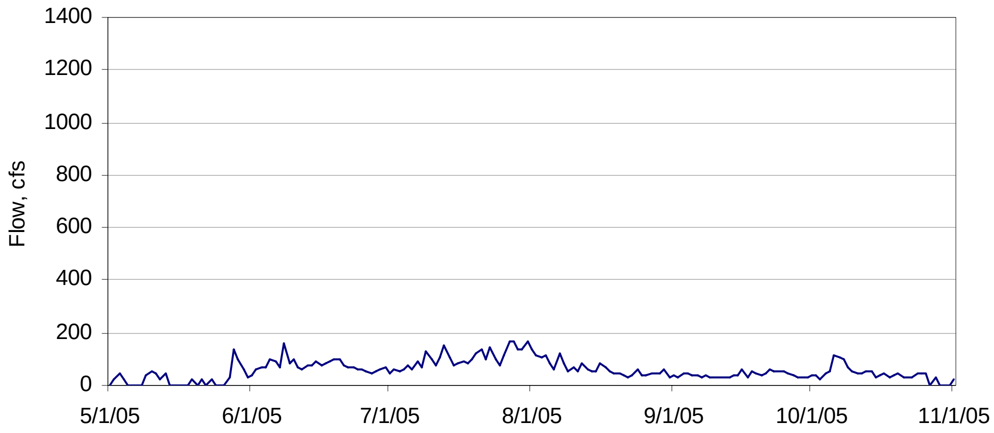


Figure 44. North Canal flow into Klamath River.

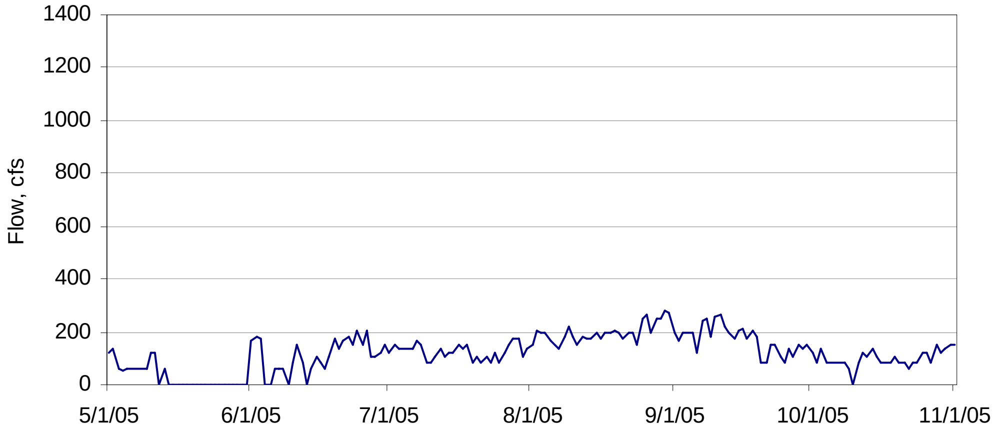


Figure 45. ADY Canal flow into Klamath River.

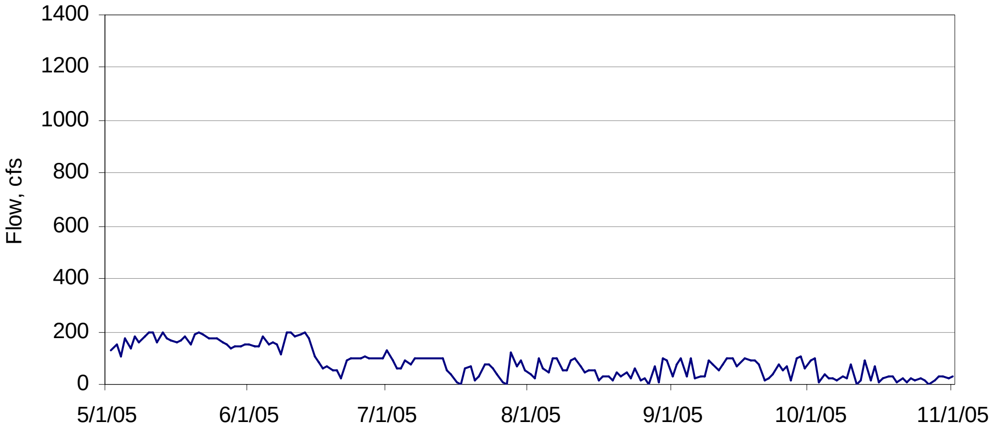


Figure 46. KSD flow into Klamath River.

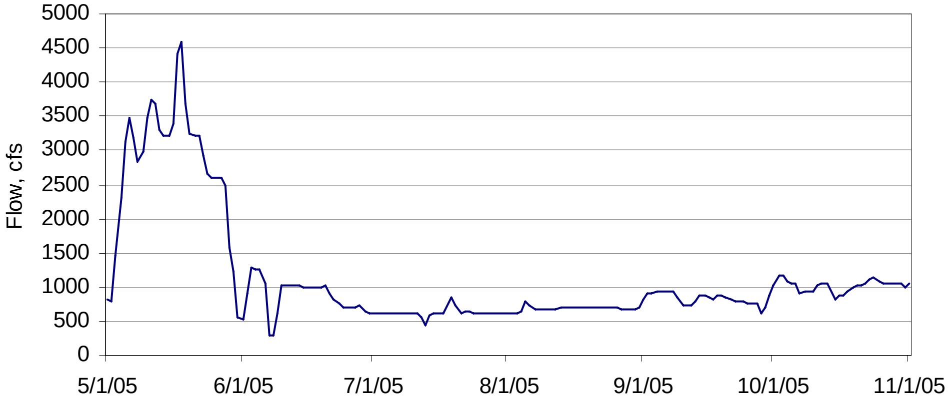


Figure 47. Daily mean flow at Klamath River at Keno Dam - USGS 11509500

9.4. Appendix D: Physical Data

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					°C	mph	direction	1st	2nd	3rd	(m)	Bloom
5/3/2005 8:07	13.69	119	0.077	85.8	7.7	0.1	6.6	KR254.4	Link River	Link Dam	10.0	4	E	6.00	6.33	5.70	1.30	1
5/3/2005 8:08	13.69	119	0.077	84.4	7.57	0.6	6.76	KR254.4	Link River	Link Dam								
5/3/2005 8:10	13.69	119	0.077	83.8	7.52	1.0	6.88	KR254.4	Link River	Link Dam								
5/3/2005 8:13	13.69	119	0.077	83.9	7.53	2.0	6.99	KR254.4	Link River	Link Dam								
5/3/2005 8:14	13.68	119	0.077	83.2	7.47	3.0	7.03	KR254.4	Link River	Link Dam								
5/3/2005 10:42	14.63	312	0.203	81.2	7.13	0.1	7.59	KR234.9	Keno	Keno Bridge	13.0	5	E	6.47	6.27	5.79	1.10	1
5/3/2005 10:44	14.6	312	0.203	80.8	7.1	0.5	7.49	KR234.9	Keno	Keno Bridge								
5/3/2005 10:46	14.55	312	0.203	79.6	7.01	1.0	7.46	KR234.9	Keno	Keno Bridge								
5/3/2005 10:47	14.29	314	0.204	78.1	6.91	2.0	7.4	KR234.9	Keno	Keno Bridge								
5/3/2005 10:49	14.16	316	0.205	75.7	6.72	3.0	7.33	KR234.9	Keno	Keno Bridge								
5/3/2005 10:50	14.15	316	0.205	74.8	6.64	4.0	7.31	KR234.9	Keno	Keno Bridge								
5/3/2005 10:52	14.15	316	0.205	74	6.57	4.8	7.3	KR234.9	Keno	Keno Bridge								
5/3/2005 12:10	15.15	287	0.187	89.6	7.78	0.1	7.84	KR238.2	KRS12A	Quarry	16.0	2	V(ariable)	6.33	6.38	6.62	1.00	1
5/3/2005 12:11	15.15	287	0.187	89.5	7.77	0.5	7.79	KR238.2	KRS12A	Quarry								
5/3/2005 12:14	15.12	287	0.187	88.8	7.72	1.0	7.76	KR238.2	KRS12A	Quarry								
5/3/2005 12:16	14.68	294	0.191	85.7	7.52	2.0	7.63	KR238.2	KRS12A	Quarry								
5/3/2005 12:18	14.36	298	0.194	81.9	7.24	3.0	7.48	KR238.2	KRS12A	Quarry								
5/3/2005 12:20	14.46	431	0.28	65.8	5.8	4.0	7.43	KR238.2	KRS12A	Quarry								
5/3/2005 12:24	14.2	474	0.308	41.1	3.64	5.0	7.29	KR238.2	KRS12A	Quarry								
5/3/2005 12:26	14.2	476	0.309	40.3	3.57	5.3	7.3	KR238.2	KRS12A	Quarry								
5/3/2005 13:09	17.09	748	0.486	89.4	7.44	0.1	8.25	KSD97	KSD	Straits Drain	16.0	4	E	9.71	10.30	10.30	0.55	0
5/3/2005 13:10	17.08	747	0.486	89	7.41	0.5	8.24	KSD97	KSD	Straits Drain								
5/3/2005 13:12	16.93	747	0.486	87.9	7.34	1.0	8.21	KSD97	KSD	Straits Drain								
5/3/2005 13:14	16.78	749	0.487	86.7	7.26	1.4	8	KSD97	KSD	Straits Drain								
5/3/2005 14:39	16.99	165	0.107	112.1	9.36	0.1	8.1	KR246.0	Miller Island	Miller Island	17.5	4	SW	7.89	7.51	7.39	0.95	1
5/3/2005 14:41	16.81	166	0.108	112.9	9.47	0.5	8.06	KR246.0	Miller Island	Miller Island								
5/3/2005 14:43	16.15	169	0.11	114.6	9.74	1.0	7.95	KR246.0	Miller Island	Miller Island								
5/3/2005 14:46	14.89	169	0.11	100	8.74	2.0	7.44	KR246.0	Miller Island	Miller Island								
5/3/2005 14:48	14.39	171	0.111	82.1	7.25	3.0	7.1	KR246.0	Miller Island	Miller Island								
5/3/2005 14:50	14.29	171	0.111	78.9	6.99	4.0	7.08	KR246.0	Miller Island	Miller Island								
5/3/2005 14:53	14.27	171	0.111	77.5	6.87	5.0	7.14	KR246.0	Miller Island	Miller Island								

DateTime M/D/Y	Temp C	SpCond uS/cm	TDS g/L	DO %Local %	DO Conc mg/L	Depth m	pH	Rivermile	Site Name	Common Name	Air Temp °C	Wind Spd mph	Wind direction	NTU 1st	NTU 2nd	NTU 3rd	Secchi (m)	Algal Bloom
5/3/2005 16:03	15.74	127	0.083	93.9	8.06	0.1	7.22	KR251.7	RR Bridge	Trestle	17.5	12	SW	5.98	5.79	6.13	1.50	1
5/3/2005 16:04	15.7	127	0.083	94.1	8.08	0.5	7.11	KR251.7	RR Bridge	Trestle								
5/3/2005 16:07	15.63	127	0.083	93.8	8.07	1.0	7.07	KR251.7	RR Bridge	Trestle								
5/3/2005 16:09	14.91	128	0.083	93.7	8.18	2.0	7.04	KR251.7	RR Bridge	Trestle								
5/3/2005 16:11	14.09	133	0.086	93.5	8.32	3.0	6.9	KR251.7	RR Bridge	Trestle								
6/7/2005 8:09	14.02	115	0.074	103.7	9.19	0.1	8.69	KR254.4	Link River	Link Dam	6.5	1	N	7.04	7.32	8.57	1.00	3
6/7/2005 8:11	14.03	115	0.075	103.1	9.13	0.5	8.69	KR254.4	Link River	Link Dam								
6/7/2005 8:11	14.04	115	0.075	102.8	9.1	1.0	8.69	KR254.4	Link River	Link Dam								
6/7/2005 8:14	14.03	115	0.075	103.1	9.13	2.0	8.7	KR254.4	Link River	Link Dam								
6/7/2005 8:15	14.03	115	0.075	102.6	9.09	3.0	8.7	KR254.4	Link River	Link Dam								
6/7/2005 8:16	14.04	115	0.075	102.3	9.06	4.0	8.68	KR254.4	Link River	Link Dam								
6/7/2005 11:24	15.21	239	0.155	102.2	8.82	0.1	9.2	KR234.9	Keno	Keno Bridge	8.5	5	W	6.54	6.04	6.20	1.25	2
6/7/2005 11:26	15.21	239	0.155	102.3	8.82	0.5	9.2	KR234.9	Keno	Keno Bridge								
6/7/2005 11:29	15.2	239	0.155	103.2	8.83	1.0	9.2	KR234.9	Keno	Keno Bridge								
6/7/2005 11:37	15.14	239	0.156	101.4	8.76	2.0	9.18	KR234.9	Keno	Keno Bridge								
6/7/2005 11:40	15.07	240	0.156	98.8	8.55	3.0	9.16	KR234.9	Keno	Keno Bridge								
6/7/2005 11:42	15	240	0.156	96.2	8.34	4.0	9.14	KR234.9	Keno	Keno Bridge								
6/7/2005 11:43	15	239	0.155	95.1	8.25	5.0	9.13	KR234.9	Keno	Keno Bridge								
6/7/2005 12:14	15.13	241	0.157	114.5	9.9	0.1	9.25	KR238.2	KRS12A	Quarry	8.5	5	W	6.17	6.41	5.87	1.05	3
6/7/2005 12:16	15.04	238	0.155	115.2	9.97	0.5	9.25	KR238.2	KRS12A	Quarry								
6/7/2005 12:18	14.92	237	0.154	115.3	10.01	1.0	9.25	KR238.2	KRS12A	Quarry								
6/7/2005 12:20	14.51	234	0.152	105.2	9.22	2.0	9.17	KR238.2	KRS12A	Quarry								
6/7/2005 12:22	14.47	242	0.158	100.3	8.79	3.0	9.15	KR238.2	KRS12A	Quarry								
6/7/2005 12:23	14.43	240	0.156	98.6	8.66	4.0	9.14	KR238.2	KRS12A	Quarry								
6/7/2005 12:24	14.35	242	0.157	96.2	8.46	5.0	9.13	KR238.2	KRS12A	Quarry								
6/7/2005 12:26	14.08	239	0.156	85.9	7.59	5.5	9.08	KR238.2	KRS12A	Quarry								
6/7/2005 13:14	13.81	828	0.538	104.5	9.28	0.1	9.19	KSD97	KSD	Straits Drain	8.5	3	E	14.10	14.80	14.00	0.55	1
6/7/2005 13:15	13.82	827	0.538	104.5	9.27	0.5	9.19	KSD97	KSD	Straits Drain								
6/7/2005 13:17	13.81	828	0.538	104.4	9.27	1.0	9.19	KSD97	KSD	Straits Drain								
6/7/2005 13:24	13.84	828	0.538	102.5	9.09	1.6	9.18	KSD97	KSD	Straits Drain								
6/7/2005 14:24	15.21	125	0.081	123.9	10.69	0.1	9.05	KR246.0	Miller Island	Miller Island	9.0	5	E	6.80	7.09	8.03	0.95	3
6/7/2005 14:38	15.14	124	0.081	118	10.2	0.5	9.02	KR246.0	Miller Island	Miller Island								
6/7/2005 14:39	15.09	124	0.081	120.6	10.44	1.0	9.02	KR246.0	Miller Island	Miller Island								
6/7/2005 14:41	14.68	125	0.081	115.1	10.05	2.0	8.9	KR246.0	Miller Island	Miller Island								

DateTime M/D/Y	Temp C	SpCond uS/cm	TDS g/L	DO %Local %	DO Conc mg/L	Depth m	pH	Rivermile	Site Name	Common Name	Air Temp ^{o}C	Wind Spd mph	Wind direction	NTU 1st	NTU 2nd	NTU 3rd	Secchi (m)	Algal Bloom
6/7/2005 14:42	14.27	125	0.081	105.3	9.27	3.0	8.74	KR246.0	Miller Island	Miller Island								
6/7/2005 14:45	14.18	125	0.081	103.2	9.1	4.0	8.73	KR246.0	Miller Island	Miller Island								
6/7/2005 15:24	14.8	116	0.076	116	10.1	0.1	8.91	KR251.7	RR Bridge	Trestle	9.0	3	NW	9.92	9.47	10.30	1.00	3
6/7/2005 15:28	14.74	116	0.076	116.1	10.12	0.5	8.91	KR251.7	RR Bridge	Trestle								
6/7/2005 15:30	14.6	116	0.076	114.9	10.05	1.0	8.91	KR251.7	RR Bridge	Trestle								
6/7/2005 15:32	13.92	118	0.077	100.5	8.92	2.0	8.6	KR251.7	RR Bridge	Trestle								
6/7/2005 15:37	13.5	147	0.095	99.8	8.94	3.0	8.52	KR251.7	RR Bridge	Trestle								
6/28/2005 7:55	18.65	115	0.074	116.1	9.37	0.1	9.52	KR254.4	Link River	Link Dam	12.5	9	NW	7.63	10.60	9.63	0.55	4
6/28/2005 7:58	18.65	115	0.074	115.7	9.34	0.5	9.49	KR254.4	Link River	Link Dam								
6/28/2005 7:59	18.66	121	0.078	115.4	9.31	1.0	9.49	KR254.4	Link River	Link Dam								
6/28/2005 8:01	18.64	115	0.074	115.6	9.33	2.0	9.5	KR254.4	Link River	Link Dam								
6/28/2005 8:02	18.66	115	0.075	115.3	9.31	3.0	9.5	KR254.4	Link River	Link Dam								
6/28/2005 8:04	18.65	115	0.075	114.8	9.27	4.0	9.5	KR254.4	Link River	Link Dam								
6/28/2005 9:21	19.03	115	0.075	95.1	7.62	0.1	9.37	KR251.7	RR Bridge	Trestle	14.0	3	NW	17.30	10.00	9.54	0.65	4
6/28/2005 9:24	19.02	116	0.075	93.1	7.46	0.5	9.37	KR251.7	RR Bridge	Trestle								
6/28/2005 9:26	19.07	116	0.075	92.4	7.4	1.0	9.37	KR251.7	RR Bridge	Trestle								
6/28/2005 9:28	18.9	116	0.075	88.8	7.13	2.1	9.34	KR251.7	RR Bridge	Trestle								
6/28/2005 9:29	18.75	134	0.087	84.6	6.82	3.0	9.26	KR251.7	RR Bridge	Trestle								
6/28/2005 10:36	19.93	121	0.079	125.5	9.87	0.1	9.38	KR246.0	Miller Island	Miller Island	18.0	4	NW	9.15	9.02	9.23	0.60	4
6/28/2005 10:38	19.72	121	0.079	119.8	9.47	0.5	9.36	KR246.0	Miller Island	Miller Island								
6/28/2005 10:40	19.58	121	0.079	111.5	8.83	1.0	9.3	KR246.0	Miller Island	Miller Island								
6/28/2005 10:42	19.42	123	0.08	102	8.11	2.0	9.2	KR246.0	Miller Island	Miller Island								
6/28/2005 10:43	19.37	124	0.08	96.5	7.68	3.0	9.16	KR246.0	Miller Island	Miller Island								
6/28/2005 10:45	19.28	122	0.079	83.7	6.67	4.0	9.03	KR246.0	Miller Island	Miller Island								
6/28/2005 10:49	18.7	125	0.081	7.6	0.61	5.0	7.91	KR246.0	Miller Island	Miller Island								
6/28/2005 11:36	22.53	194	0.126	157.6	11.78	0.1	9.29	KR238.2	KRS12A	Quarry	17.0	6	NE	5.12	5.90	7.92	1.10	3
6/28/2005 11:39	20.83	198	0.129	149.6	11.56	0.5	9.27	KR238.2	KRS12A	Quarry								
6/28/2005 11:40	19.83	216	0.14	115.7	9.12	1.1	9.01	KR238.2	KRS12A	Quarry								
6/28/2005 11:42	19.56	200	0.13	98.2	7.78	2.0	8.95	KR238.2	KRS12A	Quarry								
6/28/2005 11:42	19.41	194			7.37	3.0	8.92	KR238.2	KRS12A	Quarry								
6/28/2005 11:45	19.28	179	0.117	83.7	6.67	4.0	8.89	KR238.2	KRS12A	Quarry								
6/28/2005 11:45	19.22	184			6.08	5.0	8.83	KR238.2	KRS12A	Quarry								
6/28/2005 11:49	19.15	180	0.117	68.7	5.49	5.4	8.75	KR238.2	KRS12A	Quarry								
6/28/2005 12:55	20.26	177	0.115	126.6	9.9	0.1	9.22	KR234.9	Keno	Keno Bridge	19.0	3	NW	4.51	4.70	4.74	1.10	4

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					°C	mph	direction	1st	2nd	3rd	(m)	Bloom
6/28/2005 12:58	19.56	176	0.114	125.7	9.96	0.5	9.23	KR234.9	Keno	Keno Bridge								
6/28/2005 13:00	18.93	180	0.117	103.2	8.28	1.0	9.09	KR234.9	Keno	Keno Bridge								
6/28/2005 13:03	18.67	177	0.115	83.3	6.72	2.0	8.95	KR234.9	Keno	Keno Bridge								
6/28/2005 13:05	18.64	175	0.114	80.7	6.52	3.0	8.93	KR234.9	Keno	Keno Bridge								
6/28/2005 13:07	18.62	174	0.113	78.7	6.36	4.0	8.92	KR234.9	Keno	Keno Bridge								
6/28/2005 13:09	18.61	175	0.114	77.9	6.29	5.0	8.92	KR234.9	Keno	Keno Bridge								
6/28/2005 14:09	23.13	551	0.358	49	3.62	0.1	7.72	KSD97	KSD	Straits Drain	21.0	2	S	10.70	10.20	11.20	0.45	3
6/28/2005 14:11	22.72	551	0.358	44.4	3.31	0.5	7.7	KSD97	KSD	Straits Drain								
6/28/2005 14:13	22.47	551	0.358	41.1	3.07	1.0	7.68	KSD97	KSD	Straits Drain								
6/28/2005 14:20	22.47	550	0.357	35.9	2.68	1.5	7.67	KSD97	KSD	Straits Drain								
7/12/2005 8:32	21.88	116	0.075	111.6	8.43	0.1	9.62	KR254.4	Link River	Link Dam	19.0	1	NW	5.55	5.62	5.72	0.65	4
7/12/2005 8:35	21.86	116	0.075	110.3	8.34	0.5	9.61	KR254.4	Link River	Link Dam								
7/12/2005 8:38	21.87	116	0.075	110.2	8.33	1.0	9.62	KR254.4	Link River	Link Dam								
7/12/2005 8:39	21.86	116	0.075	110.4	8.34	2.0	9.62	KR254.4	Link River	Link Dam								
7/12/2005 8:41	21.87	116	0.075	109.6	8.29	3.0	9.61	KR254.4	Link River	Link Dam								
7/12/2005 8:42	21.87	116	0.075	107.5	8.13	3.9	9.6	KR254.4	Link River	Link Dam								
7/12/2005 10:03	23.18	127	0.082	172.4	12.7	0.1	9.86	KR251.7	RR Bridge	Trestle	22.5	0	-	17.60	20.00	30.70	0.45	4
7/12/2005 10:05	22.11	121	0.079	107.5	8.09	0.5	9.58	KR251.7	RR Bridge	Trestle								
7/12/2005 10:06	21.89	119	0.078	82	6.19	1.0	9.46	KR251.7	RR Bridge	Trestle								
7/12/2005 10:08	21.7	117	0.076	54.2	4.11	2.0	9.33	KR251.7	RR Bridge	Trestle								
7/12/2005 10:10	21.41	246	0.16	47.9	3.65	3.0	8.97	KR251.7	RR Bridge	Trestle								
7/12/2005 10:38	24.04	124	0.081	93.1	6.75	0.1	9.34	KR246.0	Miller Island	Miller Island	23.0	0	-	7.45	8.17	6.34	0.85	3
7/12/2005 10:40	23.01	124	0.081	84.2	6.23	0.5	9.31	KR246.0	Miller Island	Miller Island								
7/12/2005 10:42	22.67	124	0.081	68.4	5.09	1.0	9.24	KR246.0	Miller Island	Miller Island								
7/12/2005 10:44	22.32	125	0.081	39.7	2.98	2.0	9.07	KR246.0	Miller Island	Miller Island								
7/12/2005 10:45	21.74	125	0.081	4.5	0.34	3.0	8.82	KR246.0	Miller Island	Miller Island								
7/12/2005 10:48	21.68	125	0.081	3.3	0.25	4.0	8.82	KR246.0	Miller Island	Miller Island								
7/12/2005 10:49	21.51	131	0.085	2.8	0.21	4.9	8.53	KR246.0	Miller Island	Miller Island								
7/12/2005 11:31	24.6	195	0.126	30.3	2.17	0.1	7.88	KR238.2	KRS12A	Rock Quarry	23.5	3	SE	2.46	2.59	2.33	1.95	1
7/12/2005 11:35	24.12	194	0.126	28	2.03	0.5	7.86	KR238.2	KRS12A	Rock Quarry								
7/12/2005 11:37	22.97	193	0.126	24.4	1.81	1.0	7.8	KR238.2	KRS12A	Rock Quarry								
7/12/2005 11:41	22.55	193	0.125	22.2	1.65	2.1	7.79	KR238.2	KRS12A	Rock Quarry								
7/12/2005 11:43	22.09	176	0.114	9.8	0.74	3.1	7.82	KR238.2	KRS12A	Rock Quarry								
7/12/2005 11:44	21.7	186	0.121	1.7	0.13	4.1	7.76	KR238.2	KRS12A	Rock Quarry								

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					°C	mph	direction	1st	2nd	3rd	(m)	Bloom
7/12/2005 11:46	21.53	171	0.111	1.3	0.1	5.1	7.82	KR238.2	KRS12A	Rock Quarry								
7/12/2005 11:48	21.52	171	0.111	1.2	0.09	5.3	7.83	KR238.2	KRS12A	Rock Quarry								
7/12/2005 12:52	23.84	202	0.132	25.6	1.86	0.1	7.63	KR234.9	Keno	Keno Bridge	27.0	6	W	1.82	1.71	1.75	2.30	1
7/12/2005 12:54	23.64	202	0.131	24.3	1.77	0.5	7.63	KR234.9	Keno	Keno Bridge								
7/12/2005 12:56	22.57	204	0.132	18.5	1.38	1.1	7.61	KR234.9	Keno	Keno Bridge								
7/12/2005 12:57	21.66	208	0.135	14.3	1.09	2.0	7.58	KR234.9	Keno	Keno Bridge								
7/12/2005 12:59	21.57	209	0.136	13.5	1.03	3.0	7.56	KR234.9	Keno	Keno Bridge								
7/12/2005 13:00	21.53	212	0.138	13.5	1.03	4.1	7.55	KR234.9	Keno	Keno Bridge								
7/12/2005 13:03	21.51	214	0.139	12.7	0.96	5.0	7.54	KR234.9	Keno	Keno Bridge								
7/12/2005 14:02	25.81	490	0.319	48.9	3.43	0.1	7.48	KSD97	KSD	Straits Drain	27.5	3	NE	5.20	5.24	5.67	0.90	1
7/12/2005 14:05	25.7	491	0.319	47.7	3.35	0.5	7.48	KSD97	KSD	Straits Drain								
7/12/2005 14:08	25.25	491	0.319	43.4	3.08	1.0	7.46	KSD97	KSD	Straits Drain								
7/26/2005 7:58	22.18	116	0.076	94.2	7.09	0.1	9.21	KR254.4	Link River	Link Dam	18.0	7	N	7.99	10.40	10.50	0.35	3
7/26/2005 7:59	22.18	116	0.076	94.3	7.09	0.5	9.24	KR254.4	Link River	Link Dam								
7/26/2005 8:00	22.21	116	0.076	93.9	7.06	1.0	9.25	KR254.4	Link River	Link Dam								
7/26/2005 8:02	22.21	116	0.076	93.1	7	2.0	9.31	KR254.4	Link River	Link Dam								
7/26/2005 8:03	22.21	116	0.076	92.3	6.94	3.0	9.34	KR254.4	Link River	Link Dam								
7/26/2005 8:05	22.21	117	0.076	91.1	6.85	3.8	9.35	KR254.4	Link River	Link Dam								
7/26/2005 9:22	21.77	118	0.077	33.6	2.54	0.1	9.15	KR251.7	RR Bridge	Trestle	20.0	4	NW	14.20	9.65	8.76	0.75	4
7/26/2005 9:26	21.73	118	0.077	32.4	2.46	0.5	9.17	KR251.7	RR Bridge	Trestle								
7/26/2005 9:29	21.73	118	0.077	33.4	2.54	1.0	9.18	KR251.7	RR Bridge	Trestle								
7/26/2005 9:31	21.69	118	0.077	29.4	2.23	2.0	9.16	KR251.7	RR Bridge	Trestle								
7/26/2005 9:32	21.59	121	0.079	25.8	1.96	3.0	9.11	KR251.7	RR Bridge	Trestle								
7/26/2005 10:28	23.16	140	0.091	2.7	0.2	0.2	8.34	KR246.0	Miller Island	Miller Island	21.5	2	N	6.62	6.73	6.65	0.85	2
7/26/2005 10:31	23.04	140	0.091	1.5	0.11	0.5	8.35	KR246.0	Miller Island	Miller Island								
7/26/2005 10:33	22.8	140	0.091	1.3	0.09	1.1	8.34	KR246.0	Miller Island	Miller Island								
7/26/2005 10:35	22.7	141	0.092	1.2	0.09	1.9	8.33	KR246.0	Miller Island	Miller Island								
7/26/2005 10:36	22.67	141	0.092	1.1	0.08	2.0	8.32	KR246.0	Miller Island	Miller Island								
7/26/2005 10:39	22.48	141	0.092	1	0.08	3.0	8.31	KR246.0	Miller Island	Miller Island								
7/26/2005 10:40	22.44	142	0.092	1	0.08	4.1	8.29	KR246.0	Miller Island	Miller Island								
7/26/2005 10:42	22.43	142	0.092	0.8	0.06	4.3	8.26	KR246.0	Miller Island	Miller Island								
7/26/2005 11:34	25.42	152	0.099	79.7	5.64	0.1	8.89	KR238.2	KRS12A	Rock Quarry	24.0	0	-	6.52	6.59	7.29	0.70	1
7/26/2005 11:36	24.03	155	0.101	57.8	4.2	0.5	8.55	KR238.2	KRS12A	Rock Quarry								
7/26/2005 11:40	23.56	157	0.102	6.5	0.48	1.0	8.14	KR238.2	KRS12A	Rock Quarry								

DateTime M/D/Y	Temp C	SpCond uS/cm	TDS g/L	DO %Local %	DO Conc mg/L	Depth m	pH	Rivermile	Site Name	Common Name	Air Temp °C	Wind Spd mph	Wind direction	NTU 1st	NTU 2nd	NTU 3rd	Secchi (m)	Algal Bloom
7/26/2005 11:42	23.21	160	0.104	2.3	0.17	2.0	8.1	KR238.2	KRS12A	Rock Quarry								
7/26/2005 11:46	23.09	162	0.105	1.8	0.13	3.0	8.04	KR238.2	KRS12A	Rock Quarry								
7/26/2005 11:47	23.02	165	0.107	1.6	0.12	4.0	7.92	KR238.2	KRS12A	Rock Quarry								
7/26/2005 11:49	22.97	167	0.109	1.5	0.11	5.0	7.84	KR238.2	KRS12A	Rock Quarry								
7/26/2005 11:52	22.96	167	0.109	1.3	0.1	5.4	7.86	KR238.2	KRS12A	Rock Quarry								
7/26/2005 13:22	24.61	186	0.121	48.5	3.48	0.1	8.41	KR234.9	Keno	Keno Bridge	26.0	1	E	5.30	5.45	5.19	0.70	1
7/26/2005 13:24	24.28	186	0.121	44.4	3.21	0.5	8.36	KR234.9	Keno	Keno Bridge								
7/26/2005 13:26	23.03	188	0.122	27.2	2.01	0.9	8.12	KR234.9	Keno	Keno Bridge								
7/26/2005 13:30	22.47	190	0.123	3.9	0.29	2.0	7.78	KR234.9	Keno	Keno Bridge								
7/26/2005 13:32	22.46	190	0.123	1.5	0.11	3.1	7.76	KR234.9	Keno	Keno Bridge								
7/26/2005 13:33	22.46	190	0.123	1.3	0.1	4.0	7.74	KR234.9	Keno	Keno Bridge								
7/26/2005 13:37	22.45	190	0.123	1.1	0.08	5.0	7.74	KR234.9	Keno	Keno Bridge								
7/26/2005 14:20	25.41	456	0.297	38.9	2.75	0.1	7.59	KSD97	KSD	Straits Drain	28.0	1	W	6.66	7.06	6.45	0.75	1
7/26/2005 14:23	23.28	450	0.292	26.2	1.93	0.5	7.53	KSD97	KSD	Straits Drain								
7/26/2005 14:24	21.66	438	0.285	18.5	1.41	1.0	7.61	KSD97	KSD	Straits Drain								
7/26/2005 14:29	21.35	435	0.283	6.8	0.52	1.4	7.72	KSD97	KSD	Straits Drain								
8/9/2005 7:46	24.79	121		97.3	6.93	0.1	8.93	KR254.4	Link River	Link Dam	20.5	4	N	12.4	15.3	4.96	0.75	3
8/9/2005 7:48	24.79	121		96.5	6.88	0.5	8.93	KR254.4	Link River	Link Dam								
8/9/2005 7:50	24.81	121		93.5	6.66	1.0	8.90	KR254.4	Link River	Link Dam								
8/9/2005 7:51	24.86	121		93.1	6.62	2.0	8.86	KR254.4	Link River	Link Dam								
8/9/2005 7:52	24.85	121		90.1	6.41	3.0	8.85	KR254.4	Link River	Link Dam								
8/9/2005 7:53	24.35	122		89.9	6.46	3.5	8.90	KR254.4	Link River	Link Dam								
8/9/2005 9:52	24.97	172		7.4	0.53	0.1	7.29	KR234.9	Keno	Keno Bridge	23.0	3	SE	4.11	4.51	4.38	0.80	1
8/9/2005 9:55	24.88	173		5.7	0.41	0.5	7.30	KR234.9	Keno	Keno Bridge								
8/9/2005 9:58	24.58	172		2.6	0.18	1.0	7.24	KR234.9	Keno	Keno Bridge								
8/9/2005 9:59	24.36	171		-0.4	-0.03	2.0	7.16	KR234.9	Keno	Keno Bridge								
8/9/2005 10:01	24.32	171		-0.5	-0.03	3.0	7.09	KR234.9	Keno	Keno Bridge								
8/9/2005 10:02	24.27	172		-0.4	-0.03	4.0	7.07	KR234.9	Keno	Keno Bridge								
8/9/2005 10:04	24.26	172		-0.7	-0.05	5.0	7.06	KR234.9	Keno	Keno Bridge								
8/9/2005 10:07	23.54	174		-0.4	-0.03	5.3	7.17	KR234.9	Keno	Keno Bridge								
8/9/2005 11:10	25.87	182		58.6	4.09	0.1	7.97	KR238.2	KRS12A	Rock Quarry	24.5	3	E	3.71	4.07	4.27	0.85	1
8/9/2005 11:12	24.49	179		56.7	4.06	0.5	7.93	KR238.2	KRS12A	Rock Quarry								
8/9/2005 11:12	24.51	179		56.6	4.05	0.5	7.92	KR238.2	KRS12A	Rock Quarry								
8/9/2005 11:14	24.08	178		38.4	2.77	1.0	7.45	KR238.2	KRS12A	Rock Quarry								

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					^{o}C	mph	direction	1st	2nd	3rd	(m)	Bloom
8/9/2005 11:17	23.93	180		24.6	1.78	2.0	7.26	KR238.2	KRS12A	Rock Quarry								
8/9/2005 11:20	23.86	180		22.6	1.64	3.0	7.28	KR238.2	KRS12A	Rock Quarry								
8/9/2005 11:22	23.52	152		-0.2	-0.01	4.0	6.87	KR238.2	KRS12A	Rock Quarry								
8/9/2005 11:24	23.47	152		-0.4	-0.03	5.0	6.79	KR238.2	KRS12A	Rock Quarry								
8/9/2005 12:01	26.05	485		29.9	2.08	0.1	7.53	KSD97	KSD	Klamath Straits Drain	28.0	2	NE	6.60	6.95	7.06	0.50	1
8/9/2005 12:02	25.14	489		27.9	1.97	0.5	7.51	KSD97	KSD	Klamath Straits Drain								
8/9/2005 12:04	24.78	492		24.2	1.72	1.0	7.36	KSD97	KSD	Klamath Straits Drain								
8/9/2005 12:07	24.78	492		22.0	1.57	1.5	7.21	KSD97	KSD	Klamath Straits Drain								
8/9/2005 13:47	27.50	131		126.7	8.59	0.1	8.95	KR246.0	Miller Island	Miller Island	28.5	5	SW	75.7	4.43	47.1	0.90	4
8/9/2005 13:49	26.28	131		96.2	6.67	0.5	8.87	KR246.0	Miller Island	Miller Island								
8/9/2005 13:50	25.01	134		13.5	0.95	1.0	7.93	KR246.0	Miller Island	Miller Island								
8/9/2005 13:51	24.84	135		1.2	0.09	2.0	7.35	KR246.0	Miller Island	Miller Island								
8/9/2005 13:53	24.76	135		0.7	0.05	2.9	7.22	KR246.0	Miller Island	Miller Island								
8/9/2005 13:54	24.55	138		0.5	0.04	4.1	7.06	KR246.0	Miller Island	Miller Island								
8/9/2005 13:56	24.48	139		0.4	0.03	4.5	6.81	KR246.0	Miller Island	Miller Island								
8/9/2005 14:39	26.59	125		110.1	7.59	0.1	8.66	KR251.7	RR Bridge	Train Trestle	28.5	9	SW	11.5	13.3	8.79	0.80	4
8/9/2005 14:46	26.04	126		87.7	6.11	0.5	8.68	KR251.7	RR Bridge	Train Trestle								
8/9/2005 14:48	25.82	126		86.5	6.05	1.0	8.81	KR251.7	RR Bridge	Train Trestle								
8/9/2005 14:49	24.53	134		32.6	2.33	2.0	8.32	KR251.7	RR Bridge	Train Trestle								
8/9/2005 14:50	24.25	137		16.8	1.21	3.0	7.80	KR251.7	RR Bridge	Train Trestle								
8/23/2005 7:43	21.23	113		89.1	6.82	0.1	9.47	KR254.4	Link River	Link Dam	15.0	2	SE	13.7	8.52	10.4	0.60	3
8/23/2005 7:45	21.23	113		88.6	6.78	0.5	9.48	KR254.4	Link River	Link Dam								
8/23/2005 7:47	21.22	113		88.9	6.81	1.0	9.48	KR254.4	Link River	Link Dam								
8/23/2005 7:49	21.20	113		88.8	6.80	2.0	9.47	KR254.4	Link River	Link Dam								
8/23/2005 7:53	21.22	113		87.8	6.73	3.0	9.45	KR254.4	Link River	Link Dam								
8/23/2005 9:42	22.47	125		34.9	2.61	0.1	8.90	KR246.0	Miller Island	Miller Island	18.0	2	E	4.99	4.83	4.61	0.90	3
8/23/2005 9:44	22.45	124		37.8	2.83	0.5	8.94	KR246.0	Miller Island	Miller Island								
8/23/2005 9:45	22.16	124		30.7	2.31	1.0	8.90	KR246.0	Miller Island	Miller Island								
8/23/2005 9:48	22.06	124		29.3	2.21	2.0	8.88	KR246.0	Miller Island	Miller Island								
8/23/2005 9:50	22.04	124		28.4	2.14	3.0	8.86	KR246.0	Miller Island	Miller Island								
8/23/2005 9:52	22.02	124		27.9	2.10	4.0	8.85	KR246.0	Miller Island	Miller Island								
8/23/2005 9:53	22.01	124		26.8	2.02	5.0	8.75	KR246.0	Miller Island	Miller Island								
8/23/2005 10:57	22.64	381		13.9	1.03	0.1	7.57	KSD97	KSD	Klamath Straits Drain	21.0	0	-	4.19	3.97	4.08	1.10	1
8/23/2005 11:00	22.46	387		14.4	1.08	0.5	7.57	KSD97	KSD	Klamath Straits Drain								

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					^{o}C	mph	direction	1st	2nd	3rd	(m)	Bloom
8/23/2005 11:02	22.24	396		18.4	1.38	1.0	7.60	KSD97	KSD	Klamath Straits Drain								
8/23/2005 11:05	21.98	401		19.5	1.47	1.6	7.61	KSD97	KSD	Klamath Straits Drain								
8/23/2005 13:05	22.45	139		72.3	5.40	0.1	8.63	KR234.9	Keno	Keno Bridge	24.5	8	W	4.20	4.22	4.51	1.85	3
8/23/2005 13:08	22.12	139		62.4	4.70	0.5	8.53	KR234.9	Keno	Keno Bridge								
8/23/2005 13:10	21.76	139		58.9	4.47	1.0	8.49	KR234.9	Keno	Keno Bridge								
8/23/2005 13:12	21.65	140		49.3	3.74	2.0	8.38	KR234.9	Keno	Keno Bridge								
8/23/2005 13:15	21.44	140		44.7	3.41	3.0	8.28	KR234.9	Keno	Keno Bridge								
8/23/2005 13:16	21.40	140		42.7	3.26	4.0	8.24	KR234.9	Keno	Keno Bridge								
8/23/2005 13:18	21.40	140		42.2	3.22	5.0	8.23	KR234.9	Keno	Keno Bridge								
8/23/2005 13:53	24.26	141		87.6	6.33	0.1	8.96	KR238.2	KRS12A	Rock Quarry	24.5	10	SW	2.97	3.09	2.71	1.25	3
8/23/2005 13:57	22.80	142		70.4	5.23	0.5	8.85	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:01	22.31	143		36.1	2.71	1.0	8.60	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:02	22.11	145		31.9	2.40	2.0	8.54	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:04	21.98	145		36.7	2.77	3.0	8.60	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:07	21.88	145		32.2	2.43	4.0	8.53	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:09	21.80	145		29.3	2.22	5.0	8.48	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:10	21.79	146		22.5	1.71	5.6	8.34	KR238.2	KRS12A	Rock Quarry								
8/23/2005 14:50	24.22	120		176.9	12.80	0.1	9.73	KR251.7	RR Bridge	Train Trestle	24.5	12	NW	4.93	7.81	7.50	0.40	4
8/23/2005 14:54	24.15	119		173.9	12.60	0.5	9.72	KR251.7	RR Bridge	Train Trestle								
8/23/2005 14:59	23.95	119		154.1	11.21	1.0	9.66	KR251.7	RR Bridge	Train Trestle								
8/23/2005 15:01	22.07	124		72.3	5.45	2.0	9.27	KR251.7	RR Bridge	Train Trestle								
8/23/2005 15:03	21.42	135		38.0	2.90	3.0	9.08	KR251.7	RR Bridge	Train Trestle								
9/20/2005 7:52	15.75	117		121.8	10.51	0.1	9.51	KR254.4	Link River	Link Dam	9.5	1	N	9.27	11.4	9.38	0.55	3
9/20/2005 7:54	15.75	117		122.6	10.58	0.5	9.52	KR254.4	Link River	Link Dam								
9/20/2005 7:56	15.75	117		122.4	10.57	1.0	9.54	KR254.4	Link River	Link Dam								
9/20/2005 7:58	15.75	117		122.5	10.57	2.0	9.54	KR254.4	Link River	Link Dam								
9/20/2005 7:59	15.75	117		122.0	10.53	3.0	9.55	KR254.4	Link River	Link Dam								
9/20/2005 9:21	15.79	118		69.2	5.97	0.1	9.41	KR251.7	RR Bridge	Trestle	13.5	3	N	32.0	31.1	35.6	0.55	4
9/20/2005 9:22	15.78	118		68.7	5.93	0.5	9.40	KR251.7	RR Bridge	Trestle								
9/20/2005 9:23	15.72	118		63.1	5.45	1.0	9.36	KR251.7	RR Bridge	Trestle								
9/20/2005 9:24	15.63	120		56.1	4.85	2.0	9.32	KR251.7	RR Bridge	Trestle								
9/20/2005 9:28	15.23	199		31.5	2.75	3.0	8.88	KR251.7	RR Bridge	Trestle								
9/20/2005 10:31	17.13	139		90.6	7.59	0.1	9.17	KR246.0	Miller Island	Miller Island	17.0	1	NW	9.36	6.49	9.05	0.65	3
9/20/2005 10:33	15.82	141		71.5	6.16	0.5	9.11	KR246.0	Miller Island	Miller Island								

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					^{o}C	mph	direction	1st	2nd	3rd	(m)	Bloom
9/20/2005 10:35	15.50	143		50.4	4.37	1.0	8.96	KR246.0	Miller Island	Miller Island								
9/20/2005 10:36	15.32	144		30.2	2.63	2.0	8.79	KR246.0	Miller Island	Miller Island								
9/20/2005 10:39	15.24	144		19.8	1.72	3.0	8.68	KR246.0	Miller Island	Miller Island								
9/20/2005 10:40	15.17	144		11.3	0.98	4.0	8.58	KR246.0	Miller Island	Miller Island								
9/20/2005 10:41	15.16	144		10.3	0.90	5.0	8.56	KR246.0	Miller Island	Miller Island								
9/20/2005 11:34	15.65	312		40.9	3.53	0.1	7.54	KSD97	KSD	Klamath Straits Drain	19.5	1	S	8.48	8.89	9.80	0.65	1
9/20/2005 11:35	15.22	315		40.3	3.52	0.5	7.55	KSD97	KSD	Klamath Straits Drain								
9/20/2005 11:36	15.14	317		40.4	3.53	1.0	7.55	KSD97	KSD	Klamath Straits Drain								
9/20/2005 11:37	15.10	318		39.8	3.48	1.4	7.55	KSD97	KSD	Klamath Straits Drain								
9/20/2005 12:57	17.80	159		31.5	2.60	0.1	7.94	KR238.2	KRS12A	Quarry	22.5	1	NW	4.33	4.24	4.30	1.70	1
9/20/2005 12:58	17.48	158		31.7	2.64	0.5	7.94	KR238.2	KRS12A	Quarry								
9/20/2005 12:59	15.89	160		27.3	2.35	1.0	7.91	KR238.2	KRS12A	Quarry								
9/20/2005 13:01	15.56	160		19.8	1.72	2.0	7.83	KR238.2	KRS12A	Quarry								
9/20/2005 13:03	15.15	159		8.0	0.70	3.0	7.67	KR238.2	KRS12A	Quarry								
9/20/2005 13:04	15.04	160		5.3	0.46	4.0	7.62	KR238.2	KRS12A	Quarry								
9/20/2005 13:05	14.97	159		3.8	0.34	5.0	7.59	KR238.2	KRS12A	Quarry								
9/20/2005 13:06	14.97	159		3.0	0.26	5.5	7.57	KR238.2	KRS12A	Quarry								
9/20/2005 13:49	17.58	153		22.0	1.83	0.1	7.63	KR234.9	Keno	Keno Bridge	23.0	3	E	4.19	4.10	3.97	1.80	1
9/20/2005 13:51	17.50	153		22.5	1.87	0.5	7.65	KR234.9	Keno	Keno Bridge								
9/20/2005 13:53	15.75	152		13.1	1.13	1.0	7.58	KR234.9	Keno	Keno Bridge								
9/20/2005 13:54	15.11	152		11.2	0.98	2.0	7.57	KR234.9	Keno	Keno Bridge								
9/20/2005 13:55	15.08	152		10.8	0.95	3.0	7.55	KR234.9	Keno	Keno Bridge								
9/20/2005 13:56	15.05	152		10.7	0.93	4.0	7.55	KR234.9	Keno	Keno Bridge								
9/20/2005 13:57	15.04	152		10.5	0.92	5.0	7.54	KR234.9	Keno	Keno Bridge								
9/20/2005 13:58	15.04	152		10.4	0.91	5.5	7.54	KR234.9	Keno	Keno Bridge								
10/18/2005 8:03	12.09	118		101.9	9.43	0.1	8.94	KR254.4	Link River	Link Dam	-	-	SW	8.64	9.48	9.28	0.85	3
10/18/2005 8:04	12.09	118		101.7	9.41	0.5	8.96	KR254.4	Link River	Link Dam								
10/18/2005 8:06	12.09	118		102.1	9.45	1.0	8.97	KR254.4	Link River	Link Dam								
10/18/2005 8:07	12.09	118		102.3	9.46	2.0	8.98	KR254.4	Link River	Link Dam								
10/18/2005 8:08	12.09	118		102.1	9.45	3.0	8.98	KR254.4	Link River	Link Dam								
10/18/2005 9:32	11.71	125		45.0	4.20	0.1	8.42	KR251.7	RR Bridge	Train Trestle	-	-	SE	8.69	8.59	9.39	0.80	2
10/18/2005 9:33	11.68	125		46.4	4.34	0.5	8.42	KR251.7	RR Bridge	Train Trestle								
10/18/2005 9:34	11.59	125		45.7	4.28	1.0	8.40	KR251.7	RR Bridge	Train Trestle								
10/18/2005 9:36	11.54	128		43.3	4.06	2.0	8.36	KR251.7	RR Bridge	Train Trestle								

DateTime	Temp	SpCond	TDS	DO %Local	DO Conc	Depth	pH	Rivermile	Site Name	Common Name	Air Temp	Wind Spd	Wind	NTU	NTU	NTU	Secchi	Algal
M/D/Y	C	uS/cm	g/L	%	mg/L	m					°C	mph	direction	1st	2nd	3rd	(m)	Bloom
10/18/2005 9:38	11.51	182		36.0	3.38	3.0	8.06	KR251.7	RR Bridge	Train Trestle								
10/18/2005 10:21	12.26	154		7.9	0.73	0.1	7.39	KR246.0	Miller Island	Miller Island	-	-	SW	5.72	5.87	5.96	1.40	1
10/18/2005 10:22	12.18	154		7.5	0.70	0.5	7.40	KR246.0	Miller Island	Miller Island								
10/18/2005 10:24	12.12	154		6.6	0.61	1.0	7.39	KR246.0	Miller Island	Miller Island								
10/18/2005 10:26	12.08	154		6.0	0.56	2.0	7.38	KR246.0	Miller Island	Miller Island								
10/18/2005 10:27	12.07	155		5.4	0.50	3.0	7.38	KR246.0	Miller Island	Miller Island								
10/18/2005 10:29	12.05	155		5.3	0.49	4.0	7.38	KR246.0	Miller Island	Miller Island								
10/18/2005 10:30	11.99	156		5.6	0.52	4.7	7.32	KR246.0	Miller Island	Miller Island								
10/18/2005 11:03	11.92	412		67.8	6.29	0.1	7.56	KSD97	KSD	Klamath Straits Drain	-	-	SE	6.40	7.19	6.55	0.80	1
10/18/2005 11:04	11.91	413		68.2	6.33	0.5	7.57	KSD97	KSD	Klamath Straits Drain								
10/18/2005 11:06	11.61	417		73.4	6.86	1.0	7.61	KSD97	KSD	Klamath Straits Drain								
10/18/2005 11:07	11.63	416		73.4	6.86	1.4	7.61	KSD97	KSD	Klamath Straits Drain								
10/18/2005 12:30	12.78	165		32.9	2.99	0.1	7.41	KR234.9	Keno	Keno Bridge	-	-	SE	5.61	5.25	5.71	1.45	1
10/18/2005 12:32	12.59	164		31.3	2.86	0.5	7.41	KR234.9	Keno	Keno Bridge								
10/18/2005 12:33	12.39	164		30.8	2.83	1.0	7.41	KR234.9	Keno	Keno Bridge								
10/18/2005 12:35	12.02	164		28.0	2.59	2.0	7.39	KR234.9	Keno	Keno Bridge								
10/18/2005 12:36	11.96	164		27.6	2.56	3.0	7.38	KR234.9	Keno	Keno Bridge								
10/18/2005 12:37	11.95	164		27.4	2.54	4.0	7.38	KR234.9	Keno	Keno Bridge								
10/18/2005 12:39	11.94	164		27.1	2.51	5.0	7.38	KR234.9	Keno	Keno Bridge								
10/18/2005 12:41	11.94	164		26.6	2.47	5.7	7.38	KR234.9	Keno	Keno Bridge								
10/18/2005 13:19	14.02	166		34.9	3.09	0.1	7.49	KR238.2	KRS12A	Rock Quarry	-	-	-	5.17	5.20	5.10	1.70	1
10/18/2005 13:21	13.18	167		32.8	2.96	0.5	7.49	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:22	12.71	168		30.1	2.74	1.0	7.47	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:24	12.28	175		23.3	2.14	2.0	7.41	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:25	12.22	178		21.0	1.94	3.0	7.39	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:27	12.13	173		20.0	1.85	4.0	7.38	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:28	12.12	172		19.3	1.78	5.0	7.37	KR238.2	KRS12A	Rock Quarry								
10/18/2005 13:30	12.12	172		18.1	1.67	5.4	7.37	KR238.2	KRS12A	Rock Quarry								

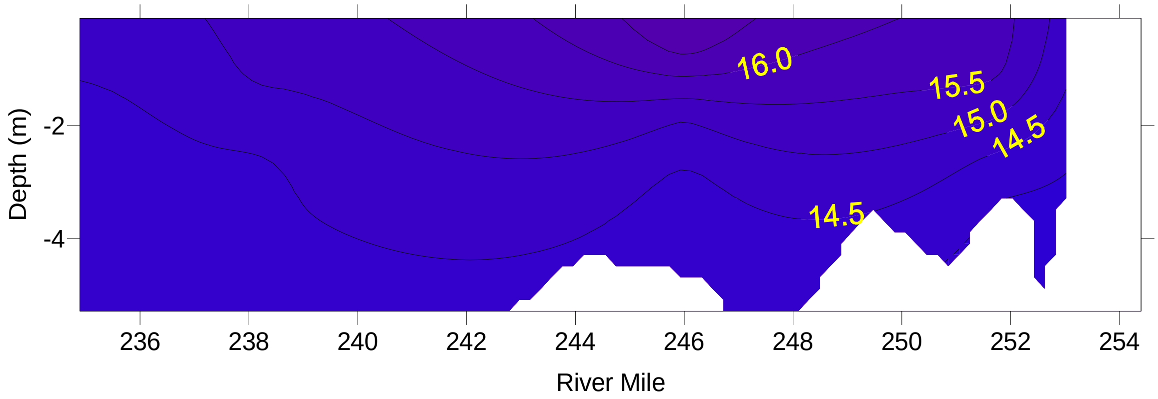


Figure 48. 5-3-05 water temperature, C

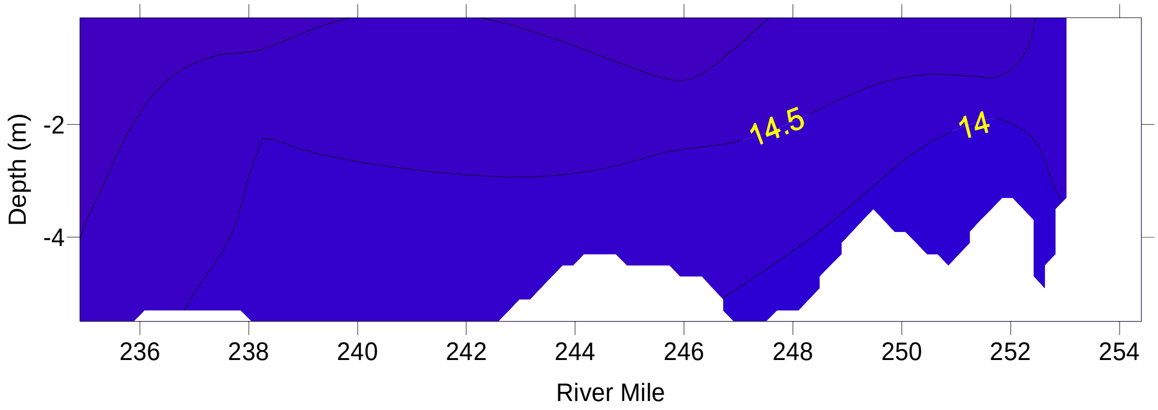


Figure 49. 6-7-05 water temperature, C

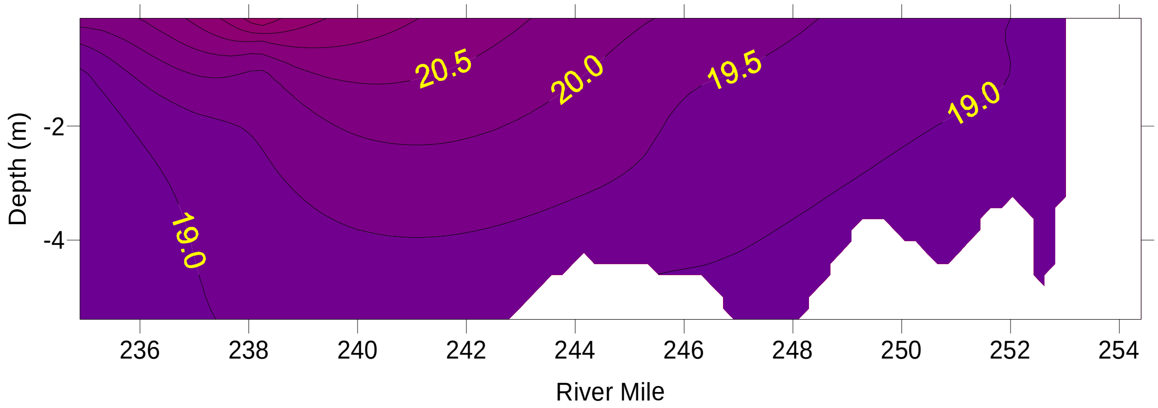
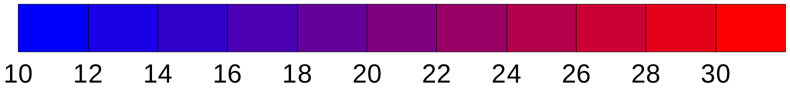


Figure 50. 6-28-05 water temperature, C



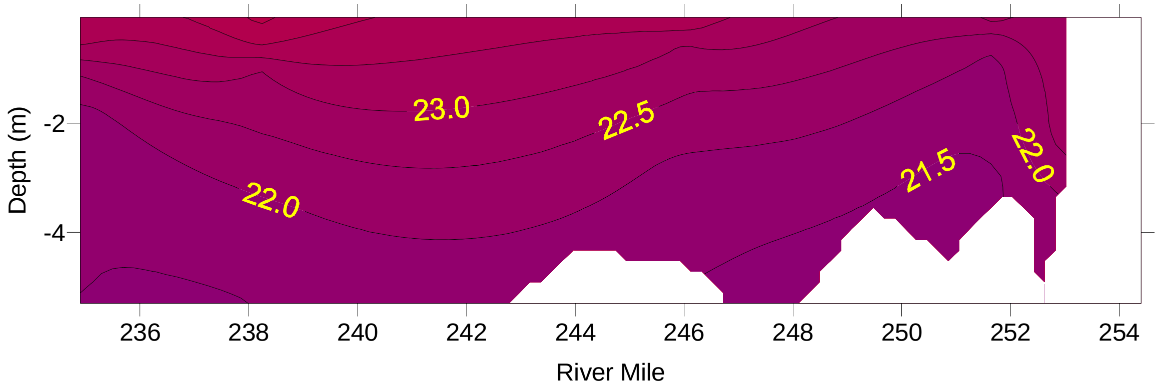
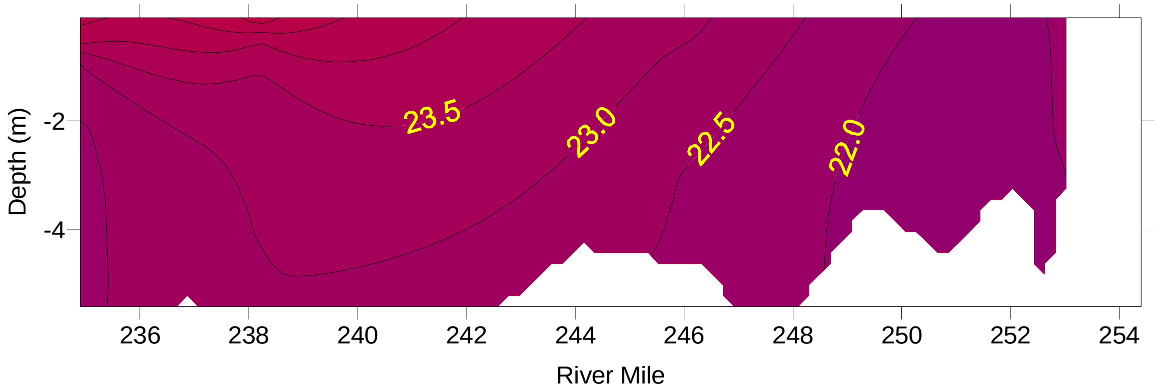


Figure 51. 7-12-05 water temperature, C



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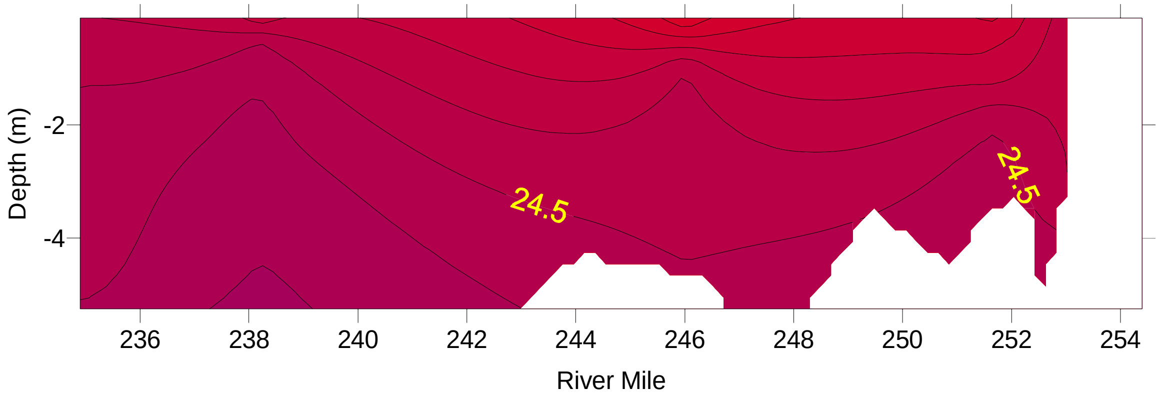
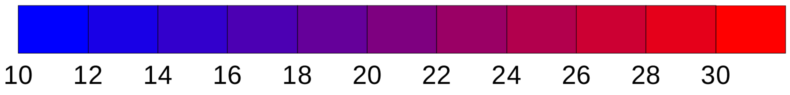


Figure 53. 8-9-05 water temperature, C



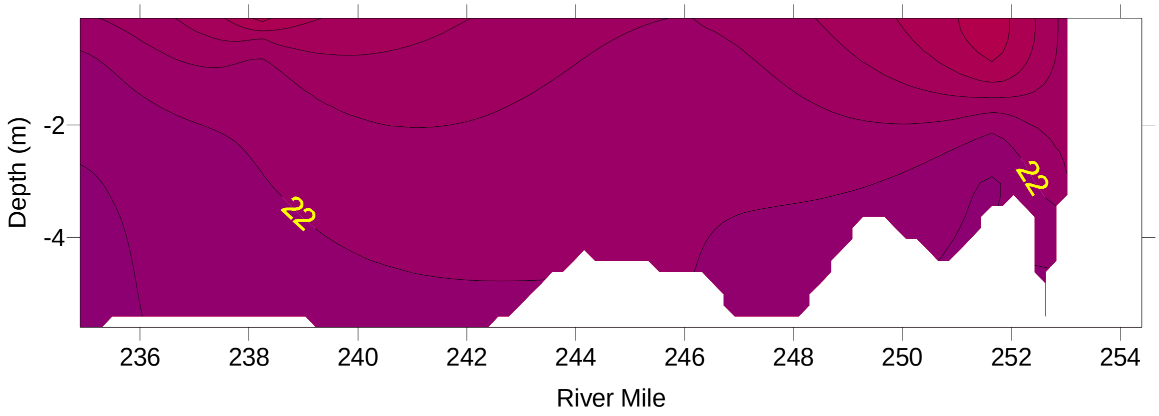


Figure 54. 8-23-05 water temperature, C

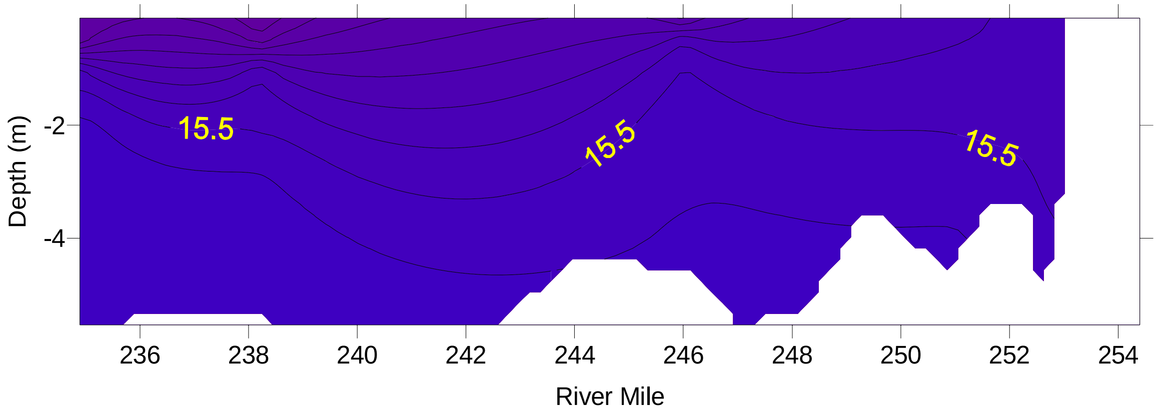


Figure 55. 9-20-05 water temperature, C

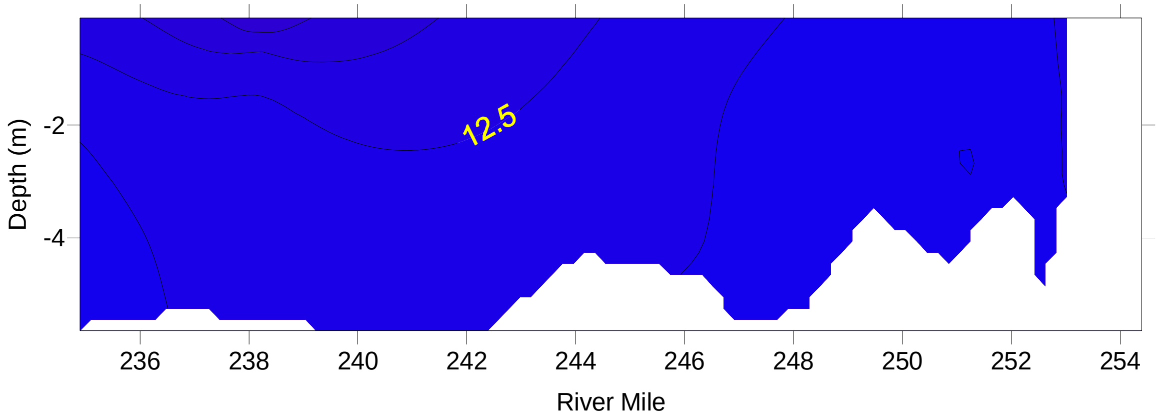
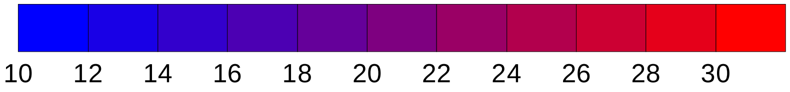


Figure 56. 10-18-05 water temperature, C



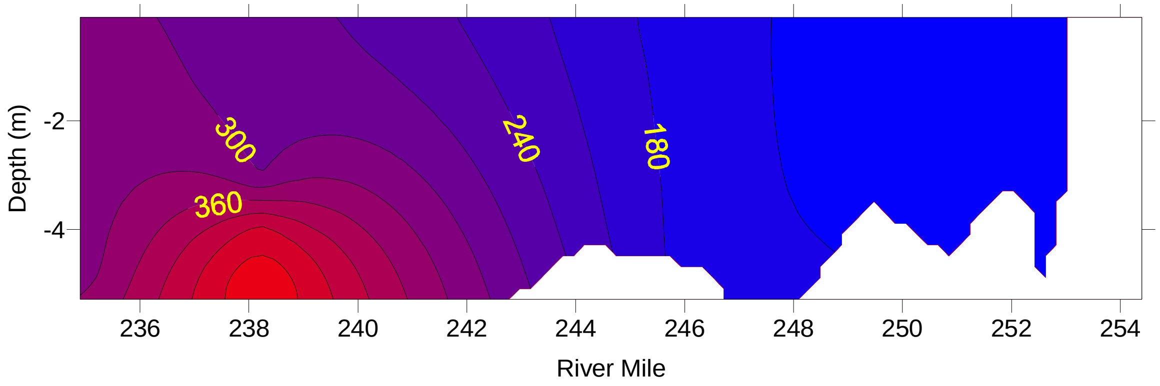


Figure 57. 5-3-05 electrical conductivity, uS/cm

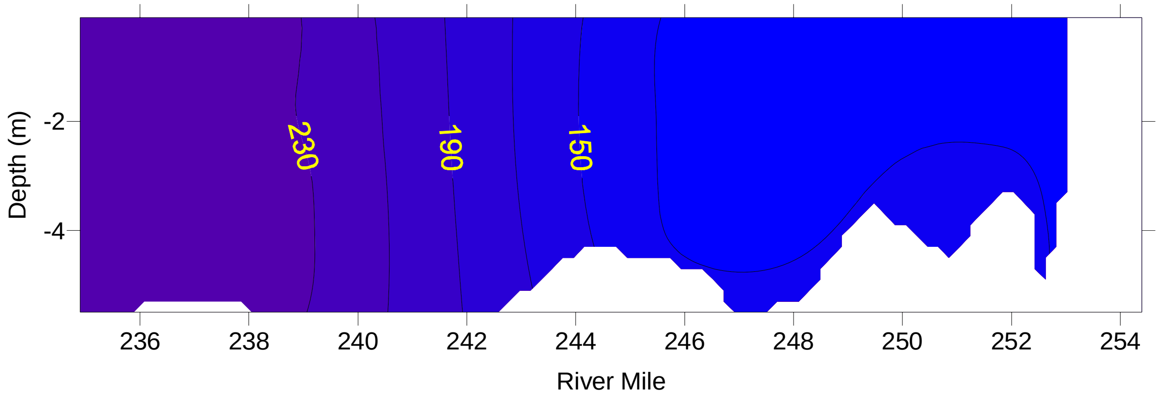


Figure 58. 6-7-05 electrical conductivity, uS/cm

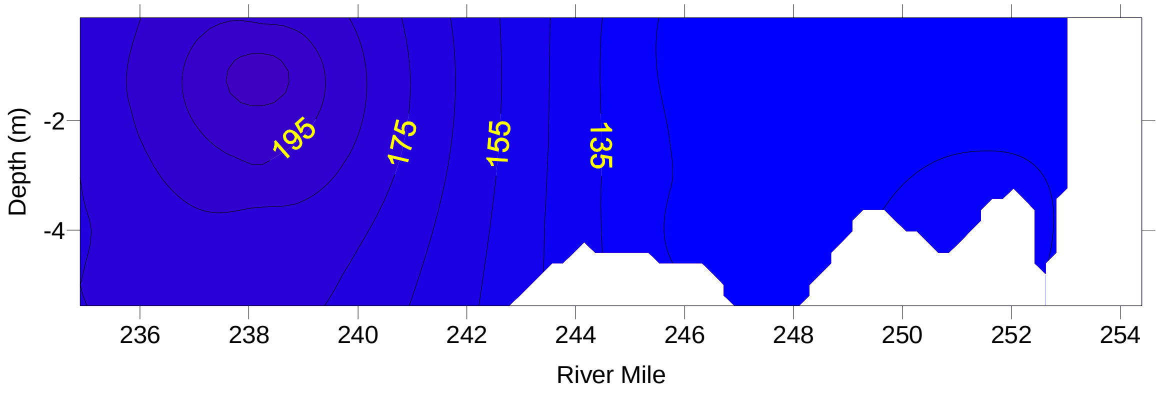
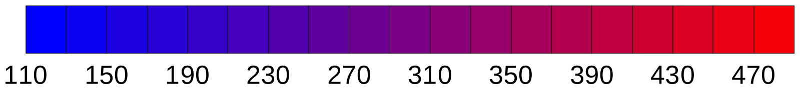


Figure 59. 6-28-05 electrical conductivity, uS/cm



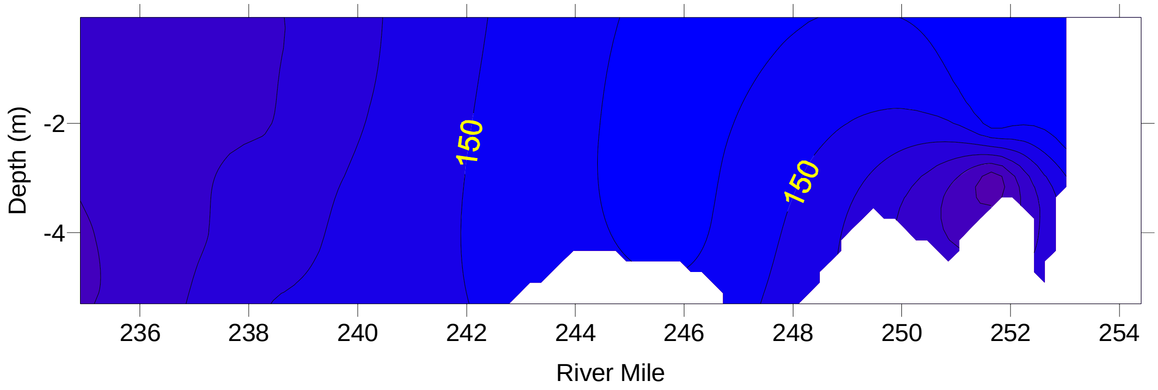


Figure 60. 7-12-05 electrical conductivity, uS/cm

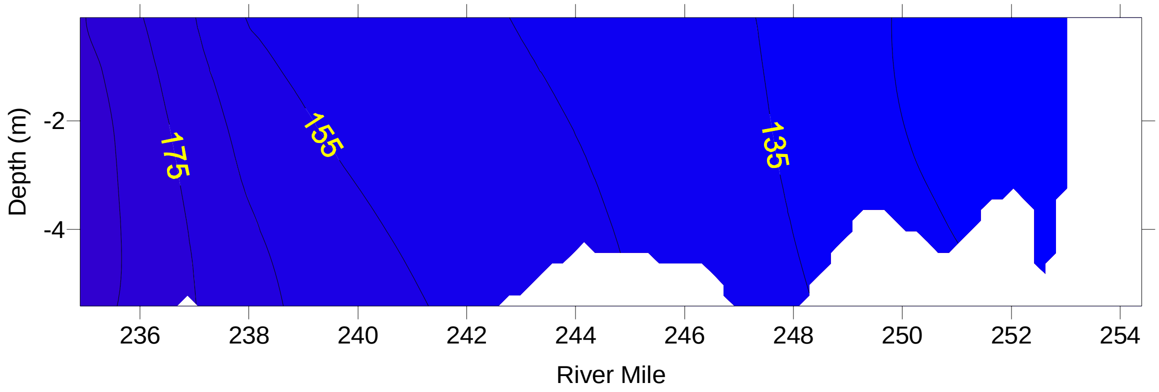


Figure 61. 7-26-05 electrical conductivity, uS/cm

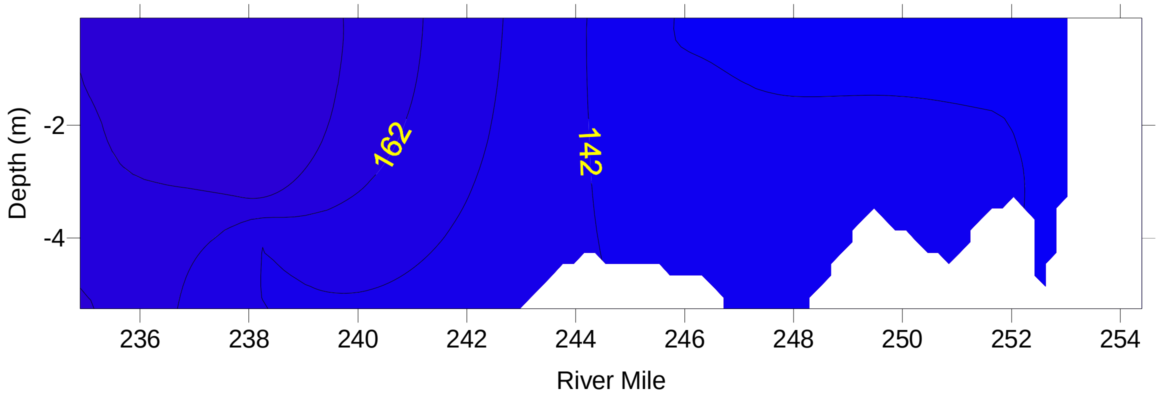
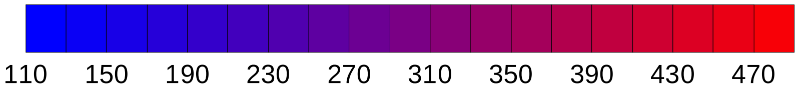


Figure 62. 8-9-05 electrical conductivity, uS/cm



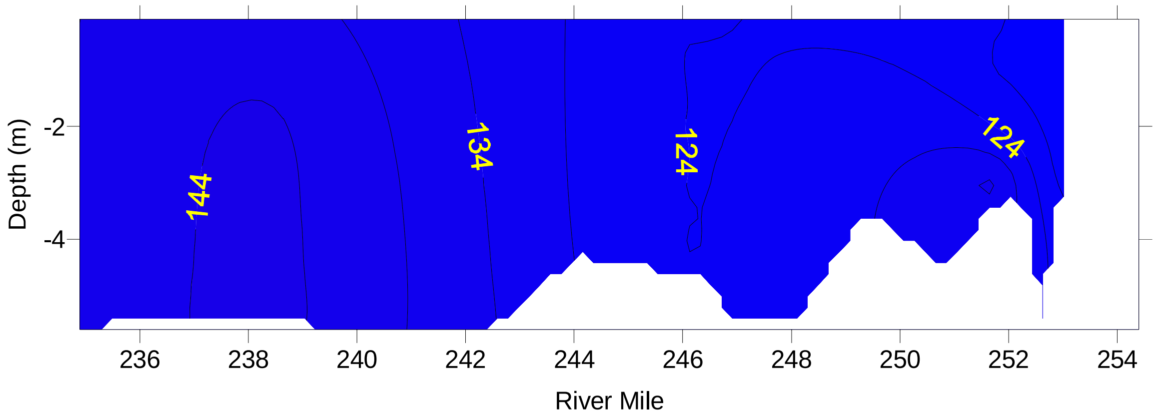


Figure 63. 8-23-05 electrical conductivity, uS/cm

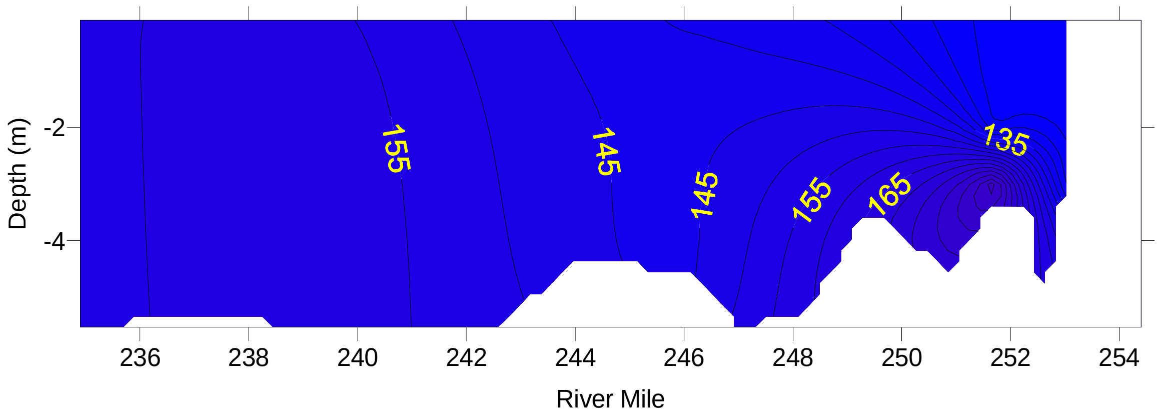


Figure 64. 9-20-05 electrical conductivity, uS/cm

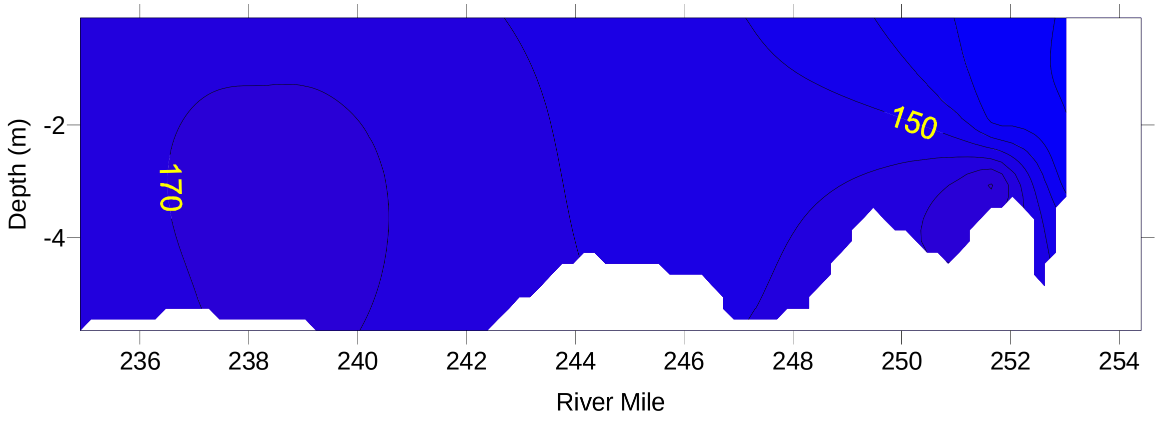
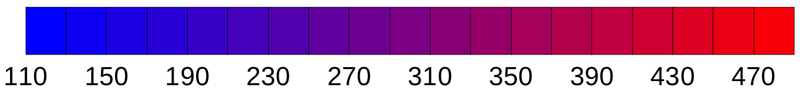


Figure 65. 10-18-05 electrical conductivity, uS/cm



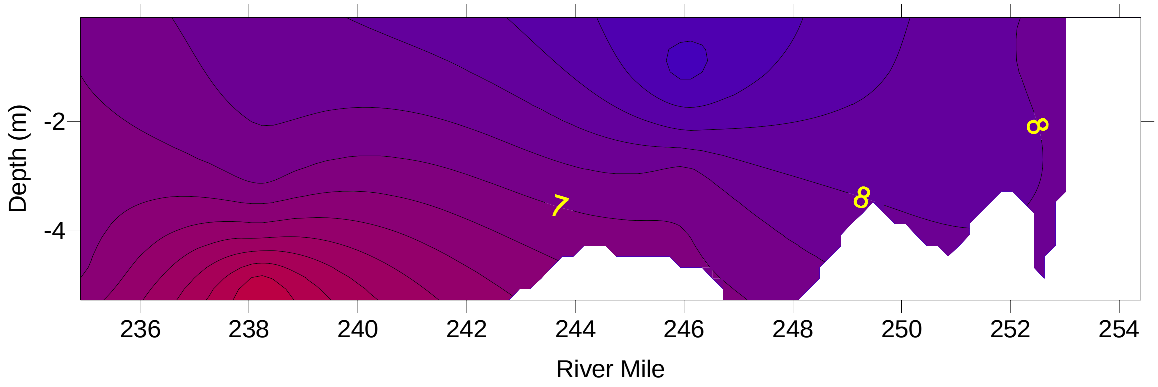


Figure 66. 5-3-05 dissolved oxygen, mg/l

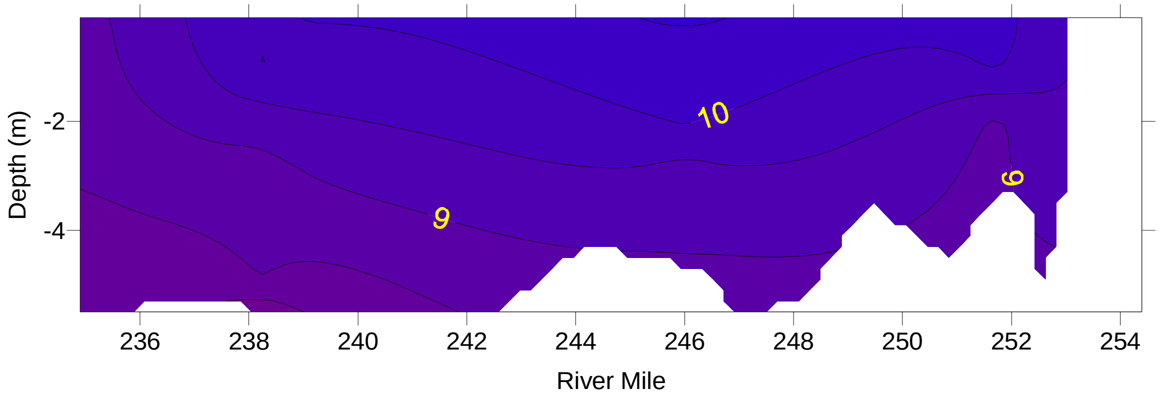


Figure 67. 6-7-05 dissolved oxygen, mg/l

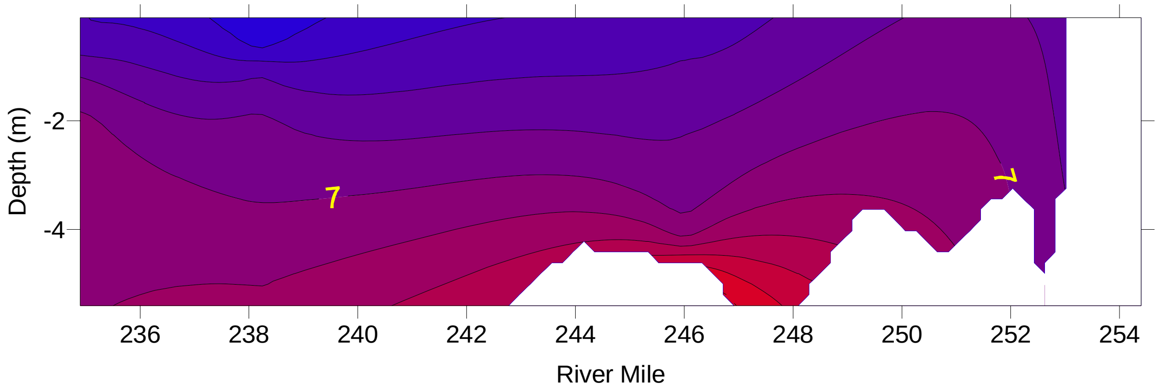
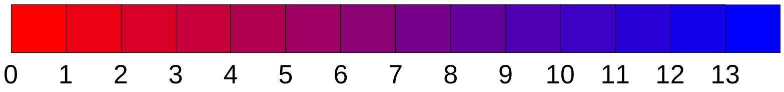


Figure 68. 6-28-05 dissolved oxygen, mg/l



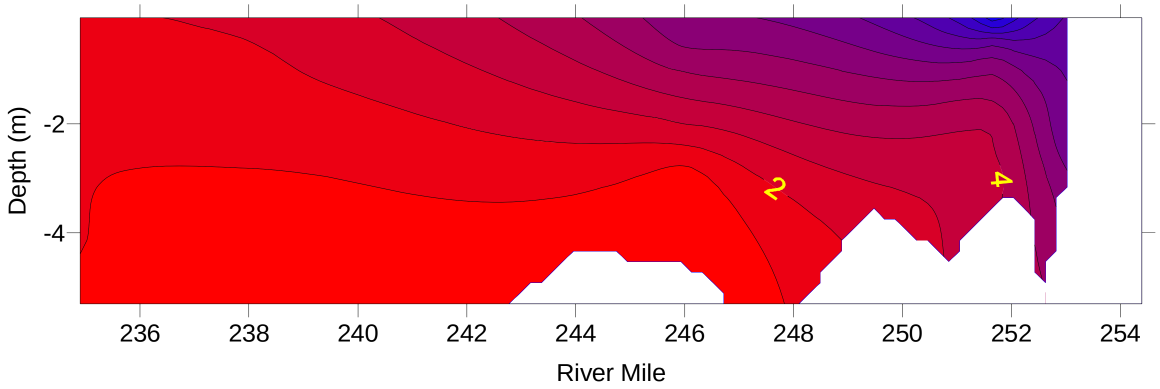


Figure 69. 7-12-05 dissolved oxygen, mg/l

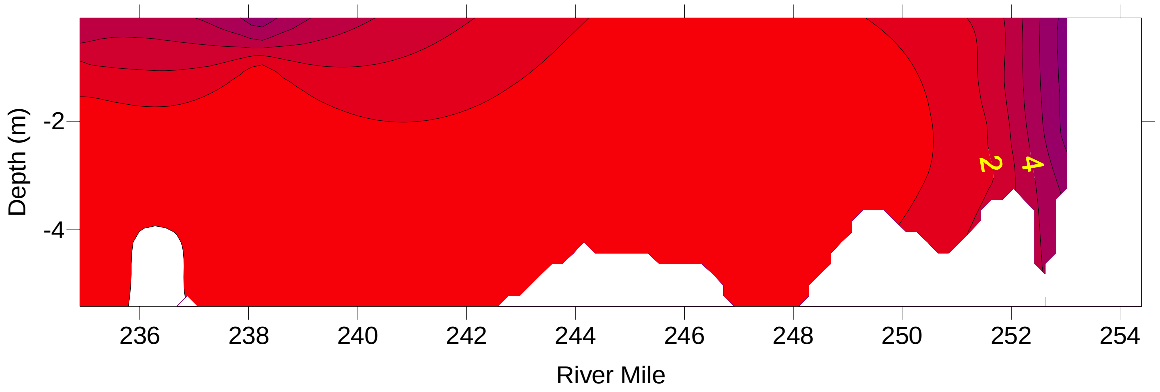


Figure 70. 7-26-05 dissolved oxygen, mg/l

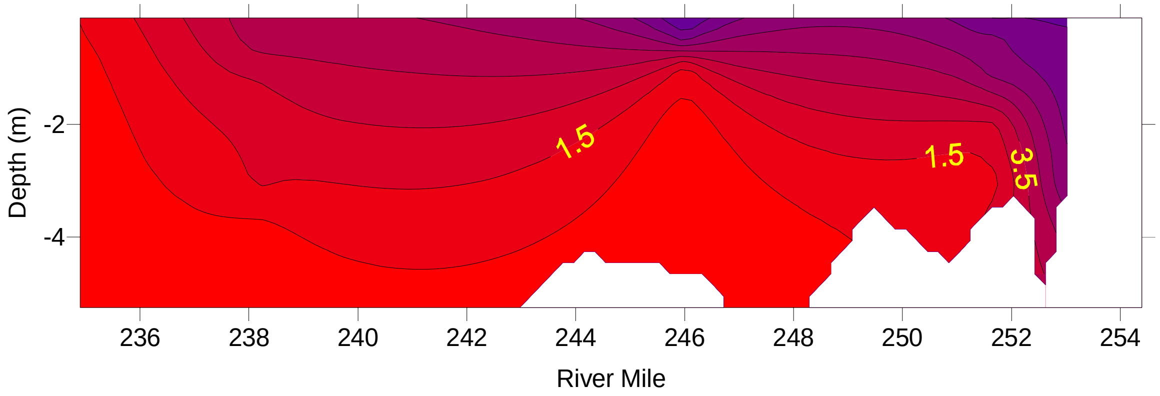
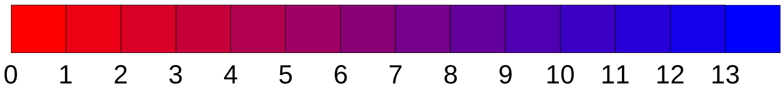


Figure 71. 8-9-05 dissolved oxygen, mg/l



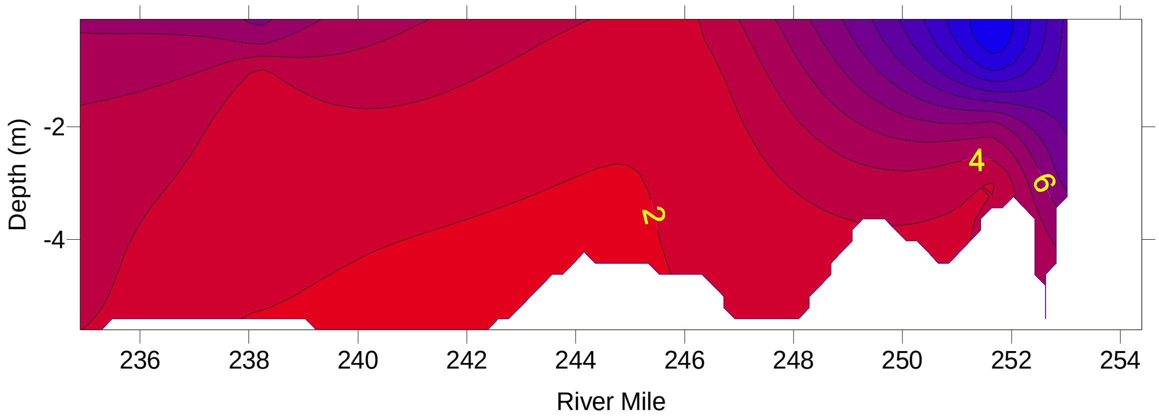


Figure 72. 8-23-05 dissolved oxygen, mg/l

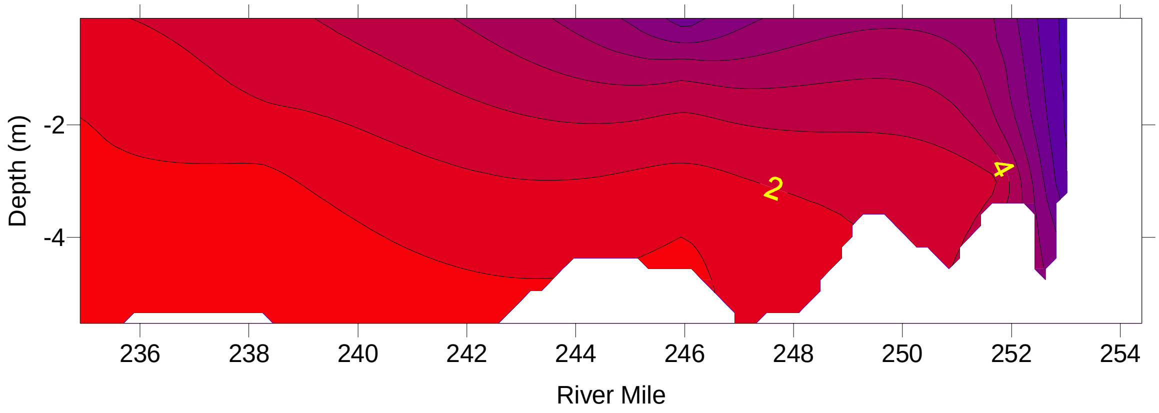


Figure 73. 9-20-05 dissolved oxygen, mg/l

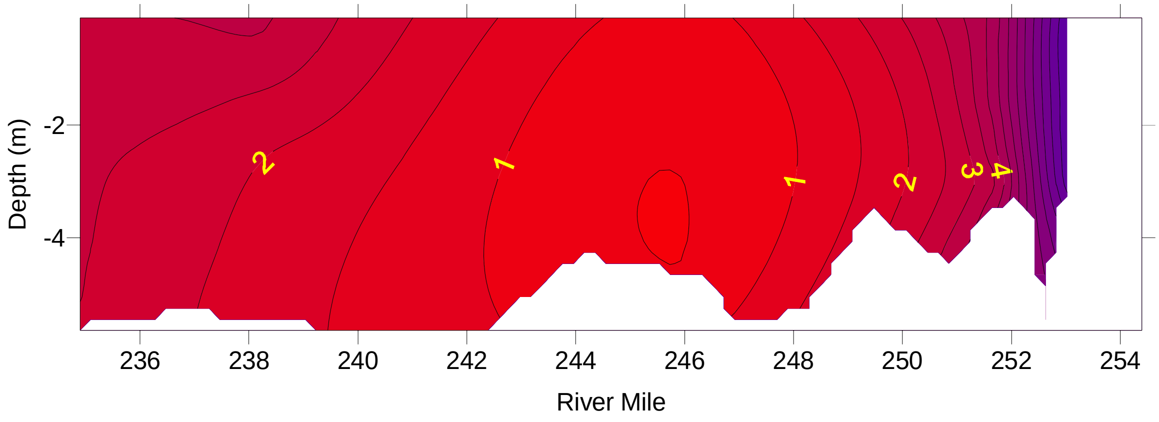
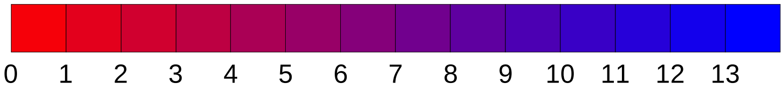


Figure 74. 10-18-05 dissolved oxygen, mg/l



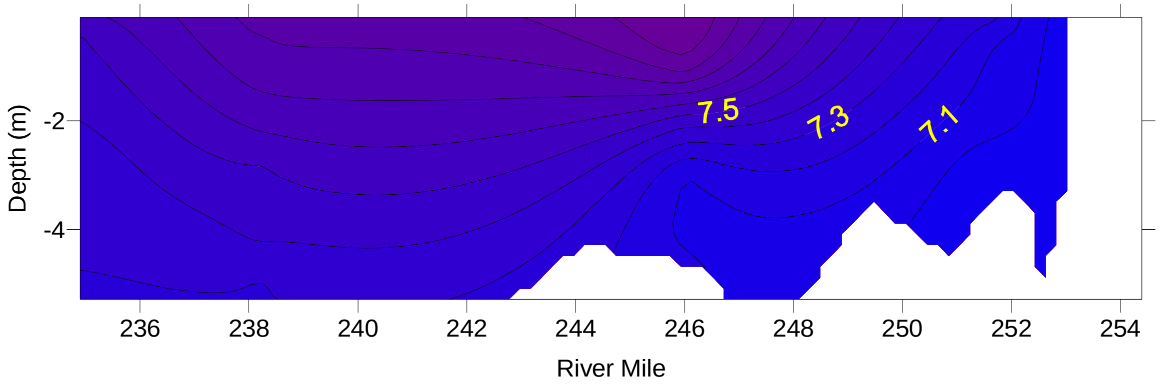


Figure 75. 5-3-05 pH

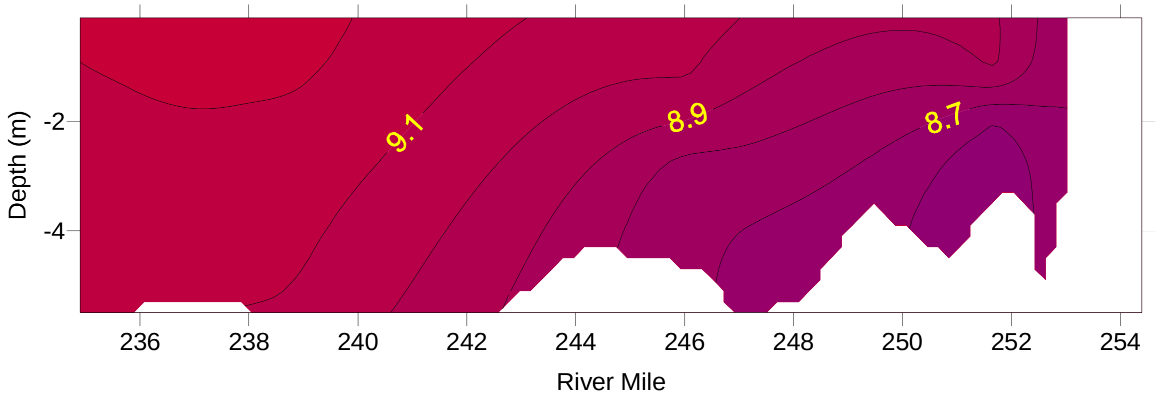


Figure 76. 6-7-05 pH

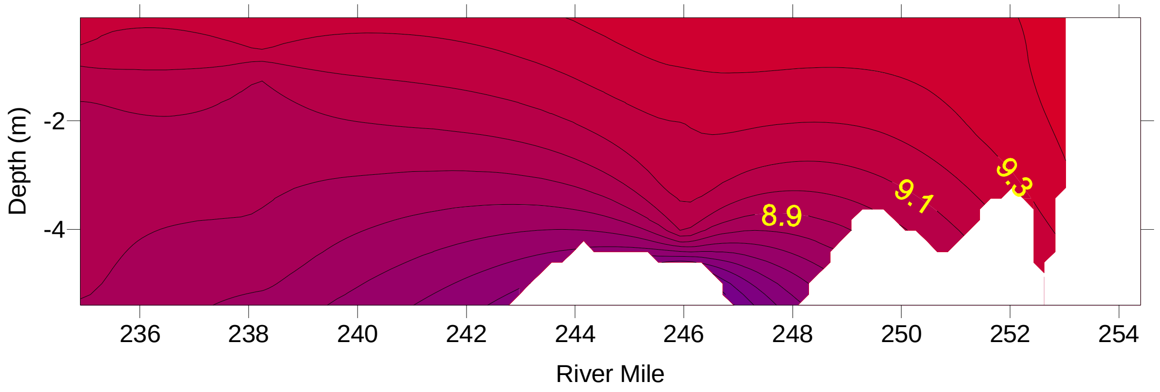
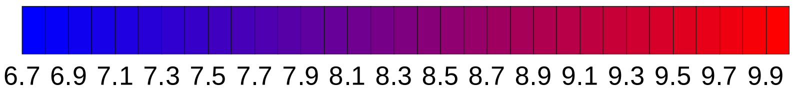


Figure 77. 6-28-05 pH



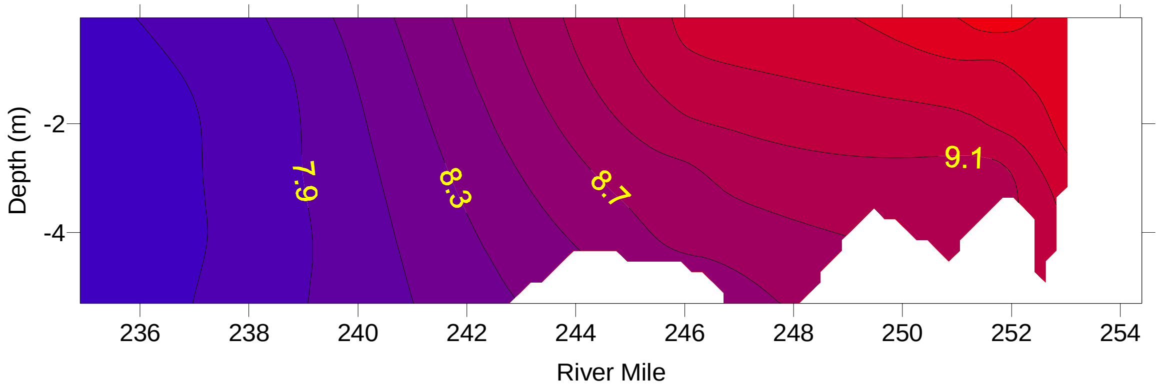


Figure 78. 7-12-05 pH

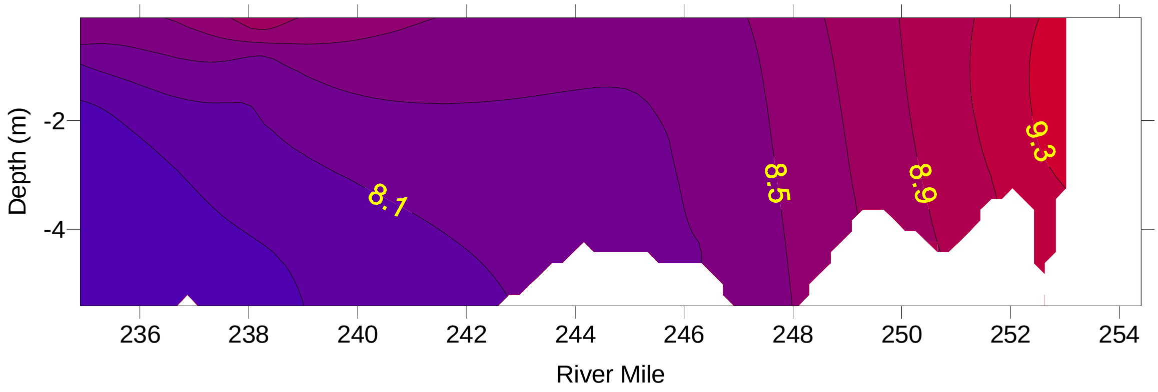


Figure 79. 7-26-05 pH

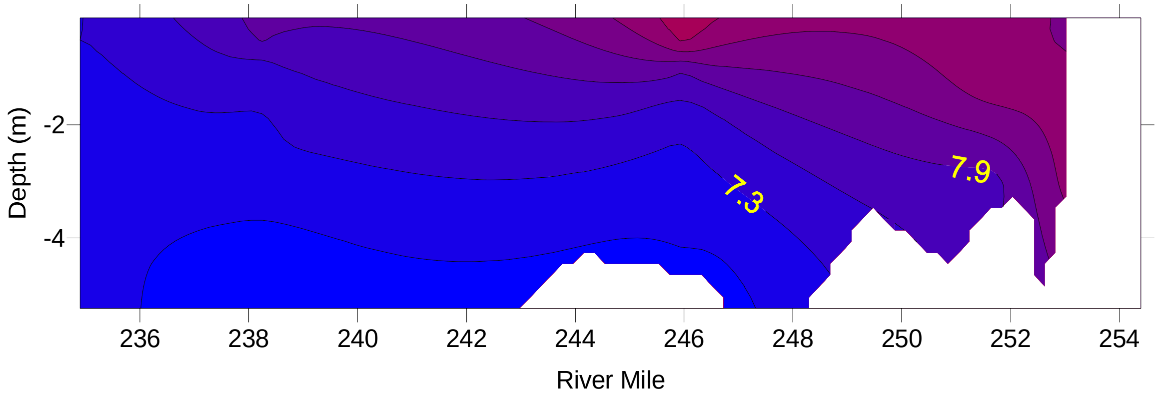
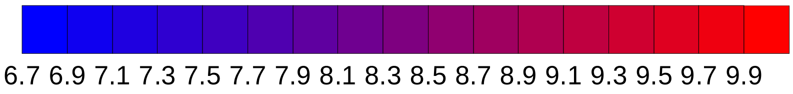


Figure 80. 8-9-05 pH



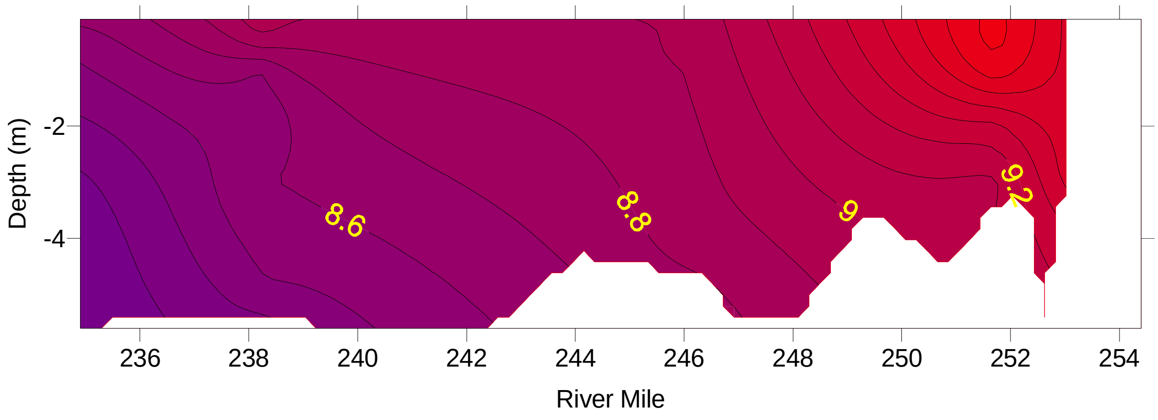


Figure 81. 8-23-05 pH

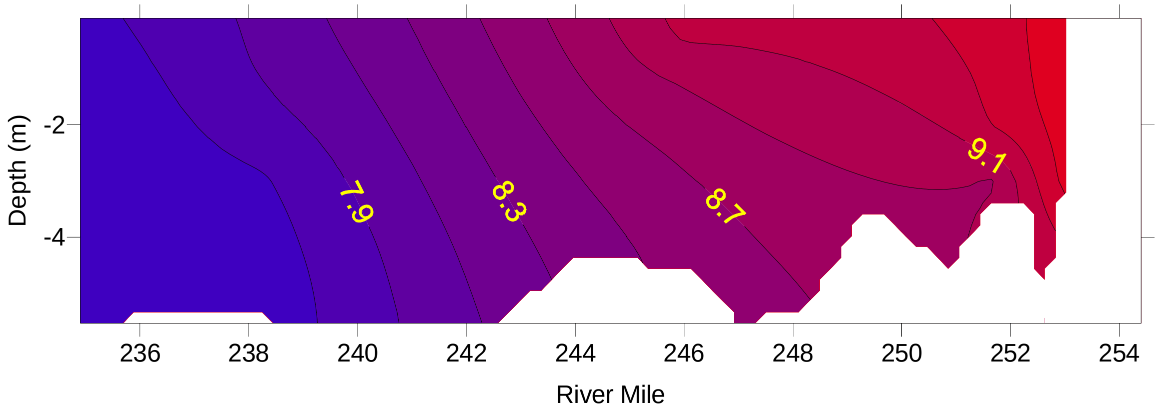


Figure 82. 9-20-05 pH

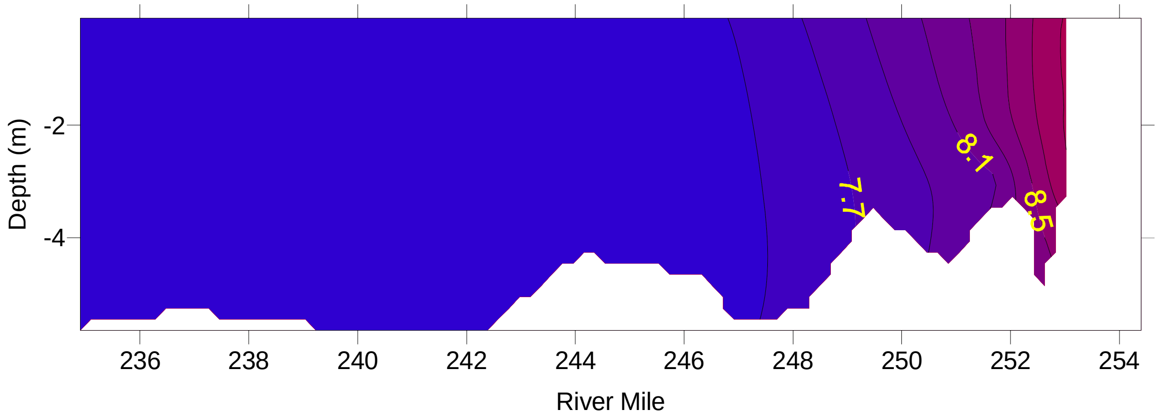
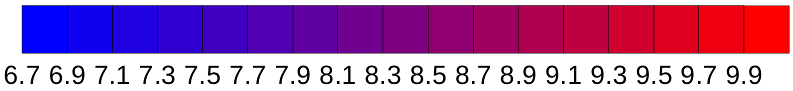


Figure 83. 10-18-05 pH



9.5. *Appendix E: Light Extinction Information*

9.5.1. Introduction

To estimate the light extinction properties Keno Reservoir and environs, Photosynthetically Active Radiation (PAR) measurements were collected at multiple depths. Field methods, field data, and estimates of light extinction coefficients are discussed.

9.5.2. Field Methods

Measurement of PAR (400-700 nm) in aquatic environments was accomplished using either the LI-192 Underwater Quantum Sensor. Applicable to extremely turbid conditions, radiation levels with the LI-192 can be measured with resolution to 0.01 μmol s^{-1} m^{-2}, with a response time of 10 microseconds. The LI-192 measures underwater (or atmospheric) Photosynthetic Photon Flux Density (PPFD). The sensor uses a high stability silicon photovoltaic detector (blue enhanced) in a corrosion resistant metal housing with acrylic diffuser. The LI-192 is cosine corrected and features corrosion resistant construction for use in freshwater or saltwater and pressures up to 800 psi (5500 kPa, 560 meters depth) (LI-COR, 2006).

The SI unit of radiant energy flux is the watt (W); however, there is no official SI unit of photon flux. A mole of photons is commonly used to designate Avogadro's number of photons (6.022 $x10^{23}$ photons). Although the einstein (E) has been used in the past in plant science, most societies now recommend the use of the mole since the mole is an SI unit. When either of these definitions is used, the quantity of photons in a mole is equal to the quantity of photons in an einstein (1 mole = 1 einstein = 6.022 $x10^{23}$ photons). Photosynthetically Active Radiation (PAR) is defined as radiation in the 400 to 700 nm waveband. Photosynthetic Photon Flux Density (PPFD) is defined as the photon flux density of PAR. This is the number of photons in the 400-700 nm waveband incident per unit time on a unit surface. The ideal PPFD sensor responds equally to all photons in the 400-700 nm waveband and has a cosine response. Units: 1 μmol s^{-1} m^{-2} ≡ 1 μE s^{-1} m^{-2} ≡ 6.022 • 1017 photons s^{-1} m^{-2} (Biggs, 2006).

9.5.3. Field Observations

The LI-192 was mounted on a modified lowering frame attached to an extendable pole. Direct attachment to the pole allowed the technician to maintain a stable depth and orientation, as well as clearance from the boat, in the advective environment of Keno Reservoir and associated sampling sites. Measurements were completed at 0.72 ft intervals between zero (<0.025 ft) and 3.54 feet. An integrating meter (LI-COR Model XYZ) was used to average observations over 15 second periods. Data were collected at the six sampling points for each of the nine sampling dates. Measurements were not completed at Miller Island on May 5th, 2005 due to time constraints.

Observations were not completed at Link Dam in September and October due to reduced water levels in Upper Klamath Lake. Further, the full range of depth measurements was not always feasible at Link Dam for the same reason. Field data are presented in below.

9.5.4. Light Extinction Coefficients

Light extinction coefficients were estimated based on field observations using the light extinction equation: $I_d = I_o e^{-kd}$ (Martin and McCutcheon, 1999), where

I_d = intensity of light at depth, d
I_o = intensity of light at the surface
k = light extinction coefficient (1/ft)

d = depth (ft)

An exponential curve was fit to each data set to determine the k values for each data and site (Table 24). Values vary from 0.4048/ft to 1.583/ft, with a mean of 0.777 for all sites (n=51). The data suggest there is variability in space and time. Light extinction generally diminishes in the downstream direction with the largest declines above the KSD, as depicted in box and whisker plots (Figure 84 and Figure 85). It is also evident that the upstream locations experience wider variability than the downstream locations, possibly associated with variable conditions occurring in Upper Klamath Lake through the sampling period. The KSD mean light extinction is of similar magnitude with Link Dam and Miller Island, but with notably less variability. Seasonal variations are also apparent, with higher mean light extinction values and greater variability in the summer period, versus the late spring and early fall.

Table 24. Calculated light extinction coefficients: Keno Reservoir and environs: 2006

Site	River Mile	Light Extinction Coefficients, 1/ft								
		5/3/05	**6/7/05**	**6/28/05**	**7/12/05**	**7/26/05**	**8/9/05**	**8/23/05**	**9/20/05**	**10/18/05**
Link Dam	253.1	0.5771	0.6171	0.5600	1.503	1.034	1.050	1.099	N/A	N/A
Klamath River at Railroad Bridge	251.7	0.4048	0.4361	1.065	1.189	0.8056	1.005	1.583	1.191	0.7213
Klamath River at Miller Island	245.6	N/A	0.5470	0.8451	0.5876	0.4998	0.8632	0.8472	1.059	0.5656
KRS12A	239.0	0.7073	0.5628	0.5357	0.4299	0.6862	0.7065	0.6270	0.4984	0.5189
Klamath River at Keno	234.9	0.5763	0.6133	0.5997	0.4449	0.6477	0.7054	0.5386	0.5351	0.5370
KSD	240.5	0.8000	0.7845	1.083	1.146	0.9510	1.086	0.7983	0.9978	0.8491

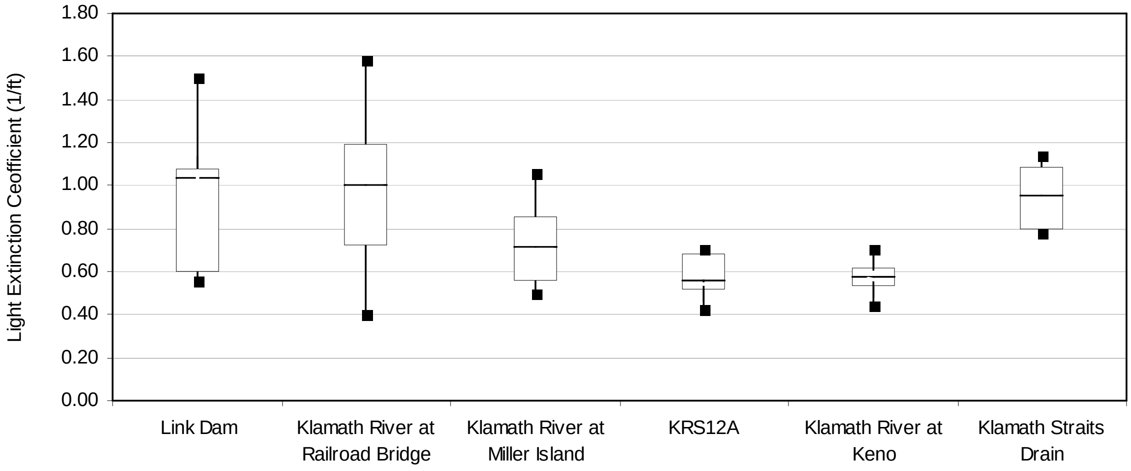


Figure 84. Box and whisker plots of light extinction by location

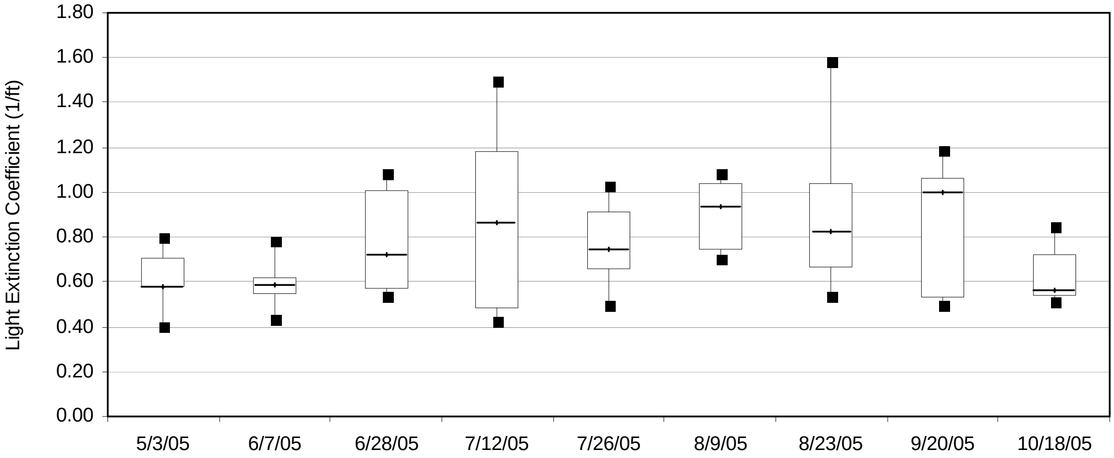
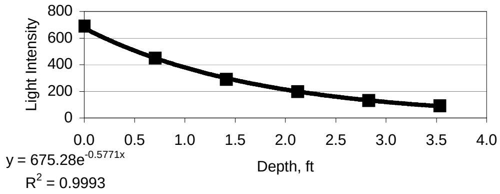


Figure 85. Box and whisker plots of light extinction by date

5/3/2005 8:05

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	688.8	100%
1	0.71	450	65%
2	1.41	290	42%
3	2.12	198	29%
4	2.83	130	19%
5	3.54	90	13%



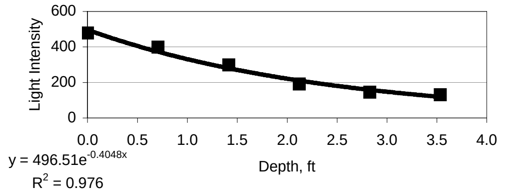
Light Extinction Coefficient = 0.5771

R2 = 0.9993

5/3/2005 16:00

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	478.7	100%
1	0.71	398.8	83%
2	1.41	299.1	62%
3	2.12	190.8	40%
4	2.83	144.8	30%
5	3.54	129.7	27%



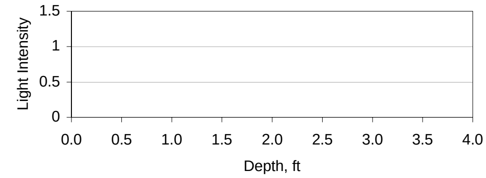
Light Extinction Coefficient = 0.4048

R2 = 0.976

5/3/2005 14:40

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00		N/A
1	0.71		N/A
2	1.41		N/A
3	2.12		N/A
4	2.83		N/A
5	3.54		N/A



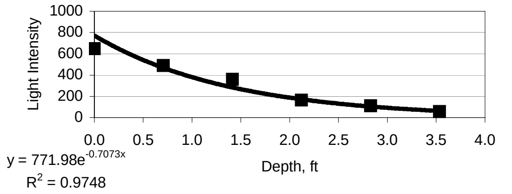
Light Extinction Coefficient = N/A

R2 = N/A

5/3/2005 12:10

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	646.9	100%
1	0.71	490.3	76%
2	1.41	360.8	56%
3	2.12	165.3	26%
4	2.83	111.1	17%
5	3.54	55.6	9%



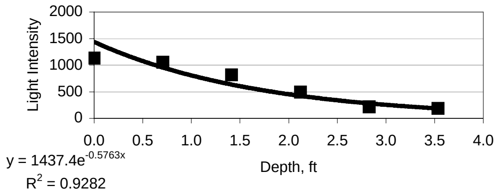
Light Extinction Coefficient = 0.7073

R2 = 0.9748

5/3/2005 10:35

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1134.5	100%
1	0.71	1053.7	93%
2	1.41	819.4	72%
3	2.12	493.1	43%
4	2.83	215.3	19%
5	3.54	187.9	17%



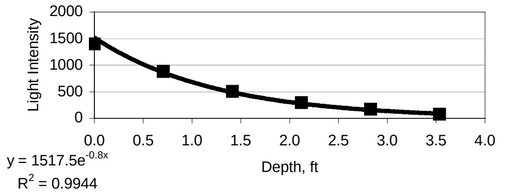
Light Extinction Coefficient = 0.5763

R2 = 0.9282

5/3/2005 13:01

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1398.5	100%
1	0.71	883.2	63%
2	1.41	508.4	36%
3	2.12	295.6	21%
4	2.83	170.3	12%
5	3.54	79.8	6%



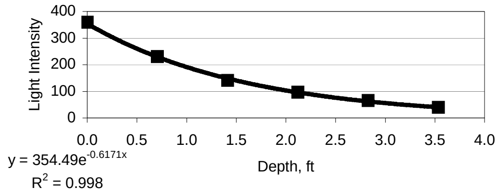
Light Extinction Coefficient = 0.8000

R2 = 0.9944

6/7/2005 7:55

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	359.7	100%
1	0.71	230.4	64%
2	1.41	140.4	39%
3	2.12	96.4	27%
4	2.83	65.2	18%
5	3.54	39	11%



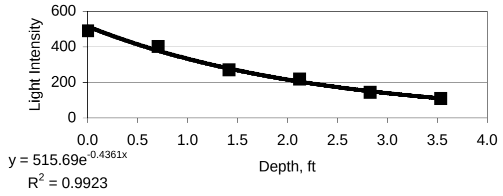
Light Extinction Coefficient = 0.6171

R2 = 0.9980

6/7/2005 15:20

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	490.7	100%
1	0.71	402	82%
2	1.41	269.9	55%
3	2.12	218.9	45%
4	2.83	145.4	30%
5	3.54	108.8	22%



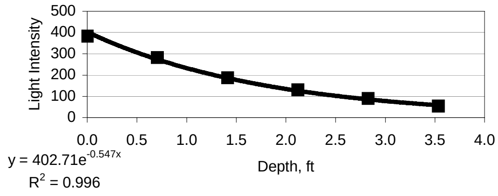
Light Extinction Coefficient = 0.4361

R2 = 0.9923

6/7/2005 14:25

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	383.2	100%
1	0.71	282.6	74%
2	1.41	186.6	49%
3	2.12	130	34%
4	2.83	89.7	23%
5	3.54	54.7	14%



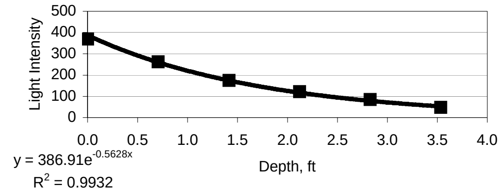
Light Extinction Coefficient = 0.5470

R2 = 0.9960

6/7/2005 11:50

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	370	100%
1	0.71	262.8	71%
2	1.41	175.3	47%
3	2.12	122.5	33%
4	2.83	85.2	23%
5	3.54	48.2	13%



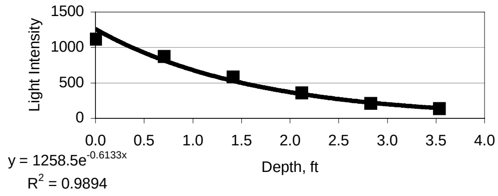
Light Extinction Coefficient = 0.5628

R2 = 0.9932

6/7/2005 10:15

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1115.1	100%
1	0.71	871.9	78%
2	1.41	582.1	52%
3	2.12	360.1	32%
4	2.83	211.1	19%
5	3.54	138.1	12%



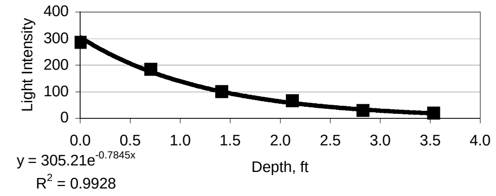
Light Extinction Coefficient = 0.6133

R2 = 0.9894

6/7/2005 12:40

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	285.6	100%
1	0.71	184.3	65%
2	1.41	100.6	35%
3	2.12	65.7	23%
4	2.83	29.3	10%
5	3.54	19.3	7%



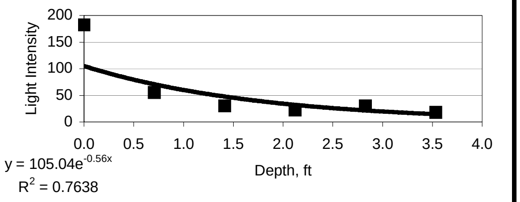
Light Extinction Coefficient = 0.7845

R2 = 0.9928

6/28/2005

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	182.4	100%
1	0.71	55.2	30%
2	1.41	30.1	17%
3	2.12	22.3	12%
4	2.83	29.9	16%
5	3.54	17.5	10%



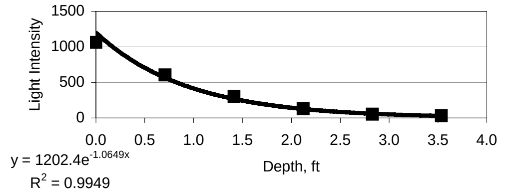
Light Extinction Coefficient = 0.5600

R2 = 0.7638

6/28/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1065.6	100%
1	0.71	605.3	57%
2	1.41	304	29%
3	2.12	129.45	12%
4	2.83	52.7	5%
5	3.54	28.1	3%



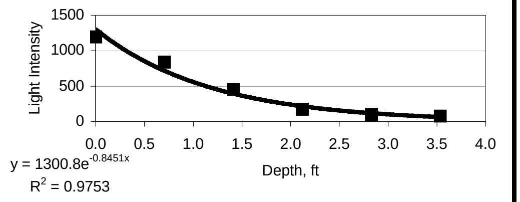
Light Extinction Coefficient = 1.065

R2 = 0.9949

6/28/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1192.9	100%
1	0.71	839.9	70%
2	1.41	449.7	38%
3	2.12	173.7	15%
4	2.83	101.1	8%
5	3.54	78.4	7%



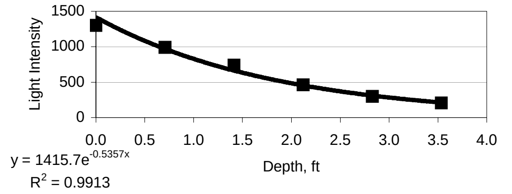
Light Extinction Coefficient = 0.8451

R2 = 0.9753

6/28/2005

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1301.3	100%
1	0.71	991.3	76%
2	1.41	740	57%
3	2.12	463.1	36%
4	2.83	301	23%
5	3.54	206.1	16%



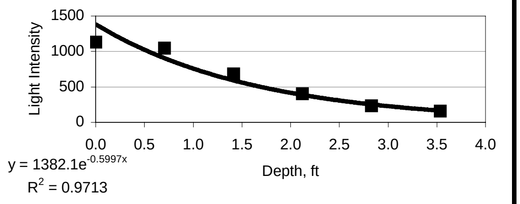
Light Extinction Coefficient = 0.5357

R2 = 0.9913

6/28/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1129	100%
1	0.71	1045.5	93%
2	1.41	682.3	60%
3	2.12	404.4	36%
4	2.83	233.6	21%
5	3.54	158.3	14%



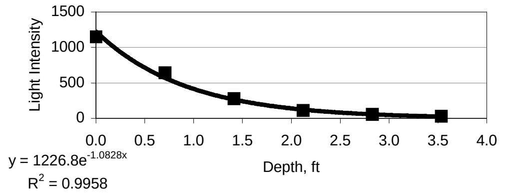
Light Extinction Coefficient = 0.5997

R2 = 0.9713

6/28/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1148.1	100%
1	0.71	643.5	56%
2	1.41	278.1	24%
3	2.12	109.7	10%
4	2.83	54.2	5%
5	3.54	28.7	2%



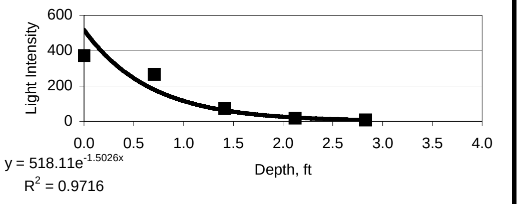
Light Extinction Coefficient = 1.083

R2 = 0.9958

7/12/2005

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	372	100%
1	0.71	265.4	71%
2	1.41	73.1	20%
3	2.12	17.7	5%
4	2.83	7.1	2%
5	3.54		N/A

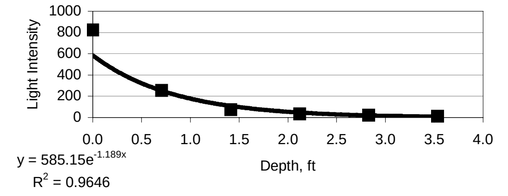


Light Extinction Coefficient = 1.503
R2 = 0.9716

7/12/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	823.5	100%
1	0.71	253.8	31%
2	1.41	73.2	9%
3	2.12	34.6	4%
4	2.83	21.8	3%
5	3.54	11.6	1%

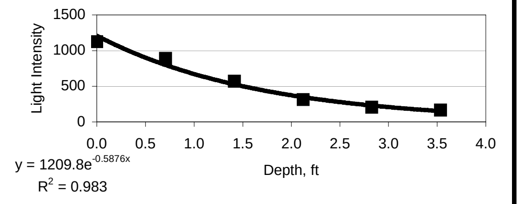


Light Extinction Coefficient = 1.189
R2 = 0.9646

7/12/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1126.3	100%
1	0.71	891.4	79%
2	1.41	568.1	50%
3	2.12	314	28%
4	2.83	207.1	18%
5	3.54	166.1	15%

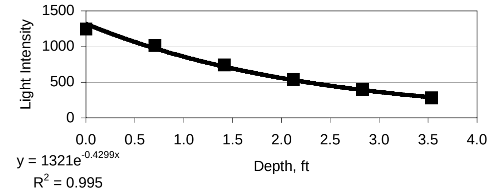


Light Extinction Coefficient = 0.5876
R2 = 0.9830

7/12/2005

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1245.7	100%
1	0.71	1015.2	81%
2	1.41	742.7	60%
3	2.12	535.3	43%
4	2.83	398.3	32%
5	3.54	277.7	22%

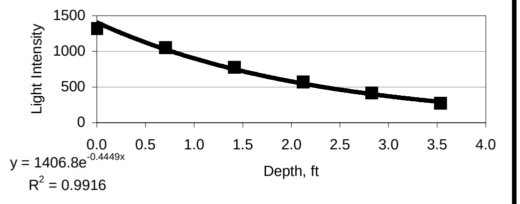


Light Extinction Coefficient = 0.4299
R2 = 0.9950

7/12/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1318.7	100%
1	0.71	1052.1	80%
2	1.41	777.1	59%
3	2.12	570.8	43%
4	2.83	414.9	31%
5	3.54	271.1	21%

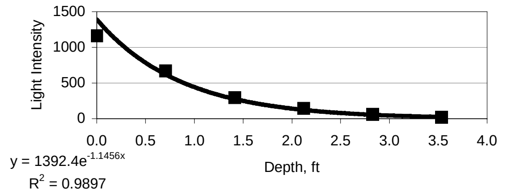


Light Extinction Coefficient = 0.4449
R2 = 0.9916

7/12/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1161.1	100%
1	0.71	669.2	58%
2	1.41	293.7	25%
3	2.12	143.6	12%
4	2.83	59.6	5%
5	3.54	19.7	2%

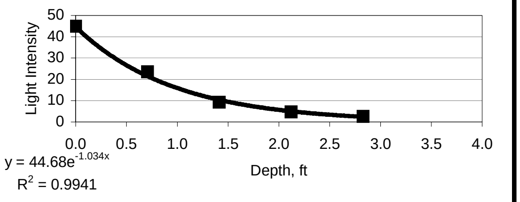


Light Extinction Coefficient = 1.146
R2 = 0.9897

7/26/2005

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	45	100%
1	0.71	23.5	52%
2	1.41	9.2	20%
3	2.12	4.7	10%
4	2.83	2.6	6%
5	3.54		N/A



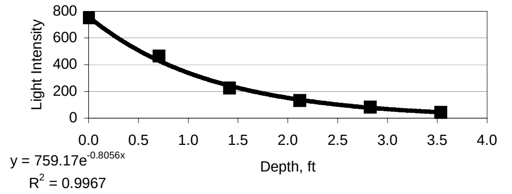
Light Extinction Coefficient = 1.034

R2 = 0.9941

7/26/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	751	100%
1	0.71	465	62%
2	1.41	225	30%
3	2.12	131	17%
4	2.83	82.8	11%
5	3.54	43.7	6%



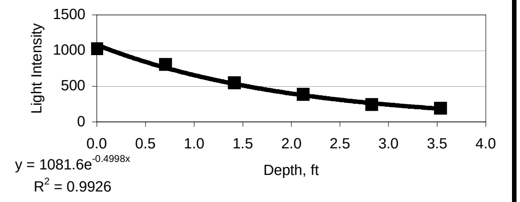
Light Extinction Coefficient = 0.8056

R2 = 0.9967

7/26/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1025	100%
1	0.71	805	79%
2	1.41	546	53%
3	2.12	385	38%
4	2.83	241	24%
5	3.54	191	19%



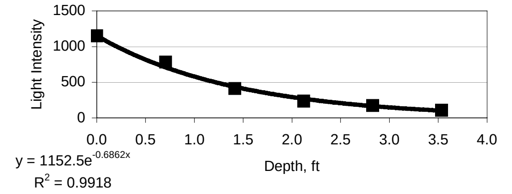
Light Extinction Coefficient = 0.4998

R2 = 0.9926

7/26/2005

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1150	100%
1	0.71	784	68%
2	1.41	413	36%
3	2.12	236	21%
4	2.83	172	15%
5	3.54	107	9%



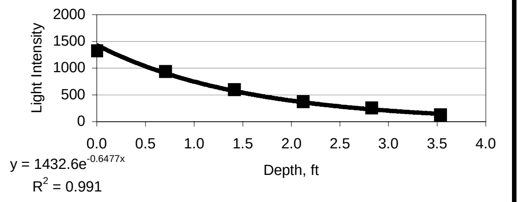
Light Extinction Coefficient = 0.6862

R2 = 0.9918

7/26/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1325	100%
1	0.71	935	71%
2	1.41	596	45%
3	2.12	371	28%
4	2.83	254	19%
5	3.54	129	10%



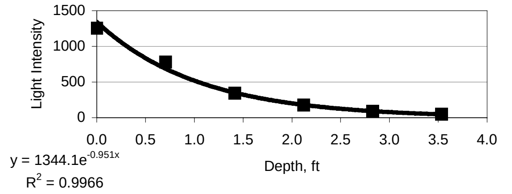
Light Extinction Coefficient = 0.6477

R2 = 0.9910

7/26/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1255	100%
1	0.71	781.2	62%
2	1.41	341	27%
3	2.12	175	14%
4	2.83	86.5	7%
5	3.54	48.5	4%



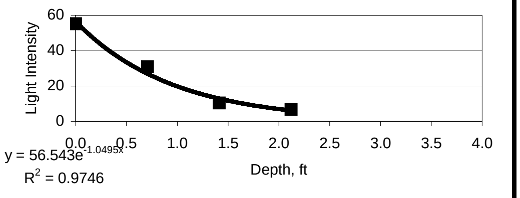
Light Extinction Coefficient = 0.9510

R2 = 0.9966

8/9/2005

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	55.3	100%
1	0.71	30.9	56%
2	1.41	10.4	19%
3	2.12	6.7	12%
4	2.83		N/A
5	3.54		N/A

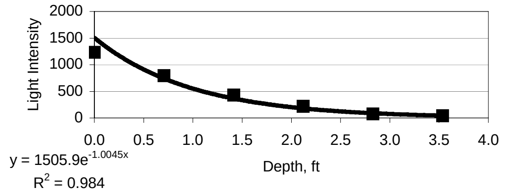


Light Extinction Coefficient = 1.050
R2 = 0.9746

8/9/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1229.2	100%
1	0.71	794.5	65%
2	1.41	430	35%
3	2.12	217.5	18%
4	2.83	74.8	6%
5	3.54	40.3	3%

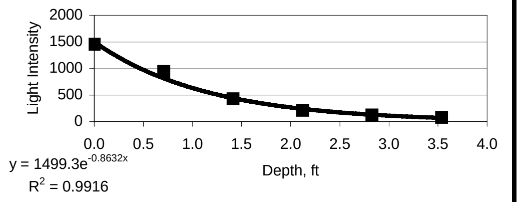


Light Extinction Coefficient = 1.005
R2 = 0.9840

8/9/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1454.9	100%
1	0.71	939.1	65%
2	1.41	426.8	29%
3	2.12	212.9	15%
4	2.83	121.6	8%
5	3.54	79.5	5%

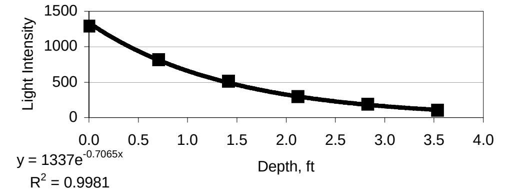


Light Extinction Coefficient = 0.8632
R2 = 0.9916

8/9/2005

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1289.4	100%
1	0.71	817.6	63%
2	1.41	514.7	40%
3	2.12	294.1	23%
4	2.83	190.2	15%
5	3.54	104.8	8%

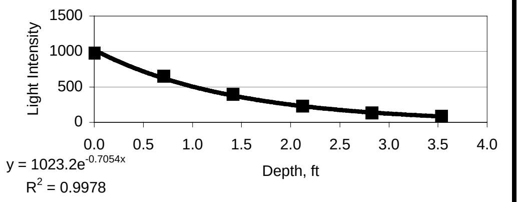


Light Extinction Coefficient = 0.7065
R2 = 0.9981

8/9/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	974.9	100%
1	0.71	650.8	67%
2	1.41	393.5	40%
3	2.12	227.5	23%
4	2.83	131.7	14%
5	3.54	86.4	9%

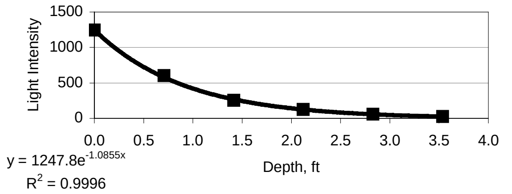


Light Extinction Coefficient = 0.7054
R2 = 0.9978

8/9/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1243.5	100%
1	0.71	601.8	48%
2	1.41	255.9	21%
3	2.12	124.5	10%
4	2.83	58.8	5%
5	3.54	26.9	2%

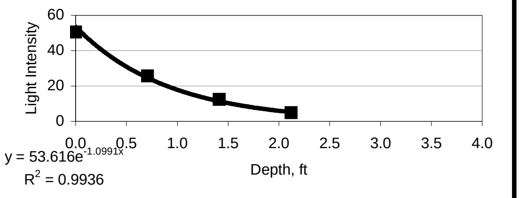


Light Extinction Coefficient = 1.086
R2 = 0.9996

8/23/2005

Link Dam

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	50.61	100%
1	0.71	25.65	51%
2	1.41	12.44	25%
3	2.12	4.83	10%
4	2.83		N/A
5	3.54		N/A

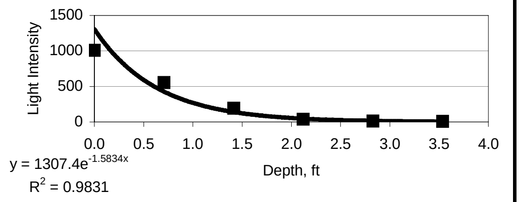


Light Extinction Coefficient = 1.099
R2 = 0.9936

8/23/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1009.9	100%
1	0.71	553.8	55%
2	1.41	190.9	19%
3	2.12	36.6	4%
4	2.83	11.4	1%
5	3.54	5.7	1%

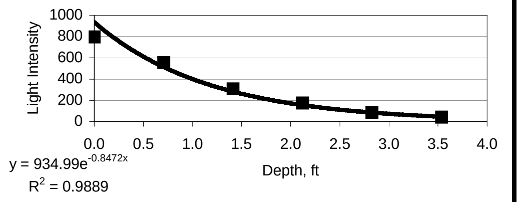


Light Extinction Coefficient = 1.583
R2 = 0.9831

8/23/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	796	100%
1	0.71	553	69%
2	1.41	307	39%
3	2.12	175	22%
4	2.83	86.2	11%
5	3.54	41	5%

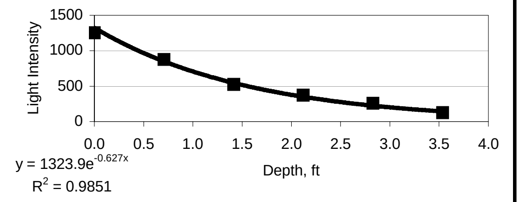


Light Extinction Coefficient = 0.8472
R2 = 0.9889

8/23/2005

KRS12A

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1251.3	100%
1	0.71	873.8	70%
2	1.41	526.2	42%
3	2.12	374.5	30%
4	2.83	259.5	21%
5	3.54	124.6	10%

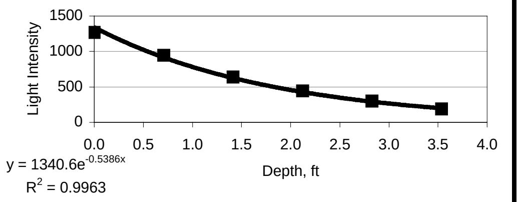


Light Extinction Coefficient = 0.6270
R2 = 0.9851

8/23/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1267	100%
1	0.71	945.2	75%
2	1.41	638.2	50%
3	2.12	444.9	35%
4	2.83	298	24%
5	3.54	189.3	15%

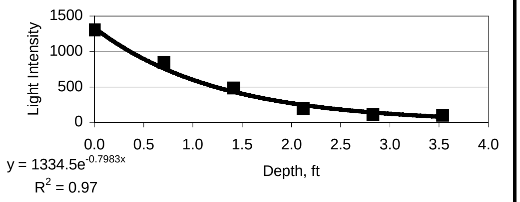


Light Extinction Coefficient = 0.5386
R2 = 0.9963

8/23/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, μmol/s-m^2	% of surface Intensity
surface	0.00	1305.1	100%
1	0.71	840.7	64%
2	1.41	484.7	37%
3	2.12	197.6	15%
4	2.83	112.6	9%
5	3.54	100.3	8%

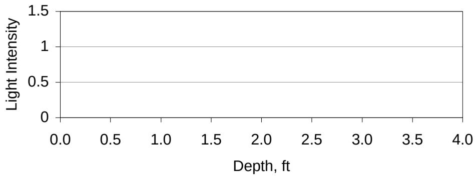


Light Extinction Coefficient = 0.7983
R2 = 0.9700

9/20/2005 *Lake level too low to take light measurements*

Link Dam

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00		N/A
1	0.71		N/A
2	1.41		N/A
3	2.12		N/A
4	2.83		N/A
5	3.54		N/A

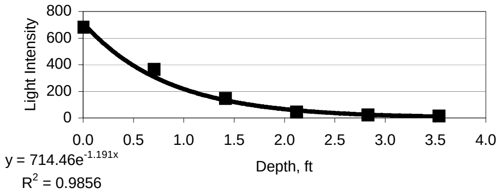


Light Extinction Coefficient =
R2 =

9/20/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00	680.8	100%
1	0.71	363.6	53%
2	1.41	145.2	21%
3	2.12	43.3	6%
4	2.83	21.3	3%
5	3.54	13.1	2%

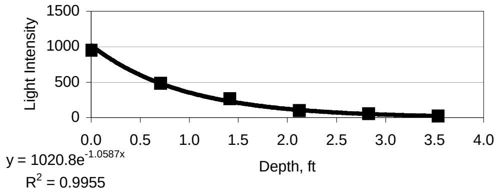


Light Extinction Coefficient = 1.191
R2 = 0.9856

9/20/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00	950.4	100%
1	0.71	485.4	51%
2	1.41	266.6	28%
3	2.12	98.4	10%
4	2.83	54.2	6%
5	3.54	22.9	2%

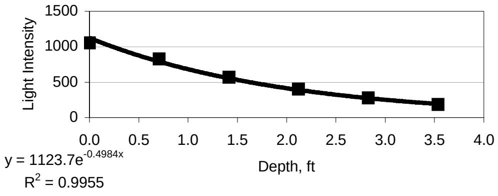


Light Extinction Coefficient = 1.059
R2 = 0.9955

9/20/2005

KRS12A

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00	1052.8	100%
1	0.71	827.2	79%
2	1.41	569.5	54%
3	2.12	401.9	38%
4	2.83	276.6	26%
5	3.54	184.8	18%

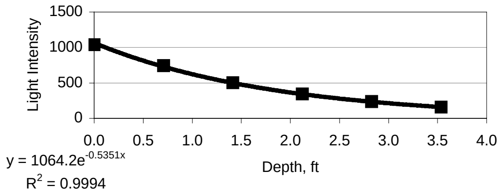


Light Extinction Coefficient = 0.4984
R2 = 0.9955

9/20/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00	1039.8	100%
1	0.71	741.1	71%
2	1.41	503.4	48%
3	2.12	344.2	33%
4	2.83	237.3	23%
5	3.54	157.2	15%

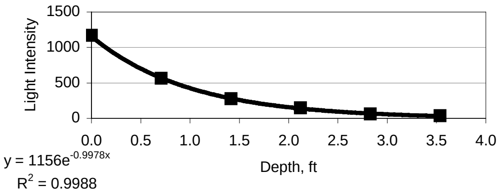


Light Extinction Coefficient = 0.5351
R2 = 0.9994

9/20/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, µmol/s-m^2	% of surface Intensity
surface	0.00	1170.3	100%
1	0.71	564	48%
2	1.41	277.7	24%
3	2.12	146.8	13%
4	2.83	63.8	5%
5	3.54	35.2	3%

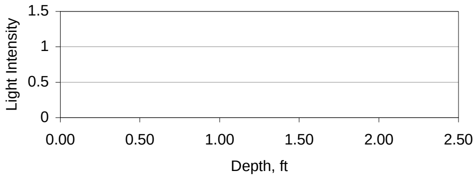


Light Extinction Coefficient = 0.9978
R2 = 0.9988

10/18/2005 *Lake level too low to take light measurements*

Link Dam

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00		N/A
1	0.71		N/A
2	1.41		N/A
3	2.12		N/A
4	2.83		N/A
5	3.54		N/A

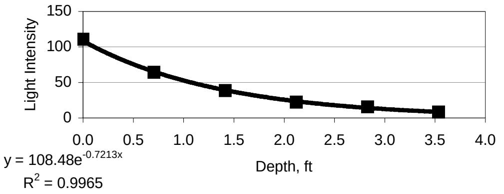


Light Extinction Coefficient =
R2 =

10/18/2005

Klamath River at Railroad Bridge

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00	110.98	100%
1	0.71	64.43	58%
2	1.41	38.32	35%
3	2.12	22.22	20%
4	2.83	15.63	14%
5	3.54	8.15	7%

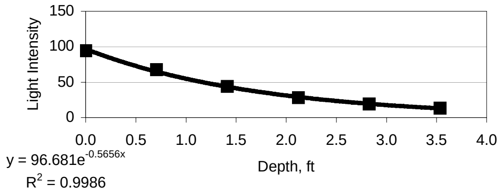


Light Extinction Coefficient = 0.7213
R2 = 0.9965

10/18/2005

Klamath River at Miller Island

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00	94.17	100%
1	0.71	67.49	72%
2	1.41	44.07	47%
3	2.12	28.24	30%
4	2.83	19.31	21%
5	3.54	13.27	14%

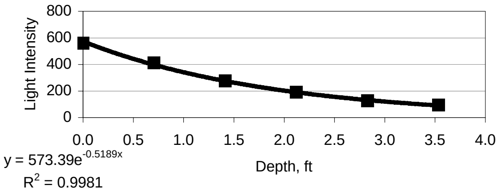


Light Extinction Coefficient = 0.5656
R2 = 0.9986

10/18/2005

KRS12A

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00	559.2	100%
1	0.71	412.5	74%
2	1.41	276.8	49%
3	2.12	190.76	34%
4	2.83	126.76	23%
5	3.54	93.76	17%

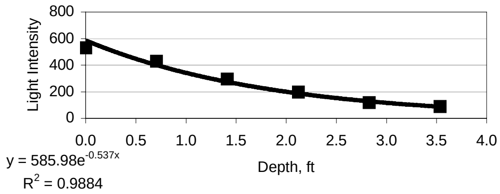


Light Extinction Coefficient = 0.5189
R2 = 0.9981

10/18/2005

Klamath River at Keno

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00	530.9	100%
1	0.71	428.7	81%
2	1.41	294.8	56%
3	2.12	196.77	37%
4	2.83	117.5	22%
5	3.54	87.72	17%

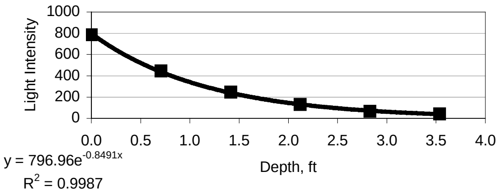


Light Extinction Coefficient = 0.5370
R2 = 0.9884

10/18/2005

Klamath Straits Drain

Mark, ft	Depth, ft	Intensity, $\mu mol/s\text{-}m^2$	% of surface Intensity
surface	0.00	785.2	100%
1	0.71	445.8	57%
2	1.41	246.2	31%
3	2.12	130.7	17%
4	2.83	67.35	9%
5	3.54	41.41	5%



Light Extinction Coefficient = 0.8491
R2 = 0.9987

Figure 86. Light extinction data and coefficient calculations

9.6. *Appendix F: BOD, Nutrient, and Other Data*

				< 10.0 um BOD5	< 1.0 um BOD5	< 0.45 um BOD5	BOD5	BOD10	< 0.45 um BOD10	COD	< 0.45 um COD	TOC	NH4	NO3-NO2	TKN	TP	OPO4	TSS
Bottle ID	Date	Time	Site Name	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
KW102	5/3/2005	8:05	Link Dam	ND	ND	ND	ND	ND	ND	ND	ND	5.3	0.2	0.06	0.7	0.03	0.02	4
KW103	5/3/2005	16:00	Klamath River at Railroad Bridge			ND	ND			ND	ND	5.2	0.22	0.09	0.7	0.08	0.06	4
KW106	5/3/2005	14:40	Klamath River at Miller Island	6		ND	5			5	ND	5.8	0.28	0.07	0.9	0.2	0.1	8
KW107	5/3/2005	10:35	Klamath River at Keno	ND		ND	ND			ND	7	11	0.32	0.1	1.2	0.2	0.15	6
KW108	5/3/2005	12:10	KRS12A	ND		ND	4			4	4	9	0.33	0.08	1.4	0.24	0.15	7
KW101	5/3/2005	13:05	Klamath Straits Drain	4		ND	5			32	28	22	0.46	0.16	2.5	0.44	0.31	15
KW111	6/7/2005	7:55	Link Dam	ND		ND	3	5	ND	23	16		0.1	0.03	1.2	0.11	0.01	10
KW112	6/7/2005	15:20	Klamath River at Railroad Bridge	ND		ND	4			19	19		0.13	0.03	1.1	0.08	0.01	9
KW115	6/7/2005	14:25	Klamath River at Miller Island	ND		ND	3			26	35		0.19	0.03	1.1	0.1	0.02	8
KW116	6/7/2005	10:15	Klamath River at Keno	ND		ND	ND			28	21		0.18	0.04	1.2	0.15	0.07	9
KW117	6/7/2005	11:50	KRS12A	ND		ND	4			31	20		0.13	0.03	1.3	0.13	0.06	8
KW110	6/7/2005	12:40	Klamath Straits Drain	6		ND	3			66	57		0.46	0.15	2.6	0.31	0.17	21
KW120	6/28/2005	7:55	Link Dam	3	ND	ND	8	14	ND	37	14	6.8	0.35	0.03	2.2	0.06	ND	16
KW121	6/28/2005	9:20	Klamath River at Railroad Bridge	5	5	ND	15			45	9	7.2	1.14	0.06	2.4	0.06	0.02	16
KW124	6/28/2005	10:30	Klamath River at Miller Island	ND	ND	ND	11			38	14	7.6	0.53	0.06	2	0.08	0.01	16
KW125	6/28/2005	12:50	Klamath River at Keno	ND	ND	ND	5			38	25	9.3	0.77	0.05	1.6	0.14	0.13	8
KW126	6/28/2005	11:35	KRS12A	ND	ND	ND	10			50	28	12	1.02	0.04	2.1	0.15	0.04	11
KW119	6/28/2005	14:05	Klamath Straits Drain	5	ND	3	7			64	58	32	0.72	0.09	2.3	0.41	0.33	11
KW129	7/12/2005	8:00	Link Dam			ND	12			49	20	9.4	0.17	0.02	2.4	0.13	0.02	11
KW130	7/12/2005	9:25	Klamath River at Railroad Bridge			ND	17			46	22	9.4	0.27	0.03	2.7	0.12	0.04	11
KW133	7/12/2005	10:35	Klamath River at Miller Island			ND	8			34	23	9.8	0.57	ND	2.3	0.16	0.06	10
KW134	7/12/2005	12:50	Klamath River at Keno			ND	3			27	26	11	1.07	0.02	2.5	0.31	0.27	2

Bottle ID	Date	Time	Site Name	< 10.0 um BOD5 mg/l	< 1.0 um BOD5 mg/l	< 0.45 um BOD5 mg/l	BOD5 mg/l	BOD10 mg/l	< 0.45 um BOD10 mg/l	COD mg/l	< 0.45 um COD mg/l	TOC mg/l	NH4 mg/l	NO3-NO2 mg/l	TKN mg/l	TP mg/l	OPO4 mg/l	TSS mg/l
KW135	7/12/2005	11:25	KRS12A			6	5			27	26	11	1.09	ND	2.3	0.28	0.24	2
KW128	7/12/2005	14:00	Klamath Straits Drain			ND	5			57	58	28	1.02	0.08	2.8	0.36	0.3	8
KW138	7/26/2005	7:40	Link Dam	4	ND	ND	19	38	7	44	17	9.5	0.13	0.02	2.8	0.17	0.06	12
KW139	7/26/2005	9:20	Klamath River at Railroad Bridge	4	ND	ND	10			38	23	9.1	0.67	0.03	2.6	0.15	0.09	13
KW142	7/26/2005	10:20	Klamath River at Miller Island	6	ND	3	8			35	27	9.4	1.95	ND	3	0.2	0.12	7
KW143	7/26/2005	13:15	Klamath River at Keno	8	4	ND	9			37	25	21	2.04	ND	3.5	0.25	0.15	5
KW144	7/26/2005	11:30	KRS12A	10	4	ND	13			42	27	10	2.15	ND	3.6	0.23	0.13	6
KW137	7/26/2005	14:15	Klamath Straits Drain	4	4	ND	5			53	45	21	1.07	0.14	2.6	0.57	0.49	11
KW147	8/9/2005	7:45	Link Dam			ND	12			39	27	12	0.15	0.03	2.8	0.18	0.06	10
KW148	8/9/2005	14:30	Klamath River at Railroad Bridge			ND	14			40	19	10	0.44	0.04	2.9	0.25	0.07	12
KW151	8/9/2005	13:30	Klamath River at Miller Island			ND	10			54	28	12	0.93	ND	3.9	0.31	0.11	11
KW152	8/9/2005	9:45	Klamath River at Keno			ND	7			37	28	14	1.58	ND	3.5	0.34	0.18	3
KW153	8/9/2005	11:10	KRS12A			ND	9			43	34	14	1.11	ND	2.9	0.29	0.17	5
KW146	8/9/2005	12:00	Klamath Straits Drain			ND	6			70	65	27	1.08	0.07	3.6	0.63	0.48	11
KW156	8/23/2005	7:45	Link Dam	ND	ND	ND	10	17	ND	41	22	12	0.23	0.03	2.7	0.15	ND	11
KW157	8/23/2005	14:45	Klamath River at Railroad Bridge	ND	ND	ND	33			32	22	16	0.37	0.06	4.8	0.31	ND	16
KW160	8/23/2005	9:35	Klamath River at Miller Island	4	ND	ND	11			35	23	12	0.94	0.03	2.7	0.19	0.04	8
KW161	8/23/2005	12:50	Klamath River at Keno	ND	ND	ND	6			27	17	10	0.55	0.04	1.9	0.15	0.05	4
KW162	8/23/2005	13:45	KRS12A	4	ND	ND	10			29	28	11	0.87	ND	2.8	0.21	0.08	6
KW155	8/23/2005	10:55	Klamath Straits Drain	4	ND	ND	4			43	49	18	1	0.16	2.6	0.44	0.33	6
KW165	9/20/2005	7:50	Link Dam	4	4	ND	22	31	ND	70	30	14	0.26	ND	4.8	0.29	0.05	15
KW166	9/20/2005	9:20	Klamath River at Railroad Bridge	4	5	ND	22			64	24	16	0.72	0.03	4.1	0.26	0.03	13
KW169	9/20/2005	10:20	Klamath River at Miller Island	ND	ND	ND	13			41	28	12	1.12	0.05	3	0.21	0.02	5
KW170	9/20/2005	13:45	Klamath River at Keno	ND	ND	ND	ND			35	31	12	1.61	0.06	2.5	0.23	0.11	3
KW171	9/20/2005	13:00	KRS12A	ND	ND	ND	ND			34	31	11	1.32	0.05	2.3	0.16	0.06	4

Bottle ID	Date	Time	Site Name	< 10.0 um BOD5 mg/l	< 1.0 um BOD5 mg/l	< 0.45 um BOD5 mg/l	BOD5 mg/l	BOD10 mg/l	< 0.45 um BOD10 mg/l	COD mg/l	< 0.45 um COD mg/l	TOC mg/l	NH4 mg/l	NO3-NO2 mg/l	TKN mg/l	TP mg/l	OPO4 mg/l	TSS mg/l
KW164	9/20/2005	11:30	Klamath Straits Drain	5	4	ND	7			43	44	16	1	0.25	2.3	0.24	0.13	11
KW174	10/18/2005	7:55	Link Dam	ND	ND	ND	6	14	ND	37	24	9.7	0.25	0.07	1.3	0.13	ND	9
KW175	10/18/2005	9:20	Klamath River at Railroad Bridge	ND	ND	ND	5			28	27	9.1	0.76	0.08	2.2	0.15	0.03	6
KW178	10/18/2005	10:15	Klamath River at Miller Island	ND	ND	ND	ND			22	22	8.9	1.22	0.04	2.1	0.13	0.06	4
KW179	10/18/2005	12:20	Klamath River at Keno	ND	ND	ND	ND			27	25	9.4	1.23	0.1	2.4	0.16	0.06	3
KW180	10/18/2005	13:15	KRS12A	ND	ND	ND	ND			20	23	9.6	1.16	0.08	2.2	0.14	0.07	4
KW173	10/18/2005	11:00	Klamath Straits Drain	ND	ND	ND	ND			34	33	16	0.84	0.61	2.2	0.18	0.11	8

9.7. Appendix G: Algal Data

9.7.1. Chlorophyll-a and Phaeophytin

Table 25. Chlorophyll-a and Phaeophyton data

Date	Site	Location	Chlorphyll (ug/L)	Pheophytin (ug/L)
5/3/2005	KW 102	Link Dam	6.3	0.7
5/3/2005	KW 103	RR Bridge	3.9	1.8
5/3/2005	KW 106	Miller Island	26.0	7.2
5/3/2005	KW 101	KSD	29.0	6.0
5/3/2005	KW 108	KRS12A	9.7	2.3
5/3/2005	KW 107	KR at Keno	8.7	3.5
6/7/2005	KW 111	Link Dam	23.4	6.7
6/7/2005	KW 112	RR Bridge	17.5	6.5
6/7/2005	KW 115	Miller Island	23.4	6.7
6/7/2005	KW 110	KSD	8.8	6.7
6/7/2005	KW 117	KRS12A	21.9	9.0
6/7/2005	KW 116	KR at Keno	11.7	5.5
6/28/2005	KW 120	Link Dam	46.7	39.0
6/28/2005	KW 121	RR Bridge	11.7	1.6
6/28/2005	KW 124	Miller Island	24.8	6.5
6/28/2005	KW 119	KSD	14.6	3.0
6/28/2005	KW 126	KRS12A	20.7	7.0
6/28/2005	KW 125	KR at Keno	13.1	4.5
7/12/05	KW 129	Link Dam	26.3	8.9
7/12/05	KW 130	RR Bridge	2.9	2.2
7/12/05	KW 133	Miller Island	2.9	2.2
7/12/05	KW 128	KSD	2.4	3.0
7/12/05	KW 135	KRS12A	1.0	0.5
7/12/05	KW 134	KR at Keno	1.0	0.5
7/26/05	KW 138	Link Dam	14.6	2.6
7/26/05	KW 139	RR Bridge	5.8	2.7
7/26/05	KW 142	Miller Island	8.8	7.6
7/26/05	KW 137	KSD	2.0	2.3
7/26/05	KW 144	KRS12A	3.7	14.0
7/26/05	KW 143	KR at Keno	3.7	6.4
8/9/05	KW 147	Link Dam	8.0	4.2
8/9/05	KW 148	RR Bridge	8.0	4.2
8/9/05	KW 151	Miller Island	2.2	14.3
8/9/05	KW 146	KSD	5.1	12.0
8/9/05	KW 153	KRS12A	2.9	13.8
8/9/05	KW 152	KR at Keno	5.8	16.4
8/23/05	KW 156	Link Dam	157.0	0.2
8/23/05	KW 157	RR Bridge	359.0	19.5
8/23/05	KW 160	Miller Island	10.2	10.4
8/23/05	KW 155	KSD	6.6	7.4
8/23/05	KW 162	KRS12A	61.0	13.4
8/23/05	KW 161	KR at Keno	10.2	8.7
9/20/05	KW 165	Link Dam	7.8	1.4
9/20/05	KW 166	RR Bridge	210.0	16.0
9/20/05	KW 169	Miller Island	2.0	8.1
9/20/05	KW 164	KSD	4.8	2.9
9/20/05	KW 171	KRS12A	1.0	6.8
9/20/05	KW 170	KR at Keno	2.9	0.8
10/18/05	KW 174	Link Dam	10.2	12.0
10/18/05	KW 175	RR Bridge	2.0	8.0
10/18/05	KW 178	Miller Island	2.0	3.5
10/18/05	KW 173	KSD	2.9	10.0
10/18/05	KW 180	KRS12A	3.4	4.5
10/18/05	KW 179	KR at Keno	2.0	2.9

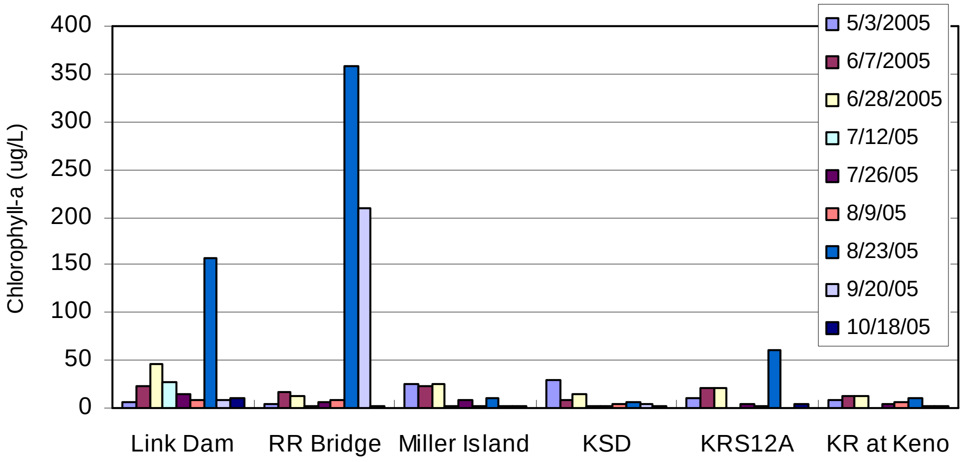


Figure 87. Chlorophyll-a during study period

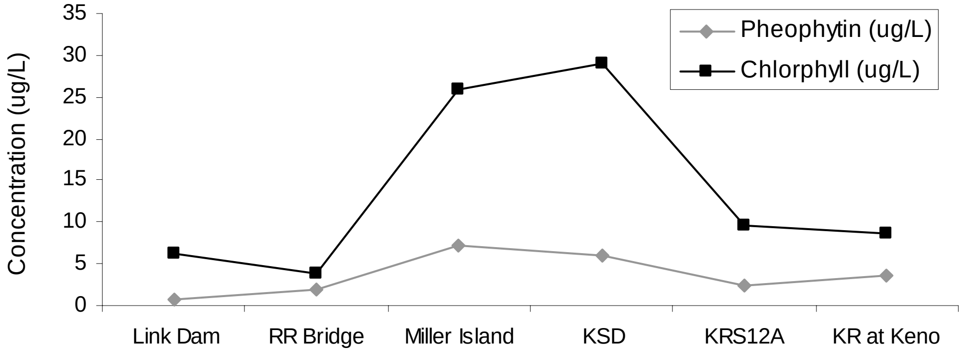


Figure 88. Chlorophyll-a on 5/3/2005

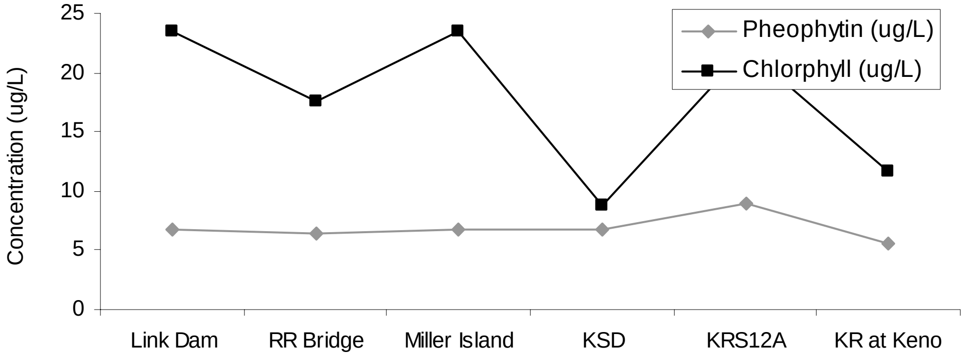


Figure 89. Chlorophyll-a on 6/7/2005

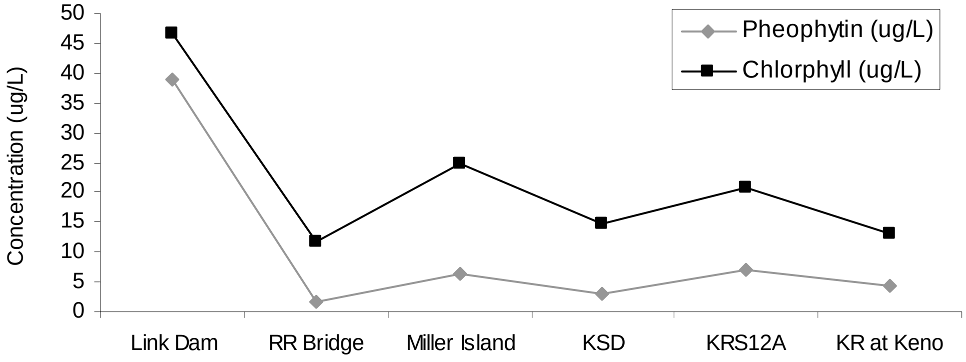


Figure 90. Chlorophyll-a on 6/28/2005

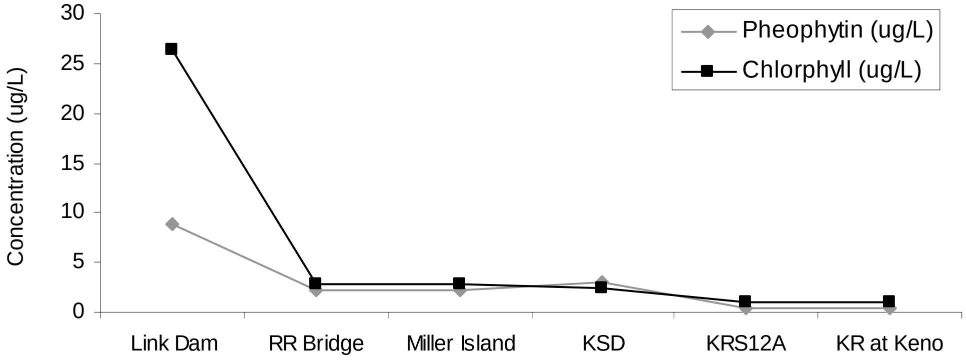


Figure 91. Chlorophyll-a on 7/12/2005

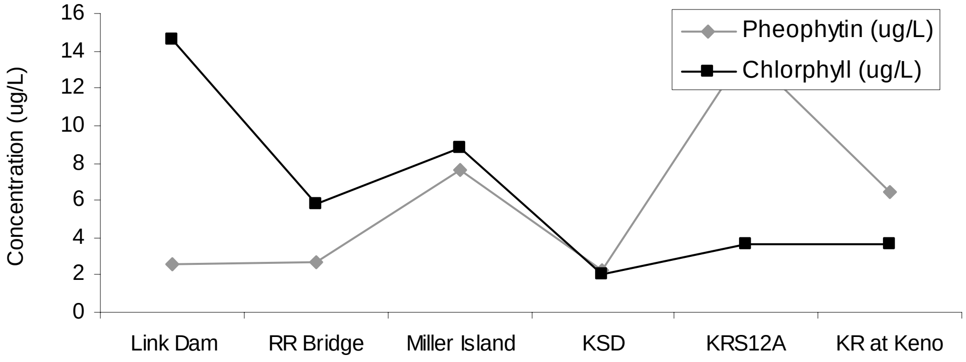


Figure 92. Chlorophyll-a on 7/26/2005

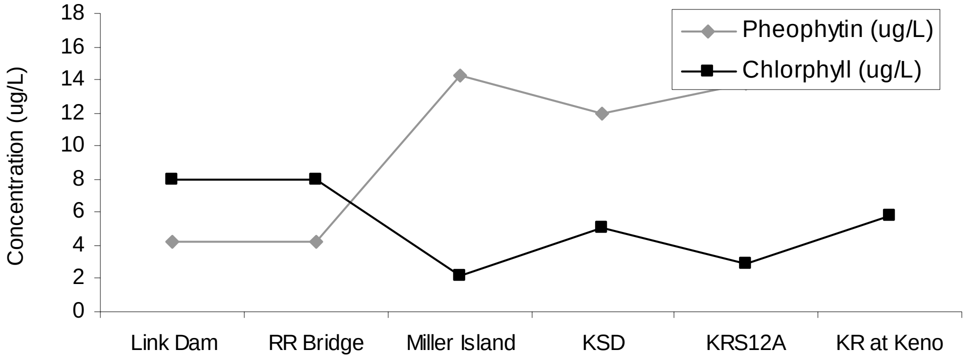


Figure 93. Chlorophyll-a on 8/9/2005

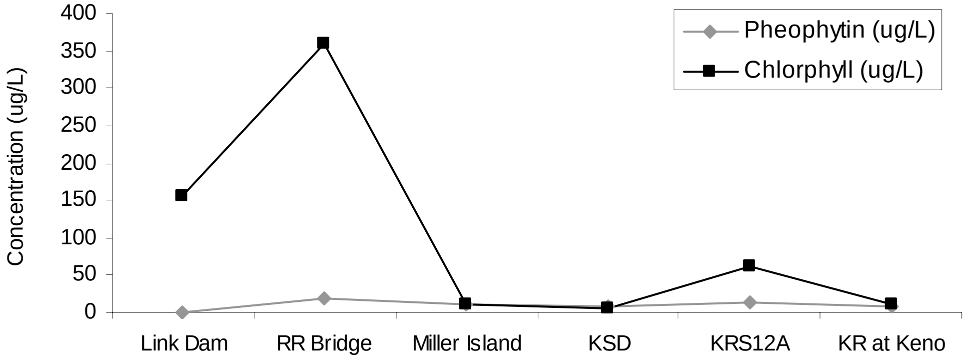


Figure 94. Chlorophyll-a on 8/23/2005

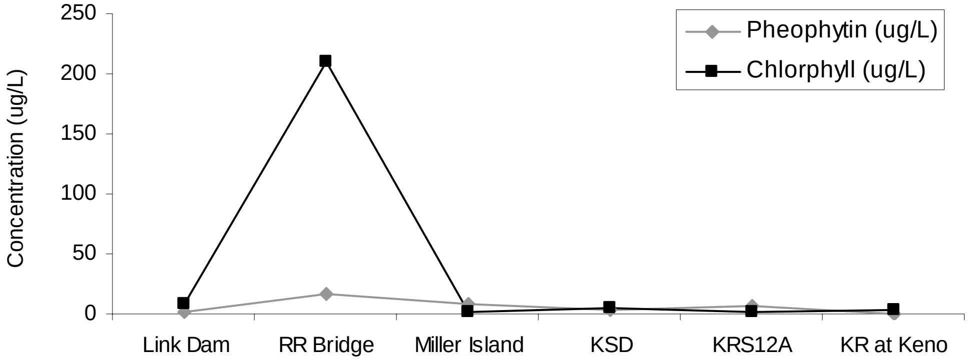


Figure 95. Chlorophyll-a on 9/20/2005

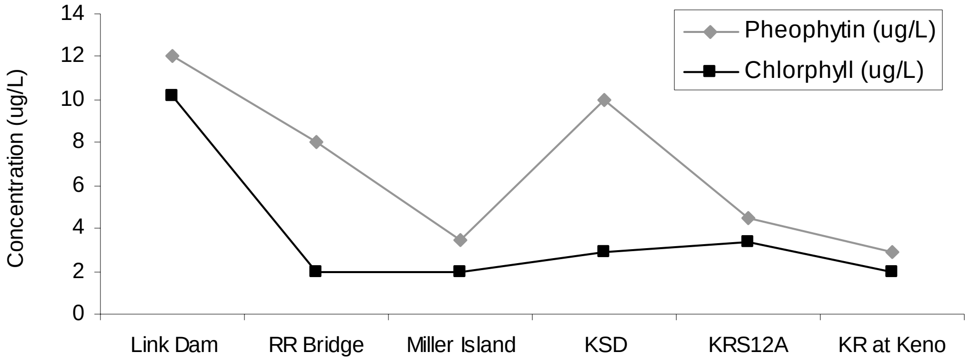
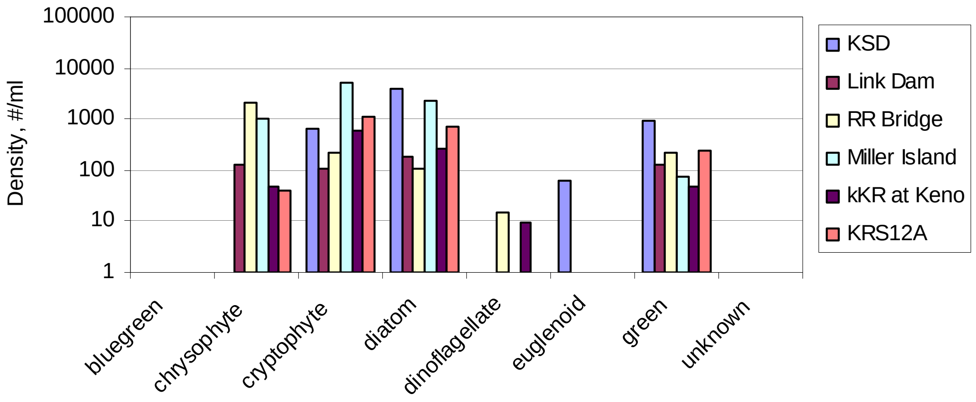


Figure 96. Chlorophyll-a on 10/18/2005

9.7.2. Species

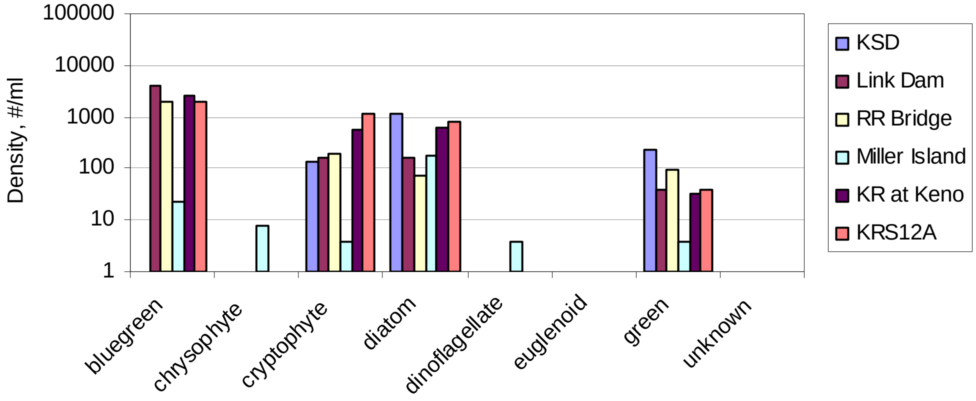
Table 26. Algal species, Keno Reservoir, May through October, 2005

Species	Group	Species	Group
Achnanthes exigua	diatom	*Mougeotia sp.*	green
Achnanthes lanceolata	diatom	*Navicula anglica*	diatom
Achnanthes minutissima	diatom	*Navicula capitata*	diatom
Actinastrum hantzschii	green	*Navicula cascadensis*	diatom
Amphora coffeiformes	diatom	*Navicula cryptocephala*	diatom
Amphora ovalis	diatom	*Navicula cryptocephala veneta*	diatom
Amphora perpusilla	diatom	*Navicula gregaria*	diatom
Anabaena flos-aquae	bluegreen	*Navicula minima*	diatom
Anabaena planctonica	bluegreen	*Navicula pupula*	diatom
Ankistrodesmus falcatus	green	*Navicula rhynchocephala*	diatom
Aphanizomenon flos-aquae	bluegreen	*Navicula sp.*	diatom
Asterionella formosa	diatom	*Nitzschia acicularis*	diatom
Ceratium hirundinella	dinoflagellate	*Nitzschia amphibia*	diatom
Chlamydomonas sp.	green	*Nitzschia capitellata*	diatom
Chodatella wratislawiensis	green	*Nitzschia communis*	diatom
Chromulina sp.	chrysophyte	*Nitzschia constricta*	diatom
Chrysococcus rufescens	chrysophyte	*Nitzschia dissipata*	diatom
Closteriopsis longissima	green	*Nitzschia fonticola*	diatom
Cocconeis placentula	diatom	*Nitzschia frustulum*	diatom
Coelastrum microporum	green	*Nitzschia linearis*	diatom
Cryptomonas erosa	cryptophyte	*Nitzschia microcephala*	diatom
Cryptomonas ovata	cryptophyte	*Nitzschia palea*	diatom
Cyclotella atomus	diatom	*Nitzschia paleacea*	diatom
Cyclotella meneghiniana	diatom	*Nitzschia sp.*	diatom
Cyclotella pseudostelligera	diatom	*Nitzschia tryblionella*	diatom
Cymbella affinis	diatom	*Oocystis pusilla*	green
Cymbella minuta	diatom	*Pediastrum boryanum*	green
Diatoma tenue	diatom	*Pediastrum duplex*	green
Diatoma vulgare	diatom	*Pediastrum tetras*	green
Euglena sp.	euglenoid	*Pinnularia sp.*	diatom
Fragilaria capucina mesolepta	diatom	*Rhodomonas minuta*	cryptophyte
Fragilaria construens	diatom	*Rhoicosphenia curvata*	diatom
Fragilaria construens venter	diatom	*Scenedesmus abundans*	green
Fragilaria pinnata	diatom	*Scenedesmus acuminatus*	green
Fragilaria vaucheria	diatom	*Scenedesmus quadricauda*	green
Fragilaria virescens	diatom	*Selenastrum minutum*	green
Glenodinium sp.	dinoflagellate	*Sphaerocystis schroeteri*	green
Gloeocystis sp.	green	*Stauroneis sp.*	diatom
Gomphonema angustatum	diatom	*Stephanodiscus astraea minutula*	diatom
Gomphonema olivaceum	diatom	*Stephanodiscus hantzschii*	diatom
Gomphonema sp.	diatom	*Surirella linearis*	diatom
Gomphonema subclavatum	diatom	*Surirella ovata*	diatom
Gomphonema ventricosum	diatom	*Synedra cyclopum*	diatom
Hantzschia amphioxys	diatom	*Synedra parasitica*	diatom
Kephyrion littorale	chrysophyte	*Synedra rumpens*	diatom
Kephyrion sp.	chrysophyte	*Synedra tenera*	diatom
Mallomonas sp.	chrysophyte	*Synedra ulna*	diatom
Melosira ambigua	diatom	*Tetraedron minimum*	green
Melosira granulata	diatom	*Tetrastrum staurogeniaforme*	green
Melosira granulata angustissima	diatom	*Trachelomonas volvocina*	euglenoid
Melosira varians	diatom	*Ulothrix sp.*	green
		Unidentified flagellate	unknown



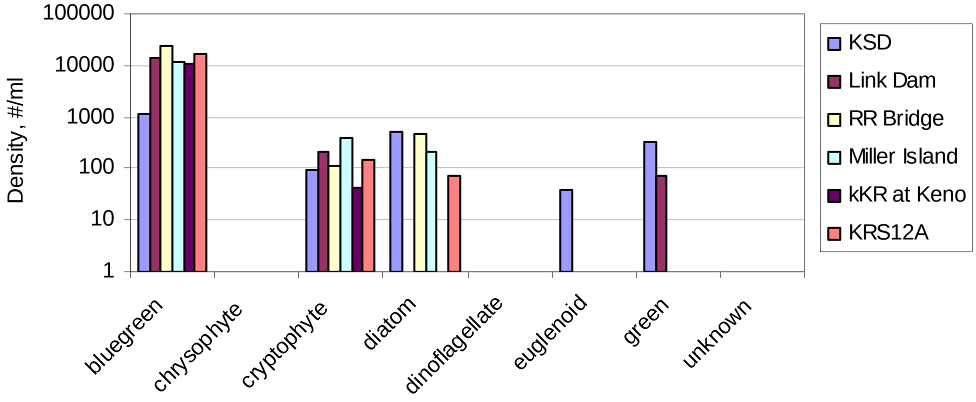
May 3, 2005

Figure 97. Algal density by group, Keno Reservoir, May 3, 2005



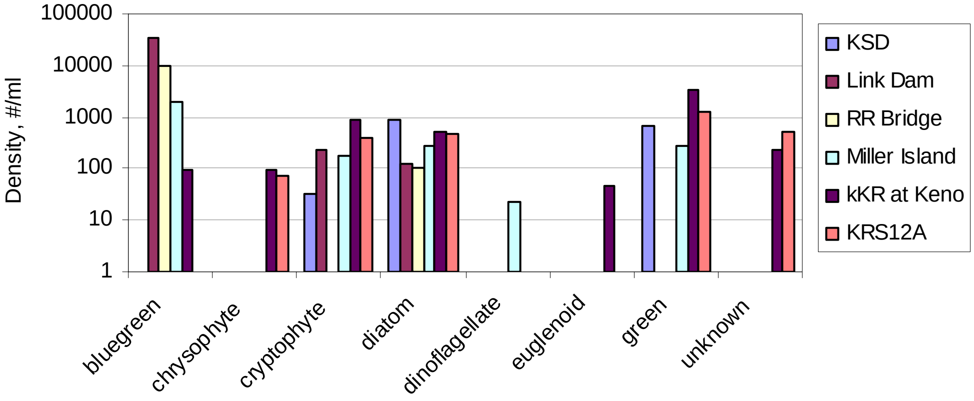
'June 7, 2005

Figure 98. Algal density by group, Keno Reservoir, Jun e7, 2005



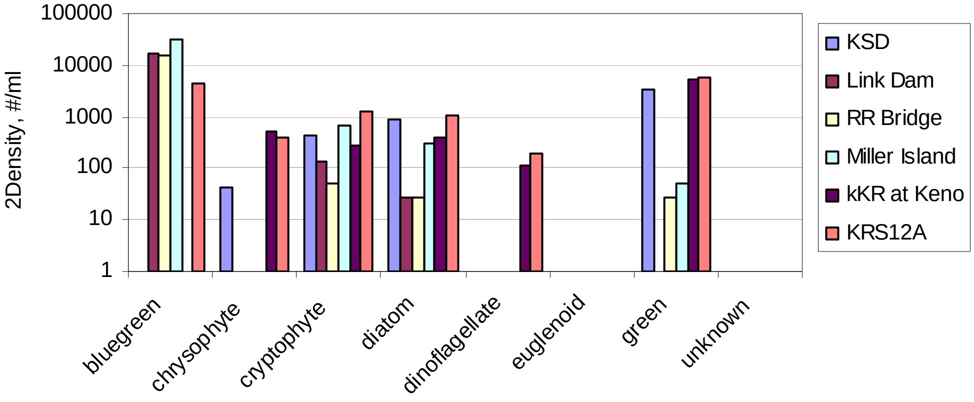
'June 28, 2005

Figure 99. Algal density by group, Keno Reservoir, June 28, 2005



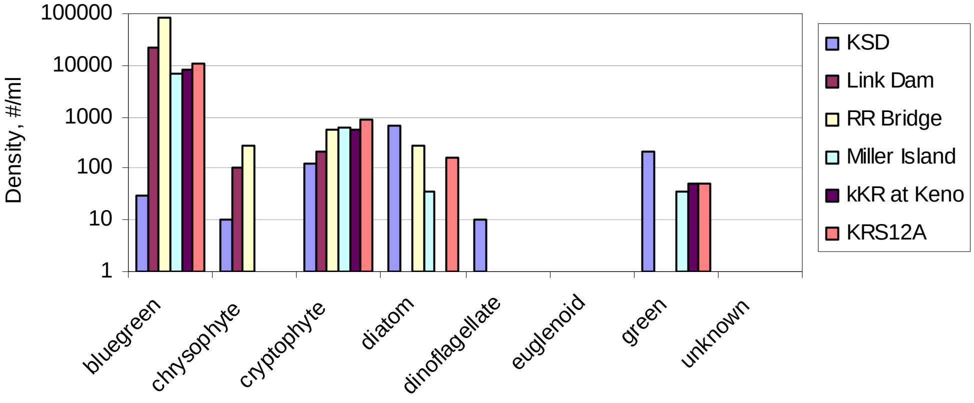
'July 26, 2005

Figure 100. Algal density by group, Keno Reservoir, July 26, 2005



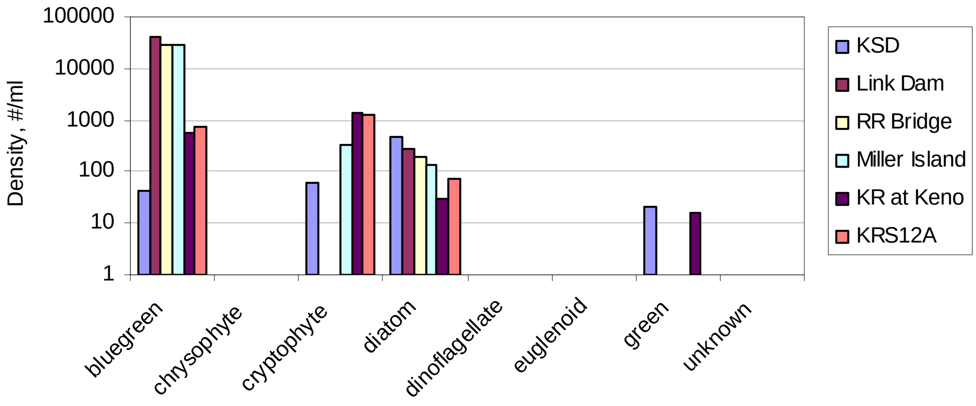
'August 9, 2005

Figure 101. Algal density by group, Keno Reservoir, August 9, 2005



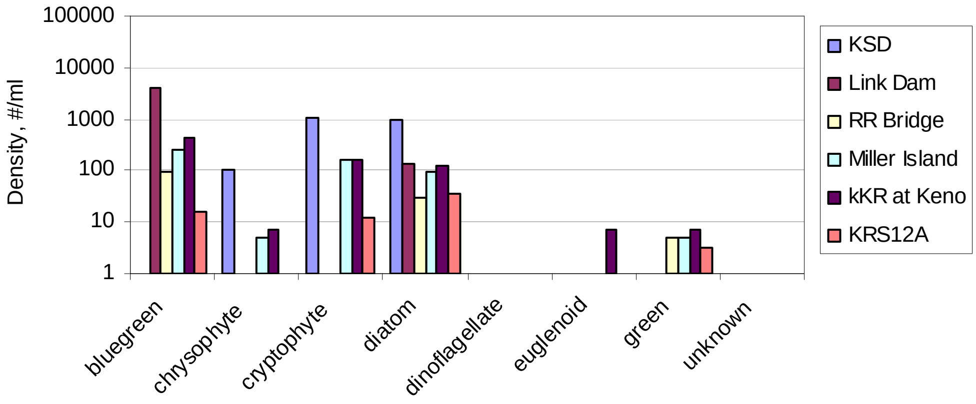
'August 23, 2005

Figure 102. Algal density by group, Keno Reservoir, August 23, 2005



'September 20, 2005

Figure 103. Algal density by group, Keno Reservoir, September 20, 2005



'October 18, 2005

Figure 104. Algal density by group, Keno Reservoir, October 18, 2005

9.8. Appendix H: An Assessment of the Zooplankton Species Composition from Keno Reservoir

ZP's Taxonomic Services
P.O. Box 18646
Salem, Oregon 97305
e-mail: llvogel@teleport.com

3 February 2006

To: Michael L. Deas
Watercourse Engineering, Inc.
133 D Street, Suite F
Davis, CA 95616
From: Allan Hayes Vogel
Subject: An Assessment of the Zooplankton Species Composition from Keno Reservoir

Note: Normally when I prepare a report, I am analyzing the presence and relative abundance of various important taxa, and have some idea as to what's going on in the lake, pond, or reservoir. Since I do not have any extensive ancillary physical and chemical data from Keno Reservoir, this report will be restricted to a description of the ecological importance of the various taxa found in this system.

Cladocerans

Over the course of 2005, nine species of cladocerans were recorded in the Keno Reservoir samples. Of these, the numerically predominant species were *Daphnia pulicaria* and *Chydorus sphaericus* with *D. pulicaria* being more common in the samples after June and on several occasions, it was the predominant arthropod taxon found. *Daphnia pulicaria* is one of several common species that belong to the "large daphnid" species guild (not all daphnids belong to this guild, including several other species in the same genus). This particular species is typical of mesotrophic to eutrophic lakes and reservoirs.

The large daphnid guild is considered to be a keystone freshwater zooplankton component. First, it frequently controls the plankton assemblage, determining which species of both zooplankton and phytoplankton are present in the body of water, and, second, it is one of the two significant sources of pelagic food for temperate zone freshwater fish (the other being the large calanoid copepods which did not have a breeding population present in Keno Reservoir in 2005). Large daphnids are considered to be the group of zooplankton that is the most effective grazers of freshwater phytoplankton (Carpenter and Kitchell 1993, Kerfoot 1980). They even eat many species of cyanobacteria (Arnold 1971), and their loss from Diamond Lake, OR, due to tui chub predation, has contributed to the cyanobacteria blooms now found there (Eilers, et al., paper submitted for publication). They also reduce (as do the large calanoids through direct predation - McNaught, *et al.* 1999, Neill 1984, Paul and Schindler 1994) the populations of most species of rotifers through a process known as interference competition (Gilbert 1988a,b, Schneider 1990), and directly out-compete smaller cladocerans for planktonic algae as they are able to process larger volumes of water in a given time (Hutchinson 1967, Kerfoot 1980). In turn, due to their large size (in excess of 1.25 mm, exclusive of their spine), they represent an important source of food for young-of-the-year salmonids past the yolksac stage and before the fish switch over to feeding on large epibenthic insects, etc. (Carpenter and Kitchell 1993, Zaret 1980). Depending upon water temperatures, young salmonids feed on these crustaceans for 10 days to three weeks (and a few apparently never change over to feeding on epibenthic organisms as stomach analyses from rainbow trout populations in various Cascade lakes have shown that some individuals caught in the central limnetic zone still are eating a diet largely of planktonic crustaceans even when they reach legal size for being caught by fishermen (W. Wall, personal communication). In addition, sockeye salmon are exclusively planktivorous throughout their lifecycle as is their freshwater race, the kokanee, and brook trout populations resident in lakes have been repeatedly documented as eliminating large daphnids.) Thus, freshwater plankton species composition, as well as the maintenance of many fisheries, is largely determined by the population of species in this guild, hence its designation as a “keystone taxon.”

By contrast, *Chydorus sphaericus* is able to flourish in the presence of *D. pulicaria* by partly avoiding direct competition for food as it also eats epiphytic algae as well as phytoplanktonic green algae. Hence this small chydorid is able to co-exist with large daphnids, particularly if there is macrophytic cover for it (i.e., rooted aquatic vegetation visible to the naked eye).

Of the seven other species of cladocerans, *Ceriodaphnia dubia, Bosmina longirostris* and *Diaphanosoma brachyurum* all are euplanktonic (i.e., living their entire life cycle in the water column) herbivores, and they all have suppressed population numbers in Keno Reservoir due to competition from *D. pulicaria*, and in the case of *Bosmina*, the additional factor of predation by *Leptodora kindti. L. kindti* is a rare predatory cladoceran (one of only two such species found in freshwater) that eats copepod nauplii and rotifers as well as *Bosmina* (Cummins, *et al*. 1969). Because *Leptodora* is a predator, it is always collected in fewer numbers than the herbivorous forms. The remaining three species of cladocerans observed in Keno Reservoir, *Alona costata, Pleuroxus aduncus,* and *Eurycercus lamellatus*, are species of chydorids which are characteristic of the benthic environment and largely feed on algae that are either growing directly on the bottom or on macrophytes. Their presence in these samples is probably mostly due to accidental collection of individuals that have been swept by water currents off the bottom or the plants that they were perched on. Samples taken in shallow systems typically have a greater occurrence of such chydorids than if the collections are from either a deeper lake or closer to the surface (the only species of chydorid that is regarded as euplanktonic is *C. sphaericus* – Dodson 1992).

Copepods

Two species of calanoids and three species of cyclopoids were collected in these samples. Although the calanoid *Epischura nevadensis* is large enough to be eaten by fish, only three individuals, were observed in the August and September collections, a pattern suggesting that they were "wash ins" from upstream rather than members of a breeding population. The only calanoid that appeared to be breeding in Keno Reservoir was the small species, *Leptodiaptomus ashlandi*. This species is found in mesotrophic to eutrophic lakes across eastern Oregon, eastern Washington, and the Midwest (Pennak 1989), and can be quite common in some of these lakes (Wells 1970, Whittaker and Fairbanks 1958). It is not common in lakes in either the High Cascades or west of the mountains (Vogel, personal data). Its relatively low numbers in Keno Reservoir suggest that it is not doing very well.

Of the three cyclopoids, *Diacyclops thomasi* is both the only euplanktonic species and the only copepod with adequate numbers in these samples (it was frequently the third most abundant crustacean in the collections and most of the cyclopoid copepodites were probably immatures belonging to this species as well). Both *Macrocyclops albidus* and *Microcyclops varicans* are epibenthic forms that, like the chydorids except *C. sphaericus*, were probably swept off the bottom into the water column by currents.

Euplanktonic cyclopoids, such as *Diacyclops thomasi*, are opportunistic feeders that will take anything they can get, including large daphnid eggs still inside their parent (Hutchinson 1967). Due to their swimming pattern (which is more like Brownian motion than the more direct ones of both calanoid copepods and cladocerans – Hutchinson 1967, Wetzel 1975), even the species that are big enough to be eaten by pelagic fish seldom are (not to mention the fact that most of the larger species of cyclopoids are epibenthic organisms). *D. thomasi* requires lake productivity of at least a mesotrophic level, if not higher, and does not do well in oligotrophic systems, so this species is regarded as characteristic of more productive lakes and reservoirs.

Miscellaneous Zooplankton

There were six species of miscellaneous zooplankters found in these samples: five are exclusively epibenthic (only chironomid larvae are routinely found in plankton samples and this taxon was the only member of this group commonly observed in the Keno Reservoir collections). The presence of these five species again indicated how shallow this system is. In addition, with the exception of the mayfly larvae, all of these animals are characteristic of mesotrophic to eutrophic waters. The fact that there were only two individual mayfly larvae found, and one, from a September collection, was most likely a "wash in", suggests that these animals are not breeding in Keno Reservoir, so indicates that the overall water quality is not very good in this system.

Rotifers

This group of animals is regarded as important water quality indicators (Pontin 1978, Ruttner-Kolisko 1974, Stemberger 1979). The 19 species observed in these samples fall into several distinct groups, each of which indicates something about this reservoir, and their relative abundances point towards the relative strengths of these different factors. The first group comprises the widespread euplanktonic species. These include the predatory *Asplanchna, Conochilius unicornis, Keratella irregularis* and its more abundant co-genitor, *K. hiemalis, Polyarthra vulgaris,* and *Synchaeta* sp. *Conochilius,* *Keratella hiemalis*, and *Synchaeta* prefer colder waters than most of the rest of the group (Stemberger 1979), so were more abundant during June than later in the season. *Asplanchna* had a spotty occurrence in the samples, probably due more to accidentally collecting a "swarm" of them rather than real irregularity in seasonal distribution. *Polyarthra vulgaris* is a widespread euplanktonic species that lacks any significant correlations with any specific water factor other than temperature though it does not do well in poorly oxygenated waters (Pontin 1978), so was probably absent from Keno Reservoir in the latter half of the summer due to the late July anoxic episode. *Keratella irregularis* is a heavily armored form of the abundant *K. cochlearis* and like *P. vulgaris*, is considered to be characteristic of warm waters (Pontin 1978, Ruttner-Kolisko 1974). Its absence in Keno Reservoir during the summer suggested that it may also be sensitive to anoxia.

The next group of species represents those that are found in both shallow waters and/or open moderate to highly eutrophic waters. These include both species of *Brachionus* and both *Monostyla* species as well as the two *Platyias* species and *Euchlanis dilatata*. The third group is composed of exclusively littoral forms which are strictly accidentals in these samples. Animals in this group include *Colurella* sp., *Proales* sp., *Rotaria* sp., *Testudinella patina*, and the unidentified bdelloid. The fourth group was represented by a single species, *Collotheca pelagica* (which, despite its species name, is characteristic of both open waters and the littoral zone and is often found in ponds). It is not, however, usually found in highly eutrophic waters and only one individual was observed in these collections, again supporting the fact that Keno Reservoir is highly enriched. Of these later three groups, the most common species was *Euchlanis dilatata*. It is considered to be characteristic of aquatic ecosystems with large numbers of macrophytes (Pontin 1978, Ruttner-Kolisko 1974, Stemberger 1979), hence with high concentrations of nutrients and organic debris present. (By contrast, *Collotheca* is more typically found in such ultraoligotrophic Oregon lakes as Crater and Waldo –Vogel, personal data.)

In summary, the rotifers indicate that Keno Reservoir is a shallow, rich system with large amounts of organic material in the sediments and confirm that it went anoxic in late July.

Protists

The armored protist, Difflugia, was present only in the two early June samples. It is regularly found during the summer in High Cascades lakes and in mesotrophic Midwestern and Appalachian lakes with adequate levels of dissolved oxygen present (Vogel, personal data). Since its peak in the Midwest and Appalachian lakes is midsummer and the reservoirs of the Klamath Basin have a similar climatic regime to these lakes and reservoirs, its absence in Keno Reservoir after early June suggests that it may require cleaner and more oxygenated water than was present in Keno Reservoir during the summer.

Summary

The low numbers of calanoid copepods and high numbers of *Diacyclops* as well as the particular assortment of rotifer species and their relative numbers indicate that Keno Reservoir is a mesotrophic to eutrophic system that experiences low dissolved oxygen levels during the late summer. The high proportion of epibenthic animals indicate that it is a relatively shallow system as well. The presence of a large population of large daphnids in this body of water suggests that fish numbers are relatively low. The large population of large daphnids is probably reducing the severity of cyanobacterial water blooms, though not preventing them, and the water quality situation would likely be much worse in their absence.

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9.9. Appendix I: Quality Assurance Summary

9.9.1. Basic Laboratory

The 2005 field work consisted of monthly sampling in May, September and October and bimonthly sampling in June, July and August. U.S. Bureau of Reclamation and Watercourse Engineering, Inc. performed the sampling. There were a total of nine sampling sessions during the 2002 collection. Field personnel collected 81 sets of water samples from 6 sites along the Klamath River near Klamath Falls, Oregon, from May 3 through October 18, 2005. The water sample sets were sent to Basic Laboratory in Redding, California to be analyzed for total Kjedhal nitrogen, ammonia, nitrate/nitrite, total phosphorus, ortho-phosphate, and biological oxygen demand (both 5 and 10 day), chemical oxygen demand, total organic carbon, and total suspended solids. Total organic carbon samples were subsequently sent to BSK Analytical Laboratory in Fresno, California. Watercourse Engineering, Inc (Watercourse), in Davis, California was responsible for ensuring the reliability of the data. To ensure data reliability, field personnel incorporated external quality assurance samples (QA samples) with the production samples, or non-QA samples, at a rate if 10% for spikes and duplicates and 5% for blanks per sampling session during the entire sampling period, as per the Quality Assurance Project Plan (QAPP) adopted by Watercourse and the U.S. Bureau of Reclamation (USBR).

The laboratory results for the external QA samples were overall acceptable. QA samples exceeding the adopted acceptance criteria were submitted for reanalysis. Reanalysis results which confirmed the original results for the QA samples could have indicated a manufacture error in QA spikes or an error produced by field personnel while preparing and incorporating the QA sampling into the production samples. Due to these possible errors, QAPP guidelines accept the original results of a QA sample as reliable when the laboratory is able to confirm the original result with reanalysis. If the laboratory is unable to confirm the original results for a QA sample, the guidelines assert the need to submit the whole sample batch of production and QA samples for reanalysis.
While USBR also checks QA performance of the reanalysis results, and will on occasion request secondary or tertiary reanalysis of a QA sample, such a procedure was cost-prohibitive in this instance and no secondary reanalyzes were requested. If QA results were not confirmed, the entire batch of production samples was reanalyzed, and the results from reanalysis were viewed as reliable and used in the final data set, excluding BOD samples.

Quality Assurance Criteria: Constituents and QA Samples

There were several criteria used for determining the acceptability of sample results. The blank sample concentrations had to be less than ten percent of the lowest sample concentrations reported in the process batch or less than or equal to twice the reporting limit. For a duplicate sample, if the results were greater than or equal to five times the reporting limit, the Relative Percent Difference (RPD) should be less than 20% (Equation (10). If the results are less than five times the reporting limit, the values of the duplicate sample and the regular sample can vary plus or minus the reporting limit. For a spike sample (or reference solution), if the sample result does not exceed the spike concentration by five times or more, the Recovery should fall between 80 and 120% (Equations (11) and (12)). If the sample result does exceed the spike concentration by five times or more, there are no criteria to determine the acceptability of the result; however, this was not the case in 2005. Most results were either well inside or well outside the acceptability limits. However, nine sample QA criteria values had results only slightly outside of the acceptability limits. These samples are presented in Table 27. Because reanalysis can be costly, these three samples were not sent for reanalysis, but deemed acceptable.

Reanalysis ideally would be completed within the recommended hold times for each constituent. Due to lab turn around time and data QA processing time, most samples were reanalyzed at or just beyond the identified hold times.

$$\text{RPD} = \frac{\left|[\text{Regular}] - [\text{Duplicate}]\right|}{[\text{M}]} \text{ x } 100 \qquad (10)$$

$$\text{Recovery for Added Spike} = \frac{[\text{Spike}] - [\text{M}]}{[\text{Spike Material Added}]} \text{ x } 100 \qquad (11)$$

$$\text{Recovery for Reference Solution} = \frac{[\text{Spike}]}{[\text{Reference Solution}]} \text{ x } 100 \qquad (12)$$

where: M = Mean of Regular and Duplicate Concentrations.
Regular = Concentration of regular sample
Duplicate = Concentration of duplicate sample
Spike = Concentration of either spiked sample or reference solution

Table 27. QA samples excluded from reanalysis due to criteria being close to acceptable limits.

Bottle ID(s)	QA Type	Constituent (s)	QA Criteria	QA Criteria Value(s)
KW105	Spike	COD	Recovery	125%
KW119 / KW127	Regular / Duplicate	TKN	RPD	23%
KW132	Spike	NH4	Recovery	123%
KW141	Spike	NH4	Recovery	128%
KW146 / KW154	Regular / Duplicate	NO3-NO2	RPD	33%
KW164 / KW172	Regular / Duplicate	NO3-NO2	RPD	22%
KW168	Spike	NH4	Recovery	124%
KW177	Spike	COD, NH4	Recovery	76%, 131%

Constituents

Total Kjeldhal Nitrogen (TKN)

There were a total of 27 QA samples for TKN. Of those samples, 2 did not have results within acceptable QA limits and were reanalyzed. Of those samples reanalyzed, no results were confirmed.

Ammonia

There were a total of 27 QA samples for ammonia. Of those samples, 3 did not have results within acceptable QA limits and were reanalyzed. Of those samples reanalyzed, 2 results were confirmed.

Nitrate / Nitrite

There were a total of 27 QA samples for nitrate/nitrite. Of those samples, 1 did not have results within acceptable QA limits and was reanalyzed. No results were confirmed.

Total Phosphorus

There were a total of 27 QA samples for total phosphorus. Of those samples, all results within acceptable QA limits.

Ortho-Phosphate

There were a total of 27 QA samples for ortho-phosphate. Of those samples, all results within acceptable QA limits.

Biological Oxygen Demand

Only the unfiltered BOD – 5 day samples were used in the QA process. There were a total of 27 QA samples for biological oxygen demand (5 day unfiltered). Of those samples, 8 did not have results within acceptable QA. However, Basic Laboratory will not perform reanalysis on BOD samples due to short hold time. These 8 sample results and all BOD results in their lab batches are therefore qualified data.

Chemical Oxygen Demand (COD)

Only the unfiltered COD samples were used in the QA process. There were a total of 27 QA samples for COD. Of those samples, 2 did not have results within acceptable QA limits and were reanalyzed. Of those samples, 2 results were confirmed.

Total Organic Carbon (TOC)

There were a total of 24 QA samples for TOC. Of those samples, 3 did not have results within acceptable QA limits. However, as TOC was being analyzed by a sub-laboratory, there was not a QA sample agreement with that lab, and it would have been cost-prohibitive to reanalyze TOC samples. Therefore, no reanalysis was performed on TOC samples and all TOC results in their lab batches are therefore qualified data.

Total Suspended Solids (TSS)

TSS was not included in the quality assurance effort, and all TSS results are therefore qualified data.

Quality Assurance Samples

Blanks

There were a total of 54 QA blank samples which could be reanalyzed (71 including BOD and TOC samples). Of those samples, all had results within acceptable QA limits and none were reanalyzed.

Regulars / Duplicates

There were a total of 54 regular and 54 duplicate samples which could be reanalyzed (71 of each including BOD and TOC samples). Of those samples, 1 regular-duplicate set did not have results within acceptable QA limits and so 1 set of regular and duplicate samples were reanalyzed (2 samples total). Of those samples reanalyzed, no regular sample or duplicate sample results were confirmed.

Spikes

There were a total of 54 QA spike samples which could be reanalyzed (71 including BOD and TOC samples). Of those samples, 7 did not have results within acceptable QA limits and were reanalyzed. Of those samples reanalyzed, 4 results were confirmed.

Laboratory QC Reports

All laboratory QC reports were acceptable.

9.9.2. Summary

A total of 213 QA samples were submitted to Basic Laboratories, 162 of which could be reanalyzed. Of those samples, 8 (4%) had results that were unacceptable within the criteria set by Reclamation. Those 8 samples were reanalyzed (5% of those samples which could be reanalyzed) and 4 (50%) sample results were confirmed.

There are a total of 935 samples (QA or production), 486 of those were included in the QA analysis. Samples not included in the QA analysis (or excluded due to lack of reanalysis opportunity) were BOD 5 day samples, filtered BOD 5 day samples, all BOD 10 day samples, TOC samples, dissolved COD samples and TSS samples. Of the 486 samples included in the QA analysis, 432 samples either were associated with QA samples that were within acceptable QA limits or had their results confirmed by reanalysis. 54 samples were associated with QA samples that were not confirmed by reanalysis when they were found to be outside of the acceptable QA limits.

The completeness (Equation(13)) of the data set wherein QA was applied was 89% - very close to the target value of 90 percent.

$$\text{Completeness} = \frac{v}{n} \qquad (13)$$

Where: v = The number of measurements judged valid

N = total number of QA measurements

Overall, the laboratory performed well and, with the exception of BOD, performance was excellent. (Incidentally, following the 2005 season, Reclamation audited the laboratory and identified potential improvements in the BOD process. These suggestions were implemented by Basic Laboratory in 2006.)

9.9.3. Recommendations

Based on findings from the 2005 Keno Wetlands Project Quality Assurance summary, recommendations include:

- Include as many constituents as possible in the reanalysis agreement so that reanalysis is not cost-prohibitive for any single constituent.
- In 2005 a larger than typical number of BOD samples were collected. If larger numbers of BOD sampled are collected in the future, consider additional BOD QA, particularly in light of short hold-times and inability for reanalysis.

Table 28. Data QA validation results for 2005 – Concentrations from Lab.

Bottle ID	Date	Time	Site #	Site Name	QA Type	< 10.0 µm BOD5, mg/l	< 1.0 µm BOD5, mg/l	< 0.45 µm BOD5, mg/l	BOD5, mg/l	BOD10, mg/l	< 0.45 µm BOD10, mg/l	COD, mg/l	< 0.45 µm COD, mg/l	DOC, mg/l	TOC, mg/l	NH4, mg/l	NO3-NO2, mg/l	TKN, mg/l	TP,
KW101	5/3/2005	13:05	6	Klamath Straits Drain	Regular	4		ND	5			32	28	20	22	0.46	0.16	2.5	0.4
KW104	5/3/2005	13:55	6	Klamath Straits Drain	Blank				ND			ND			0.25	ND	ND	ND	ND
KW105	5/3/2005	11:30	6	Klamath Straits Drain	Spike				37			53			26	2.99	3.43	5	3.8
KW109	5/3/2005	9:15	6	Klamath Straits Drain	Duplicate				4			30			22	0.56	0.15	2.4	0.4
KW110	6/7/2005	12:40	6	Klamath Straits Drain	Regular	6		ND	3			66	57			0.46	0.28	2.6	0.3
KW113	6/7/2005	16:05	6	Klamath Straits Drain	Blank				ND			ND				0.05	0.05	ND	ND
KW114	6/7/2005	11:05	6	Klamath Straits Drain	Spike				30			54				4.2	3.77	5.1	3.7
KW118	6/7/2005	8:35	6	Klamath Straits Drain	Duplicate				6			67				0.45	0.2	2.7	0.3
KW119	6/28/2005	14:05	6	Klamath Straits Drain	Regular	5	ND	3	7			64	58	18	32	0.64	0.09	2.3	0.4
KW122	6/28/2005	8:40	6	Klamath Straits Drain	Blank				ND			ND			0.41	0.04	ND	ND	ND
KW123	6/28/2005	12:10	6	Klamath Straits Drain	Spike				48			43			21	1.17	3.31	1.9	3.8
KW127	6/28/2005	15:00	6	Klamath Straits Drain	Duplicate				7			65			23	0.62	0.09	2.9	0.4
KW128	7/12/2005	13:59	6	Klamath Straits Drain	Regular			ND	5			57	58	16	28	1.02	0.08	2.8	0.3
KW131	7/12/2005	8:45	6	Klamath Straits Drain	Blank				ND			ND			0.8	ND	ND	ND	ND
KW132	7/12/2005	12:04	6	Klamath Straits Drain	Spike				27			43			22	4.51	3.26	5.9	3.7
KW136	7/12/2005	14:55	6	Klamath Straits Drain	Duplicate				9			54			27	0.99	0.07	2.8	0.3
KW137	7/26/2005	14:15	6	Klamath Straits Drain	Regular	4	4	ND	5			53	45	15	21	1.07	0.14	2.6	0.5
KW140	7/26/2005	15:04	6	Klamath Straits Drain	Blank				ND			ND			0.38	ND	ND	ND	ND
KW141	7/26/2005	12:10	6	Klamath Straits Drain	Spike				35			42			21	4.73	3.47	5.5	4.1
KW145	7/26/2005	8:35	6	Klamath Straits Drain	Duplicate				6			49			23	1.02	0.13	2.8	0.5
KW146	8/9/2005	12:00	6	Klamath Straits Drain	Regular			ND	6			70	65	29	27	1.08	0.07	3.6	0.6
KW149	8/9/2005	15:15	6	Klamath Straits Drain	Blank				ND			ND			ND	ND	ND	ND	ND
KW150	8/9/2005	10:25	6	Klamath Straits Drain	Spike				30			47			21	4.23	3.22	5.2	4.4
KW154	8/9/2005	8:55	6	Klamath Straits Drain	Duplicate				6			77			26	0.93	0.05	3.5	0.6
KW155	8/23/2005	10:55	6	Klamath Straits Drain	Regular	4	ND	ND	4			43	49	17	18	1	0.16	2.6	0.4
KW158	8/23/2005	15:35	6	Klamath Straits Drain	Blank				ND			ND			ND	0.05	ND	ND	ND
KW159	8/23/2005	11:40	6	Klamath Straits Drain	Spike				10			17			8	5.14	3.5	5.5	3.9
KW163	8/23/2005	13:45	6	Klamath Straits Drain	Duplicate				4			47			18	0.89	0.16	2.6	0.4
KW164	9/20/2005	11:29	6	Klamath Straits Drain	Regular	5	4	ND	7			43	44	16	16	1	0.25	2.3	0.2
KW167	9/20/2005	11:29	6	Klamath Straits Drain	Blank				ND			ND			ND	ND	ND	ND	ND
KW168	9/20/2005	12:20	6	Klamath Straits Drain	Spike				13			18			7.9	4.54	3.54	5	3.8
KW172	9/20/2005	8:35	6	Klamath Straits Drain	Duplicate				4			47			3.3	0.96	0.2	2.3	0.2
KW173	10/18/2005	10:59	6	Klamath Straits Drain	Regular	ND	ND	ND	ND			34	33	12	16	0.84	0.61	2.2	0.1
KW176	10/18/2005	14:39	6	Klamath Straits Drain	Blank				ND			ND			ND	ND	ND	ND	ND
KW177	10/18/2005	13:59	6	Klamath Straits Drain	Spike				9			16			8.6	4.58	3.65	4.9	3.3
KW181	10/18/2005	0.361	6	Klamath Straits Drain	Duplicate				ND			40			15	0.82	0.6	2.1	0.1

Table 29. Data QA validation results for 2005 – Concentrations for QA calculations.

Bottle ID	Date	Time	Site #	Site Name	QA Type	< 10.0 µm BOD5, mg/l	< 1.0 µm BOD5, mg/l	< 0.45 µm BOD5, mg/l	BOD5, mg/l	BOD10, mg/l	< 0.45 µm BOD10, mg/l	COD, mg/l	< 0.45 µm COD, mg/l	DOC, mg/l	TOC, mg/l	NH4, mg/l	NO3-NO2, mg/l	TKN, mg/l	
KW101	5/3/2005	13:05	6	Klamath Straits Drain	Regular	4		3	5			32	28	20	22	0.46	0.16	2.5	0.
KW104	5/3/2005	13:55	6	Klamath Straits Drain	Blank				3			3			0.25	0.03	0.02	0.1	0.
KW105	5/3/2005	11:30	6	Klamath Straits Drain	Spike				37			53			26	2.99	3.43	5	3.
KW109	5/3/2005	9:15	6	Klamath Straits Drain	Duplicate				4			30			22	0.56	0.15	2.4	0.
KW110	6/7/2005	12:40	6	Klamath Straits Drain	Regular	6		3	3			66	57			0.46	0.28	2.6	0.
KW113	6/7/2005	16:05	6	Klamath Straits Drain	Blank				3			3				0.05	0.05	0.1	0.
KW114	6/7/2005	11:05	6	Klamath Straits Drain	Spike				30			54				4.2	3.77	5.1	3.
KW118	6/7/2005	8:35	6	Klamath Straits Drain	Duplicate				6			67				0.45	0.2	2.7	0
KW119	6/28/2005	14:05	6	Klamath Straits Drain	Regular	5	3	3	7			64	58	18	32	0.64	0.09	2.3	0.
KW122	6/28/2005	8:40	6	Klamath Straits Drain	Blank				3			3			0.41	0.04	0.02	0.1	0.
KW123	6/28/2005	12:10	6	Klamath Straits Drain	Spike				48			43			21	1.17	3.31	1.9	3
KW127	6/28/2005	15:00	6	Klamath Straits Drain	Duplicate				7			65			23	0.62	0.09	2.9	0
KW128	7/12/2005	13:59	6	Klamath Straits Drain	Regular			3	5			57	58	16	28	1.02	0.08	2.8	0.
KW131	7/12/2005	8:45	6	Klamath Straits Drain	Blank				3			3			0.8	0.03	0.02	0.1	0.
KW132	7/12/2005	12:04	6	Klamath Straits Drain	Spike				27			43			22	4.51	3.26	5.9	3.
KW136	7/12/2005	14:55	6	Klamath Straits Drain	Duplicate				9			54			27	0.99	0.07	2.8	0.
KW137	7/26/2005	14:15	6	Klamath Straits Drain	Regular	4	4	3	5			53	45	15	21	1.07	0.14	2.6	0.
KW140	7/26/2005	15:04	6	Klamath Straits Drain	Blank				3			3			0.38	0.03	0.02	0.1	0.
KW141	7/26/2005	12:10	6	Klamath Straits Drain	Spike				35			42			21	4.73	3.47	5.5	4.
KW145	7/26/2005	8:35	6	Klamath Straits Drain	Duplicate				6			49			23	1.02	0.13	2.8	0.
KW146	8/9/2005	12:00	6	Klamath Straits Drain	Regular			3	6			70	65	29	27	1.08	0.07	3.6	0.
KW149	8/9/2005	15:15	6	Klamath Straits Drain	Blank				3			3			0.03	0.03	0.02	0.1	0.
KW150	8/9/2005	10:25	6	Klamath Straits Drain	Spike				30			47			21	4.23	3.22	5.2	4.
KW154	8/9/2005	8:55	6	Klamath Straits Drain	Duplicate				6			77			26	0.93	0.05	3.5	0.
KW155	8/23/2005	10:55	6	Klamath Straits Drain	Regular	4	3	3	4			43	49	17	18	1	0.16	2.6	0.
KW158	8/23/2005	15:35	6	Klamath Straits Drain	Blank				3			3			0.03	0.05	0.02	0.1	0.
KW159	8/23/2005	11:40	6	Klamath Straits Drain	Spike				10			17			8	5.14	3.5	5.5	3.
KW163	8/23/2005	13:45	6	Klamath Straits Drain	Duplicate				4			47			18	0.89	0.16	2.6	0.
KW164	9/20/2005	11:29	6	Klamath Straits Drain	Regular	5	4	3	7			43	44	16	16	1	0.25	2.3	0.
KW167	9/20/2005	11:29	6	Klamath Straits Drain	Blank				3			3			0.03	0.03	0.02	0.1	0.
KW168	9/20/2005	12:20	6	Klamath Straits Drain	Spike				13			18			7.9	4.54	3.54	5	3.
KW172	9/20/2005	8:35	6	Klamath Straits Drain	Duplicate				4			47			3.3	0.96	0.2	2.3	0.
KW173	10/18/2005	10:59	6	Klamath Straits Drain	Regular	3	3	3	3			34	33	12	16	0.84	0.61	2.2	0.
KW176	10/18/2005	14:39	6	Klamath Straits Drain	Blank				3			3			0.03	0.03	0.02	0.1	0.
KW177	10/18/2005	13:59	6	Klamath Straits Drain	Spike				9			16			8.6	4.58	3.65	4.9	3.
KW181	10/18/2005	8:39	6	Klamath Straits Drain	Duplicate				3			40			15	0.82	0.6	2.1	0.

Table 30. Data QA validation results for 2005 – QA Criteria Values.

Bottle ID	Date	Time	Site #	Site Name	QA Type	< 10.0 µm BOD5, mg/l	< 1.0 µm BOD5, mg/l	< 0.45 µm BOD5, mg/l	BOD5, mg/l	BOD10, mg/l	< 0.45 µm BOD10, mg/l	COD, mg/l	< 0.45 µm COD, mg/l	DOC, mg/l	TOC, mg/l	NH4, mg/l	NO3-NO2, mg/l	TKN, mg/l	
KW101	5/3/2005	13:05	6	Klamath Straits Drain	Regular				22.222			6.5			0	19.61	6.452	4.1	7.
KW104	5/3/2005	13:55	6	Klamath Straits Drain	Blank				0.40			3			2.2	0.046	0.02	0.2	0.
KW105	5/3/2005	11:30	6	Klamath Straits Drain	Spike				131.81			125			138.4	87.32	106	90	97
KW109	5/3/2005	9:15	6	Klamath Straits Drain	Duplicate														
KW110	6/7/2005	12:40	6	Klamath Straits Drain	Regular				66.667			1.5				2.198	33.33	3.8	3.
KW113	6/7/2005	16:05	6	Klamath Straits Drain	Blank				0.30			6.6				0.045	0.02	0.3	0
KW114	6/7/2005	11:05	6	Klamath Straits Drain	Spike				85.499			102				131.9	114.2	86	98
KW118	6/7/2005	8:35	6	Klamath Straits Drain	Duplicate														
KW119	6/28/2005	14:05	6	Klamath Straits Drain	Regular				0			1.6			32.73	3.175	0	23	2.
KW122	6/28/2005	8:40	6	Klamath Straits Drain	Blank				0.70			6.4			2.3	0.062	0.01	0.2	0
KW123	6/28/2005	12:10	6	Klamath Straits Drain	Spike				171			101			111.7	19.01	104.2	-25	96
KW127	6/28/2005	15:00	6	Klamath Straits Drain	Duplicate														
KW128	7/12/2005	13:59	6	Klamath Straits Drain	Regular				57.143			5.4			3.636	2.985	13.33	0	8.
KW131	7/12/2005	8:45	6	Klamath Straits Drain	Blank				0.50			5.4			2.7	0.099	0.01	0.3	0.
KW132	7/12/2005	12:04	6	Klamath Straits Drain	Spike				96.187			101			117.1	123.4	103.1	109	97
KW136	7/12/2005	14:55	6	Klamath Straits Drain	Duplicate														
KW137	7/26/2005	14:15	6	Klamath Straits Drain	Regular				18.182			7.8			9.091	4.785	7.407	7.4	1.
KW140	7/26/2005	15:04	6	Klamath Straits Drain	Blank				0.50			4.9			2.1	0.102	0.01	0.3	0.
KW141	7/26/2005	12:10	6	Klamath Straits Drain	Spike				122.55			88			100.6	128.5	106.8	98	10
KW145	7/26/2005	8:35	6	Klamath Straits Drain	Duplicate														
KW146	8/9/2005	12:00	6	Klamath Straits Drain	Regular				0			9.5			3.774	14.93	33.33	2.8	3.
KW149	8/9/2005	15:15	6	Klamath Straits Drain	Blank				0.60			7			2.6	0.093	0.01	0.4	0.
KW150	8/9/2005	10:25	6	Klamath Straits Drain	Spike				102.12			99			111.7	112.4	101.2	58	10
KW154	8/9/2005	8:55	6	Klamath Straits Drain	Duplicate														
KW155	8/23/2005	10:55	6	Klamath Straits Drain	Regular				0			8.9			0	11.64	0	0	
KW158	8/23/2005	15:35	6	Klamath Straits Drain	Blank				0.40			4.3			1.8	0.089	0.02	0.3	0.
KW159	8/23/2005	11:40	6	Klamath Straits Drain	Spike				84.459			181			103.9	146.2	107	101	98
KW163	8/23/2005	13:45	6	Klamath Straits Drain	Duplicate														
KW164	9/20/2005	11:29	6	Klamath Straits Drain	Regular				54.545			8.9			131.6	4.082	22.22	0	4.
KW167	9/20/2005	11:29	6	Klamath Straits Drain	Blank				0.40			4.3			0.33	0.096	0.02	0.2	0.
KW168	9/20/2005	12:20	6	Klamath Straits Drain	Spike				110.03			192			102.6	124.1	106.2	94	10
KW172	9/20/2005	8:35	6	Klamath Straits Drain	Duplicate														
KW173	10/18/2005	10:59	6	Klamath Straits Drain	Regular				0			16			6.452	2.41	1.653	4.7	5.
KW176	10/18/2005	14:39	6	Klamath Straits Drain	Blank				0.30			3.4			1.5	0.082	0.06	0.2	0.
KW177	10/18/2005	13:59	6	Klamath Straits Drain	Spike				68.927			76			103	130.7	97.56	96	88
KW181	10/18/2005	8:39	6	Klamath Straits Drain	Duplicate				22.222			6.5			0	19.61	6.452	4.1	7.

Table 31. Data QA validation results for 2005 – QA acceptability violations.

Bottle ID	Date	Time	Site #	Site Name	QA Type	< 10.0 µm BOD5, mg/l	< 1.0 µm BOD5, mg/l	< 0.45 µm BOD5, mg/l	BOD5, mg/l	BOD10, mg/l	< 0.45 µm BOD10, mg/l	COD, mg/l	< 0.45 µm COD, mg/l	DOC, mg/l	TOC, mg/l	NH4, mg/l	NO3-NO2, mg/l	TKN, mg/l
KW101	5/3/2005	13:05	6	Klamath Straits Drain	Regular				>20%									
KW104	5/3/2005	13:55	6	Klamath Straits Drain	Blank													
KW105	5/3/2005	11:30	6	Klamath Straits Drain	Spike				>120%			>120%			>120%			
KW109	5/3/2005	9:15	6	Klamath Straits Drain	Duplicate													
KW110	6/7/2005	12:40	6	Klamath Straits Drain	Regular				>20%								>20%	
KW113	6/7/2005	16:05	6	Klamath Straits Drain	Blank													
KW114	6/7/2005	11:05	6	Klamath Straits Drain	Spike											>120%		
KW118	6/7/2005	8:35	6	Klamath Straits Drain	Duplicate													
KW119	6/28/2005	14:05	6	Klamath Straits Drain	Regular										>20%			>20%
KW122	6/28/2005	8:40	6	Klamath Straits Drain	Blank													
KW123	6/28/2005	12:10	6	Klamath Straits Drain	Spike				>120%							<80%		<80%
KW127	6/28/2005	15:00	6	Klamath Straits Drain	Duplicate													
KW128	7/12/2005	13:59	6	Klamath Straits Drain	Regular				>20%									
KW131	7/12/2005	8:45	6	Klamath Straits Drain	Blank													
KW132	7/12/2005	12:04	6	Klamath Straits Drain	Spike											>120%		
KW136	7/12/2005	14:55	6	Klamath Straits Drain	Duplicate													
KW137	7/26/2005	14:15	6	Klamath Straits Drain	Regular													
KW140	7/26/2005	15:04	6	Klamath Straits Drain	Blank													
KW141	7/26/2005	12:10	6	Klamath Straits Drain	Spike				>120%							>120%		
KW145	7/26/2005	8:35	6	Klamath Straits Drain	Duplicate													
KW146	8/9/2005	12:00	6	Klamath Straits Drain	Regular												>20%	
KW149	8/9/2005	15:15	6	Klamath Straits Drain	Blank													
KW150	8/9/2005	10:25	6	Klamath Straits Drain	Spike													<80%
KW154	8/9/2005	8:55	6	Klamath Straits Drain	Duplicate													
KW155	8/23/2005	10:55	6	Klamath Straits Drain	Regular													
KW158	8/23/2005	15:35	6	Klamath Straits Drain	Blank													
KW159	8/23/2005	11:40	6	Klamath Straits Drain	Spike							>120%				>120%		
KW163	8/23/2005	13:45	6	Klamath Straits Drain	Duplicate													
KW164	9/20/2005	11:29	6	Klamath Straits Drain	Regular				>20%						>20%		>20%	
KW167	9/20/2005	11:29	6	Klamath Straits Drain	Blank													
KW168	9/20/2005	12:20	6	Klamath Straits Drain	Spike							>120%				>120%		
KW172	9/20/2005	8:35	6	Klamath Straits Drain	Duplicate													
KW173	10/18/2005	10:59	6	Klamath Straits Drain	Regular													
KW176	10/18/2005	14:39	6	Klamath Straits Drain	Blank													
KW177	10/18/2005	13:59	6	Klamath Straits Drain	Spike				<80%			<80%				>120%		
KW181	10/18/2005	8:39	6	Klamath Straits Drain	Duplicate													

9.10. Appendix J: Sensitivity Analysis Summary Tables

Table 32. Summary table of scenario results - depth of 1.5 ft (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.93	0.64	0.91	0.99	0.78	0.80	0.71	0.60
Wetland length	Calculated	mile	3.70	2.57	3.63	3.96	3.12	3.19	2.83	2.41

Table 33. BOD5 reduction, required detention time and area for each scenario – depth of 1.5 ft (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933

Table 34. Summary table of scenario results - depth of 2.5 ft

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Organic Load	Calculated	lb BOD / ac-day	39.34	20.10	27.19	34.41	21.81	20.82	18.40	19.61
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	1315	632	1268	1504	934	979	767	560
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.72	0.50	0.70	0.77	0.60	0.62	0.55	0.47
Wetland length	Calculated	mile	2.87	1.99	2.82	3.07	2.42	2.47	2.19	1.87

Table 35. BOD5 reduction, required detention time and area for each scenario – depth of 2.5 ft

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	1315	632	1268	1504	934	979	767	560

Table 36. Summary table of scenario results - depth of 3.0 ft

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	3	3	3	3	3	3.0	3.0	3
Organic Load	Calculated	lb BOD / ac-day	47.21	24.13	32.63	41.29	26.18	24.98	22.09	23.53
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	1096	527	1057	1253	779	816	639	466
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.65	0.45	0.64	0.70	0.55	0.56	0.50	0.43
Wetland length	Calculated	mile	2.62	1.81	2.57	2.80	2.21	2.26	2.00	1.71

Table 37. BOD5 reduction, required detention time and area for each scenario – depth of 3.0 ft

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	1096	527	1057	1253	779	816	639	466

Table 38. Summary table of scenario results – internal plant decay BOD of 1.0 mg/l

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Design BOD	Calculated	mg/l	3.7	3.7	2.7	2.5	3.2	2.9	3.1	3.7
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.23	1.16	3.09	3.81	2.08	2.22	1.57	0.94
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	29.10	19.87	20.29	24.73	17.83	16.74	16.34	21.16
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	1777	640	1700	2092	1143	1217	864	519
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.83	0.50	0.81	0.90	0.67	0.69	0.58	0.45
Wetland length	Calculated	mile	3.33	2.00	3.26	3.62	2.67	2.76	2.32	1.80

Table 39. BOD5 reduction, required detention time and area for each scenario – internal plant decay BOD of 1.0 mg/l

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.23	1.16	3.09	3.81	2.08	2.22	1.57	0.94
Wetland Area	Calculated	acres	1777	640	1700	2092	1143	1217	864	519

Table 40. Summary table of scenario results – internal plant decay BOD of 3.0 mg/l (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.93	0.64	0.91	0.99	0.78	0.80	0.71	0.60
Wetland length	Calculated	mile	3.70	2.57	3.63	3.96	3.12	3.19	2.83	2.41

Table 41. BOD5 reduction, required detention time and area for each scenario – internal plant decay BOD of 3.0 mg/l (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933

Table 42. Summary table of scenario results – internal plant decay BOD of 5.0 mg/l

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Design BOD	Calculated	mg/l	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.7
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	5.61	3.54	5.47	6.18	4.45	4.59	3.95	3.32
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	16.78	6.54	11.48	15.23	8.33	8.08	6.51	6.02
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	3082	1945	3005	3396	2448	2522	2168	1823
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	1.10	0.87	1.08	1.15	0.98	0.99	0.92	0.84
Wetland length	Calculated	mile	4.39	3.49	4.33	4.61	3.91	3.97	3.68	3.38

Table 43. BOD5 reduction, required detention time and area for each scenario – internal plant decay BOD of 5.0 mg/l

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	5.61	3.54	5.47	6.18	4.45	4.59	3.95	3.32
Wetland Area	Calculated	acres	3082	1945	3005	3396	2448	2522	2168	1823

Table 44. Summary table of scenario results – plant void ratio of 60%

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	20.23	10.34	13.98	17.69	11.22	10.71	9.47	10.09
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	2557	1230	2466	2924	1817	1903	1491	1088
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	1.00	0.69	0.98	1.07	0.84	0.86	0.76	0.65
Wetland length	Calculated	mile	4.00	2.77	3.93	4.27	3.37	3.45	3.05	2.61

Table 45. BOD5 reduction, required detention time and area for each scenario – plant void ratio of 60%

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	2557	1230	2466	2924	1817	1903	1491	1088

Table 46. Summary table of scenario results – plant void ratio of 70% (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.93	0.64	0.91	0.99	0.78	0.80	0.71	0.60
Wetland length	Calculated	mile	3.70	2.57	3.63	3.96	3.12	3.19	2.83	2.41

Table 47. BOD5 reduction, required detention time and area for each scenario – plant void ratio of 70% (original parameter value)

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	2192	1054	2114	2506	1557	1631	1278	933

Table 48. Summary table of scenario results – plant void ratio of 80%

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD5-avg	Calculated	mg/l	8.1	8.1	10.6	13.7	8.0	6.8	4.7	5.0
BOD5-max	Calculated	mg/l	33.0	33.0	22.0	33.0	13.0	13.0	9.0	7.0
BOD5-min	Calculated	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD5-stdev	Calculated	mg/l	6.0	6.0	6.6	9.7	3.6	3.7	2.2	1.5
Probability	Assumed	%	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Coefficient of reliability	Calculated	-	0.737	0.737	0.540	0.500	0.635	0.579	0.620	0.738
Desired effluent BOD	Assumed	mg/l	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
plant decay BOD	Assumed	mg/l	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Design BOD	Calculated	mg/l	2.2	2.2	1.6	1.5	1.9	1.7	1.9	2.2
Influent BOD	Assumed	mg/l	33.0	8.1	22.0	33.0	13.0	13.0	9.0	7.0
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant based void ratio	Assumed	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
water depth	Assumed	ft	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic Load	Calculated	lb BOD / ac-day	26.98	13.79	18.64	23.59	14.96	14.28	12.62	13.45
fraction of river flow treated	Assumed	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Q average in wetland	Calculated	cfs	187.97	187.97	187.97	187.97	187.97	187.97	187.97	187.97
Wetland area	Calculated	acres	1918	922	1850	2193	1362	1427	1118	816
aspect ratio of wetland	Assumed	-	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Wetland width	Calculated	mile	0.87	0.60	0.85	0.93	0.73	0.75	0.66	0.56
Wetland length	Calculated	mile	3.46	2.40	3.40	3.70	2.92	2.99	2.64	2.26

Table 49. BOD5 reduction, required detention time and area for each scenario – plant void ratio of 80%

			Scenario							
Parameter	Method	Units	1	2	3	4	5	6	7	8
BOD data	-	-	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BODinf type	-	-	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD reduction	Calculated	mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD reduction	Calculated	%	82%	26%	73%	82%	54%	54%	33%	14%
Detention time	Calculated	days	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Wetland Area	Calculated	acres	1918	922	1850	2193	1362	1427	1118	816

Table 50. Summary of sensitivity analysis: detention time, wetland area, and organic load

Detention time, day	Scenario							
	1	2	3	4	5	6	7	8
BOD_5 data	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD_5 inflow assumed	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD_5 reduction, mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD_5 reduction, %	82%	26%	73%	82%	54%	54%	33%	14%
Depth = 1.5 ft	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Depth = 2.5 ft	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Depth = 3.0 ft	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant Decay = 1 mg /l	3.23	1.16	3.09	3.81	2.08	2.22	1.57	0.94
Plant Decay = 3 mg /l	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Plant Decay = 5 mg /l	5.61	3.54	5.47	6.18	4.45	4.59	3.95	3.32
Void Ratio = 60 %	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Void Ratio = 70 %	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70
Void Ratio = 80 %	3.99	1.92	3.85	4.56	2.83	2.97	2.32	1.70

Wetland Area, acres	Scenario							
	1	2	3	4	5	6	7	8
BOD_5 data	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD_5 inflow assumed	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD_5 reduction, mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD_5 reduction, %	82%	26%	73%	82%	54%	54%	33%	14%
Depth = 1.5 ft	2192	1054	2114	2506	1557	1631	1278	933
Depth = 2.5 ft	1315	632	1268	1504	934	979	767	560
Depth = 3.0 ft	1096	527	1057	1253	779	816	639	466
Plant Decay = 1 mg /l	1777	640	1700	2092	1143	1217	864	519
Plant Decay = 3 mg /l	2192	1054	2114	2506	1557	1631	1278	933
Plant Decay = 5 mg /l	3082	1945	3005	3396	2448	2522	2168	1823
Void Ratio = 60 %	2557	1230	2466	2924	1817	1903	1491	1088
Void Ratio = 70 %	2192	1054	2114	2506	1557	1631	1278	933
Void Ratio = 80 %	1918	922	1850	2193	1362	1427	1118	816

Organic Load, lb BOD / ac-day	Scenario							
	1	2	3	4	5	6	7	8
BOD_5 data	All	All	Link River	RR Bridge	Miller Island	KRS12A	Keno	KSD
BOD_5 inflow assumed	maximum	average	maximum	maximum	maximum	maximum	maximum	maximum
BOD_5 reduction, mg/l	27.0	2.1	16.0	27.0	7.0	7.0	3.0	1.0
BOD_5 reduction, %	82%	26%	73%	82%	54%	54%	33%	14%
Depth = 1.5 ft	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
Depth = 2.5 ft	39.34	20.10	27.19	34.41	21.81	20.82	18.40	19.61
Depth = 3.0 ft	47.21	24.13	32.63	41.29	26.18	24.98	22.09	23.53
Plant Decay = 1 mg /l	29.10	19.87	20.29	24.73	17.83	16.74	16.34	21.16
Plant Decay = 3 mg /l	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
Plant Decay = 5 mg /l	16.78	6.54	11.48	15.23	8.33	8.08	6.51	6.02
Void Ratio = 60 %	20.23	10.34	13.98	17.69	11.22	10.71	9.47	10.09
Void Ratio = 70 %	23.61	12.06	16.31	20.64	13.09	12.49	11.04	11.77
Void Ratio = 80 %	26.98	13.79	18.64	23.59	14.96	14.28	12.62	13.45