YUROK TRIBE

Water Year 2003 (WY03) Report
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1 Introduction

This Water Year 2003 (WY03) Report is the second in a series of annual water reports documenting water quality and hydrologic data gathered by the Yurok Tribe Environmental Program (YTEP) data collection network in the Lower Klamath River watershed, specifically within and adjacent to the Yurok Indian Reservation (YIR). The long-term monitoring activities outlined in this report include water quality monitoring on the Klamath mainstem and within the tributaries, macroinvertabrate population sampling in selected tributaries, hydrologic monitoring performed on McGarvey, Blue, and Turwar Creeks, and rainfall information from the Notchko Weather Station and other available rain gauges. The Water Year 2002 (WY02) Report is currently available for review at the Yurok Tribal Offices in Klamath, California.

2 Background

2.1 Klamath River

The health of the Klamath River and associated fisheries has been central to the life of the Yurok Tribe since time immemorial fulfilling subsistence, commercial, cultural, and ceremonial needs. Yurok oral tradition reflects this. The Yurok did not use terms for north or east, but rather spoke of direction in terms of the flow of water (Kroeber 14). The Yurok word for salmon, *nepuy*, refers to “that which is eaten”. Likewise, the local waterways and watershed divides have traditionally defined Yurok aboriginal territories. Yurok ancestral land covers about 360,000 acres and is distinguished by the Klamath and Trinity Rivers, their surrounding lands, and the Pacific Coast extending from Little River to Damnation Creek.

The fisheries resource continues to be vital to the Yurok today. The September 2002 Klamath River fish kill, where a conservative estimate of 33,000 fish died in the Lower Klamath before reaching their natal streams to spawn, was a major tragedy for the Yurok people.

2.2 The Yurok Indian Reservation

The current YIR consists of a 56,000-acre corridor extending for one mile from each side of the Klamath River from the Trinity River confluence to the Pacific Ocean, including the channel (Figure 2-1). There are approximately two dozen major anadromous tributaries within that area. The mountains defining the river valley are as much as 3,000 feet high. Along most of the river, the valley is quite narrow with rugged steep slopes. The vegetation is principally redwood and douglas fir forest with little area available for agricultural development. Historically, prevalent open prairies provided complex and diverse habitat.

At this time within the reservation 3,653 acres are held in trust status, 115 acres are Tribal Housing, 4,222 acres are Tribal fee lands and 3,499 acres are allotments (Yurok Tribal Planning Department). The majority of the remaining lands in the YIR are fee lands, (mostly owned by Simpson Resource Company), which are managed intensively for timber products. A small portion of the YIR consists of public lands managed by Redwood National/State Parks, the United States Forest Service (USFS) and private landholdings.

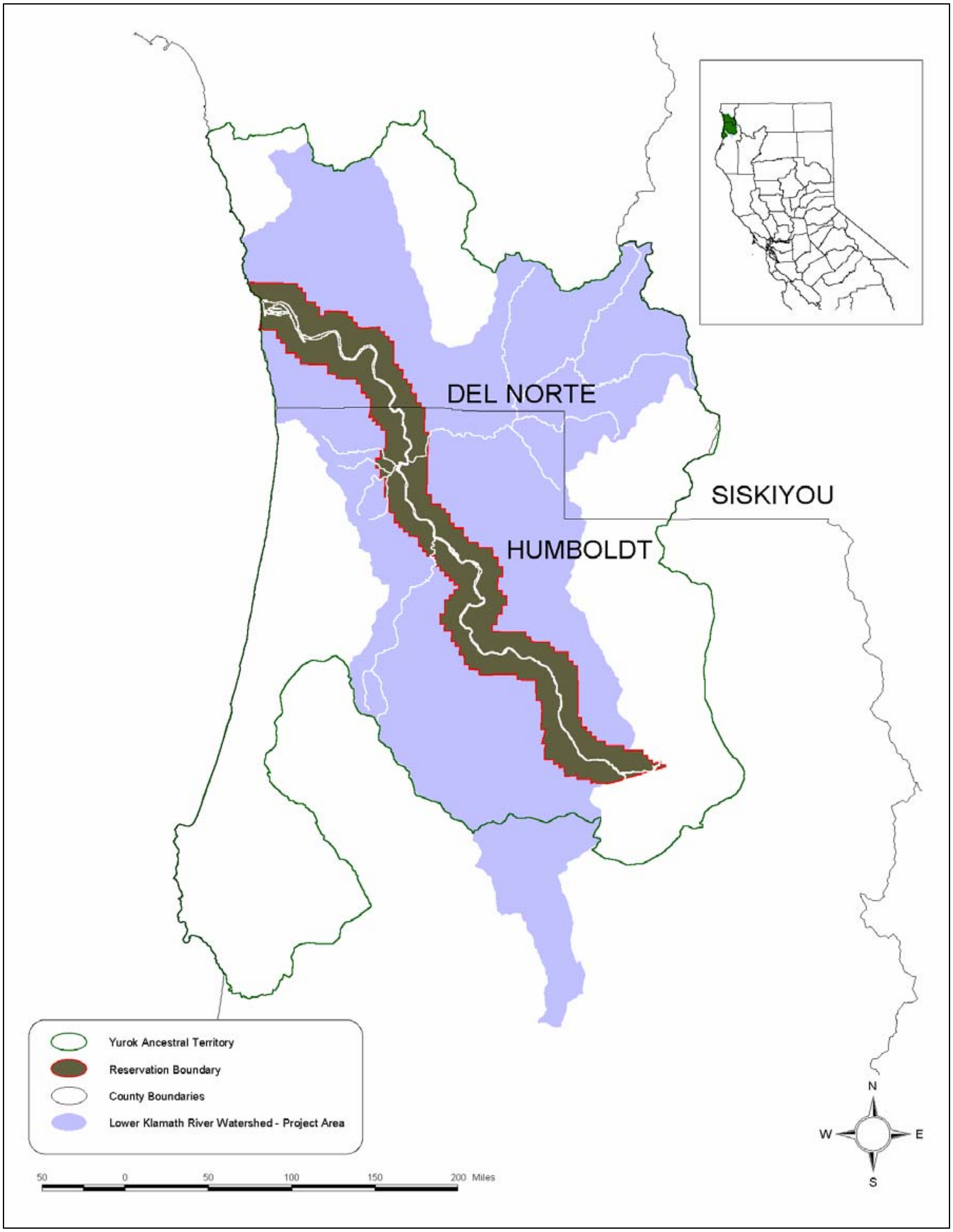


Figure 2-1 The Yurok Indian Reservation and Yurok Ancestral Territory

The Yurok Reservation exists one mile on each side of the Klamath River from the village of Weitchpec, at the confluence of the Trinity and Klamath Rivers, to the mouth of the Pacific Ocean.

2.3 The Klamath River Watershed

The Klamath River system drains much of Northwestern California and South-Central Oregon (Figure 2-1). Thus, even activities taking place on land hundreds miles off the YIR can affect water conditions within the Reservation's boundaries. For example, upriver hydroelectric and diversion projects have altered natural flow conditions for decades. The majority of water flowing through the Reservation is derived from scheduled releases of impounded water from the Upper Klamath Basin that is often of poor quality with regards to human needs as well as the needs of fish and wildlife.

Some historically perennial streams now have ephemeral lower reaches and seasonal fish migration blockages because of inadequate dam releases from water diversion projects along the Klamath and Trinity Rivers. The releases contribute to lower mainstem levels, excessive sedimentation which in turn causes subsurface flow and aggraded deltas. Additionally, the lower slough areas of some of the Lower Klamath tributaries that enter the estuary experience eutrophic conditions during periods of low flow. These can create water quality barriers to fish migration when dissolved oxygen levels are inadequate for migrating fish. The Klamath River is on California State Water Resource Control Board's 1998 303(d) List as impaired for temperature, dissolved oxygen, and nutrients.

The basin's fish habitat has also been greatly diminished in area and quality during the past century by accelerated sedimentation from mining, timber harvest practices, and road construction, as stated by Congress in the Klamath River Act of 1986. Management of private lands in the basin (including fee land within Reservation boundaries) has been, and continues to be, dominated by timber harvest for the last 100 years. Associated road building and slope destabilization have contributed to aggradations from increased sediment input into many of the tributaries to the Klamath River on the YIR. The steep terrain, granular soil matrix, and high precipitation have helped to produce erosive conditions throughout the area. Mass wasting is common. These conditions make road conditions difficult to stabilize and cause considerable siltation and turbidity problems in the Klamath River. The North Coast Region Quality Control Board (NCRQCB) suggests in their 303(d) Update List (2001) that sediment conditions within the channel and immoderate sediment loading have impaired beneficial uses within the Klamath watershed.

Nearly all of the Reservation streams that have perennial flow and no physical barriers to fish migration provide spawning, incubation, and rearing habitats for anadromous fish species. Perennial tributaries also provide important thermal refugia for fish of the Klamath River during periodic mainstem warm water episodes. Sufficient flows of clean water are essential to the long-term viability of a healthy fishery.

Water quality barriers, high sediment load, and herbicide spraying within anadromous and domestic watersheds all create the need for comprehensive, continuous water quality, hydrology and herbicide monitoring.

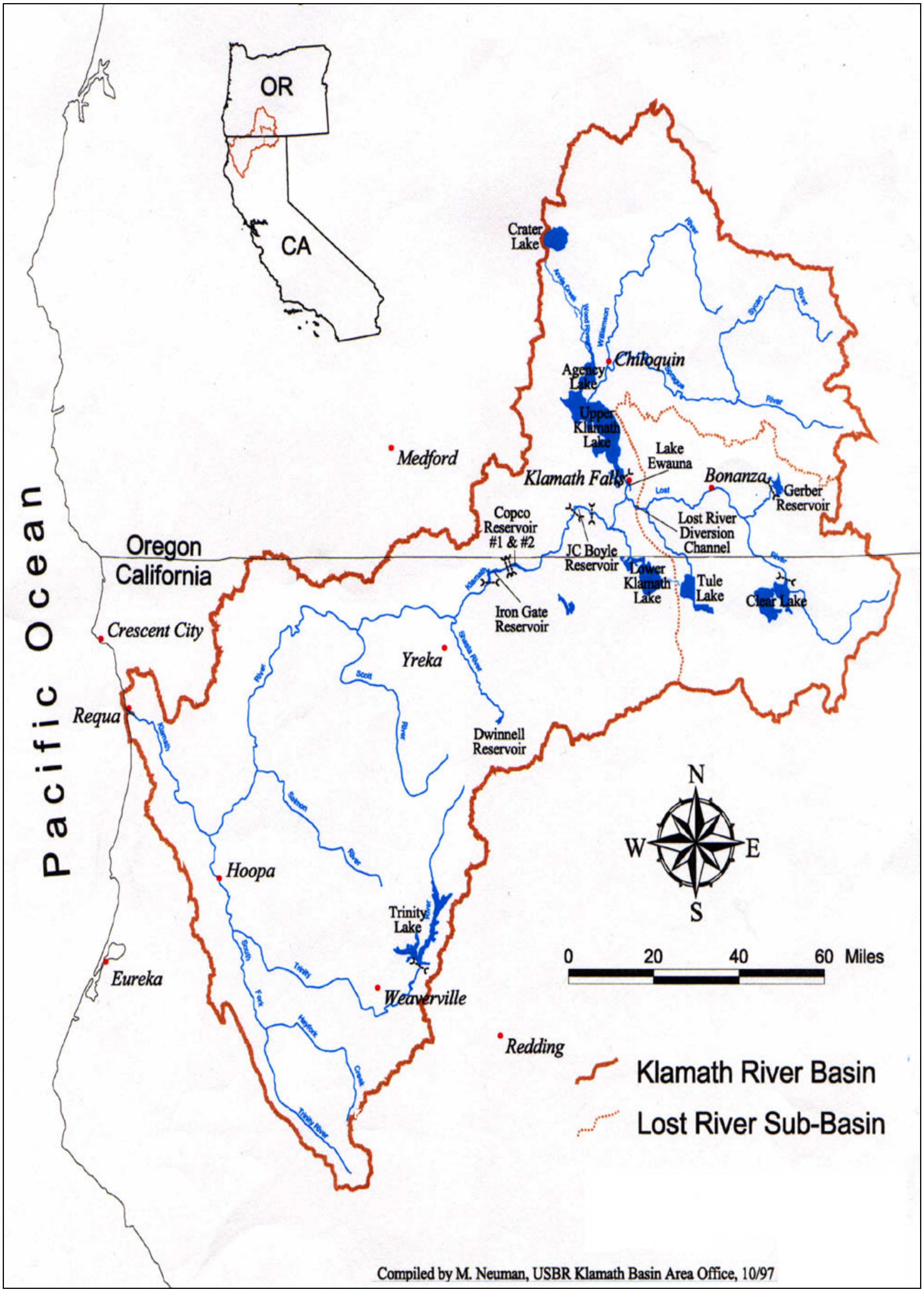


Figure 2-2 The Klamath River Basin

3 Yurok Tribe Water Monitoring Program

In 1998, YTEP was created to protect and restore tribal natural resources through high quality scientific practices. YTEP is dedicated to improving and protecting the natural and cultural resources of the Yurok Tribe through collaboration and cooperation with local, private, state, tribal, and federal entities such as the Yurok Tribe Fisheries Program, US Fish and Wildlife Service (USFWS), the United States Environmental Protection Agency (USEPA), Simpson Resource Company, the NCRWQCB, and the United States Geological Survey (USGS). A USEPA General Assistance Program (GAP) Grant and funding allocated under the Clean Water Act Sections 104, 106, and 319 primarily fund YTEP's water monitoring activities.

The purpose of this document is to present a synthesis of YTEP's hydrologic and water quality data collected in the Lower Klamath watershed for WY03. This report is part of YTEP's comprehensive program of monitoring and assessment of the chemical, physical, and biological integrity of the Klamath River and its tributaries in a scientific and defensible manner.

4 Quality Assurance

YTEP staff undertook many measures to assure high quality hydrological, macroinvertabrate, herbicide, and water quality data during WY03. YTEP staff responsible for collecting this data consists of the Water Quality Program Coordinator, Hydrologist, Pesticide Program Coordinator an Environmental Program Coordinator and two AmeriCorps Watershed Stewards Project members. The staff report to the Environmental Program Director, who is responsible for overseeing the USEPA-approved Quality Assurance Program Plan (QAPP) for Water Quality Assessment and Monitoring.

The QAPP details the quality assurance (QA) and quality control (QC) procedures used to ensure and document that data is accurate, precise, complete, and representative of actual field conditions. The QAPP additionally describes the planning, implementation, and assessment criteria required for projects performed by YTEP for the generation, acquisition, and use of environmental water quality data. The QAPP is also applied for water quality monitoring and sampling activities undertaken by the Yurok Tribe outside of the YIR. The QAPP further states that YTEP will follow protocols developed by another agency when collaborating on monitoring projects with other parties. Changes to the QAPP are approved by the Environmental Program Director.

In order to ensure comparability and accuracy of data, YTEP uses Standard Operating Procedures (SOPs). Where an SOP does not exist for a certain instrument or procedure, YTEP follows the manufacturer’s suggested procedures. Detailed logs are kept in waterproof field notebooks and data sheets. In these logs, any malfunctions, unusual circumstances, and/or variations are noted.

A large portion of the data was collected at sites using continuous monitoring instruments such as the Hydrolab® Datasonde 4A (datasonde) and H-350XL data logger. QC involves crosschecking the data from the field. For example, at the gaging stations the water level on a fixed, graduated staff plate was compared to the transducer/data collection platform reading. Equipment was also calibrated before deployment and post-calibrated after extraction. These procedures help ensure that the data is of the highest quality.

Data screening and validation are conducted on an ongoing basis. At no time is more than one month of data collected without that data being reviewed. The reviewer looks for missing data, large shifts in values, and applies common sense and her/his knowledge of the location. In addition, data validation includes checking information that has been transmitted from one form into another (e.g., field logbook to computer file) and making sure that there have been no errors in transmission. Daily maximums and minimums were disregarded when more than five measurements were missing from a 24-hour period and when the daily maximum or minimum was expected to occur during the gap.

Water quality data collected in the mainstem Klamath River has been graded by USFWS according to the parameters given in Table 4-1. Data for which grading could not be completed is assigned a grade of “I” for incomplete. Data gradings for specific deployments at each site are given in Tables 4-2 through 4-10.

The quality of the data collected with datasondes was evaluated by the USFWS using an ACCESS database. The data was assigned a grade rating for each deployment period based upon comparing the datasonde’s probes to a standard after extraction. Pre and post-season testing of each instrument’s temperature probe revealed the instruments to be within 0.2°C of one another and a NIST traceable thermometer (Zedonis and Cunanan 2002 and Turner and Zedonis 2003). This information suggested that there was no need to rate water temperature data from independent datasets (Pers. Comm., Randy Turner, USFWS 2003). pH probes were compared to standard solutions and the DO probes were compared to a standard of 100% saturation using the same procedures as in the initial calibration process.

The grade ratings should be referenced to determine the accuracy and precision of the data when assessing the results in section 7.1. However, care needs to be incorporated into interpreting the results along with the data set grade rating.

Table 4-1 Quality Ratings Reference Table

Quality Ratings For Raw Data				
Parameter	**A (excellent)**	**B (Good)**	**C (Fair)**	**D (Poor)**
pH	= ± 0.2 unit	> ± 0.2 to 0.5 unit	> ± 0.5 to 0.8 unit	> ± 0.8 unit
Dissolved Oxygen (% Sat)	= ± 3%	> ± 3 to 5%	> ± 5 to 8%	> ± 8%

Table 4-2 Data Grading Klamath River at Aiken's Hole

Site	StartDate	pH Grade	DO% Grade
AH	5/20/2003	A	C
AH	6/5/2003	A	A
AH	6/13/2003	A	D
AH	6/18/2003	A	C
AH	6/25/2003	A	A
AH	7/2/2003	A	D
AH	7/9/2003	A	B
AH	7/16/2003	A	D
AH	7/23/2003	A	A
AH	8/6/2003	I	I

Table 4-3 Data Grading Klamath River above Trinity River

Site	StartDate	pH Grade	DO% Grade	Site	StartDate	pH Grade	DO% Grade
WE	4/28/2003	A	C	WE	7/23/2003	A	B
WE	5/8/2003	A	A	WE	8/6/2003	A	A
WE	5/14/2003	I	I	WE	8/13/2003	A	A
WE	5/22/2003	A	A	WE	8/21/2003	A	B
WE	5/29/2003	A	C	WE	8/27/2003	A	A
WE	6/5/2003	A	A	WE	9/4/2003	A	B
WE	6/13/2003	A	A	WE	9/11/2003	A	B
WE	6/18/2003	A	A	WE	9/17/2003	A	A
WE	6/25/2003	A	A	WE	9/24/2003	A	A
WE	7/2/2003	A	B	WE	10/1/2003	A	A
WE	7/9/2003	A	C	WE	10/9/2003	A	A
WE	7/16/2003	A	C				

Table 4-4 Data Grading Trinity River above Klamath River

Site	StartDate	pH Grade	DO% Grade	Site	StartDate	pH Grade	DO% Grade
TR	4/28/2003	A	B	TR	7/23/2003	A	B
TR	5/8/2003	A	C	TR	8/6/2003	A	B
TR	5/14/2003	I	I	TR	8/13/2003	A	A
TR	5/22/2003	A	A	TR	8/21/2003	A	A
TR	5/29/2003	A	A	TR	8/27/2003	A	A
TR	6/5/2003	A	A	TR	9/4/2003	A	A
TR	6/13/2003	A	A	TR	9/11/2003	A	C
TR	6/18/2003	A	B	TR	9/17/2003	A	A
TR	6/25/2003	A	B	TR	9/24/2003	A	D
TR	7/2/2003	A	C	TR	10/1/2003	I	A
TR	7/9/2003	A	C	TR	10/9/2003	A	C
TR	7/16/2003	A	C				

Table 4-5 Data Grading Klamath River above Martin's Ferry

Site	StartDate	pH Grade	DO% Grade
MF	4/28/2003	A	A
MF	5/8/2003	A	A
MF	5/14/2003	A	A
MF	5/22/2003	I	I
MF	5/29/2003	A	C
MF	6/5/2003	A	B

Table 4-6 Data Grading Klamath River above Tully Creek

Site	StartDate	pH Grade	DO% Grade	Site	StartDate	pH Grade	DO% Grade
TC	6/13/2003	A	A	TC	8/21/2003	A	A
TC	6/18/2003	A	A	TC	8/27/2003	A	B
TC	6/25/2003	A	D	TC	9/4/2003	A	C
TC	7/2/2003	A	A	TC	9/11/2003	I	I
TC	7/9/2003	A	A	TC	9/18/2003	D	A
TC	7/16/2003	A	B	TC	9/25/2003	A	A
TC	7/23/2003	A	A	TC	10/1/2003	A	A
TC	8/6/2003	A	A	TC	10/9/2003	A	A
TC	8/13/2003	A	B				

Table 4-7 Data Grading Klamath River above Blue Creek – 6 Feet Deep

Site	StartDate	pH Grade	DO% Grade
KB2	9/15/2003	A	A
KB2	9/22/2003	A	A
KB2	9/29/2003	A	A
KB2	10/6/2003	A	A

Table 4-8 Data Grading Klamath River above Blue Creek - 25 Feet Deep

Site	StartDate	pH Grade	DO% Grade	Site	StartDate	pH Grade	DO% Grade
BC	6/23/2003	A	A	BC	8/25/2003	A	A
BC	6/30/2003	A	A	BC	9/2/2003	A	A
BC	7/7/2003	A	B	BC	9/8/2003	A	B
BC	7/14/2003	A	A	BC	9/15/2003	A	B
BC	7/21/2003	A	C	BC	9/22/2003	A	A
BC	8/4/2003	A	A	BC	9/29/2003	A	C
BC	8/11/2003	A	B	BC	10/6/2003	A	A
BC	8/18/2003	A	A				

Table 4-9 Data Grading Blue Hole

Site	StartDate	pH Grade	DO% Grade
BH	8/18/2003	A	A
BH	8/25/2003	A	C
BH	9/8/2003	A	C
BH	9/15/2003	A	C
BH	9/29/2003	A	C
BH	10/6/2003	A	A

Table 4-10 Data Grading Klamath River at Turwar Gauge

Site	StartDate	pH Grade	DO% Grade
TG	4/28/2003	A	A
TG	5/8/2003	A	A
TG	5/14/2003	I	I
TG	5/22/2003	A	A
TG	5/29/2003	A	A
TG	6/5/2003	A	A
TG	6/13/2003	A	A
TG	6/18/2003	A	A

Water chemistry data analyzed by North Coast Labs (NCL) was reviewed and validated before it was included into this annual water report. Spike, duplicate and blank QA/QC samples were submitted to the lab by the field crew to show recovery, precision and verify that no contamination occurred during the collection of the sample water and transportation of the sample bottles. These QA/QC sample results are also reviewed to evaluate the performance of the contract and sub-contract labs.

The contract and sub-contract labs perform their own spike, duplicate and blank QA/QC samples to verify the performance of their methods and analytical equipment. These QA/QC results are reported to YTEP and are reviewed by YTEP staff to determine the quality of the data received. These QA/QC results are verified to meet the appropriate percent recovery for the particular analysis that is performed. All of the data in this document has been reviewed and verified to meet the acceptable percent recoveries suggested for each analysis.

Water quality data collected in the mainstem Klamath River using datasondes will be corrected by the USFWS. The data quality grade ratings are used to determine which data sets need to be corrected. Data sets with grades that are below grade A (excellent) will be corrected to remove the error that was introduced by bio-fouling and/or electronic drift. Corrections will be based on revised field sampling methods designed to record post cleaning and post calibration measurements in the field. These revised methods differ from field sampling methods followed during last year's data collection efforts. YTEP initiated the new field sampling methods on June 18, 2003. Data collected during the 2003 field sampling season prior to June 18th followed the protocol used during the 2002 field sampling season. Both of these protocols are located in ***Appendix A***. Once the corrected data is peer reviewed and released the data will be incorporated into this report. The water temperature sensors on the datasondes are not calibrated and cannot be corrected. Therefore, the water temperature data reported in this report can be considered final.

5 Site Selection

The various sampling locations were chosen because the conditions at the site met the needs of the sampling project. Table 5-1 shows sampling locations, their site IDs, name of the sub-watershed and measured parameters.

Table 5-1 Sampling sites WY03 and their respective parameters in the Lower Klamath River Basin

Sub-watershed	Site Name	Site ID	Long	Lat	Stage	Temp	DO	Turb	SpCond	pH	Macro	Nutrients	SSC	Air Temp/Rel Hum
Middle Klamath	Klamath River at Aikens Hole	AH	123 39 9	41 13 45		C	C	C	C	C				
Middle Klamath	Klamath River above Trinity River	WE	123 42 11	41 11 10		C	C	C	C	C		D		C
Middle Klamath	Klamath River above Trinity River - New	WE03	123 42 11	41 11 10		C	C	C	C	C		D		C
Lower Trinity	Trinity River above Klamath River	TR	123 42 15	41 11 2		C	C	C	C	C		D		C
Lower Trinity	Trinity River above Klamath River - New	TR03	123 42 15	41 11 2		C	C	C	C	C		D		C
Lower Klamath	Klamath River above Tully Creek	TC	123 46 19	41 13 36		C	C	C	C	C		D		
Tully	Tully Creek	Ty1	123 46 31	41 13 43		D	D	D	D	D				
Lower Klamath	Klamath River at Martins Ferry	MF	123 45 19	41 12 27		C	C	C	C	C		D		
Tectah	Tectah Creek	Te1	123 56 27	41 18 4		D	D		D	D	D			
NF Tectah	North Fork Tectah Creek	Te2	123 57 49	41 15 48		D	D		D	D	D			
SF Tectah	South Fork Tectah Creek	Te3	123 57 48	41 15 47		D	D		D	D	D			
Lower Klamath	Klamath River above Blue Creek -25 Feet	BC	123 55 41	41 25 17		C	C	C	C	C				
Lower Klamath	Klamath River above Blue Creek - 6 Feet	KB2	123 55 41	41 25 17		C	C	C	C	C		D		
Lower Blue	Lower Blue 1	Lb1	123 54 4	41 26 55	C	C	D	C	C	D			D	
Lower Blue	Lower Blue 2	Lb2	123 54 30	41 26 34		D	D		D	D	D			
Lower Klamath	Blue Hole	BH	123 55 41	41 25 29		C	C	C	C	C				
Lower Klamath	Klamath River Below Blue Hole	BB	123 55 44	41 25 50		D	D	D	D	D				
Lower Klamath	Klamath River at State Stranded Bar	SB	123 55 56	41 26 6		D	D	D	D	D				
Lower Klamath	Klamath River at S-Curve	SC	123 56 18	41 27 44		D	D	D	D	D				
Lower Klamath	Klamath River at Osprey Nest	OS	123 56 49	41 27 50		D	D	D	D	D				
McGarvey	McGarvey Creek	Mc1	124 00 34	41 29 10	C	C	D		C	D	D		D	
Lower Klamath	Klamath River at Turwar Gauge	TG	124 00 2	41 30 43		C	C	C	C	C		D		C
Lower Klamath	Turwar Gauge - Right Bank	TGRB	123 59 55	41 30 40		C	C	C	C	C				C
Turwar	Turwar Creek 1	Tu1	123 58 43	41 32 6		D	D		D	D	D			
Turwar	Turwar Creek 2	Tu2	123 58 6	41 32 47	C	C	D	C	C	D	D		D	

INACTIVE SITES

Roach	Roach Creek	Ro1	123 51 2	41 16 31
Mettah	Mettah Creek	Me1	123 52 21	41 18 31
East Fork Pecwan	East Fork Pecwan Creek	EP1	123 50 39	41 20 35
West Fork Pecwan	West Fork Pecwan Creek	WP1	123 53 46	41 20 35
Johnsons	Klamath River at Johnsons Bar 1	Jo1	123 52 4	41 20 38
Lower Klamath	Klamath River at Johnsons Bar 2	KJ1	123 52 35	41 21 5
West Fork Blue	West Fork Blue Creek	Wb1	123 53 46	41 28 4

C=Continuous Monitoring at Site; D=Discrete Monitoring at Site
DO=Dissolved Oxygen; Turb=Turbidity; SpCond=Specific Conductivity; Macro=Macroinvertebrates; SSC=Suspended Sediment Concentration;
Air Temp/Rel Hum=Air Temperature/Relative Humidity

Table 5-2 Dates of Deployment at Continuous Monitoring Locations WY03

Site Name	Site ID	Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03
Klamath River at Aikens Hole	AH								🟩 20	🟩	🟩	🟩 13		
Klamath River above Trinity River	WE							🟩 28	🟩	🟩 18				
Klamath River above Trinity River - New	WE03									🟩 18	🟩	🟩	🟩	🟩 15
Trinity River above Klamath River	TR							🟩 28	🟩	🟩 25				
Trinity River above Klamath River - New	TR03									🟩 25	🟩	🟩	🟩	🟩 15
Klamath River above Tully Creek	TC									🟩 13	🟩	🟩	🟩	🟩 15
Klamath River at Martins Ferry	MF							🟩 28	🟩	🟩 12				
Klamath River above Blue Creek -25 Feet	BC									🟩 23	🟩	🟩	🟩	🟩 13
Klamath River above Blue Creek - 6 Feet	KB2												🟩 15	🟩 13
Lower Blue 1	Lb1	🟦	▨ 14	▨ 2 🟦	🟦 ▨ 22	▨ 5 🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Blue Hole	BH											🟩 18	🟩	🟩 13
McGarvey Creek	Mc1	🟦	🟦	▨ 11 25	▨ 10	▨ 5 🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Klamath River at Turwar Gauge	TG									🟩 13 23				
Turwar Gauge - Right Bank	TGRB							🟩 28	🟩	🟩 13				
Turwar Creek 2	Tu2	🟦	🟦	🟦	🟦	🟦	▨ 13 27	🟦	🟦	🟦	🟦	🟦	▨ 16 30	🟦

🟦 Gage Height Only
▨ Gage Height and Water Quality
🟩 Water Quality Only

*Dates within bars indicate dates of initial deployment/ultimate retrieval

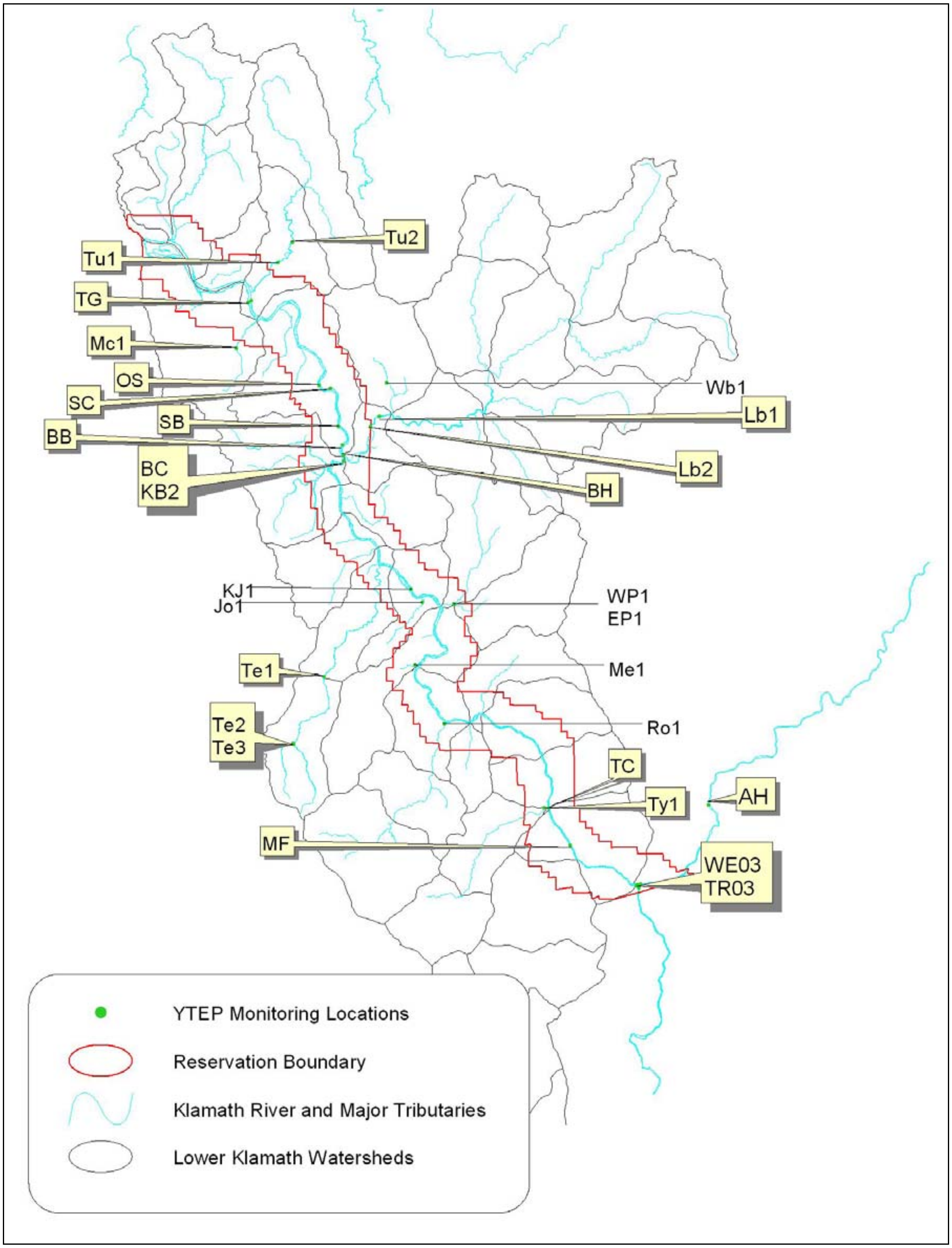


Figure 5-1 Lower Klamath Basin Monitoring Locations, Active (in boxes) and Inactive (without boxes)

5.1 Water Quality

5.1.1 Mainstem

In conjunction with the U.S. Fish and Wildlife Service (USFWS) and the Karuk Tribe, YTEP participated in a water quality study on the mainstem Klamath River. YTEP operated datasondes, continuous multi-probe water quality monitoring instruments, at locations detailed in this section. Latitude and longitude coordinates for these sampling sites are located in Figure 5-1.

Site selection depended on the goals and objectives of the monitoring project. Accessibility and security also play a role in the decision making process. For example, sites for the water quality study on the Klamath River were chosen to develop a spatially distributed network on the river throughout the YIR. The Turwar monitoring site (Figure 5-21) was chosen for its close proximity to the mouth of the river. The monitoring sites on the Klamath River at Martin's Ferry Bridge (Figure 5-6), in Weitchpec on the Klamath upstream of the Trinity River confluence (Figure 5-4), and in the Trinity upstream of the Klamath represent conditions before the two rivers merge and the conditions downstream after mixing has occurred (Figure 5-4).

Sampling sites were added, removed and relocated during the 2003 sampling season. During the beginning of the monitoring season YTEP received a request from Yurok Fisheries Biologist Scott Turo to monitor water quality with a datasonde in Aiken's Hole (AH), located upstream of Aiken's Creek (Figure 5-2). This site was chosen to record water quality parameters in known green sturgeon spawning grounds. Water quality monitoring began in Aiken's Hole on May 20th and ended on August 13th.

Scott Turo also requested that the datasonde be relocated to Blue Hole (BH) after monitoring was completed in Aiken's Hole. The Blue Hole site (Figure 5-14) was established to document water quality parameters in a large cold water refuge located downstream of the mouth of Blue Creek. This cold water refuge is formed by intergravel flow from Blue Creek and is considered an anomaly on the river. Water quality monitoring began in Blue Hole on August 18th and ended on October 13, 2003

On June 12th the Martin's Ferry (MF) site was abandoned due to safety issues related to the steep trail leading to the river's edge and occasional vandalism to the monitoring equipment. On June 13th the datasonde used to monitor at MF was relocated to a site upstream of Tully Creek (TC), approximately one mile downstream of Martin's Ferry Bridge. Site conditions at the two sites are considered comparable by YTEP. This site is illustrated in Figure 5-6.

On June 23rd the Turwar Gage (TG) site was abandoned due to the fact that the USGS was operating a YSI datasonde at the same location. YTEP installed a Hobo® tidbit temperature sensor, provided by the USFWS, at the TG site to document water temperature continuously throughout the monitoring season. YTEP chose to monitor water quality at a new location that is approximately 500 feet upstream of Blue Creek (BC), approximately 10 miles upstream of the TG site. This site was chosen in order to close a data gap that existed in between the TC and TG sites. This site is also important because many salmon and steelhead hold in the area near Blue Creek, resulting in the largest numbers of dead fish reported on the Klamath River during the fish kill in 2002. This site represents Klamath River conditions prior to the addition of water from Blue Creek, a major tributary. The Blue Creek site is illustrated in Figure 5-14.

On June 18th the Weitchpec (WE) site was relocated approximately 900 feet downstream to the large gravel bar located at the confluence of the Trinity and Klamath Rivers. On June 25th the Trinity River (TR) site was relocated approximately 1,200 feet downstream to the large gravel bar located at the confluence of the Trinity and Klamath Rivers. These two datasondes were relocated to record the water quality of the two rivers just before they flow together. These new locations were also chosen in order to help YTEP staff collect data more efficiently by accessing two sites with one trail. These sites are illustrated in Figure 5-4.

On August 25th YTEP performed a special study at Blue Hole at the request of Dave Hillemeier of the Yurok Tribe Fisheries Department. This special study was performed to map the water quality, bathymetry, and stratification of Blue Hole. Transects were laid out across the Hole, and every other transect was sampled. An illustration of transects identified and sampled is given in Figure 5-16.

On September 8th YTEP performed a survey of four deep holes in the lower Klamath River between Blue Hole and Turwar Gauge. These four deep holes were studied to determine how water quality changed as depth increased, specifically to identify dissolved oxygen stratification or mixing. These four locations were chosen because of their known status as deep holes on the Klamath. These sites were named by YTEP according to their familiar characteristics: Below Blue Hole (BB), State Stranded Bar (SB), S-Curve (SC), and Osprey Nest (OS); the sites are illustrated in Figure 5-14.

On September 15th a new datasonde was added to the Klamath River monitoring network. The datasonde was located at the Blue Creek site to record water quality parameters at the surface. The datasonde was attached to a cable and was submerged approximately six feet deep. This site was added to determine if water quality parameters were significantly different between the existing datasonde that was located approximately 25 feet deep and the surface. This site's identification initials are KB2 (see Figure 5-14).

5.1.2 Tributaries

The water quality monitoring sites were selected for their importance to fish habitat, potential for Tribal water sources, and current land management activities such as timber harvest and restoration projects. Water quality monitoring in the tributaries were located near the gaging stations so that water quality conditions can be linked to water levels and flow. Other factors contributing to site selection include accessibility and relative safety from vandalism.

In November of 2002, one grab sample set was collected on McGarvey Creek to determine if there are pollutants entering the stream from the runoff associated with Highway 101. The sampling was timed to collect the first-flush rainfall of the fall season. Samples and duplicates were collected both upstream and downstream of the Highway 101 culvert on McGarvey Creek. The samples were analyzed for metals.

5.2 Hydrologic Monitoring

WaterLog Pressure Transducer/Data Collection Platforms, or gaging stations, on McGarvey Creek (Figure 5-21), Blue Creek, (Figure 5-19), and Turwar Creek (Figure 5-25) monitor water levels and flow. Flow and sediment samples are collected at Den Creek, (a tributary to McGarvey Creek); however, there is not a gaging station located on Den Creek. Flow measurements are necessary at Den Creek when a flow measurement is taken in McGarvey Creek using the crane. The bridge downstream from the confluence of McGarvey and Den Creeks is the only possible site to take a measurement using a crane. The sediment and flow measurements are subtracted from the total flow and sediment concentrations to coincide with the flow measurements and sediment samples collected upstream from the confluence at the gaging station on McGarvey Creek.

Site locations were based on the presence of fish habitat and current land management activities, such as timber harvest and restoration projects. Sites were selected low enough in the watershed to document most of the water draining from the watershed. Employee safety and the protection of equipment also required that gaging stations be in locations which do not become inundated during high flows. Site locations were chosen to represent the different geologies of Lower Klamath Basin tributaries. McGarvey Creek's geology is primarily from the Fransiscan formation; the geology of Blue and Turwar Creeks is from the Fransiscan and Jurassic Galice formations. Substrate in Blue and Turwar Creeks is larger than that of McGarvey Creek; while all three creeks become turbid following rain events, Blue and Turwar Creeks become clear much more quickly than McGarvey Creek.

5.3 Macroinvertabrate Sampling

Site selection criteria for macroinvertabrate sampling include spatial distribution, herbicide application activity, watershed restoration activities, proposed future development, and other concurrent water quality monitoring activities. Sites were located in the lower reaches of watersheds that characterize the water quality and watershed health condition throughout the Lower Klamath (Figure 5-11, Figure 5-19, Figure 5-21, and Figure 5-25). YTEP is in the process of developing baseline conditions to document the magnitude and duration of water quality impacts. The following reasons were used as selection criteria for macroinvertabrate sampling:

1. *Spatial Distribution* - Sites located in the lower reaches of watersheds that characterize the water quality and watershed health condition throughout the Lower Klamath. Areas chosen to monitor baseline and long-term trends.

2. *Activity Specific* -Sites located above and/or below herbicide applications and other activities that may potentially impact water quality.

3. *Watershed Restoration Activities*- Sites located in watersheds and sub-watersheds that have active or proposed restoration activities. Sites are selected to monitor the long-term trends by tracking the watershed's recovery.

4. *Proposed Future Development*- Sites near locations of resource and proposed resource development.

5. *Klamath Mainstem Water Quality Characterization*- Sites located in the main stem Klamath River in order to compliment the on going water quality studies and characterization.

Table 5-3 Selection criteria priority matrix for macroinvertabrate sampling

Creek	Watershed	Sub-Watershed	Site ID	Primary Criteria	Secondary Criteria	Other
Lower Blue	Blue	Lower Blue	LB1	1	3	2
McGarvey	McGarvey	McGarvey	Mc1	3	1	
Tectah	Tectah	Tectah	Te1	3	1	
NF Tectah	Tectah	NF Tectah	Te2	3	1	
SF Tectah	Tectah	SF Tectah	Te3	3	1	
Turwar	Turwar	Turwar	Tu1	1	3	2
Turwar	Turwar	Turwar	Tu2	1	3	2

5.4 Herbicide Monitoring

During the August 21, 2002 Yurok Environmental Monitoring Workgroup (YEMWG) meeting priorities were established for surface water monitoring based on proximity of Simpson's proposed spray units to surface water sources and herbicide(s) to be applied. Units sprayed with Oust (sulfometuron methyl) are not sampled due to the availability of laboratory methodologies for analysis and cost. During fall of 2002, Tully Creek (Ty1) was selected by the YEMWG for surface water monitoring based on information concerning application areas in relation to water sources (Figure 5-6). Atrazine ground applications in the Williams Ridge area, located within the Tully Creek watershed, occurred between 10/7/2002 and 10/10/2002.

5.5 Notchko Remote Automated Weather Station

During the initial stages of meteorological station installation several locations were assessed as to relative accessibility, vegetation cover, elevation, slope, ownership, threat of vandalism and other siting criteria as described in the Yurok Tribe Air Quality Program QAPP. The Notchko site (Figure 5-9) was selected because of its exposure to canyon winds, placement outside of the 100 year floodplain, and its elevation above the Klamath River. Additionally, this site is owned by the Yurok Tribe, accessible year-round and not visible from the main road, thereby limiting threats of vandalism.

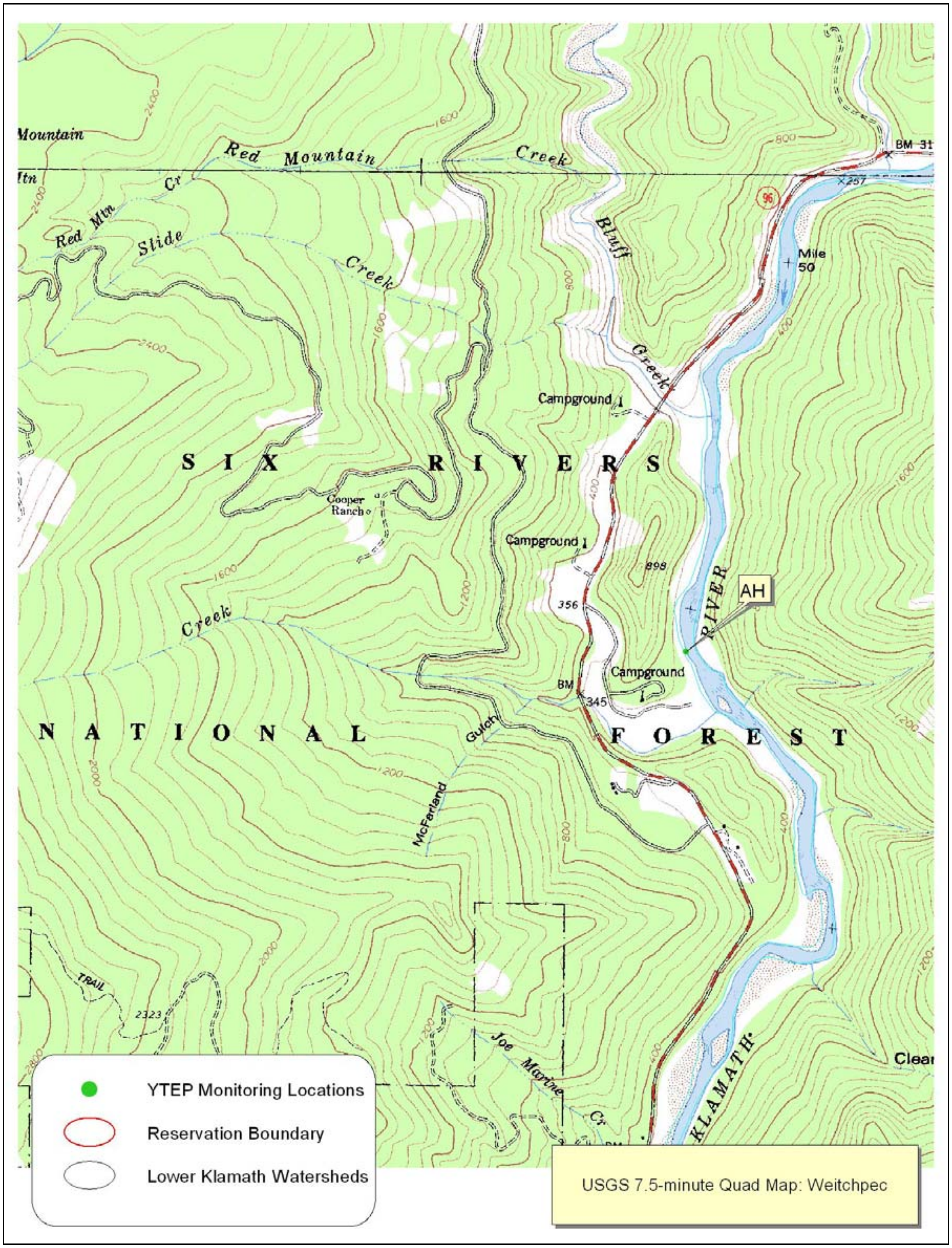
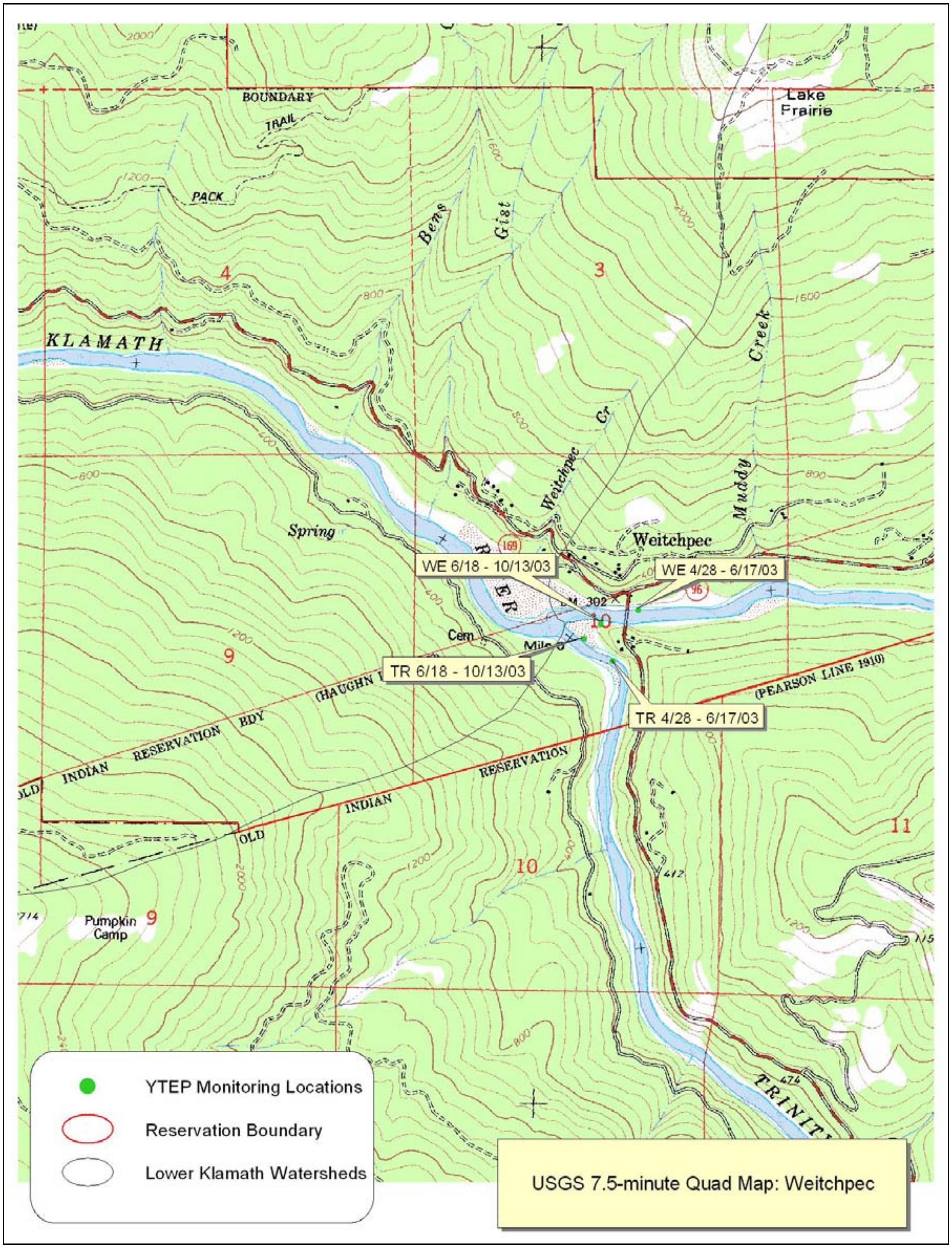


Figure 5-2 Klamath River at Aiken's Hole (AH) Monitoring Location WY03

Figure 5-3 Klamath River at Aiken's Hole (AH) Monitoring Location 6/13/2003



WE 6/18 - 10/13/03

WE 4/28 - 6/17/03

TR 6/18 - 10/13/03

TR 4/28 - 6/17/03

USGS 7.5-minute Quad Map: Weitchpec

Figure 5-4 Klamath River above Trinity River (WE) and Trinity River above Klamath River (TR) Monitoring Locations WY03

Figure 5-5 Klamath River/Trinity River Confluence 8/27/2003

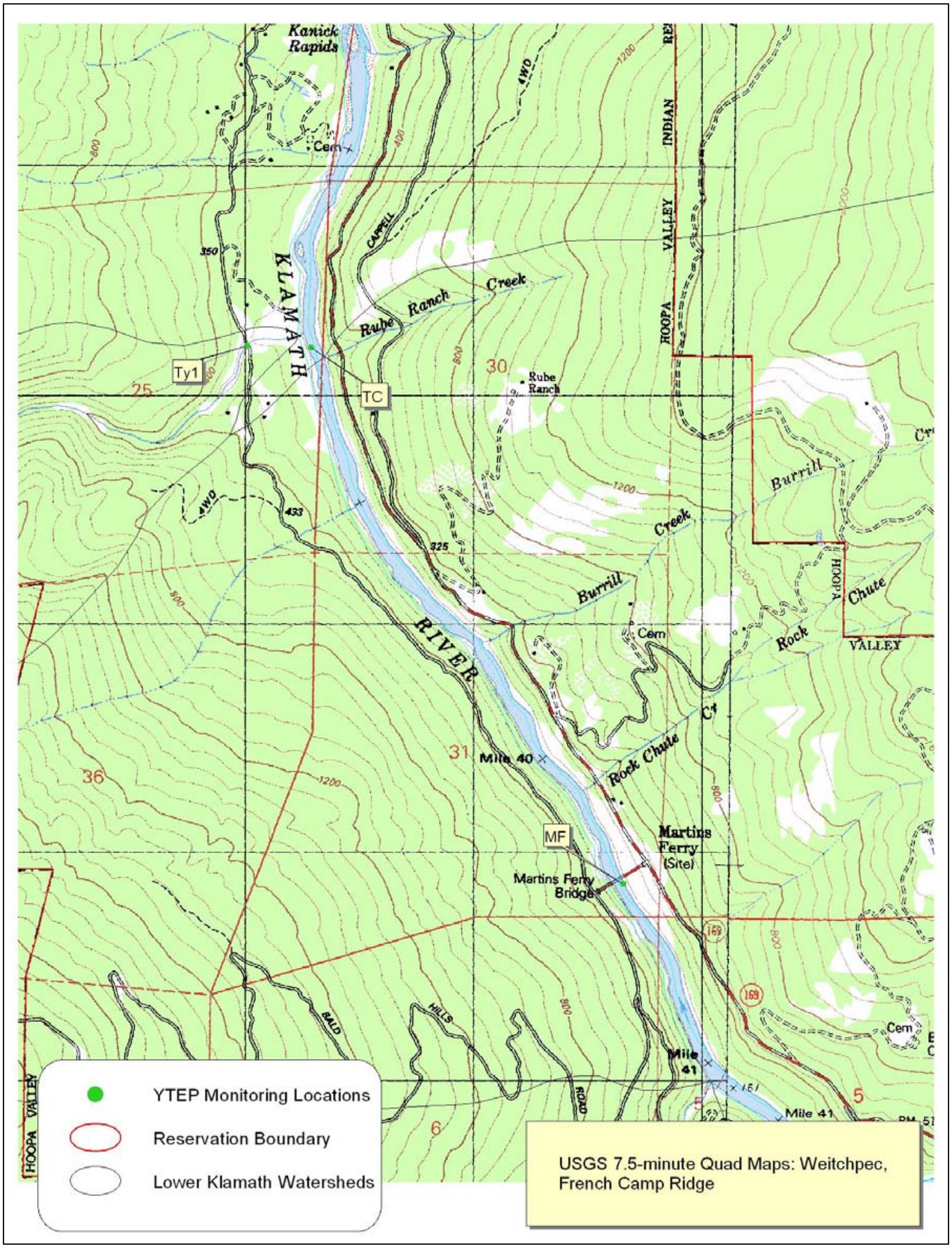


Figure 5-6 Klamath River above Martin's Ferry (MF), Klamath River above Tully Creek (TC), and Tully Creek (Ty1) Monitoring Locations WY03

Figure 5-7 Klamath River At Martin's Ferry Bridge Looking Upstream WY03

Figure 5-8 Klamath River Above Tulley Creek (TC) Looking Downstream 6/10/2003

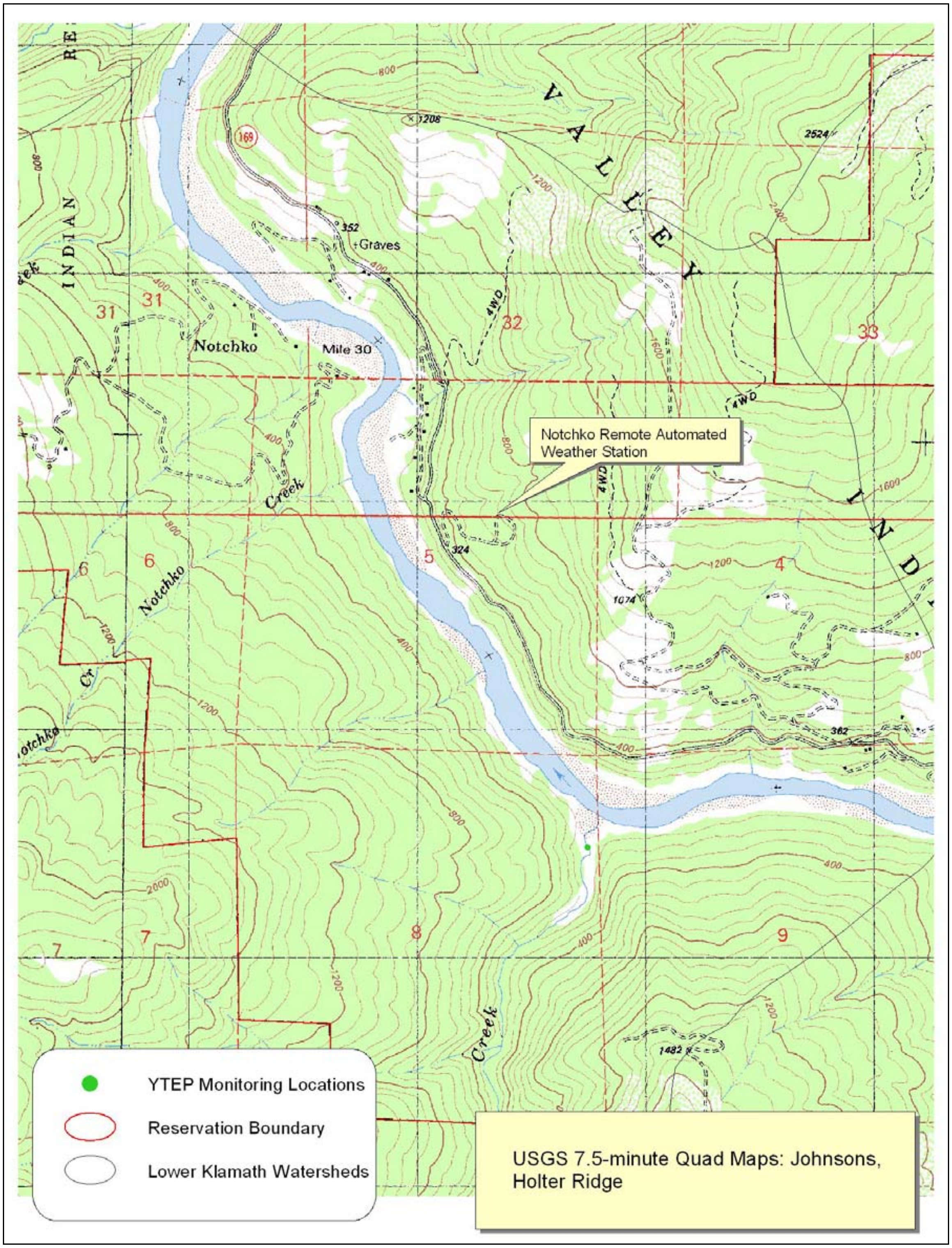


Figure 5-9 Notchko Remote Automated Weather Station Monitoring Location WY03

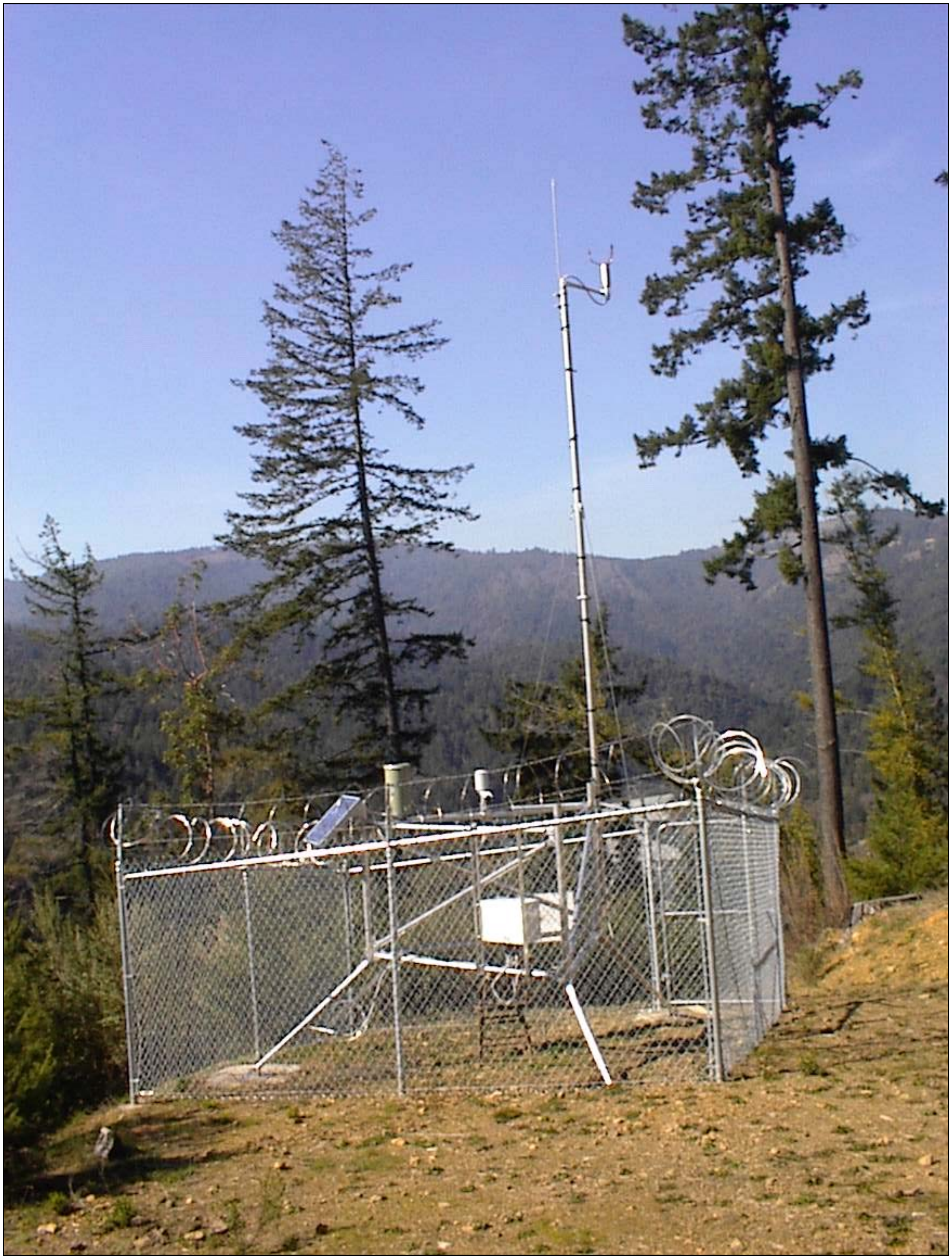


Figure 5-10 Notchko RAWS WY03

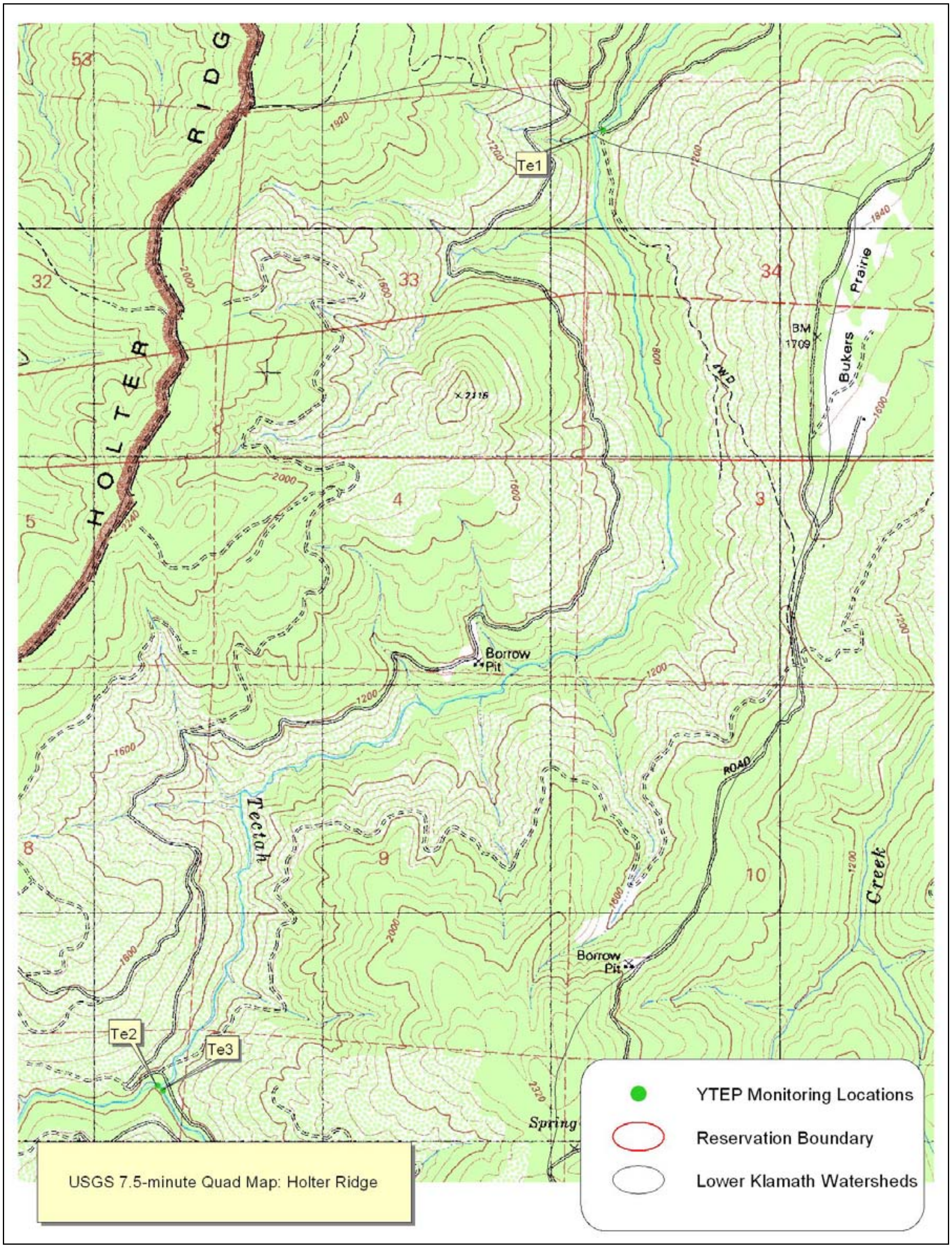


Figure 5-11 Tectah Creek (Te1, Te2, and Te3) Monitoring Locations WY03

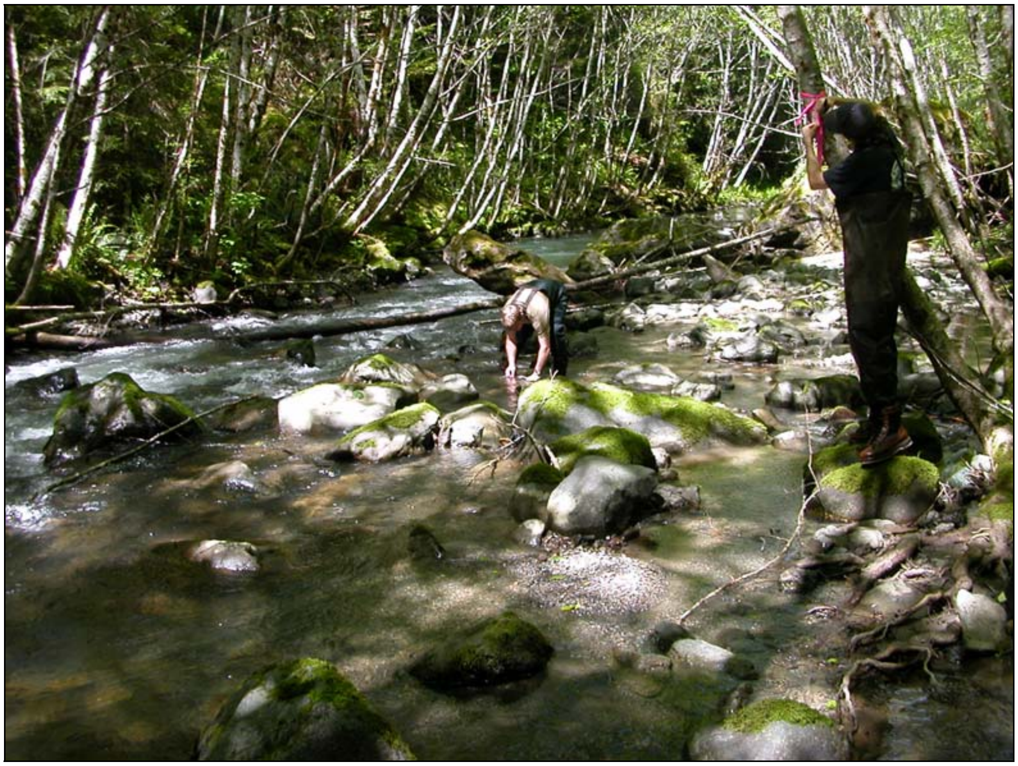


Figure 5-12 Lower Tectah Creek (Te1) 5/13/2003

Figure 5-13 South Fork Tectah Creek (Te3) 5/13/2003

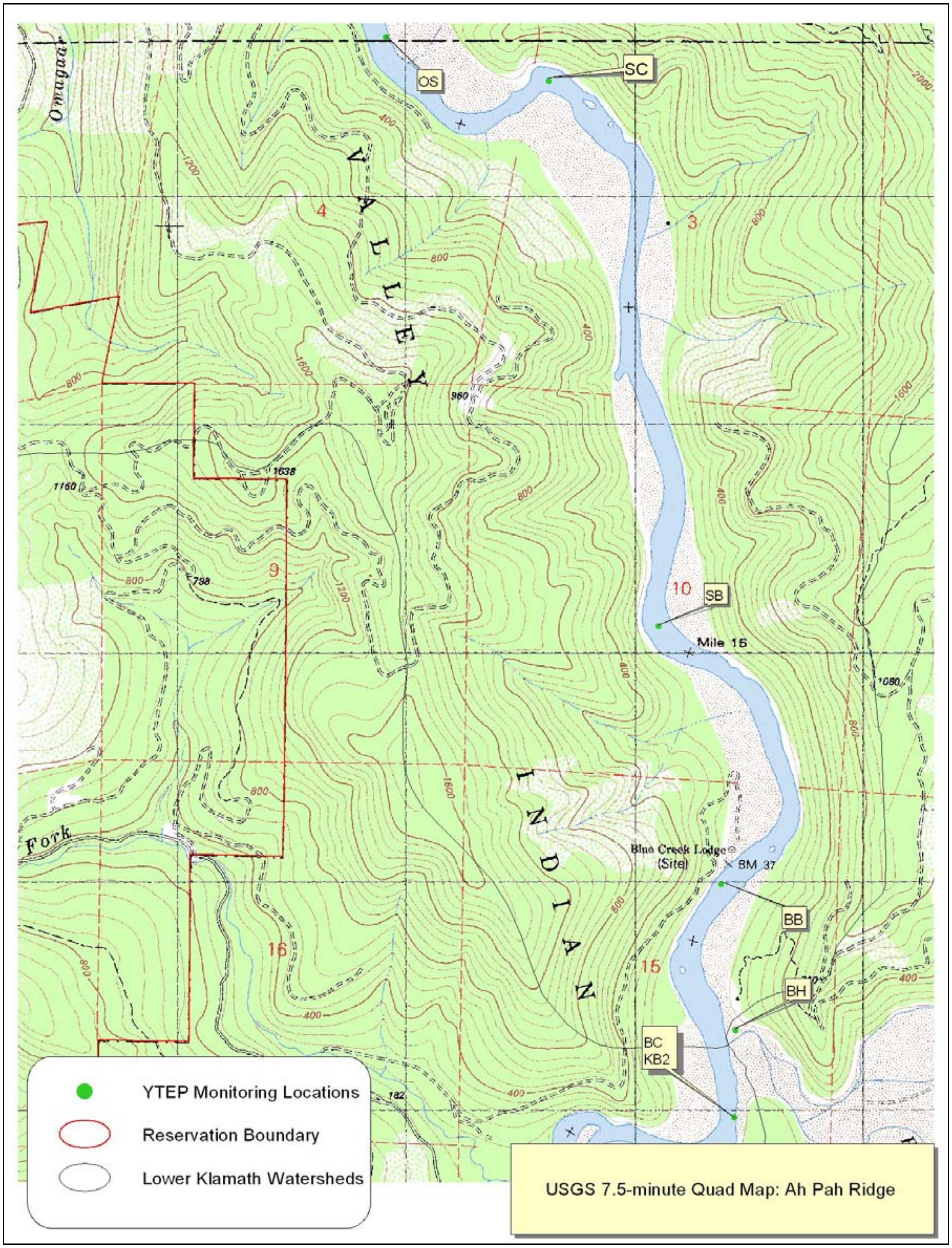


Figure 5-14 Klamath River above Blue Creek (6- and 25-feet) (KB2 and BC), Blue Hole (BH), Below Blue Creek (BB), State Stranded Bar (SB), S-Curve (SC), and Osprey Nest (OS) Monitoring Locations WY03

Figure 5-15 Klamath River Above Blue Creek (BC, KB2) WY03, USFWS Biologist Randy Turner Assisting YTEP

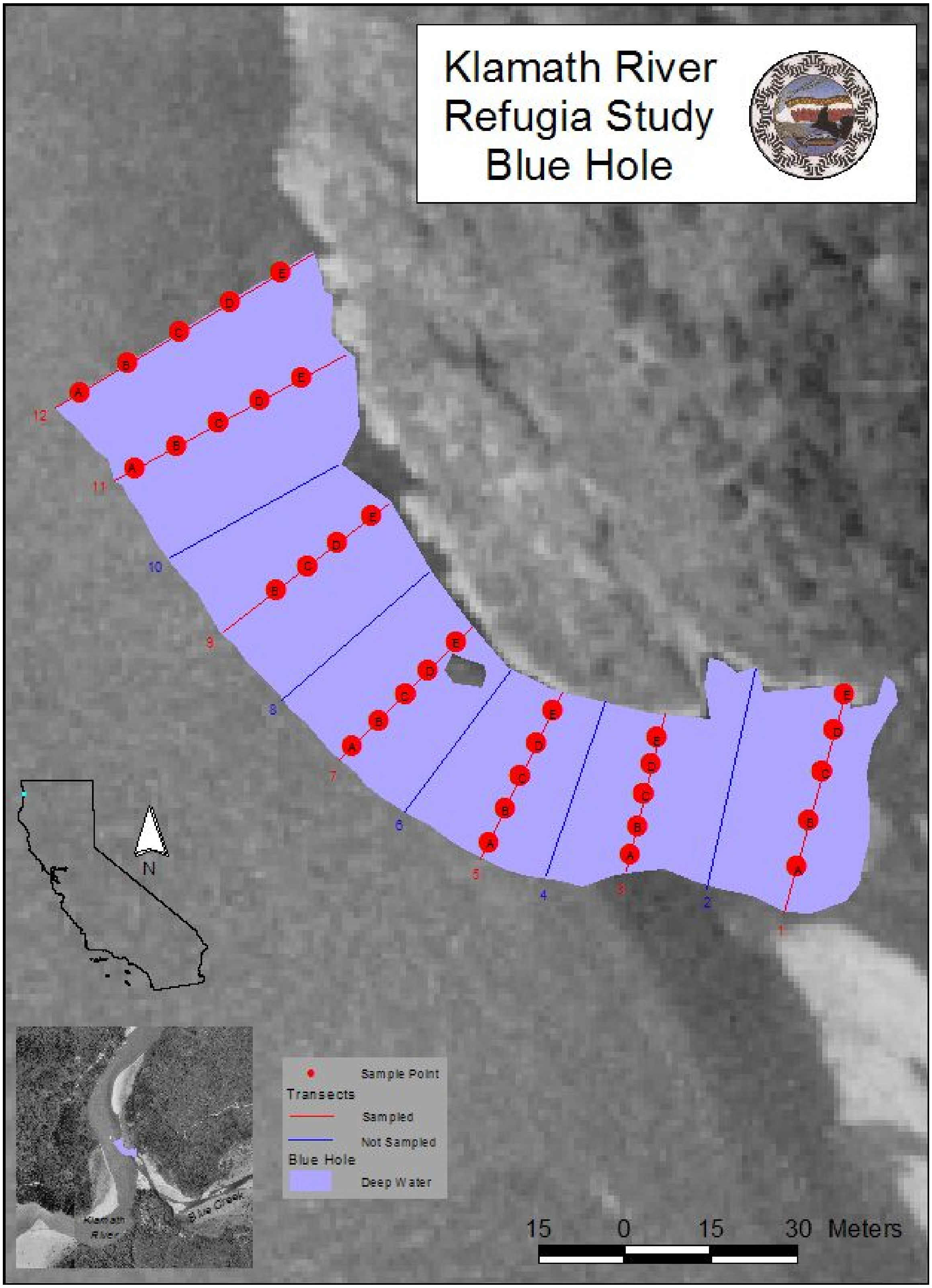


Figure 5-16 Blue Hole Special Study Monitoring Locations WY03

Figure 5-17 Blue Hole (BH) Looking West; Seep in Foreground, Klamath River in Background WY03

Figure 5-18 Blue Hole (BH) 8/26/03, YTEP Director Kevin McKernan and Water Quality Coordinator Ken Fetcho Performing Transect 7

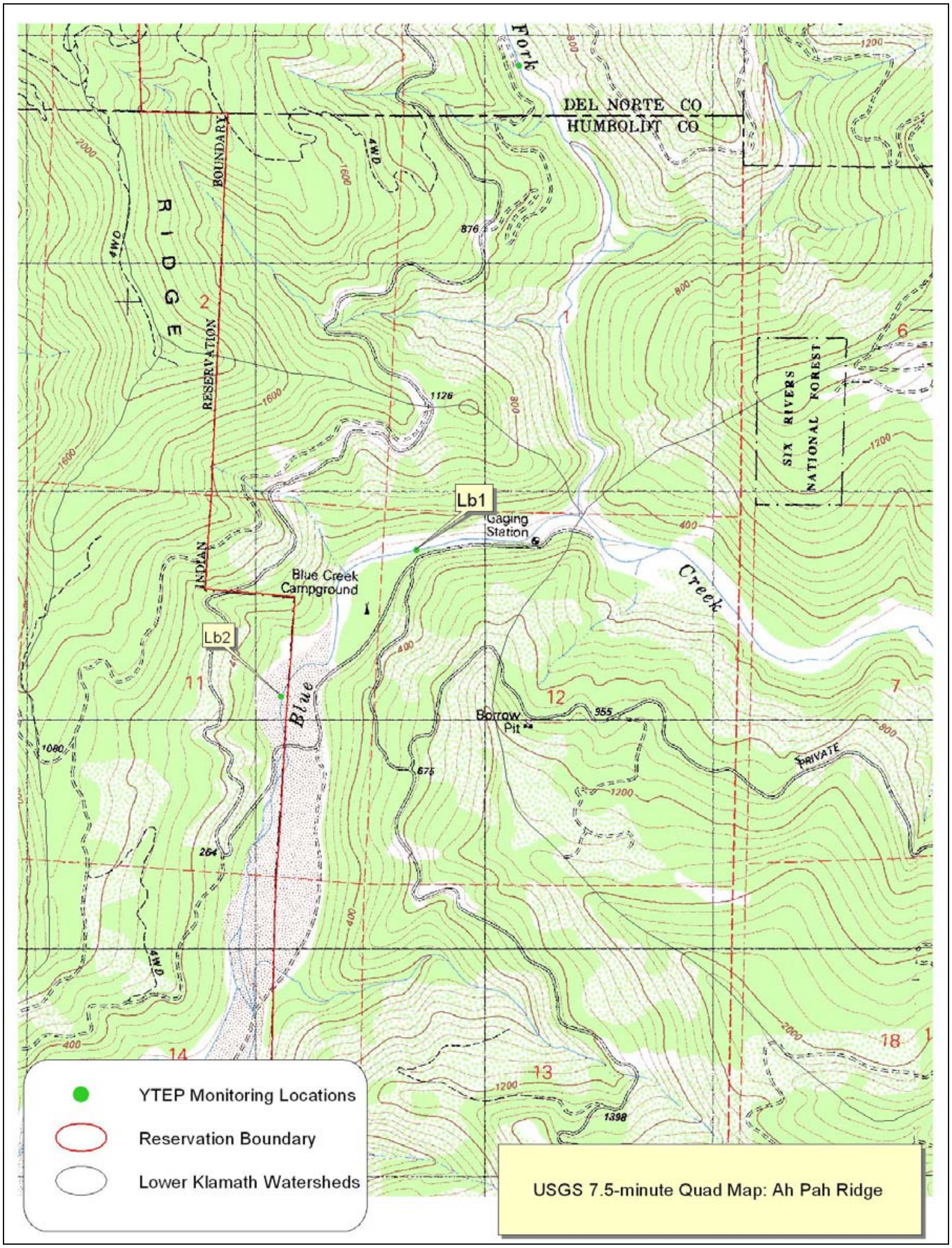
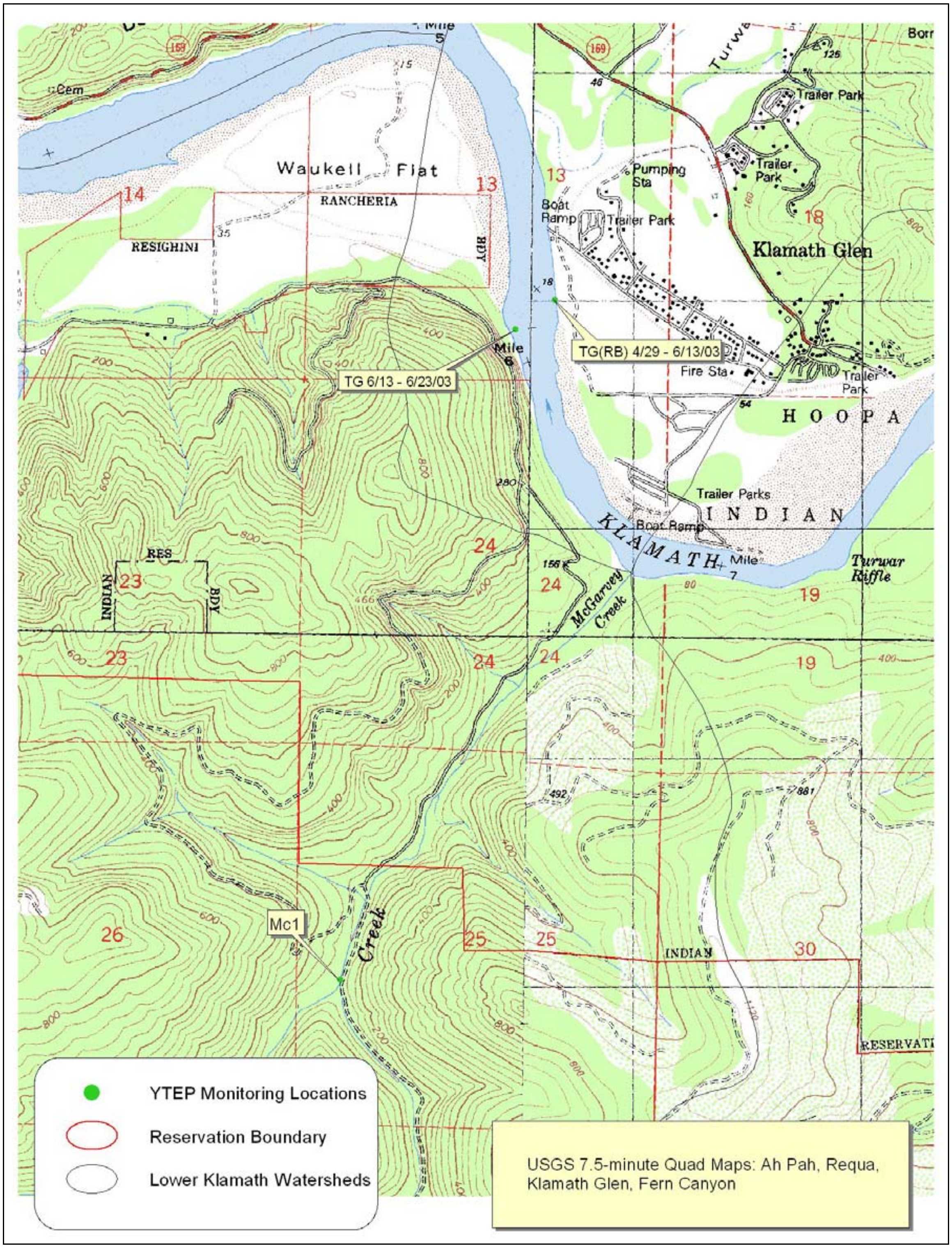


Figure 5-19 Lower Blue Creek (Lb1 and Lb2) Monitoring Locations WY03

Figure 5-20 Blue Creek (Lb1) Gage WY03



TG(RB) 4/29 - 6/13/03

TG 6/13 - 6/23/03

Mc1

USGS 7.5-minute Quad Maps: Ah Pah, Requa, Klamath Glen, Fern Canyon

Figure 5-21 McGarvey Creek (Mc1) and Klamath River at Turwar Gauge (TG) Monitoring Locations WY03

Figure 5-22 West Fork and Mainstem McGarvey Creek Confluence (Mc1) 2/6/2003

Figure 5-23 Klamath River at Turwar Gauge (TG) Looking Downstream

Figure 5-24 Klamath River at Turwar Gauge (TG) Looking Upstream

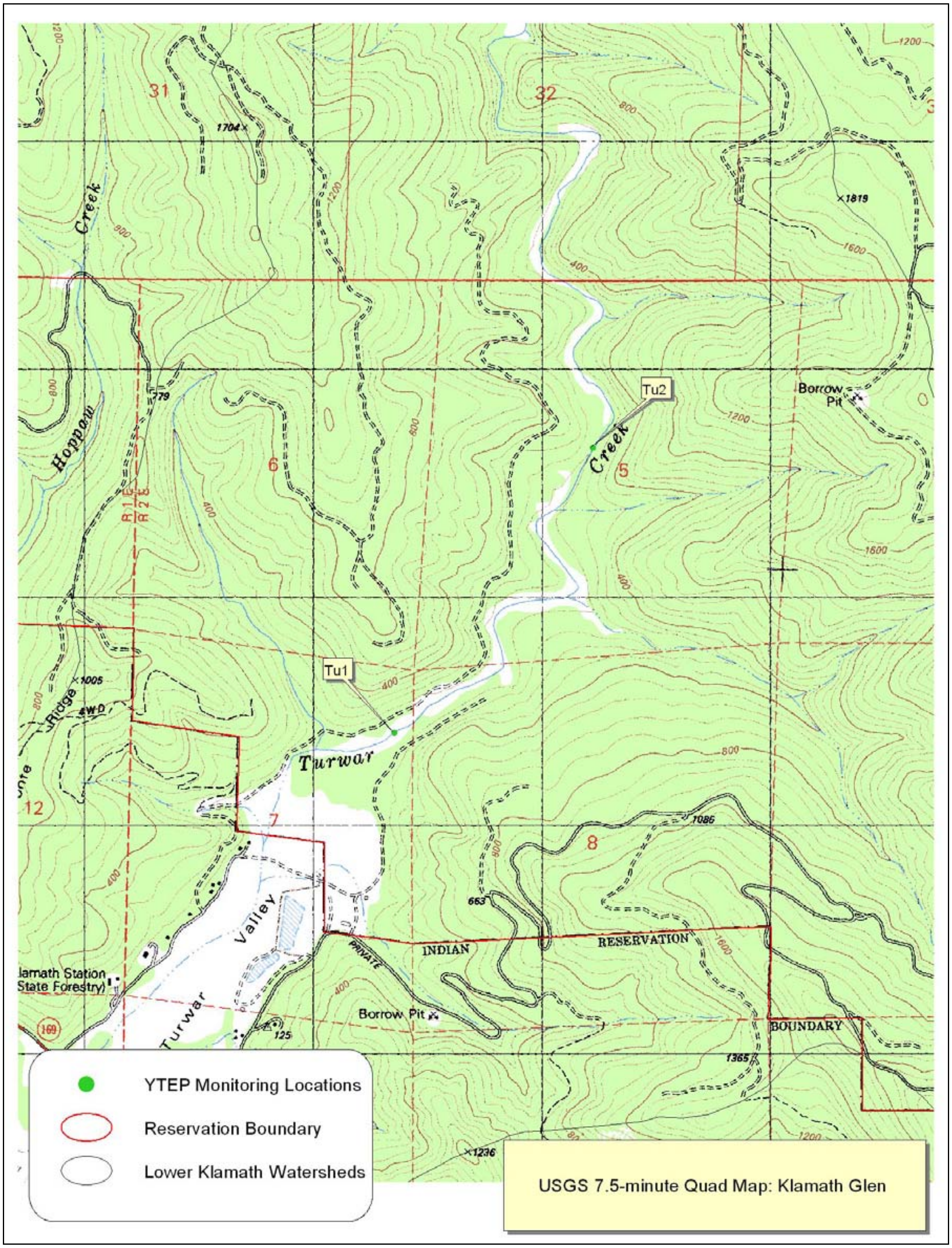


Figure 5-25 Turwar Creek (Tu1 and Tu2) Monitoring Locations WY03

Figure 5-26 Riffle at Lower Turwar Creek (Tu1) WY03

Figure 5-27 Riffle at Upper Turwar Creek (Tu2) WY03, YTEP Water Quality Coordinator Ken Fetcho Collecting Macroinvertabrate Samples

6 Methods

6.1 Water Quality Monitoring

6.1.1 Mainstem

The study was initiated at the end of April, continued throughout the summer months and terminated in October. Datasondes were programmed to record water temperature, pH, specific conductivity and dissolved oxygen (DO) at 30-minute intervals.

Air temperature and relative humidity sensors were provided by USFWS and deployed at the Klamath River at Turwar Gauge (TG) and Weitchpec (WE) sites to document meteorological conditions during the spring and summer months. YTEP deployed the sensor at the TG site on a red alder approximately 15 feet above the water's edge on the left bank looking downstream (LDS) on April 22nd at 12:23 and retrieved on November 11th at 13:25. The USFWS deployed the other air temperature/relative humidity sensor at the WE site on a tree behind the Yurok Tribal office approximately 50 feet above the water's edge on the right bank LDS. This sensor began logging on 7/1/2003.

Grab samples, discreet surface water samples, were also collected during the sampling season once a month. Samples were delivered to NCL in Arcata, CA for analysis. NCL subcontracts chlorophyll-a and total organic carbon to Environmental Technical Services and Sierra Foothill Laboratory Inc., respectively. In addition, one round of bacteria samples were analyzed by Humboldt County's laboratory. The parameters sampled are shown in Table 6-1, except for an extensive list of pesticides and metals that were sampled in September, found in the results section.

YTEP also assisted Watercourse Engineering Inc. (WEI) in collecting grab samples on the Klamath River at the Weitchpec, Trinity River and Martin's Ferry and Tully Creek sites in June and August. YTEP followed their protocol and WEI either took samples to their contract lab or processed samples themselves. However, one site's bottle set was analyzed by NCL because those samples were accidentally left behind.

Table 6-1 Parameters measured in the Klamath River Water Quality Study

Analysis
BOD / Biological Oxygen Demand
TSS / Total Suspended Solids
NO2 / Nitrite
NO3 / Nitrate
Alk / Akalinity
TDS / Total Dissolved Solids
TOC / Total Organic Carbon
Total-P / Total Phosphate Phosphorus
Ortho-P / Orthophosphate Phosphorus
Ca / Calcium
Mg / Magnesium
Org-P / Organic Phosphorus
Condensed P / Condensed Phosphorus
Chlorophyll-A
Ammonia and TKN / Total Kjeldahl Nitrogen
Turbidity
Bacteria

During this study, many QC measures were undertaken to ensure the data collected with the datasondes were of the highest quality. As mentioned in ***Section 4*** of this report a revised protocol was developed at the beginning of the season and incorporated into the sampling methods on June 18, 2003. Both protocols are attached in ***Appendix A***. According to the revised protocol, datasondes were pre- and post-calibrated on site once a week in order to account for electronic drift and bio-fouling. When the datasondes were deployed and extracted, an audit was performed with a Hydrolab® Quanta (Quanta), a portable multi-probe instrument. Effort was made to record the Quanta measurements as close as possible to the datasonde and within five minutes of the datasonde recording a measurement.

Once the datasonde was extracted the sensors were thoroughly cleaned, the datasonde was redeployed while attached to a laptop or Hydrolab® Surveyor. Datasonde and Quanta measurements were then recorded once the sensors stabilized. The datasonde was then removed from the water and a post-calibration check for dissolved oxygen was performed, using the wet towel method (see data collection methods, ***Appendix A***). Also at this time a post-calibration check and calibration of specific conductivity and pH was performed. This entails the normal two part calibration which established the electronic drift from the initial readings of a known standard and additionally functioned as a calibration for the next deployment. Once this was done, the dissolved oxygen membrane was replaced and other steps such as downloading the previous files, creating a new file and changing the batteries were completed. The datasonde was then redeployed to record temperature, specific conductivity and pH to maintain a continuous dataset for those parameters. The next day, YTEP staff returned to the site to calibrate dissolved oxygen percent saturation. While monitoring for temperature, specific conductivity, and pH remains consistent, on average two days of dissolved oxygen data must be disregarded during the calibration and overnight relaxation period.

In addition, sampling crews began collecting dissolved oxygen samples and processing as Winkler titrations using the Hach® Digital Winkler Titration Kit at the beginning of the sampling season. After inconsistent readings were experienced by both YTEP and USGS staff, it was decided that dissolved oxygen would not be measured with Winkler titrations in an effort to minimize confounding numbers and time spent in the field.

During this study, many QC measures were undertaken to ensure the grab sample data that was collected was of the highest quality. Upon arrival at each site, a sampling churn was rinsed three times with deionized (DI) water. After rinsing with DI water, the churn was rinsed three times with stream water. The churn was then fully submerged into the stream and filled to the lid with sample water. Completely filling the churn allowed for all samples to be filled from one churn; thereby minimizing differences in water properties and quality between samples.

Proper use of the churn guaranteed the water was well mixed before the sample was collected. The churn was stirred at a uniform rate by raising or lowering the splitter at approximately 9 inches per second (Bel-Art Products, 1993). This mixing continued while the bottles were being filled. If filling had stopped for some reason, the stirring rate was resumed before the next sample was drawn from the churn.

The sample bottles and chemical preservatives used were provided by NCL and were considered sterile prior to field usage. Sample bottles without chemical preservatives were rinsed with stream water from the churn once before filling with sample water. In the case of bottles that contained chemical preservatives, bottles were not rinsed before sample collection and care was taken to avoid over-spillage that would result in chemical preservative loss. Collected samples were placed in coolers on ice for transport to NCL for analysis.

The special study performed at Blue Hole measured depth, width, time, water temperature, specific conductivity, pH, and dissolved oxygen. For the purposes of this study, the hole was identified as having a mouth located at the point where water from the hole enters the Klamath River in a downstream direction (see Figure 5-16). Transects were developed starting at the point along the bank of Blue Hole furthest upstream from the hole's mouth, where a spring provides surface flow into the hole. From that point, flags were placed along the "left" bank at 40-foot increments from that starting point LDS.

From the flagged points, transects were laid crossing the hole in an orientation approximating perpendicular to the longitudinal axis of the hole. Every other transect was measured (due to time constraints), and five sampling points were identified at equal intervals along the transect. At the four sampling points on either side of center, two samples were taken: one at the bottom (noted in the charts as "Benthic") and one 1 foot below the water surface. At the center point, samples were taken at five equal intervals through the water column.

At shallow points, no surface measurement was taken, resulting in five benthic points and only four surface points. The following data were collected:

Time: time each set of measurements was taken, given in 24-hour clock units.

Transect Number: Transects were numbered relative to their proximity to the starting point, in increasing order. Sampling points along each transect were lettered relative to their proximity to the left bank in the following order: A, B, C, D, E.

Width of Transect: The total transect width, in meters.

Distance from Left Bank: The location of the sampling point along the given transect in meters (taken using a measuring tape).

Total Depth: The total depth of the hole at the given sampling location, taken in feet using the sampling equipment.

Measurement Depth: The depth at which the sample was taken in feet (taken using the sampling equipment).

Water Temperature: Water temperature at the sampling point, in degrees Celsius. Measured with a Quanta.

Specific Conductivity: The specific conductivity at the sampling point, in microsiemens. Measured with a Quanta.

Dissolved Oxygen: The dissolved oxygen measurement at the sampling point, in milligrams per liter. Measured with a Quanta. Dissolved Oxygen levels are not expected to be highly accurate, as the time-sensitivity of completing transects quickly eliminated the ability to wait for DO measurement stabilization.

Dissolved Oxygen %: The percentage of dissolved oxygen at the sampling point relative to the ambient air. Measured with a Quanta. Dissolved Oxygen levels are not expected to be highly accurate, as the time-sensitivity of completing transects quickly eliminated the ability to wait for DO measurement stabilization.

pH: The pH at the sampling point, in pH units. Measured with a Quanta

Comments: Additional comments at the sampling location.

The special study of deep holes in the Lower Klamath River was performed with a datasonde. The unit was calibrated at Blue Creek on 09/08/2003. The unit's clock was synchronized with a field watch to allow for accurate timing of measurements. The unit was programmed to take measurements every five minutes. The unit was weighted to prevent the current from carrying the sensor downstream. All measurements were taken with the calibration cup attached to the unit, without the end cap, except for the surface measurement downstream of Blue Creek, which was taken without the calibration cup. The unit was placed in the water with the sensors pointing up to prevent air from being trapped in the calibration cup.

Measurement Collection: YTEP used a boat to navigate between sampling sites and measurements were taken while onboard the boat. A depth sounder was used to gauge the depth of holes and to maintain position over the deepest section of each hole. Samples were taken approximately 2 feet below water surface and near the bottom of the hole at each site using a datasonde. Attempts were made at each hole to place the sensor in the deepest section of the hole. The unit recorded the following parameters at 5-minute intervals: Date, Time, Temperature, pH, Specific Conductivity, Dissolved Oxygen (% saturation), and Dissolved Oxygen (mg/L). In a field notebook, YTEP recorded the following parameters: Time of sample, Location of sample.

6.1.2 Tributaries

YTEP monitors water quality in the Lower Klamath tributaries. During the fall and winter months datasondes are deployed at the McGarvey, Turwar and Blue Creeks gaging stations. These instruments are programmed to measure turbidity, specific conductivity, and water temperature on a fifteen-minute time step. The datasondes were calibrated every two weeks as prescribed in QC procedure due to bio-fouling and electronic drift during datasonde deployment and extraction. Audits were performed with a Quanta®. Measurements were recorded within five minutes of programmed datasonde measurement.

Figure 6-1 Datasonde Location at McGarvey Creek (Mc1) 2/6/2003, AmeriCorps Member Robin Tibbals Performing Quanta Measurement

6.2 Hydrologic Monitoring

The NCRWQCB lists the Lower Klamath River on its “impaired watch list” for excessive sediment loading, suggesting that more research is needed. YTEP hydrologic monitoring and pre-TMDL research in selected tributaries is filling this data gap. Among other objectives, the data will be used to help develop a sediment budget for the Lower Klamath River basin.

Physical variables such as flow and gage height were measured at computerized gaging stations with WaterLog® Pressure Transducer/Data Collection Platforms (model H-350XL) at McGarvey, Blue, and Turwar Creeks. Stream levels were recorded every 15 minutes. This data was downloaded from the gaging station onto a portable laptop computer during site visits. The stage height was compared visually to staff plate readings and was adjusted accordingly when found to be more than 0.05 feet off. Stream discharge was measured using a Price AA® flow meter and an AquaCalc® flow computer that were attached to a four-foot top set wading rod.. Discharge was measured by wading or bridge crane using USGS methods (USGS, 1999) (Appendix A). YTEP also sampled for suspended sediment concentrations (SSC) in the lower basin in WY03. SSC samples were gathered by using a wadable sediment sampler or by crane. The SSC samples were analyzed by Graham Mathews and Associates following all USGS protocols.

Figure 6-2 Stream Flow Measurement From Blue Creek Bridge 2/19/2003, YTEP Hydrologist Eric Brunton

6.3 Macroinvertabrate Sampling

Evaluating the biological community of a stream or river through assessments of macroinvertabrates provides a sensitive and cost effective means of determining stream condition. Macroinvertabrates (invertebrates large enough to be seen with the naked eye) are fairly stationary, and are responsive to human disturbances. In addition, the relative sensitivity or tolerances of many macroinvertabrates to stream conditions is well known. Sampling of stream macroinvertabrates for biological assessments is an essential component of any comprehensive stream condition evaluation. The object of studying macroinvertabrates communities is to monitor the general health and water quality of the Klamath River and its tributaries. According to the California Stream Bioassessment Procedure developed by the California Department of Fish and Game (DFG), benthic macroinvertabrate communities indicate physical and habitat characteristics that determine the stream integrity and ecological health.

YTEP sampled benthic macroinvertabrate populations in selected tributaries of the Lower Klamath River during the spring months (see table 5.1.1-a). Sampling was performed using the non-point source assessment methods located in the California Stream Bioassessment Procedure (May 1999) that the DFG has adapted from the USEPA's "Rapid Bioassessment Protocols of use in Streams and Rivers". This protocol is located in ***Appendix A***. The Water Quality Program Coordinator and two AmeriCorps members collected specimens which were sent to a lab where a certified taxonomist identified and calculated the number and types of species.

A variety of QC measures were undertaken in the macroinvertabrate sampling. Sample labels were properly completed, including the sample identification code, date, stream name, sampling location, and collector's name and placed into the sample container. The outside of the container was labeled with the same information. Chain-of-custody forms, when needed, included the same information as the sample container labels. After sampling had been completed at a given site, all nets, pans, etc. that had come in contact with the sample were rinsed thoroughly, examined carefully, and picked free of organisms and debris. The equipment was examined again prior to use at the next sampling site.

Data generated in the field and laboratory is reviewed prior to being released internally or to an outside agent. Laboratory processing is contracted to Jonathan Lee, a qualified local California Stream Bioassessment Protocol (CSBP) taxonomist and California Bioassessment Laboratories Network (CAMLnet) member. The CSBP has three levels of Benthic Macroinvertabrate (BMI) identification. Level 3 is the professional level equivalent and requires identification of BMIs to a standard level of taxonomy, usually the genus and/or species. If questionable macroinvertabrates are encountered, the DFG Aquatic Bioassessment Laboratory is used as a reference to verify the specimens.

After processing the samples, the biological matrices are received from the taxonomist in an Excel spreadsheet format identifying the sample ID and the breakdown of BMI species into standard taxonomic levels. Following the CSBP, a table is generated showing sample values and means for the biological metrics listed.

6.4 Herbicide Monitoring

Surface water samples were collected in conformance with the California Department of Pesticide Regulation: *Surface Water Monitoring for Forest Herbicides in the Yurok Aboriginal Territory Protocol, April 1999 (SOP:FSWA002.00).* Two methods, an automatic sampler and a grab sample, were used to collect water samples. Seventeen surface water samples were collected from Tully Creek. All water samples were screened by YTEP using a RaPid Assay Atrazine Kit. Over fifty percent of the surface water samples collected were sent to Department of Pesticide Regulation (DPR) labs for traditional analysis.

An ISCO auto-sampler was manually programmed by YTEP staff to collect one surface water sample every thirty minutes with two rinse cycles between samples. The sampler was programmed with a delayed start to begin taking samples based on a rise in stream stage height. The auto-sampler contains twenty-four 250ml sterile glass bottles; three 250ml bottles are required for one composite sample. The sampler is powered by an external rechargeable battery. The site required a twenty-one foot suction hose from the auto-sampler to the water. The suction hose was held in place to a 5-foot steel bar installed in the middle of the creek bed. The end of the suction line was set at approximately 0.9 feet deep with a 4-inch steel suction head. A toggle cup was attached to the steel bar approximately 0.75 inches above the surface of the water.

Water quality parameters were collected by two datasondes deployed on Tully Creek, one approximately 10 feet above the sampling location and one below the Tully Creek Bridge. The datasondes collected water quality parameters on a fifteen minute continuous basis for temperature, dissolved oxygen, pH, specific conductivity, and turbidity between 11/6/02 and 11/12/02. Datasondes were programmed, calibrated, and installed in conformance with the *Yurok Tribe Quality Assurance Program Plan: Water Quality Assessment and Monitoring, April 2001.* A bucket-type rain gauge was secured to a tree near the site; rainfall data was recorded during each site visit and the gauge was reset.

YTEP staff deployed the auto sampler on 11/6/02 upstream from the bridge at Tully Creek. YTEP staff visited the site on 11/7/03. According to the rain gauge less than one half inch of rain had fallen. However, the creek rose enough to trigger the toggle cup and start the sampling program. Samples were discarded because it was determined that not enough rain had fallen to produce significant runoff, based on DPR protocol. The sampler was reset.

YTEP staff visited the site on 11/8/02 and found that the sampler was erroneously programmed to take continuous samples. All samples were determined cross-contaminated and not kept. YTEP staff took a grab sample at 14:51 due to continued rain and creek height increases and the sampler was reset.

Eight samples were collected by the auto-sampler at 30-minute intervals. The auto-sampler collected the first sample on 11/9/02 at 08:30 and finished the last sample at 12:03. YTEP staff removed samples from the sampler at 12:49. Samples were poured into one liter amber glass bottles, labeled, and stored on blue ice in coolers during transport. Following sample retrieval, YTEP staff collected an equipment rinse blank with deionized water at 13:24.

Due to continued rain and increased creek height the auto-sampler was filled with sterile bottles and set to start at 13:52 on 11/9/02. The auto-sampler began collecting samples on 11/9/02 at 13:52 and finished collecting samples at 17:24. YTEP staff retrieved samples on 11/10/02 at 08:25. YTEP staff collected an equipment rinse blank with deionized water on 11-10-02 at 8:55. Sampling was discontinued for equipment and personnel safety reasons due to increased creek height and flow.

Samples were stored in YTEP’s refrigerator prior to shipping and analysis in order to preserve sample integrity. Water samples analyzed by DPR laboratories by traditional analysis were shipped via UPS with blue ice on 11/21/02.

Figure 6-3 Tully Creek Herbicide Monitoring Location, Looking Downstream WY03

6.5 Notchko Remote Automated Weather Station (RAWS)

A Remote Automated Weather Station (RAWS) located across the Klamath River from Notchko Creek measures ambient weather conditions. The weather station is on loan from the Tribal Air Monitoring Support (TAMS) Center and the Institute for Tribal Environmental Professionals (ITEP). Certain procedures such as pesticide monitoring are dependant upon the amount of rainfall that has occurred. Meteorological data, specifically rainfall, provides information related to monitoring surface water for the presence of herbicides, and provides baseline information for hydrologic and water quality studies.

The Notchko RAWS began operating on October 10, 2001. The station is located at 41º 17’ 23” North latitude, 123º 51’ 27” West longitude, approximately 495 feet above sea level. The following parameters were measured at the site on an hourly basis throughout the year: air temperature; rainfall; average and gust wind speed/direction; barometric pressure; relative humidity; solar radiation and fuel moisture/temperature. Historic data from this site can be retrieved on the internet at http://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?caCYUR. For the purposes of this report, only rainfall data is presented due to its relevance to the water quality and hydrology data presented.

7 Results

7.1 Water Quality (Mainstem)

7.1.1 Klamath River at Aiken's Hole

7.1.1.1 Temperature

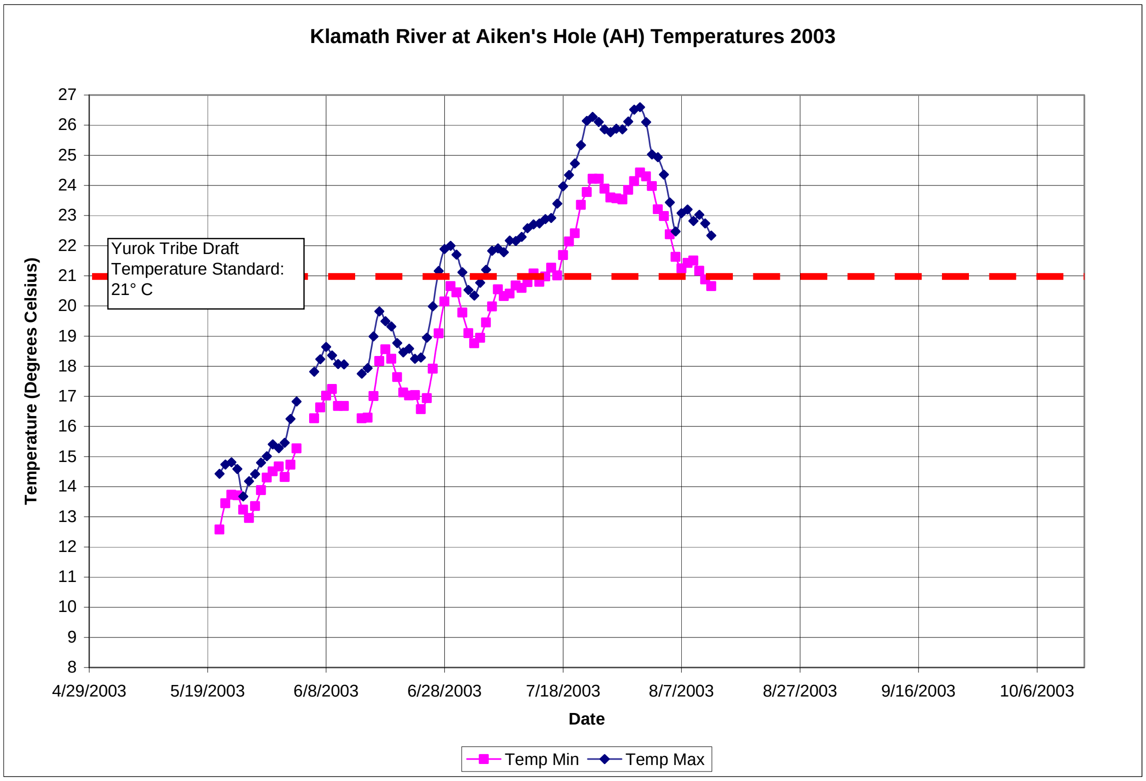


Figure 7-1 Water Temperature values for the Klamath River at Aiken's Hole WY03

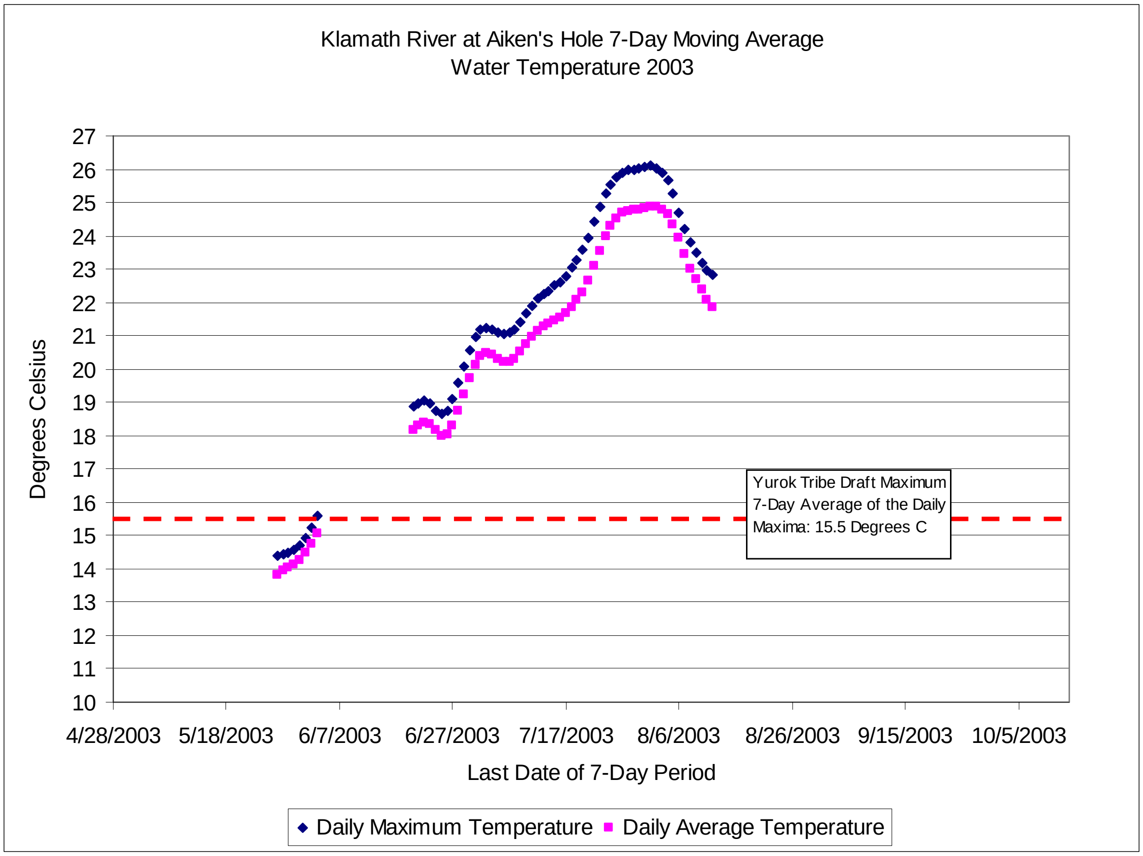


Figure 7-2 7-Day Moving Average Water Temperature for the Klamath River at Aiken's Hole WY03

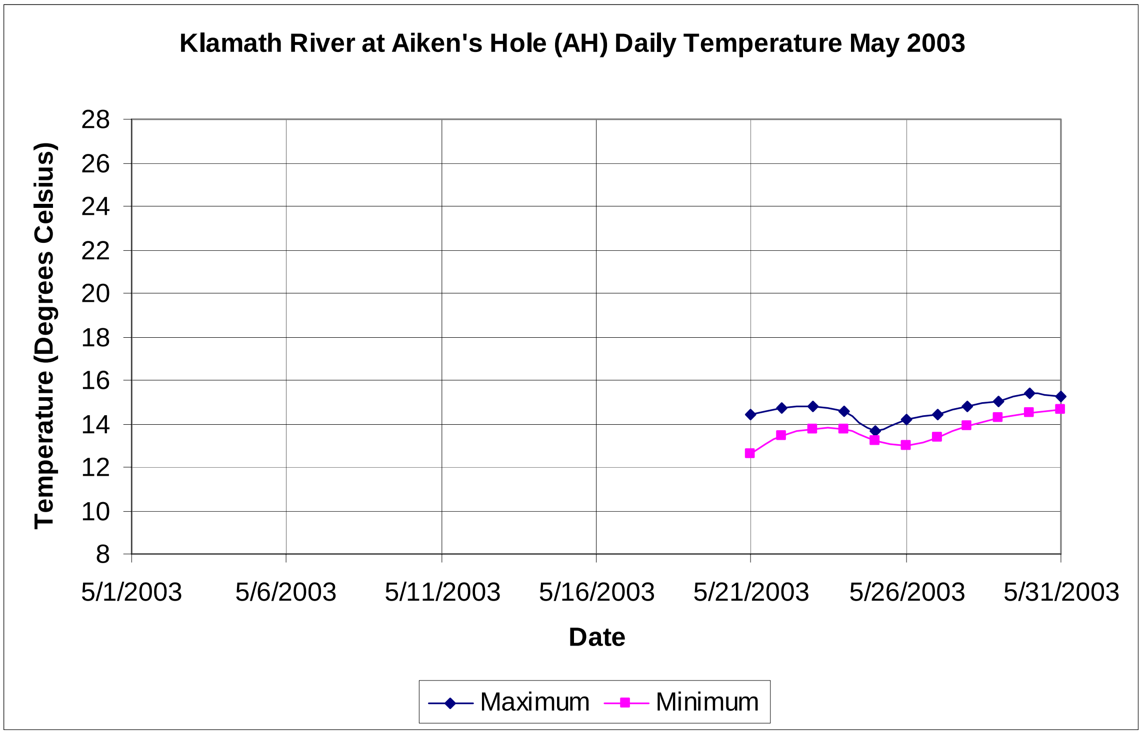


Figure 7-3 Water Temperature values for the Klamath River at Aiken's Hole May 2003

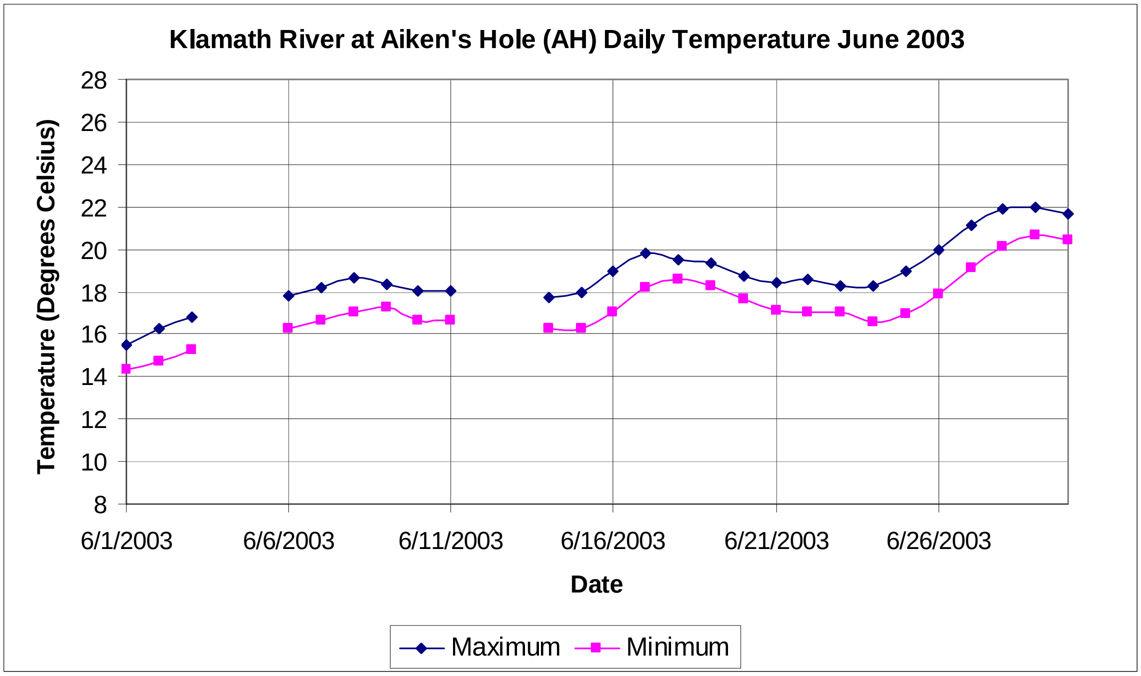


Figure 7-4 Water Temperature values for the Klamath River at Aiken's Hole June 2003

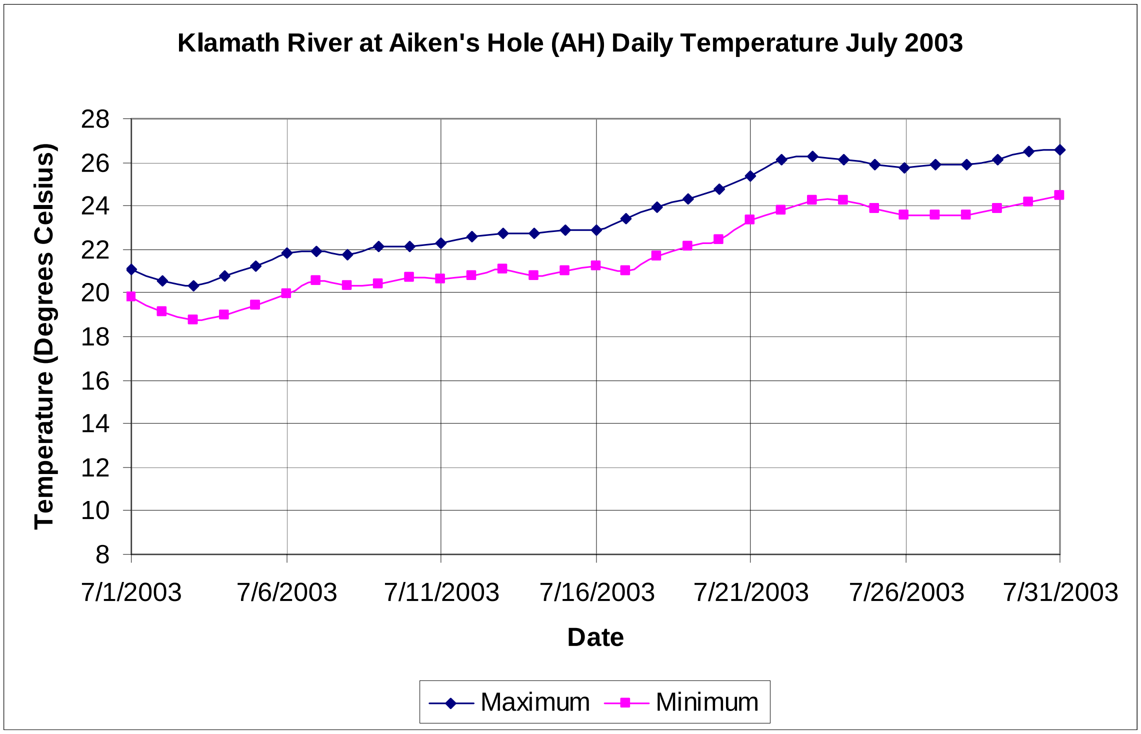


Figure 7-5 Water Temperature values for the Klamath River at Aiken's Hole July 2003

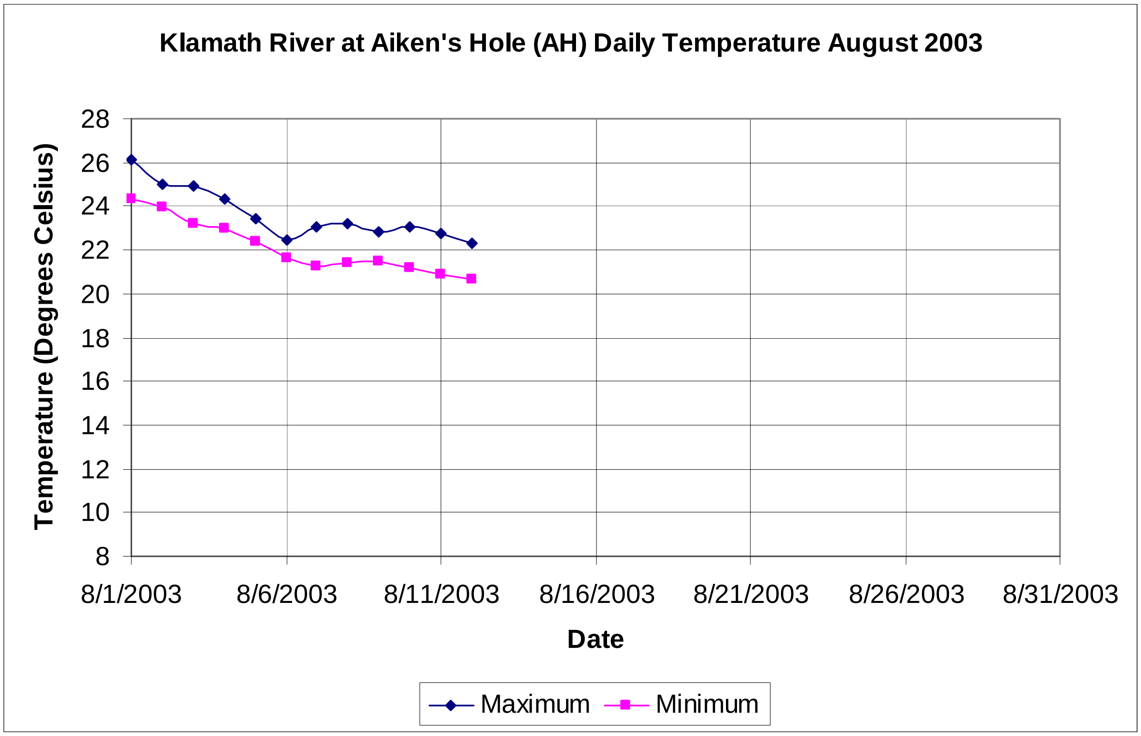


Figure 7-6 Water Temperature values for the Klamath River at Aiken's Hole August 2003

7.1.1.2 Dissolved Oxygen

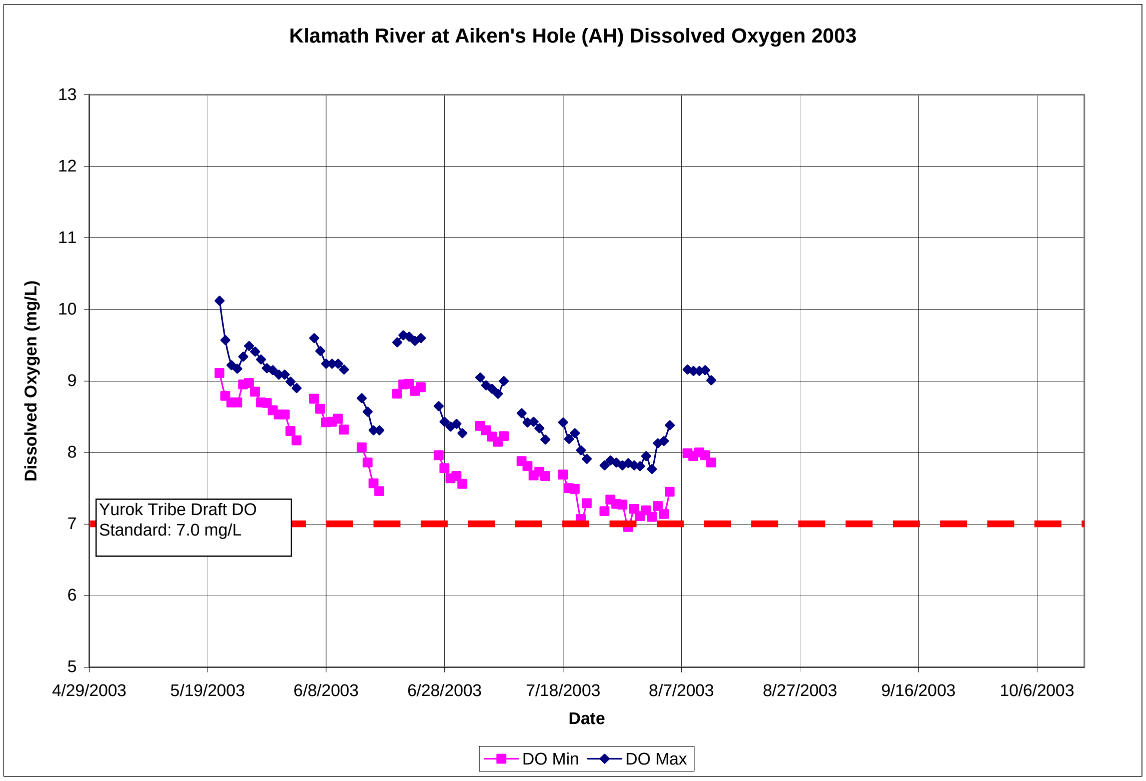


Figure 7-7 Dissolved Oxygen Values for the Klamath River at Aiken's Hole WY03

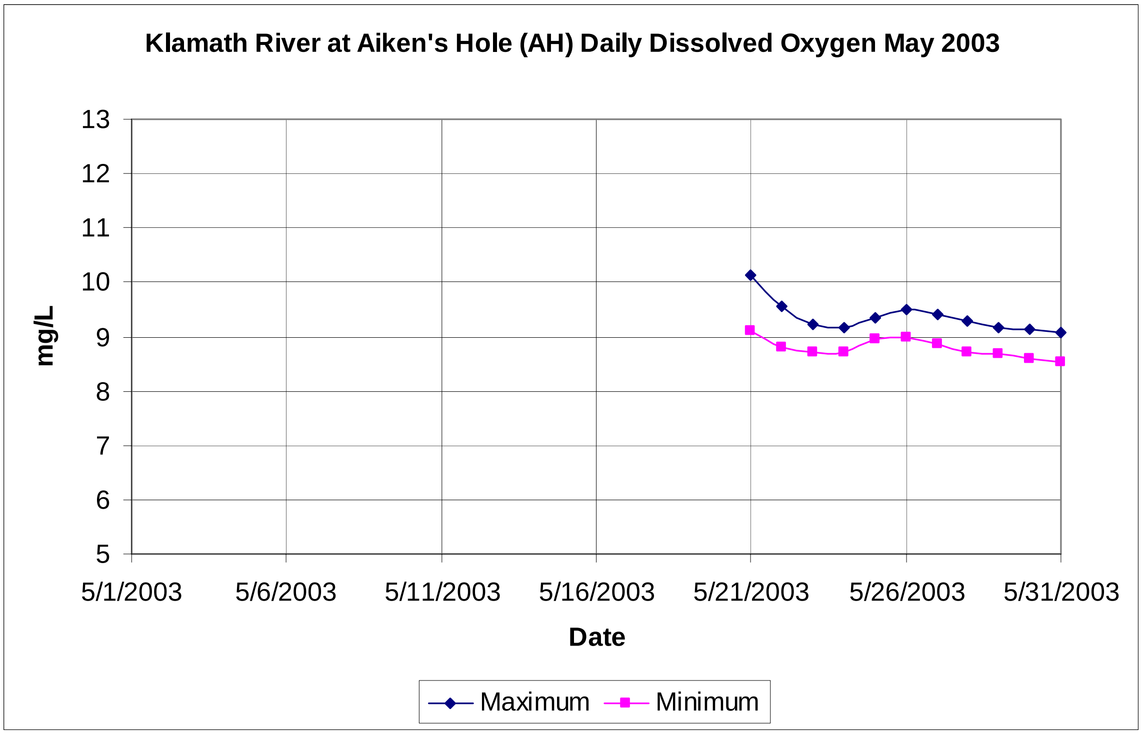


Figure 7-8 Dissolved Oxygen Values for the Klamath River at Aiken's Hole May 2003

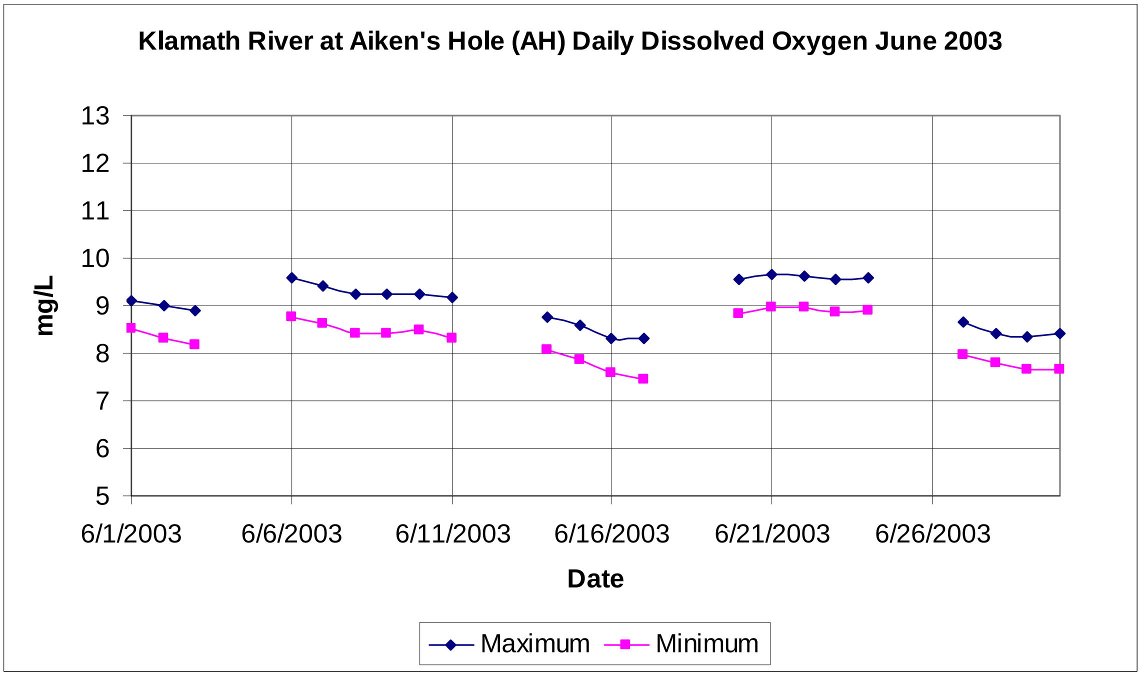


Figure 7-9 Dissolved Oxygen Values for the Klamath River at Aiken's Hole June 2003

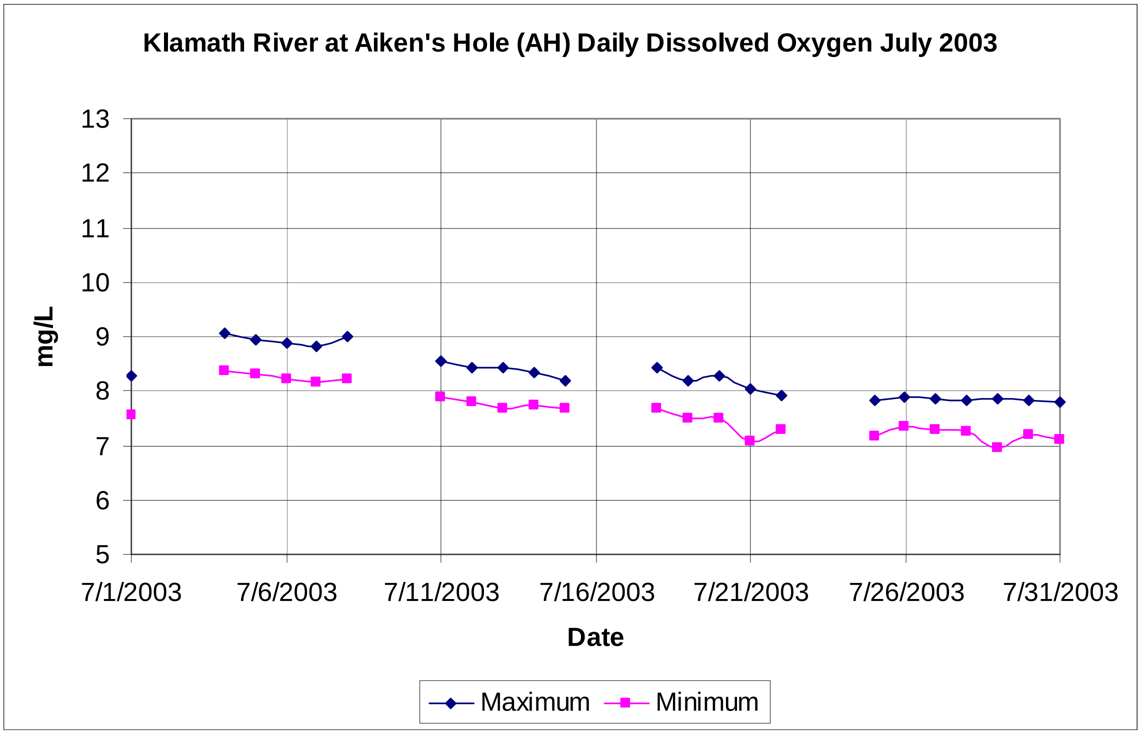


Figure 7-10 Dissolved Oxygen Values for the Klamath River at Aiken's Hole July 2003

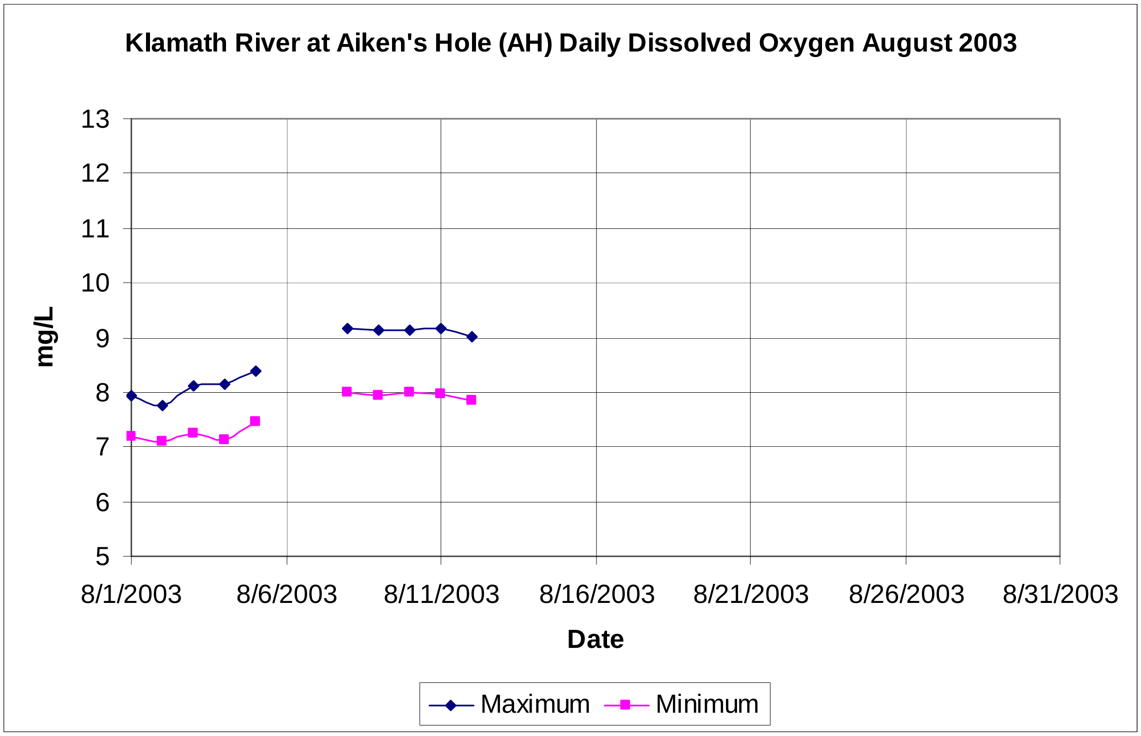


Figure 7-11 Dissolved Oxygen Values for the Klamath River at Aiken's Hole August 2003

7.1.1.3 pH

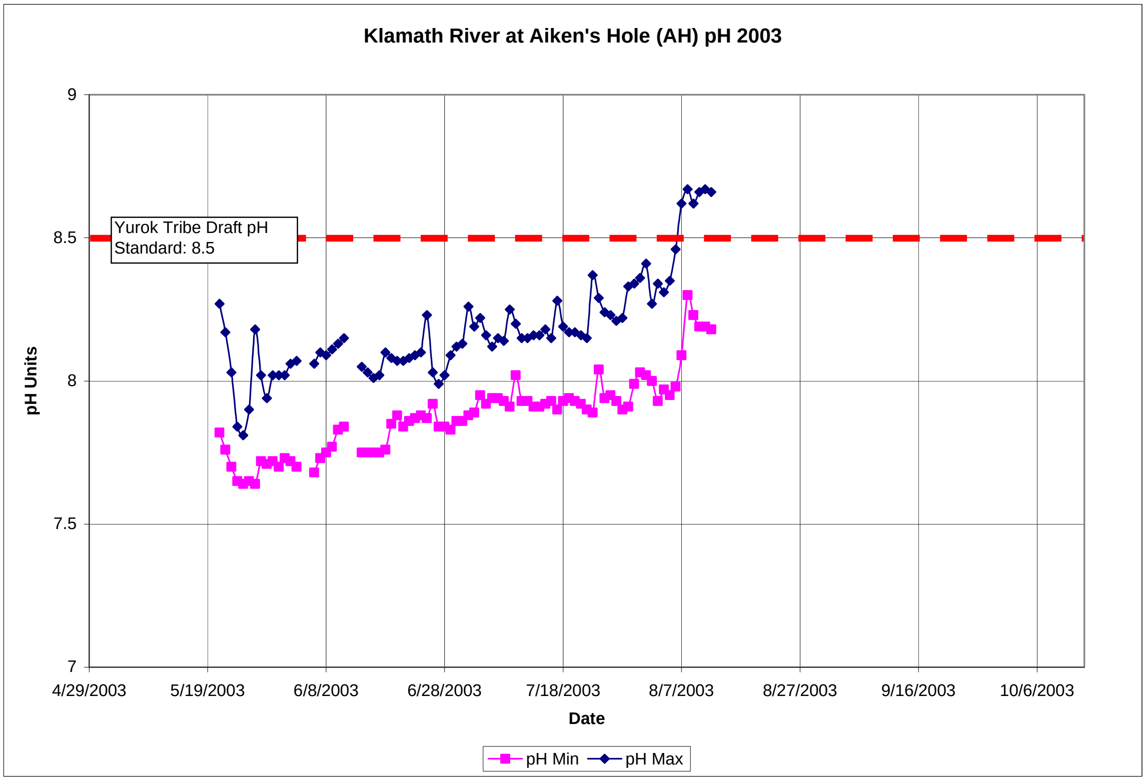


Figure 7-12 pH Values for the Klamath River at Aiken's Hole WY03

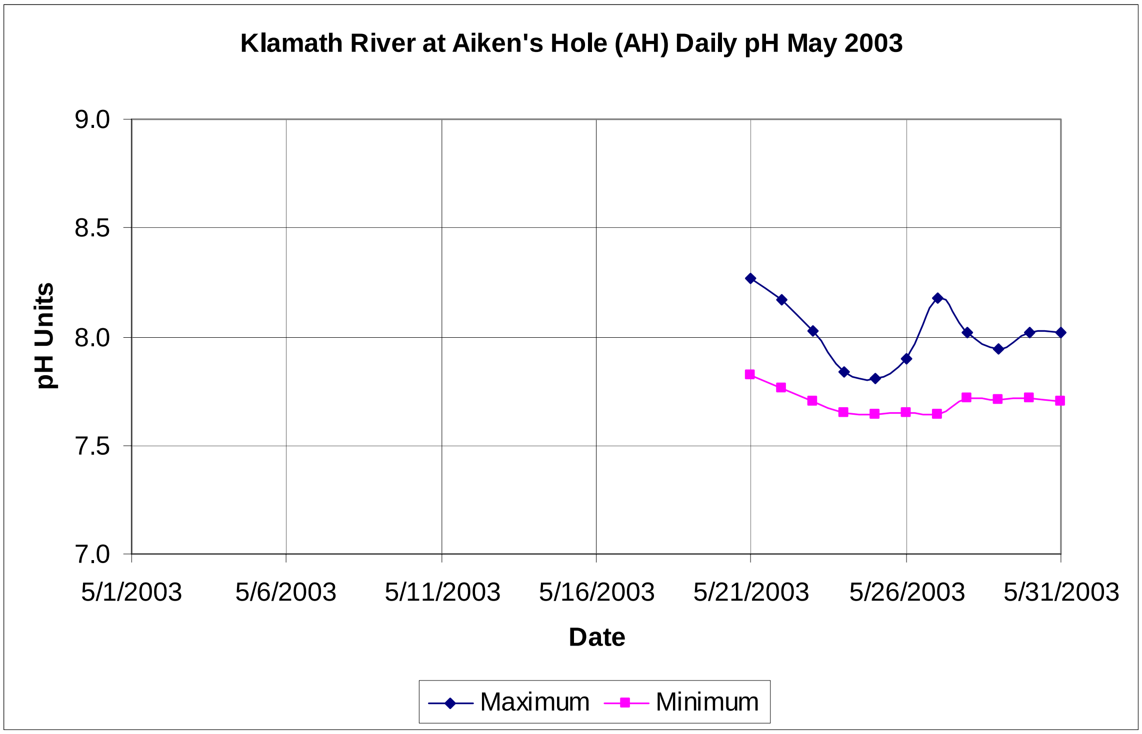


Figure 7-13 pH Values for the Klamath River at Aiken's Hole May 2003

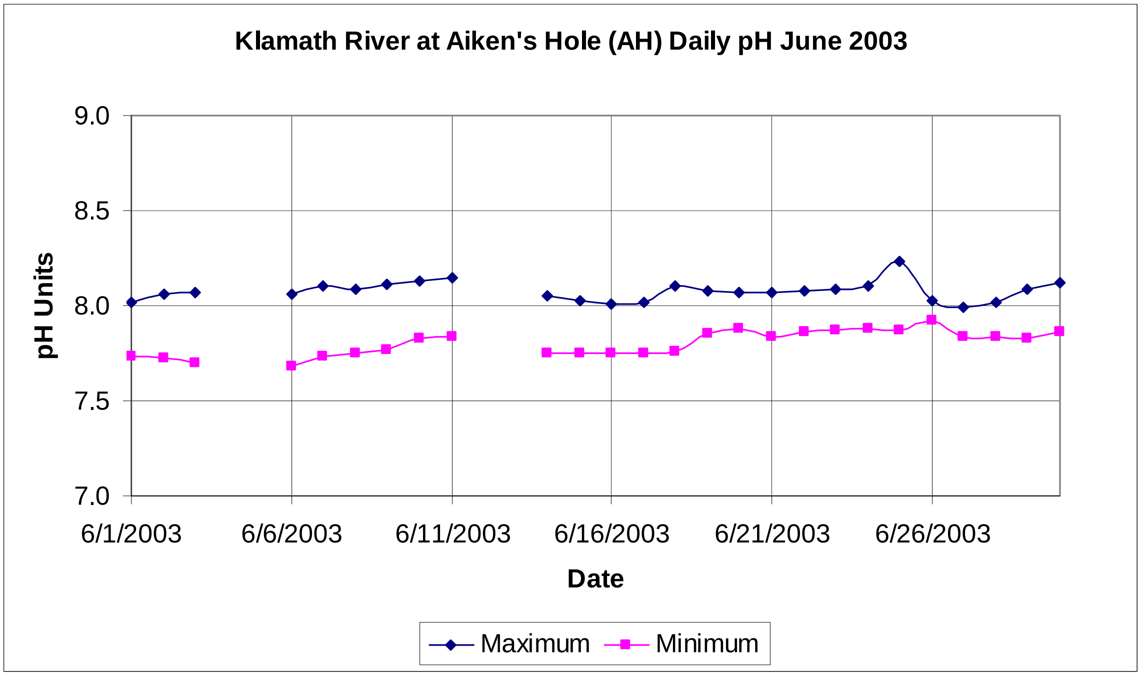


Figure 7-14 pH Values for the Klamath River at Aiken's Hole June 2003

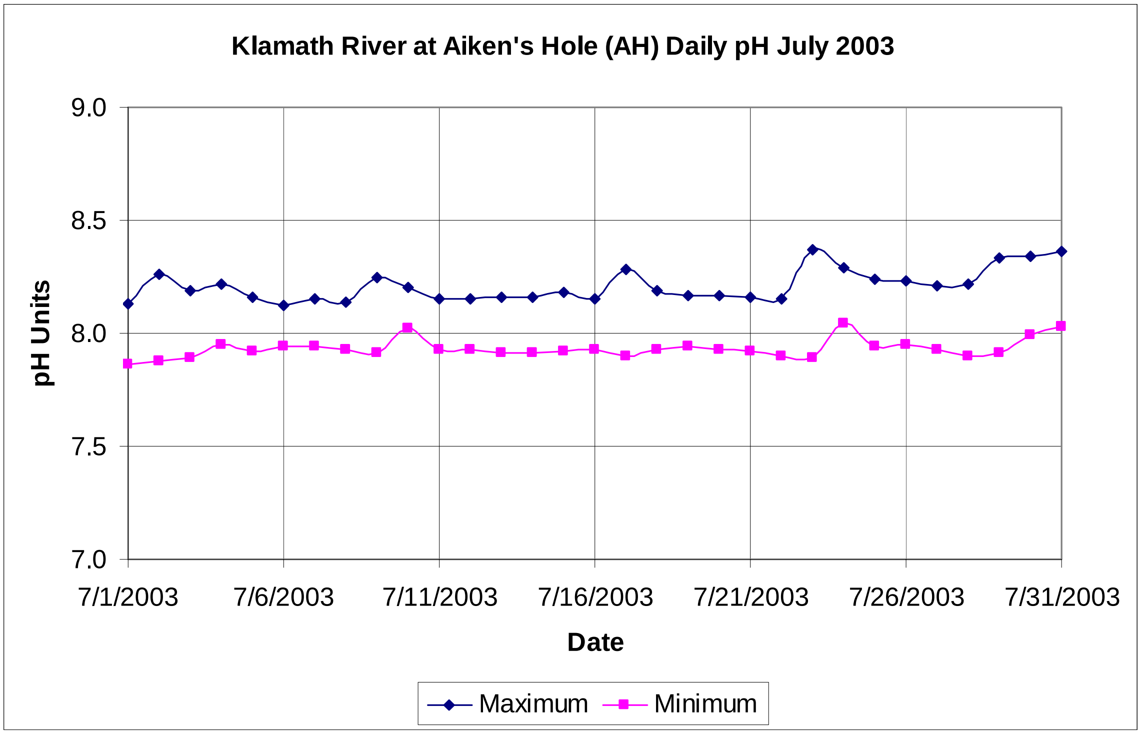


Figure 7-15 pH Values for the Klamath River at Aiken's Hole July 2003

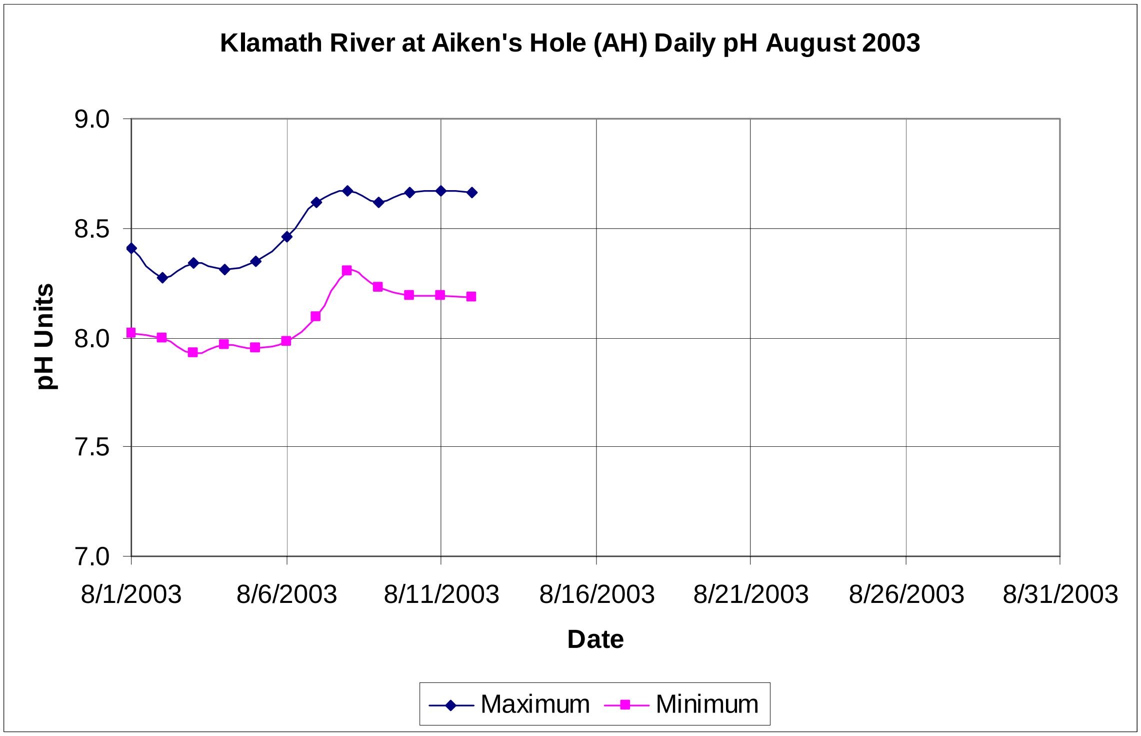


Figure 7-16 pH Values for the Klamath River at Aiken's Hole August 2003

7.1.2 Klamath River above Trinity River (Weitchpec)

7.1.2.1 Temperature

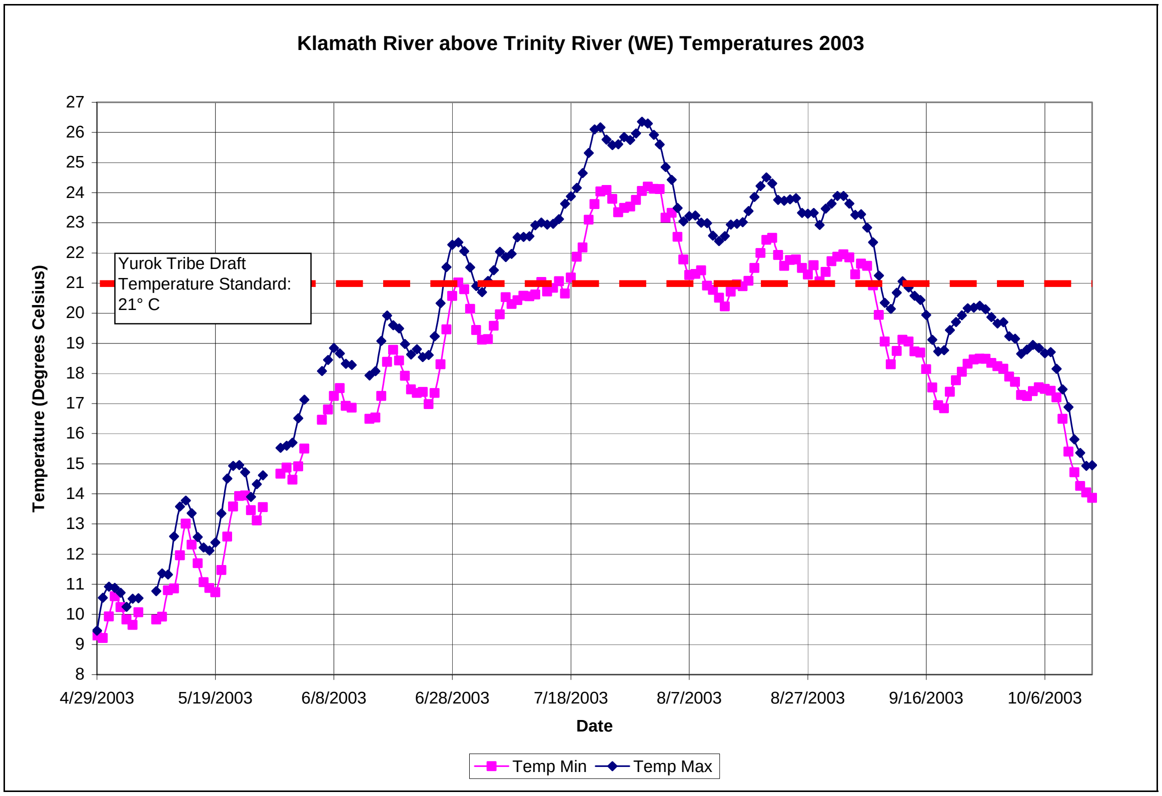


Figure 7-17 Water Temperature values for the Klamath River above Trinity River WY03

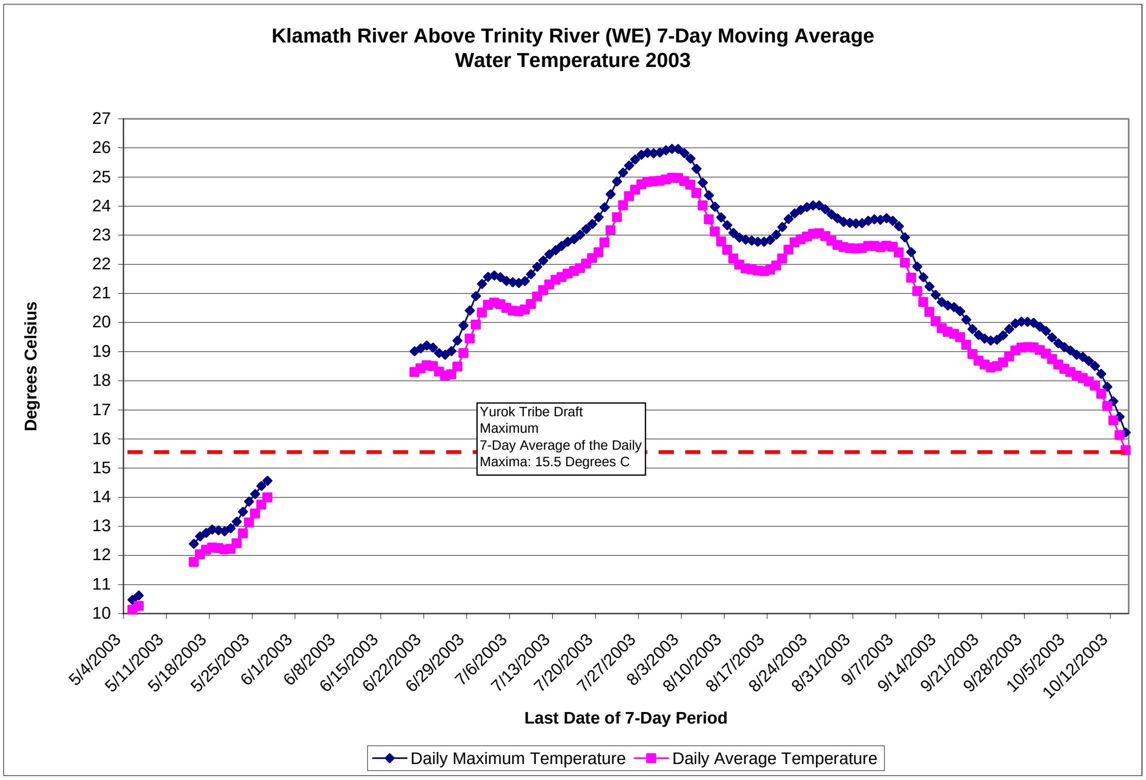


Figure 7-18 7-Day Moving Average Water Temperature for the Klamath River above Trinity River WY03

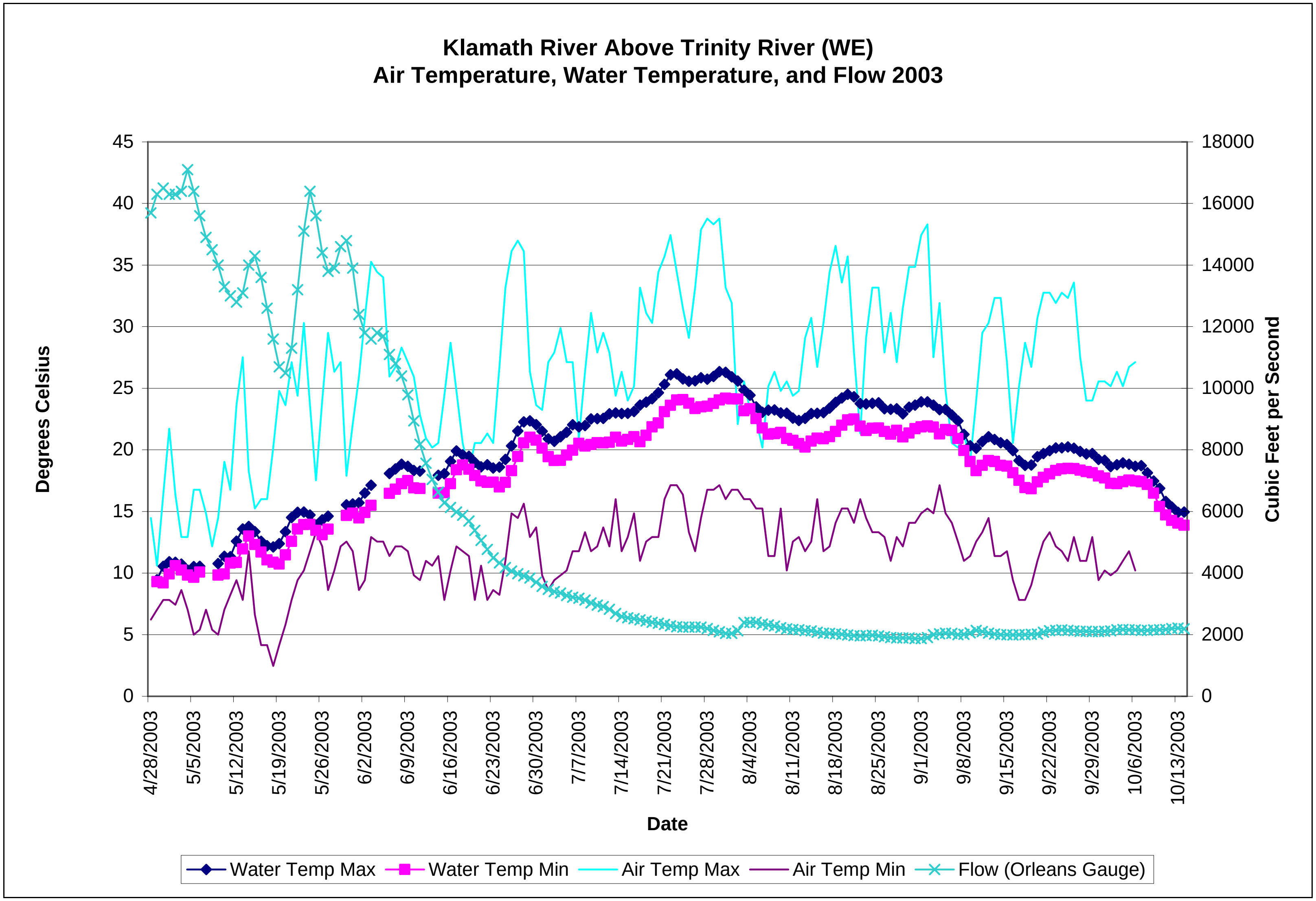


Figure 7-19 Air and Water Temperature and Flow Values for the Klamath River above Trinity River WY03

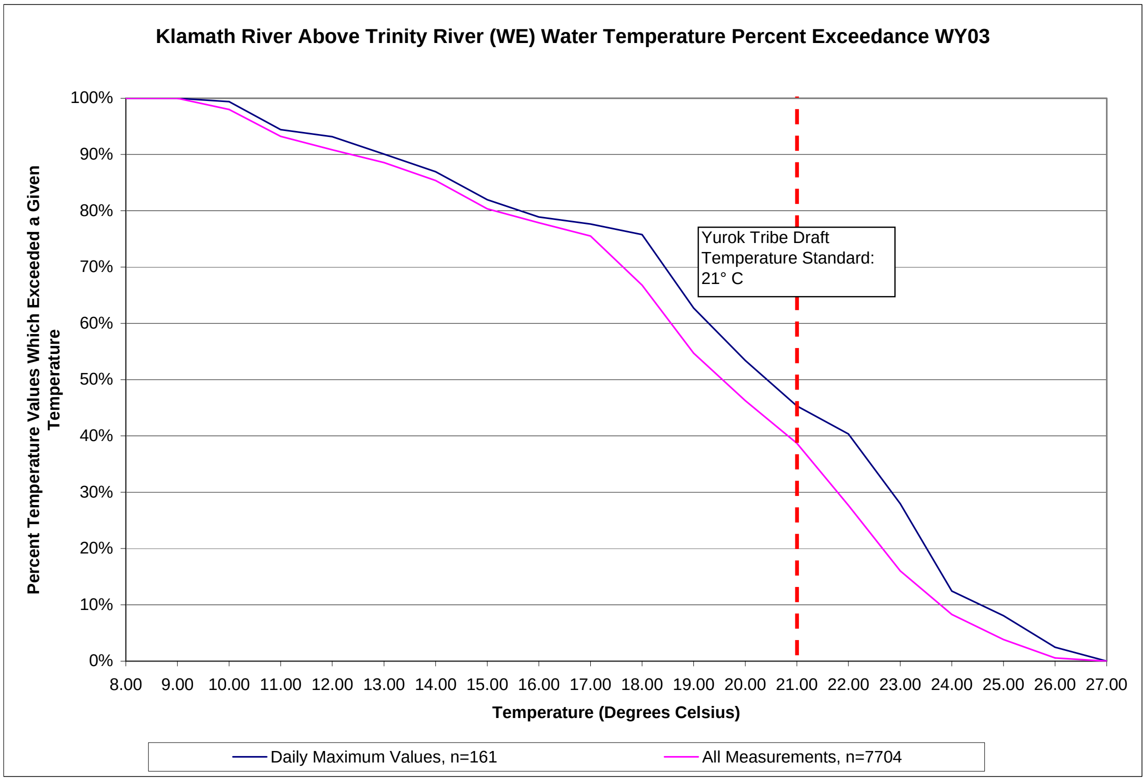


Figure 7-20 Klamath River Above Trinity River Water Temperature Percent Exceedance WY03

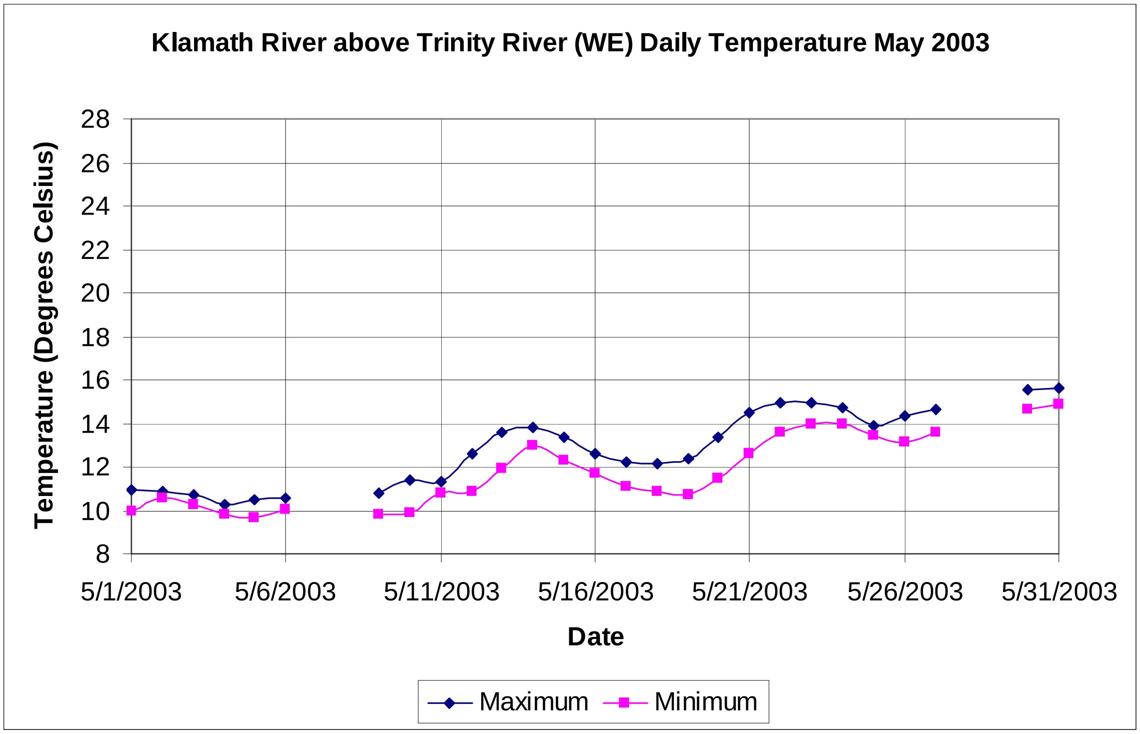


Figure 7-21 Water Temperature values for the Klamath River above Trinity River May 2003

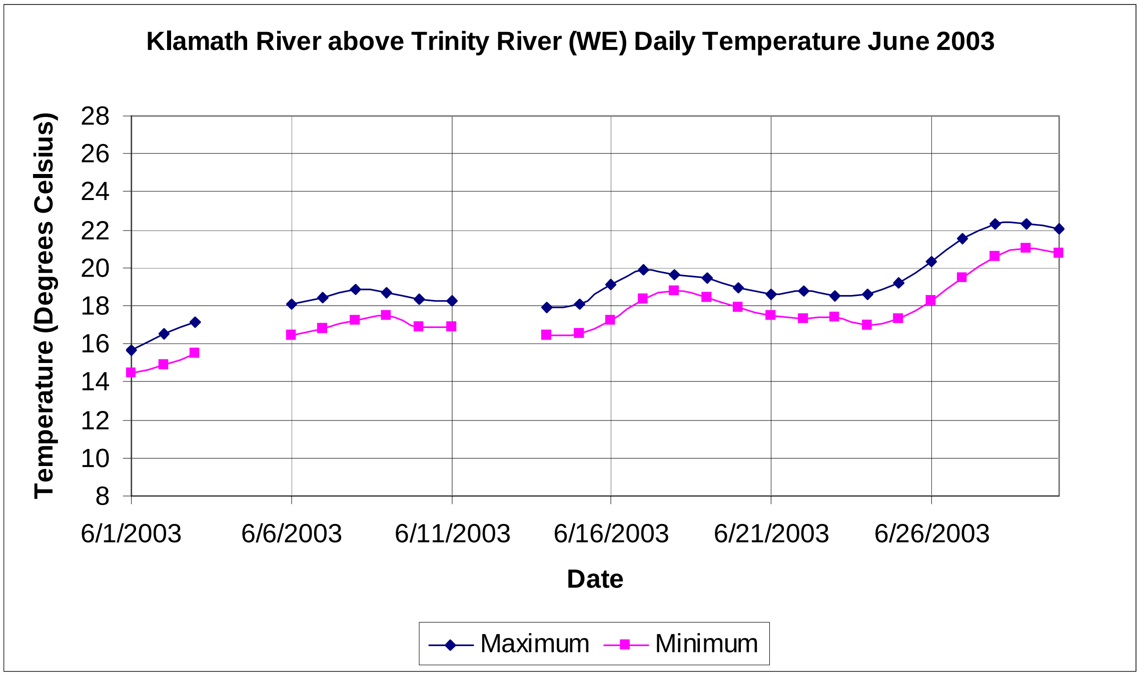


Figure 7-22 Water Temperature values for the Klamath River above Trinity River June 2003

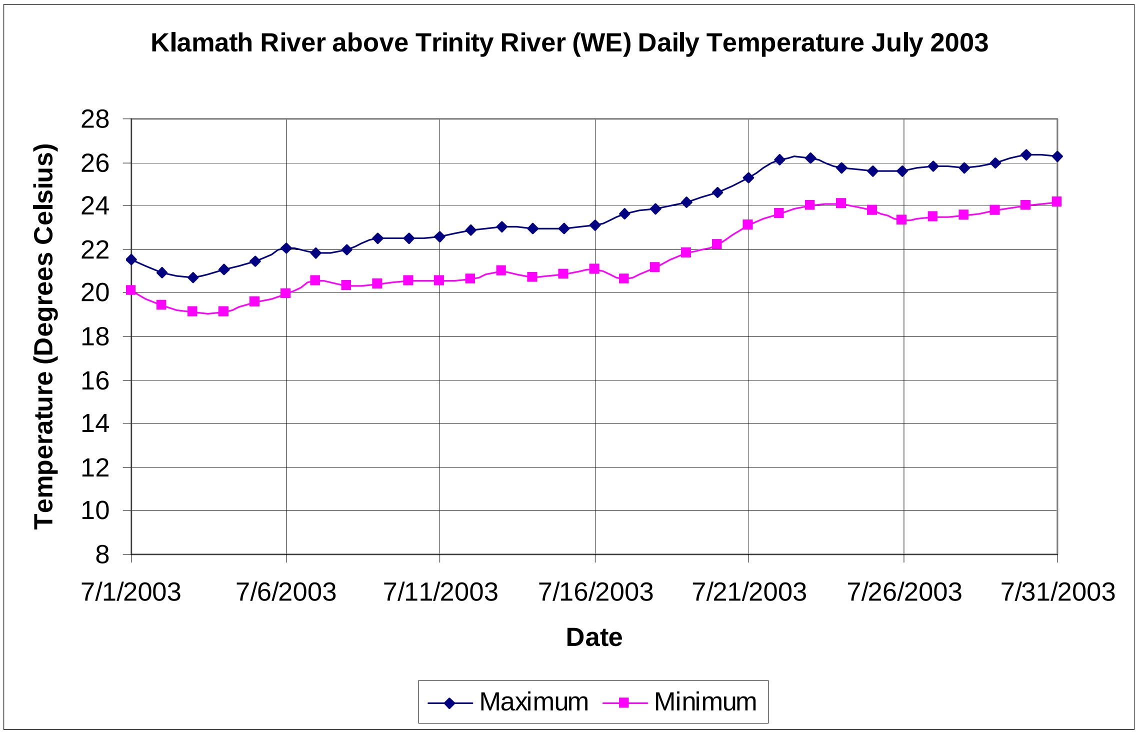


Figure 7-23 Water Temperature values for the Klamath River above Trinity River July 2003

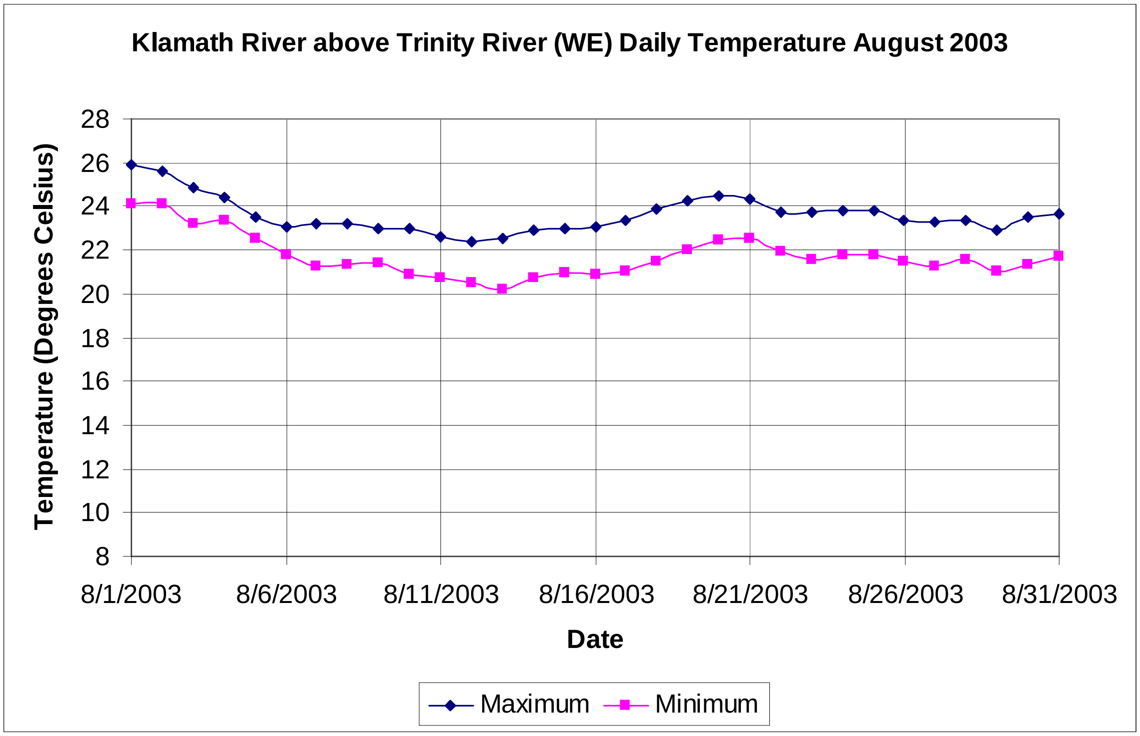


Figure 7-24 Water Temperature values for the Klamath River above Trinity River August 2003

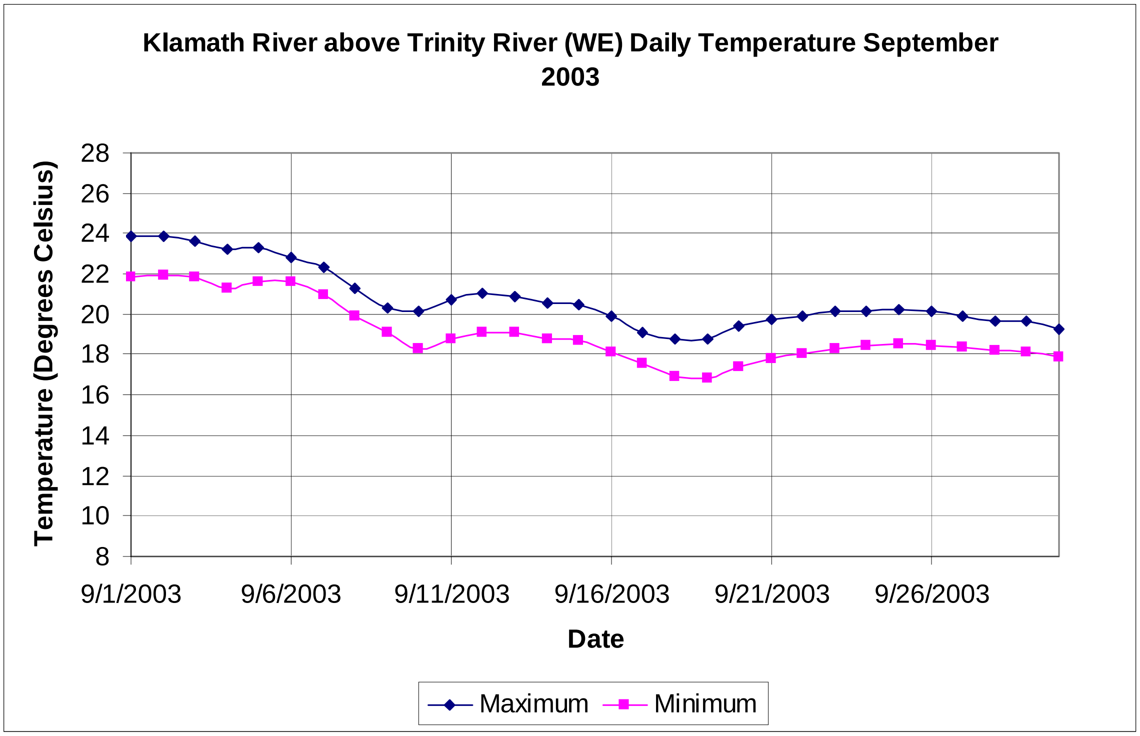


Figure 7-25 Water Temperature values for the Klamath River above Trinity River September 2003

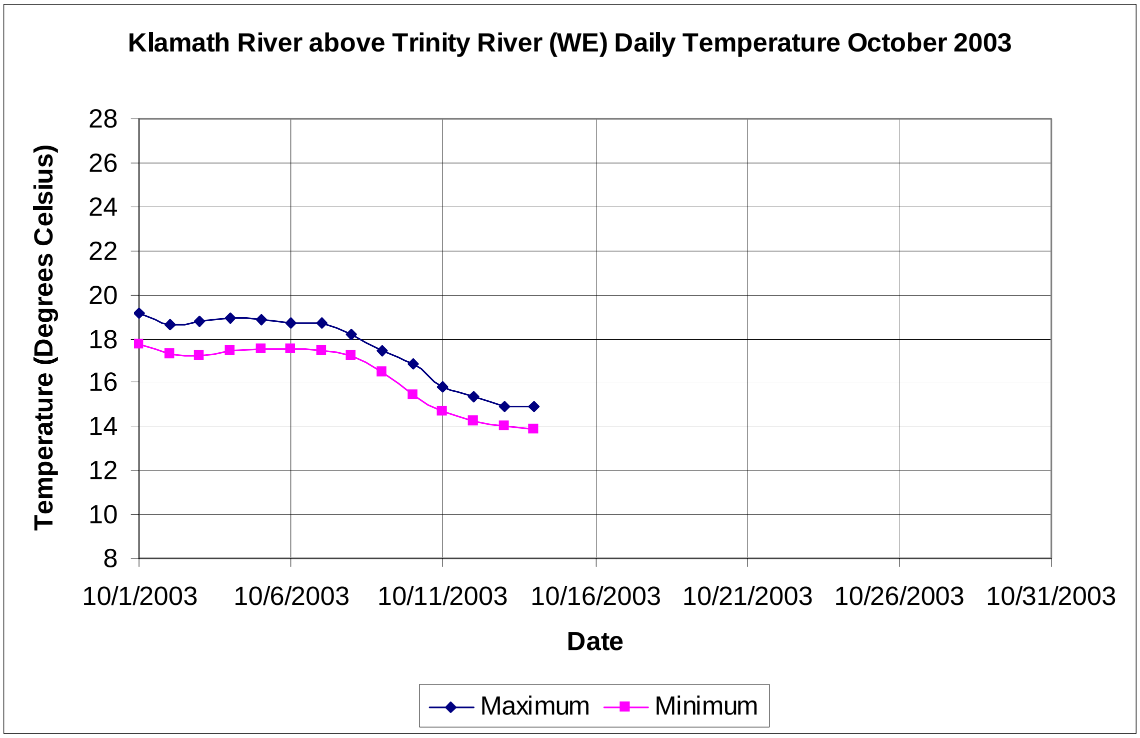


Figure 7-26 Water Temperature values for the Klamath River above Trinity River October 2003

7.1.2.2 Dissolved Oxygen

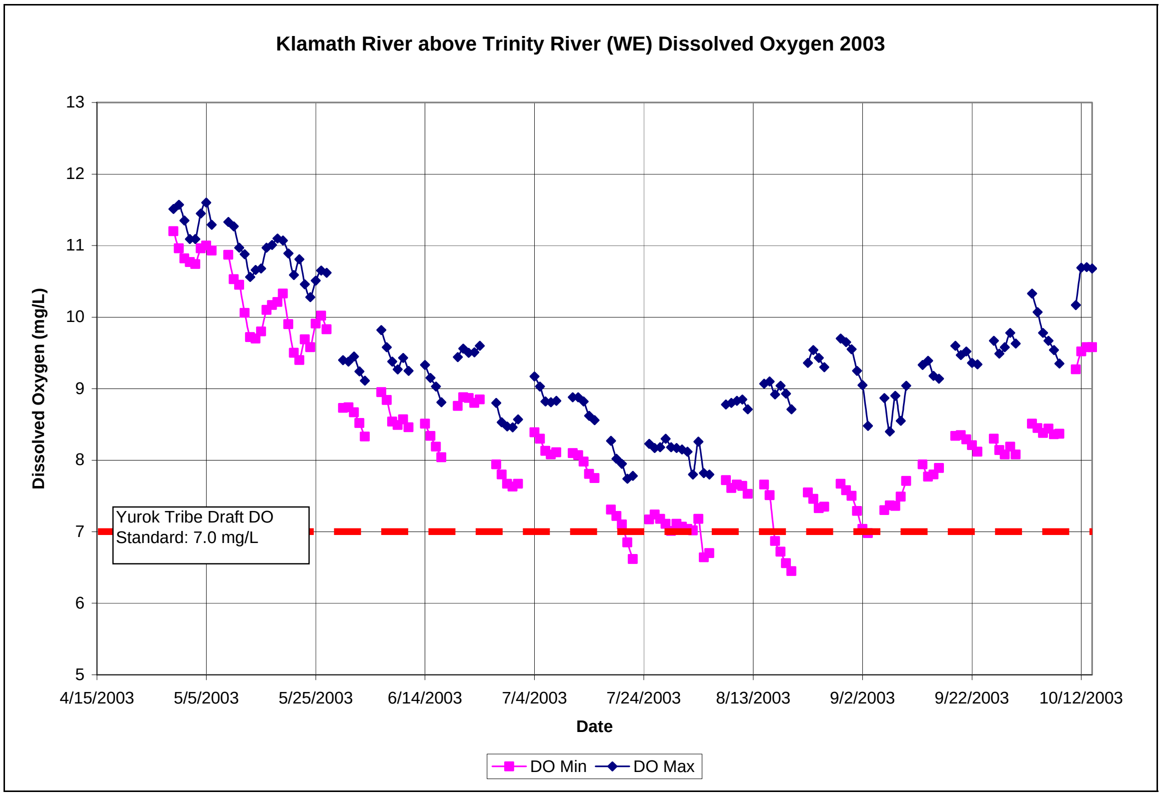


Figure 7-27 Dissolved Oxygen Values for the Klamath River above Trinity River WY03

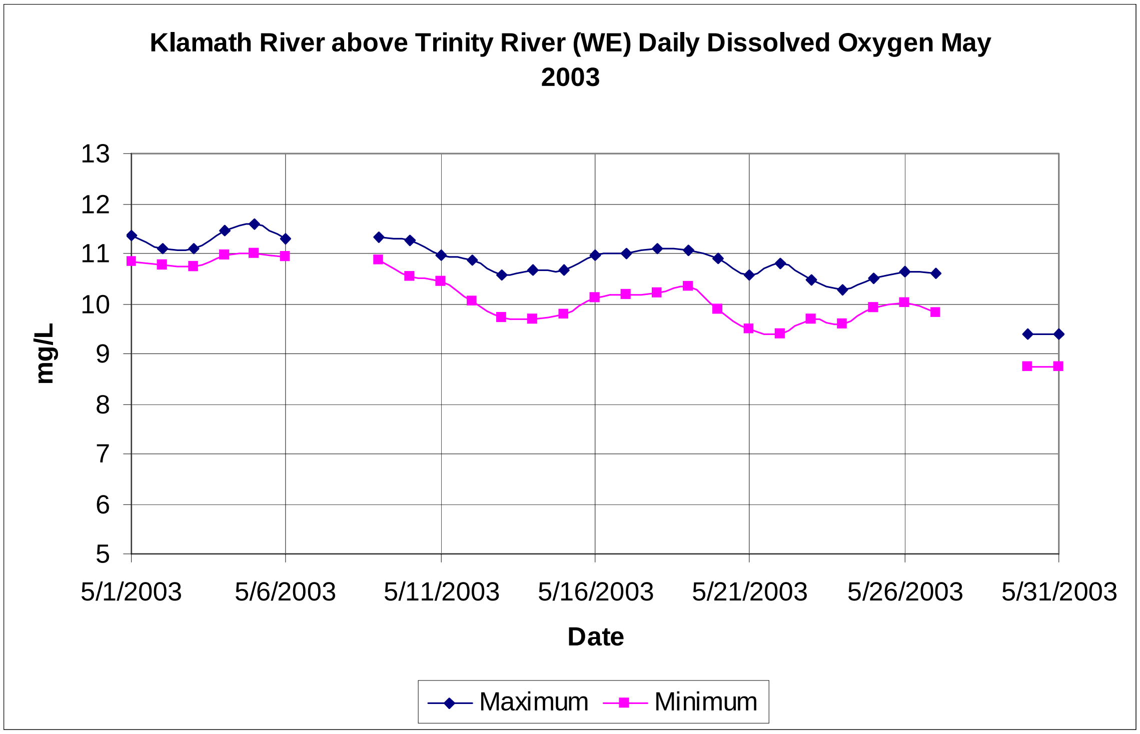


Figure 7-28 Dissolved Oxygen Values for the Klamath River above Trinity River May 2003

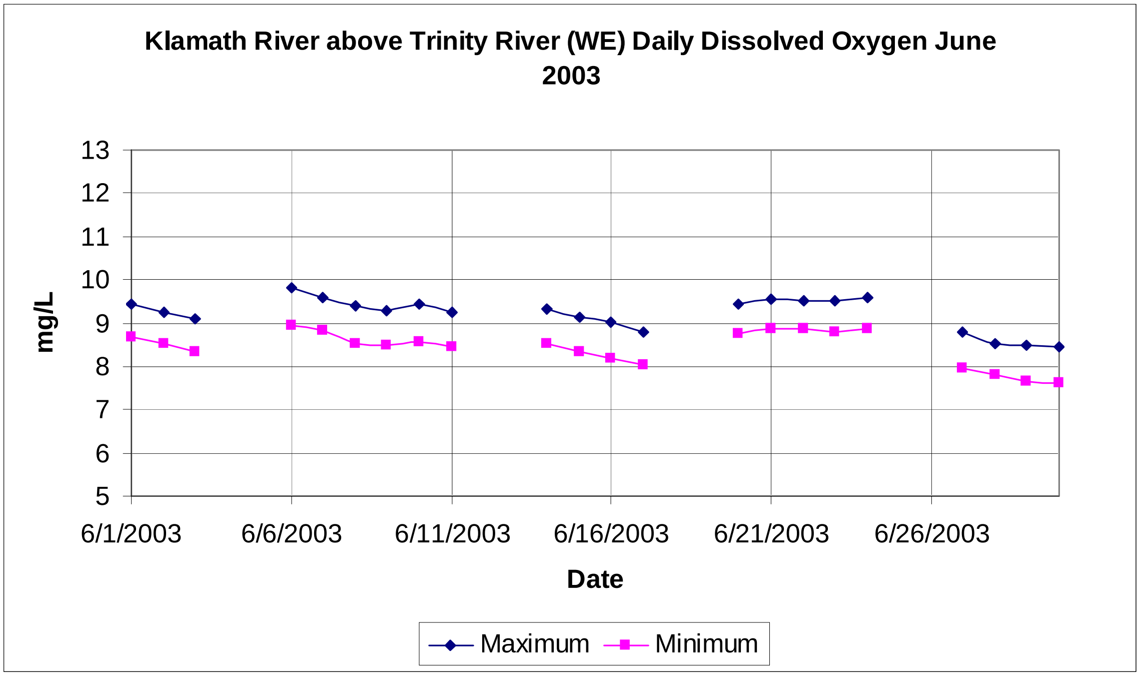


Figure 7-29 Dissolved Oxygen Values for the Klamath River above Trinity River June 2003

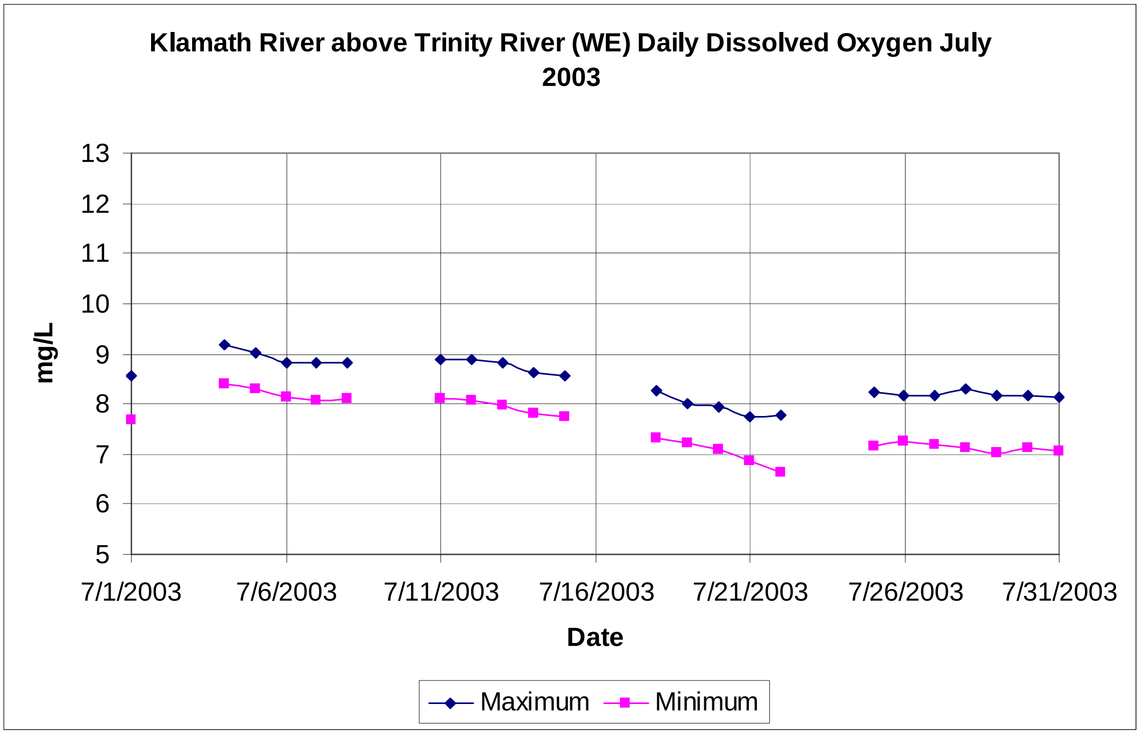


Figure 7-30 Dissolved Oxygen Values for the Klamath River above Trinity River July 2003

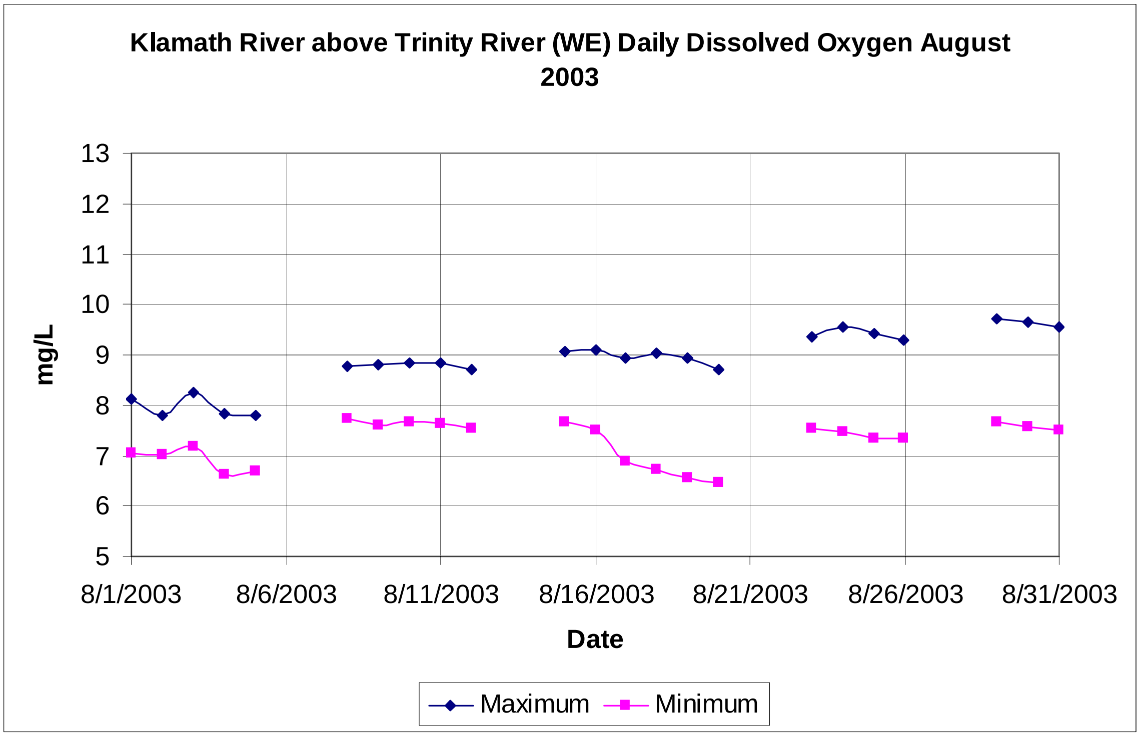


Figure 7-31 Dissolved Oxygen Values for the Klamath River above Trinity River August 2003

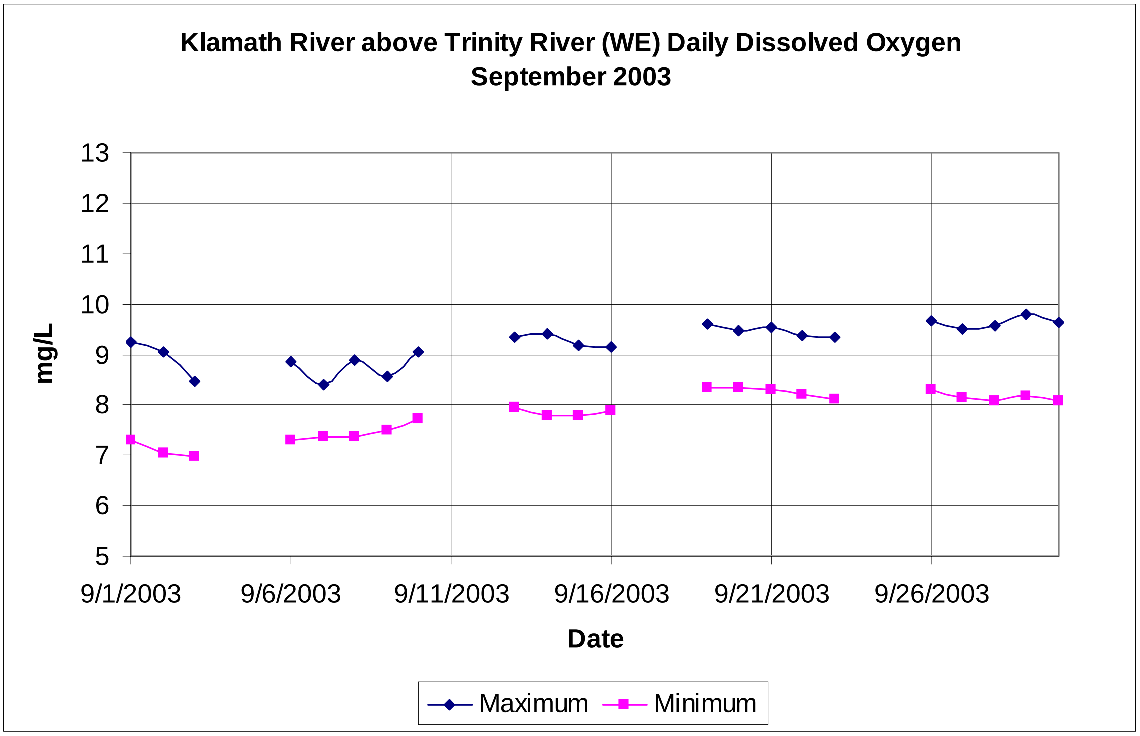


Figure 7-32 Dissolved Oxygen Values for the Klamath River above Trinity River September 2003

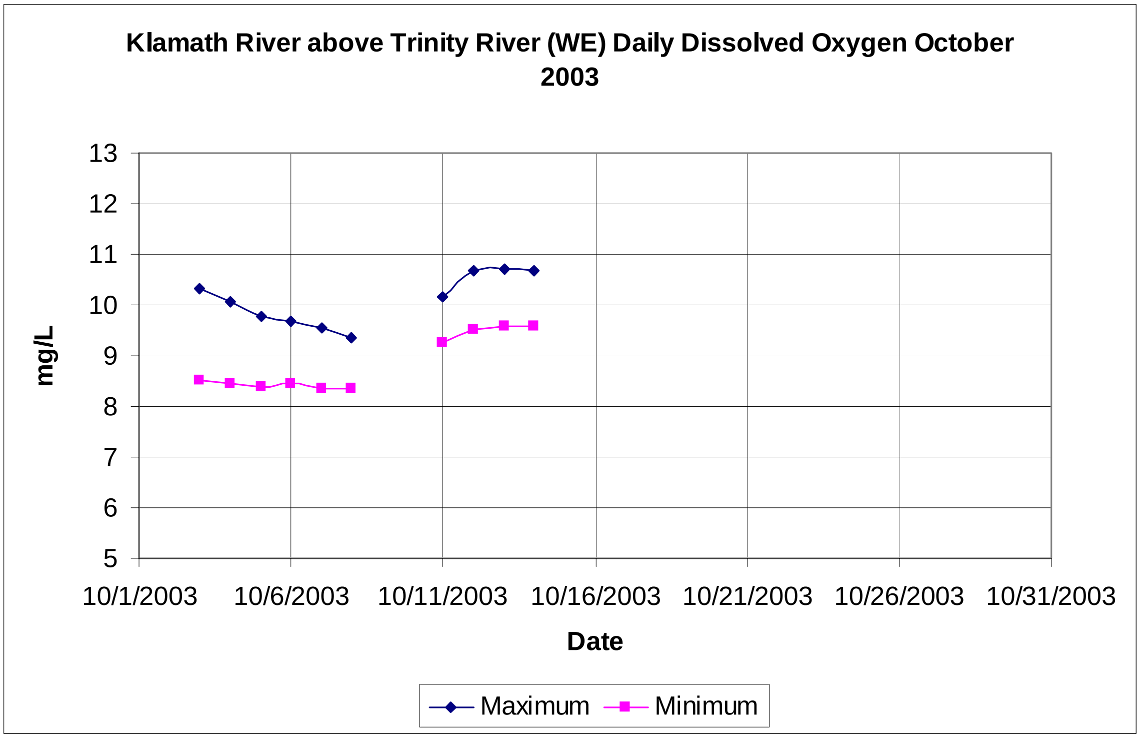


Figure 7-33 Dissolved Oxygen Values for the Klamath River above Trinity River October 2003

7.1.2.3 pH

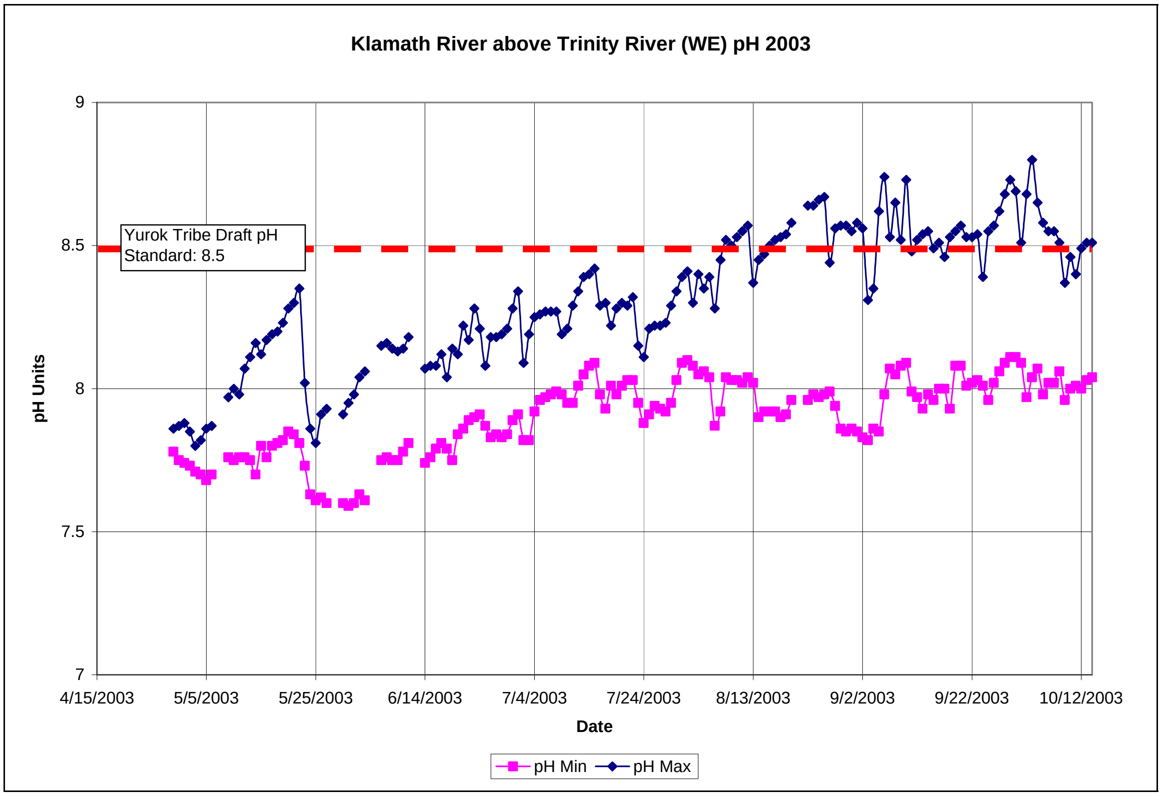


Figure 7-34 pH Values for the Klamath River above Trinity River WY03

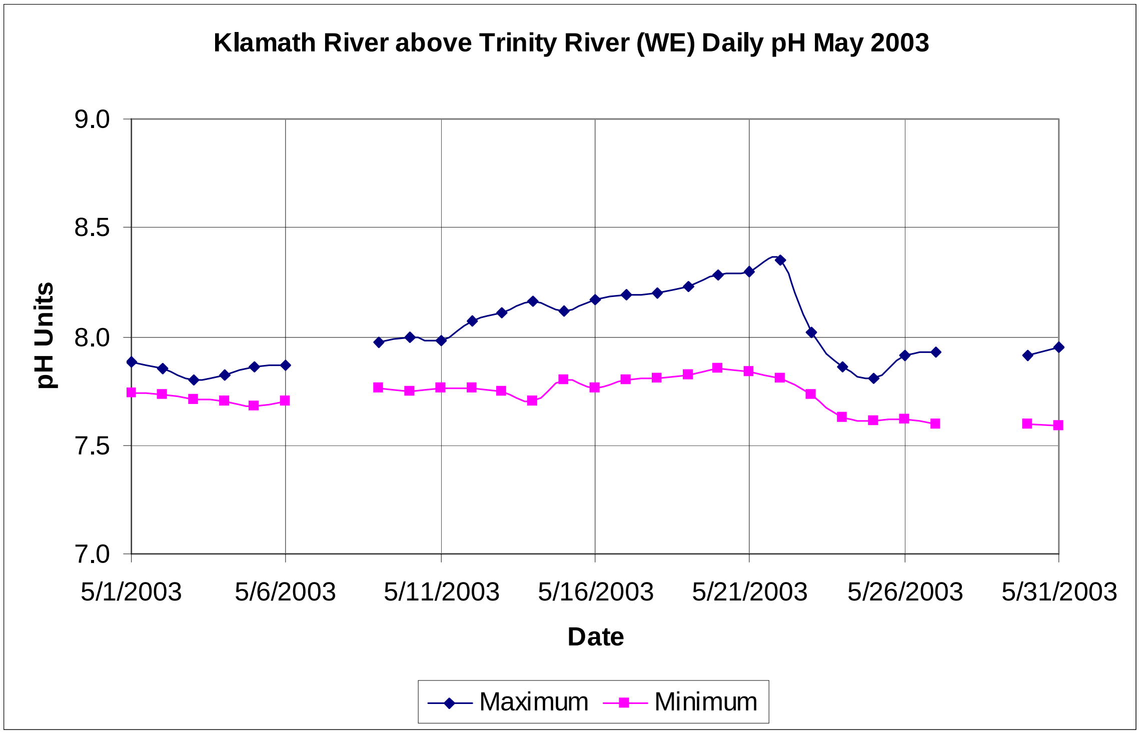


Figure 7-35 pH Values for the Klamath River above Trinity River May 2003

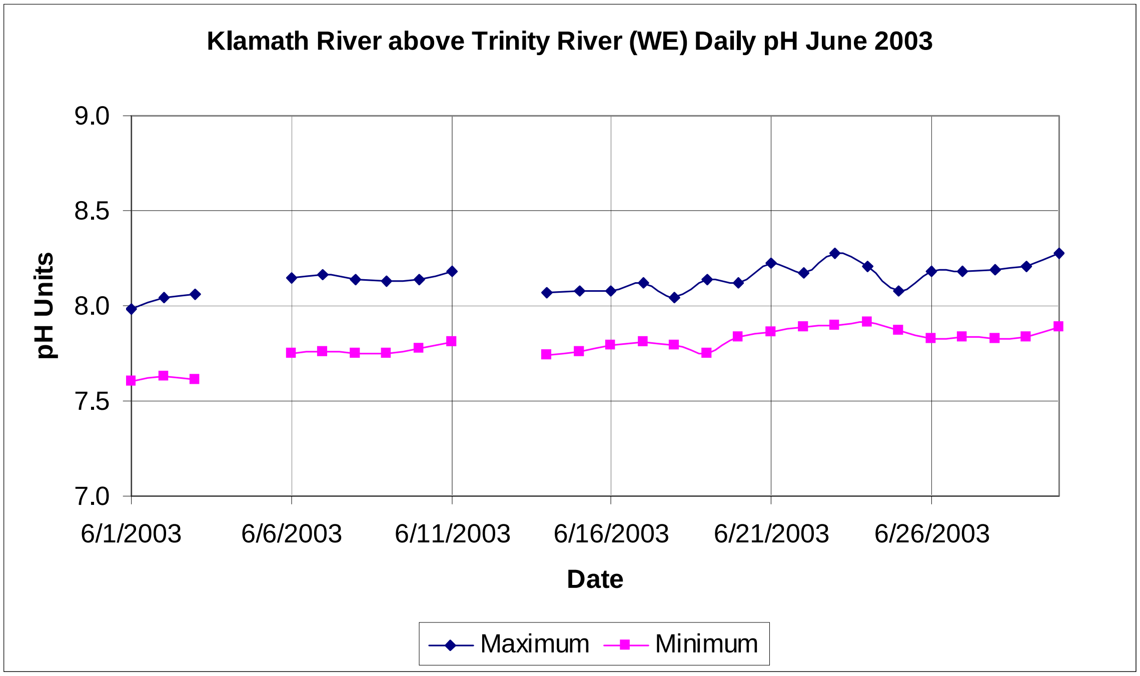


Figure 7-36 pH Values for the Klamath River above Trinity River June 2003

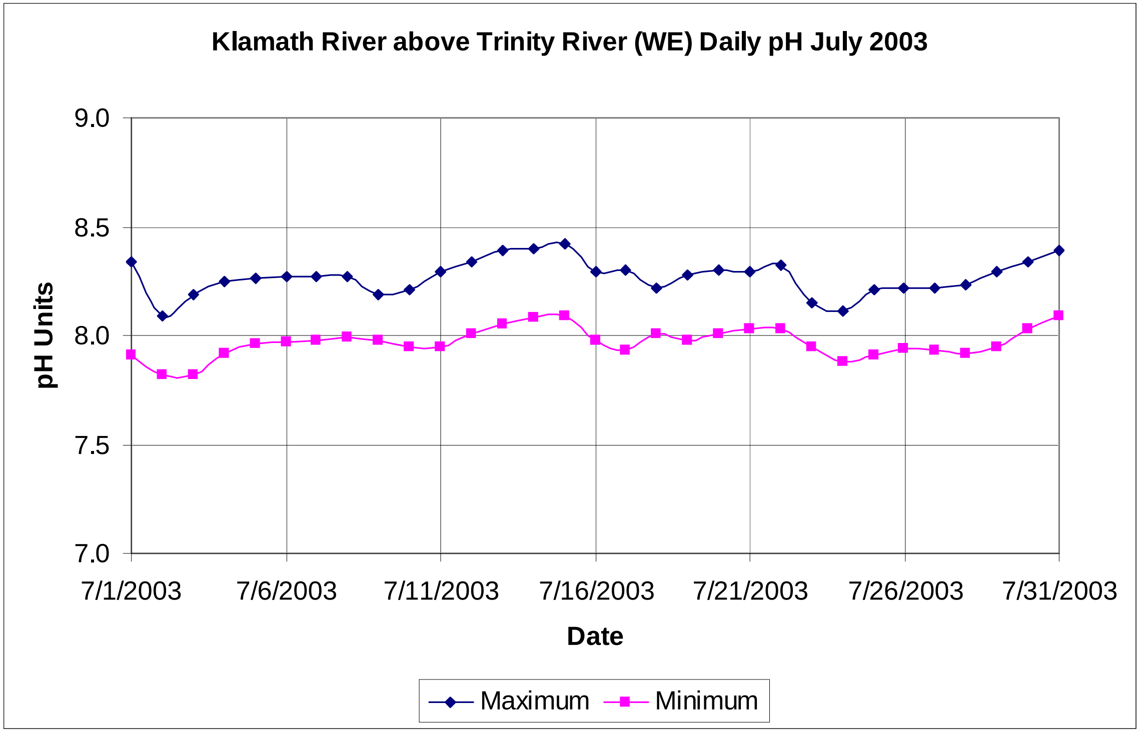


Figure 7-37 pH Values for the Klamath River above Trinity River July 2003

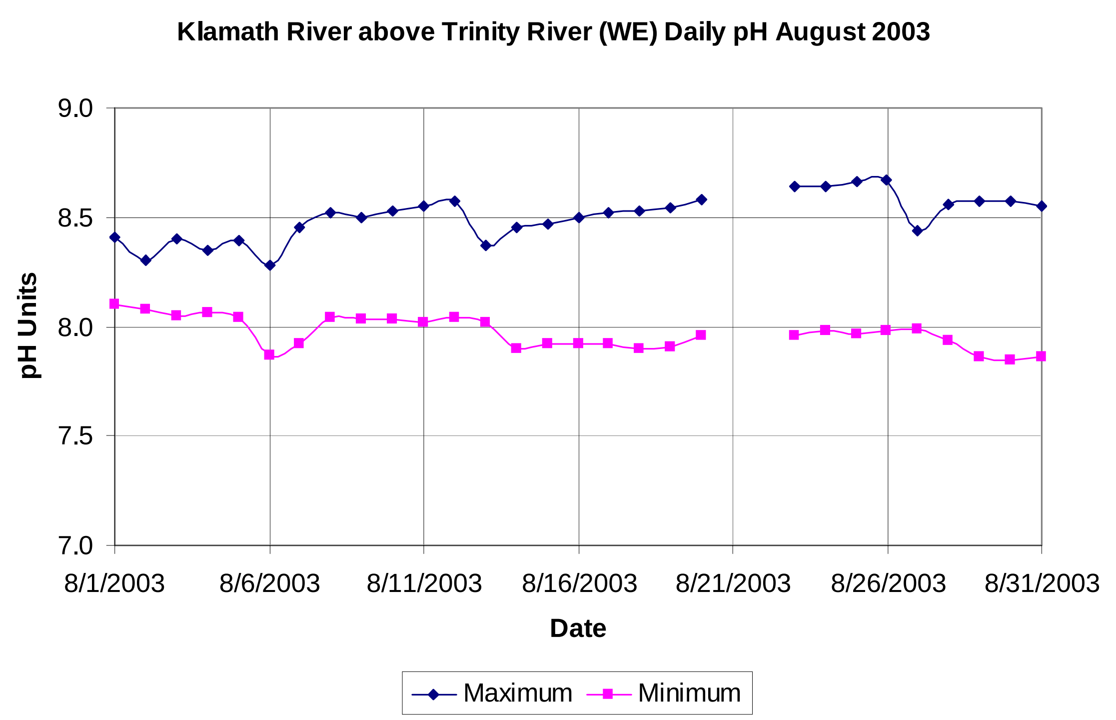


Figure 7-38 pH Values for the Klamath River above Trinity River August 2003

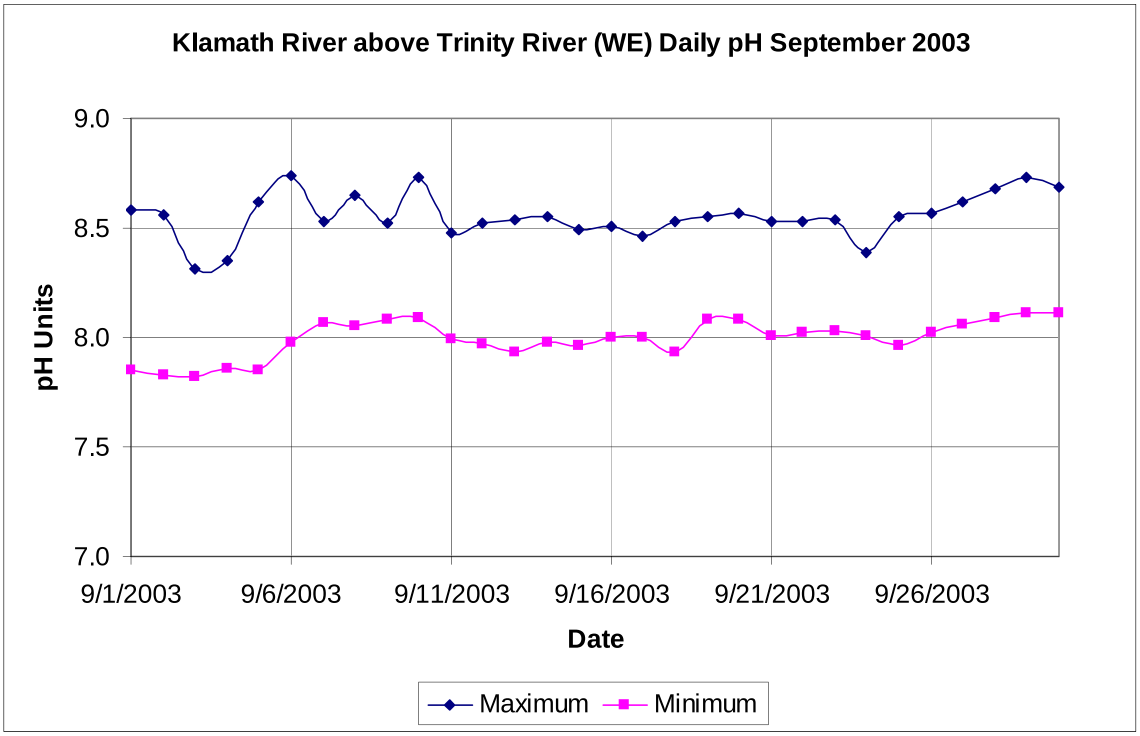


Figure 7-39 pH Values for the Klamath River above Trinity River September 2003

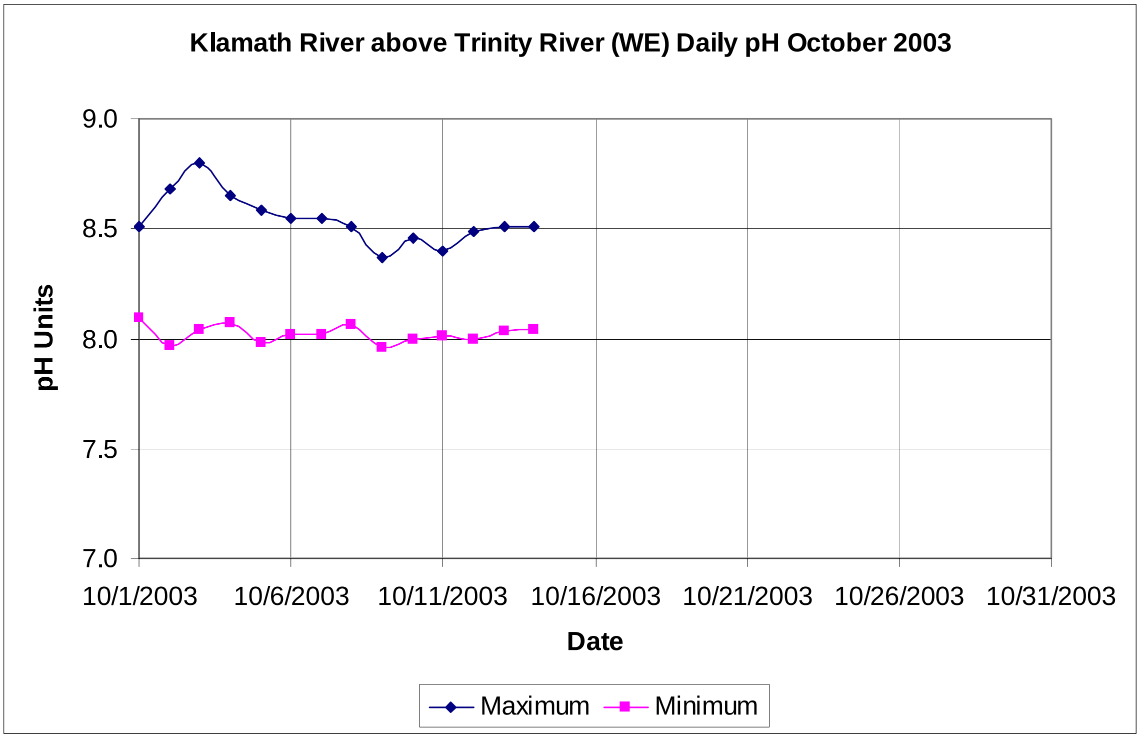


Figure 7-40 pH Values for the Klamath River above Trinity River October 2003

7.1.3 Trinity River above Klamath River

7.1.3.1 Temperature

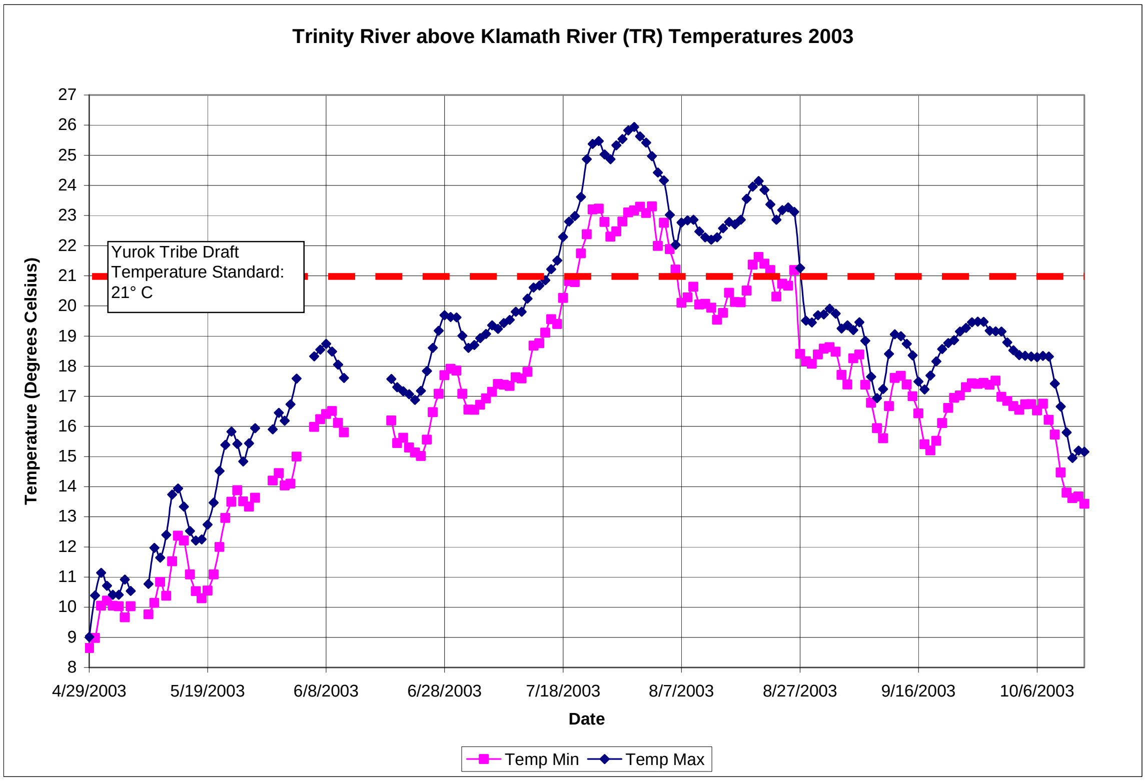


Figure 7-41 Water Temperature Values for the Trinity River Above Klamath River WY03

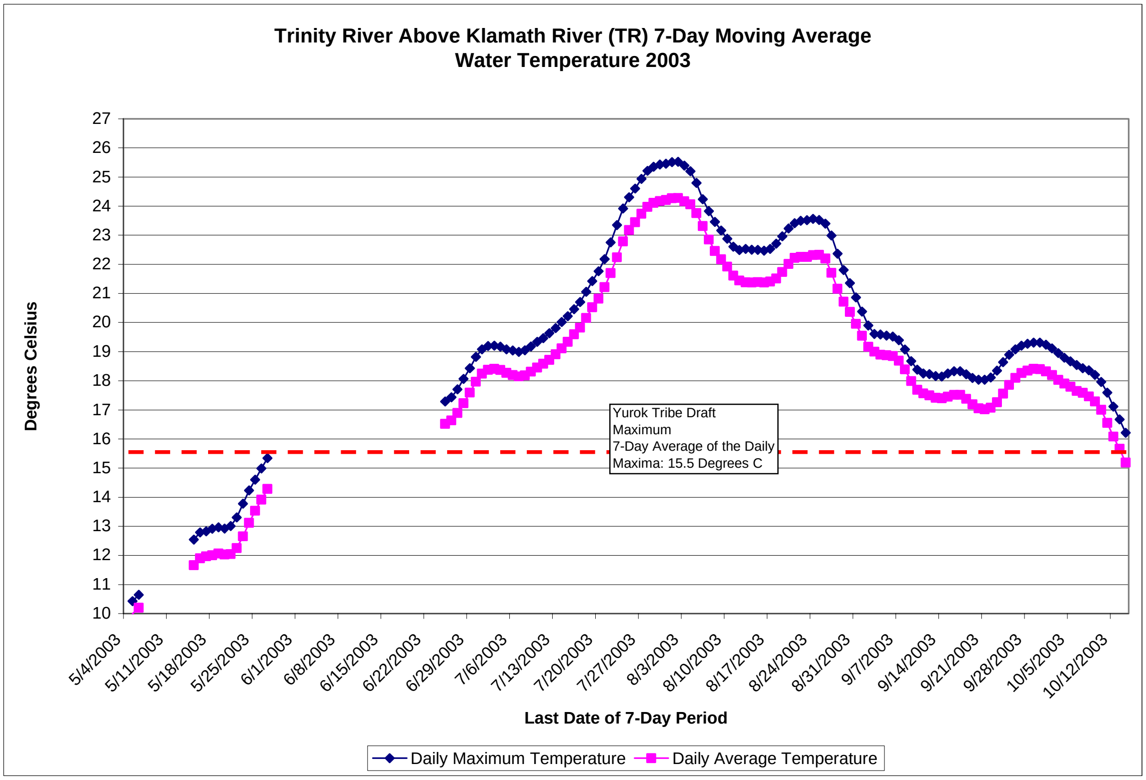


Figure 7-42 7-Day Moving Average Water Temperature for the Trinity River Above Klamath River WY03

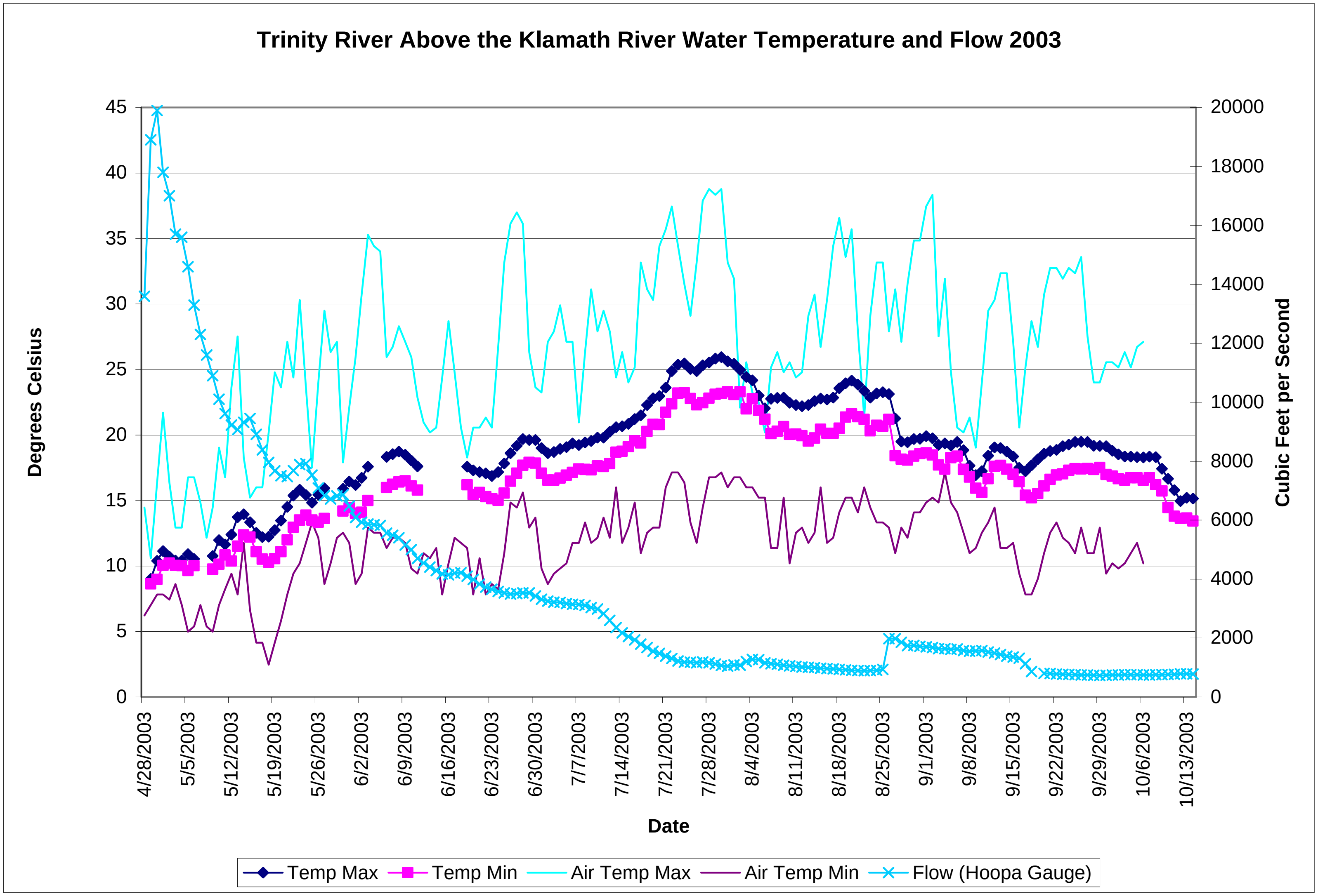


Figure 7-43 Water Temperature and Flow Values for the Trinity River Above Klamath River WY03

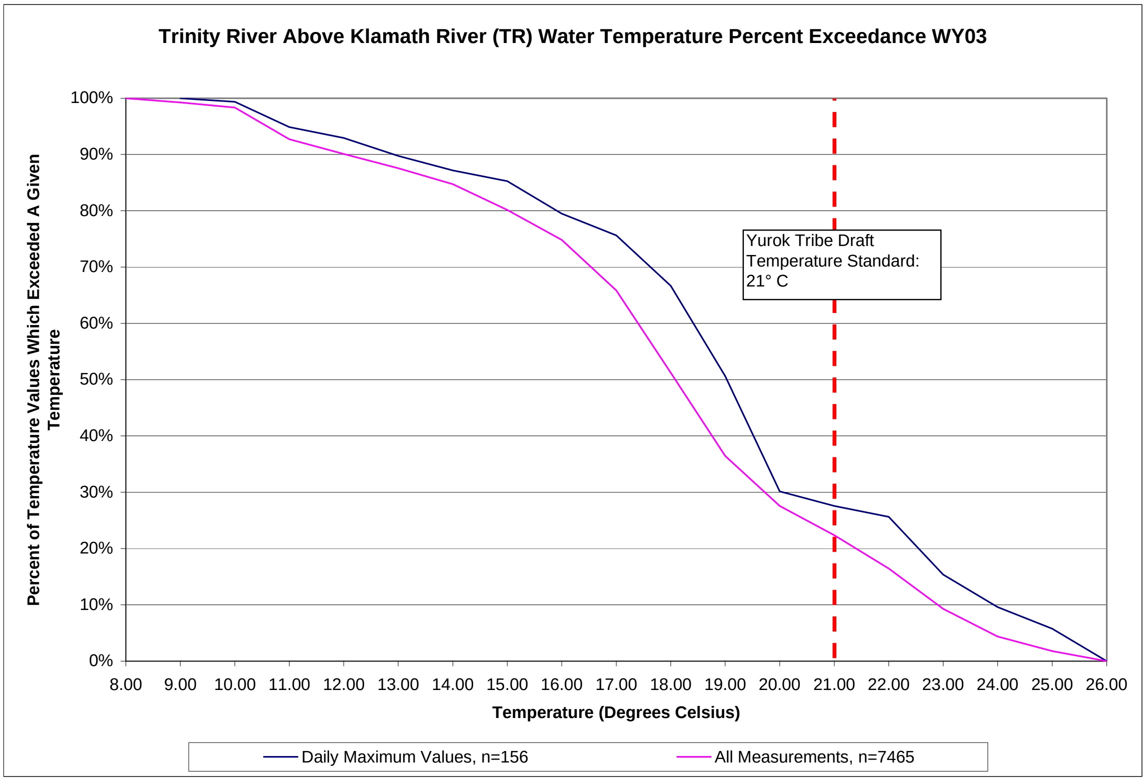


Figure 7-44 Water Temperature Percent Exceedance for Trinity River above Klamath River WY03

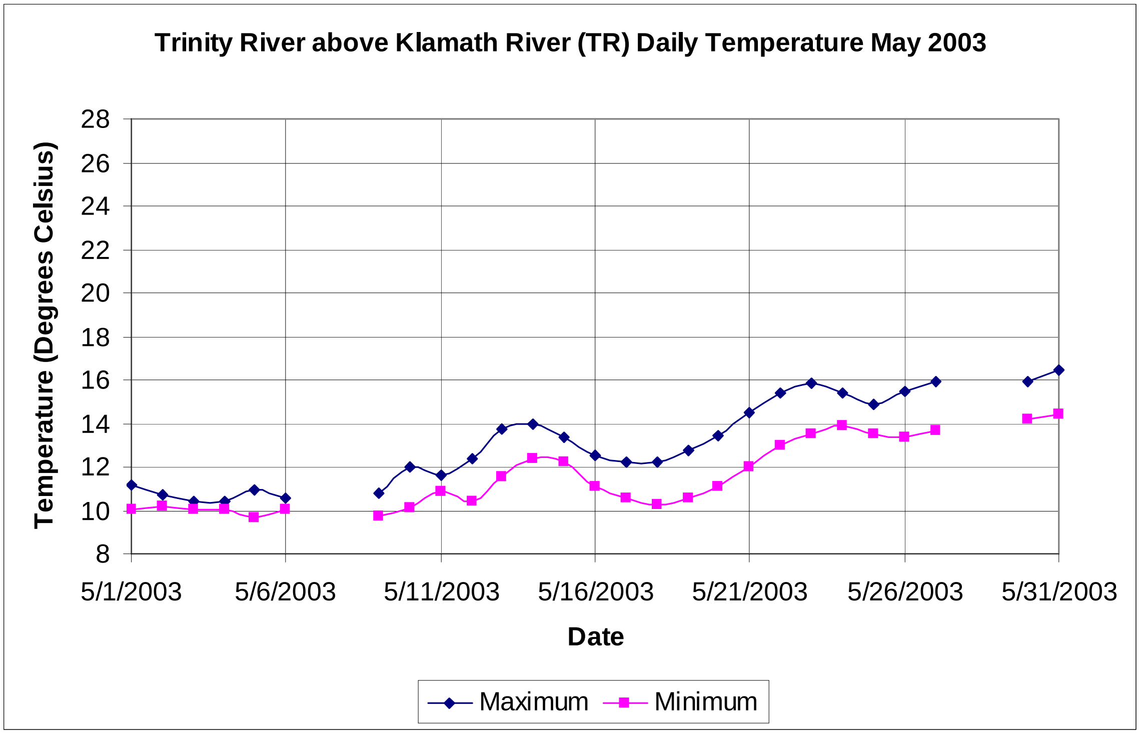


Figure 7-45 Water Temperature Values for the Trinity River Above Klamath River May 2003

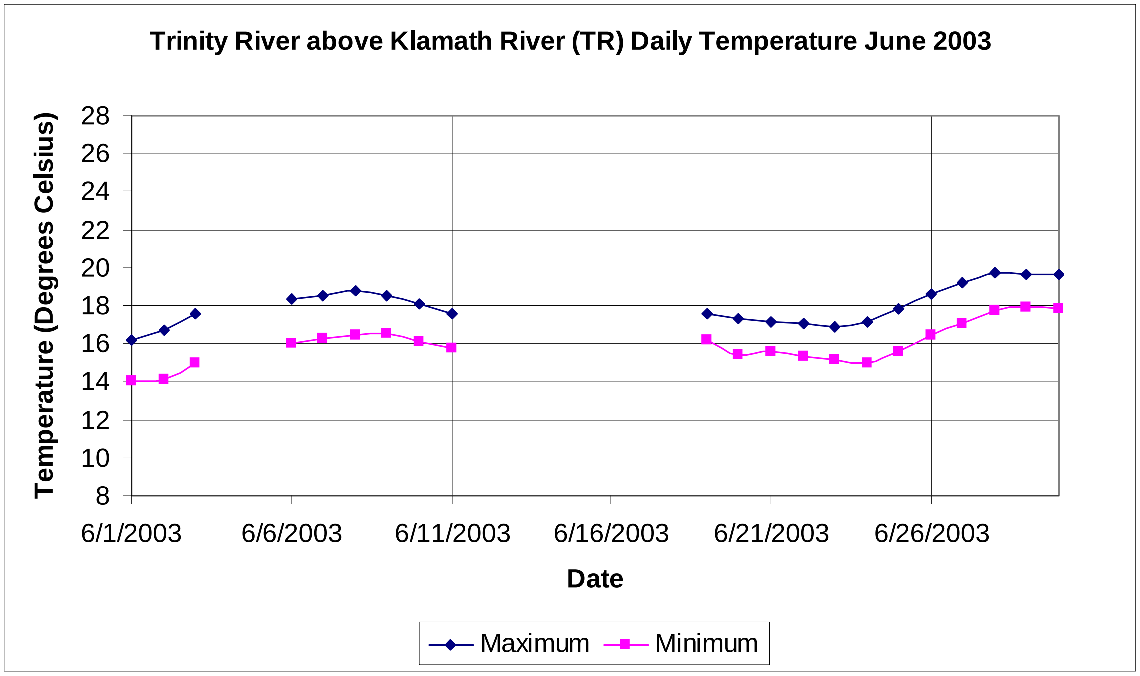


Figure 7-46 Water Temperature Values for the Trinity River Above Klamath River June 2003

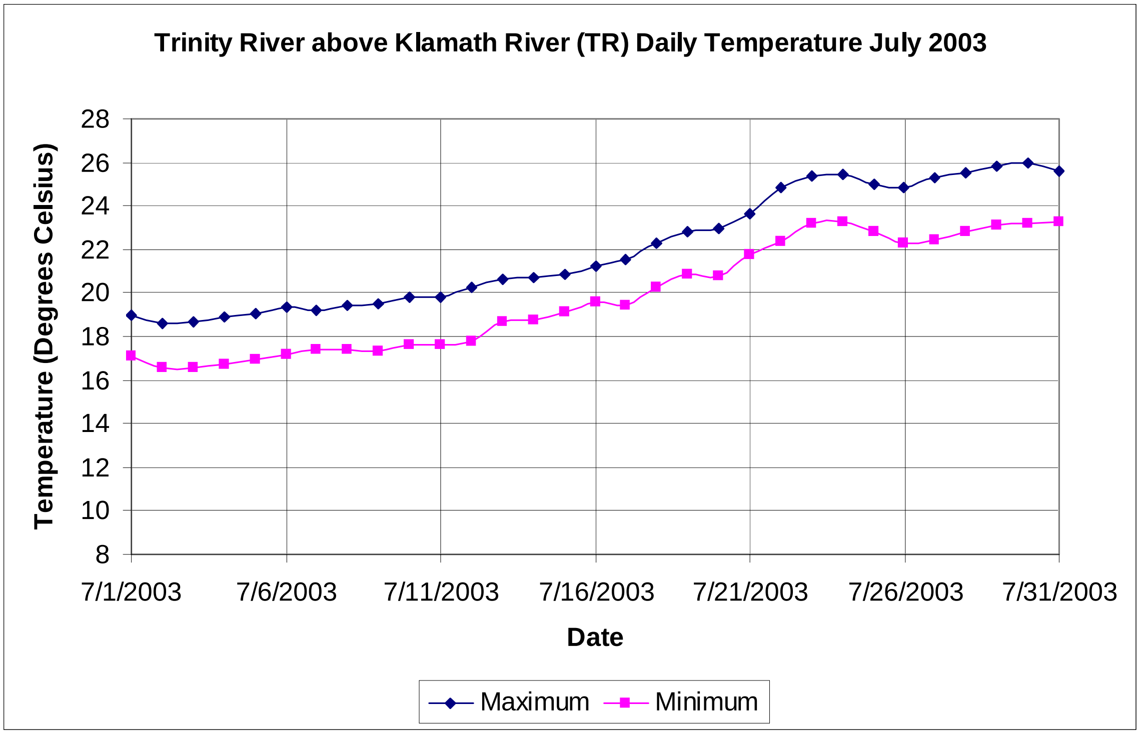


Figure 7-47 Water Temperature Values for the Trinity River Above Klamath River July 2003

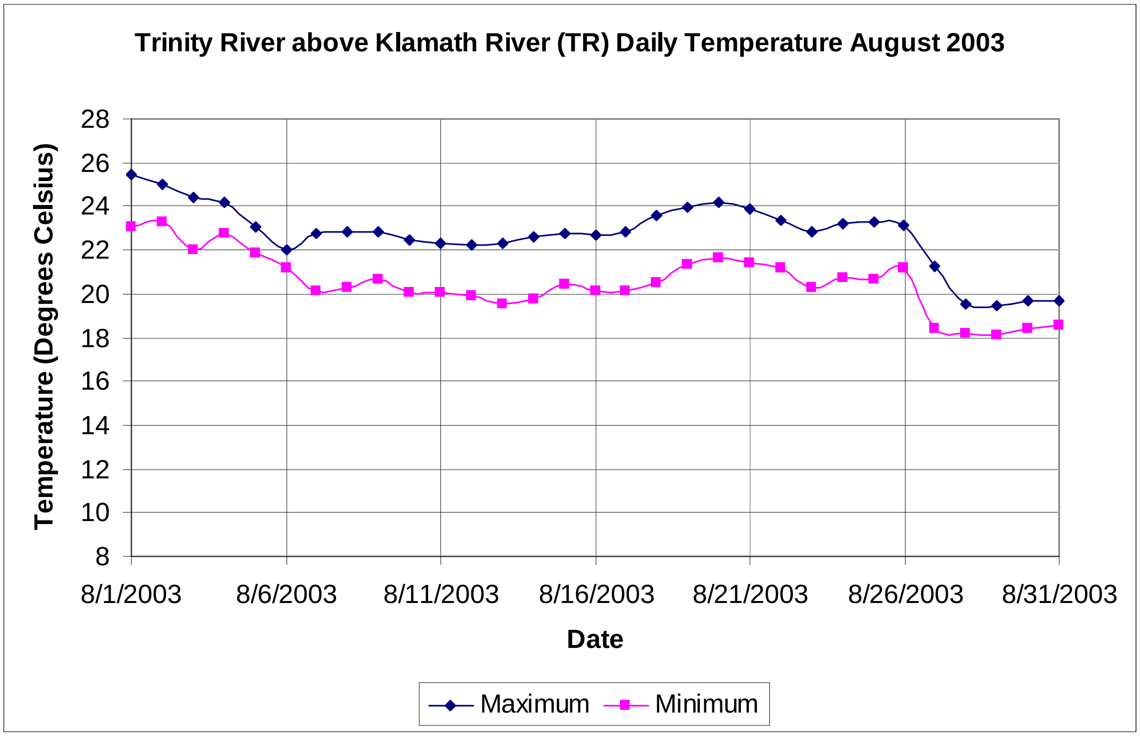


Figure 7-48 Water Temperature Values for the Trinity River Above Klamath River August 2003

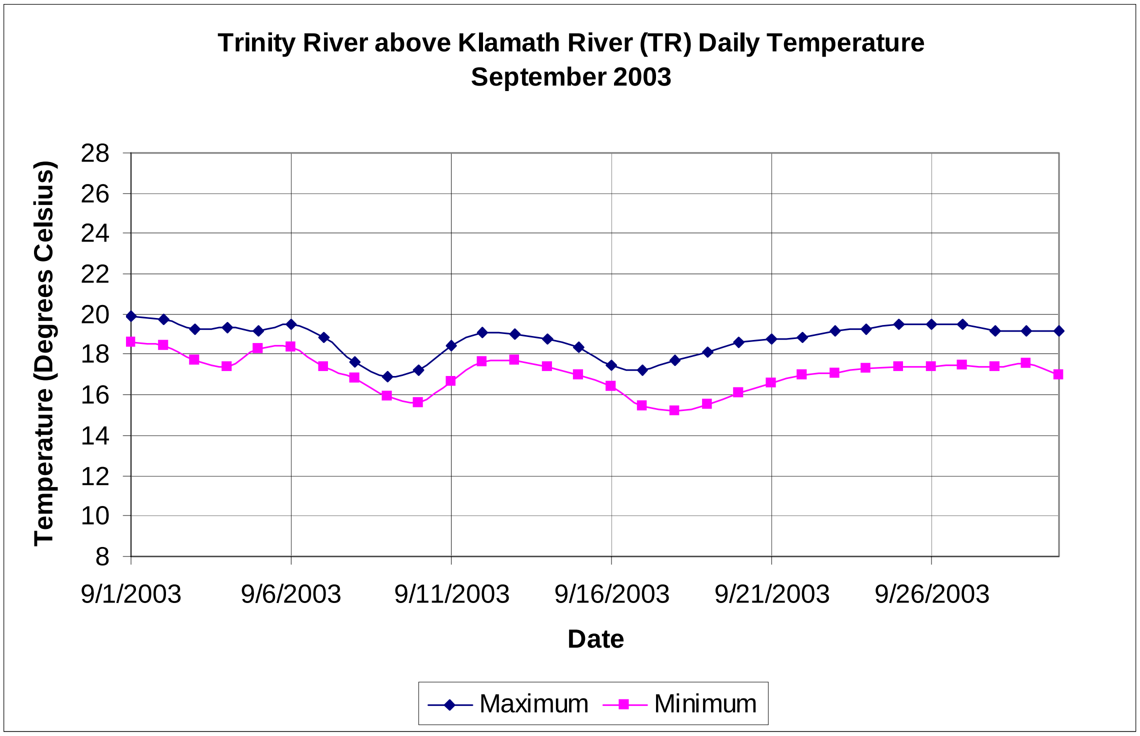


Figure 7-49 Water Temperature Values for the Trinity River Above Klamath River September 2003

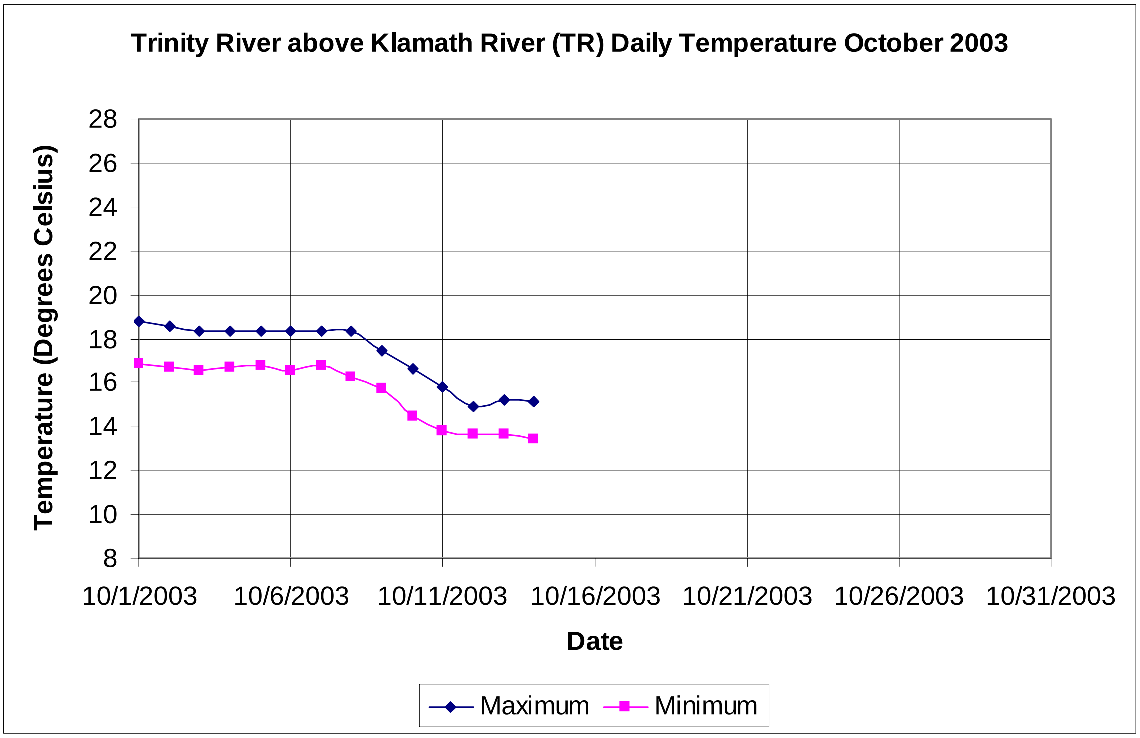


Figure 7-50 Water Temperature Values for the Trinity River Above Klamath River October 2003

7.1.3.2 Dissolved Oxygen

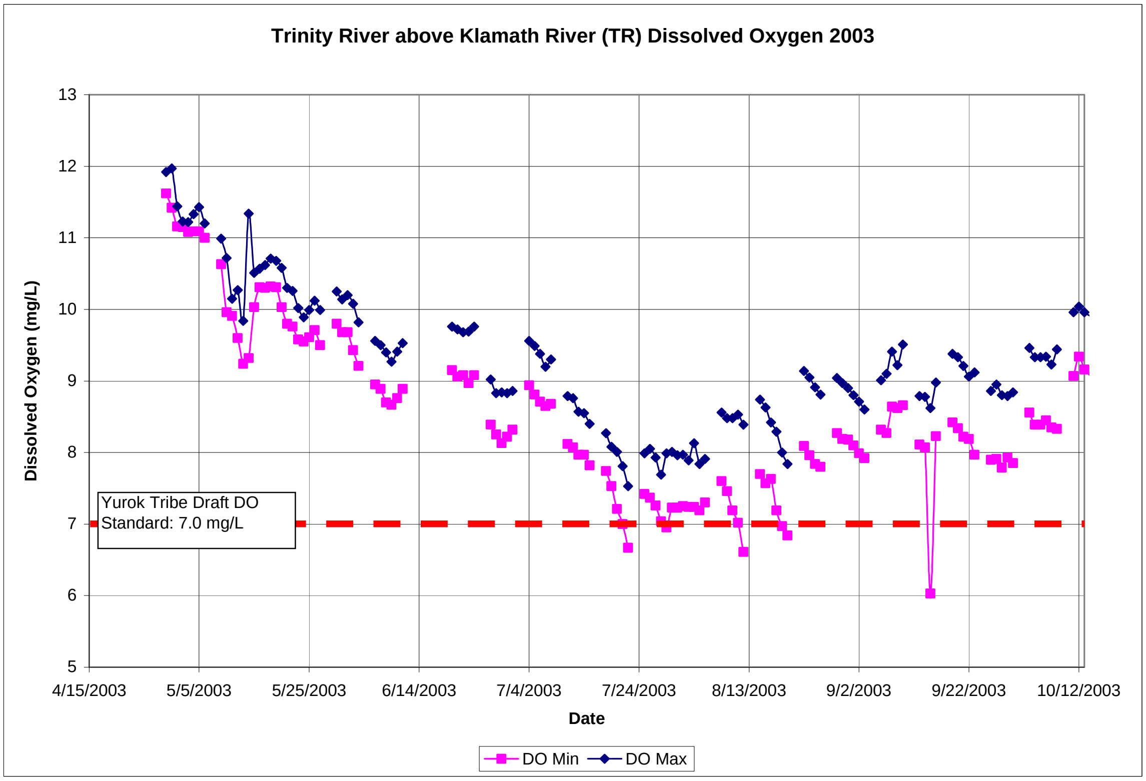


Figure 7-51 Dissolved Oxygen Values for the Trinity River Above Klamath River WY03

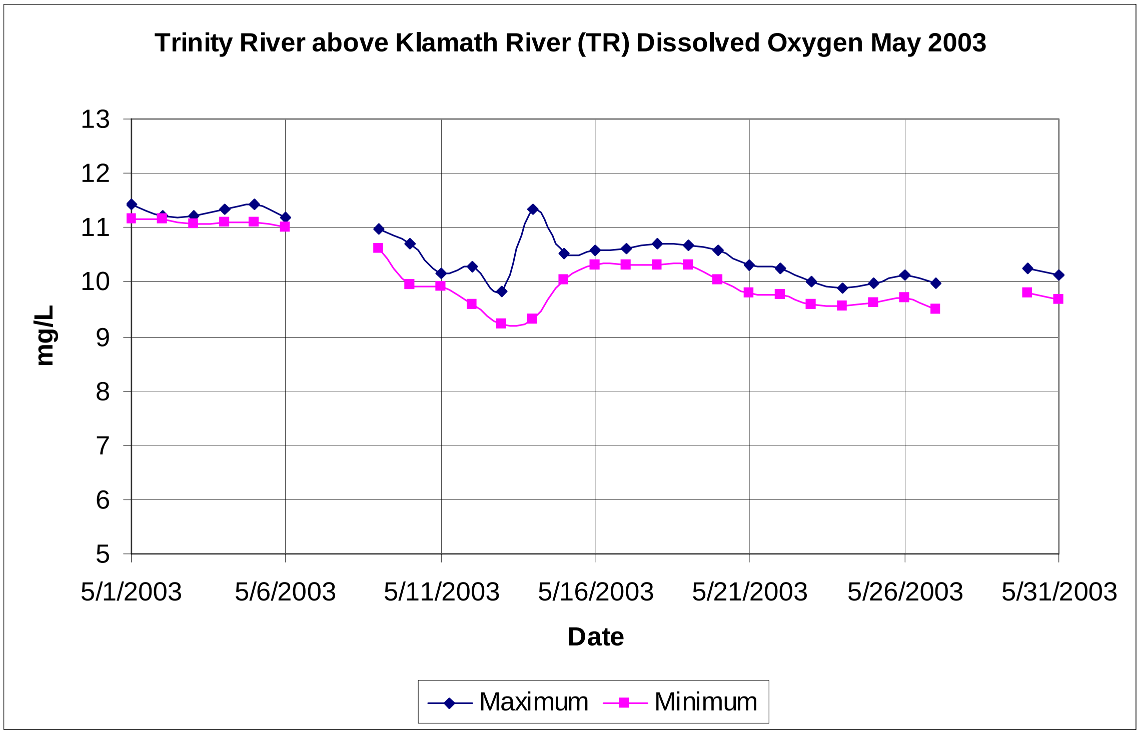


Figure 7-52 Dissolved Oxygen Values for the Trinity River Above Klamath River May 2003

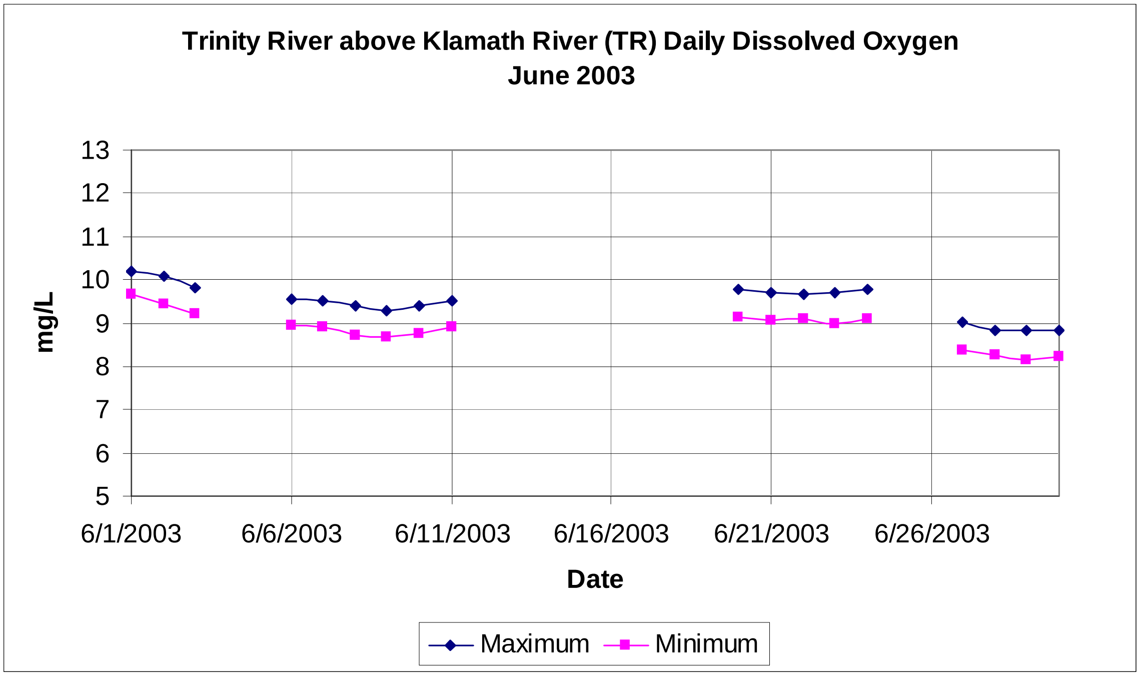


Figure 7-53 Dissolved Oxygen Values for the Trinity River Above Klamath River June 2003

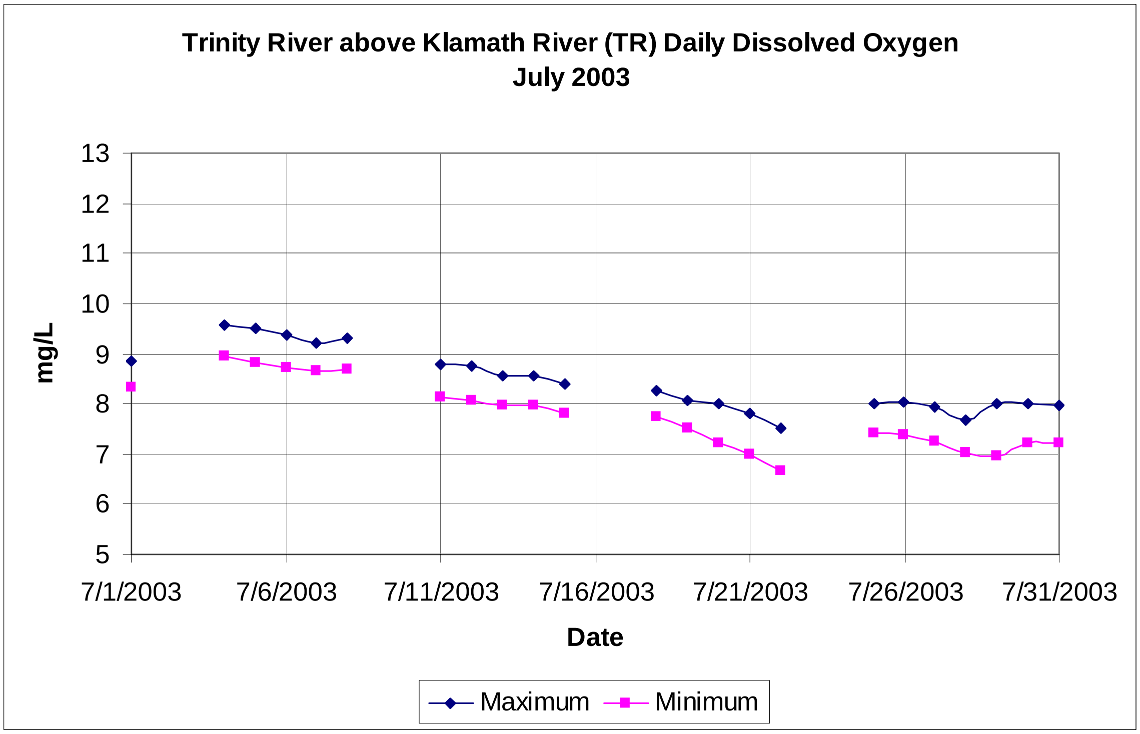


Figure 7-54 Dissolved Oxygen Values for the Trinity River Above Klamath River July 2003

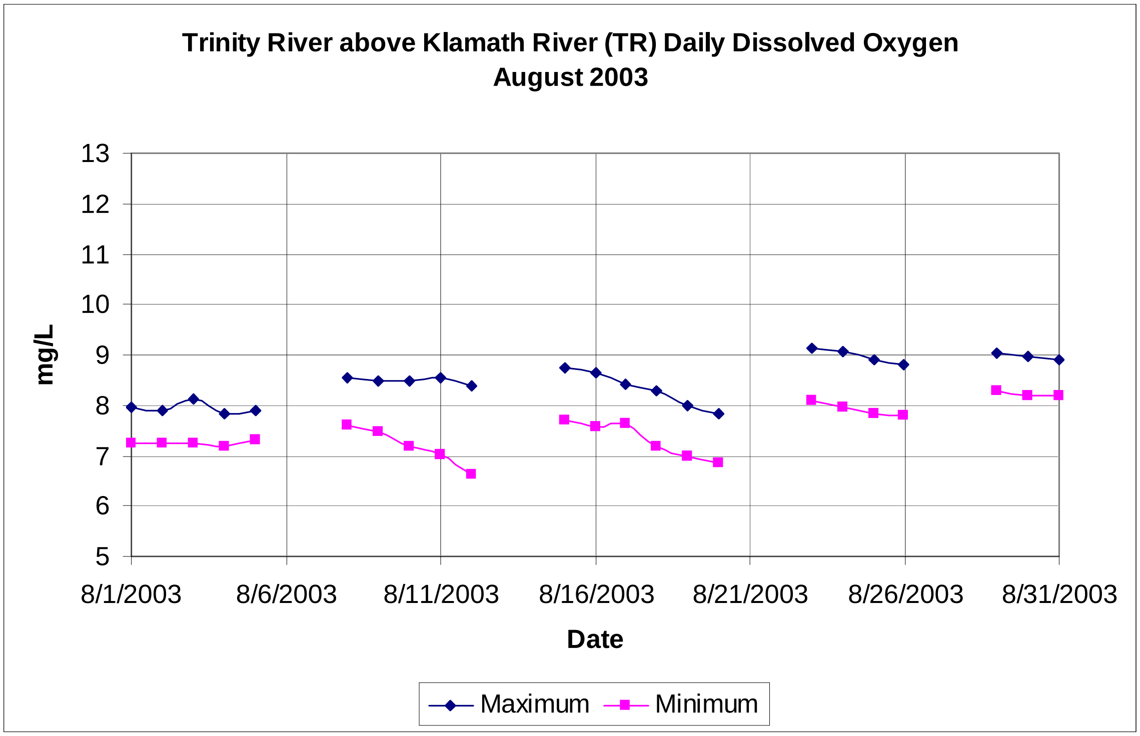


Figure 7-55 Dissolved Oxygen Values for the Trinity River Above Klamath River August 2003

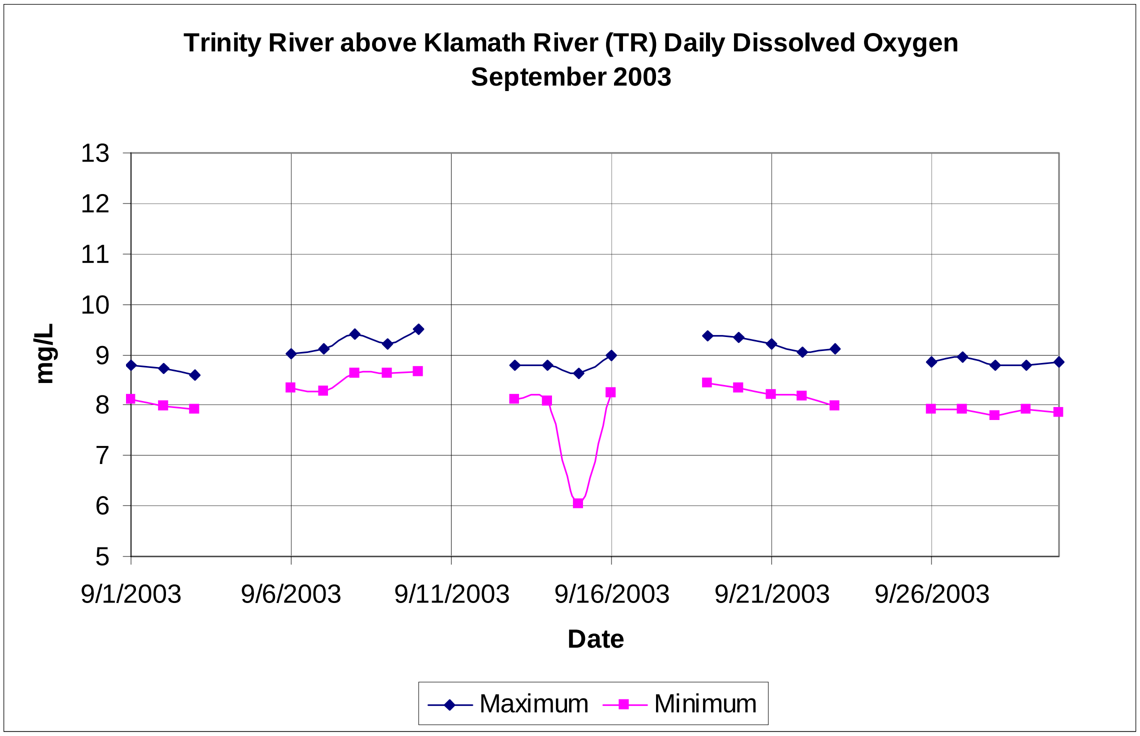


Figure 7-56 Dissolved Oxygen Values for the Trinity River Above Klamath River September 2003

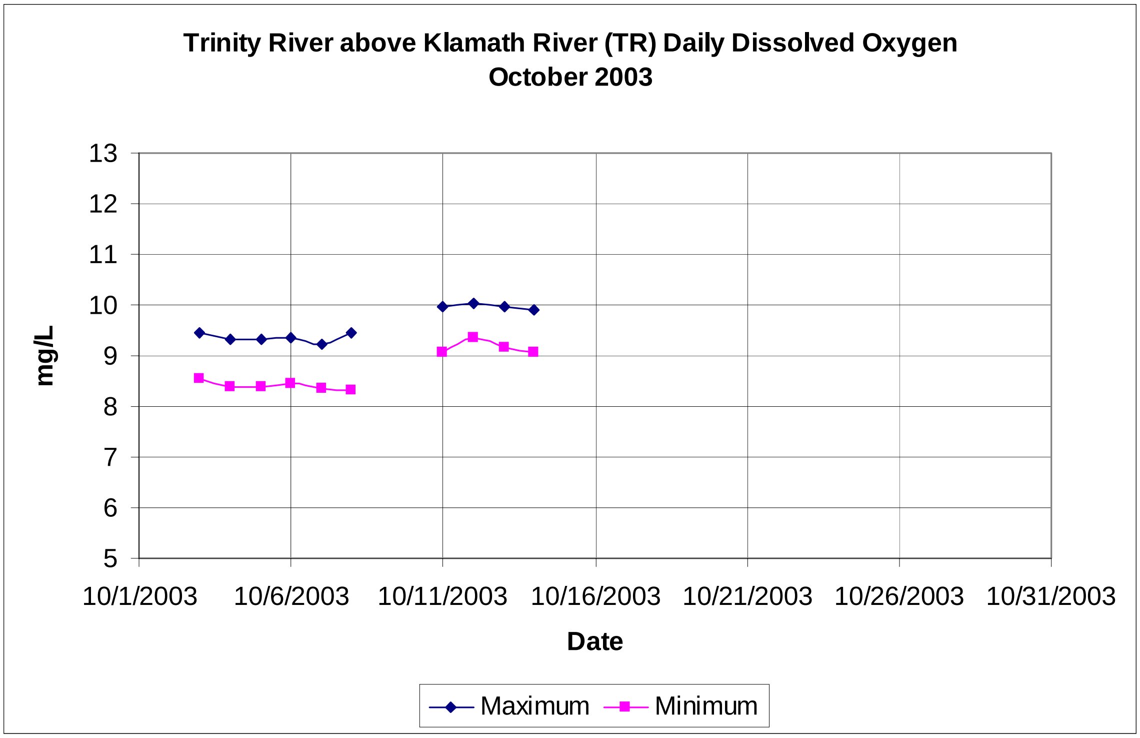


Figure 7-57 Dissolved Oxygen Values for the Trinity River Above Klamath River October 2003

7.1.3.3 pH

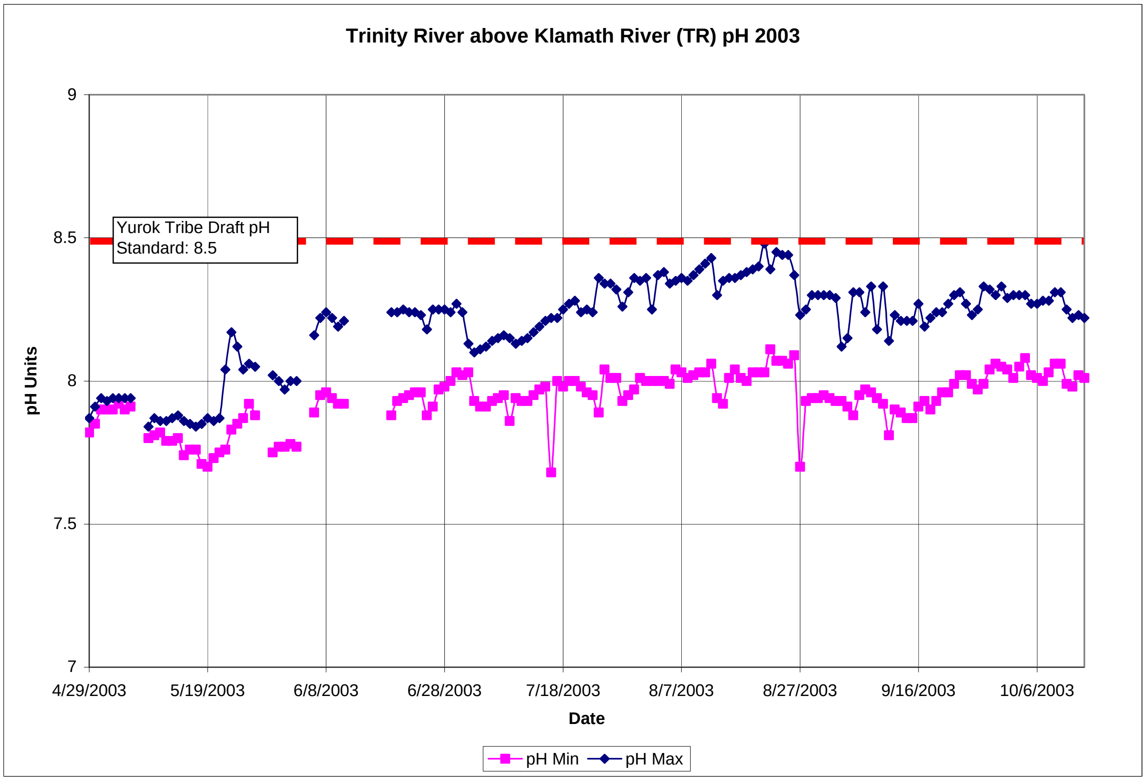


Figure 7-58 pH Values for the Trinity River Above Klamath River WY03

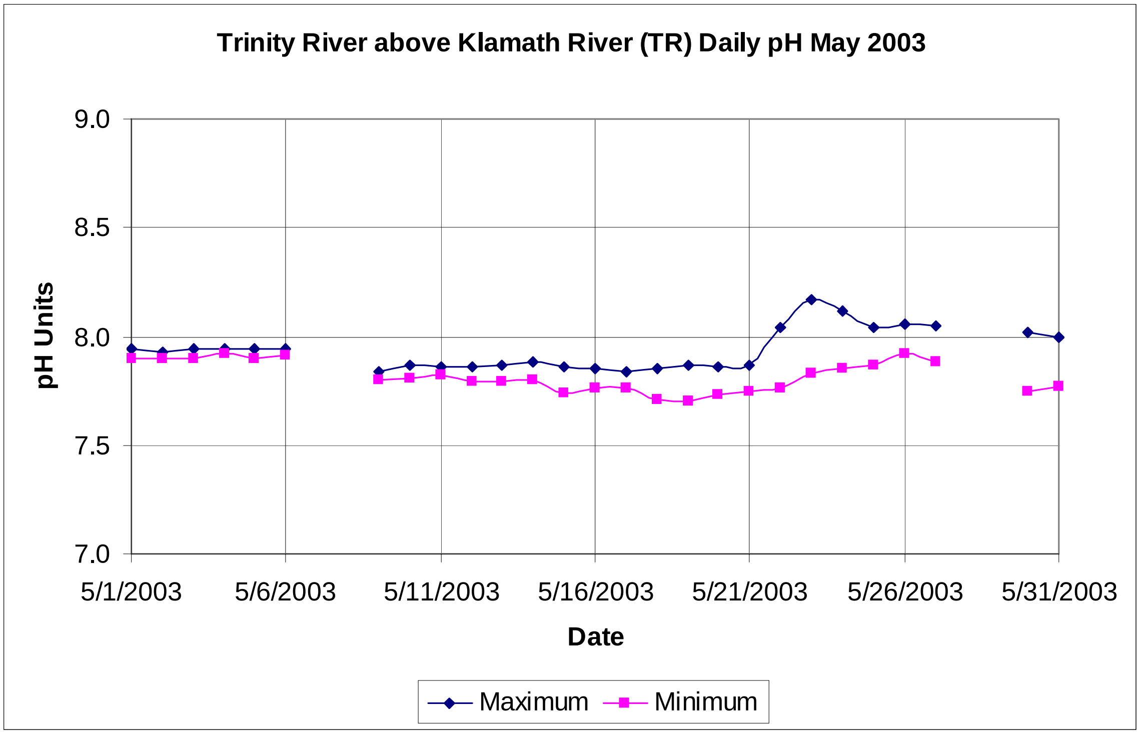


Figure 7-59 pH Values for the Trinity River Above Klamath River May 2003

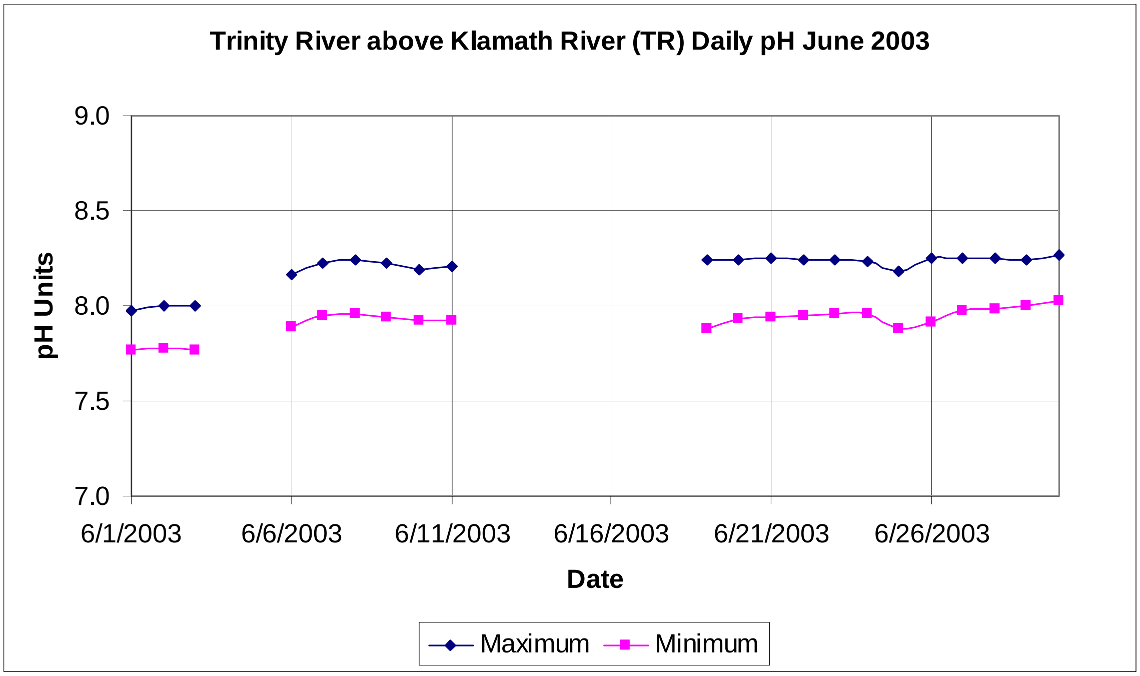


Figure 7-60 pH Values for the Trinity River Above Klamath River June 2003

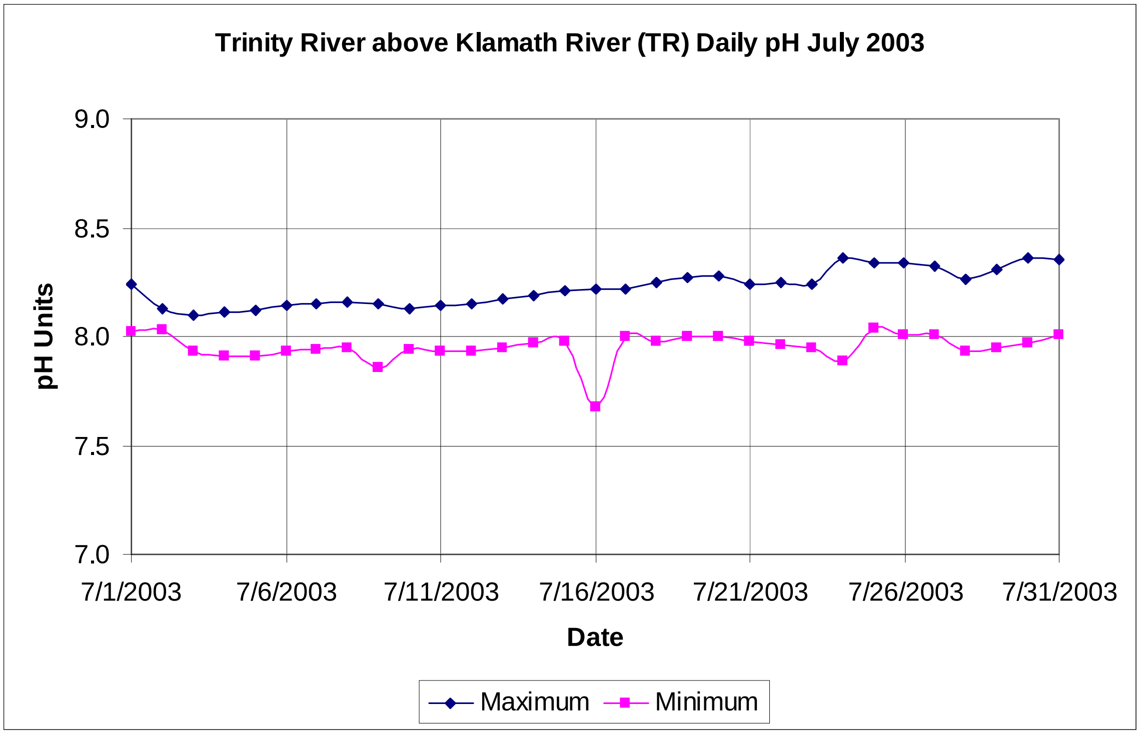


Figure 7-61 pH Values for the Trinity River Above Klamath River July 2003

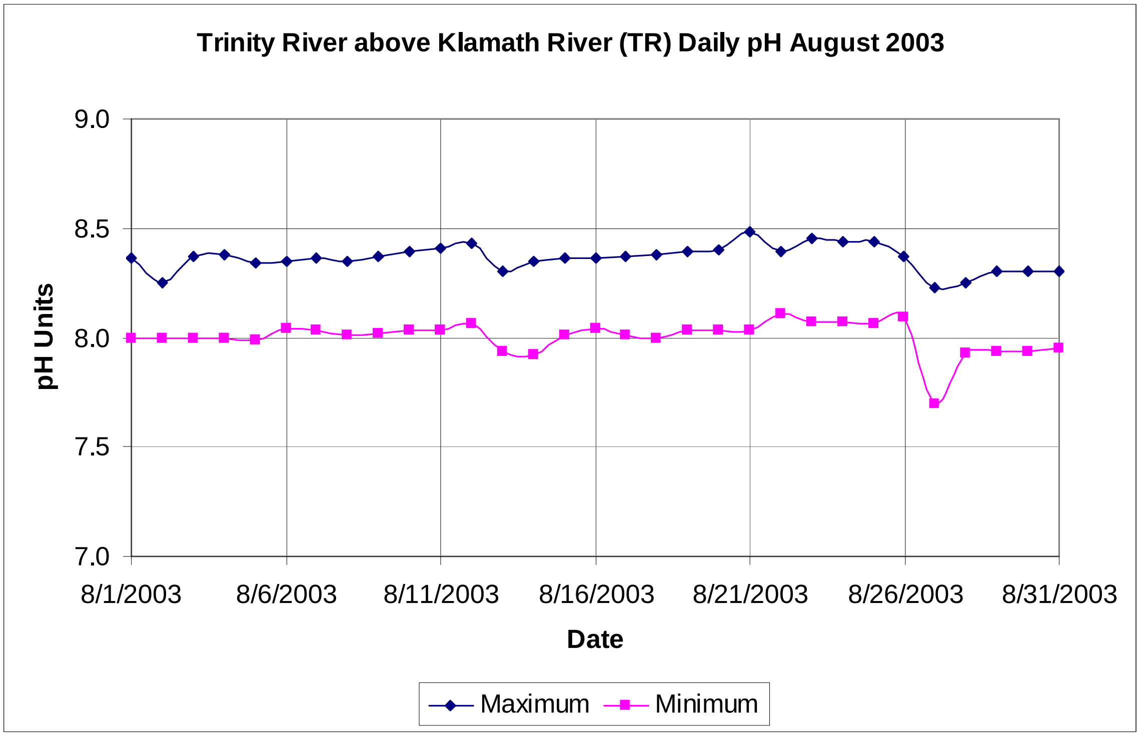


Figure 7-62 pH Values for the Trinity River Above Klamath River August 2003

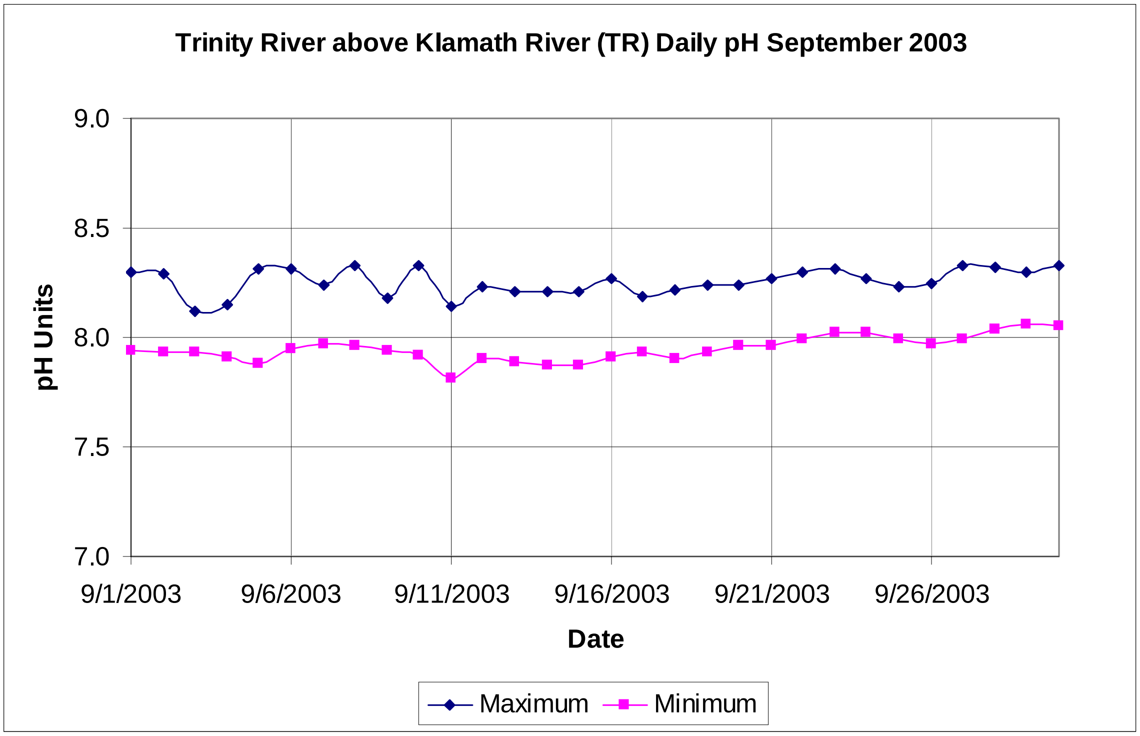


Figure 7-63 pH Values for the Trinity River Above Klamath River September 2003

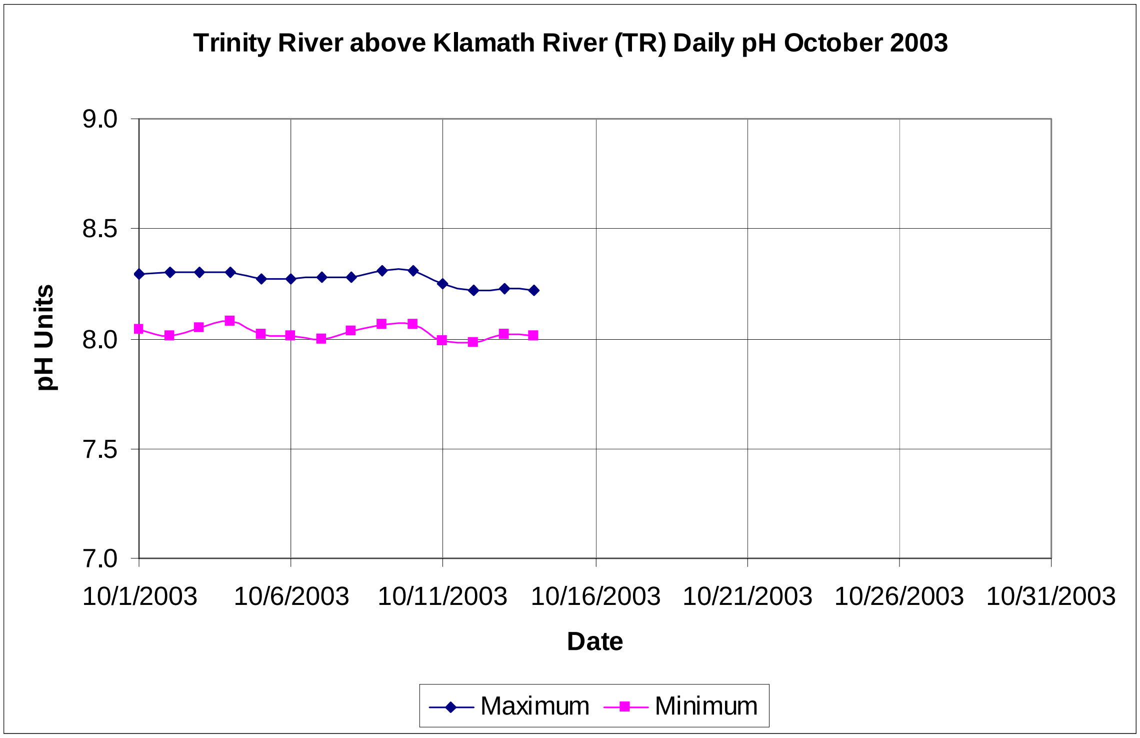


Figure 7-64 pH Values for the Trinity River Above Klamath River October 2003

7.1.4 *Klamath River at Martin's Ferry*

7.1.4.1 Temperature

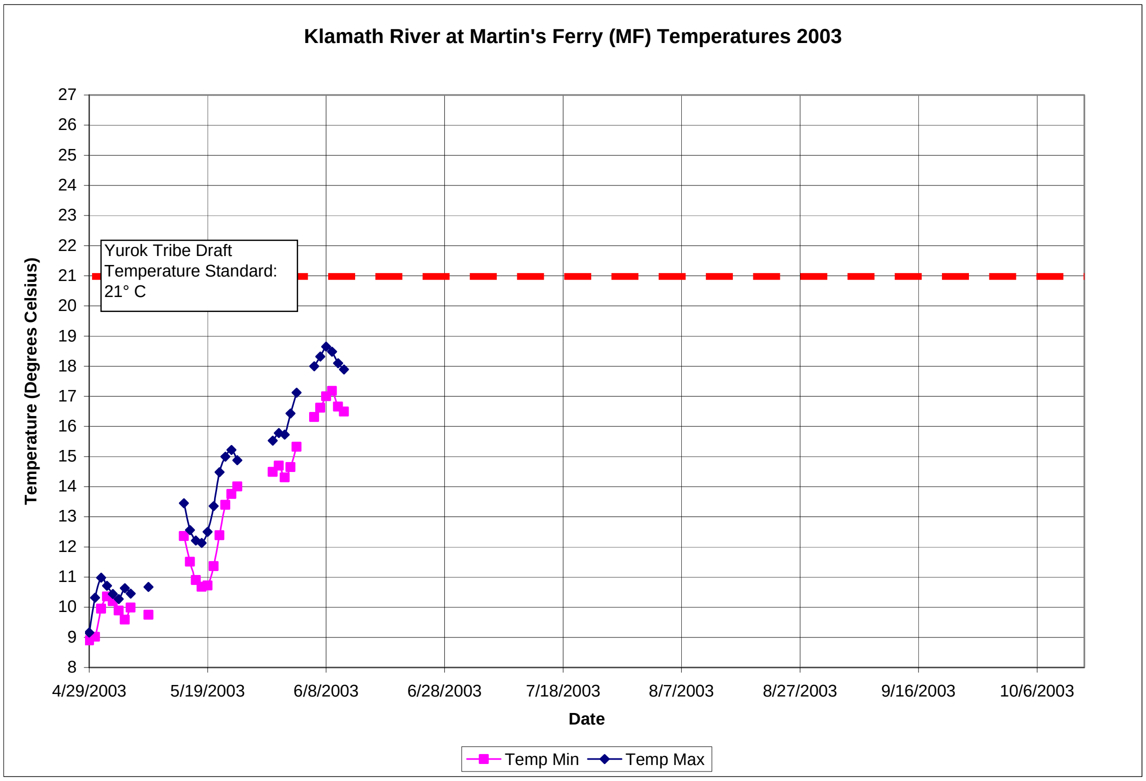


Figure 7-65 Daily Water Temperature values for the Klamath River at Martin's Ferry WY03

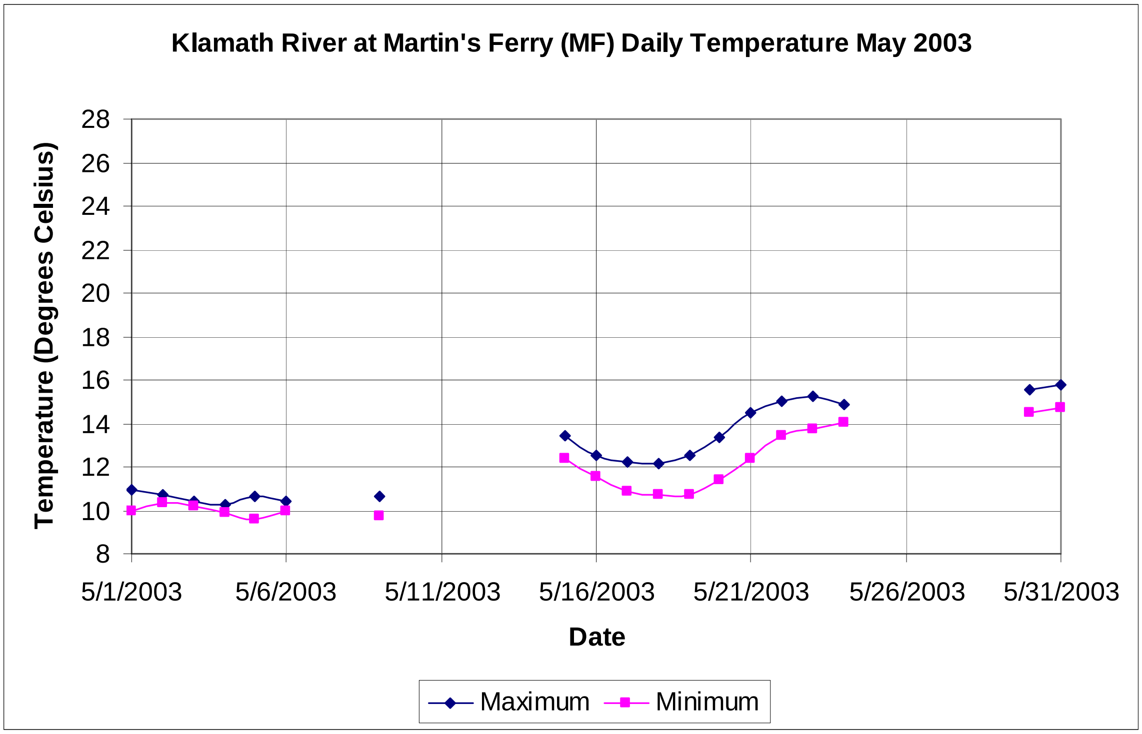


Figure 7-66 Daily Water Temperature values for the Klamath River at Martin's Ferry May 2003

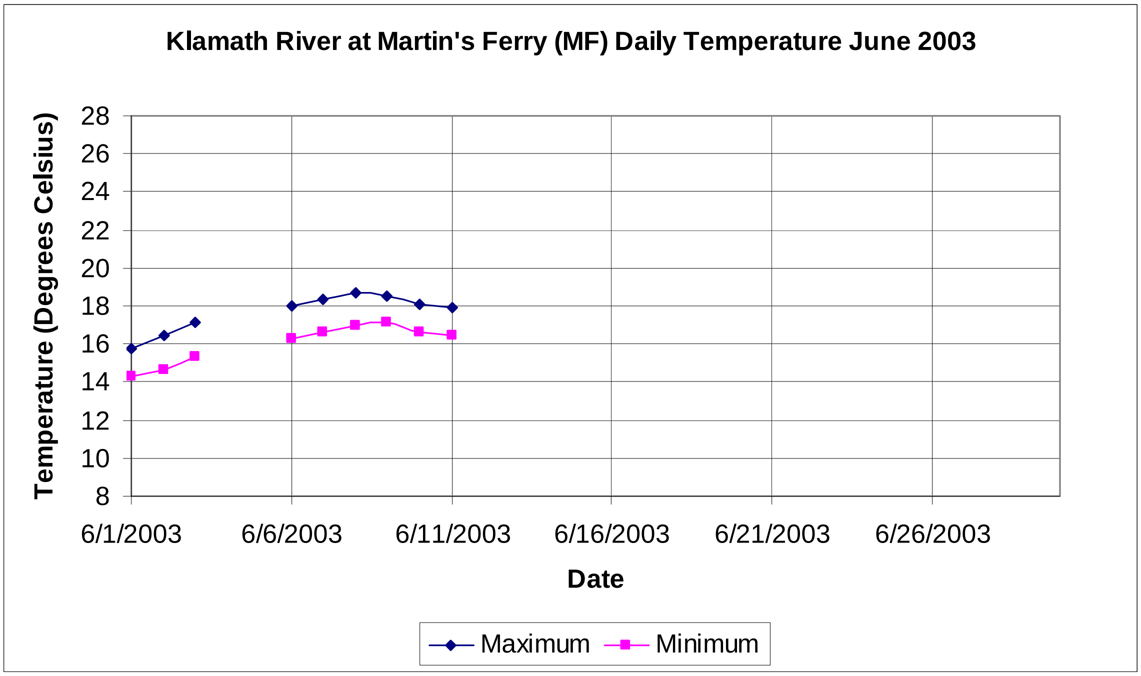


Figure 7-67 Daily Water Temperature values for the Klamath River at Martin's Ferry June 2003

7.1.4.2 Dissolved Oxygen

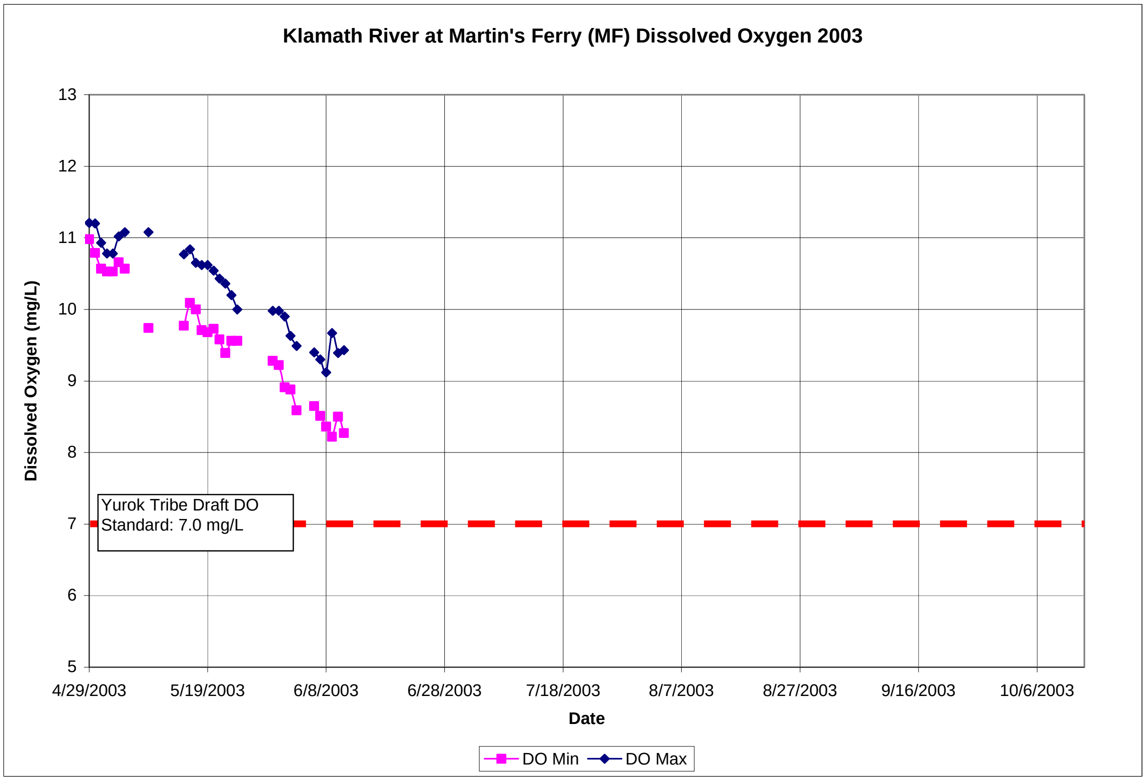


Figure 7-68 Daily Dissolved Oxygen values for the Klamath River at Martin's Ferry WY03

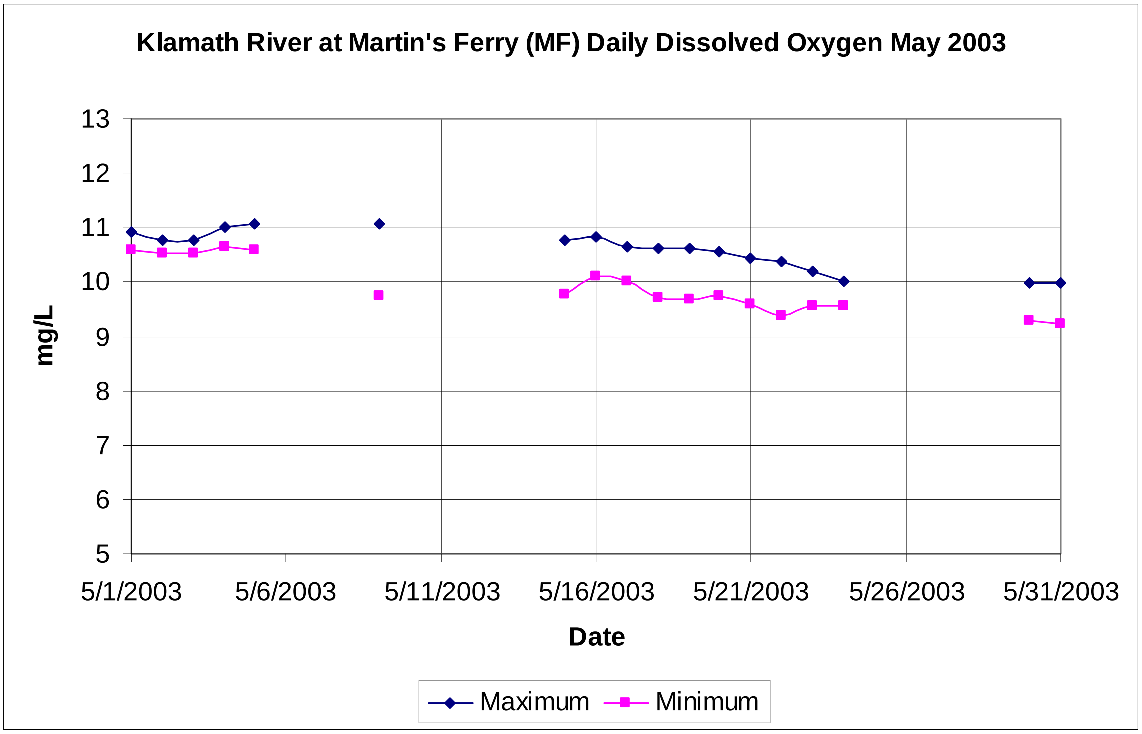


Figure 7-69 Daily Dissolved Oxygen values for the Klamath River at Martin's Ferry May 2003

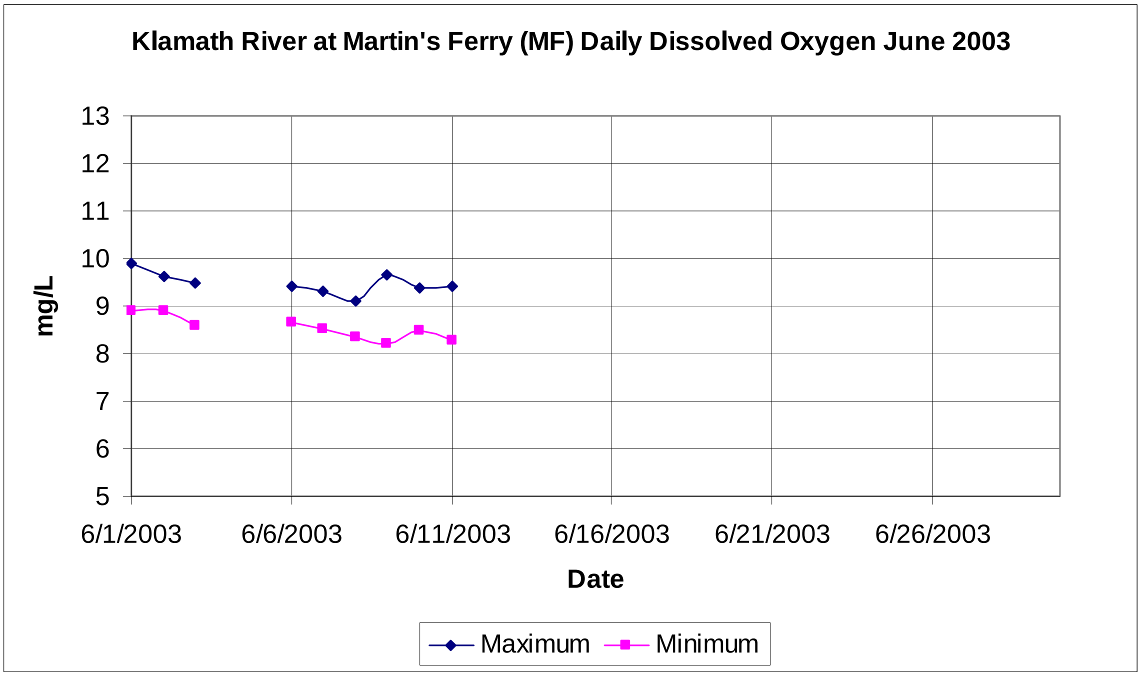


Figure 7-70 Daily Dissolved Oxygen values for the Klamath River at Martin's Ferry June 2003

7.1.4.3 pH

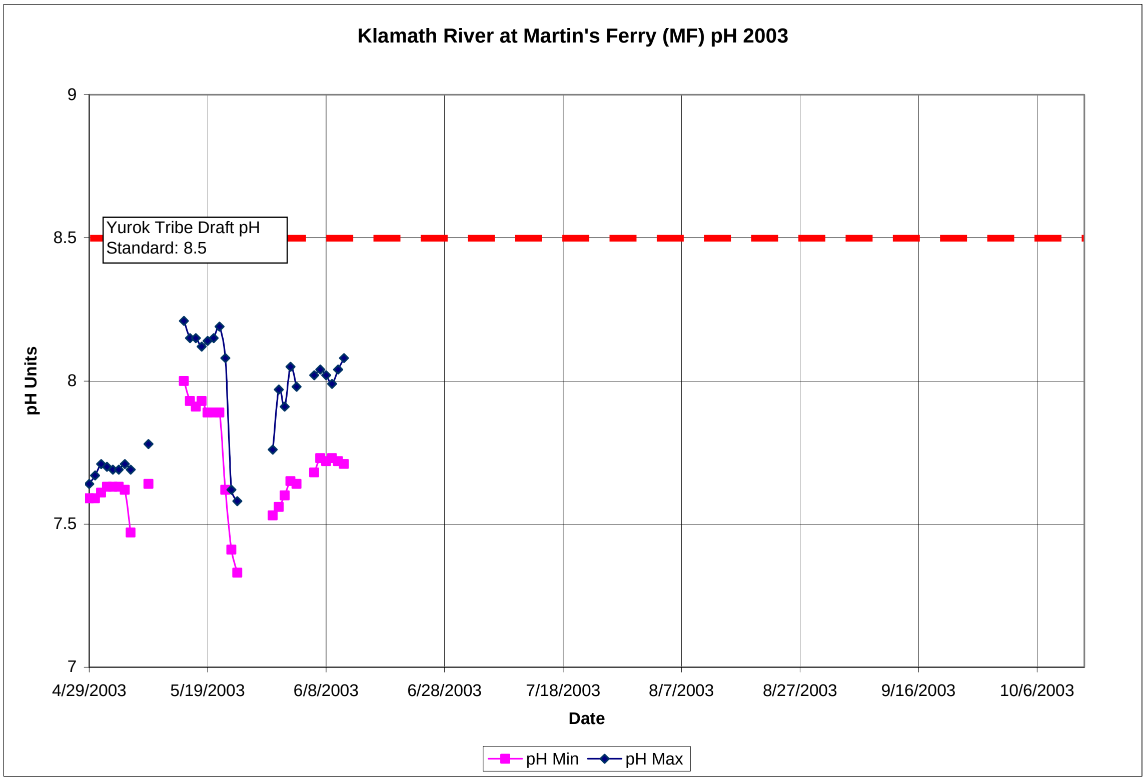


Figure 7-71 Daily pH values for the Klamath River at Martin's Ferry WY03

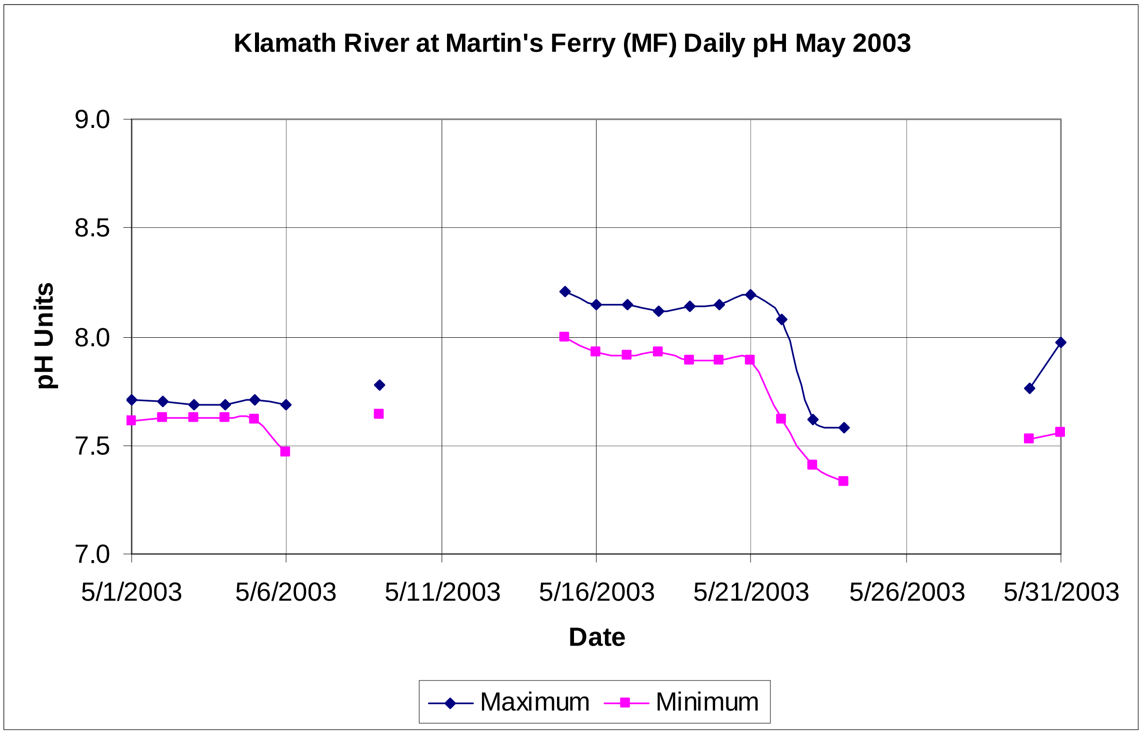


Figure 7-72 Daily pH values for the Klamath River at Martin's Ferry May 2003

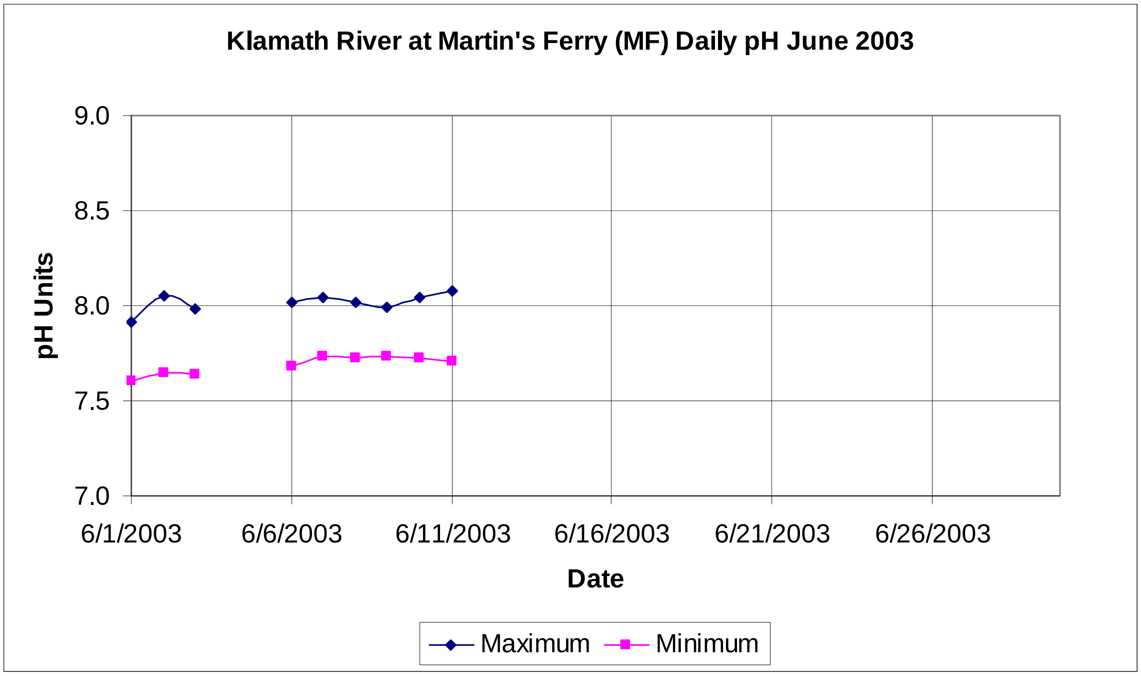


Figure 7-73 Daily pH values for the Klamath River at Martin's Ferry June 2003

7.1.5 Klamath River Above Tully Creek

7.1.5.1 Temperature

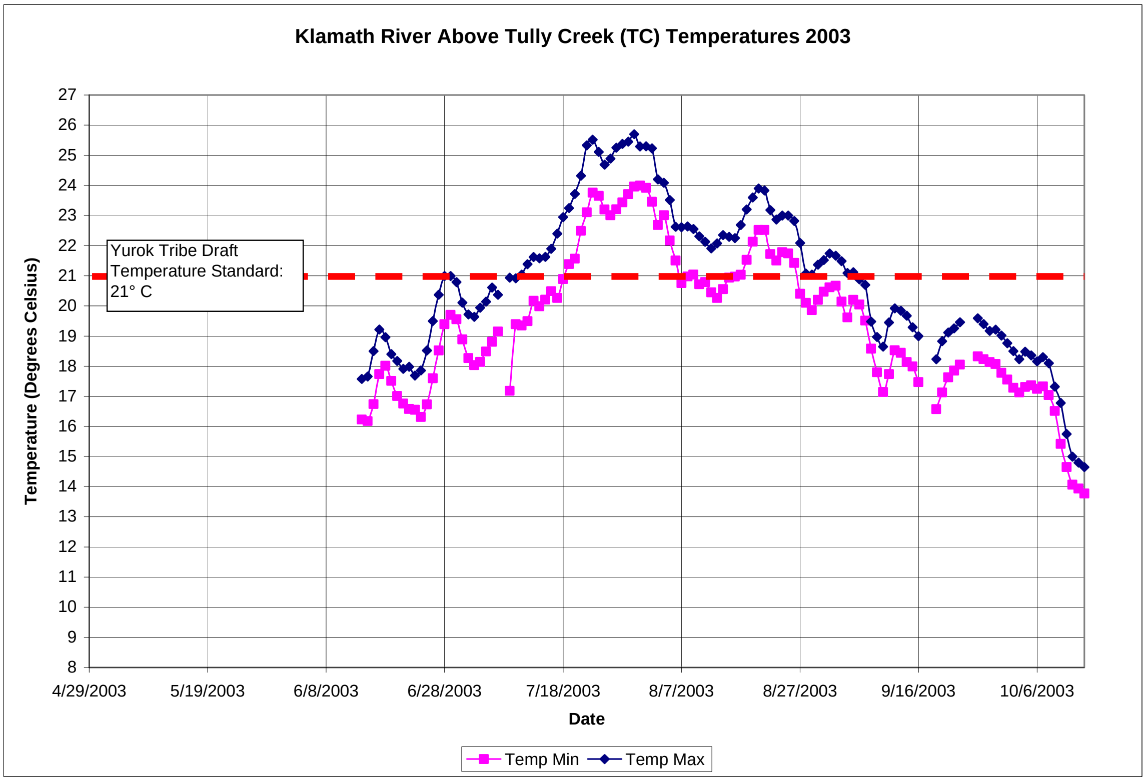


Figure 7-74 Water Temperature Values for the Klamath River above Tully Creek WY03

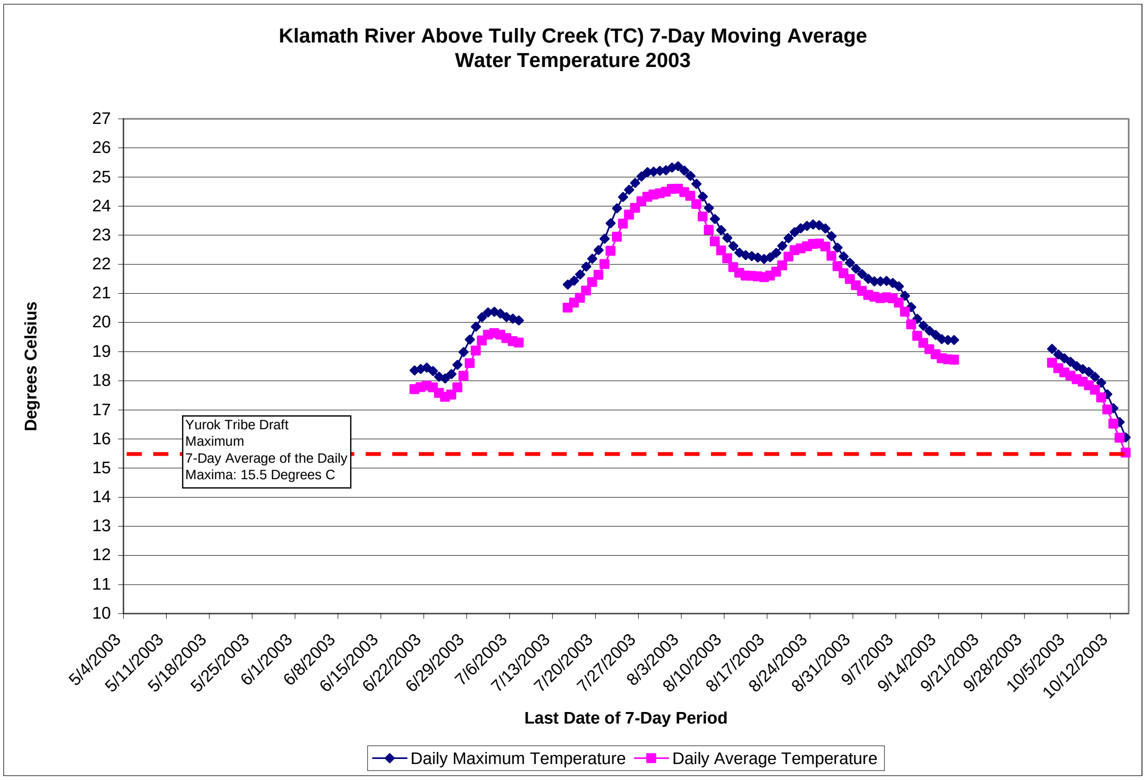


Figure 7-75 7-Day Moving Average Water Temperature for the Klamath River above Tully Creek WY03

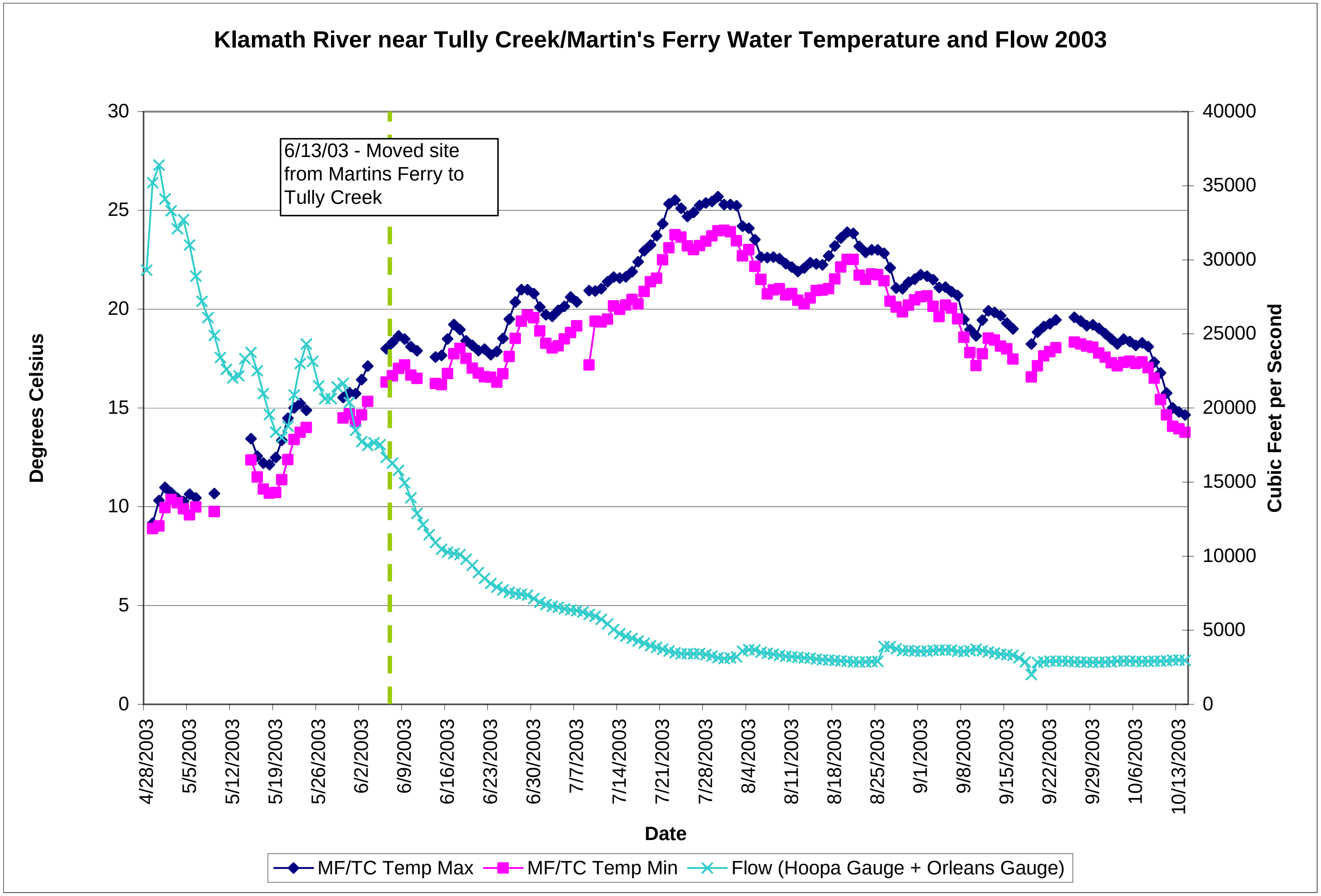


Figure 7-76 Water Temperature and Flow Values for the Klamath River near Tully Creek/Martin's Ferry WY03

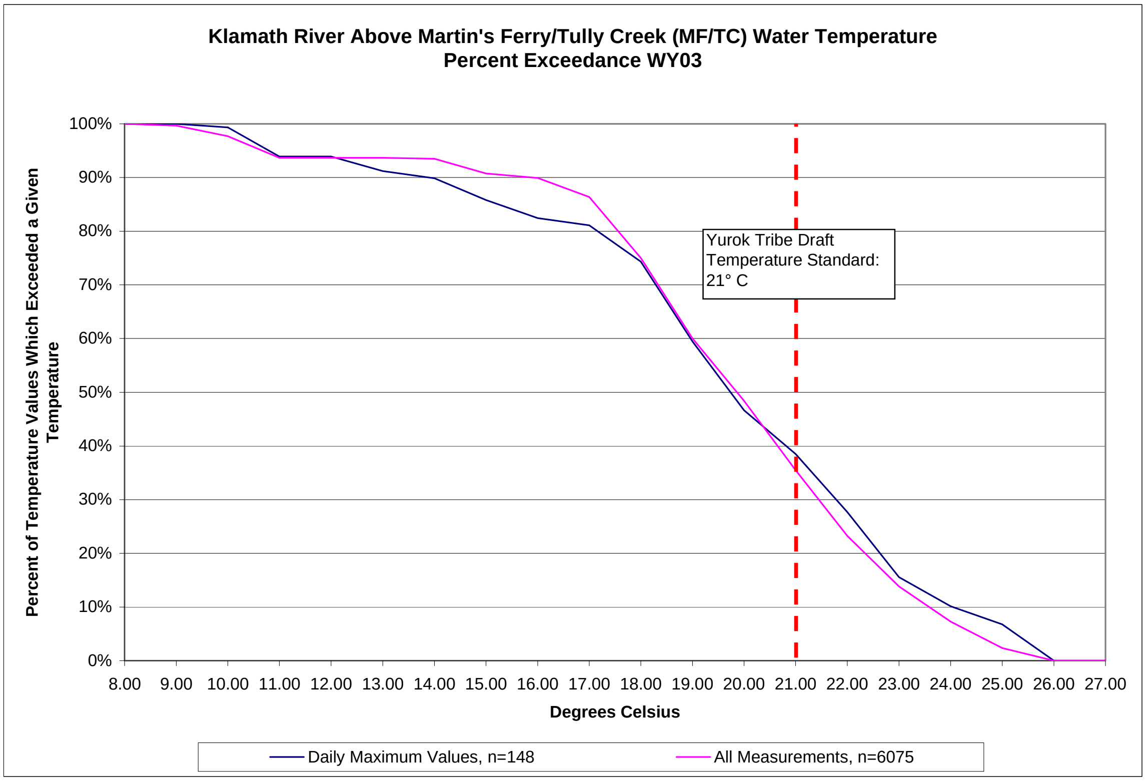


Figure 7-77 Percent Exceedance of Daily Maximum and Half-Hourly Water Temperatures for Klamath River Above Martin’s Ferry and Tully Creek WY03

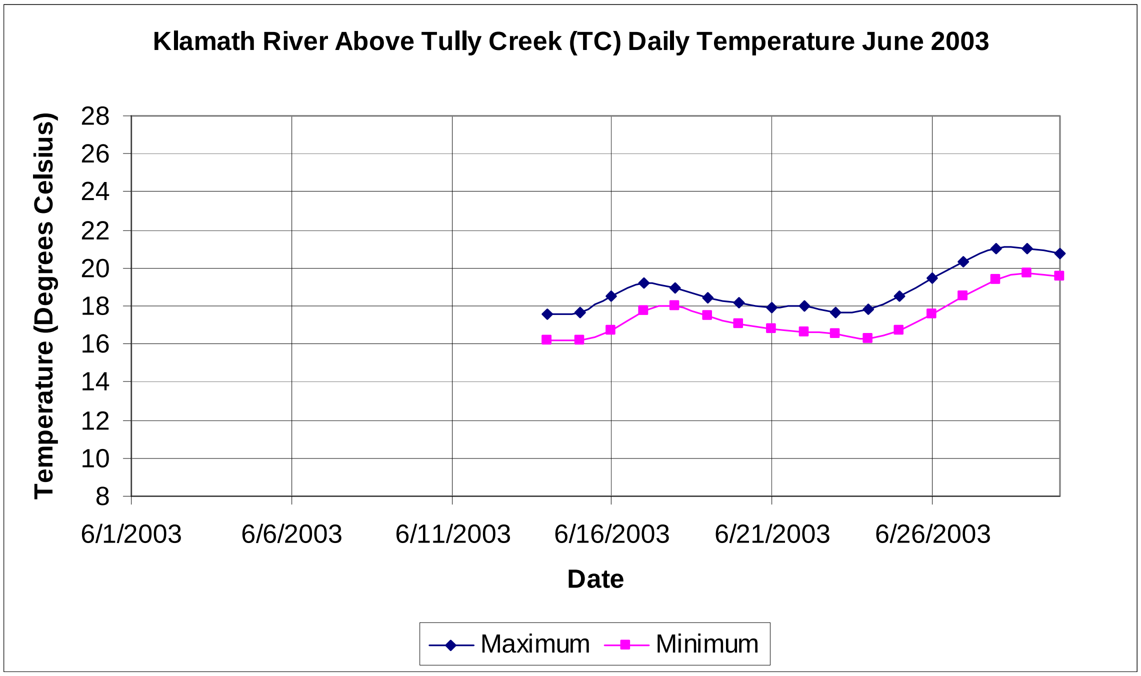


Figure 7-78 Water Temperature Values for the Klamath River above Tully Creek June 2003

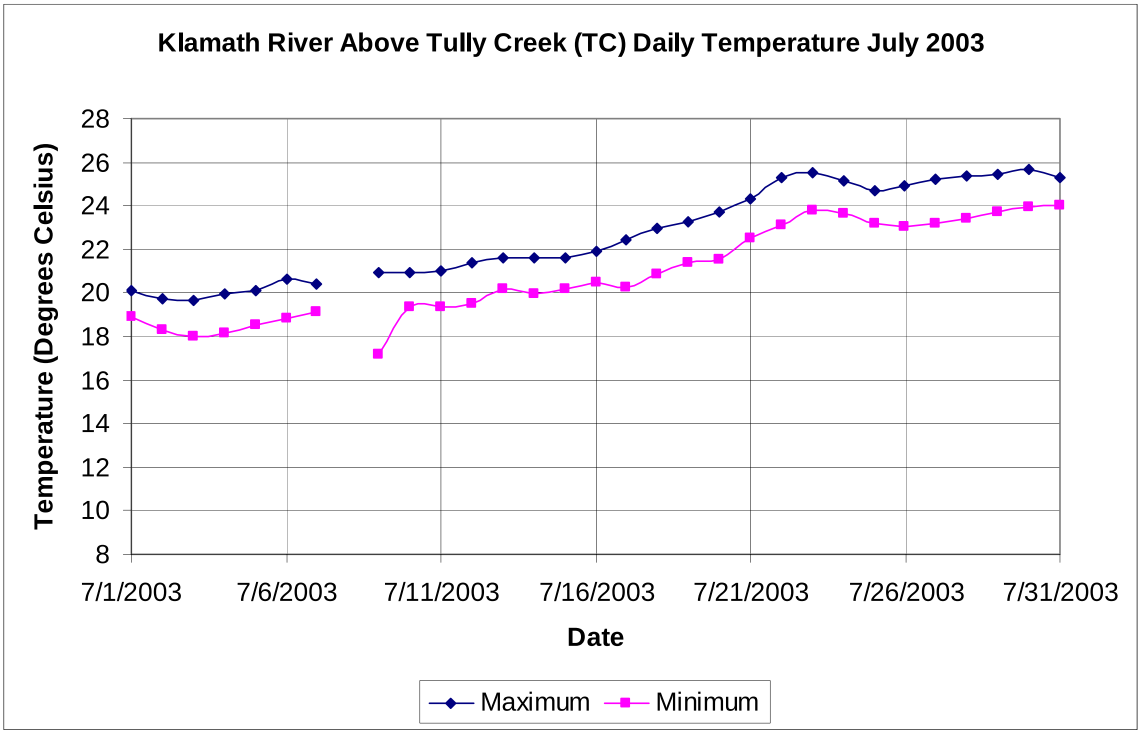


Figure 7-79 Water Temperature Values for the Klamath River above Tully Creek July 2003

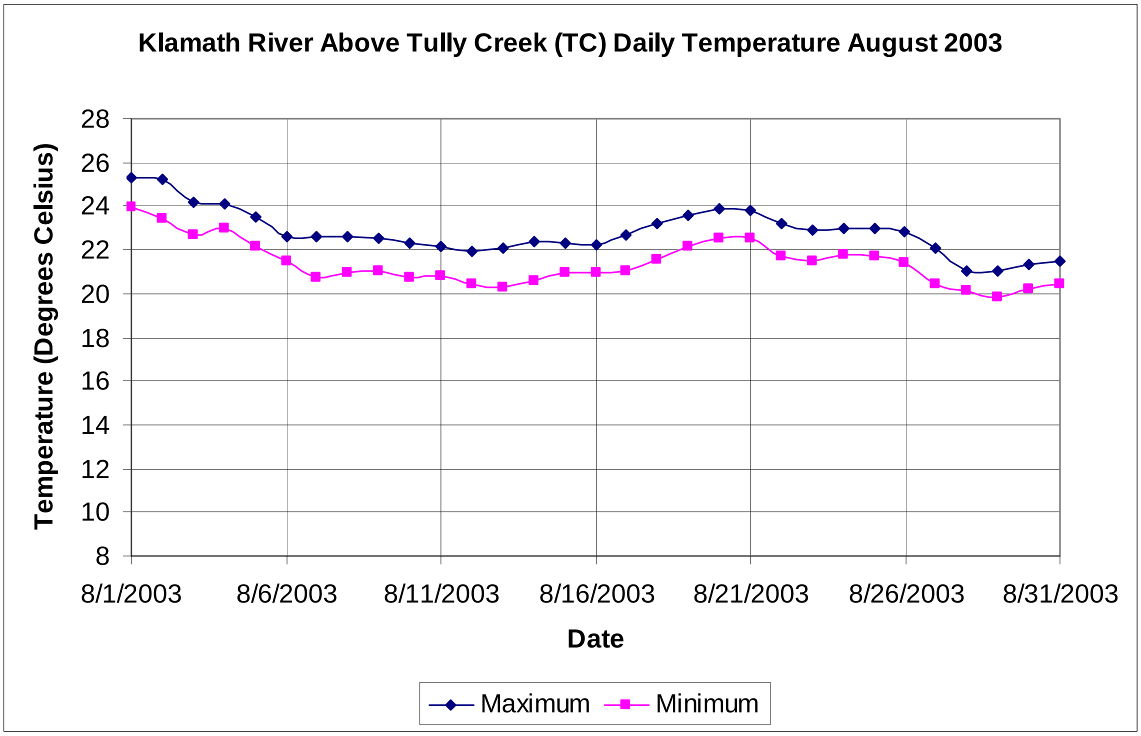


Figure 7-80 Water Temperature Values for the Klamath River above Tully Creek August 2003

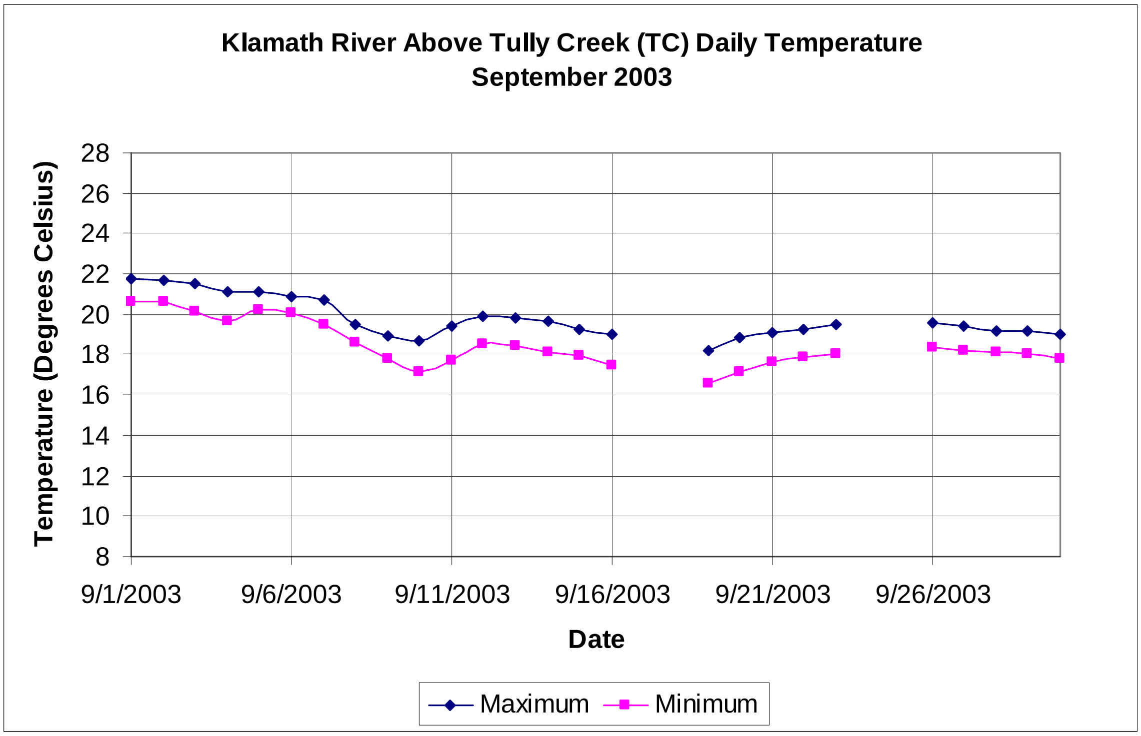


Figure 7-81 Water Temperature Values for the Klamath River above Tully Creek September 2003

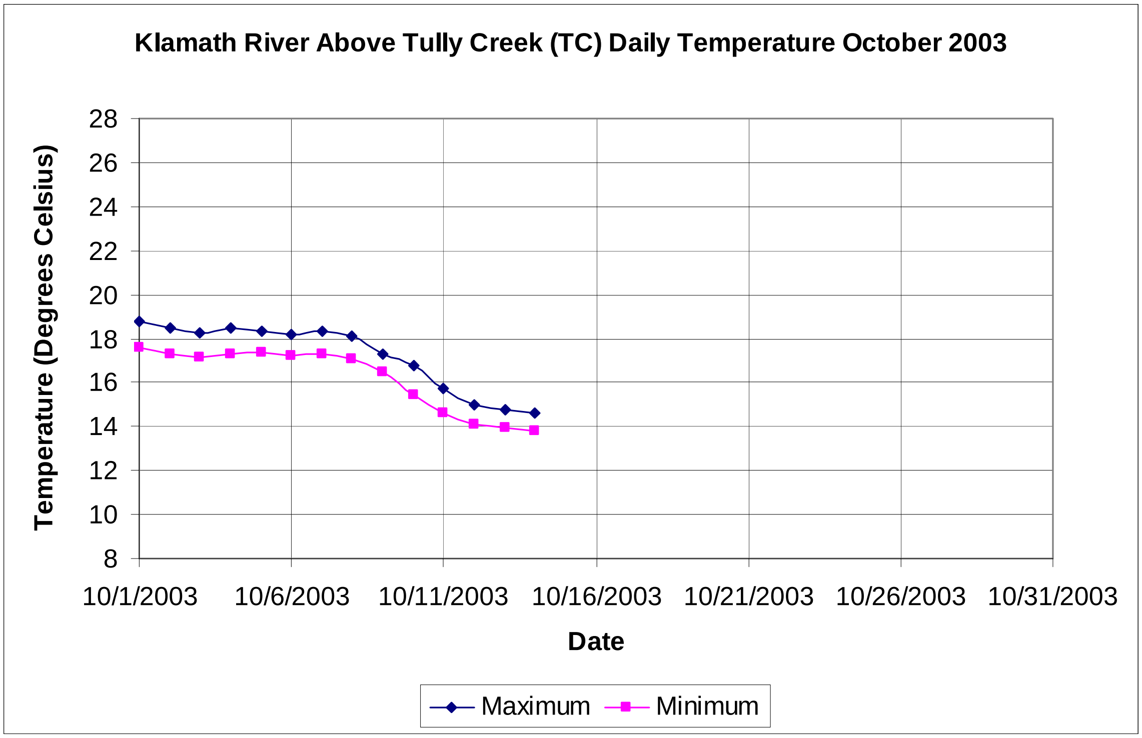


Figure 7-82 Water Temperature Values for the Klamath River above Tully Creek October 2003

7.1.5.2 Dissolved Oxygen

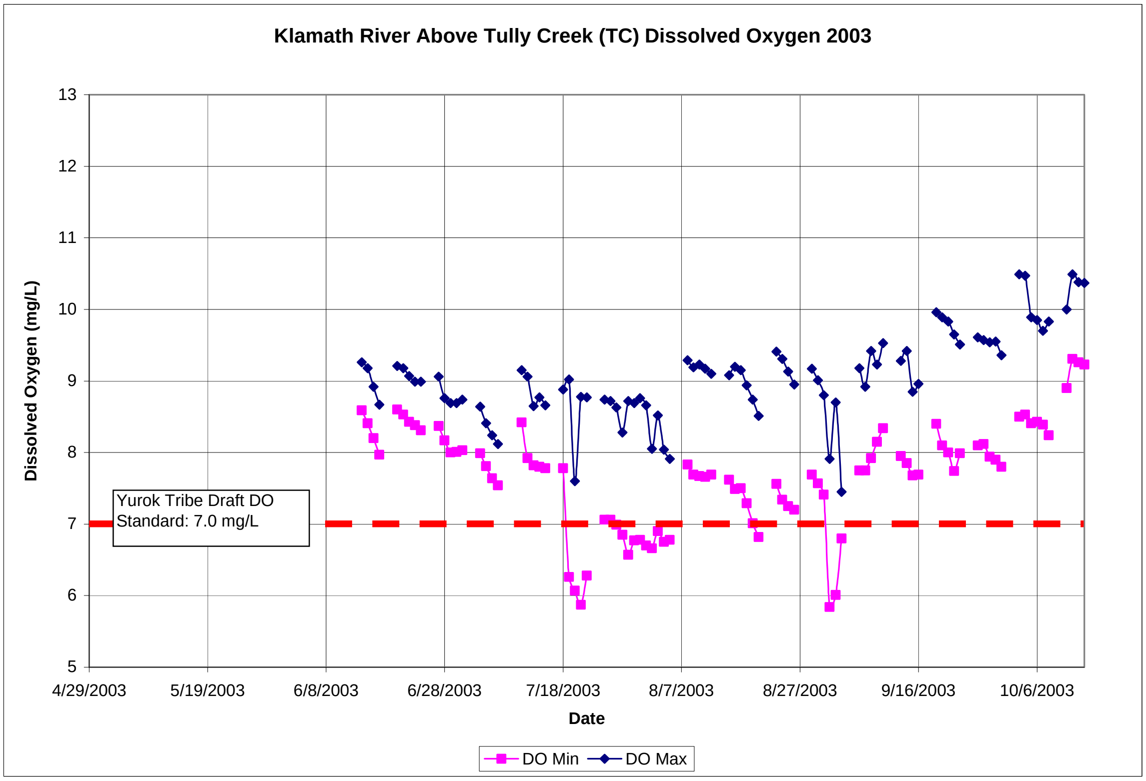


Figure 7-83 Dissolved Oxygen Values for the Klamath River above Tully Creek WY03

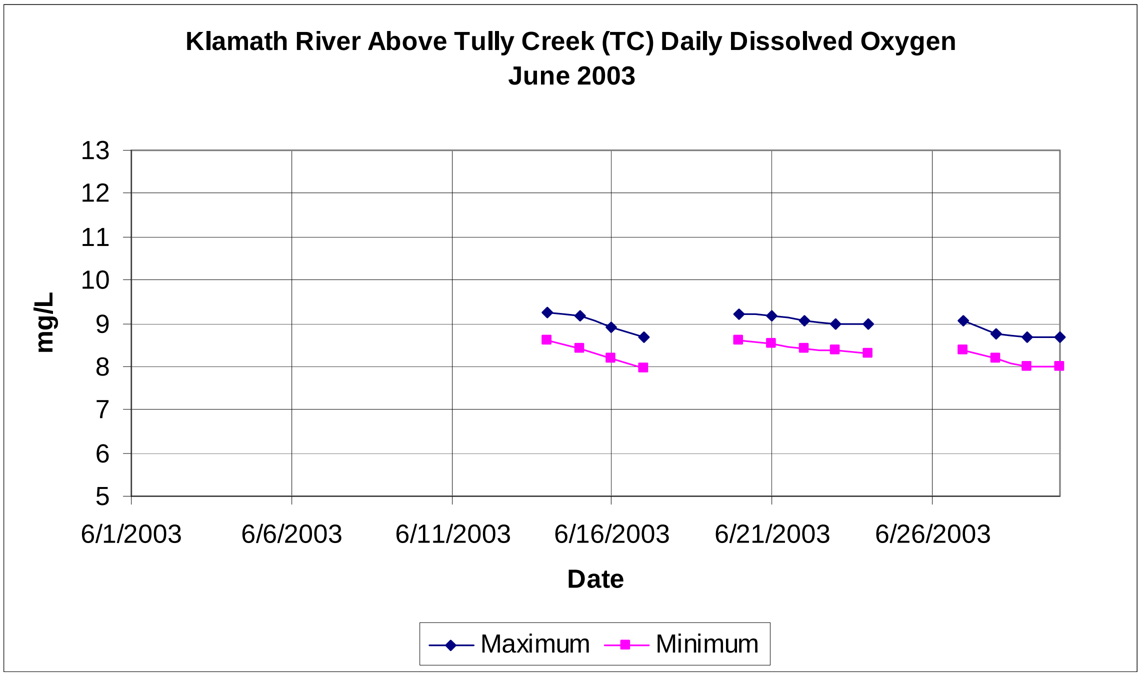


Figure 7-84 Dissolved Oxygen Values for the Klamath River above Tully Creek June 2003

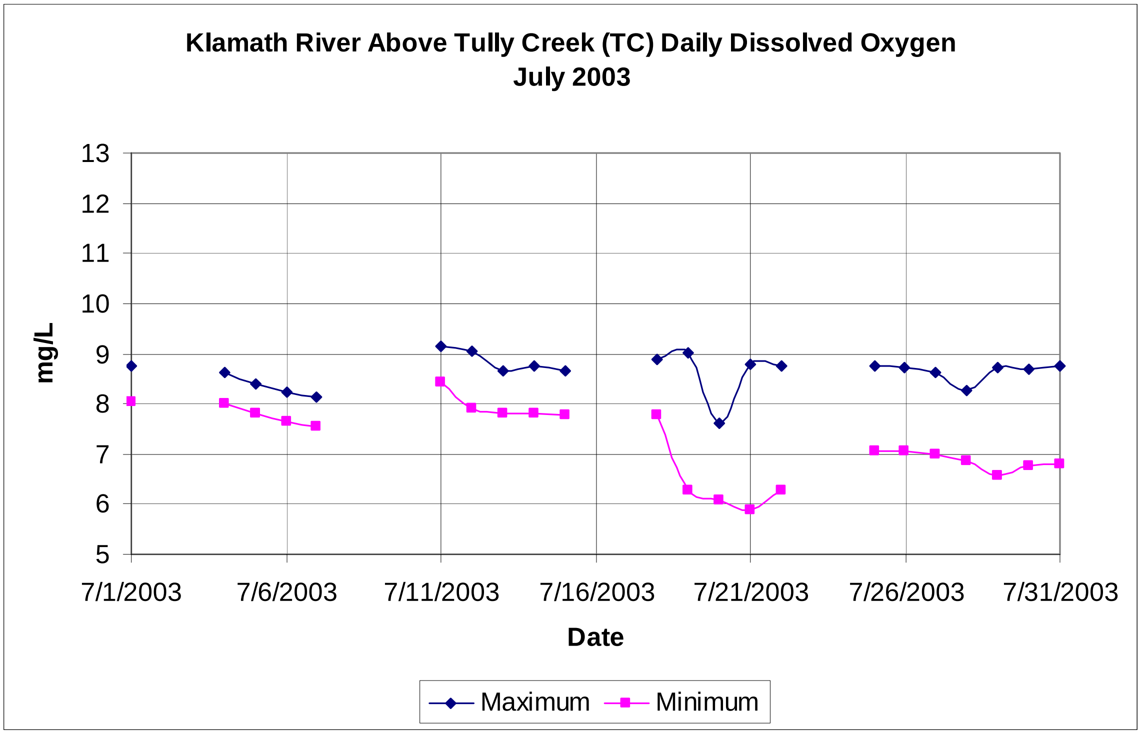


Figure 7-85 Dissolved Oxygen Values for the Klamath River above Tully Creek July 2003

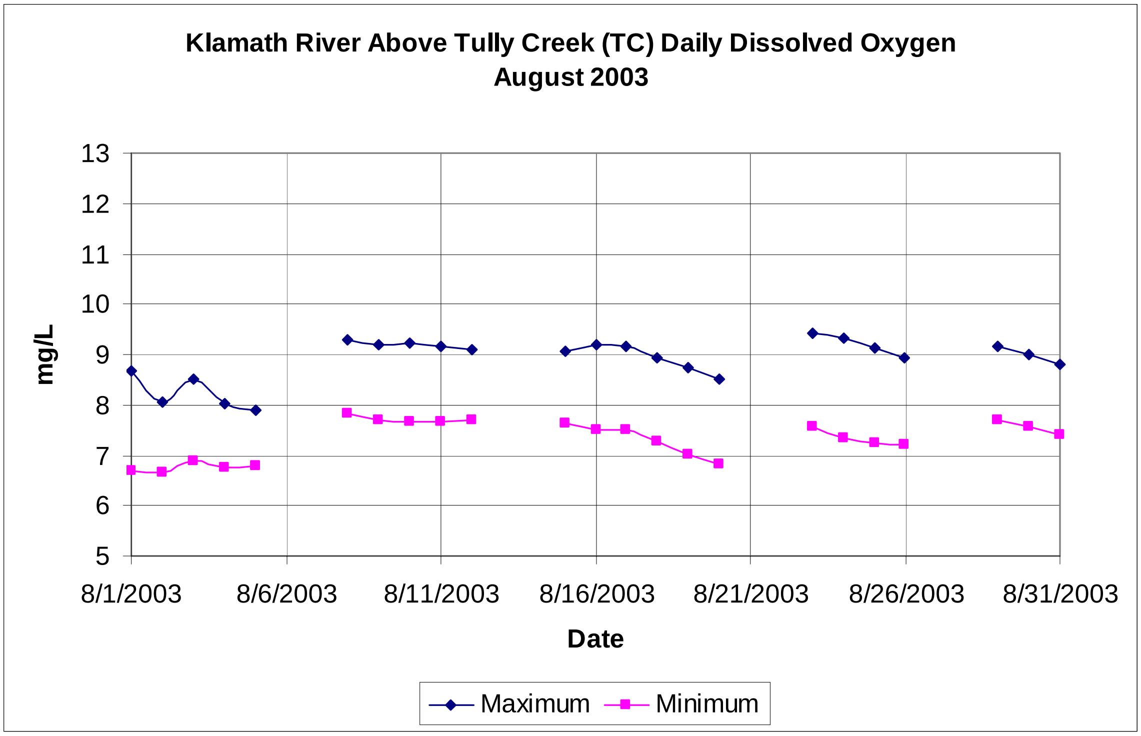


Figure 7-86 Dissolved Oxygen Values for the Klamath River above Tully Creek August 2003

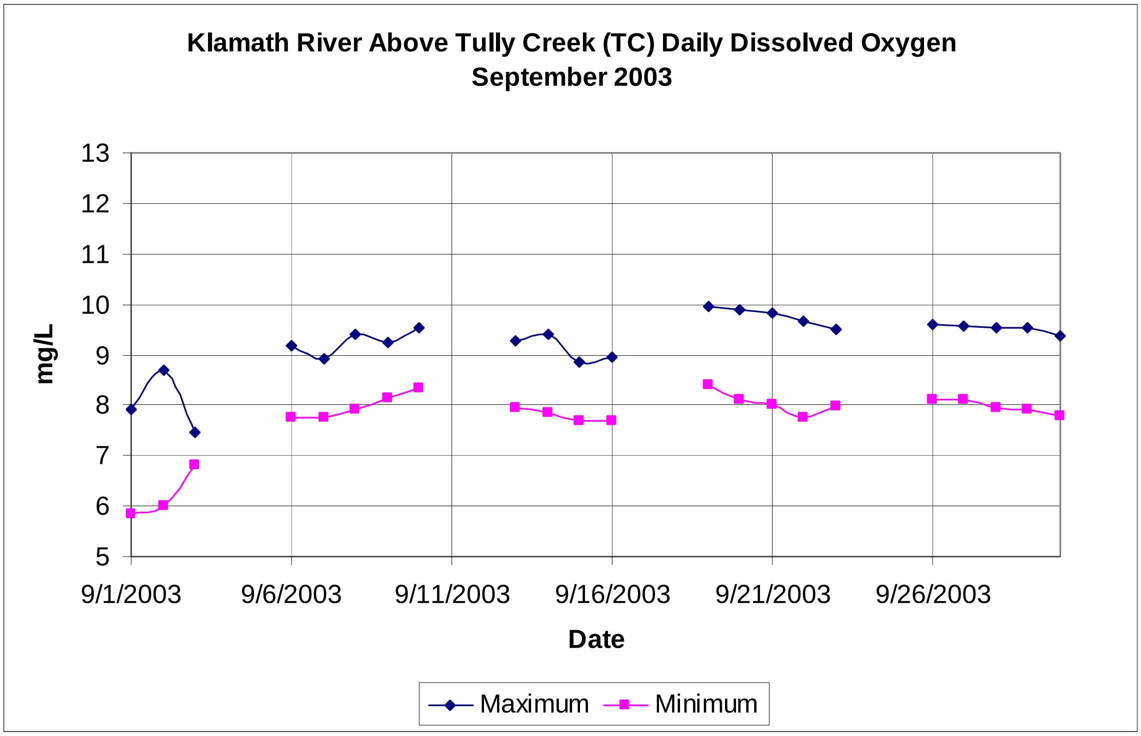


Figure 7-87 Dissolved Oxygen Values for the Klamath River above Tully Creek September 2003

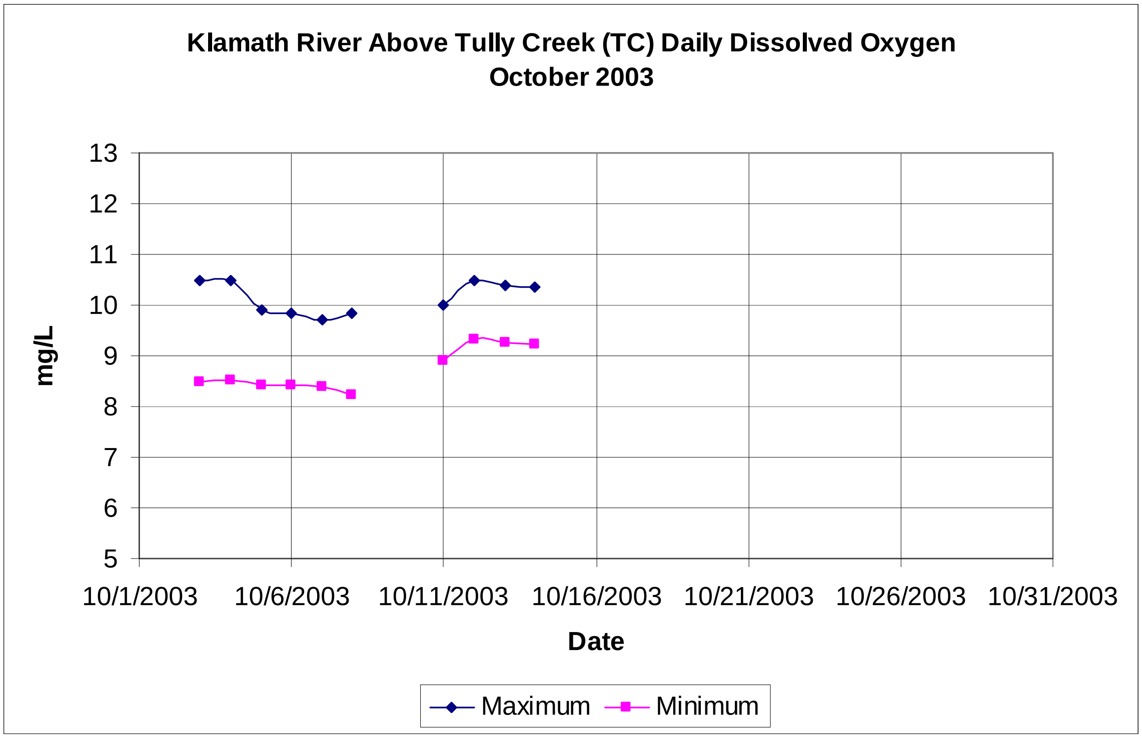


Figure 7-88 Dissolved Oxygen Values for the Klamath River above Tully Creek October 2003

7.1.5.3 pH

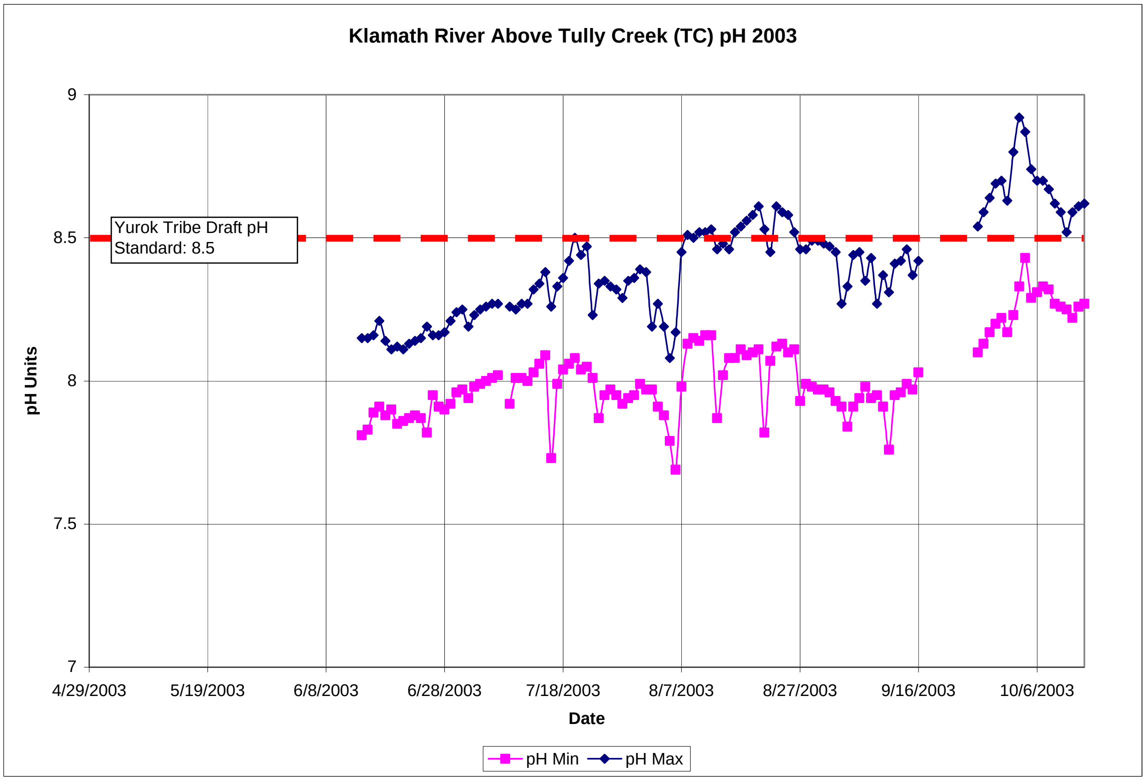


Figure 7-89 pH Values for the Klamath River above Tully Creek WY03

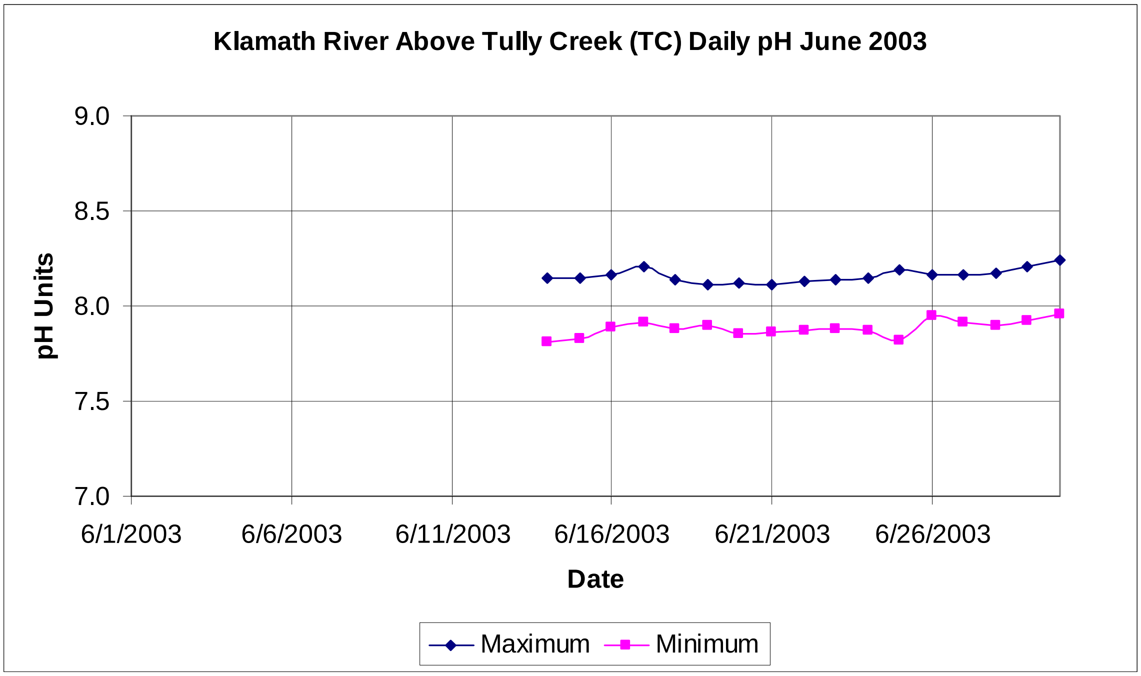


Figure 7-90 pH Values for the Klamath River above Tully Creek June 2003

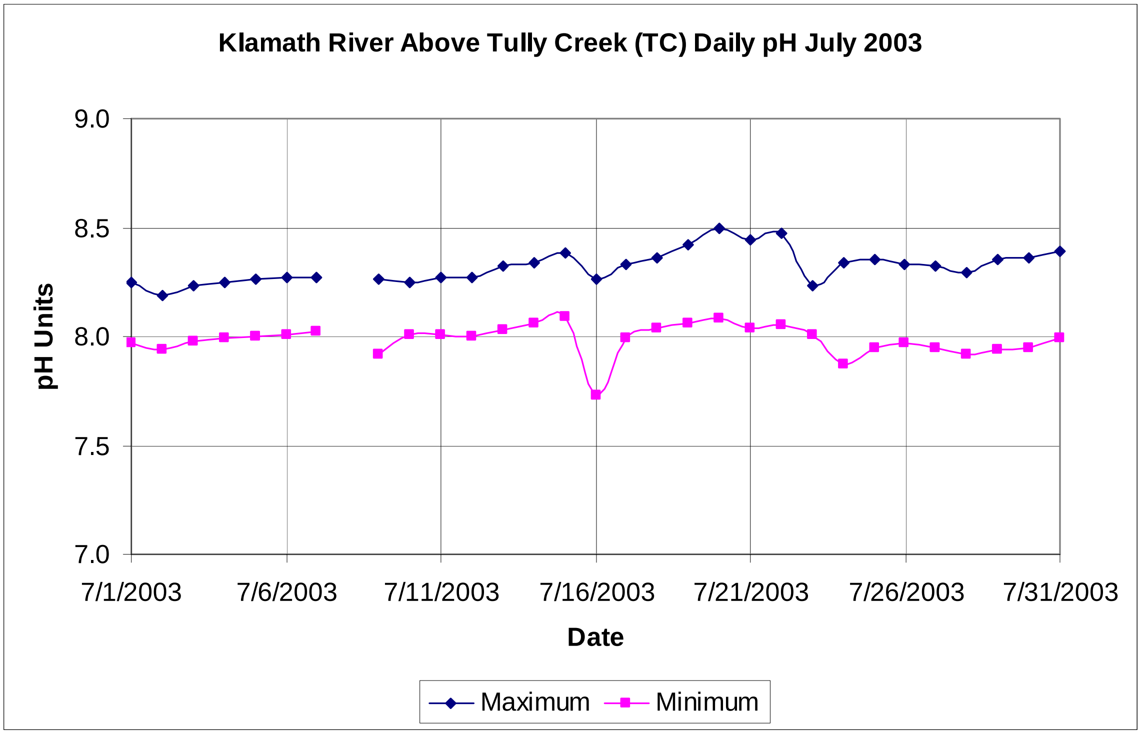


Figure 7-91 pH Values for the Klamath River above Tully Creek July 2003

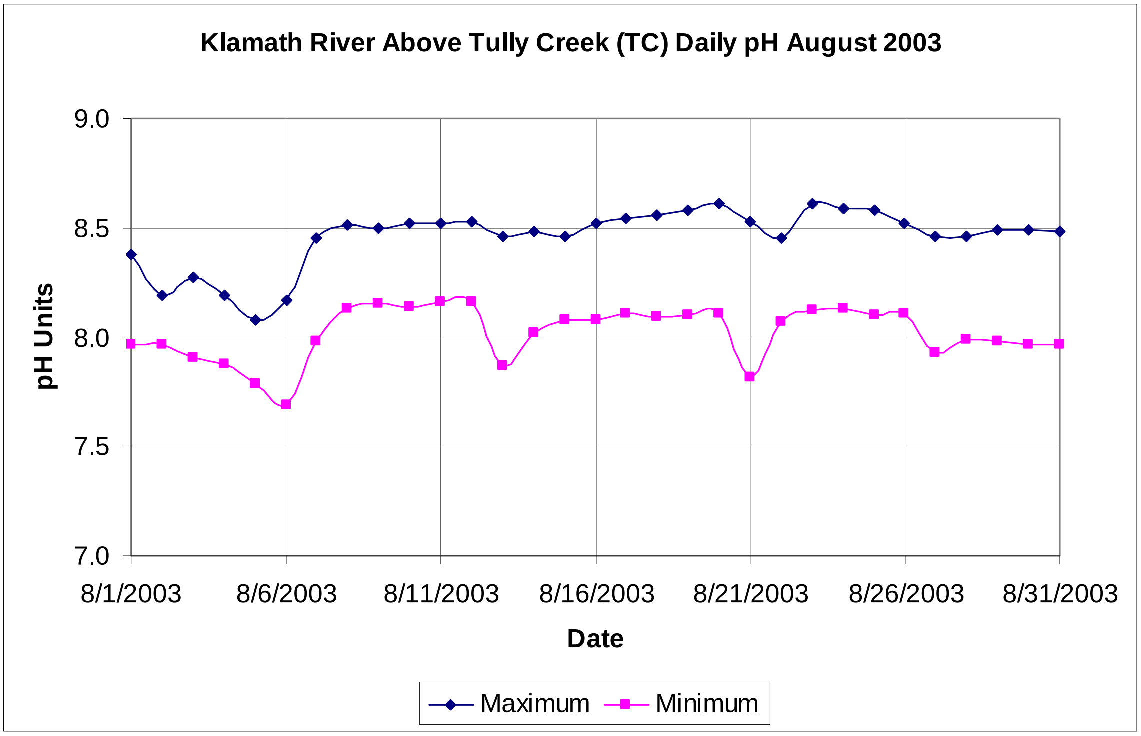


Figure 7-92 pH Values for the Klamath River above Tully Creek August 2003

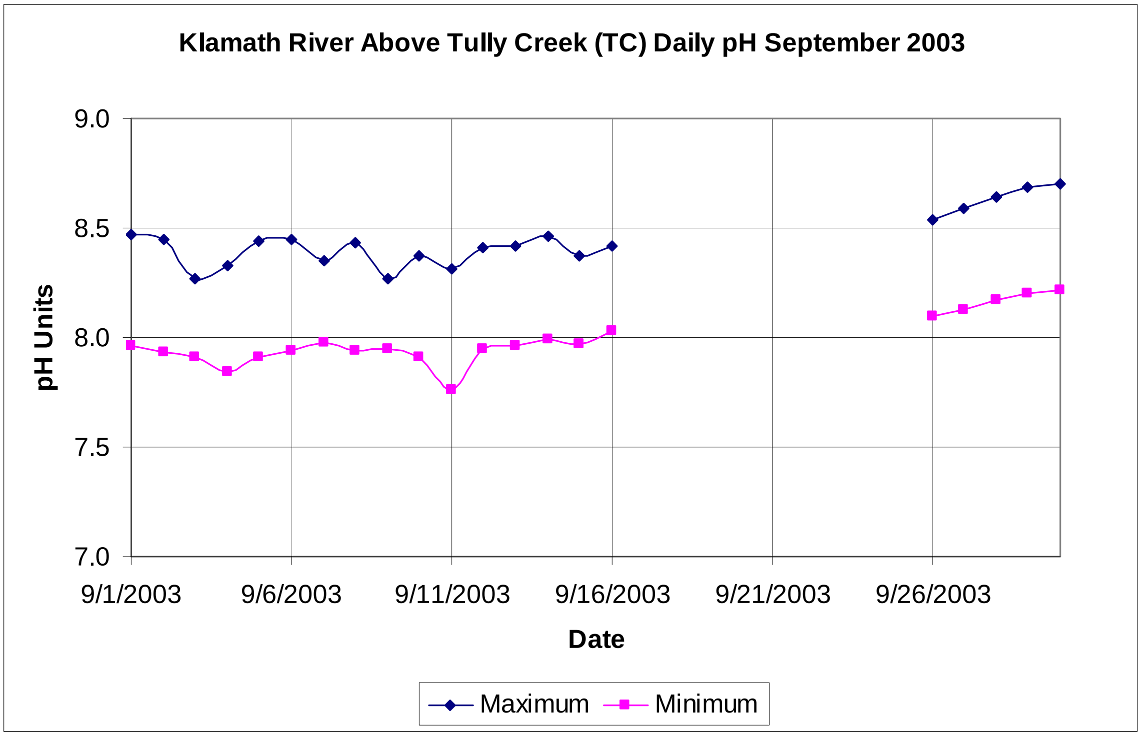


Figure 7-93 pH Values for the Klamath River above Tully Creek September 2003

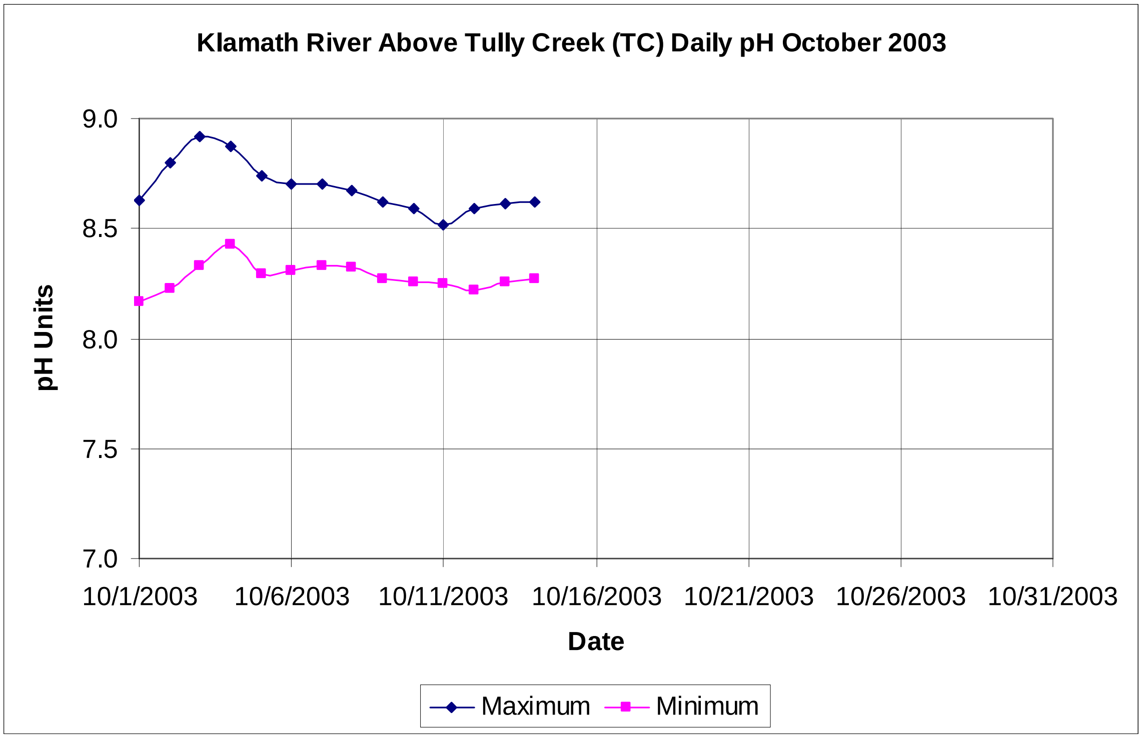


Figure 7-94 pH Values for the Klamath River above Tully Creek October 2003

7.1.6 Klamath River above Blue Creek – 6 Feet Deep

7.1.6.1 Temperature

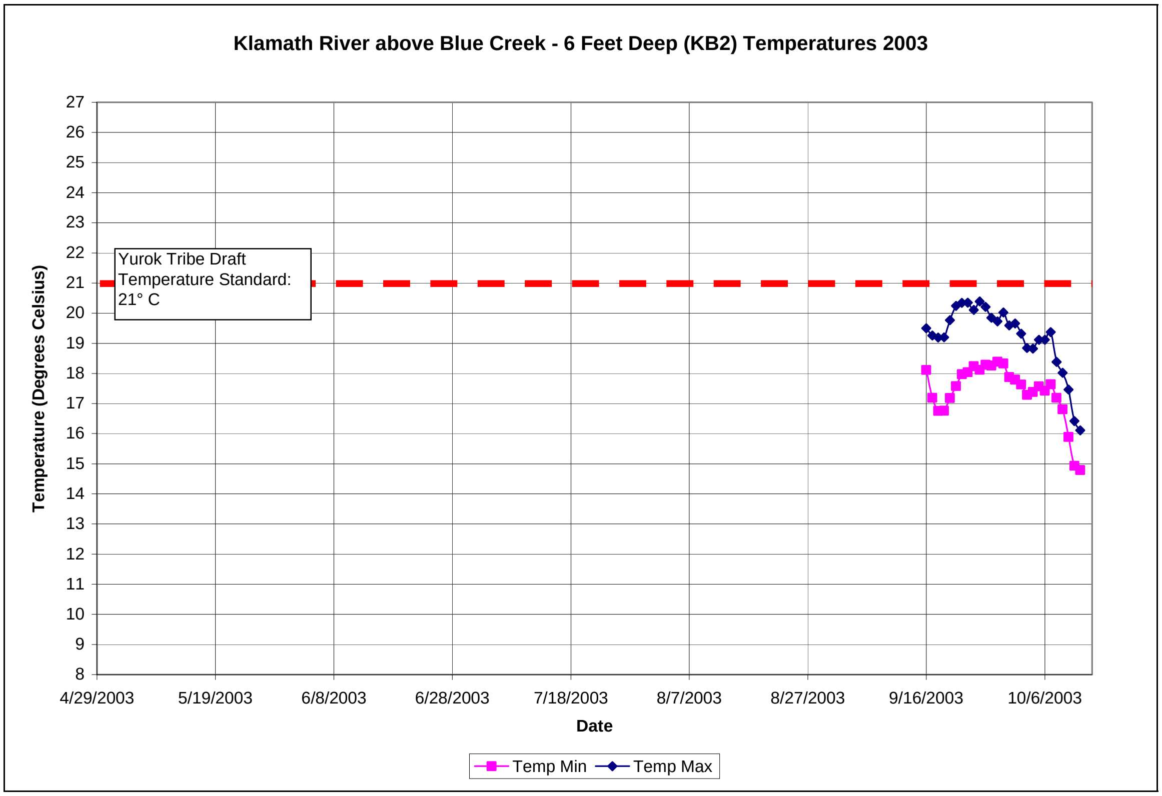


Figure 7-95 Water Temperature Values for the Klamath River above Blue Creek – 6 Feet Deep WY03

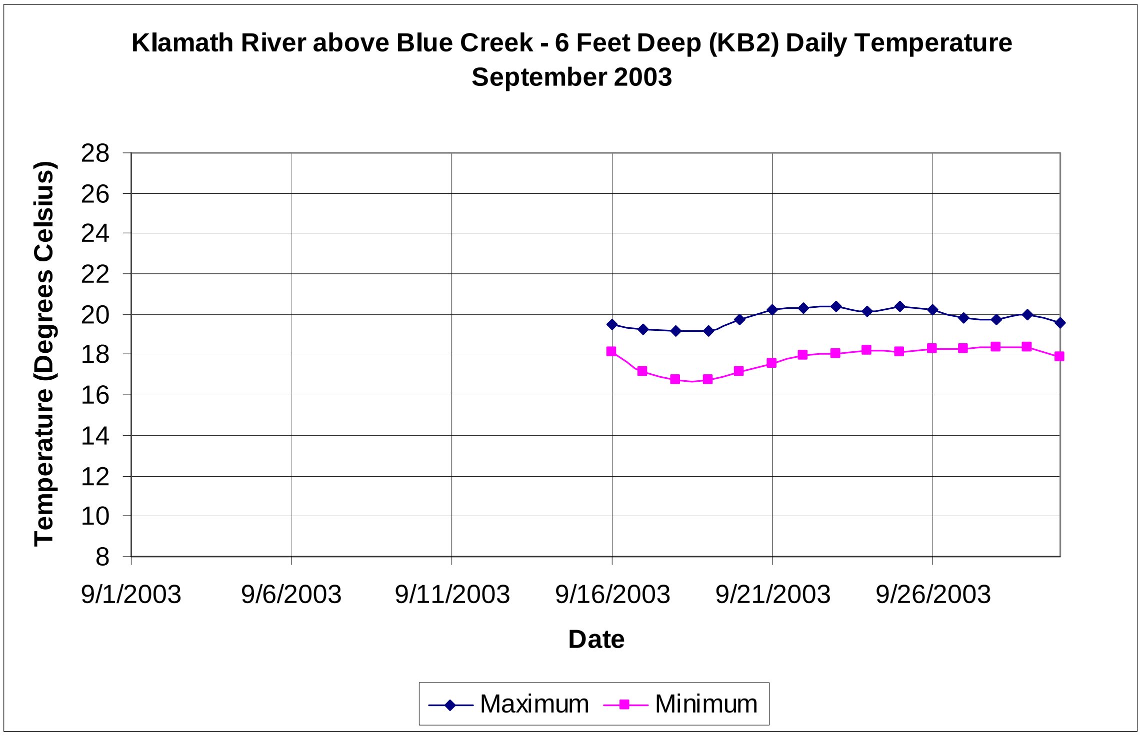


Figure 7-96 Water Temperature Values for the Klamath River above Blue Creek – 6 Feet Deep September 2003

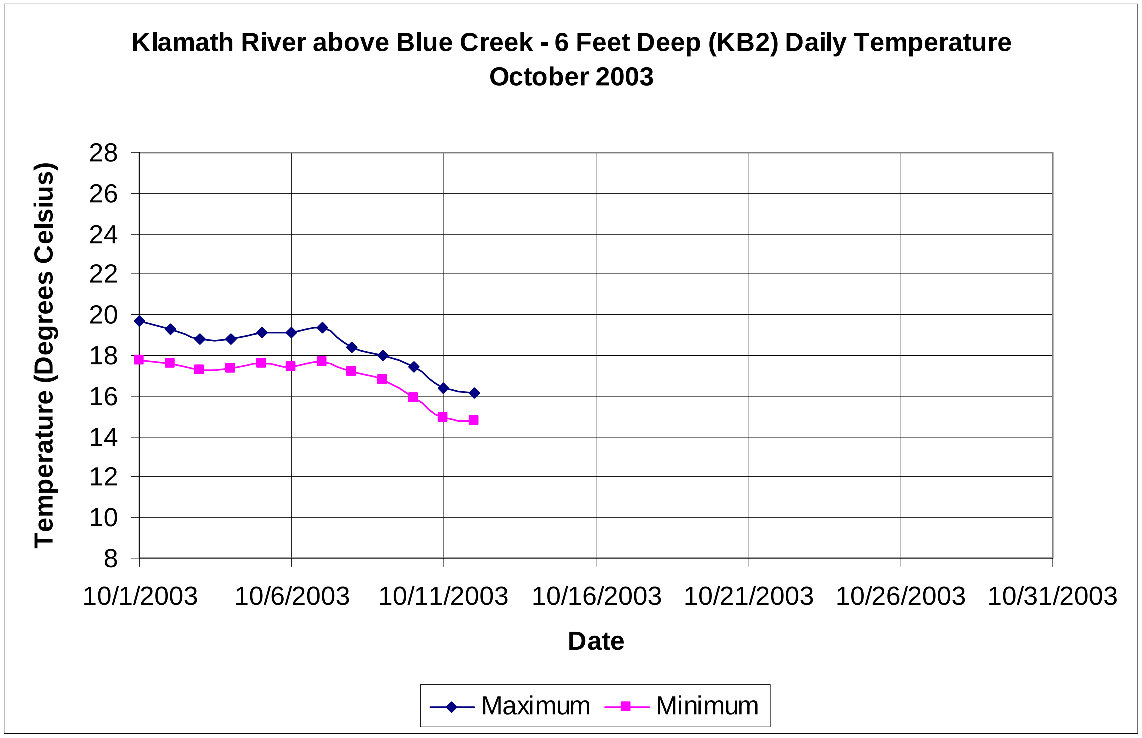


Figure 7-97 Water Temperature Values for the Klamath River above Blue Creek – 6 Feet Deep October 2003

7.1.6.2 Dissolved Oxygen

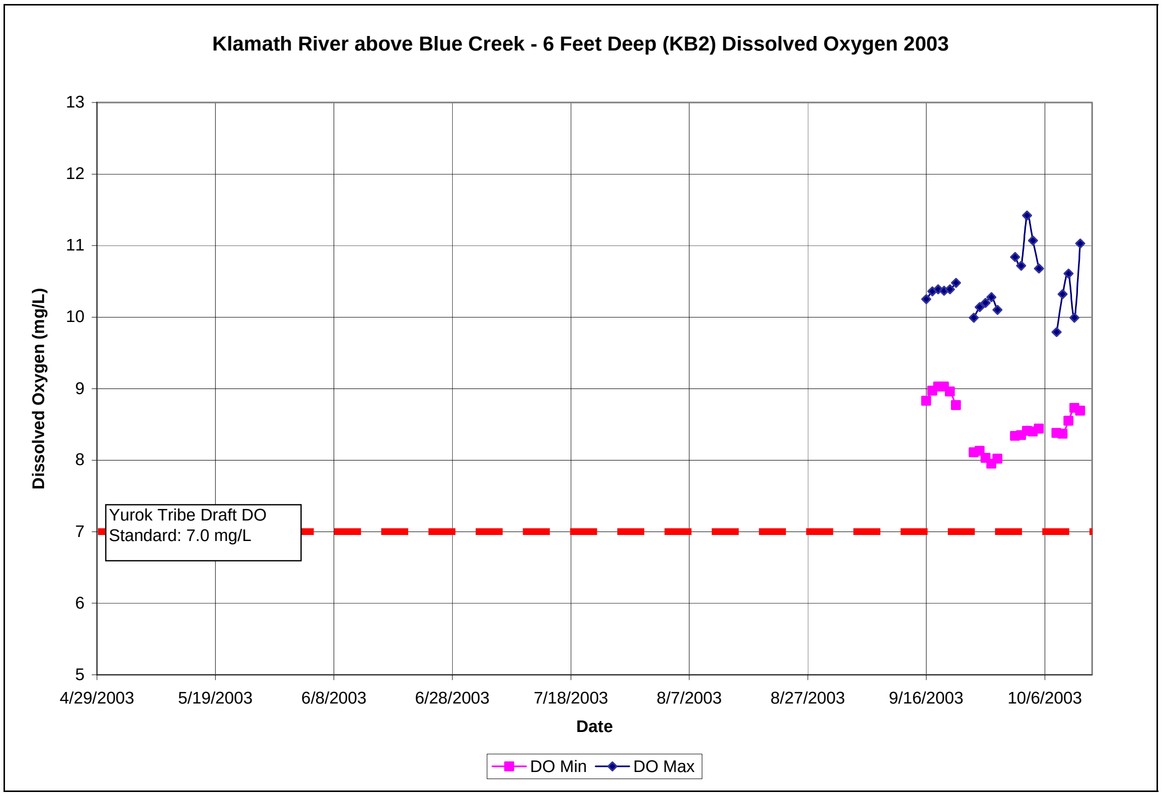


Figure 7-98 Dissolved Oxygen Values for the Klamath River above Blue Creek – 6 Feet Deep WY03

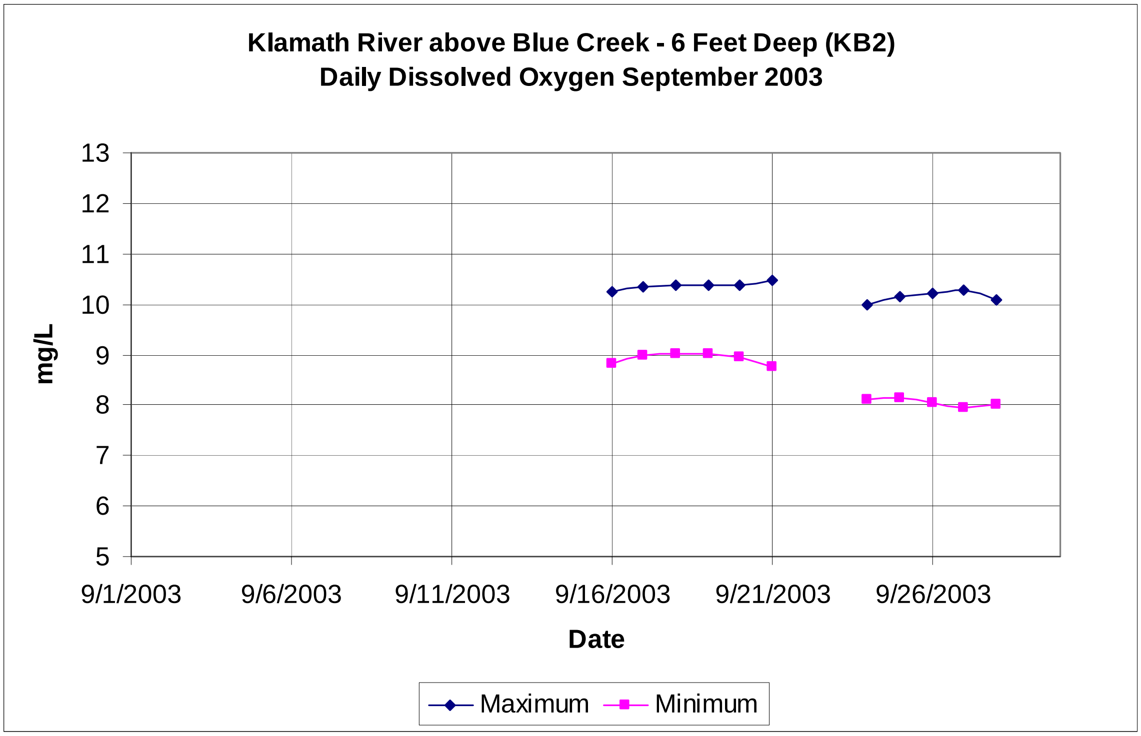


Figure 7-99 Dissolved Oxygen Values for the Klamath River above Blue Creek – 6 Feet Deep September 2003

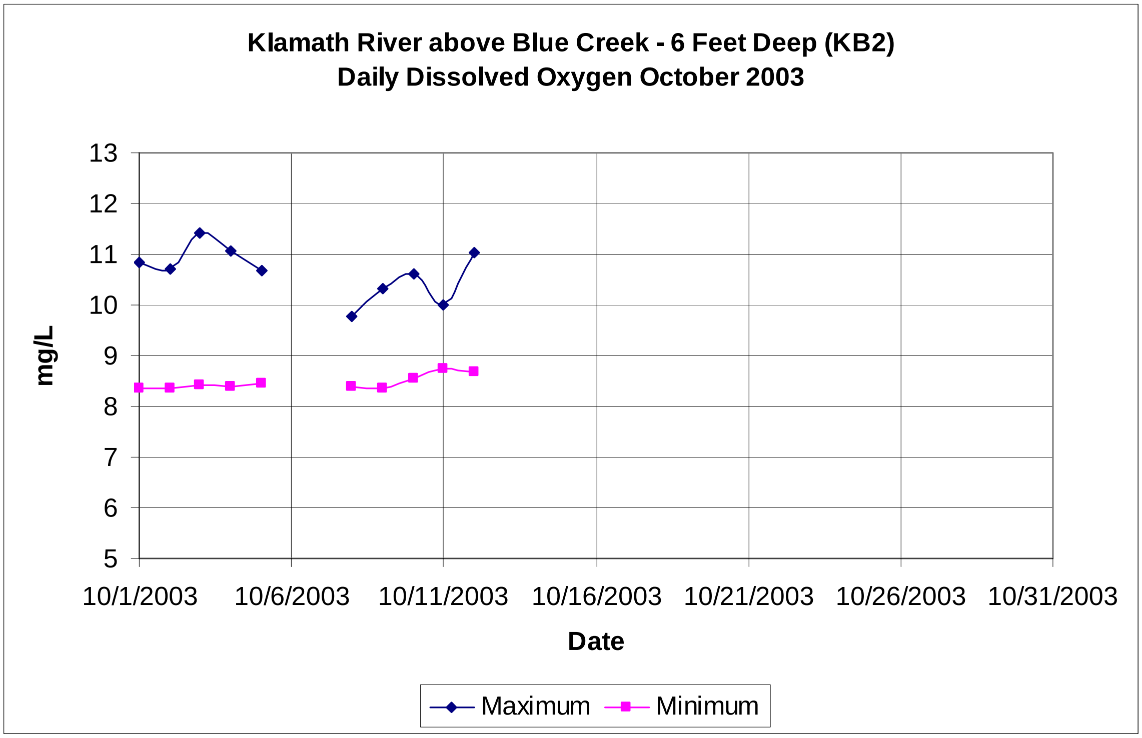


Figure 7-100 Dissolved Oxygen Values for the Klamath River above Blue Creek – 6 Feet Deep October 2003

7.1.6.3 pH

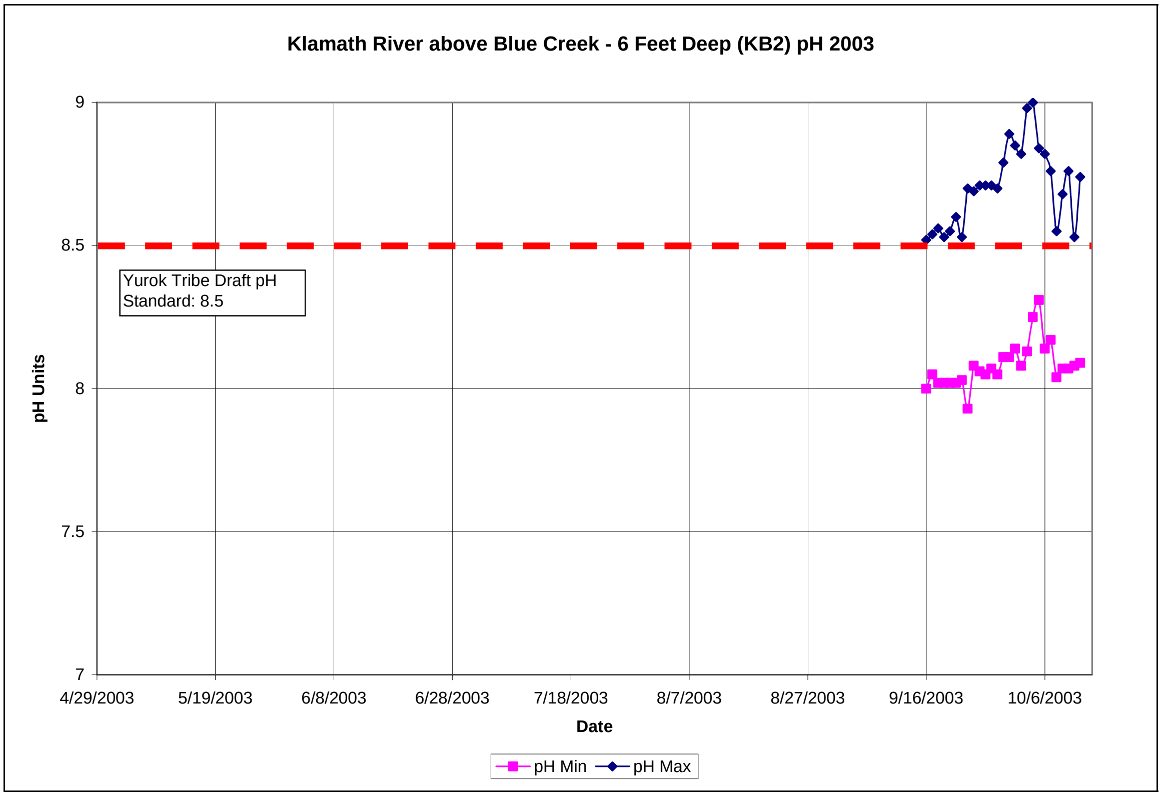


Figure 7-101 pH Values for the Klamath River above Blue Creek – 6 Feet Deep WY03

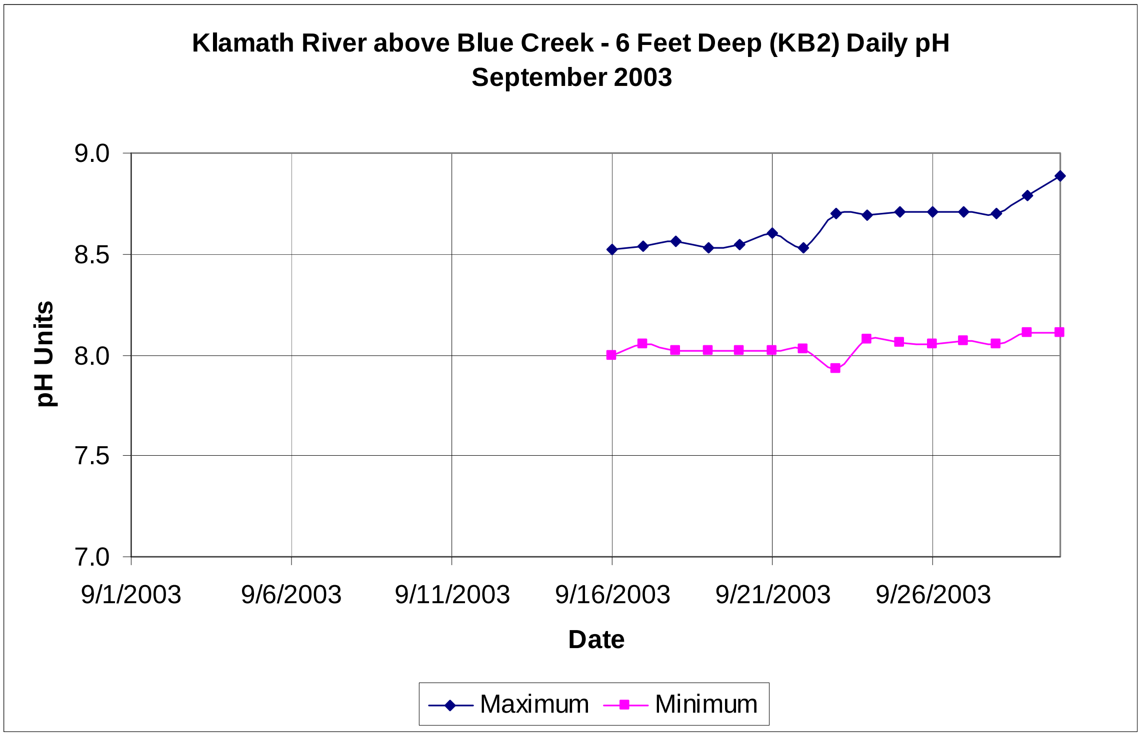


Figure 7-102 pH Values for the Klamath River above Blue Creek – 6 Feet Deep September 2003

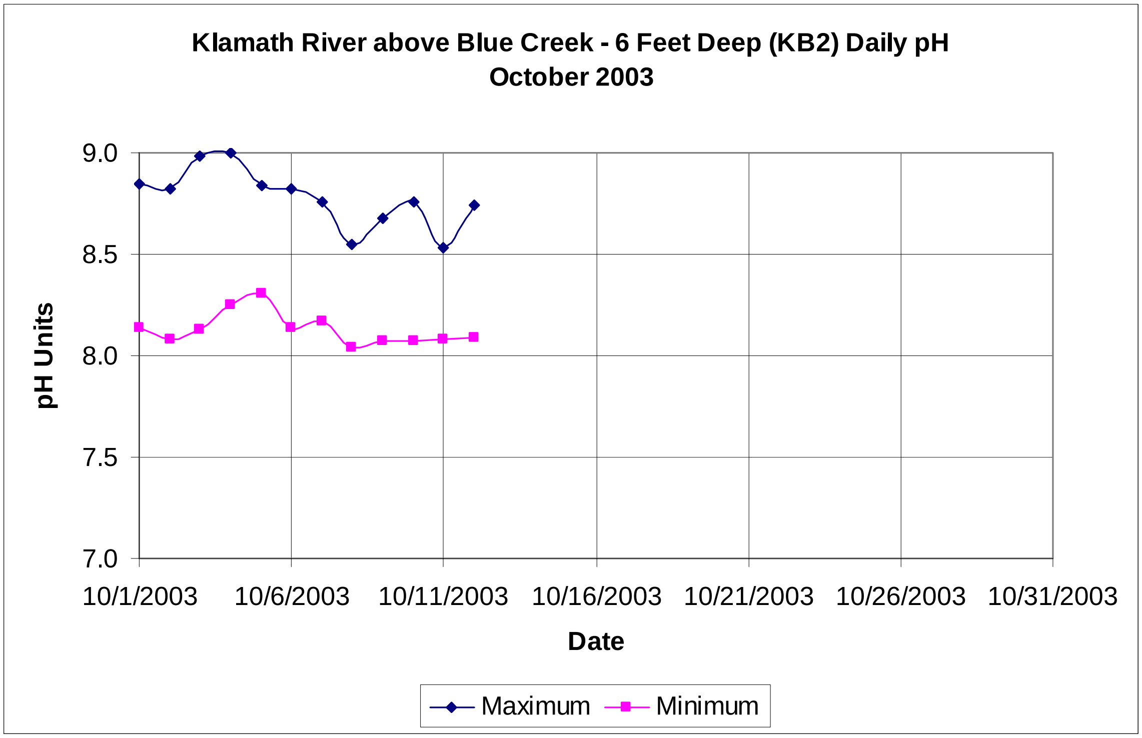


Figure 7-103 pH Values for the Klamath River above Blue Creek – 6 Feet Deep October 2003

7.1.7 Klamath River above Blue Creek – 25 Feet Deep

7.1.7.1 Temperature

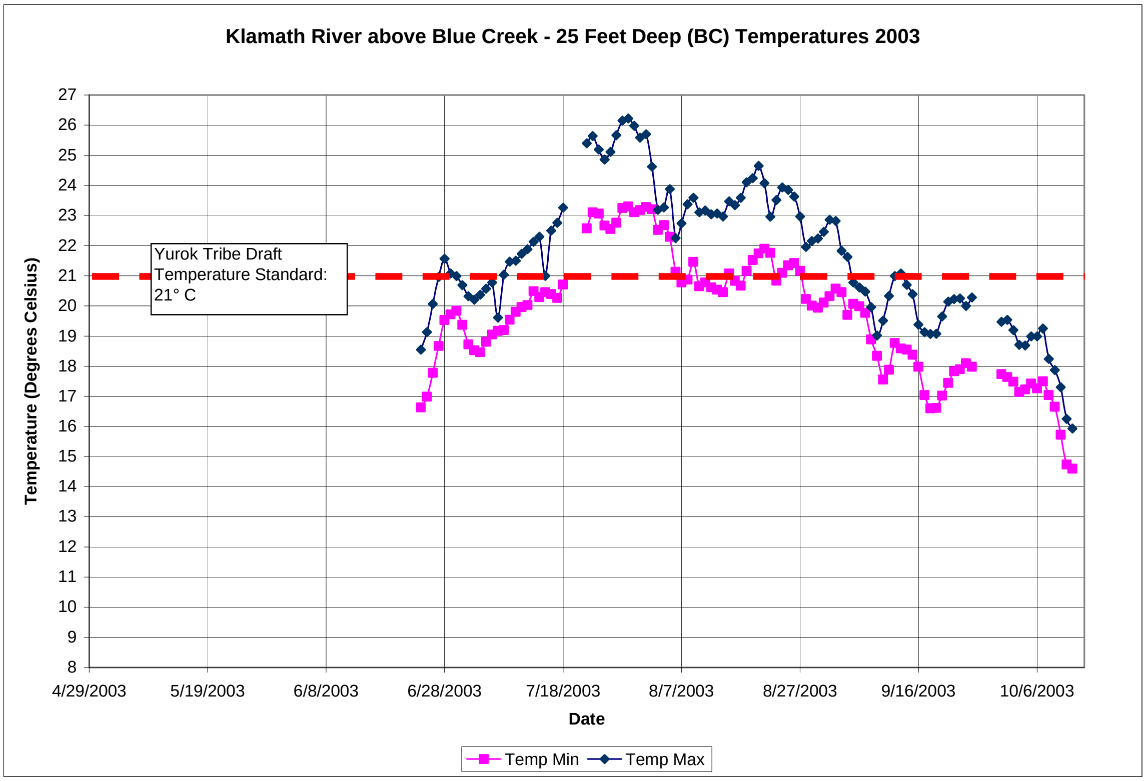


Figure 7-104 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep WY03

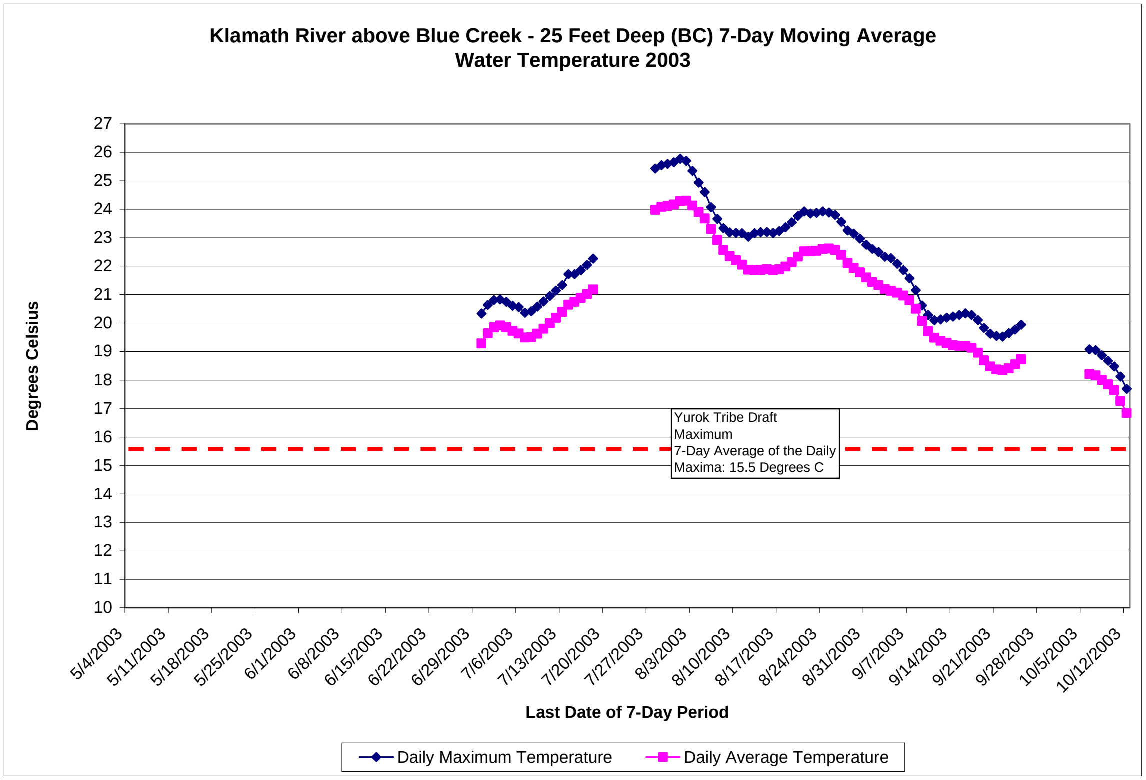


Figure 7-105 7-Day Moving Average Water Temperature for the Klamath River above Blue Creek – 25 Feet Deep WY03

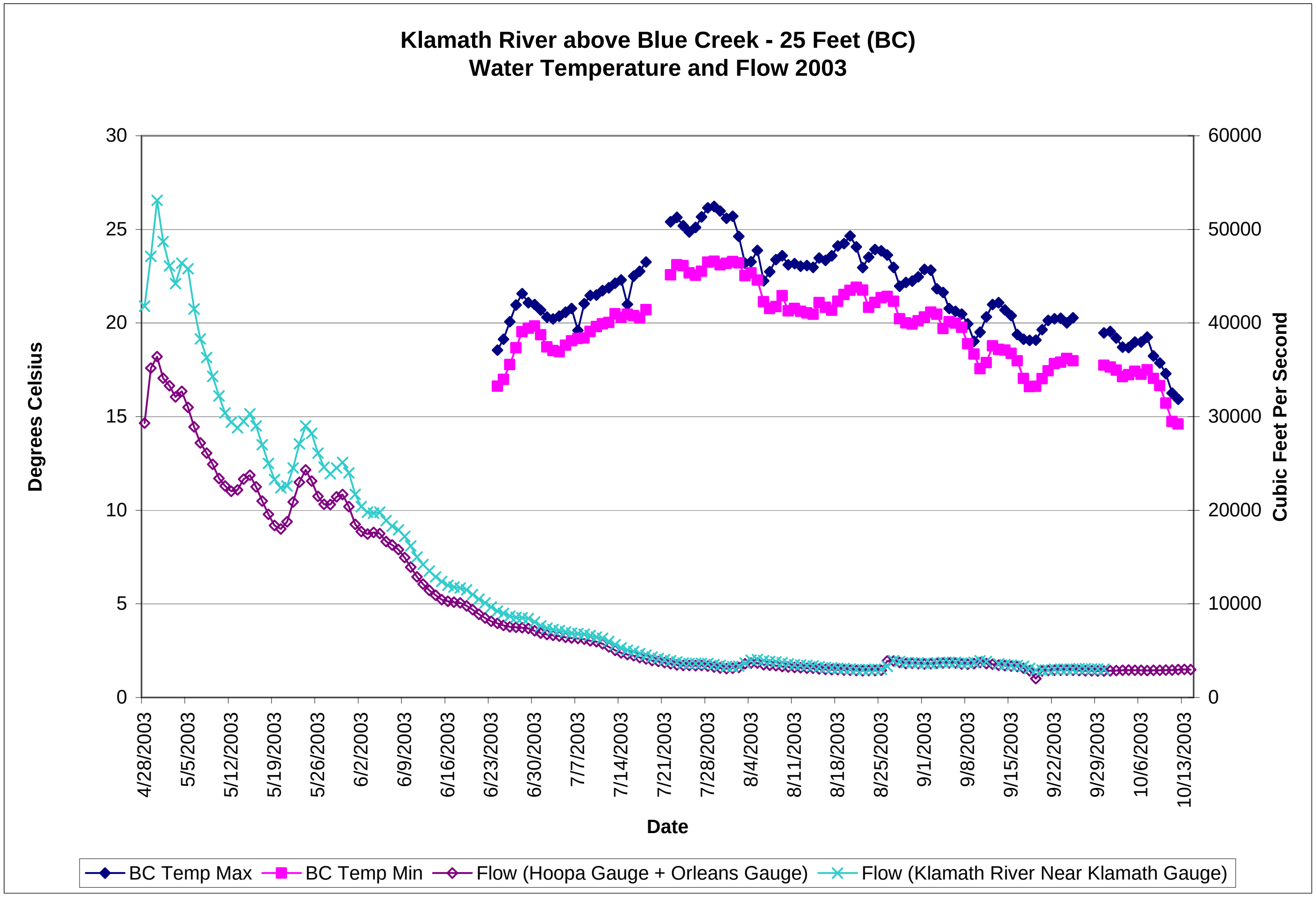


Figure 7-106 Water Temperature and Flow Values for the Klamath River above Blue Creek – 25 Feet Deep WY03

Note: Flow values for the Klamath River Near Klamath Gauge in the above figure have not been corrected for tidal influence by USGS. USGS estimates that the values given above are within 5% of the correct value; corrected data has not been released by USGS at the time of this report.

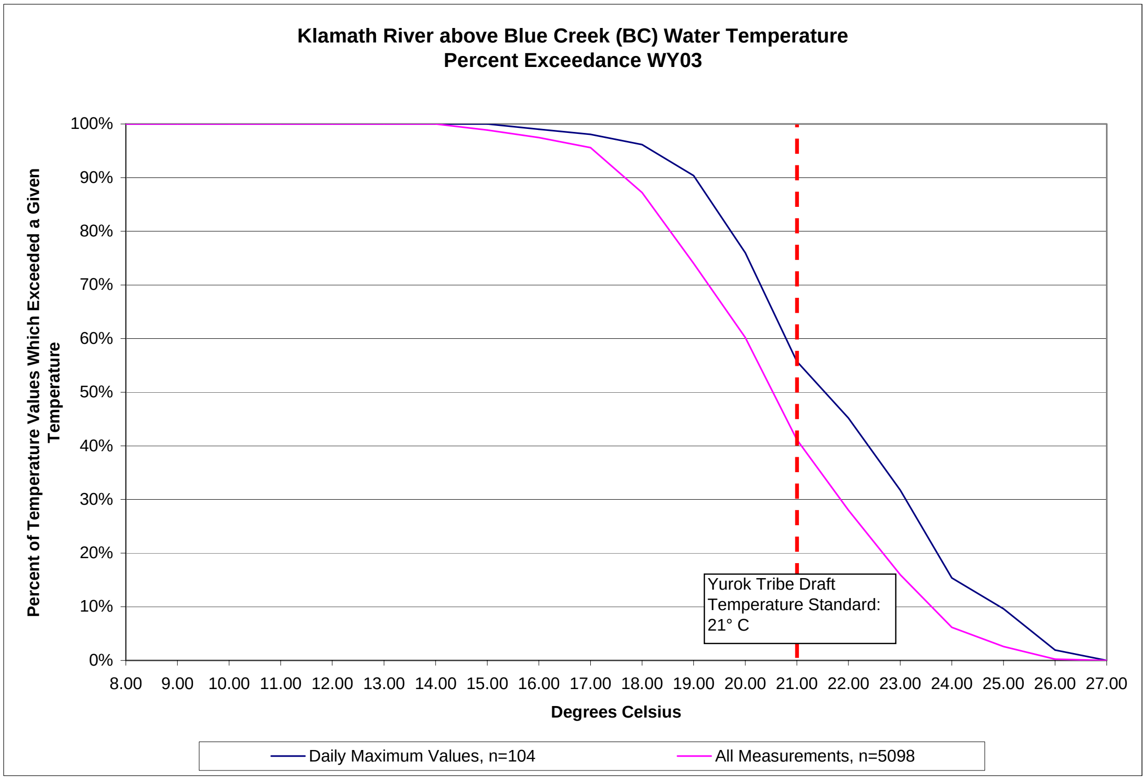


Figure 7-107 Klamath River Above Blue Creek - 25 Feet Deep Water Temperature Percent Exceedance WY03

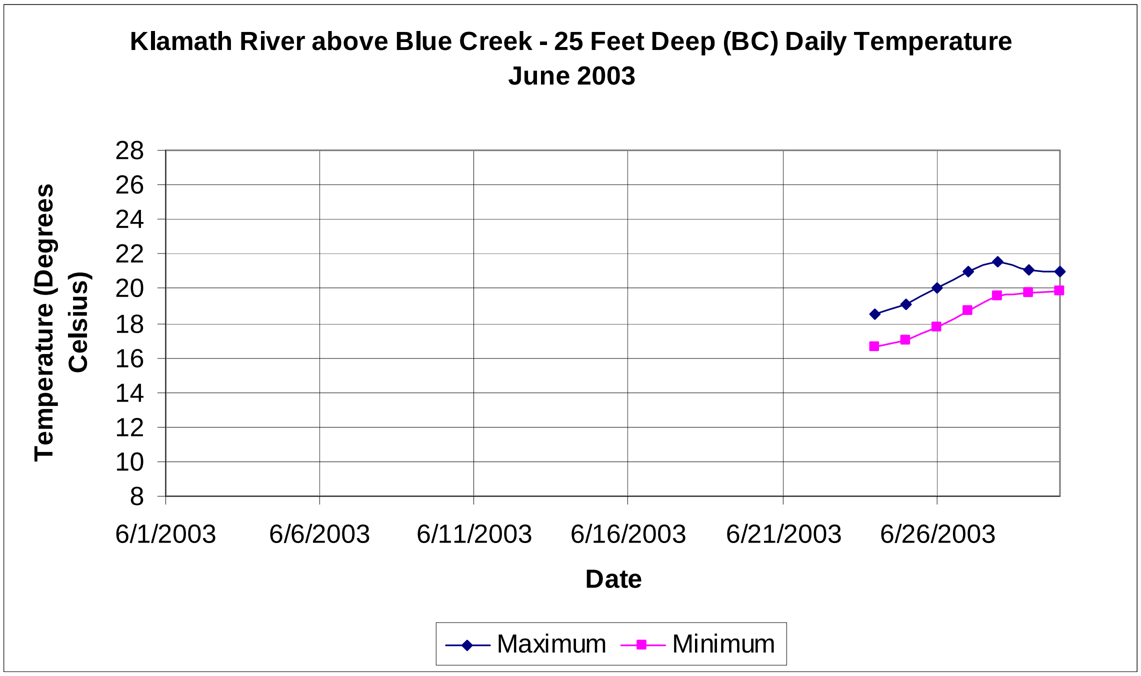


Figure 7-108 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep June 2003

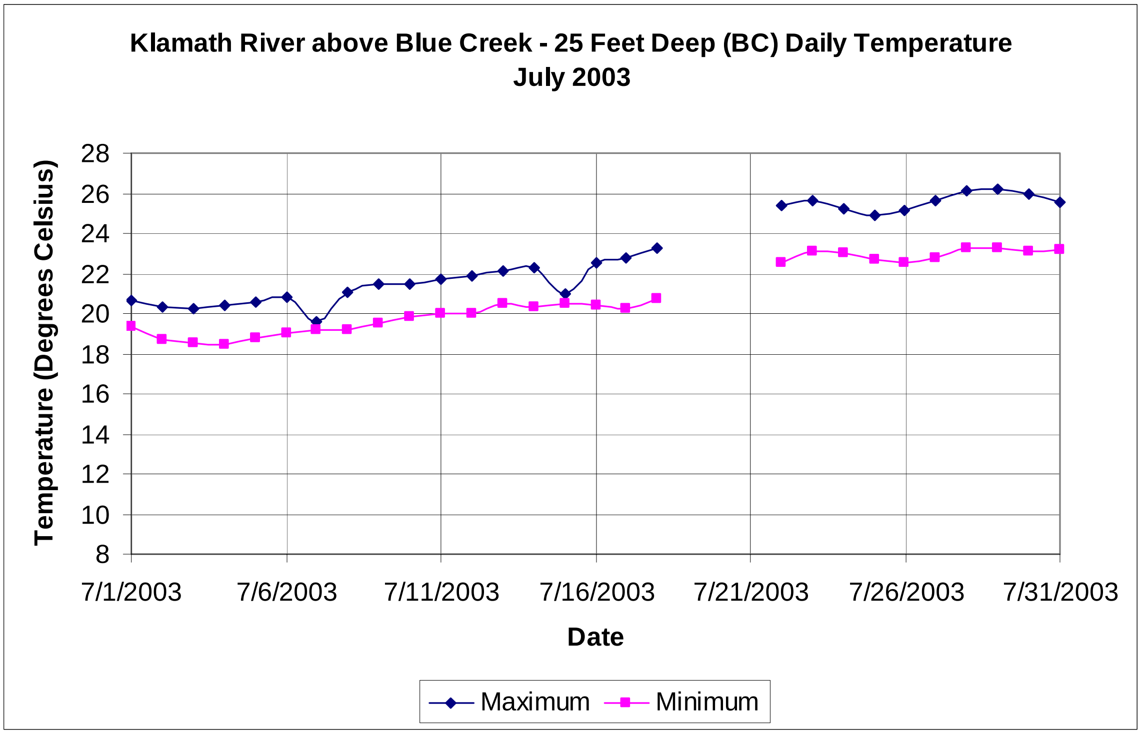


Figure 7-109 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep July 2003

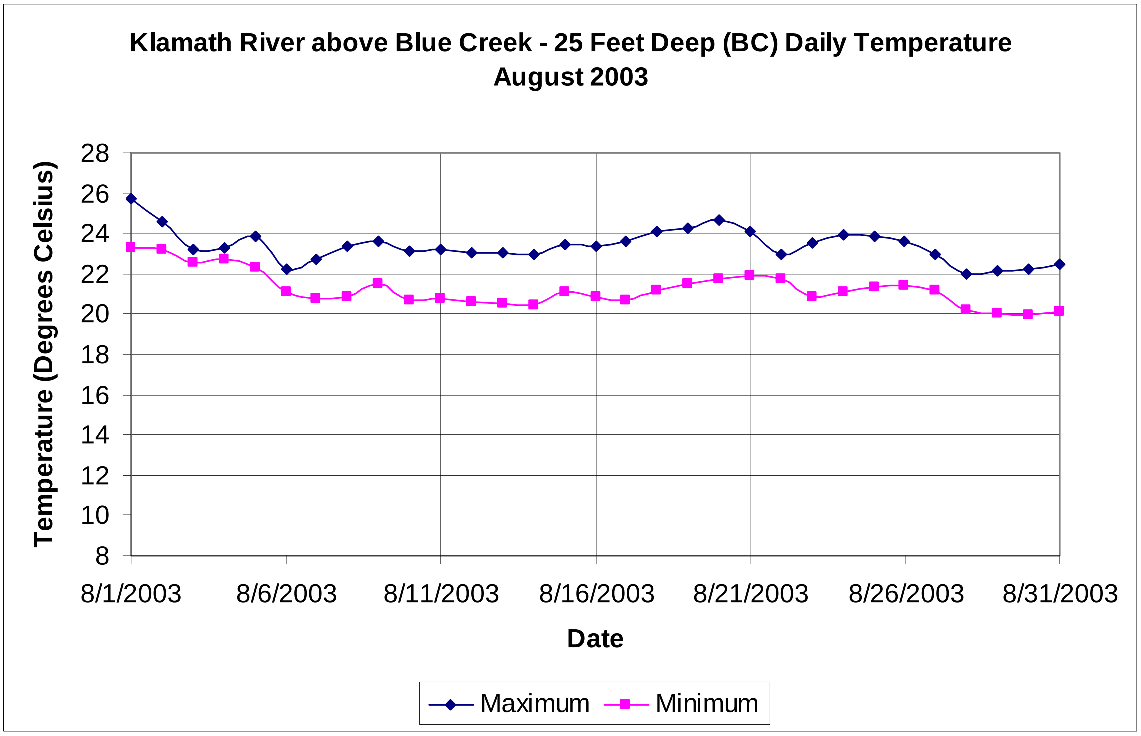


Figure 7-110 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep August 2003

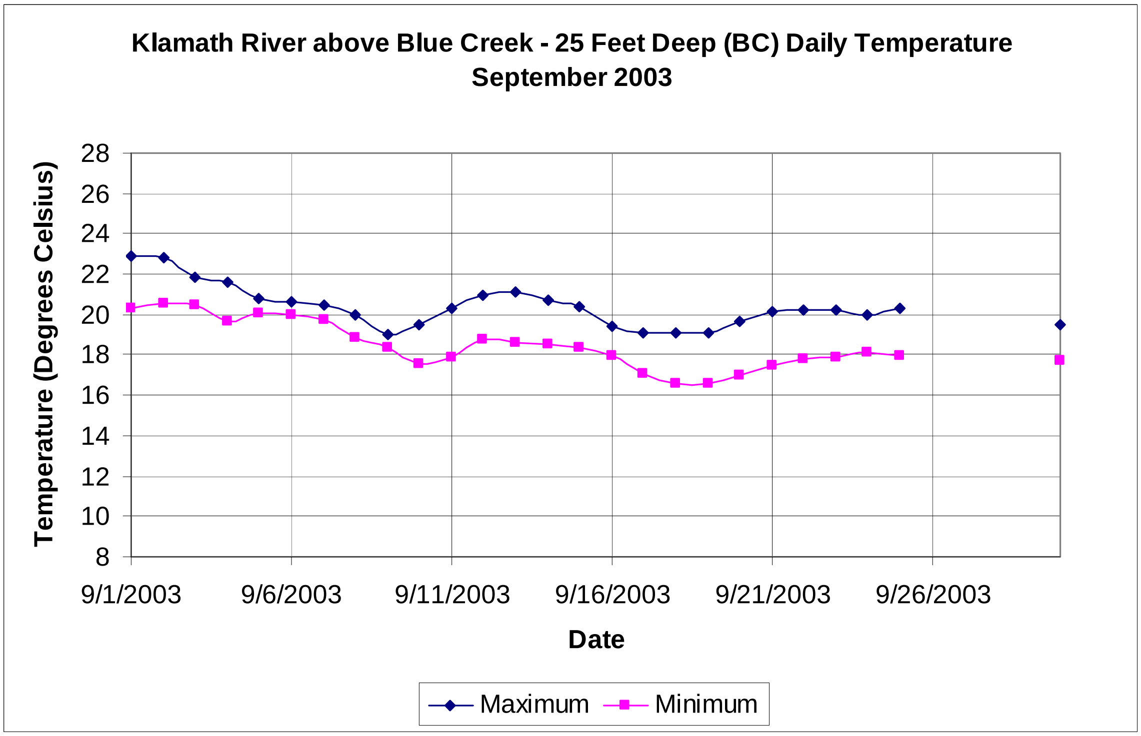


Figure 7-111 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep September 2003

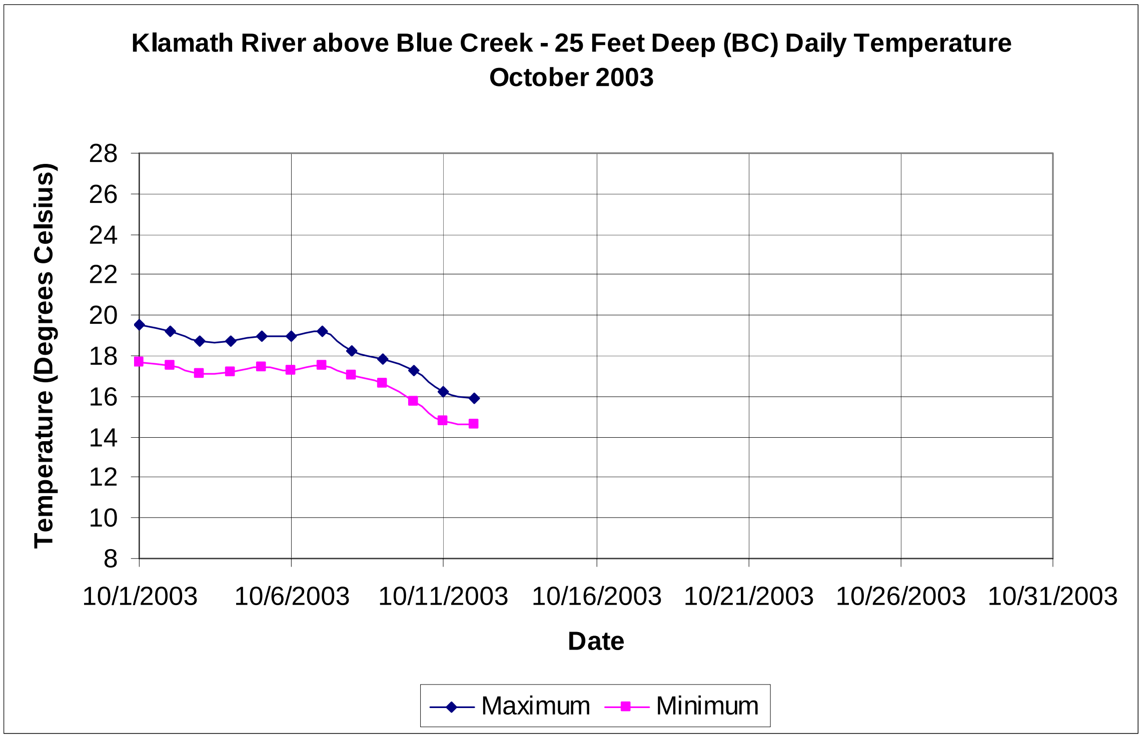


Figure 7-112 Water Temperature Values for the Klamath River above Blue Creek – 25 Feet Deep October 2003

7.1.7.2 Dissolved Oxygen

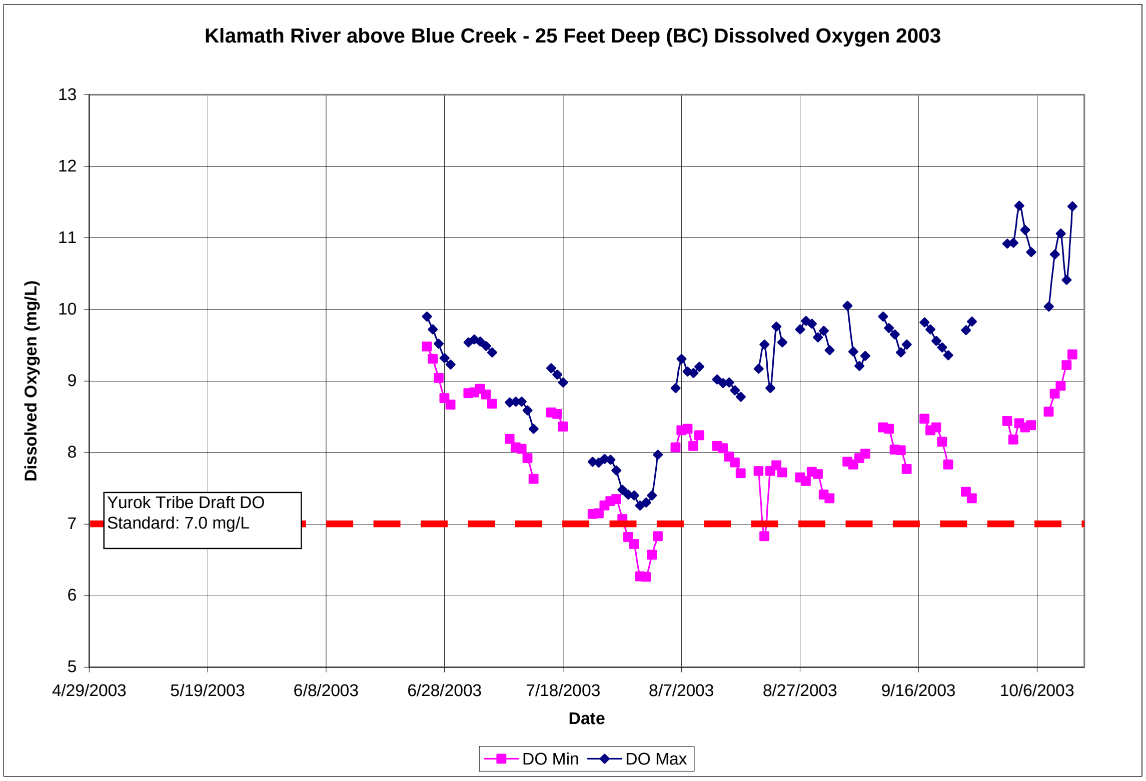


Figure 7-113 Dissolved Oxygen Values for the Klamath River above Blue Creek – 25 Feet Deep WY03

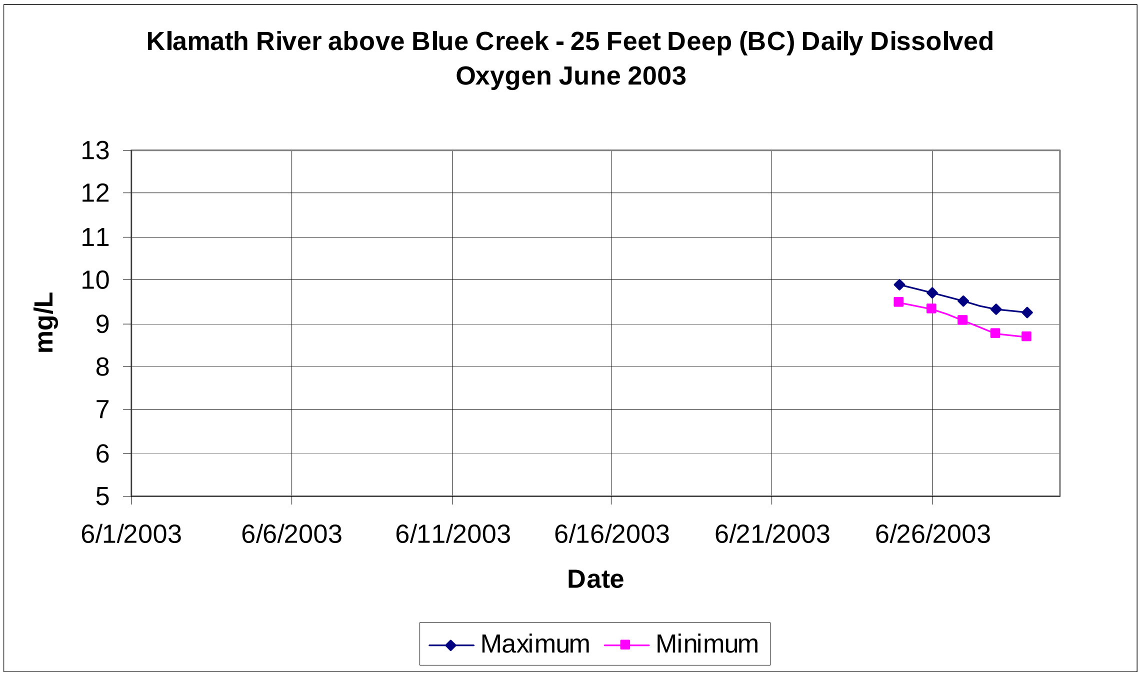


Figure 7-114 Dissolved Oxygen Values for the Klamath River above Blue Creek – 25 Feet Deep June 2003

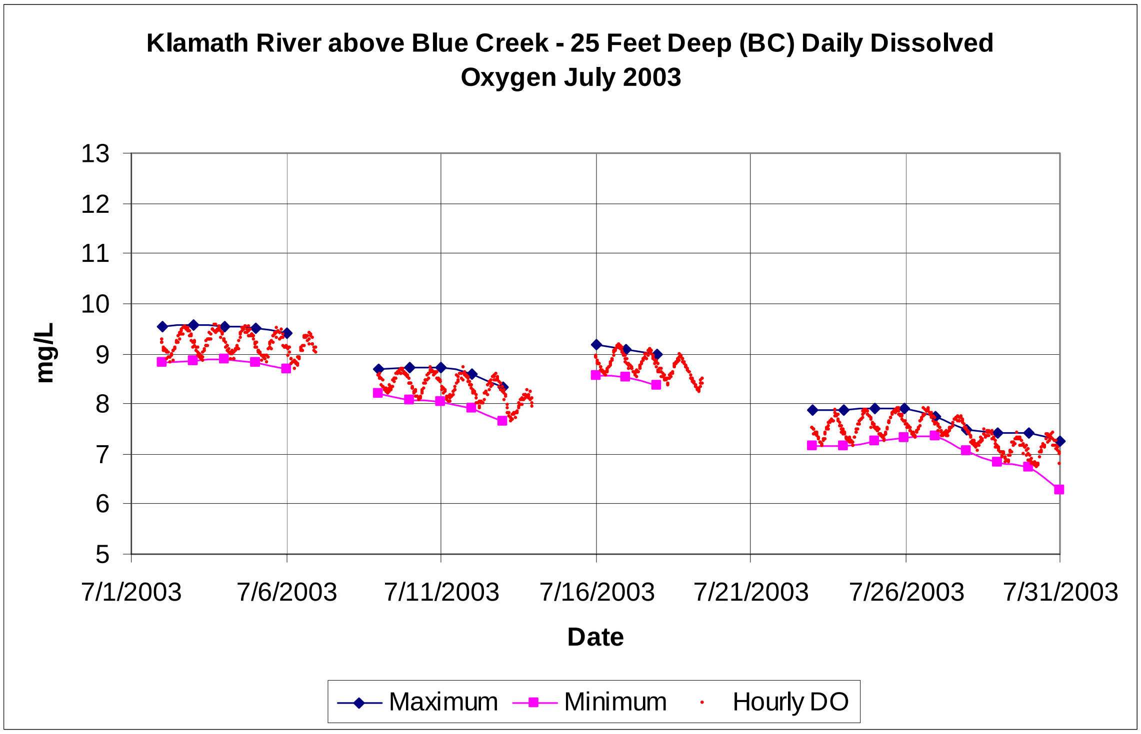


Figure 7-115 Dissolved Oxygen Half-Hourly and Daily Maximum Values for the Klamath River above Blue Creek – 25 Feet Deep July 2003

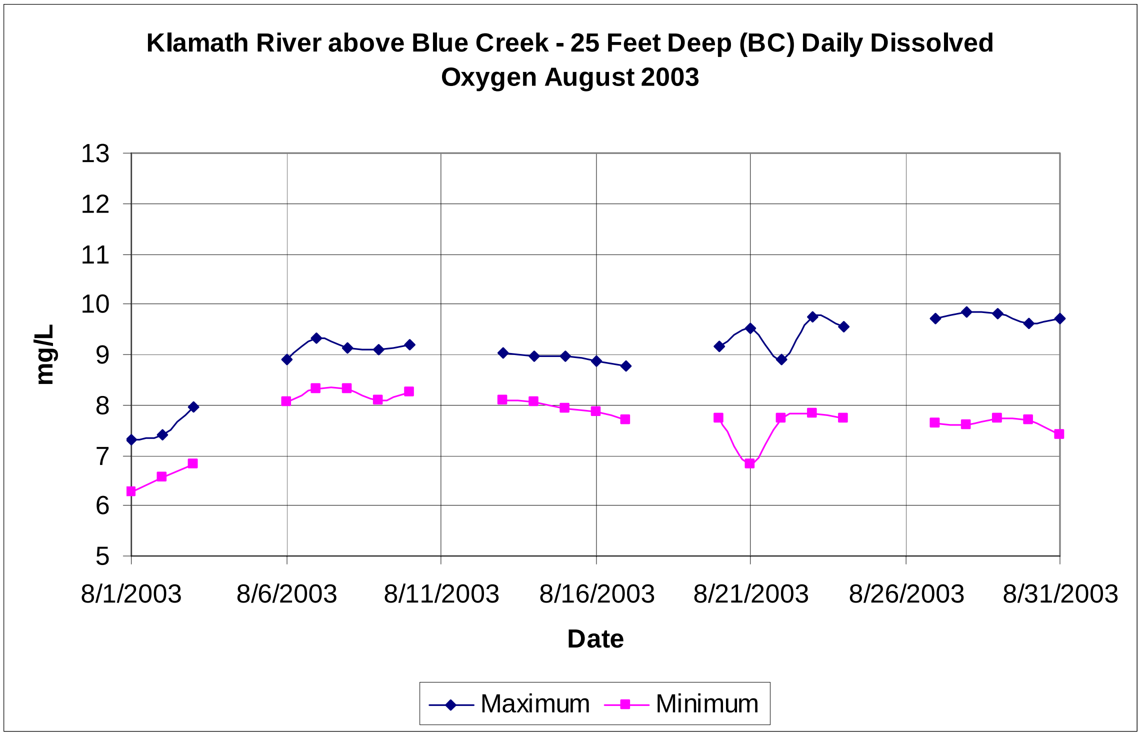


Figure 7-116 Dissolved Oxygen Values for the Klamath River above Blue Creek – 25 Feet Deep August 2003

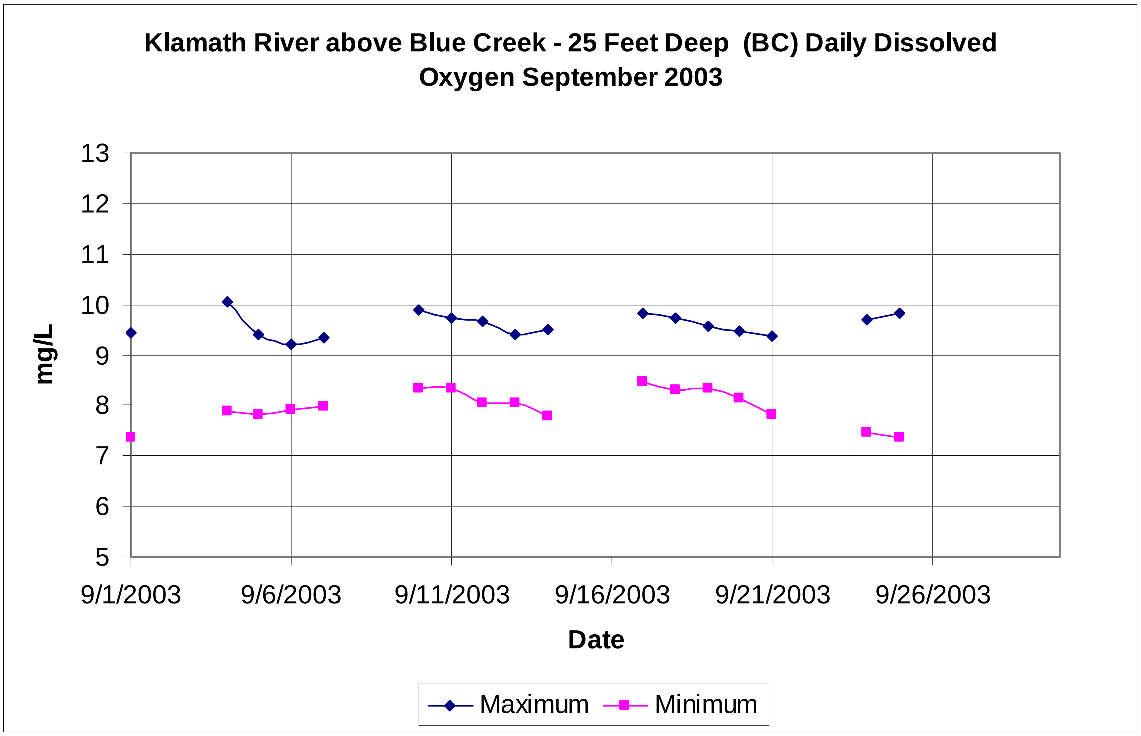


Figure 7-117 Dissolved Oxygen Values for the Klamath River above Blue Creek – 25 Feet Deep September 2003

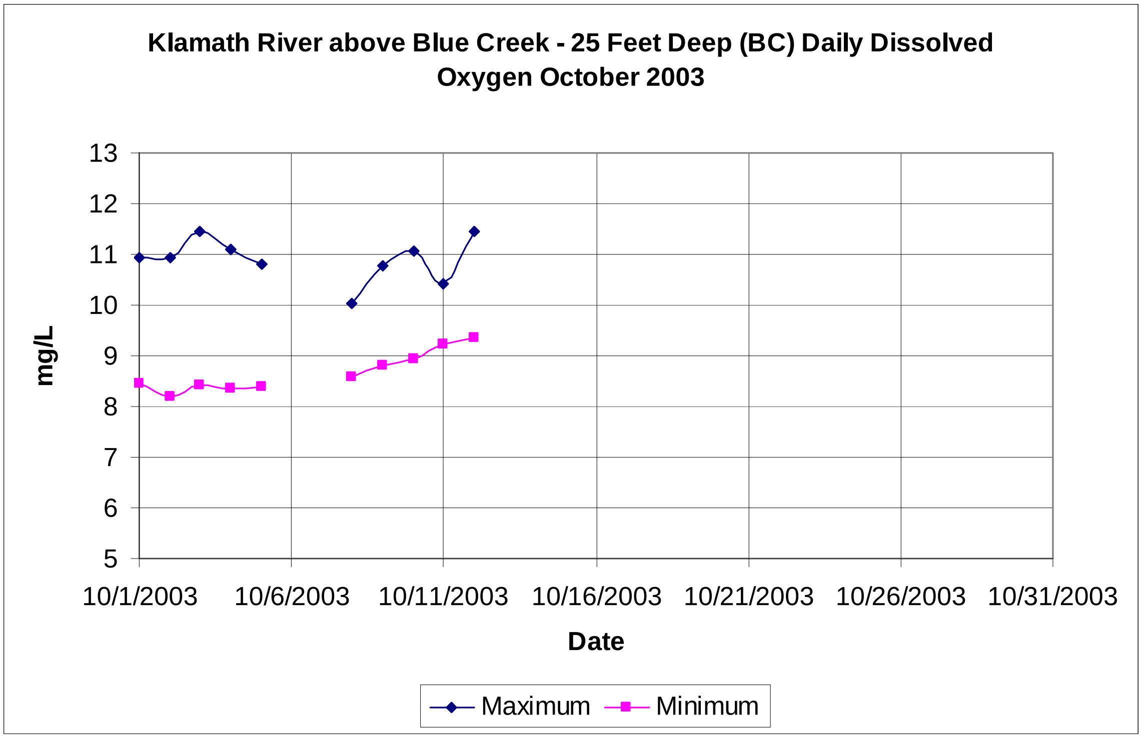


Figure 7-118 Dissolved Oxygen Values for the Klamath River above Blue Creek – 25 Feet Deep October 2003

7.1.7.3 pH

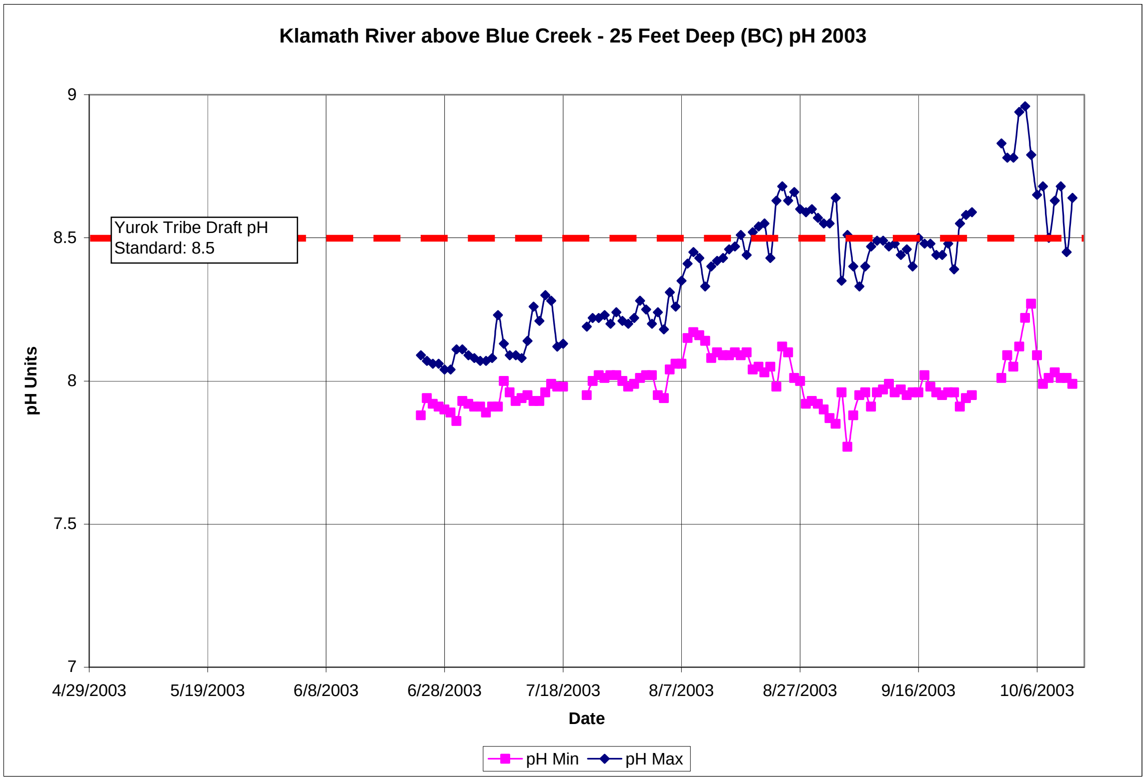


Figure 7-119 pH Values for the Klamath River above Blue Creek – 25 Feet Deep WY03

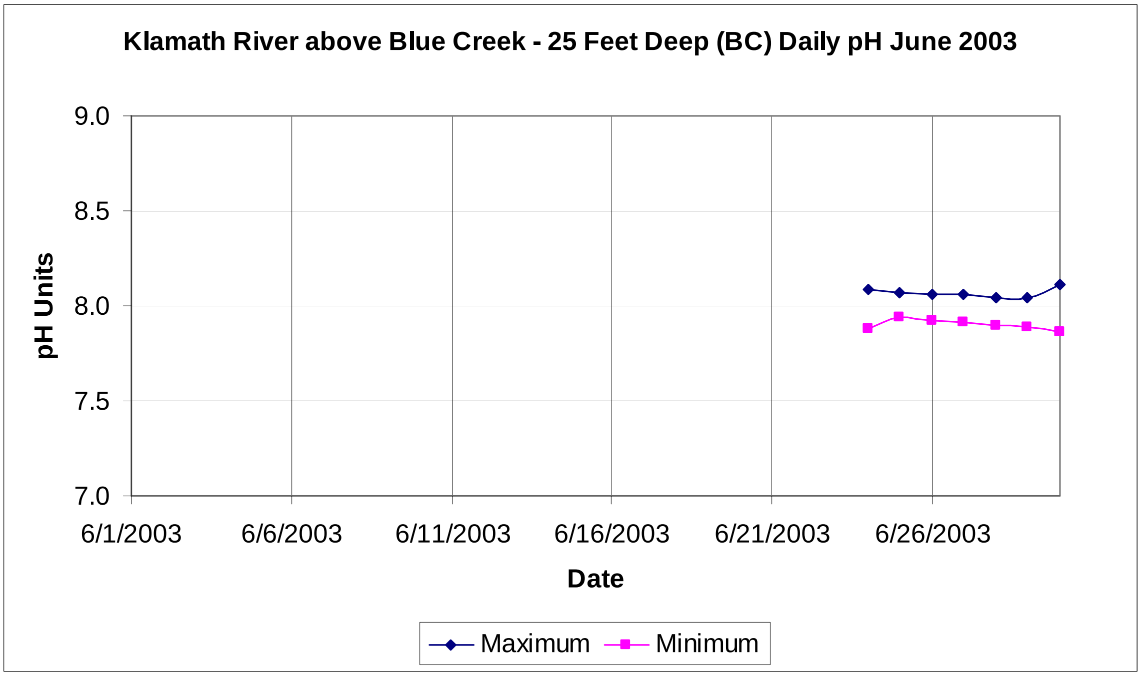


Figure 7-120 pH Values for the Klamath River above Blue Creek – 25 Feet Deep June 2003

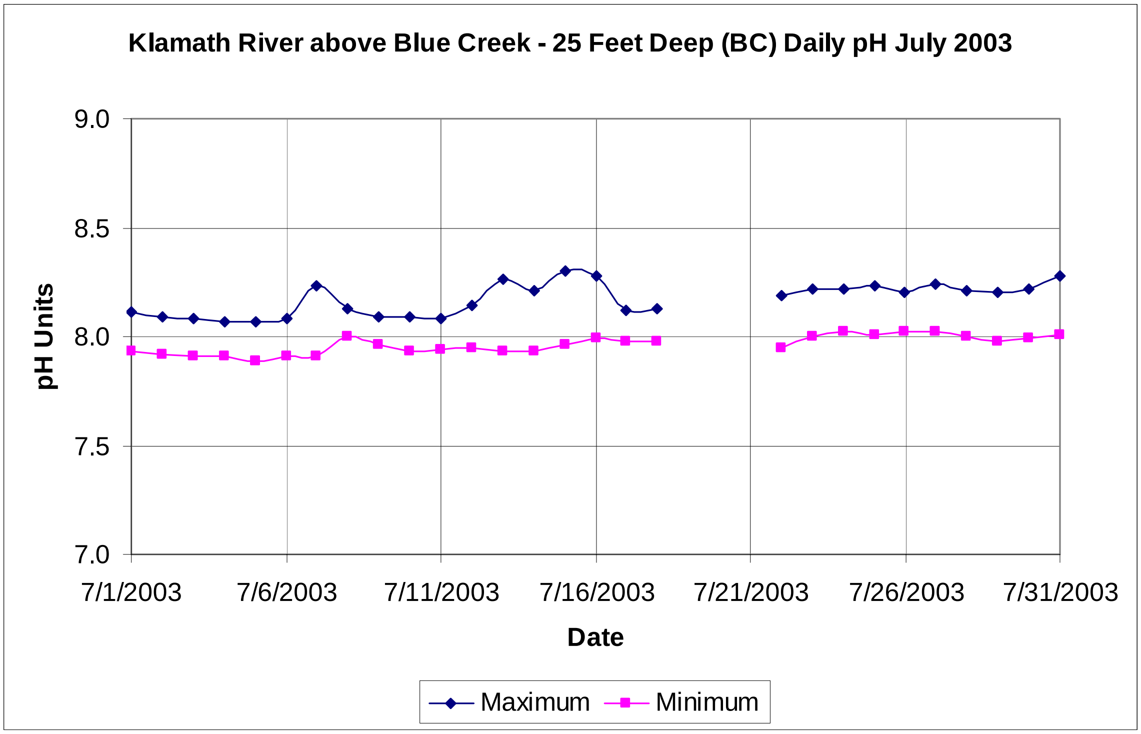


Figure 7-121 pH Values for the Klamath River above Blue Creek – 25 Feet Deep July 2003

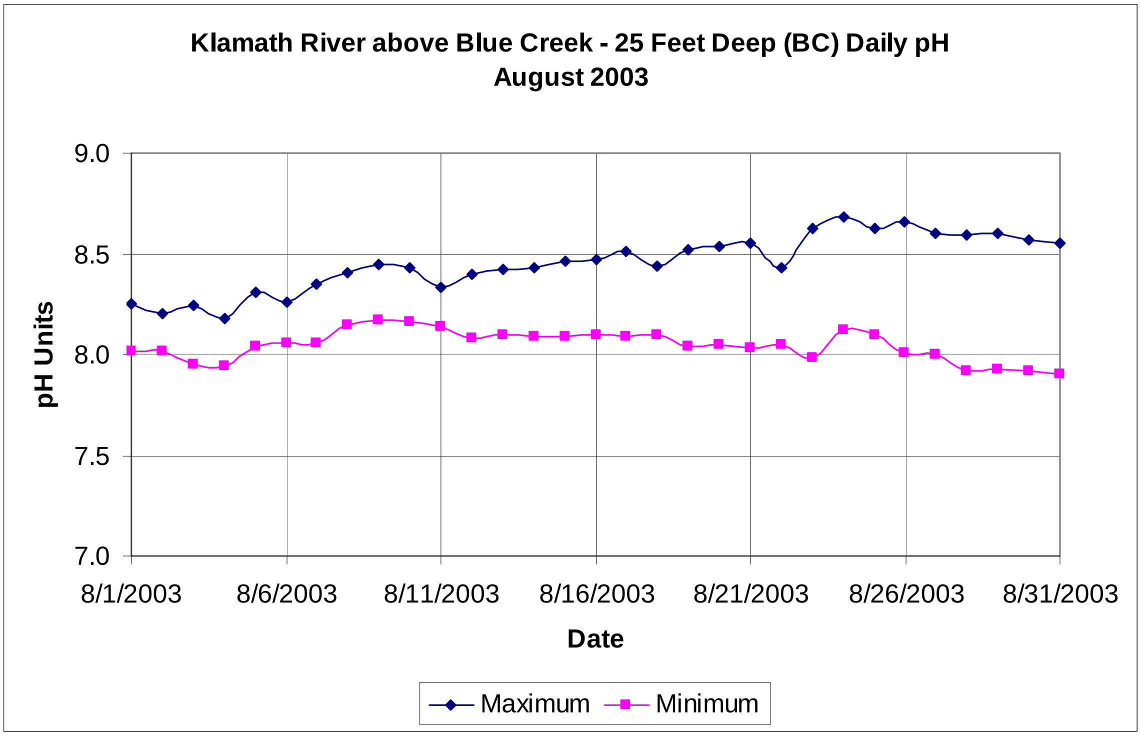


Figure 7-122 pH Values for the Klamath River above Blue Creek – 25 Feet Deep August 2003

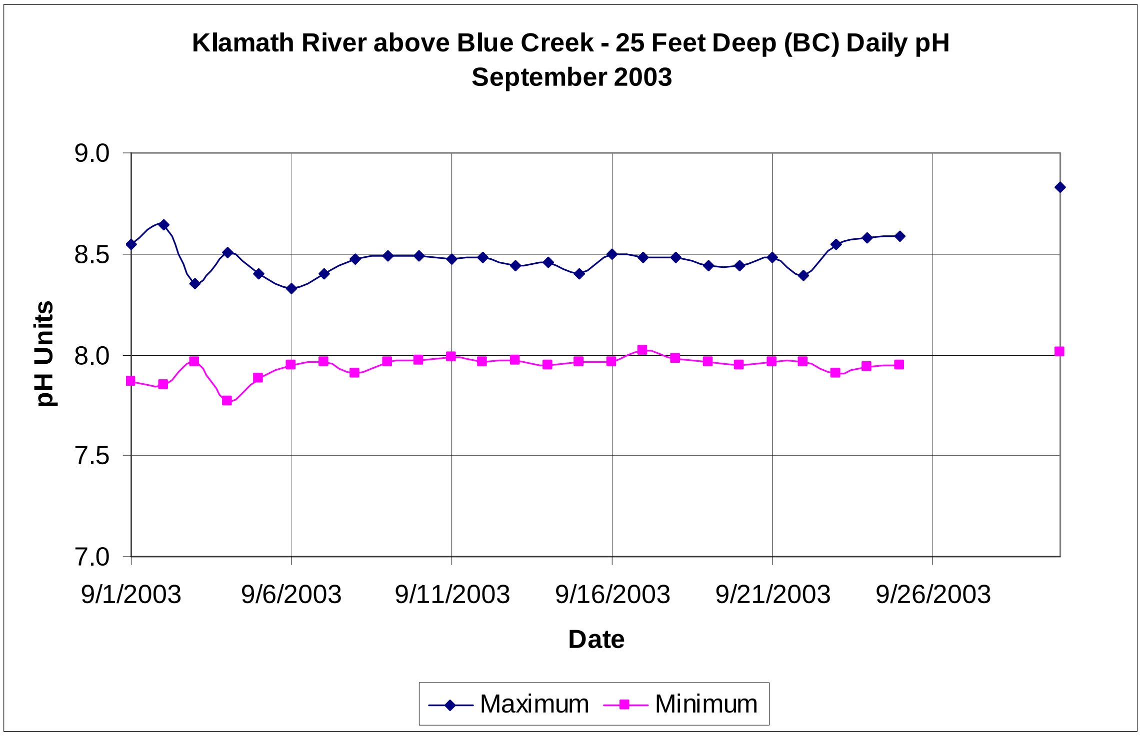


Figure 7-123 pH Values for the Klamath River above Blue Creek – 25 Feet Deep September 2003

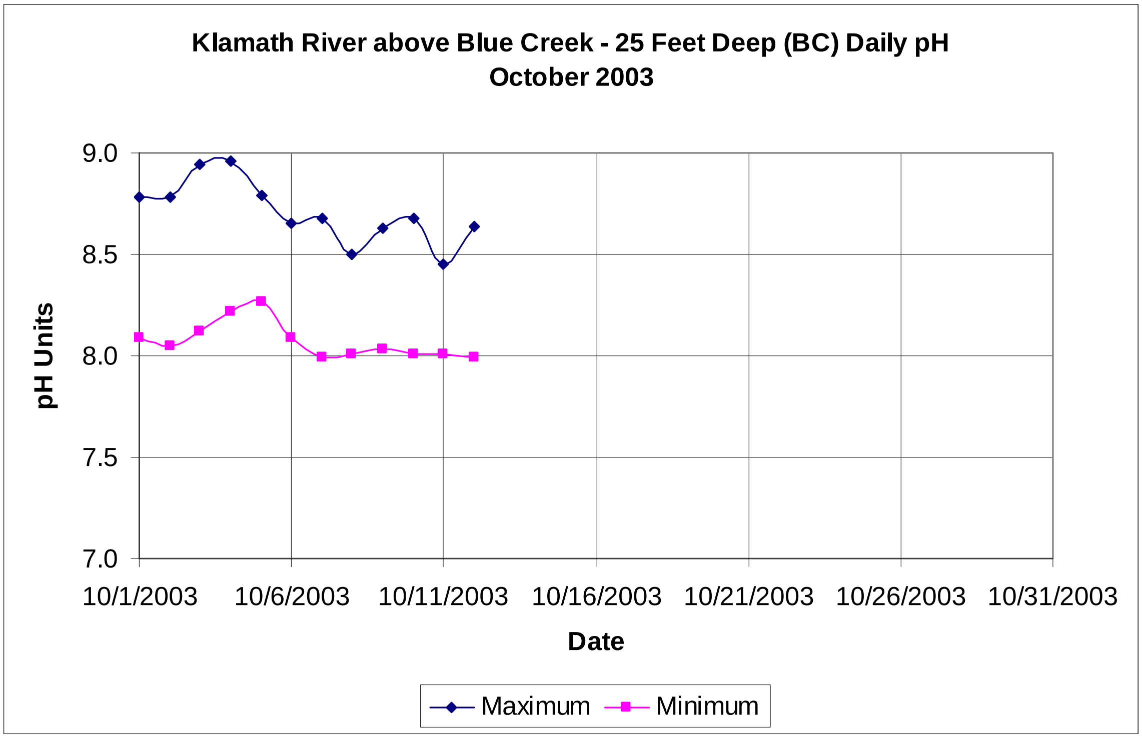


Figure 7-124 pH Values for the Klamath River above Blue Creek – 25 Feet Deep October 2003

7.1.8 Blue Hole

7.1.8.1 Temperature

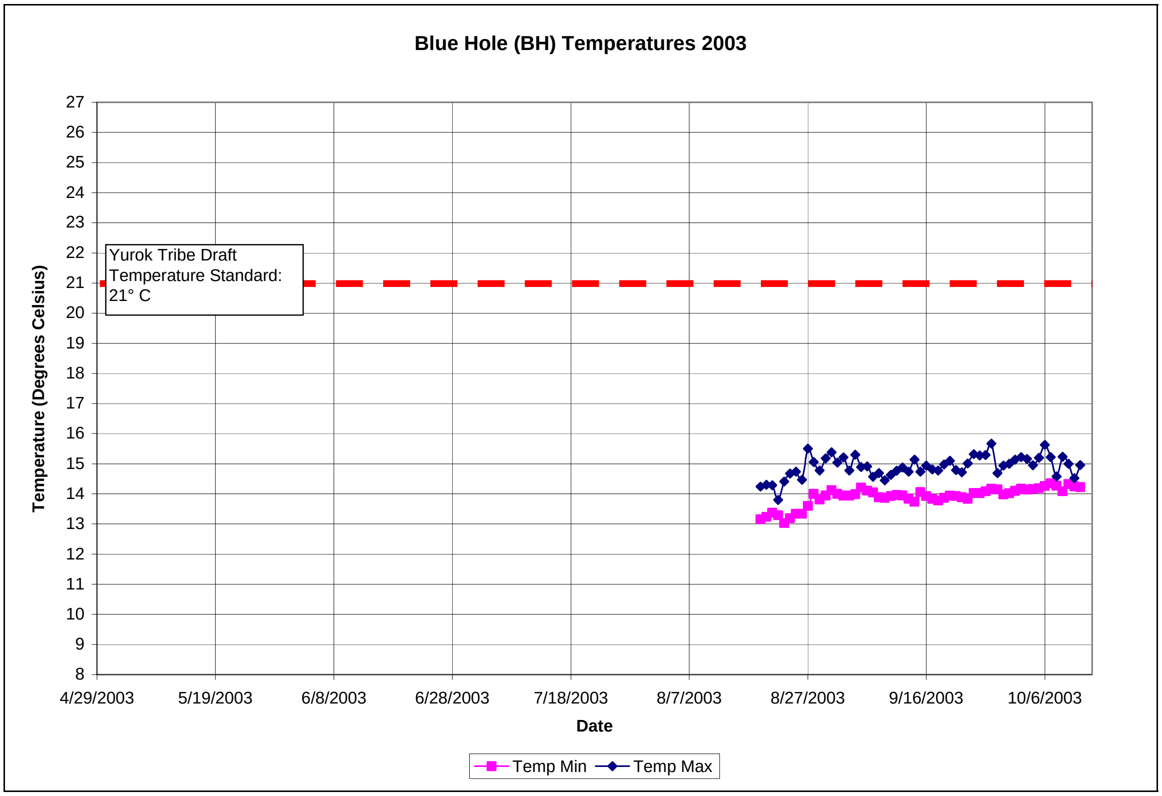


Figure 7-125 Water Temperature Values for Blue Hole WY03

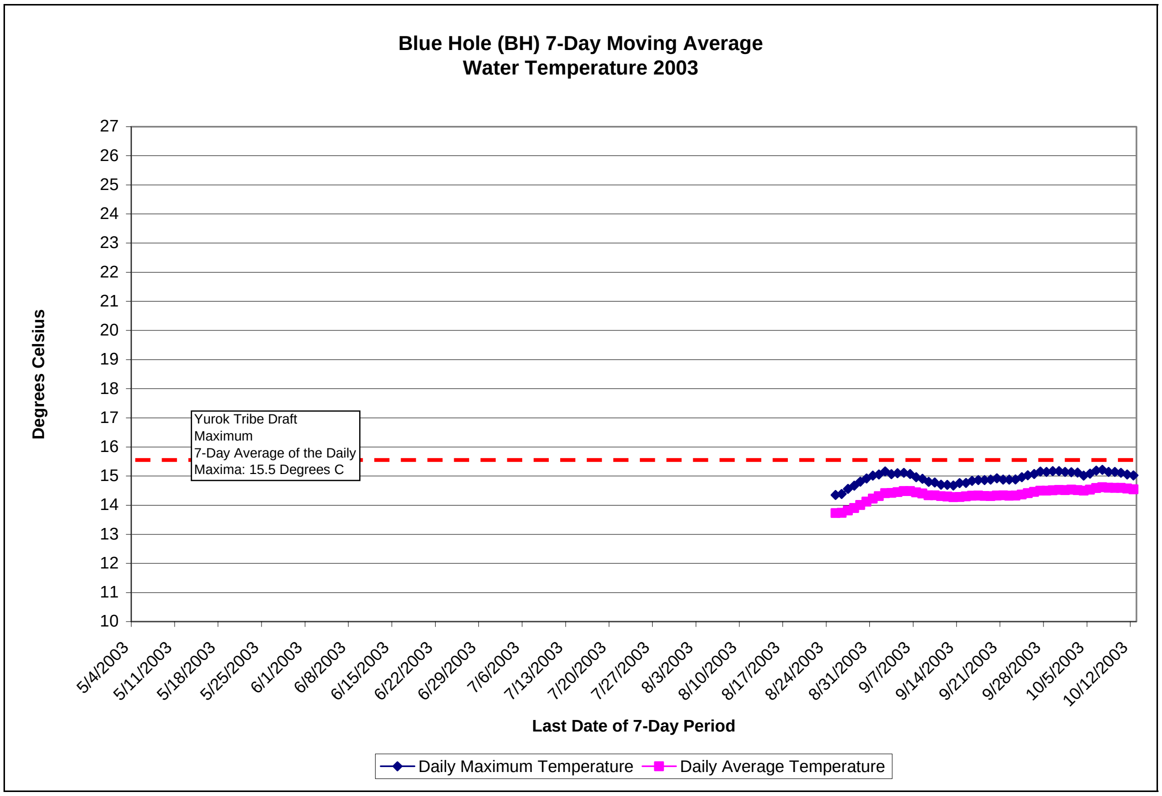


Figure 7-126 7-Day Moving Average Water Temperature for Blue Hole WY03

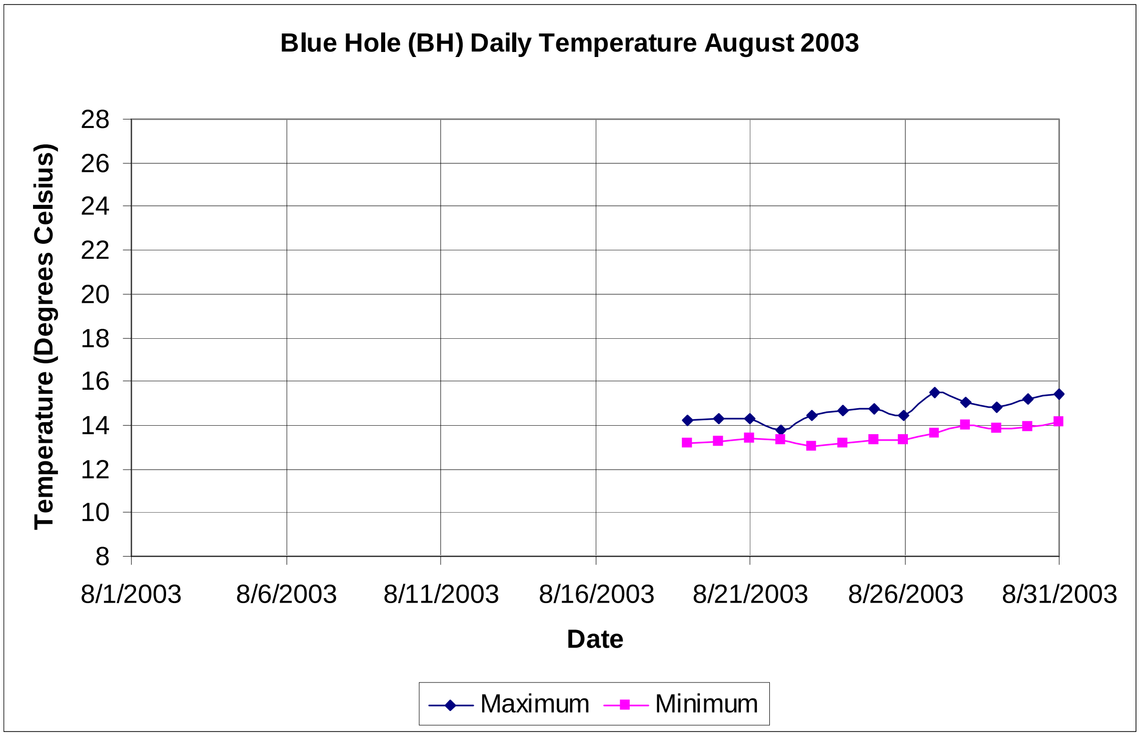


Figure 7-127 Water Temperature Values for Blue Hole August 2003

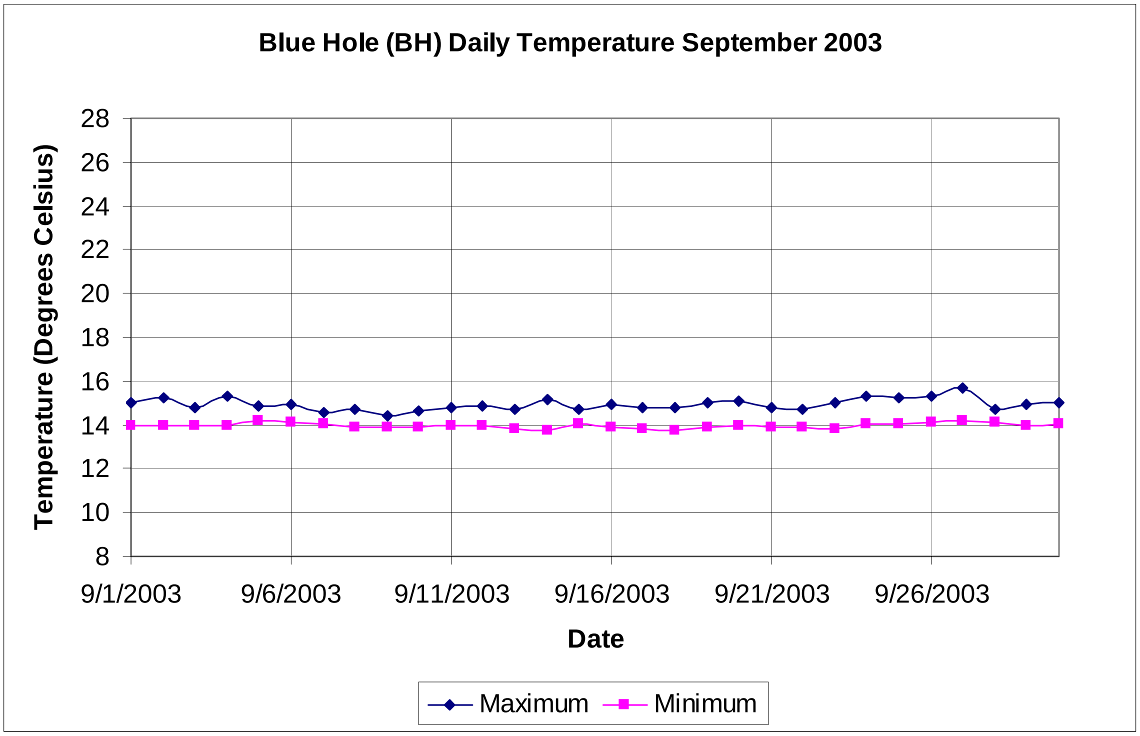


Figure 7-128 Water Temperature Values for Blue Hole September 2003

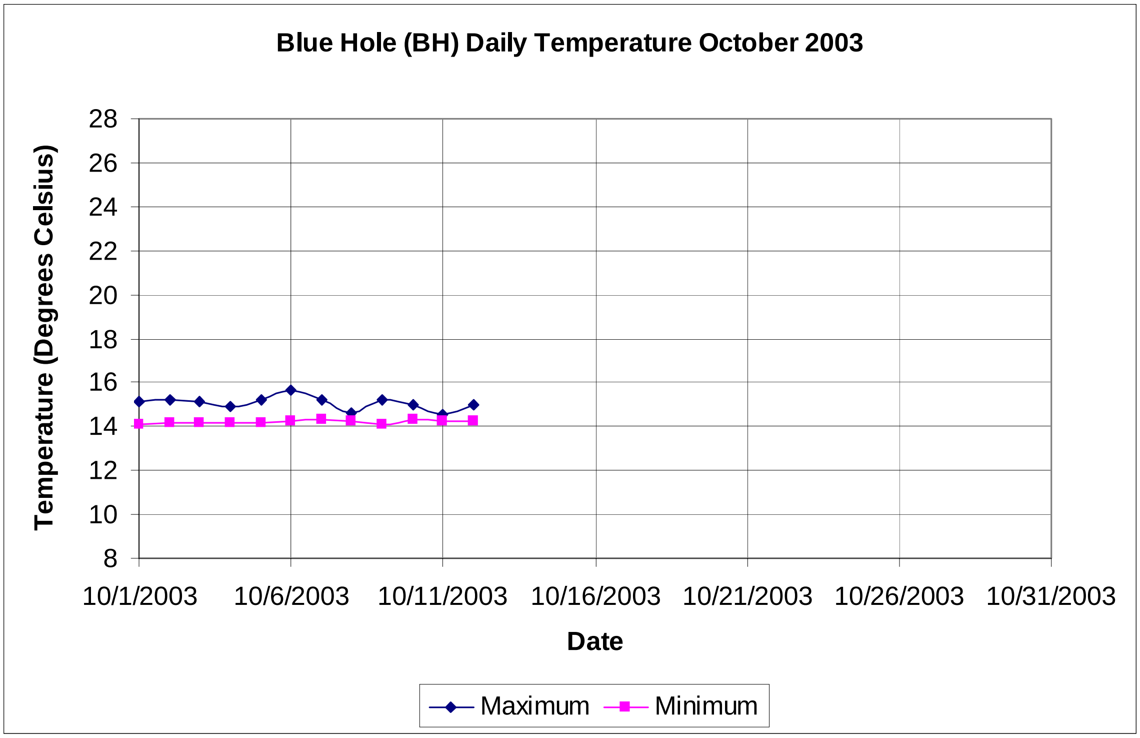


Figure 7-129 Water Temperature Values for Blue Hole October 2003

7.1.8.2 Dissolved Oxygen

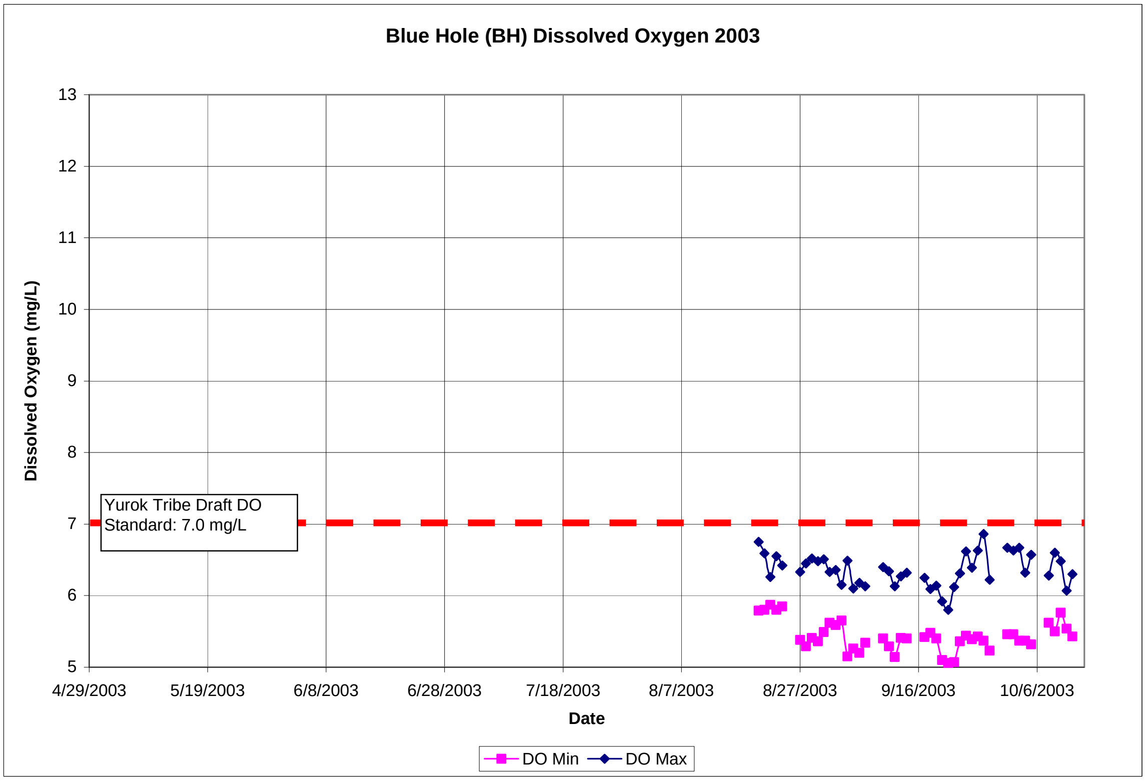


Figure 7-130 Dissolved Oxygen Values for Blue Hole WY03

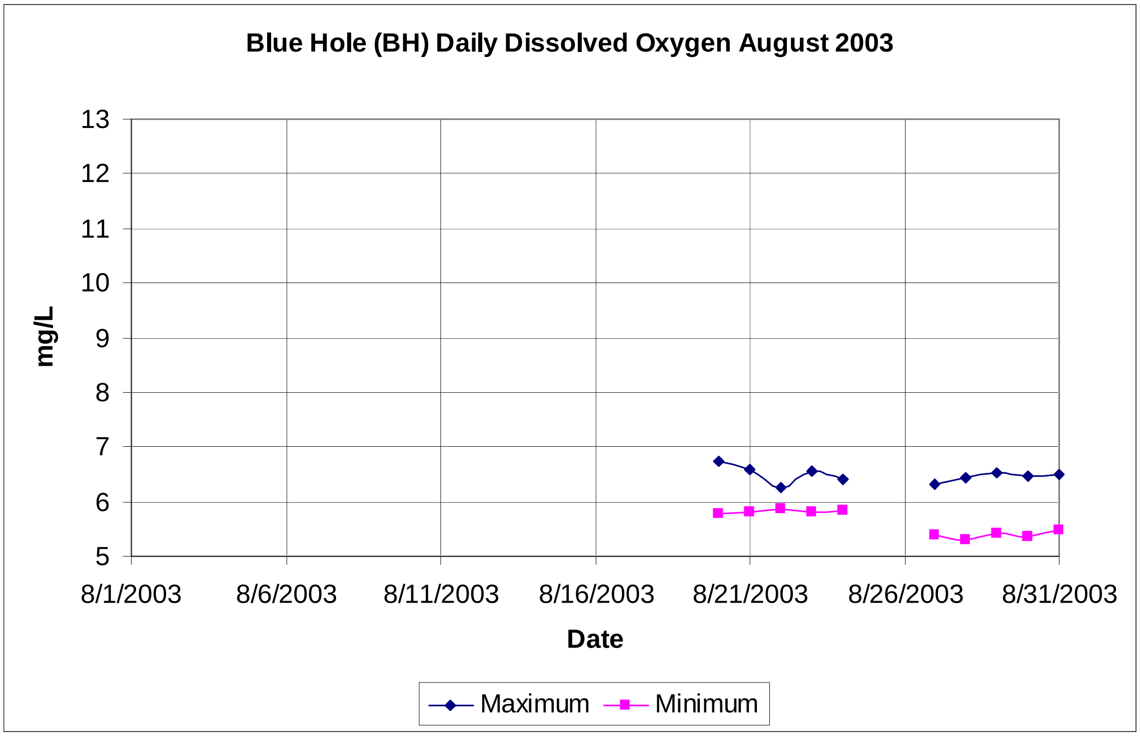


Figure 7-131 Dissolved Oxygen Values for Blue Hole August 2003

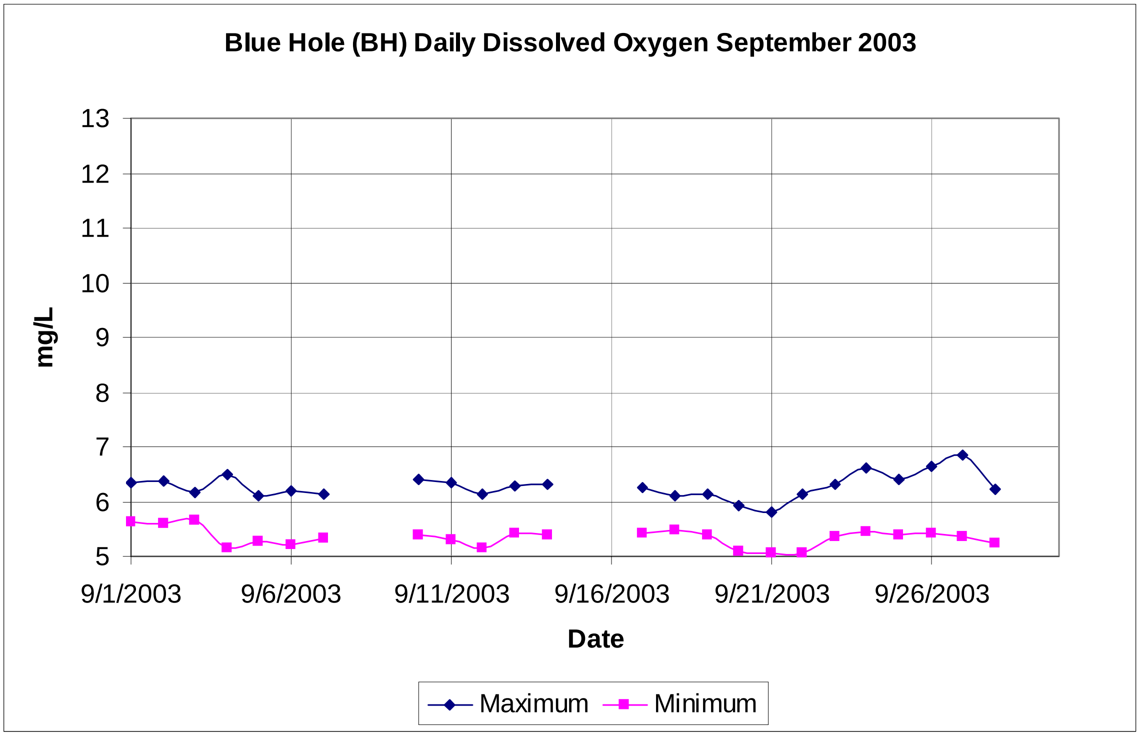


Figure 7-132 Dissolved Oxygen Values for Blue Hole September 2003

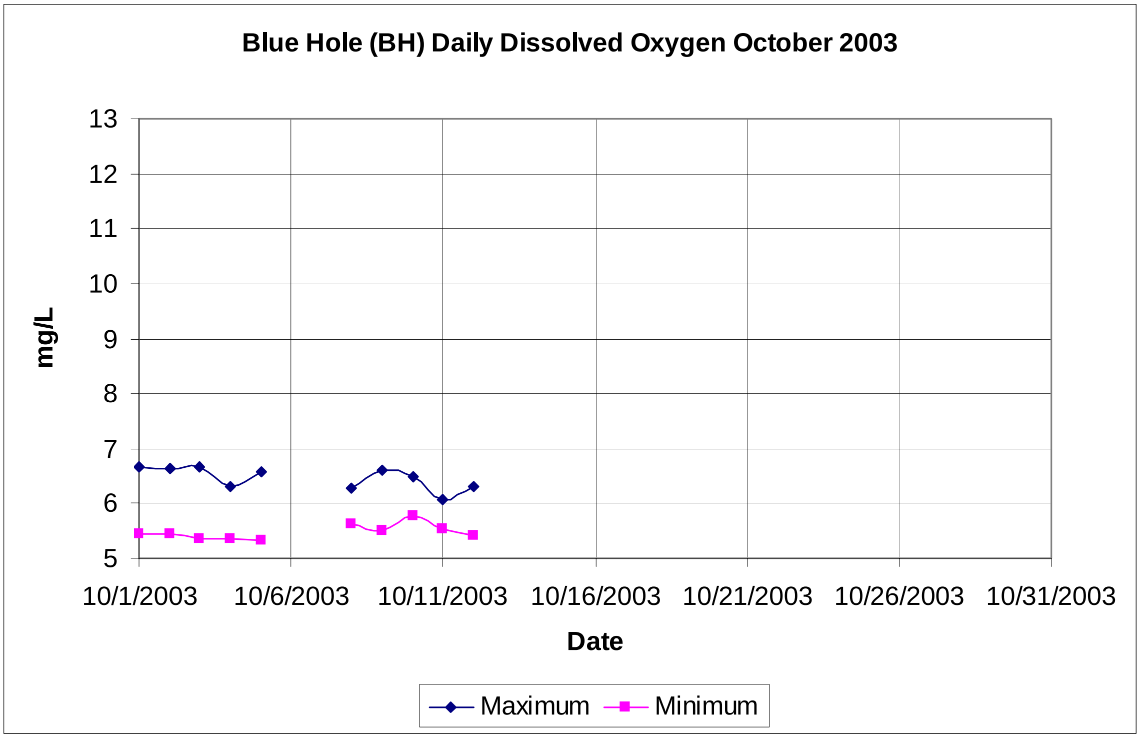


Figure 7-133 Dissolved Oxygen Values for Blue Hole October 2003

7.1.8.3 pH

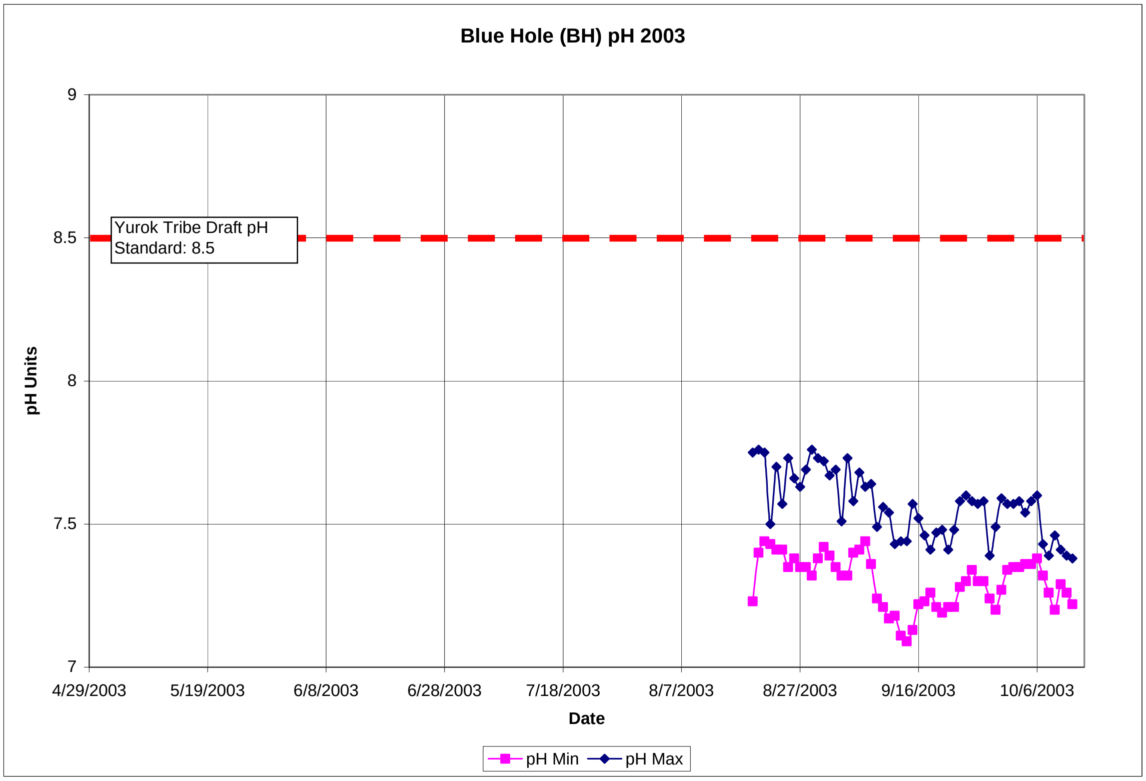


Figure 7-134 pH Values for Blue Hole WY03

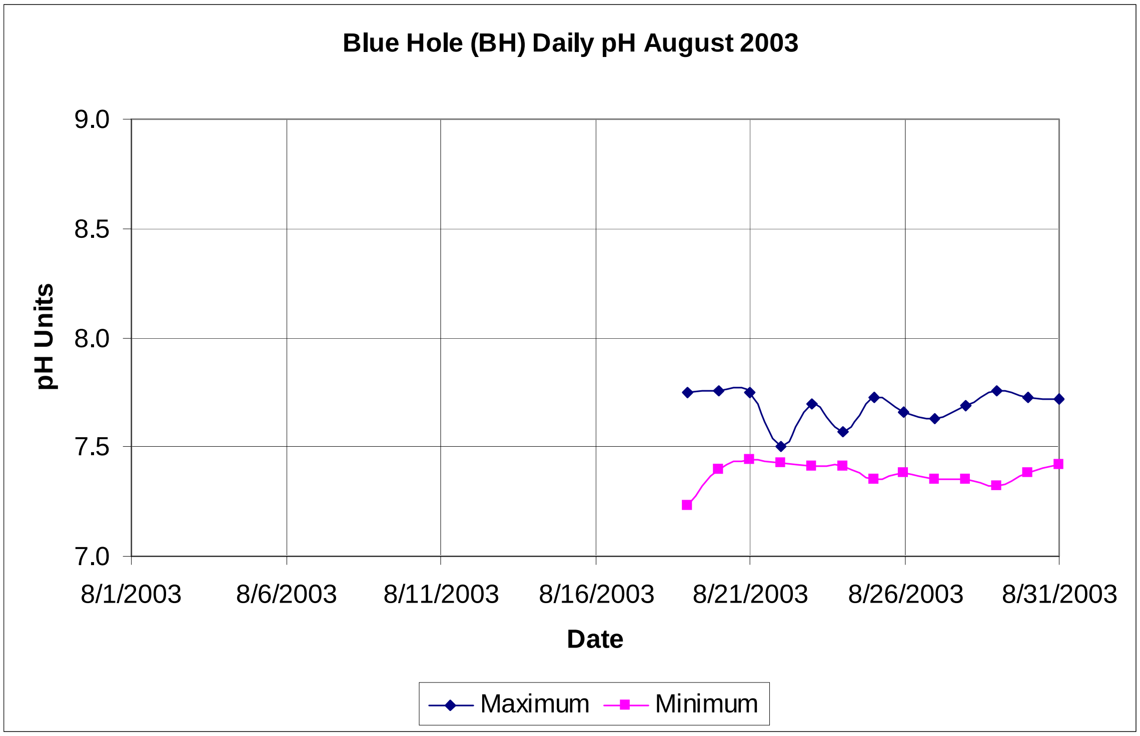


Figure 7-135 pH Values for Blue Hole August 2003

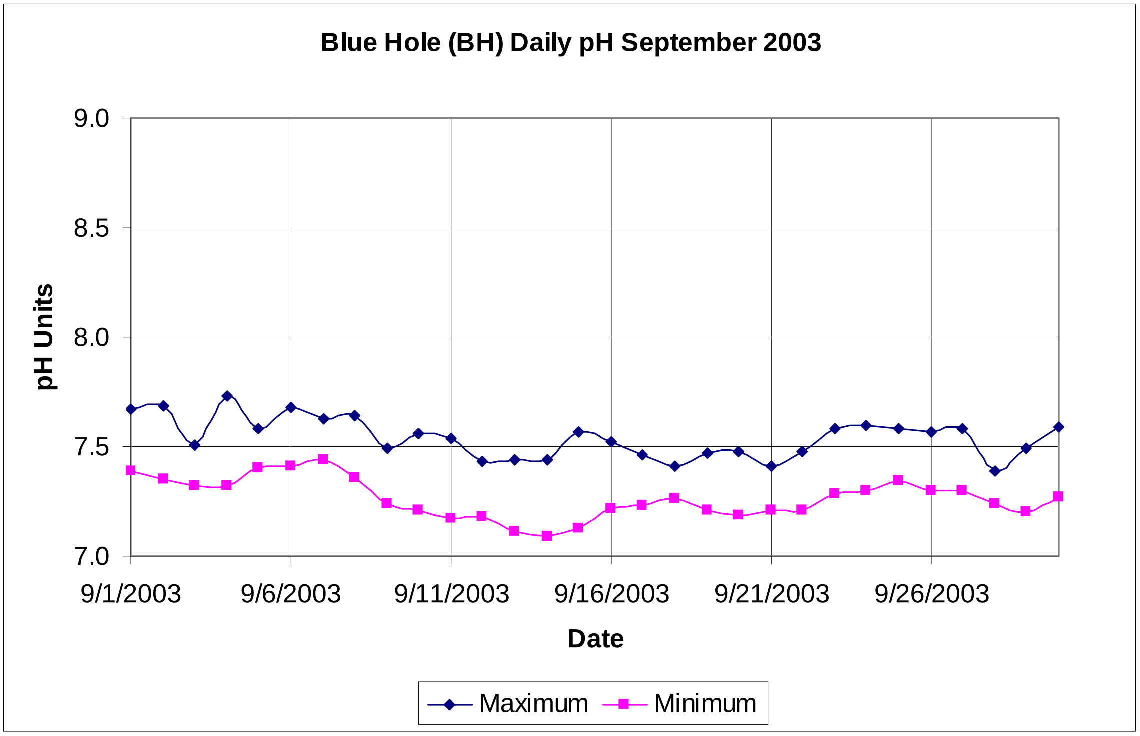


Figure 7-136 pH Values for Blue Hole September 2003

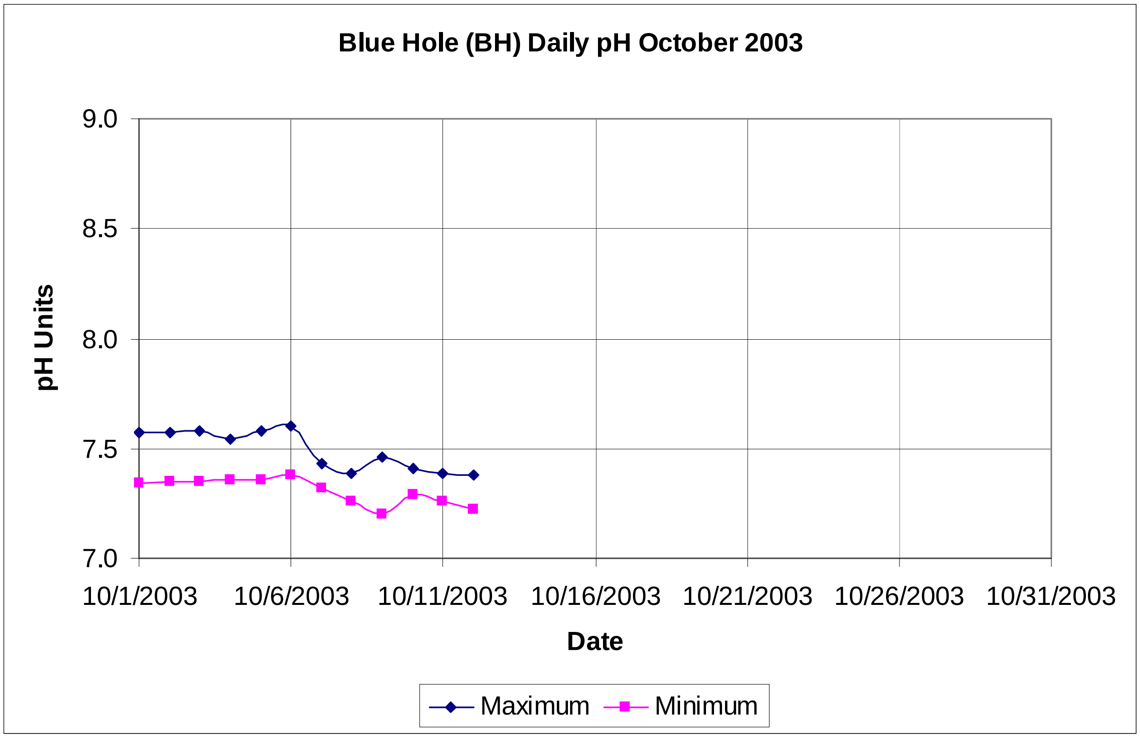


Figure 7-137 pH Values for Blue Hole October 2003

7.1.9 Klamath River at Turwar Gauge

7.1.9.1 Temperature

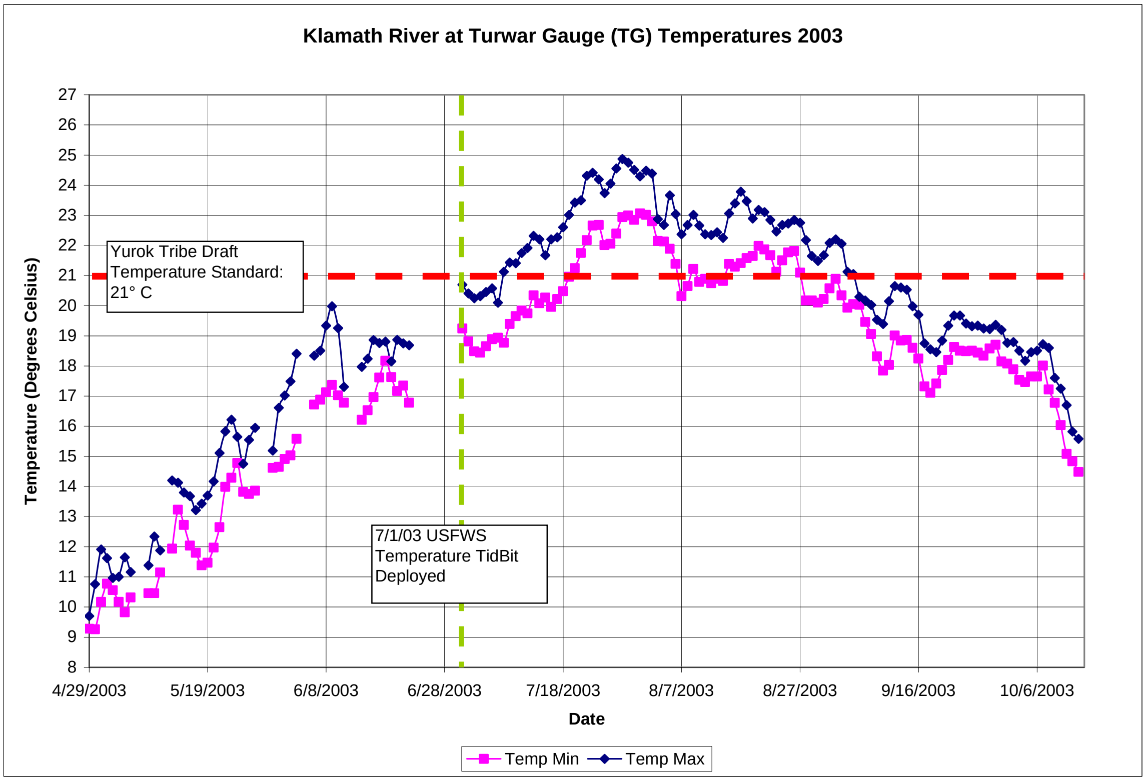


Figure 7-138 Annual Temperatures for the Klamath River at Turwar Gauge WY03

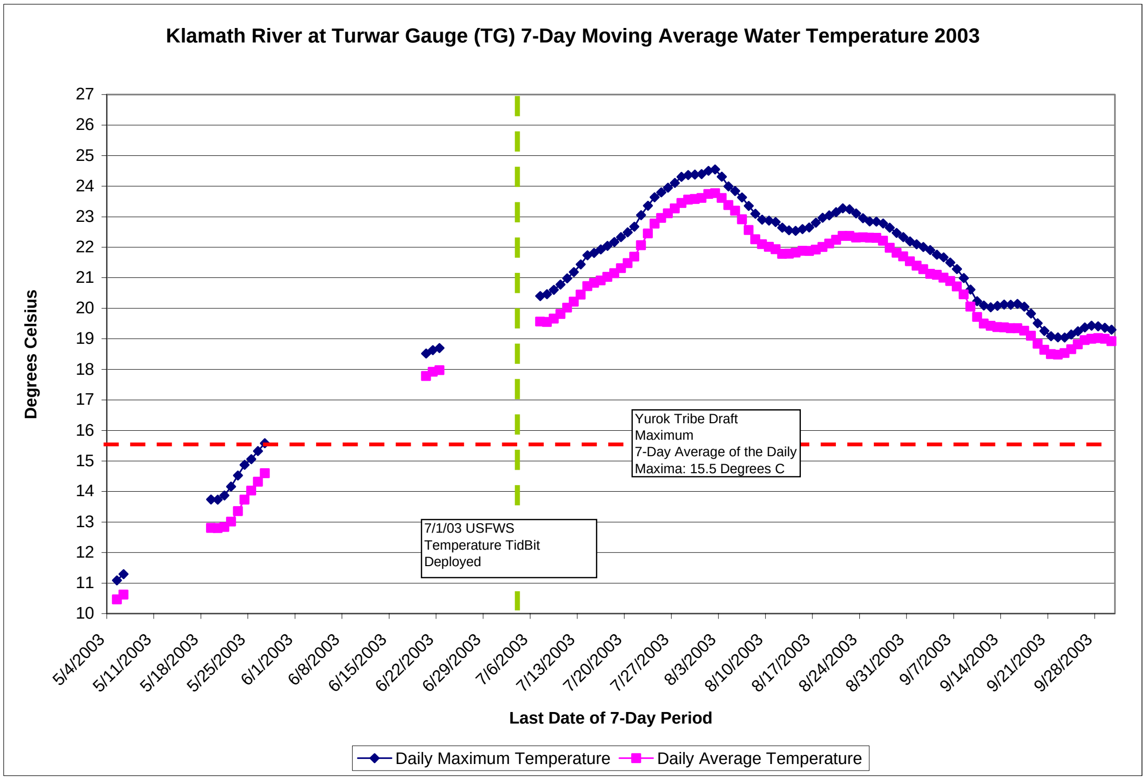


Figure 7-139 Klamath River at Turwar Gauge Water Temperature 7-Day Moving Average WY03

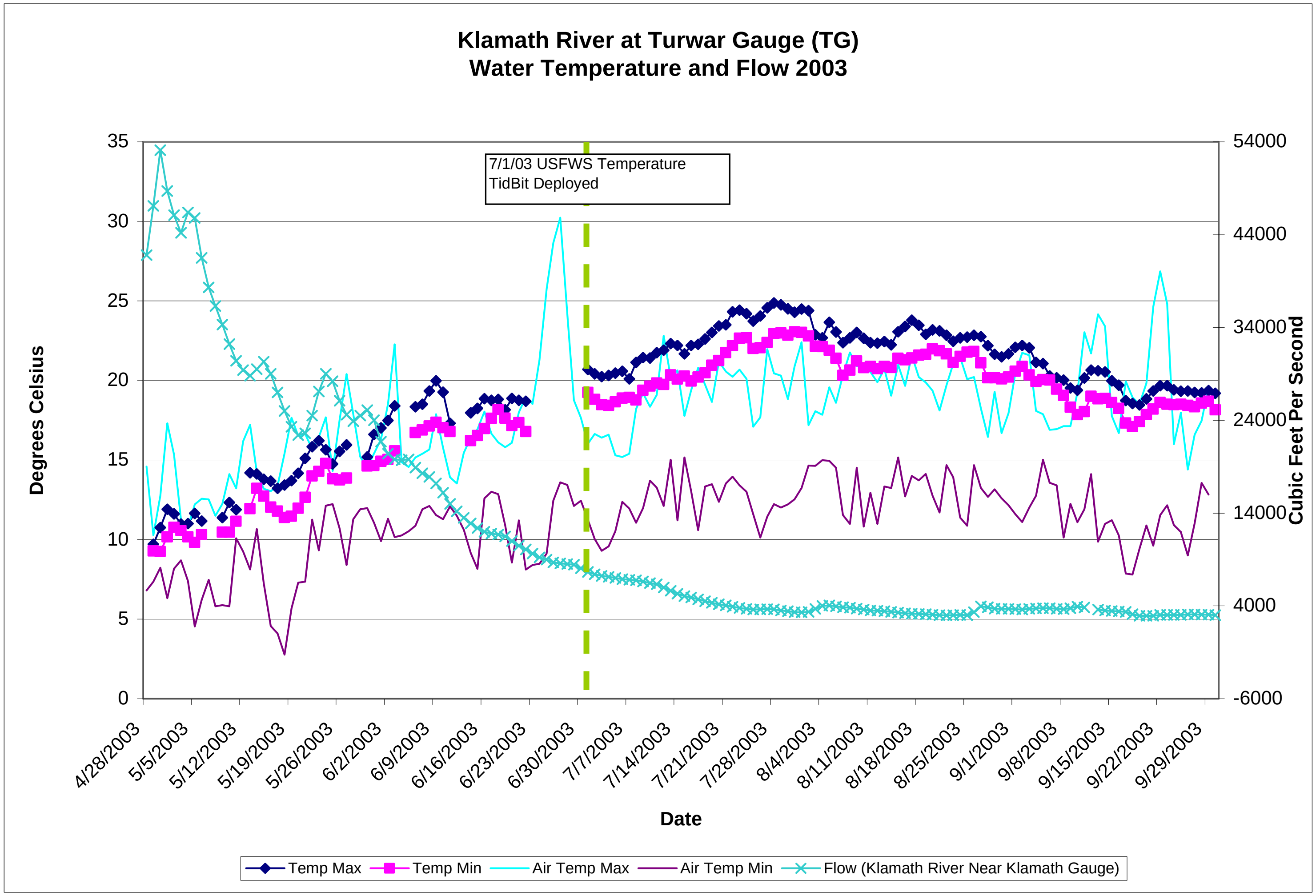


Figure 7-140 Daily Air and Water Temperature and Flow values for the Klamath River at Turwar Gauge WY03

Note: Flow values in the above figure have not been corrected for tidal influence by USGS. USGS estimates that the values given above are within 5% of the correct value; corrected data has not been released by USGS at the time of this report.

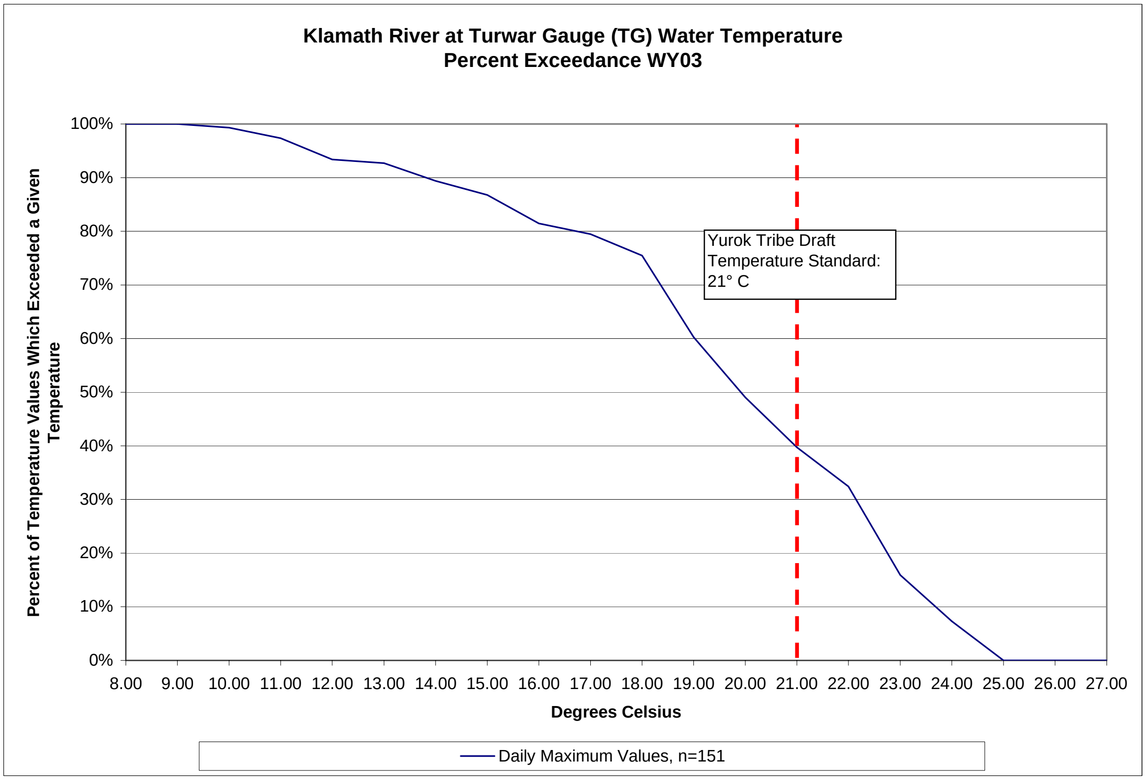


Figure 7-141 Klamath River at Turwar Gauge Water Temperature Percent Exceedance WY03

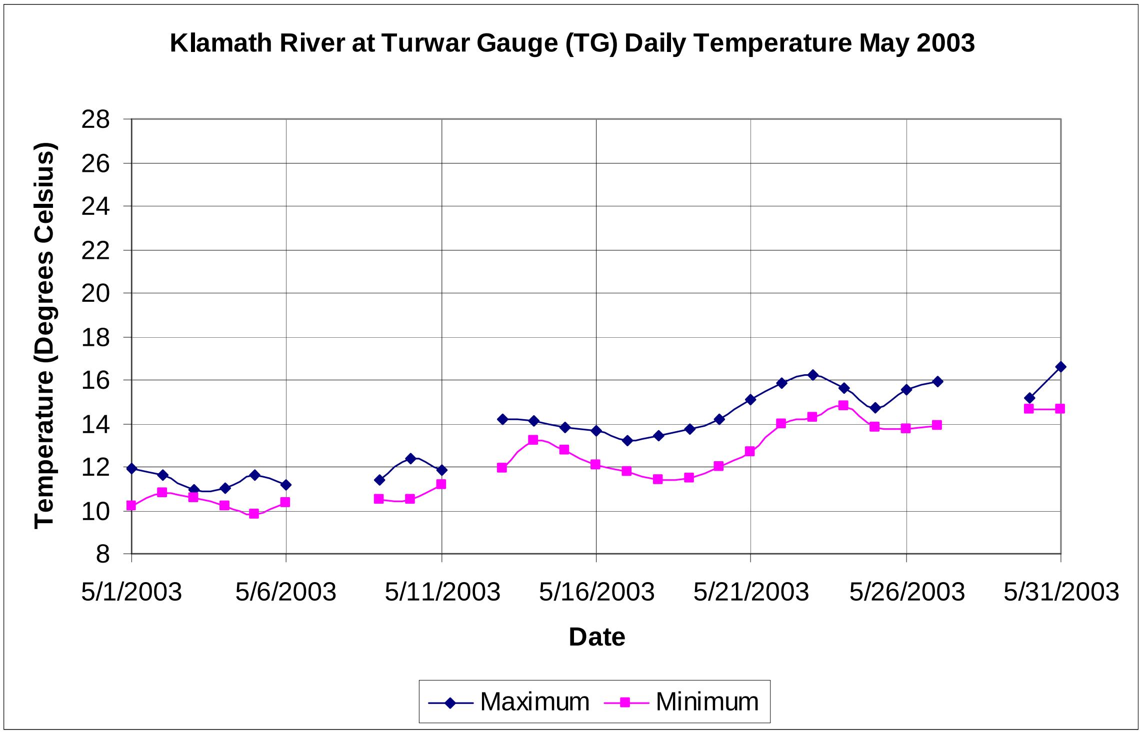


Figure 7-142 Daily Temperatures for the Klamath River at Turwar Gauge May 2003

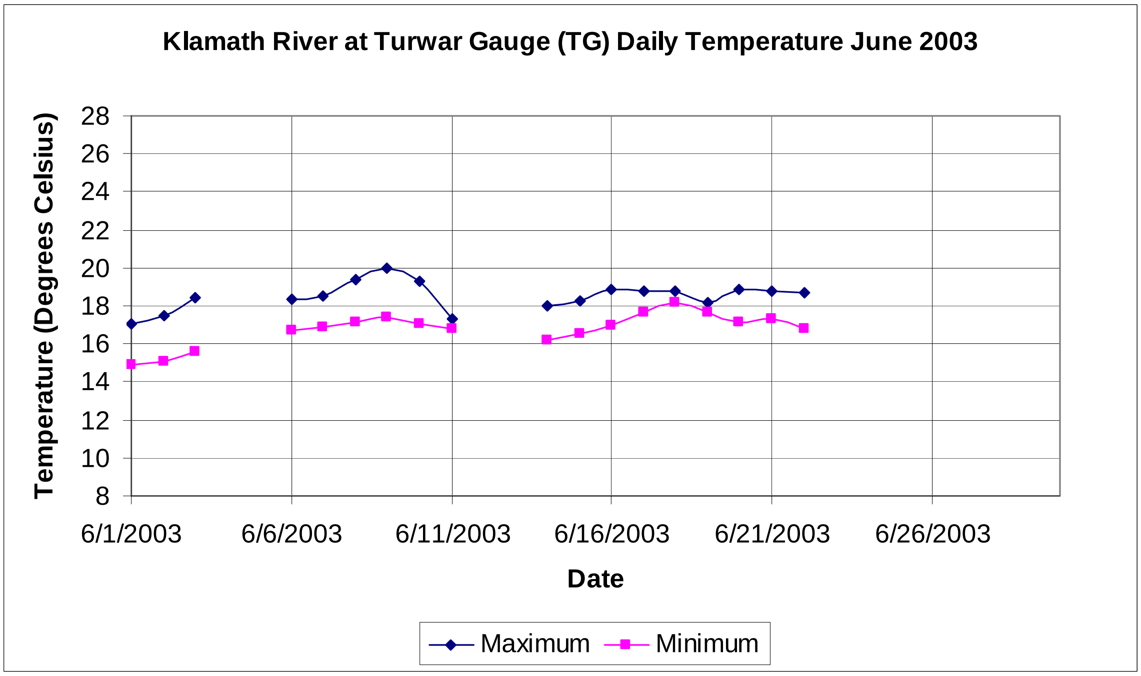


Figure 7-143 Daily Temperatures for the Klamath River at Turwar Gauge June 2003

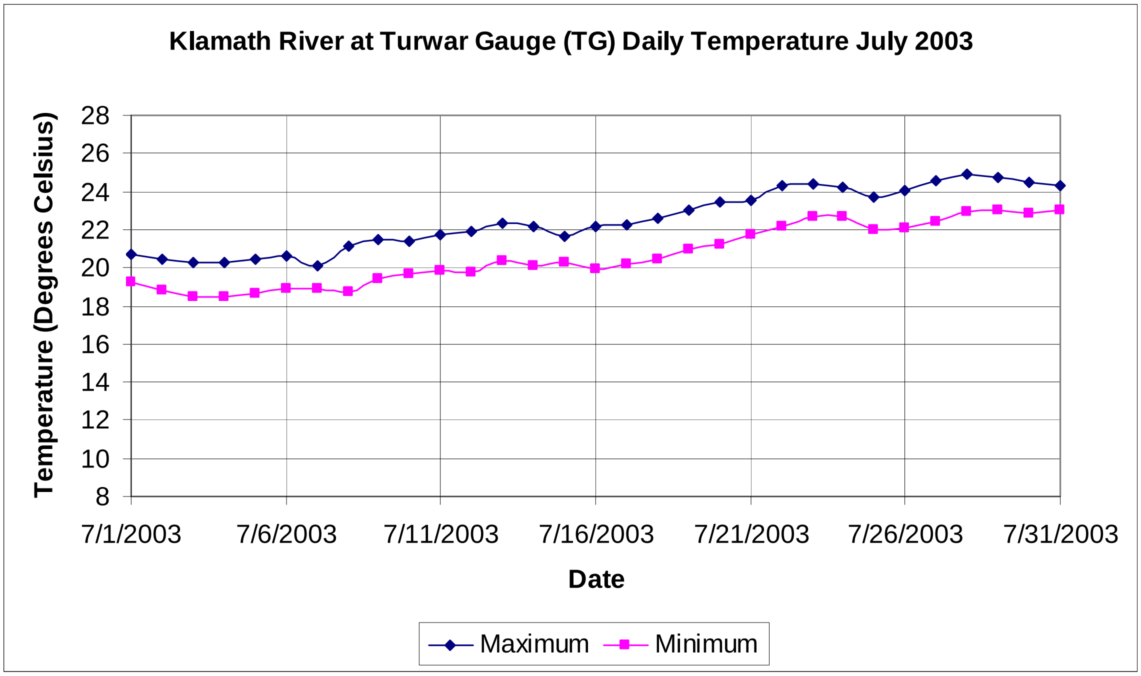


Figure 7-144 Daily Temperatures for the Klamath River at Turwar Gauge July 2003

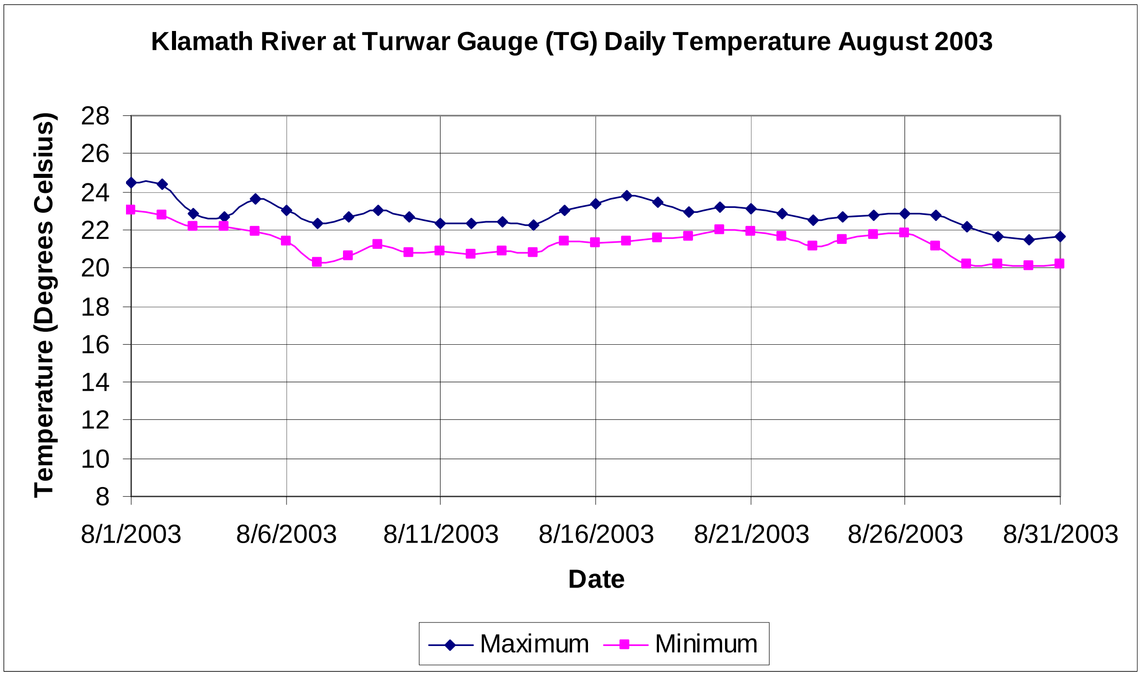


Figure 7-145 Daily Temperatures for the Klamath River at Turwar Gauge August 2003

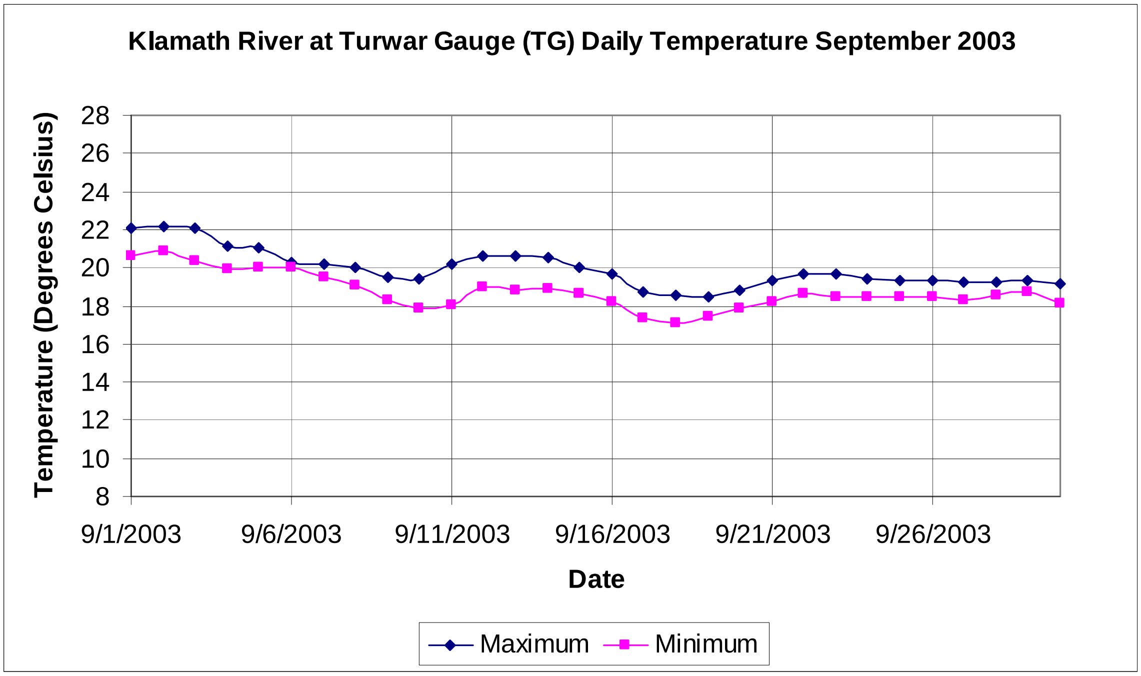


Figure 7-146 Daily Temperatures for the Klamath River at Turwar Gauge September 2003

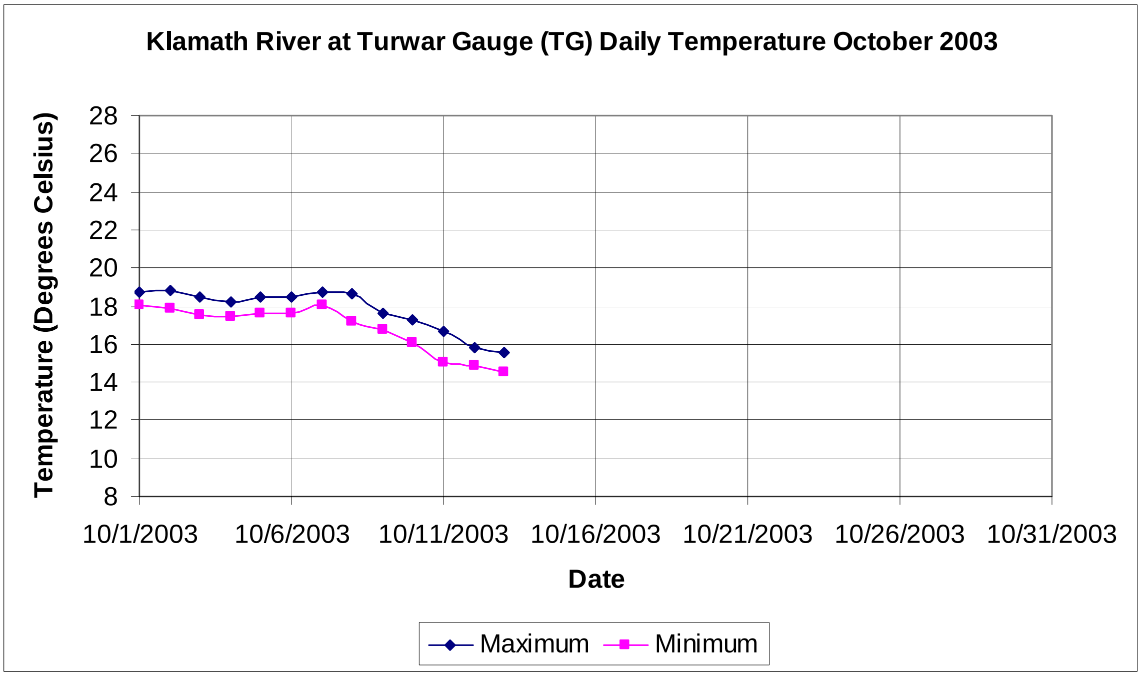


Figure 7-147 Daily Temperatures for the Klamath River at Turwar Gauge October 2003

7.1.9.2 Dissolved Oxygen

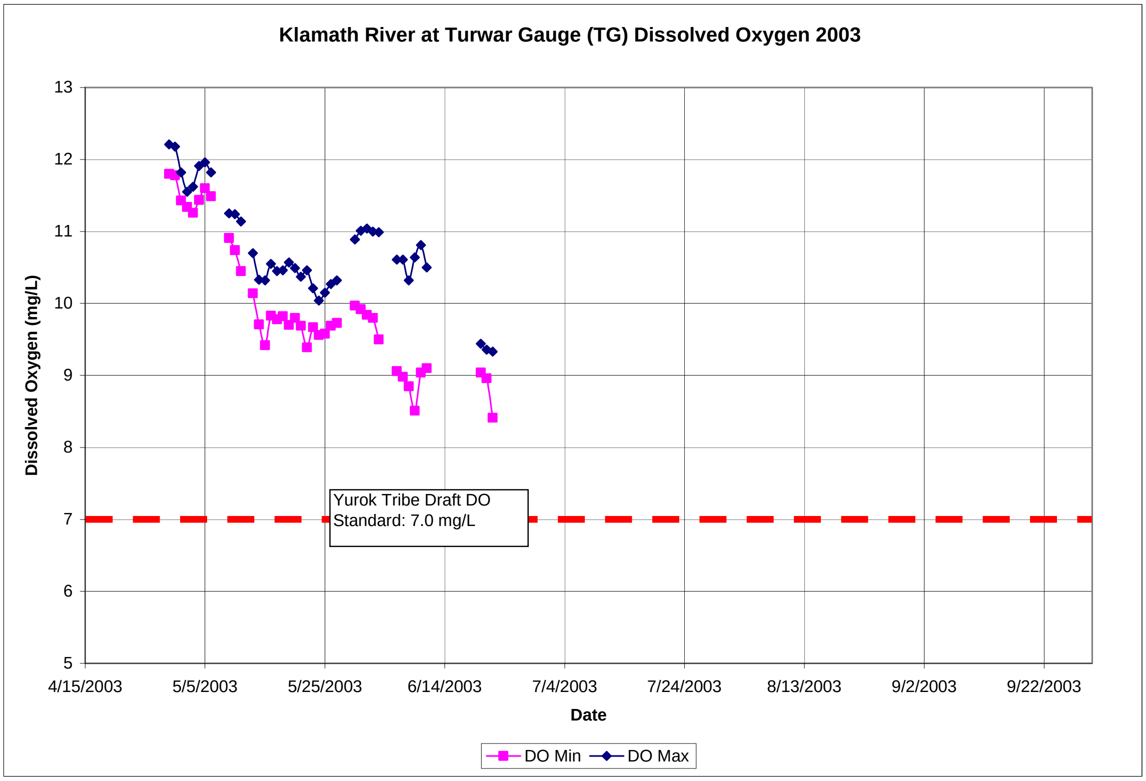


Figure 7-148 Daily DO values for the Klamath River at Turwar Gauge WY03

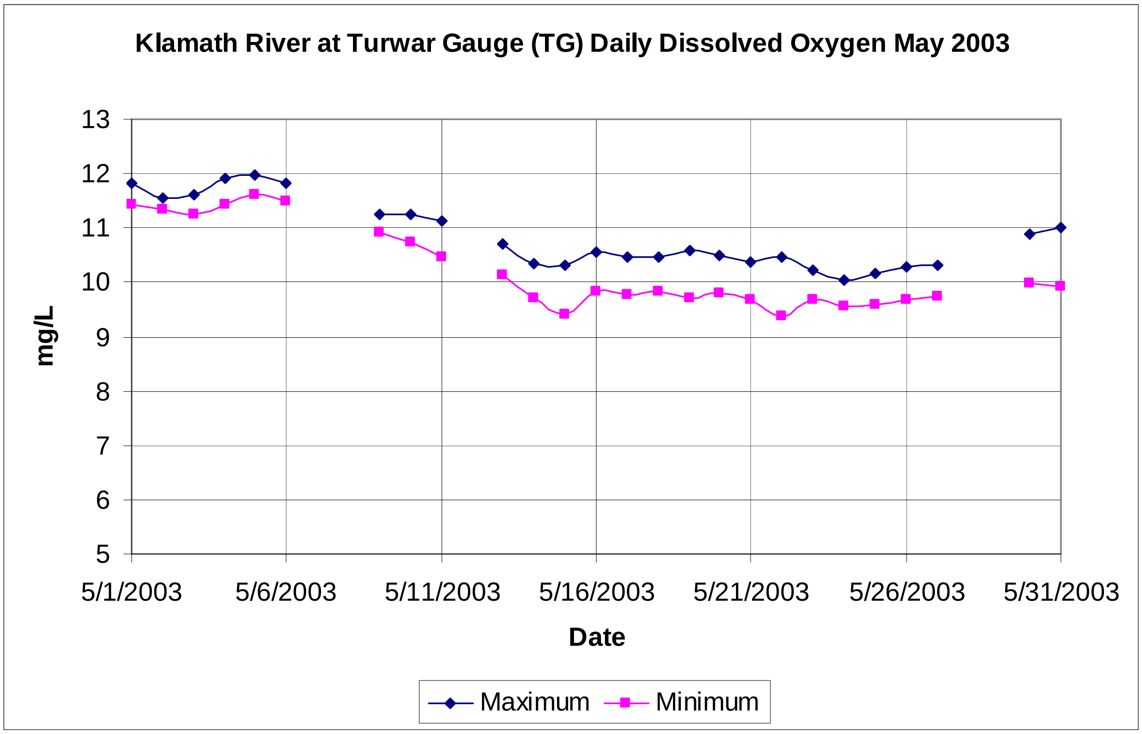


Figure 7-149 Daily DO values for the Klamath River at Turwar Gauge May 2003

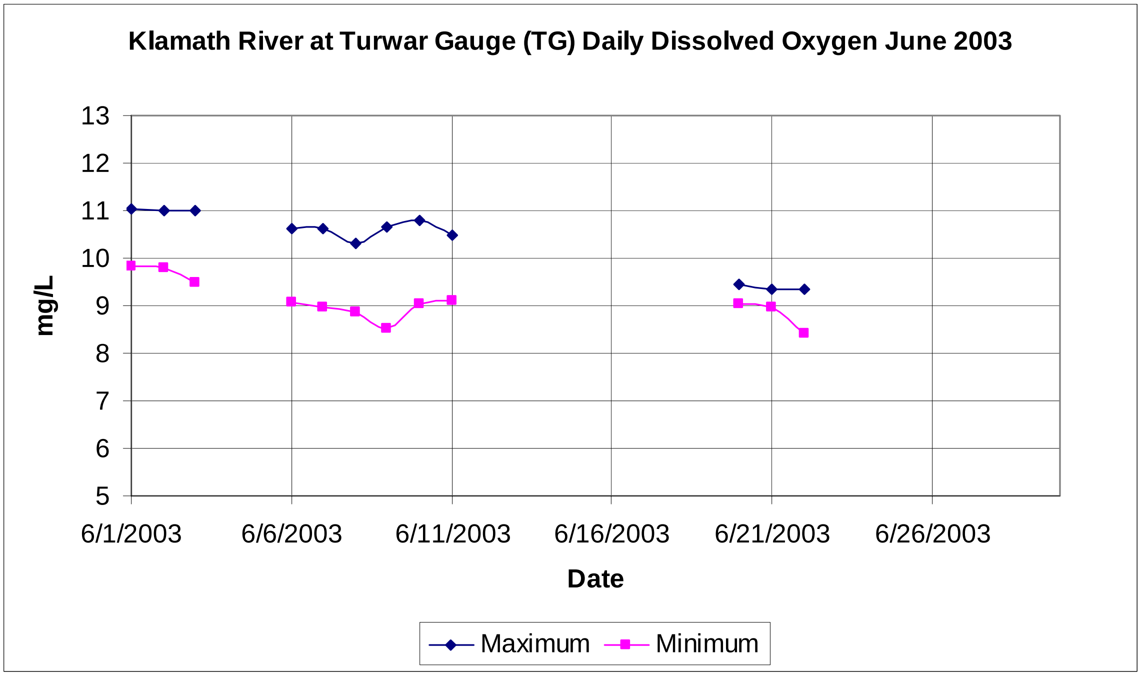


Figure 7-150 Daily DO values for the Klamath River at Turwar Gauge June 2003

7.1.9.3 pH

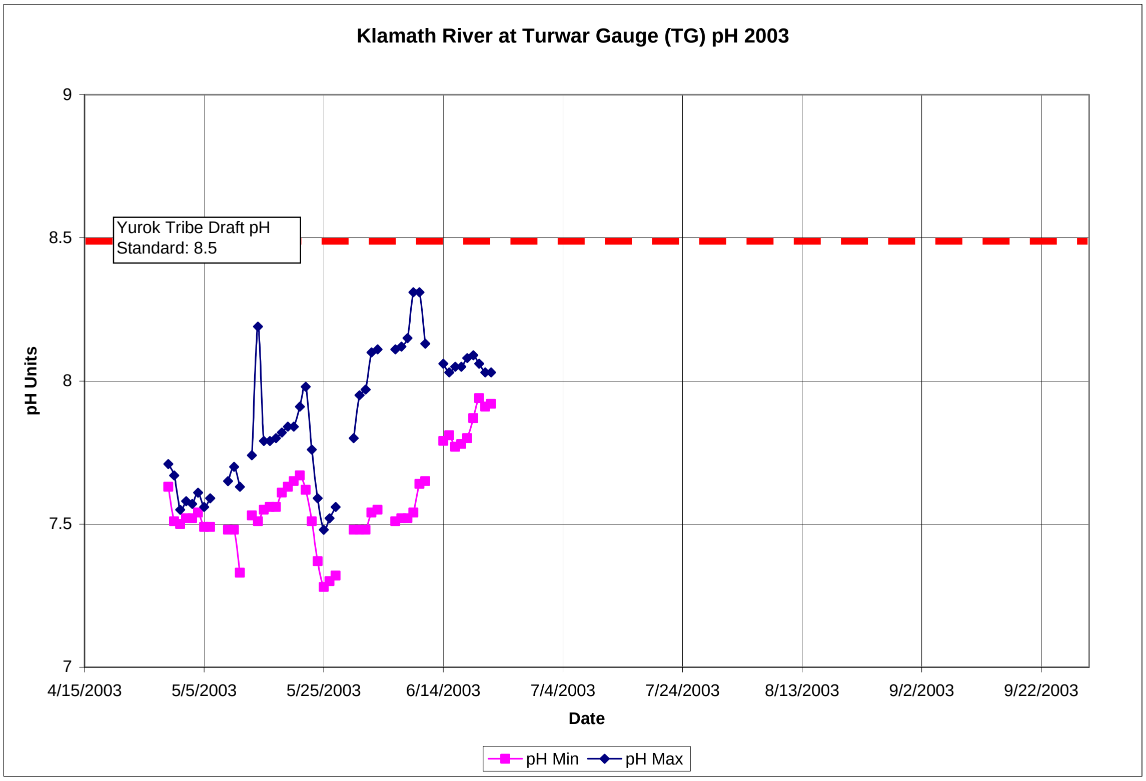


Figure 7-151 Daily pH values for the Klamath River at Turwar Gauge WY03

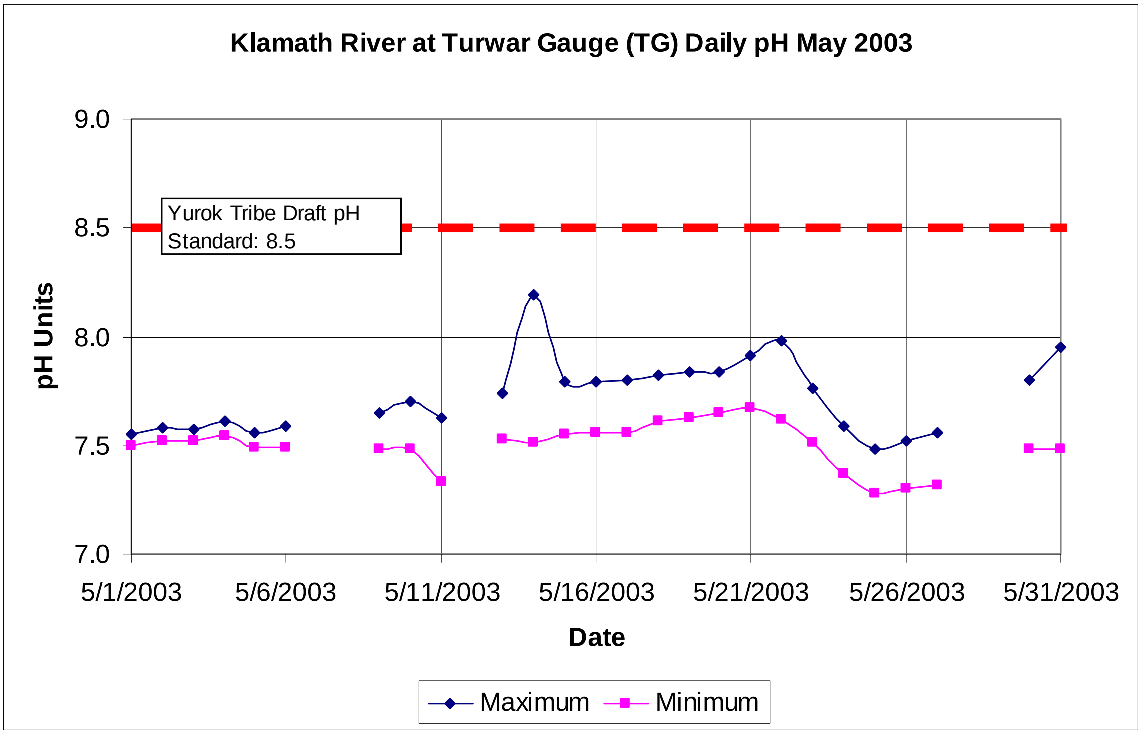


Figure 7-152 Daily pH values for the Klamath River at Turwar Gauge May 2003

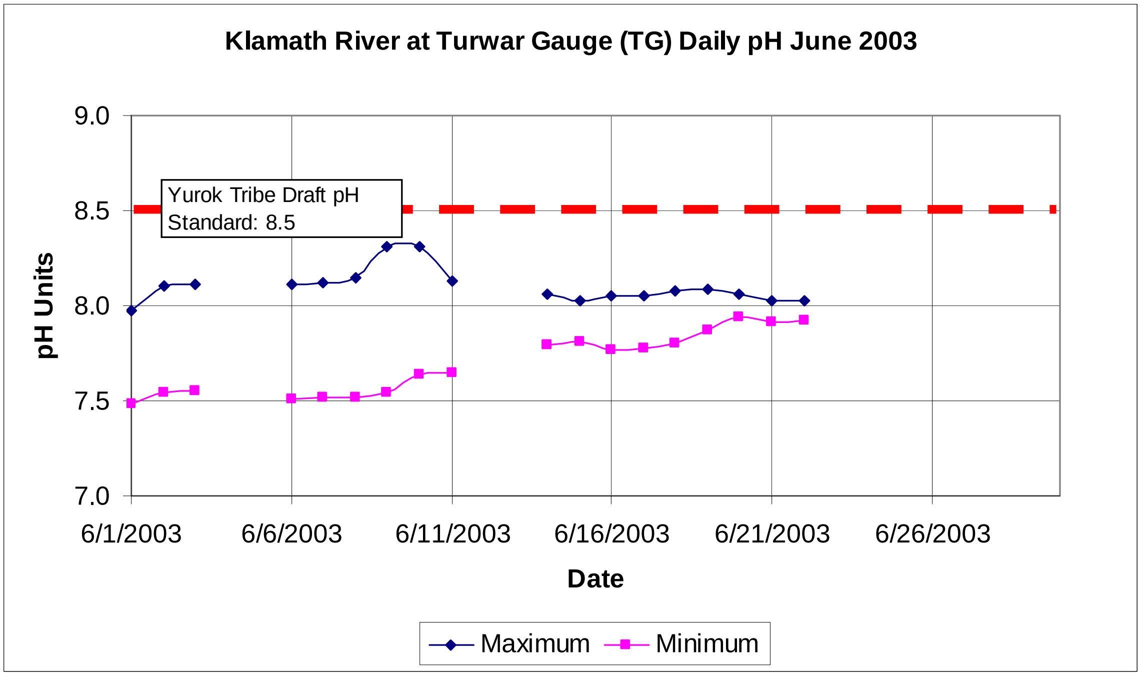


Figure 7-153 Daily pH values for the Klamath River at Turwar Gauge June 2003

7.1.10 Multi-Site Comparisons

7.1.10.1 Comparison: Maximum Water Temperatures Across All Sites Sampled for WY03

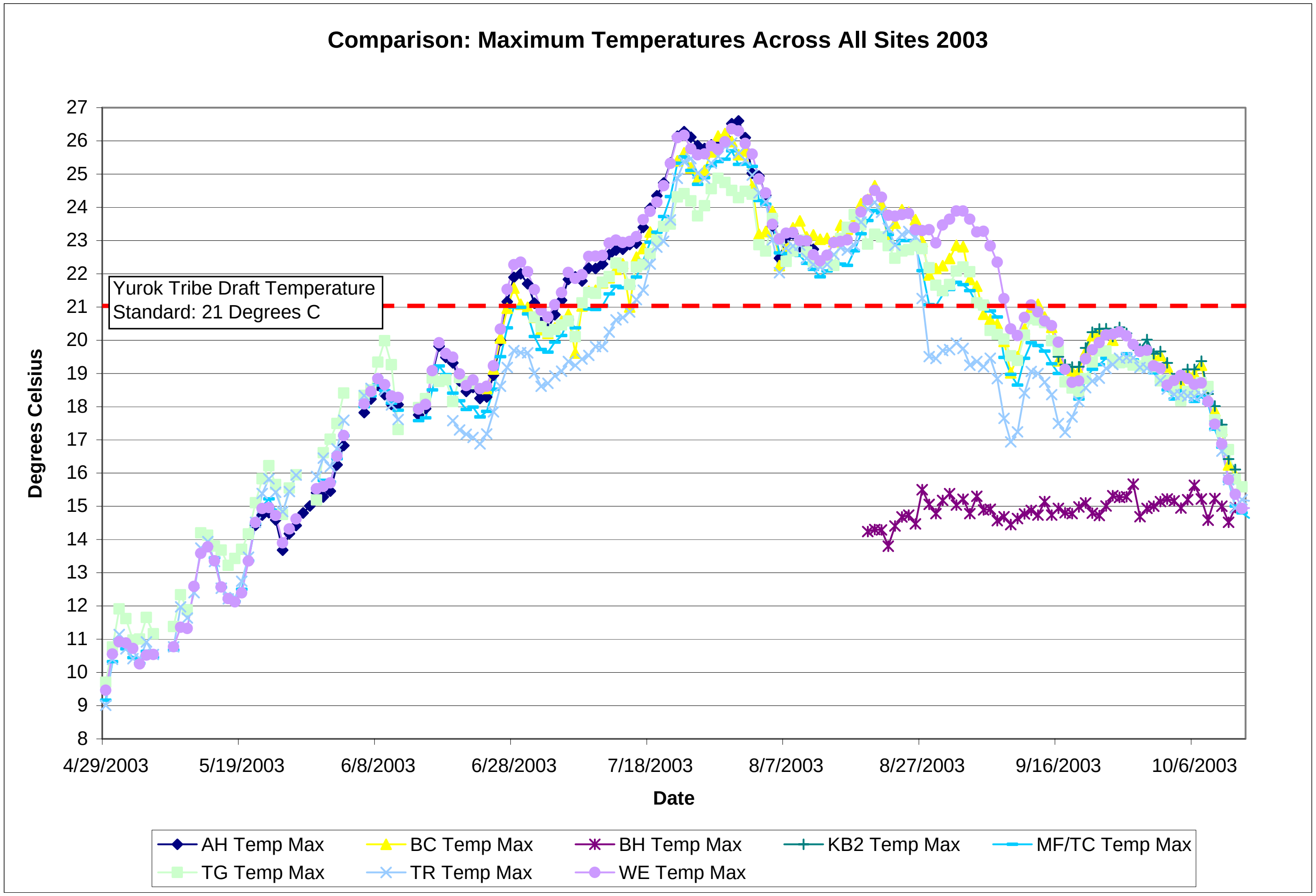


Figure 7-154 Comparison of Maximum Water Temperatures Across All Sites for WY03

7.1.10.2 Comparison: Klamath River Mainstem versus Known Klamath River Refugia Temperature and Dissolved Oxygen: Klamath River Above Blue Creek as compared with Blue Hole

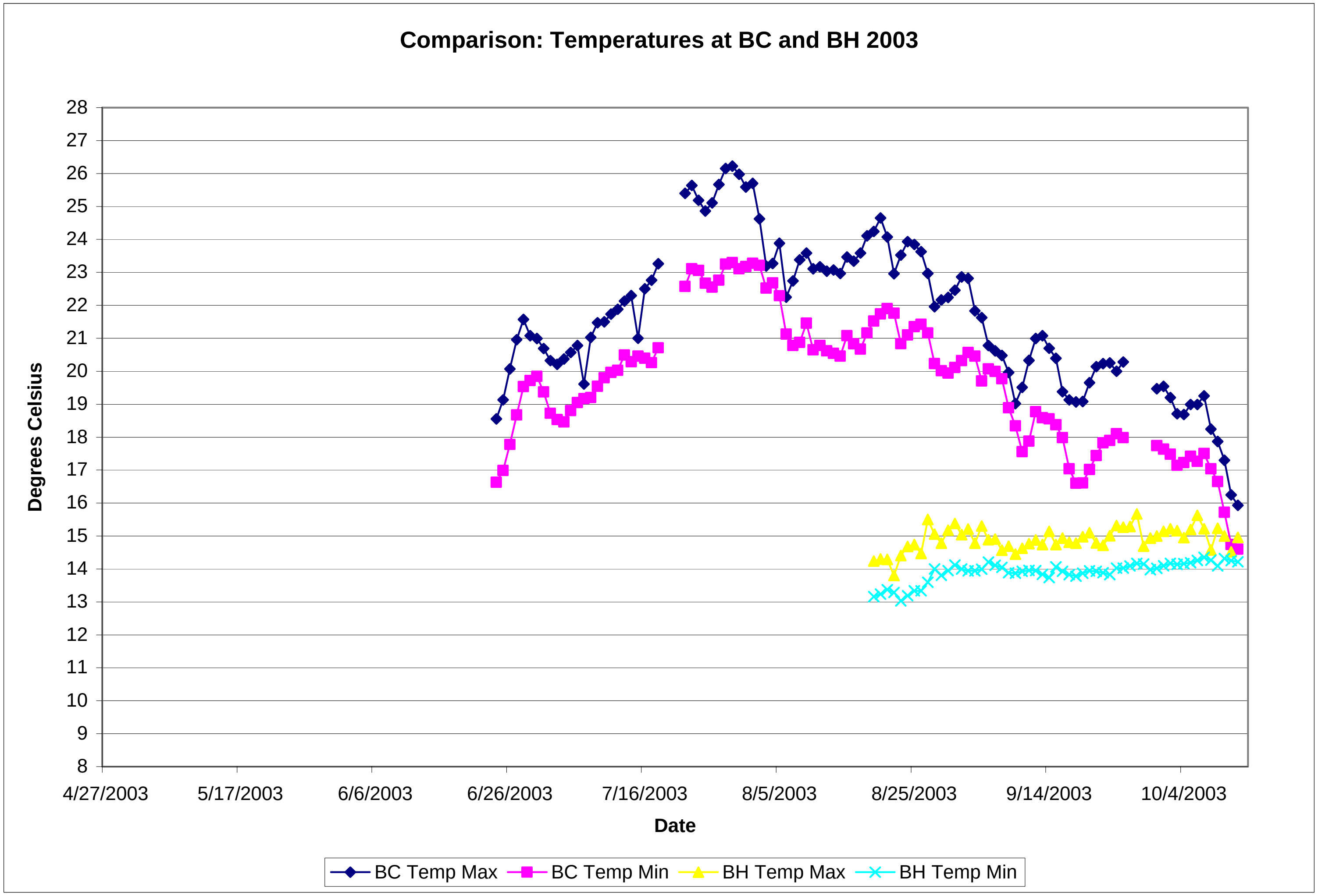


Figure 7-155 Comparison of Water Temperatures in the Klamath River Mainstem (above Blue Creek) with Temperatures in known refugia (Blue Hole)

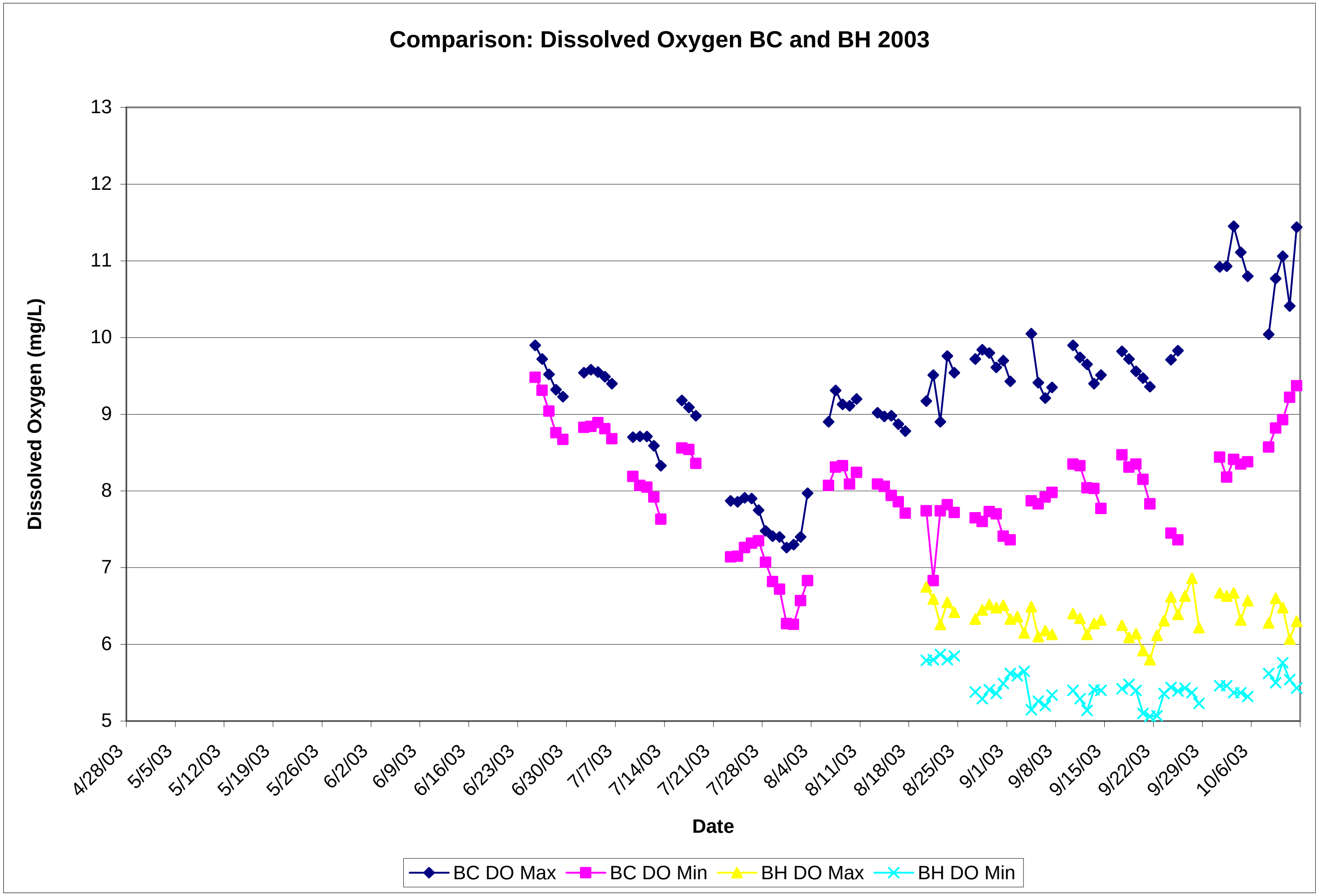


Figure 7-156 Comparison of Dissolved Oxygen Levels in the Klamath River Mainstem (above Blue Creek) with Levels in known refugia (Blue Hole)

7.1.10.3 *Comparison: Depth-Correlated Differential in Temperature and Dissolved Oxygen: Klamath River above Blue Creek at 6 Feet Deep as compared with Klamath River above Blue Creek at 25 Feet Deep*

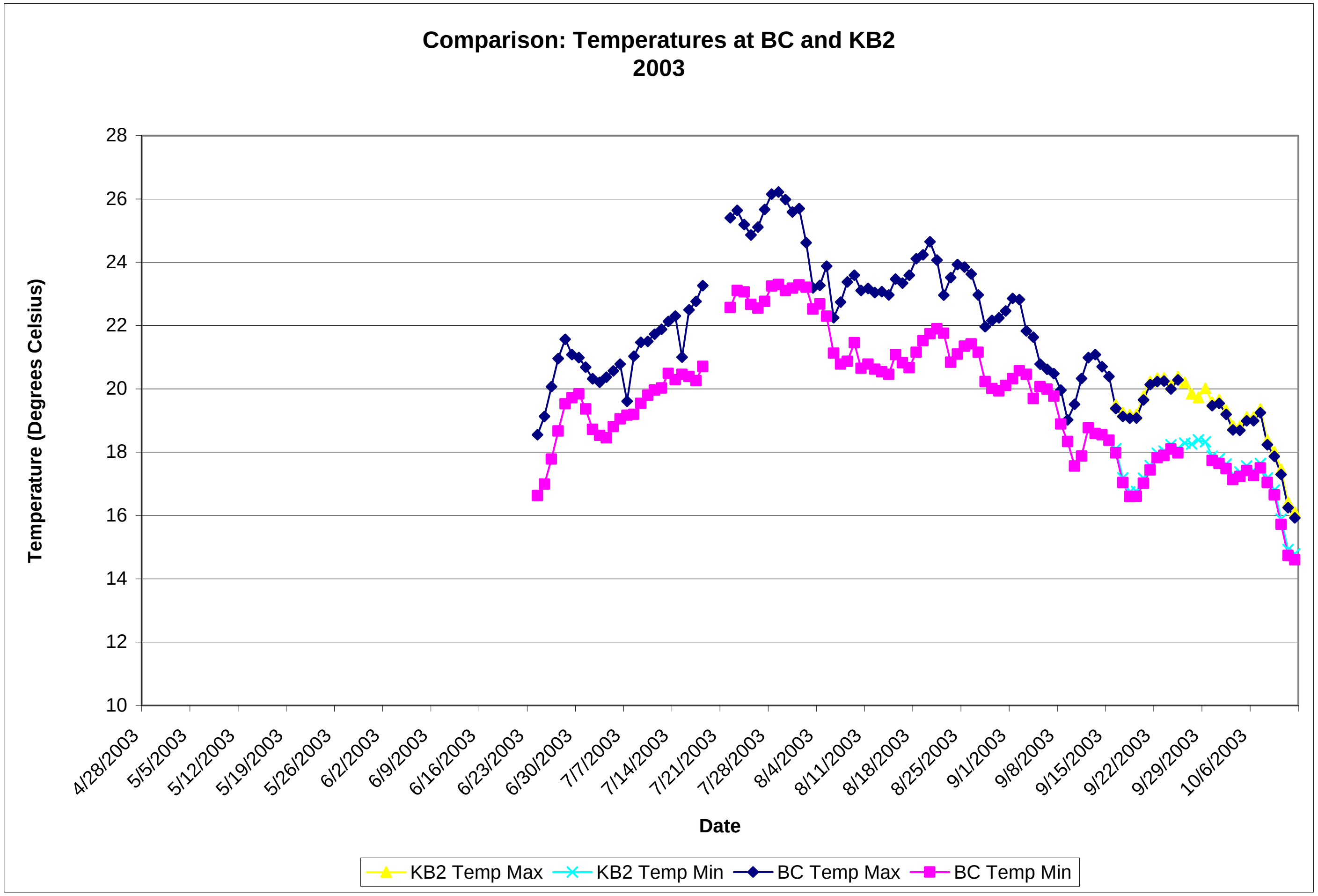


Figure 7-157 Comparison of Temperatures correlated with depth in the Klamath River Above Blue Creek (6 Feet Deep (KB2) compared with 25 Feet Deep (BC))

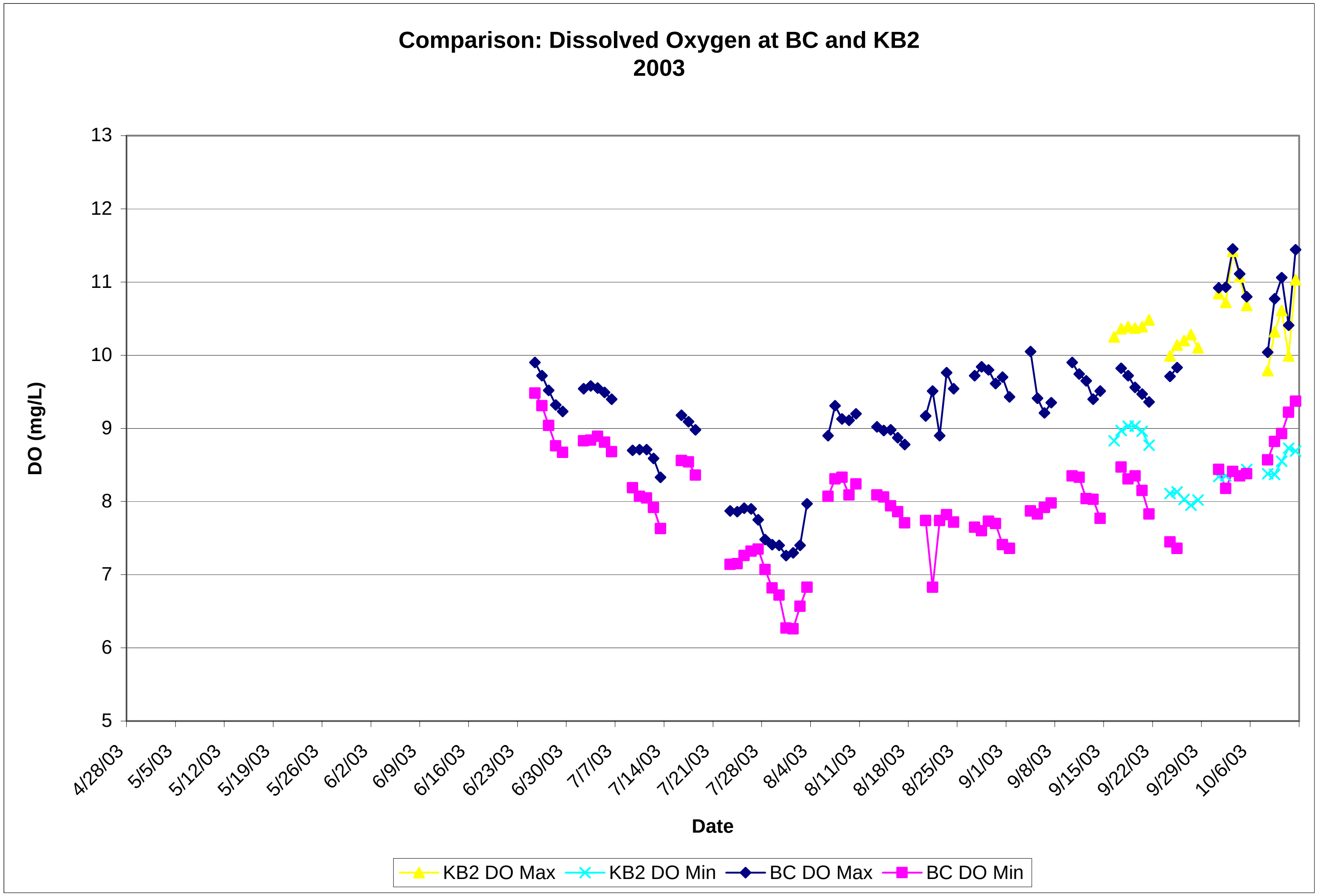


Figure 7-158 Comparison of Dissolved Oxygen Levels correlated with depth in the Klamath River Above Blue Creek (6 Feet Deep (KB2) compared with 25 Feet Deep (BC))

7.1.10.4 Comparison: Impacts of the Trinity River on Temperature in the Mainstem: Klamath River Above the Trinity River as compared with Klamath River Above Tully Creek/At Martin's Ferry

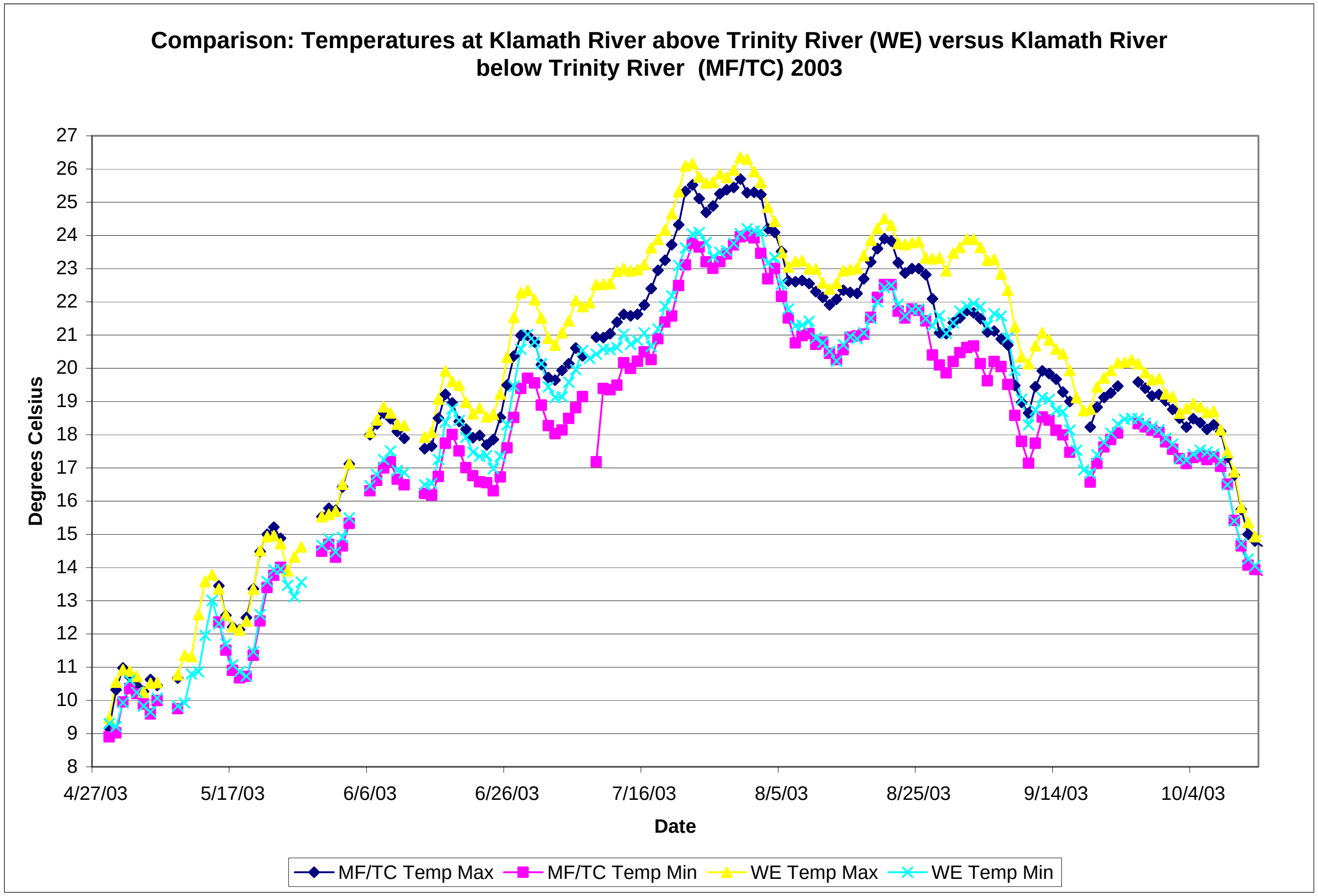


Figure 7-159 Comparison of Temperature Values in the Klamath River prior to the introduction of Trinity River Flow (Klamath River Above Trinity River) with Values Subsequent to the introduction of Trinity River Flow (Klamath River Above Martin's Ferry/Tully Creek)

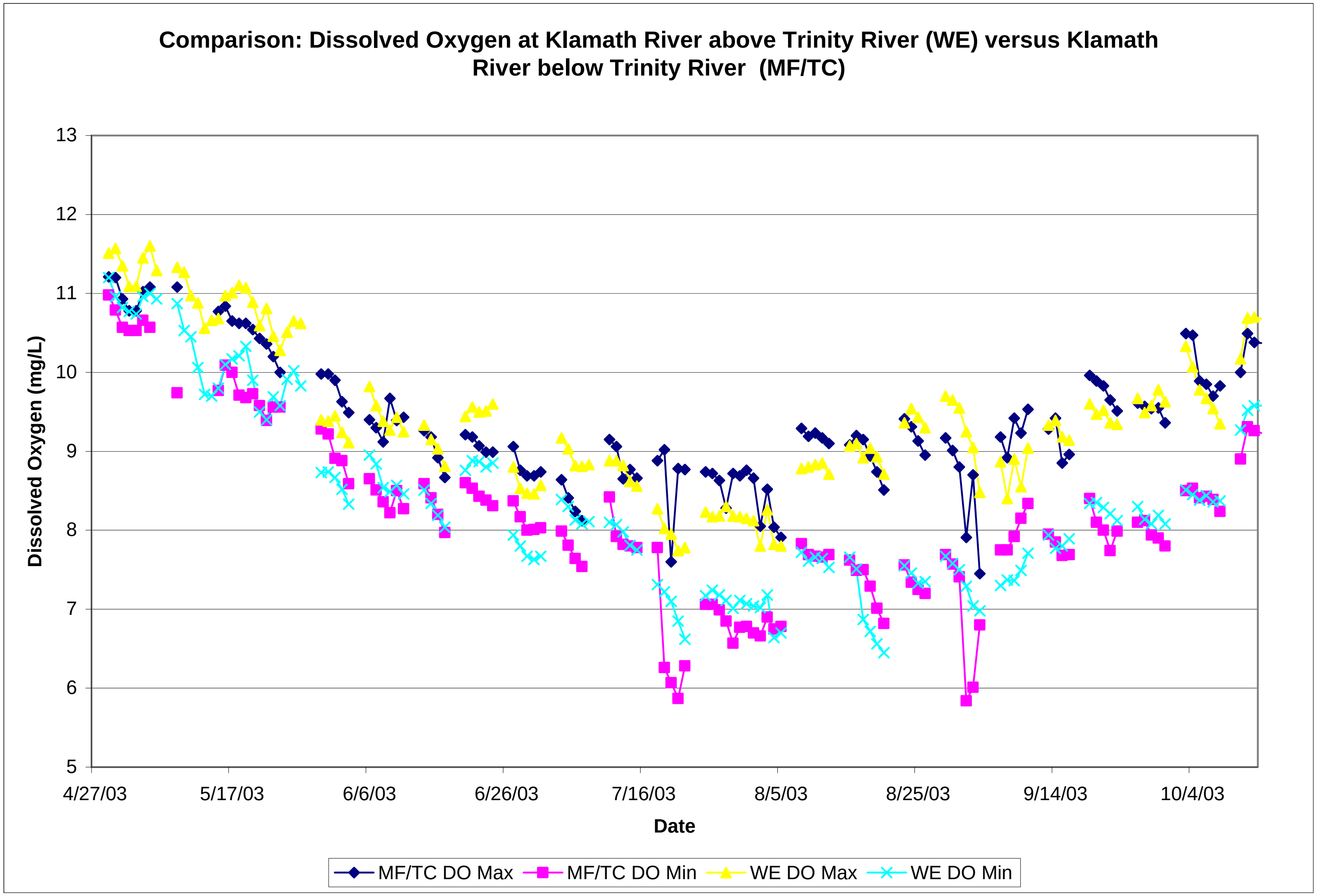


Figure 7-160 Comparison of Dissolved Oxygen Values in the Klamath River prior to the introduction of Trinity River Flow (Klamath River Above Trinity River) with Values Subsequent to the introduction of Trinity River Flow (Klamath River Above Martin's Ferry/Tully Creek)

7.1.11 Special Studies – Blue Hole and Known Deep Holes in the Lower Klamath River

7.1.11.1 Blue Hole Special Study – 8/26/03

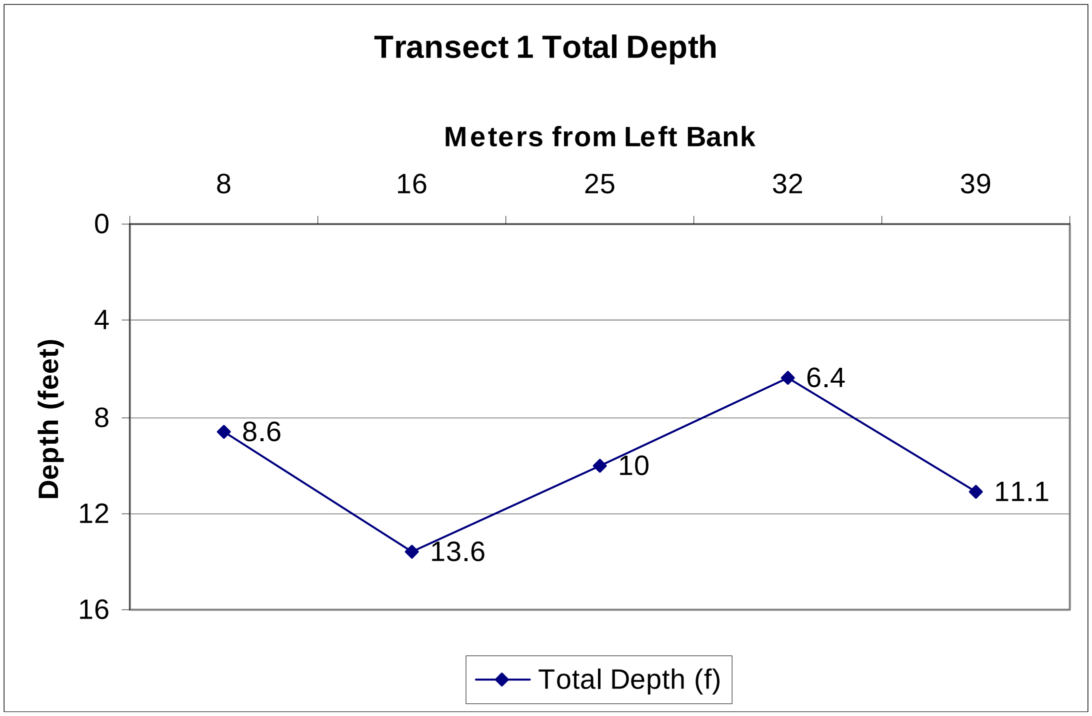


Figure 7-161 Blue Hole Special Study Transect 1 Total Depth

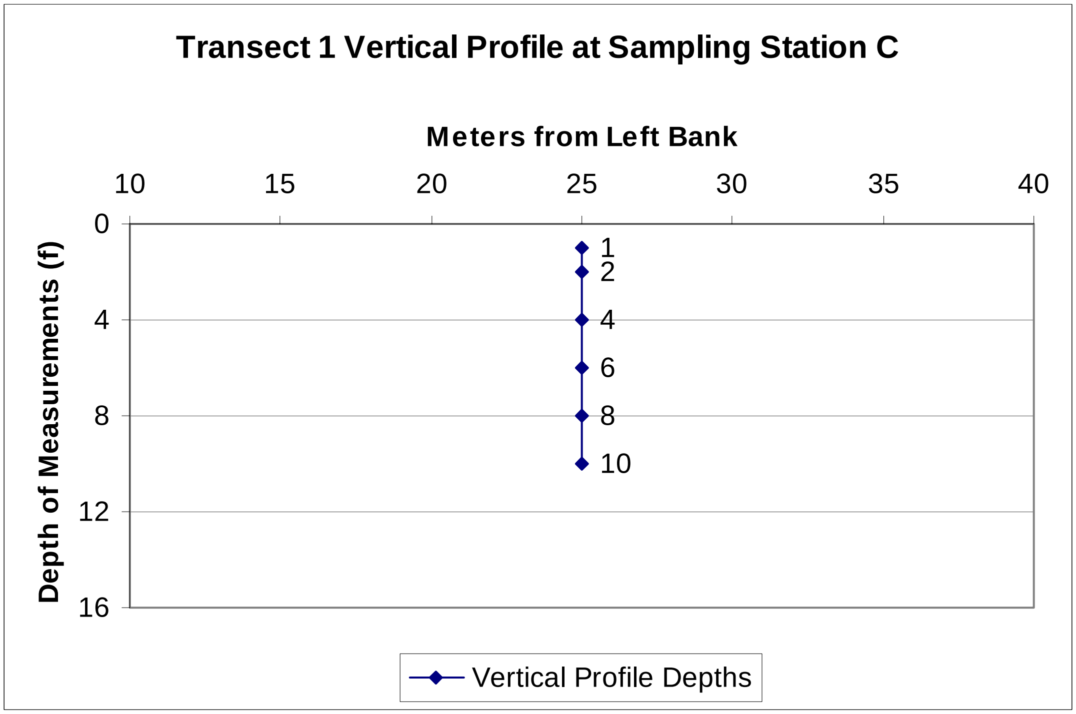


Figure 7-162 Blue Hole Special Study Transect 1 Vertical Profile

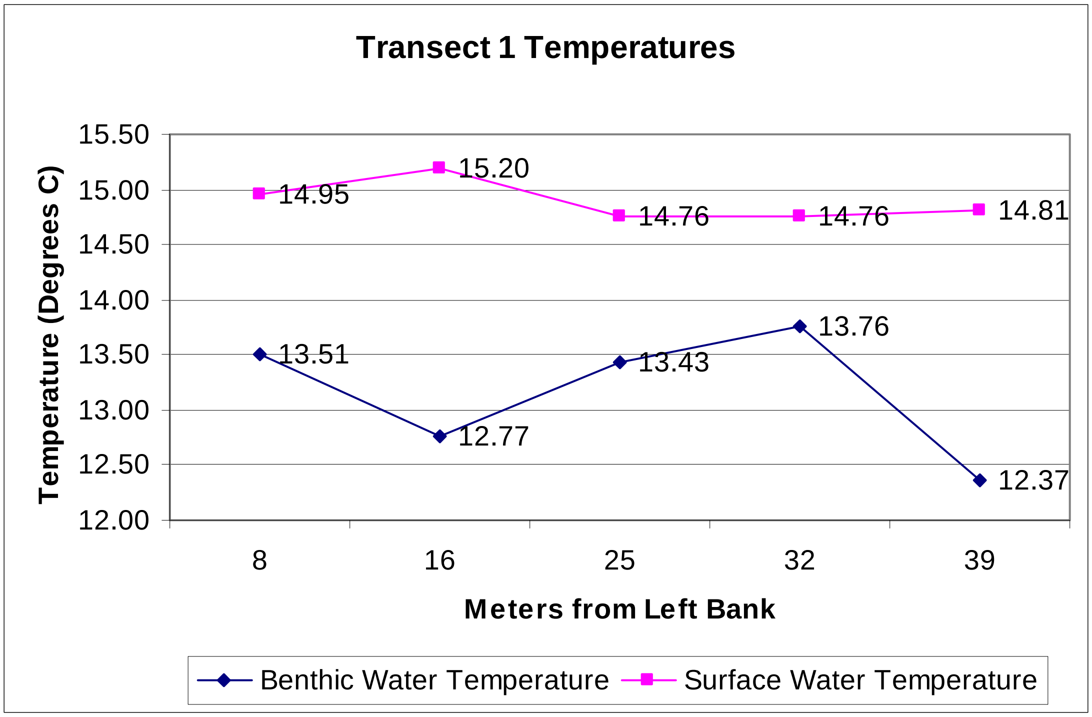


Figure 7-163 Blue Hole Special Study Transect 1 Temperatures

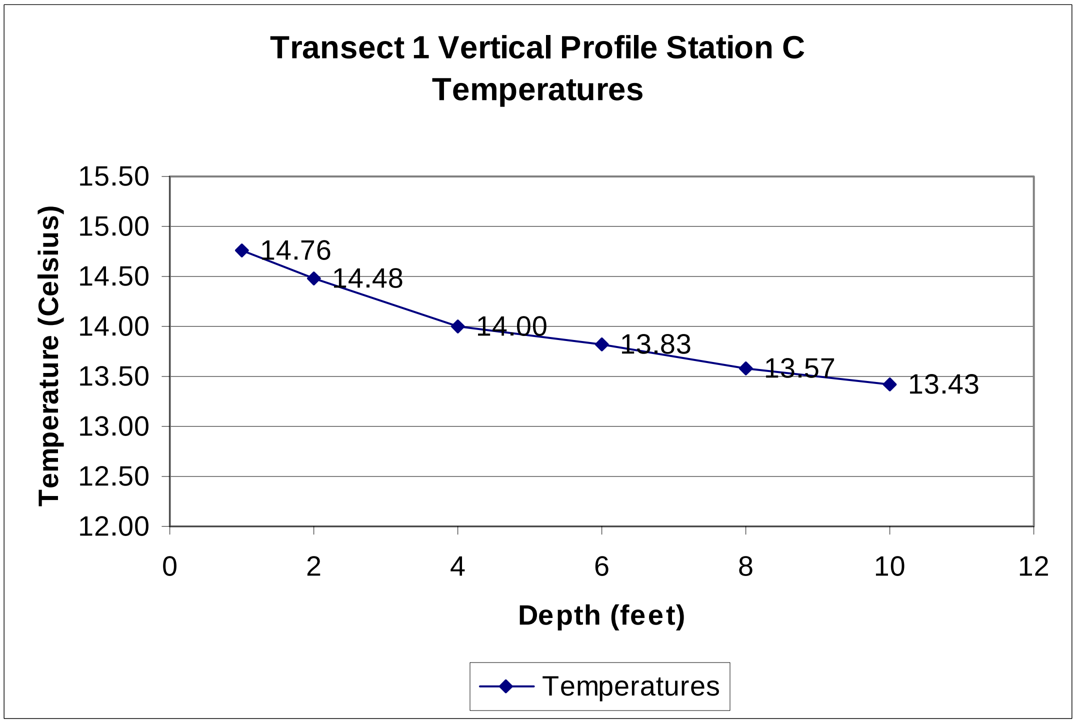


Figure 7-164 Blue Hole Special Study Transect 1 Station C Temperatures

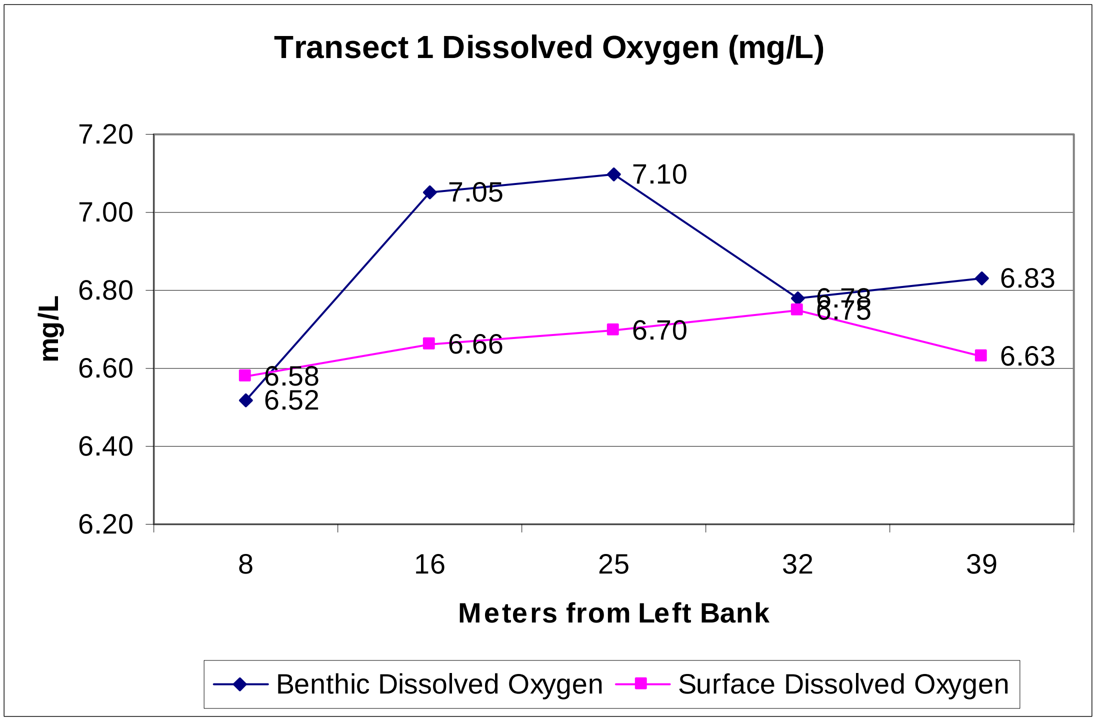


Figure 7-165 Blue Hole Special Study Transect 1 Dissolved Oxygen

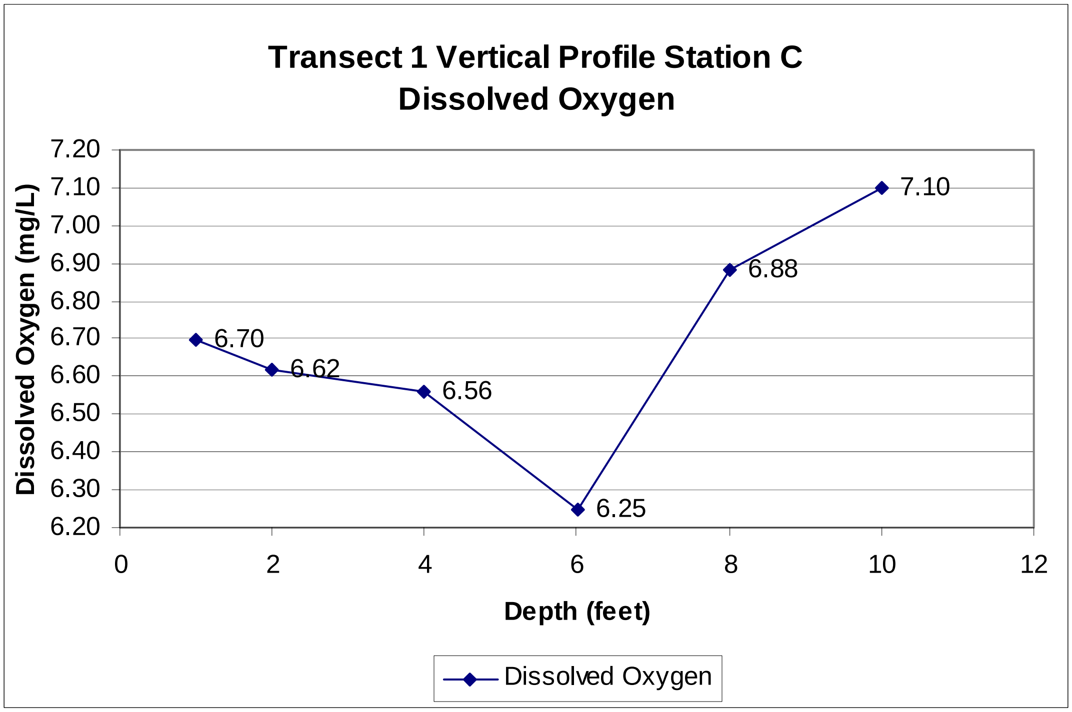


Figure 7-166 Blue Hole Special Study Transect 1 Station C Dissolved Oxygen

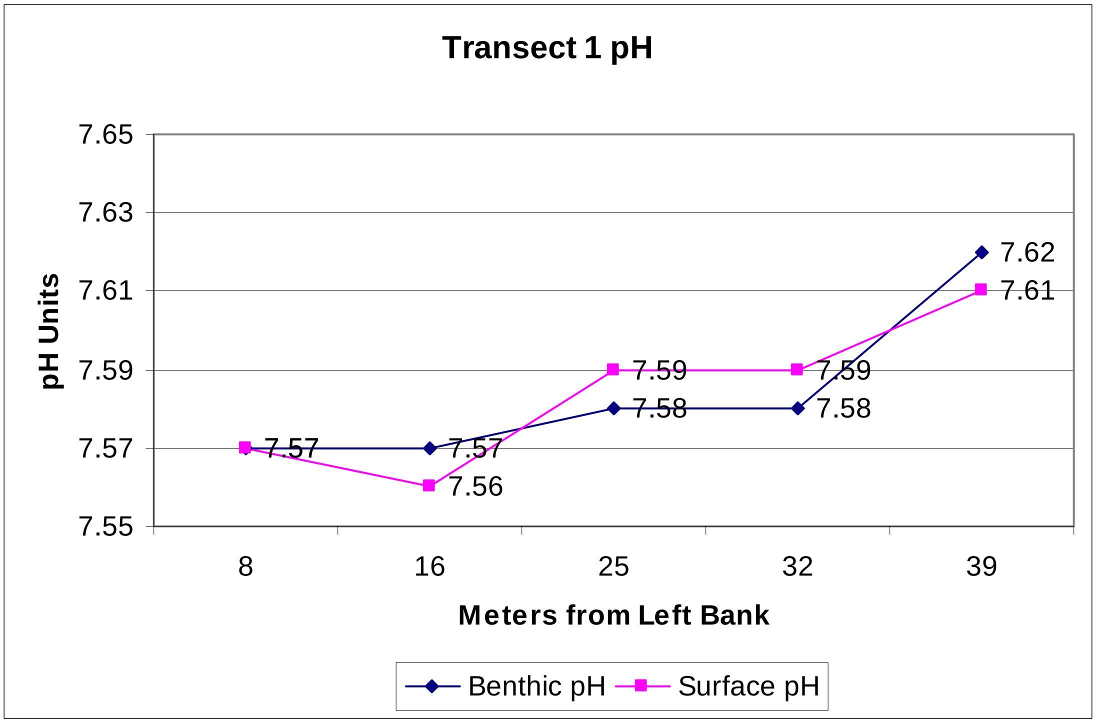


Figure 7-167 Blue Hole Special Study Transect 1 pH

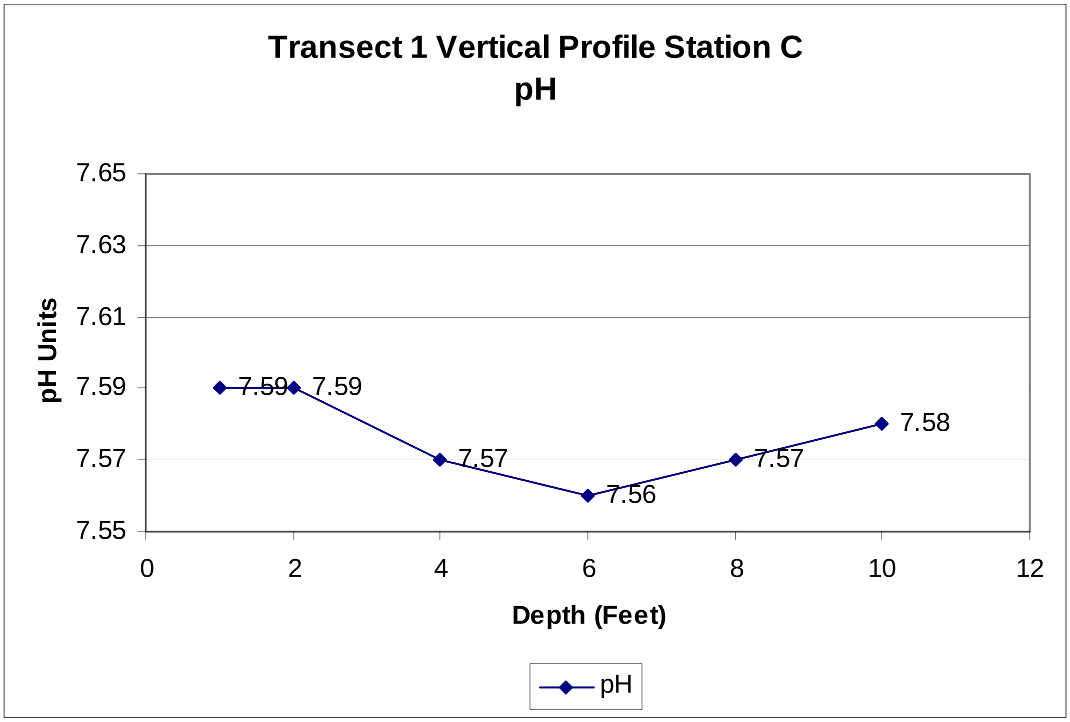


Figure 7-168 Blue Hole Special Study Transect 1 Station C pH

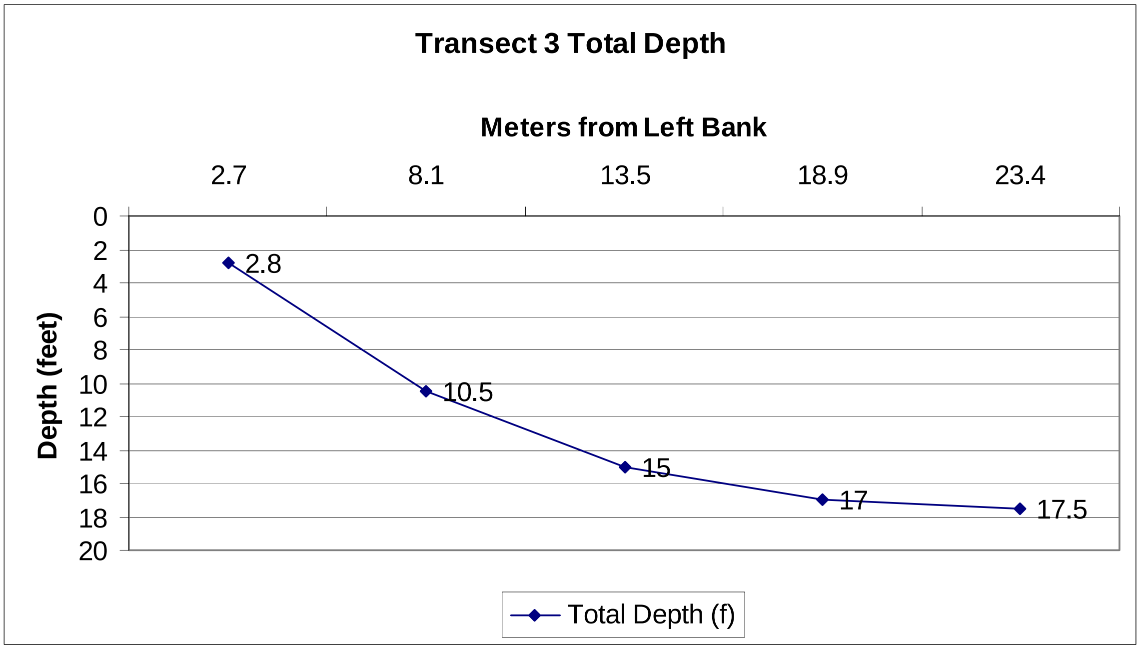


Figure 7-169 Blue Hole Special Study Transect 3 Total Depth

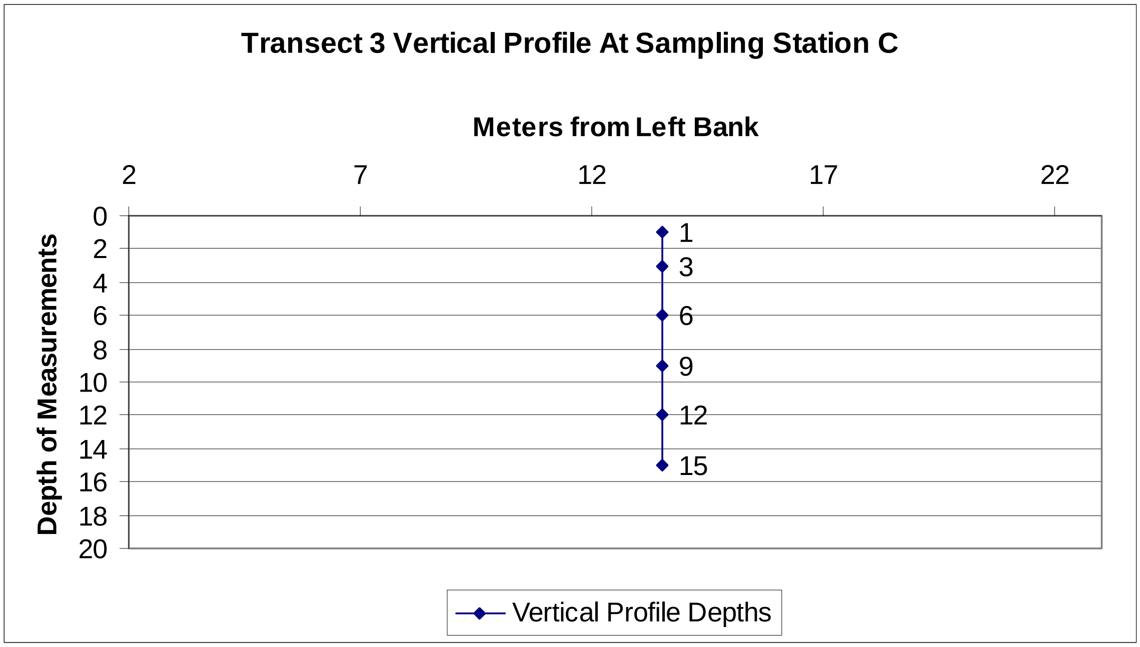


Figure 7-170 Blue Hole Special Study Transect 3 Station C Vertical Profile

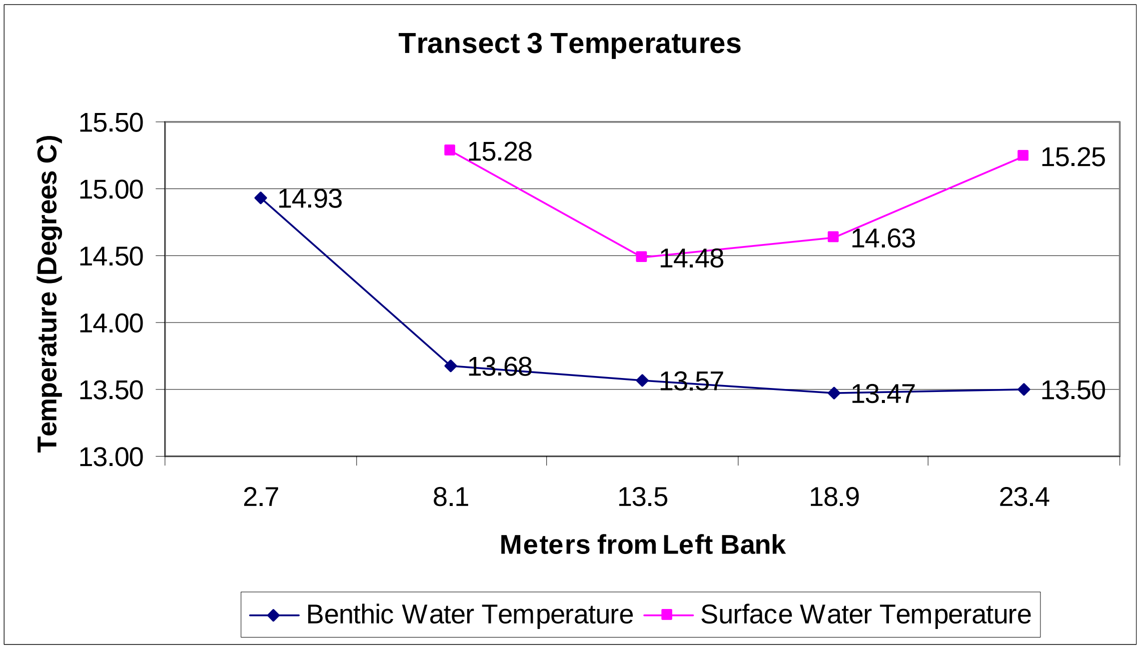


Figure 7-171 Blue Hole Special Study Transect 3 Temperatures

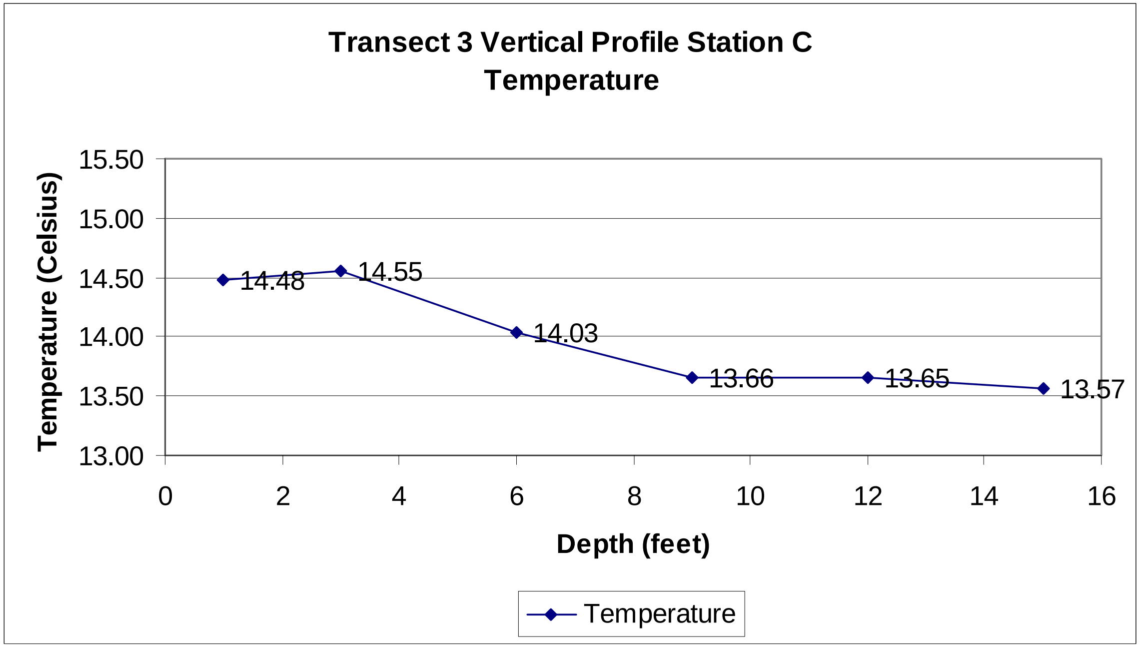


Figure 7-172 Blue Hole Special Study Transect 3 Station C Temperature

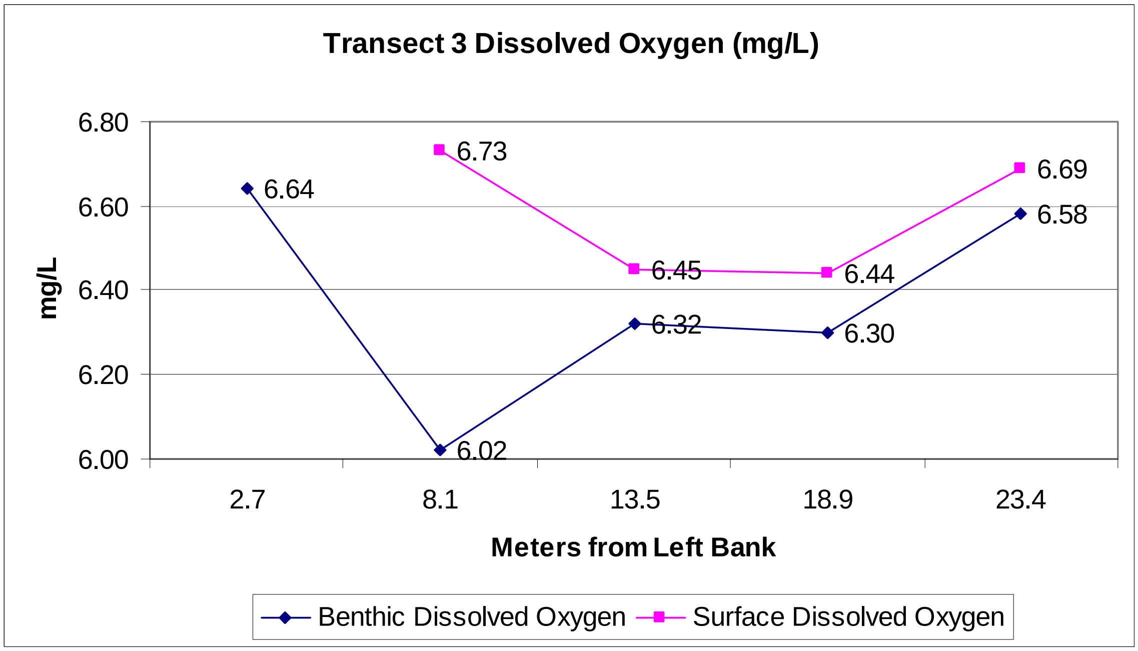


Figure 7-173 Blue Hole Special Study Transect 3 Dissolved Oxygen

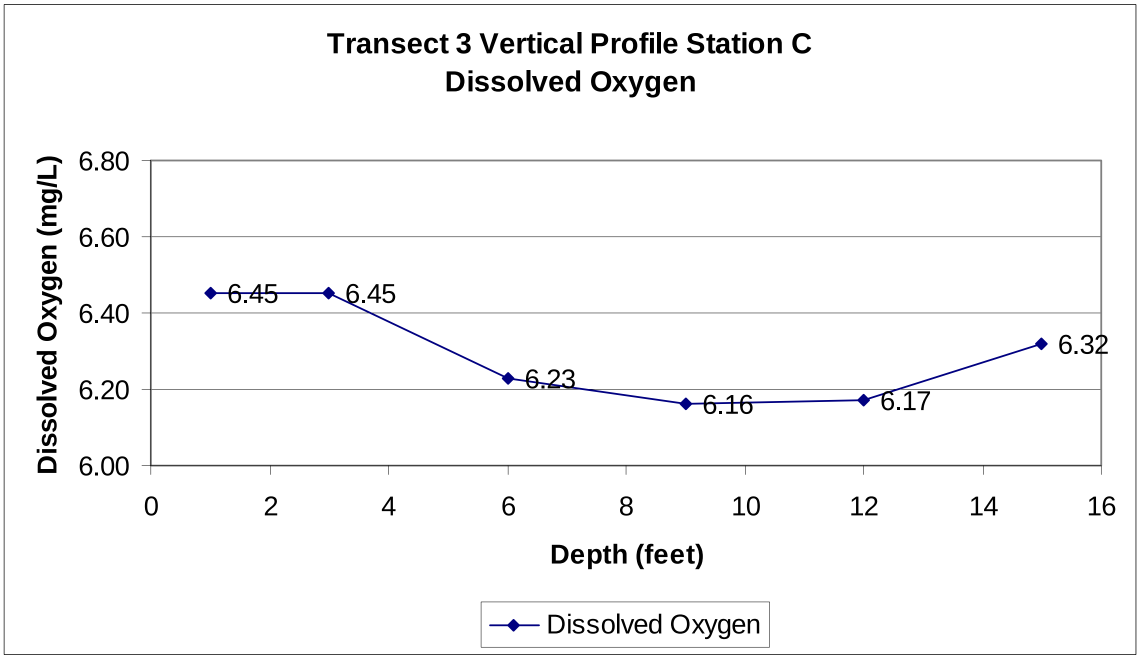


Figure 7-174 Blue Hole Special Study Transect 3 Station C Dissolved Oxygen

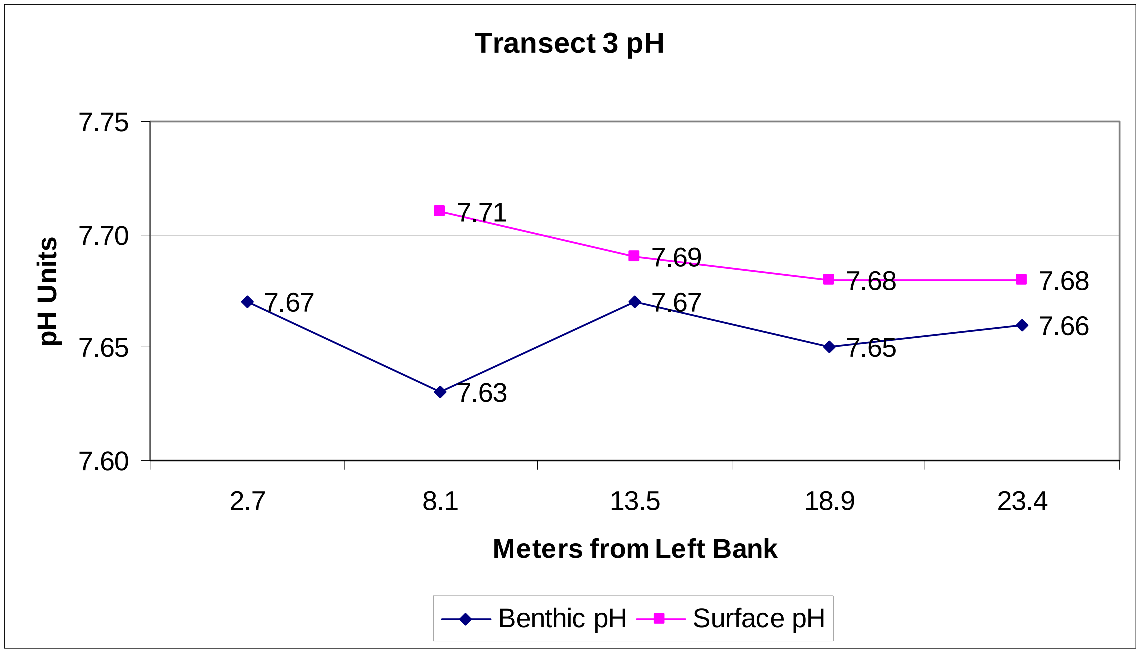


Figure 7-175 Blue Hole Special Study Transect 3 pH

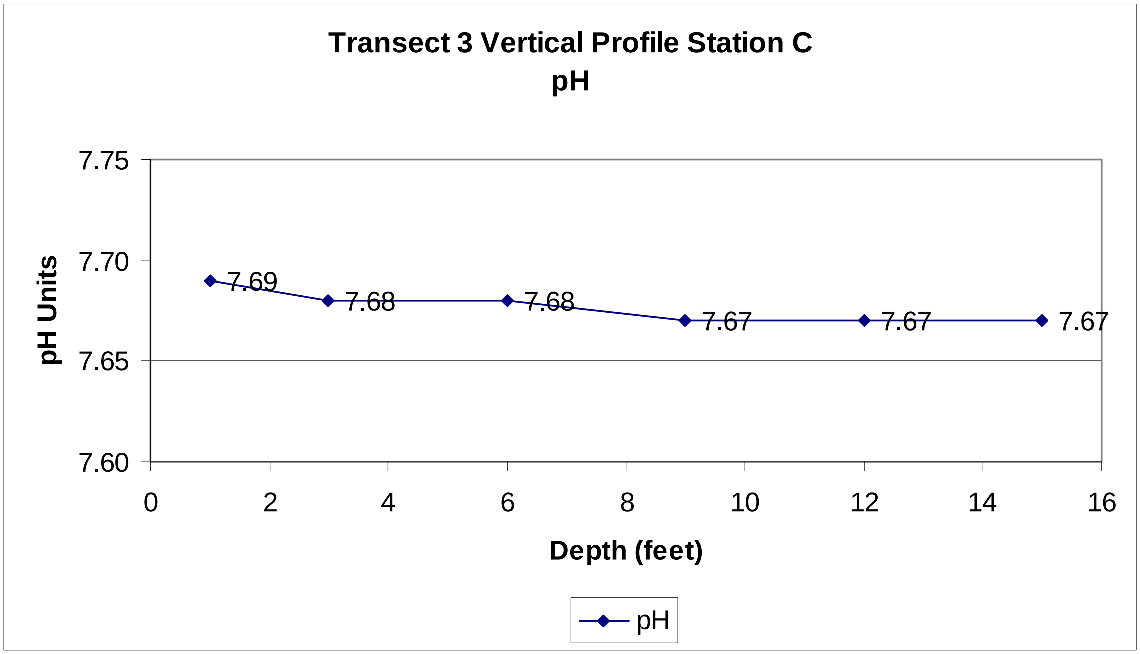


Figure 7-176 Blue Hole Special Study Transect 3 Station C pH

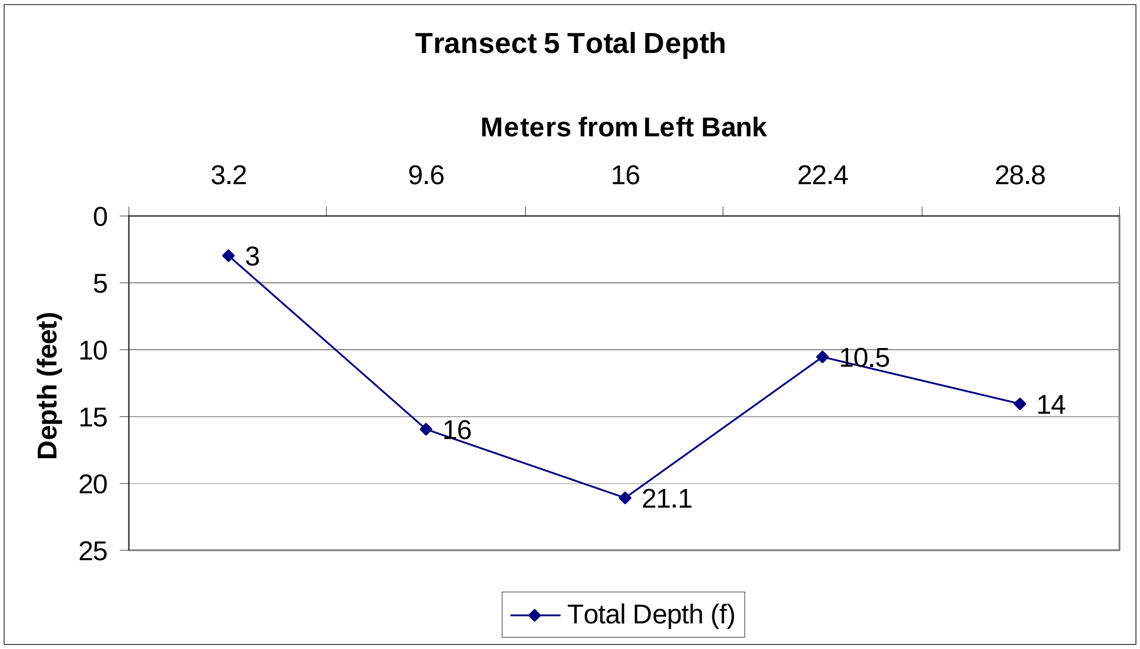


Figure 7-177 Blue Hole Special Study Transect 5 Total Depth

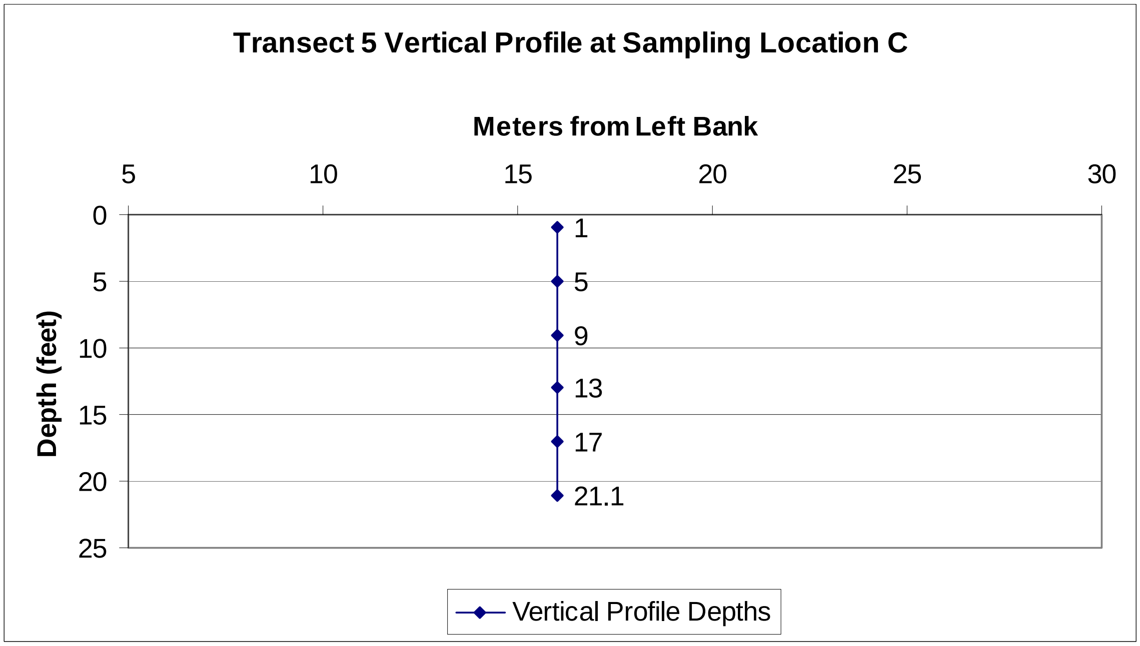


Figure 7-178 Blue Hole Special Study Transect 5 Station C Vertical Profile

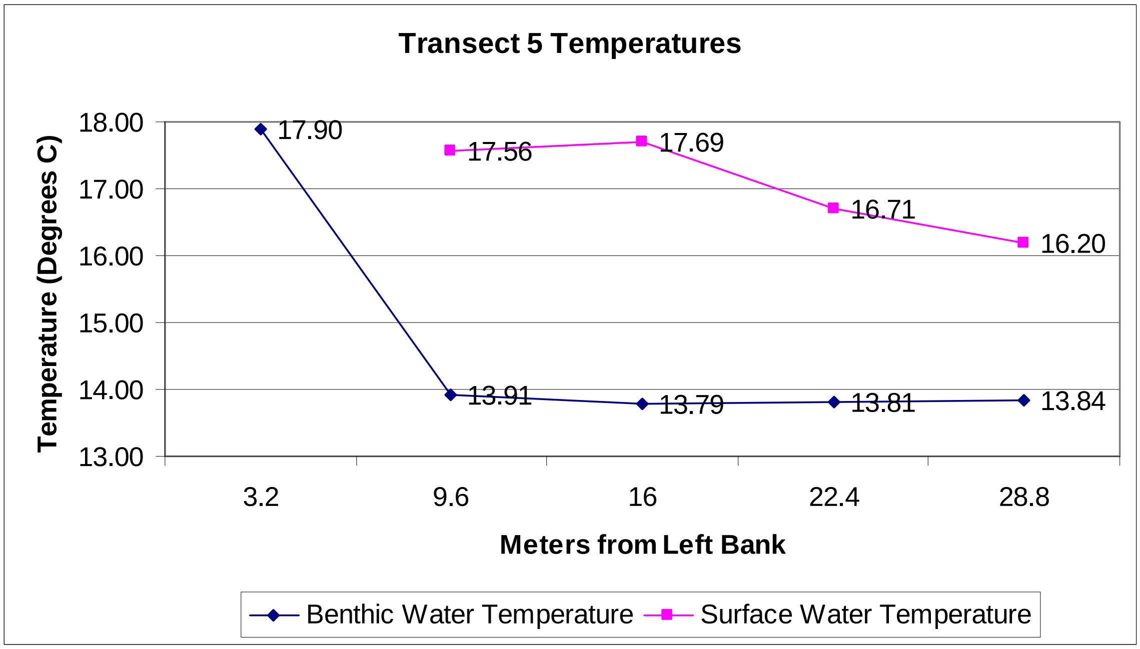


Figure 7-179 Blue Hole Special Study Transect 5 Temperatures

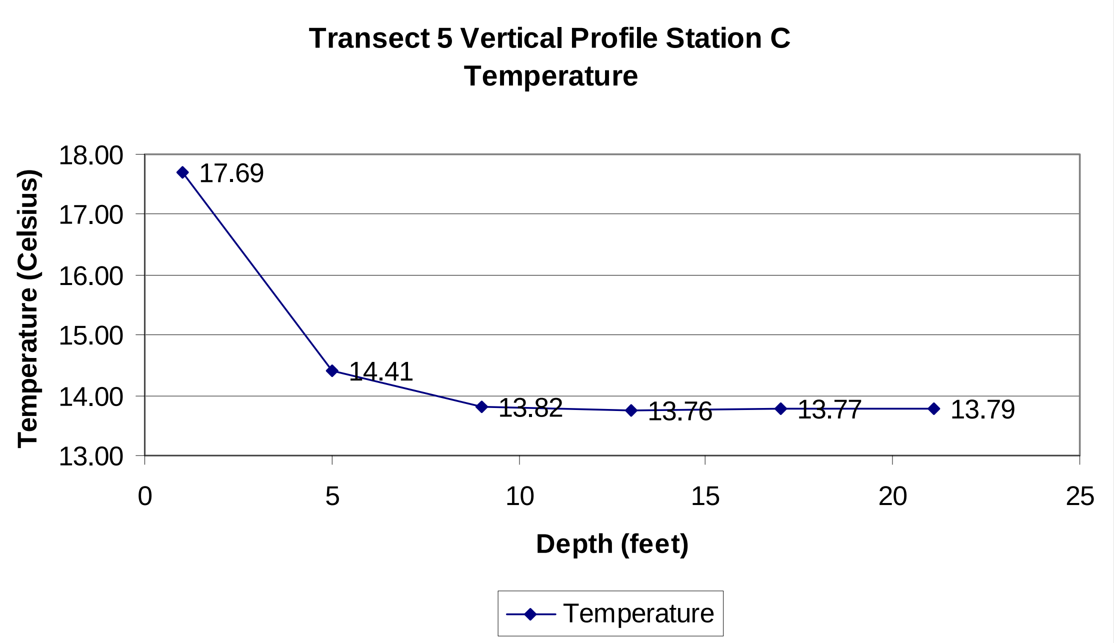


Figure 7-180 Blue Hole Special Study Transect 5 Station C Temperature

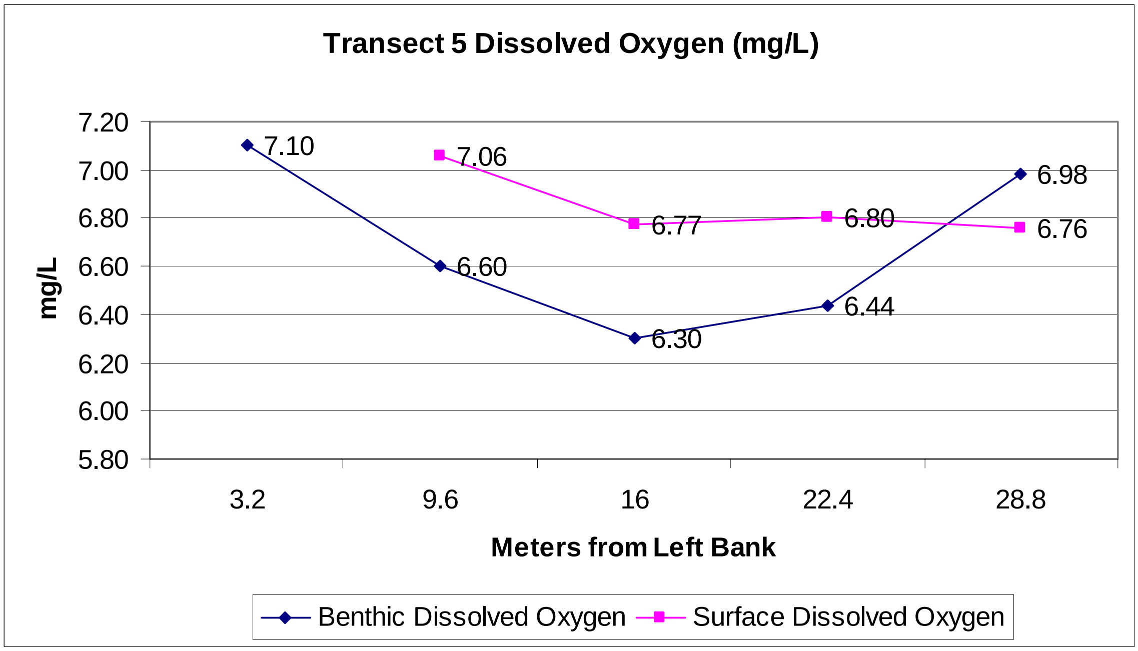


Figure 7-181 Blue Hole Special Study Transect 5 Dissolved Oxygen

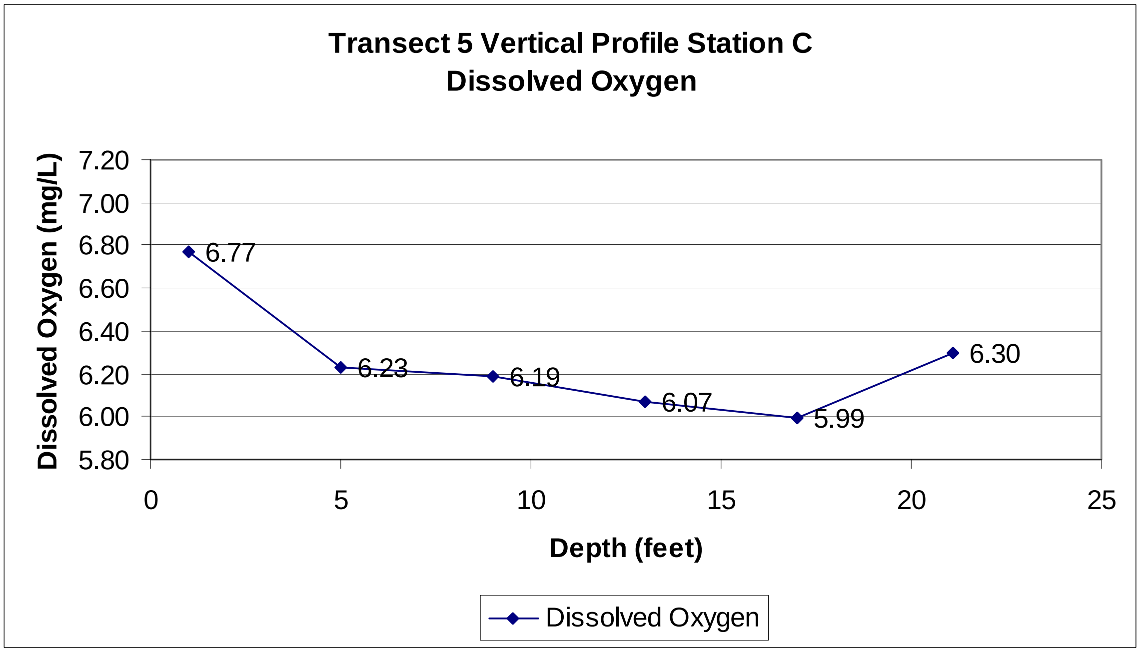


Figure 7-182 Blue Hole Special Study Transect 5 Station C Dissolved Oxygen

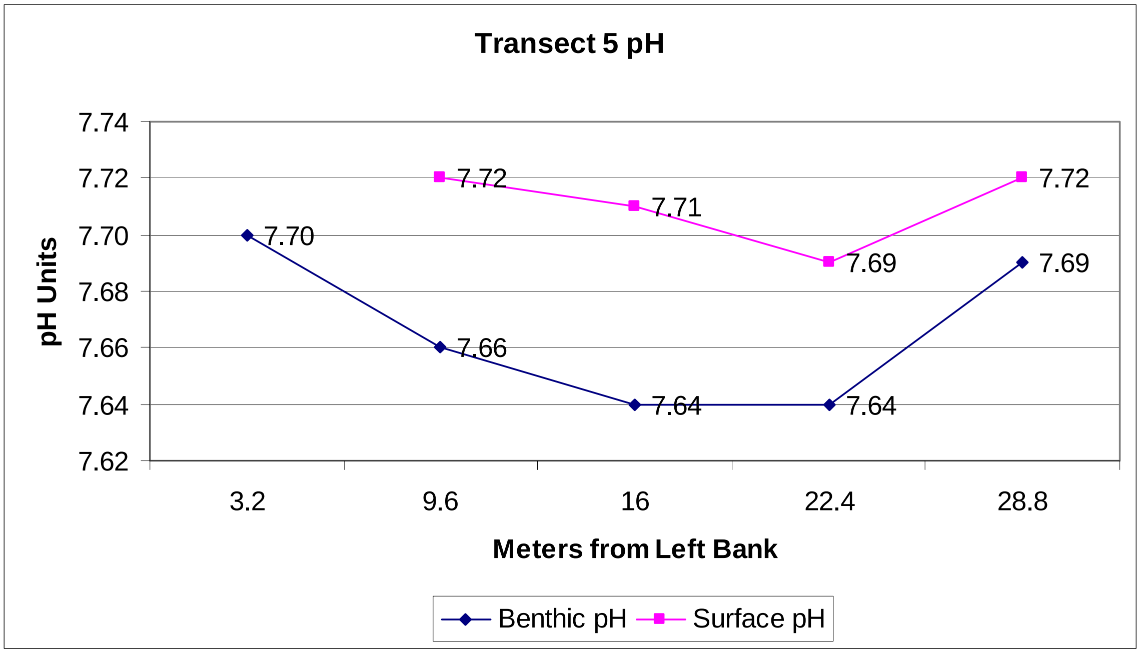


Figure 7-183 Blue Hole Special Study Transect 5 pH

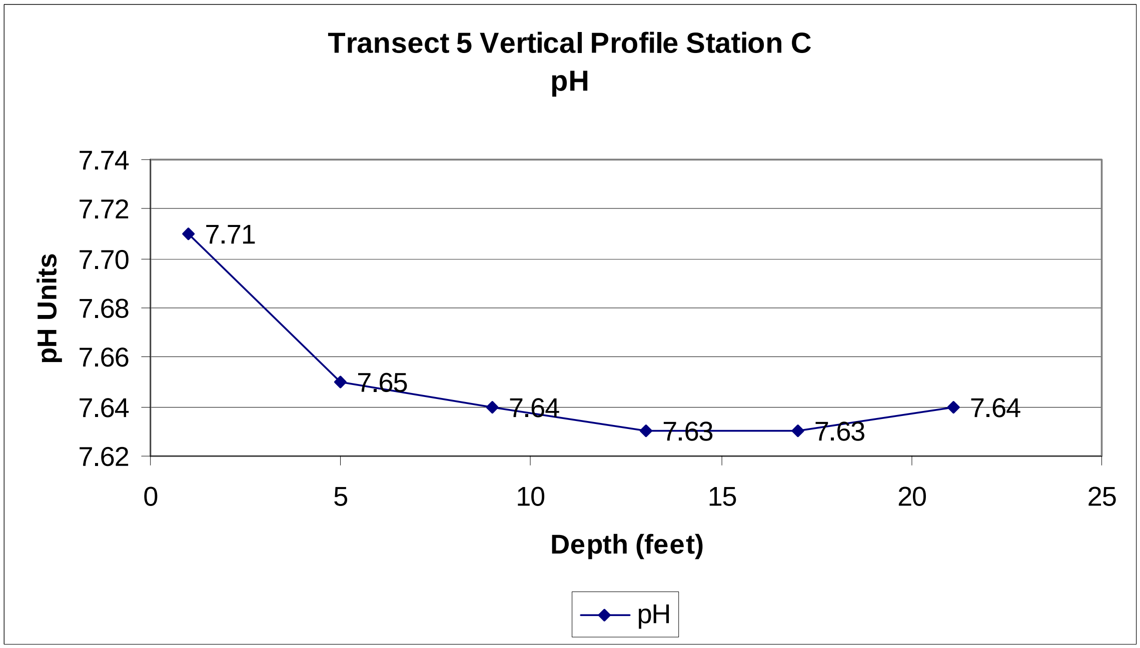


Figure 7-184 Blue Hole Special Study Transect 5 Station C pH

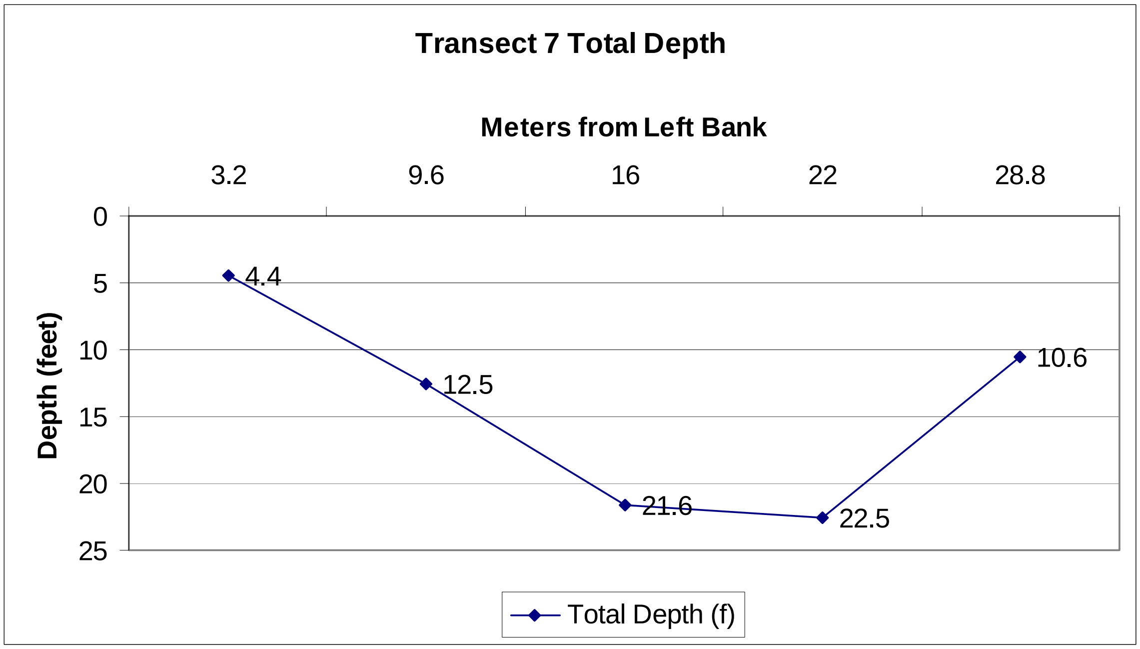


Figure 7-185 Blue Hole Special Study Transect 7 Total Depth

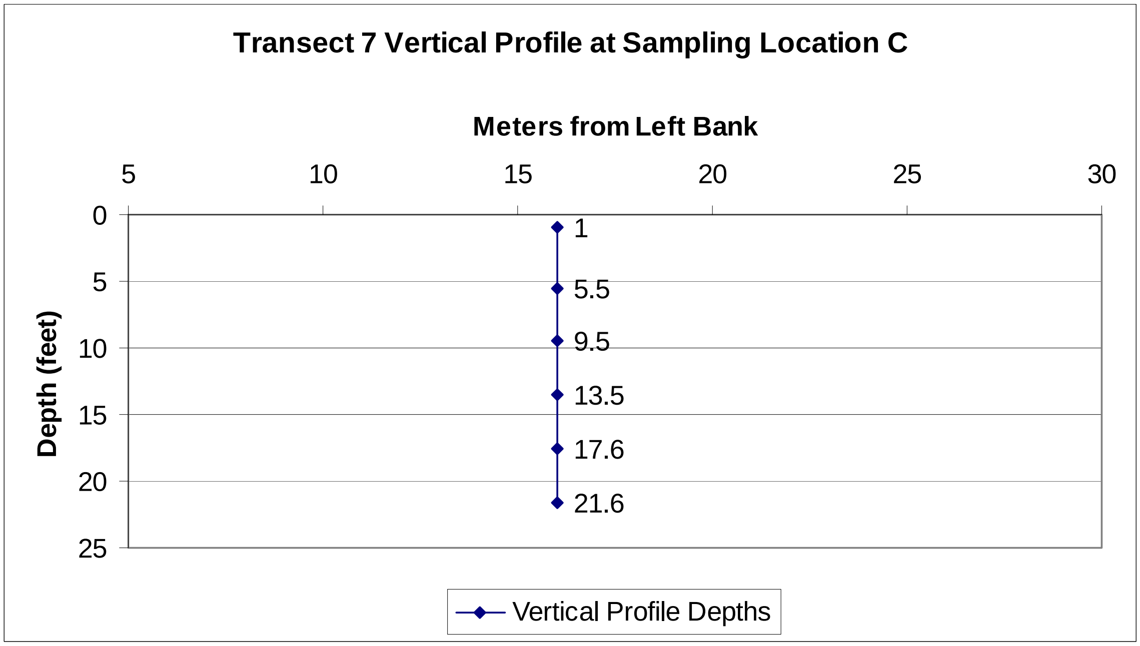


Figure 7-186 Blue Hole Special Study Transect 7 Station C Vertical Profile

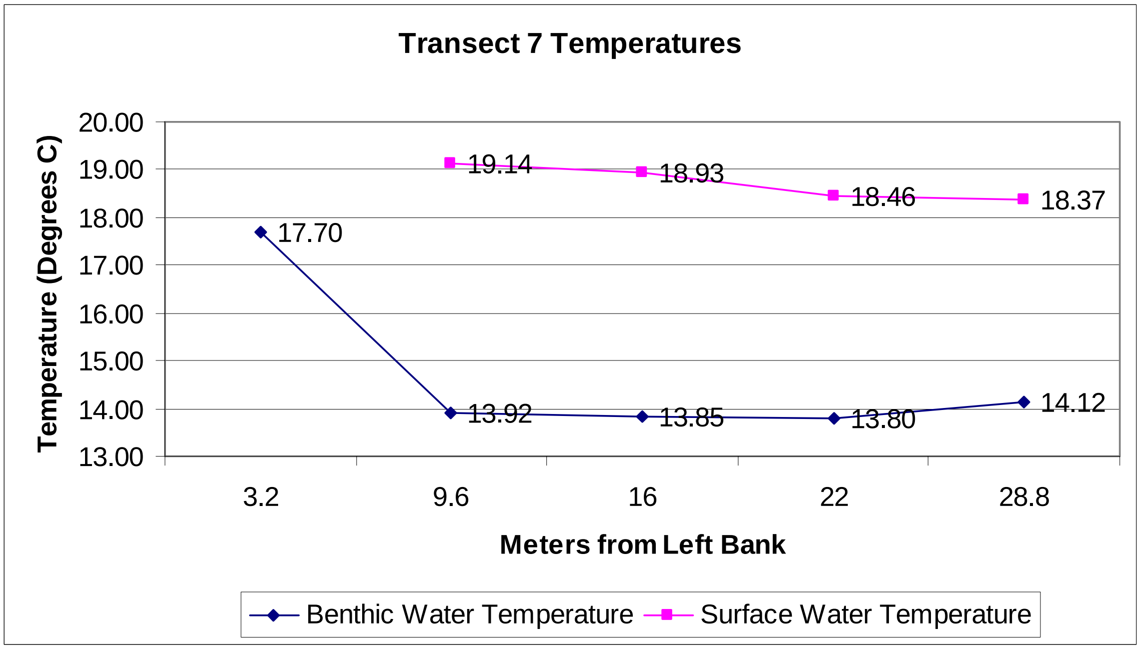


Figure 7-187 Blue Hole Special Study Transect 7 Temperatures

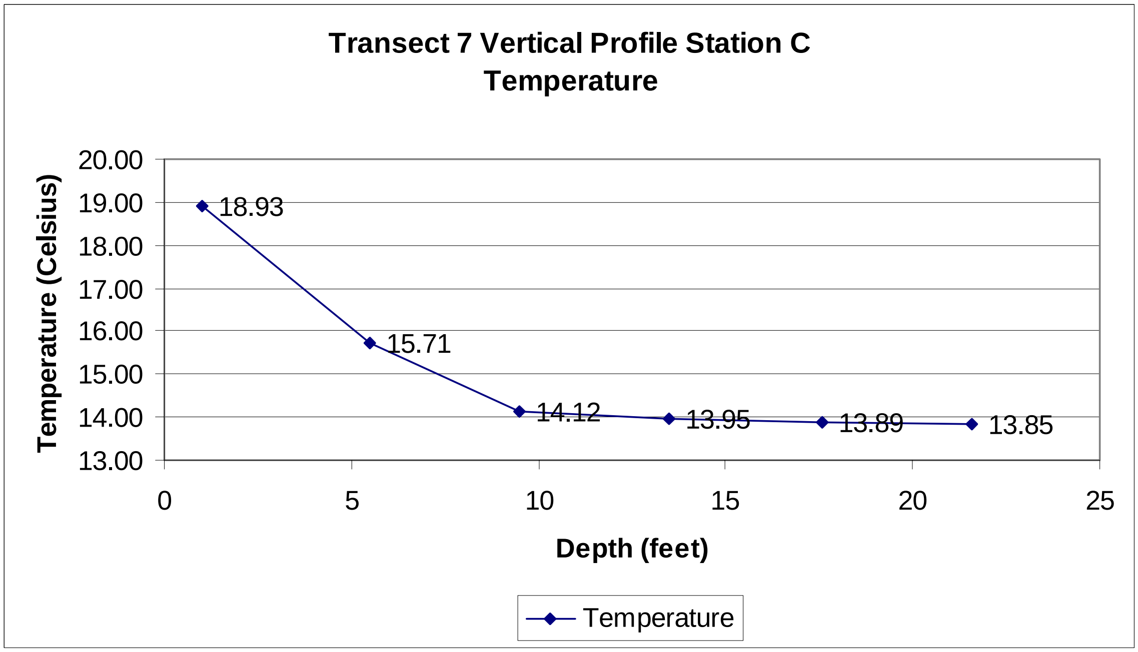


Figure 7-188 Blue Hole Special Study Transect 7 Station C Temperature

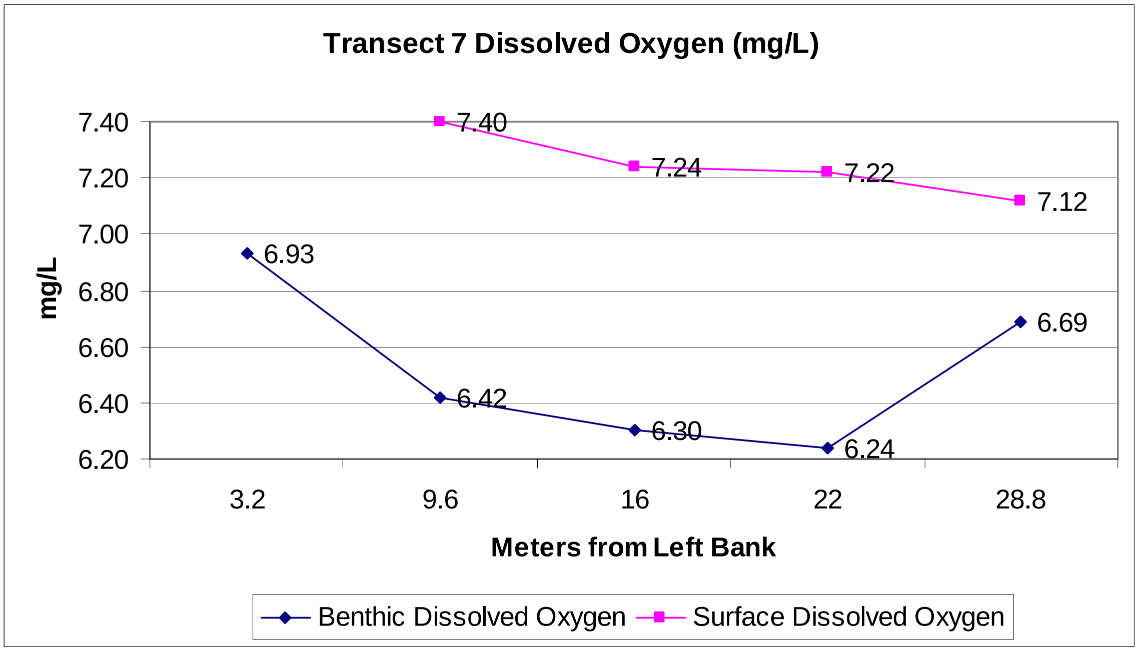


Figure 7-189 Blue Hole Special Study Transect 7 Dissolved Oxygen

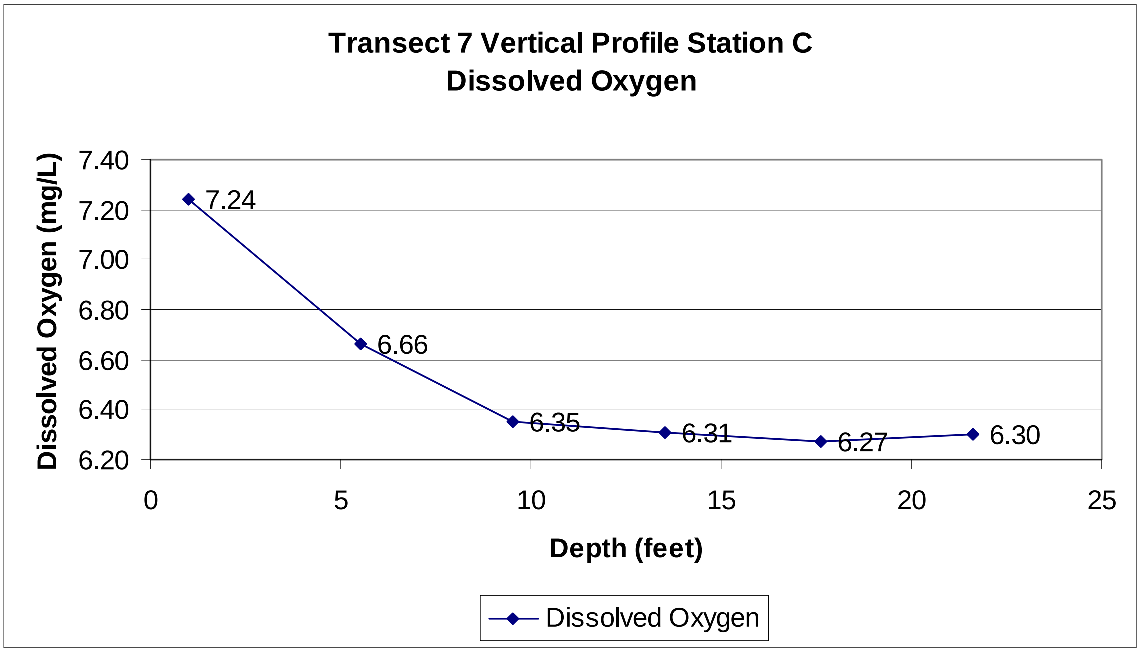


Figure 7-190 Blue Hole Special Study Transect 7 Station C Dissolved Oxygen

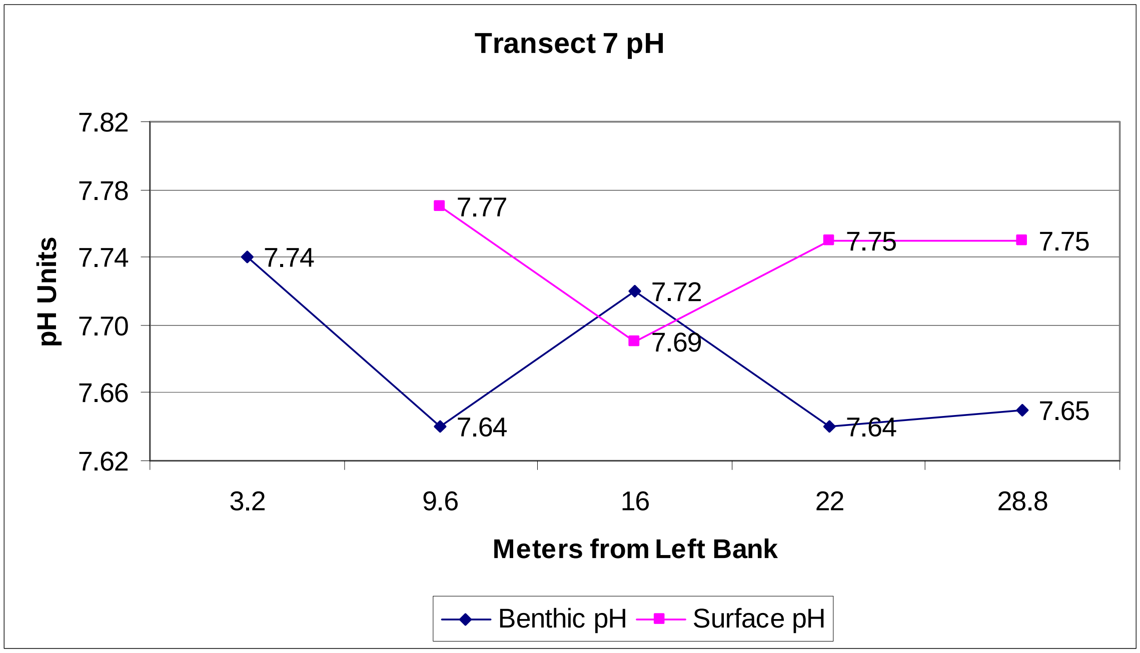


Figure 7-191 Blue Hole Special Study Transect 7 pH

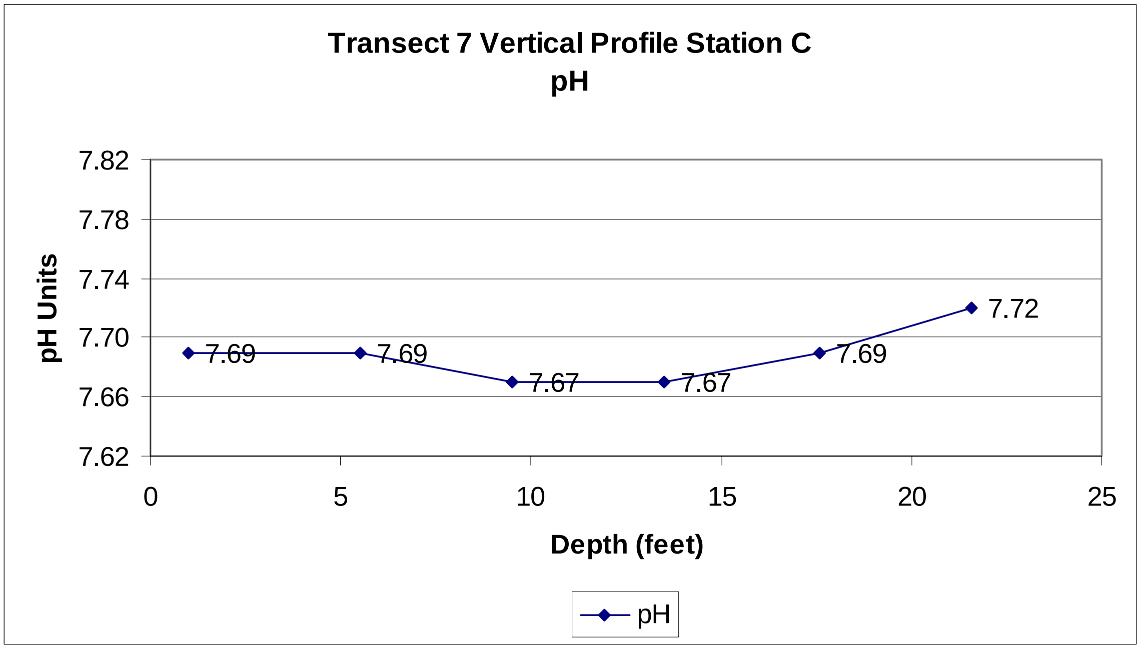


Figure 7-192 Blue Hole Special Study Transect 7 Station C pH

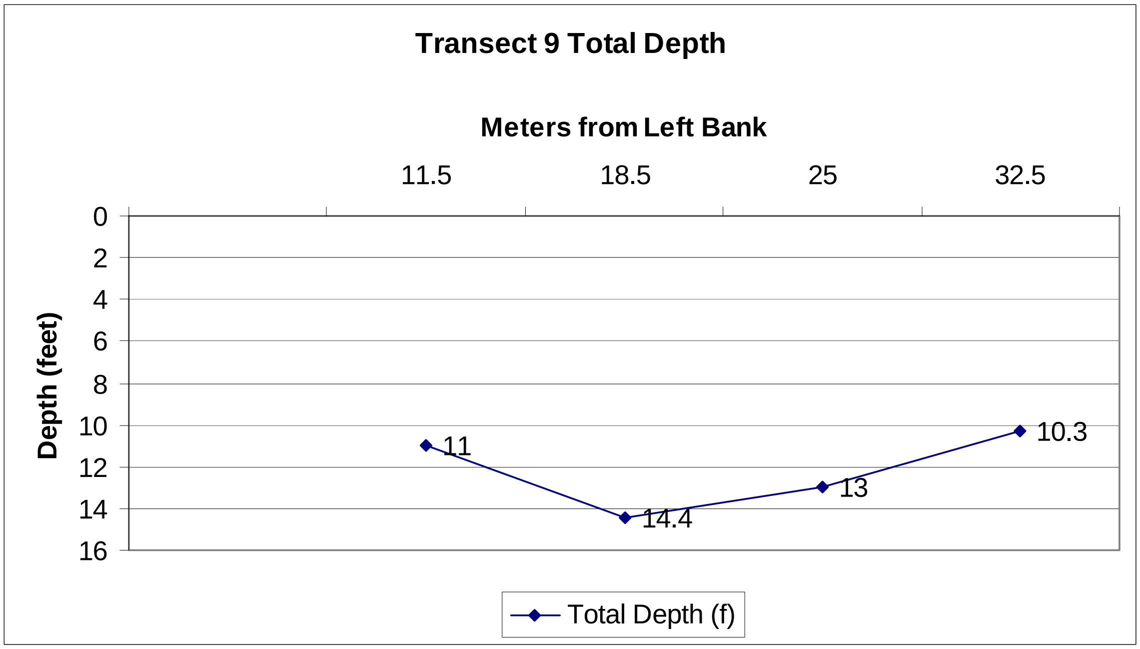


Figure 7-193 Blue Hole Special Study Transect 9 Total Depth

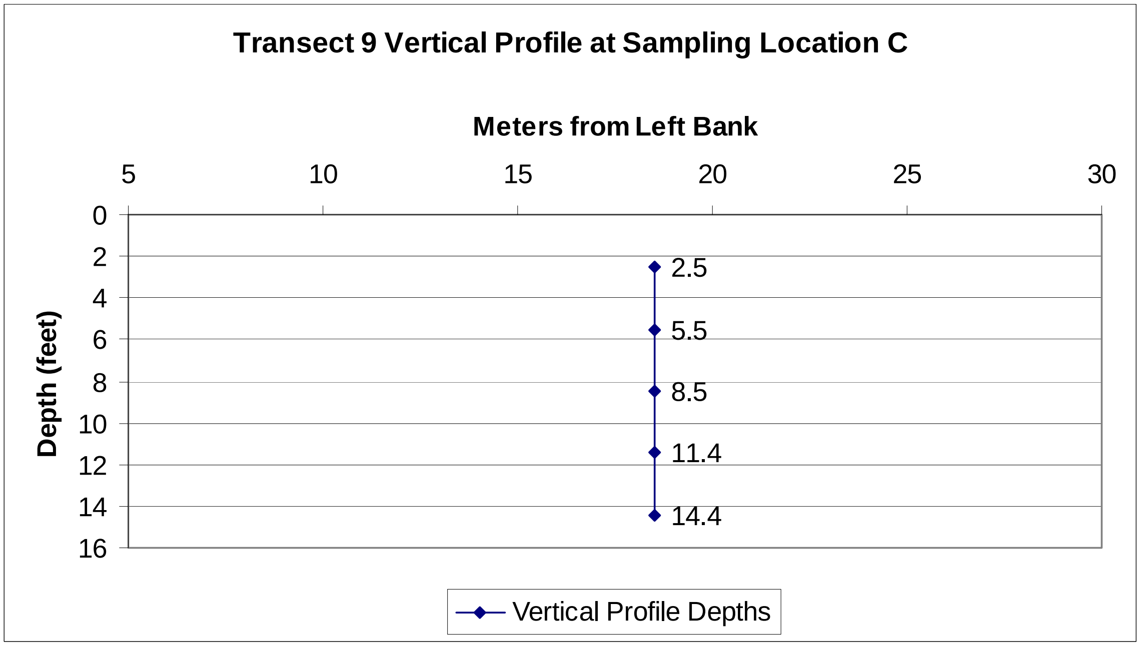


Figure 7-194 Blue Hole Special Study Transect 9 Station C Vertical Profile

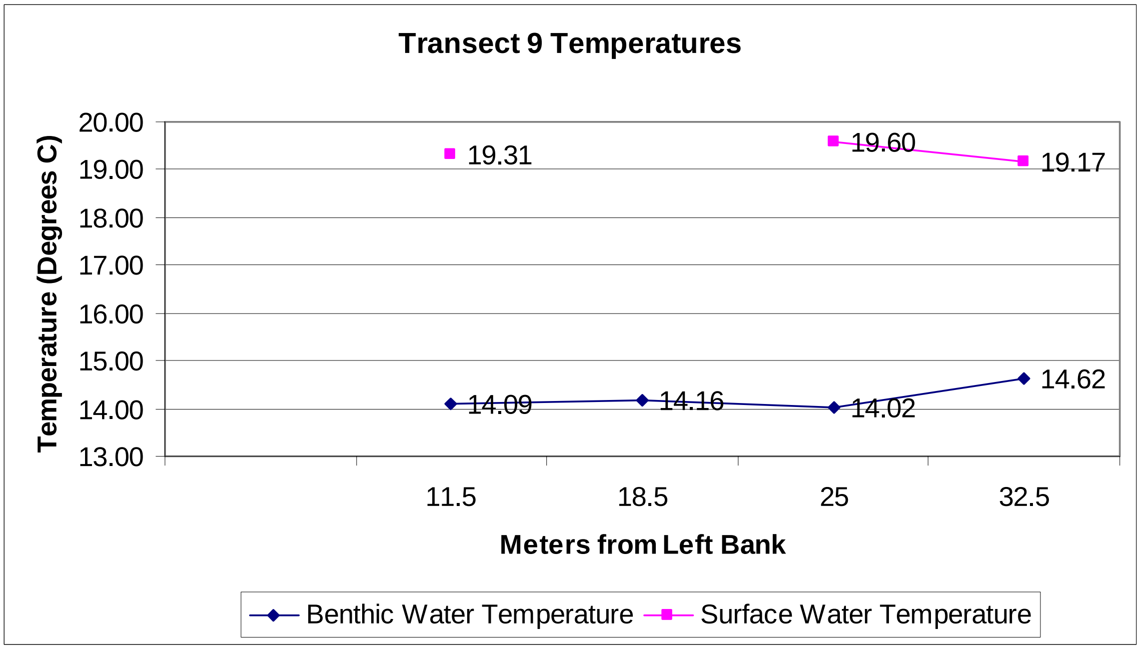


Figure 7-195 Blue Hole Special Study Transect 9 Temperatures

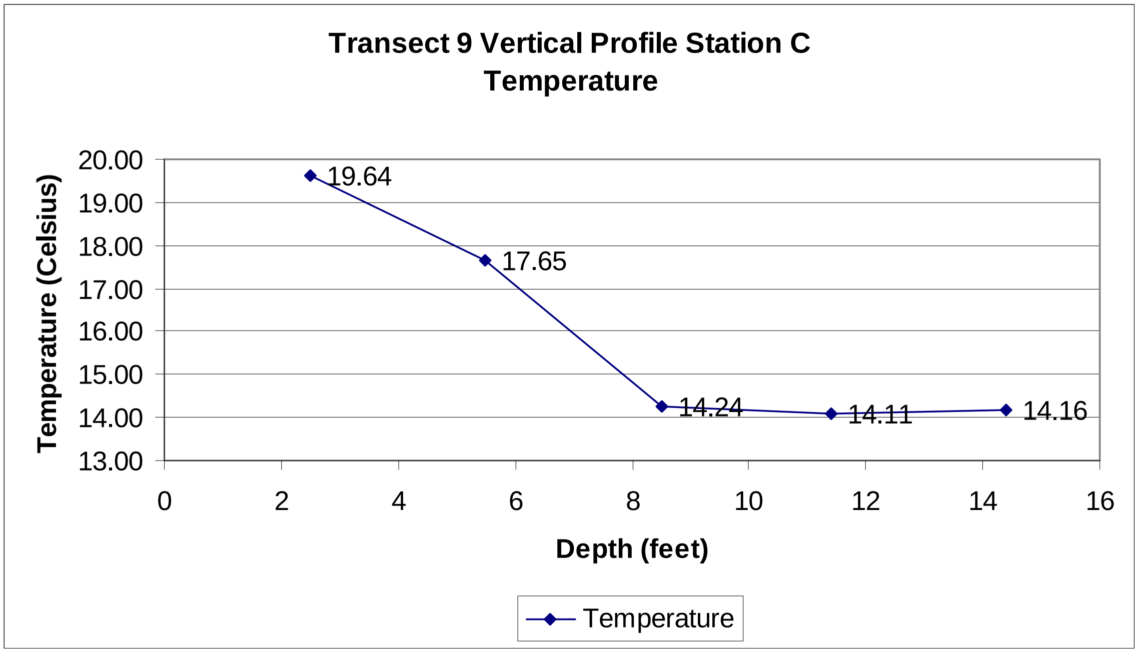


Figure 7-196 Blue Hole Special Study Transect 9 Station C Temperature

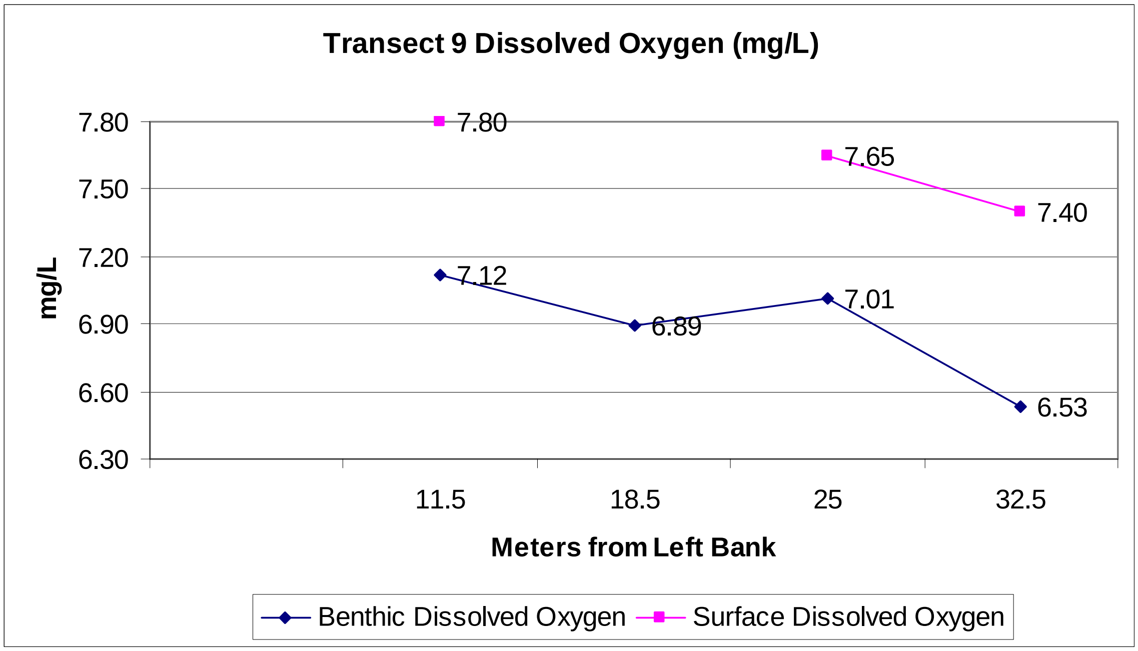


Figure 7-197 Blue Hole Special Study Transect 9 Dissolved Oxygen

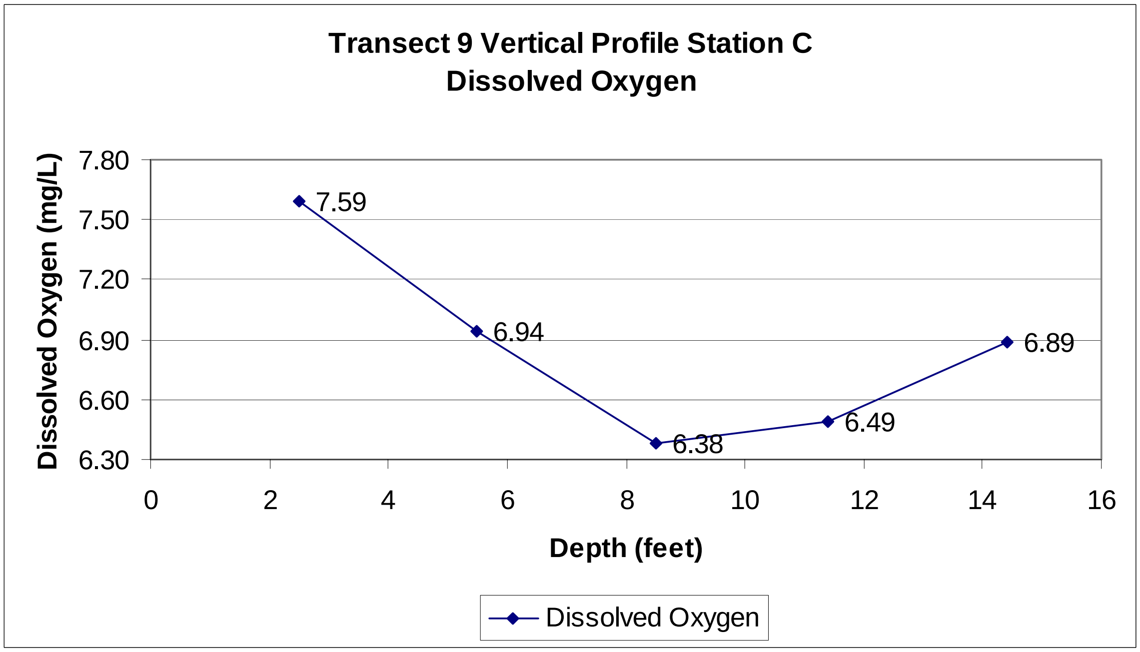


Figure 7-198 Blue Hole Special Study Transect 9 Station C Dissolved Oxygen

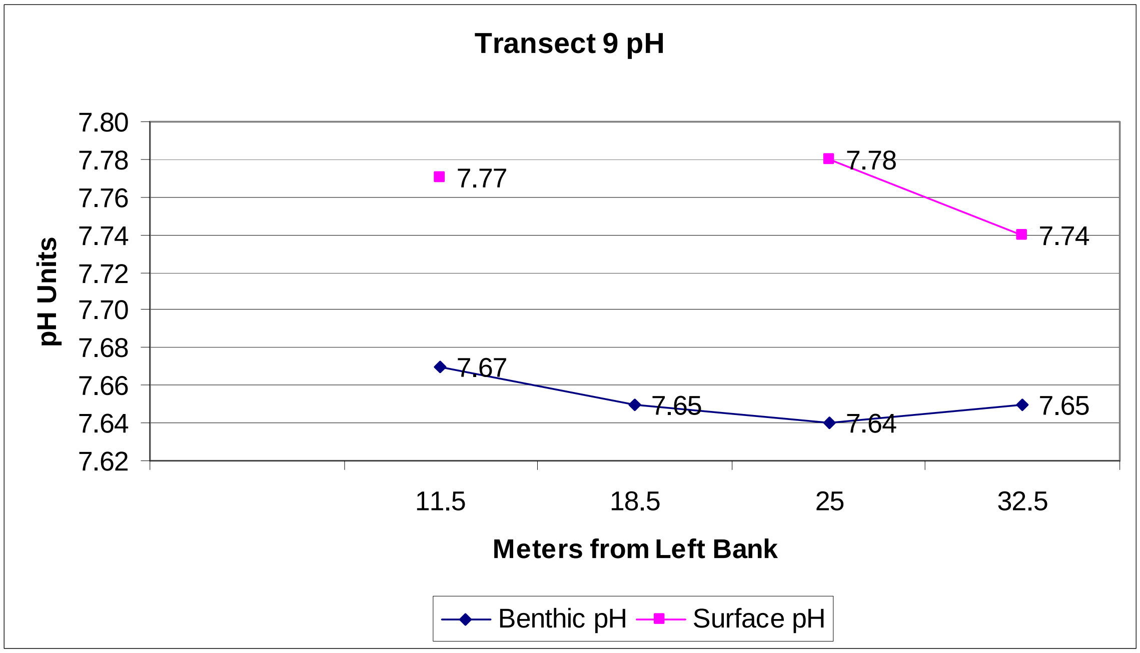


Figure 7-199 Blue Hole Special Study Transect 9 pH

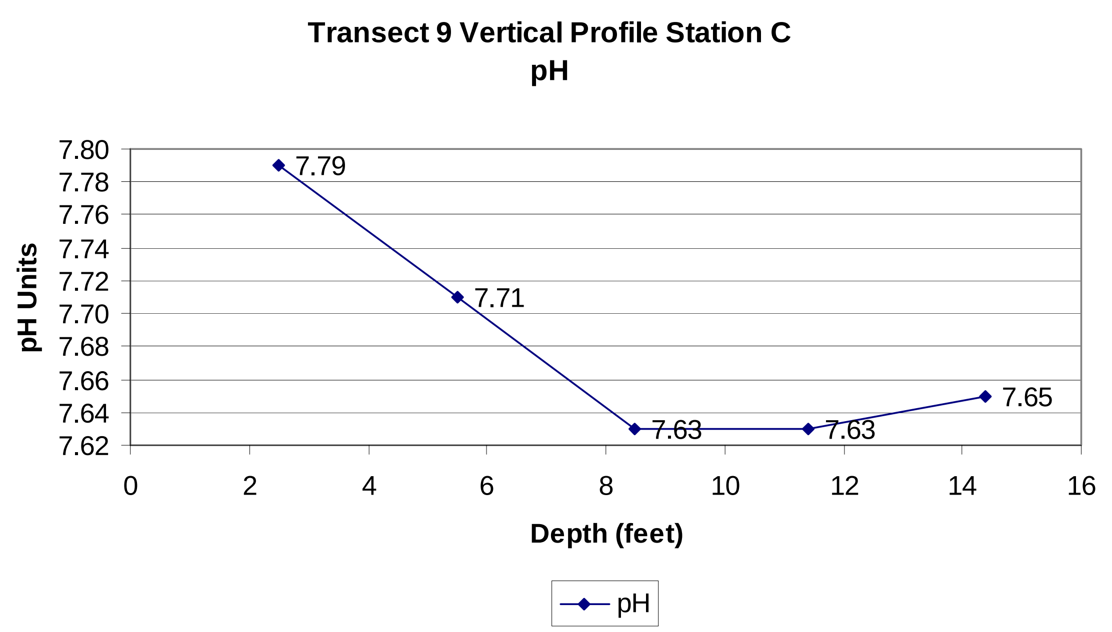


Figure 7-200 Blue Hole Special Study Transect 9 Station C pH

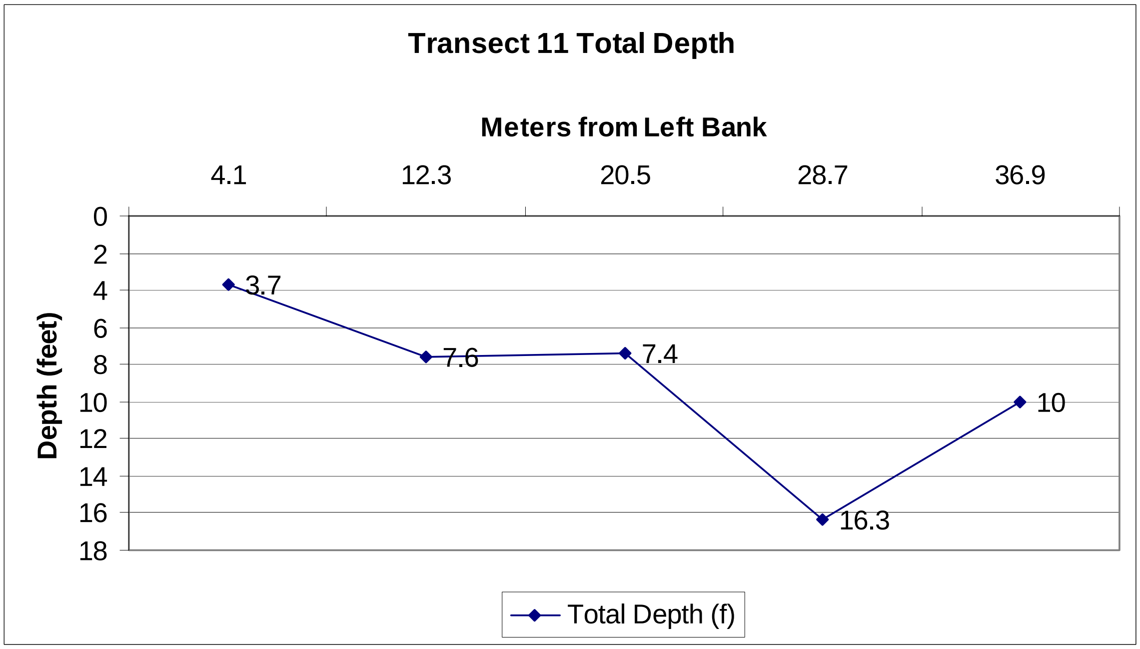


Figure 7-201 Blue Hole Special Study Transect 11 Total Depth

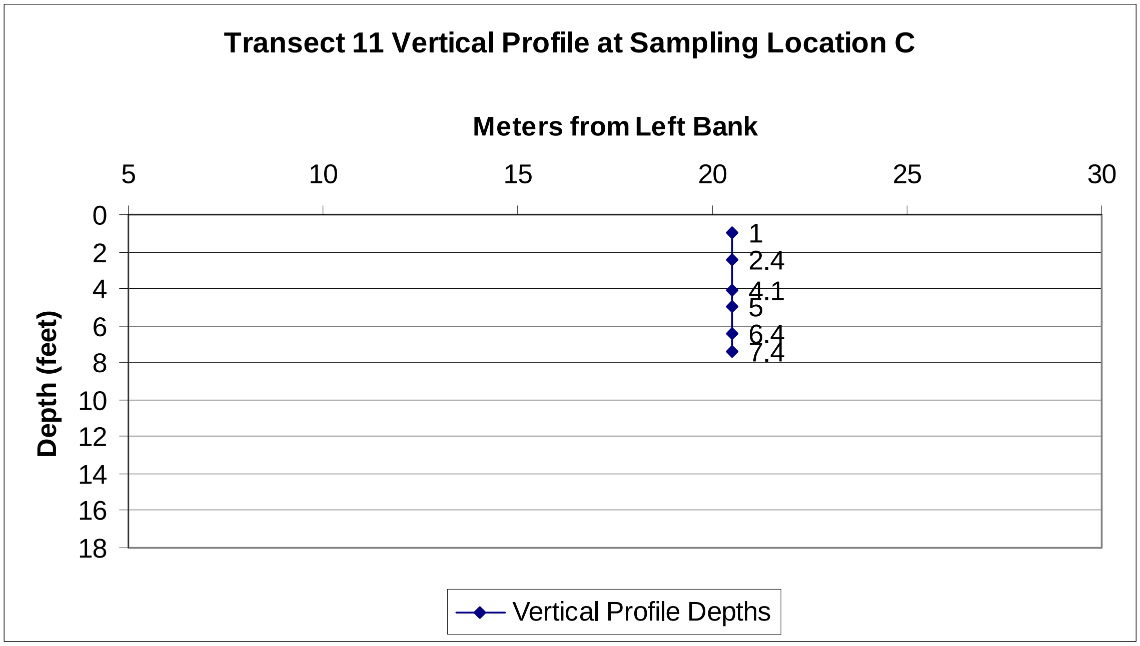


Figure 7-202 Blue Hole Special Study Transect 11 Station C Vertical Profile

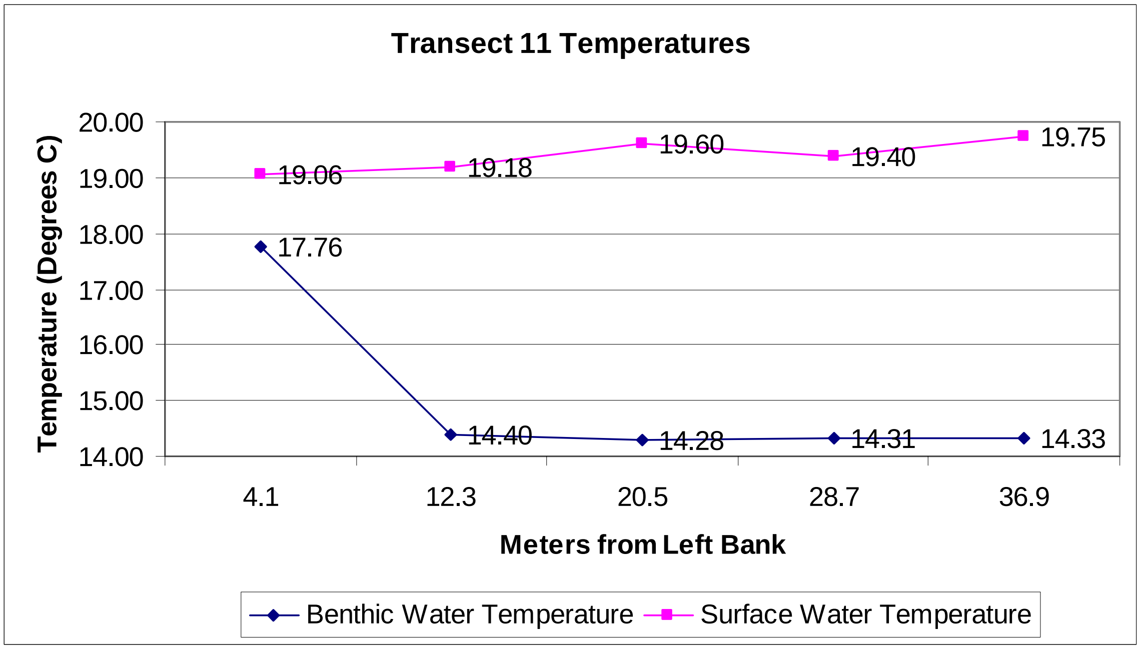


Figure 7-203 Blue Hole Special Study Transect 11 Temperatures

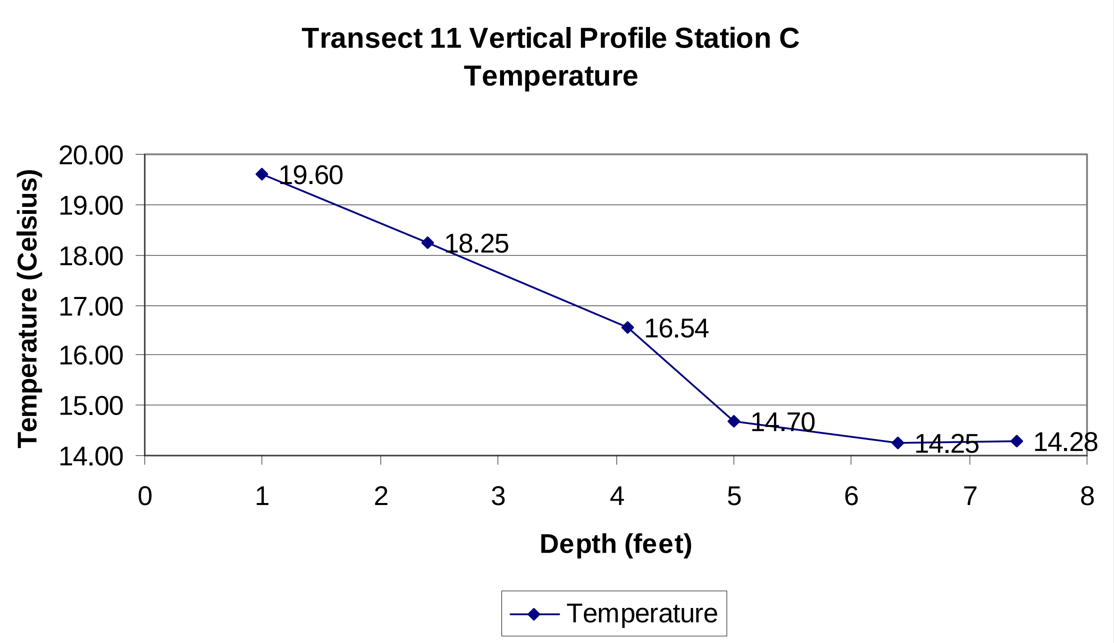


Figure 7-204 Blue Hole Special Study Transect 11 Station C Temperature

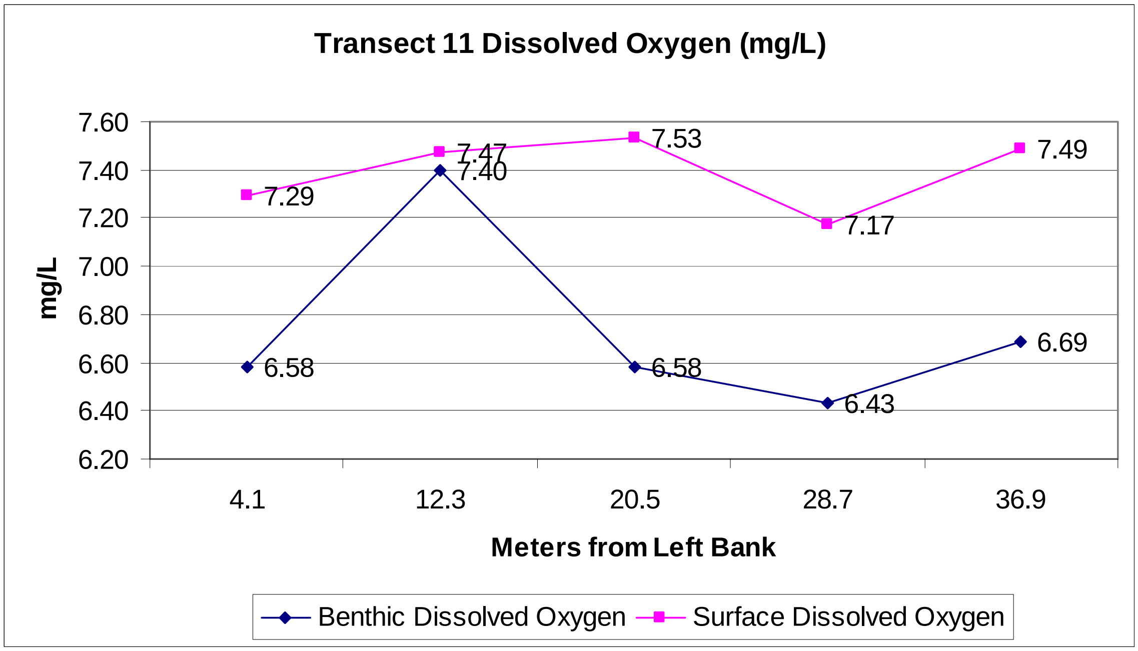


Figure 7-205 Blue Hole Special Study Transect 11 Dissolved Oxygen

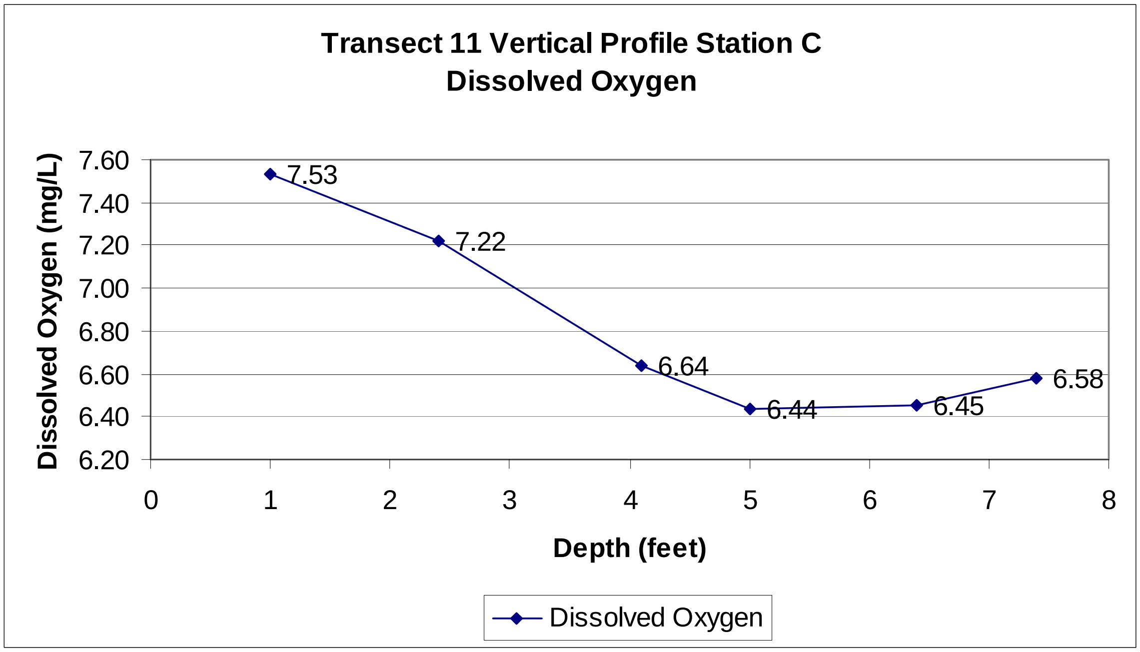


Figure 7-206 Blue Hole Special Study Transect 11 Station C Dissolved Oxygen

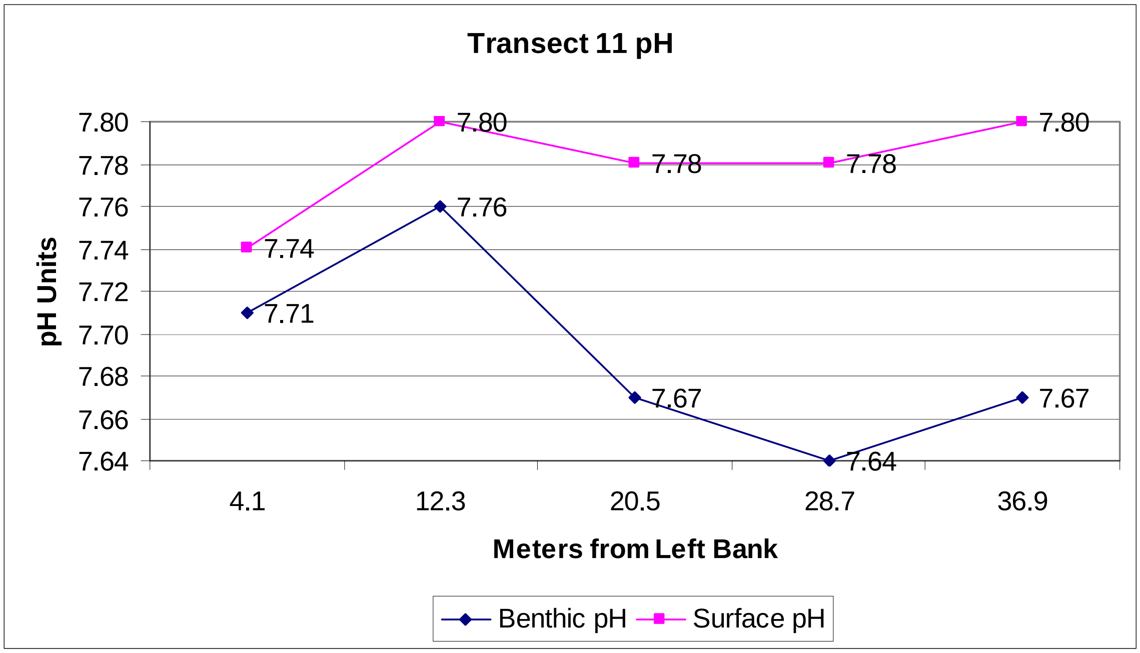


Figure 7-207 Blue Hole Special Study Transect 11 pH

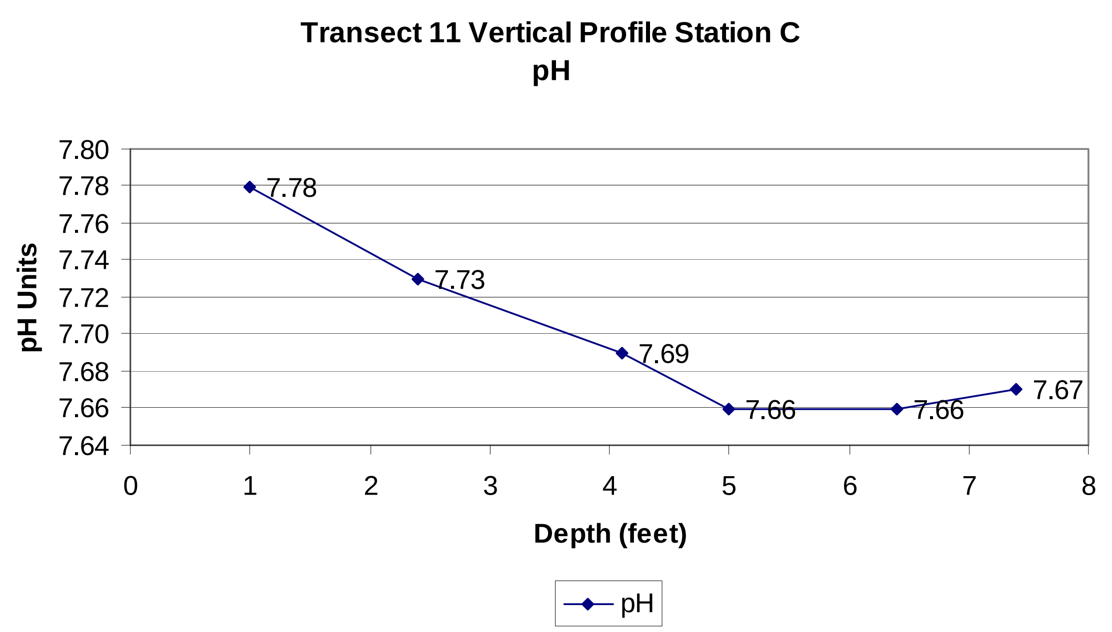


Figure 7-208 Blue Hole Special Study Transect 11 Station C pH

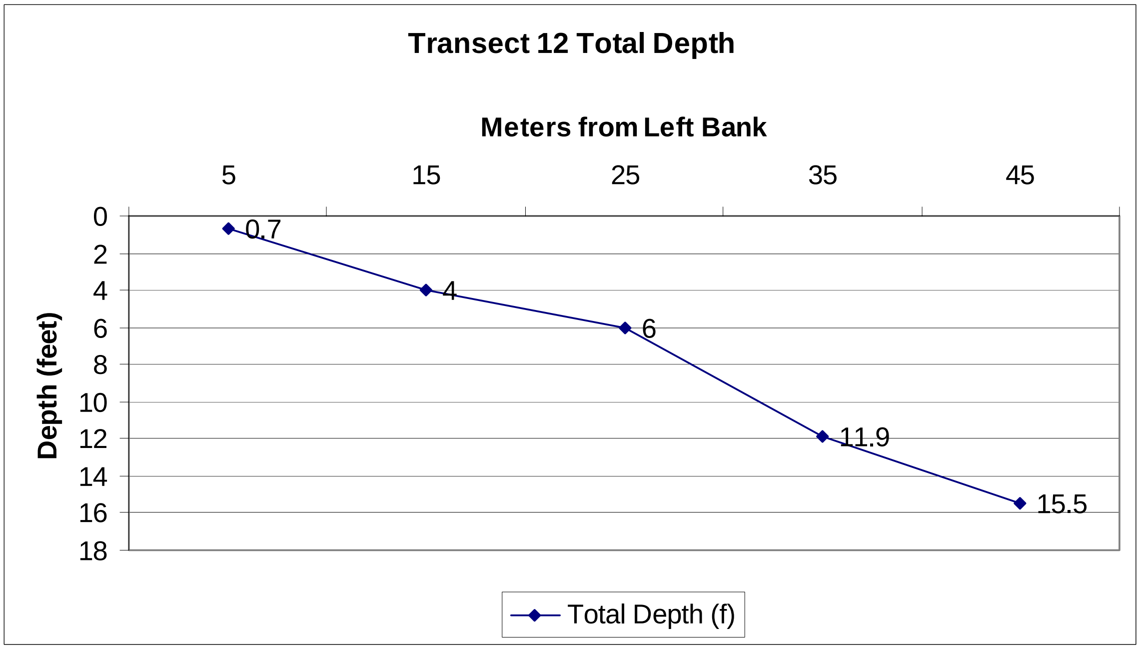


Figure 7-209 Blue Hole Special Study Transect 12 Total Depth

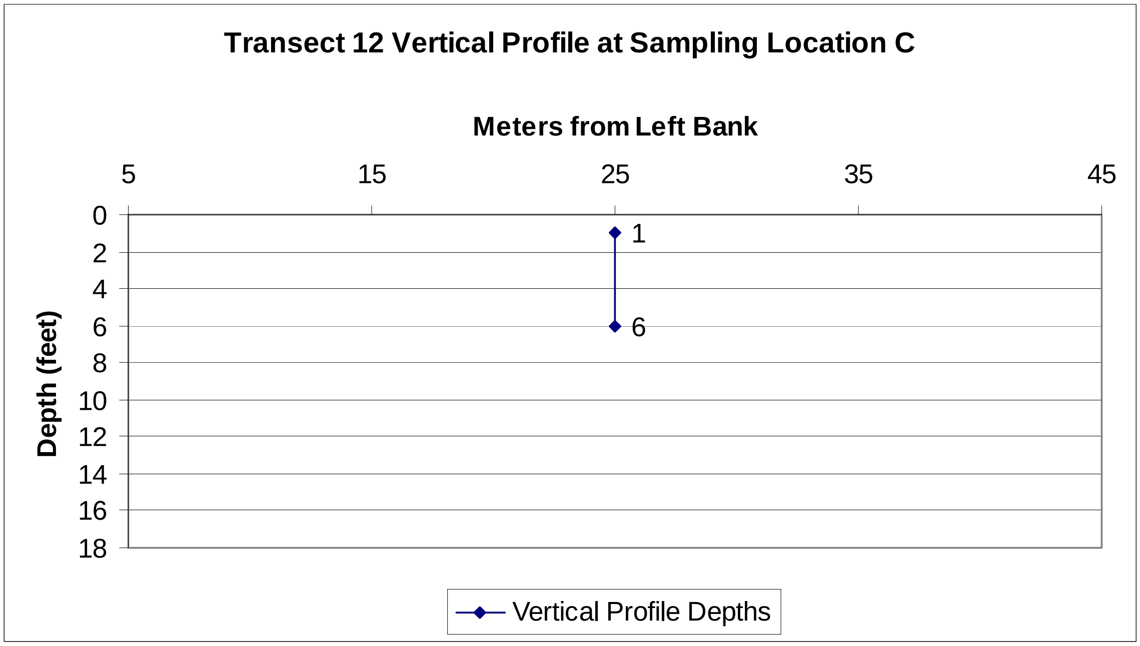


Figure 7-210 Blue Hole Special Study Transect 12 Station C Vertical Profile

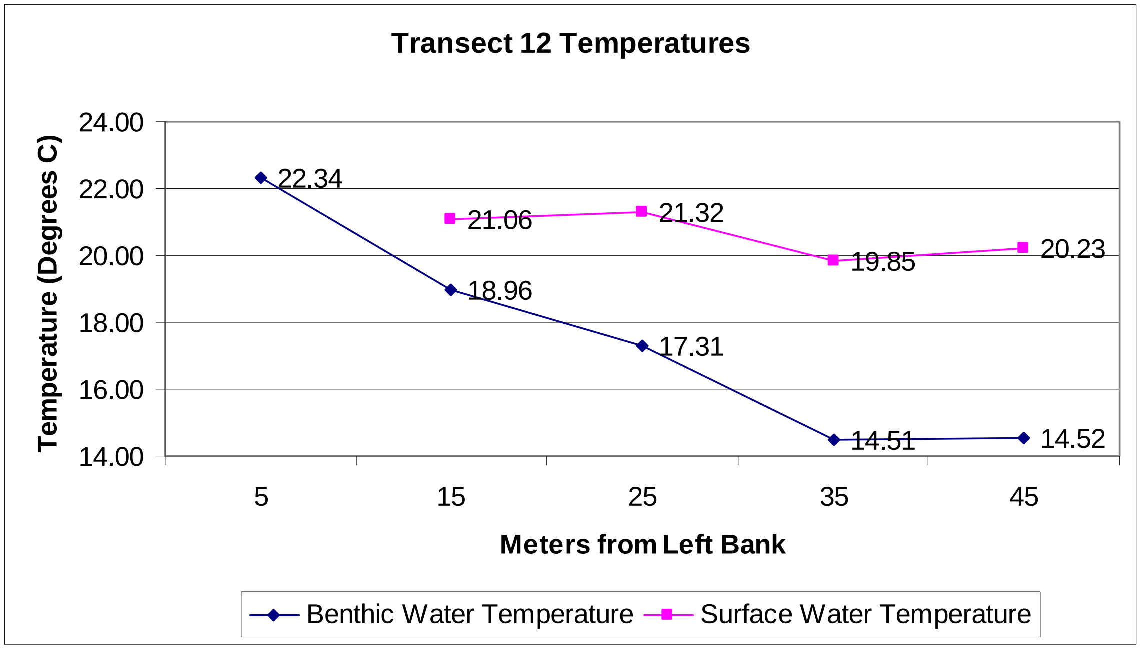


Figure 7-211 Blue Hole Special Study Transect 12 Temperatures

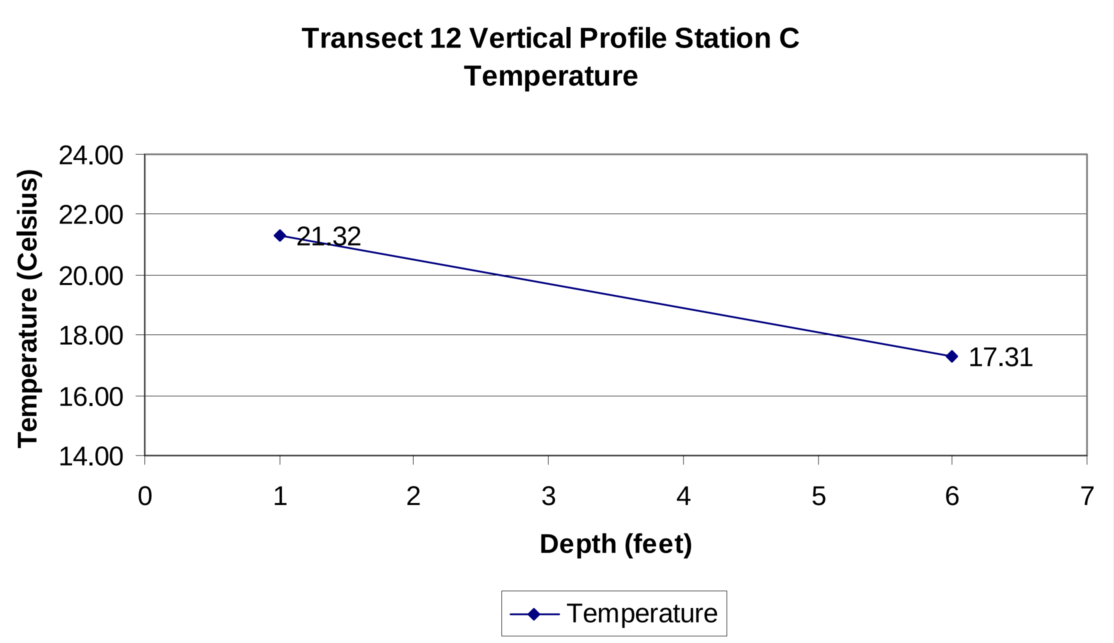


Figure 7-212 Blue Hole Special Study Transect 12 Station C Temperature

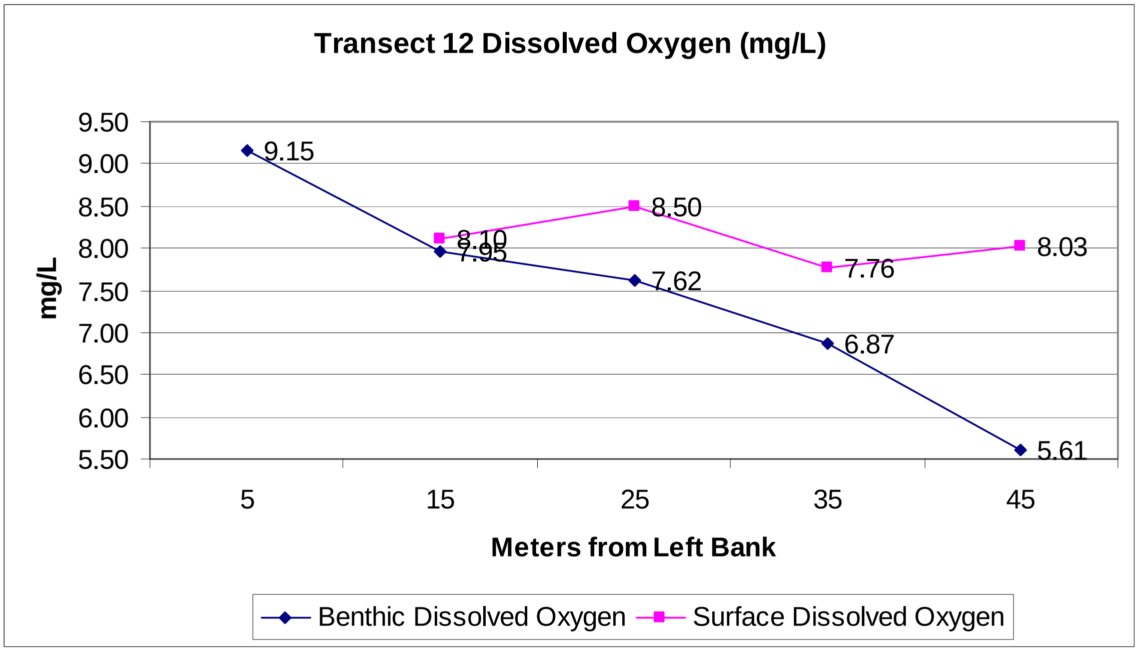


Figure 7-213 Blue Hole Special Study Transect 12 Dissolved Oxygen

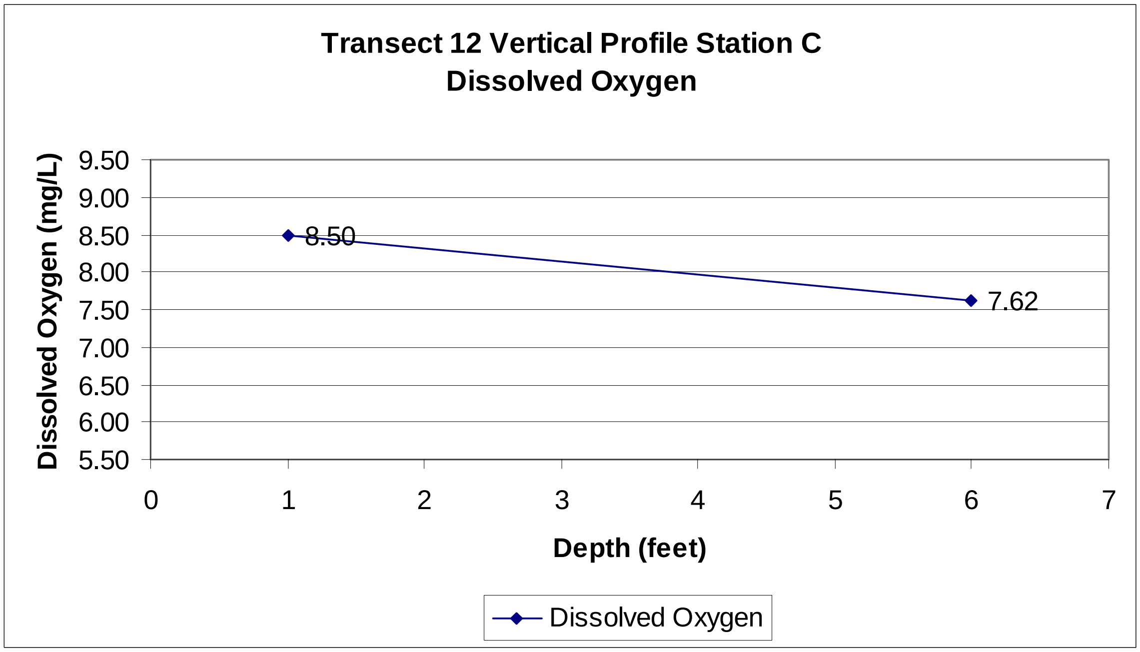


Figure 7-214 Blue Hole Special Study Transect 12 Station C Dissolved Oxygen

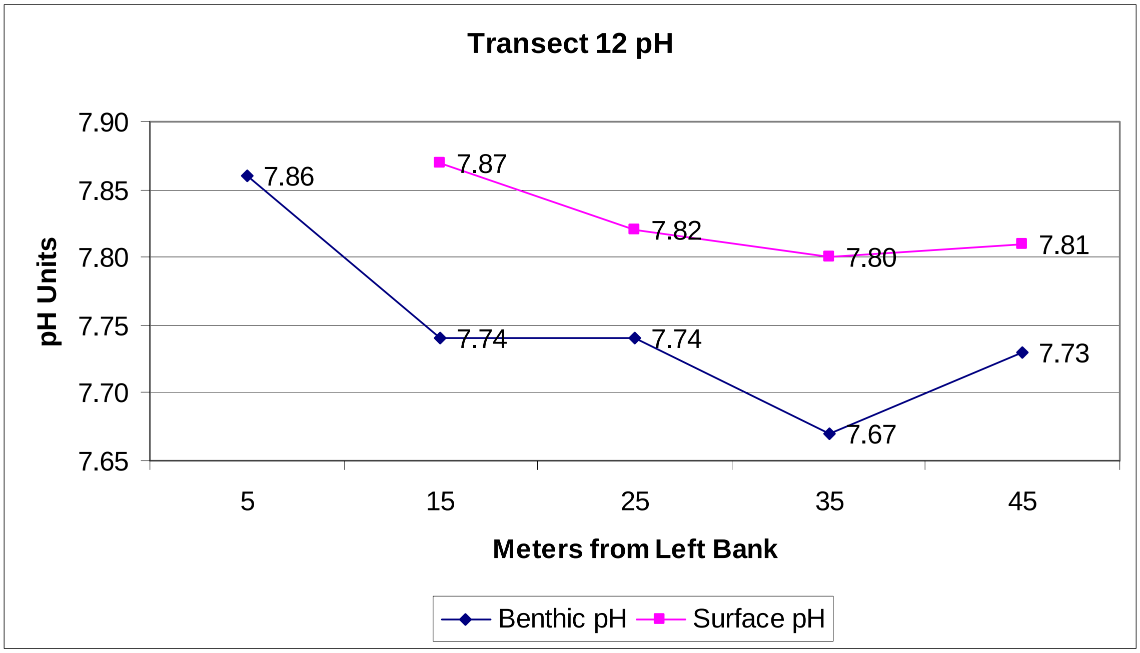


Figure 7-215 Blue Hole Special Study Transect 12 pH

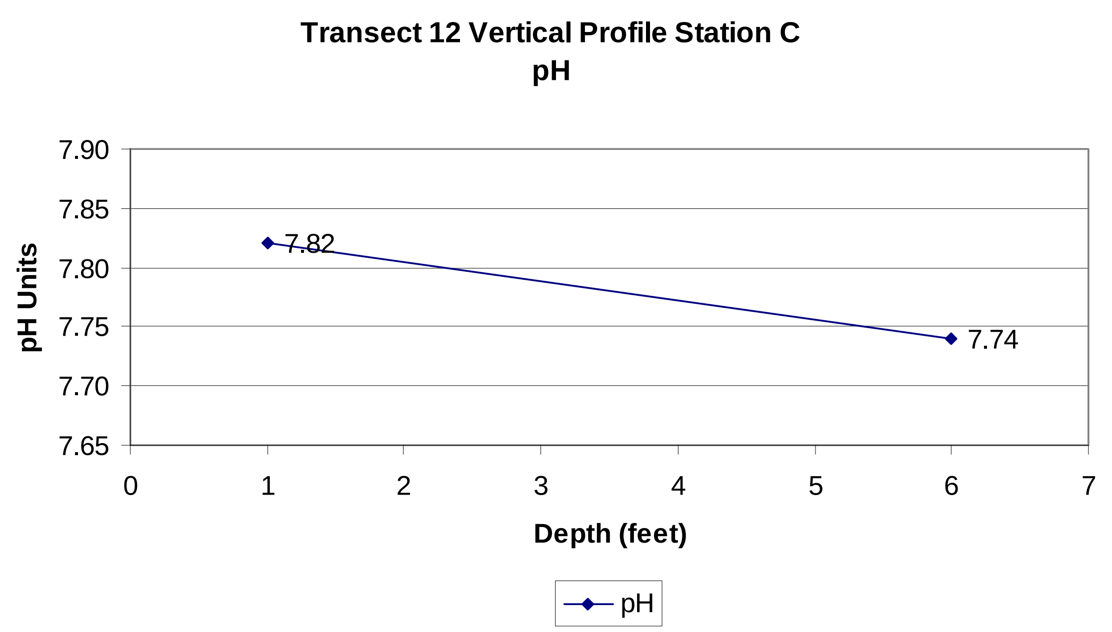


Figure 7-216 Blue Hole Special Study Transect 12 Station C pH

7.1.11.2 *Known Deep Holes in the Lower Klamath River Special Study – 9/8/03*

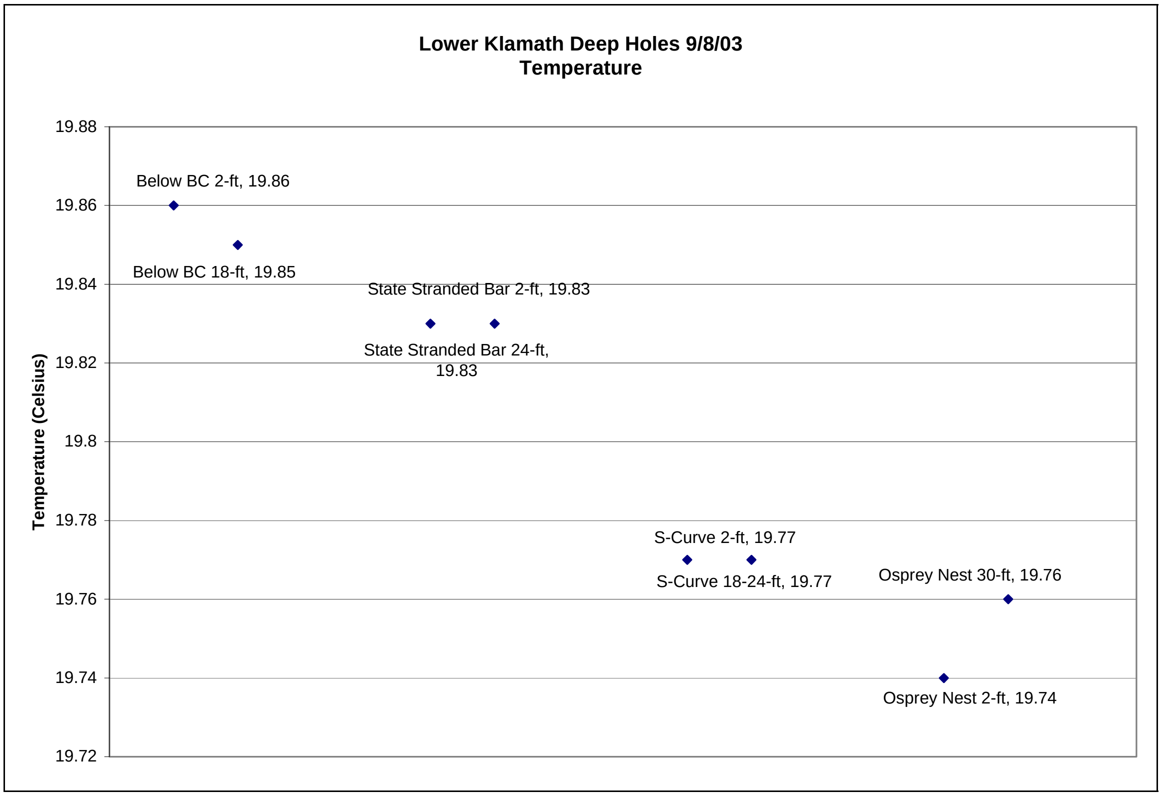


Figure 7-217 Known Deep Holes Special Study Temperatures

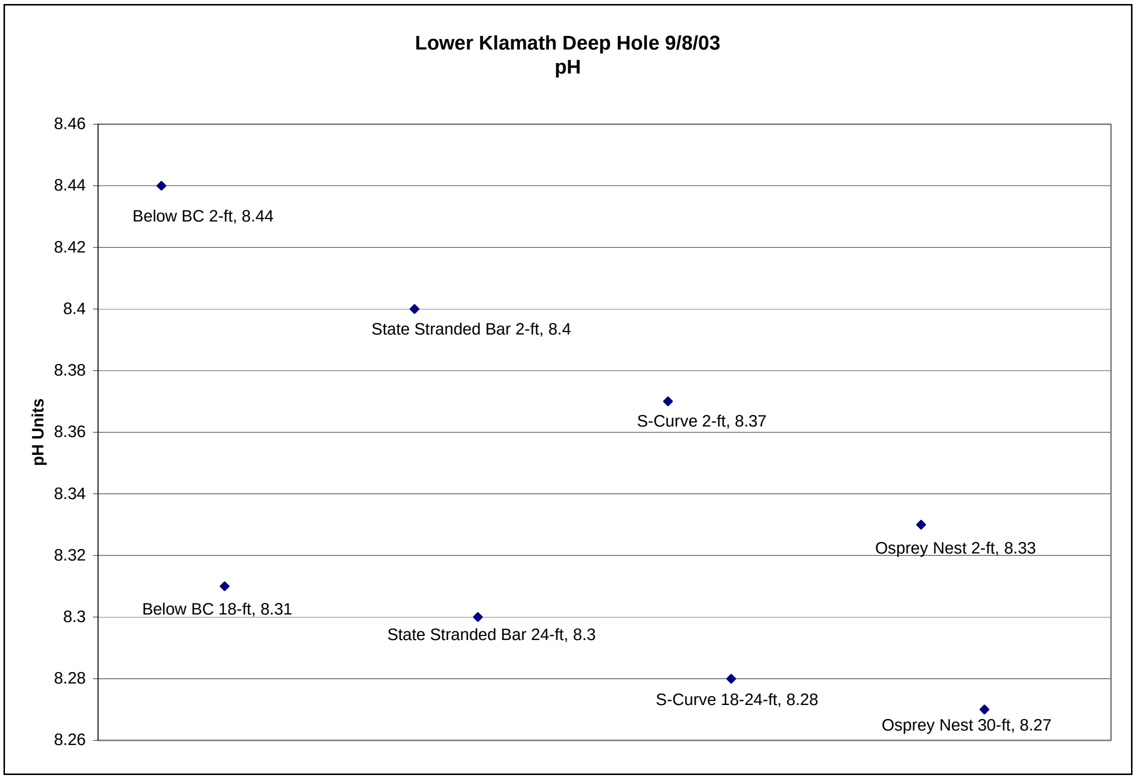


Figure 7-218 Known Deep Holes Special Study pH

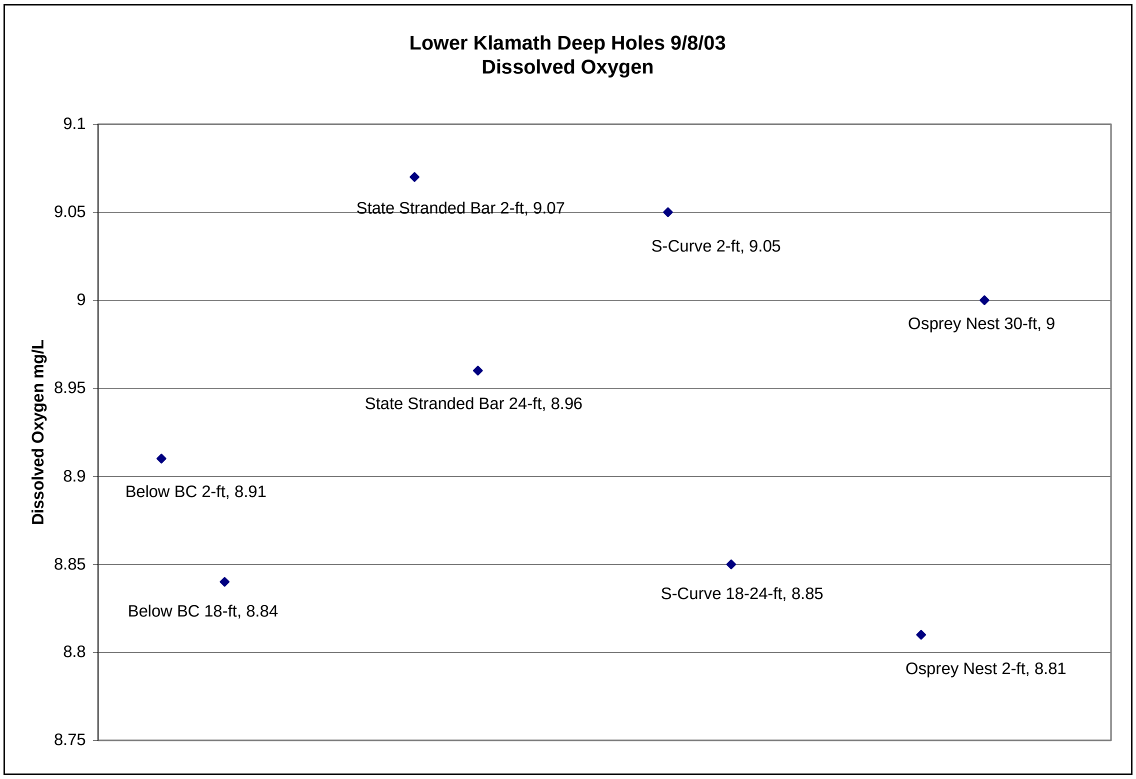


Figure 7-219 Known Deep Holes Special Study Dissolved Oxygen

7.1.12 Mainstem Grab Samples

7.1.12.1 Nutrients

Nutrients

Chlorophyll a

mg/m^3; Report Limit: 0.1

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					ND	
MF	0.3		ND					ND	*						
TC															ND
TG	ND		0.5				ND	ND	*						0.3
TR	0.5		0.1					ND	*					ND	
WE	1.1		0.3				ND	ND	*						2.1

Pheophytin

mg/m^3; Report Limit: 0.1

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					4.8	
MF	0.1		1.9					ND	*						
TC															3.2
TG	0.5		0.8				0.4	ND	*					3.9	
TR	ND		3.8					ND	*						1.1
WE	ND		3.1				ND	ND	*						4.5

Total Nitrogen

mg/L; Report Limit 1.0

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC														ND	
TC															ND
TG														ND	
TR															ND
WE															ND

Total Organic Nitrogen

mg/L; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC														ND	
TC															ND
TG														ND	
TR															ND
WE															ND

Nitrate (as Nitrogen)

mg/L; Report Limit: 0.050

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					ND	
ES		ND			ND										ND
MF	0.084		ND	0.019	0.023	0.026	0.026	ND	*						
TC										ND	ND	ND	ND		ND
TG	0.092		ND				ND	ND	*					ND	
TR	ND		ND	ND	0.032	0.007		ND	*	ND	ND	0.010	ND		ND
WE	0.110		ND	0.025	ND	0.035	ND	ND	*	ND	ND	ND	ND		ND

Nitrite (as Nitrogen)

mg/L; Report Limit: 0.050

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					ND	
ES		ND			ND										ND
MF	ND		ND					ND	*						
TC														ND	
TG	ND		ND				ND	ND	*						ND
TR	ND		ND					ND	*						ND
WE	ND		ND				ND	ND	*						ND

Nitrogen - Total Kjeldahl

mg/L; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					ND	
ES		ND			ND										ND
MF	ND		ND	0.89	1.10	1.14	1.3	ND	*						
TC										ND	ND	ND	ND	ND	
TG	ND		ND				ND	ND	*						ND
TR	ND		ND	1.20	0.87	1.11	0.92	ND	*	ND	ND	ND	ND		ND
WE	ND		ND	0.85	0.66	1.21	ND	ND	*	ND	ND	ND	ND		ND

Ammonia Nitrogen

mg/L; Report Limit: 0.20

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					ND	
ES		ND			ND										ND
TC										ND	ND	ND	ND	ND	
MF	ND		ND	ND	ND	ND	ND	ND	*						
TG	ND		ND				ND	ND	*					ND	
TR	ND		ND	ND	ND	ND	ND	ND	*	ND	ND	ND	ND	ND	
WE	ND		ND	ND	ND	ND	ND	ND	*	ND	ND	ND	ND	ND	

Ammonia Nitrogen - Un-Ionized

mg/L; Report Limit: 0.010

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC														ND	
TC															ND
TG														ND	
TR															ND
WE															ND

Total Phosphorous

mg/L; Report Limit: 0.01

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
MF	0.076		0.030												
TC										ND	ND	ND	ND		
TG	0.056		0.037												
TR	0.178		0.032							ND	0.050	ND	ND		
WE	0.029		0.044							ND	0.050	ND	ND		

Total Phosphate Phosphorous

mg/L; Report Limit: 0.020

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					0.120	
ES		0.084			0.095										0.110
MF	0.130		0.059	ND	ND	ND	ND	0.095	*						
TC														0.130	
TG	0.110		0.060				0.058	0.071	*						0.150
TR	0.270		0.044	ND	ND	ND	0.079	0.056	*						0.047
WE	0.083		0.059	ND	ND	ND	0.079	0.099	*						0.160

Condensed Phosphorous

mg/L; Report Limit: 0.01

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
MF	ND		0.005												
TG	0.003		0.004												
TR	0.054		0.001												
WE	ND		0.024												

Hydrolyzable Phosphorous

mg/L; Report Limit: 0.01

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
MF	0.039		0.021												
TG	0.037		0.024												
TR	0.178		0.025												
WE	0.014		0.024												

Organic Phosphorous

mg/L; Report Limit: 0.01

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
MF	0.037		0.009												
TG	0.019		0.013												
TR	0.050		0.008												
WE	0.015		0.020												

Orthophosphate Phosphorous

mg/L; Report Limit: 0.010

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*					0.032	
ES		0.059			0.011										0.029
MF	0.039		0.016	ND	ND	ND	ND	0.015	*						
TC													ND	0.036	
TG	0.034		0.020				0.018	0.014	*						0.029
TR	0.074		0.024	ND	ND	ND	ND	ND	*				ND		ND
WE	0.015		ND	ND	ND	ND	0.022	0.032	*				ND		0.073

Orthophosphorous

mg/L; Report Limit: 0.01

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
MF	0.039		0.016												
TG	0.034		0.02												
TR	0.074		0.024												
WE	0.015		ND												

Total Organic Carbon

mg/L; Report Limit: 0.20 - 0.50

Site	4/29/03	5/6/03	5/20/03	6/9/03	6/10/03	6/11/03	6/12/03	7/10/03	8/5/03	8/18/03	8/19/03	8/20/03	8/21/03	9/16/03	9/18/03
BC									*						
MF	2.20		1.50					2.10	*						
TG	2.00		1.30				1.90	1.80	*						
TR	1.90		0.98					1.20	*						
WE	2.30		2.00					2.60	*						

*USFWS collected data at this site for this analyte on 8/5/03; the results are not presently available to the Yurok Tribe for reporting purposes.

7.1.12.2 Pesticides

Pesticides

2, 4, 5-T

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

2, 4, 5-TP

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

2, 4-D

µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

2, 4-DB

µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

4, 4'-DDD

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

4, 4'-DDE

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

4, 4'-DDT

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Aldrin

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Alpha-BHC

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Ametryn

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Atraton

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Atrazine

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Azinphos

µg/L; Report Limit: 2.5

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Barbane

µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Beta-BHC
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Coumaphos
µg/L; Report Limit: 2.5

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Bromacil
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dalapon
µg/L; Report Limit: 2.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Carbaryl
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Deet
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Carbofuran
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Delta-BHC
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Chlordane
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Demeton-S
µg/L; Report Limit: 2.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Chlorpropham
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Diazinon
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Chlorpyrifos
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dicamba
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dichlorprop
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Endosulfan I
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dichlorvos
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Endosulfan II
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dieldrin
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Endosulfan sulfate
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dimethoate
µg/L; Report Limit: 2.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Endrin
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Dinoseb
µg/L; Report Limit: 2.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Endrin Aldehyde
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Disulfoton
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Ethion
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Diuron
µg/L; Report Limit 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Ethoprophos
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Fensulfothion
µg/L; Report Limit: 5.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Hexazinon
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Fenthion
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Lindane
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Fenuron
µg/L; Report Limit: 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Linuron
µg/L; Report Limit 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Fluometuron
µg/L; Report Limit: 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Malathion
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Glyphosate
µg/L; Report Limit: 5.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

MCPA
µg/L; Report Limit: 250

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Heptachlor
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

MCPP
µg/L; Report Limit: 250

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Heptachlor Epoxide
µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Methiocarb
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Methomyl

µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Oxamyl

µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Methoxychlor

µg/L; Report Limit: 0.10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Parathion

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Methyl Parathion

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Phorate

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Metribuzin

µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Prometon

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Mevinphos

µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Prometryn

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Monuron

µg/L; Report Limit: 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Propazine

µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Neburon

µg/L; Report Limit 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Propham

µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Propoxur
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Ronnel
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Siduron
µg/L; Report Limit: 10

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Simazine
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Simetryn
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Swep
µg/L; Report Limit 4.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Terbacil
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Terbutryn
µg/L

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Tetrachlorvinphos
µg/L; Report Limit: 0.50

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Toxaphene
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Triadimefon
µg/L; Report Limit: 1.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

Tricyclazole
µg/L; Report Limit: 5.0

Site	9/16/03	9/18/03
BC	ND	
TC		ND
TG	ND	
TR		ND
WE		ND

7.1.12.3 Other

Minerals

Antimony

µg/L; Report Limit: 50

EPA: For human health, consumption of water and organisms, Report Limit is 5.6; for consumption of organisms only, Report Limit is 640.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Arsenic

µg/L; Report Limit: 10

EPA: CMC is 340, CCC is 150. For human health, consumption of water and organisms, Report Limit is 0.018; for consumption of organisms only, Report Limit is 0.14.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Beryllium

µg/L; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Boron

µg/L; Report Limit: 100

YTWQCP: Boron levels shall have a 90% upper Report Limit of 0.5 mg/L and a 50% upper Report Limit of 0.2 mg/L.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Cadmium

µg/L; Report Limit: 10

EPA: CMC is 2.0, CCC is 0.25.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Calcium

µg/L; Report Limit: 1,000

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC							*		16000	
ES		15000		12000						22000
MF	16000		14000			15000	*			
TC									15000	
TG	16000		14000		13000	15000	*			16000
TR	20000		16000			13000	*			14000
WE	13000		13000			16000	*			16000

Chromium

µg/L; Report Limit: 10

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Hexavalent Chromium

µg/L; Report Limit: 10

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Copper

µg/L; Report Limit: 10

EPA: CMC is 13, CCC is 9.0. For human health, consumption of water and organisms, Report Limit is 1,300.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Fluoride

mg/L; Report Limit 0.10

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										0.12

Lead

µg/L; Report Limit: 10

EPA: CMC is 65, CCC is 2.5.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Magnesium

µg/L; Report Limit: 250

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC							*		7800	
ES		7200		5700						28000
MF	8900		6700			7800	*			
TC									8200	
TG	8200		6700		6000	7600	*			7800
TR	13000		7100			7300	*			7500
WE	6800		6500			8200	*			8400

Mercury

µg/L; Report Limit: 1.0

EPA: CMC is 1.4, CCC is 0.77.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Nickel

µg/L; Report Limit: 20

EPA: CMC is 470, CCC is 52. For human health, consumption of water and organisms, Report Limit is 610; for consumption of organisms only, Report Limit is 4,600.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Potassium

µg/L; Report Limit: 5,000

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Selenium

µg/L; Report Limit: 10

EPA: CCC is 5.0. For human health, consumption of water and organisms, Report Limit is 170; for consumption of organisms only, Report Limit is 4,200.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Silver

µg/L; Report Limit: 10

EPA: CMC is 3.2.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Sodium

µg/L; Report Limit: 1,000

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									7300	
TC										8300
TG									7100	
TR										3000
WE										11000

Sulfate

mg/L; Report Limit: 0.50

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									4.9	
TC										5.2
TG									4.9	
TR										3.9
WE										7.3

Thallium

µg/L; Report Limit: 10

EPA: For human health, consumption of water and organisms, Report Limit is 1.7; for consumption of organisms only, Report Limit is 6.3.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Zinc

µg/L; Report Limit: 20

EPA: CMC is 120, CCC is 120. For human health, consumption of water and organisms, Report Limit is 7,400; for consumption of organisms only, Report Limit is 26,000.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Bacteria

E. Coli

These results are unitless; Report Limit: 1.0

YTWQCP: E. Coli single sample maximum 300CFU/100mL

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
MF					5.2					
TG					1					
TR					1					
WE					1					

Fecal Coliform

These results are unitless; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
MF			2		4					
TG			4		2					
TR			2		8					
WE			ND		ND					

Strep. Faecalis

These results are unitless; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
MF					2.0					
TG					ND					
TR					3.1					
WE					ND					

Total Coliform

These results are unitless; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
MF			300.0		240.0	517.2				
TG			46.0		240.0	648.8				
TR			22.0		80.0	517.2				
WE			240.0		240.0	1732.9				

Other Analytes

Biochemical Oxygen Demand
mg/L; Report Limit: 2.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
ES				2.1						ND
MF			ND			ND				
TG			ND			ND				
TR			ND			ND				
WE			ND			ND				

Bicarbonate
mg/L CaCO3; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									60	
TC										77
TG									76	
TR										63
WE										82

Carbonate
mg/L CaCO3; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										1.1
TG									1.8	
TR										ND
WE										1.5

Chloride
mg/L; Report Limit: 0.10
EPA: CMC is 860,000.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									3.2	
TC										3.5
TG									3.1	
TR										2.2
WE										4.1

Hydroxide
mg/L CaCO3; Report Limit 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

MBAS

mg/L; Report Limit: 0.050

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									ND	
TC										ND
TG									ND	
TR										ND
WE										ND

Alkalinity

mg/L CaCO3; Report Limit: 1.0

EPA: CCC is 20,000.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC							*		61.0	
ES		58.0		53.0						76.0
MF	63.0		60.0			66.0	*			
TC									78.0	
TG	59.0		58.0		53.0	64.0	*			78.0
TR	66.0		62.0			59.0	*			64.0
WE	59.0		56.0			73.0	*			84.0

Conductivity

µmhos/cm; Report Limit: 1.0

YTWQCP: Conductivity levels shall have a 90% upper Report Limit of 300 umhos/cm and a 50% upper Report Limit umhos/cm at 25 degrees celsius.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									160	
TC										170
TG									160	
TR										140
WE										180

Hardness

mg/L CaCO3; Report Limit: 7.0

YTWQCP: Hardness levels shall have a 50% upper Report Limit of 80 mg/L CaCO3.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									72	
TC										72
TG									72	
TR										65
WE										75

pH

pH Units; Report Limit: N/A

YTWQCP: pH shall not be below 6.5 nor exceed 8.5 due to human caused activities.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC									8.2	
TG									8.4	
TR										8.0
WE										8.3

Non-Filterable Residue (TSS)

mg/L; Report Limit: 1.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC							*			
ES		30.0		10.0						3.6
MF	75.0		11.0		6.0	2.2				
TC								ND		
TG	55.0		14.0		7.1	2.6				
TR	170.0		16.0		5.0	5.0		ND		
WE	7.8		5.4		7.3	1.0		ND		

Total Dissolved Solids

mg/L; Report Limit: 10

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
BC							*		110.0	
ES		96.0		71.0						710.0
MF	100.0		91.0			86.0	*			
TC									100.0	
TG	95.0		96.0		82.0	140.0	*			38.0
TR	100.0		99.0			72.0	*			77.0
WE	100.0		95.0			100.0	*			130.0

Turbidity

NTU; Report Limit: 0.10

YTWQCP: Turbidity shall not exceed 5 NTU over background turbidity when the background is 50 NTU or less, or have more than a 10% increase when the background is >50NTU.

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
ES				8.20						3.00
MF	37.50		8.40		4.27					
TC								0.90		
TG	40.00		12.00							
TR	93.75		12.00		3.30			0.30		
WE	4.18		3.40		6.10			0.72		

Volatile Suspended Solids

mg/L; Report Limit: 10, with the exception of 6/12 at MF and TR, as well as 8/21 TC, TR, and WE, for which the Report Limit was 2.0

Site	4/29/03	5/6/03	5/20/03	6/10/03	6/12/03	7/10/03	8/5/03	8/21/03	9/16/03	9/18/03
MF					ND					ND
TC								ND		
TR					2			ND	ND	
WE					ND			ND		

*USFWS collected data at this site for this analyte on 8/5/03; the results are not presently available to the Yurok Tribe for reporting purposes.

YTWQCP = Yurok Tribe Water Quality Control Plan
EPA = Environmental Protection Agency
CMC = Criterion Maximum Concentration
CCC = Criterion Continuous Concentration

7.2 Water Quality and Hydrology (Tributaries)

Water quality monitoring was periodically performed during the winter. Most of the data collected were measurements to assist hydrologic studies in the basin. These parameters include but were not limited to turbidity, temperature, and specific conductivity. Other data collected were used for multiple restoration and monitoring projects within close proximity of one another. Table 7-1 lists the dates and locations where monitoring efforts took place.

Table 7-1 Location, time period, and parameters for water quality monitoring in tributaries, WY03

		Parameters					
Location	**Time Period**	**Turbidity (NTU)**	**Temperature (deg. C)**	**Specific Conductivity (uS/cm)**	**pH**	**DO %sat**	**DO mg/L**
Blue	11/14/02-12/2/02	X	X	X			
Blue	1/22/03-2/5/03	X	X	X			
McGarvey	12/11/02-12/25/02	X	X	X			
McGarvey	1/10/03-1/22/03	X	X	X			
McGarvey	1/22/03-2/5/03	X	X	X			
Tulley	11/6/02-11/12/02	X	X	X	X	X	X
Turwar	3/13/03-3/27/03	X	X	X			

7.2.1 McGarvey Creek

The McGarvey gaging station has been in operation since December 1, 2001. The station is located at 41° 29’ 11.29” north latitude, 124° 00’ 34.46” west longitude, upstream of the confluence of McGarvey and Den Creeks. The total drainage area of the watershed is 8.9 square miles. The following parameters are measured at the site on a fifteen-minute time step throughout the year: date, time, stage, air temperature (inside the gaging box), and battery voltage. Flow measurements are collected at the gaging station periodically. The YTFD monitored water temperature at various locations throughout McGarvey

Creek including at the gaging station site. Those data are not presented in this report. Turbidity, water temperature, and specific conductivity were periodically monitored during the winter. Those data were recorded using a datasonde.

YTFD monitored rainfall events in McGarvey Creek using tipping bucket rain gages. The gage records rainfall events equivalent to 1/100 of an inch of rainfall. The McGarvey Creek Rain Gage is located near the north end of the Simpson M920 road, south of the junction near the M900 road entrance.

7.2.1.1 Discharge

Table 7-2 Minimum Daily Discharge (cfs) Values for McGarvey Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	Aug	September
1		3.43	'	8.07	131.03	66.18	17.47	26.04	49.38	10.62	6.58	2.76	2.27
2		2.27	'	8.30	107.28	56.83	16.67	34.60	43.48	10.34	6.38	2.86	2.27
3		1.26	'	8.30	59.83	47.64	15.52	33.93	38.85	10.34	6.38	3.43	2.27
4		0.62	'	8.78	58.82	41.12	14.43	43.48	49.38	10.34	6.19	3.43	2.37
5		0.39	'	8.78	57.82	35.29	13.73	'	47.64	10.34	6.19	3.19	2.37
6		0.21	'	8.78	49.38	31.97	13.06	'	41.89	10.07	6.01	3.08	2.46
7		0.09	'	8.30	43.48	28.89	12.74	'	36.68	9.80	5.82	2.97	2.56
8		0.01	15.52	8.30	38.85	26.04	12.10	'	33.27	9.54	5.65	2.76	2.65
9		0.00	18.73	8.78	34.60	24.43	12.10	'	29.49	9.54	5.47	2.76	2.65
10		0.00	'	17.06	19.16	22.90	16.28	41.12	27.15	9.54	5.47	2.65	2.97
11		0.00	'	14.78	18.30	18.73	15.89	'	25.49	9.28	5.47	2.65	2.76
12		0.00	'	14.43	21.92	17.88	17.88	'	23.40	9.28	5.30	2.65	2.56
13		0.00	'	41.89	30.71	17.47	17.47	'	21.92	9.03	4.97	2.65	2.46
14		0.00	'	60.85	90.99	16.28	30.10	'	20.50	8.78	4.22	2.65	2.27
15		0.00	'	112.07	84.23	16.28	39.60	'	19.16	8.78	3.94	2.56	2.27
16		0.00	'	223.24	69.53	55.86	34.60	'	18.30	8.78	3.81	2.56	2.27
17		0.00	'	194.86	59.83	45.11	29.49	'	17.47	8.54	3.68	2.56	2.19
18		0.00	'	134.72	52.08	42.68	25.49	'	16.67	8.54	3.55	2.46	2.19
19		'	'	110.46	47.64	41.89	24.96	'	15.89	8.30	3.55	2.46	2.10
20		'	'	107.28	43.48	61.89	42.68	'	15.52	7.84	3.43	2.46	2.10
21		'	'	138.48	41.89	47.64	38.12	'	14.78	7.84	3.43	2.46	2.10
22		'	'	107.28	26.04	38.12	37.40	'	14.43	7.62	3.31	2.56	1.94
23		'	'	89.61	25.49	32.61	52.08	'	14.08	7.40	3.19	2.46	1.78
24		'	'	80.36	24.43	28.30	41.89	'	13.73	7.40	3.19	2.37	1.64
25		'	'	70.68	38.12	24.96	40.35	'	13.39	7.40	3.19	2.27	1.57
26		'	9.28	69.53	35.29	22.40	60.85	'	12.42	7.19	3.19	2.27	1.57
27		'	9.28	79.10	57.82	20.05	49.38	'	12.10	7.19	3.08	2.27	1.64
28		'	8.78	289.08	58.82	18.73	39.60	'	11.80	7.19	2.97	2.27	1.78
29		'	6.78	178.26	52.08	'	32.61	'	11.80	6.98	2.86	2.46	1.78
30		'	7.19	150.24	56.83	'	28.30	57.82	11.49	6.78	2.86	2.37	1.71
31		'		194.86	65.08	'	26.04	'	10.91	'	2.86	2.37	'

Monthly Statistics

Total	8.29	75.56	2555.55	1600.84	948.14	868.89	236.99	732.46	260.69	136.23	81.67	65.52
Mean	0.46	10.79	82.44	51.64	33.86	28.03	39.50	23.63	8.69	4.39	2.63	2.18
Max	3.43	18.73	289.08	131.03	66.18	60.85	57.82	49.38	10.62	6.58	3.43	2.97
Min	0.00	6.78	8.07	18.30	16.28	12.10	26.04	10.91	6.78	2.86	2.27	1.57

Table 7-3 Maximum Daily Discharge (cfs) Values for McGarvey Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		4.08	'	9.54	212.59	82.93	19.16	45.94	58.82	11.49	6.78	3.31	2.65
2		3.43	'	9.28	136.59	68.40	17.47	42.68	50.27	11.49	6.58	3.31	2.65
3		2.27	'	9.28	117.03	57.82	17.88	42.68	48.50	10.91	6.38	3.81	2.46
4		1.26	'	9.28	77.85	48.50	15.89	61.89	68.40	10.62	6.38	3.68	2.65
5		0.73	'	9.28	66.18	41.12	14.78	'	53.94	10.34	6.19	3.68	2.56
6		0.47	'	9.28	57.82	35.98	14.08	'	47.64	10.34	6.19	3.43	2.76
7		0.23	'	9.03	50.27	31.97	13.73	'	45.11	10.07	6.01	3.43	2.86
8		0.11	132.86	9.28	43.48	28.89	13.06	'	38.12	9.80	5.82	3.31	3.08
9		0.00	26.59	17.47	38.85	26.04	20.50	'	33.27	9.80	5.65	3.19	6.19
10		0.00	'	38.12	35.29	24.43	20.05	41.12	29.49	9.54	5.47	3.08	4.66
11		0.00	'	17.47	21.92	23.40	20.50	'	27.15	9.54	5.47	3.08	3.08
12		0.00	'	138.48	31.97	19.16	19.60	'	25.49	9.28	5.47	3.08	2.86
13		0.00	'	140.39	134.72	19.60	35.98	'	23.91	9.28	5.30	3.08	2.76
14		0.00	'	345.32	129.22	17.47	41.89	'	22.40	9.03	4.97	2.97	2.56
15		0.00	'	234.28	108.86	65.08	48.50	'	20.97	8.78	4.22	2.97	2.46
16		0.00	'	783.85	104.17	68.40	40.35	'	19.60	8.78	4.36	2.86	2.46
17		0.00	'	245.73	70.68	61.89	34.60	'	18.73	8.78	4.08	2.86	2.46
18		0.00	'	192.42	59.83	49.38	30.10	'	17.88	8.54	4.08	2.86	2.37
19		'	'	134.72	52.08	123.88	53.01	'	17.06	8.54	4.08	2.76	2.37
20		'	'	220.54	46.78	93.81	51.17	'	16.28	8.30	3.94	2.76	2.37
21		'	'	173.71	48.50	61.89	43.48	'	15.89	7.84	3.81	2.76	2.27
22		'	'	138.48	41.89	48.50	102.64	'	15.52	7.84	3.81	2.97	2.27
23		'	'	108.86	30.10	38.12	69.53	'	14.78	7.62	3.68	2.86	2.10
24		'	'	90.99	49.38	32.61	53.01	'	14.78	7.40	3.68	2.65	1.86
25		'	'	80.36	47.64	28.30	86.89	'	14.78	7.40	3.68	2.56	1.78
26		'	10.62	79.10	56.83	25.49	99.63	'	13.73	7.40	3.68	2.56	1.78
27		'	9.80	811.81	150.24	22.40	68.40	'	13.06	7.19	3.55	2.56	1.86
28		'	18.73	568.68	99.63	20.50	53.01	'	12.74	7.19	3.43	2.56	2.02
29		'	8.78	295.71	61.89	'	40.35	'	12.42	7.19	3.43	2.76	2.02
30		'	8.78	239.95	79.10	'	33.27	65.08	12.42	6.98	3.31	2.65	1.94
31		'	'	422.23	73.01	'	29.49	'	12.10	'	3.31	2.65	'

Monthly Statistics

Total		216.17	5592.93	2334.36	1265.97	1222.00	299.40	835.25	267.38	146.81	93.03	78.16
Mean		30.88	180.42	75.30	45.21	39.42	49.90	26.94	8.91	4.74	3.00	2.61
Max		132.86	811.81	212.59	123.88	102.64	65.08	68.40	11.49	6.78	3.81	6.19
Min		8.78	9.03	21.92	17.47	13.06	41.12	12.10	6.98	3.31	2.56	1.78

Table 7-4 Average Daily Discharge (cfs) Values for McGarvey Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		3.72	'	8.67	163.81	73.70	18.21	28.89	54.52	10.96	6.73	2.97	2.37
2		3.03	'	8.72	120.06	62.68	17.08	37.19	46.76	10.68	6.49	3.12	2.33
3		1.71	'	8.71	82.64	52.47	16.68	35.84	41.59	10.54	6.38	3.64	2.31
4		0.99	'	8.93	67.25	44.83	15.14	49.51	59.14	10.48	6.27	3.52	2.41
5		0.57	'	8.85	61.52	38.67	14.16	'	50.67	10.34	6.19	3.36	2.42
6		0.34	'	8.83	53.89	33.87	13.49	'	44.85	10.30	6.08	3.24	2.54
7		0.16	'	8.71	46.47	30.20	13.28	'	39.40	9.94	6.00	3.13	2.68
8		0.06	28.26	8.75	41.05	27.57	12.62	'	36.02	9.78	5.70	2.98	2.83
9		0.00	22.88	10.13	36.71	25.46	16.51	'	31.53	9.60	5.50	2.91	4.13
10		0.00	'	21.33	27.17	23.82	17.84	41.12	28.56	9.54	5.47	2.78	3.59
11		0.00	'	15.87	19.65	21.13	17.94	'	26.43	9.31	5.47	2.76	2.88
12		0.00	'	19.43	24.70	18.44	18.74	'	24.63	9.28	5.45	2.76	2.64
13		0.00	'	61.67	68.72	18.15	22.30	'	22.91	9.09	5.19	2.75	2.52
14		0.00	'	185.02	113.28	16.86	36.69	'	21.53	8.84	4.70	2.71	2.38
15		0.00	'	141.68	94.33	24.87	43.30	'	20.11	8.78	4.13	2.70	2.30
16		0.00	'	369.40	77.61	62.79	37.82	'	18.95	8.78	4.01	2.61	2.29
17		0.00	'	221.24	65.22	52.24	32.43	'	18.08	8.70	3.80	2.61	2.27
18		0.00	'	161.51	56.16	46.50	27.84	'	17.23	8.54	3.73	2.57	2.24
19		'	'	123.08	49.86	74.27	30.54	'	16.45	8.37	3.71	2.57	2.18
20		'	'	150.85	45.18	71.79	46.51	'	15.78	8.03	3.62	2.57	2.17
21		'	'	158.42	44.53	54.36	40.97	'	15.28	7.84	3.55	2.54	2.14
22		'	'	121.58	36.15	42.97	53.90	'	14.75	7.68	3.48	2.66	2.08
23		'	'	98.44	27.12	35.74	60.11	'	14.32	7.45	3.43	2.64	1.90
24		'	'	86.39	30.06	30.41	46.90	'	13.99	7.40	3.37	2.44	1.74
25		'	'	75.69	41.82	26.65	52.72	'	14.03	7.40	3.36	2.38	1.66
26		'	9.66	73.93	39.68	23.92	76.02	'	13.15	7.33	3.32	2.35	1.63
27		'	9.35	304.33	116.40	21.45	59.13	'	12.46	7.19	3.24	2.34	1.73
28		'	9.81	402.48	75.33	19.52	45.17	'	12.05	7.19	3.14	2.36	1.85
29		'	7.64	220.57	57.63	'	36.58	'	12.05	7.15	3.07	2.52	1.89
30		'	8.06	174.04	69.95	'	30.93	60.73	11.91	6.95	3.03	2.47	1.81
31		'	'	291.45	68.83	'	27.72	'	11.40	'	3.00	2.43	'

Monthly Statistics

	October	November	December	January	February	March	April	May	June	July	August	September
Total	10.59	95.65	3558.71	1922.74	1075.32	999.25	253.28	780.52	263.49	140.64	85.39	69.92
Mean	0.59	13.66	114.80	62.02	38.40	32.23	42.21	25.18	8.78	4.54	2.75	2.33
Max	3.72	28.26	402.48	163.81	74.27	76.02	60.73	59.14	10.96	6.73	3.64	4.13
Min	0.00	7.64	8.67	19.65	16.86	12.62	28.89	11.40	6.95	3.00	2.34	1.63

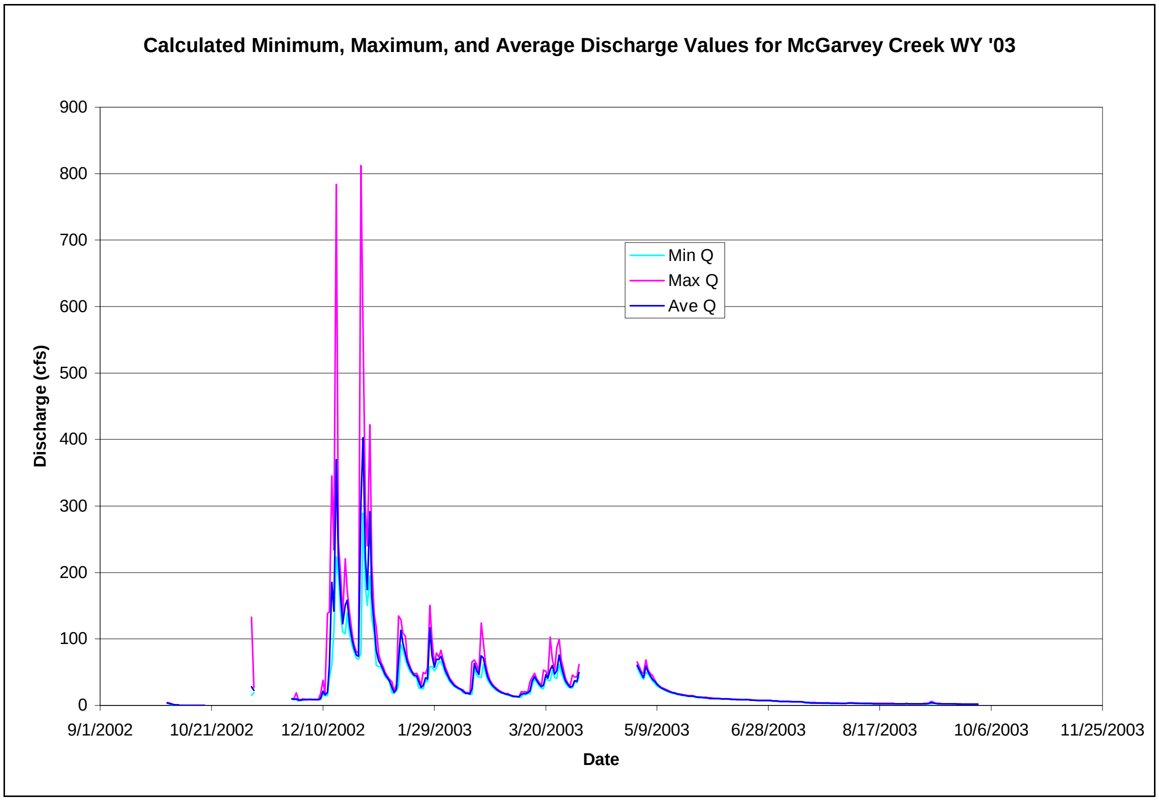


Figure 7-220 Mean, minimum, and maximum discharges estimated for McGarvey Creek gaging station

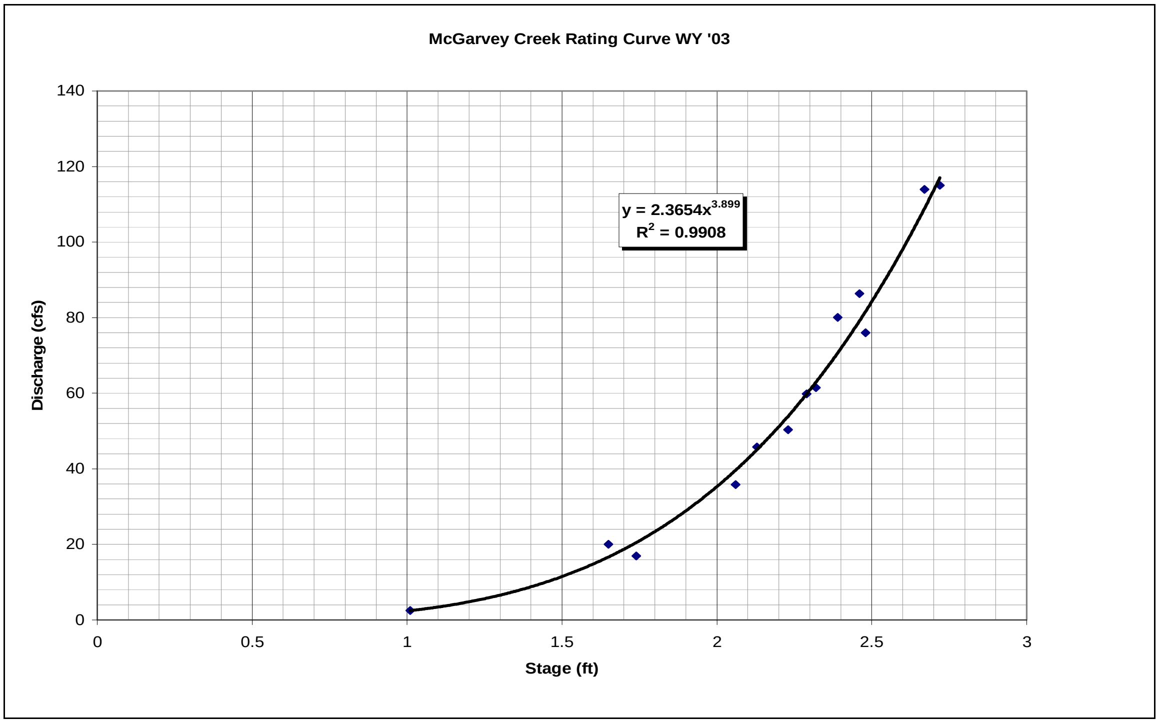


Figure 7-221 Discharge rating curve values for McGarvey Creek gaging station

7.2.1.2 Turbidity

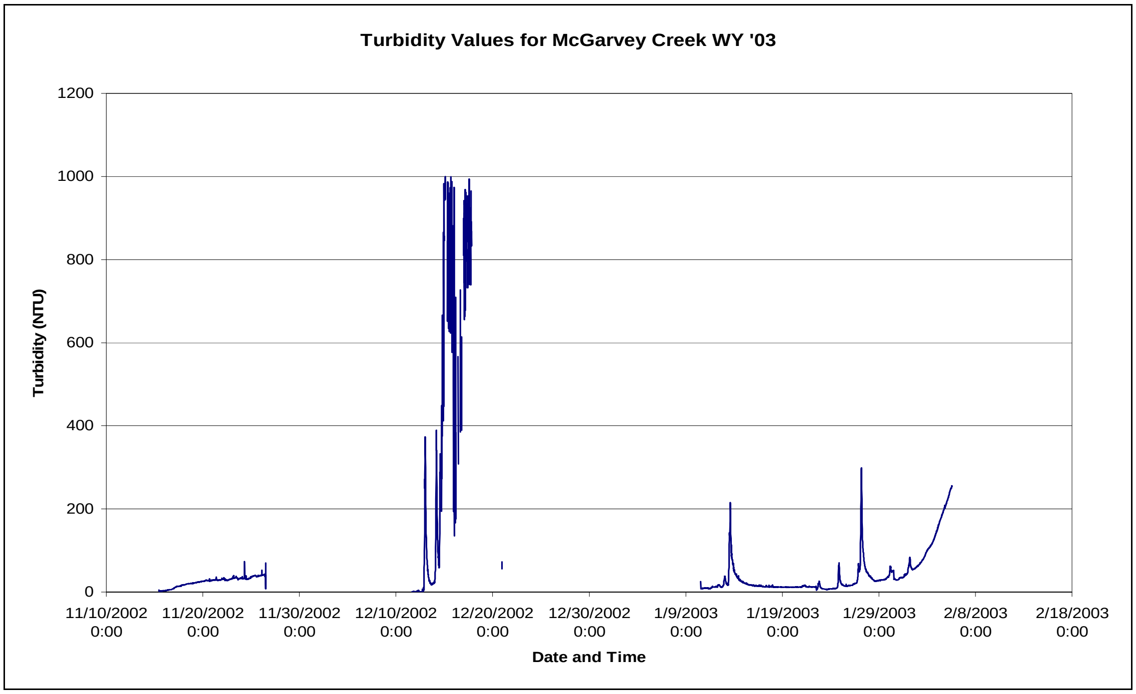


Figure 7-222 Fifteen minute turbidity data for McGarvey Creek WY03

7.2.1.3 Water Temperature

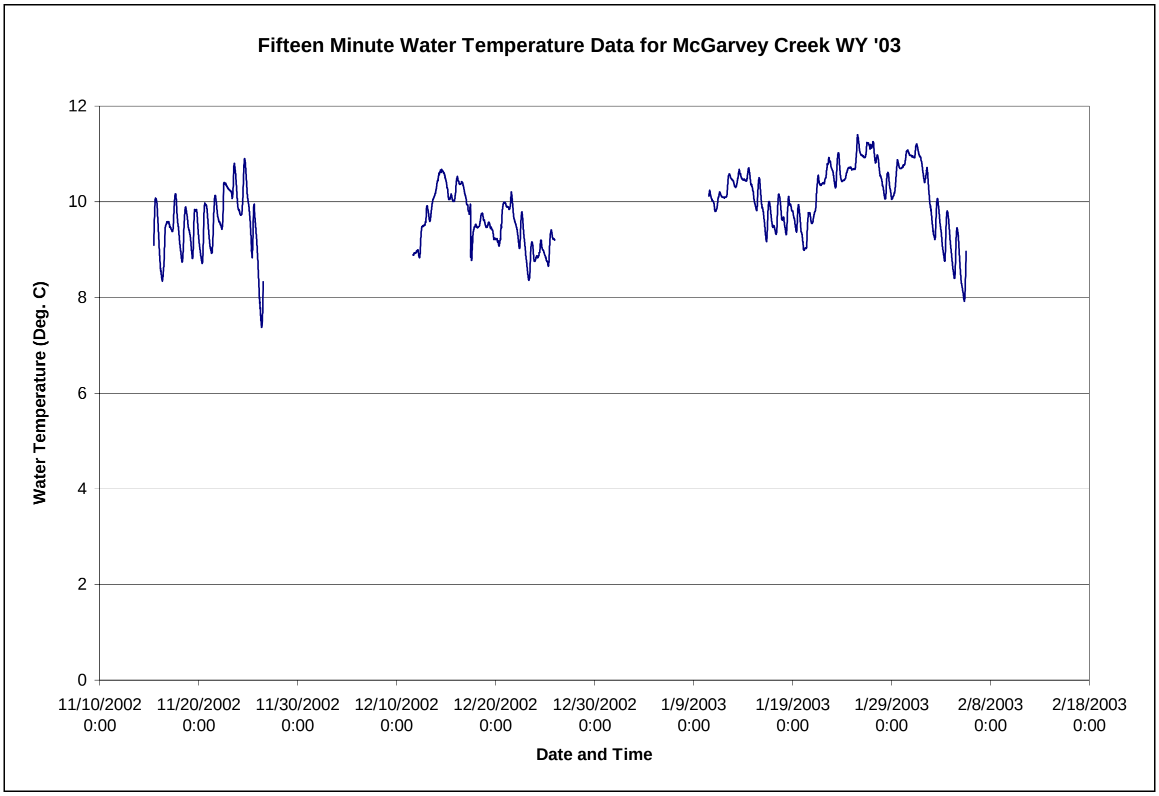


Figure 7-223 Fifteen minute water temperature data for McGarvey Creek WY03

7.2.1.4 Specific Conductivity

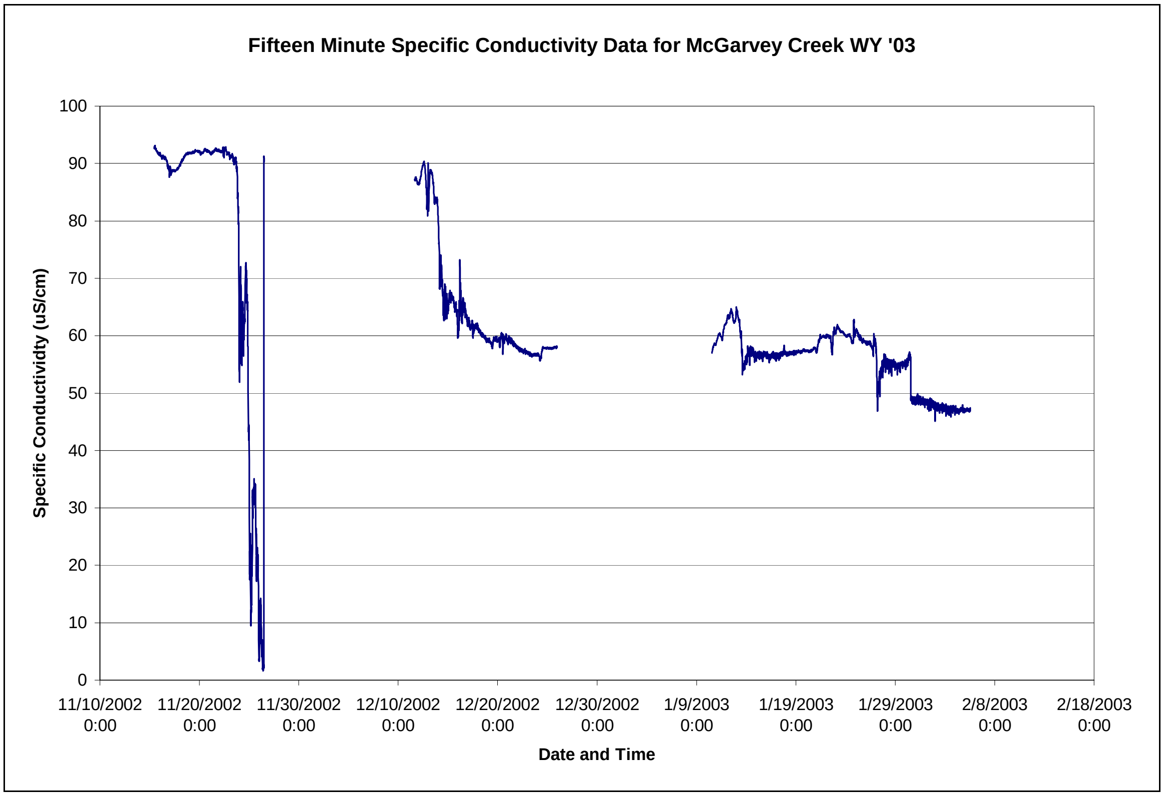


Figure 7-224 Fifteen Minute specific conductivity data for McGarvey Creek WY03

7.2.1.5 Suspended Sediment

Table 7-5 McGarvey Creek Suspended Sediment Values WY03

Sample ID	Bottle #	Location	Date Collected	Time Collected	SSC (mg/L)	Gage Height (ft)	Flow Est (cfs)
McGar	1+2+3+4	McGarvey	12/14/2002	12:28	156	3.29	250.21
McGar	5	McGarvey	12/14/2002	12:45	307	3.3	253.23
McGar	6	McGarvey	1/13/2003	12:30	116	2.57	94.34
McGar	7	McGarvey	1/13/2003	12:57	125	2.6	98.76
McGar	8	McGarvey	1/13/2003	13:00	110	2.6	98.76
McGar	1	McGarvey	4/4/2003	13:30	10.4	2.28	58.79
McGar	2	McGarvey	4/4/2003	13:40	9.52	2.28	58.79
McGar	3	McGarvey	4/4/2003	13:45	8.57	2.28	58.79
McGar	9	McGarvey	4/30/2003	12:30	7.31	2.3	60.85
McGar	10	McGarvey	4/30/2003	12:45	6.15	2.3	60.85

7.2.1.6 Precipitation

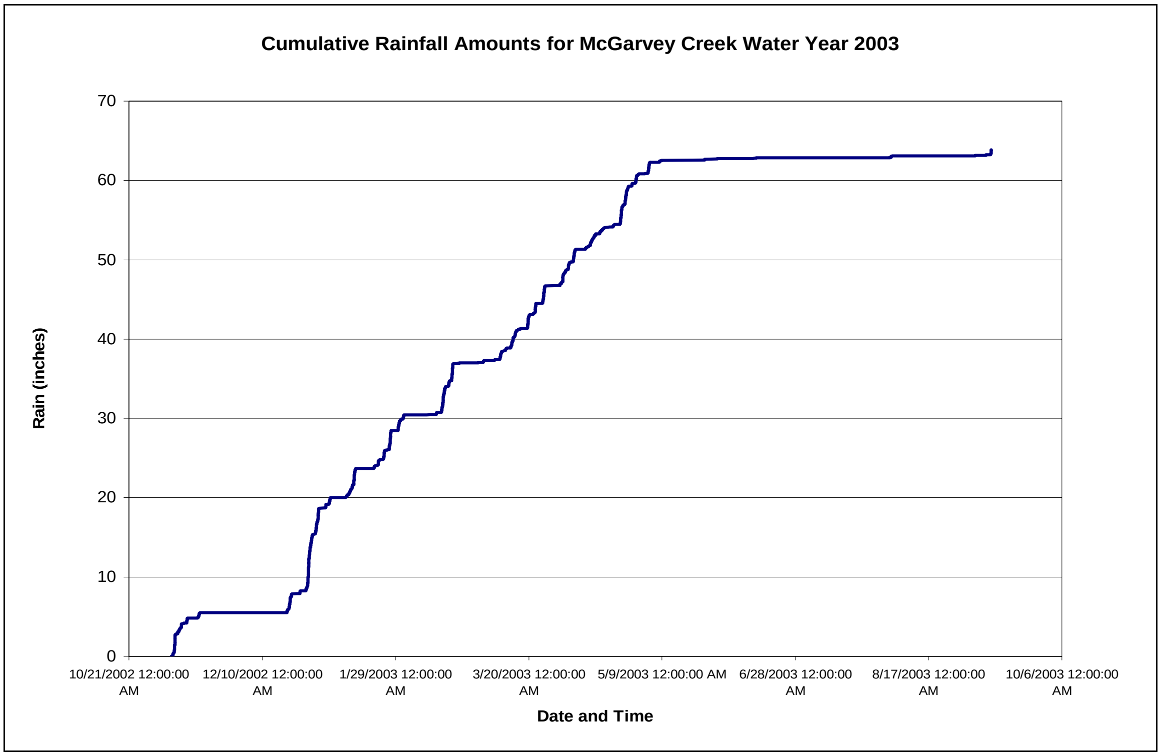


Figure 7-225 McGarvey Creek Cumulative Rainfall WY03

Table 7-6 Monthly Rainfall Totals for McGarvey Creek WY03

Month	**Rainfall (in.)**
November	5.49
December	13.2
January	11.43
February	6.88
March	10
April	13.84
May	1.92
June	0.09
July	0
August	0.25
September	0.77
October	0

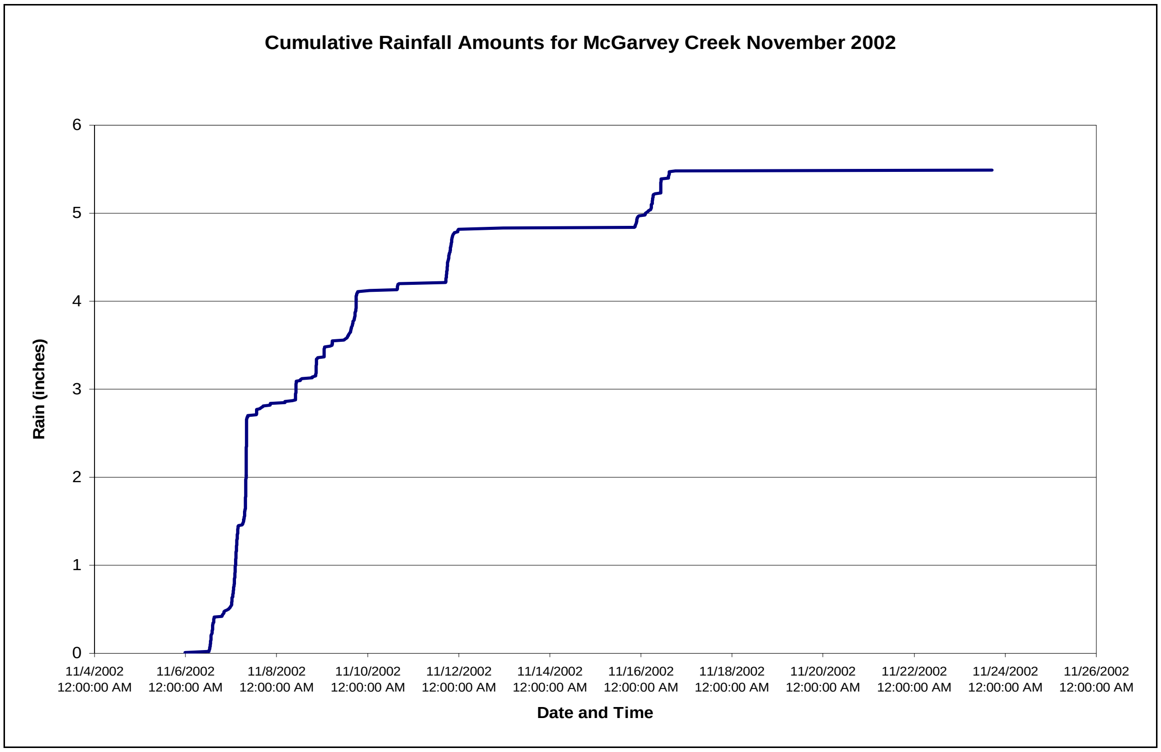


Figure 7-226 McGarvey Creek Rainfall November 2002

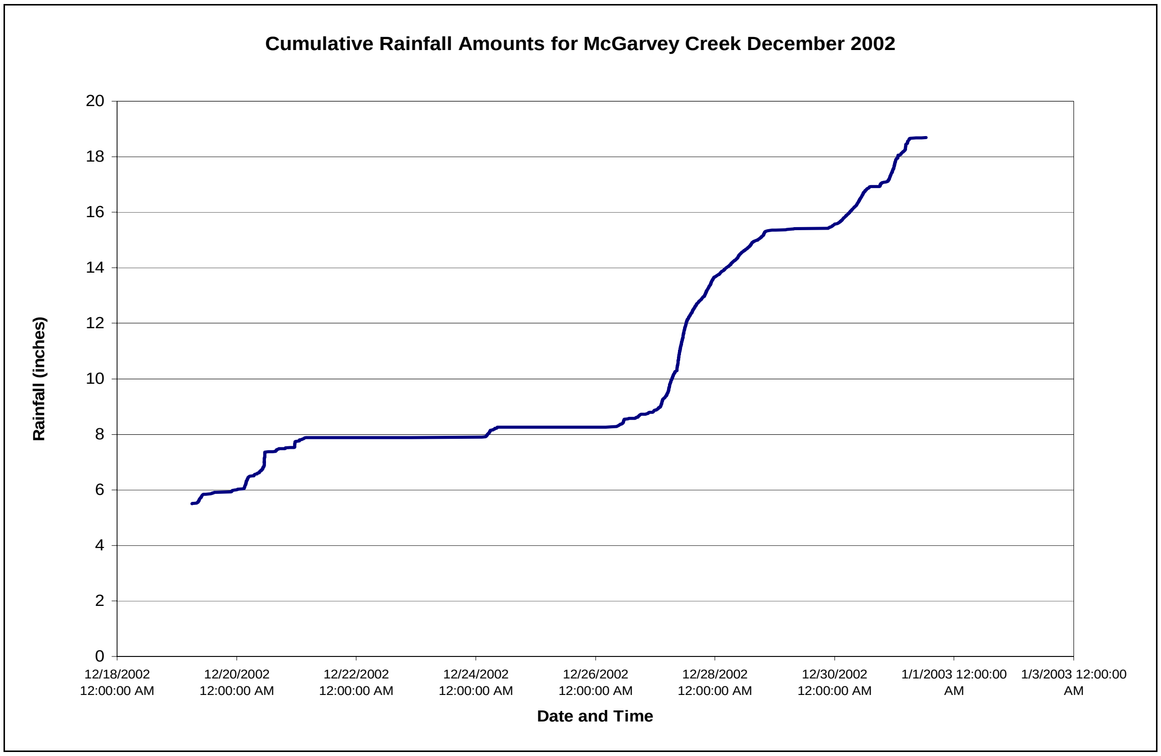


Figure 7-227 McGarvey Creek Rainfall December 2002

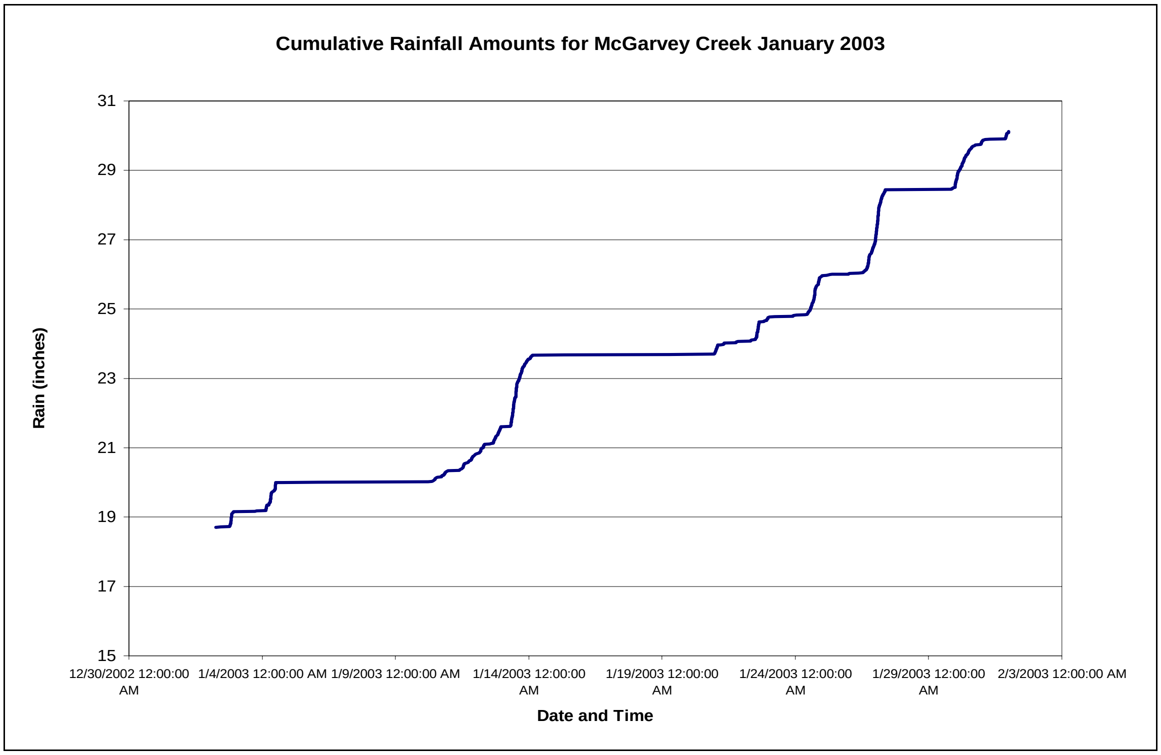


Figure 7-228 McGarvey Creek Rainfall January 2003

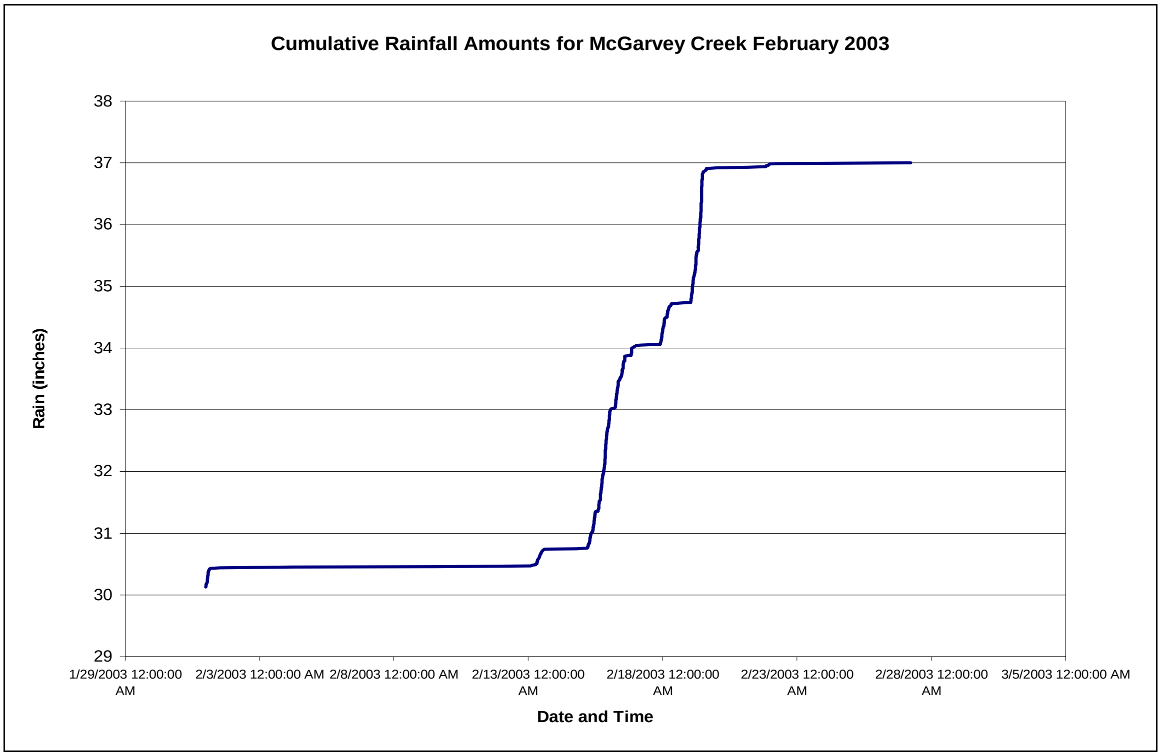


Figure 7-229 McGarvey Creek Rainfall February 2003

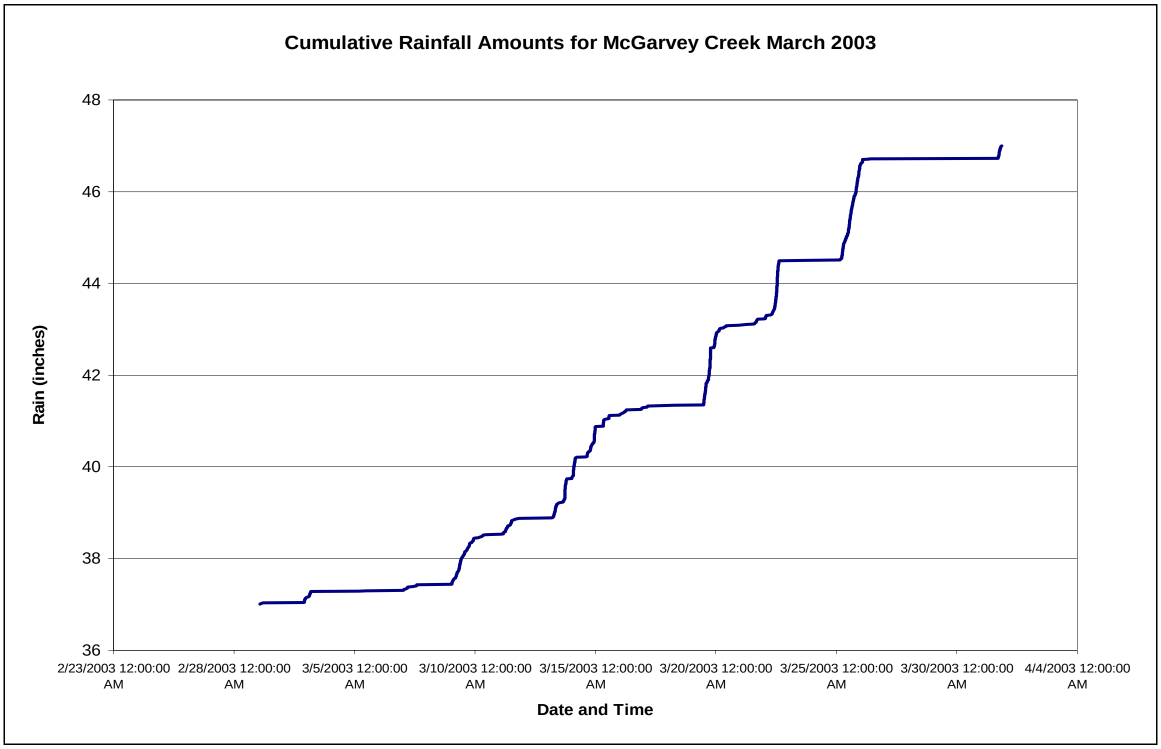


Figure 7-230 McGarvey Creek Rainfall March 2003

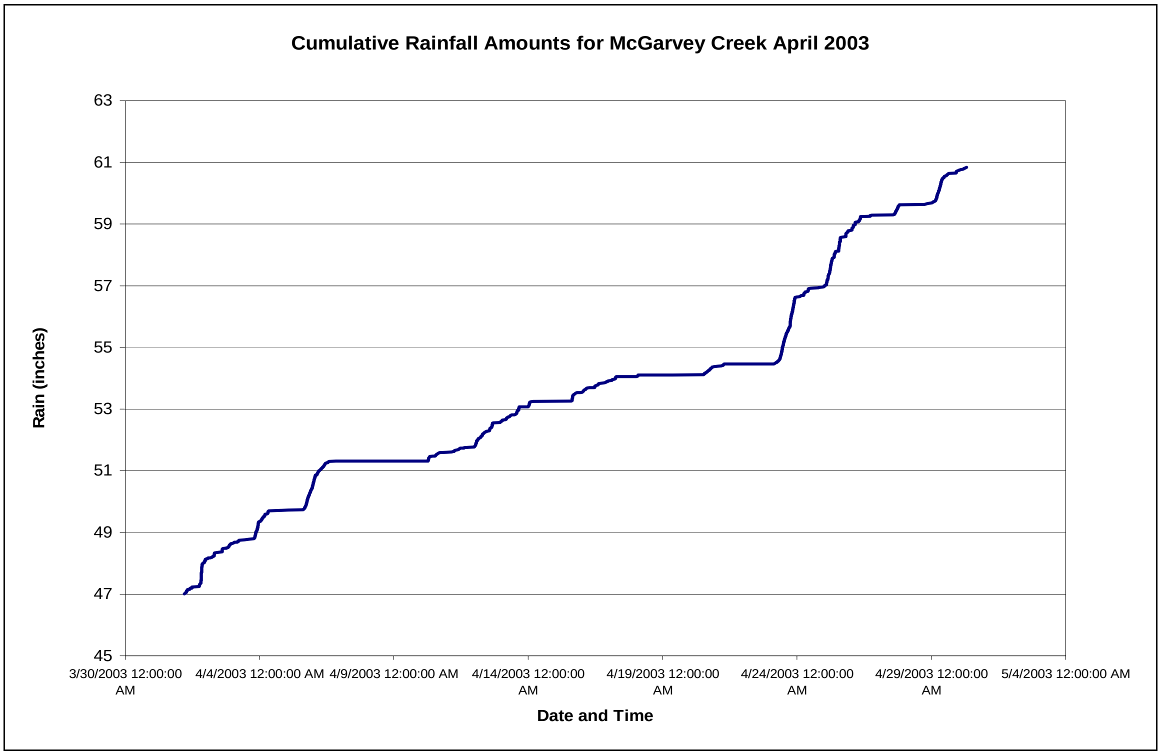


Figure 7-231 McGarvey Creek Rainfall April 2003

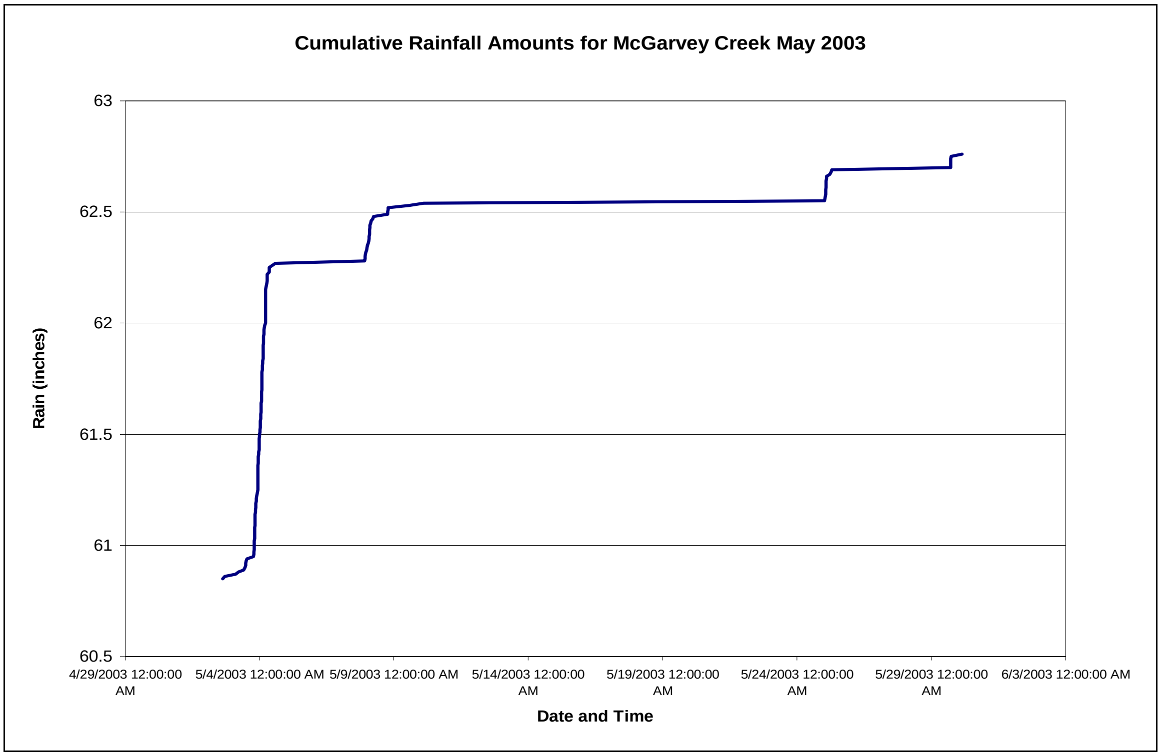


Figure 7-232McGarvey Creek Rainfall May 2003

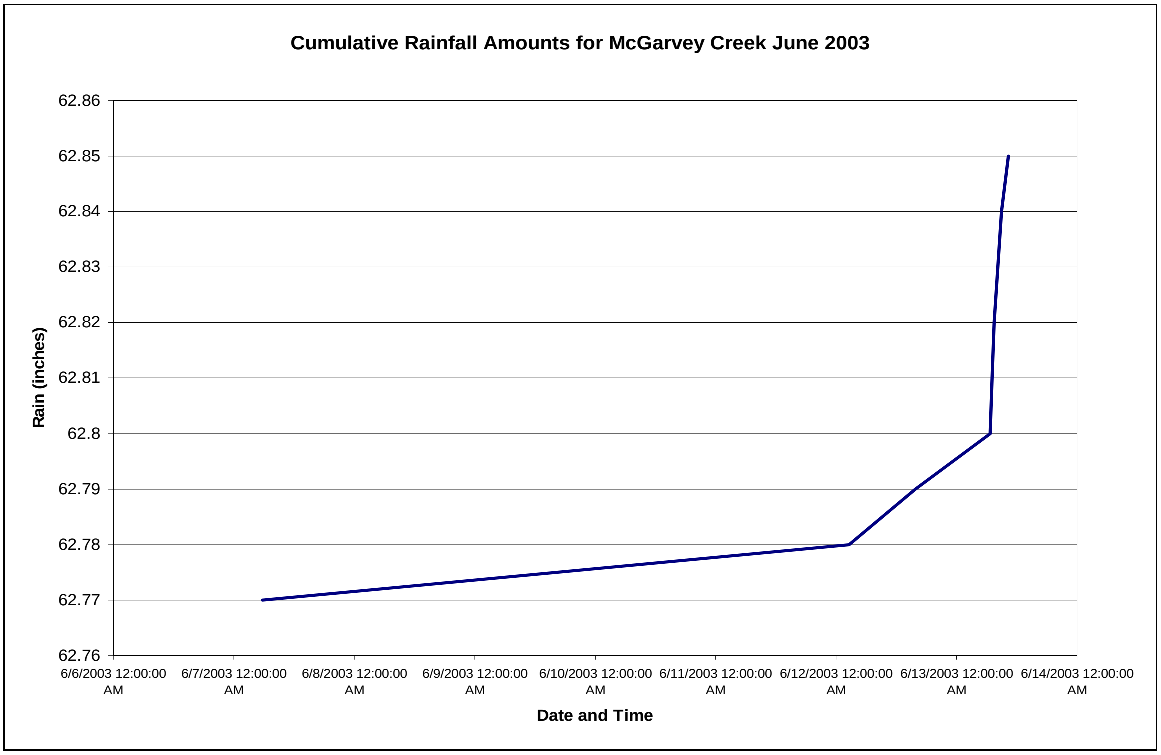


Figure 7-233 McGarvey Creek Rainfall June 2003

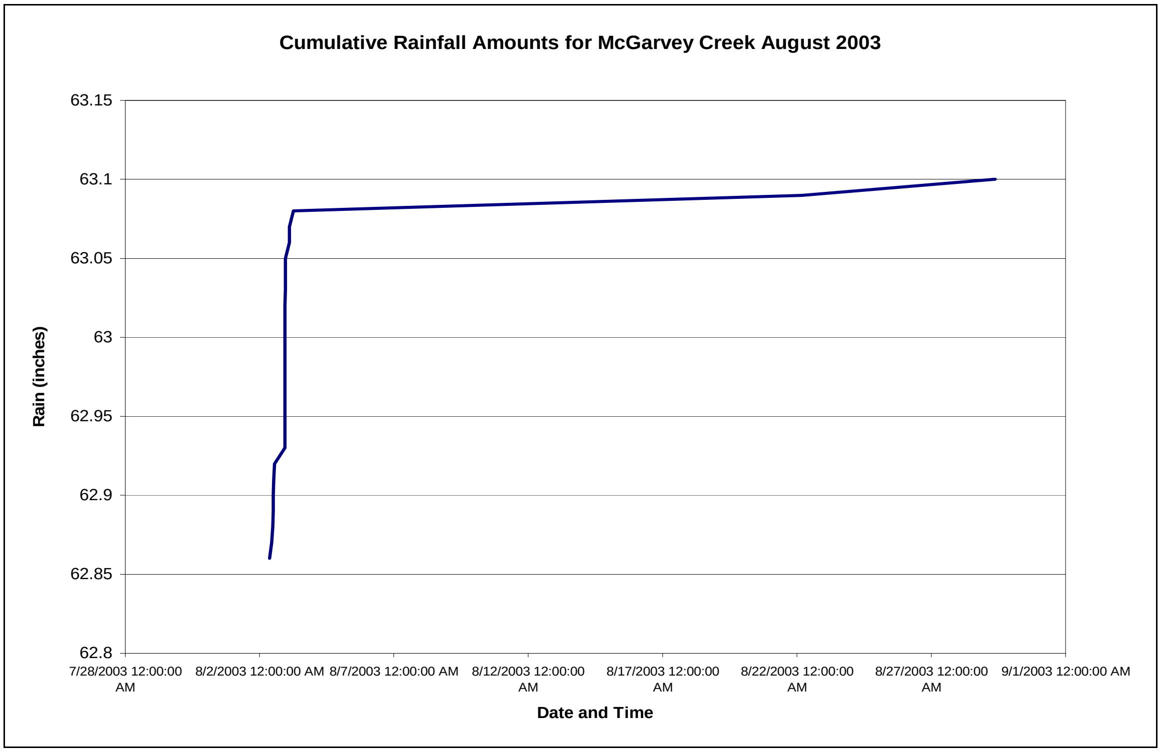


Figure 7-234 McGarvey Creek Rainfall August 2003

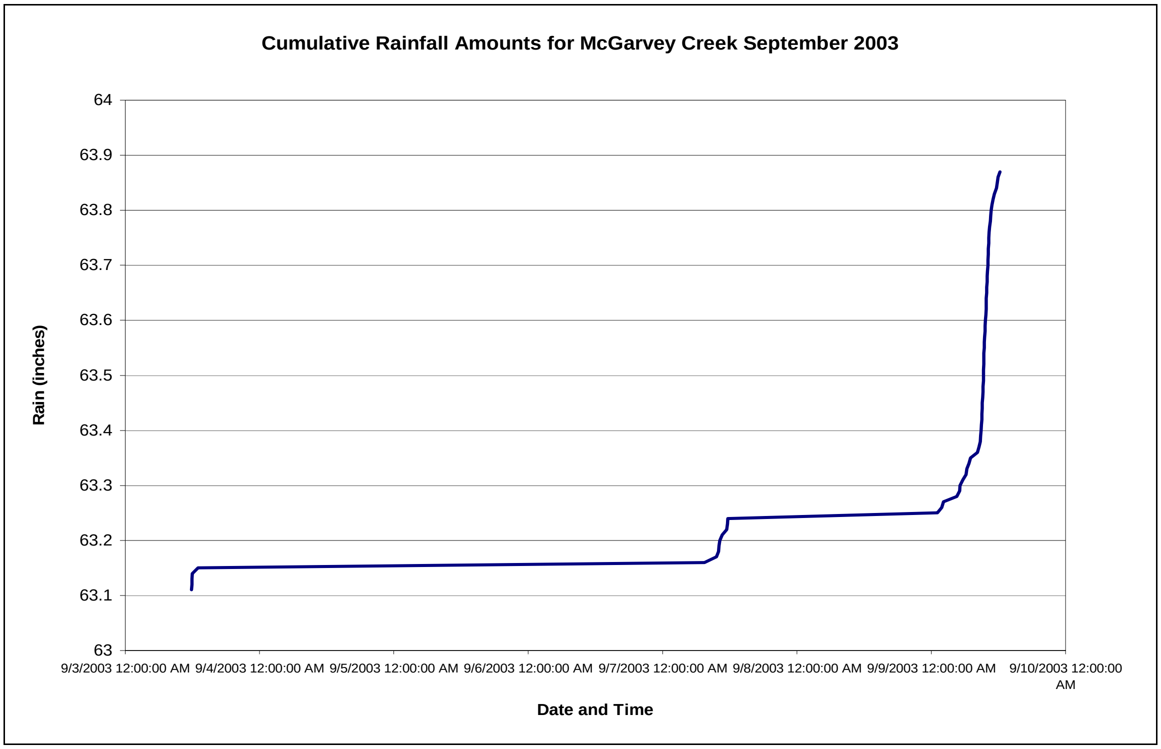


Figure 7-235 McGarvey Creek Rainfall September 2003

7.2.2 Den Creek

7.2.2.1 Discharge

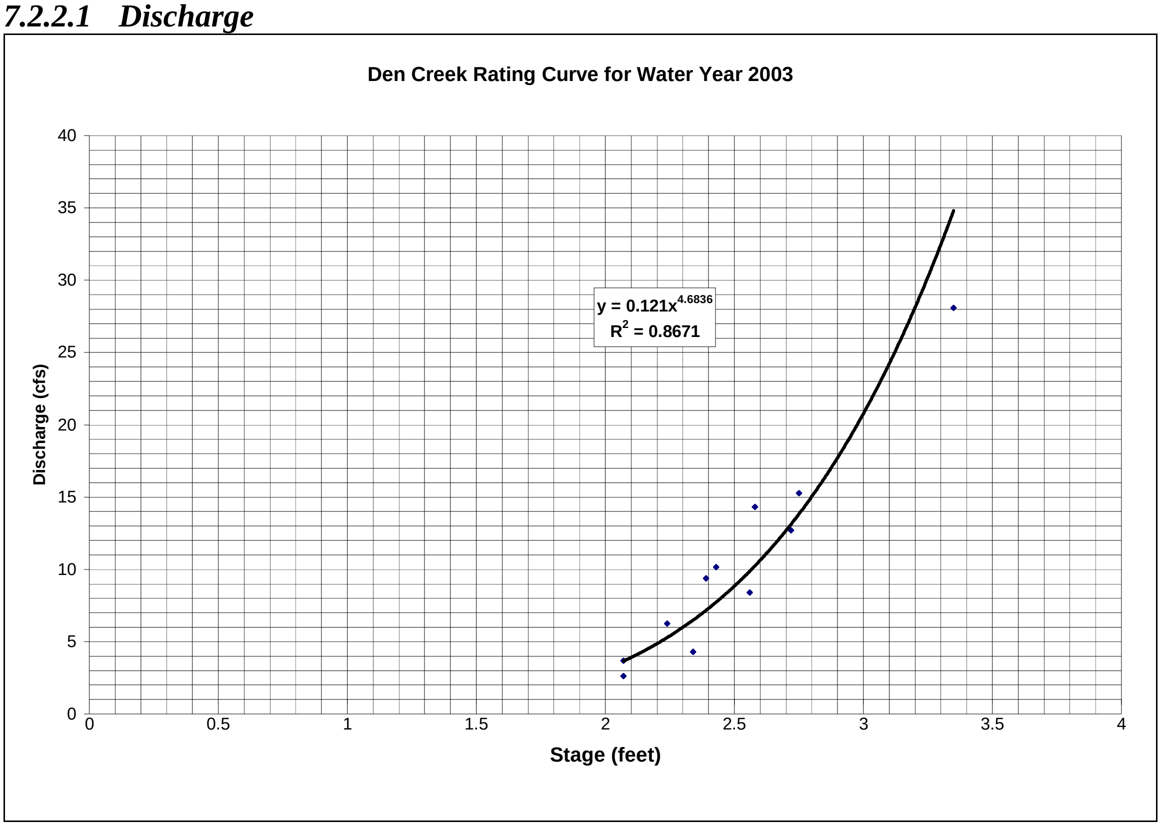


Figure 7-236 Rating Curve for Den Creek WY03

Den Creek is a tributary to McGarvey Creek that enters the flow regime of McGarvey Creek approximately one-half a mile downstream from the gaging station. Den Creek is a small tributary to McGarvey Creek, but it does experience measurable flows large enough to influence flow measurements taken at a bridge downstream from the gaging station. The majority of flow measurements taken at McGarvey Creek are measured by wading in the creek and using a sounding rod and flow meter. During large storm events, McGarvey Creek flows are high enough that flows cannot be taken by wading the cross section. In order to measure high flows, YTEP staff uses a crane and B-reel to lower a sounding weight and flow meter from the bridge downstream of the gaging station. The bridge is located just below the confluence of McGarvey and Den Creek, making it necessary to collect flow measurements in Den Creek so that the measurements may be subtracted from the flow measurements collected from the bridge. This is also true for suspended sediment samples that may be collected from the bridge.

The Den Creek rating curve was created by taking staff plate measurement readings at the McGarvey Creek gaging site and comparing them to the flow measurements taken at Den Creek. The discharge rating curve shows a strong linear relationship when stage and flow are compared to one another (Figure 7-236).

7.2.3 Blue Creek

The Blue Creek gaging station began operating on April 30th, 2002 at 1:45 PM. The station is located at 41° 27’ 00” north latitude, 123° 53’ 40” west longitude. The following parameters are measured at the site on a fifteen-minute time step throughout the year: date, time, stage, air temperature (inside the gaging box), and battery voltage. YTFD also monitors water temperature at various locations throughout Blue Creek including a site near the gaging station. Those data are not presented in this report. YTEP monitored water temperature along with turbidity and specific conductivity using the datasondes.

The rain gage in Blue Creek is run by the YTFD. The gage is located on flood terrace adjacent to lower Blue Creek, just upstream of Simpson Timber Company’s PC10 road washout (0.75 miles south of Blue Creek bridge and the junction of the PC10 and B10 roads).

7.2.3.1 *Discharge*

Table 7-7 Minimum Daily Discharge (cfs) Values for Blue Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		54.69	47.10	75.43	3009.07	1945.27	679.53	1166.55	1500.92	373.21	171.17	97.62	68.12
2		54.69	47.10	73.56	2307.66	1645.45	643.26	1125.92	1454.33	355.67	168.26	95.48	64.61
3		53.12	47.10	75.43	2043.83	1399.47	625.53	1070.33	1417.63	347.07	165.38	106.46	64.61
4		54.69	47.10	75.43	2021.70	1216.34	590.87	1233.19	1567.48	334.38	159.71	101.99	66.35
5		53.12	47.10	79.24	2167.86	1093.97	562.79	1158.37	1715.35	321.94	159.71	99.79	66.35
6		53.12	47.10	75.43	1745.79	963.68	540.86	1241.66	1472.87	313.79	156.91	99.79	68.12
7		50.06	47.10	73.56	1500.92	891.18	540.86	1310.54	1310.54	301.78	156.91	97.62	68.12
8		50.06	198.54	71.72	1301.82	814.94	524.72	1328.07	1199.62	297.83	151.39	95.48	71.72
9		50.06	231.52	71.72	1166.55	748.81	530.07	1345.73	1086.06	282.32	148.67	93.36	71.72
10		50.06	317.85	87.15	1109.88	698.07	1150.21	1408.53	1001.08	278.51	145.97	91.26	87.15
11		50.06	211.40	198.54	1078.18	655.23	1046.97	1463.59	934.31	270.98	140.67	91.26	75.43
12		48.57	189.17	301.78	1109.88	619.68	941.61	1519.78	884.10	270.98	143.31	89.20	71.72
13		48.57	192.27	405.00	2122.30	613.86	912.61	1756.00	884.10	267.25	138.05	89.20	68.12
14		48.57	140.67	1039.24	2538.66	568.35	1500.92	1596.48	877.04	259.89	138.05	87.15	66.35
15		48.57	115.71	1828.37	1891.65	562.79	1849.33	1372.46	821.72	249.04	138.05	85.14	64.61
16		48.57	111.03	3064.00	1529.26	1319.29	1705.27	1293.13	748.81	241.95	132.91	85.14	64.61
17		48.57	130.37	1645.45	1354.61	1150.21	1372.46	1275.85	698.07	234.97	130.37	83.14	64.61
18		48.57	140.67	1101.91	1191.31	1158.37	1158.37	1150.21	649.23	234.97	127.86	81.18	64.61
19		48.57	118.09	905.43	1046.97	1390.43	1117.88	1054.72	619.68	234.97	'	79.24	62.90
20		50.06	108.73	884.10	971.10	1529.26	1319.29	1008.65	602.30	221.34	120.49	77.32	62.90
21		50.06	101.99	1596.48	948.93	1328.07	1310.54	956.29	596.57	218.00	118.09	77.32	61.21
22		50.06	99.79	1117.88	941.61	1191.31	1408.53	884.10	585.19	211.40	115.71	77.32	59.54
23		50.06	95.48	877.04	1070.33	1078.18	1881.02	877.04	562.79	208.15	113.36	77.32	57.90
24		50.06	91.26	761.79	1008.65	971.10	1500.92	1625.77	535.45	201.71	113.36	77.32	57.90
25		50.06	87.15	655.23	1817.93	912.61	1454.33	1567.48	514.10	195.39	111.03	73.56	56.28
26		50.06	83.14	643.26	1548.30	835.37	3719.02	1786.82	482.96	189.17	108.73	73.56	56.28
27		50.06	81.18	1062.51	2032.75	774.90	2677.84	1645.45	452.86	183.06	106.46	73.56	56.28
28		50.06	79.24	4928.30	1999.70	716.87	2043.83	1548.30	433.37	180.05	101.99	73.56	56.28
29		48.57	77.32	3009.07	1615.97	'	1665.26	1548.30	419.06	177.06	99.79	71.72	56.28
30		48.57	77.32	2900.81	1655.34	'	1426.76	1675.22	409.66	177.06	99.79	69.91	56.28
31		48.57	'	4493.54	2122.30	'	1267.25	'	391.20	'	97.62	69.91	'
Monthly Statistics													
Total		1558.52	3409.59	34178.43	49970.84	28793.04	39668.73	39994.54	26828.46	7633.92	3979.78	2641.89	1936.96
Mean		50.33	113.65	989.50	1594.95	1028.32	1280.05	1333.15	881.24	254.46	133.87	85.73	64.57
Max		54.69	317.85	4928.30	3009.07	1945.27	3719.02	1786.82	1715.35	373.21	171.17	106.46	87.15
Min		48.57	47.10	71.72	941.61	562.79	524.72	877.04	391.20	177.06	97.62	69.91	56.28

Table 7-8 Maximum Daily Discharge (cfs) Values for Blue Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		57.90	48.57	77.32	4682.17	2439.95	735.94	1354.61	1705.27	400.37	180.05	101.99	71.72
2		56.28	48.57	77.32	3077.81	1988.75	691.86	1224.75	1586.78	386.66	177.06	106.46	69.91
3		56.28	48.57	77.32	2513.79	1665.26	667.32	1258.69	1567.48	373.21	174.10	111.03	68.12
4		56.28	48.57	83.14	3627.74	1417.63	637.32	1328.07	2367.30	355.67	168.26	108.73	69.91
5		59.54	48.57	83.14	3119.46	1258.69	602.30	1301.82	2133.64	342.81	165.38	106.46	69.91
6		54.69	48.57	79.24	2225.54	1117.88	573.93	1463.59	1766.24	330.20	162.53	104.21	69.91
7		53.12	192.27	75.43	1817.93	1001.08	562.79	1445.11	1500.92	326.06	162.53	108.73	71.72
8		51.58	313.79	75.43	1538.76	905.43	562.79	1445.11	1336.89	313.79	159.71	101.99	75.43
9		51.58	377.66	87.15	1345.73	835.37	1567.48	1463.59	1224.75	301.78	156.91	99.79	122.92
10		51.58	631.41	198.54	1207.97	768.33	1655.34	1645.45	1117.88	293.91	154.13	97.62	122.92
11		51.58	355.67	391.20	1174.77	716.87	1158.37	1645.45	1023.88	286.16	148.67	95.48	87.15
12		50.06	373.21	414.34	2439.95	667.32	1109.88	2066.09	963.68	278.51	143.31	95.48	77.32
13		50.06	355.67	1070.33	4561.65	643.26	1510.34	1988.75	956.29	274.73	145.97	93.36	73.56
14		50.06	192.27	4442.82	4210.21	625.53	1797.16	1849.33	971.10	274.73	143.31	93.36	69.91
15		50.06	143.31	3734.36	2626.76	1372.46	2538.66	1596.48	948.93	263.56	143.31	89.20	68.12
16		50.06	132.91	7586.86	1945.27	1529.26	2225.54	1417.63	835.37	256.24	140.67	89.20	68.12
17		50.06	204.92	3022.75	1567.48	1491.54	1715.35	1390.43	774.90	249.04	138.05	87.15	68.12
18		50.06	177.06	1655.34	1363.52	1426.76	1381.43	1293.13	723.20	245.48	135.47	85.14	66.35
19		50.06	140.67	1117.88	1233.19	2111.00	1293.13	1199.62	673.41	241.95	'	83.14	66.35
20		51.58	120.49	2403.48	1093.97	2021.70	1586.78	1093.97	649.23	238.45	127.86	83.14	66.35
21		51.58	111.03	2415.60	1031.55	1548.30	1463.59	1046.97	637.32	231.52	125.38	81.18	64.61
22		50.06	108.73	1586.78	1586.78	1345.73	3147.40	978.55	643.26	224.71	122.92	81.18	62.90
23		50.06	99.79	1133.98	1510.34	1216.34	2781.57	2367.30	625.53	218.00	120.49	83.14	61.21
24		51.58	95.48	905.43	2626.76	1101.91	1902.31	2391.39	596.57	218.00	118.09	81.18	61.21
25		51.58	91.26	768.33	2729.44	1016.25	4981.93	1913.00	557.26	204.92	115.71	79.24	59.54
26		51.58	89.20	1062.51	2021.70	927.05	6800.63	1923.73	530.07	201.71	113.36	77.32	59.54
27		53.12	85.14	11507.56	4112.58	863.03	3827.07	1859.87	498.40	195.39	113.36	77.32	57.90
28		51.58	81.18	8659.18	2874.08	788.13	2703.57	1725.47	472.81	189.17	108.73	81.18	57.90
29		50.06	81.18	4981.93	2043.83	'	2088.48	1838.84	457.80	183.06	106.46	75.43	57.90
30		50.06	79.24	6590.43	2626.76	'	1685.20	1838.84	438.20	183.06	104.21	73.56	57.90
31		50.06	'	7100.89	2601.43	'	1435.92	'	423.80	'	101.99	73.56	'
Monthly Statistics													
Total		1613.79	4924.92	73466.02	73138.94	34810.83	57391.40	47355.62	30708.20	8082.89	4178.00	2805.95	2124.41
Mean		52.12	164.16	2212.17	2351.25	1243.24	1865.18	1578.52	1009.48	269.43	140.55	91.08	70.81
Max		59.54	631.41	11507.56	4682.17	2439.95	6800.63	2391.39	2367.30	400.37	180.05	111.03	122.92
Min		50.06	48.57	75.43	1031.55	625.53	562.79	978.55	423.80	183.06	101.99	73.56	57.90

Table 7-9 Average Daily Discharge (cfs) Values for Blue Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		56.13	48.32	76.17	3753.41	2178.49	709.07	1234.86	1607.63	388.83	176.97	99.34	69.46
2		55.32	48.03	75.84	2600.51	1810.56	669.29	1169.03	1516.04	374.78	173.37	101.25	67.60
3		54.62	48.20	75.45	2279.86	1526.49	649.92	1111.63	1468.71	361.05	169.14	108.12	67.07
4		54.87	48.47	78.13	2664.62	1315.09	616.16	1286.28	2085.21	347.47	165.53	105.68	68.08
5		55.04	48.41	81.01	2529.58	1160.49	582.37	1214.07	1900.20	334.25	162.47	103.26	68.02
6		54.05	48.50	77.20	1970.01	1040.37	556.46	1358.50	1608.55	323.27	160.61	102.29	68.54
7		52.56	72.89	75.14	1645.97	942.52	551.02	1369.66	1401.82	314.43	159.47	102.06	70.57
8		51.23	251.73	73.66	1416.58	862.52	543.75	1374.04	1278.81	305.97	157.72	99.00	72.89
9		50.45	313.42	76.82	1256.82	790.97	853.03	1402.11	1149.30	294.89	153.85	96.59	97.13
10		50.25	427.42	150.99	1152.84	731.81	1401.26	1486.57	1051.33	286.72	149.68	95.08	103.72
11		50.47	270.20	236.45	1120.81	685.04	1100.50	1534.70	984.00	280.65	146.48	93.31	81.44
12		49.65	242.06	355.89	1557.48	643.33	1012.37	1859.10	926.67	276.03	143.31	92.72	74.82
13		49.28	254.10	715.95	3104.68	629.27	1035.15	1834.36	917.71	272.19	141.96	91.63	70.59
14		49.33	162.41	2686.53	3259.43	594.25	1690.63	1707.47	924.78	266.33	141.02	90.33	67.75
15		48.98	127.71	2569.55	2208.63	736.34	2345.21	1490.47	876.97	257.00	139.41	87.70	66.42
16		49.22	115.79	5299.44	1711.46	1427.04	1938.98	1359.52	795.55	249.64	138.60	86.96	66.30
17		49.42	183.10	2195.16	1444.25	1298.11	1527.58	1340.20	736.61	243.49	135.04	85.37	66.44
18		49.73	154.82	1350.54	1286.46	1319.75	1272.80	1223.70	687.74	239.98	132.12	83.33	65.79
19		49.86	128.25	1014.19	1149.44	1804.40	1179.07	1118.55	649.05	237.80	'	81.77	64.67
20		50.25	113.02	1265.29	1031.55	1746.11	1492.81	1046.89	627.73	232.53	125.69	80.55	64.31
21		50.47	107.29	1994.34	995.34	1427.90	1379.37	1002.10	618.83	225.27	122.95	78.65	63.29
22		50.06	103.96	1327.07	1091.90	1275.31	1971.03	928.48	612.53	219.18	120.24	78.77	61.13
23		50.06	97.42	998.24	1234.77	1145.89	2216.84	1138.45	593.30	214.31	117.62	80.28	59.69
24		50.72	93.07	839.09	1296.39	1040.21	1693.76	1870.87	566.72	208.35	115.22	79.34	58.99
25		51.37	89.93	708.61	2247.99	962.60	2138.85	1743.24	538.04	202.28	114.02	76.86	58.48
26		51.55	85.97	760.91	1707.89	885.05	5099.95	1869.11	505.95	196.04	112.22	75.43	57.47
27		51.55	82.90	5794.97	3292.37	814.45	3173.41	1732.86	477.18	190.01	109.43	75.10	56.90
28		50.52	80.59	6495.71	2377.45	755.83	2352.06	1624.75	457.34	184.68	106.48	74.63	57.12
29		50.00	78.99	3811.54	1785.96	'	1864.37	1674.08	439.87	180.58	104.00	73.66	57.32
30		49.47	77.42	4811.53	2237.05	'	1549.40	1753.98	426.63	179.21	101.92	72.66	57.73
31		48.66	'	5881.61	2372.43	'	1349.52	'	408.25	'	100.52	71.06	'

Monthly Statistics

Total	1585.12	4004.38	51953.03	59783.93	31550.18	46515.98	42859.63	28839.03	7887.19	4097.07	2722.80	2029.73
Mean	51.13	133.48	1675.90	1928.51	1126.79	1500.52	1428.65	930.29	262.91	136.57	87.83	67.66
Max	56.13	427.42	6495.71	3753.41	2178.49	5099.95	1870.87	2085.21	388.83	176.97	108.12	103.72
Min	48.66	48.03	73.66	995.34	594.25	543.75	928.48	408.25	179.21	100.52	71.06	56.90

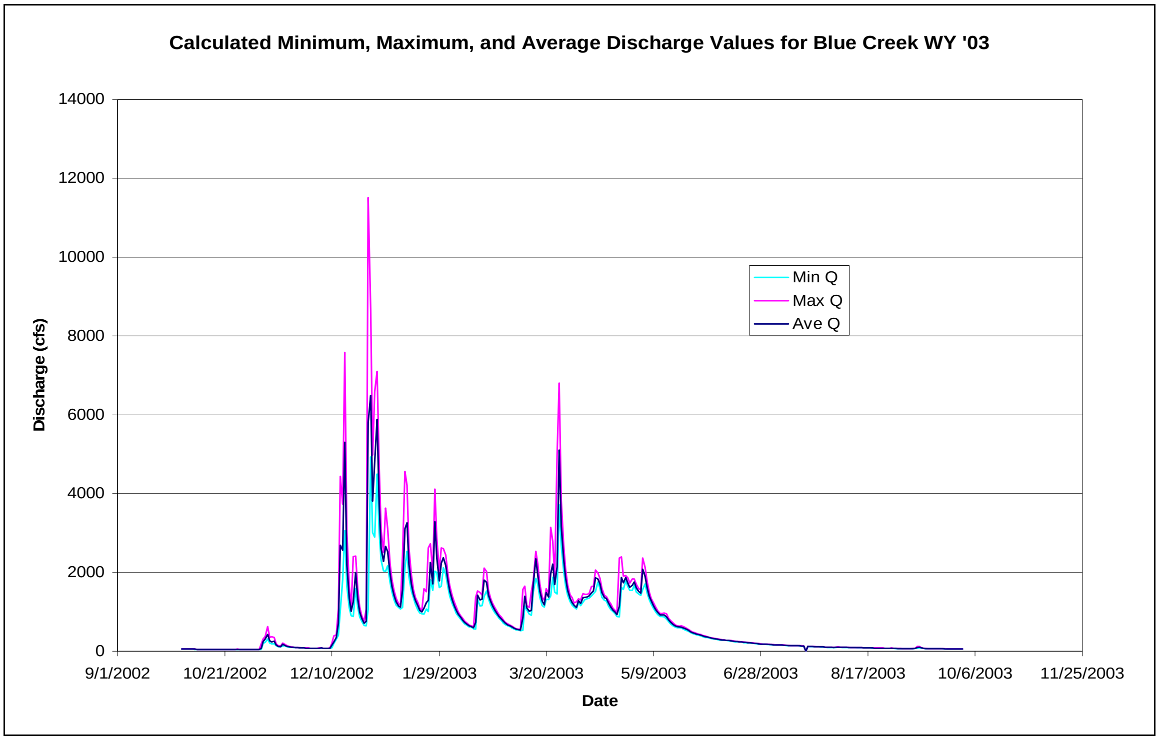


Figure 7-237 Mean, minimum, and maximum discharges recorded at Blue Creek gaging site from October 1, 2002 through September 30, 2003

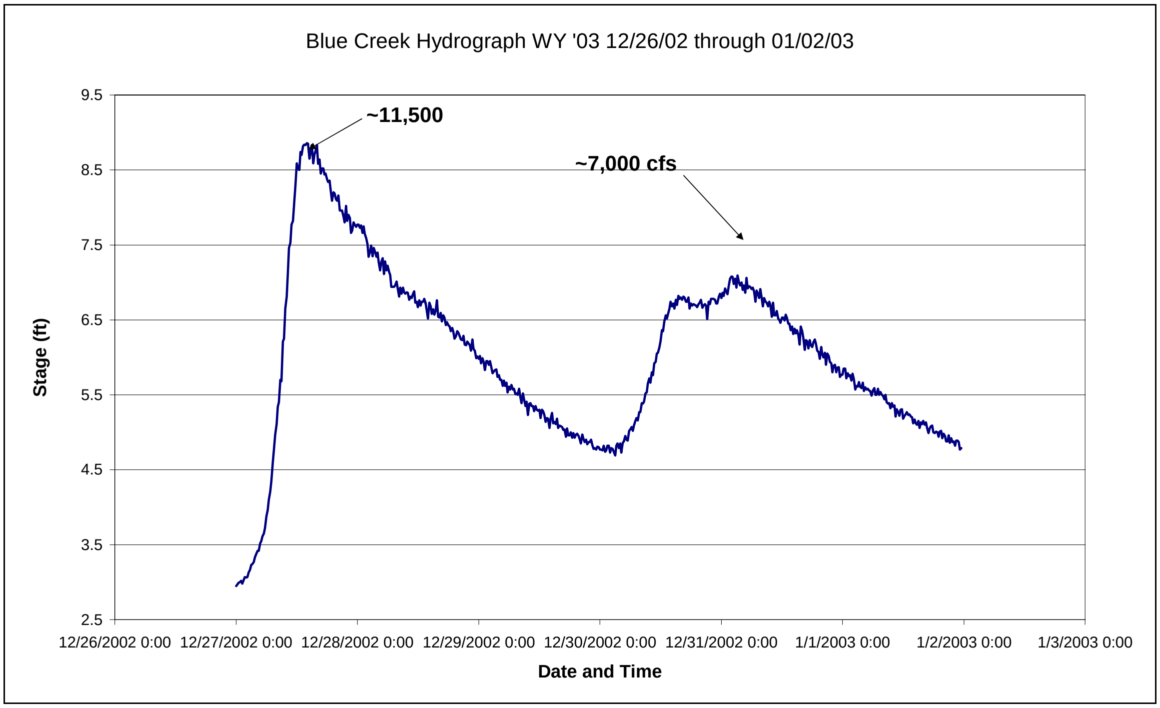


Figure 7-238 Blue Cree Hydrograph from 12/26/02 through 1/2/03 displaying the highest instantaneous peak stage/discharge

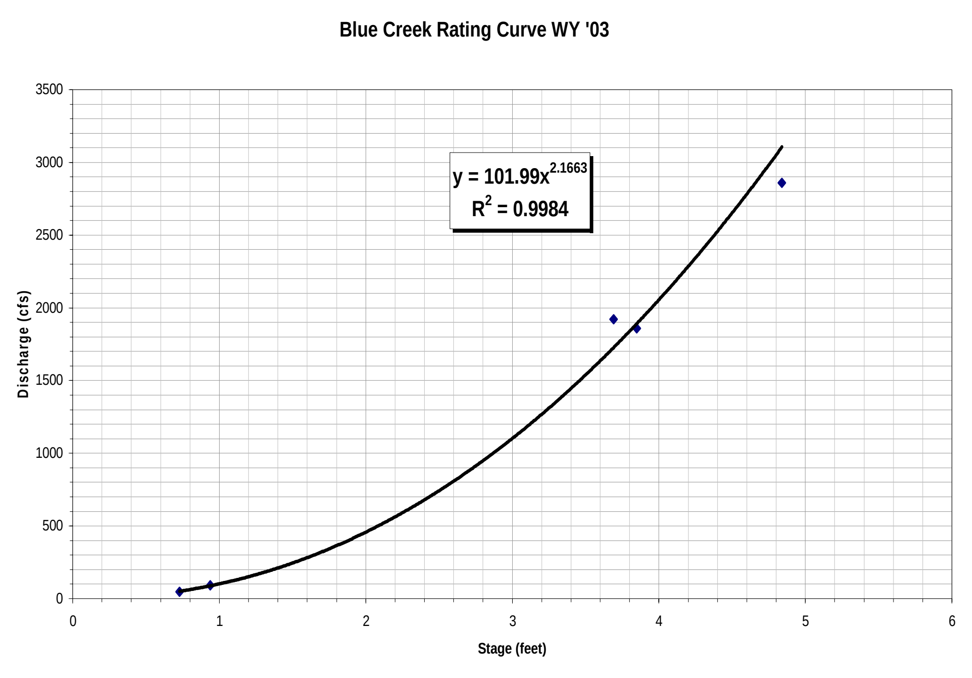


Figure 7-239 Discharge rating curve values for Blue Creek gaging station

7.2.3.2 Turbidity

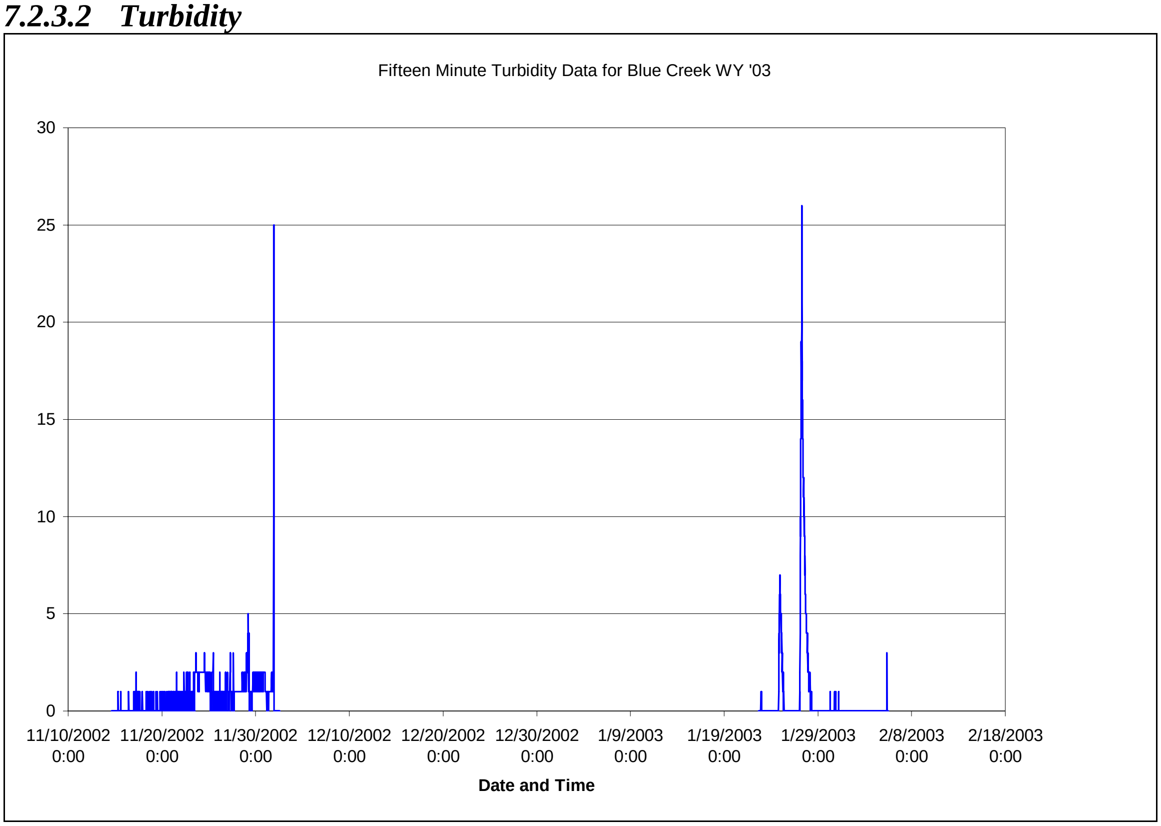


Figure 7-240 Blue Creek Fifteen-Minute Turbidity Data WY03

7.2.3.3 Water Temperature

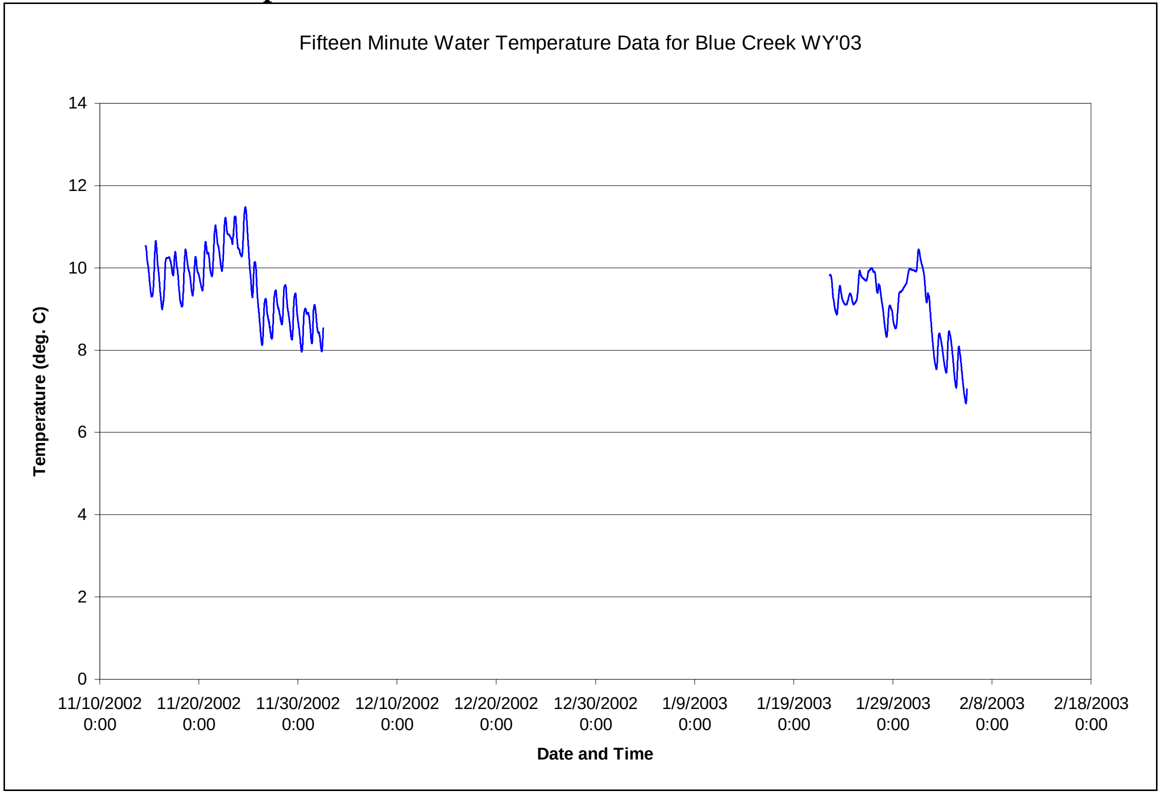


Figure 7-241 Fifteen minute water temperature data for Blue Creek WY03

7.2.3.4 Specific Conductivity

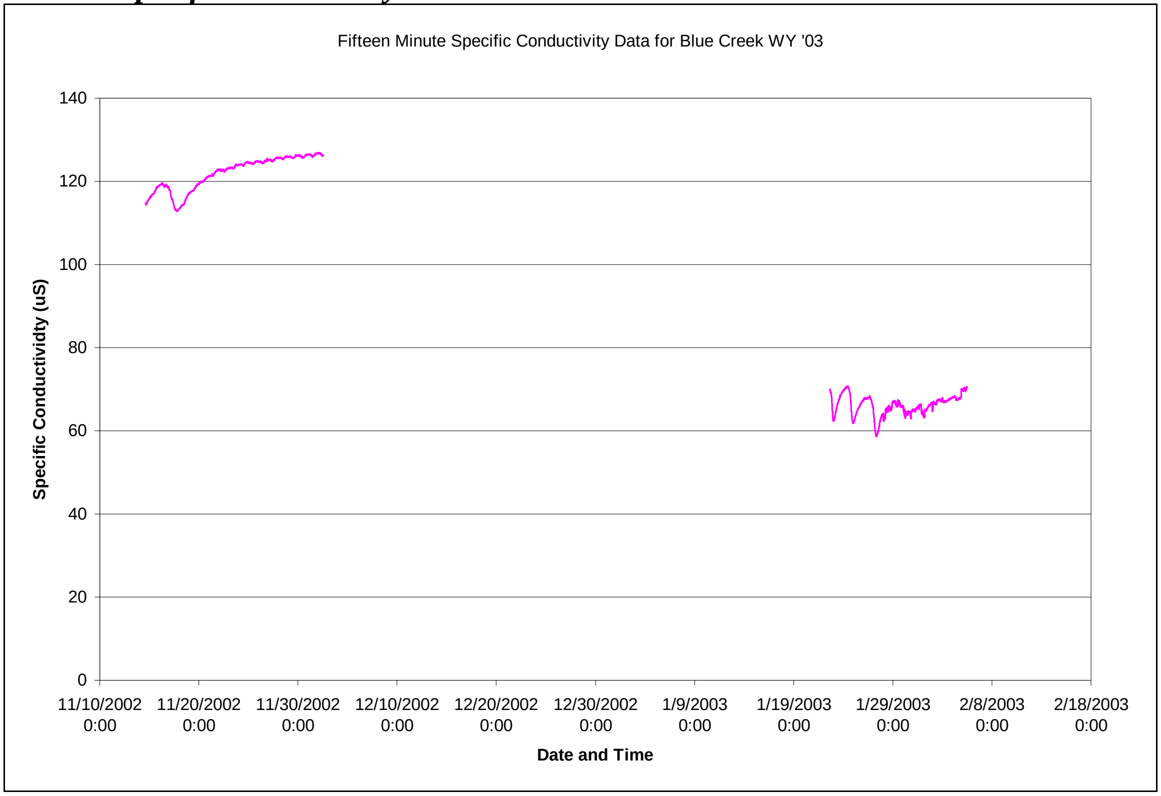


Figure 7-242 Blue Creek Fifteen-Minute Specific Conductivity WY03

7.2.3.5 Suspended Sediment

Table 7-10 Blue Creek Suspended Sediment Data WY03

Sample ID	Bottle #	Location	Date Collected	Time Collected	SSC (mg/L)	Gage Height (ft)	Flow Est (cfs)
Blue	11+12+13+14+15+16	Blue	4/28/2003	12:28	5.05	3.63	1665.26

7.2.3.6 Precipitation

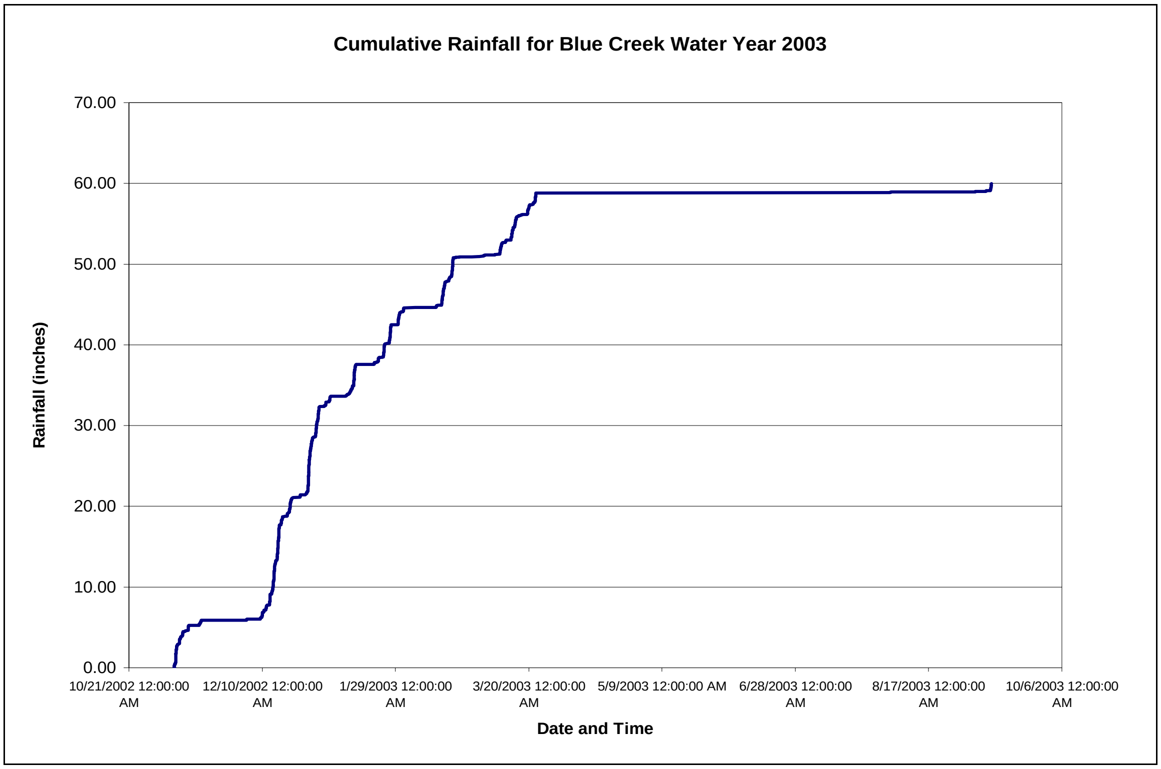


Figure 7-243 Cumulative Rainfall for Blue Creek WY03

Table 7-11 Monthly Rainfall Totals for Blue Creek WY03

Month	**Rainfall (in.)**
November	5.89
December	26.48
January	11.84
February	6.71
March	7.91
April	*
May	*
June	*
July	*
August	0.12
September	1
October	0

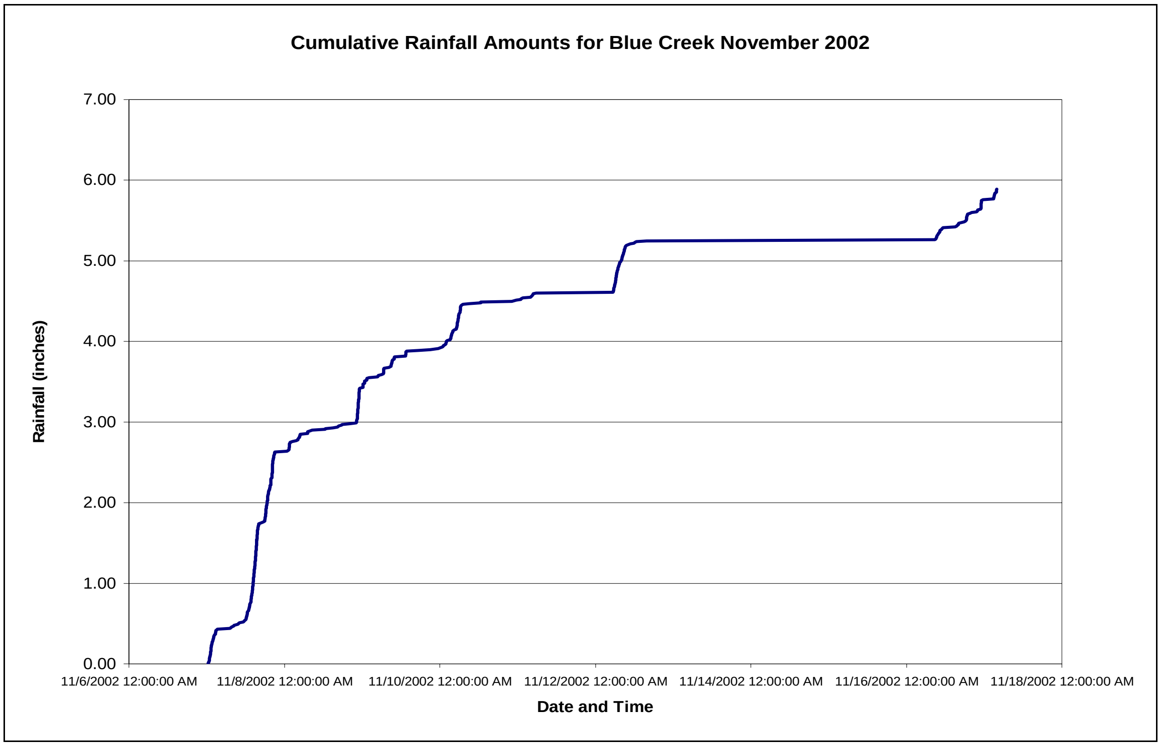


Figure 7-244 Blue Creek Rainfall November 2002

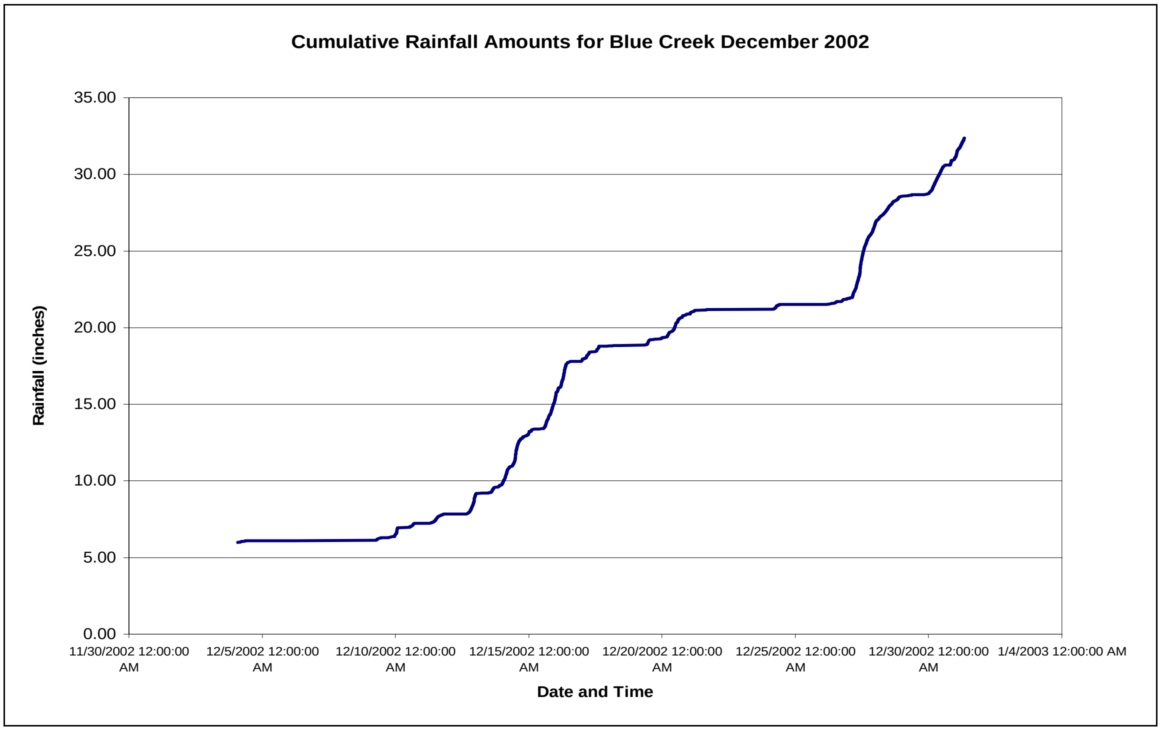


Figure 7-245 Blue Creek Rainfall December 2002

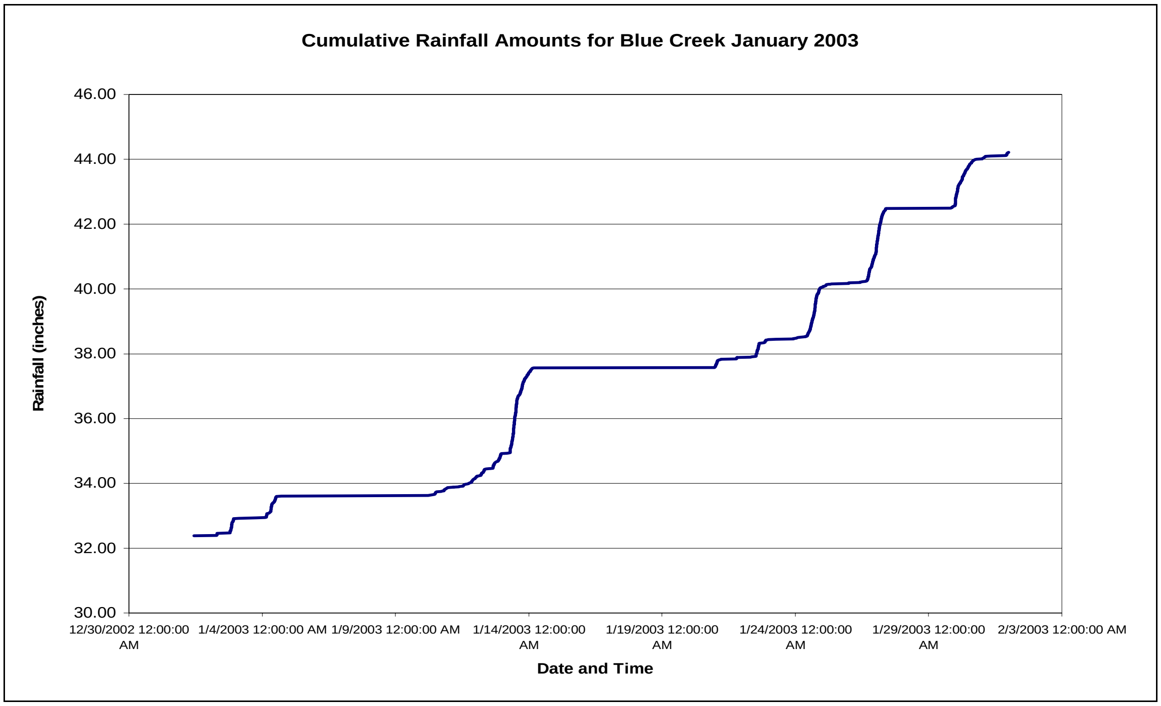


Figure 7-246 Blue Creek Rainfall January 2003

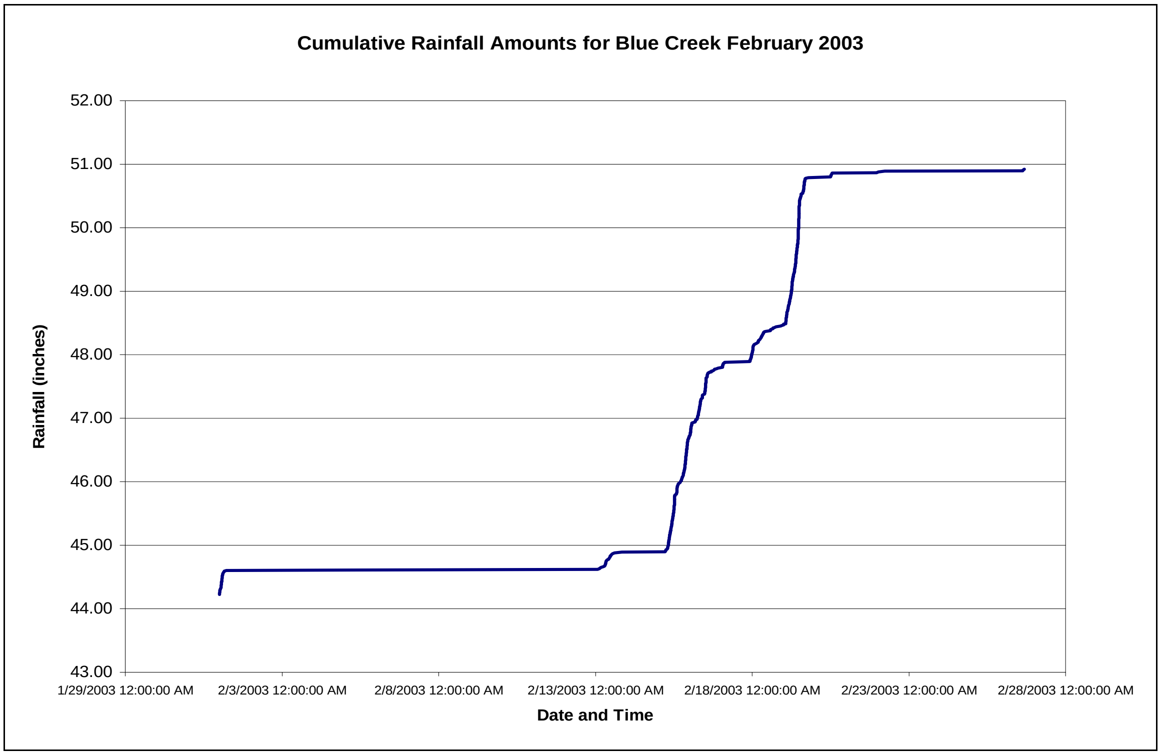


Figure 7-247 Blue Creek Rainfall February 2003

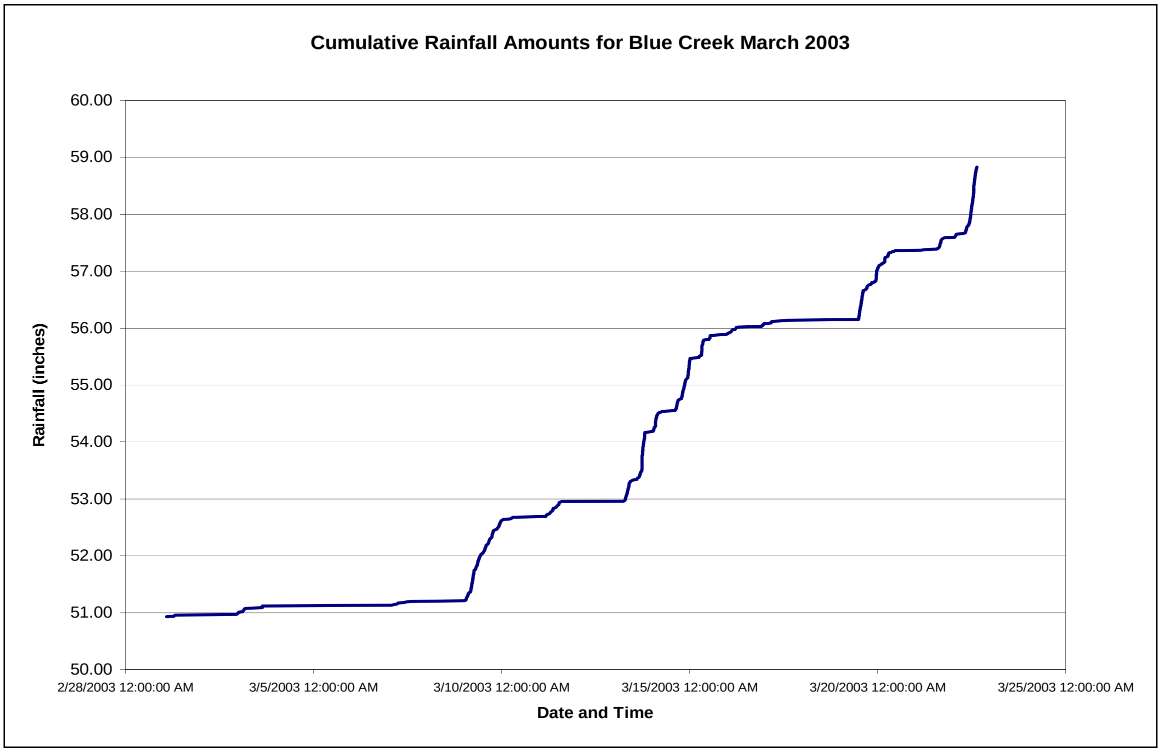


Figure 7-248 Blue Creek Rainfall March 2003

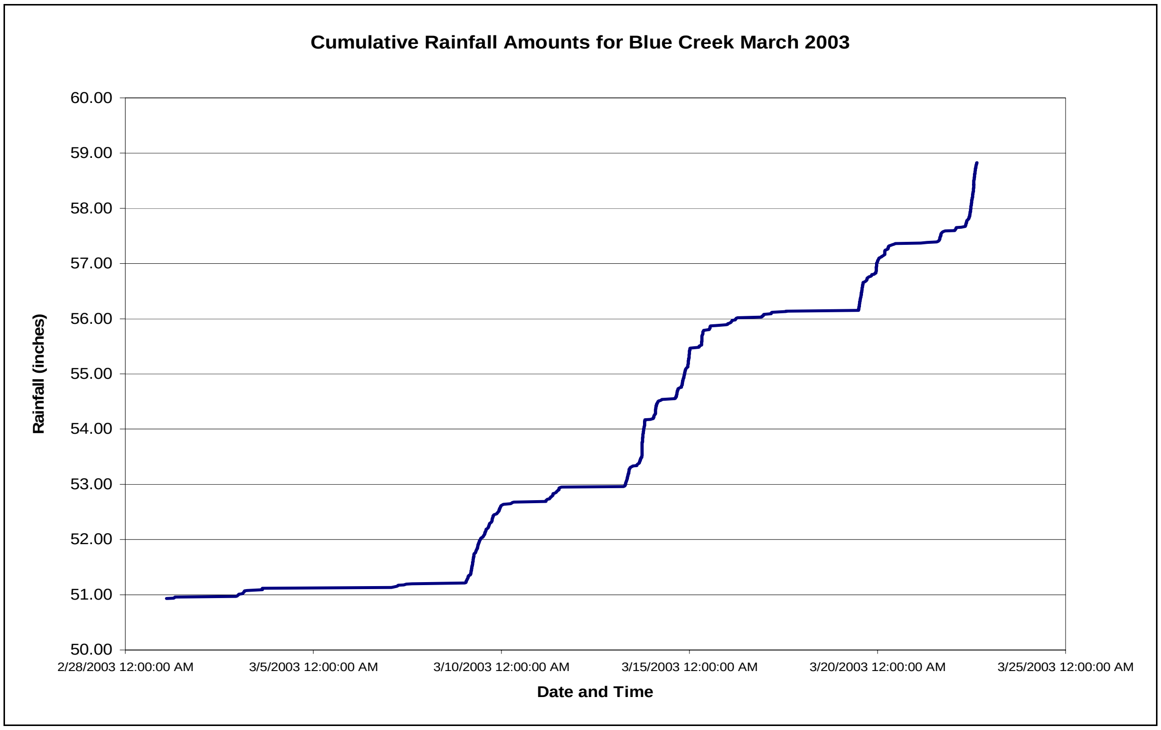


Figure 7-249 Blue Creek Rainfall August 2003

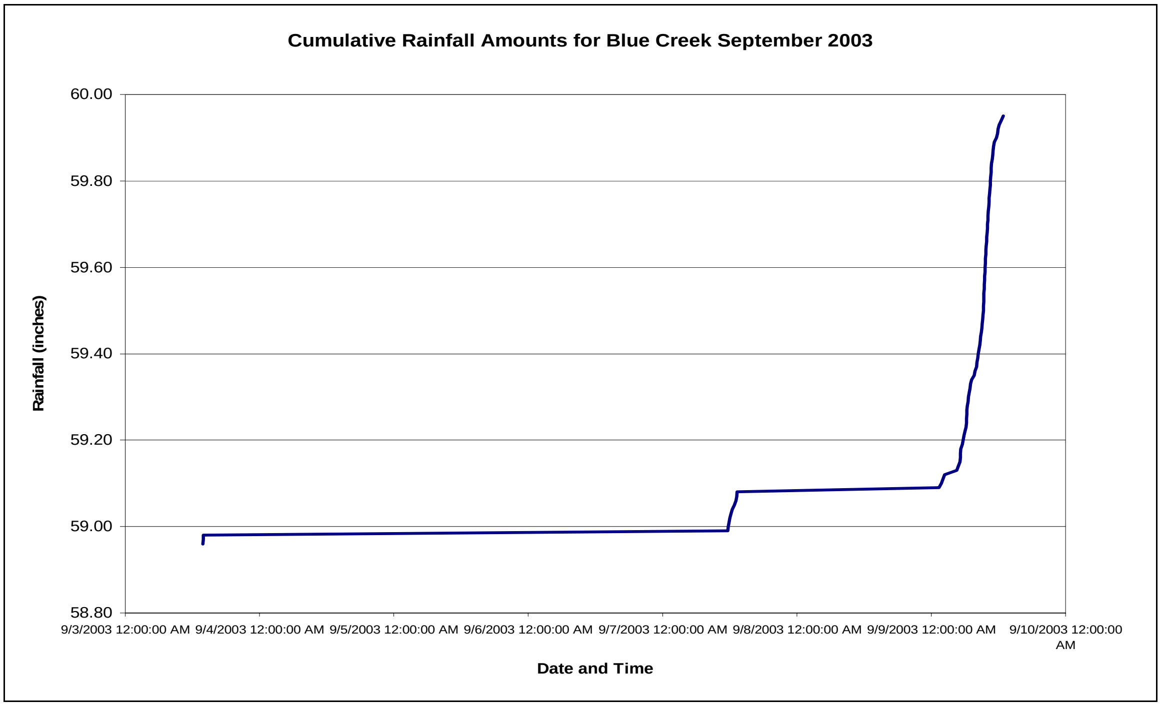


Figure 7-250 Blue Creek Rainfall September 2003

7.2.4 Turwar Creek

The Turwar gaging station began operating on October 9th, 2002 at 3:00 PM. The station is located at 41° 32’ 6” north latitude, 123° 58’ 43” west longitude. The following parameters are measured at the site on a fifteen-minute time step throughout the year: date, time, stage, air temperature (inside the gaging box), water temperature, turbidity, and battery voltage. A continuous turbidity probe was installed near the end of water-year ‘03 on September 15th, 2003. The SDI-12 probe measures turbidity and water temperature on a fifteen minute time step in conjunction with all of the other parameters previously mentioned. YTFD also monitors water temperature at various locations throughout Turwar Creek; those data are not presented in this report.

7.2.4.1 Discharge

Table 7-12 Minimum Daily Discharge (cfs) Values for Turwar Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	Aug	Sept
1		'	0.05	17.14	811.50	572.08	106.71	191.98	'	50.89	34.01	20.38	17.19
2		'	0.08	17.09	472.79	388.57	99.89	212.11	'	50.89	29.05	20.96	16.70
3		'	0.16	16.70	335.68	289.04	95.55	248.04	'	48.45	29.05	22.15	16.23
4		'	0.18	16.70	323.46	229.48	87.35	395.66	'	46.12	28.29	22.77	14.02
5		'	0.41	16.70	388.57	191.98	83.48	341.93	'	44.98	28.29	22.15	16.23
6		'	2.09	16.70	311.62	163.16	79.76	425.11	'	44.98	27.54	22.15	16.23
7		'	8.85	16.70	238.61	144.05	79.76	622.77	'	43.88	27.54	21.55	17.19
8		'	22.77	16.70	199.83	126.87	77.96	'	'	43.88	29.05	20.96	17.69
9		11.36	22.15	16.70	170.00	116.42	77.96	'	'	41.73	26.81	20.38	17.69
10		11.36	25.40	21.55	153.35	106.71	203.85	'	'	41.73	26.81	20.38	19.81
11		8.85	17.69	39.67	144.05	99.89	188.16	'	'	41.73	26.10	20.38	17.69
12		6.84	20.38	47.27	156.56	93.44	199.83	'	'	41.73	25.40	19.81	16.70
13		6.62	4.88	138.12	199.83	89.34	188.16	'	113.93	42.79	26.10	19.81	15.76
14		6.84	1.71	156.56	489.66	83.48	262.80	'	104.39	39.67	25.40	19.81	15.31
15		6.62	21.55	440.53	300.15	83.48	432.76	'	97.70	39.67	25.40	19.26	15.31
16		7.79	20.90	1063.39	229.48	354.74	354.74	'	91.37	38.68	25.40	19.26	15.31
17		7.54	30.79	591.91	199.83	354.74	257.80	'	85.40	37.70	24.72	19.26	15.31
18		6.62	29.28	348.29	180.70	367.96	207.94	'	79.76	37.70	24.06	18.73	15.31
19		4.88	25.33	257.80	156.56	498.29	191.98	'	76.18	37.70	23.41	18.73	14.87
20		7.07	23.47	248.04	144.05	602.05	317.49	'	74.45	35.82	22.77	18.20	14.87
21		5.99	21.91	572.08	138.12	381.60	329.52	'	71.07	34.90	22.77	18.20	14.87
22		6.62	20.96	323.46	132.39	278.29	323.46	'	67.83	34.01	22.77	18.20	14.44
23		6.62	20.32	225.02	203.85	225.02	448.41	'	66.25	33.14	22.15	19.81	14.02
24		6.84	19.76	180.70	188.16	188.16	323.46	'	64.71	33.14	22.15	22.77	14.02
25		7.54	19.10	150.19	417.58	159.83	300.15	'	64.71	33.14	22.15	22.77	14.02
26		7.30	18.46	144.05	335.68	141.05	1131.48	'	61.72	31.45	22.15	22.77	14.02
27		1.40	18.05	163.16	760.27	126.87	572.08	'	57.45	29.83	22.15	22.15	14.02
28		0.33	17.69	1930.59	572.08	116.42	395.66	'	57.45	29.83	21.55	22.15	14.44
29		0.66	17.49	838.20	354.74	'	278.29	'	54.74	29.83	21.55	18.20	14.44
30		0.22	17.34	798.43	361.30	'	225.02	'	54.74	30.63	20.38	17.19	14.44
31		0.10	'	1720.64	644.09	'	203.85	'	54.74	'	20.38	16.70	'

Monthly Statistics

Total	135.97	469.21	10550.81	9714.52	6573.04	8125.30	2437.61	1398.61	1170.62	775.39	628.03	468.09
Mean	5.91	15.64	340.35	313.37	234.75	262.11	348.23	73.61	39.02	25.01	20.26	15.60
Max	11.36	30.79	1930.59	811.50	602.05	1131.48	622.77	113.93	50.89	34.01	22.77	19.81
Min	0.10	0.05	16.70	132.39	83.48	77.96	191.98	54.74	29.83	20.38	16.70	14.02

Table 7-13 Maximum Daily Discharge (cfs) Values for Turwar Creek WY03

Day		Oct	Nov	Dec	January	February	March	April	May	June	July	August	September
1		'	10.04	18.20	1796.97	723.68	116.42	243.29	'	54.74	38.68	21.55	18.73
2		'	10.04	18.36	735.71	572.08	106.71	257.80	'	52.15	30.63	22.15	17.69
3		'	10.68	18.25	562.37	388.57	102.12	395.66	'	52.15	36.75	22.77	17.19
4		'	10.04	17.19	798.43	289.04	95.55	464.54	'	49.66	37.70	23.41	17.69
5		'	10.04	17.19	654.98	229.48	87.35	425.11	'	47.27	29.05	23.41	17.19
6		'	13.21	17.19	410.16	191.98	83.48	760.27	'	47.27	29.05	22.77	17.69
7		'	29.83	16.70	335.68	163.16	83.48	760.27	'	49.66	28.29	22.77	18.73
8		'	41.73	16.70	262.80	144.05	83.48	'	'	47.27	28.29	21.55	18.73
9		14.02	36.75	20.96	203.85	129.61	216.34	'	'	44.98	27.54	21.55	27.54
10		12.44	47.27	47.27	177.07	116.42	248.04	'	'	42.79	27.54	21.55	25.40
11		11.01	35.82	52.15	156.56	106.71	220.65	'	'	43.88	26.81	20.96	20.38
12		12.07	32.28	118.96	195.87	99.89	225.02	'	'	44.98	26.10	20.96	18.20
13		11.71	25.40	257.80	1014.65	95.55	262.80	'	118.96	43.88	26.10	21.55	17.19
14		12.07	32.28	2131.83	1080.08	89.34	440.53	'	116.42	42.79	25.40	22.15	16.70
15		11.01	24.12	1695.82	515.93	341.93	572.08	'	104.39	41.73	26.10	20.96	16.23
16		9.73	30.39	3953.70	305.84	633.35	498.29	'	97.70	41.73	26.81	19.81	16.23
17		9.73	46.12	1046.93	243.29	602.05	354.74	'	93.44	40.69	26.10	19.81	16.23
18		10.36	37.41	591.91	207.94	515.93	257.80	'	89.34	38.68	25.40	19.81	16.23
19		10.36	29.91	348.29	188.16	1876.16	311.62	'	79.76	39.67	26.10	19.81	16.23
20		11.01	25.75	922.84	159.83	1278.86	534.10	'	79.76	40.69	24.06	19.26	16.23
21		10.04	23.93	952.62	156.56	602.05	440.53	'	77.96	35.82	24.06	19.81	15.76
22		8.31	22.46	562.37	252.88	374.73	908.25	'	72.74	35.82	23.41	19.81	15.31
23		7.79	21.55	323.46	252.88	278.29	811.50	'	69.43	34.90	23.41	23.41	15.31
24		8.05	20.78	229.48	591.91	225.02	464.54	'	66.25	35.82	22.77	24.72	14.87
25		12.82	20.32	180.70	838.20	188.16	2254.64	'	67.83	48.45	23.41	24.06	15.31
26		12.07	19.65	163.16	760.27	159.83	2923.78	'	66.25	46.12	23.41	24.06	14.87
27		10.36	19.37	7917.46	3167.40	141.05	1166.90	'	61.72	33.14	22.77	24.06	14.87
28		10.04	18.94	4322.70	1259.59	126.87	581.92	'	58.84	30.63	22.77	24.06	15.31
29		10.04	18.67	2192.50	581.92	'	395.66	'	58.84	30.63	22.77	24.06	15.31
30		10.36	18.46	1958.31	772.82	'	317.49	'	58.84	37.70	22.15	18.73	15.31
31		10.04		3853.34	811.50	'	234.00	'	58.84	'	21.55	18.73	'

Monthly Statistics

Tota	245.41	743.24	33984.32	19452.11	10683.85	15399.82	3306.94	1497.34	1275.69	824.99	674.06	518.62
Mea	10.67	24.77	1096.27	627.49	381.57	496.77	472.42	78.81	42.52	26.61	21.74	17.29
Ma	14.02	47.27	7917.46	3167.40	1876.16	2923.78	760.27	118.96	54.74	38.68	24.72	27.54
Mi	7.79	10.04	16.70	156.56	89.34	83.48	243.29	58.84	30.63	21.55	18.73	14.87

Table 7-14 Average Daily Discharge (cfs) Values for Turwar Creek WY03

Day		October	November	December	January	February	March	April	May	June	July	August	September
1		'	0.88	17.50	1123.68	663.83	111.12	205.33	'	52.75	36.28	21.12	17.94
2		'	1.02	17.49	568.73	461.82	102.90	238.61	'	51.36	29.83	21.44	17.23
3		'	1.54	17.22	406.57	331.07	98.86	280.78	'	8.10	32.71	22.52	16.77
4		'	1.70	17.14	470.46	256.51	91.69	439.63	'	49.66	32.71	22.85	16.87
5		'	2.30	17.10	509.71	209.06	85.62	380.37	'	46.12	28.67	22.75	16.74
6		'	5.51	16.77	351.03	176.74	81.78	634.02	'	46.12	28.29	22.29	16.99
7		'	13.07	16.70	270.39	152.76	82.54	675.62	'	46.69	27.91	22.03	17.83
8		'	28.67	16.70	222.23	135.53	80.11	'	'	45.55	28.67	21.33	18.03
9		13.45	30.37	17.78	185.10	121.69	125.50	'	'	43.33	27.18	21.24	21.78
10		11.75	34.71	34.06	163.90	111.30	228.08	'	'	42.26	27.18	20.84	22.86
11		10.34	23.56	44.47	149.77	103.23	202.08	'	'	42.79	26.45	20.43	18.95
12		9.73	24.55	53.35	166.69	95.97	214.92	'	'	43.33	25.75	20.29	17.53
13		8.85	12.36	173.50	408.78	92.42	207.04	'	117.15	43.33	26.10	20.47	16.64
14		9.14	9.55	960.35	725.05	86.66	385.36	'	110.90	41.21	25.40	20.79	16.11
15		8.54	22.85	605.78	378.36	121.71	537.47	'	101.28	40.69	25.74	19.93	15.80
16		8.84	22.56	2193.14	268.36	519.86	420.78	'	94.14	40.18	26.45	19.57	15.86
17		8.69	39.96	760.79	216.43	450.57	300.44	'	89.24	39.17	25.40	19.41	15.88
18		8.45	32.97	444.46	194.85	457.51	232.77	'	84.08	38.19	24.65	19.30	15.66
19		7.29	27.36	300.68	169.27	979.19	219.92	'	78.93	38.68	24.65	19.04	15.53
20		8.77	24.54	388.13	150.52	850.55	469.17	'	76.77	38.19	23.82	18.85	15.55
21		7.67	22.81	775.19	149.09	464.63	373.38	'	74.19	35.36	23.37	18.60	15.38
22		7.00	21.59	415.25	161.46	322.96	497.74	'	71.17	34.90	23.25	19.08	14.99
23		6.98	20.83	268.57	217.59	249.30	596.44	'	67.88	34.01	22.83	21.62	14.65
24		7.34	20.17	207.09	258.06	204.02	383.84	'	65.64	34.45	22.53	24.02	14.53
25		9.52	19.73	164.53	562.37	172.07	524.47	'	66.37	40.18	22.68	23.49	14.64
26		9.79	19.03	151.93	418.52	150.62	1828.24	'	63.98	38.19	22.83	23.13	14.48
27		4.51	18.63	2150.63	1769.61	133.80	796.67	'	59.91	31.45	22.53	23.03	14.54
28		2.36	18.25	3037.18	806.31	120.68	470.46	'	57.52	30.23	22.04	23.14	14.84
29		2.77	17.87	1528.10	437.60	'	342.13	'	56.56	30.23	21.97	21.05	15.03
30		1.83	17.73	1256.40	571.57	'	255.58	'	56.71	34.01	21.39	18.19	14.92
31		1.11		2480.18	735.20	'	220.42	'	55.76	0.00	20.77	17.82	'

Monthly Statistics

Total	174.73	556.67	18548.18	13187.26	8196.02	10567.52	2854.37	1448.17	1180.67	800.01	649.66	494.56
Mean	7.60	18.56	598.33	425.40	292.72	340.89	407.77	76.22	38.09	25.81	20.96	16.49
Max	13.45	39.96	3037.18	1769.61	979.19	1828.24	675.62	117.15	52.75	36.28	24.02	22.86
Min	1.11	0.88	16.70	149.09	86.66	80.11	205.33	55.76	0.00	20.77	17.82	'

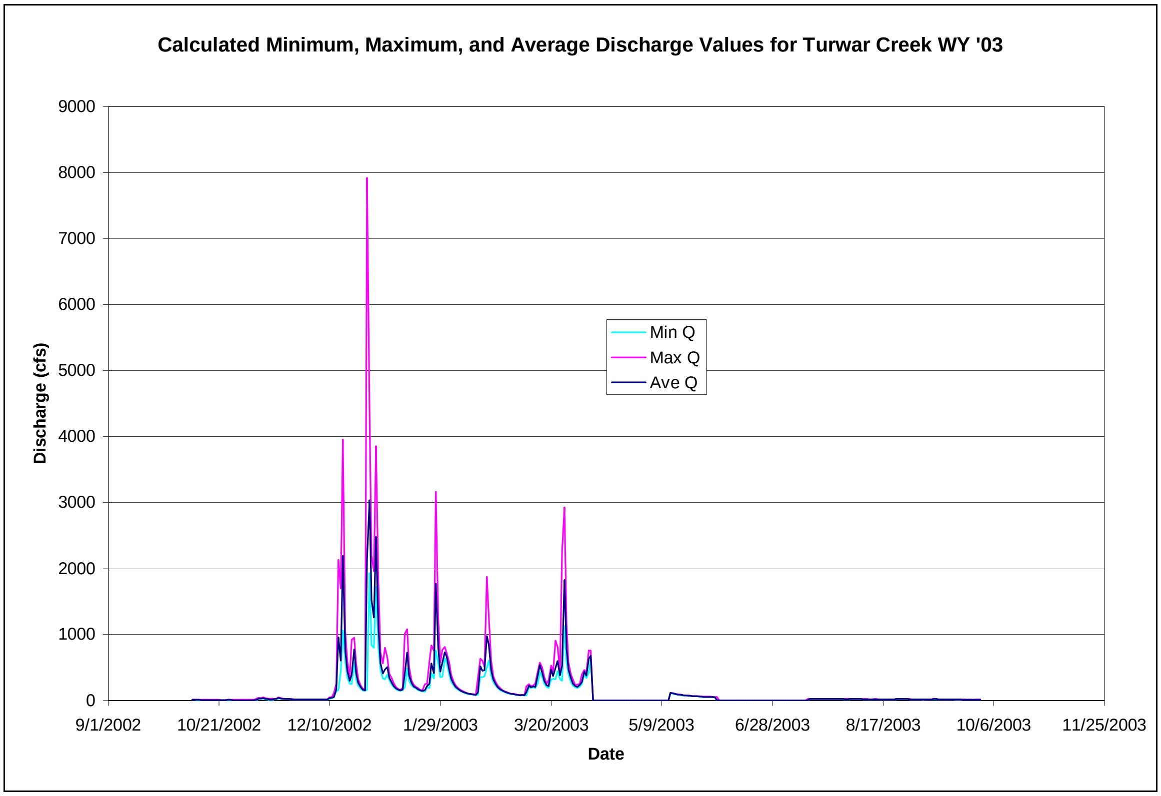


Figure 7-251 Mean, minimum, and maximum discharges recorded at Turwar Creek gaging site from October 9, 2002 through September 30, 2003

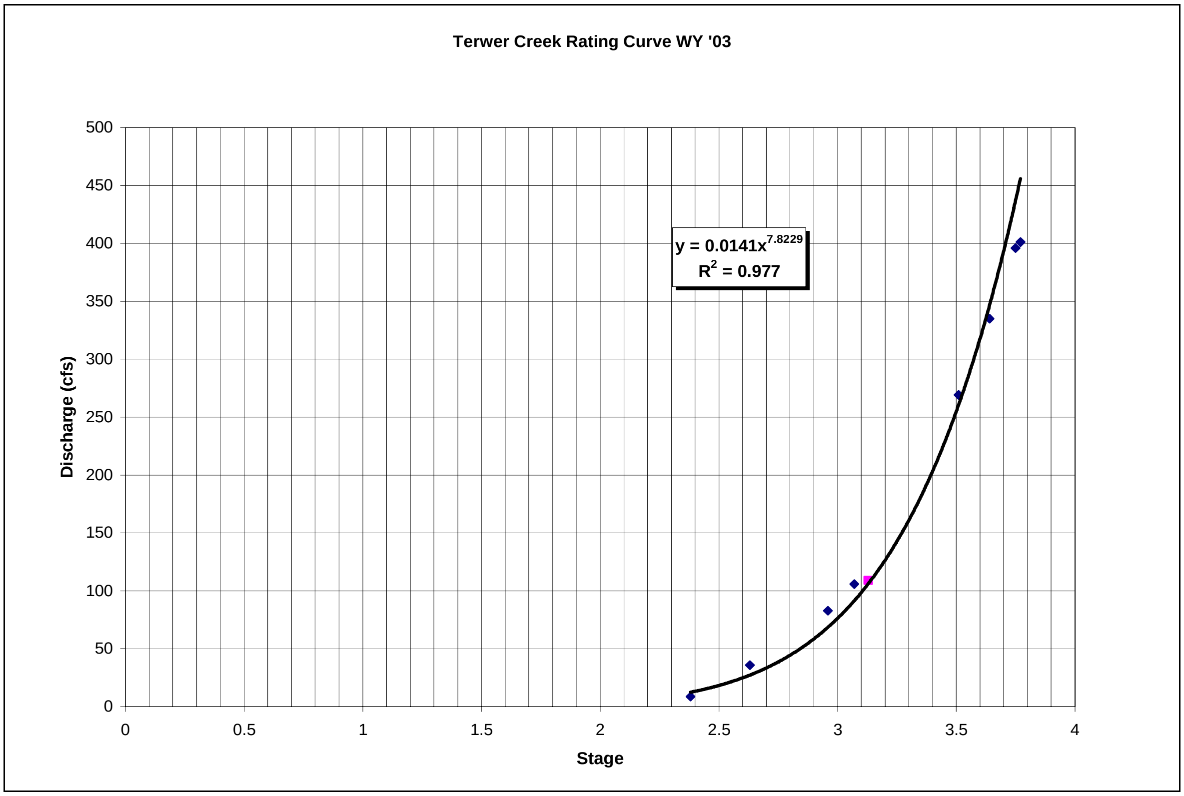


Figure 7-252 Turwar Creek Rating Curve WY03

7.2.4.2 Turbidity

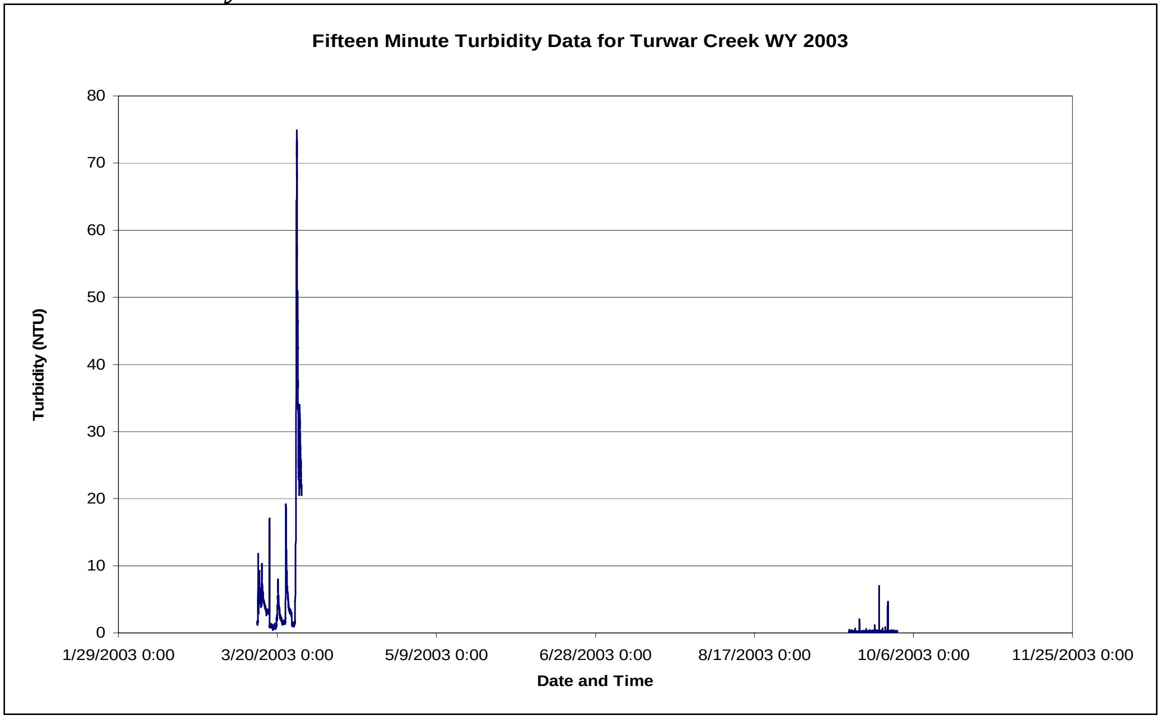


Figure 7-253 Turwar Creek Fifteen-Minute Turbidity WY03

7.2.4.3 Water Temperature

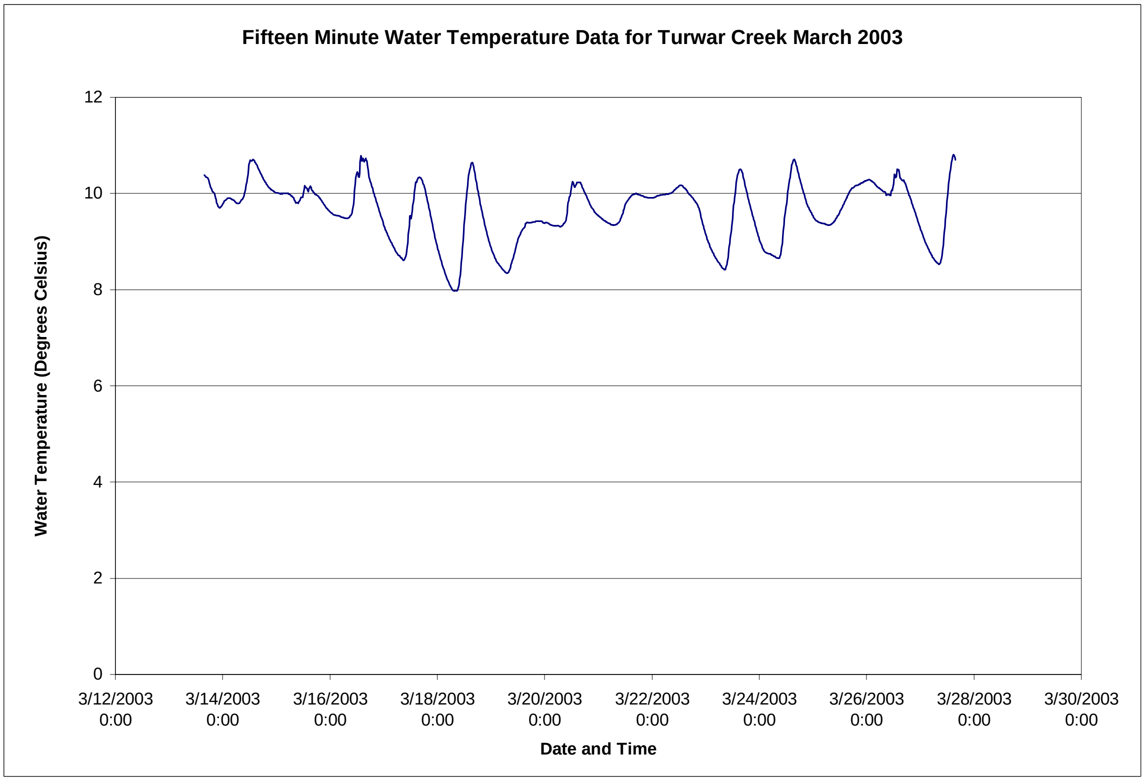


Figure 7-254 Turwar Creek Fifteen-Minute Water Temperature Data

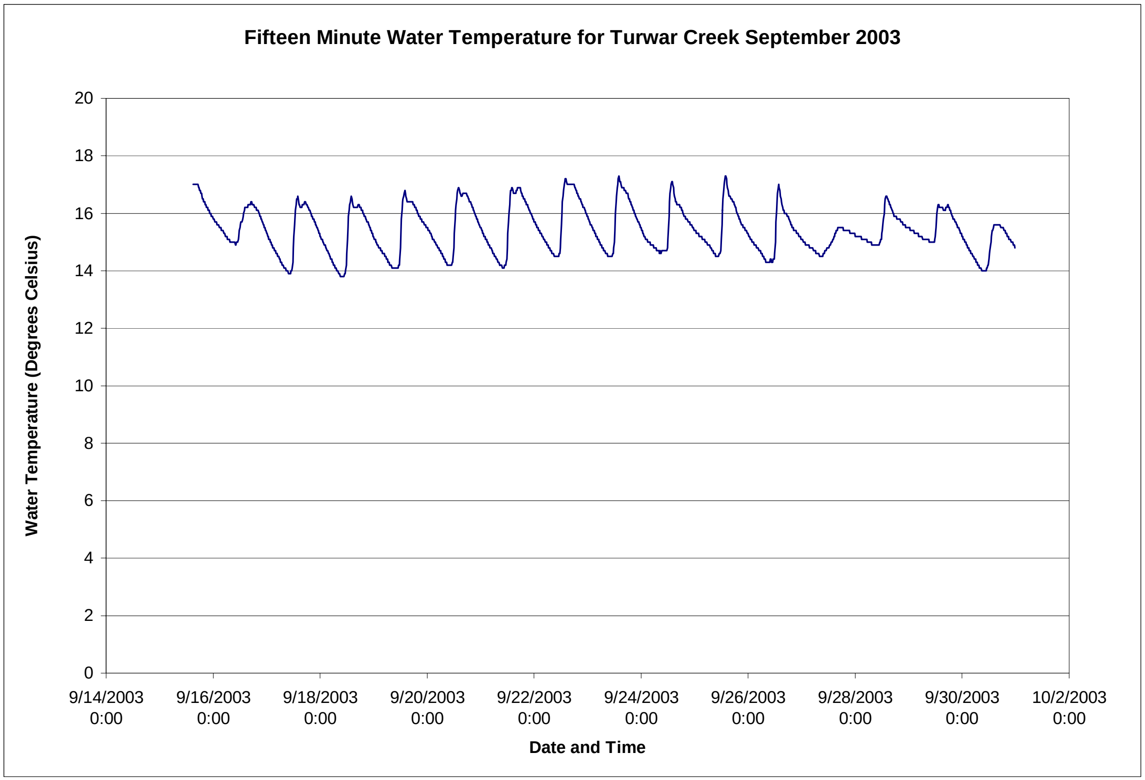


Figure 7-255 Turwar Creek Fifteen-Minute Water Temperature WY03

7.2.4.4 Specific Conductivity

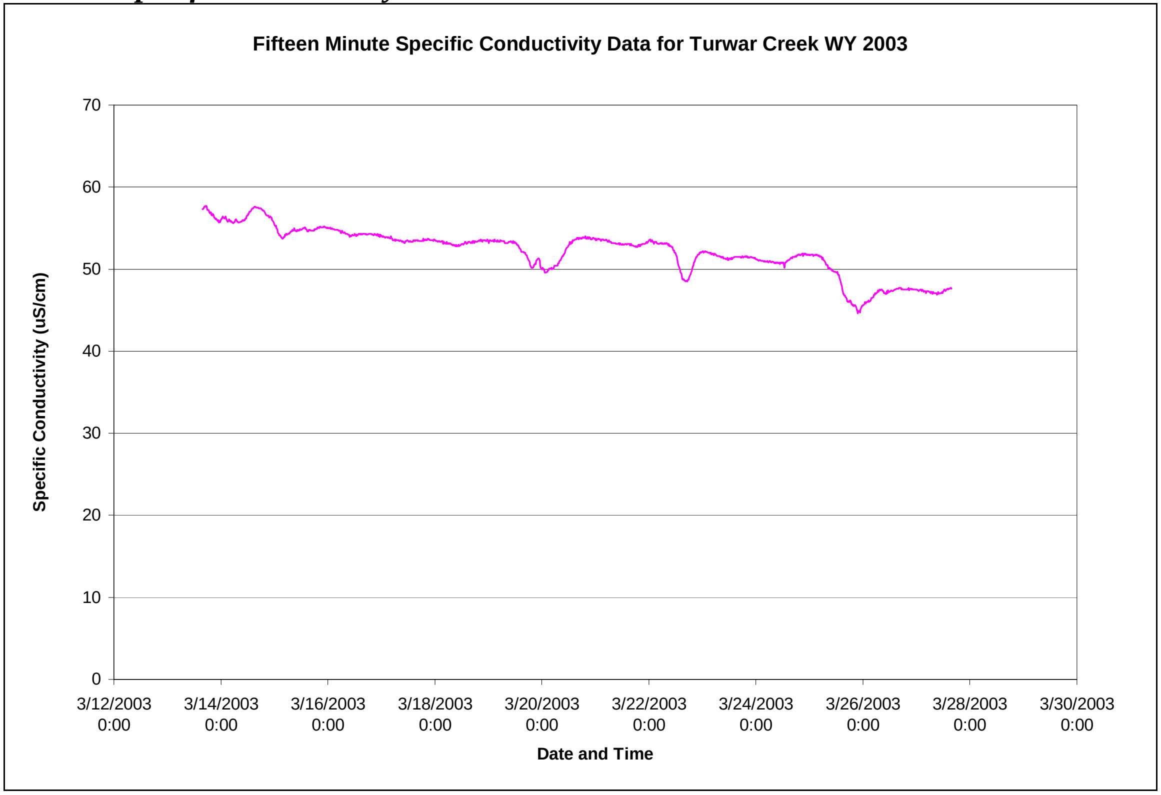


Figure 7-256 Fifteen Minute Specific Conductivity Data for Turwar Creek WY 03.

7.2.4.5 Suspended Sediment

Table 7-15Turwar Creek Suspended Sediment Data WY03

Sample ID	Bottle #	Location	Date Collected	Time Collected	SSC (mg/L)	Gage Height (ft)	Flow Est (cfs)
Turwar	1+2+3+4+5+6+7	Turwar	4/29/2003	12:00	3.63	3.81	494.01
Turwar	4 replicate	Turwar	4/29/2003	12:10	4.61	3.81	494.01
Turwar	8 replicate	Turwar	4/29/2003	12:20	2.15	3.81	494.01

7.2.5 Tully Creek

7.2.5.1 Turbidity

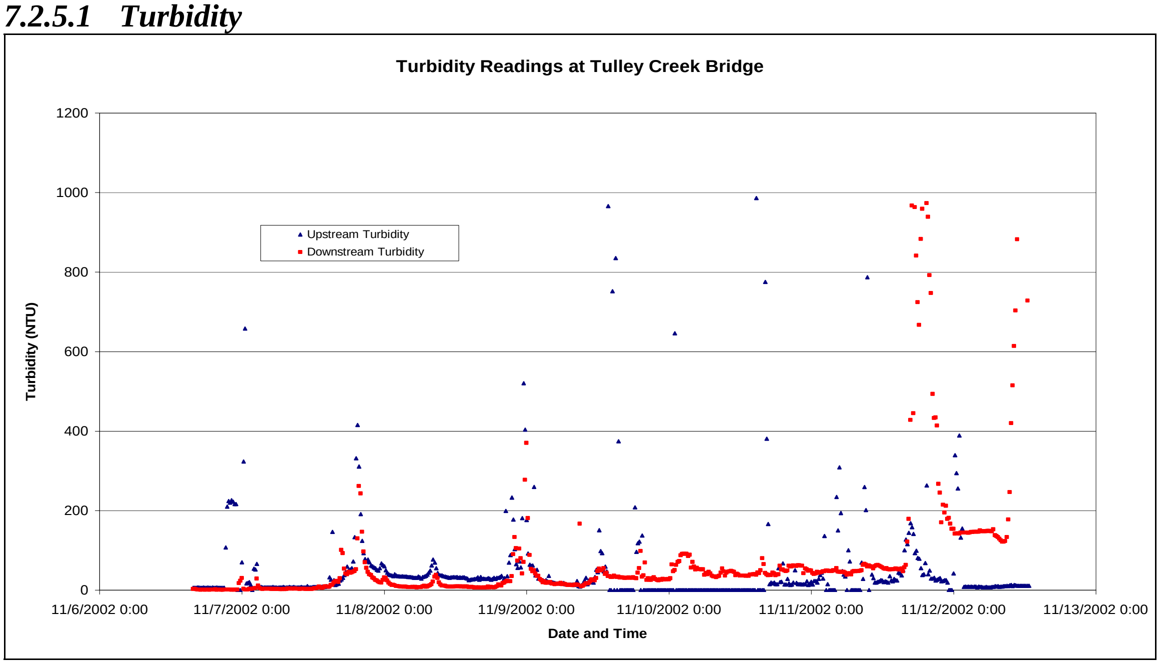


Figure 7-257 Fifteen minute turbidity data for Tully Creek WY 03.

7.2.5.2 Water Temperature

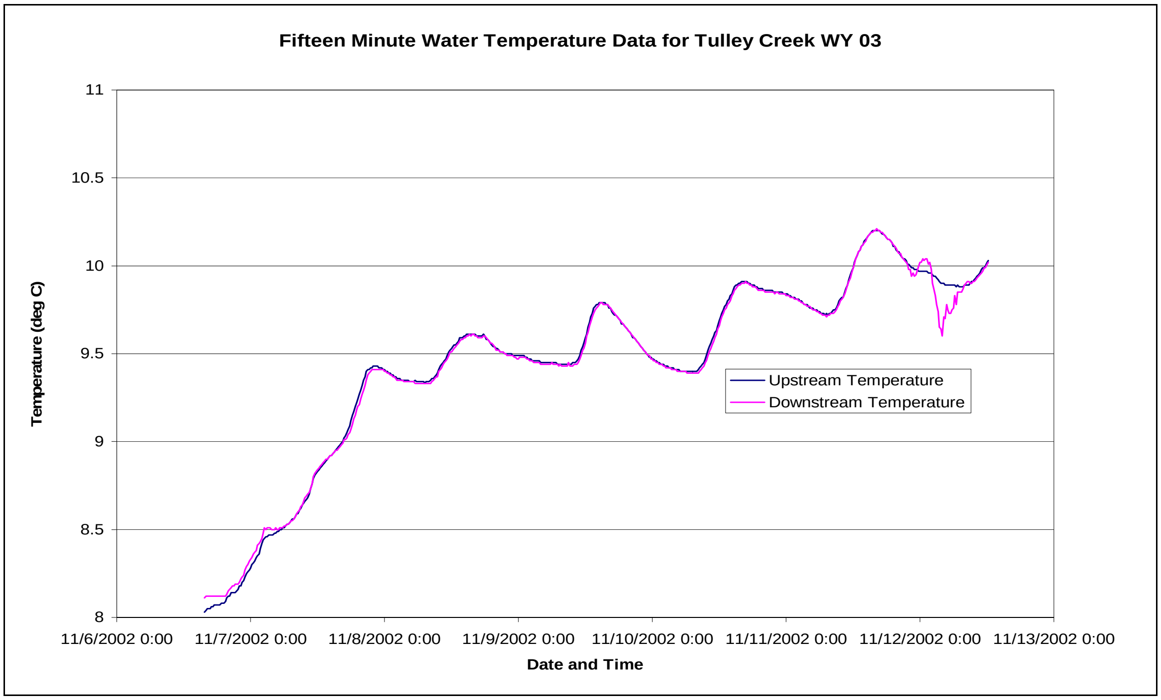


Figure 7-258 Fifteen minute water temperature data for Tully Creek WY03

7.2.5.3 Specific Conductivity

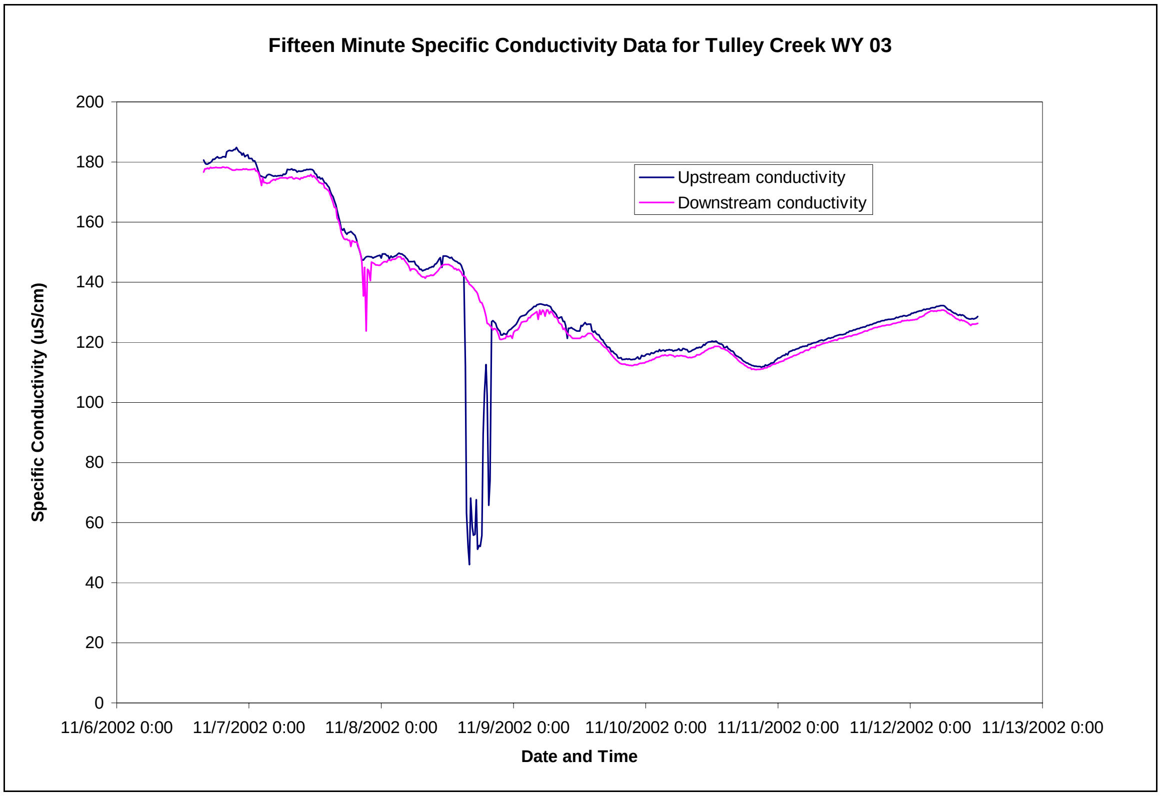


Figure 7-259 Fifteen minute specific conductivity data for Tully Creek WY03

7.2.6 McGarvey Creek Grab Samples

Table 7-16 McGarvey Creek Grab Sample Results 11/7/02

McGarvey Creek Sampling

Arsenic

µg/L; Report Limit: 10

EPA: CMC is 340, CCC is 150. For human health, consumption of water and organisms, Report Limit is 0.018; for consumption of organisms only, Report Limit is 0.14.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Barium

µg/L; Report Limit: 5.0

Site	11/7/02
Upstream 1/2	35
Upstream 2/2	35
Downstream 1/2	45
Downstream 2/2	47

Cadmium

µg/L; Report Limit: 10

EPA: CMC is 2.0, CCC is 0.25.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Chromium

µg/L; Report Limit: 10

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Iron

µg/L; Report Limit: 100

Site	11/7/02
Upstream 1/2	6,600
Upstream 2/2	6,300
Downstream 1/2	28,000
Downstream 2/2	29,000

Silver

µg/L; Report Limit: 10

EPA: CMC is 3.2.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Lead

µg/L; Report Limit: 10

EPA: CMC is 65, CCC is 2.5.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Mercury

µg/L; Report Limit: 1.0

EPA: CMC is 1.4, CCC is 0.77.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

Selenium

µg/L; Report Limit: 10

EPA: CCC is 5.0. For human health, consumption of water and organisms, Report Limit is 170; for consumption of organisms only, Report Limit is 4,200.

Site	11/7/02
Upstream 1/2	ND
Upstream 2/2	ND
Downstream 1/2	ND
Downstream 2/2	ND

7.3 Macroinvertabrate Sampling

Table 7-17 Macroinvertabrate Sampling WY03

Sample I.D.	Riffle #	Date Sampled	Total Number of Specimens	Taxa Richness	EPT Taxa Richness	Sensitive EPT Index (%)	% Dominant Taxon	Tolerance Value	Shannon's Diversity Index	Estimated Relative Abundance
Lower Blue	1	6/2/2003	304	38	18	21.38	37.8	4.47	2.42	1003
Lower Blue	2	6/2/2003	302	41	22	25.83	32.8	4.27	2.79	1008
Lower Blue	3	6/2/2003	300	37	20	21	39.3	4.54	2.49	741
McGarvey	1	4/10/2003	300	28	20	36.33	36.7	3.01	2.18	433
McGarvey	2	4/10/2003	105	21	11	31.43	42.9	3.44	2.27	105
McGarvey	3	4/10/2003	250	22	12	30	46.4	3.18	2	250
Tectah Mainstem	1	5/15/2003	300	39	24	31	32.7	3.81	2.76	986
Tectah Mainstem	2	5/15/2003	300	43	27	38.33	18	3.43	3.03	644
Tectah Mainstem	3	5/15/2003	301	36	21	30.90	14	3.42	2.75	824
North Fork Tectah	1	5/16/2003	305	41	26	40	33.4	3.23	2.76	616
North Fork Tectah	2	5/16/2003	296	42	23	46.96	15.2	3.16	3.09	26.00
North Fork Tectah	3	5/16/2003	300	37	25	48.67	14.3	3.06	2.93	411
South Fork Tectah	1	5/16/2003	300	36	21	42.66	22.3	3.37	2.75	348
South Fork Tectah	2	5/16/2003	318	41	28	48.43	22	2.99	2.59	318
South Fork Tectah	3	5/16/2003	198	28	20	57.07	17.7	2.57	2.69	198
Upper Turwar	1	5/2/2003	300	26	19	28	26.3	3.59	2.32	949
Upper Turwar	2	5/2/2003	302	35	22	30.79	32.1	3.54	2.53	871
Upper Turwar	3	5/2/2003	311	32	20	35.05	22.8	3.16	2.63	596
Lower Turwar	1	5/2/2003	305	23	16	40.66	22	3.14	2.24	431
Lower Turwar	2	5/2/2003	300	28	19	32.33	31.7	3.65	2.41	614
Lower Turwar	3	5/6/2003	306	29	18	16.34	27.8	4.17	2.13	1800

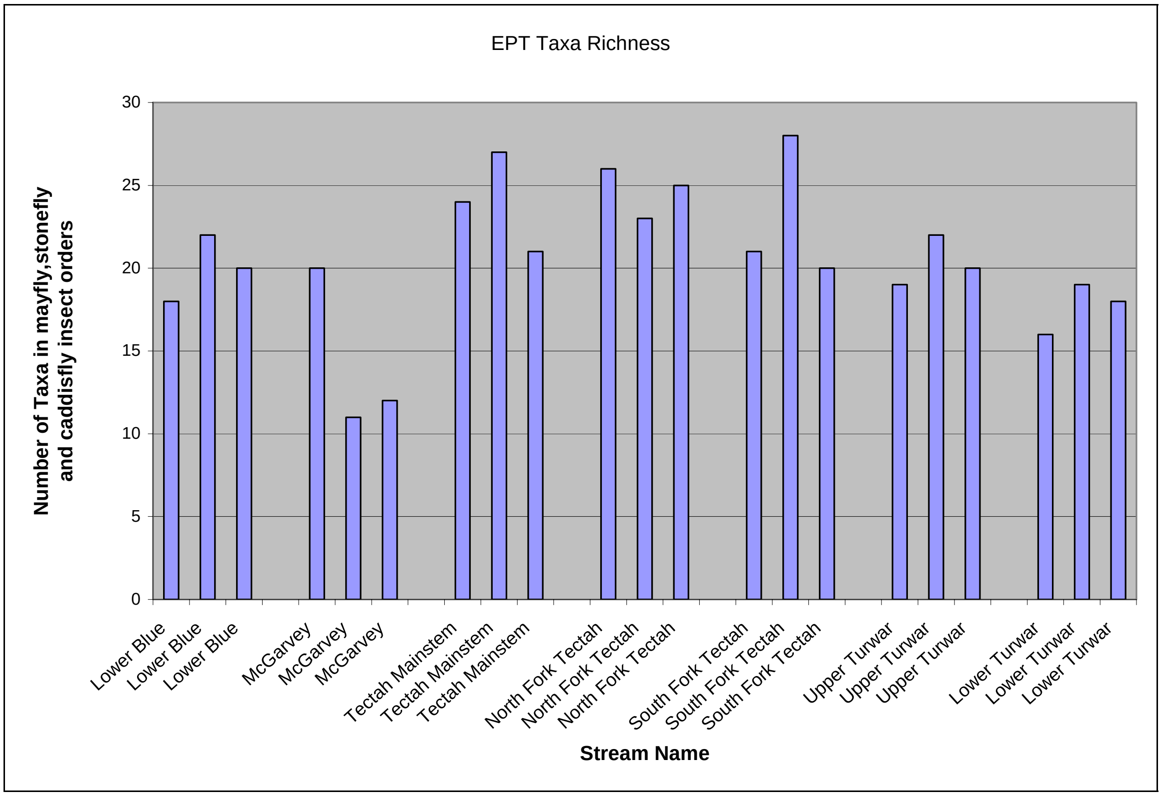


Figure 7-260 Macroinvertabrate EPT Taxa Richness

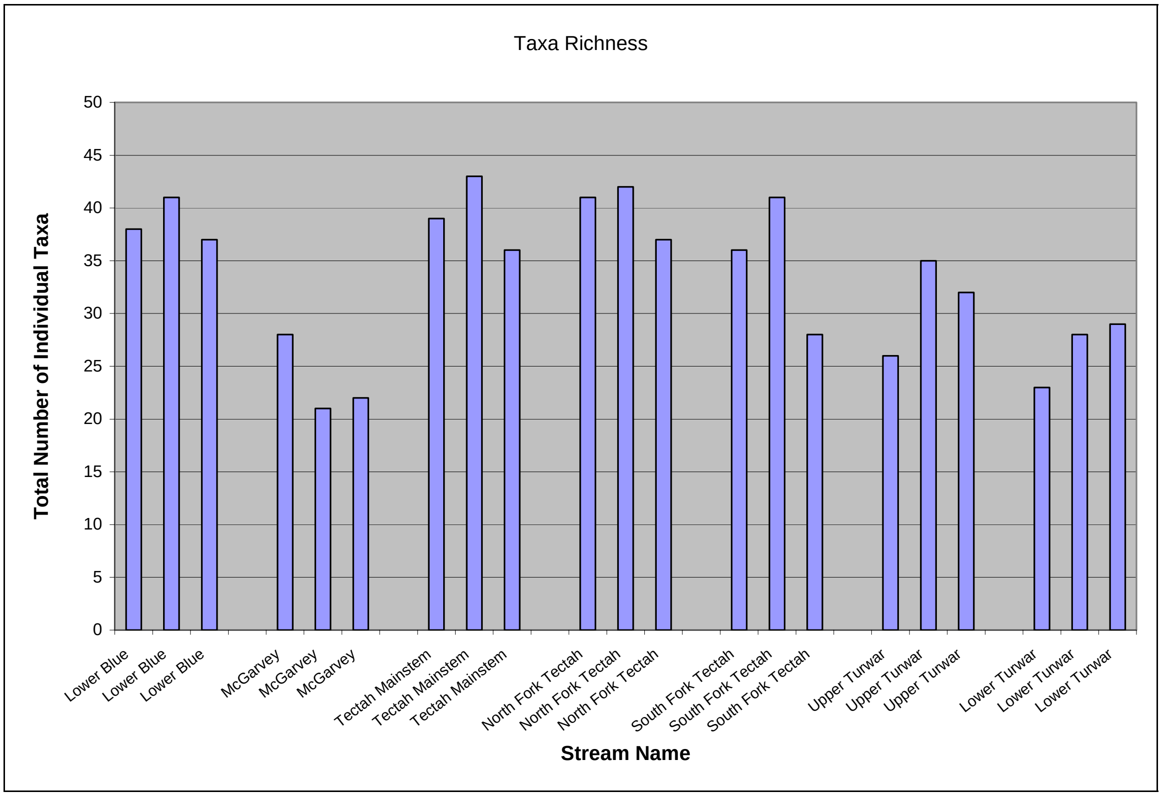


Figure 7-261 Macroinvertabrate Taxa Richness

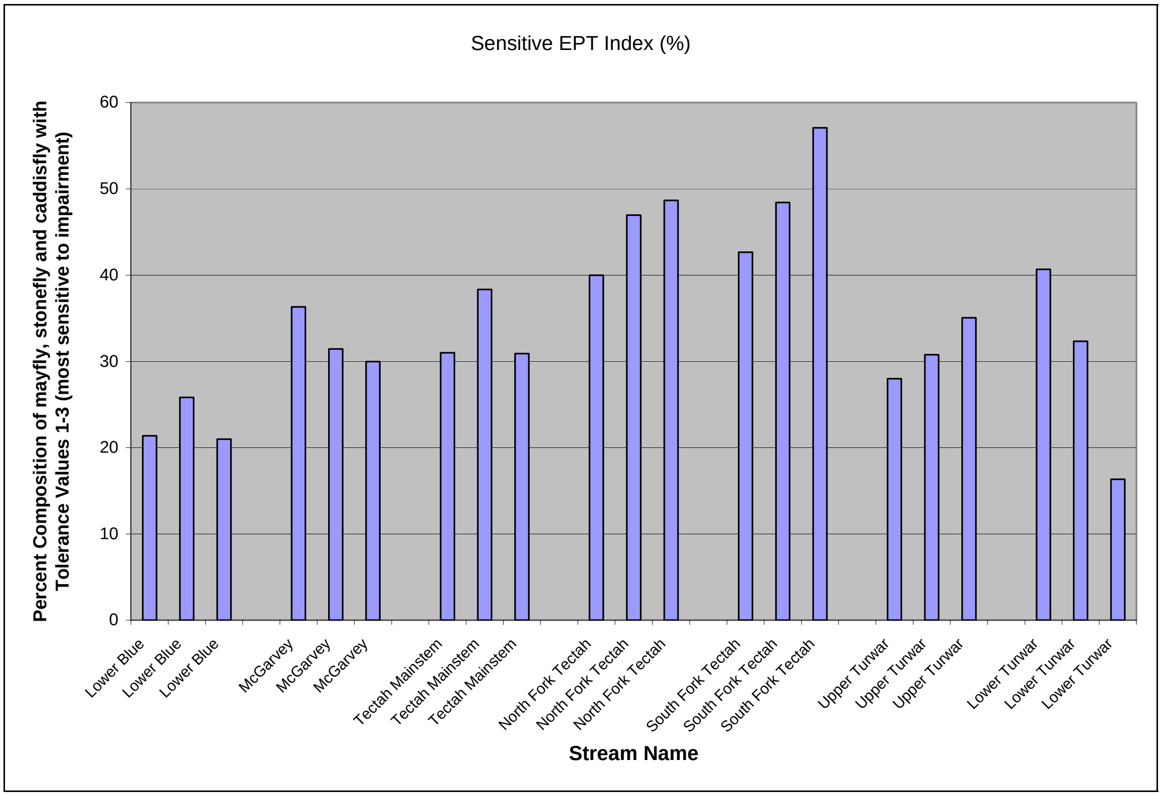


Figure 7-262 Macroinvertabrate Sensitive EPT Index

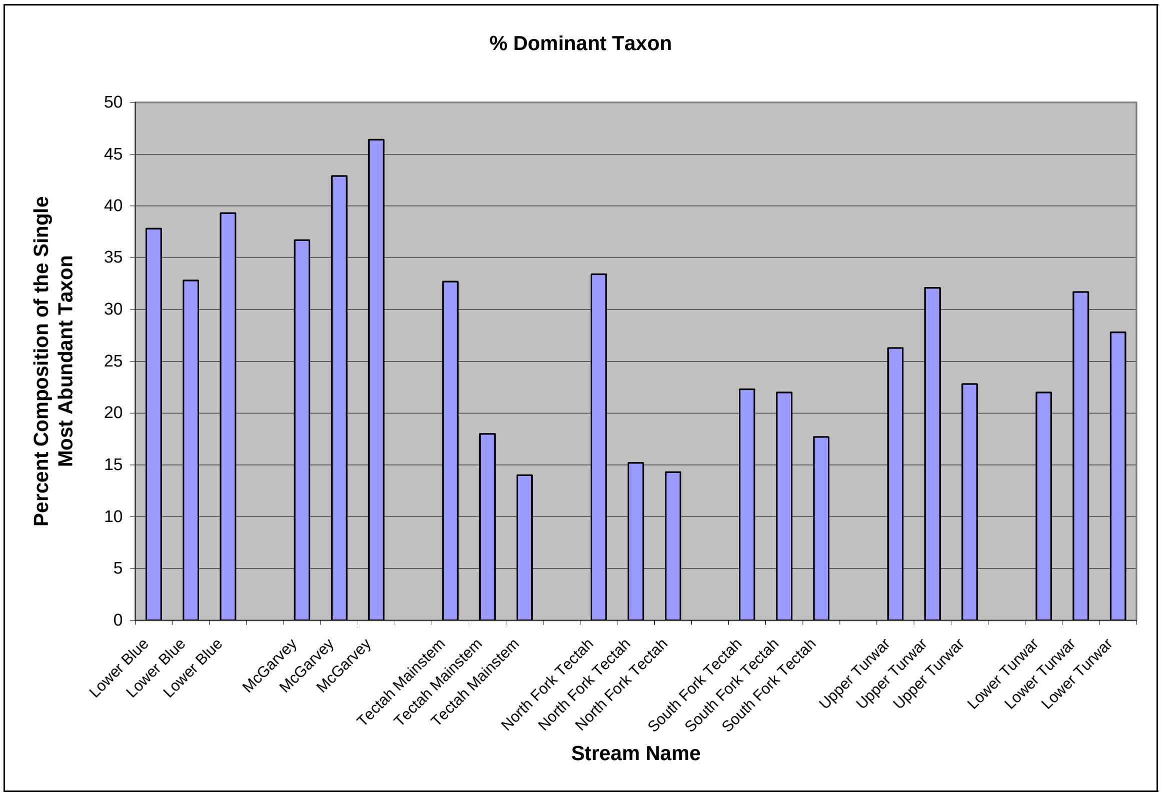


Figure 7-263 Macroinvertabrate Percent Dominant Taxon

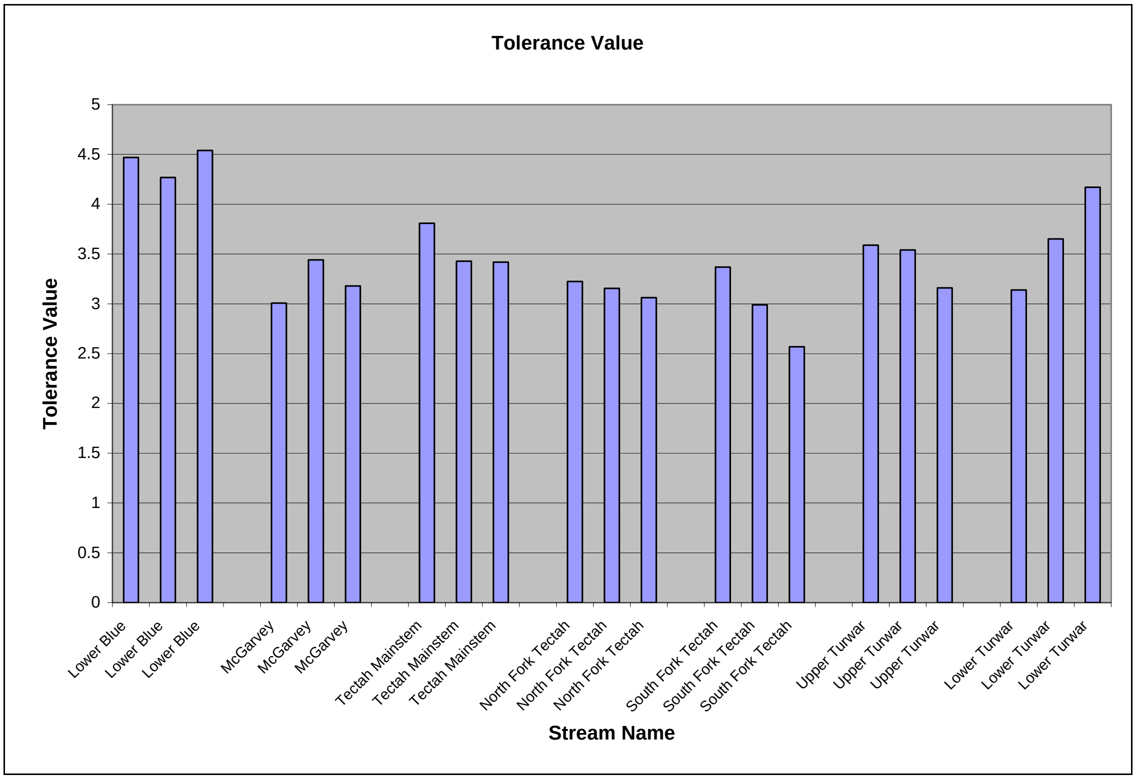


Figure 7-264 Macroinvertabrate Tolerance Value

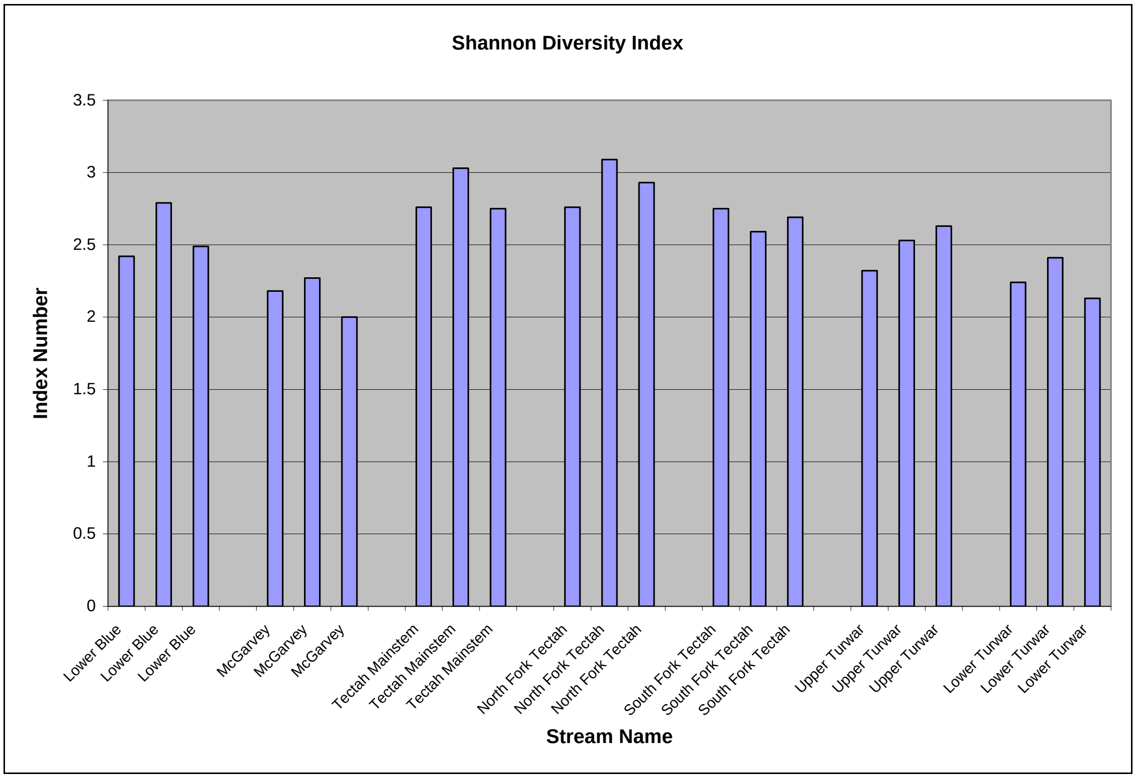


Figure 7-265 Macroinvertabrate Shannon Diversity Index

7.4 Herbicide Monitoring

YTEP Sample #	DPR Sample #	Date Sampled	Time Sampled	Sample Type	Atrazine Kit Analysis Result (ppb)	DPR laboratory Results
1462	1462	11-8-02	14:51	Grab	ND	ND
11-9-1-3	1466	11-9-02	8:31	Auto Sampler	ND	ND
11-9-4-6		11-9-02	9:01	Auto Sampler	0.07	
11-9-7-9	1463	11-9-02	9:31	Auto Sampler	0.10	ND
11-9-10-12		11-9-02	10:01	Auto Sampler	ND	
11-9-13-15	1469	11-9-02	10:31	Auto Sampler	0.10	ND
11-9-16-18		11-9-02	11:01	Auto Sampler	ND	
11-9-19-21	1461	11-9-02	11:31	Auto Sampler	0.06	ND
11-9-22-24		11-9-02	12:01	Auto Sampler	ND	
11-9 QC	1459	11-9-02	13:24	Auto Sampler	ND	ND
11-10-1-3		11-9-02	13:52	Auto Sampler	ND	
11-10-4-6	1455	11-9-02	14:22	Auto Sampler	ND	ND
11-10-7-9		11-9-02	14:52	Auto Sampler	ND	
11-10-10-12	1464	11-9-02	15:22	Auto Sampler	0.09	ND
11-10-13-15		11-9-02	15:52	Auto Sampler	ND	
11-10-16-18	1458	11-9-02	16:22	Auto Sampler	0.13	ND
11-10-19-21		11-9-02	16:52	Auto Sampler	ND	
11-10-22-24	1465	11-9-02	17:22	Auto Sampler	0.06	ND
11-10 QC	1460	11-10-02	8:55	Auto Sampler	ND	ND

Figure 7-266 Herbicide Monitoring Results WY03

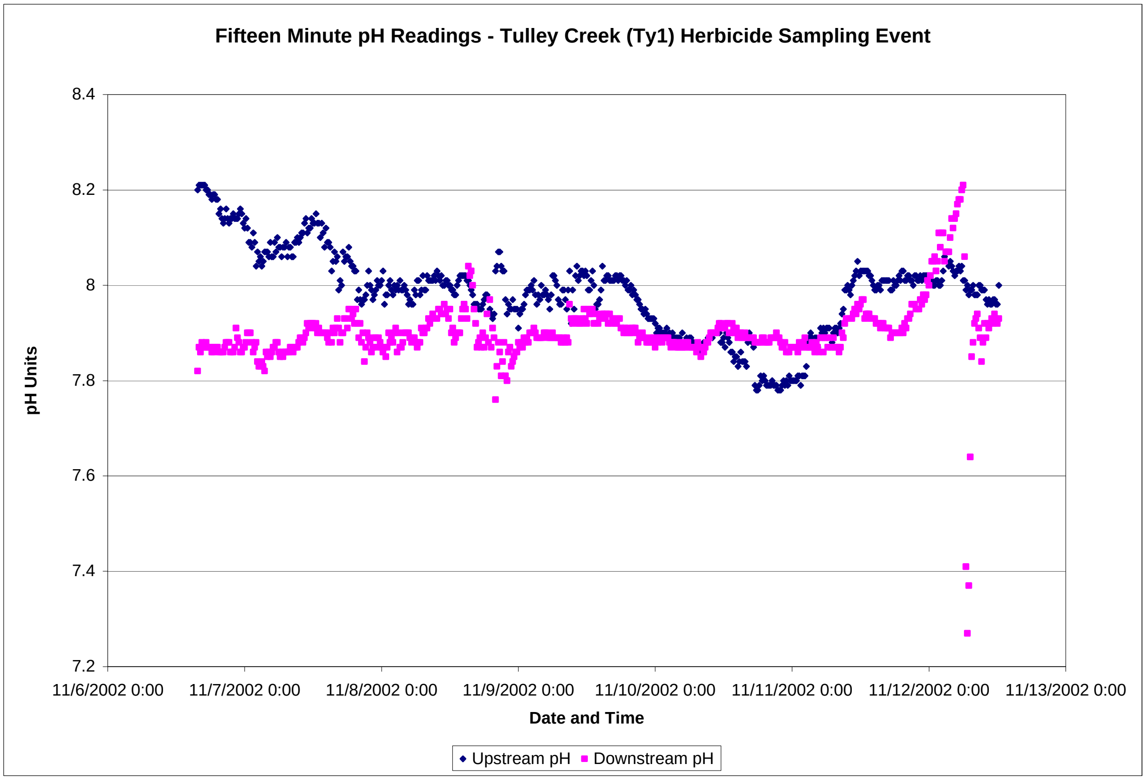


Figure 7-267 Tully Creek Monitoring Results - pH

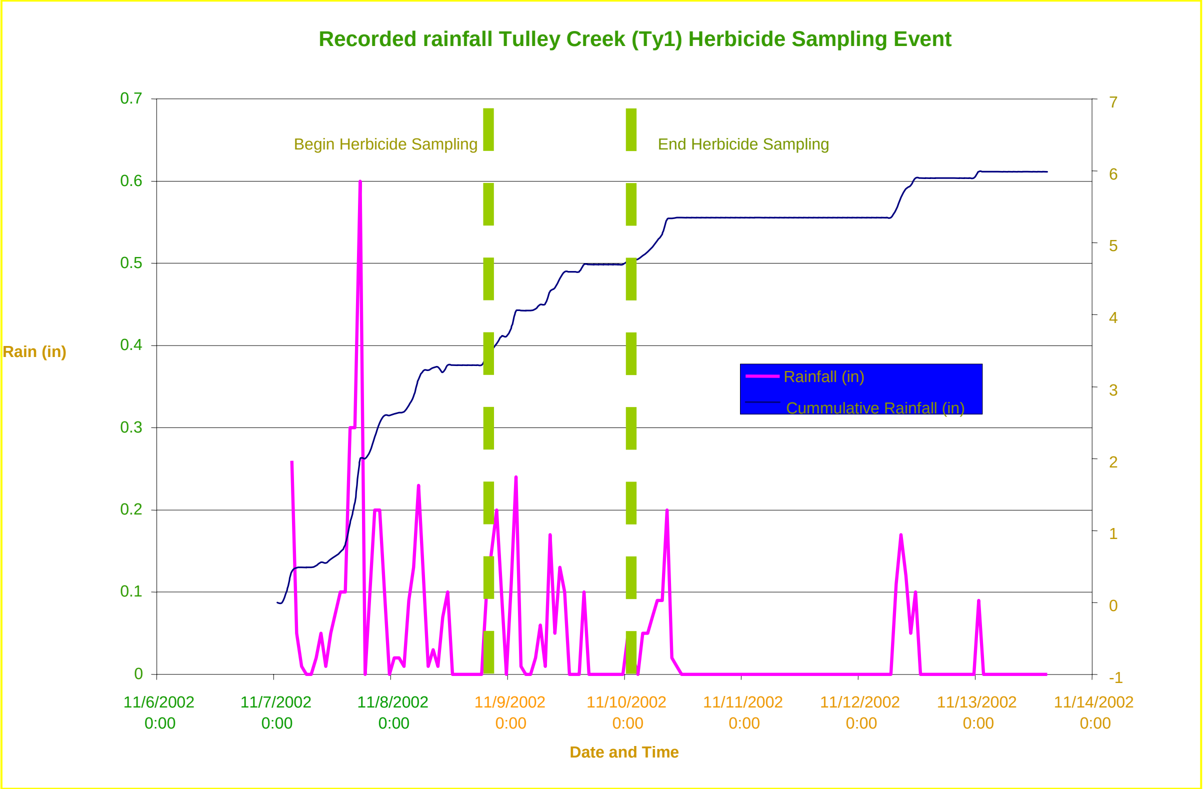


Figure 7-268 Tully Creek Monitoring Results - Rainfall

Notchko RAWS Rainfall Data

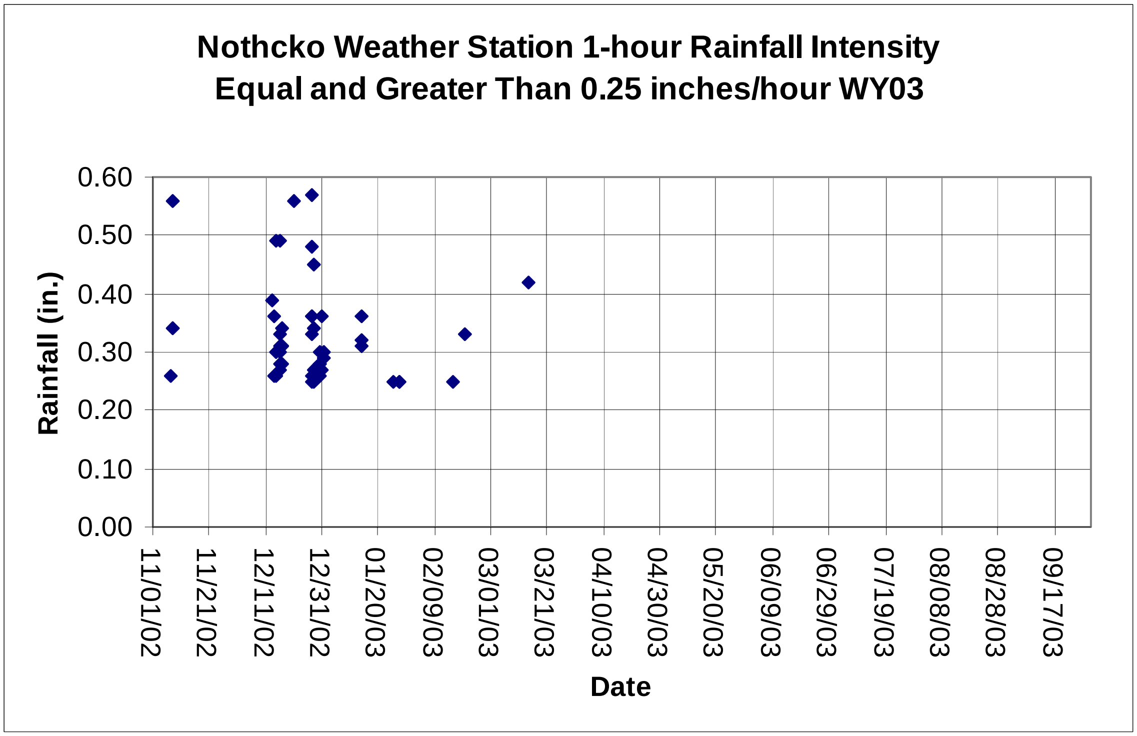


Figure 7-269 Notchko Weather Station One-Hour Rainfall Intensity Greater than 0.25 inches/hour

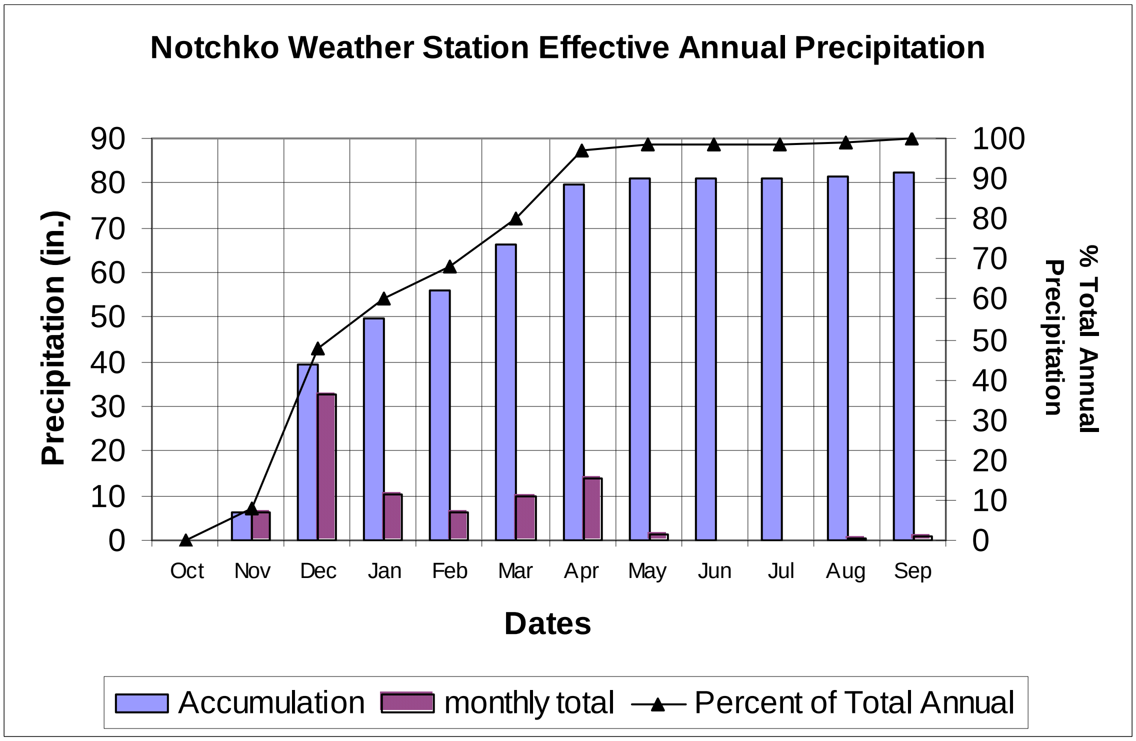


Figure 7-270 Notchko Weather Station Effective (represents 100% annual precipitation)

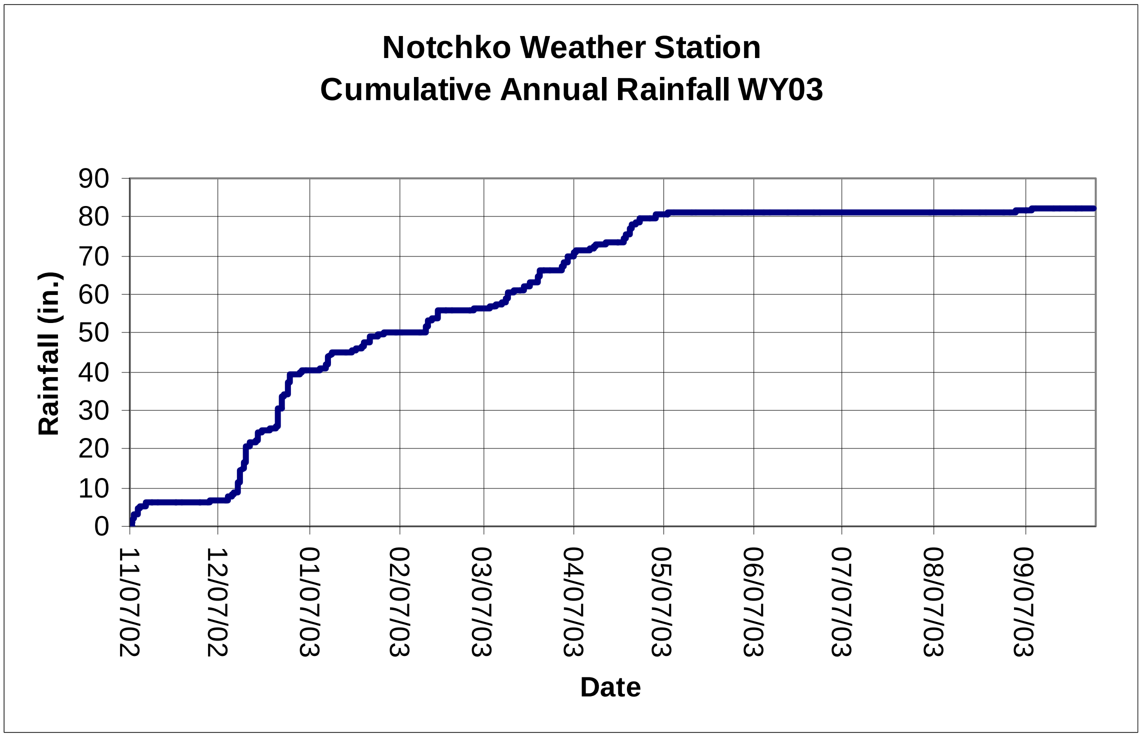


Figure 7-271 Notchko Weather Station Cumulative Annual Precipitation

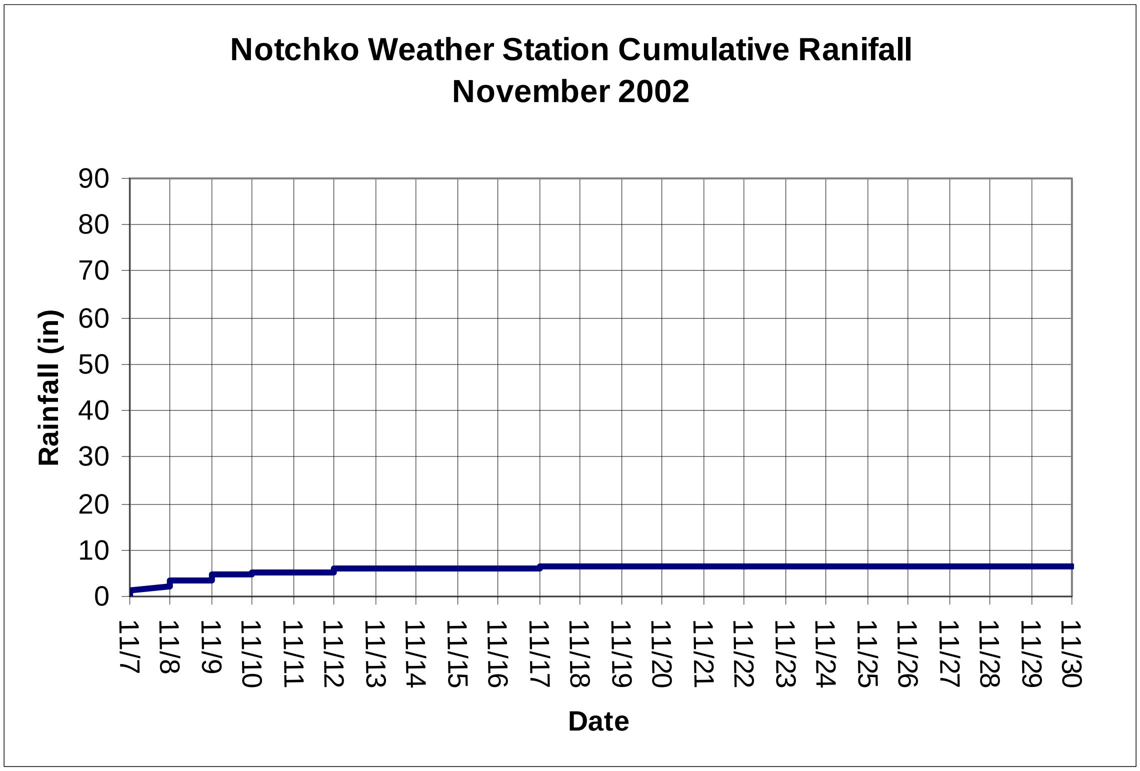


Figure 7-272 Notchko Weather Station Cumulative Rainfall November 2002

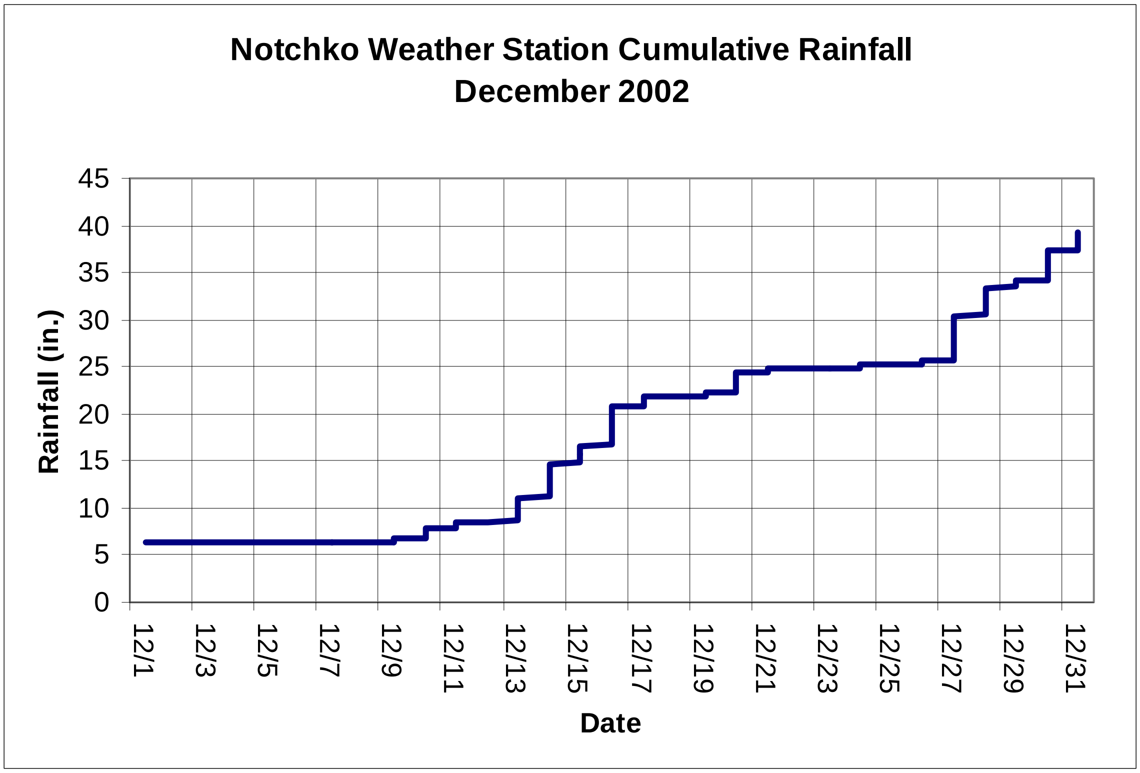


Figure 7-273 Notchko Weather Station Cumulative Rainfall December 2002

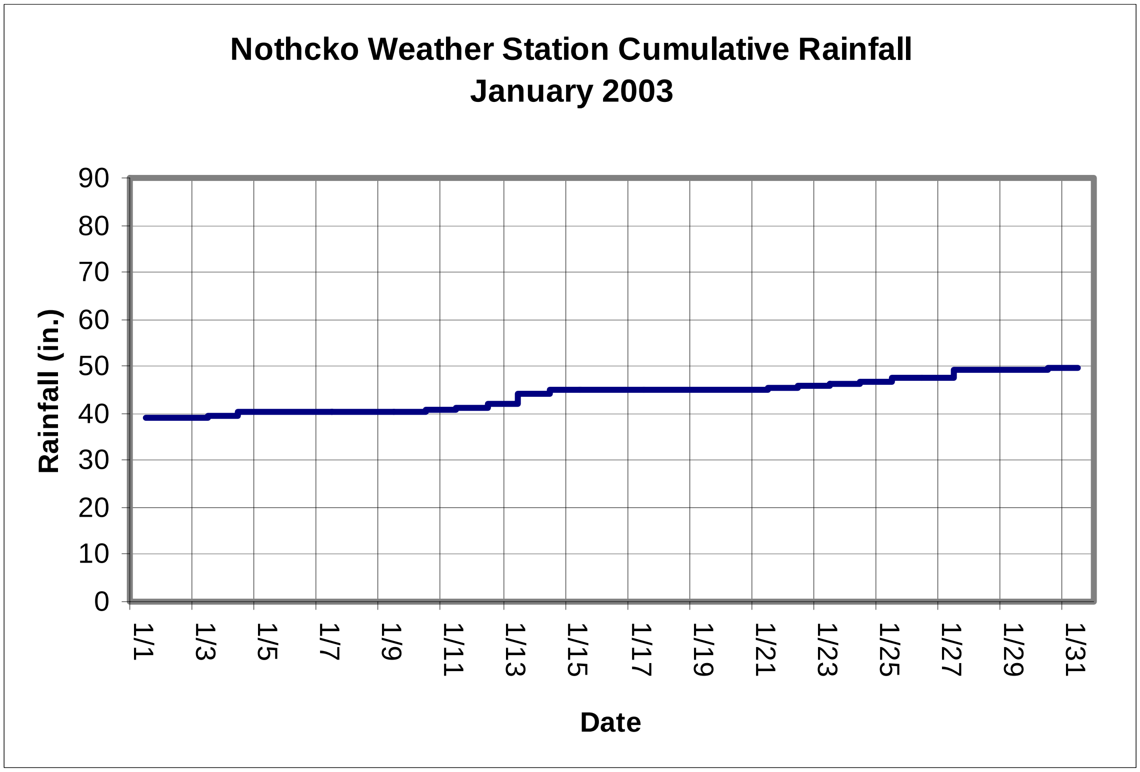


Figure 7-274 Notchko Weather Station Cumulative Rainfall January 2003

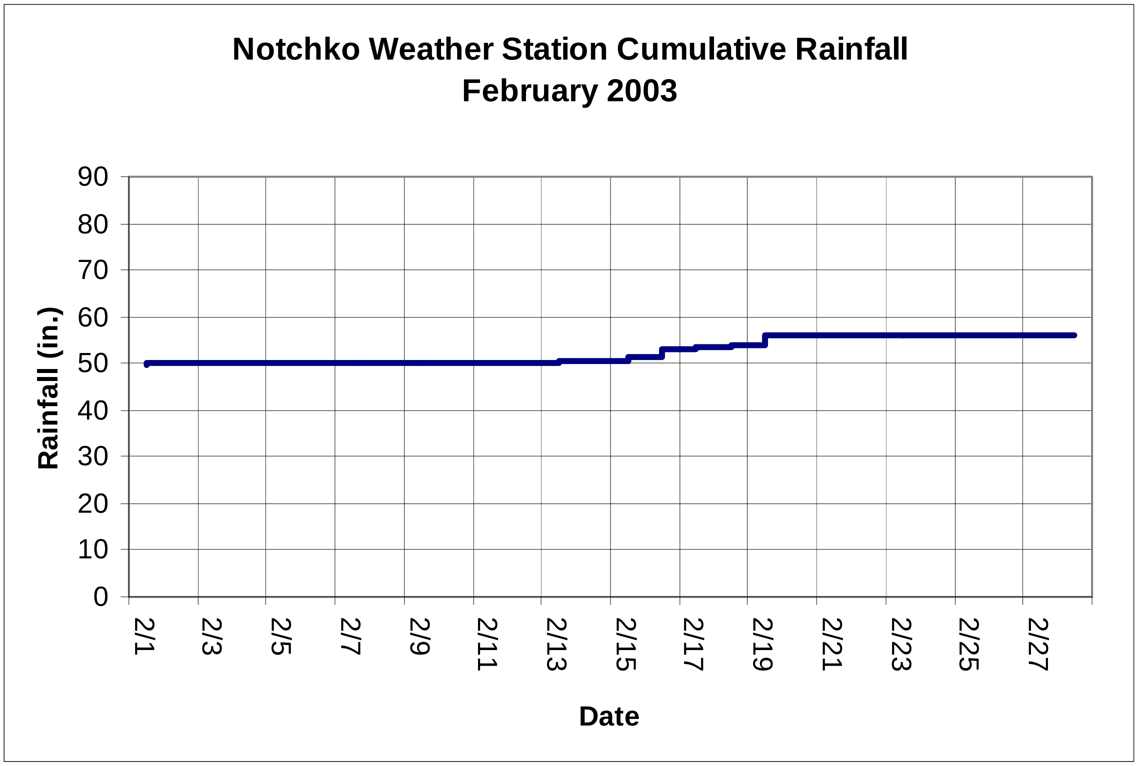


Figure 7-275 Notchko Weather Station Cumulative Rainfall February 2003

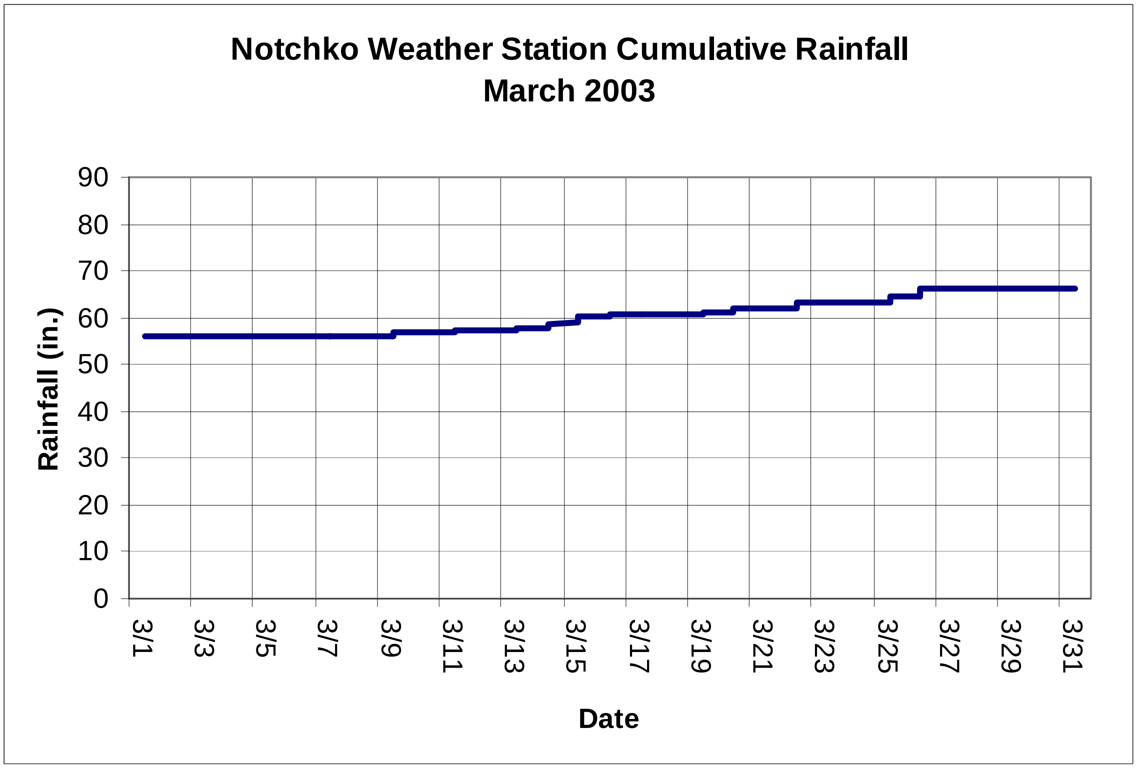


Figure 7-276 Notchko Weather Station Cumulative Rainfall March 2003

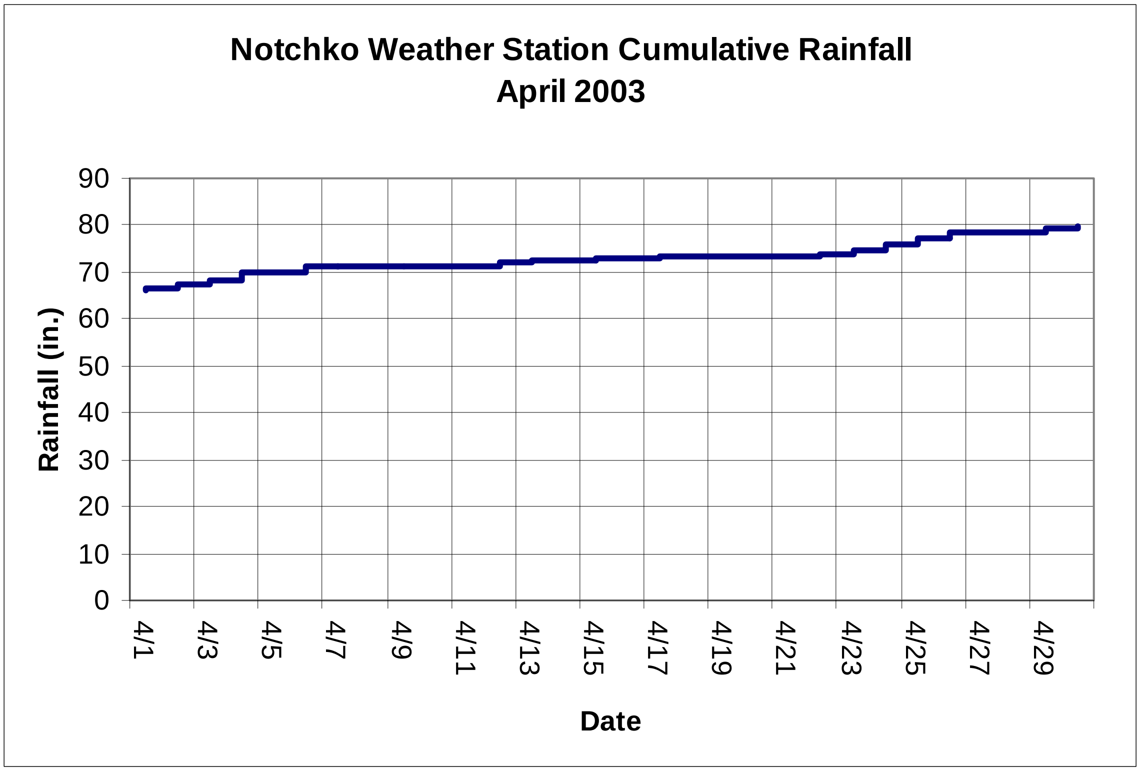


Figure 7-277 Notchko Weather Station Cumulative Rainfall April 2003

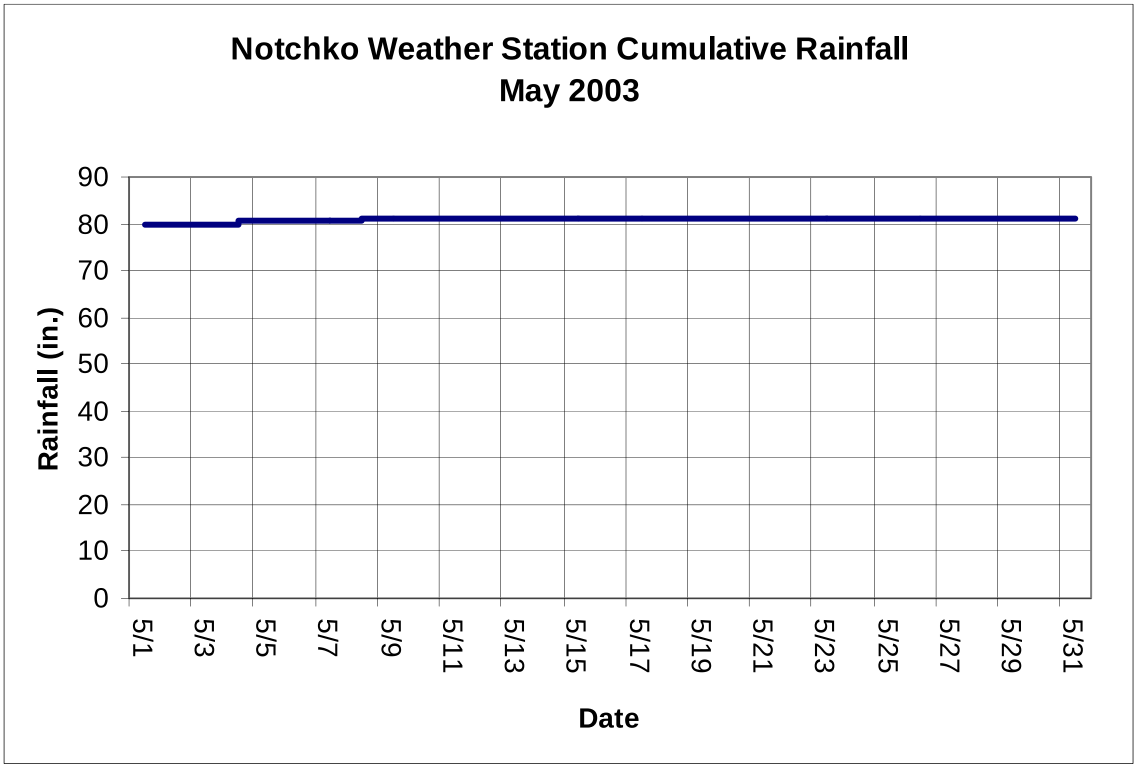


Figure 7-278 Notchko Weather Station Cumulative Rainfall May 2003

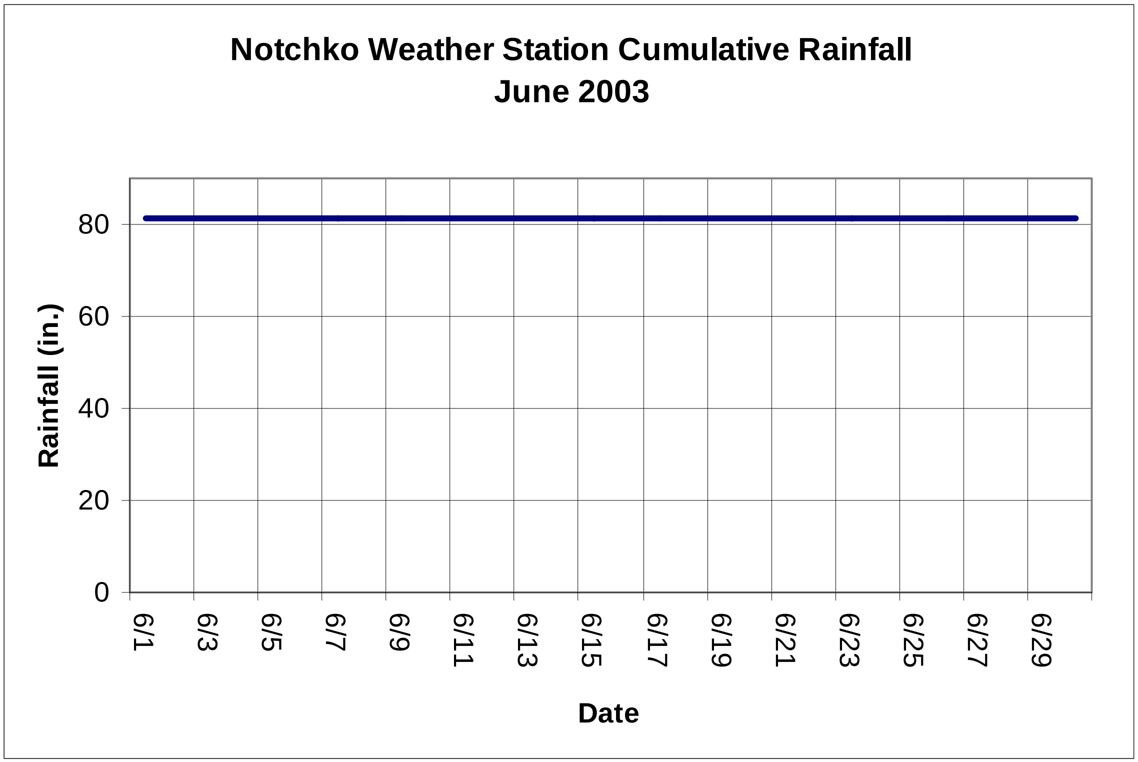


Figure 7-279 Notchko Weather Station Cumulative Rainfall June 2003

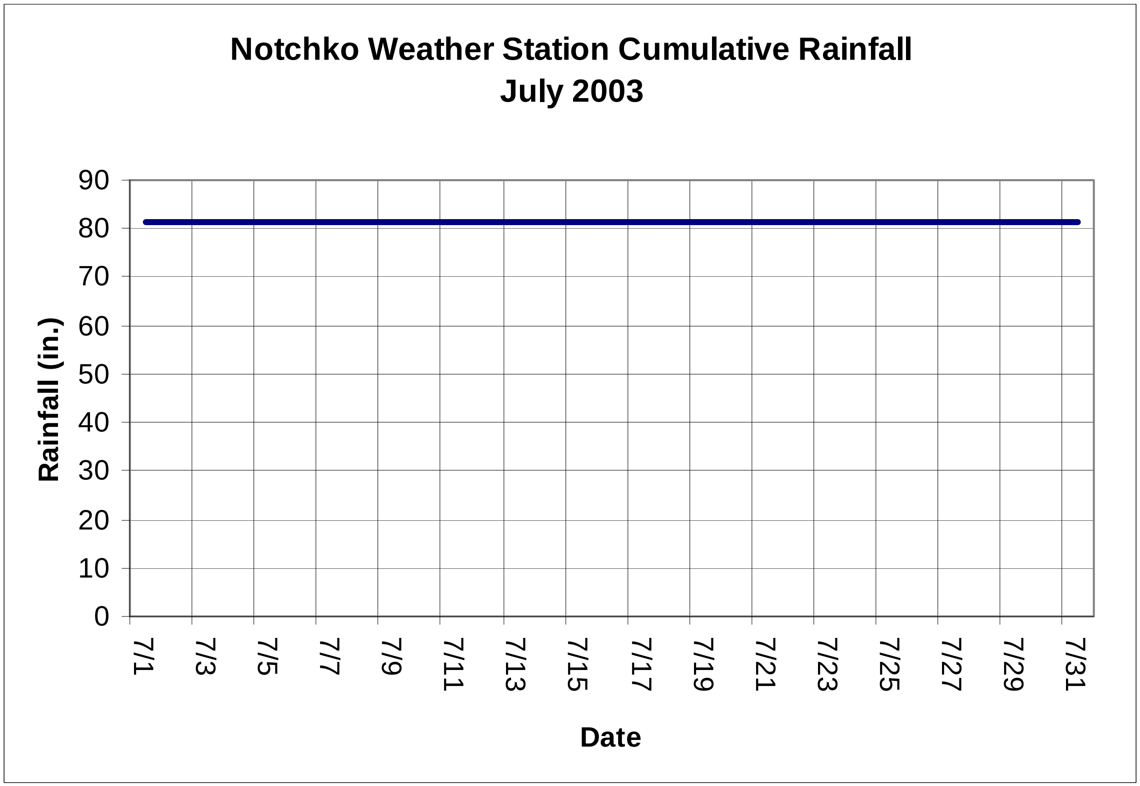


Figure 7-280 Notchko Weather Station Cumulative Rainfall July 2003

8 Cooperation with Outside Agencies

The Yurok Tribe regularly coordinates its water quality monitoring activities with outside agencies. YTEP specifically coordinates with agencies conducting water quality and hydrologic monitoring on the YIR and Lower Klamath tributaries. Every effort is made to coordinate various sampling protocols, site location, data distribution and staffing. Those interested in data collected by partner agencies should contact the cooperating agencies listed below:

North Coast Regional Water Quality Control Board
U.S. Geological Survey
California Department of Fish and Game
U.S. Fish and Wildlife Service
Dynamac Incorporated – collecting EPA Environmental Monitoring and Assessment Program (EMAP) data
Watercourse Engineering, Incorporated – collecting data for Pacificorp

9 Discussion

9.1 Water Quality (Mainstem)

9.1.1 Temperature

9.1.1.1 Water Temperature – All Sites

Daily maximums and minimums were disregarded when more than five measurements were missing from a 24-hour period and when the daily maximum or minimum was expected to occur during the gap. Gaps in data may occur during service or due to instrument malfunction or vandalism.

Water temperatures of the Lower Klamath and Trinity River varied greatly over the spring and summer of 2003 (see figure 7-155). The coolest water temperature recorded was 8.64° Celsius on April 29th at the TR site. Water temperatures steadily increased until the end of July. The warmest water temperature recorded was 26.6° Celsius on July 31st at the AH site. After August 1st water temperatures steadily dropped until August 13th when the trend rose for a week until August 20th. Afterwards the temperature trend generally decreased from August 20th until the end of the monitoring season in October.

The recorded water temperatures were compared to the Yurok Tribe's Draft water temperature standards in order to assess the water temperatures of the Klamath and Trinity Rivers. Metrics have been generated to illustrate the amount of time the temperature standard was exceeded. The minimum and maximum water temperatures have been graphed by site to show how recorded conditions compare to the Yurok Tribe's Draft maximum water temperature standard of 21° Celsius. The seven-day moving average of the daily maxima and the seven-day moving average of the daily average water temperature has been graphed and compared to the Yurok Tribe's Draft water temperature standard for a seven-day average of the daily maxima of 15.5° Celsius. Another graph has been included to illustrate the percent of the time the daily maximum water temperature and half-hour water temperature measurements exceeded the maximum water temperature standard of 21° Celsius. Percent exceedance graphs are only provided for sites that had an entire season of water temperature data.

At some sites additional graphs have been generated to illustrate how the water temperatures may have been affected by the ambient air temperature and volume of water present in the river at that time. Air temperature data used to generate these graphs are from air temperature/relative humidity sensors that were mounted at the TG and WE sites. Flow discharge data used to generate these graphs was downloaded from the USGS website. These graphs provide additional information when trying to determine the impact air temperature or flow had on the water temperature.

9.1.1.2 Klamath River at Aiken's Hole

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 12.58° Celsius on May 21st and the highest water temperature recorded was 26.6 °C on July 31st . The daily maximum water temperature of the Klamath River at the AH site exceeded 21° Celsius beginning on June 27th. Water temperatures dipped slightly below 21° Celsius from July 2-4 and rose above 21° Celsius on July 5th. Water temperatures remained above this standard for the rest of the time YTEP monitored water quality at AH (through August 12th).

The seven-day moving average of the daily maxima began to exceed 15.5° Celsius on June 3rd and continued to exceed this standard for the remaining time YTEP monitored water quality at AH. A gap in the graph after June 3rd occurred because there were less than seven consecutive days of data to generate the seven-day average. However, a review of the monthly graphs of water temperatures illustrate that minimum and maximum water temperatures continued to increase throughout the time water quality was monitored at AH. Therefore, it is reasonable to assume that the seven-day moving average of the daily maxima at AH exceeded 15.5° Celsius during the gap from June 3rd to June 21st.

9.1.1.3 Klamath River above Trinity River

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 9.65° Celsius on May 5th and the highest water temperature recorded was 26.36°C on July 30th. The daily maximum water temperature of the Klamath River at the

WE site exceeded 21° Celsius beginning on June 27th. Water temperatures dipped slightly below 21° Celsius on July 2nd and 3rd and rose above 21° Celsius on July 4th. Maximum water temperatures remained above this standard until September 12th with the exception of water temperatures slightly dipping below 21° Celsius from September 9th-11th. Daily maximum water temperatures of the Klamath River at the WE site exceeded 21° Celsius 45% of the time or 72 of 161 days during the monitoring season. This metric was created for days with at least 43 measurements per day. Maximum water temperatures exceeded 21° Celsius 39% of the time when looking at all half-hourly measurements (7,704) during the monitoring season.

The seven-day moving average of the daily maxima began to exceed 15.5° Celsius on June 20th and continued to exceed this standard for the remaining time YTEP monitored water quality at the WE site (through October 14th). A gap in the graph from May 27th to June 20th occurred because there were less than seven consecutive days of data to generate the seven-day average. However, a review of the monthly graphs of water temperatures illustrates that minimum and maximum water temperatures were above 15.5° Celsius on June 3rd and continued to increase until June 20th. This information and gathered from the AH site suggests that the seven-day moving average of the daily maxima exceeded 15.5° Celsius sometime before June 20th.

9.1.1.4 Trinity River above Klamath River

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 8.64° Celsius on April 29th and the highest water temperature recorded was 25.94°C on July 30th. The daily maximum water temperature at the TR site exceeded 21° Celsius on July 16th and continued to exceed this standard until August 27th. Daily maximum water temperatures at TR exceeded 21° Celsius 28% of the time during the monitoring season or 43 or 156 days during the monitoring season. This metric was created for days with at least 43 measurements per day. Water temperatures exceeded 21° Celsius 22% of the time when looking at all half-hourly measurements (7,465) during the monitoring season.

The seven-day moving average of the daily maxima began to exceed 15.5° Celsius on June 25th and continued to exceed this standard for the remaining time YTEP monitored water quality at the TR site (through October 14th). A gap in the graph from May 27th to June 25th occurred because there were less than seven consecutive days of data to generate the seven-day average.

The pulse flow from the Lewiston Dam that began on August 24th and ended September 16th appears to have reduced the maximum water temperatures of the Trinity River by approximately 3.5° Celsius over the course of two days. After the pulse flow reached the monitoring site on the Trinity River maximum water temperatures dropped below 20° Celsius within two days and remained below 20° Celsius for the remainder of the monitoring season (through October 14th). The water temperatures of the Trinity River were also influenced from slightly cooler ambient air temperatures that occurred prior to the pulse flow arriving at the TR site location.

9.1.1.5 Klamath River above Tully Creek/Martin's Ferry

As mentioned in Section 5.1.1, the monitoring site at Martin's Ferry Bridge was moved approximately one mile downstream to a new location above Tully Creek. YTEP considers the water quality conditions at these two sites to be comparable. Therefore, this discussion will include both sites.

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 8.9° Celsius on April 29th and the highest water temperature recorded was 25.7° Celsius on July 30th. The daily maximum water temperature of the Klamath River at the TC/MF site exceeded 21° Celsius on July 12th and continued to exceed this standard until September 5th. Daily maximum water temperatures at the TC/MF site exceeded 21° Celsius 39% of the time during the monitoring season or 57 days of 148 days during the monitoring season. This metric was created for days with at least 43 measurements per day. Water temperatures at the TC/MF exceeded 21° Celsius 36% of the time at the TC/MF site when looking at all half-hourly measurements (6,075) during the monitoring season.

The seven-day moving average of the daily maxima began to exceed 15.5° Celsius on June 20th and continued to exceed this standard for the remaining time YTEP monitored water quality at the TC/MF site (through October 14th). Gaps in the graph occurred because there were less than seven consecutive days of data to generate the seven-day average. According to the monthly water temperature graphs for the Klamath River at the MF site, it appears that the seven-day moving average of the daily maxima exceeded 15.5° Celsius before June 20th for this section of the river. Unfortunately, gaps in data prevented YTEP from generating this seven-day average prior to June 20th.

The pulse flow from the Lewiston Dam that began on August 24th and ended September 16th appears to have reduced the maximum water temperatures of the Klamath River at the TC site by 1.75° Celsius over the course of two days. However, the Trinity River's pulse flow impacted the water temperature of the Klamath River by more than 1.75° Celsius when comparing water temperatures above the confluence (WE) with water temperatures below the confluence (TC) (see figure 7-160). On August 28th when the pulse flow was most likely at its peak at the confluence (see flow schedule located in ***Appendix B***) the maximum water temperature of the Klamath River recorded at the WE site was 23.33° Celsius and the maximum water temperature of the Klamath River recorded below the confluence (TC) was 21.07° Celsius. This resulted in a temperature difference of 2.26° Celsius when comparing maximum water temperatures above and below the confluence. The water temperatures of the Klamath River were also influenced from slightly cooler ambient air temperatures that occurred prior to the pulse flow arriving at the TR site location.

9.1.1.6 Klamath River above Blue Creek – 6 Feet Deep

The water temperature record for this site is relatively short (September 15th to October 13th). For the period that water quality was monitored at this site the lowest water temperature was 14.79° Celsius on October 12th and the highest water temperature recorded was 19.5° Celsius on September 16th. Percent exceedance and the seven-day average charts were not generated because of the short interval involved.

9.1.1.7 Klamath River above Blue Creek – 25 Feet Deep

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 14.6° Celsius on October 12th and the highest water temperature recorded was 26.22° Celsius on July 29th. The daily maximum water temperature at BC exceeded 21° Celsius on July 8th and continued to exceed this standard until September 5th. Water temperatures remained below 21° Celsius for the rest of the monitoring season except for on September 15th when the maximum water temperature recorded was 21.08° Celsius. Daily maximum water temperatures at BC exceeded 21° Celsius 56% of the time during the monitoring season or 58 of 104 days during the monitoring season. This metric was created for days with at least 43 measurements per day. Water temperatures at BC exceeded 21° Celsius 41% of the time at BC when looking at all half-hourly measurements (5,098) during the monitoring season.

The seven-day moving average of the daily maxima exceeded 15.5° Celsius the entire time YTEP monitored water quality at BC (June 23rd to October 12th). Gaps in the graph occurred because there were less than seven consecutive days of data to generate the seven-day average. According to the monthly water temperature graphs for BC, the water temperatures remained above 15.5° Celsius. Therefore, the seven-day moving average of the daily maxima water temperatures most likely exceeded 15.5° Celsius during days that the data is missing.

9.1.1.8 Blue Hole

Water temperatures remained relatively constant during the sampling period, the lowest water temperature recorded was 13.03° Celsius on August 23rd and the highest water temperature recorded was 15.67° Celsius on September 27th. The seven-day moving average of the daily maxima water temperatures did not exceed 15.5° Celsius during the monitoring season. Water temperatures in Blue Hole do not appear to be influenced by the air temperature and/or the water temperature of the mainstem Klamath River. Water temperatures in Blue Hole have a shorter diurnal cycle compared to sites monitored in the Klamath River.

9.1.1.9 Klamath River at Turwar Gauge

As mentioned in section 5.1.1, the datasonde at the TG was relocated to the Blue Creek site on June 23rd. On July 1st YTEP deployed a temperature logger at TG to continue recording water temperatures throughout the monitoring season. The water temperature summary that follows combines the data stream generated from these two pieces of equipment.

Water temperatures varied greatly over the sampling period, the lowest water temperature recorded was 9.26° Celsius on April 30th and the highest water temperature recorded was 24.87° Celsius on July 28th. The daily maximum water temperature of the Klamath River at TG exceeded 21° Celsius on July 8th and continued to exceed this standard until September 5th. Water temperatures remained below 21° Celsius for the rest of the monitoring season (October 13th). Daily maximum water temperatures of the Klamath River at TG exceeded 21° Celsius 40% of the time during the monitoring season or for 60 of 151 days during the monitoring season. This metric was created for days with at least 43 measurements per day. A percent exceedance slope was not generated for all half-hourly measurements because the temperature logger deployed on July 1st recorded temperature every hour.

The seven-day moving average of the daily maxima began to exceed 15.5° Celsius on May 27th and continued to exceed this standard for the remaining time YTEP monitored water quality at TG (through October 13th). Gaps in the graph occurred because there were less than seven consecutive days of data to generate the seven-day average. A review of the monthly graphs of water temperatures illustrate that maximum water temperatures were above 16° Celsius from May 31st and continued to increase until June 14th. This information suggests that the seven-day moving average of the daily maxima exceeded 15.5° Celsius during the gap in the graph from May 28th until June 20th. Monthly graphs of water temperature also suggest that the seven-day moving average of the daily maxima water temperatures were above 15.5° Celsius from June 23rd to July 6th.

9.1.2 Dissolved Oxygen

9.1.2.1 Dissolved Oxygen – All Sites

Dissolved oxygen (DO) results are reported in milligrams per liter (mg/L). The datasonde also recorded DO in percent saturation and this information is available to those that request it from YTEP. It is important to note that DO is the most difficult parameter to monitor continuously. Electronic drift and biofouling contribute to lower DO readings. Therefore, the low DO levels that are reflected in the DO graphs may not be accurate. DO levels significantly rise when the DO membrane on the datasonde's DO probe was changed and calibrated. This trend can be observed throughout the entire data set and is problematic when analyzing the data. This information needs to be kept in mind when determining if the DO levels fell below the Yurok Tribe's Draft DO standard of 7.0 mg/L. The grade ratings summarized in section 4 may be of assistance when determining the level of confidence in the data.

In general the DO levels of the Lower Klamath and Trinity Rivers followed a trend similar to water temperature. DO levels decreased from the beginning of May to the end of July. DO levels generally increased near the beginning of August until the end of the monitoring season (October 13th-14th). Daily minimum values at occurred late at night and/or early in the morning. This trend is related to the period of time when aquatic vegetation is respiring and photosynthesis is not occurring. Daily minimum and maximum DO values have not been reported if there were less than 48 measurements per day. Gaps in the data may also result due to equipment malfunction or other problems associated with DO membrane integrity.

9.1.2.2 Klamath River at Aiken's Hole

DO levels varied over the sampling period, the lowest DO level recorded was 6.96 mg/L on July 29th and the highest DO level recorded was 10.12 mg/L on May 21st. The minimum DO level fell below the Yurok Tribe's Draft DO standard of 7 mg/L for one day. The Aiken's Hole site is adjacent to a riffle in a turbulent pool which experiences mechanical aeration, which may have had a site-specific effect on DO levels.

9.1.2.3 Klamath River above Trinity River

DO levels varied over the sampling period, the lowest DO level recorded was 6.45 mg/L on August 20th and the highest DO level recorded was 11.6 mg/L on May 5th. The minimum DO level fell below the Yurok Tribe's Draft DO standard of 7 mg/L for six days (July 22, August 4, 5 and 18-20). It is possible that biofouling and electronic drift contributed to the low DO levels recorded on these days. Low DO levels on July 22nd and August 4th and 5th occurred at the end of the datasonde deployment period. However, low DO levels on August 18th-20th began to occur on the third day of deployment.

9.1.2.4 Trinity River above Klamath River

DO levels varied over the sampling period, the lowest DO level recorded was 6.03 mg/L on September 15th and the highest DO level recorded was 11.97 mg/L on April 30th. The minimum DO level fell below the Yurok Tribe's Draft DO standard of 7 mg/L for six days (July 22, 29 Aug 12,19 and 20 and Sept 15). It is possible that biofouling and electronic drift contributed to the low DO levels recorded on these days. Low DO levels were recorded at the end of the datasonde deployment period. On September 15th at 7am the datasonde recorded a DO level of 6.03 mg/L. The readings before and after 7am were in the low 8 mg/L range. When the datasonde was retrieved on September 17th at 11am it was noted that the probes experienced a larger amount of biofouling than previous deployments. YTEP is uncertain if biofouling contributed to this low DO recording or if the datasonde accurately measured DO at 6.03 mg/L.

9.1.2.5 Klamath River above Tully Creek/Martin's Ferry

As mentioned in Section 5.1.1 the monitoring site at MF was moved approximately one mile downstream to a new location above Tully Creek. YTEP considers the water quality conditions comparable to each other. Therefore, this discussion will include both sites.

DO levels varied over the sampling period, the lowest DO level recorded was 5.84 mg/L on September 1st and the highest DO level recorded was 11.21 mg/L on April 29th. The minimum DO level fell below the Yurok Tribe's Draft DO standard of 7 mg/L for 17 days. The minimum daily values began to drop below 7.0 mg/L on July 19th and by September 3rd minimum DO levels remained above the DO standard of 7.0 mg/L.

9.1.2.6 Klamath River above Blue Creek – 6 Feet Deep

Water quality was monitored for a short period of time at KB2. In that short period of time the lowest DO level recorded was 7.95 mg/L on September 27th and the highest DO level recorded was 11.42 mg/L. The DO level did not fall below the Yurok Tribe's Draft DO standard of 7.0 mg/L.

9.1.2.7 Klamath River above Blue Creek – 25 Feet Deep

DO levels varied over the sampling period, the lowest DO level recorded was 6.26 mg/L on August 1st and the highest DO level recorded was 11.45 mg/L on October 3rd. The minimum DO level fell below the Yurok Tribe's Draft DO standard of 7 mg/L for 7 days. The minimum daily values dropped below 7.0 mg/L from July 29th until August 3rd and on August 21st. Figure 7-115 includes the daily values to illustrate the half-hour measurements within the minimum and maximum values for that day. This data was also included to illustrate what the conditions were when the data was removed because it was not collected over the entire day.

9.1.2.8 Blue Hole

DO levels in Blue Hole were relatively constant, the lowest DO level recorded was 5.06 mg/L on September 21st and the highest DO level recorded was 6.86 mg/L on September 27th. The minimum and maximum DO levels were below the Yurok Tribe's Draft DO standard of 7 mg/L for the entire time YTEP monitored water quality in Blue Hole (August 18-Octobert 13). DO percent saturation values were between 50 – 70%. The low DO levels in Blue Hole may occur because the subsurface flow is not as aerated as surface water. The low DO levels may also occur because of the cold dense water at the bottom of Blue Hole does not allow aquatic organisms to thrive and respire oxygen into the hypolimnion.

9.1.2.9 Klamath River at Turwar Gauge

There is a limited amount of DO data for the Klamath River at TG (April 29th to June 22nd). YTEP did not document the period of time when DO was at the lowest levels. The USGS operated a YSI datasonde at TG for a longer period of time. Data collected after June 22nd can be requested from the USGS Eureka satellite office. The lowest DO level recorded was 8.41 mg/L on June 22nd and the highest DO level recorded was 12.21 mg/L on April 29th.

9.1.3 pH

9.1.3.1 Klamath River at Aiken's Hole

The pH of the Klamath River at AH was variable over time. At Aiken's Hole and at all other sites pH values are greatest during the day and lowest late at night and early in the morning. The pH gradually increased throughout the time water quality was monitored in Aiken's Hole. A trend in pH was observed after the datasonde was deployed. It appears that the pH values slightly spiked after the datasonde was cleaned and calibrated for another week of data collection (see figure 7-12). pH values would then drop to values similar to those before the datasonde was deployed. All of the pH data collected at AH has been graded "A" data. YTEP has not been able to determine what may have caused this trend.

The minimum pH value recorded at AH was 7.64 on May 25th and 27th and the maximum pH value recorded was 8.67 on August 8th. Daily maximum pH values began to exceed the Yurok Tribe's Draft pH standard of 8.5 on August 7th and remained above this standard for the remainder of the time water quality was monitored at AH (through August 12, 2003).

9.1.3.2 Klamath River above Trinity River

The pH at WE was variable over time. pH values in general gradually increased throughout the monitoring season. Near the end of the monitoring season it appears that the pH values began to drop. The lowest pH value recorded at WE was 7.59 on May 31st and the highest pH value recorded was 8.8 on October 3rd.

9.1.3.3 Trinity River above Klamath River

The pH at TR appears to be less variable than the other Klamath River sites. The lowest pH value recorded was 7.68 on July 16th and the highest pH value recorded was 8.48 on August 21st. The pH did not exceed the Yurok Tribe's Draft pH standard of 8.5.

9.1.3.4 Klamath River above Tully Creek/Martin's Ferry

As mentioned in Section 5.1.1 the monitoring site at MF was moved approximately one mile downstream to a new location above Tully Creek. YTEP considers the water quality conditions comparable to each other. Therefore, this discussion will include both sites.

pH values were variable at both sites during the monitoring season. In general, pH values gradually increased throughout the monitoring season. The lowest pH value recorded was 7.33 on May 24th and the highest pH value recorded was 8.92 on October 3rd. Maximum pH values began to exceed the Yurok Tribe's Draft pH standard of 8.5 on August 8th. Maximum pH values exceeded 8.5 for 15 days between August 8th and August 26th. From August 27th to September 16th maximum pH values dropped below 8.5. After September 26th maximum pH values rose above 8.5 and were above this standard until the end of the monitoring season.

9.1.3.5 Klamath River above Blue Creek – 6 Feet Deep

Water quality was monitored for a short period of time at KB2. In that short period of time the lowest pH level recorded was 7.93 on September 23rd and the highest pH level recorded was 9.0 on October 4th. The maximum pH level was above the Yurok Tribe's Draft pH standard of 8.5 for the entire time water quality was monitored at this site.

9.1.3.6 Klamath River above Blue Creek – 25 Feet Deep

pH values were variable in the Klamath River at BC during the monitoring season. In general pH values gradually increased throughout the monitoring season. The lowest pH value recorded was 7.77 on September 4th and the highest pH value recorded was 8.96 on October 4th. Maximum pH values began to exceed the Yurok Tribe's Draft pH standard of 8.5 on August 17th. Maximum pH values exceeded 8.5 from August 17th to September

2nd. From September 3rd to September 22nd maximum pH values dropped below 8.5. After September 23rd maximum pH values rose above 8.5 and were above this standard until the end of the monitoring season except for October 11th when the maximum value was 8.45.

9.1.3.7 Blue Hole

pH values were lower and less variable in Blue Hole. pH values in general gradually decreased throughout the monitoring season. The lowest pH value recorded was 7.09 on September 14th and the highest pH value recorded was 7.76 on August 20th. Maximum pH values did not exceed the Yurok Tribe's Draft pH standard of 8.5.

9.1.3.8 Klamath River at Turwar Gauge

There is a limited amount of pH data for TG (April 29th to June 22nd). YTEP did not document the period of time when pH was at the highest levels. The USGS operated a YSI datasonde at TG for a longer period of time. Data collected after June 22nd can be requested from the USGS Eureka satellite office. The lowest pH level recorded was 7.28 on May 25th and the highest pH level recorded was 8.31 on June 9th and 10th. Maximum pH values did not exceed the Yurok Tribe's Draft pH standard of 8.5.

9.1.4 Specific Conductivity

9.1.4.1 Specific Conductivity – All Sites

Specific conductivity was monitored by YTEP but has not been reported due to problems with the calibration standards. At times throughout the monitoring season YTEP used different values of calibration standards for specific conductivity. When this occurred, recorded specific conductivity values abruptly shifted up or down. After consultation with USFWS, it was determined that there was probably a bad batch of calibration standards used by YTEP at some time. After communication with the manufacturer it could not be determined which batch of standards were faulty.

There were no large shifts in specific conductivity values during datasonde deployments. Large shifts only occurred at the beginning of datasonde deployments when calibration standards had been changed. In general specific conductivity values increased throughout the monitoring season. Even after large false shifts in specific conductivity, values did not exceed the Yurok Tribe's Draft specific conductivity standard of a 90% upper limit of 300 µmhos/cm @ 25° Celsius and a 50% upper limit of 200 µmhos/cm @ 25° Celsius. Copies of this data are available through YTEP.

9.1.5 Multi-Site Comparisons

9.1.5.1 Maximum Water Temperatures – All Sites

Water temperatures recorded at the Blue Hole site were much lower than those recorded in the Lower Klamath and Trinity River (see figure 7-154). The water that fills this bedrock-formed lateral scour pool is fed by subsurface flow from seeps adjacent to Blue Creek. Water temperatures were measured at the point where the seeps come to the surface just before entering Blue Hole on October 13th at approximately 3:15 pm when the datasonde was extracted for the season.

From 4/29/03 to 6/16/03 cooler water temperatures at up-river locations were cooler than down-river locations. After June 16th this trend reversed and warmer water temperatures occurred at up-river locations compared to down-river locations. This trend continued until August 8th with the exception of water temps at the BC site being slightly warmer than WE or AH sites on July 28th and 29th. After August 8th the BC site was slightly warmer water temperatures than the WE site until August 20th.

Shortly after flows from the Lewiston Dam were increased on August 24th all Klamath River monitoring sites below the Trinity River confluence recorded cooler water temperatures than were recorded above the confluence. During the time of the pulse flow (August 24-September 16) the Trinity River had the greatest cooling effect on the Klamath River. This trend continued until September 18th when water temperatures in the Klamath River recorded at the Blue Creek sites were slightly warmer than the WE and TC sites. After September 18th the Blue Creek sites recorded warmer water temperatures than the WE and TC sites until the end of the monitoring season on October 13th.

9.1.5.2 Klamath River Mainstem versus Known Klamath River Refugia: Klamath River Above Blue Creek as Compared with Blue Hole

Temperature

Figure 7-155 includes water temperature data collected in the Klamath River adjacent and slightly upstream to Blue Hole and in Blue Hole. The monitoring site above Blue Creek is the closest Klamath River site to Blue Hole and illustrates that the water temperature in Blue Hole is significantly cooler than the Klamath River. Water temperatures in Blue Hole do not have a high diurnal variation compared to the Klamath River. By mid-October Klamath River water temperatures had cooled down significantly. At the end of the monitoring season the daily maximum water temperature in Blue Hole was greater than the daily minimum water temperature in the Klamath River above Blue Creek.

Dissolved Oxygen

Figure 7-156 includes DO data collected in the Klamath River adjacent and slightly upstream to Blue Hole and in Blue Hole. DO levels in Blue Hole are significantly lower than in the Klamath River above Blue Creek. The diurnal fluctuation of DO in Blue Hole is much less than in the Klamath River.

9.1.5.3 Depth-Correlated Differential in Temperature: Klamath River above Blue Creek – 6 Feet Deep as Compared With Klamath River Above Blue Creek – 25 Feet Deep

Temperature

As mentioned in section 5.1.1 an additional datasonde was deployed at the Klamath River above Blue Creek site to document water quality conditions near the surface (six feet deep). This was done to compare the water quality conditions with the existing datasonde that was deployed at a depth of 25 feet.

The water temperatures in the Klamath River above Blue Creek at six feet deep and at 25 feet deep are comparable (see figure 7-157). Daily minimum water temperatures at deeper depths are 0.1 – 0.2° Celsius cooler than daily minimum water temperatures near the surface. Daily maximum water temperatures at deeper depths are also 0.1 – 0.2° Celsius cooler than daily maximum water temperatures near the surface. Moderate velocities causes the water column to be mixed at this location. This site is similar to other deep pools in the Lower Klamath River where the flow has scoured out holes adjacent to bedrock formed bends in the river.

Dissolved Oxygen

The DO levels recorded in six feet of water appear to be slightly different than DO levels recorded in 25 feet of water (see figure 7-158). During the weeks of 9/19-9/21 and 9/24-9/28 higher DO levels were recorded in six feet of water than in 25 feet of water. During the weeks of 10/1-10/5 and 10/8-10/12 the trend reversed and DO levels were higher in 25 feet of water than in six feet of water. During the last two weeks (10/1-10/5 and 10/8-10/12) of monitoring the difference in DO between the two different depths was less than the difference observed in the first two weeks (9/19-9/21 and 9/21-9/28). Although these two different depths experienced different DO levels the difference is not believed to be within a crucial threshold that is detrimental to salmonids. Both datasondes recorded DO levels above the Yurok Tribe's Draft DO standard of 7.0 mg/L.

9.1.5.4 Impacts of the Trinity River on Temperature in the Mainstem: Klamath River Above Trinity River as Compared With Klamath River Above Tully Creek/Martin's Ferry

Temperature

Water temperatures of the Klamath River below the Trinity River confluence change over time (see figure 7-159). From April 27th to June 10th water temperatures recorded above the confluence are comparable to water temperatures recorded below the confluence. Water temperatures are noticeably cooler below the Trinity River confluence after June 10th. This general trend can be observed until October 8th when water temperatures above the Trinity River confluence are comparable to water temperatures below the confluence. The Trinity River had its greatest cooling effect on the Klamath River during the pulse flow from Lewiston Dam during August 24-September 16.

Dissolved Oxygen

DO levels of the Klamath River above and below the confluence change over time (see figure 7-160). In general at the beginning and at the end of the monitoring season DO levels were comparable above and below the Trinity River confluence. During the warmest time of the year (end of July) the DO levels recorded below the confluence exhibited the greatest difference than above the confluence. From July 18th to August 12th daily maximum DO levels were higher below the confluence than above the confluence by approximately 0.50 mg/L.

9.1.5.5 Special Study – Blue Hole

It should be noted that the function of time influences the water quality between transects. When comparing water quality in different transects one must keep in mind that Transect 1 was completed at 11:50 a.m. and the last transect (Transect 12) was completed at 3:00 p.m.

The special study performed in Blue Hole on August 26th aided in characterizing the water quality in Blue Hole (see figures 7-161—7-216). The water quality in Blue Hole changes in time and space. In general water temperatures in Blue Hole decreased as depth increased. The water quality of the Klamath River influences the water quality at the downstream end of Blue Hole where a mixing of the two water bodies occurs. This is best illustrated by viewing graphs of Transect 1 and Transect 12. Water temperatures in Blue Hole increased as measurements were made closer in a downstream direction. DO in Blue Hole increased as the distance to the Klamath River decreased. With the exception of Transect 1 DO generally decreased as depth increased. In general pH was relatively stable within Blue Hole. Transect 5 Station E is the closest sample point to the datasonde that YTEP operated in Blue Hole. It appears that the datasonde's recordings are representative of Blue Hole in deep sections that are located near the bedrock.

9.1.5.6 Special Study – Known Deep Holes in the Klamath River

In four deep holes (pools) located below Blue Hole water quality is not significantly different when comparing surface water measurements with deep water measurements (see figures 7-217—7-219). At the four deep holes sampled water temperatures were slightly cooler or stayed the same as depth increased. At all sites pH levels were slightly lower as depth increased. Dissolved oxygen decreased as depth increased except for the deep hole located near the osprey nest where the surface water had less DO than the deep water measurement. This difference in DO may have occurred due to the turbulent nature of these deep holes. It has been observed that DO levels in the river are dynamic, DO levels at a specific time commonly fluctuate through a range of 0.1-0.2 mg/L and 1-5% saturation.

9.1.6 Grab Samples

9.1.6.1 Mainstem Grab Samples

Nutrient grab samples were performed within the YIR at monthly intervals. YTEP also assisted Watercourse Engineering Incorporated (Watercourse) in collecting nutrient grab samples as part of their synoptic surveys in June and August. Watercourse performed these synoptic surveys as part of the model calibration procedures for the FERC relicensing process for PacifiCorp's hydroelectric project. Watercourse crews collected grab samples once daily for four days along the Klamath River between Iron Gate Dam and Orleans while YTEP collected samples from the Trinity River confluence to Martin's Ferry (June) and Tully Creek (August). Watercourse shared this data with YTEP which are included in the tables of section 7.1.12.1. The grab samples were analyzed for ammonia, nitrate, nitrite, total Kjeldahl nitrogen and total phosphorus. On the last day of the survey, grab samples were also collected to be analyzed for ortho-phosphate, total suspended solids, volatile suspended solids, turbidity and chlorophyll- a. On each day of the survey additional samples were collected to perform field analysis for dissolved oxygen, orthophosphate and turbidity. All samples were delivered to the CH2MHill Applied Sciences Laboratory in Corvallis, OR with the exception of one bottle set, which was sent to Northcoast Labs due to an oversight. The results of the entire synoptic surveys for June and August are located in ***Appendix C***.

YTEP also performed a set of grab samples in September that included many more analytes that were not regularly sampled for during the monitoring season. This set of grab samples included pesticides, heavy metals and different forms of nitrogen. This grab sample event was performed to establish background conditions before any potential fish kill may have occurred.

Nutrient Grab Samples-All Sites

Nutrient levels in the Lower Klamath and Trinity Rivers were at low levels or at levels that are below the lab reporting limits (see tables in section 7.1.12.1). Nitrate and total Kjeldahl nitrogen (TKN) levels decreased over time. Ammonia (ionized and un-ionized) results were non-detect throughout the monitoring season. Phosphorous levels remained at low levels throughout the monitoring season. Chlorophyll-a and pheophytin levels were variable throughout the season. The September sampling event captured the supposed algae bloom in the Lower River that was reported in a front page article in the Times-Standard newspaper. Chlorophyll-a and pheophytin results suggest that there was a large amount of dead algae being flushed through the river system.

Pesticides-All Sites

All pesticides sampled for in the Klamath and Trinity Rivers were not detected above the labs reporting limits (see tables in section 7.1.12.2).

Minerals-All Sites

All the minerals and metals tested for were not detected above the labs reporting limits except for calcium, magnesium, fluoride, sodium and sulfate. The levels detected are below the Yurok Tribe's Draft standards for these constituents.

Bacteria-All sites

Bacteria levels detected are below Yurok Tribe's Draft bacteria standards.

Other Analytes-All Sites

There are no alarming results for the remaining analytes sampled in WY 2003. Turbidity results illustrate that the Trinity River was more turbid than the Klamath River early in the Spring when runoff from melting snow is still occurring. As the season progressed the Klamath River was slightly more turbid than the Trinity River.

9.2 Water Quality and Hydrology (Tributaries)

9.2.1 McGarvey Creek

9.2.1.1 Discharge

Discharge values were calculated using the rating curve produced by flow measurements taken in the field. Statistical data is compiled from the discharge estimations and displayed in tabular form (Table 7-3 and Table 7-4). McGarvey Creek experiences subsurface flows in the late summer, therefore no stage measurements or discharge estimations are calculated. The minimum estimated flow at McGarvey Creek was approximately 0.1 cfs (prior to subsurface) occurring on 10/07/02. The maximum estimated flow at McGarvey was 811 cfs on 12/27/02. The gap in the hydrograph (Figure 7-220) from 4/4/03 to 4/30/03 was a result of equipment failure.

The highest flow measurement taken at McGarvey Creek during the water year was 115 cfs (Figure 7-221); therefore, the flows calculated above the maximum flow were extrapolated from the rating curve. The estimates of these discharges above the maximum flow should be considered with caution because they are only as robust as the rating curve is. The quality of discharge values higher than the maximum flow measured are only as good as the accuracy of the rating curve. This stresses the importance of measuring peak discharge flows for all of the tributaries.

9.2.1.2 Turbidity

Turbidity data was recorded periodically throughout WY03 at McGarvey Creek. Typically, turbidity is apparent during the winter months when storms produce large amounts of runoff creating higher flow events and higher velocities. The turbidity data show that the highest recorded value was 1000 NTUs. Turbidity levels greater than 1000 NTUs could not be recorded by the datasonde as a real value. The turbidity values over 1000 NTUs exceeded the capabilities of the recorder and could not be displayed in this report.

9.2.1.3 Water Temperature

Water temperature data was recorded periodically throughout WY03 at McGarvey Creek as part of the turbidity and specific conductivity monitoring. Water temperature is not necessarily a parameter of concern in the winter, however the data can show the improvements in the watershed or lack there of over time when the data is paired with other parameters such as turbidity or sediment data.

The lowest water temperature recorded was approximately 7.5 °C on 11/26/02 at 10:15 AM. The highest water temperature for the period of record was 11.3 °C on 1/25/03 at 4:30 PM.

9.2.1.4 Specific Conductivity

Specific conductivity data was recorded periodically from mid-November ’02 through early February ’03. Monitoring specific conductivity helps provide information about the turbidity data being collected simultaneously. Specific conductivity can indicate false high turbidity readings. An increase in turbidity is usually followed with an increase in conductivity in a natural water body.

The low specific conductivity readings on and around 11/26/02 may be an indication of the conductivity probe not functioning correctly. Another explanation may be that the probe could have been exposed to the air because the conductivity of air is approximately zero. McGarvey Creek does experience little or no flow during this time of the year so this conclusion about the data is well supported. The extreme jump of the specific conductivity is an indication that the stream began flowing at this point in time after the first measurable period of precipitation.

9.2.1.5 Suspended Sediment

The suspended sediment samples collected represent only an instantaneous rate of sediment transport within the system. Samples at McGarvey Creek were collected using a wadable sediment sampler (DH-81). The highest SSC value was 307 mg/L at an estimated flow rate of 253 cfs. The second highest SSC value was 156 mg/L at nearly the same flow rate of 250 cfs. The large difference in concentration may be due to human error during sample collection. Some of the excess sediment may be contaminating the sample during the collection process. Another explanation may be that the concentration numbers are correct and that the sediment sample was collected during an accelerated increase in sediment transport. A closer look at the hydrograph does reveal that during the sampling period on 12/14/02, there was a fast rate of change in the flow rate which may be the reason for the large increase in sediment concentration.

9.2.1.6 Precipitation

The cumulative precipitation graph (Figure 7-225) does not reflect the total rainfall in the watershed due to data losses between November 23, 2002 and December 19, 2002. No data was recorded for October 2002 or July 2003 because there was no measurable precipitation recorded by the loggers.

Flow estimates (Figure 7-220) show that there was a large amount of runoff and rainfall during the period where rainfall data was not recorded. The data logger did measure near 64 inches of rainfall during the water year. The largest amount of rainfall accumulated in December (13.2 inches). The amount of rainfall including the lost data is almost consistent with the rainfall recorded at the Yurok Tribe Meteorological Station of 12.92 inches located near the Notchko Village Site.

9.2.2 Den Creek

9.2.2.1 Discharge

Den Creek discharge is compared to the staff plate readings recorded at McGarvey Creek. An R-squared value of .87 indicates a strong relationship between the staff plate readings at McGarvey Creek and the flows measured at Den Creek.

9.2.3 Blue Creek

9.2.3.1 Discharge

Blue Creek flows continuously throughout the year at the gaging station site. The estimated minimum daily flow was approximately 47.1 cfs on 11/7/02. The highest estimated flow for WY03 was 11,508 cfs on 12/27/02 (Figure 7-238). A typical water-year for Blue Creek may produce instantaneous flows near or over 11,000 cfs in the winter (USGS, 2004).

The highest discharge measured at Blue Creek was approximately 2,860 cfs. All other discharge values above this are extrapolated from the rating curve and rating curve equation(Figure 7-239). Approximately one day of data was not recorded at Blue Creek on July 19, 2003. There were no apparent reasons for the missing data, however, the gaging data continued to log correctly after this day.

9.2.3.2 Turbidity

Hourly turbidity data was recorded periodically during WY03 from mid-November through early February. Turbidity reached a maximum value near 26 NTUs on 1/27/03 and turbidity approaches zero or had reached zero many times in the fall before the first measurable precipitation.

The monitoring period during WY03 at Blue Creek does not represent a typical turbidity data set for a whole water year. Due to limited equipment, personnel, and other monitoring projects occurring during the same time, there was not an extensive use of the datasondes at Blue Creek in WY03.

9.2.3.3 Water Temperature

Blue Creek water temperature was measured periodically through the winter. Water temperatures ranged from 6.9 degrees Celsius to 11.5 degrees Celsius.

9.2.3.4 Specific Conductivity

Specific conductivity was measured during the same period as turbidity and water temperature had been. The values ranged from 58 uS/cm to 128 uS/cm. The values of the conductivity vary greatly from November to February. The high conductivity values early in the water year are a result of the large amount of rain in November.

9.2.3.5 Suspended Sediment

Suspended sediment samples were taken on April 28, 2003 at Blue Creek. The samples were collected using a crane and sediment sampler from a bridge. The bridge is approximately a half-mile downstream from the gaging station and datasonde deployment site.

9.2.3.6 Precipitation

Rainfall data was recorded in the Blue Creek watershed through water year 2003. Data was not recorded between March 22, 2003 and July 3, 2003 due to a power failure in the data logger. The largest recorded rainfall was near 26.5 inches for the month of December. There was no data recorded for October 2002.

9.2.4 Turwar Creek

9.2.4.1 Discharge

The highest estimated discharge at Turwar Creek was approximately 7,900 cfs on December 27, 2002. The minimum estimated discharge was near 0 cfs. Turwar Creek experiences very little flow at the gaging station site during the summer months and late into the fall. Turwar Creek does experience subsurface flows approximately ¼ mile downstream from the gaging station.

The highest measured discharge taken at Turwar Creek was near 400 cfs. All other discharge values above this value are only estimates extrapolated from the rating curve equation (Table 7-12,Table 7-13,Table 7-14).

9.2.4.2 Water Temperature

Water temperature at Turwar Creek is recorded with a DTS-12 turbidity probe that is connected to the gaging station. Some water temperature data was recorded by a datasonde that was deployed in March 2003 before the DTS probe was installed.
The turbidity probe was installed and activated on September 15, 2003 at 3:00 PM. The probe collects temperature and turbidity data every fifteen minutes simultaneously as the data logger collects its information. Temperature ranged from 13.9°C to 17.0°C for the period of record in WY03.

9.2.4.3 Specific Conductivity

Specific conductivity was measured only for a short period of time in March 2003 at the gaging station site using a datasonde. Values of conductivity ranged from 45 uS/cm to 57 uS/cm.

9.2.4.4 Turbidity

Turbidity measurements were recorded with the DTS-12 probe in conjunction with the temperature measurements. Turbidity readings were minimal due to the time of year they were recorded. The Lower Klamath Basin experiences very little measurable precipitation historically for the short period of record. Maximum turbidity readings reached 7 NTUs while the minimum turbidity readings were near zero.

9.2.4.5 Suspended Sediment

Suspended sediment samples were collected at Turwar Creek on 4/29/2003. The samples contained little suspended sediment due to the time they were taken. The samples were collected on the receding end of the hydrograph. Most suspended sediment movement in the Lower Klamath Basin occurs during the rising portion of the hydrograph or when the rainfall intensity is increasing. The trend in sediment movement can be seen when turbidity is graphed with a storm hydrograph.

9.2.5 Tully Creek

On November 6th, 2003, YTEP proceeded to monitor conditions in Tully Creek upstream and downstream from the Tully Creek Bridge. The slopes surrounding the bridge abutment had been re-graded to accommodate the project. The surrounding soil had also been disturbed by the use of heavy equipment during construction of the new abutments and headwalls. The proximity of the creek and loose soil sparked concern that the slopes may become unstable or that large amounts of soil may be delivered to the creek. YTEP monitored turbidity, specific conductivity, and temperature on a continuous fifteen minute basis for approximately one week to observe the effects of the project.

9.2.5.6 Turbidity

Turbidity measurements downstream from the bridge project do show a significant increase from the upstream turbidity measurements. Turbidity readings exceeded 1000 NTU in the downstream probe early in the morning of 11/12. The readings were much higher than the maximum turbidity readings recorded upstream (~200 NTU). The turbidity data shows that the project did have an effect on stream conditions in Tully Creek for the short period that water quality data was recorded.

9.2.5.7 Water Temperature

Water temperature readings upstream and downstream from the bridge were relatively similar (Figure 7-258) to one another. A small drop in temperature in the downstream data may be a result of the probe being exposed to air. Further investigation shows that during the same time specific conductivity readings did not drop. A drop in specific conductivity (values near zero) would reveal that the datasonde was exposed to the air, however, there was not a significant drop in specific conductivity which may indicate that the temperature probe may be faulty. The comparison between both temperature values (Figure 7-258) further supports the theory of a faulty temperature probe. A similar decrease in temperature was not recorded in the upstream probe.

9.2.5.8 Specific Conductivity

Specific conductivity readings were also similar except for a short period in the upstream conductivity data. A significant drop in specific conductivity upstream from the bridge was observed on November 8, 2003. The drop in conductivity may be a result of a plume of sediment passing by the probe. Further inspection of the turbidity graph shows that there was an increase of turbidity at the same time that the specific conductivity values had dropped. One would conclude that the downstream probe should have recorded a similar drop in specific conductivity. However, this is not the case, which would support the conclusion that the specific conductivity probe may have been faulty.

9.3 McGarvey Creek Grab Sampling

Samples taken from McGarvey Creek upstream and downstream of the Highway 101 culvert indicate that there were higher levels of iron and barium below the Highway 101 culvert that flows into McGarvey Creek.

9.4 Macroinvertabrate Sampling

Macroinvertabrate results are presented for WY03. These data are presented as baseline data at this point. YTEP is not attempting to make conclusions at this early stage in this program, but expects to have the ability to do so once five years of data have been collected. The program recognizes the need to run more multi-variate analyses on the wide array of biological and physical metrics that are associated with macroinvertabrate sampling. The results displayed are variable and the trends are not consistent among the three reaches per stream sampled. The trends are also variable when looking at different metrics. Once the CAF&G develop the North Coast Index of Biological Integrity (IBI) these metrics will be used to generate a single value to gauge their stream health.

It is important to note that two out of the three samples collected in McGarvey Creek yielded less than 300 total number of specimens. According to the CSBP a minimum of 300 total number of specimens is required to generate appropriate statistics for the stream. The reason why two out of the three sites did not yield 300 specimens is most likely due to the fact that YTEP collected macroinvertabrate samples in McGarvey Creek two days after a rain event. Benthic macroinvertabrates tend to travel in a lateral and subterranean direction during rain events (pers. Comm. Jon Lee 2003).

9.5 Herbicide Monitoring

Water samples were analyzed at YTEP's Water Quality Laboratory on 11/22/2002, using the Atrazine Rapid Assay kit in conformance with the YTEP: *Surface Water Monitoring Sampling and Analysis Plan For Forestry Herbicides With Immunochemical Analysis, August 2002.* The lowest method detection limit (MDL) for the Atrazine kit is 0.046 parts per billion (ppb). The limit of quantitation (LOQ) (0.1ppb) is an approximate concentration required to yield a positive result at the lowest standard, this is the lowest concentration of the compound that can be quantified in the Atrazine kit. The DPR labs reporting limit for atrazine, Method number 62.9, is 0.05ppb. DPR reports any amount above 0.05ppb as a detection and any number below as a non-detection. Results from the Atrazine assay kit and the Department of Pesticide Regulation can be found in Figure 7-266.

Figure 7-266 illustrates surface water sample results for atrazine assay kit analysis and gas chromatography (GC) laboratory analysis. Eleven of the nineteen samples were analyzed by both analytical procedures. The atrazine assay kit showed detections of atrazine in seven of the samples analyzed, whereas none of the samples analyzed by GC showed detections. Both of the equipment rinse blanks showed no detections for either analytical procedure.

YTEP staff did not inspect Atrazine applications in the Williams Ridge area. YTEP did not verify through tank sampling or pesticide use reporting that atrazine was actually used in the Williams Ridge area. Based on the information and results contained in this report, YTEP determines that during monitoring of Tully Creek surface water there was no presence of atrazine above 0.1ppb. Presence of atrazine in surface water below 0.1 ppb is unconfirmed. The maximum contaminant level (MCL) for atrazine in California drinking water is set at 3ppb (California Safe Drinking Water Act, 2000).

False positive detections for atrazine are likely due to sediment interference from unfiltered samples. Results for the assay kit are determined based on the color in the tubes through the photometer. Color is inversely proportional to the amount of atrazine actually in the sample; the more color in the tube the less atrazine in the sample. According to technical support from the kit manufacturer, particles in the water can block the ability of the labeled antibody from binding to the magnetic particles. YTEP staff did not filter surface water samples prior to analysis.

9.6 Notchko Weather Station

The Notchko RAWS was operational from October 16, 2002 to September 30, 2003. Notchko Weather data has been validated and reviewed according to the Yurok Tribe Air Program QAPP (January 2003). The Notchko RAWS was offline for repairs from 10/1/2002 to 10/15/2002, during which time no rainfall data is available. According to data from the USGS Turwar Gauge there was no precipitation during the offline period. Based on this information Notchko RAWS cumulative rainfall data is considered accurate.

The first rain event of the year occurred between 08:00 hours on November 7, 2002 to 16:00 hours on November 10,2002 with an accumulation of 5.34 inches. In WY03, a total of 82.37 inches of rainfall were recorded at the Notchko RAWS. The highest monthly total and hourly intensity both occurred in December 2002. The highest hourly rainfall intensity occurred between 17:00 to 18:00 hours on December 27, 2002 at a rate of 0.57 inches per hour. In all, there were 35 occurrences of rainfall intensity equal and over 0.25 inches per hour in the month of December 2002. Hourly rainfall intensities exceeding 0.25 inches per hour are illustrated in (Figure 7-269).

A total of 32.83 inches of accumulated rainfall were recorded in December, making up approximately 40% of the total annual rainfall.

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Appendix A – Protocols, Methods, and Processes Utilized by YTEP during WY03

Included herein:

1. Protocol for the operation of the datasonde – Arcata Fish and Wildlife's Multi-Probe Maintenance and Deployment Protocol
2. Updated protocol for the operation of the datasonde
3. Protocol for the collection of grab samples
4. Protocol for Macroinvertabrate Sampling – Rapid Bioassessment Protocol
5. Protocol for Flow Measurement
6. Protocol for Sediment Sampling

ARCATA FISH AND WILDLIFE SERVICE'S MULTI-PROBE MAINTENANCE AND DEPLOYMENT PROTOCOL

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PURPOSE STATEMENT

The challenge associated with water quality monitoring is to collect data that consistently represents the environmental conditions (Ministry 1999). To be able to best represent these conditions, it is important to develop a thorough protocol to obtain comparable data. To ensure the collection of good data, a quality assurance/quality control (QA/QC) program must be incorporated into the plans.

This document is the first of its kind for the USFWS in Arcata, California. It was largely put together to assure that persons involved with the Water Quality Monitoring Project are consistent in the protocols that they use. Specifically, this document covers protocols for the calibration and collection of continuous and spot data with multimeter probes (e.g. Hydrolab DataSondes and Quantas).

QUALITY ASSURANCE/QUALITY CONTROL

Two major components of QA/QC are accuracy and precision. Accuracy is how close the results are to a true or expected value. Instrument calibration is a necessary first step to assure accurate performance in the field. Precision, on the other hand, is the amount of agreement (or random error) among repeated independent measurements of the same parameter. The protocol identified herein, strives to obtain accurate and precise data.

DATASONDE AND QUANTA UTILIZATION

Step 1: Is your DataSonde/ Quanta ready to be used?

If you have not operated these instruments before, it is necessary that you spend a small amount of time reading the users guide, past reports, and practicing calibration of instrumentation. Demonstration of the instrumentation by veteran users is valuable and should be sought where available. As with any equipment, the more knowledgeable you are about the instrumentation, the better you will be able to collect good quality information. Attention to detail is required in order to obtain good quality and defensible results.

Upon receiving a DataSonde from the manufacturer or pulling one out of storage, there are many things to consider before the start of the field season. For example, how long since the pH reference solution was changed? If there is a low ionic strength reference probe, how old is it and should it be replaced? Is the gold cathode or the silver anode of the DO sensor discolored? These are but a few questions you must ask yourself before using the instrumentation. A thorough examination of the manufacturers recommended maintenance schedule will generally supply you with a list of things to consider. In some cases, previously collected data may provide some evidence as to where probes are starting to fail, allowing one to obtain a replacement probe early in the season. Making sure the instruments have met the maintenance schedules and are running correctly before the season starts serves as a first line of defense to help assure that data collection efforts are successful. Furthermore, doing so will limit instrumentation failures in the field and prevent excessive bias from being introduced into the data.

Step 2: Preparation of the Instrument for Deployment

Study Sites, Housing and Security
The monetary value of the instruments and the importance of the data collected require that water quality instruments be secure when in the field. Study locations are chosen at the discretion of the researchers and their objectives. In many cases, instrument placement includes considerations towards vandalism, ecological effects, access etc. An ideal site is one that is representative of the section of water being measured and has some object such as riparian trees, large boulders, bridge abutments or pilings that can provide a secure point of attachment for the equipment. The DataSonde is placed in a 4”-6” diameter perforated aluminum housing with a length of attached chain that is locked on site. Avoid sites that have lots of visitors and try and conceal the unit so it doesn’t attract unnecessary attention.

Sampling Intervals
Water quality units should be deployed for one week or less at a time. This strict protocol helps prevent loss of data if the unit prematurely malfunctions and reduce the amount of error due to biofouling and electronic drift. Units may be left in the field longer because of unforeseen circumstances but this is not recommended.

Parameter Set-up
The DataSonde multiprobe is used in conjunction with a computer program called Hyperterminal. This program allows the user to set the DataSonde unit to record the desired parameters, calibrate the instrument and download the files onto the computer. When installed on a laptop, these tasks can be performed at the field site and result in more flexibility in performing field operations while maintaining consistent quality data. For specific methods on using the Hyperterminal program, refer to the Hydrolab Maintenance and Calibration Workshop Training Manual (EDS, 2001).

When first hooking up the DataSonde to the Hyperterminal program, the first item to set is the DataSonde date and time. This step is crucial to maintaining consistent data throughout the season. Using a calibrated clock, enter the time ten to fifteen seconds in the future and press enter on the computer when that time is reached. This calibrates the DataSonde clock with your own calibrated clock.

All parameters to be measured should be set up through the computer to record in the following sequence and units for consistency. Each of these parameters must be entered separately and in the order they are to be displayed on the screen (from left to right). Parameters include: Date, Time, Temp (^{o}C), Specific Conductivity (µS/cm), pH, Dissolved Oxygen (mg/L), Dissolved Oxygen (% Saturation) and I Batt (internal battery level).

File Creation

The creation of a file describes where an instrument will be placed, the time frame in which it will be deployed and extracted and its recording interval. To define the file name, a two-letter abbreviation of the site is used followed by the underline symbol and then the deployment date. An example would be TR_070302 for a unit that was deployed in the Trinity River on July 3rd, 2002. This pattern is important to allow accurate tracking and management of files. The instrument should be scheduled to start at a time prior to your arrival and deployment; this makes sure the deployment does not take place before the unit turns on. (Not doing so will invalidate any field audit performed at deployment). The stop date should be set for at least a week past the date you expect to extract the unit. This gives the user time to reschedule an extraction in case of unforeseen circumstances. Stop time should be set for sometime after dark so that an extraction audit is not missed in the middle of the last day of the file. Interval time should be set at 003000 which produces a recording every 30 minutes. Sensor and circulator warm up is set for 000200 to give the instruments two minutes to warm up before taking the recording. At this point, the file setup is complete.

Step 3: Calibration Procedures

The calibration process is the second line of defense for obtaining good water quality data. Consistently following the procedures outlined below will help ensure the data is of good quality. In addition, inconsistent application of a rigid protocol weakens the confidence of the data that in turn may inhibit our ability to draw any conclusions from the study.

Water Temperature

Before and after the field season, it is pertinent to verify that the thermisters of each instrument are recording to within the manufacturer's specifications. Although it is commonplace for manufacturers to mention that calibration is not required, it is necessary to verify that the instruments are performing as specified. Verification builds the researchers confidence that the data that has been or will be collected is of good quality; this may be especially true as the instruments age. The verification process takes place in a water bath and should span a temperature range that is representative of the field setting. This should be done both at the beginning and end of the field season; In multiyear studies this can be accomplished with one experiment. A verification study conducted by Zedonis and Cunanan (2001) on year-old instruments found all mulitprobes were within ± 0.2°C when compared to a NIST thermometer. It is not necessary to calibrate for temperature on a weekly basis. A check between the DataSonde and auditing Quanta will reveal differences that need further attention. Additionally, other calibrated temperature probes (e.g. Optic Stowaways) can be placed at sites to collect continuous temperature data throughout the season.

Specific Conductivity

Calibration for conductivity is performed in the laboratory with standards that have been allowed to equilibrate to ambient temperature. Because different temperatures affect conductivity it is important that the standards be in equilibrium with the expected temperature of the water to be sampled.

Calibration should occur with a standard that brackets the range of conditions expected in the field. A two-point calibration of zero to 447µS/cm is appropriate for most northern California streams. In the Klamath River this range of standards is appropriate for most sites except the highly conductive Shasta River where a standard of 718µS/cm should be used.

<u>Procedure:</u>
Rinse the probes three times with DI water. Empty the calibration cup and dry the probe thoroughly. When the computer reads 0.0 for conductivity, enter that as the first calibration. Follow this by rinsing sparingly three times with the standard solution. When rinsing, be sure to swirl the solution adequately to remove or continually dilute any residual DI water remaining in the calibration cup. Discard standards after each use. Fill the calibration cup with enough standard to cover the probe and allow a few minutes for the readings to stabilize. After stabilization, use the labtop computer to enter the standard solution value as your final reading.

pH

Calibration for pH is also performed in the laboratory with buffers that have been allowed to reach room temperature. Again, use standards that bracket expected environmental conditions. For the Klamath River, pH standards of 7.0 and 10.0 are appropriate.

<u>Procedure:</u>
Rinse the calibration cup and associated probes three times with DI water. Rinse sparingly three times with pH 7.0 buffer. Again, be sure to swirl the solution adequately to remove or continually dilute any residual DI water in the calibration cup. Fill with pH 7.0 buffer and allow meter reading to stabilize for a few minutes. Record this as the initial value and then enter the buffer value of 7.0 into the laptop. This will be the final calibration value. Now pH 10.0 must be calibrated. Repeat the same process this time switching to pH 10.0 buffer.

Dissolved Oxygen

Dissolved oxygen instruments and sensors are sophisticated electronic equipment that requires frequent maintenance and delicate handling. Care should be taken so as to prevent the membrane from drying out, as well as protecting the instruments from sudden impacts, drastic temperature changes, and extremes of heat and cold.

Maintenance issues of the dissolved oxygen probe generally are associated with the membrane. This membrane is subject to biofouling and the electrolyte solution under the membrane slowly leaches into the environment. Exchanging the membrane and electrolyte solution regularly (i.e., every 6 or 7 days) should eliminate or limit any temporal bias due to any change in electrolyte concentration. Although dependent on the frequency of sampling and environmental conditions where the samples are being taken (e.g. eutrophic water), extended use of the instrument without consistently replacing the solution probably lessens the accuracy and precision of data. Calibration for dissolved oxygen percent saturation also effectively calibrates for dissolved oxygen in mg/L.

Procedure:
DO calibrations of the multiprobe instruments are performed at the laboratory or study site (preferred) with a 100-percent saturation method (EDS 2001). Following membrane replacement and overnight relaxation, fill the calibration cup with DI water until the water level is just below the DO membrane o-ring. All water must be removed from the DO membrane by gently dabbing the surface using a non-abrasive tissue such as a Kim-wipe. Use the corner of the Kim-wipe to absorb any water on the membrane that lies near the o-ring. To prevent airflow from interfering with the calibration, place the lid upside down over the calibration cup. Allow the readings to stabilize (about 5 minutes) and record the % saturation value as the initial reading. To calibrate, enter the site barometric pressure under BP: mmHg. Enter this final value on the datasheet.

Step 4: DataSonde Deployment

Upon arrival at each monitoring site, numerous tasks must be performed to successfully meet the QA/QC protocol and deploy the DataSonde (Table 1). Percent saturation must be calibrated with the above procedures for both the DataSonde and the auditing instrument (e.g. Quanta) using the average site barometric pressure (B.P.). after calibration, it is important to place both the DataSonde and Quanta in the water at least 5 minutes before the half hour to allow the instruments to stabilize. Care should be taken to avoid placement of the probe-end of the DataSonde or Quanta in areas with silt or algae. Likewise, wading upstream of a deployed DataSonde or Quanta should be avoided to prevent erroneous readings by dislodging sediments or algae.

Because the DataSondes and Quantas measure the same parameters, comparisons of their readings are used as part of the QA/QC analysis. In order to record similar environmental conditions, a watch synchronized to the computer and DataSonde is used to time the collection of audit information so that Quanta readings and Winkler samples are collected within five minutes of the time when the DataSonde will record river conditions. Upon review of the data, it was noticed that many audits were recorded outside of the five minute window. In order to retain the valuable information from these audits an exception was made to allow audits within twenty minutes of the DataSonde recording time. The Winkler test is used to represent an additional validation point for DO and will serve as the primary criteria for judgment of DataSonde data quality. It is imperative that all field personnel are certified in conducting titration tests for DO concentration (See instructions that follow). These procedures are performed at the time of both deployment and extraction.

Table 1. Schedule of events for a DataSonde deployment/ extraction event.

Duties	Arrival at the field site	On-site DO calibrations of Hydrolab and Quanta	Placement of newly calibrated DataSonde and Quanta	Record Quanta readings (collect DO Winkler sample)	Remove previous DataSonde and post-calibrate
Time	8:35	8:45	8:50	9:00	9:10

Though it is not necessary for quality control purposes, auditing the DataSondes performance between the time of deployment and extraction can help verify instrument readings. This is especially valuable at times of the day or season when water quality conditions are poor (e.g. low DO) and additional supporting information is needed to confirm conditions.

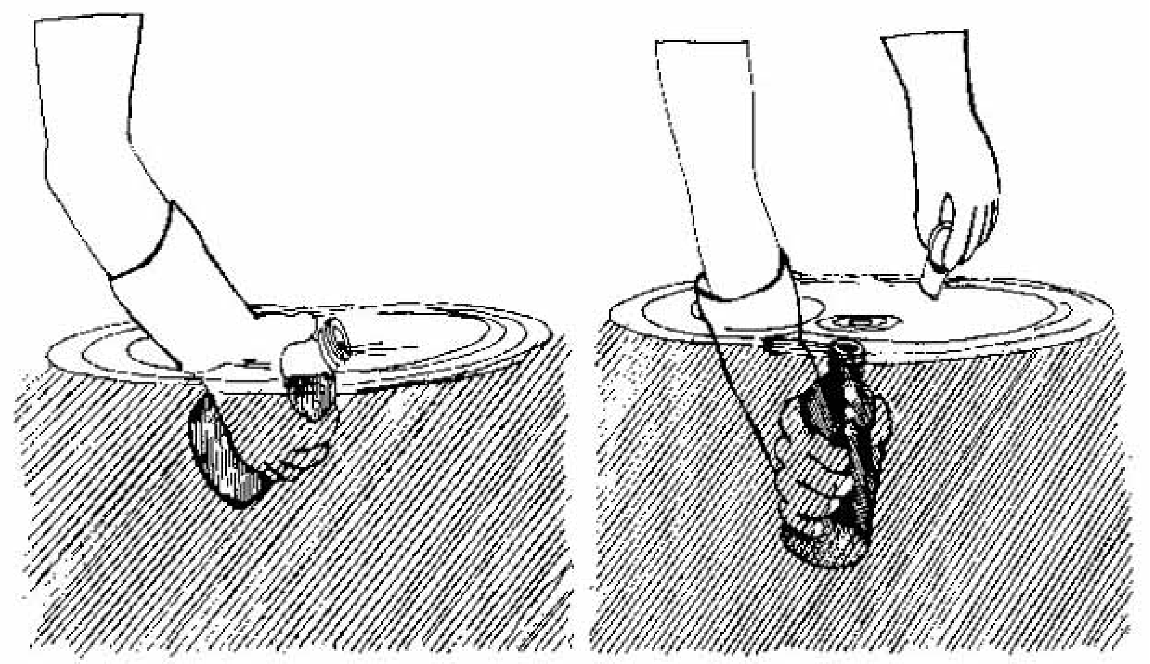
If additional DataSonde units are available, deploying a newly calibrated unit before extracting the previous one is recommended. Doing so allows for one set of audit information to validate the extraction of one datasonde and the deployment of another. Swapping the previous weeks' DataSonde with a newly calibrated DataSonde allows for collection of a continuous data string and reduces the number of visits necessary at each site. When not swapping, data is lost for the time needed for weekly membrane replacement and overnight relaxation between extraction and redeployment. Analysis using daily averages results in a loss of two days of data and may result in missing a poor water quality episode.

Winkler Titration Method

The Winkler titration method is a useful tool in obtaining spot checks or validation points. It is the most accurate chemical method for measuring the concentration of dissolved oxygen (Oregon 1999). The accuracy of this method depends on the experience and technique of the data collector. As stated earlier, each person performing this test is required to be certified through laboratory exercises. The Winkler Titration Method requires preventing exposure of the sample to atmospheric oxygen, which makes accurate and precise field determinations difficult (Wagner et al. 2000). The accuracy also depends on the quality of the kit used. For the quality of data collection used for water quality sampling it is important to use kits that produce similar results. The Hach Digital Titrator is an example of a test kit that AFWO uses to produce accurate and reproducible results.

The following procedure for collecting a sample for titration by the Winkler method should be applied (taken from the EPA's Volunteer Stream Monitoring: A methods manual):
Obtain a <u>clean</u> 300 mL glass BOD bottle (available with the Hach kit).
When selecting a site, the water must be deeper than the sample bottle. The water sample must be collected in a way that the bottle can be capped while it is submerged.
Wade into the stream and face either bank.

The sample is to be collected so that you are not standing upstream of the bottle. Slowly lower the bottle into the water, pointing it downstream, until the lower lip of the opening is just submerged. Allow the water to fill gradually, avoiding any turbulence. When water level in the bottle has stabilized, slowly turn the bottle upright to fill it completely. Keep the bottle submerged and allow it to overflow for 2 or 3 minutes to ensure no air bubbles are trapped.
Cap the bottle while it is submerged. Lift the bottle and inspect for any bubbles. If there are any bubbles repeat the process.



Immediately fix the sample.

To fix the sample (taken from Hach Digital Titrator Methods 8215 and 8332):
To the bottle add the contents of one Manganous Sulfate Pillow and one Alkaline Iodide-Azide Reagent Pillow.
Immediately insert the stopper so that no air is trapped in the bottle. Invert several times to mix.
Wait till the floc settles then again invert several times to mix.
Remove the stopper and add the contents of one Sulfamic Acid Pillow. Replace the cap without trapping any bubbles and invert again to mix.
Insert a clean delivery tube into a titration cartridge and place it into the digital titrator.
Turn the digital titrator knob to eliminate any bubbles present within the delivery tube.
Reset the digital titrator to zero and wipe the tip.
Measure out 100 mL using a graduated cylinder, and transfer the sample to the Erlenmeyer flask.
Place the delivery tube into the solution and swirl the flask while titrating with sodium thiosulfate till it reaches a pale yellow color.
Add two milliliters of Starch Indicator Solution and swirl to mix.
Continue the titration to a colorless end point. Record the number on the digital titrator.

Following the titration, rinse **ALL** equipment with deionized water, including the small delivery tube used to dispense the sodium thiosulfate. Cover glassware to prevent contamination. Clean laboratory equipment is essential.
Dispose of the Acid pillows properly.

Step 5: DataSonde Extraction

Extraction of DataSondes is similar to deployment in many ways. The procedure of the Quanta and Winkler tests to audit or verify environmental conditions are no different than during deployment. Calibrate the Quanta for dissolved oxygen and be sure to place the Quanta in the water for at least five minutes before recording to stabilize to ambient conditions. Record the Quanta information and collect a Winkler sample within five minutes (preferred) or twenty minutes (maximum) of the DataSonde extraction interval. Do not extract the DataSonde before it has recorded.

Step 6: Post Calibration

Post calibration of the instruments to a standard of known value is necessary to understand the amount of drift that occurred over the deployment period. This drift can be due to bio-fouling and/or electronic drift. Post calibration is an important part of the QA/QC process and provides a necessary evaluation of the instrumentation used in the previous deployment. Probes for specific conductance, pH and percent saturation are evaluated in the post calibration process within 24 hours of extraction. Temperature probes do not undergo a weekly post-calibration process. However, thermisters must be subjected to an annual performance test to verify accuracy.

Specific Conductivity
A temperature-equilibrated standard is used to post calibrate for specific conductivity. Rinse the cup probe three times with DI water and then three times with small amounts of the conductivity solution. Fill reservoir with standard and allow a few minutes for readings to stabilize. After stabilization, record the specific conductance reading. The difference of this value and the value of the known standard are then divided by the standard value and multiplied by 100 to determine the percent error or percent recovery of the instrument.

pH
At the end of the recording period, determine the probes precision for quality control purposes through a post calibration check of uncleaned probes (Radke 1998). Rinse the probe three times with DI water and then three times with small amounts of the pH buffer solution. Fill the cup with the pH solution, wait for the value to stabilize, then record the value. The recorded value is compared to the standard to obtain the post calibration difference.

Dissolved Oxygen
Post calibration of dissolved oxygen (mg/L) is not done directly but through the post calibration of percent saturation (see below). Winkler titrations performed in the field at

the time of extraction represent a good method of determining bias of data collected by the instrument.

Percent Saturation

A post calibration is performed immediately after the extraction of the datasonde. The post-calibration process should be conducted on site. Fill the calibration cup of the uncleaned probe with DI water, carefully remove any water from the membrane, cover and allow the unit to stabilize. Input the correct barometric pressure, wait for the unit to stabilize, and record the reading displayed.

DATABASE DEVELOPMENT AND USE

Quality assurance and control does not just pertain to the time of data collection, but also extends to the processing of the recorded data. To process the large amount of data that is generated from water quality monitoring, a database is recommended. AFWO created a database in MS ACCESS to critique, summarize, manage, and store information collected during each deployment. As part of this process, the database offers the capability to provide graphics on water quality trends at any site, problems with instrumentation, calibration procedures or protocols.

Data processing begins with receipt of calibration records and DataSonde data files for each DataSonde deployment from cooperators and Service staff who participate in the monitoring program. This information is expected to be available to the database manager during the week the data has been extracted. Other necessary information required in the database includes:

Evaluation and correction of DataSonde file names
Importation of *.csv file into the database
Verification of data file content
Entry of ALL calibration/post-calibration/audit information into the database

REPORTING AND DATA QUALITY

It is recommended that continuous water quality records be characterized by the accuracy of the data collected. AFWO uses several comparisons in an attempt to describe the accuracy of each dataset of every DataSonde deployment.

Data Quality Ratings

As part of the quality assurance program of the AFWO, each dataset is evaluated and given a quality rating. This is done so as to provide some level of confidence that the measured and recorded data are accurately reflecting field conditions; in this case referring to the water quality of the mainstem Klamath River as well as some of its major tributaries. Quality assurance methods used to provide confidence levels of each DataSonde dataset include: 1) comparisons to field verification audits taken with an independent, calibrated instrument; and 2) evaluations of post-extraction comparisons to standards. In combination, these evaluations provide a means of identifying potential error of the instrumentation and thus each dataset. Quality ratings of each dataset are currently based upon the criteria shown in Table 2. Required information to establish a grade is provided in Table 3.

The methodology that is used to establish the final grading of each dataset incorporates error estimates from each applicable component of the quality control program. Grading for each parameter of a dataset is based upon different criteria (Table 2). For example, water temperature receives a grade better than a "D", only if there had been field audits at the time of deployment and extraction and the largest difference between audits and the DataSonde is less than 0.8 ^{o}C. In the absence of one or both field audits the dataset is graded "D". The importance of quality water temperature data cannot be overemphasized as this parameter has a significant influence on other parameter measurements.

Grading of specific conductivity, pH, and percent saturation (dissolved oxygen) data requires more information (Table 2). Here, the requirements include: 1) field audits using a calibrated multiprobe within 5 minutes of the DataSonde reading at the time of deployment and extraction; and 2) a post-extraction comparison to a standard (post calibration). In the absence of any one of these requirements, the data are graded "D". Post-calibration of the DataSondes is completed within 24 hours of extraction and are intended to account for differences (drift) between the time of deployment and extraction. For specific conductance and pH, standard solutions are used to check overall drift, where as the air-calibration method is used to determine drift for percent saturation readings.

Grading of dissolved oxygen concentration data, as opposed to the percent saturation, is also different from the other parameters (Table 2). Here, two types of field audits are used (Winkler titrations and Quanta measurements) to estimate the potential error of DataSonde information. When available, Winkler titrations are preferred over the Quanta readings in terms of determining a quality rating. Here again, the largest difference between the Winkler and DataSonde reading is used to establish the grade. In the absence of one or both Winklers, however, the grading of the data is based upon the largest difference with the two hand-held Quanta audits. In the absence of both the Winkler and multiprobe audit at either the time of deployment or extraction, the dataset is given a grade "D".

Table 2. Rating continuous records (adopted from USGS 2000)

Measured Physical Property	QUALITY RATING			
	A (Excellent)	B (Good)	C (Fair)	D (Poor or No QA/QC)
Water Temperature	≤ ± 0.2°C	> ± 0.2 to 0.5°C	> ± 0.5 to 0.8°C	> ± 0.8°C
Specific Conductance	≤ ± 3%	> ± 3 to 10 %	> ± 10 to 15%	> ± 15%
Dissolved Oxygen	≤ ± 0.3 mg/L	> ± 0.3 to 0.5 mg/L	> ± 0.5 to 0.8 mg/L	> ± 0.8 mg/L
pH	≤ ± 0.2 unit	> ± 0.2 to 0.5 unit	> ± 0.5 to 0.8 unit	> ± 0.8 unit
Percent Saturation [a]	≤ ± 3%	> ± 3% to 5%	> ± 5% to 8%	> ± 8%
Air Temperature [a]	≤ ± 0.2°C	> ± 0.2 to 0.5°C	> ± 0.5 to 0.8°C	> ± 0.8°C
Relative Humidity [a]	≤ ± 3%	> ± 3% to 5%	> ± 5% to 8%	> ± 8%

a – rating established by AFWO

Table 3. Required information used to estimate the quality rating of each dataset collected by DataSondes.

Parameter	**Grading of DataSonde and Air Temperature/Relative Humidity Data**				
	Field Audit: Multiprobe Instrument at Deployment	Field Audit: Multiprobe Instrument at Extraction	Post-Extraction Comparison of DataSonde to a Standard	Field Audit: Winkler Titration upon Deployment	Field Audit: Winkler Titration upon Extraction
Water Temperature	R [a]	R	NR [b]	NA [c]	NA
Specific Conductance	R	R	R	NA	NA
pH	R	R	R	NA	NA
Dissolved Oxygen (mg/L)	R [d]	R [d]	NR	R [e]	R [e]
% Saturation (Dissolved Oxygen)	R	R	R	NA	NA
Air Temperature	NR	NR	R	NA	NA
Relative Humidity	NR	NR	R	NA	NA

a - Required, b – Not Required, c – Not Applicable, d – Secondary audit data used to grade DO data, e – Primary audit data used to grade DO data

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Updated Calibration Protocol

With the advent of field calibrations this year, some tasks will take longer than last year, while others will be quicker or eliminated all together. Overall, the time spent in the field will be greater, while the lab time will decrease. Upon arrival at a field site there are many tasks that take some time so an organized approach will allow these all to happen in the minimum amount of time.

There are two options for the acclimation of standards and DI water to ambient stream conditions. Collect water from the stream that is representative of ambient conditions. This water will be placed in a cooler to equalize pH and conductivity buffers as well as some DI water to stream temperature. This acclimation procedure can take 15-30 minutes. Be very careful to have all lids properly capped so that no mixing of buffers with the stream water takes place. Alternatively, place the standards and DI water in a durable mesh laundry bag and secure it in the stream. This will allow for a quicker and more precise acclimation to stream temperature.

Record current barometric pressure at the site along with other environmental conditions such as weather, changing water levels, etc. If the Quanta is not yet calibrated, do that now. If it is calibrated, adjust the DO % Sat for current barometric pressure. At the time of a DataSonde recording, collect a Winkler sample and use the calibrated Quanta to record audit information. After ensuring that the DataSonde has recorded, remove it from the stream, clean the probes and place it back in the stream, this time having it hooked up to the laptop so you don't have to wait for the next half hour interval. Record Quanta readings and DataSonde data from the laptop. Within five minutes of this also collect another Winkler sample. The two measurements before and after cleaning will act to show the drift relating to biofouling. Next, remove the unit from the stream and do a post-calibration check for dissolved oxygen. Also at this time a post-calibration check /calibration of specific conductance and pH will be done. This entails the normal two part calibration and will not only provide the electronic drift from the initial readings of a known standard, but will also function as a calibration for the next deployment. Once this is done the DO membrane can be replaced and other steps such as downloading the previous files, creating a new file, changing the batteries, etc. can be done. The DataSonde can then be redeployed so as to record temperature, specific conductance and pH. The next day, return to the site to calibrate for DO % saturation. This method will allow for continuous uninterrupted readings of temperature, sp cond., and pH if the unit can be returned to the field site before the next half hour reading after calibration. Dissolved oxygen will lose two days of average daily values with the overnight relaxation period.

This change in the protocol will require additional resources and certain steps will take more time. Hopefully the benefits of these steps will improve the accuracy of the data and therefore, its worth. Additional equipment necessary in the field starts with a laptop computer. This is necessary for the calibration and file management of the DataSondes. Standard solutions for pH and specific conductance will also be necessary, along with distilled water. These would be best transported in small ~1 L bottles that are well labeled with the contents and the known value at a given temperature. Having a cooler in the vehicle with water at the estimated stream temperature will allow for quicker acclimation and preserve the standard from high summer temperatures. In general the steps are as follows:

Arrive at site and place standards in cooler of river water to acclimate to ambient stream temp.
Compare Sonde recording to independent instrument (Quanta) and Winkler on the half-hour
Remove Sonde and clean probes. Return to water for additional recording, this time while it is hooked up to a laptop
Compare again to independent instrument (Quanta) and Winkler
Remove from stream and post calibrate for DO % sat
Post-calibrate/calibrate for specific conductance and pH using stream acclimated standards.
Perform file maintenance- download old file, back it up, create new file, delete older files but not the last one.
Change batteries if necessary
Replace DO membrane
Redeploy DataSonde and get audit information from Quanta for Temp, sp cond, and pH. (Not DO)
The next day, return and perform a DO calibration procedure and get Quanta readings and a Winkler sample after redeploying. Do not pull the DataSonde until after it records a reading that way you will have enough time to calibrate and get it back in the water before the next reading.

Calibrations

Dissolved Oxygen

Remove the storage cup of both the DataSonde and Quanta and allow the DO probes to air dry just enough to evaporate any water present on the membrane. Dab the edges with a kim wipe if necessary to remove any remaining water. Add a small amount of stream water to the storage cup, being careful not to let it come into contact with the membrane. Rest the lid on the top of the cup and place the unit in the shade. Allow the % saturation readings to stabilize (about 10-15 minutes) and record the % saturation value as the initial reading. To calibrate, enter the actual barometric pressure from a handheld barometer. Enter this final value on the datasheet.

Dissolved Oxygen (Wet Towel Method)

Remove the storage cup of both the DataSonde and Quanta and replace it with the field cup. Allow the DO probes to air dry just enough to evaporate any water present on the membrane. Wrap the sonde in a white towel that has been soaked in tap water, the towel should cover the entire sonde and go around the body at least twice. Allow the % saturation readings to stabilize (about 10-15 minutes) and record the % saturation value as the initial reading. To calibrate, enter the actual barometric pressure from a handheld barometer. Enter this final value on the datasheet.

Specific Conductance

At this point the conductivity and pH solutions should be acclimated to the stream temperature. Calibration should occur with a standard that brackets the range of conditions expected in the field. A two-point calibration of zero to 447µS/cm is appropriate for most northern California freshwater. In the Klamath River this range of standards is appropriate for most sites except the highly conductive Shasta River where a standard of 718µS/cm should be used.

Rinse the probes three times with DI water. Follow this by rinsing sparingly three times with the standard solution. When rinsing, be sure to swirl the solution adequately to remove or continually dilute any residual DI water remaining in the calibration cup. Discard standards after each use. Fill calibration cup with enough standard to cover probe and allow a few minutes for readings to stabilize. After stabilization, record the value as the post-calibration check. Enter the standard solution value (value @ 25 °C) into the laptop and record your final reading. . Rinse the probes again three times with DI water. Drain the calibration cup and dry the probe thoroughly. When the computer reads 0.0 for conductivity, enter that as the low value for calibration. Ideally, a third solution that is close to the expected value should be used as well to verify that it reads correctly.

pH

Calibration for pH is also performed in field with buffers that have been allowed to reach ambient stream temperature. Again, use standards that bracket expected environmental conditions. For the Klamath River, pH standards of 7.0 and 10.0 are appropriate.

Rinse the calibration cup and associated probes three times with DI water. Rinse sparingly three times with pH 7.0 buffer that has been equilibrated to ambient stream temperature. Again, be sure to swirl the solution adequately to remove or continually dilute any residual DI water in the calibration cup. Fill with pH 7.0 buffer and allow meter reading to stabilize. Record this as the initial value (which also is the post-calibration check) and then enter the buffer value of 7.0_ (based on temperature of the standard) into the laptop. This will be the final calibration value. Now pH 10.0 must be calibrated. Repeat the same process this time switching to pH 10.0 buffer. Be sure to rinse with DI water and buffer three times before calibrating.

Quanta

The Quanta should be calibrated in the field at the initial site for all parameters. The format similar to the DataSonde should be followed with the standards being adjusted to stream temperature. Conductivity for the Quanta is only a one point calibration. There is no need to attain a zero point for calibration. At ensuing sites for the deployment period, adjusting for barometric pressure is enough to correct for local conditions. To accomplish this, the calibration mode of the Quanta is used to input the current barometric pressure for the local site under the heading BP. This will adjust the % saturation readings to reflect the current site conditions.

Winkler Titration Method

The Winkler titration method is a useful tool in obtaining spot checks or validation points. It is the most accurate chemical method for measuring the concentration of dissolved oxygen (Oregon 1999). The accuracy of this method depends on the experience and technique of the data collector. As stated earlier, each person performing this test is required to be certified through laboratory exercises. The Winkler Titration Method requires preventing exposure of the sample to atmospheric oxygen, which makes accurate and precise field determinations difficult (Wagner et al. 2000). The accuracy also depends on the quality of the kit used. For the quality of data collection used for water quality sampling it is important to use kits that produce similar results. The Hach Digital Titrator is an example of a test kit that AFWO uses to produce accurate and reproducible results.

The following procedure for collecting a sample for titration by the Winkler method should be applied (taken from the EPA's Volunteer Stream Monitoring: A methods manual):

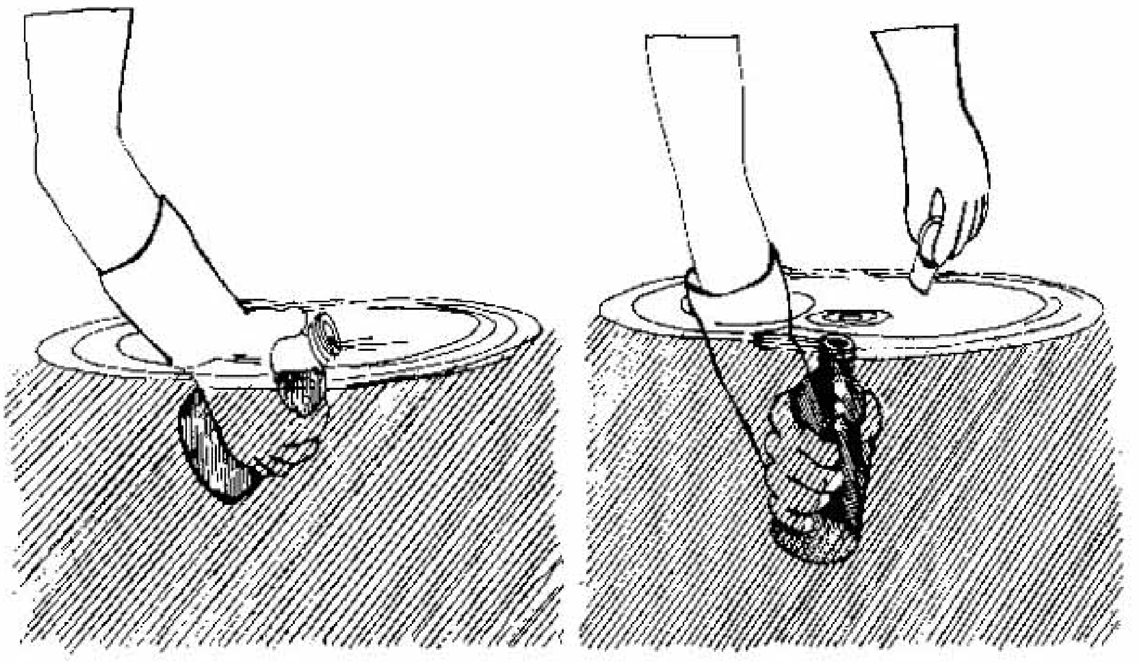
Obtain a clean 300 mL glass BOD bottle (available with the Hach kit).

When selecting a site, the water must be deeper than the sample bottle. The water sample must be collected in a way that the bottle can be capped while it is submerged.

Wade into the stream and face either bank.

The sample is to be collected so that you are not standing upstream of the bottle. Slowly lower the bottle into the water, pointing it downstream, until the lower lip of the opening is just submerged. Allow the water to fill gradually, avoiding any turbulence. When water level in the bottle has stabilized, slowly turn the bottle upright to fill it completely. Keep the bottle submerged and allow it to overflow for 2 or 3 minutes to ensure no air bubbles are trapped.

Cap the bottle while it is submerged. Lift the bottle and inspect for any bubbles. If there are any bubbles repeat the process.



Immediately fix the sample.

To fix the sample (taken from Hach Digital Titrator Methods 8215 and 8332):
To the bottle add the contents of one Manganous Sulfate Pillow and one Alkaline Iodide-Azide Reagent Pillow.
Immediately insert the stopper so that no air is trapped in the bottle. Invert several times to mix.
Wait till the floc settles then again invert several times to mix.
Remove the stopper and add the contents of one Sulfamic Acid Pillow. Replace the cap without trapping any bubbles and invert again to mix.
Insert a clean delivery tube into a titration cartridge and place it into the digital titrator.
Turn the digital titrator knob to eliminate any bubbles present within the delivery tube.
Reset the digital titrator to zero and wipe the tip.
Measure out 100 mL using a graduated cylinder, and transfer the sample to the Erlenmeyer flask.
Place the delivery tube into the solution and swirl the flask while titrating with sodium thiosulfate till it reaches a pale yellow color.
Add two milliliters of Starch Indicator Solution and swirl to mix.
Continue the titration to a colorless end point. Record the number on the digital titrator.
Following the titration, rinse **ALL** equipment with deionized water, including the small delivery tube used to dispense the sodium thiosulfate. Cover glassware to prevent contamination. Clean laboratory equipment is essential.
Dispose of the Acid pillows properly.

Grab Samples

'Grab sampling' refers to water samples obtained by dipping a collection container into the upper layer of a body of water and collecting a water sample (USGS File Report - 00213). Monthly grab samples are to be taken from June to October 2003 at select monitoring sites. For quality assurance/ quality control (QA/QC) purposes duplicate, blank, and spiked bottle sets were prepared and collected for one site each sampling period. These additional bottle sets were handled, prepared and filled following the same protocol used for regular bottle sets and samples. General water quality parameters were also measured with a Hydrolab Quanta during grab samples and recorded onto data sheets.

Upon arrival at each site, the sampling churn was rinsed three times with deionized (D.I.) water. The goal of rinsing is 'equipment decontamination – the removal from equipment, residues from construction and machining and the removal of substances adhering to equipment from previous exposure to environmental and other media' (USGS Open File Report 00213). After rinsing with D.I. water, the churn was rinsed three times with stream water. The churn is then fully submerged into the stream and filled to the lid with sample water. Completely filling the churn allowed for all samples to be filled from one churn; thereby minimizing differences in water properties and quality between samples.

Proper use of the churn guarantees the water is well mixed before the sample is collected. The churn should be stirred at a uniform rate by raising or lowering the splitter at approximately 9 inches per second (Bel-Art Products, 1993). This mixing must continue while the bottles are being filled. If filling is stopped for some reason, the stirring rate must be resumed before the next sample is drawn from the churn. As the volume of water in the churn decreases, the round trip frequency increases as the velocity of the churn splitter remains the same. Care must be taken to avoid breaking the surface of the water as the splitter rises toward the top of the water in the churn.

Sample bottles and chemical preservatives used were provided by associated laboratories and were considered sterile prior to field usage. Sample bottles without chemical preservatives were rinsed with stream water from the churn 2-3 times before filling with sample water. In the case of bottles that contained chemical preservatives, bottles were not rinsed before sample collection and care was taken to avoid over-spillage that would result in chemical preservative loss. Collected samples were placed in coolers on ice or dry ice for transport to contracted laboratories for analysis.

QA/QC – Duplicate, Spike and Blank bottle sets

To ensure laboratory and sampling accuracy, one site every sampling period was randomly selected to receive three additional QA/QC bottle sets. These bottle sets contain duplicate, spike, and blank water samples. Duplicate samples are obtained using the same process as regular samples. These are used to assure the laboratory maintains precision within results.

A limited bottle set containing 'spiked' samples is also collected. Known concentrations of the appropriate analyte are added directly to the bottle instead of sample water to provide a sample with known levels of the specified analyte. Data forms containing the known spike concentrations are kept to verify that the lab is attaining accurate results. Spike concentrations are determined based on past findings for each analyte. The spikes should be between 5 and 50 times the minimum detection limit or between 1 and 10 times the ambient level, whichever is greater (Eaton *et. al*., 1995).

Blank sample bottles are utilized to assess accuracy of the analysis and verify that the sampling method or equipment does not influence the results. After collection of all other samples at the QA/QC site, the churn is rinsed three times with D.I. water before being filled with D.I. water. The blank bottle sets are collected in the same way as other samples, except using D.I. water in place of stream water. Blank samples are collected after all stream water samples are taken and act as a final rinse to decontaminate the churn.

All bottle sets are then placed on ice and are transported to the associated laboratories. When necessary, dry ice was used for preserving samples. All grab samples were processed within 24 hours or within known laboratory holding periods.

Turbidity Samples

Turbidity samples are drawn directly from the flowing stream. The turbidity bottle should be rinsed with stream water three times before taking sample. Once the bottle has been rinsed, it is submerged and allowed to fill to the top, excluding air bubbles. Care should be taken to avoid the collection of surface water in the bottle. Once the bottle is filled, it is capped and placed into a cooler with ice and the other water samples.

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CALIFORNIA STREAM BIOASSESSMENT PROCEDURE

(Protocol Brief for Biological and Physical/Habitat Assessment in Wadeable Streams)

The California Stream Bioassessment Procedure (CSBP) is a standardized protocol for assessing biological and physical/habitat conditions of wadeable streams in California. The CSBP is a regional adaptation of the national Rapid Bioassessment Protocols outlined by the U.S. Environmental Protection Agency in "Rapid Bioassessment Protocols for use in Streams and Rivers" (EPA 841-D-97-002). The CSBP is a cost-effective tool which utilizes measures of the stream=s benthic macroinvertebrate (BMI) community and its physical/habitat characteristics to determine the stream=s biological and physical integrity. BMIs can have a diverse community structure with individual species residing within the stream for a period of months to several years. They are also sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution. Biological and physical assessment measures integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality and can provide the public with a familiar expression of ecological health.

The purpose of this Protocol Brief is to introduce the techniques of bioassessment to aquatic resource professionals and, hopefully, to encourage them to incorporate measures of biological and physical/habitat into their water quality programs. The use of this procedure will ensure that the data they generate can be used by state regulatory agencies and will be compatible with a statewide bioassessment effort. The Protocol Brief is only a summary and does not contain all the information that may be required to implement a bioassessment program. Additional information and updates on bioassessment can be obtained by visiting the **California Aquatic Bioassessment Web Site at www.dfg.ca.gov/cabw/cabwhome.html**.

CALIFORNIA DEPARTMENT OF FISH AND GAME SCIENTIFIC COLLECTING PERMIT

Anyone who collects fish, amphibians, or invertebrates from the waters of the state must have in their possession a DFG Scientific Collecting Permit. The permit can be obtained from the DFG License and Revenue Branch in Sacramento (916 227-2225). Those people conducting bioassessment in California should specify on the permit application, that they will take freshwater invertebrates (authorization 5) and incidental fish (authorization 6) and amphibians (authorization 8). It is also advisable to contact the local Game Warden and District Fisheries Biologist at the closest Regional Office prior to collecting. Starting in summer 1999, everyone indicating that they will be conducting bioassessment in California will receive the most recent version of the CSBP Protocol Brief and an Access[7] database program to store, process and return a copy of the collected data.

FIELD PROCEDURES FOR COLLECTING BMI SAMPLES AND ASSESSING PHYSICAL/ HABITAT QUALITY

The CSBP can be used to detect aquatic impacts from point and non-point sources of pollution and for assessing ambient biological condition. The sampling unit is an individual riffle or riffles within a reach of stream depending on the type of sampling design used. Riffles are used for collecting biological samples because they are the richest habitat for BMIs in wadeable streams. **The BMI sampling procedures described in this Protocol Brief are intended for sampling wadeable, running water streams with available riffle habitats.** There are approved modifications of this procedure for narrow (< 1m) streams, wadeable streams with sand or mud bottoms and channelized streams. There are also procedures for lentic or still water environments. Contact DFG or visit the California Aquatic Bioassessment Web Site for more information.

Point Source Sampling Design

FIELD EQUIPMENT AND SUPPLIES

- Measuring tape
- D-shaped kick net (0.5mm mesh)
- Standard Size 35 sieve (0.5mm mesh)
- Wide-mouth 500 ml plastic jars
- White sorting pan and forceps
- 95% ethanol
- California Bioassessment Worksheet (CBW)
- Physical/ Habitat Quality form
- Chain of Custody form
- Random number table
- pH, temperature, DO and conductivity meter
- Stadia rod and hand level/ clinometer
- Densiometer/ Solar Pathfinder
- GPS unit or watershed topographic map

There will be discernable perturbations, impacting structures or discharges into the stream with point sources of pollution. The sampling units will be individual riffles within the affected section of stream and an upstream unaffected section. At least one riffle in the unaffected section should be sampled and one or more riffles in the affected section depending on the amount of detail that is required on downstream recovery. The riffles used for sampling BMIs should have relatively similar gradient, substrate and physical/habitat characteristics and quality. **One sample will be collected from 3 randomly chosen transects in each riffle**.

Use the following step-by-step procedures for collecting BMIs using the point source sampling design:

Step 1. Place the measuring tape along the bank of the entire riffle while being careful not to walk in the stream. Each meter or 3 foot mark represents a possible transect location. Select 3 transects from all possible meter marks along the measuring tape using a random number table. Walk to the lowest transect before proceeding to Step 2.

Step 2. Inspect the transect before collecting BMIs by imagining a line going from one bank to the other, perpendicular to the flow. Choose 3 locations along that line where you will place your net to collect BMIs. If the substrate is fairly similar and there is no structure along the transect, the 3 locations will be on the side margins and the center of the stream. If there is substrate and structure complexity along the transect, then as much as possible, select the 3 collections to reflect it.

Step 3. After mentally locating the 3 areas, collect BMIs by placing the D-shaped kick-net on the substrate and disturbing a 1x2 foot portion of substrate upstream of the kick-net to approximately 4-6 inches in depth. Pick-up and scrub large rocks by hand under water in front of the net. Maintain a consistent sampling effort (approximately 1-3 minutes) at each site. Combine the 3 collections within the kick-net to make one Acomposite@ sample.

Step 4. Place the contents of the kick-net in a standard size 35 sieve (0.5 mm mesh) or white enameled tray. Remove the larger twigs, leaves and rocks by hand after carefully inspecting for clinging organisms. If the pan is used, place the material through the sieve to remove the water before placing the material in the jar. Place the sampled material and label (see box) in a jar and completely fill with 95% ethanol. Never fill a jar more than 2/3 full with sampled material and gently agitate jars that contain primarily mud or sand.

Step 5. Proceeding upstream, repeat Steps 2 through 4 for the next two randomly chosen transects within the riffle.

Non-point Source Sampling Design

There will be no obvious perturbations or discharges into the stream with non-point sources of pollution. This sampling design is appropriate for assessing an entire stream or large section of stream. The sampling units will be riffles within a reach of stream. The stream reach must contain at least 5 riffles within the same stream order and relative gradient. **One sample will be collected from the upstream third of 3 randomly chosen riffles.**

Bioassessment Sample Label

Riffle/ Reach Number:___________
Transect Number: ______________
Stream Name: ________________
Date/ Time: __________________
Sample by: ___________________

Use the following step-by-step procedures for collecting BMIs using the non-point source sampling design:

Step 1. Randomly choose 3 of the 5 riffles within the stream reach using the random number table.

Step 2. Starting with the downstream riffle, place the measuring tape along the bank of the entire riffle while being careful not to walk in the stream. Select 1 transect from all possible meter marks along the top third of the riffle using a random number table.

Step 3. (See Point Source Sampling Design Step 2)

Step 4. (See Point Source Sampling Design Step 3)

Step 5. (See Point Source Sampling Design Step 4)

Step 6. Proceeding upstream, Repeat Steps 2 through 5 for the next two riffles within the stream reach.

Sampling Design for Assessing Ambient Biological Conditions

Assessment of ambient biological condition utilizes both the point and non-point source sampling designs to cover an entire watershed or larger regional area. Ambient bioassessment programs are used to evaluate the biological and physical integrity of targeted inland surface waters. Stream reaches should be established in the upper, middle and lower portions of each watershed and above and below areas of particular interest. Quite often bioassessment is incorporated into an existing chemical or toxicological sampling design. In most cases, the water quality information is being collected at a particular point on the stream. Although there will be the tendency to use the point source design, try to convert to a non-point reach design for biological sampling.

Measuring Physical/Habitat Quality

The physical/habitat scoring criteria is an EPA nationally standardized method. It is used to measure the physical integrity of a stream and can be a stand-alone evaluation or used in conjunction with a bioassessment sampling event. DFG recommends that this procedure be conducted on every reach of stream sampled as part of a bioassessment program. Fill out the Physical/Habitat Quality Form for the entire reach where the BMI samples were collected as part of a non-point source sampling design. Some of the parameters do not apply to a single riffle, so this procedure is usually not performed as part of the point source sampling design. **This procedure is an effective measure of a stream=s physical/habitat quality, but requires field training prior to using it and implementation of quality assurance measures throughout the field season.** A detailed description of the scoring criteria is available through the California Aquatic Bioassessment Web Site.

Measuring Chemical and Physical/Habitat Characteristics

Measurements of the chemical and physical/habitat characteristics are used to describe the riffle environment and help the water resource specialist interpret the BMI data. The information can be used to classify stream reaches and to explain anomalies that might occur in the data. **They are not necessarily a good substitute for a quantitative fisheries habitat survey**.

Use the following step-by-step procedures to measure chemical and physical/habitat characteristics:
Step 1. Water temperature, specific conductance, pH and dissolved oxygen should be measured at the sampling site using approved standardized procedures and instruments.

Step 2. Record the riffle length determine for the procedure to choose the transect locations. Estimate the average riffle width by averaging several measurements along its length. Measure the riffle depth by placing the stadia rod at several places within the riffle and averaging the measurements.

Step 3. Estimate or measure the entire length of the reach where the three riffles are chosen as part of the non-point source sampling design.

Step 4. Measure the riffle velocity using a flow meter placed in front of the three locations along the transect(s) where the BMI samples were collected. Average the readings.

Step 5. Estimate the percent of the riffle surface that is covered by shade from streamside vegetation (canopy cover) using a densiometer at several places along the riffle and averaging the readings.

Step 6. Determine substrate complexity and embeddedness by applying Parameters 1 and 2, respectively from the Physical/Habitat Quality Form to the riffle where the BMI sample was collected. Use the entire riffle to assess these parameters and make note if the area along the transect(s) is considerably different from the rest of the riffle.

Step 7. Visually estimate the percent of riffle in each of the following substrate categories: fines (<0.1"), gravel (0.1-2"), cobble (2-10"), boulder (>10") and bedrock (solid). Use the entire riffle to assess this parameter and make note if the area along the transect(s) is considerable different from the rest of the riffle.

Step 8. Estimate substrate consolidation by kicking the substrate with the heel of your wader boots to note whether it is loosely, moderately or tightly cemented. The estimate should also take into consideration the hands-on experience obtained from collecting the BMI sample.

Step 9. Measure the gradient or slope of the riffle using a stadia rod and hand level or a clinometer.

Using the California Bioassessment Worksheet

A California Bioassessment Worksheet (CBW) should be filled out for each individual riffle when following the Point Source Sampling Design and for the entire reach when using the Non-point Sampling Design. Use the following step-by-step procedures for filling out the CBW:

Step 1. Enter the watershed and stream name, date and time of sample collection, name of the company or agency collecting the samples, sample identification number(s), and a short site description on the CBW.

Step 2. Enter the names of each crew member in the Crew Member Box.

Step 3. Determine the longitude and latitude coordinates and elevation from a GPS unit or watershed topographic map. Determine which California ecoregion or sub-ecoregion the site is located in by using the U.S. Forest Service map obtained by visiting the California Aquatic Bioassessment Web Site. Record this information and any other comments on the sampling site in the Site Location Box.

Step 4. Record the water temperature, specific conductance, pH and dissolved oxygen measurements in the Chemical Characteristics Box.

Step 5. Record the physical/habitat characteristics in the Riffle/Reach Characteristics Box. For the Point Source Sampling Design, record the riffle length, the 3 transect locations along the riffle and the physical/habitat characteristics information (starting with Ave. Riffle Width) on the lines below the Ariffle 1" column. For the Non-point Source Sampling Design, record the reach length, the total score from the Physical/Habitat Quality Form and all physical/habitat characteristics information on the lines below the Ariffle 1" through Ariffle 3" columns.

Step 6. Record the name and address of the Bioassessment Laboratory that received the samples along with the laboratory sample numbers if they are different than the field sample identification numbers.

Using the Chain of Custody (COC) Form

The Chain of Custody (COC) form is a necessary part of collecting BMI samples. It is an official document for tracking the samples from the field to the laboratory and then to their final storage area. The COC will also provide important information if samples are lost or misplaced. Use the following step-by-step procedures for using the COC:

Step 1. At the end of the field day, record the following information on the COC for each group of BMI samples: program name; watershed name; field ID numbers; sampling dates; and name, address, telephone number and signature of one of the crew members collecting the sample.

Step 2. Field samples and COCs must remain in a locked sample depository until a decision has been made to send them to a bioassessment laboratory for processing.

Step 3. When transporting to a bioassessment laboratory, each group of samples must be accompanied by a COC. Upon delivery, a Bioassessment Laboratory Number will be assigned to each sample. Record this number on the COC and each individual CBW along with the name and address of the bioassessment laboratory. When all samples listed on the COC are accounted for, then the individual delivering the samples will sign the "Released By" portion and the laboratory personnel will sign the "Received By" portion of the COC. The original COC will remain at the laboratory and a copy will be retained by the project supervisor.

PROFESSIONAL (LEVEL 3) LABORATORY PROCEDURES

The CSBP has three levels of BMI identification. Level 3 is the professional level equivalent and requires identification of BMIs to a standard level of taxonomy, usually to genus and/or species level. **All professional Bioassessment Laboratories should belong to the California Bioassessment Laboratories Network (CAMLnet).** This organization was conceived to provide technical assistance to laboratories and ensure that laboratory efforts are consistent throughout California. Contact DFG or visit the California Aquatic Bioassessment Web Site for information on CAMLnet.

LABORATORY EQUIPMENT

- Dissecting microscopes
- Standard Size 35 sieve (0.5 mm)
- Gridded picking tray
- Wide-mouth glass jars
- Glass petri dishes
- Vials
- Taxonomic Keys
- 70% EtOH/ 5% glycerol
- Fine dissection forceps
- Standardized taxonomic list
- Waterproof paper/ pencils
- Laboratory benchsheets
- Random number generator
- Chain of Custody form

Subsampling

Step 1. Retrieve the sample from the sample depository and cross-check the sample number with the bioassessment laboratory number on the COC.

Step 2. Empty the contents of the sample jar into the # 35 sieve (0.5 mm mesh) and thoroughly rinse with water.

Step 3. Once the sample is rinsed, clean and remove debris larger than **2** inch. Remove and discard green leaves, twigs and rocks. Do not remove filamentous algae and skeletonized leaves.

Step 4. After cleaning, place the material into a plastic tray marked with equally sized, numbered grids (approximately 2x2 inches). Do not allow any excess water into the tray. Spread the moist, cleaned debris on the bottom of the tray using as many grids necessary to obtain an approximate thickness of **2** inch. Make an effort to distribute the material as evenly as possible.

Step 5. Remove and count macroinvertebrates from randomly chosen grids until 300 BMIs are removed. Place the BMIs in a clean petri dish containing 70% ethanol/5% glycerin. Completely count the remaining organisms in the last grid but do not include them with the 300 used for identification. The final count should be recorded on the benchsheet for eventual abundance calculations.

Step 6. The debris from processed grids should be put in a clean Aremnant@ jar and the remaining contents of the tray should be placed back into the original sample jar. Both jars should be filled with fresh 70% ethanol, labeled (bioassessment laboratory number and either Aoriginal@ or Aremnant@) and returned to the sample depository.

Identification of BMIs

Step 7. Identify the 300 BMIs from each sample to the standardized level recommended by CAMLnet using appropriate taxonomic keys.

Step 8. Place identified BMIs in individual glass vials for each taxon. Each vial should contain a label with taxonomic name, bioassessment laboratory number, stream, county, collection date and collector's name. This voucher collection should be labeled and returned to the Sample Depository.

Step 9. Record taxonomic information on a Macroinvertebrate Laboratory Bench Sheet. The bench sheet should include the following information: watershed or project name; sampling date; sample ID number; bioassessment laboratory number; date of subsampling; name of subsampler; remnant jar number; taxonomy completion date; name of taxonomist; taxonomic list of organism and enumeration; total number of organisms; total number of taxa; list of unknowns, problem groups and comments.

Step 10. Maintain a reference collection of representative specimens of all accurately identified BMI taxa.

QUALITY ASSURANCE (QA) PROCEDURES FOR THE FIELD AND LABORATORY

QA for Collecting BMIs

The CSBP is designed to produce consistent, random samples of BMIs. It is important to prevent bias in riffle choice and transect placement. The following procedures will help field crews collect unbiased and consistent BMI samples:

1. In using the CSBP, most sampling reaches should contain riffles that are at least 10 meters long, one meter wide and have a homogenous gravel/cobble substrate with swift water velocity. **There are approved modifications of the CSBP when these conditions do not exist. Contact DFG or visit the California Aquatic Bioassessment Web Site for methods to sample narrow streams, wadeable streams with muddy bottoms and channelized streams.**

2. A DFG biologists or project supervisor should train field crews in the use of the BMI sampling procedures described in the CSBP. Field personnel should review the CSBPs before each field season.

3. During the training, crew members should practice collecting BMI samples as described in the CSBP. The 2 ft^2 area upstream of the sampling device should be delineated using the measuring tape or a metal grid and the collection effort should be timed. Practice repeatedly until each crew member has demonstrated sampling consistency. Throughout the sampling season, assure that effort and sampling area remain consistent by timing sampling effort and measuring sampled area for approximately 20% of the sampling events. The results should be discussed immediately and need not be reported.

QA for Measuring Physical/Habitat Quality

Physical/habitat parameters are assessed using a ranking system ranging from optimal to poor condition. This rapid ranking system relies on visual evaluation and is inherently subjective. The following procedures will help to standardize individual observations to reduce differences in scores:

1. A DFG biologist or a project supervisor should train field crews in the use of the EPA physical/habitat assessment procedures. Contact DFG or visit the California Aquatic Bioassessment Web Site for a detailed description of the procedures. Field personnel should review these procedures before each field season.

2. At the beginning of each field season, all crew members should conduct a physical/habitat assessment of two practice stream reaches. Assess the first stream reach as a team and discuss in detail each of the 10 physical/habitat parameters described in the EPA procedure. Assess the second stream reach individually and when members are finished, discuss the 10 parameters and resolve discrepancies.

3.Crews or individuals assessing physical/habitat quality should frequently mix personnel or alternate assessment responsibilities. At the end of each field day, crew members should discuss habitat assessment results and resolve discrepancies.

4.The Project Supervisor should randomly pre-select 10 - 20% of the stream reaches where each crew member will be asked to assess the physical/habitat parameters separately. The discrepancies in individual crew member scores should be discussed and resolved with the Project Supervisor.

QA for the Laboratory

Laboratory analysis of macroinvertebrate samples can be a significant cost for bioassessment programs. The CSBP specifies identification of BMIs to a standard level of taxonomy, usually to genus and/or species level. The CSBP also requires subsampling procedures using a fixed count of 300 organisms. Employing these procedures with confidence requires an effective quality assurance program. Complete quality assurance compliance will require a minimal 10% cost overhead. However, it will allow for testing whether subsampling, organism enumeration and taxonomic identification are consistent and accurate. Use the following procedures in the bioassessment laboratory to ensuring that quality data is produced:

The California Macroinvertebrate Laboratory Network (CAMLnet) - All individuals, private consulting firms and agency personnel using the CSBP laboratory procedures should contact the WPCL for information on CAMLnet. This group consists of personnel from bioassessment laboratories throughout California. The group provides a forum where laboratory procedures are discussed and the BMI taxonomic levels are determined. It also provides taxonomic workshops and assistance with interlaboratory taxonomic verification.

Standard Operation Procedures (SOP) - Each bioassessment laboratory should produce an SOP manual following the procedures outlined in the CSBP, but with detailed instructions specific to each laboratory. The SOP manual should be maintained for all laboratory operations and updated regularly. The assigned personnel and the duties of a Laboratory Supervisor and QA Taxonomist should be specified in the SOP manual. Customized benchsheets should be developed for each phase of subsampling and identification.

Sample Handling and Custody - When samples arrive, laboratory staff should inspect the samples for a sufficient volume of ethanol and labels for pertinent information including water-body name, sample date and time, location, transect number and sampler name. The steps discussed in the AUsing the Chain of Custody (COC)@ section in this protocol should be followed. The sample description information should be recorded in the Laboratory Sample Inventory Log and each sample given a unique identification number. A written and electronic record should be maintained to trace the samples from entry into the laboratory through final analysis. Samples should be stored in the a Sample Repository until processing and returned after processing.

Subsampling - Subsampling involves removing 300 organisms from each sample, or all organisms if the entire sample contains fewer than 300. The procedure to estimate abundance usually requires removing more than 300 organisms from each sample; however, only 300 are retained for identification. The Subsampling Technician systematically transfers organisms from the sample to a collection vial then transfers the processed sample debris (remnant) into a Remnant jar. At least 10% of the Remnant samples should be examined by the QA Taxonomist for organisms that may have been overlooked during subsampling. For subsamples containing 300 or more organisms, the Remnant sample should contain fewer than 10% of the total organisms subsampled. The Remnant for samples containing fewer than 300 organisms should contain fewer than 30 organisms.

Taxonomic Identification and Enumeration - The CSBP requires that all organisms are identified to a standardized taxonomic level using established taxonomic keys and references. The QA Taxonomist should check at least 10% of the samples for taxonomic accuracy and enumeration of individuals within each taxon. The same sample numbers that were selected randomly for the subsampling quality control should be used for this procedure. Misidentifications and/or taxonomic discrepancies as well as enumeration errors should be noted on the laboratory benchsheets. The Laboratory Supervisor determines if the errors warrant corrective action.

Organism Recovery - During the sorting and identification process organisms may be lost, miscounted or discarded. Taxonomists will record the number of organisms discarded and a justification for discarding on the laboratory benchsheets. Organisms may be discarded for several reasons including: 1) subsampler mistakes (e.g. inclusion of terrestrial or semi-aquatic organisms or exuviae), 2) small size (< 0.5 mm), 3) poor condition or 4) fragments of organisms. The number of organisms recovered at the end of sample processing will also be recorded and a percent recovery determined for all samples. Concern is warranted when organism recoveries fall below 90%. Samples with recoveries below 90% should be checked for counting errors and laboratory benchsheets should be checked to determine the number of discarded organisms. If the number of discarded organisms is high, then the technician that performed the subsampling should be informed and re-trained if necessary.

Corrective Action - Any quality control parameter that is considered out of range should be followed by a standard corrective action that includes two levels. Level I corrective action includes an investigation for the source of error or discrepancy derived from the quality control parameter. Level II corrective action includes checking all samples for the error derived from the quality control parameter but is initiated only after the results of the Level 1 process justify it. The decision to initiate Level II corrective action and reanalyze samples or conduct quality control on additional samples should be made by the Laboratory Supervisor.

Interlaboratory Taxonomic Validation - An external laboratory or taxonomic specialist should be consulted on a regular basis to verify taxonomic accuracy. External validation can be performed on selected taxa to help the laboratory taxonomists with problem groups of BMIs and to verify representative specimens of all taxa assembled in a reference collection.

Bioassessment Validation - The CSBP recommends at least 10% bioassessment validation where whole samples of 300 identified BMIs are randomly selected from all samples either for a particular project or for all samples processed within a set time period such as each 6 months or a year. The labels should be removed from the vials and replaced with a coded label that does not show the taxonomic name of the BMIs. The validation laboratory or specialist should be instructed to identify and enumerate all specimens in each vial and produce a taxonomic list. There will inevitably be some disagreements between the bioassessment and the external laboratory on taxonomic identification. These taxa should be re-examined by both parties and a resolution reached before a final QA report is written. **DFG is working on this QA technique to determine the acceptable level of misidentification and appropriate corrective actions.**

DATA DEVELOPMENT AND ANALYSIS

The CSBP analysis procedures are based on the EPA=s multi-metric approach to bioassessment data analysis. The EPA is developing procedures for multi-variate analysis of bioassessment data, but that method is not presented here. However, the sampling protocols presented in this document were designed to facilitate the use of multi-variate analysis and more information will be presented when standardizes techniques for California become available.

A taxonomic list of the BMIs identified for each sample should be generated for each project along with a table of sample values and means for the biological metrics listed on the last page of this document. Variability of the sample values should be expressed as the coefficient of variability (CV). Significance testing can be use for point source sampling programs and ranking procedures can be used to compare sites sampled using the non-point sampling design (contact DFG for information on ranking formulas). Ultimately, there will be a regional Index of Biological Integrity (IBI) to compare sample site mean values.

Starting in summer 1999, an Access[7] database program to store, process and return a copy of the collected data will be available. Contact DFG or visit the California Aquatic Bioassessment Web Site to learn more about the availability of regional IBIs and the database program.

Measuring Stream Discharge with the AquaCalc and the Price AA or Pygmy Meter

Field SOP
10/16/02

Attaching the Flow Meter to the Wading Rod

1. Remove the flow meter from its storage case
2. Attach the flow meter to the wading rod by slipping the flow meter attachment end over the wading rod nub and tightening the screw on the flow meter with a straight slot screwdriver. **(Making sure the flow meter is perpendicular with the flow meter)**
3. Attach the electrical wire that is connected to the wading rod to the flow meter and tighten the nut gently with a pair of pliers

Attaching the AquaCalc to the Wading Rod

1. Remove the AquaCalc from its storage case
2. Attach the AquaCalc to the top of the wading rod with the Velcro
3. Attach the AquaCalc's 8 pin connector "pig tail" to the cable that is mounted on top of the wading rod

Field Testing the Instrumentation

1. Turn on the AquaCalc and hit **Enter** when the Date and Time is displayed
2. Press the **go to Transect #** and enter an unused and available transect number
3. Hit the **Next Observe** key to select any observation but #1
4. Spin the cups on the current meter and press the **Measure** key
5. The timer will immediately start and then restart after the first revolution of the cups. After the first revolution, the counter will show revolutions.
6. Visually count the revolutions
7. Compare this to the amount counted by the AquaCalc
8. If the AquaCalc does not match you visual count refer to the *Troubleshooting* chapter in the owner's manual

Spin Testing the Flow Meter

1. Give the current meter a rapid spin in still air and record the time until the cups stop spinning.

USGS spin tests for Price Type AA and Pygmy meters are shown in the following table:

Meter	Normal Spin	Minimum Spin
Price "AA"	4 min	1.5 min
Pygmy	1.5 min	0.5 min

Measuring stream discharge across a transect

(This SOP will be set up to perform a simple 6 tenths wading measurement, good for stream depths below 2.5 feet. For streams with a depth greater than 2.5 feet consult the Owner's Manual for changing the AquaCalc setting to calculate the 2 tenths and 8 tenths measurements.)

1. Secure the tape measurer or Kevlar tag line to one side of the stream bed (trees work good or use a metal stake)
2. Carefully walk across the stream and secure the tape or tag line on the other side of the stream bed so that the transect is perpendicular to the stream.
3. Determine what the stream width is and divide by 25
4. This will determine what your sampling interval will be
5. Turn on the AquaCalc
6. Press the **Go To Transect #** key and select the Transect # that has been assigned to the stream you are measuring at (see cheat sheet on back of AquaCalc)
7. If there are existing measurements in the rest of the thransect's stations, you can erase them by pressing and holding the **Erase** key for three seconds while in Observation #1.
8. Repeatedly press the **Previous Observe** key to go to Observation #1 in the AquaCalc
9. Establish the Edge-of-Water (EOW) in the AquaCalc. No measurements can be made at Station #1. Just press the **Set Distance** key and enter the number that is on the measuring tape or tag line that coincides with the EOW
10. If you are at a wall or a vertical bedrock edge, enter the depth at the wall by pressing the **Set Depth** key and entering the stream depth from the top of the water to the bottom of the wall and then press the **Enter** key **(do not press the Measure key at this observation point)**
11. Press the **Next Observe** key to move to Station #2.
12. Move to your first measurement location in the stream.
13. Press the **Set Distance** key. Enter the distance from the measuring tape or tag line.
14. Press the **Set Depth** key (by pressing the Set Depth instead of Enter the AquaCalc will automatically enter the distance and ready the AquaCalc to accept the Depth) Enter the depth of the stream at your location
15. Push the rubber button on the wading rod handle that will allow you to adjust the flow meter to its correct height. Slide the rod up or down to match the rod height inscribed on the wading rod handle with the correct stream depth.
16. Press the **Measure** key. The AquaCalc will immediately start counting revolutions after the first revolution and display the running mean velocity.
17. When the AquaCalc has satisfactorily completed its measurement the **Measurement Complete** screen will appear, showing counts, elapsed time and velocity for the measurement.
18. Press the **Enter** key to continue
19. Press the **Next Station** key to move to the next station

20. Move to your next measurement location and repeat the previous steps for each station in the transect
21. After completing the measurement at the last station, press **Next Station** key and enter the ending EOW location as read on the tape or tag line and input a depth of zero.
22. In the case of ending the transect at a vertical wall or bedrock, enter the ending distance at the wall and the depth at the wall as usual, but ***add a station following the wall with a depth of zero.*** The distance you enter in this next station is not critical, so long as it is greater than zero. It is helpful to use a distance beyond the closing wall location.
23. Press the **Calculate Discharge** key and record this number in the logbook in the gaging station box
24. Enter the Gage Height and the Staff Height into the AquaCalc. (For these purposes the stage height displayed on the data logger at the gaging station will be used for the gage height and the water level at the graduated Staff plate will be the staff height.)
25. Press the **Menu** key
26. Press the **Enter** key to scroll to Set Gage HT.
27. Press the **+/-** key and enter the height displayed on the data logger.
28. Press the **Enter** key
29. Press the **+/-** key and enter the water height on the graduated Staff plate
30. Press the **Enter** key
31. Turn off the AquaCalc by holding down the **OFF** key for a couple of seconds
32. Detach the AquaCalc and current meter from the wading rod and put them in their protective cases
33. Do not close the lid on the current meter so it can air dry, when you return to the office rinse with tap water and dry off with the supplied yellow cloth

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Techniques of Water-Resources Investigations of the U.S. Geological Survey

Book 3, Applications of Hydraulics

Chapter C2

Field Methods for Measurement of Fluvial Sediment

By Thomas K. Edwards and G. Douglas Glysson

This manual is a revision of "Field Methods for Measurement of Fluvial Sediment," by Harold P. Guy and Vernon W. Norman, U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C2, published in 1970.

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[1] This manual is a revision of "Measurement of Time of Travel and Dispersion in Streams by Dye Tracing," by E.F. Hubbard, F.A. Kilpatrick, L.A. Martens, and J.F. Wilson, Jr., Book 3, Chapter A9, published in 1982.

[2] Spanish translation also available.

[3] This manual is a revision of "Field Methods for Measurement of Fluvial Sediment," by Harold P. Guy and Vernon W. Norman, Book 3, Chapter C2, published in 1970.

[4] This manual is a revision of TWRI 5-A3, "Methods of Analysis of Organic Substances in Water," by Donald F. Goerlitz and Eugene Brown, published in 1972.

[5] This manual supersedes TWRI 5-A4, "Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples," edited by P.E. Greeson and others, published in 1977.

CONTENTS

ILLUSTRATIONS

TABLES

UNIT CONVERSION

Multiply inch-pound unit	*By*	*To obtain SI unit*
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
square inch (in.^{2})	6.452	square centimeter (cm^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
	Volume	
U.S. liquid pint (pt)	0.4732	liter (L)
U.S. liquid quart (qt)	0.9464	liter (L)
U.S. liquid gallon (gal)	3.785	liter (L)
U.S. liquid gallon (gal)	3,785	milliliter (mL)
U.S. liquid gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	28,317	cubic centimeter (cm^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Multiply inch-pound unit	*By*	*To obtain SI unit*
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
ounce, avoirdupois (oz)	28,350	milligram (mg)
pound, avoirdupois (lb)	453.6	gram (g)
ton, short	0.9072	megagram (Mg)
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F–32)	degree Celsius (°C)
	Pressure	
pound per square inch (lb/in.^{2})	6.895	kilopascal (kPa)
	Concentration (Mass/Volume)	
parts per million (ppm)[1]	1.0	milligrams per liter (mg/L)
ounces per quart (oz/qt)	29,955	milligrams per liter (mg/L)
pounds per cubic foot (lb/ft^3)	16,017	grams per cubic meter (g/m^3)

---

[1] This conversion is true for

$$\text{mg/L} = c(\text{ppm}) = c$$

when the ratio of weight of sediment to weight of water-sediment mixture is between 0 and 15,900. If this ratio is greater than 15,900, the investigator is referred to Guy (1969, table 1, p. 4) for the correct conversion factor to be used in the formula.

FIELD METHODS FOR MEASUREMENT OF FLUVIAL SEDIMENT

By Thomas K. Edwards and G. Douglas Glysson

Abstract

This chapter describes equipment and procedures for collection and measurement of fluvial sediment. The complexity of the hydrologic and physical environments and man's ever-increasing data needs make it essential for those responsible for the collection of sediment data to be aware of basic concepts involved in processes of erosion, transport, deposition of sediment, and equipment and procedures necessary to representatively collect sediment data.

In addition to an introduction, the chapter has two major sections. The "Sediment-Sampling Equipment" section encompasses discussions of characteristics and limitations of various models of depth- and point-integrating samplers, single-stage samplers, bed-material samplers, bedload samplers, automatic pumping samplers, and support equipment. The "Sediment-Sampling Techniques" section includes discussions of representative sampling criteria, characteristics of sampling sites, equipment selection relative to the sampling conditions and needs, depth- and point-integration techniques, surface and dip sampling, determination of transit rates, sampling programs and related data, cold-weather sampling, bed-material and bedload sampling, measuring total sediment discharge, and measuring reservoir sedimentation rates.

INTRODUCTION

Perspective

Knowledge of the erosion, transport, and deposition of sediment relative to land surface, streams, reservoirs, and other bodies of water is important to those involved directly or indirectly in the development and management of water and land resources. It also is becoming more important that such development and management be carried out in a manner that yields or conforms to a socially acceptable environment. The need for a clear understanding of hydrogeomorphologic processes associated with sediment requires the measurement of suspended and bed sediments for a wide range of hydrologic environments. The complex phenomena of fluvial sedimentation cause the required measurements and related analyses of sediment data to be relatively expensive in comparison with other kinds of hydrologic data. Accordingly, the purpose of this manual is to help standardize and improve efficiency in the techniques used to obtain sediment data, so the quantity and quality of the data can be maximized for a given investment of labor and resource.

Sediment data needs are of practical concern. Some of the general categories include:

1. The evaluation of sediment yield with respect to different natural environmental conditions—geology, soils, climate, runoff, topography, ground cover, and size of drainage area.
2. The evaluation of sediment yield with respect to different kinds of land use.
3. The time distribution of sediment concentration and transport rate in streams.
4. The evaluation of erosion and deposition in channel systems.
5. The amount and size characteristics of sediment delivered to a body of water.
6. The characteristics of sediment deposits as related to particle size and flow conditions.
7. The relations between sediment chemistry, water quality, and biota.

The scope of these requirements indicates that a wide variety of measurements are needed on streams and other bodies of water, ranging from large river basins to very small tributaries that drain areas such as parcels of land under urban development.

The equipment and methods discussed in this report for the collection of a suspended-sediment sample are designed to yield a representative sample of the water sediment mixture. This representative sample may be analyzed for sediment concentration, particle-size distribution, or, if collected with the proper type sampler, any other dissolved, suspended, or total water-quality constituent. Therefore, the equipment and methods described in this report should be used to collect a representative sample for water-quality analysis.

Sediment Characteristics, Source, and Transport

Sediment is fragmental material transported by, suspended in, or deposited by water or air, or accumulated in beds by other natural agents. Sediment particles range in size from large boulders to colloidal-size fragments and vary in shape from rounded to angular. They also vary in mineral composition and specific gravity, the predominant mineral being quartz and the representative specific gravity being 2.65.

Sediment is derived from any parent material subjected to erosional processes by which particles are detached and transported by gravity, wind, water, or a combination of these agents. When the transporting agent is water, the sediment is termed "fluvial sediment." The U.S. Geological Survey (USGS) defines fluvial sediment as fragmentary material that originates mostly from weathering of rocks and is transported by, suspended in, or deposited from water (Federal Inter-Agency Sedimentation Project, 1963b); it includes chemical and biological precipitates and decomposed organic material, such as humus.

Erosion by water is classified as either sheet or channel erosion, with no distinct division between the two. Sheet erosion occurs when sediments are removed from a surface in a sheet of relatively uniform thickness by raindrop splash and sheet flow. Sediment-particle movement and the energy of the raindrops compact and partially seal the soil surface, effectively decreasing the infiltration rate and increasing the amount of flow available to erode and transport the sediment. The amount of material removed by sheet erosion is a function of surface slope, erodibility, and precipitation intensity and drop size.

Land-surface irregularities inhibit continuous sheet flow over large areas. This inhibition serves to concentrate the flow into small rills or channels and streams, which increase in size as they join together downstream. Within these channels, eroded material from the banks or bed of the stream is contributed to the flow until, in theory, the stream is transporting as much sediment as the energy of the stream will allow. Such channel erosion may be general or local along the stream but is primarily local in nature.

Some sediment is carried to streams by wind, but direct contribution to the stream channel by this conveyance usually accounts for only a small part of the total fluvial sediments. Aside from bank caving as a result of stream erosion or processes of mass wasting (Thornbury, 1969), gravitational transfer of sediments occurs toward and into streams. Conveyance by gravitational means ranges from slow creep to rapid landslide. Other significant sources of local sediments are glacial-melt outwash, volcanic activity, mining, earth movement, construction, or additional land-disturbance activities by man.

The stream usually transports sediment by maintaining the finer particles in suspension with turbulent currents and by rolling or skipping the coarser particles along the streambed. Generally, the finer sediments move downstream at about the same velocity as the water, whereas the coarsest sediments may move only occasionally and remain at rest much of the time.

Vertical distributions of suspended-sediment particle sizes may vary among streams and among cross sections within a stream. However, as a general rule, the finer particles are uniformly distributed throughout the vertical, and the coarser particles are concentrated near the streambed. Occasionally, coarse particles may reach the water surface, generally carried by turbulent flow or as a result of dispersive grain stress (Leopold and others, 1964). Thus, with use of the depth- or point-integrating suspended-sediment samplers described here, the sample obtained generally contains a range of particle sizes representative of the suspended-sediment discharge at the sampled vertical. The vertical is divided into two zones, as illustrated by figure 1. This separation is due to the design of the sampler, which limits the effective sampled depth. Sampling the entire depth is not possible because the physical location of the sampler nozzle relative to the bottom of the sampler prevents the nozzle from passing through the zone close to the bed. This portion of the depth is termed the unsampled zone and characteristically carries the higher concentration and coarser particles. The unsampled suspended sediment moving within this zone may or

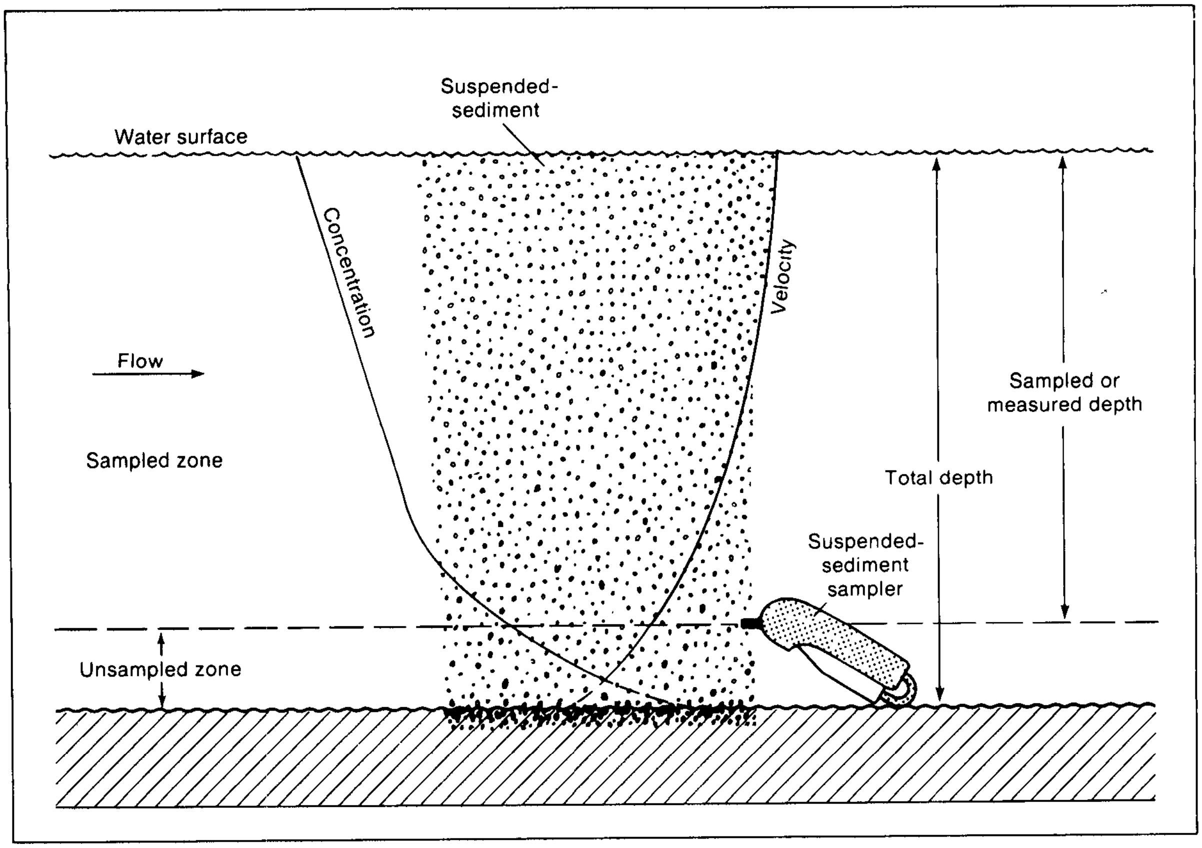


Figure 1. Sampled and unsampled zones in a stream sampling vertical, with respect to velocity of flow and sediment concentration.

may not account for a large part of the total suspended sediment, depending upon the depth, velocity, and turbulence of the flow through the vertical. The measured sediment discharge is nearly equal to the total sediment discharge if the velocity and turbulence conditions within the sampled vertical overcome the tractive force transporting the bedload in the unmeasured zone and effectively disperse all of the sediment being transported into suspension throughout the total depth.

The preceding discussion illustrates the complexity of the study of fluvial sediment transport and some of the many variables involved. The interested reader is directed to more detailed works concerning fluvial-sediment concepts and geomorphic processes, such as the contributions by Colby (1963), Leopold and others (1964), Guy (1970), and Vanoni (1975). The investigator also can obtain pertinent information on the subject by contacting the Federal Inter-Agency Sedimentation Project (F.I.S.P.), Waterways Experiment Station, Vicksburg, Mississippi.

Data Needs

No matter how precise the theoretical prediction of sedimentation processes becomes, it is inevitable that man's activities will continue to cause changes in the many variables affecting sediment erosion, transportation, and deposition; thus, there will be an increasing need for direct and indirect measurement of fluvial-sediment movement and its characteristics. Because of the rapid advances in technology, it seems of little value to list the many specific kinds of sediment problems and the kinds of sediment data required to solve such problems. However, some general areas of concern may be of interest. Sediment data are useful in coping with problems and goals related to water utilization. Many industries require sediment-free water in their processes. A knowledge of the amount and characteristics of sediment in the water resource is needed so that the sediment may be removed as economically as possible before the water is allowed to enter a distribution system. Information on sediment movement and particle-size characteristics is needed in the design of hydraulic structures, such as dams, canals, and irrigation works. Streams and reservoirs that are free of sediment are highly regarded for recreation. Data on sediment movement and particle characteristics are needed to determine and understand how radionuclides, pesticides, and many organic materials are absorbed and concentrated by sediments, thus causing potential health hazards in some streams, estuaries, and water-storage areas. Knowledge concerning the effect of natural and man-made changes in drainage basins on the amount and characteristics of sediment yielded from the drainage basins is useful in helping to predict the stream environment when future basin changes are made. Knowledge about present fluvial-sediment conditions is being used to help establish criteria for water-quality standards and goals.

These data needs require sediment programs that will provide (1) comprehensive information on a national network basis, (2) special information about specific problem areas for water management, and (3) a description and understanding of the relations between water, sediment, and the environment (basic research). The reader is referred to Book 3, Chapter C1 of this series (Guy, 1970, p. 47) for a description of the kinds of sediment records commonly obtained at stream sites. Briefly, the records are of (1) the continuous or daily-record type, where sampling is sufficiently comprehensive to permit computation of daily loads, (2) the partial-record type, where a daily record is obtained for only a part of the year, and (3) the periodic-record type, where samples are taken periodically or intermittently. Usually a series of reconnaissance measurements is made prior to implementing any of these three programs. Even after a specific program is started, it is possible that adjustments may be necessary with respect to equipment, sample timing, or even measurement location. Realignment of efforts in this manner can be avoided in many instances by carefully applying design criteria to adequately meet the objectives of the project.

SEDIMENT-SAMPLING EQUIPMENT

General

In the early days of fluvial-sediment investigations, each investigator, or at least each agency concerned with sediment, developed methods and equipment individually as needed. It soon became apparent that consistent data could not be obtained unless equipment, data collection, and analytical methods were standardized. To overcome this difficulty, representatives of several Federal agencies (the Corps of Engineers of the Department of the Army, the Flood Control Coordinating Committee of the Department of Agriculture, the U.S. Geological Survey, the Bureau of Reclamation, the Office of Indian Affairs of the Department of the Interior, and the Tennessee Valley Authority) met in 1939 to form an interdepartmental committee, with the expressed purpose of standardizing sediment data-collection equipment, methods, and analytical techniques. The test facility for this work was initially located at the Iowa University Hydraulics Laboratory, in Iowa City, Iowa, and remained there for 9 years. In 1946, the committee became known as the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee. In 1948, the subcommittee moved the test facility to the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, in Minneapolis, Minnesota. The subcommittee reorganized the project in 1956 to its present structure as the Federal Inter-Agency Sedimentation Project (F.I.S.P.). In 1992, F.I.S.P. was moved to its present location at the Waterways Experiment Station in Vicksburg, Mississippi. The project is sponsored by a technical committee composed of representatives of the U.S. Army Corps of Engineers, U.S. Geological Survey, Bureau of Reclamation, Agricultural Research Service, U.S. Forest Service, and Bureau of Land Management, working under a formal Guidance Memorandum describing the project's objectives and organization. The F.I.S.P. is overseen by the Technical Committee of the Subcommittee on Sedimentation of the Interagency Advisory Committee on Water Data.

Since its initiation in 1939, approximately 50 reports, dealing with nearly all aspects of measurement and analysis of fluvial sediment movement, have been published by F.I.S.P. The intent of this chapter is not to replace the Inter-Agency Project reports, but to condense and combine their information regarding sediment measurements. The interested reader should contact F.I.S.P. for a listing of individual reports presenting further background material and details on the standard samplers. Sampling equipment is available for purchase by any interested investigator from the F.I.S.P., 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

The samplers developed by the F.I.S.P. are designated by the following codes: US, United States standard sampler. (In the following discussions this code will appear in the initial reference but will be dropped from succeeding references to the sampler designations.)

D, depth integrating

P, point integrating

H, hand-held by rod or line. (This code is placed after the primary letter designation and is omitted when referring to cable- and reel-suspended samplers.)

BM, bed material

BP, battery pack

BL, bedload sampler

U or SS, single stage

PS or CS, pumping-type sampler

Year, last two digits of the year in which the sampler was developed.

Sediment samplers available from F.I.S.P. or Hydrologic Instrumentation Facility (HIF) include suites of depth-integrating suspended-sediment samplers, point-integrating suspended-sediment samplers, pumping samplers, bed-material samplers, and a bedload sampler. In addition, an array of instruments has been developed to fulfill the need for collecting samples during unpredictable high-flow events. One sampler of particular interest for use in the future is a suspended-sediment sampler that utilizes bags as sample containers to overcome the depth limits of standard samplers due to container size, nozzle diameter, and stream velocity (Federal Inter-Agency Sedimentation Project, 1982b).

Suspended-Sediment Samplers

The purpose of a suspended-sediment sampler is to obtain a representative sample of the water-sediment mixture moving in the stream in the vicinity of the sampler. The F.I.S.P. committee set up several criteria for the design and construction of suspended-sediment samplers:

1. To allow water to enter the nozzle isokinetically. (In isokinetic sampling, water approaching the nozzle undergoes no change in speed or direction as it enters the orifice.)
2. To permit the sampler nozzle to reach a point as close to the streambed as physically possible. (This varies from 3 to 7 inches, depending on the sampler.)
3. To minimize disturbance to the flow pattern of the stream, especially at the nozzle.
4. To be adaptable to support equipment already in use for streamflow measurement.
5. To be as simple and maintenance-free as possible.
6. To accommodate a standard bottle size [that is, 1-pint (473 mL) glass milk bottle, 1-quart (946 mL) glass, 1-liter (1,000 mL) plastic, 2-liter (2,000 mL) plastic, or 3-liter (3,000 mL) plastic, as listed in table 1].

When a suspended-sediment sampler is submerged with the nozzle pointing directly into the flow, a part of the streamflow enters the sampler container through the nozzle as air in the container exhausts under the combined effect of three forces:

1. The positive dynamic head at the nozzle entrance, due to the flow.
2. A negative head at the end of the air-exhaust tube, due to flow separation.
3. A positive pressure due to a difference in elevation between the nozzle entrance and the air-exhaust tube.

When the sample in the container reaches the level of the air exhaust, the flow rate drops, and circulation of the streamflow in through the nozzle and out through the air-exhaust tube occurs. Because the velocity of the water flowing through the bottle is less than the stream velocity, the coarser particles settle out, causing the concentration of coarse particles in the bottle to gradually increase.

Table 1. Sampler designations and characteristics

[Epoxy-coated versions of all samplers are available for collecting trace metal samples; US, United States; in., inches; lbs., pounds; ft/s, feet per second; cd, cadmium, do., ditto; X, type of sampler container size used; --, type of sampler container size not used]

Sampler designation (US)	Construction material	Sampler dimensions			Nozzle distance from bottom (in.)	Suspension type	Maximum velocity (ft/s)	Maximum depth (ft)	Sampler container size		Intake size (in.)	Nozzle color
		Length (in.)	Width (in.)	Weight (lbs.)					Pint	Quart		
DH-48	aluminum	13	3.2	4.5	3.5	rod	8.9	8.9	X	--	1/4	yellow
DH-75P[1]	cd-plated	9.25	4.25	1.5	3.27	do.	6.6	15	X	--	3/16	white
DH-75Q[1]	do.	9.25	4.25	1.5	4.49	do.	6.6	15	--	X	3/16	white
DH-75H[1]	do.	9.25	4.25	1.5	--	do.	6.6	15	(2 liter)		3/16	white
DH-59	bronze	15	3.5	22	4.49	handline	5.0	15	X	--	1/8	red
DH-59	do.	15	3.5	22	4.49	do.	5.0	15	X	--	3/16	red
DH-59	do.	15	3.5	22	4.49	do.	5.0	9	X	--	1/4	red
DH-76	do.	17	4.5	22	3.15	do.	6.6	15	--	X	1/8	red
DH-76	do.	17	4.5	22	3.15	do.	6.6	15	--	X	3/16	red
DH-76	do.	17	4.5	22	3.15	do.	6.6	15	--	X	1/4	red
DH-81	plastic	[1]7.5	4.0	.5	(2)	rod	8.9	9	(7)	--	3/16	white
DH-81	do.	[1]7.5	4.0	.5	(2)	do.	8.9	9	(7)	--	1/4	white
DH-81	do.	[1]7.5	4.0	.5	(2)	do.	8.9	9	(7)	--	5/16	white
D-49	bronze	24	5.25	62	4.00	cable reel	6.6	15	X	--	1/8	green
D-49	do.	24	5.25	62	4.00	do.	6.6	15	X	--	3/16	green
D-49	do.	24	5.25	62	4.00	do.	6.6	9	X	--	1/4	green
D-74	do.	24	5.25	62	4.06	do.	6.6	15	X[8]	X	1/8	green
D-74	do.	24	5.25	62	4.06	do.	6.6	15	X[8]	X	3/16	green
D-74	do.	24	5.25	62	4.06	do.	6.6	[3]9, [4]15	X[8]	X	1/4	green
D-74AL	aluminum	24	5.25	42	4.06	do.	5.9	15	X[8]	X	1/8	green
D-74AL	do.	24	5.25	42	4.06	do.	5.9	15	X[8]	X	3/16	green
D-74AL	do.	24	5.25	42	4.06	do.	5.9	[3]9, [4]15	X[8]	X	1/4	green
D-77	bronze	29	9.0	75	7.0	do.	8.0	15	(3 liter)		5/16	white
P-61	do.	28	7.34	105	4.29	do.	6.6	[5]180, [6]120	X[8]	X	3/16	blue
P-63	do.	37	9.0	200	5.91	do.	6.6	[5]180, [6]120	X[8]	X	3/16	blue
P-72	aluminum	28	7.34	41	4.29	do.	5.3	[5]72.2, [6]50.9	X[8]	X	3/16	blue

[1] Without sample bottle attached.

[2] Depends on bottle size used. Calibrated brass nozzles no longer available.

[3] Depth using pint sample container.

[4] Depth using quart sample container.

[5] Depth using pint sample container to transit in 15 to 30 foot increments until entire traverse is completed

[6] Depth using quart sample container to transit in 15 to 30 foot increments until entire traverse is completed.

[7] Any size bottle with standard mason jar treads.

[8] Pint milk bottle can be used with adapter sleeve.

Depth- and Point-Integrating Samplers

A depth-integrating sampler is designed to isokinetically and continuously accumulate a representative sample from a stream vertical while transiting the vertical at a uniform rate (Federal Inter-Agency Sedimentation Project, 1952, p. 22). The simple depth-integrating sampler collects and accumulates a velocity or discharge-weighted sample as it is lowered to the bottom of the stream and raised back to the surface.

The point-integrating sampler, on the other hand, uses an electrically activated valve, enabling the operator to isokinetically sample points or portions of a given vertical. For stream cross sections less than 30 feet deep, the full depth can be traversed in one direction at a time by opening the valve and depth integrating either from surface to bottom or vice versa. Stream cross sections deeper than 30 feet can be integrated in segments of 30 feet or less by collecting integrated-sample pairs consisting of a downward integration and a corresponding upward integration in separate containers.

To eliminate confusion and more adequately differentiate between depth- and point-integrating samplers, a direct reference to Inter-Agency Report 14 (Federal Inter-Agency Sedimentation Project, 1963b, p. 60) is presented here to describe the characteristics of the point-integrating samplers that make them useful in conditions beyond the limits of the simpler depth-integrating samplers.

> Point-integrating samplers are more versatile than the simpler depth-integrating types. They can be used to collect a suspended-sediment sample representing the mean sediment concentration at any point from the surface of a stream to within a few inches of the bed, as well as to integrate over a range in depth. These samplers were designed for depth integration of streams too deep (or too swift) to be sampled in a continuous round-trip integration. When depth integrating, sampling can begin at any depth and proceed either upward or downward from that initial point through a maximum vertical distance of 30 feet.

A point-integrating sampler uses a 3/16-inch nozzle oriented parallel to the streamflow with the cross-sectional area exposed to approaching particles. The air is exhausted from the sample container and directed downstream away from the nozzle area as the sample enters. The intake and exhaust passages are controlled by a valve that can be activated on demand. When the valve is activated (opened to the sampling position), the sampling procedure is identical to that used for depth-integrating samplers. The increased effective depth to which a point-integrating sampler can be used, as compared to the maximum sampling depth to which a depth-integrating sampler is limited, is made possible by a pressure-equalizing chamber (diving-bell principle) enclosed in the sampler body. This chamber equalizes the air pressure in the sample container with the external hydrostatic head near the intake nozzle at all depths to alleviate the inrush of sample water, which would otherwise occur when the intake and air exhaust are opened at depth.

Hand-held samplers—US DH-81, US DH-75, US DH-48, US DH-59, and US DH-76

Where streams are wadable or access can be obtained from a low bridge span or cableway, a choice of five lightweight samplers can be used to obtain suspended-sediment samples via a wading rod or handline.

The DH-81 (fig. 2) consists of a DH-81A adapter and D-77 cap and nozzle. All parts are autoclavable. This construction enables the sampler to be used for collection of depth-integrated samples for bacterial analysis. The DH-81 can be used with 1/8-inch, 3/16-inch, or 1/4-inch nozzles and is suspended from a rod. Any bottle having standard mason jar threads can be used with this sampler. Obviously, the height of the unmeasured zone will vary depending on the size of

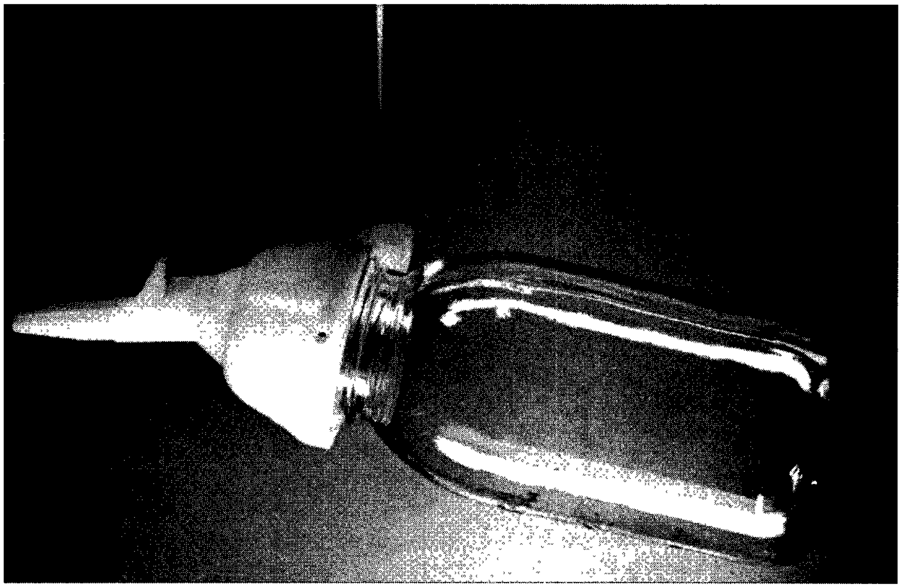


Figure 2. US DH-81 suspended-sediment sampler shown with a US DH-81A adapter, D-77 cap and nozzle, wading rod handle, and quart glass bottle.

bottle used. The DH-81 should be useful for sampling during cold weather because the plastic sampler head and nozzle attach directly to the bottle, eliminating a metal body (which would more rapidly conduct heat away from the nozzle, air exhaust, and bottle and create a more severe sampler-freezeup condition).

The DH-75 (fig. 3) weighs 0.9 pound and is available in two versions, the DH-75P and DH-75Q, which accept plastic containers of pint and quart volumes, respectively. The sampler consists of a cadmium-plated sheet-steel body 9 1/4 inches long, excluding the nozzle and sample container, with a retainer piece and shock cord assembly to hold the sample container against a cast silicone stopper through which the 3/16-inch nozzle and 180-degree air-exhaust tube pass to the mouth of the bottle. The DH-75 was developed as a freeze-resistant sampler. This sampler is not recommended for use as a general purpose depth-integrating suspended-sediment sampler.

The DH-48 sampler (fig. 4) features a streamlined aluminum casting 13 inches long that partly encloses the sample container. The container, usually a round pint glass milk bottle, is sealed against a gasket recessed in the head cavity of the sampler by a hand-operated spring-tensioned pull-rod assembly at the tail of the sampler. A modified version of this sampler is available to accommodate square pint milk bottles also. The sample enters the container through the intake nozzle as the air from the container is displaced and exhausted downstream through the air exhaust. The sampler, including container, weighs 4 1/2 pounds and can sample to within 3 1/2 inches of the streambed. This instrument is calibrated with an intake nozzle 1/4 inch in diameter, but may be used with a 3/16-inch nozzle in high-flow velocity situations (Federal Inter-Agency Sedimentation Project, 1963b, p. 57–60).

Two lightweight (24 and 25 pounds) handline samplers designated "DH-59" and "DH-76" (figs. 5 and 6) are designed for use in shallow unwadable streams with flow velocities up to 5 ft/s (feet per second). These samplers feature streamlined bronze castings 15 and 17 inches in length for the DH-59 and DH-76, respectively. The DH-59 accommodates a round pint sample bottle, while the DH-76, a more recent version of the sampler, is designed to take a quart container. The tail assembly extends below the body of the casting to ensure sampler alignment parallel to the flow direction with the intake nozzle entrance oriented upstream. Intake nozzles of 1/8-inch, 3/16-inch, and 1/4-inch diameters are calibrated for use with these samplers and may be interchanged as necessary when varying flow conditions are encountered from stream to stream. Suspended sediment can be collected to within 4 1/2 inches of the streambed with the DH-59, while the DH-76 can sample to within about 3 inches from the bottom.

These lightweight hand samplers are the most commonly used for sediment sampling during normal flow in small- and, perhaps, intermediate-sized streams. Because they are small, light, durable, and adaptable, they are preferred by hired observers and field people on routine or reconnaissance measurement trips. At many locations, a heavier sampler will be needed only for high-flow periods. It is often desirable, however, to require the observer to use a heavier sampler installed at a fixed location. The small size of the hand samplers also enables the person taking a sample in cold weather to warm the sampler readily if water freezes in the nozzle or air exhaust.

Cable-and-Reel Samplers—US D-74, US D-77, US P-61, US P-63, and US P-72

When streams cannot be waded, but are shallower than about 15 feet, depth-integrating samplers designated "D-74" and "D-77" can be used to obtain suspended-sediment samples. Forerunners of these samplers were the US D-43 and US D-49 samplers, both of which are no longer manufactured. These latter two are only mentioned here because many of these earlier designed instruments are still used at some locations. Sampling techniques for using the older samplers are identical to those presented later in this text relative to operation of the newer D-74 and D-77 samplers.

The D-74 (fig. 7) is a 62-pound sampler (approximately 40 pounds for the aluminum version) designed to be suspended from a bridge crane or cableway by means of a standard hanger bar and cable-and-reel system. This sampler replaces the earlier D-49, which replaced the D-43 for general use. The D-74 has a streamlined cast bronze (or aluminum) body 24 inches long that completely encloses the sample container. This sampler accommodates a round quart bottle, or with addition of an adapter sleeve, a standard pint milk bottle may be used. The sampler head is hinged at the bottom and swings downward to provide access to the sample-container chamber. In this manner, sample containers can be changed during the normal sampling

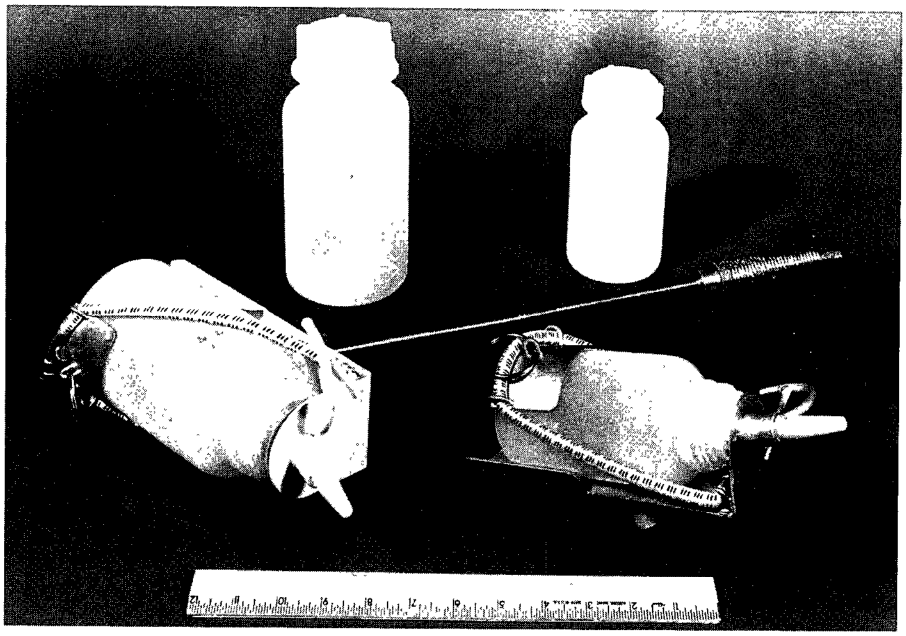


Figure 3. US DH-75 (P and Q) suspended-sediment samplers with sample containers and wading rod.

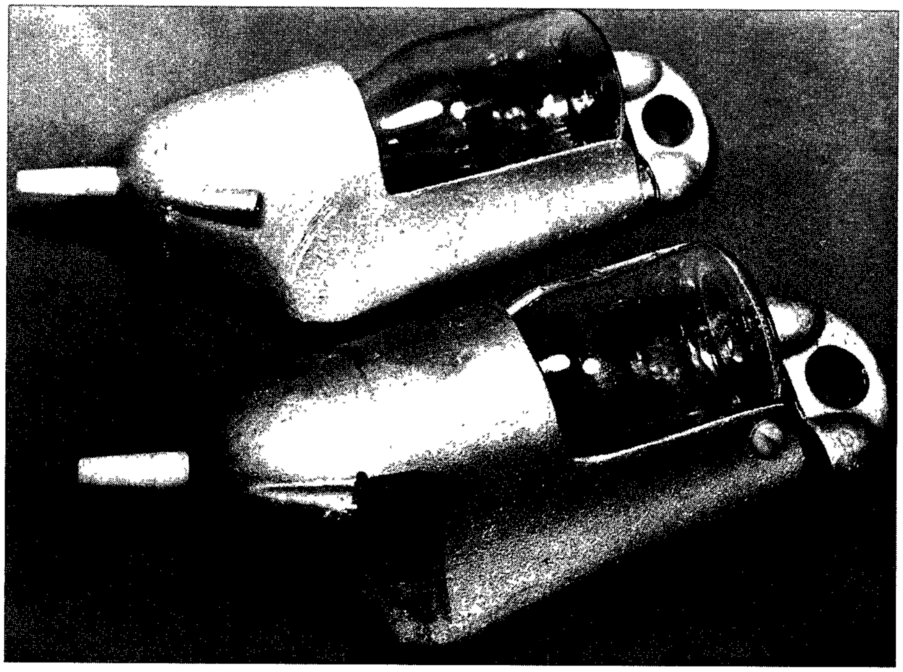


Figure 4. US DH-48 suspended-sediment sampler.

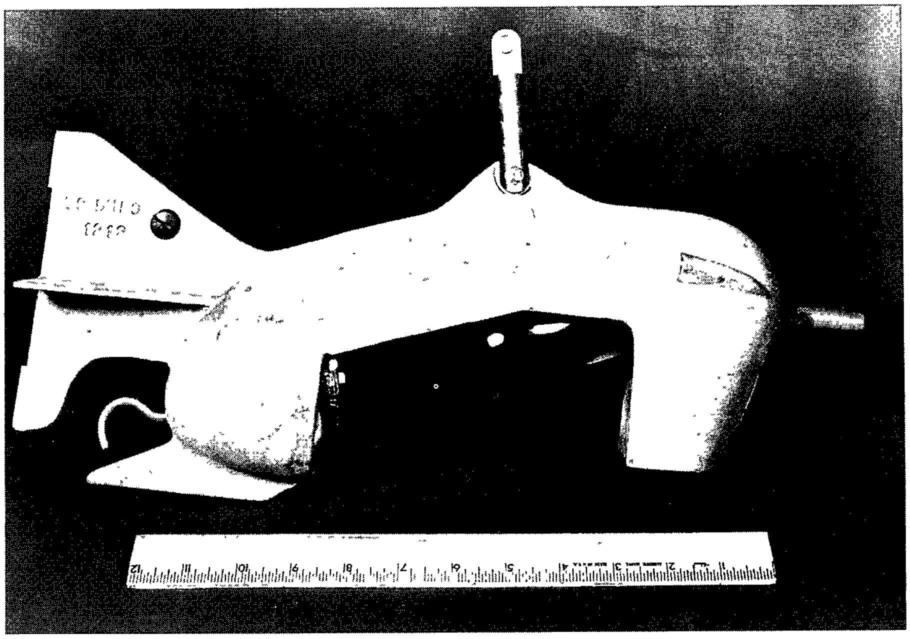


Figure 5. US DH-59 suspended-sediment sampler.

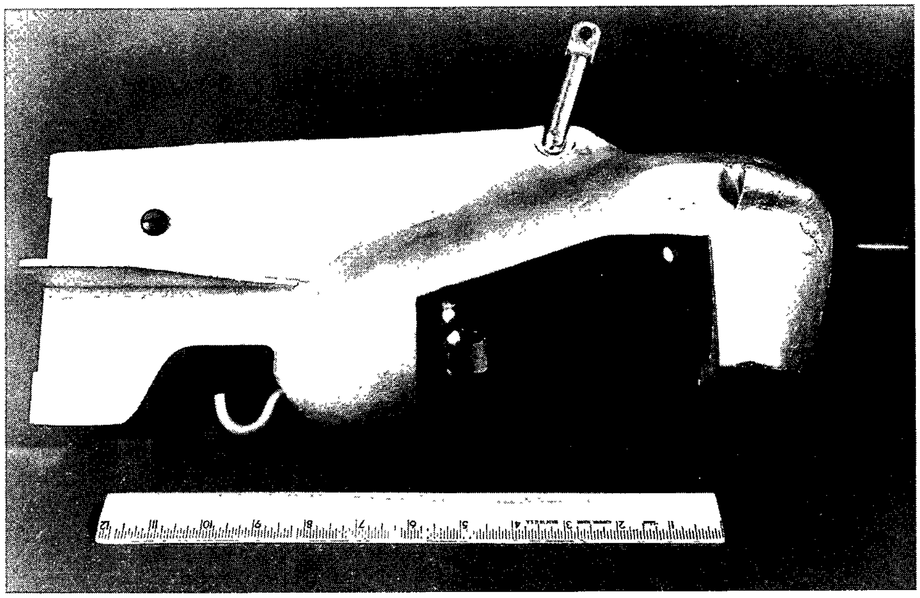


Figure 6. US DH-76 suspended-sediment sampler.

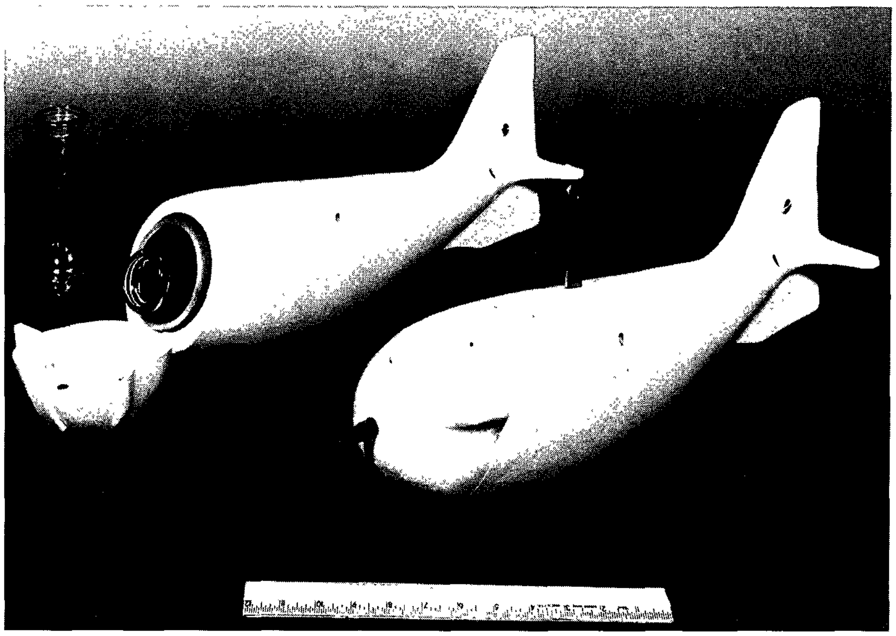


Figure 7. US D-74 suspended-sediment sampler.

routine. The body includes tail vanes that serve to align the sampler and the intake nozzle with the flow. Intake nozzles of 1/8-inch, 3/16-inch, and 1/4-inch diameters are available for use with the sampler and can be interchanged as varying flow conditions dictate. The sample container fills as a filament of water passes through the intake nozzle and displaces air from the container. The air is expelled in the downstream direction through an air-exhaust port in the side of the sampler head. The intake nozzle can be lowered to within about 4 inches of the streambed during sampling (approximately 4 1/3 inches for the aluminum version).

The D-77 is a dramatically different design (fig. 8) as compared to the design configuration of the D-74 and its predecessors. The sampler is 29 inches long and weighs 75 pounds; it has a bronze casting attached to a tail cone with four sheet-metal vanes welded in place to provide a means of orienting the intake nozzle into the flow. The casting is structured to accommodate a 3-liter autoclavable sample container that slides into the sample container chamber and is held in place by means of a spring clip on the bottom of the chamber. This sampler is constructed without a head assembly to cover the mouth of the container and facilitate attachment of the intake nozzle. Instead, a cap, nozzle, and air-exhaust assembly, constructed of autoclavable plastic, is screwed onto the mouth of the sample container, which is entirely exposed at the front of the sampler. This configuration was purposely chosen to allow collection of a large volume (2,700 mL), depth-integrated biological or chemical sample at near- or below-freezing temperatures. Although 1/8-inch, 1/4-inch, 3/16-inch, and 5/16-inch nozzles are available, only 5/16-inch nozzles are recommended for use with this sampler. The distance between the nozzle and sampler bottom is 7 inches.

A version of the D-77 sampler was tested by F.I.S.P. to eliminate the depth-range limit dictated by sample container size, nozzle size, and stream velocity (Federal Inter-Agency Sedimentation Project, 1982b). This version, commonly referred to as a "bag sampler," incorporates a sample bag inside a special rigid container. Information about this sampler and other bag samplers can be obtained from F.I.S.P.

Point-integrating samplers currently manufactured and widely used are the P-61, P-63, and P-72. Forerunners of these samplers were the P-46 and P-50 samplers, which are no longer manufactured but are mentioned here because several of these instruments are still used. The sampling techniques used for obtaining a sample with these older samplers are the same as for the newer samplers. The primary differences between these old and new versions are valve mechanisms and cost. The new versions have a simpler valve and are less expensive.

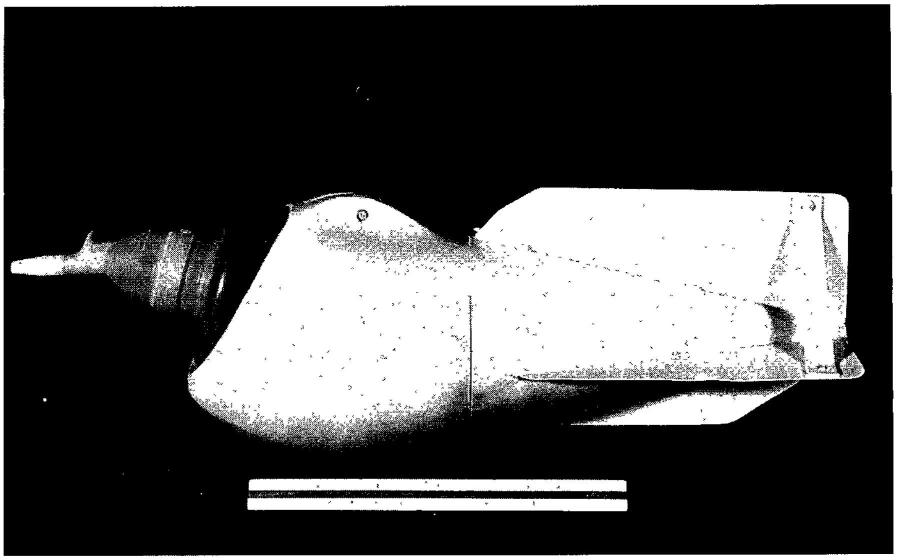


Figure 8. US D-77 suspended-sediment sampler.

The 105-pound P-61 (fig. 9) can be used for depth integration as well as for point integration to a maximum stream depth of 180 feet. The sampler valve for the P-61 has two positions. When the solenoid is not energized, the valve is in the nonsampling position, in which the intake and air-exhaust passages are closed, the air chamber in the body is connected to the cavity in the sampler head, and the head cavity is connected through the valve to the sample container. When the solenoid is energized, the valve is in the sampling position, in which the intake and air exhaust are open, and the connection from the sample container to the head cavity is closed. A P-61 sampler that has been modified to accommodate a quart bottle is illustrated in figure 9. When the ordinary pint bottle is used, the cylindrical adapter must be inserted into the bottle cavity. The maximum sampling depth is about 120 feet when the quart container is used.

The P-63 (fig. 10) is a 200-pound point-integrating suspended-sediment sampler and is better adapted to high velocities. The solenoid head is basically the same as that on the P-61. The P-63 differs from the P-61 mainly in size and weight. The P-63 is cast bronze, is 34 inches long, and has the capacity for a quart-sized round mayonnaise bottle. An adapter is furnished so that a round pint-sized milk bottle can be used. The maximum sampling depth is the same as for the P-61, about 180 feet with a pint sample container and about 120 feet with a quart container.

The 41-pound P-72 is a light-weight version of the P-61. It features a streamlined cast-aluminum shell rather than the bronze used to construct the P-61. The outward appearance of the P-72, the 3/16-inch intake nozzle, the solenoid head, and the accommodation for pint- and quart-sized containers are similar to the P-61. However, the listed maximum stream velocity at which the P-72 is recommended for use is 5.3 ft/s, as opposed to 6.6 ft/s for the P-61, and the depth limit to which this sampler should be used is about 72 feet using the pint container and 51 feet with the quart container. These depths are less than one-half of the maximum usable depths for the P-61 with the same container sizes.

All the point samplers are designed for suspension with a steel cable having an insulated inner conductor core. By pressing a switch located at the operator's station, the operating current may be supplied through the cable to the solenoid in the sampler head by storage batteries connected in series to produce 24 to 48 volts. If the suspension cable is longer than 100 feet, a higher voltage may be desirable. The US BP-76 battery pack has been designed as a portable power source for activating the P-61, P-63, and P-72 samplers and is available from the F.I.S.P. and HIF.

Because of the complex nature of point-integrating samplers, the user may find it necessary to seek additional information given in the Inter-Agency reports (Federal Inter-Agency Sedimentation Project, 1952, 1963b, and 1966).

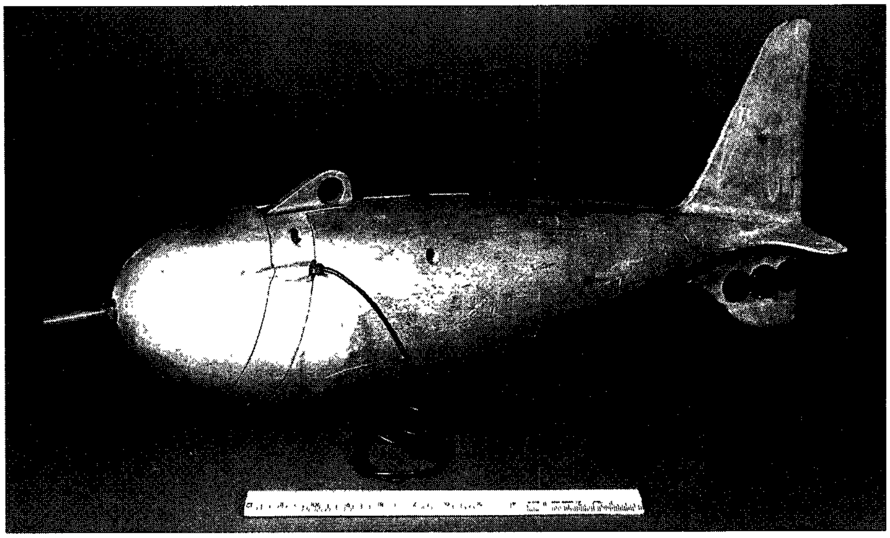


Figure 9. US P-61 point-integrating suspended-sediment sampler.

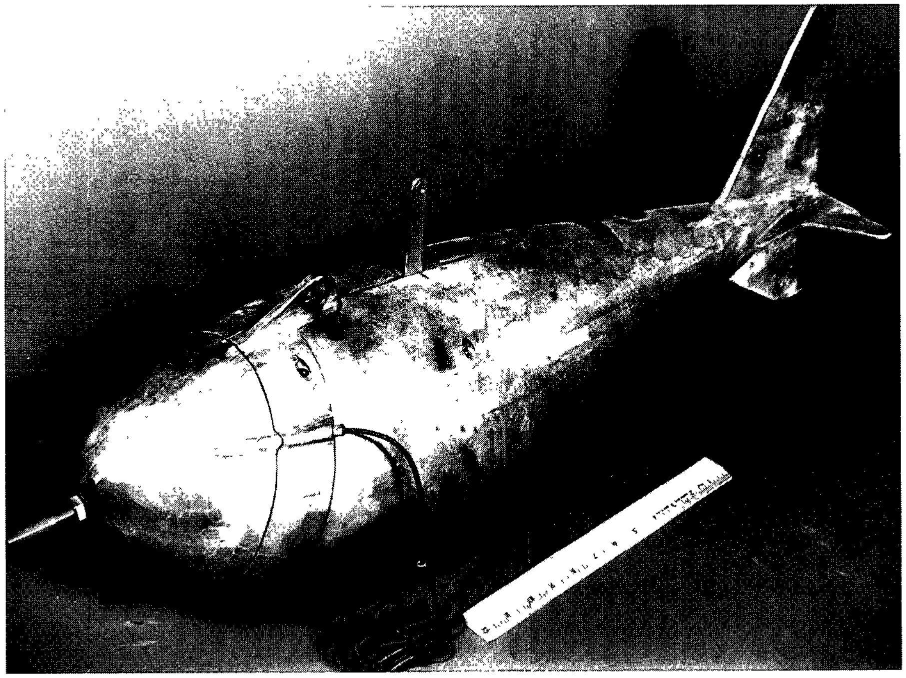


Figure 10. US P-63 point-integrating suspended-sediment sampler.

Sampler Accessories

Nozzles

Each suspended-sediment sampler is equipped with a set of nozzles specifically designed for the particular sampler. These nozzles are cut and shaped externally and internally to ensure that the velocity of water after entering the nozzle is within 8 percent of the ambient stream velocity when the stream velocity is greater than 1 ft/s. It has been found that a deviation in intake velocity from the stream velocity at the sampling point causes an error in the sediment concentration of the sample, especially for sand-sized particles. For example, a plus-10-percent error in sediment concentration is likely for particles of sediment 0.45 mm in diameter, when the intake velocity is 0.75 of the stream velocity (Federal Inter-Agency Sedimentation Project, 1941, p. 38–41). The relation between intake-velocity deviation and errors in concentration resulting from collecting a sample enriched or deficient in sand-size particles (greater than 0.062 mm) is illustrated by figure 11. When sand-size particles are entrained in

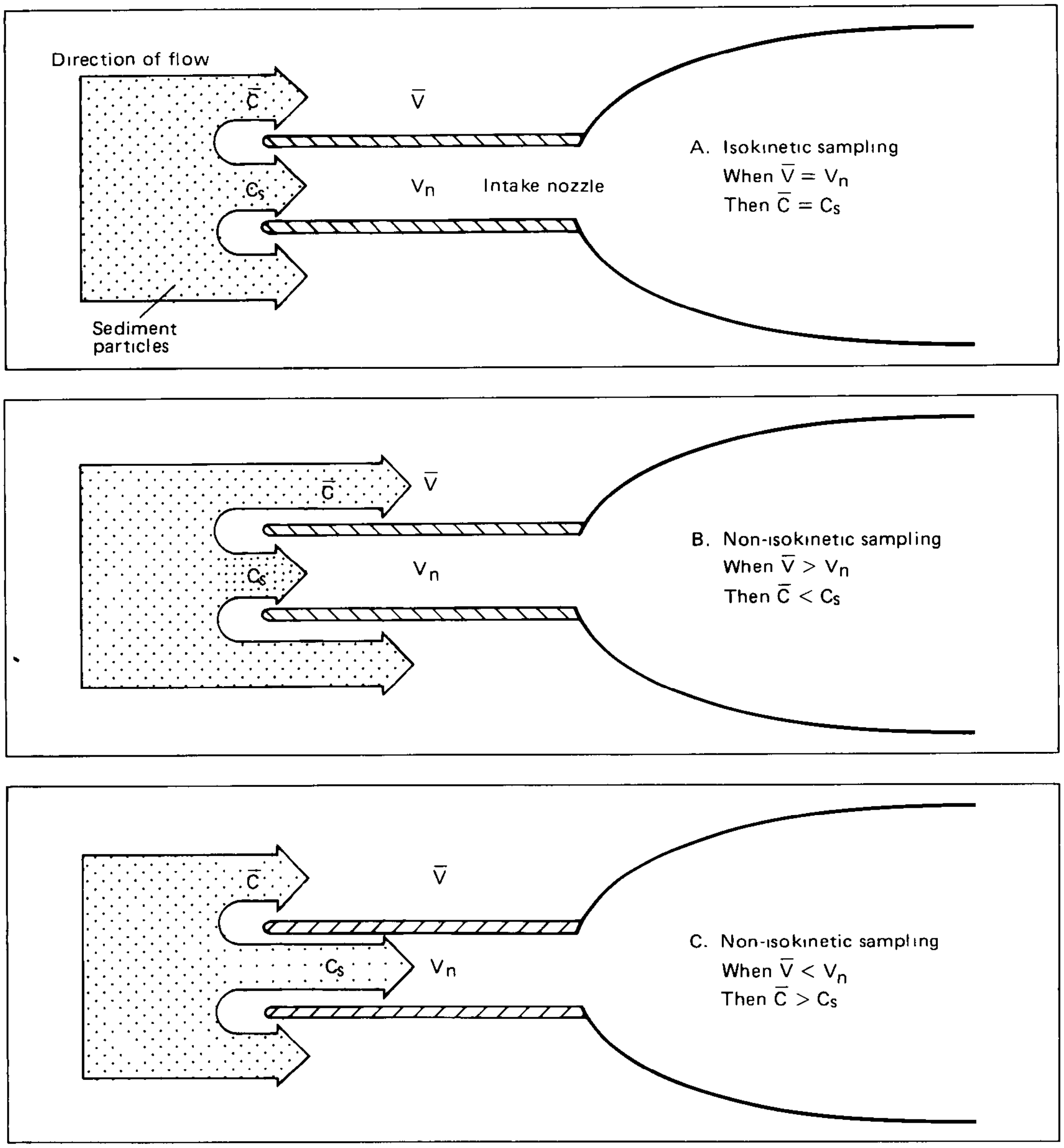


Figure 11. Relation between intake velocity and sample concentration for (*A*) isokinetic and (*B*, *C*) non-isokinetic sample collection of particles greater than 0.062 mm. When $\bar{V}$ = mean stream velocity, V_n = velocity in the sampler nozzle, $\bar{C}$ = mean sediment concentration in the stream, and C_s = sample sediment concentration.

the flow, the intake velocity within the sampler nozzle must be equal to the ambient stream velocity (isokinetic), in order to collect a sample representative of the mean discharge-weighted sediment concentration (fig. 11*A*). The resulting sediment concentration of the sample will be equal to the average discharge-weighted sediment concentration of the approaching flow. However, when the velocity in the nozzle is less than the stream velocity (non-isokinetic, fig. 11*B*), some water that should flow into the nozzle now curves to the side and flows around it. Inertia resists the curving flow and forces the approaching particles (greater than 0.062 mm) to follow straight-line paths into the nozzle. This combination of curved and straight-line movement increases the concentration of coarse particles in the sample. As a result, the sediment concentration in the sample is greater than the concentration in the approaching flow. Likewise, when the velocity in the nozzle is greater than the stream velocity (non-isokinetic, fig. 11*C*), some water that should flow past the nozzle curves to the side and flows into it. Again, inertia resists the curving flow and forces the particles (greater than 0.062 mm) to follow straight-line paths and flow past the nozzle. The result of this combination of curved and straight-line movement is a decrease in the sample concentration relative to the concentration of the approaching flow.

Because, in general, each sampler nozzle is designed for a particular series of samplers, it must be emphasized that a nozzle for one series of samplers should not be used in another series of samplers. However, there are two exceptions to this rule—the same nozzle can be used in the P-61, P-63, and P-72 series, and a nozzle can be interchanged between the D-49 and D-74. To ensure against incorrectly matching samplers and nozzles, all nozzles are color coded to specific sampler designs (table 1).

The reasons for the differences between the nozzles of different series are that (1) the length of flow paths for water and air are different, resulting in differences of flow resistance; and (2) the differential heads between the nozzle entrance and the air exhaust are different. Thus, interchanging nozzles among samplers of various series results generally in an incorrect intake velocity and, thus, incorrect sediment concentration and particle-size distribution in the sample. Therefore, when a nozzle is bent or broken, be certain to use a correct replacement nozzle.

If extra nozzles are needed for a sampler, they can be ordered from the F.I.S.P. at the address in the latest Inter-Agency report. The order must indicate the sampler series. If the exhaust tubes, tail fins, or any other part of a sampler are damaged, the entire sampler should be sent to the F.I.S.P. for repair and recalibration.

Three nozzle diameters—1/4 inch, 3/16 inch, and 1/8 inch—are available for use with all depth-integrating samplers, except for the DH-48, DH-75, D-77, and the point-integrating samplers. The D-77 sampler is the only depth-integrating sampler that uses a 5/16-inch nozzle. Although a nozzle may physically fit a sampler, the match may not be correct. For example, it is possible, but incorrect, to interchange any one of the 1/4-inch, 3/16-inch, and 1/8-inch nozzles listed in table 1 among the depth-integrating or point-integrating samplers. For instance, it is possible, but incorrect, to put DH-48 nozzles in DH-59 samplers. One exception is the D-77, which will not accept any nozzle other than the correct one. To help prevent the incorrect interchange of color-coded nozzles among samplers, new samplers ordered from F.I.S.P. are delivered with a color-coded plastic screw in the tail vane assembly, which indicates the correct color of nozzle to be used with the sampler (for example, DH-59 has a red screw and uses a red nozzle).

The reason for different size nozzles is that stream velocities and depths occur that will cause the sample bottle to overfill for a specific transit rate when using the largest nozzle. More specifically, for depth-integrating samplers with a pint bottle, the maximum theoretical sampling depths for round-trip integration are about 9 feet for the 1/4-inch, and 15 feet with both the 3/16-inch, and 1/8-inch nozzles. Therefore, to reduce the quantity of sample entering the bottle at depths over 9 feet, use a smaller bore nozzle in combination with a pint sample bottle. For a given situation, the largest nozzle should be used to reduce the chance of excluding large sand particles that may be in suspension.

Possible errors caused by using too small a nozzle are usually minor when dealing with fine material (less than 0.062 mm), but tend to increase in importance with increasing particle size. Small nozzles also are more likely than large ones to plug with organic material, sediment, and ice particles. This means that problems with nozzles can exist even when sampling streams transporting mostly fine material.

Point-integrating samplers are supplied only with a 3/16-inch nozzle to match the opening through the valve mechanism.

Gaskets

Of equal importance to using the correct nozzle in the instrument is the necessity for using the proper gasket to seal the bottle mouth sufficiently. Gaskets for this purpose are made of a sponge-like neoprene that deteriorates somewhat with use and time. When samples are being collected for water quality, such as for trace metal analysis, the gasket should be made of silicone rubber to avoid biasing the sample chemistry.

To check the gasket for adequate seal, insert a bottle in the proper position in the sampler; then block the air-exhaust port and force air into the sampler nozzle. **CAUTION**: A field person should never force air into the sampler by placing the mouth directly in contact with the nozzle—due to the possibility of questionable water quality at the site or the likelihood of receiving an electrical shock (if a brass nozzle is in use) upon activating the solenoid of a point-integrating sampler when opening the intake. A safe procedure to perform this check would be to block the air exhaust with a finger and place a short length of clean plastic or rubber tubing snugly over the nozzle and then apply air pressure by blowing into the tubing to force air through the nozzle. If air escapes around the bottle mouth, replace the gasket. If the problem persists, check the spring that pushes the bottle against the gasket. Each sampler series uses a different size or shape of gasket, so it is necessary to have spares for each series in use. Appropriate gaskets may be obtained from the F.I.S.P. (address can be obtained from the latest Inter-Agency report). Gaskets in the "P" series samplers also may be tested by lowering the sampler, with sample bottle in place, into the stream without opening the solenoid. After a minute or so, raise the sampler to the surface and inspect the sample bottle. If the gasket is sealing properly, less than a few milliliters of water should be present in the bottle.

Bottles

Depth- and point-integrating samplers accommodate different bottle sizes and types (fig. 12). Many field people still use pint glass milk bottles, which have been used for many years and can be adapted to every sampler series with the exception of the DH-81 and D-77. Quart-sized glass mayonnaise bottles (Owens-Illinois #6762) are increasing in general use because versions of all samplers, except the DH-48 and D-77, use this size sample container. The D-77

Figure 12. Sample containers to fit PS-69 pumping sampler (left to right): pint glass milk bottle, quart glass mayonnaise bottle, and quart plastic container to fit the PS-69 pumping sampler.

sampler holds a 3-liter plastic autoclavable bottle with standard mason jar threads (Nalge 2115-3000); the DH-81 holds any bottle with standard mason jar threads; and the DH-75 holds a plastic bottle (Bel-Art #F-10906, 1,000 mL) and a variety of other quart/liter bottles. Ideally, each type of glass bottle should have an etched surface to provide a labeling area to accommodate a record of pertinent information concerning each sample. Hydrofluoric acid has been used for this purpose, but care must be exercised when handling and storing this substance. In the past, commercial etching agents have been available for general use. However, the authors do not know of any such agent that is available at this time. This etched labeling surface should easily accept medium-soft blue or black pencil markings of sufficient durability to withstand handling and yet be easily removed during cleaning. Plastic bottles also require an area for labeling. However, this is less of a problem because a grease pencil or other marker that is not readily soluble in water, but that can be removed using a solvent, can be used to write on the side of the bottle.

The practice of using plain bottles with attached tags or marked caps for recording purposes should be avoided whenever possible. These labeling areas are generally small and provide little writing space. Additionally, the use of these labeling devices can result in tags being torn off during transport or in bottles being mislabeled by interchanging caps.

Plastic and teflon bottles are increasing in use throughout the Water Resources Division of the USGS. Several samplers have been designed to use plastic sample containers (the DH-75 series, the DH-81 and D-77 samplers). Compared to glass, these bottles are lightweight, strong, and useful when sampling for certain chemicals.

During depth integration, a collapsible bottle or bag would be the ideal arrangement to eliminate the problem of depth limitation due to the size of the sample container. Depth-integrating samplers incorporating this collapsible sample bag/bottle concept, are currently under development by F.I.S.P.

Bottles are usually stored and transported in wire, wooden, fiberboard, or plastic cases holding 12 to 30 bottles each. In the field, a small bottle carrier, which holds 6, 8, or 10 bottles, is more convenient; eliminates the need to handle the heavier 12- to 30-bottle cases while making a measurement; and provides a neat, convenient, and relatively safe place to set the bottles. When making wading measurements, both hands can be free to operate the sampler if the bottle carrier is suspended from the shoulder with a strap or rope.

Single-Stage Samplers

The single-stage samplers, US U-59 (fig. 13), also designated US SS-59, and US U-73, were designed and tested by the F.I.S.P. to meet the needs for instruments useful in obtaining sediment data on streams where remoteness of site location and rapid changes in stage make it impractical to use a conventional depth-integrating sampler.

The U-59 (SS-59) consists of a pint milk bottle or other sample container, a 3/16-inch inside diameter air exhaust, and 3/16-inch or 1/4-inch inside diameter intake constructed of copper tubing. Each tube is bent to an appropriate shape and inserted through a stopper

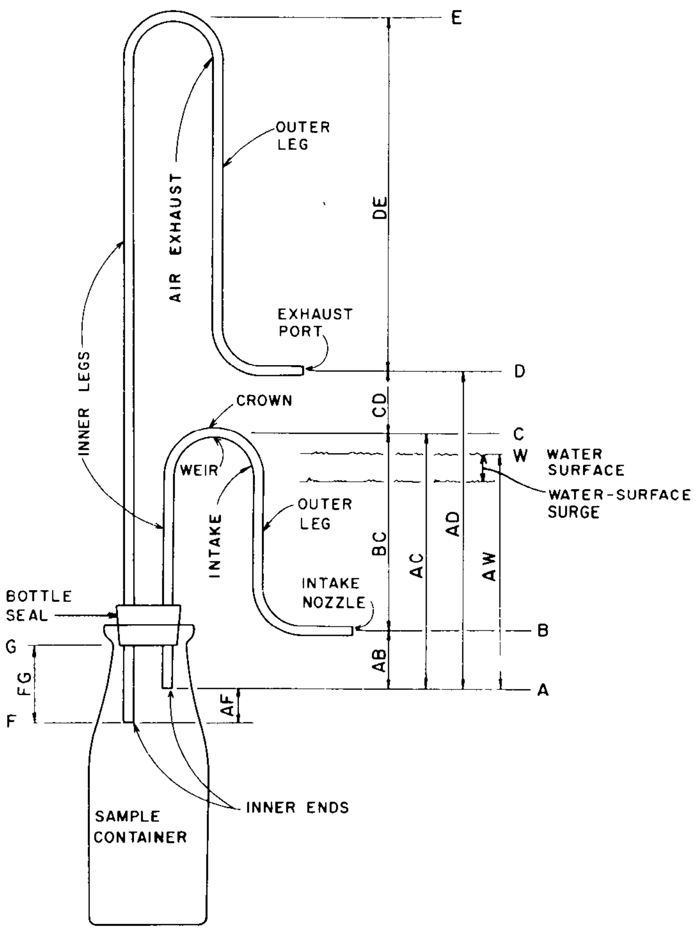


Figure 13. US U-59 single-stage suspended-sediment sampler. Sampling operation using designated letters is described in text (see also Federal Inter-Agency Sedimentation Project, 1961).

sized to fit and seal the mouth of the sample container. There are two general types of this sampler, one with a vertical intake and the other with a horizontal intake. The horizontal-intake type is further divided into three versions, each distinguished from the others by the height of the intake and air-exhaust tubes. Under some conditions either type could be used, but the two are not always interchangeable.

The vertical-intake sampler is used to sample streams carrying sediments finer than 0.062 mm. The vertical-intake sampler has the advantage of somewhat less tendency to fouling by debris and deposits of sediment in the intake nozzle than does the horizontal type of intake. Conversely, the horizontal-intake sampler should be used to sample streams carrying a considerable amount of sediment coarser than 0.062 mm.

The basic sampling operation of the instrument when velocities and turbulences are small is described by F.I.S.P. (1961, p. 17):

> When the stream surface rises to B, the elevation of the intake nozzle, the water-sediment mixture enters; and as the water surface continues to rise in the stream, it also rises in the intake. (The general elevation and dimensions are expressed without regard to the inside diameter of the tube or without distinction between the weir and the crown of the siphon.) When the water-surface elevation W reaches C, flow starts over the weir of the siphon, primes the siphon, and begins to fill the sample bottle under the head AC.
>
> Filling continues until the sample rises to F in the bottle, and water is forced up the air exhaust to the elevation W. Actually the momentum of flow in the tubes causes a momentary rise above W in the air exhaust. Water drains out of the inner leg of the intake. When the stream rises to D, air is trapped in the air exhaust. As long as sufficient air remains in the tubes, no flow can pass through to alter the original sample unless a differential head that exceeds the height of invert is built up. (If the legs of an invert are not symmetrical, the inverts have different effective air-trap heights resisting flow into and out of the bottle.) For conditions without significant surge and velocity effects at the intake nozzle or exhaust port, the heights BC and DE may be small.
>
> If, after the normal time of sampling, the depth of submergence over the sample bottle increases, the air in the bottle is compressed, and a small additional sample enters the bottle. This additional sample will enter through the tube having the smallest height of invert. Under variable submergence, the entrance of water will compress the air in the bottle on rising stages, and some expanding air will escape on falling stages; thus the quantity of air in the bottle becomes less and less, and the water rises in the bottle.

The sampling operation just described is somewhat idealistic because, in reality, the operation is affected by the flow velocity and turbulence, which alter the effective pressure at the nozzle entrance.

The U-59 has many limitations with respect to good sampling objectives. It must be considered a type of point sampler because it samples a single point in the stream at whatever stage the intake nozzle is positioned before a flow event occurs. Its primary purpose is to collect a sample automatically, and it is used at stations on flashy streams or other locations where extreme difficulty is encountered in trying to reach a station to manually collect samples. Besides being automatic, it is inexpensive; a "battery" of them can be used to obtain a sample at several elevations or times during the rising hydrograph. However, despite these seemingly important advantages, the U-59 has many limitations. Following are the most important:

1. Samples are collected at or near the stream surface, so that, in the analysis of the data, theoretical adjustments for vertical distribution of sediment concentration or size are necessary.
2. Samples are usually obtained near the edge of the stream or near a pier or abutment; therefore, theoretical adjustments for lateral variations in sediment distribution are required.
3. Even though several combinations of size, shape, and orientation of intake and air-exhaust tubes are available, the installed system may not result in intake ratios sufficiently close to unity to sample sands accurately for a specific runoff event.
4. Covers or other protection from trash, drift, and vandalism often create unnatural flow lines at the point of sampling.
5. Water from condensation may accumulate in the sample container prior to sampling.
6. Sometimes the sediment content of the sample changes during subsequent submergence.
7. The device is not adapted to sampling on falling stages or on secondary rises.
8. No specific sampler design is best for all stream conditions.
9. The time and gage height at which a sample was taken may be uncertain.
10. Under high velocities, circulation of flow into the intake nozzle and out the air exhaust can occur. This will increase the concentration of coarse material in the sample and can make the sample concentration several orders of magnitude higher than stream concentration.

To cover a wide range of operating conditions, four "standard" models of the U-59 are available. The many specific details of these are further described in F.I.S.P. (1961).

Before a bank of the U-59 samplers can be designed and installed, it is necessary to have some knowledge of the seasonal stage characteristics of the stream so that several samples can be obtained for a given storm event and throughout the season. The stream stage and flow-velocity characteristics not only affect the design with respect to the vertical spacing of the samplers, but also the support necessary for the bank of samplers.

The U-73 (fig. 14) is a more sophisticated single-stage sampling device. The sampler's design configuration solves several of the problems characteristic of the U-59. Specifically, this sampler (1) can be used to sample either a rising or falling stage, (2) has no problem of condensation in the sample container before the spring-loaded stoppers are tripped, and (3) features an exterior design that allows for a degree of protection from trash or drift without additional covers or deflection shields. Aside from these few advantages, the U-73 has the same limitations and should be used under the same conditions as the U-59.

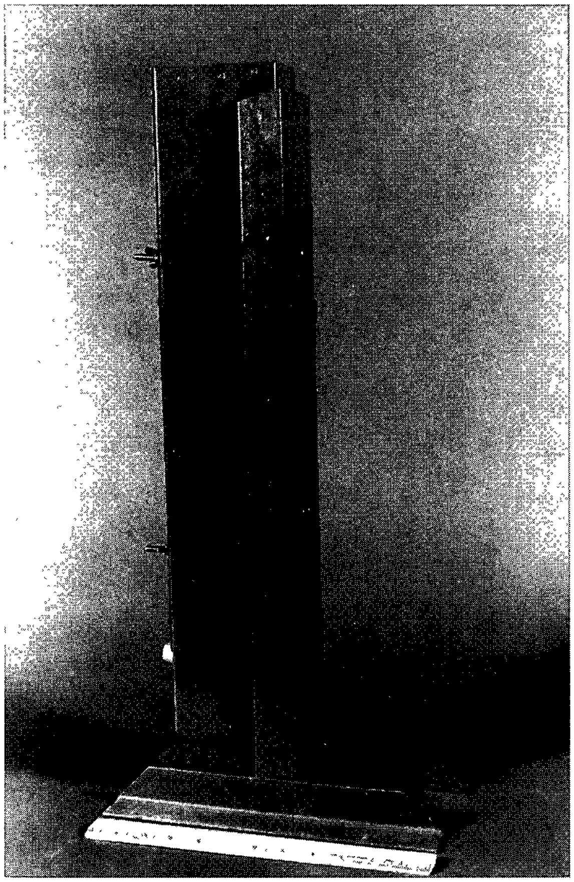


Figure 14. US U-73 single-stage suspended-sediment sampler.

The investigator using either the U-59 or U-73 may find protective measures necessary to avoid blockage of intakes or air exhausts due to nesting insects. In freezing climates, precaution may be warranted against sample-container breakage due to expansion of a freezing sample. Samples for water-quality analysis can be collected using the U-73-TM version of the U-73. However, do not use insecticides or antifreeze solutions if samples are to be analyzed for water quality because these will obviously contaminate the sample.

Bed-Material Samplers

Limitations

To properly sample bed material for interpretation, it is first necessary to establish what constitutes bed material and understand its relation to transported load, especially to bedload. Bedload is best defined as sediment that moves by sliding, rolling, or bouncing along on or near the streambed (Hubbell, 1964; Leopold and others, 1964; Emmett, 1980a). Bed material, on the other hand, is best defined in the Office of Water Data Coordination (1978) National Handbook, chapter 3, p. 3–5, which describes bed material as "the sediment mixture of which the bed is composed." In alluvial streams, bed-material particles are likely to be moved at any moment or during some future flow conditions. From the perspective of Leopold and others (1964), the streambed is composed of two elements, distinguished one from the other by particle size and their reaction to stream velocity. The first element consists of particles frequently transported as part of the suspended load or bedload, but considered as bed material when at rest. The second element consists of particles and aggregates of particles that compose definite structures on the streambed and reside there indefinitely or at least for long periods of time. The size fractions comprising the second element may only be moved by the most extreme flow events during which streambed erosion and scour occur.

The samplers described in this section can only accommodate bed material consisting of particles finer than about 30 or 40 mm in diameter. These bed-material samplers cannot accurately collect representative samples of particles larger than 16 mm, however. As noted in the description of individual samplers, there also may be limitations with respect to some very fine sediments because of poor sealing of the sampler after collection. This limits bed-material sampling, with standard US type samplers, to fine material that might be transported in suspension or as bedload at higher flows. The collection and analysis of material larger than coarse gravel are more difficult and costly because other techniques are required to handle heavy samples. Due to this difficulty in collecting large particle sizes, little information regarding bed-material size distribution is available for streams having gravel, cobble, and boulder beds. Therefore, much of the equipment for measurement of large bed material is of an experimental nature, and standard equipment for sampling large particles is unavailable. The interested investigator is directed to several references on direct and indirect methods of sampling and analysis of coarse bed materials, however, and is encouraged to contact Chief, Office of Surface Water, Reston, Virginia, or the F.I.S.P. for information (Lane and Carlson, 1953; Kellerhals, 1967; Wolman, 1954).

Hand-Held Samplers—US BMH-53, US BMH-60, and US BMH-80

Three types of instruments for hand sampling of bed material finer than medium gravel have been developed for general use. The BMH-53 (fig. 15) is designed to sample bed material in wadable streams. The instrument is 46 inches long and is made of corrosion-resistant materials. The sample container is a stainless-steel thin-walled cylinder 2 inches in diameter and 8 inches long with a tight-fitting brass piston. The piston is held in position by a rod that passes through the handle to the opposite end. The piston creates a partial vacuum above the material being sampled. This vacuum aids in overcoming the frictional resistance required to force the sampler into the bed. When sampling fine-grained material, this partial vacuum also aids in retaining the shallow core in the cylinder when the sampler is removed from the bed. The piston then serves to remove the sample from the cylinder by forcing it downward toward the bottom of the cylinder. In soft cohesive beds, this technique generally provides shallow cores with a minimum of distortion, from which sediment variations with depth and subsamples can be obtained. (See Federal Inter-Agency Sedimentation Project, 1963b and 1966, for more detailed information.) A version of this sampler, developed by the F.I.S.P. incorporates a “core catcher”

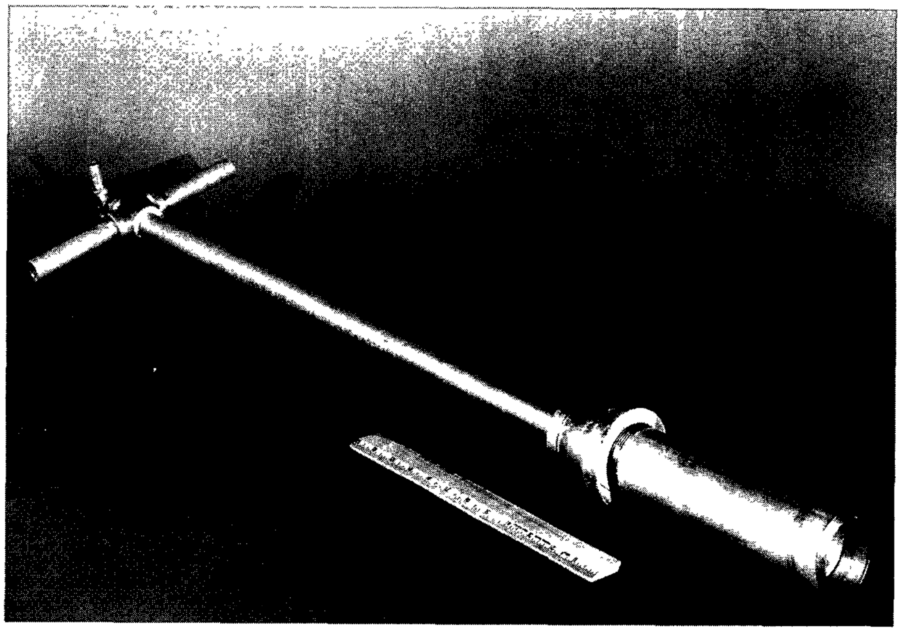


Figure 15. US BMH-53 bed-material sampler.

mechanism in the cylinder to retain samples containing a high percentage of sand.

The bed material of some wadable streams or lakes can be sampled with the US BMH-60 (fig. 16). This handline sampler is about 22 inches long, is made of cast aluminum, and weighs 30 pounds. Because of its light weight, it is useful only in streams of moderate depths and velocities. The bed material must be moderately firm and contain little or no gravel.

The sampler mechanism of the US BMH-60 consists of a scoop or bucket driven by a constant-torque spring that rotates the bucket from front to back. The scoop, when activated by release of tension on the hanger rod, can penetrate into the bed about 1.7 inches and can hold approximately 175 cubic centimeters of material. The scoop is aided in penetration of the bed by extra weight in the sampler nose. To cock the bucket into an open position for sampling (that is, retract it into the body), the sampler must first be supported by the handline, then the bucket can be rotated (back to front) with an allen wrench to an open cocked position.

The hanger rod to which the handline is attached is grooved so that a safety yoke can be placed in position to maintain tension on the hanger rod assembly. **CAUTION**: At no time should the hand or fingers be placed in the bucket opening because the bucket may accidentally close with sufficient force to cause permanent injury! A piece of wood or a brush can be used to remove any material adhering to the inside of the sample bucket. (See Federal Inter-Agency Sedimentation Project, 1963b and 1966, for more detailed information.)

After the safety yoke is removed, the bucket closes when tension on the handline is released, which occurs as the sampler strikes the streambed. A gasket on the closure plate prevents sampled material from being contaminated or being washed from the bucket.

Another bed-material hand-sampling instrument available for general use is designated BMH-80 (fig. 17). This sampler is 56 inches in total length and is used to sample the bed of wadable streams. The sampling mechanism is a semi-cylindrical bucket, resembling the BMH-60 bucket assembly, which is operated by positioning the lever on the handle to open or close the bucket. When the bucket is closed and a sample volume of approximately 175 cubic centimeters of bed material is captured, the closure is sufficiently sealed to prevent erosion of the sample while the instrument is lifted through the water column.

An additional handline sampler, used successfully for bed-material chemistry sampling on the Willamette and Columbia Rivers in Oregon, is the Ponar sampler.

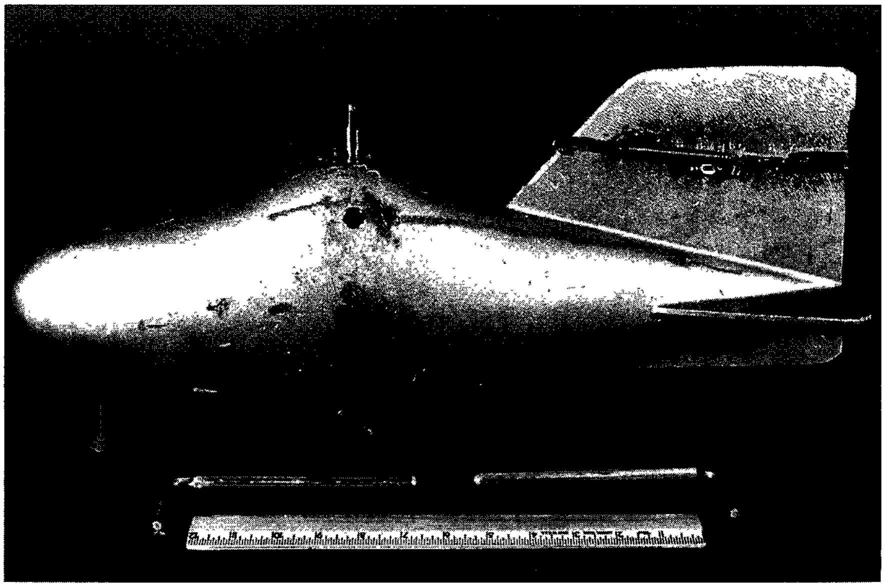


Figure 16. US BMH-60 bed-material sampler.

This is a clam-shell type sampler, consisting of two quarter-cylinder sections hinged together at the top. The sampler, which is constructed of galvanized or stainless steel, weighs about 25 pounds and can be suspended on a handline. The jaws of the instrument are held in the open position by a system of solid-notched bars and by the downward force created by the weight of the sampler on the suspension line. Gravity provides the necessary force for bottom penetration during sampling. The solid-notched bars holding the sampler jaws open are released when the downward force of the sampler's weight is released from the suspension line as the sampler strikes the bed. The sampler then closes as an upward force is applied to lift the sampler with the captured sediment. This sampler is particularly effective where bottom sediments consist of unconsolidated fines with no armoring present. Under these conditions, bottom penetration is 6 to 8 inches, resulting in a sample volume range of 8,000 cubic centimeters to 10,000 cubic centimeters of material. Some protection against erosion of the captured sediment is provided by an overlapping lip on the bottom and sides. However, a watertight seal does not exist, so care must be exercised when raising the sampler to the surface.

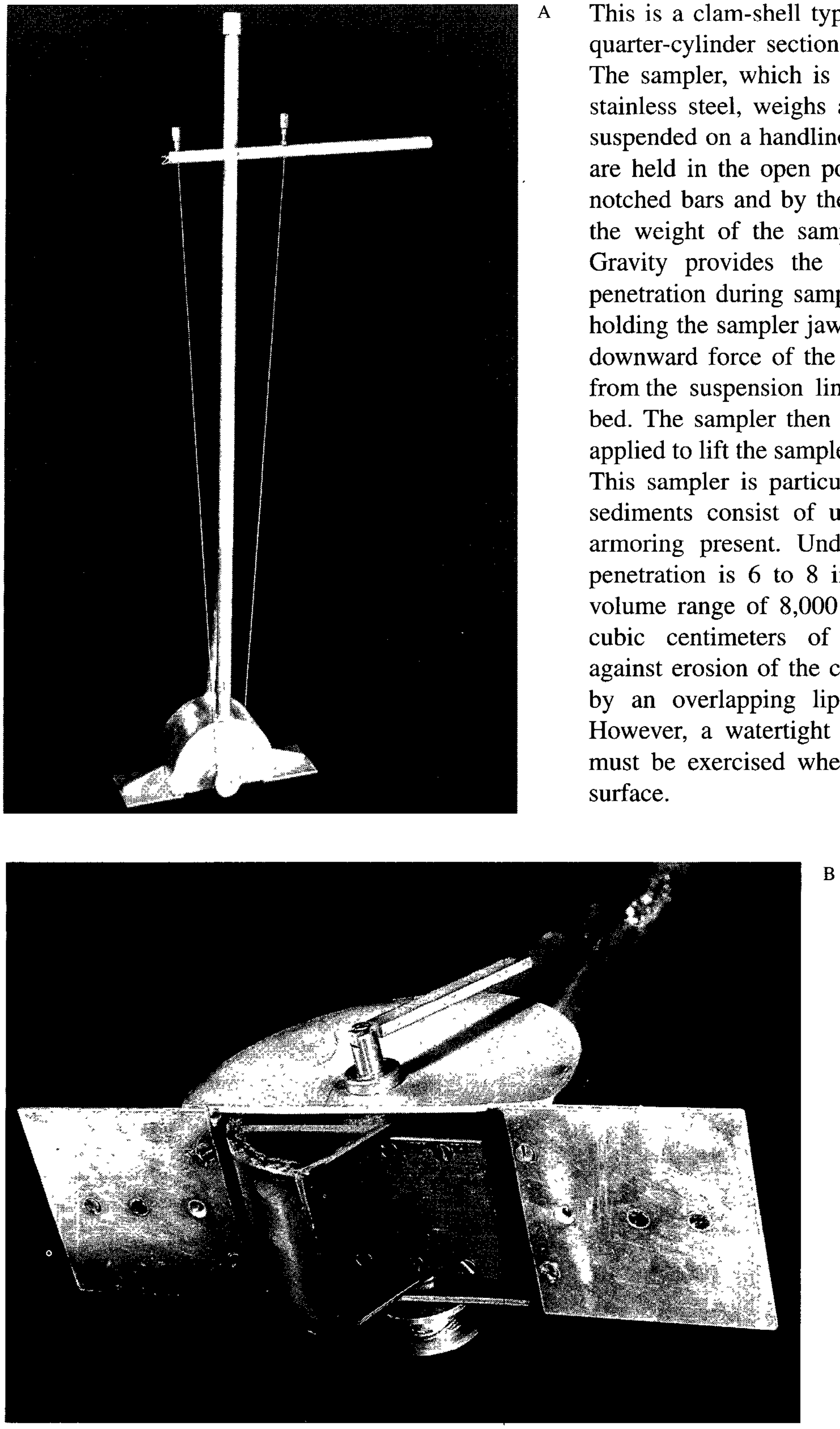


Figure 17. US BMH-80 rotary-scoop bed-material sampler. *A*, complete hand-sampling instrument (approximately 5 feet tall). *B*, Rotary-scoop assembly (approximately 12 inches long).

Cable-and-Reel Sampler—US BM-54

The 100-pound cable-and-reel suspended BM-54 sampler (fig. 18) can be used for sampling bed material of streams and lakes of any reasonable depth, except for streams with extremely high velocities. The body of the BM-54 is cast steel. Its physical configuration is similar to the cast aluminum BMH-60, 22 inches long and with tail vanes. Its operation also is similar to the BMH-60 in that it takes a sample when tension on the cable is released as the sampler touches the bed. The sampling mechanism externally looks similar to that of the BMH-60, but its operation is somewhat different.

The driving force of the bucket comes not from a constant-torque spring, but rather from a conventional coil-type spring. The tension on the spring is adjusted by the nut-and-bolt assembly protruding from the front of the sampler. The spring is powerful enough to obtain a sample from a bed of very compacted sand. It is suggested that the tension on the spring be released during extended periods of idleness even though the bucket is closed. Maximum tension need be used only when the streambed is very firm. Unlike the BMH-60, the spring and cable assembly rotates the bucket from the back to the front of the sampler. The trapped sample is kept from washing out by a rubber gasket. (See Federal Inter-Agency Sedimentation Project, 1963b, 1964, and 1966, for more complete description and details.)

BM-54 samplers obtained after 1956 are equipped with a safety mechanism similar to the safety yoke used on the BMH-60. This safety bar can be rotated over the cutting edge of the sample bucket when cocked into the open position. The bar keeps the bucket open when in the safety position, even if there is no tension on the hanger bar. As with the BMH-60, the cable tension on the catch mechanism holds the bucket open while the sampler is lowered. Safety bars can be obtained from F.I.S.P. and should be installed on any unit that does not have one. Again, personnel operating these samplers are cautioned to KEEP ONE'S HANDS AWAY FROM THE BUCKET CAVITY EVEN IF A SAFETY BAR IS IN USE. The power of the bucket is demonstrated by the fact that upon release, it has been observed to lift the 100-pound sampler from a hard surface.

A bed-material sampler incorporating the heavy streamlined body of the P-61 sampler and the spring-driven bucket of the BM-54 has been developed (C.W. O'Neal, Federal Inter-Agency Sedimentation Project, written commun., 1998). This sampler, the BM-84, is intended for use in large, swift rivers.

Prych and Hubbell (1966) developed a core sampler for use in deep flowing water in studies of the Columbia River estuary. This cable-suspended

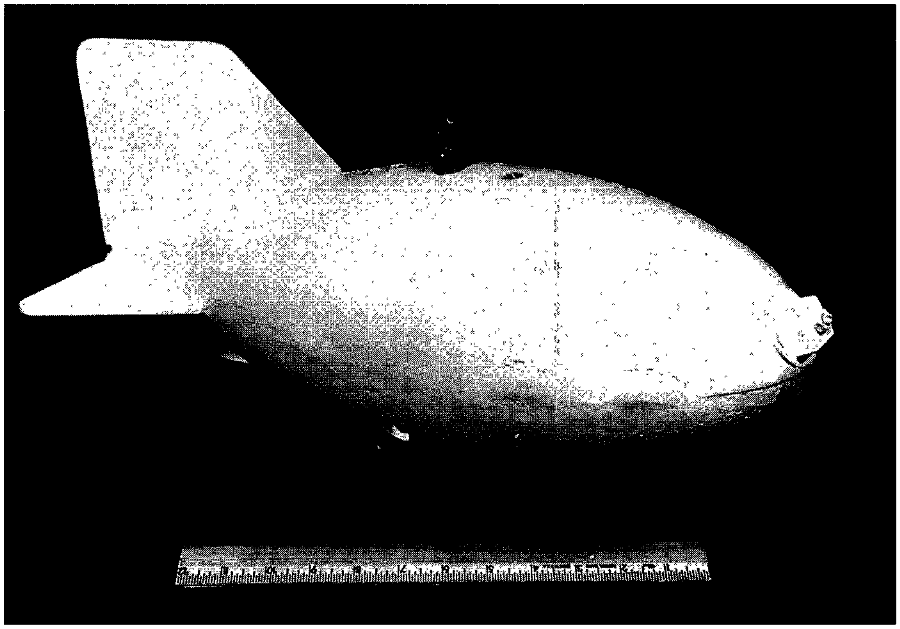


Figure 18. US BM-54 bed-material sampler.

sampler (fig. 19) is used to collect a 1 7/8-inch diameter by 6-foot-long core, by means of the combined action of vibration, suction, and an axial force derived through cables connected to a 250-pound streamlined stabilizing weight that rests on the streambed.

Smaller estuaries along the Oregon coast and other places have been successfully sampled using the Gravity Corer available from Benthos, Inc. This sampler is allowed to plunge to the bottom where, under the force of the gravitational pull on the sampler coupled with the momentum of its 250-pound total weight, it can penetrate up to 5 feet deep in soft bed material. However, much less penetration can be expected if the bed material consists of sand or gravel. The sampler is retrieved from the bed using a cable-reel boom assembly. The 2 5/8-inch diameter by 5-foot long core is retained in a core liner held in place by a core catcher at the bottom and protected against sample washout by a watertight valve at the top. The length of core and depth of penetration depend upon the degree of hardness of the bed being sampled. Other slightly more crude devices have been used with some success to sample bed material and thus deserve mention here. The two most notable of these devices are (1) the pipe dredge, which is lowered to the streambed and dragged a short distance to collect a sample; and (2) the "can on a stick" sampler, consisting of a rod with a scoop connected to the end, which can be used in wadable streams by lowering it to the streambed and scooping bed material from the bottom.

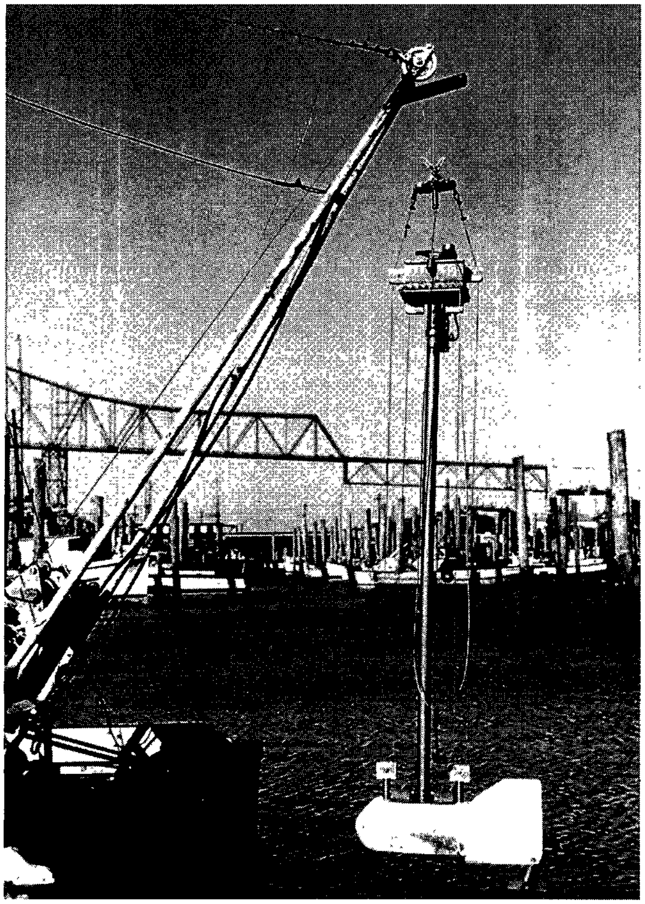


Figure 19. Vibra-core sampler prepared for coring (barrel approximately 5 feet long). From Prych and Hubbell (1966, plate 1).

Bedload Samplers

At this time, the reader should note the difference between bedload and unmeasured sediment. Remember from the bed-material section that bedload is the sediment that moves by sliding, rolling, or bouncing along on or very near the streambed. Unsampled sediment is comprised of bedload particles and particles in suspension in the flow below the sampling zone of the suspended-sediment samplers (fig. 1).

Bedload is difficult to measure for several reasons. Any device placed on or near the bed may disturb the flow and rate of bedload movement. More importantly, bedload transport rate and the velocity of water close to the bed vary considerably with respect to both space and time. Therefore, any sample obtained at a given point may not be representative of the mean transport rate for a reasonable interval of time because the bed particles move intermittently at a mean velocity much less than that of the water. Thus, a bedload sampler must be able to representatively sample, directly or indirectly, the mass or volume of particles moving along the bed through a given width in a specified period of time if bedload discharge is to be accurately determined.

Prior to 1940, most bedload was measured using some type of direct-collecting sampler. Bedload samplers developed during this era can be grouped into four categories: (1) box or basket, (2) pan or tray, (3) pressure difference, and (4) slot or pit samplers (Hubbell, 1964). Essentially, box or basket samplers consist of a heavy open-front box or basket apparatus, which is lowered to the streambed and positioned to allow collection of bedload particles as they migrate downstream. The basket type, displaying various sampling efficiencies, has been used preferentially over box types. Pan or tray samplers consist of an entrance ramp leading to a slotted or partitioned box. These samplers also have varying sampling efficiencies. Pressure-difference samplers are designed to create a pressure drop at the sampler's exit and thus maintain entrance velocities approximately equal to the ambient stream velocity. Sampling efficiencies may be higher with this type of sampler than with others, and the deposition of sediments at the sampler entrance, inherent with basket or tray samplers, is eliminated. The best known early pressure-difference sampler is probably the Arnhem or Dutch sampler, after which the Helley-Smith bedload sampler is designed. Ideally, the best measurement of bedload would occur when all of the bedload moving through a given width during a specific time period was measured. The category of samplers that most closely meet this ideal is the slot or pit sampler. This type of sampler has efficiencies close to 100 percent. The slot openings of these pits are 100- to 200-grain diameters wide to ensure the high sampling efficiency. However, samples collected in the pits are removed only with great difficulty or by use of an elaborate conveyor device. A variation of this technique, consisting of a collection trough accessed by a series of hydraulically operated gates, extends from bank to bank at a site on the East Fork River, near Pinedale, Wyoming (Emmett, 1980a). Sediment trapped in the trough during sampling is removed by means of a continuous conveyor belt, which carries the sample to a weighing station on the stream bank.

The original Helley-Smith bedload sampler, introduced in 1971, was a variation of the Arnhem pressure-difference sampler. This sampler consists of an expanding nozzle, sample bag, and frame (fig. 20). The sampler design enables collection of particle sizes less than 76 mm at mean velocities to 9.8 ft/s. The sampler has a 3-inch by 3-inch square entrance nozzle, an area ratio (ratio of nozzle exit to entrance area) of 3.22, and a 295-square-inch polyester mesh sample bag that is 18 inches long with mesh openings of varying sizes (0.25 mm most commonly used), attached to the rear of the nozzle assembly with a rubber "O" ring. The total weight of the original sampler design is 66 pounds, requiring the use of a cable-reel suspension system. However, a lighter version incorporating a wading rod assembly also is available. Heavier versions weighing 99 pounds, 165 pounds, and 550 pounds (used on the Amazon River) have been used by USGS personnel (Emmett, 1980a). A scaled-up version of the sampler having a 6-inch by 6-inch square entrance has been used to sample streams with large particle sizes.

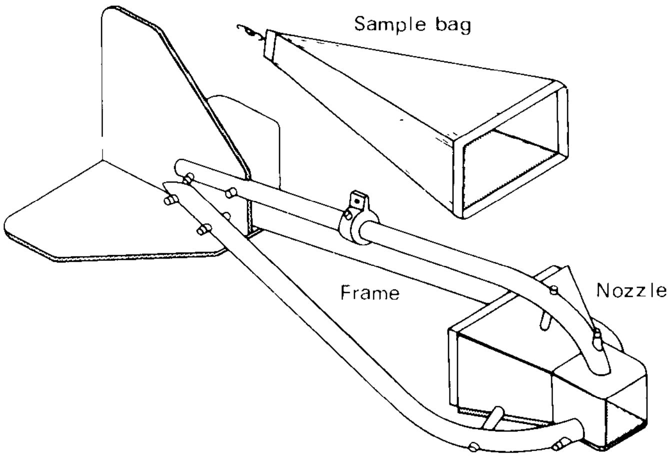


Figure 20. Helley-Smith bedload sampler. From Emmett (1980a, p. 2).

The standard 3-inch by 3-inch sampler has been calibrated in two different laboratory studies and in an extensive field study. Results of one laboratory study (Helley and Smith, 1971) indicated an average sampling efficiency of about 160 percent. Emmett (1980a) concluded from his field study that the overall sampling efficiency was close to 100 percent. A laboratory investigation (Hubbell and others, 1985) of varying bed materials and a range of transport rates indicates that the sampling efficiency of the standard 3-inch by 3-inch sampler varies with particle size and transport rate, displaying an approximate efficiency of 150 percent for sand and small gravel and close to 100 percent for coarse gravel. The standard 6-inch by 6-inch sampler had generally higher efficiencies. Tests of a Helley-Smith type sampler, which has a 3-inch by 3-inch nozzle with less expansion than the standard nozzle (an area ratio of 1.40), resulted in fairly constant efficiencies close to 100 percent for all transport rates and particle sizes. In May 1985, the 1.40 nozzle was approved by the Technical Committee on Sediment as a provisional standard sampler for use by U.S. Federal agencies. After some modifications to the frame, the 3-inch by 3-inch nozzle with 1.40-area-expansion ratio was designated the BL-84 sampler. The Water Resources Division of the USGS endorses the use of this new sampler with the 1.40-area-ratio nozzle; however, until additional testing is done, data obtained using the original 3.22-area-ratio Helley-Smith sampler will continue to be accepted.

Automatic Pumping-Type Samplers

Development and Design

Some sediment studies require frequent collection of suspended sediment at a site. Site location, flow conditions, frequency of collection, and operational costs frequently make collection of sediment data by manual methods impractical. For these reasons, F.I.S.P. and USGS personnel have developed and evaluated several models of automatic pumping-type samplers. The US PS-69 sampler is probably the best known of these samplers to be designed, tested, and used by USGS personnel. The US CS-77 (designed and tested by the Agricultural Research Service in Durant, Oklahoma) and the US PS-82 (Federal Inter-Agency Sedimentation Project, 1983) have been used. A number of automatic pumping-type samplers also have been designed by and are available through commercial sources. The Manning S-4050 and the ISCO 1680 are common commercially used samplers. (Manning Corp. is no longer in business.)

Automatic pumping-type samplers generally consist of (1) a pump to draw a suspended-sediment sample from the streamflow and, in some cases, to provide a back flush to clear the sampler plumbing before or after each sampling cycle; (2) a sample-container unit to hold sample bottles in position for filling; (3) a sample distribution system to divert a pumped sample to the correct bottle; (4) an activation system that starts and stops the sampling cycle, either at some regular time interval or in response to a rise or fall in streamflow (gage height); and (5) an intake system through which samples are drawn from a point in the sampled cross section. Ideally, this combination of components should be designed to meet the 17 optimum criteria as set forth by W.F. Curtis and C.A. Onions (U.S. Geological Survey, written commun., 1982).

1. Stream velocity and sampler intake velocity should be equal to allow for isokinetic sample collection if the intake is aligned with the approaching flow.
2. A suspended-sediment sample should be delivered from stream to sample container without a change in sediment concentration and particle-size distribution.
3. Cross contamination of sample caused by sediment carryover in the system between sample-collection periods should be prevented.
4. The sampler should be capable of sediment collection when concentrations approach 50,000 milligrams per liter and particle diameters reach 0.250 millimeter.
5. Sample-container volumes should be at least 350 milliliters.
6. The intake inside diameter should be 3/8 or 3/4 inch, depending upon the size of the sampler used.
7. The mean velocity within the sampler plumbing should be great enough to exceed the fall velocity of the largest particle sampled.
8. The sampler should be capable of vertical pumping lifts to 35 feet from intake to sample container.
9. The sampler should be capable of collecting a reasonable number of samples, dependent upon the purpose of sample collection and the flow conditions.
10. Some provision should be made for protection against freezing, evaporation, and dust contamination.
11. The sample-container unit should be constructed to facilitate removal and transport as a unit.
12. The sampling cycle should be initiated in response to a timing device or stage change.
13. The capability of recording the sample-collection date and time should exist.
14. The provision for operation using DC battery power or 110-volt AC power should exist.
15. The weight of the entire sampler or any one of its principal components should not exceed 100 pounds.
16. The maximum dimensions of the entire sampler or any one of its components should not exceed 35 inches in width or 79 inches in height.
17. The required floor area for the fully assembled sampler should not exceed 9 square feet (3 feet by 3 feet).

Installation and Use Criteria

The decision to use a pumping sampler for collection of sediment samples is usually based on both physical and fiscal criteria. These are real considerations; yet it should be understood that automatic pumping samplers can be as labor intensive and costly as the manual sediment-data collection they were designed to supplement. Installation of an automatic pumping sampler requires intensive planning before installation, including careful selection of the sampler-site location and detailed background data, to ensure the collection of useful pumped sample data.

Before installation of an automatic pumping-type sampler, many of the problems associated with installing stream-gaging equipment must be dealt with. In addition, much data concerning the sediment-transport characteristics at the proposed sampling site must be obtained and evaluated prior to emplacement of the sampler and location of the intake within the streamflow. Logistically, the sample site must be evaluated as to ease of access, availability of electrical power, location of a bridge or cableway relative to the site, normal range of ambient air temperatures inherent with local weather conditions, and the availability of a local observer to collect periodic reference samples. The sediment-transport characteristics should include detailed information on the distribution of concentrations and particle sizes throughout the sampled cross section over a range of discharges.

Placement of Sampler Intake

The primary concept to consider when placing a sampler intake in the streamflow at a sample cross section is that only one point in the flow is being sampled. Therefore, to yield reliable and representative data, the intake should be placed at the point where the concentration approximates the mean sediment concentration for the cross section across the full range of flows. This idealistic concept has great merit, but the mean cross-section concentration almost never exists at the same point under varying streamflow conditions. It is even less likely that specific guidelines for locating an intake under given stream conditions at one stage would produce the same intake location relative to the flow conditions at a different stage. These guidelines would have even less transfer value from cross section to cross section and stream to stream. For these reasons, some very generalized guidelines presented by W.F. Curtis and C.A. Onions (written commun., 1982) are outlined here and should be considered on a case-by-case basis when placing a sampler intake in the streamflow at any given cross section.

1. Select a stable cross section of reasonably uniform depth and width to maximize the stability of the relation between sediment concentration at a point and the mean sediment concentration in the cross section. This guideline is of primary importance in the decision to use a pumping sampler in a given situation; if a reasonably stable relation between the sample-point concentration and mean cross-section concentration cannot be attained by the following outlined steps, the sampler should not be installed and an alternate location considered.
2. Consider only the part of the vertical that could be sampled using a standard US depth- or point-integrating suspended-sediment sampler, excluding the unsampled zone, because data collected with a depth- or point-integrating sampler will be used to calibrate the pumping sampler.
3. Determine, if possible, the depth of the point of mean sediment concentration in each vertical for each size class of particles finer than 0.250 mm, from a series of carefully collected point-integrated samples.
4. Determine, if possible, the mean depth of occurrence of the mean sediment concentration in each vertical for all particles finer than 0.250 mm.
5. Use the mean depth of occurrence of the mean sediment concentration in the cross section as a reference depth for placement of the intake.
6. Adjust the depth location of the intake to avoid interference by dune migration or contamination by bed material.
7. Adjust the depth location of the intake to ensure submergence at all times.
8. Locate the intake laterally in the flow at a distance far enough from the bank to eliminate any possible bank effects.
9. Place the intake in a zone of high velocity and turbulence to improve sediment distribution by mixing, reduce possible deposition on or near the intake, and provide for rapid removal of any particles disturbed during the purge cycle.

Because of the generalized nature of these guidelines, it will often be impossible to satisfy them all when placing a pumping sampler intake into naturally occurring streamflows. The investigator is encouraged, however, to try to satisfy these guidelines or, at the very least, to satisfy as many as possible and to minimize the effects of those not satisfied.

Sampler Advantages and Disadvantages

Automatic pumping-type samplers are very useful for collecting suspended-sediment samples during periods of rapid stage changes caused by storm-runoff events and in reducing the manpower necessary to carry out intensive sediment-collection programs (Federal Inter-Agency Sedimentation Project, 1981b). However, it should be noted that pumping samplers quite often require more man-hours and cost more to operate than a conventional, observer-sampled type of station. Pumping samplers, because of their mechanical complexity, power requirements, and limited sample capacity, quite often require more frequent site visits by the field personnel than would be required at the conventional observer station. In addition, problems associated with collecting high-flow, cross-section samples are still present.

In streams with significant amounts of suspended-sand loads, the problems associated with using a pumping sampler are so great that two records may have to be calculated, one for the silt-clay size fraction load and one for the sand-size fraction load. This requires that most of the samples collected with the pumping sampler, as well as the samples collected manually, be subjected to a full particle-size analysis. Extensive laboratory work of this type increases the cost of analysis and computation of the sediment-discharge record. Another disadvantage is that the pumping lift for most samplers is relatively small and may be less than the normal fluctuations in stage at some sites. This is especially true on western rivers, where stage ranges may exceed 50 feet, making it necessary to locate the pump outside of the sampler's shelter in order to maintain a manageable pumping lift.

Intake Orientation

The orientation of the pumping sampler intake nozzle can drastically affect sampling efficiency. There are five ways in which an intake could be oriented to the flow (fig. 21): (1) normal and pointing directly upstream (fig. 21*A*), (2) normal and horizontal to flow (fig. 21*B*), (3) normal and vertical with the orifice up (fig. 21*C*), (4) normal and vertical with the orifice down (fig. 21*D*), and (5) normal and pointing directly downstream (fig. 21*E*). Of these five orientations, 1, 3, and 4 should be avoided because of high sampling errors and trash collection problems. Orientation 2, with the nozzle positioned normal and horizontal to the flow, is the most common alternative used. The major problem with this orientation is that sand-size particles may not be adequately sampled (see the following section on pumped-sample data analysis). Orientation 5, pointing directly downstream, appears to have an advantage over orientation 2 (Winterstein and Stefan, 1983). When the intake is pointing downstream, a small eddy is formed at the intake, which envelops the sand particles and thus allows the sampler to collect a more representative sample of the coarse load. Winterstein and Stefan (1983) also have demonstrated that nozzle orientations at angles to the flow other than those illustrated in figure 21 do not improve the resultant sample and, therefore, do not represent any useful advantage.

Data Analysis

A major concern when evaluating sediment data collected by automatic pumping-type samplers is the relation between the data and the true mean suspended-sediment concentration in transport at the time of sample collection. In order to determine this relation, concentrations determined from the pumping sampler must be compared with the corresponding concentrations determined from a complete depth-integrated cross-section sample over the full range of flow. This relation then is used to adjust the pumped sample data.

It must be remembered that samples collected by pumping samplers are taken from a single point in the flow. Although attempts are made to ensure that cross-sectional mean sediment concentrations are obtained, in reality this rarely happens. However, if a stable relation between the concentration at the sample point and the mean concentration in the cross section exists, the sample can be considered as representative as possible. In addition, pumping samplers do not collect samples isokinetically (as do standard US depth- or point-integrating samplers), due to the pumping rate and the orientation of the intake orifice. Not sampling isokinetically introduces concentration errors, particularly for particles greater than 0.062 mm.

Pumping samplers rely on pump speed to create a velocity in the intake tube greater than the settling velocity of particles in suspension. This higher velocity is necessary to deliver the sample to the sample container without reducing the concentration of coarser particles by depositing them within the sampler's plumbing. The pumping action at the intake

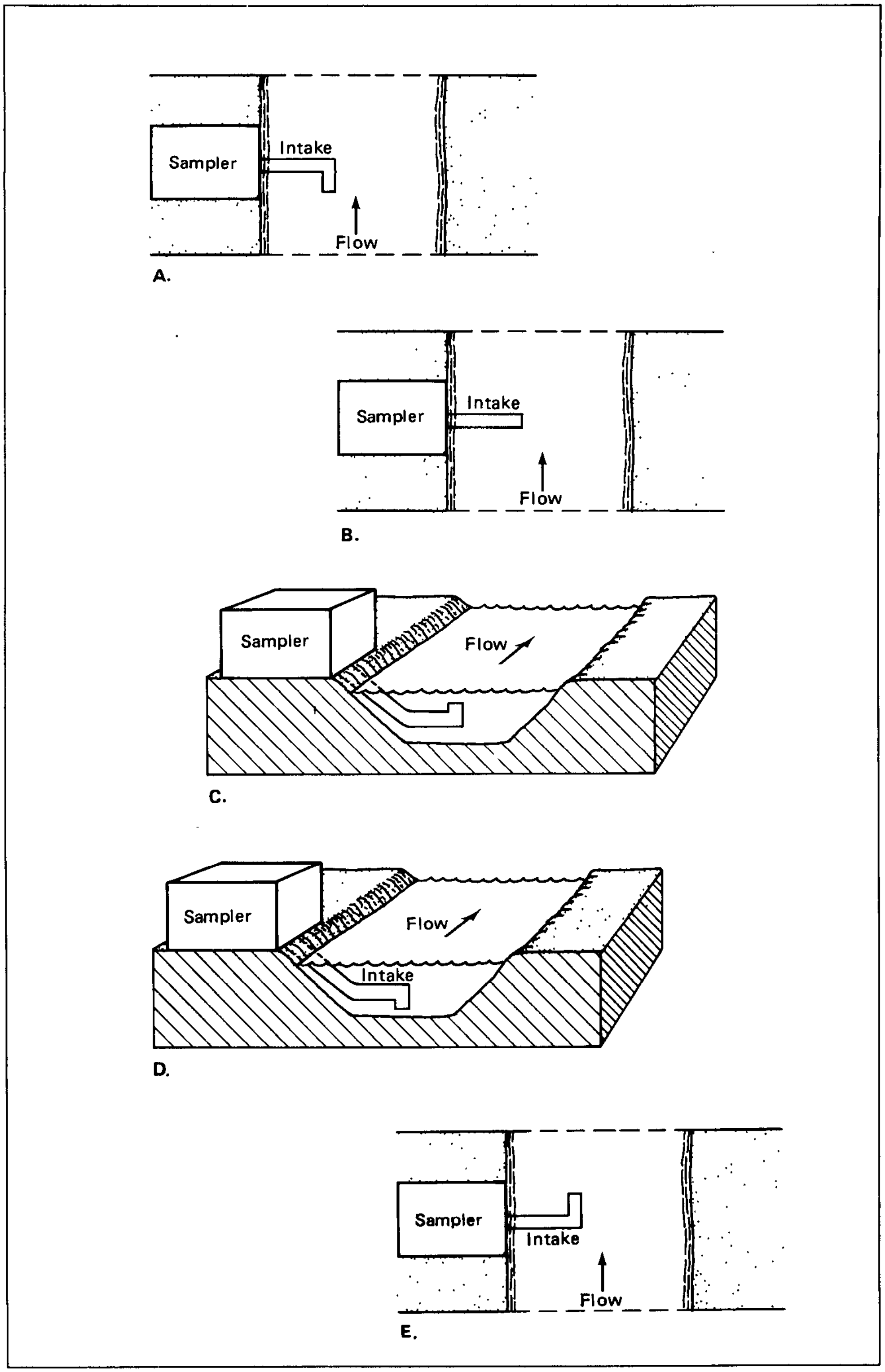
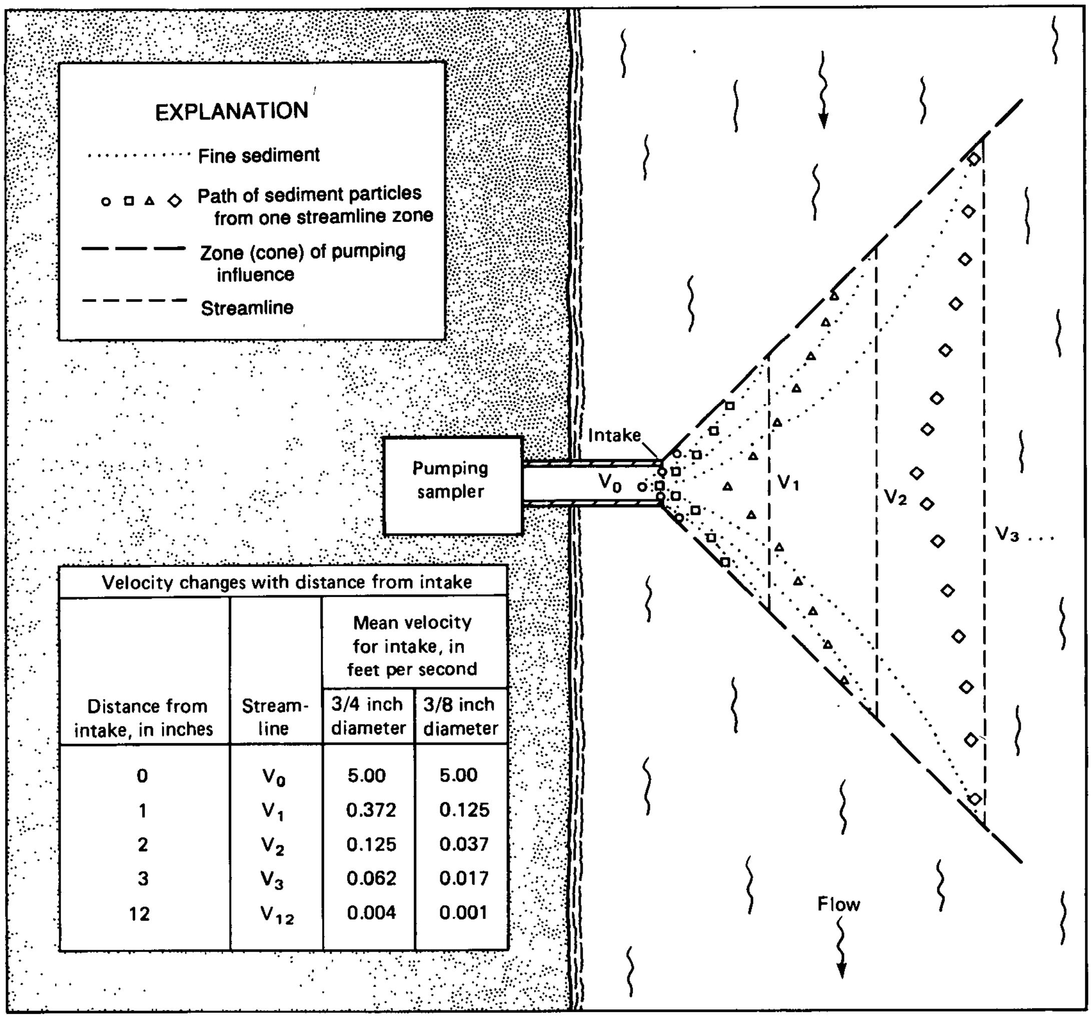


Figure 21. Examples of pumping-sampler intake orientations. *A*, Normal and pointing directly upstream. *B*, Normal and horizontal to flow. *C*, Normal and vertical with the orifice up. *D*, Normal and vertical with the orifice down. *E*, Normal and pointing directly downstream.

orifice bends the streamlines of sediment-laden flow as a sample is drawn into the intake and as particles are propelled through the sampler to the sample container. This force acts on particles carried past the orifice with varying results, dependent upon particle size and velocity (Federal Inter-Agency Sedimentation Project, 1941). That is, the pumping force attempts to pull particles laterally from their streamlines and accelerate them in the direction of the intake. At low stream velocities, when only fine silts and clays are being transported, this is not a problem. However, as stream velocity increases and particles larger than 0.062 mm begin to move in suspension, the pumping force must overcome the momentum of these larger particles, due to their mass and acceleration in the downstream direction, in order for a representative sample to be obtained. A decrease in sampling efficiency can result in a biased sample because fewer and fewer large particles are drawn into the intake as the distance from the intake increases (fig. 22). This figure shows that only those sediment particles passing directly in front of the intake, a short distance away, are greatly affected and subject to capture. It also should be realized that the zone (cone) of influence is an idealized concept, and pumping influence is much greater on sediments approaching the intake from upstream than on those sediments that have passed to the downstream side. As mentioned previously, this problem may be relieved somewhat by orienting the intake directly downstream.



Velocity changes with distance from intake

Distance from intake, in inches	Streamline	Mean velocity for intake, in feet per second: 3/4 inch diameter	Mean velocity for intake, in feet per second: 3/8 inch diameter
0	V_0	5.00	5.00
1	V_1	0.372	0.125
2	V_2	0.125	0.037
3	V_3	0.062	0.017
12	V_{12}	0.004	0.001

Figure 22. Pumping effect on sediment streamlines within the zone (cone) of influence and velocity changes with distance from intake (cone) of influence and velocity changes with distance from the intake oriented normal and horizontal to the flow for 3/4-inch and 3/8-inch diameter intakes with pumped velocity of 5 feet per second (from Federal Inter-Agency Sedimentation Project, 1966; W.F. Curtis and C.A. Onions, written commun., 1982).

Intake Efficiency

To facilitate accurate interpretation of data collected by automatic pumping-type samplers, some comparison between sediment concentration of the pumped sample (C_p) and mean sediment concentration of the streamflow (C_s) must be made. This comparison is made in terms of intake efficiency, which is the ratio of the pumped-sample sediment concentration to the mean concentration of the stream at the intake sampling point (Federal Inter-Agency Sedimentation Project, 1966), or:

$$\frac{C_p}{C_s}(100) = \text{intake efficiency.}$$

In reality, this relation is based on comparison of the pumped sample to sediment concentration of a point sample collected as close to the intake sampling point as possible, using a standard US depth- or point-integrating sampler.

Intake efficiencies should be determined for pumping samplers as soon as possible after installation-related sediment disturbances have stabilized. Additional efficiency values should be established over a broad range of flow conditions to determine actual effects of variations in particle sizes at a given sample site. These data then can be used to evaluate the sediment concentration of pumped samples and check their credibility.

Cross-Section Coefficient

Determining the degree of efficiency with which a pumping sampler obtains a representative sample is one step in the interpretation of suspended-sediment concentration data. These data should be further assessed relative to the cross-sectional mean suspended-sediment concentration. A coefficient should be determined based on how well the pumping sampler's data represents the cross-sectional mean, and this coefficient should be applied to the pumping sampler data.

From previous discussion, it should be evident that sediment samples taken at a single point of flow within a cross section seldom represent the mean sediment concentration. Therefore, cross-section coefficients must be determined to relate pumped-sample sediment concentration to the mean sediment concentration in the cross section. Because no theoretical relation exists between these parameters, an empirical comparison must be made between concentrations obtained from pumped samples and concentrations obtained from depth-integrated, cross-sectional samples collected at the same time. Obviously, it is impossible to collect an entire cross-sectional sample in the length of time it takes to cycle the pumping sampler to collect a single sample. Therefore, it is recommended that a sample collected with the pumping sampler be taken immediately before and after the cross-section sample. This procedure will help bracket any changes in concentration that might occur during the time period necessary to collect the cross-section sample. If it is suspected that the concentration is changing rapidly during the collection of the cross-section sample, try to collect one or more samples with the pumping sampler during the time that the cross-section sample is being collected. These data will help in the development of the cross-section coefficient. Collection and comparison of these check samples should be repeated during each station visit, as well as during rising and falling stages, and at peak flows for all seasonal periods (snowmelt runoff, thunderstorms, and so on). A more detailed discussion on development of cross-section coefficients is available to the interested reader in Guy (1970) and Porterfield (1972).

Description of Automatic Pumping-Type Samplers—US PS-69, US CS-77, US PS-82, Manning S-4050, and ISCO 1680

The US PS-69 pumping sampler (fig. 23) is a time- or stage-activated, electrically driven, suspended-sediment sampler capable of collecting up to 72 samples at volumes to 1,000 mL. Standard pumping lifts are to 17 feet vertically, but repositioning the pump or using multiple pumps in series can increase lift capabilities for extreme situations. This sampler must be placed in a shelter and protected against inclement weather and temperature extremes.

Particle sizes sampled range to 0.250 millimeter with some decrease in sampling efficiency for the larger particles. Sediment concentrations to 160,000 milligrams per liter have been sampled by USGS personnel in New Mexico, using an air-driven pump with the PS-69 (J.V. Skinner, written commun., 1985); extremely high concentrations also have been sampled in the vicinity of the Mount St. Helens volcano in Washington.

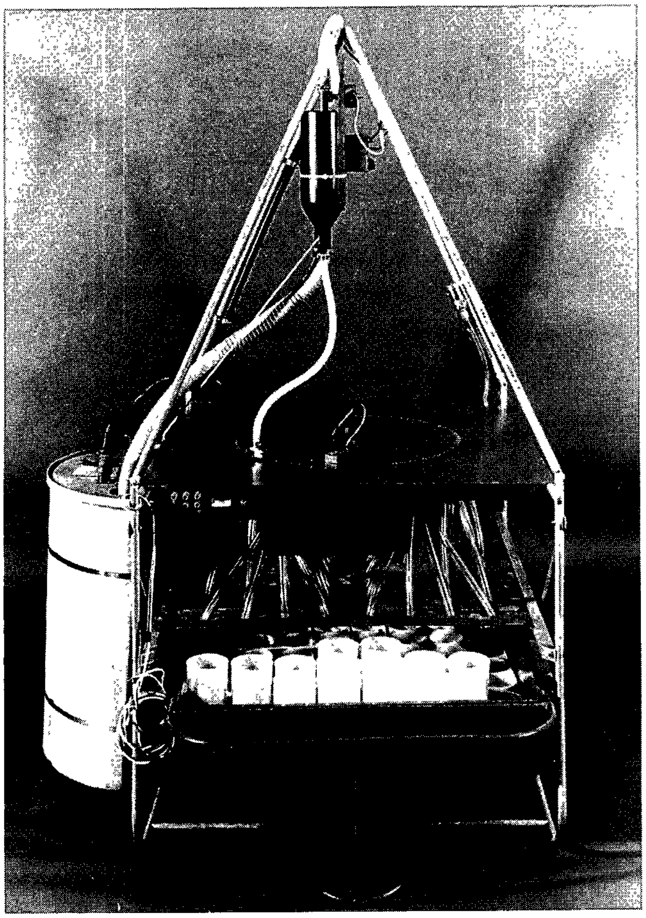


Figure 23. US PS-69 pumping sampler.

The PS-69 was evaluated by W.F. Curtis and C.A. Onions (written commun., 1982) by comparing the sampler's attributes to the 17 criteria previously listed. Results of this comparison are included in table 2.

The US CS-77, or Chickasha, sediment sampler (fig. 24) was designed and developed by the Agricultural Research Service, Durant, Oklahoma. This sampler was fashioned after an earlier design (US XPS-62, developed by F.I.S.P.) but has not been widely used by USGS personnel.

Like the PS-69, this sampler is time- or stage-activated to facilitate sampling on a predetermined schedule as well as during runoff events. Sampling times are recorded during the sampling procedure as part of the standard sampler's design of operation, in lieu of add-on modules and recording devices common to other samplers discussed here.

Table 2. Automatic pumping-type sampler evaluation

[A, US PS-69; B, US CS-77; C, US PS-82;D, Manning S-4050; E, ISCO 1680; mg/L, milligrams per liter; mL, milliliter; mm, millimeter; ≥, greater than or equal to; <, less than; >, greater than]

Evaluation criteria	Samplers meeting criteria
1. Sample collection isokinetic	None
2. Sediment concentration constant stream to sample container	A[1], B[2], C[2], D
3. Cross-contamination prevented	A, B, C, D
4. Collects concentrations to 50,000 mg/L and particles to 0.25 mm	A[1], B[2,1], C[1], D[1], E[2]
5. Sample volume >350 mL	A[3], B[3], C[3], D[3], E[3]
6. Intake diameter 3/4 inch	A
7. Mean velocity at intake and in internal plumbing great enough to ensure turbulent flow with a Reynolds number of 4,000	A[3], B[2], C[1], D[3], E[3]
8. Vertical pumping lift >35 feet	A[2], B[2], C[2]
9. Capable of collecting an adequate number of samples to accomplish the purpose of sampling	A[3], B[3], C[3], D, E
10. Sampler protected against freezing, evaporation, and dust	A[2], B[2], C, D[2], E[2]
11. Sample-container tray removable single unit	A, D, E
12. Sampling cycle activated by timer or stage change	A, B, C, D, E
13. Capable of recording sample date and time	A[2], B, C[2], D[2], E[2]
14. AC or DC power capability	A[2], B[2], C[2], D[2], E[2]
15. Sampler or principle components <100 pounds	A[2], B[2], C[3], D[3], E[3]
16. Sampler dimensions <35 inches wide by 79 inches high	A[2], B[2], C[3], D[3], E[3]
17. Required floor space <9 square feet (3 feet by 3 feet)	C[3], D[3], E[3]

[1] Sampler shows a reduction in capacity with particle sizes >0.250 mm.

[2] Sampler requires modification to meet criteria.

[3] Sampler exceeds criteria.

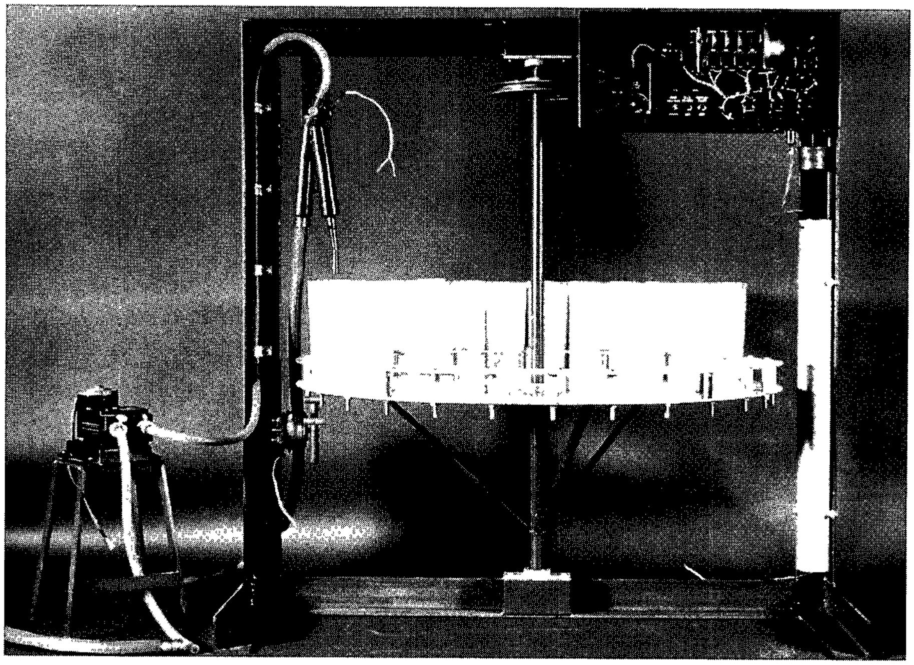


Figure 24. US CS-77 (Chickasha) pumping sampler.

Pumping lift attained by the standard CS-77 sampler configuration is 16 vertical feet; however, relocation of the pump unit to a lower elevation will establish a pull-push sequence, enabling greater sample lifts.

Further modification is necessary to improve the sampling efficiency for high concentration flows carrying greater than 10 percent sand-sized material. Additional information regarding this sampler may be obtained from the evaluation in table 2 and by contacting personnel at the F.I.S.P.

The US PS-82 automatic pumping-type sampler (fig. 25) was made available in March 1984 from F.I.S.P., but it is not widely used under field conditions. The Federal Inter-Agency Sedimentation Project (1983) describes the PS-82 as a lightweight portable pumping sampler, driven by 12-volt battery power, which is used to sample streamflows transporting particles ranging to fine sand size. These samplers weigh 35 pounds and can be housed under a 55-gallon oil drum. An evaluation of this sampler is included in table 2. For more specific information concerning the technical aspects of this sampler and its availability, the interested reader should contact the F.I.S.P.

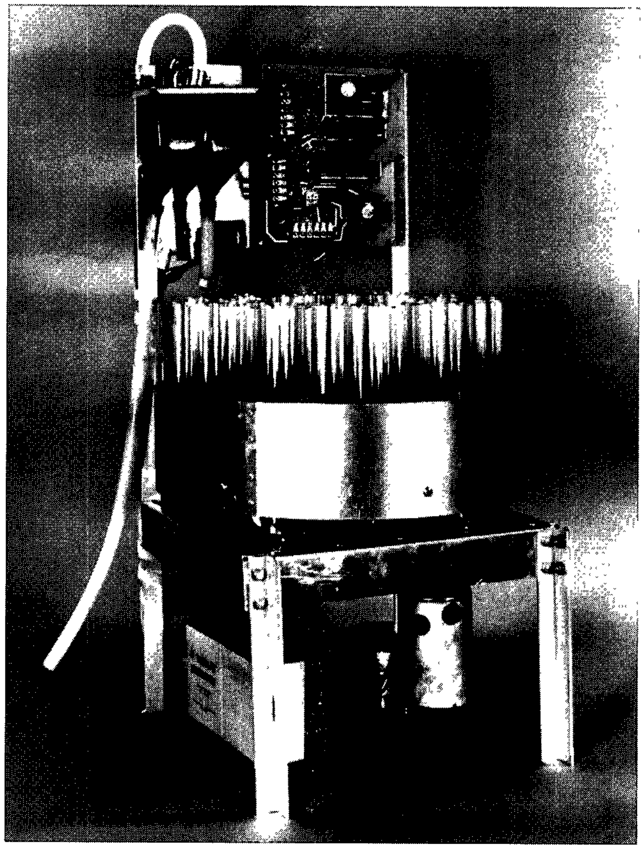


Figure 25. US PS-82 pumping sampler.

The aforementioned samplers were developed by Federal agencies concerned with the collection of suspended-sediment data in a timely, cost-effective manner and are available to the interested investigator from the F.I.S.P. at Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

The following discussion is a description of the Manning S-4050 and ISCO 1680 automatic pumping-type samplers, which are not available through F.I.S.P., but may be obtained from the individual manufacturers. These samplers are described because they represent the types of samplers that are commonly available from commercial sources and used by the USGS.

The Manning S-4050 portable sampler was originally designed as a lightweight unit for sampling sewage. Modifications to this sampler have rendered it useful as a suspended-sediment sampler.

The sampler features a time- or stage-activated electric compressor, which purges the sample intake using the pressure side and draws a sample through the intake using the suction side to create a vacuum in the line, allowing atmospheric pressure to push the sample up to a maximum of 22 feet during the sampling mode. Particle suspension within the sampler is maintained by swirling action of the sample as it passes through the measuring chamber to the sample container.

Evaluation of this sampler in the same manner used for the previously discussed samplers indicates that this instrument is well suited to conditions where extreme pumping lifts are not necessary. Results of this evaluation are included in table 2.

The ISCO 1680, with a super-speed pump sampler, was originally developed as a sewage or wastewater sampler, like the Manning sampler. Normally, wastewater does not carry significant amounts of sediment. Therefore, representation of particle distribution was not a considered criteria during its design and testing stages. The sampler features an electrically driven peristaltic pump, which is activated on a predetermined schedule by an internal timer or in response to stage change. The intake tube is purged before and after each pumping period by automatic reversal of the pump.

The ISCO sampler demonstrates two major shortcomings regarding sediment collection: (1) continuity of sediment concentration from stream to sample container is not maintained efficiently, and (2) a possibility of cross contamination exists from sample to sample as a result of residue remaining in the system after the purge cycle. These problems can be minimized by the installation of a high output pump, available as an option with recent models. A sampler evaluation included in table 2 shows less than acceptable results for representative sediment-data collection.

Support Equipment

Sediment-sampling equipment has been designed by F.I.S.P. to facilitate the use of existing support equipment normally used in stream-gaging procedures. Other than wading rods and hand lines, support equipment is generally necessary for the proper operation of the heavier versions of sediment samplers. In general, support equipment consists of steel cable, hanger bars, reels, and cranes. However, specific conditions at a site may dictate modifications to these pieces of equipment to improve ease of handling in response to the local conditions. Modifications of support equipment necessary to facilitate the handling of samplers and improve safety are encouraged. Investigators are cautioned against alterations that might adversely affect sample collection, either by disturbing the streamflow in the cross section or by changing the sediment-trapping characteristics of the sampler. To ensure sample integrity, specialists should be consulted before any modifications of this type are made.

Commonly used support items include C-type hanger bars; type-A, type-B, and type-E reels; and portable cranes with 2-, 3-, and 4-wheel bases. The C-type hanger bars can be shortened to eliminate awkward and hazardous handling. Type-A reels can be used to suspend lightweight to medium-weight samplers and have been widely used at permanent single-vertical observer sites. Type-B and type-E reels are typically used with medium and heavy samplers. The type-B reel can be used manually or with an available power unit, allowing the sampler to be lowered by releasing the brake mechanism and letting it slip until the sampler reaches the water surface, then manually integrating the sampled vertical and raising the sampler, either manually or by activating the DC-powered motor to drive the reel. The type-E reel is a DC-powered reel that lends itself more readily to permanent installations where heavy sampling equipment is required. Cranes are used to provide a mechanical advantage over hand-line or bridge-board suspended equipment, for more effective maneuvering of a sampler. The 2-, 3-, and 4-wheel base cranes are useful when sampling from a bridge deck; however, safety precautions should be taken to warn approaching traffic and to avoid blocking the roadway. Boom assemblies also are used in some instances, such as with truck- and boat-mounted installations. Reels, cranes, and powered hoists can be purchased from HIF. HIF can provide information on the availability, installation requirements, and operation of this equipment. Some additional information also may be obtained from the report "Discharge Measurements at Gaging Stations" (Buchanan and Somers, 1969).

SEDIMENT-SAMPLING TECHNIQUES

The sediment-sampling method and frequency of collection are dictated by the hydrologic and sediment characteristics of the stream, the required accuracy of the data, the funds available, and the proposed use of those data collected. When sampling sediment moving through a stream cross section, emphasis should be placed on the collection of a statistically representative population of the sediment particles in transit. To acquire a representative sample, one must first obtain a sample that adequately defines the concentration of particles over the full depth of the sampled vertical. Secondly, a sufficient number of verticals must be sampled to adequately define the horizontal variation in the cross section. The type of sampler used to collect the sample, the method of depth integration, the site at which the samples are collected, and the number of verticals needed to define the stream's concentration depend on the flow conditions at the time of sample collection, characteristics of the sediment being transported, the accuracy required of the data, and the objectives of the program for which the samples are being collected. The purpose of this section is to discuss site selection; equipment selection and maintenance; depth integration; sediment-discharge measurements; point integration; surface and dip sampling; transit rates; sample frequency, quantity, integrity, and identification; sediment-related data; cold-weather sampling; bed-material sampling; bedload sampling; total sediment discharge; and reservoir sedimentation. This section then deals with the decisions to be made and the instructions necessary to obtain the quantity and quality of samples required for computation and compilation of the desired sediment records.

Site Selection

The selection procedure for establishing a sampling location should emphasize the quest for a stream-data site. A stream-data site is best defined as a cross section displaying relatively stable hydrologic characteristics and uniform depths over a wide range of stream discharges, from which representative water-quality and sediment data can be obtained and related to a stage-discharge rating for the site. This is a rather idealized concept because the perfect site is rare at best. Therefore, it is necessary to note the limitations of the most suitable site available and build a program to minimize the disadvantages and maximize the advantages. Most often, sampling sites are located at or near existing gage sites, which may not always be well suited to water-quality and sediment-data collection. For this reason, future sites selected for stream gaging should be carefully assessed for suitability as a water-quality and sediment-sampling site.

As indicated, the site should be at or near a gaging station because of the obvious relation of sediment movement to the flow of the stream. If the sediment-measuring site is more than a few hundred feet from the water-stage recorder or at a site other than where the water-discharge measurement is made, it may be desirable to install a simple nonrecording stage indicator at the site so that a correlation of the flow conditions between the sediment and the distant water-measuring sites can be developed. The obvious difficulties with inflow between the sites from small tributaries also should be avoided where possible. Sites that may be affected by backwater conditions should be avoided whenever possible. Backwater affects both the stage-discharge and velocity-discharge relation at the site. Therefore, a given discharge may have varying stage and mean stream velocity and thus have varying sediment transport rates. If a site is affected by backwater, samples will have to be collected more frequently, and the cost in both man-hours and money will be significantly higher than for more "normal" sites.

A sediment-measuring site downstream from the confluence of two streams also may require extra sediment measurements. The downstream site may be adequate for water-discharge measurement, but could present problems if used as a sediment-measuring site due to incomplete mixing of the flows from the tributaries. Therefore, it might be desirable to move far enough downstream to ensure adequate mixing of the tributary flows. As indicated in Book 3, Chapter C1, "Fluvial Sediment Concepts" (Guy, 1970, p. 24), the distance downstream from a confluence that is required for complete mixing depends on the stream velocity, depth, and mixing width. If the flow at a sediment-measuring site is not mixed, extra samples will be required on a continuing basis because the relative flow quantity and sediment concentration from the two tributaries will change with time.

Aside from the confluence or tributary problem, the type of cross section for flow both in the channel and on the flood plain may affect the ease with which data can be obtained and the quality of the samples. The ratio of suspended load to total load and its variation with time can be greatly affected by the width-depth ratio, especially for sand-bed streams. For sites where the data are expected to be correlated with channel properties and the landforms of the region, a normal or average section should be used. When a fixed-routine sampling installation is used, a measuring section at a bend may provide a more stable thalweg and, hence, a more uniform adjustment coefficient with respect to time than one at a crossover. Sites in areas of active bank erosion should be avoided.

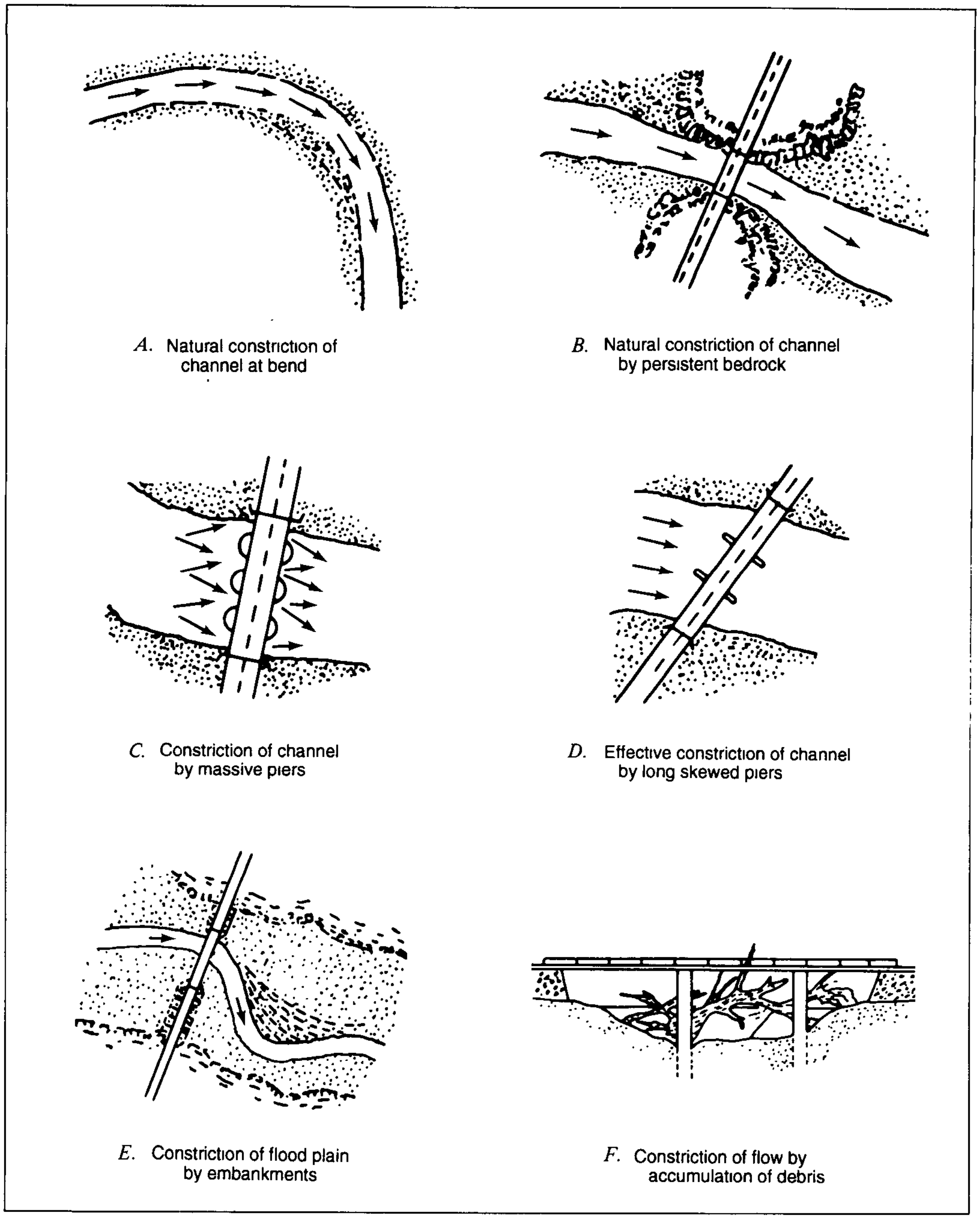
As a result of economic necessity, most sediment-measuring sites are located at highway bridges. These bridges are often constructed so that they restrict the flow width, or they may be located at a section where the channel is naturally restricted in width. Figure 26 (Culbertson and others, 1967) illustrates the conditions at several kinds of natural and artificially induced flow constrictions. As expected, the sand-bed type of stream causes the most serious flow problems with respect to scour in the vicinity of such constrictions. Even if the bridge abutments do not interfere with the natural width of the stream, the bridge may be supported by several midstream piers that can interfere with the streamflow lines and, thereby, reduce the effective cross-sectional area. As indicated in figure 26*F*, midstream piers can catch debris and, thereby, interfere with effective sediment sampling.

Because sediment samples must be obtained more frequently during floods, it is imperative that a site be selected where obtaining data during times of flooding is feasible. That is, particular attention should be given to the ease of access to the water-stage recorder and to a usable bridge or cable during a flood. Because of the need to collect samples frequently during floods, many of which occur at night, sites accessible only by poorly maintained backroads or trails should be avoided. Sometimes the choice of a sediment-measuring site also must be determined by the availability of a suitable observer to collect the routine samples.

In choosing a sediment-measurement site, it should be emphasized that samples need to be collected at the same cross-section location throughout the period of record. Different sampling cross sections can be used, if absolutely necessary, during the low-water wading stage and the higher stages requiring the use of a bridge or cableway. Although the total sediment transported through the different cross sections is probably equal at a given flow stage, the percentage of that total load represented by suspended-sediment load may be drastically different from one cross section to the other, due to differences in hydraulic and sediment-transport characteristics. When data computations are performed, these differences must be considered because the data may not be compatible, and the usefulness of the data in answering the objectives of the sampling program could be threatened. Sites where highway or channel realignment or other construction is anticipated during the period of record should be avoided. Good photographs of proposed or selected sediment-measuring sites are necessary to help document such features as channel alignment, water-surface conditions at various stages, composition of bed and bank material (at low flow), and natural or man-made features, which could affect the water-discharge and (or) sediment-discharge relations. Such pictures and extensive field notes are particularly useful when deciding on alternatives among sites and in later consideration of environmental changes at the site(s).

Equipment Selection and Maintenance

Before departing on a field trip where sediment data are to be collected, a field person should assemble and check all equipment needed to collect the best samples and related measurements. For example, if data are



A. Natural constriction of channel at bend

B. Natural constriction of channel by persistent bedrock

C. Constriction of channel by massive piers

D. Effective constriction of channel by long skewed piers

E. Constriction of flood plain by embankments

F. Constriction of flow by accumulation of debris

Figure 26. Examples of natural and artificially induced streamflow constrictions encountered at sediment-measurement sites. Modified from Culbertson and others (1967).

needed for total-load computation, equipment is needed for water-discharge measurement, suspended-sediment sampling, bedload sampling, and (or) bed-material sampling. If suspended-sediment concentration and particle-size profiles are required, point samplers and water-discharge-measuring equipment will be needed. Some of the special equipment used only at one location may be stored in the station gage house, with the observer, or in special storage shelters or boxes. However, a sampler or some support equipment could be damaged or stolen without the observer noticing or reporting the loss. Hence, it is necessary for field personnel to carry repair equipment, spare parts (including nozzles and gaskets), and perhaps even an extra sampler.

The streamflow conditions and sampling structures (bridge, cableway, or other) determine more specifically which sampler or samplers should be used at a station. Stream depth determines whether hand samplers, such as the DH-48 or the BMH-53, or cable-suspended samplers, such as the D-74 or the P-61, should be used. Depths over 15 feet will require the use of point samplers as depth-integrating samplers to avoid overfilling or using too fast a transit rate. Stream velocity as well as depth are factors in determining whether or not a stream can be waded. A general rule is that when the product of depth in feet and velocity in feet per second equals 10 or greater, a stream's wadability is questionable. Application of this rule will vary considerably among field persons according to an individual's stature and the condition of the streambed. That is, if footing is good on the streambed, a heavier field person with a stocky build will generally wade more easily than will a lighter, thinner person when a stream depth-velocity product approaching 10 exists.

The depth-velocity product also affects the action of each sampler. The larger this product, the heavier and more stable the sampler must be to collect a good sample. At a new station or for inexperienced persons, considerable trial and error may be necessary to determine which sampler is best for a given stream condition.

All sampler nozzles, gaskets, and air exhausts, as well as the other necessary equipment, should be checked regularly and replaced or serviced if necessary. Sampler nozzles in particular should be checked to ensure that they are placed in the appropriate instrument or series. See the guidelines presented in table 1 to determine whether the nozzle is correct. The correct size of nozzle to use for a given situation must often be determined by trial. As mentioned in the previous section, it is best to use the largest nozzle possible that will permit depth integration without overfilling the sample bottle or exceeding the maximum transit rate (about 0.4 of the mean velocity in the sampled vertical for most samplers with pint containers).

If a sample bottle does not fill in the expected time, the nozzle or air-exhaust passages may be partly blocked. The flow system can be checked, as described in the section titled "Gaskets," by sliding a length of clean rubber or plastic tubing over the nozzle and blowing through the nozzle with a bottle in the sampler. This procedure should be performed carefully, avoiding direct contact with the nozzle, thus eliminating the possibility of ingesting any pollutant that might exist on the sampler. When air pressure is applied in this manner, circulation will occur freely through the nozzle, sample container, and out the air exhaust. Obstructions can be cleared by removing and cleaning the nozzle and (or) air exhaust, using a flexible piece of multistrand wire. This procedure should be adequate for most airway obstruction problems. However, if blockage results from accumulation of ice or from damage to the sampler, a heat source must be used to melt the ice or the sampler must be sent to the F.I.S.P. or HIF repair facility. Point samplers can be checked using the same technique, if the valve mechanism is placed in the sampling position while air is forced into the nozzle and through the air exhaust.

All support equipment required for sampling, such as cranes, waders, taglines, power sources, and current meters, should be examined periodically, and as used, to ensure an effective and safe working condition. For example, be certain that the supporting cable to the sampler or current meter is fastened securely in the connector; if worn or frayed places are noted, the cable should be replaced. Power equipment used with the heavier samplers and point samplers need a periodic operational check and battery charge. Point samplers should be checked immediately before use to determine, among other things, if the valve is opening and closing properly. By exercising such precautions, the field person will avoid unnecessary exposure to traffic on the bridge and will avoid lost sampling time should repairs and adjustments be required.

Maintenance of samplers and support equipment will be facilitated if a file of instructions for assembly, operation, and maintenance of equipment can be accumulated in the field office. Such a file could include F.I.S.P. reports as well as other pertinent information available from HIF.

Suspended-Sediment Sampling Methods

Sediment-Discharge Measurements

The usual purpose of sediment sampling is to determine the instantaneous mean discharge-weighted suspended-sediment concentration at a cross section. Such concentrations are combined with water discharge to compute the measured suspended-sediment discharge. A mean discharge-weighted suspended-sediment concentration for the entire cross section is desired for this purpose and for the development of coefficients to adjust observer and automatic pumping-type sampler data.

Ideally, the best procedure for sampling any stream to determine the sediment discharge would be to collect the entire flow of the stream over a given time period, remove the water, and weigh the sediment. Obviously, this method is a physical impossibility in the majority of instances. Instead, the sediment concentration of the flow is determined by (1) collecting depth-integrated suspended-sediment samples that define the mean discharge-weighted concentration in the sample vertical and (2) collecting sufficient verticals to define the mean discharge-weighted concentration in the cross section.

Single Vertical

The objective of collecting a single-vertical sample is to obtain a sample that represents the mean discharge-weighted suspended-sediment concentration in the vertical being sampled at the time the sample was collected. The method used to do this depends on the flow conditions and particle size of the suspended sediment being transported. These conditions can be generalized to four types of situations: (1) low velocity (v<2.0 ft/s) when little or no sand is being transported in suspension; (2) high velocity (2.0<v<12.0 ft/s) when depths are less than 15 feet; (3) high velocity (2.0<v<12.0 ft/s) when depths are greater than 15 feet; and (4) very high velocities (v>12.0 ft/s).

First case.—In the first case, the velocity is low enough that no sand is being transported as suspended sediment. The distribution of sediment (silt and clay) is relatively uniform from the stream surface to bed (Guy, 1970, p. 15). The sampling error for this case, when only sediment particles less than 0.062 mm are in suspension, is small, even with intake velocities somewhat higher or lower than the ambient mean stream velocities. Therefore, it is not as important to collect the sample isokinetically with fines in suspension as it is when particles greater than 0.062 mm are in suspension. In shallow streams, a sample may be collected by submerging an open-mouthed bottle into the stream by hand. The mouth should be pointed upstream and the bottle held at approximately a 45-degree angle from the streambed. The bottle should be filled by moving it from the surface to the streambed and back. Care should be taken to avoid touching the mouth of the bottle to the streambed. An unsampled zone of about 3 inches should be maintained in order to obtain samples that are compatible with depth-integrated samples collected at higher velocities.

If the stream is not wadable, a weighted-bottle type sampler may be used. Remember that these samples are not discharge-weighted samples and that, if possible, their analytical results should be verified by or compared to data obtained using a standard sampler and sampling technique.

Second case.—In the second case, when 2.0<v<12.0 ft/s and the depth is less than 15 feet, the standard depth-integrating samplers, such as DH-48, DH-75, DH-59, D-49, and D-74 may be used. The method of sample collection is basically the same for all these samplers, whether used while wading or from a bridge or cableway. Insert a clean sample bottle into the sampler and check to see that there are no obstructions in the nozzle or air-exhaust tube. Then lower the sampler to the water surface so that the nozzle is above the water, and the lower tail vane or back of the sampler is in the water for proper upstream-downstream orientation. After orientation of the sampler, depth integration is accomplished by traversing the full depth and returning to the surface with the sampler at a constant transit rate.

When the bottom of the sampler touches the streambed, immediately reverse the sampler direction and raise the sampler to clear the surface of the flow at a constant transit rate. The transit rate used in raising the sampler need not be the same as the one used in lowering, but both rates must be constant in order to obtain a velocity- or discharge-weighted sample. The rates should be such that the bottle fills to near its optimum level (approximately 3 inches below the top or 350 to 420 milliliters, for the pint milk bottle, or 2 inches below the top or 650 to 800 milliliters for the quart bottle).

For streams that transport heavy loads of sand, and perhaps for some other streams, at least two complete depth integrations of the sample vertical should be made as close together in time as possible, one bottle for each integration. Each bottle then constitutes a sample and can be analyzed separately or, for the purposes of computing the sediment record, concentrations from two or more bottles can be averaged, whereby they are called a set. This set then is a sample in time with respect to the record. Sample analyses from two or more individual bottles for a given observation are useful for checking sediment variations among bottles—an obvious advantage in the event the sediment concentration in one bottle is quite different from the concentration in the other bottles for the same observation. Immediately after collection, every bottle or sample should be inspected visually by swirling the water in the bottle and observing the quantity of sand particles collected at the bottom. If there is an unusually large quantity or a difference in the quantity of sands between bottles, another sample from the same vertical should be taken immediately. The sample suspected of having too much sand should be discarded. If it is saved, an explanation such as "too much sand" should be clearly written on the bottle. If by chance, a bottle is overfilled or if a spurt of water is seen coming out of the nozzle when the sampler is raised past the water surface, the sample should be discarded. A clean bottle must be used to resample the vertical.

To help avoid the problem of striking the nozzle into a dune or settling the sampler too deeply into a soft bed, it is recommended that a slow downward integration be used, followed by a more rapid upward integration. Because most of the sand is transported near the bed, it is essential that the transit direction of the sampler be immediately reversed as the sampler touches the bed.

Pertinent information as shown in figure 27 must be available with each bottle for use in the laboratory and in compiling the record. Most districts provide bottles with an etched area on which a medium-soft lead (blue or black) or wax pencil can be used. Other districts use

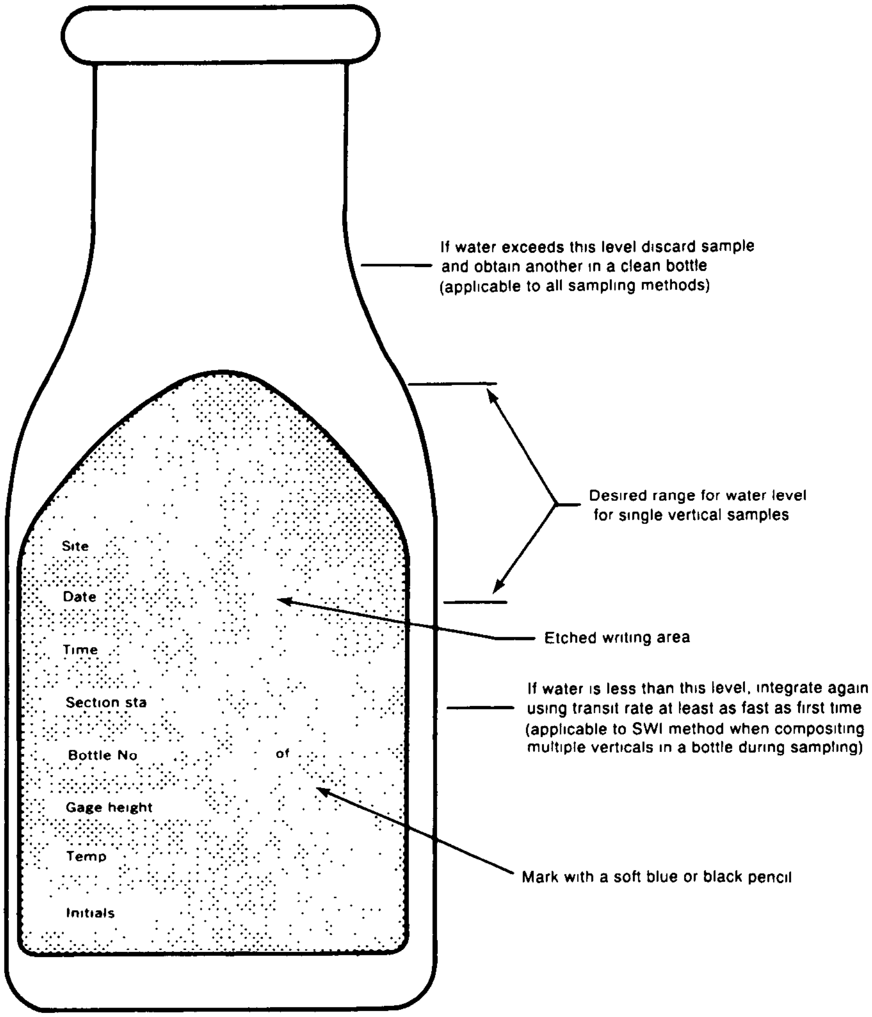


Figure 27. Sample bottle showing desired water levels for sampling methods indicated and essential record information applicable to all sampling methods.

plain bottles and attach tags for recording the required information. The required information may be recorded on the bottle cap if there are no other alternatives, but this should be avoided because of the small writing space and because of the possibility of putting the cap on the wrong bottle. Paper caps should not be used because they do not form as good a seal as do the plastic caps and may allow evaporation of the sample.

Third case.—In the third case, the depth-integrating samplers cannot be used because the depth exceeds the maximum allowable depth for these samplers. In this case, one of the point-integrating or bag-type samplers must be used. Because the bag sampler is still new and sufficient field data have not been collected to verify its sampling efficiency, USGS personnel who wish to use it must contact the Chief, Office of Surface Water, Reston, Virginia, and must set up a comparability sampling system to verify the sampler's efficiency under their specific conditions. The technique for collection of a sample using the bag-type sampler is similar to that used with the depth-integrating samplers.

The point samplers may be used to collect depth-integrated samples in verticals where the depth is greater than 15 feet. For streams with depths between 15 and 30 feet, the procedure is as follows:

1. Insert a clean bottle in the sampler and close the sampler head.
2. Lower the sampler to the streambed, keeping the solenoid closed and note the depth to the bed.
3. Start raising the sampler to the surface, using a constant transit rate. Open the solenoid at the same time the sampler begins the upward transit.
4. Keep the solenoid open until after the sampler has cleared the water surface. Close the solenoid.
5. Remove the bottle containing the sample, check the volume of the sample, and mark the appropriate information on the bottle. (If the sample volume exceeds allowable limits, discard the sample and repeat depth integration at a slightly higher transit rate.)
6. Insert another clean bottle into the sampler and close the sampler head.
7. Lower the sampler until the lower tail vane is touching the water, allowing the sampler to align itself with the flow.
8. Open the solenoid and lower the sampler at a constant transit rate until the sampler touches the bed.
9. Close the solenoid the instant the sampler touches the bed. (By noting the depth to the streambed in step 2 above, the operator will know when the sampler is approaching the bed.)

The transit rate used when collecting the sample in the upward direction need not be the same as that used in the downward direction, If the stream depth is greater than 30 feet, the process is similar, except that the upward and downward integrations are broken into segments no greater than 30 feet. Figure 28 illustrates the procedure for sampling a stream with a depth of 60 feet. Note the transit rate used in the upward direction (RT_3 and RT_4) is not equal to the transit rate in the downward direction (RT_1 and RT_2), but $RT_1 = RT_2$ and $RT_3 = RT_4$. Samples collected by this technique are composited for each vertical, and a single mean concentration is computed for the vertical. In addition to the usual information (fig. 27), the label on each bottle should indicate the segment or range of depth sampled and whether it was taken on a descending or ascending trip.

Samples **must** be obtained at a given vertical for both the downward and upward directions. Tests in the Colorado River (Federal Inter-Agency Sedimentation Project, 1951, p. 34) have shown an increase in the intake ratio of about 4 percent when descending versus a decrease in the intake ratio of about 4 percent on ascent.

Surface and Dip Sampling

Fourth case.—In the fourth case, circumstances are often such that surface or dip sampling is necessary. When the velocities are too high to use the depth- or point-integrating samplers or when debris makes normal sample collection dangerous or impossible, surface or dip samples may be collected.

A surface sample is one taken on or near the surface of the water, with or without a standard sampler. At some locations, stream velocities are so great that even the heaviest samplers will not reach the streambed while attempting to integrate the sampled vertical. Under such conditions, it can be expected that all, except the largest, particles of sediment will be thoroughly mixed within the flow; and, therefore, a sample near the surface is representative of the entire vertical. Extreme care should be used, however, because often such high velocities occur during floods when large debris is moving, especially on the rising part of the hydrograph. This debris may strike or

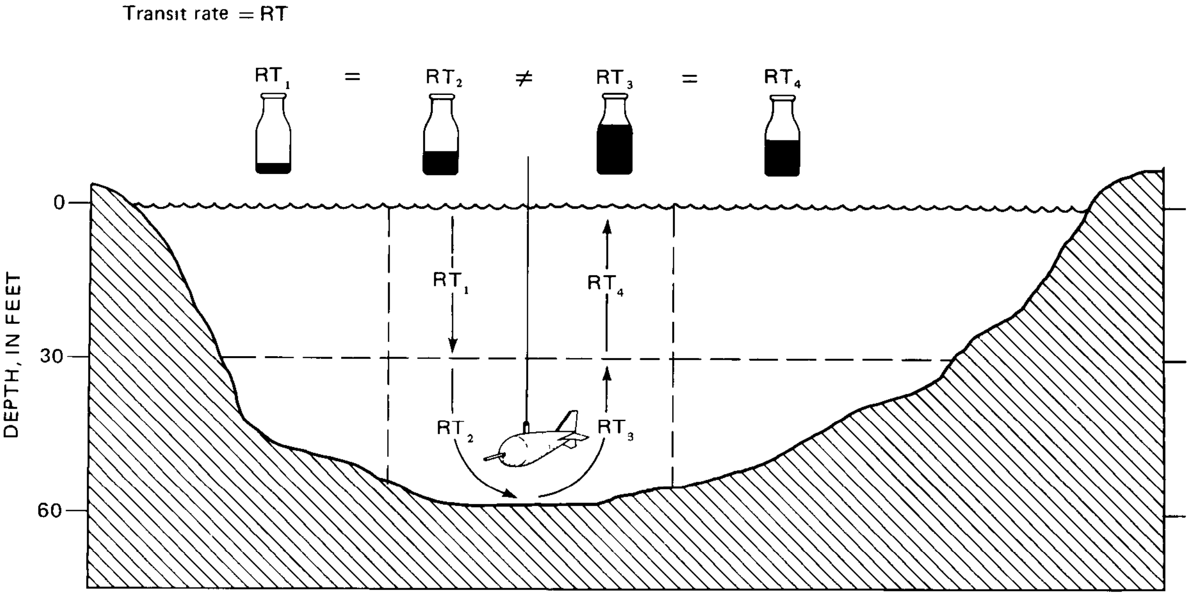


Figure 28. Uses of point-integrating sampler for depth integration of deep streams. RT, transit rate.

become entangled with the sampler and, thereby, damage the sampler, break the sampler cable, or injure the field person. Of course, a full explanation of sampling conditions should be noted on the bottle and in the field notes in order that special handling may be given the samples in the laboratory and in computing the records. The amount of debris in the flow may decrease considerably after the flood crest; even the velocity might decrease somewhat.

Because of the many problems associated with surface and dip sampling, these samples should be correlated to regular depth-integrated samples collected under more normal flow conditions, as soon as possible after the high flow recedes. Along with the depth-integrated sample, a sample should be collected in a manner duplicating the sampling procedure used to collect the surface or dip sample. These samples will be used to adjust the analytical results of the surface or dip sample collected during the higher flow, if necessary, to facilitate the use of these data in sediment-discharge computations and data analyses.

Multivertical

A depth-integrated sample collected using the procedures outlined in the previous section will accurately represent the discharge-weighted suspended-sediment concentration along the vertical at the time of the sample collection. As mentioned before, the purpose of collecting sediment samples is to determine the instantaneous sediment concentration at a cross section. The question now becomes, how do we locate the verticals in the cross section so that the end result will be a sample that is representative of the mean discharge-weighted sediment concentration?

The USGS uses two basic methods to define the location or spacing of the verticals. One is based on equal increments of water discharge; the second is based on equal increments of stream or channel width.

The Equal-Discharge-Increment Method

With the equal-discharge-increment method (EDI), samples are obtained from the centroids of equal-discharge increments (fig. 29). This method requires some knowledge of the distribution of streamflow in the cross section, based on a long period of discharge record or on a discharge measurement made immediately prior to selecting sampling verticals. If such knowledge can be obtained, the EDI method can save time and labor (compared to the equal-width-increment method, discussed in the next section), especially on the larger streams, because fewer verticals are required (Hubbell and others, 1956).

To use the EDI method without the benefit of previous knowledge of the flow distribution in the sampling cross section, first measure the discharge of the stream and determine the flow distribution across the channel at the sampling cross section prior to sampling. From the discharge measurement preceding the sampling (fig. 30) or from historic discharge-measurement records, equal-discharge increments can

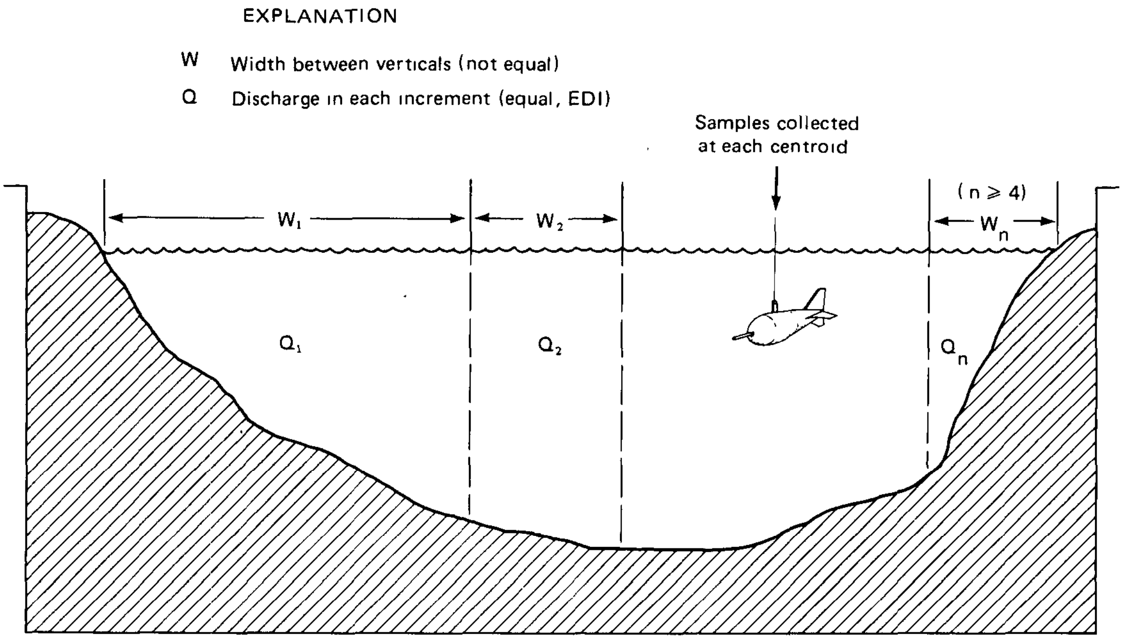


Figure 29. Example of equal-discharge-increment (EDI) sampling technique. Samples are collected at the centroids of flow of each increment.

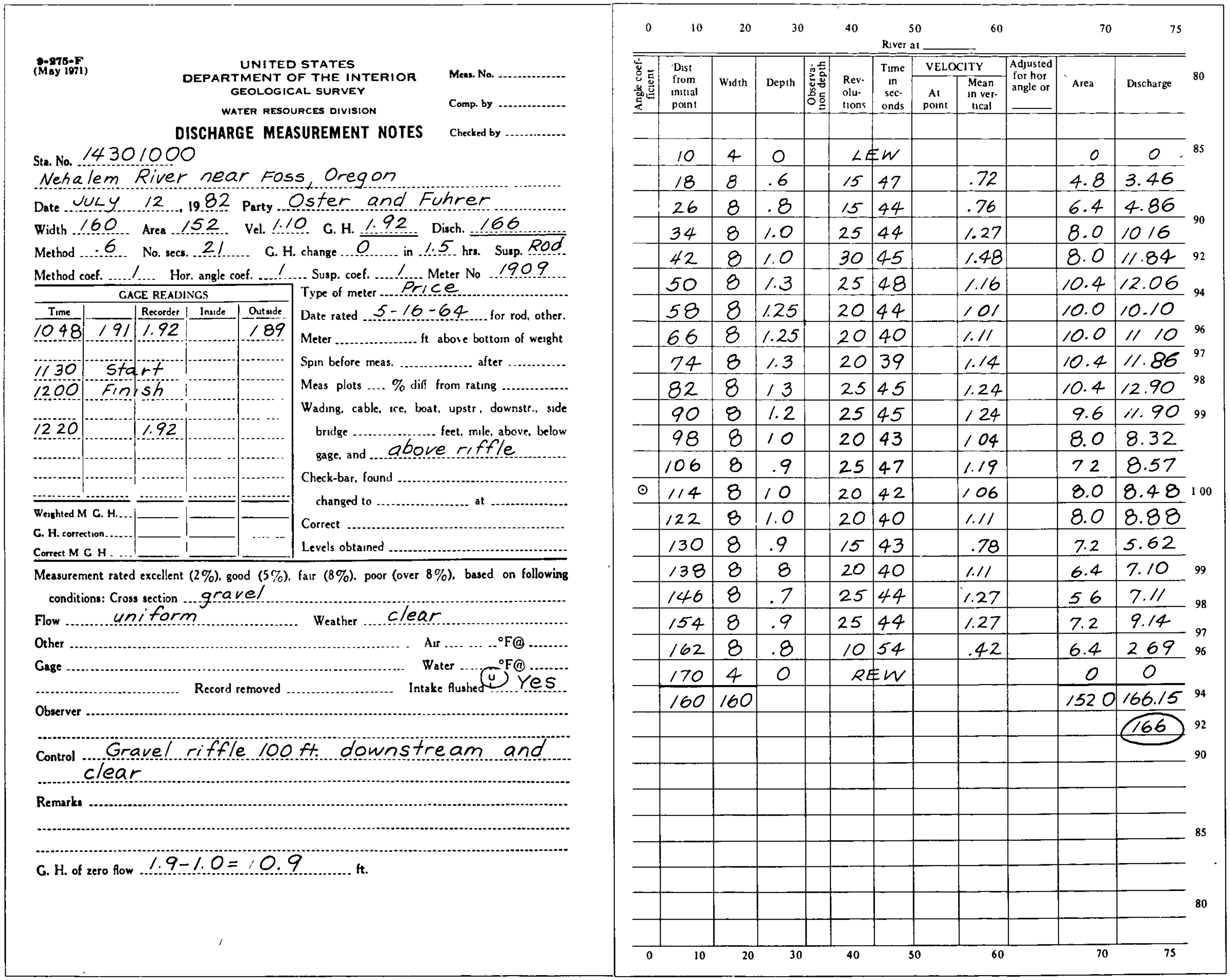
be determined and centroids at which samples are to be collected can be located. In this example, the total discharge is equal to 166 ft^3/s (cubic feet per second). For illustration purposes, it was determined, by methods to be discussed later, that five verticals would be sampled. The equal increments of discharge (EDI's) then are computed by dividing the total discharge by the number of verticals (166 divided by 5 = 33.2 ft^3/s). The first vertical (A) is located at the centroid of the initial EDI or at a point where the cumulative discharge from the left edge of water (LEW) is one-half of the EDI, in this case 33.2 divided by 2 = 16.6 ft^3/s.

Subsequent centroids (B, C, and so on) are located by adding the increment discharge to the discharge at the previously sampled centroid; in this example, A = 16.6 ft^3/s, B = A + 33.2 ft^3/s, C = B + 33.2 ft^3/s, and so on. Samples are, therefore, collected at points where the cumulative discharge relative to the LEW is 16.6, 49.8, 83.0, 116.2, and 149.4 ft^3/s.

A minimum of four and a maximum of nine verticals should be used when using the EDI method. This method assumes that the sample collected at the centroid represents the mean concentration for the subsection.

To determine the stationing of the centroids, the field person must include a cumulative discharge column (ΣQ) on the discharge-measurement notes by adding the discharges shown in the "discharge" column and keeping a running total as shown in figure 31. The next step is to estimate the stationing of the above centroids. Each centroid is located at the station in the cross section corresponding to the occurrence of its computed cumulative discharge. As shown in figure 31, the cumulative discharge at station 26 equals 8.32 ft^3/s, while station 34 corresponds to 18.5 ft^3/s. Actually, the cumulative discharge is computed to the point midway between stations (far midpoint, fig. 31). Therefore, the point where the cumulative discharge equals 8.32 ft^3/s is located halfway between stations 26 and 34, at station 30. In like manner, the cumulative discharge of 18.5 ft^3/s occurs at the far mid-point between stations 34 and 42, at station 38. The first centroid then would be located between stations 30 and 38. Interpolating between these stations, the centroid discharge of 16.6 ft^3/s would be located at a station closer to station 38, where 18.5 ft^3/s occurs, in this case near station 37. Using the same procedure, estimates of centroid stationing yield stations 60, 83, 109, and 144 for the four remaining centroids.

If the cross section at the measurement site is stable and the control governing the stage at the measurement cross section also is stable, previous measure-



9-275-F
(May 1971)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Meas. No. ....
Comp. by ....
Checked by ....

DISCHARGE MEASUREMENT NOTES

Sta. No. 14301000
Nehalem River near Foss, Oregon
Date July 12, 1982 Party Oster and Fuhrer
Width 160 Area 152 Vel. 1.10 G. H. 1.92 Disch. 166
Method .6 No. secs. 21 G. H. change 0 in 1.5 hrs. Susp. Rod
Method coef. 1 Hor. angle coef. 1 Susp. coef. 1 Meter No 1909

GAGE READINGS

Time		Recorder	Inside	Outside
1048	191	1.92		1.89
1130	Start			
1200	Finish			
1220		1.92		
Weighted M G. H.				
G. H. correction				
Correct M G H				

Type of meter Price
Date rated 5-16-64 for rod, other.
Meter .... ft above bottom of weight
Spin before meas. .... after ....
Meas plots .... % diff from rating ....
Wading, cable, ice, boat, upstr., downstr., side bridge .... feet, mile, above, below gage, and above riffle
Check-bar, found ....
changed to .... at ....
Correct ....
Levels obtained ....

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section gravel
Flow uniform Weather clear
Other .... Air .... °F@ ....
Gage .... Water .... °F@ ....
.... Record removed .... Intake flushed Yes
Observer ....
Control Gravel riffle 100 ft. downstream and clear
Remarks ....
G. H. of zero flow 1.9-1.0= 0.9 ft.

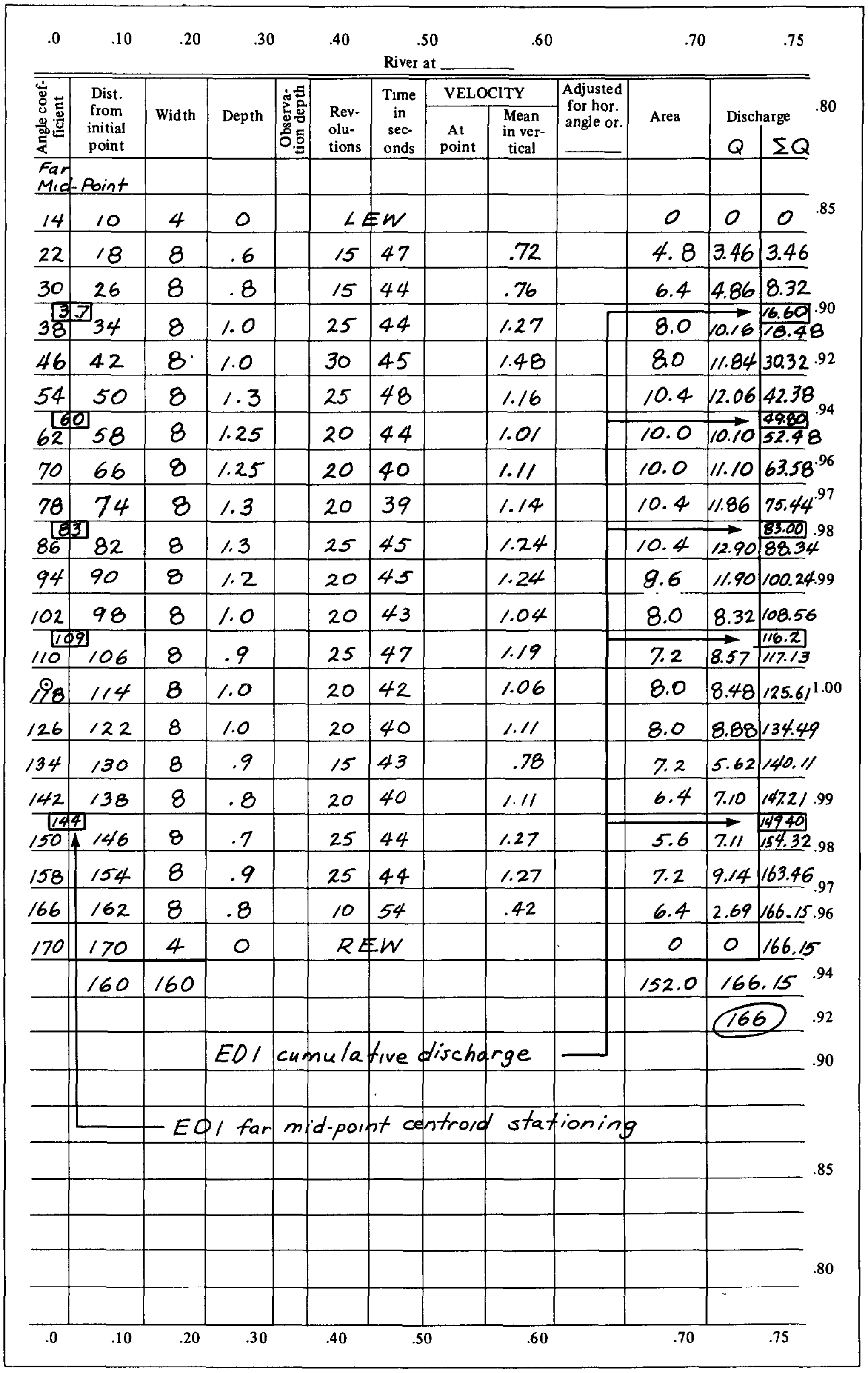
0 10 20 30 40 50 60 70 75

River at ....

Angle coefficient	Dist from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted for hor angle or ___	Area	Discharge	
												80
	10	4	0		LEW					0	0	85
	18	8	.6		15	47		.72		4.8	3.46	
	26	8	.8		15	44		.76		6.4	4.86	90
	34	8	1.0		25	44		1.27		8.0	10 16	
	42	8	1.0		30	45		1.48		8.0	11.84	92
	50	8	1.3		25	48		1.16		10.4	12.06	94
	58	8	1.25		20	44		1 01		10.0	10.10	
	66	8	1.25		20	40		1.11		10.0	11 10	96
	74	8	1.3		20	39		1.14		10.4	11.86	97
	82	8	1 3		25	45		1.24		10.4	12.90	98
	90	8	1.2		25	45		1 24		9.6	11.90	99
	98	8	1 0		20	43		1 04		8.0	8.32	
	106	8	.9		25	47		1.19		7 2	8.57	
⊙	114	8	1 0		20	42		1 06		8.0	8.48	1 00
	122	8	1.0		20	40		1.11		8.0	8.88	
	130	8	.9		15	43		.78		7.2	5.62	
	138	8	8		20	40		1.11		6.4	7.10	99
	146	8	.7		25	44		1.27		5 6	7.11	98
	154	8	.9		25	44		1.27		7.2	9.14	97
	162	8	.8		10	54		.42		6.4	2 69	96
	170	4	0		REW					0	0	
	160	160								152 0	166.15	94
											166	92
												90
												85
												80

0 10 20 30 40 50 60 70 75

Figure 30. Record of discharge measurement for Nehalem River near Foss, Oregon.



River at ________

Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	VELOCITY At point	VELOCITY Mean in vertical	Adjusted for hor. angle or.	Area	Discharge Q	Discharge ΣQ
Far Mid-Point												
14	10	4	0		LEW					0	0	0
22	18	8	.6		15	47		.72		4.8	3.46	3.46
30	26	8	.8		15	44		.76		6.4	4.86	8.32
37 38	34	8	1.0		25	44		1.27		8.0	10.16	16.60 18.48
46	42	8	1.0		30	45		1.48		8.0	11.84	30.32
54	50	8	1.3		25	48		1.16		10.4	12.06	42.38
60 62	58	8	1.25		20	44		1.01		10.0	10.10	49.80 52.48
70	66	8	1.25		20	40		1.11		10.0	11.10	63.58
78	74	8	1.3		20	39		1.14		10.4	11.86	75.44
83 86	82	8	1.3		25	45		1.24		10.4	12.90	83.00 88.34
94	90	8	1.2		20	45		1.24		9.6	11.90	100.24
102	98	8	1.0		20	43		1.04		8.0	8.32	108.56
109 110	106	8	.9		25	47		1.19		7.2	8.57	116.2 117.13
118	114	8	1.0		20	42		1.06		8.0	8.48	125.61
126	122	8	1.0		20	40		1.11		8.0	8.88	134.49
134	130	8	.9		15	43		.78		7.2	5.62	140.11
142	138	8	.8		20	40		1.11		6.4	7.10	147.21
144 150	146	8	.7		25	44		1.27		5.6	7.11	149.40 154.32
158	154	8	.9		25	44		1.27		7.2	9.14	163.46
166	162	8	.8		10	54		.42		6.4	2.69	166.15
170	170	4	0		REW					0	0	166.15
	160	160								152.0	166.15	
											166	

EDI cumulative discharge

EDI far mid-point centroid stationing

Figure 31. Discharge-measurement notes used to estimate the equal-discharge-increment centroid locations based on cumulative discharge and far-midpoint stationing.

ments may be used to determine centroids of equal increments of discharge.

By plotting the cumulative discharge versus stations for our example (fig. 32), the stations of the centroids may be read directly from the curve. Their values are 36, 59, 82, 110, and 146 ft^3/s, which correspond nicely with our previously estimated values.

A number of these measurements may be plotted on the same sheet (fig. 33) and carried into the field. For discharges that fall between those plotted, the field person can estimate the locations of the centroids by interpolating between the curves.

An alternate method of estimation is to plot cumulative percent of total discharge on the y-axis, instead of cumulative discharge (fig. 34). This method entails one additional step, in that the cumulative percent must be calculated; however, it does have the advantage of showing the variation in stations for the same percentage of flow for different discharges. For example, figure 34 shows that for discharges 86 to 200 ft^3/s, the 10-percent centroid (the centroid of the first 20 percent of flow) can range from station 20 to station 50.

The transit rate used in traversing the distance from water surface to streambed and back to water surface need not be the same in both directions and can vary among centroids. This technique should facilitate collection of approximately equal sample volumes from each centroid (fig. 35).

Individual bottles collected as part of an EDI sample set can be analyzed for concentration separately and their concentrations averaged to give the mean discharge-weighted concentration for the set. The advantage of this method is that data describing the cross-sectional variation in concentration are produced. Additionally, a bottle containing an abnormally high concentration compared to others in the set (due to recirculation or to digging the nozzle into the bed) could be excluded from the concentration calculation where it might seriously affect the results. If approximately equal volumes of sample are collected at each vertical, the samples may be composited prior to analysis.

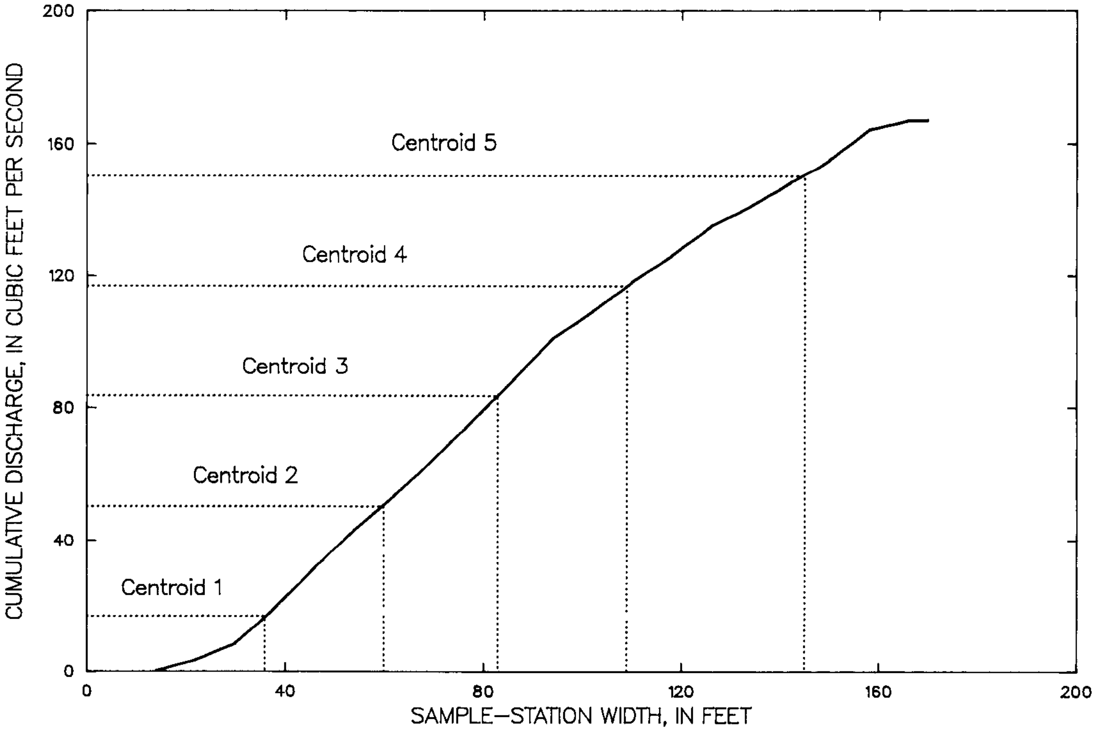


Figure 32. Cumulative discharge versus sample-station widths for determining equal-discharge-increment centroid locations.

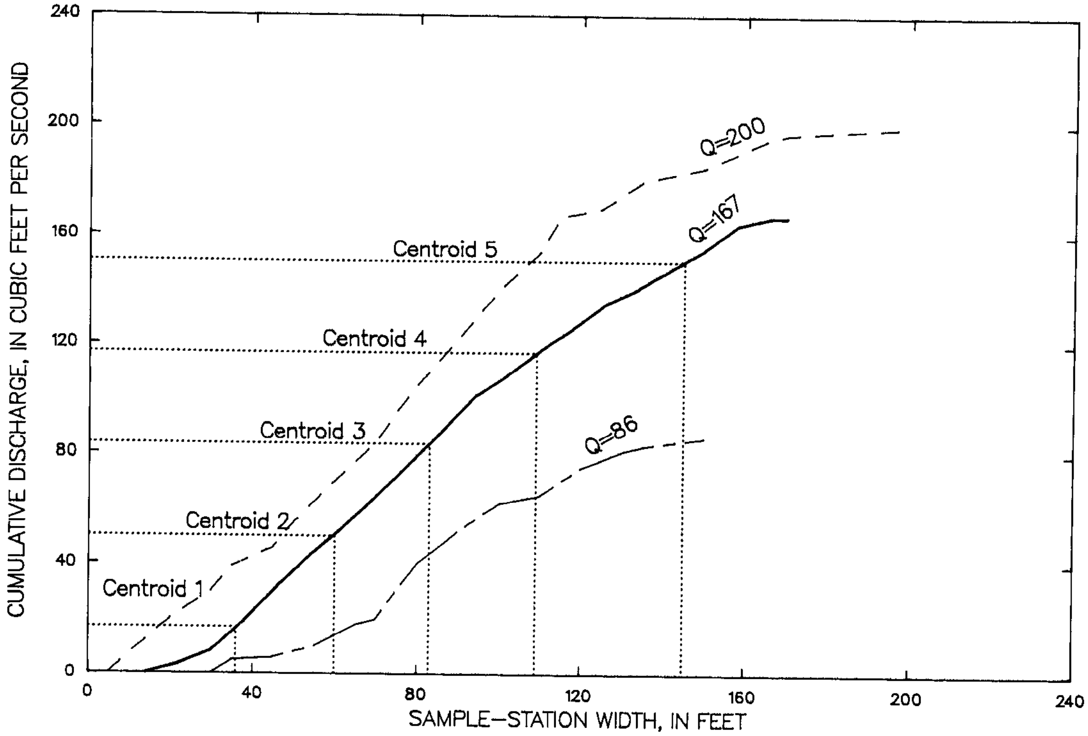


Figure 33. Cumulative discharge versus sample-station widths for determining equal-discharge-increment centroid locations. Multiple discharge-measurement plots allow users to estimate centroid locations by interpolating between curves.

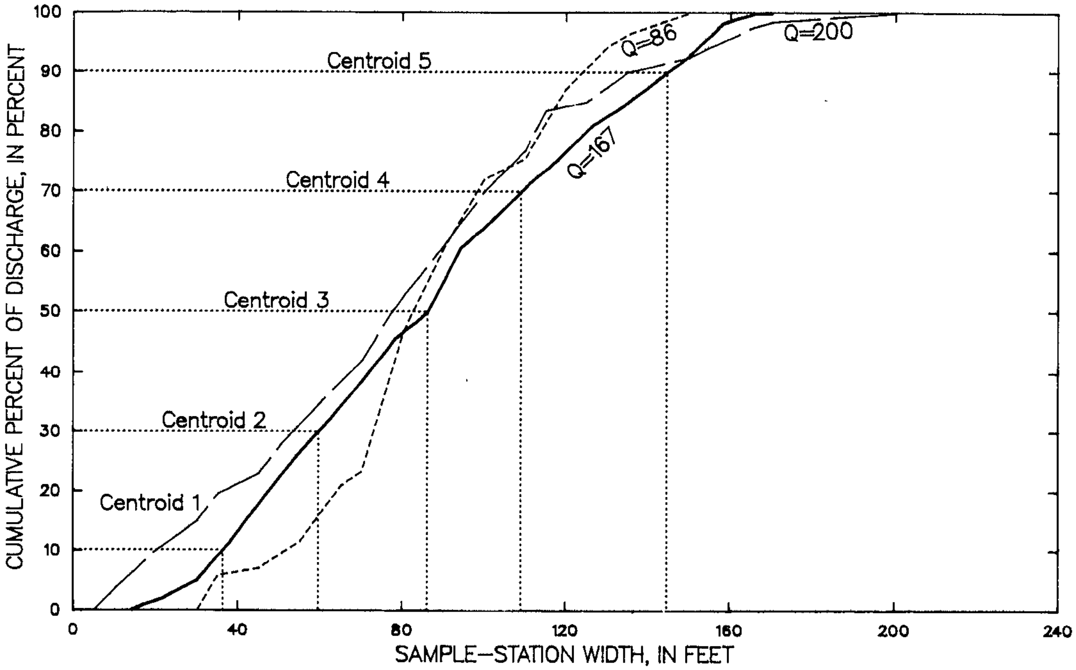


Figure 34. Cumulative percent of discharge versus sample-station widths for determining equal-discharge-increment centroid locations.

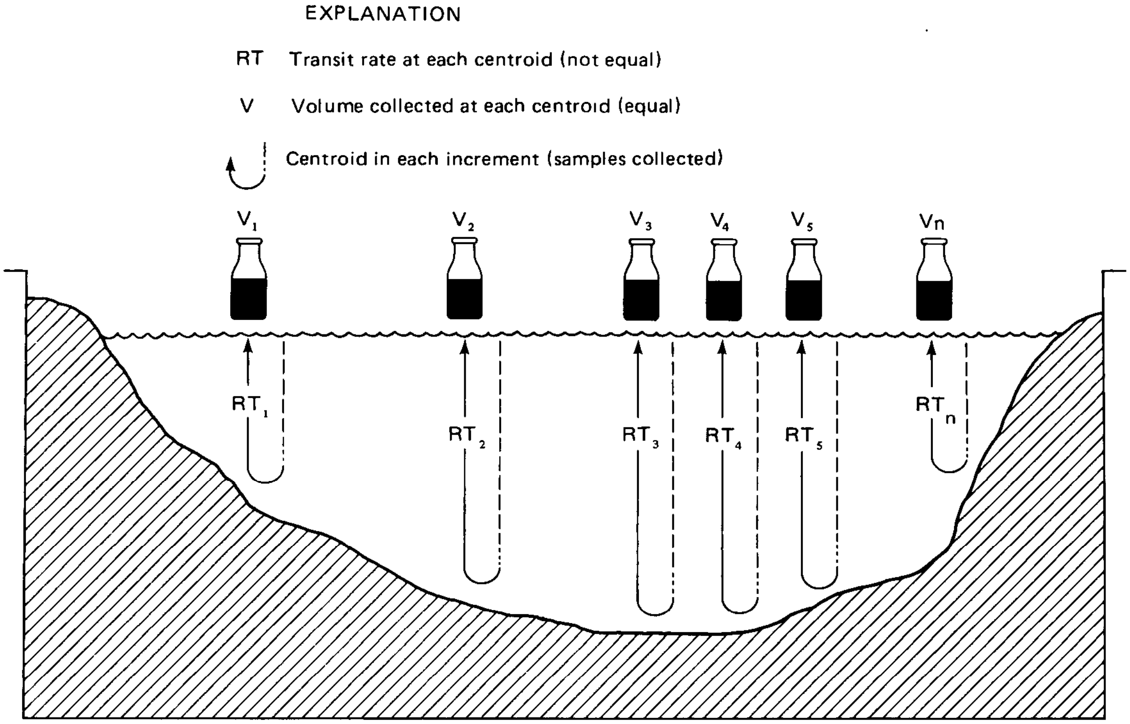


Figure 35. Vertical transit rate relative to sample volume collected at each equal-discharge-increment centroid.

The streambed of a sand-bed stream characteristically shifts radically, at single points and across segments of the width, over a period of weeks or in a matter of hours. This not only makes it impossible to establish cumulative discharge or cumulative percentage of discharge versus station curves applicable from one visit to the next, but also makes it impossible to be certain the discharge distribution does not change between the water-discharge measurement and the sediment sampling (see Guy, 1970, fig. 15).

The Equal-Width-Increment Method

A cross-sectional suspended-sediment sample obtained by the equal-width-increment (EWI) method requires a sample volume proportional to the amount of flow at each of several equally spaced verticals in the cross section. This equal spacing between the verticals (EWI) across the stream and sampling at an equal transit rate at all verticals yields a gross sample volume proportional to the total streamflow. It is important, obviously, to keep the same size nozzle in the sampler for a given measurement. This method was first used by B.C. Colby in 1946 (Federal Inter-Agency Sedimentation Project, 1963b, p. 41) and is used most often in shallow, wadable streams and (or) sand-bed streams where the distribution of water discharge in the cross section is not stable. It also is useful in streams where tributary flow has not completely mixed with the main-stem flow.

The number of verticals required for an EWI sediment-discharge measurement depends on the distribution of concentration and flow in the cross section at the time of sampling, as well as on the desired accuracy of the result. On many streams, both statistical approaches and experience are needed to determine the desirable number of verticals. Until such experience is gained, the number of verticals used should be greater than necessary. In all cases, a minimum of 10 verticals should be used for streams over 5 feet wide. For streams less than 5 feet wide, as many verticals as possible should be used, as long as they are spaced a minimum of 3 inches apart, to allow for discrete sampling of each vertical and to avoid overlaps. Through general experience with similar streams, field personnel can estimate the required minimum number of verticals to yield a desired level of accuracy. For all but the very wide and shallow streams, a maximum of 20 verticals is usually ample.

The width of the increments to be sampled, or the distance between verticals, is determined by dividing the stream width by the number of verticals necessary to collect a discharge-weighted suspended-sediment sample representative of the sediment concentration of the flow in the cross section (fig 36). For example, if the stream width determined from the tagline, cableway, or bridge-rail markings at the sample cross section is 160 feet, and the number of verticals necessary is 10, then the width (W) of each sampled increment would be 16 feet. The sample station within each width increment is located at the center of the increment (W/2), beginning at a location of 8 feet from the bank nearest the initial point for width measurement. The verticals then are spaced 16 feet apart, resulting in sample stationing at 8, 24, 40, 56, 72, 88, 104, 120, 136, and 152 feet of width. However, in the event the width increment results in a fractional measurement, the width can be rounded to the nearest integer that will yield a whole numbered station for the initial sample vertical. That is, if the increment computation yields a width of 15.5 feet, the nearest integer width would be 16 feet, and the initial vertical would be located at 8 feet from the bank; the stationing would be similar to the previous example. Results of samples obtained using this nonideal stationing will not be measurably affected because alterations in width occur in the increments nearest the streambank, where flow velocity is low compared to midstream increments.

The EWI sampling method requires that all verticals be traversed using the transit rate (fig. 37) established at the deepest and fastest vertical in the cross section. The descending and ascending transit rates must be equal during the sampling traverse of each vertical, and they must be the same at all verticals. By using this equal-transit-rate technique with a standard depth- or point-integrating sampler at each vertical, a volume of water proportional to the flow in the vertical will be collected (fig. 37).

It is often difficult to maintain an equal transit rate when collecting samples while wading. The authors have found the following procedure to be effective in alleviating this difficulty. The field person should hold the sampler at a reference point on the body (for example, the hip), at which level the downward and upward integration is started and finished (even though part of the traverse is in air). The same reference point should be used at each vertical, allowing the same amount of time to elapse during the round trip traverse of the sampler (regardless of the stream depth encountered). In this manner, the transit rate will remain constant for the entire cross section. It should be remembered that the reference point at which the sampler traverse is started and stopped must be located above the water surface at the deepest vertical sampled and must be the same for each vertical.

Because the maximum transit rate must not exceed 0.4 v_m (v_m equals the mean ambient velocity in the sampled vertical) and because the minimum rate must be sufficiently fast to keep from overfilling any of the sample bottles, it is evident that the transit rate to be used for all verticals is limited by conditions at the vertical containing the largest discharge per foot of width (largest product of depth times velocity). A discharge measurement can be made to determine where this vertical is located, but generally, it is estimated by sounding for depth and acquiring a feel for the relative velocity with an empty sampler or wading rod. The transit rate required at the maximum discharge vertical then must be used at all other verticals in the cross section and is usually set to fill a bottle to the maximum sample volume in a round trip. It is possible to sample at two or more verticals using the same bottle if the bottle is not overfilled. If a bottle is overfilled, it must be discarded, and all verticals previously sampled using that bottle must be resampled, using a sufficient number of bottles to avoid overfilling. Note: a sample bottle is overfilled when the water surface in the bottle is above the nozzle or air exhaust with the sampler held level.

Advantages and Disadvantages of Equal-Discharge-Increment and Equal-Width-Increment Methods

Some advantages and disadvantages of both the EDI and EWI methods have been mentioned in the previous discussion. It must be remembered, however, that both methods, if properly used, yield the same results. The advantages of the EDI method are—

1. Fewer verticals are necessary, resulting in a shortened collection time.
2. Sampling during rapidly changing stages is facilitated by the shorter sampling time.
3. Bottles comprising a sample set may be composited for laboratory analysis when equal volumes of sample are collected from each vertical.

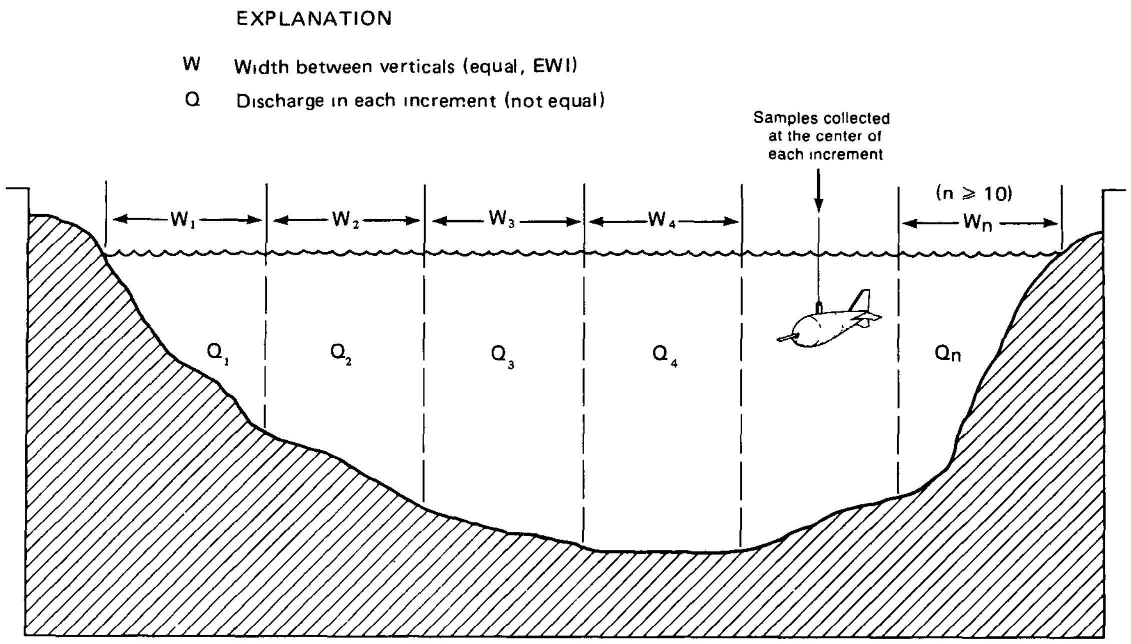


Figure 36. Equal-width-increment sampling technique.

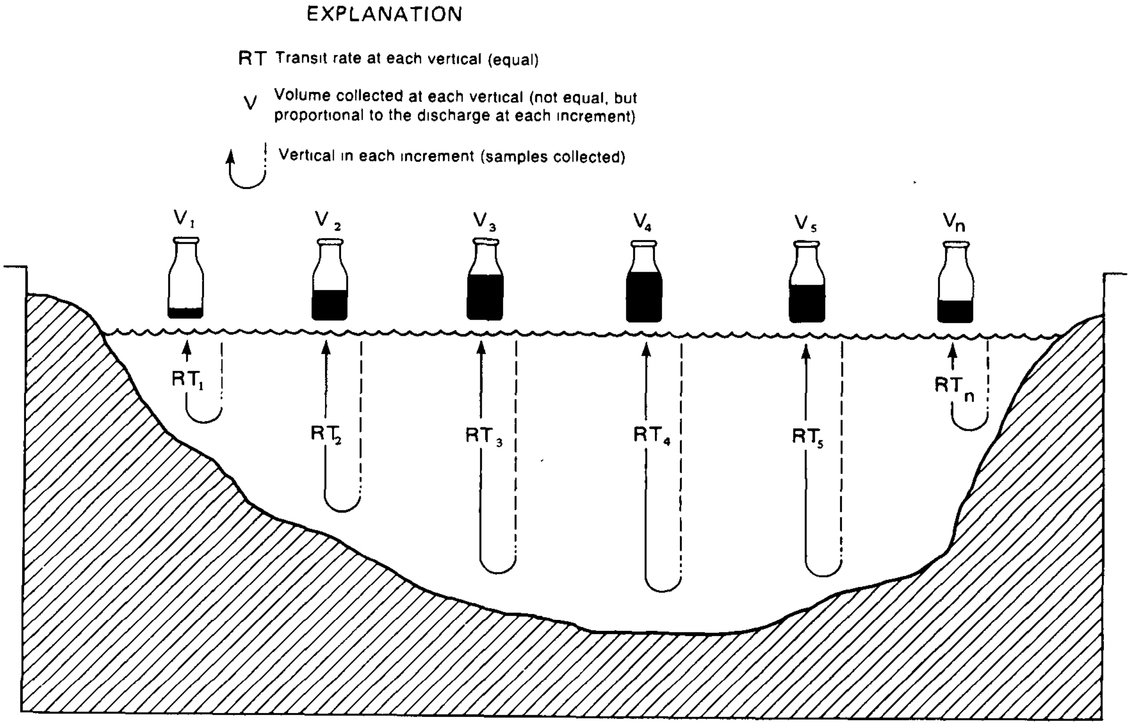


Figure 37. Equal-width-increment vertical transit rate relative to sample volume, which is proportional to water discharge at each vertical.

4. The cross-sectional variation in concentration can be determined if sample bottles are analyzed individually.
5. Duplicate cross-section samples can be collected simultaneously.
6. A variable transit rate can be used among verticals.

The advantages of the EWI method are—

1. Previous knowledge of flow distribution in the cross section is not required.
2. Variations in the distribution of concentration in the cross section may be better defined, due to the greater number of verticals sampled.
3. Analytical time is reduced as sample bottles are composited for laboratory analysis.
4. This method is easily taught to and used by observers because the spacing of sample verticals is based on the easily obtained stream width, instead of on discharge.
5. Generally less total time is required on site, if no discharge measurement is deemed necessary and the cross section is stable.

From the previous discussion it is obvious that, while both methods have definite advantages, the advantages of one method are, in many cases, the disadvantages of the other. One major disadvantage of the EWI method that should be noted is the inability to adequately distinguish obviously bad samples in the sample set, as illustrated by the following:

Example:

Vertical/bottle	1	2	3	4	5	6
Weight of sediment (g)	0.053	0.036	0.699	0.053	0.047	0.036
Weight of water sediment mixture (g)	350	300	325	330	360	355
Concentration (mg/L)	151	120	2,150	161	131	101

Mean concentration

EWI and EDI methods (composited) = 457 mg/L

EDI method (individual bottles analyzed, concentration averaged) = 469 mg/L

EDI method (individual bottles analyzed excluding bottle 3, concentration averaged) = 133 mg/L

As this example shows, if the sample were an EWI sample and composited for analysis, the computed mean concentration is 457 mg/L, which also is the mean concentration if the sample were considered as an EDI sample similarly composited for analysis. If, in the case of the EDI sample, the individual bottles were analyzed, normal computation would result in a mean concentration of 469 mg/L. From the data, bottle 3 appears to have been enriched and is not consistent with the other data points for this cross section. By exercising the flexibility of the EDI method and eliminating the number 3 bottle, the mean concentration of the remaining five bottles is computed to be 133 mg/L, which is probably more consistent with the actual mean concentration in the cross section.

Point Samples

A point sample is a sample of the water-sediment mixture collected from a single point in the cross section. It may be collected using a point-integrating sampler.

Point-integrated samples may be collected using one of the point-integrating samplers previously discussed. Data obtained in this manner may be used to define the distribution of sediment in a single vertical, such as the observer's fixed station, the vertical and horizontal distribution of sediment in a cross section, and the mean spatial sediment concentration.

The purpose for which point samples are to be collected determines the collection method to be used. If samples are collected for the purpose of defining the horizontal and vertical distribution of concentration and (or) particle size, samples collected at numerous points in the cross section, with any of the "P" type samplers, will be sufficient. Normally, 5 to 10 verticals are sufficient for horizontal definition. Vertical distribution can be adequately defined by obtaining samples from a number of points in each sample vertical. Specifically, samples should be taken at the surface, from 1 foot above the bed point, with the sampler touching the bed, and from 6 to 10 additional points in the vertical above the 1-foot-above-bed point. Each individual point sample should be analyzed separately. The results then can be plotted on a cross section relative to their instream location.

If point samples are collected to define the mean concentration in a vertical, 5 to 10 samples should be collected from the vertical. The sampling time for each sample (the time the nozzle is open) must be equal.

This will ensure that samples collected are proportional to the flow at the point of collection. These samples then are composited for laboratory analysis. If the EDI method is used to define the stationing of the verticals, the sampling time may be varied among verticals. If the EWI method is used to determine the location of verticals, a constant sampling time for samples from all verticals must be used.

Number of Verticals

The number of suspended-sediment sampling verticals at a measuring site may depend on the kind of information needed in relation to the physical aspects of the river. For example, to determine the distribution of sediment concentration or particle size across the stream, it is necessary to sample at several verticals. The number of verticals necessary to define such a cross-sectional distribution depends on the accuracy being sought and on the systematic variation of sediment concentration at different verticals across the stream.

As noted previously, suspended-sediment samplers are designed to accumulate a sample that is directly proportional to the stream discharge or velocity. The accumulated sample may be from a point in the stream cross section, a vertical line between the surface and streambed, or several such vertical lines across the entire stream cross section. Such a sample then can be considered to be representative of some element of cross-sectional flow, whether it be a few square feet adjacent to the point sample, a few square feet adjacent to both sides of a vertical line, or the area of the entire flow summed by several vertical lines. The number of verticals sampled must be adequate to represent the cross section in the sample. The number of sample bottles to be collected will depend on the kind of analysis to be made in the laboratory, and the location of the sampling verticals will depend on the concentration and size distribution of sediment moving through the stream cross section.

Both EDI and EWI methods of sediment-discharge measurement obtain a water-discharge weighted sample at each vertical. The volumetric sum from all verticals yields a sample volume proportional to the water discharge for the stream. Remember that all or nearly all of the concentration variations at different verticals across the stream may be the result of nonuniform distribution of sand-sized material and that finer sediments are generally more uniformly dispersed throughout the section. If the section is close to a tributary, mixing of main stream and tributary flows may not be complete. Therefore, locating sampling sections downstream from tributary inflows should be avoided.

Colby (1964) showed that the discharge of sand is approximately proportional to the third power of the mean velocity, with constant temperature and a given particle-size distribution for a range of velocity from about 2 to 5 ft/s and within some reasonable range of depths. Thus, $Q_s = k_1 v^3$, in which Q_s is the discharge of sand per unit width; k_1 is a constant for a given depth, particle size, and temperature; and v is the mean velocity. The sand discharge can be written as $Q_s = k_2 c v d$, in which k_2 is another constant, c is the mean discharge-weighted concentration in the sampled vertical, and d is the total sampled depth. Solving for c gives

$$c = \frac{k_1}{k_2} \frac{v^2}{d}$$

Thus, the variability of concentration at different sampling verticals should be closely related to the variability of v^2/d. In order to have a v^2/d index useful for comparison among all streams, the compound ratio

$$\frac{v^2 d_{(\max)}}{v^2 d} \text{ is suggested,}$$

where $[v^2/d_{(\max)}]$ is the ratio from the vertical having the maximum v^2/d, and v^2/d is the ratio of the mean velocity squared to the mean depth of the whole stream cross section. The mean velocity and mean depth are computed and available from water-discharge measurements.

Based on the v^2/d index concepts of variability, P.R. Jordan used data from Hubbell and others (1956) to prepare a nomograph (fig. 38) that indicates the number of sampling verticals required for a desired maximum acceptable relative standard error (sampling error) based on the percentage of sand and the v^2/d index. In the example illustrated by figure 38, the acceptable relative standard error is 15 percent, the sample is 100-percent sand, the v^2/d index is 2.0, and the required number of verticals is seven. Notice that if the sediment were 50-percent sand, the same results

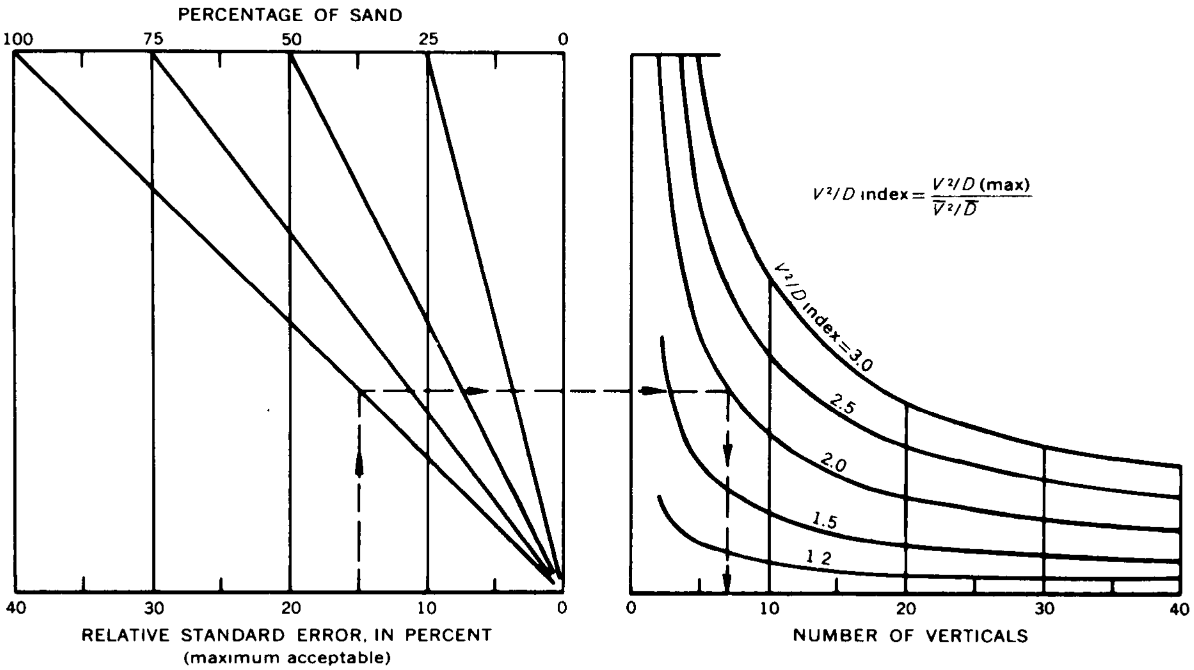


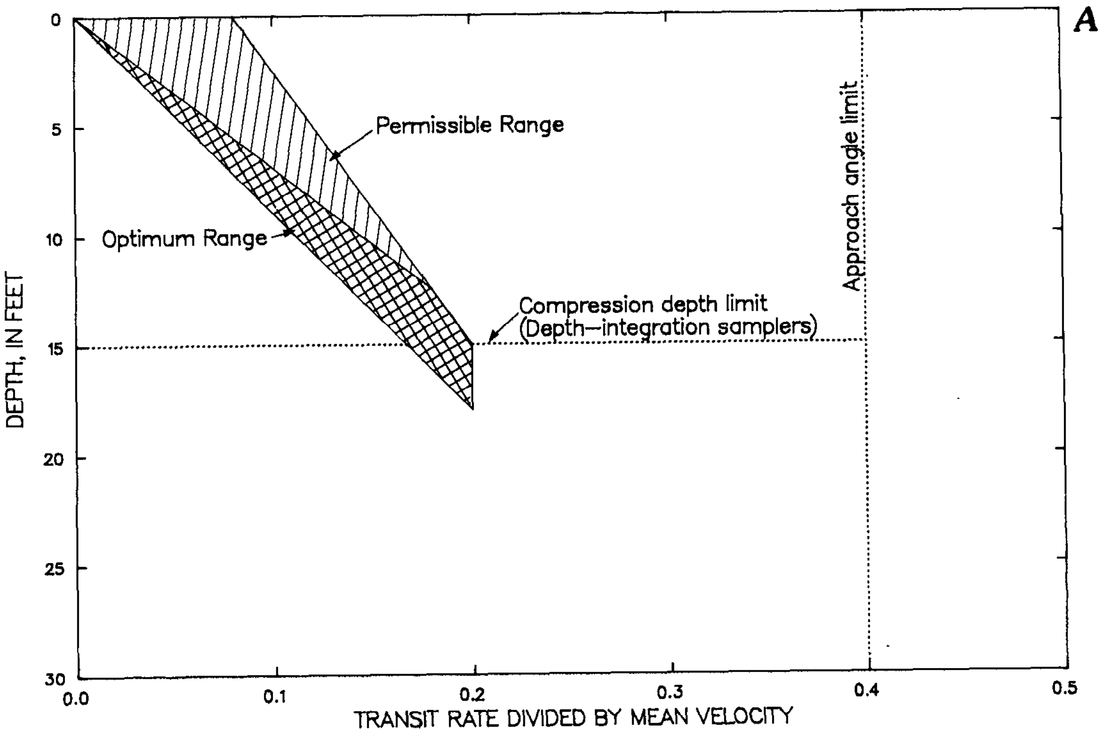
Figure 38. Nomograph to determine number of sampling verticals required to obtain results within an acceptable relative standard error.

could be obtained with three verticals; or, if seven verticals were used with 50-percent sand, the relative standard error would be about 8 percent. When the discharge of sand-sized particles is of primary interest, the 100-percent line should be used regardless of the amount of fines in the sample.

Transit Rates for Suspended-Sediment Sampling

The sample obtained by passing the sampler throughout the full depth of a stream is quantitatively weighted according to the velocity through which it passes. Therefore, if the sampling vertical represents a specific width of flow, the sample is considered to be discharge weighted because, with a uniform transit rate, suspended sediment carried by the discharge throughout the sampled vertical is given equal time to enter the sampler. In previous writings, the point was made to keep the transit rate of the samplers constant throughout at least a single direction of travel.

The maximum transit rate used with any depth-integrating sampler must be regulated to ensure the collection of representative samples. If the transit rate is too fast, the rate of air-volume reduction in the sample container is less than the rate of increase in hydrostatic pressure surrounding the sampler, and water may be forced into the intake or air exhaust. Additionally, an excessive transit rate can result in intake velocities less than the stream velocity at the intake, due to a large entrance angle between the nozzle and streamflow lines caused by the vertical movement of the sampler in the flow (Federal Inter-Agency Sedimentation Project, 1952). To alleviate these problems, transit rates should never exceed 0.4 of the mean velocity (0.4 v_m) in a vertical. Figures 39, 40, and 41 can be used to determine the appropriate transit rate to be used with a given nozzle-size/sample-container-size combination. These figures show that maximum transit rates vary from about 0.1 v_m to the approach angle limit of 0.4 v_m, previously noted. This variation is a function of both nozzle size and sample-container size. The smaller nozzle (1/8 inch) is greatly affected by approach angle intake velocity reductions; figures 39 and 40 show that the transit rate decreases directly with nozzle size. Also, by comparison of figures 39 and 40, it is obvious that transit rates are inversely affected by sample-container size because an increase in sampler container size produces a decrease in allowable transit rate due to the effects of hydrostatic pressure compressing the air within the container during the downward transit. Figures 39, 40, and 41 were constructed using procedures from F.I.S.P. (1952), Report 6, Section 8, as contained in the



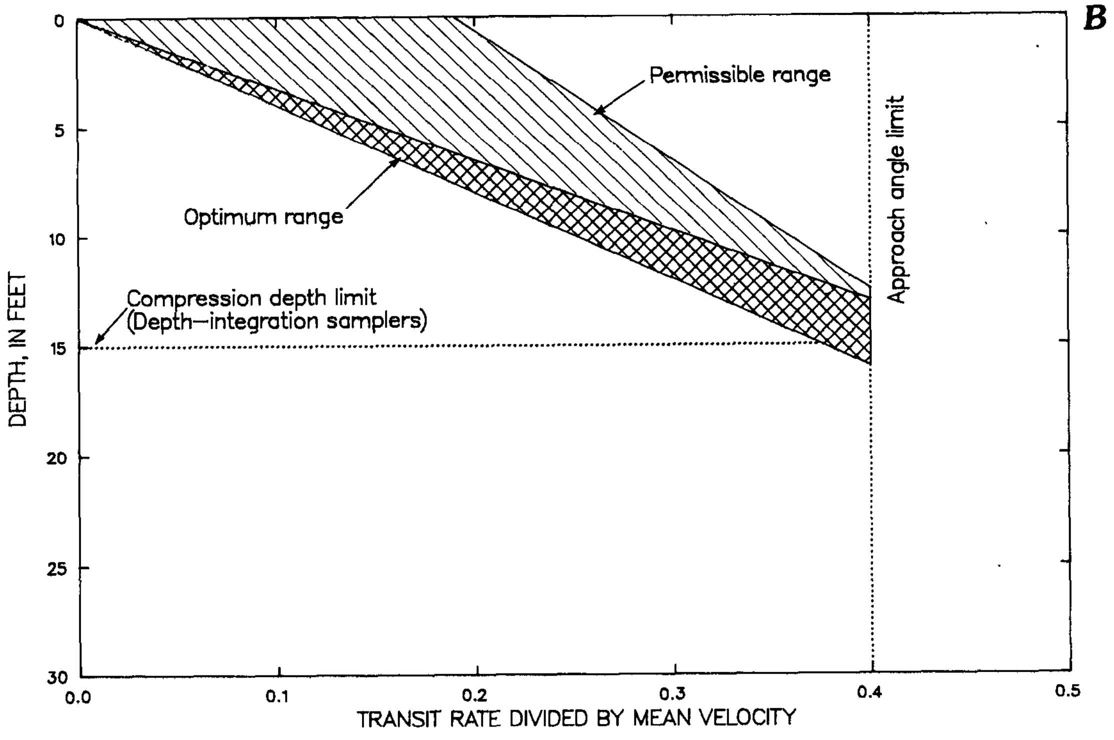


Figure 39. Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for pint-size sample container. *A*, 1/8-inch nozzle. *B*, 3/16-inch nozzle. *C*, 1/4-inch nozzle.

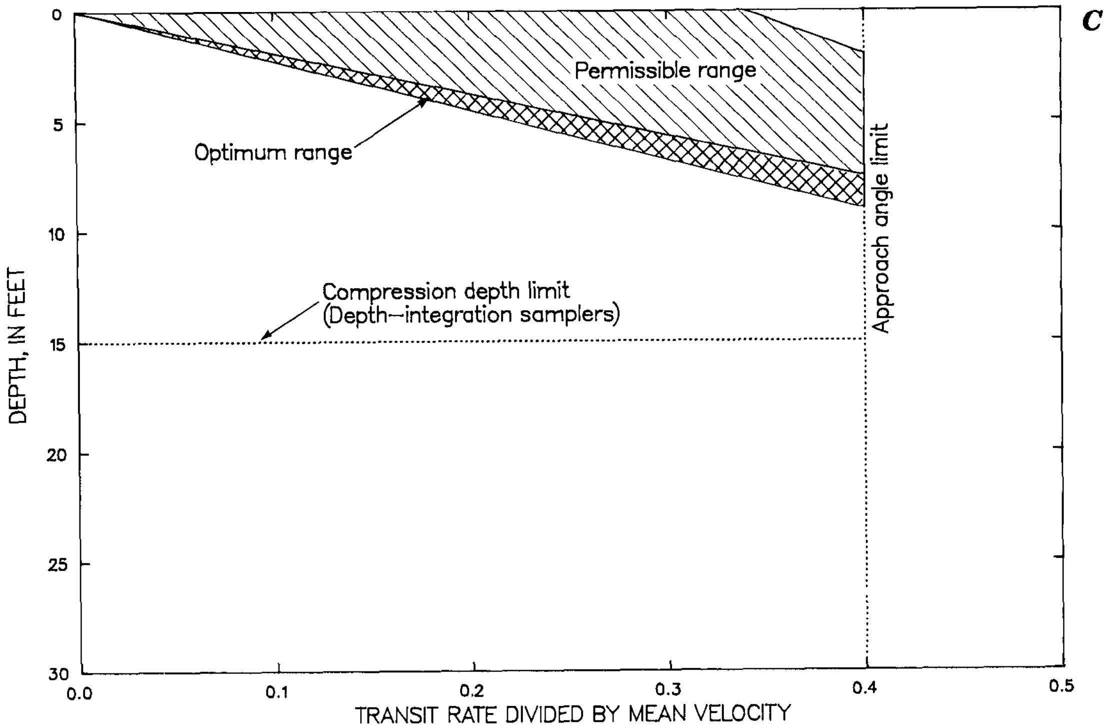


Figure 39. Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for pint-size sample container. *A*, 1/8-inch nozzle. *B*, 3/16-inch nozzle. *C*, 1/4-inch nozzle—Continued.

sampling instructions for the D-74 depth-integrating sampler.

Figure 42 is a graphic presentation of the procedure to be followed when constructing transit-rate graphs similar to those presented in figures 39, 40, and 41, using the following nomenclature and equations:

A_n = Area of intake nozzle at entrance; square feet 1/8 inch = 8.52×10^{-5}, 3/16 inch = 19.2×10^{-5}, 1/4 inch = 34.1×10^{-5}, and 5/16 inch = 53.3×10^{-5}

d_c = Stream depth where bottom compression limit equals surface compression; feet

h_1 = Atmospheric pressure at water surface = 34 feet at sea level

Q_{max} = Maximum sample volume; cubic feet (pint bottle, 420 mL = 0.015 ft^3; quart bottle, 800 mL = 0.028 ft^3; 3-liter bottle, 2,700 mL = 0.095 ft^3)

Q_{min} = Minimum sample volume; cubic feet (pint bottle, 300 mL = 0.011 ft^3; quart bottle, 650 mL = 0.023 ft^3; 3-liter bottle, 2,000 mL = 0.071 ft^3)

r_b = Relative velocity near stream bottom; feet per second

RT = Transit rate of sampler; feet per second (rising rate equals lowering rate for EWI method)

r_s = Relative velocity at stream surface; feet per second

V_1 = Volume of container; cubic feet 1 pint = 0.01671 ft^3, 1 quart = 0.03342 ft^3, and 3-liter bottle = 0.105 ft^3

V_m = Mean stream velocity in vertical; feet per second

$$\text{Point 1} \quad \frac{\mathrm{RT}}{V_m} = \frac{A_n r_b h_1}{V_1}$$

$$\text{Point 2} \quad \frac{\mathrm{RT}}{V_m} = \frac{A_n h_s h_1}{V_1}$$

$$\text{Point 3} \quad d_c = \frac{h_1(r_s - r_b)}{r_{b+1}} =$$

15 feet, for assumed velocity profile in figure 42.

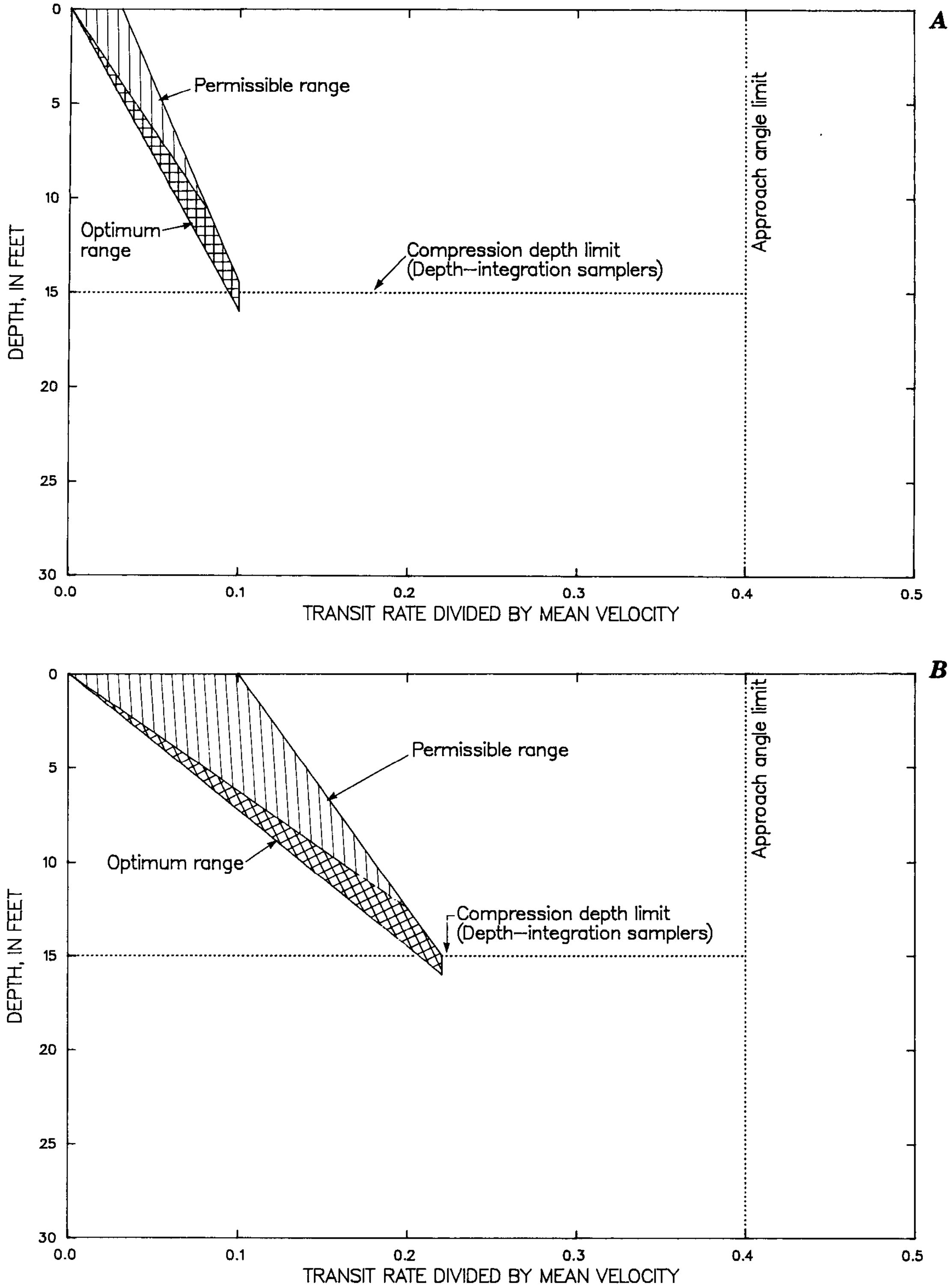


Figure 40. Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for quart-size sample container. *A*, 1/8-inch nozzle. *B*, 3/16-inch nozzle. *C*, 1/4-inch nozzle.

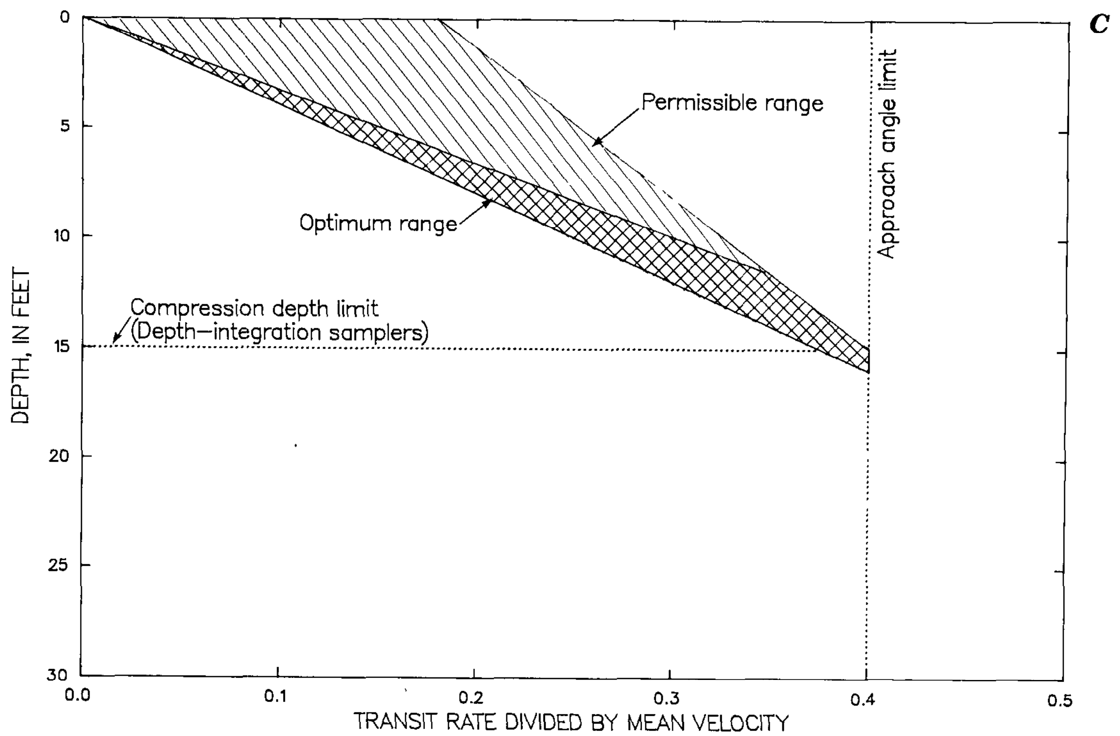


Figure 40. Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for quart-size sample container. A, 1/8-inch nozzle B, 3/16-inch nozzle. C, 1/4-inch nozzle—Continued.

Point 4 $\frac{\mathrm{RT}}{V_m} = \frac{20\ A_n}{Q_{\max}}$

Point 5 $\frac{\mathrm{RT}}{V_m} = \frac{20\ A_n}{Q_{\min}}$

For points 4 and 5, the depth is arbitrarily taken at 10 feet to facilitate plotting. Also, the following sample vertical velocity profile is assumed:

Relative depth	*Velocity/ mean velocity in vertical*
surface	1.16
.1	1.17
.2	1.16
.3	1.15
.4	1.10
.5	1.05
.6	1.0
.7	.94
.8	.84
.9	.67
1.0 bottom	.5

The technique for use of figures 39, 40, and 41 to determine the transit rate to be used in a given situation depends upon (1) the depth of the sample vertical, (2) the mean velocity of the vertical, (3) the nozzle size being used, and (4) the sample-bottle size used in the sampler. An example of transit-rate determination is presented in figure 43. The nozzle size and sample-bottle size must be known so the proper figure can be selected. In this case, a 3 /16-inch nozzle and 1-pint bottle will be used. The depth and mean velocity of the sample vertical also must be known. For this example, a depth of 10 feet and mean velocity of 2 ft/s are assumed. To determine transit rate for this example (1) select the depth of the sample vertical (10 feet); (2) draw a line perpendicular to the depth on the vertical scale that terminates at the center of the optimum range; (3) read the value of RT/V_m from the horizontal scale corresponding to this point (0.28); and (4) multiply the RT/V_m value by the mean velocity (V_m = 2 ft/s) to determine the transit rate (RT = 0.56 ft/s). Note that, if the same nozzle, depth, and mean velocity were used with a quart sample container in lieu of the pint container (fig. 40*B*), an RT value of 0.30 ft/s would be used, reducing the transit rate by almost one-half.

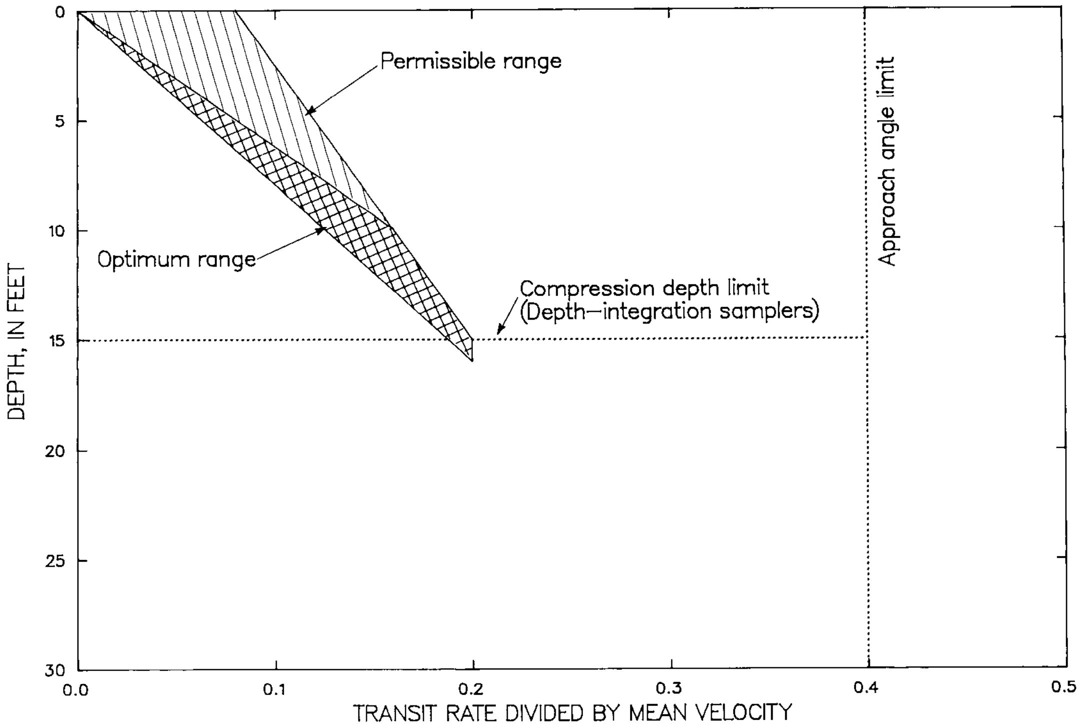


Figure 41. Range of transit rate to mean velocity ratio versus depth for 5/16-inch nozzle on a 3-liter sample bottle.

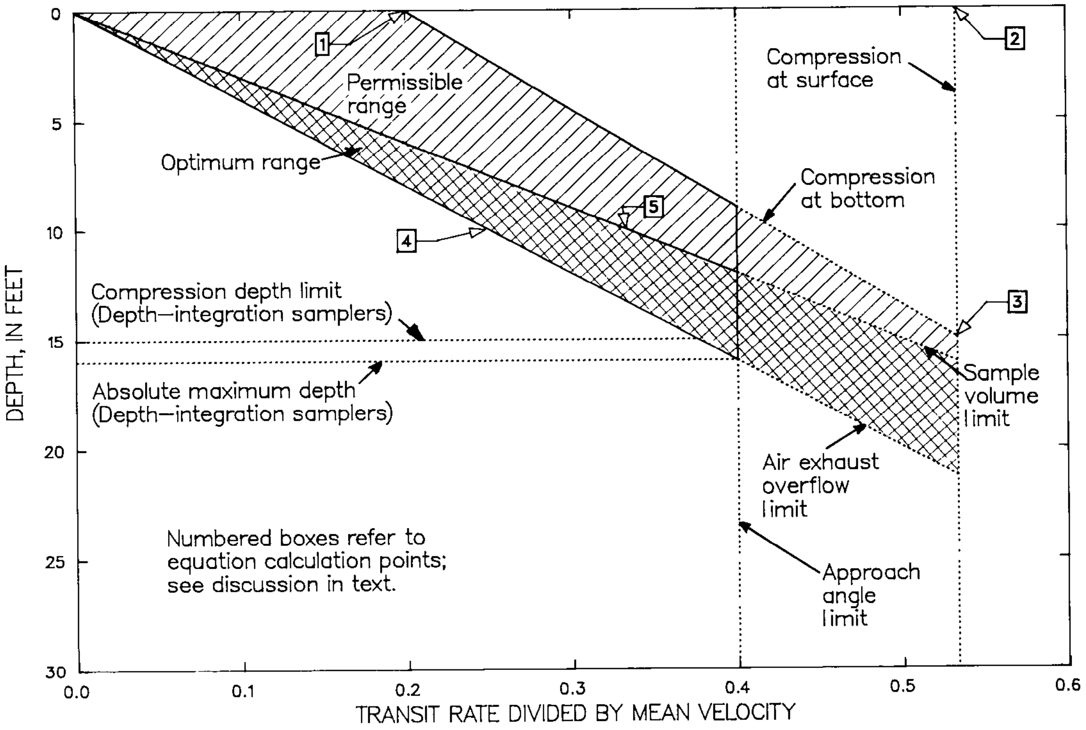


Figure 42. Construction of a transit-rate determination graph (see text for explanation of numbered points).

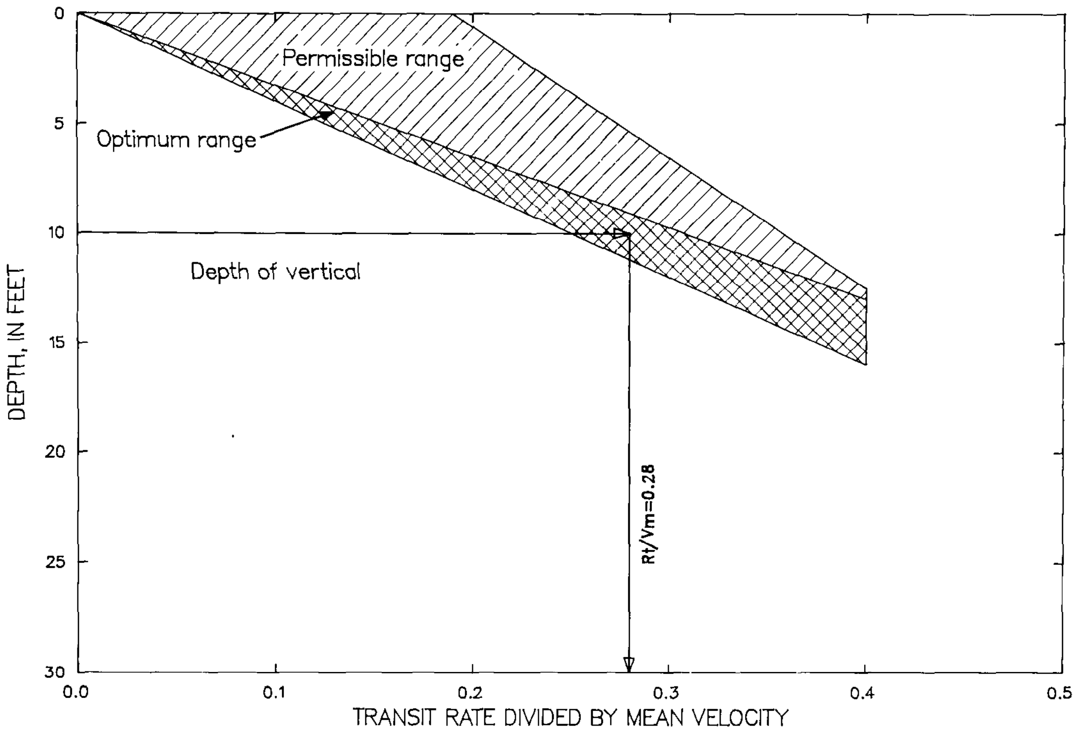


Figure 43. Example of transit rate determination using graph developed for 3/16-inch nozzle and a 1-pint sample container (see text for discussion).

Use of transit rates determined from the optimum range of figures 39, 40, or 41 will yield a representative sample of adequate volume to provide for laboratory analysis and avoid overfilling. In some instances, however, sampler operation within the optimum range is not possible. Under these conditions, operation using a transit rate determined from the permissible range is acceptable. In these cases, it should be realized that a representative sample can still be obtained, but the sample volume may be less than adequate for laboratory purposes and, therefore, more integrations may be required at each vertical to obtain the necessary volume of sample.

Additional explanation and qualifications with respect to the transit rate for depth-integrated suspended-sediment sampling include the following:

1. For cable-suspended samplers, the instantaneous actual transit rate, RT_a, may differ considerably from the computed rate, RT, if V_m exceeds about 6 ft/s and if the sampler is suspended from more than 20 feet above the water surface. Under such conditions, the sampler is dragged downstream, and the indicated depth is greater than the true depth. Corrections for indicated depth are given by Buchanan and Somers (1969, p. 50–56) for various angles and lengths of sounding line used for suspension of a weight in deep, swift water. The correct depth then would be used to enter in figures 39, 40, and 41 to determine the appropriate transit rate.

2. In theory, the allowable RT may be greater than 0.4 V_m, and sampling depth thereby increased if the sampler is cable suspended and capable of being tilted somewhat in the direction of vertical movement (that is, nozzle is slightly down when sampler is lowered and slightly up when sampler is raised, due to the effect of vertical forces on the horizontal tail-fin stabilizer). On the other hand, if the sampler cannot be tilted, the velocity at the bottom of the vertical is much less than V_m, and there is a heavy concentration of suspended sand near the bed, the use of an RT value near the 0.4 V_m limitation may cause RT to approach or even exceed the actual velocity near the bed and thus cause an excessive error in the collection of sand particles. The approach-angle theoretical depth limits will, of course, be less if either the downward or the upward transit rates, RT_d or RT_u, are different from RT. However, determining the attitude of the sampler during actual use is difficult at best and impossible under turbid flow conditions. For this reason, varying either RT or sampling beyond recommended limits is

not advisable and probably not necessary because small errors during descent will probably be cancelled during ascent.

3. The air-compression lower limit is based on the assumption that a uniform velocity distribution exists throughout the vertical. Actually, the velocity varies with the depth throughout the vertical. Therefore, where the velocity is considerably greater than the mean in the upper part of the vertical, the lower limit could be increased somewhat. In theory, the air-compression lower limit could be effectively increased by using a downward transit rate, RT_d, where RT_d is less than RT, and compensating for the extra filling of the bottle on the downward trip by using an upward transit rate, RT_u, where $RT_u = RT + (RT - RT_d)$. Note: this brief discussion is presented here as an interesting concept and should not be practiced in actual field conditions, where channel configuration and velocity profiles may not represent the ideal flow conditions found in a controlled flume environment.

4. Because of possible greater deviation from the ideal relation of intake velocity to stream velocity of 1.0, the 1/8-inch nozzle should not be used if there are significant quantities of sand larger than 0.25 mm in suspension. The 1/8-inch nozzle also is less reliable than the larger nozzles where small roots and other organic fibers are suspended in the flow.

5. In the event the sampler accommodates other than a pint-sized sample container, the RT should be carefully determined because RT for a quart container may be nearly one-half of that acceptable for a pint container with a given nozzle size. The use of a sample container larger than 1 pint does not, however, increase the sample depth range, due to the air-compression depth limit. Therefore, samples should not be taken from greater than about 15 feet with a depth-integrating sampler.

Observer Samples

At many sites, collection of suspended-sediment data is required on a frequent basis. To define the sediment-discharge trends, these data could be required once daily or more often (in the case of high-flow events). Frequent suspended-sediment data collection can put extreme pressure on a project's fiscal resources as well as on the personnel involved. In order to save money, travel time and, most importantly, to ensure timely collection of data on a regular basis and during extreme events, local residents are often contracted to work as observers.

Observers usually lack technical background, but can be trained to collect cross-section samples using either the EDI or EWI method. However, due to the complexities involved in computing centroids and a lack of expertise in obtaining the stream discharge for the EDI method, this technique is not recommended for observer-operated sites. Observers most often collect samples from an established single vertical in the cross section, as previously mentioned. The best location in the cross section for a single-vertical sediment sample is determined by data collection. Generally, each new sediment-record site is carefully investigated by means of several detailed sediment-discharge measurements to determine the concentration of sediment across the stream at different discharges. These sediment data can be collected using either the EDI or EWI method.

If the single vertical is used to obtain observer-collected samples, these data must be treated much the same as point-sample data collected with a pumping sampler. That is, cross-section samples must be taken occasionally for comparison with the observer samples in order to establish adjustment coefficients. Samples should be collected at the observer's single-vertical using the observer's equipment, both before and after each cross-section sample is taken. These samples then form the basis for a coefficient that can be used to adjust the concentration of the single-vertical samples. This adjustment coefficient, or comparison of the routine single vertical with the cross section, is determined by computing the ratio of the average concentration of cross-section samples to the average concentration of single-vertical samples. This ratio then can be applied to the daily samples taken between sediment-discharge measurements. If the coefficient is consistently above or below unity, it may be desirable to change the position of the fixed routine sampling installation to a location where the coefficient would be at or near unity. Generally, if the coefficients are within 5 percent of unity, a coefficient of 1.0 is applied, unless they are consistently high or low for long periods of time. Guy (1968) illustrated methods for determining the quality of the coefficient and the number of samples needed in a sample set. Porterfield (1972) gave further details on how coefficients are used in the computation of sediment records.

During high flows, when the depth of the single vertical exceeds the theoretical 15-foot compression depth limit of the depth-integrating sampler, the observer should try to obtain a sample by altering the technique to collect the most representative sample possible. The best collection technique under these conditions would be to depth integrate 0.2 of the vertical depth (0.2*d*), or a 10-foot portion of the vertical. These samples then can be checked and verified by collecting a set of reference samples with a point-integrating sampler. By reducing the sampled depth during periods of high flow, the transit rate can be maintained at 0.4 V_m or less in the vertical, and a partial sample can be collected without overfilling the sample container, even under conditions of higher velocities that usually accompany increases in discharge.

Sampling Frequency, Sediment Quantity, Sample Integrity, and Identification

Sampling Frequency

When should suspended-sediment samples be taken? How close can samples be spaced in time and still be meaningful? How many extra samples are required during a flood period? These are some questions that must be answered because timing of sample observations is as important to record computations (see Porterfield, 1972) as is the technique for taking them. Answering such questions is relatively easy for those who compute and assemble the records because they have the historical record before them and can easily see what is needed. However, the field person frequently does not have this record and certainly cannot know what the conditions will be in the future.

Observers should be shown typical hydrographs or recorder charts of their stations or of nearby stations to help them understand the importance of timing their samples so that each sample yields maximum information. The desirable time distribution for samples depends on many factors, such as the season of the year, the runoff characteristics of the basin, the adequacy of coverage of previous events, and the accuracy of information desired or dictated by the purpose for which the data are collected.

For many streams, the largest concentrations and 70 to 90 percent of the annual sediment load occur during spring runoff; on other streams, the most important part of the sediment record may occur during the period of the summer thunderstorms or during winter storms. The frequency of suspended-sediment sampling should be much greater during these periods than during the low-flow periods. During some parts of these critical periods, hourly or more frequent sampling may be required to accurately define the trend of sediment concentration. During the remainder of the year, the sampling frequency can be stretched out to daily or even weekly sampling for adequate definition of concentration. Hurricane or thunderstorm events during the summer or fall require frequent samples during short periods of time. Streams having long periods of low or intermittent flow should be sampled frequently during each storm event because most of the annual sediment transport occurs during these few events.

During long periods of rather constant or gradually varying flow, most streams have concentrations and quantities of sediment that vary slowly and may, therefore, be adequately sampled every 2 or 3 days; in some streams, one sampling a week may be adequate. Several samplings a day may occasionally be needed to define the diurnal fluctuation in sediment concentration. Fluctuations in power generation and evapotranspiration can cause diurnal fluctuations. Sometimes diurnal temperature fluctuations result in a snow and ice freeze/thaw cycle causing an accompanying fall and rise in stage. Diurnal fluctuations also have been noted in sand-bed streams when water-temperature changes cause a change in flow regime and a drastic change in bed roughness (Simons and Richardson, 1965).

The temporal shape of the hydrograph is an indicator of how a stream should be sampled. Sampling twice a day may be sufficient on the rising stage if it takes a day or more for a stream to reach a peak rate of discharge. During the peak, samples every few hours may be needed. During the recession, sampling can be reduced gradually until normal sampling intervals are sufficient.

The sediment-concentration peak may occur at any time relative to the water discharge; it may coincide with the water-discharge peak or occur several days prior to or after it. Hydrographs for large rivers, especially in the Midwest, typically show water-discharge peaks occurring several days after a storm event. If the sediment concentration has its source locally, the sediment peak can occur a day or more prior to the water-discharge peak. In this case, the receding limb of the sediment-concentration curve will nearly coincide with the lagging water-discharge peak. In this event, intensive sampling logically should be done prior to the water-discharge peak. Detailed sampling of hydrograph peaks during the initial stages of a monitoring program will help determine when the sediment-sampling frequency should be increased and decreased in order to optimize the sediment-sampling effort relative to peak-flow conditions.

Intermittent and ephemeral streams usually have hydrograph traces in which the stage goes from a base flow or zero flow to the maximum stage in a matter of a few minutes or hours, and the person responsible for obtaining the samples frequently does not know when such an event is to occur. A sampling scheme should be designed to define the sediment discharge by taking samples during the rising stage, then the peak stage and the recession. Generally, adequate coverage of the peak is obtained if samples on the rising limb are four times as frequent as samples collected during the recession. For example, if the recession is best sampled on a bi-hourly basis, the rising limb should be sampled every one-half hour.

Elaborate and intensive sampling schedules are not required for each and all events on small streams that drain basins of rather uniform geologic and soil conditions because similar runoff conditions will yield similar concentrations of sediment for the different runoff events. Once a concentration pattern is established, samples collected once or twice daily may suffice, even during a storm period (Porterfield, 1972).

Streams draining basins with a wide variety of soils and geologic conditions and receiving uneven distributions of precipitation cannot be adequately sampled by a rigid, predetermined schedule. Sediment concentration in the stream depends not only on the time of year, but also on the source of the runoff in the basin. Thus, each storm or changing flow event should be covered as thoroughly as possible, in a manner similar to that described for intermittent and ephemeral streams.

The accuracy needed in the sediment information also dictates how often a stream should be sampled. The greater the required accuracy and the more complicated the flow system, the more frequently it will be necessary to obtain samples. This increase in sampling frequency—with the added costs of laboratory analysis—greatly increases the cost of obtaining the desired sediment information. Often, however, the record may actually cost less when adequate samples are collected than when correlation and other synthetic means must be used to compute segments of a record because of inadequate sampling.

Stream-sediment stations may be operated or sampled on a daily, weekly, monthly, or on an intermittent or miscellaneous schedule. Usually, those operated on a daily basis are considered adequate to yield the continuous record. One should be mindful that each sample at a specific station costs about the same amount of money, but the amount of additional information obtained often decreases with each succeeding sample after the first few samples are taken. Sometimes samples obtained on a monthly basis yield more information for the money than those from a daily station, although there is a danger that too little information may be of no value or may even be misleading. For a given kind of record, the optimum number of samples should be a balance between the cost of collecting additional samples and the cost of a less precise record.

The frequency of collection of bed-material samples depends upon the stability of the streambed at the sample site. In many cases, seasonal samples may be adequate to characterize the distribution among particles comprising the bed. However, samples should be obtained whenever possible during high-flow events in order to describe the composition of bed material as compared to its composition during periods of normal or low flow. Particularly important is the collection of bed-material samples following high flows that have inundated the flood plain and greatly altered the streambed configuration.

Sediment Quantity

Previous sections discussed the number of sampling verticals required at a station to obtain a reliable sediment-discharge measurement or a sample of the cross-sectional concentration. The number of cross-sectional samples required to define the mean concentration within specific limits also has been discussed. The requirements in terms of quantity of sediment for use in the laboratory to determine particle-size gradation may at times exceed the other requirements for concentration. The size range and quantity of sediment needed for the several kinds of sediment analyses in the laboratory are given in table 3. The desirable minimum quantity of sediment for exchange capacity and mineralogical analyses is based on the requirements for radioactive cesium techniques described by Beetem and others (1962).

To estimate visually the quantity of sediment entrained in a sample or series of sample bottles

Table 3. The desired quantity of suspended sediment required for various sediment analyses

[mm, millimeter; g, gram]

Analysis	Size range (mm)	Desirable minimum quantity of sediment (g)
Size:		
Sieves:		
Fine	0.062–0.5	0.07
Medium	0.25–2	.5
Coarse	1.0–16	20
Visual accumulation tube:		
Smallest	0.062–0.5	.05
Largest	0.062–2	5
Pipette	0.002–0.062	[1].8
Bottom withdrawal tube	0.002–0.062	[1].5
Exchange capacity:		
Fine	0.002	1
Medium	0.002–0.062	2
Coarse	0.062–2	10
Mineralogical:		
Fine	0.002	1
Medium	0.002–0.062	2
Coarse	0.062–2	5

[1] Double the quantities shown if both native and dispersed media are required.

requires considerable experience. It also is difficult to determine what portion of the total sample is sands (greater than 0.062 mm) because the proportion can be different from stream to stream and from time to time in the same stream. To aid in estimating such sediment quantities, it is helpful to have, in the office or laboratory, reference bottles with various known quantities and concentrations for visual inspection. The number of bottles of sample, the amount of sand, and sample concentration needed for a given kind of analysis are shown in figure 44 (G. Porterfield, written commun., 1968).

Although it is possible to conduct the laboratory operation for particle-size analysis in a manner that also will give the sediment concentration, it is best to obtain separate samples for size analysis and concentration analysis. Such "special" samples should be plainly labeled. Generally, it is desirable to instruct the observer to collect additional samples for particle-size analysis.

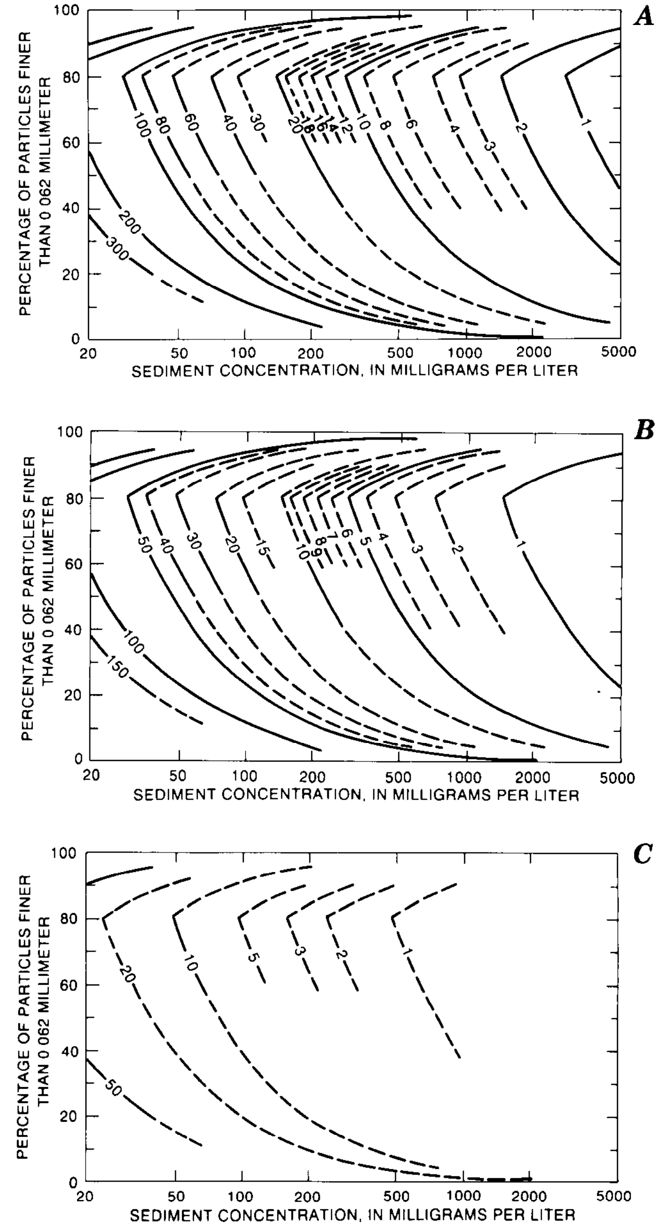


Figure 44. Minimum number of bottles containing optimum sample volume needed to yield sufficient sediment for size analysis (from Porterfield, 1972). *A*, Pint bottles each containing 400 milliliters with 1.0 gram of sediment. *B*, Quart bottles each containing 800 milliliters with 2.0 grams of sediment. *C*, Three-liter bottles each containing 2,400 milliliters with 3.0 grams of sediment.

Sample Integrity

Every sample taken by a field person should be, as previously indicated, the best sample possible considering the stream conditions, the available equipment, and the time available for sampling. Because sampling errors on sand-bed streams frequently occur in the dune regime where the nozzle of the sampler can accidentally pick up sand from the downstream side of a dune, each sample bottle must be inspected in the field immediately after removing it from the sampler. The cost of the field and laboratory work, to say nothing of the embarrassment of a bad record, is sufficient incentive to make this simple check and, if necessary, to collect another sample.

After the first bottle is taken, it can be checked by swirling the contents of the bottle, then holding the bottle where the sand on the bottom can be seen moving. A mental note is made of the quantity of sand contained in the bottle. The second and remaining bottles then can be examined and compared with the previous bottles. Any vertical or verticals where a bottle or bottles contain a significantly different quantity of medium and coarse sand should be carefully resampled. If the check sample also contains a noticeably different amount of sand in comparison to others in the set, retain both bottles and note that the high or low concentration of sand is consistent at the vertical or verticals in question. If the check sample contains a smaller or more representative amount of sand, or if the quantity of sand is different from the first but still not normal, it may be desirable to wait several minutes to take a third bottle on the assumption that the dune face would move beyond the sample vertical. This procedure is qualitative, however, and it must be noted that the extremely high errors are more likely to be detected by this method than are small errors.

A more subtle error in sample concentration may occur when a bottle is overfilled. This error also results in too high a concentration, possibly caused by overfilling the sample bottle. Such a sample should be discarded and another sample obtained using an increased transit rate. If the transit rate or the nozzle must be changed to avoid overfilling during an EWI measurement, then it is best to discard any previous samples and resample in clean bottles. The computations required to make use of an EWI measurement having two transit rates are more costly and error prone than the minor expense of discarding samples.

Sample Identification

Although most of the information needed on sample bottles is indicated by figure 27, other information may be helpful in the laboratory and in records processing. The field person will need to keep the requirements for such processing in mind so that other explanatory notes can be recorded on the sample or inspection sheets (fig. 45). Such notes, some of which have been mentioned previously, may include:

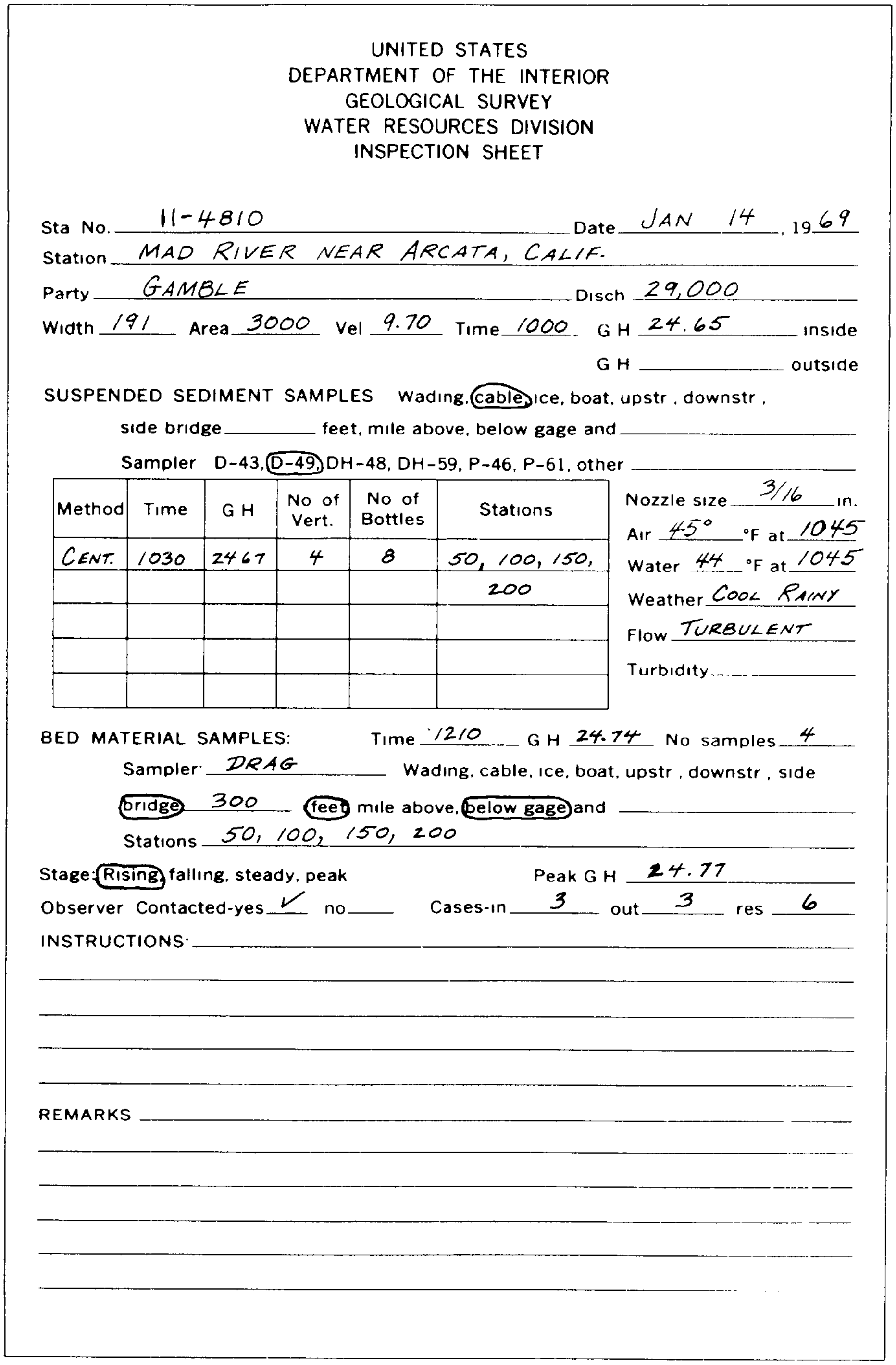
1. Time—Sometimes operations cross zone boundaries or the use of daylight time may cause confusion.
2. Method or location—Routine vertical, EDI, or EWI cross-section sample.
3. Stationing—Is it one location or sampling vertical, or is the sample an accumulation of several verticals at different locations?
4. Unusual sample conditions—Consistent sampling of sand at this location: surface sample or dip sample.
5. Variation of desired technique—Such as change of transit rate, change of sampling vertical location, depth somewhat beyond capacity of instrument, or transit rate may have exceeded 0.4 V_m.
6. Condition of stream—Such as boils noted on water surface, soft dune bed, swift smooth water, braided stream, sandbar in cross section, or slush ice present.
7. Location in the vertical—If a point sampler is used for one-way integration, mention which direction the sampler was moving, the depth dividing the integrated portions, and the total depth.
8. Gage height—Note if the inside or outside gage was used. Note any unusual conditions that may affect the reading.
9. Collector's name.

Sediment-Related Data

Water Temperature

Water-temperature data may seem unimportant in comparison with the sediment data. However, it has a growing list of uses besides the need to help evaluate the sediment-transport characteristics of the stream. The temperature or viscosity of the flow affects sediment suspension and deposition and may affect the roughness of a sand-bed stream.

The best or preferred method to obtain the correct water temperature is to submerge the thermometer while wading some distance out in the stream. The thermometer is held beneath the water for sufficient time (about one-half minute) to allow the temperature of the thermometer to equalize with the water temperature. The stem or the scale of the thermometer is raised out of the water and held so that the etched scale



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
INSPECTION SHEET

Sta No. 11-4810 Date JAN 14, 1969
Station MAD RIVER NEAR ARCATA, CALIF.
Party GAMBLE Disch 29,000
Width 191 Area 3000 Vel 9.70 Time 1000 G H 24.65 inside
G H ______ outside

SUSPENDED SEDIMENT SAMPLES Wading, [✓ cable], ice, boat, upstr, downstr,
side bridge ______ feet, mile above, below gage and ______
Sampler D-43, [✓ D-49], DH-48, DH-59, P-46, P-61, other ______

Method	Time	G H	No of Vert.	No of Bottles	Stations
CENT.	1030	2467	4	8	50, 100, 150,
					200

Nozzle size 3/16 in.
Air 45° °F at 1045
Water 44 °F at 1045
Weather COOL RAINY
Flow TURBULENT
Turbidity ______

BED MATERIAL SAMPLES: Time 1210 G H 24.74 No samples 4
Sampler DRAG Wading, cable, ice, boat, upstr, downstr, side
[✓ bridge] 300 [✓ feet] mile above, [✓ below gage] and ______
Stations 50, 100, 150, 200
Stage: [✓ Rising], falling, steady, peak Peak G H 24.77
Observer Contacted-yes ✓ no ______ Cases-in 3 out 3 res 6
INSTRUCTIONS ______

REMARKS ______

Figure 45. Example of inspection sheet for use by field person to record the kinds of measurements made and the stream conditions observed during a visit to a sediment-measurement site.

on the stem is at right angles to the line of sight; the temperature then should be read to the nearest one-half degree. The bulb of the thermometer should always remain in the water until after the reading is obtained. The reading of a wet thermometer when exposed to the air may decrease several degrees in a matter of seconds because of evaporation, if the air is dry, or the wind is blowing. Be certain that the location in the stream where the temperature is taken is not affected by the inflow from a spring or tributary.

When it is not possible to wade out into a stream, the water temperature may be taken from a sample bottle. The thermometer should be inserted first into a bottle from near midstream to let the thermometer adjust to the approximate temperature. Then, immediately after removing the next bottle from the sampler, transfer the thermometer from the previous bottle and allow about 15 seconds for the temperature to stabilize. The thermometer should be read while the bulb of the thermometer is submerged. When removing the thermometer from a bottle, lift the thermometer about 2 inches from the bottom and shake slightly to remove sediment from the case of the thermometer. Most freshwaters freeze at 0°C; therefore, if a negative reading is obtained, an error is indicated. Brackish and brine waters freeze at temperatures somewhat less than 0°C, depending on the kind and concentration of ions present.

Stream Stage

As with temperature, stream-stage data may seem insignificant but in reality can be very important. The data may be used to construct missing gage-height records for periods of recorder failure or to verify time of sampling. Gage heights also may serve to indicate whether the observer actually obtained a sample at the time and in the manner indicated by available notes.

Remember that the gage height is defined as the water-surface elevation referred to some arbitrary gage datum. For the gage height to be considered correct, the observer or field person should always note which gage is read. The streamflow and sediment records are computed on the basis of the inside or recording gage. The observer is usually instructed to read only the outside or reference gage. Because of differences in location and the effect of velocity head, it is not expected that both gages will read the same at a given time, although some relation may exist between them as the stage changes (Buchanan and Somers, 1968; Carter and Davidian, 1968). The field person should record all stream-stage information on the inspection sheet (fig. 45).

The outside reference gage may be one of two types. The most common of those exposed continuously to the flowing stream are the staff gage and the slope gage. Under turbulent flow conditions, these exposed gages should be read by noting the average of several high and low readings made within a period of 10 or 15 seconds. It is necessary to make certain that the observers understand that the scale is divided into hundredths of a foot and not feet, inches, and fractions of an inch, and that they understand the divisions of the metric system if that is used. The other type of outside gage is the wire-weight gage or chain gage that is usually attached to a bridge railing. The weight from this type of gage is lowered so that its bottom breaks the water surface about one-half the time when there are water waves or ripples. For the wire-weight gage, the gage height is read on the scale of the drum at the pointer. For the chain gage, the reading is obtained by reference to the scale provided.

The inside gage height is usually referenced by tape from a float in a stilling well to a pointer. The stilling well is connected hydraulically to the flow of the stream. The inside reference gage should correspond to the gage height being recorded, but, as mentioned previously, it may vary somewhat from the outside gage. If the variance between inside and outside gages is unusually large and the inside gage is lagging the actual gage height of the stream, the intake should be flushed to remove any obstruction caused by sediment accumulation.

The field person should record the inside gage reading at least once each visit to ensure that the gage is working properly. Also, if the observer uses the outside gage, the field person should record the readings from both the outside and the inside gages.

Cold-Weather Sampling

Subfreezing temperatures can cause surface ice, frazil ice, and anchor ice to form on or in a stream and create many difficulties with regard to suspended-sediment sampling. The surface ice usually forms at the edges of the stream first and covers the midstream part last. If it is necessary to use surface ice for support to make holes for sampling, extreme caution should be exercised because the strength of such ice can be deceiving, especially if weakened during alternating freezing and warm periods. If these auger holes are to be reused later, a cover of wood or some other low-cost insulating material can be used to protect them from refreezing. However, it should be realized that covers of this type may be lost if the weather warms sufficiently for the ice to break up. In some cases (to avoid walking out on the ice or if a warming trend is expected), it may be possible to prevent loss by attaching the cover to a line or to the sampler cable to allow its easy removal. If the sampler cable is used for this purpose, however, the sampler should be secured to or removed from the sampler shelter to avoid its loss by falling through the open bottom of the shelter. Suspended-sediment samplers should never be used to break through seemingly thin ice by dropping the sampler more than 3 or 4 inches because the sampler and nozzle can be damaged by the force of the drop. If the ice will not break by the sheer weight or very gentle drop of the sampler, a hole must be opened by some other means.

If the ice is too thin to safely support a person's weight, it is best not to obtain a sample for 1 or more days because winter samples are generally low in sediment concentration and are, therefore, most certainly not worth the chance of an accident. When the spring breakup occurs, the large slabs of floating ice can easily cause damage to the sampler or the support equipment or injure the operator. Under these conditions, a surface sample may be all that can be obtained between cakes of floating ice. Every effort should be made to obtain such a surface sample because the sediment concentration can, and usually does, change considerably under such conditions.

Frazil ice is composed of the small ice crystals formed at the surface in the turbulent part of the stream. The crystals are formed in a variety of shapes, from slender needles to flat flakes. They do not freeze together because of the swift current, but may bunch together to form a soft mass. This kind of ice may partly or completely clog the intake nozzle of the sampler. Sampling may be best accomplished by moving the sampler swiftly through the layer of frazil ice and then using a normal transit rate to sample the relatively ice-free region below. Often when such ice obstructs the nozzle, it will remove itself when the sampler is brought out of the water, and the only indication that the sample is in error would be that the quantity of water in the bottle is significantly less than would be expected under normal circumstances.

Anchor ice is formed on the bottom of shallow streams by radiation of heat during the colder nighttime hours. Incoming radiation and the warmer temperatures during the day allow this ice to break loose from the bottom and float to the top to mix with the frazil ice. Sometimes, when the nozzle contains frazil or small pieces of anchor ice as the sampler is brought out of the water, a subfreezing air temperature will cause the ice to freeze tight in the nozzle. If the ice freezes tight to the nozzle or if the sample bottle freezes to the sampler casing, it will be necessary to heat the sampler, by using the heater in the field vehicle, soaking the sampler in a container of warm water, or heating the nozzle and sampler head with a small propane torch. Care must be taken when employing the torch method because the gaskets in the sampler head and plastic nozzles can be damaged by the open flame. Some of these problems can be avoided by the use of two samplers; while one is thawing, the other can be used to sample.

If the sampler or samplers are kept beneath the heater in the field vehicle while the observer drives to the station or from one station to another, the first one or two verticals can be more easily sampled. The observer should be advised and encouraged to remove the nozzle from the sampler and leave the sampler head in the open position after completing the sampling. This will allow the gasket, nozzle, and air vent to dry more completely and may avoid a frozen sampler nozzle or sampler head frozen shut on the next visit.

Aside from the problems with plugged sampler nozzles, a very cold sampler may cause freezing of water between the sample bottle and the inside of the sampler. This problem can be minimized by removing the bottle as quickly as possible from the sampler after the integration is complete; otherwise, it may be necessary to heat the sampler as described above. It also should be obvious that samples in glass bottles must be protected from freezing after the measurement and during transport to the laboratory. Freezing itself does not harm a sample for sediment analysis, but a broken bottle will obviously result in loss of the sample.

If an extensive sampling program is to be carried out during the winter months in areas of extreme cold, it is advisable for the investigator to obtain DH-75 and D-77 samplers. These samplers are designed to be used in freezing conditions, as previously discussed. Several sample bottles and nozzle and cap assemblies can be taken to the site, where they can be easily changed if nozzle or air-exhaust freezeups occur during sampling.

Bed-Material Sampling

Data on the size of material making up the streambed (across the entire channel, including flood plains) are essential for the study of the long-range changes in channel conditions and for computations of unmeasured or total load.

Materials Finer Than Medium Gravel

Selection of a suitable bed-material sampler is dependent on the size of bed material to be sampled, and on stream depth and velocity. When a stream can be waded, the most practical of the standard samplers is the BMH-53 or BMH-80 (figs. 15 and 17). When sampling from a boat, these samplers can be used to depths of about 4 feet.

In use, the BMH-53 is placed in a vertical position on the streambed with the piston extended to the open end of the cylinder. The cylinder then is pushed a full 8 inches into the bed while the piston is held at the bed surface. Complete filling of the cylinder will help ensure a minimum of disturbance of the top 1 or 2 inches when the sampler is raised through the flow. When coarse sand or gravel material is being sampled, it is often necessary to pull on the piston rod while pushing on the cylinder. By pulling on the piston, a partial vacuum is created above the sample, which helps draw the sample into the cylinder. The sampler then is withdrawn from the bed and held in an inclined position above the water with the cylinder end highest. For most purposes, only the upper inch of material nearest the surface of the streambed is desired or needed in an analysis. This is obtained by pushing on the piston while the sampler is still inclined until only 1 inch of material remains in the tube. Any excess material is removed by smoothing off the end of the cylinder with a spatula or a straight pencil. The material left in the sampler is ejected into a container (usually a paper or plastic carton). An experienced field person can composite samples from the entire cross section into just a few cartons. The inexperienced field person would do well to use a separate container for each vertical. Before storing the sampler, it should be rinsed by stroking the piston a few times in the stream to remove sediment particles from the cylinder and piston seal.

The BMH-80 is used in a manner similar to that of the BMH-53. The sampler is extended to the streambed with the bucket in the open position. After the sampler contacts the bed material, the field person should keep a firm downward pressure on the sampler while closing the sample bucket, thus trapping a shallow sample of the streambed. This sampling procedure should be repeated until the streambed has been representatively sampled.

If the stream is too deep or swift for the BMH-53 or BMH-80, the BMH-60 or the BM-54 can be used. The 30-pound BMH-60 is easiest to use when stream velocities are under 2 or 3 ft/s and depths are less than about 10 feet. To use the BMH-60, suspend the entire weight of the sampler by the hanger rod and cock the bucket in the open position with the allen wrench provided. The energy thus imparted to the spring and the sharp edge of the bucket make it obvious that one must keep hands away from the bucket opening at all times. If necessary, the safety yoke may be fastened around the hanger bar while opening and cocking the bucket. After the safety yoke is removed and fastened to the tail, the sampler then can be lowered by hand or by cable and reel to the surface of the streambed. Any jerking motions made while lowering the sampler that would cause the cable to slack may release the catch and allow the bucket to close prematurely. This can happen if the water surface is struck too hard. After the cocked sampler touches the streambed and tension is released on the line, the sampler should be lifted slowly from the bed so the bucket will scoop a sample.

To remove the sample from the bucket, a carton or container is positioned under the sampler, and the bucket is opened with the allen wrench. The sampler need not be held by the hanger bar during sample removal unless considerable material is clinging to the flat plate within the bucket cavity. If removal of such material is required, the bucket should be cocked in the open position and the sample brushed into the container with a stick or small brush. When moving the sampler between verticals and when storing it in the vehicle, the bucket should be in the closed position to avoid an accidental closing and to reduce the tension on the spring. If the bucket is closed for transport as suggested, a stick, a piece of tire, or similar material should be used to cushion the force of the bucket when it is closed because the closing force is sometimes great enough to break welded joints in the mechanism (J.V. Skinner, Federal Inter-Agency Sedimentation Project, written commun., 1985).

The 100-pound BM-54 is used when velocities are greater than 2 or 3 ft/s and depths are greater than 10 feet. The BM-54 sampling action, described previously, is similar to the BMH-60, except that the bucket opens front to back. It is used only with a cable-and-reel suspension and is rather awkward to handle when removing the sample. The techniques for taking a sample with the BM-54 are essentially the same as for the BMH-60. One important difference in operation is the use of a safety bar on the BM-54 to hold the bucket in an open position instead of the safety yoke as on the BMH-60. As noted earlier, the sampler should be stored with the bucket in a closed position and, if extended storage is anticipated, the tension on the spring should be further reduced.

A BM-54 can be used in extremely high velocities if a C-type weight is attached to the hanger bar above the sampler. If additional weights are required with the BM-54, extreme care should be taken to avoid bending and possibly breaking the hanger bar between the sampler and the C-type weight.

Personnel of F.I.S.P. have developed a heavy bed-material sampler (the BM-84, which weighs about 160 pounds). The P-61 point-integration sampler body is used to provide a large mass. The streamlined body configuration is fitted with a spring-driven sample scoop that is activated by a solenoid system similar to that used on point samplers. Otherwise, the sampler is similar to, and performs the same function as, the BM-54. The design is an attempt to cope with bed-material sampling problems encountered in the vicinity of Mount St. Helens volcano (J.V. Skinner, Federal Inter-Agency Sedimentation Project, oral commun., 1984). The weight of this configuration is increased by filling void space within the sampler body to increase the cross-sectional density of the sampler, thus increasing its stability in deep, high velocity conditions.

As previously discussed, other sampling equipment is available commercially—for example, the ponar sampler and core samplers, such as the vibra-core unit and gravity corer. These samplers can be very useful; however, careful planning of the proposed sampling project and analytical methods is essential to obtaining a representative sample and reliable data.

Materials Coarser Than Medium Gravel

Gravels in the 2- to 16-mm range can be analyzed by mechanical dry sieving; in order to obtain a representative particle-size distribution, the size of the sample to be collected must be increased with particle size. Large sediment sizes (>16 mm) are difficult both to collect and to analyze. The method now used for size determination of these very large particles involves a pebble count, in which at least 100 pebbles from a wadable streambed are manually collected and measured. A fixed grid pattern locating the sampling points can be paced, outlined by surveys, or designated by small floats. At the intersections of the fixed grid pattern, the pebble underlying the field person's toe is retrieved, and a measurement is made of the long, intermediate, or short diameters, or all three. The measurements are tabulated as to size interval, and the percentage of the total of each interval then is determined (Wolman, 1954).

Because the pebble-count method entails the measurement of the dimensions of randomly selected particles in the field, it is laborious and usually limits the number of particles counted. Too often this results in an inadequate sample of the population,

Another method for analyzing coarse particles involves the use of an instrument known as the Zeiss Particle Size Analyzer (Ritter and Helley, 1968). For the Zeiss technique, a photograph of the streambed is made during low flow with a 35-mm camera supported by a tripod about 2 meters above the streambed—the height depends on the size of the bed material. A reference scale, such as a steel tape or surveyor's rod, must appear near the center of the photograph to provide a size reference.

In the laboratory, particle diameters are registered cumulatively or individually on exponential or linear scales of size ranges (Guy, 1969). After the data are tabulated, the sizes registered on the counter of the particle-size analyzer must be multiplied by the reduction factor of the photograph, which is calculated from the reference scale in the photograph.

In nonwadable streams, a pipe dredge is useful in sampling these large particles. However, this method entails the use of equipment capable of handling extremely heavy loads and requires special attention to safety during operation.

Location and Number of Sampling Verticals

Bed-material samples are often collected in conjunction with a discharge measurement and (or) a set of suspended-sediment samples. If the discharge measurement and (or) the suspended samples are taken first, the bed-material samples should be collected at the same stations, but not necessarily from the same number of stations. By taking them at the same stationing points, any change in bed material or radical change in discharge across the stream that would affect the sediment-discharge computations can be accounted for by subdividing the stream cross section at one or between two of the common verticals.

To avoid collection of bed-material samples from an excessively disturbed streambed, it is best to obtain the bed-material samples prior to making other measurements, especially in wadable streams. Also, by taking the bed material first, radical changes across the section in bed-material size and water discharge can be used as a basis for choosing desirable verticals for other measurements.

Most results from bed-material samples will not be noticeably affected, but it should be remembered that the sample taken with the BMH-53 or other core sampler is different from that taken with the BMH-60, BMH-80, and the BM-54. The cross section of the BMH-53 or other core sampler is constant with depth so that each increment of sample with depth is equally represented by volume. The curved buckets of the BMH-80, BMH-60, and BM-54 do not sample equal volumes of material with depth; instead, the bottom one-half inch of the 2-inch-deep bucket contains only 15 percent of the total sample, whereas the upper one-half inch contains 33 percent of the sample.

The number and location of bed-material samples required at a cross section must be adequate to provide a representative statistical population. This population should include samples collected from the entire cross section. To obtain this population, the logical procedure is to use the results from a rather detailed set of 10 to 20 uniformly spaced bed-material samples taken from the cross section. Some studies may require that flood-plain deposits be represented in the bed-material sampling scheme to get a representative population.

Sample Inspection and Labeling

As samples are obtained across the stream, the field person should visually check and compare each sample with the previous samples to see if the material varies considerably in size from one location to the next. Samples of different sizes and (or) weight should not be composited. If a given sample does contain considerable coarser or finer material, another sample should be obtained about a foot from the original location. If, after two or three tries in the vicinity of the first sample, no appreciable difference is noted, the first sample should be retained. Small deposits of material that are coarser or finer than most of the bed material are not considered representative of the bed-material size for the stream cross section.

Proper labeling of bed-material samples is not only necessary for future identification but also provides important information useful in the laboratory analysis and the preparation of records. Information desired on each bed-material sample carton should include:

Station Name
Date
Time
Gage height
Water temperature
Stationing number
Bed form and flow conditions
Carton number of the set
Kind of sampler used
Purpose of sample or special instructions for analysis and computations
Initials of field person

Bedload Sampling Technique

The sediment moving in the unsampled zone (see fig. 1) comprises suspended sediment and bedload. Bedload is the sediment that moves by sliding, rolling, or bouncing along on or within a few grain diameters of the streambed.

Although many investigations have provided extensive knowledge in the areas of how bedload moves in a channel and how pressure-differential bedload samplers operate, a great deal more work in these areas is needed. The following paragraph, taken from Hubbell (1964, p. 2), is still appropriate:

> In the past, attempts have been made to determine the bedload discharge in three general ways: by direct measurement with some type of apparatus, by definition of physical relations from which the bedload could be estimated, and by quantitative measurements of the results of some sedimentation process such as erosion or deposition. Unfortunately, direct-measuring apparatus have been useful for only a very limited range of sediment and hydraulic conditions; the definition of physical relations has not been complete enough to estimate precisely the bedload discharge; and the quantitative measurements have supplied information only on the characteristics of the reach that was studied. As a result, no single apparatus or procedure, whether theoretical or empirical, has been universally accepted as completely adequate for the determination of bedload discharge over the wide range of sediment and hydraulic conditions in nature.

Despite these difficulties, the hydrologist often is called upon to provide estimates of bedload transport from measurements. The purpose of this section is not only to outline instructions governing the collection of bedload samples, but also to present a discussion of variations in bedload-discharge rate, the problems involved in collecting samples, and considerations in the design and development of a sampling program to define bedload movement.

Bedload discharge can be extremely variable. Variations can occur both spatially and temporally during steady-flow conditions, as well as with changes in stream discharge. In order to collect a sample that represents the mean bedload-discharge rate, all variations must be taken into account.

Even for constant flow conditions, the temporal variation of bedload transport rates at a given point in a cross section is quite large. When dunes are present, bedload discharges are zero, or near zero, in the troughs, increase progressively along the upstream side of the dune, and are maximum at the crest. Even in streams with gravel beds, the bedload appears to move in cycles or slugs (Emmett, 1981). These variations have been measured in the laboratory flume by Hubbell and others (1981) and in the field by Emmett (1975) and Carey (1985) (fig. 46).

Temporal variation in sampled bedload rates collected at steady-flow conditions at a single vertical are primarily dependent on the ratio of sampling time to the time it takes one dune, cycle, or slug to pass by

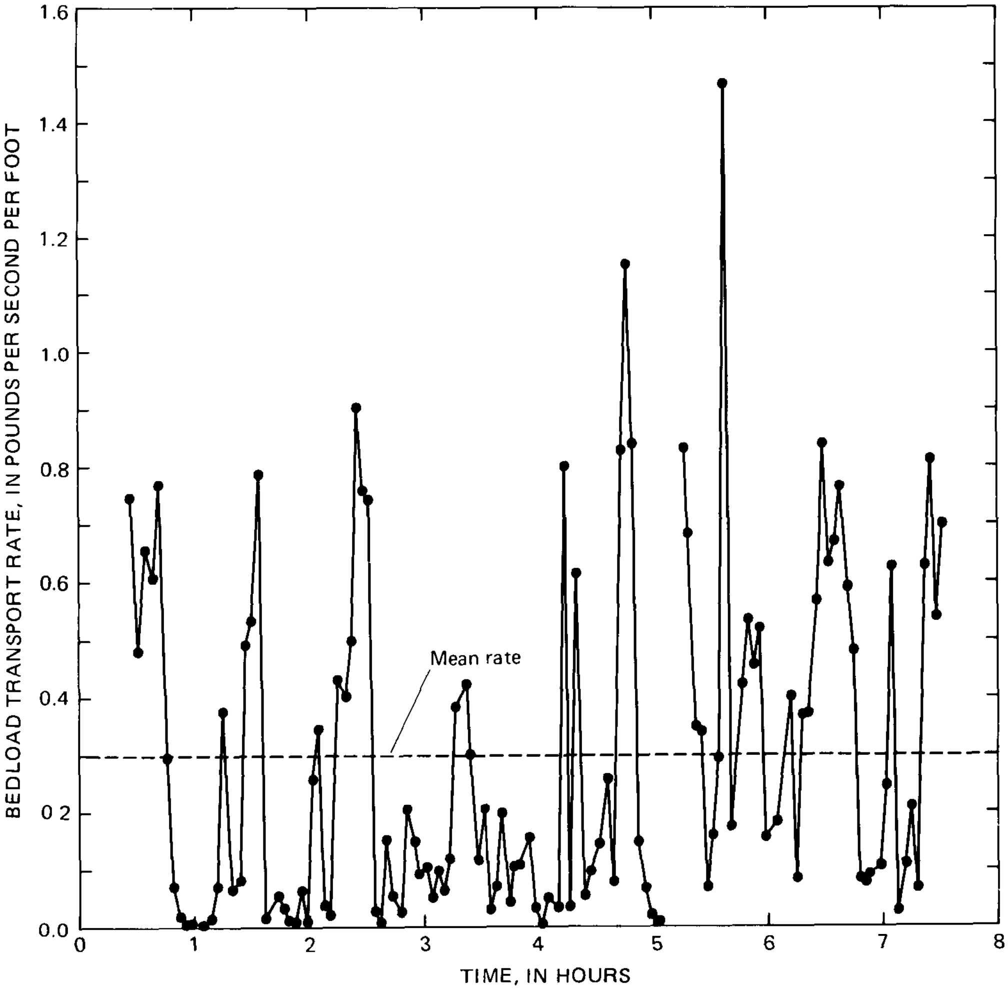


Figure 46. Temporal variation of bedload transport rates for 120 consecutive bedload samples from a stream with constant water discharge (Carey, 1985).

the sampling point. Obviously, if the sampling time were equal to the cycle period or several times greater than the cycle period, the temporal variation at a single sampling point would be small. However, as the sample time becomes less with respect to the cycle time, the temporal variation can become quite large.

Einstein (1937) and Hamamori (1962) both developed theoretical distributions to describe the temporal distribution of bedload transport rates at a vertical. Einstein based his distribution on the assumption that bedload particles move in a random series of steps and rests, with the particles generally resting a much longer period of time than they are moving. Hamamori's distribution was derived to define the temporal variation when dunes are present on the bed. Figure 47 shows a comparison of Einstein's and Hamamori's distributions. Einstein's T is defined as the nondimensional sampling time measured in terms of the average rest period. Einstein's T = 2 distribution (sample time equals the length of two average rest periods) and Hamamori's distribution are nearly identical. As T increases (sampling-time increases), the two theoretical distributions depart from one another, and Einstein's distribution indicates reduced variability.

The temporal variations in bedload transport rates measured by Carey (1985) at a single vertical in a sand-bed stream in Tennessee are shown in figure 46. The cumulative probability distribution of bedload discharges measured by Carey fit the theoretical distribution developed by Hamamori. As indicated in the figure, even for a constant flow condition, the rate determined from a sample taken from a single vertical at a point in time may differ considerably from the mean bedload discharge at that vertical. This extreme temporal variability in bedload transport rates has been known since at least 1931 (Hubbell, 1964).

The spatial or cross-channel variation in bedload discharge is usually significant. Typically, bedload transport rates vary from zero or small near banks through larger values toward midstream. The mean cross-channel distribution of bedload discharge may vary uniformly (fig. 48*A*), may be uniformly consistent (fig. 48*B*), may be erratic with varying tendencies (fig. 48*C*), or may be an unpredictable combination of varying tendencies (fig. 48*D*). Each river is likely to have a unique combination; adjacent reaches of the same river may have different configurations, and these configurations are likely to change

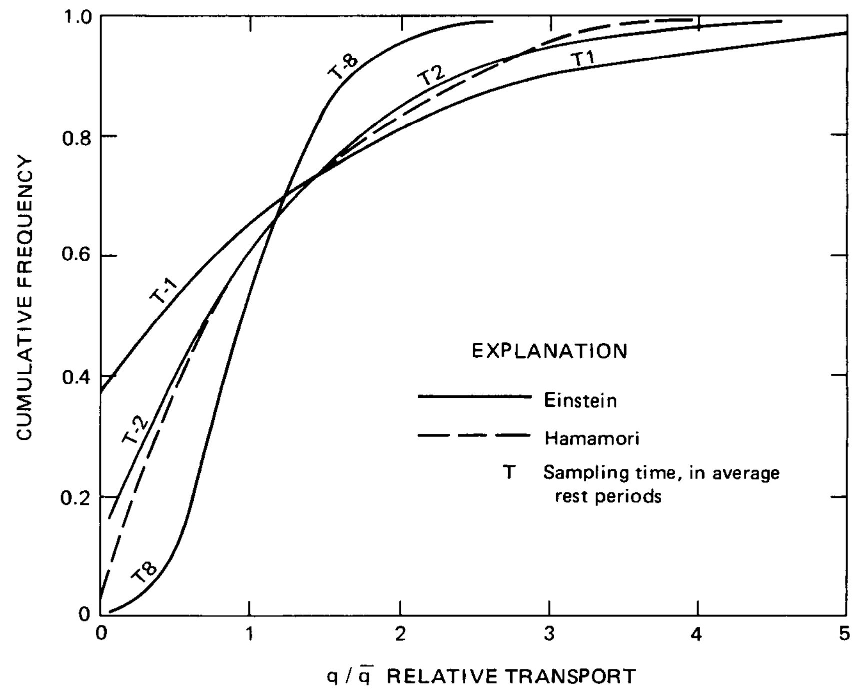


Figure 47. Comparison of cumulative probability distributions of bedload transport rates predicted by Einstein (1937) and Hamamori (1962) (D.G. McLean, University of British Columbia, written commun., 1986).

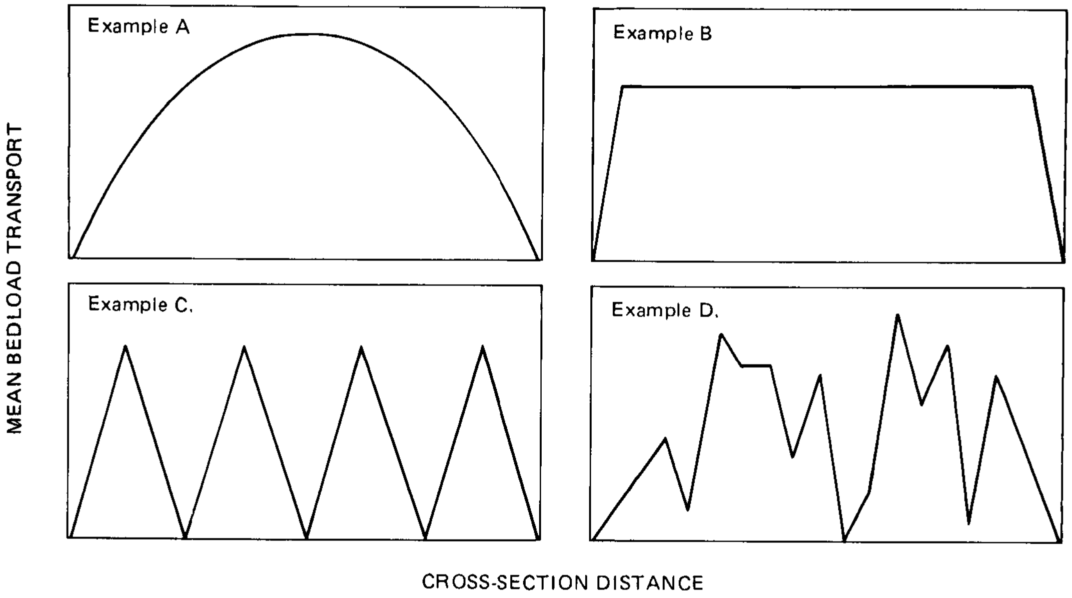


Figure 48. Examples of possible distribution of mean bedload transport rates in a cross section. *A*, Discharge varies uniformly. *B*, Discharge is uniformly consistent. *C*, Discharge is erratic with varying tendencies. *D*, Discharge is an unpredictable combination of varying tendencies.

with changing flow conditions (stages). There is little proven basis for predicting spatial variability.

The temporal and spatial variations in transport rates of bedload discharge that occur under steady-flow conditions are amplified when the stage changes rapidly. Because of these temporal and spatial variations, many samples have to be collected at many verticals in the cross section to ensure an accurate estimate of the mean bedload discharge. The samples also would have to be collected over a short enough period of time to avoid any change in transport rates due to changing stage. In most field sampling programs, the number of samples collected must represent and compromise between accuracy and economic or physical feasibility.

Another major problem encountered in bedload sampling is that of collecting a representative sample. To collect a representative sample, the sampler must (1) trap, during the sampling period, all bedload particles that would normally have passed through the width occupied by the sampler; and (2) reject all particles that normally would not have passed through the width during the same period. The degree to which this is accomplished is termed the "sampling efficiency," which is defined as the ratio of the mass of bedload collected to mass of bedload that would have passed through the sampler width in the same time period had the sampler not been there (Hubbell, 1964). For perfect representative sampling, the sampling efficiency should be 1.0 (or 100 percent) for all sizes of bedload particles in transport at the sampling point during the sampling period.

Currently, the most commonly used bedload sampler is the Helley-Smith sampler (see page 25 for discussion of recommended samplers). Over 3,000 of these samplers have been placed in use since the model was introduced in the early 1970's. It should be understood that the Helley-Smith is not a true bedload sampler because it collects some particles moving in suspension. As previously noted, bedload moves on or very near the streambed. Depending on the size of the unsampled zone, the Helley-Smith has the potential to collect a sample from the entire unsampled zone. Even if the Helley-Smith sampler has a sampling efficiency of 1.0, the total sediment discharge cannot necessarily be calculated by simply summing the measured suspended-sediment discharge and the measured bedload discharge. Figure 49 shows the percent error involved in computing total sediment discharge for a particular size range by summing the measured suspended-sediment discharge (Q_{sm}) and the bedload discharge measured with a Helley-Smith sampler (D) for that particular size range.

In order to make bedload sampling practical, methods must be used that minimize the number of samples required to obtain a reasonable estimate of the mean cross-sectional bedload discharge. Field

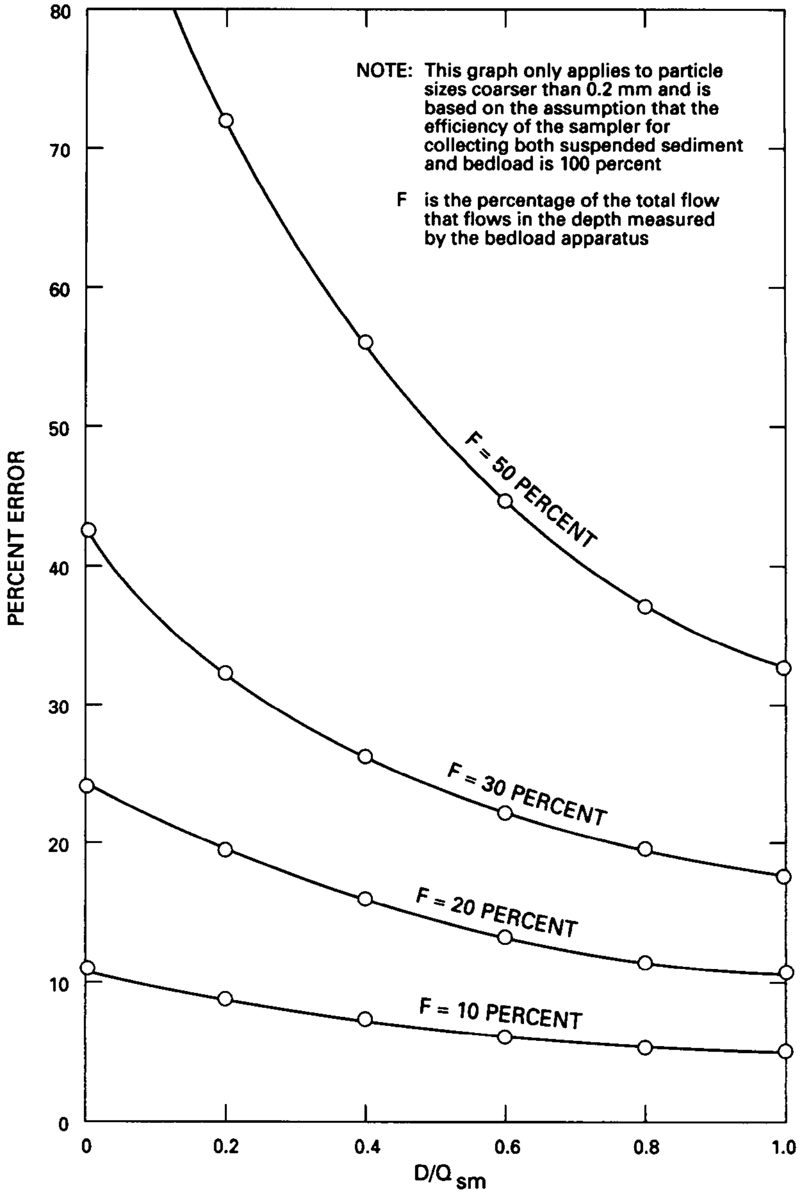


Figure 49. Percent error due to computing total sediment discharge of a size range by summing measured suspended-sediment discharge (Q_{sm}) and bedload discharge measured with a Helley-Smith sampler (D).

experience has shown that the collection of about 40 individual bedload transport rate measurements per cross-section sample is, in most cases, practical and economically feasible (Emmett, 1980a). The following general methods can be used to collect the samples.

(1) Starting at one bank and proceeding to the other, collect one sample per vertical at 20 evenly spaced verticals in the cross section, return to the bank, and repeat the process. We will refer to this method as the single equal-width-increment (SEWI) method (fig. 50). The time the sampler is left on the bottom should be equal for all verticals in a given cross section. The time the sampler is left on the bottom need not be the same for both cross sections collected. This procedure was first introduced by Emmett (1980a) and is widely used. The samples are collected at the midpoint of the evenly spaced increments. Samples collected in this manner can be composited for analytical purposes; however, a better understanding of the local bedload transport characteristics is gained if each vertical sample is analyzed individually.

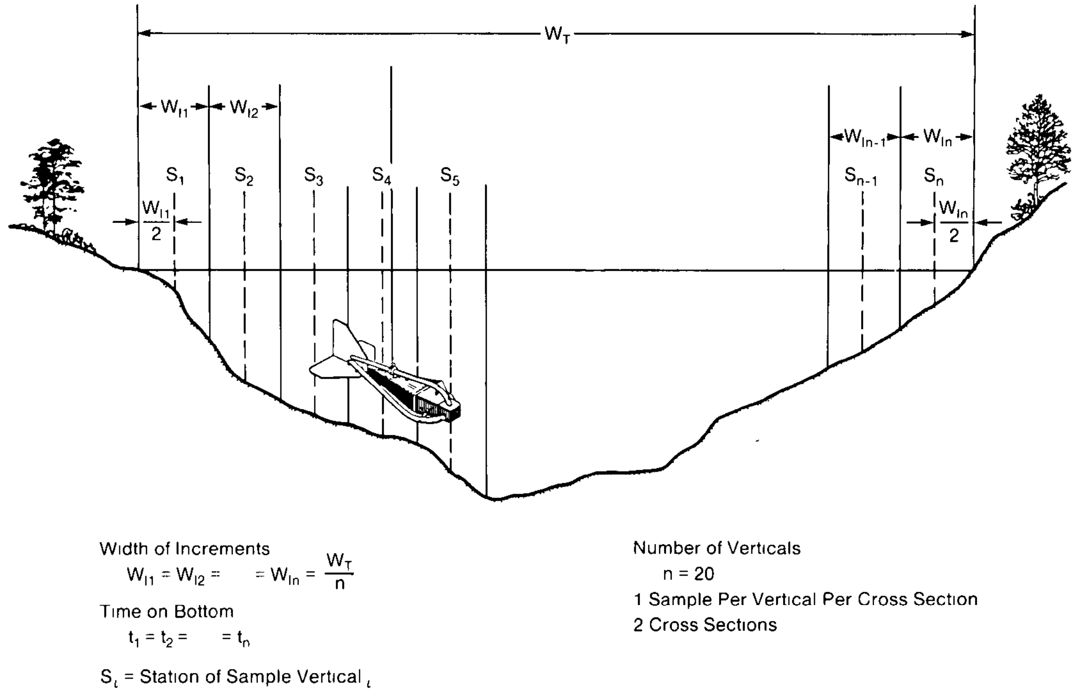
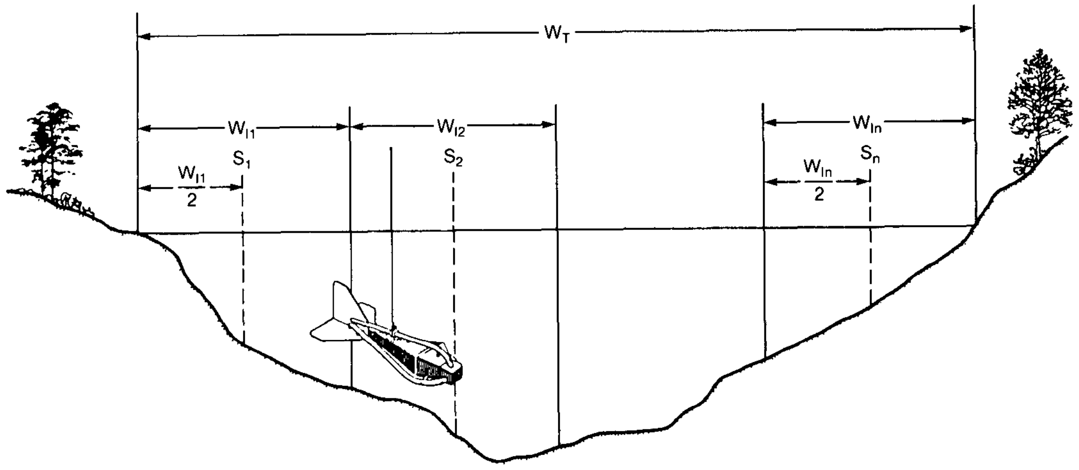


Figure 50. Single equal-width-increment bedload-sampling method.

(2) Starting at one bank and proceeding to the other, collect one sample at 4 or more evenly spaced verticals, return to the starting bank, and repeat the process multiple times until a total of 40 samples is collected. We will refer to this method as the multiple equal-width-increment (MEWI) method (fig. 51). If the sample collected at each vertical is bagged separately, the time the sampler is left on the bottom need not be equal at all verticals. If samples collected in a cross section are to be composited, sample times at each vertical in the cross section must be equal. As in the SEWI method, samples are collected at the midpoint of the evenly spaced increments.

(3) Starting at one bank and proceeding to the other, collect one sample from 4 or more unevenly spaced verticals, return to the starting bank, and repeat the process until a minimum of 40 samples is collected. We will refer to this method as the unequal-width-increment (UWI) method (fig. 52). This method requires some prior knowledge of the depths and velocities across the section. The selection of where to place the verticals in the UWI method depends, to a certain extent, on which method is to be used to calculate the bedload discharge. If the midsection method is used (see "Computation of Bedload-Discharge Measurements" section for explanation of calculation methods), the sampling verticals should be spaced unevenly in an attempt to delineate equal portions of the cross-section bedload discharge. To the extent possible, samples should be collected midway between breaks in the lateral bed slope and closer together in segments of high velocity and changing lateral bed slope. If the mean-section method is used to calculate the bedload discharge, sample verticals should be placed at the break points in the lateral cross-sectional distribution curve of mean bedload transport rate where the rate changes from one trend to another (that is, break in slope). At most sections, the lateral distribution in mean rates, once defined, can be related to velocity and lateral bed topography.

To quantify the approximate magnitude of sampling errors that could result from various sampling situations, Hubbell and Stevens (1986) developed a bedload transport simulation model. They used Hamamori's (1962) distribution to simulate temporal variations at the equally spaced sampling verticals and assumed that the sampler used had a 100-percent sampling efficiency. The results of test runs using two different spatial variations are shown in figure 53. In the first case, the lateral distribution of mean bedload transport rates is fairly uniform across the cross section and, in the second case, it is skewed. If these results were used to estimate maximum possible error for using the SEWI and MEWI methods, in the first



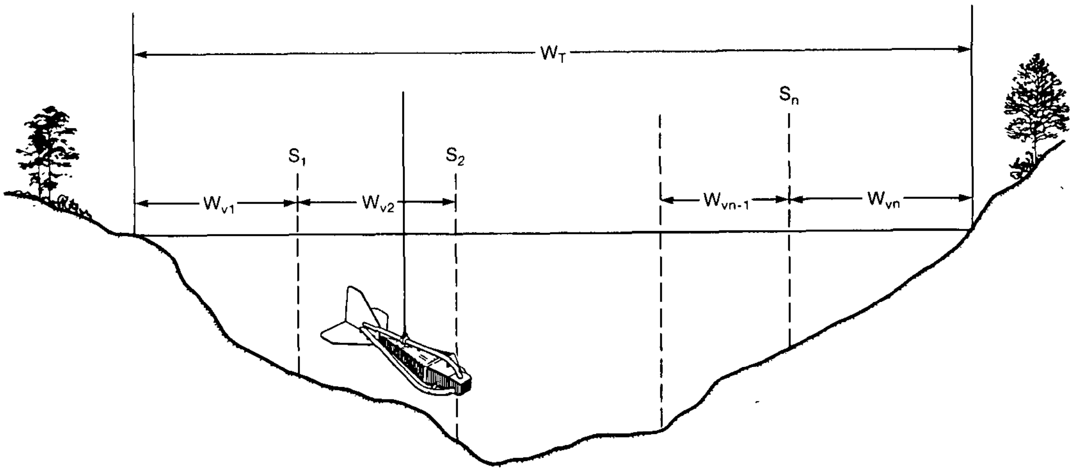
Width of Increments
$W_{I1} = W_{I2} = \quad = W_{In} = \frac{W_T}{n}$

Time on Bottom at $_i$
$t_1 \neq t_2 \neq \quad \neq t_n$

S_i = Station of Sample Vertical $_i$

Number of Verticals
n = 4-5
1 Sample Per Vertical Per Cross Section
8-10 Cross Sections

Figure 51. Multiple equal-width-increment bedload-sampling method.



Width Between Sampled Verticals
$W_{v1} \neq W_{v2} \neq \quad \neq W_{vn}$

Time on Bottom
$t_1 \neq t_2 \neq \cdot\cdot \neq t_n$

S_i = Station of Sample Vertical $_i$

Number of Verticals
n = 4-10
1 Sample Per Vertical Per Cross Section
4-10 Cross Sections

Figure 52. Unequal-width-increment bedload-sampling method.

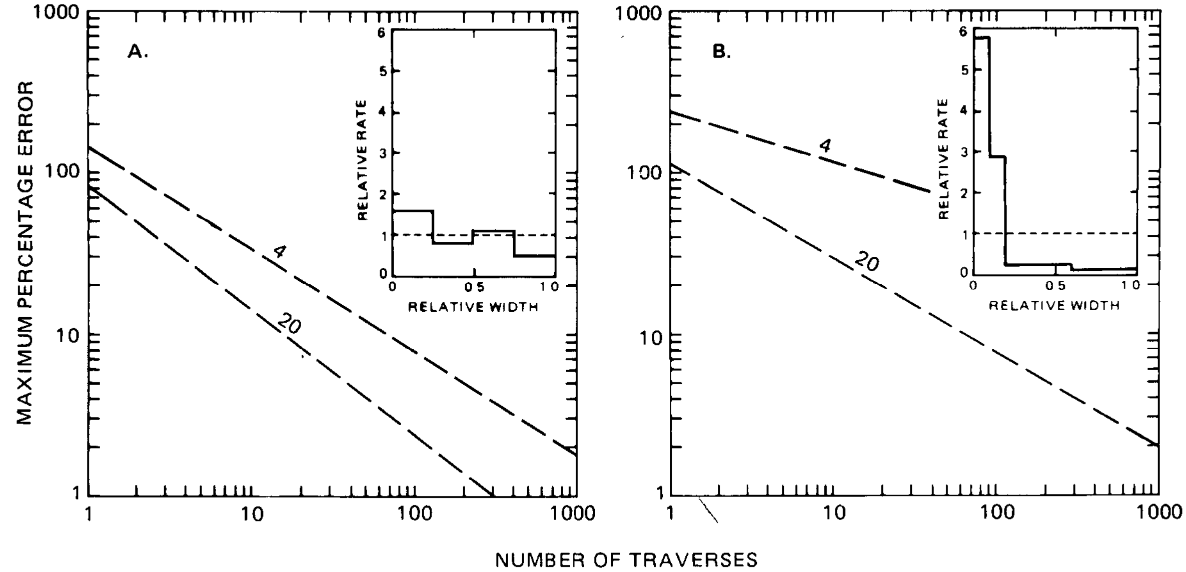


Figure 53. Variation in maximum probable errors with number of sampling traverses at 4 and 20 equally spaced verticals at cross sections with different bedload transport rates (modified from Hubbell and Stevens, 1986). *A*, Fairly uniform transport rates. *B*, Skewed transport rates.

case, the MEWI method would give a lower maximum possible error (35 percent) than would the SEWI method (50 percent). In the second case, however, using the SEWI method would result in a maximum error of 80 percent and using the MEWI method would result in a maximum error of 120 percent. The maximum probable error with the UWI method cannot be evaluated from figure 53.

From the previous discussion, it is obvious that no one method works best in all situations and that no one standard sampling protocol can be used at all stations. This should come as no surprise. There are two acceptable methods for collecting suspended-sediment samples (EWI and EDI). Both work equally as well as the other but are better suited to different stream conditions and cross-sectional sediment distributions. Likewise, a unique sampling protocol must be derived for each site at which bedload-discharge data are to be collected. Probably the best way to start sampling at a site is to do multiple sets of complete SEWI and MEWI or UWI measurements each time the site is visited and over as many flow ranges as possible. Unfortunately, human resources and budget restrictions, as well as hydrologic conditions, may prevent multiple or even single SEWI, MEWI, or UWI type cross-sectional measurements. If it is not possible or feasible to collect full SEWI, MEWI, and (or) UWI type samples, the approach listed below can be used as a minimum protocol to follow when first starting to collect bedload data at a site. Caution should be used, however, because the modified SEWI, MEWI, or UWI methods will not supply as much information as would the complete method. Therefore, more sets of samples may be needed to acquire sufficient knowledge of the cross section to design an efficient sampling protocol. (Note: The SEWI method helps define cross-sectional variations in bedload transport rates, whereas the MEWI and UWI methods are more effective in defining temporal variations at individual verticals.)

(1) Using the SEWI method, collect samples at approximately 20 equally spaced verticals in the cross section. The spacing and location of the verticals should be determined by the sampling procedure used in the EWI method. For very wide sections, where large variations in bedload rates are suspected, sampling stations should not be spaced more than 50 feet apart. For narrow cross sections, sampling stations need not be closer than 1 foot apart.

(2) Lower the sampler to the streambed and use a stopwatch to measure the time interval during which the sampler is on the streambed. The sampling-time interval should be the same for each vertical sampled

in the cross section. The time required to collect a proper sample can vary from 5 seconds or less to several hours or more. Generally, a sampling time that does not exceed 60 seconds is preferred. Because of the temporal variations in bedload transport rates, there is no easy way to determine the appropriate sampling time. Several test samples (as many as 10 or more collected sequentially at a vertical with a suspected high transport rate) may be needed in order to estimate the proper sampling-time interval to be used. The sample time should be short enough to allow for the collection of a sample from the section with the highest transport rate, without filling the sample bag more than about 40 percent full. The sample bag may be filled to 40 percent full with sediment coarser than the mesh size of the bag without reducing the hydraulic efficiency of the sampler (Druffel and others, 1976). Sediment that is approximately equal to the mesh size may clog the bag and cause a change in the sampling efficiency of the sampler.

(3) One sample should be collected at each vertical, starting at one bank and proceeding to the other. It is recommended that, during this initial data gathering stage, a minimum of one transect using the SEWI method be used. The samples should be placed in separate bags for individual analysis and labeled with the vertical's station number. They may be composited into one or several sample bags for a composite analysis, but if composited, no information on cross-sectional variability can be obtained from the data.

(4) A second sample should be collected using the UWI or MEWI methods. Four or five verticals should be sampled four or five times each, obtaining a total of 20 samples. Samples should be collected using the same procedure as described in number 2 above, except that the sample time for each sample need not be the same. All samples should be bagged and tagged for separate analysis.

(5) The following data must be recorded on a field note sheet for each cross-section sample:

Station name/number
Date
Cross-section sample starting and ending times
Gage height at the start and end of sample collection
Total width of the cross section, including stations on both banks
Width between verticals (SEWI method)
Number of verticals sampled (SEWI method)
Station of verticals sampled (UWI or MEWI method)
Time sampler was on the bottom at each vertical
Type sampler used
Name of person collecting sample

In addition, the following information should be recorded on each sample container:

Station name
Date
Designation of cross-section sample to which the container belongs (that is, if two cross-section samples were collected, one would be "A" and the other "B")
Number of containers for that cross section (for example, "1 of 2" or "2 of 2")
Stations(s) of the vertical(s) the sample was collected from
Time sampler was on the bottom and at the vertical station
Clock time the sample was collected (start and finish if composite)
Collector's initials

Analysis of the first transect (SEWI method) will give some indication of the cross-sectional variability if individual verticals are analyzed separately. Analysis of the second set of transects (UWI or MEWI method) will give some indication of temporal variability. As stated before, the procedure described above should be considered the minimum to be followed when first collecting bedload data at a site. Additional samples and transects will help define the temporal and spatial variation at the site for all flow ranges. After a cross section has been sampled several times at different flow ranges using the above procedure, it should be possible to develop a sampling protocol that fits the site better.

Computation of Bedload-Discharge Measurements

The bedload transport rate at a sample vertical may be computed by the equation

$$R_i = \frac{KM_i}{t_i} \qquad (1)$$

where

R_i = bedload transport rate, as measured by bedload sampler, at vertical i, in tons per day per foot;

M_i = mass of the sample collected at vertical i, in grams;

t_i = time the sampler was on the bottom at vertical i, in seconds; and

K = a conversion factor used to convert grams per second per foot into tons per day per foot. It is computed as

$$K = (86{,}400 \text{ seconds/day}) \frac{1 \text{ ton}}{(907{,}200 \text{ grams})} \frac{1 \text{ foot}}{(N_w)} \qquad (2)$$

where

N_w is the width of sampler nozzle in feet. (For a 3-inch nozzle, $K = 0.381$; for a 6-inch nozzle, $K = 0.190$.)

The cross-sectional bedload discharge measured by the Helley-Smith sampler may be computed using the total cross-section, midsection, or mean-section method. The simplest method of calculating bedload discharge from a sample collected with a Helley-Smith type bedload sampler is the total cross-section method (fig. 54). This method should only be used if the following three conditions are met:

1. The sample times (t_i) at each vertical are equal.
2. The verticals were evenly spaced across the cross section (that is, SEWI or MEWI method used).
3. The first sample was collected at one-half the sample width from the starting bank.

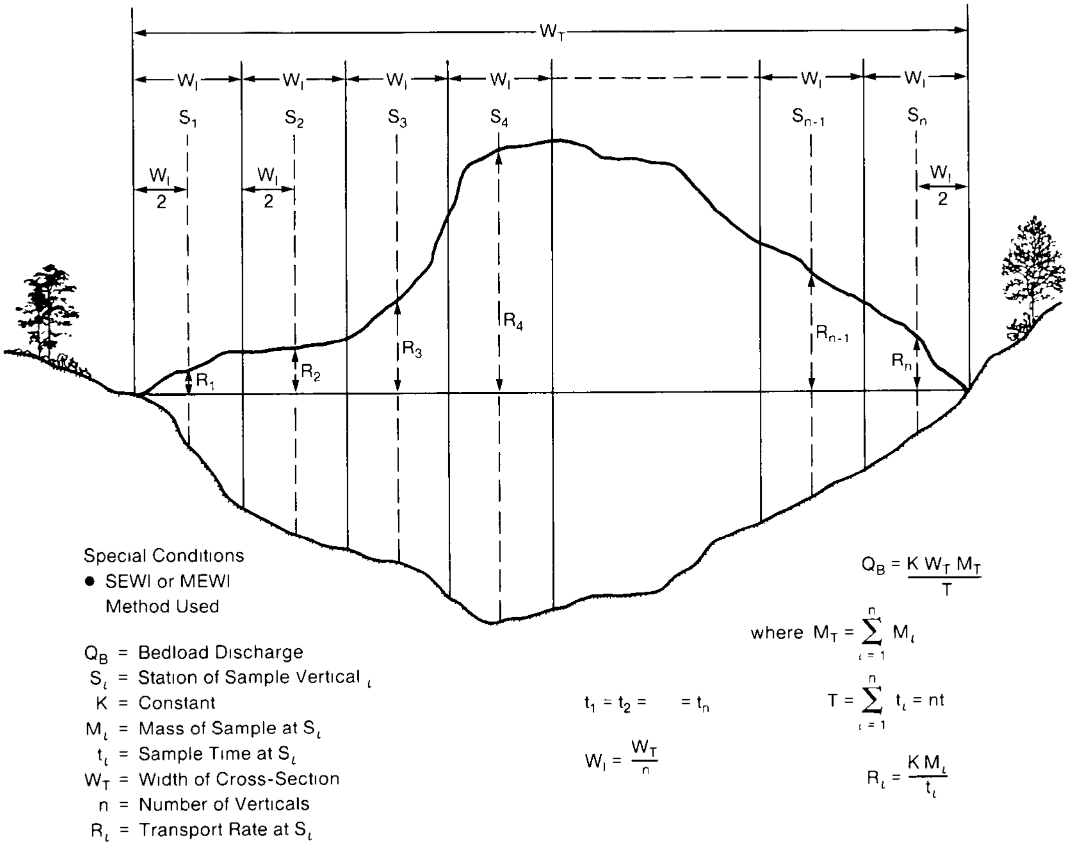


Figure 54. Total cross-section method for computing bedload discharge from samples collected with a Helley-Smith bedload sampler.

If these conditions are met, then

$$Q_B = K\frac{W_T}{t_T}M_T \qquad (3)$$

where

Q_B = bedload discharge, as measured by bedload sampler, in tons per day;

W_T = total width of steam from which samples were collected, in feet, and is equal to the increment width (W_i) times *n* (*n* = total number of vertical samples);

t_T = total time the sampler was on the bed, in seconds, computed by multiplying the individual sample time by *n*;

M_T = total mass of sample collected from all verticals sampled in the cross section, in grams; and

K = conversion factor as described in equation 2 above.

If any of the three conditions stated above are not met, then either the midsection or mean-section method should be used. Mathematically, the two methods, if used with no modifications, will produce identical answers. However, as indicated under the discussion of the UWI method, the placement of the sampling verticals with respect to breaks in the lateral cross-sectional distribution curve of mean bedload transport rate will somewhat dictate which method should be used. The midsection method (fig. 55) is computed using the following equation:

$$Q_B = \frac{R_1W_1}{2} + \sum_{i=2}^{n-1} R_i\left[\frac{(S_i - S_{i-1})}{2} + \frac{(S_{i+1} - S_i)}{2}\right] + \frac{R_nW_{n-1}}{2} \qquad (4)$$

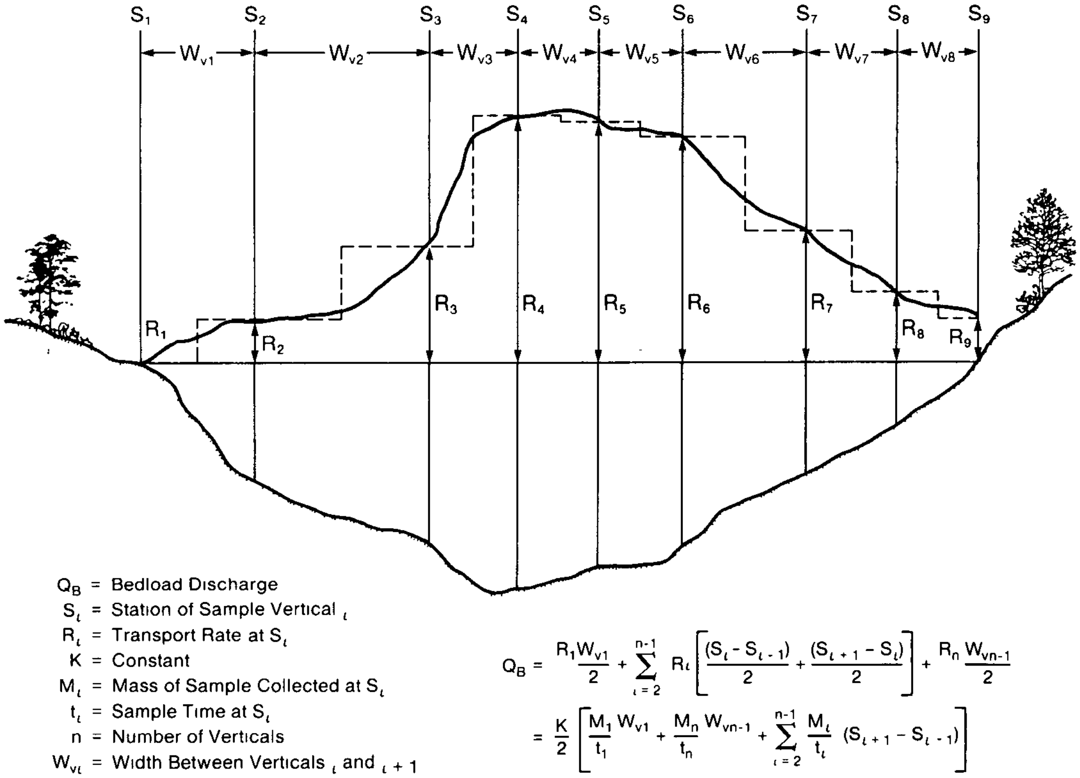


Figure 55. Midsection method for computing bedload discharge from samples collected with a Helley-Smith bedload sampler.

where

W_i = width between sampling verticals i and i+1, in feet;

S_i = stations of the vertical (i) in the cross section measured from some arbitrary starting point, in feet; and

Q_B, n, R, and K have previously been defined,

You will note that equation 3 is very similar to the equation used to compute a surface-water discharge measurement. This method corresponds to the midpoint method currently used to compute surface-water discharge measurements (Buchanan and Somers, 1969). By combining equations 1 and 4 and rearranging terms:

$$Q_B = \frac{K}{2}\left[\frac{M_1 W_1}{t_1} + \frac{M_n W_{n-1}}{t_n} + \sum_{i=2}^{n-1} \frac{M_1}{t_i}(S_{i+1} - S_{i-1})\right] \qquad (5)$$

One advantage to using the midsection method is that the distance W_1 need not necessarily be equal to the distance between sampling verticals. At times, it may become apparent, due to local conditions, that a particular R_1 should not be applied over a width equal to halfway back to the last station and halfway forward to the next, but applied to some other width. This width, sometimes referred to as the effective width, is decided on by the user. Bridge piers, large boulders, abrupt changes in velocity or lateral bed topography, or other conditions that may obstruct or cause sudden changes to bedload transport rate will affect the selection of the effective width.

The third method, the mean-section method (fig. 56), is computed using the following equation:

$$Q_B = \sum_{i=1}^{n-1} W_i \frac{(R_i + R_{i+1})}{2}, \qquad (6)$$

which is equivalent to:

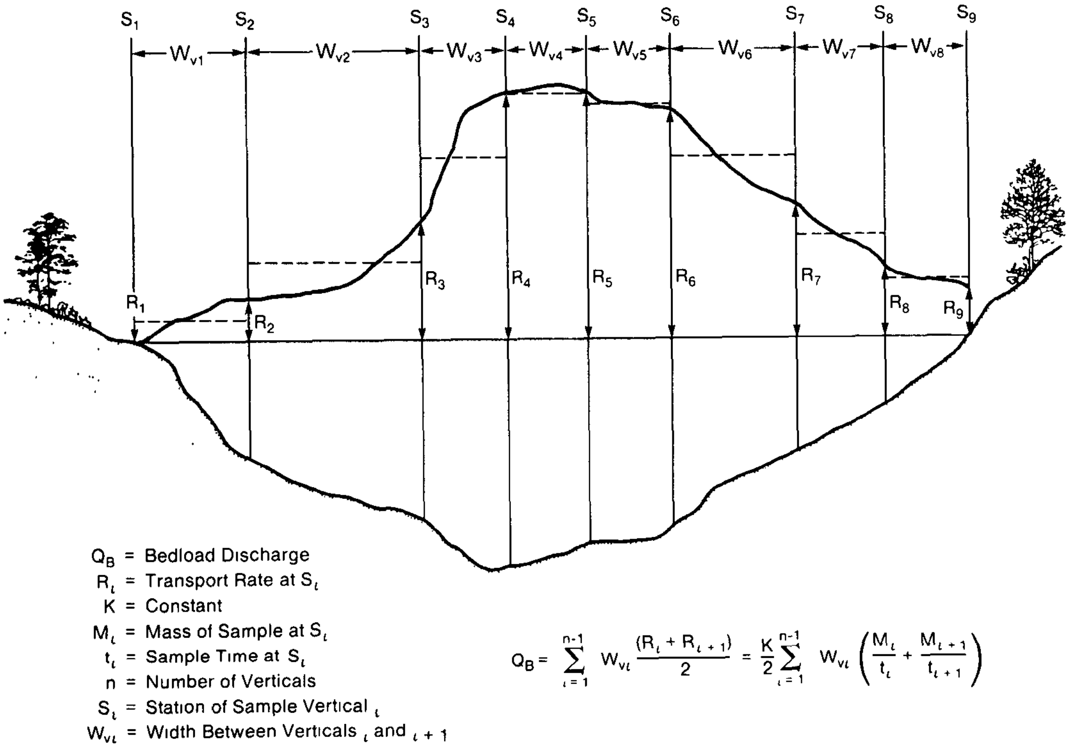


Figure 56. Mean-section method for computing bedload discharge from samples collected with a Helley-Smith bedload sampler.

$$Q_B = \frac{K}{2}\sum_{i=1}^{n-1} W_1\left(\frac{M_i}{t_i} + \frac{M_{i+1}}{t_{i+1}}\right) \tag{7}$$

All the above terms are the same as used in the midsection method. This method averages the two adjoining rates and applies the average rate over the distance between them. For this reason, it is important to try to place the sampling verticals at points where the trends in lateral mean bedload transport rate change. Under most field conditions, this might be difficult.

For situations where the total cross-section method cannot be used, it is recommended that the midsection method be used. This recommendation is made because of its similarity to the surface-water discharge-measurement method, which most field personnel are familiar with, and because of the flexibility in using the effective width concept.

Collecting bedload samples will generate 40 or more samples, creating a potential problem regarding transportation and analyses of so many samples. Carey (1984) adapted a procedure for measuring the submerged weight of bedload samples in the field and converting that measurement to dry weight from a laboratory procedure used by Hubbell and others (1981). The method uses the basic equation

$$W_{ds} = \frac{SG_s}{SG_s - 1} W_{ss} \tag{8}$$

where

W_{ds} = dry weight of the sediment;
SG_s = specific gravity of the sediment; and
W_{ss} = submerged weight of the sediment.

Measurements for Total Sediment Discharge

Total sediment discharge is the mass of all sediment moving past a given cross section in a unit of time. It can be defined as the sum of the (1) measured and unmeasured sediment discharges, (2) suspended-sediment discharge and bedload discharge, or (3) fine-material discharge (sometimes referred to as the washload) and coarse-material or bed-material discharge.

There are some sand-bed streams with sections so turbulent that nearly all sediment particles moving through the reach are in suspension. Sampling the suspended sediment in such sections with a standard suspended-sediment sampler represents very nearly the total load. Several streams with turbulent reaches are described in Benedict and Matejka (1953). Further discussion concerning total-load measurement also can be found in Inter-Agency Report 14 (Federal Inter-Agency Sedimentation Project, 1963b, p. 105–115). Turbulence flumes or special weirs can be used to bring the total load into suspension. Total load can usually be sampled with suspended-sediment samplers to a high degree of accuracy where the streambed consists of an erosion resisting material such as bedrock or a very cohesive clay. In such situations, most, if not all, the sediment being discharged is in suspension (or the bed would contain a deposit of sand).

Benedict and Matejka (1953) and Gonzales and others (1969) have described some structures used for artificial suspension of sediment to enable total-load sampling. However, most total-load sampling is usually accomplished at the crest of a small weir, dam, culvert outlet, or other place where the sampler nozzle integrates throughout the full depth of flow from the surface to the top of the weir.

Where such conditions or structures are not present, the unmeasured load must be computed by various formulas. The unmeasured load can be approximated by use of a bedload formula such as that of Meyer-Peter and Muller (1948), Einstein (1950), Colby and Hembree (1955), or Chang and others (1965). However, these computational procedures can give widely varying answers. The Colby and Hembree (1955) method [modified from Einstein (1950)] determines the total load in terms of the amount transported for different particle-size ranges. Colby and Hubbell (1961) later simplified the modified Einstein method to include the use of four nomographs in lieu of a major computational step. The essential data required for the Colby and Hubbell technique at a particular time and location are listed here:

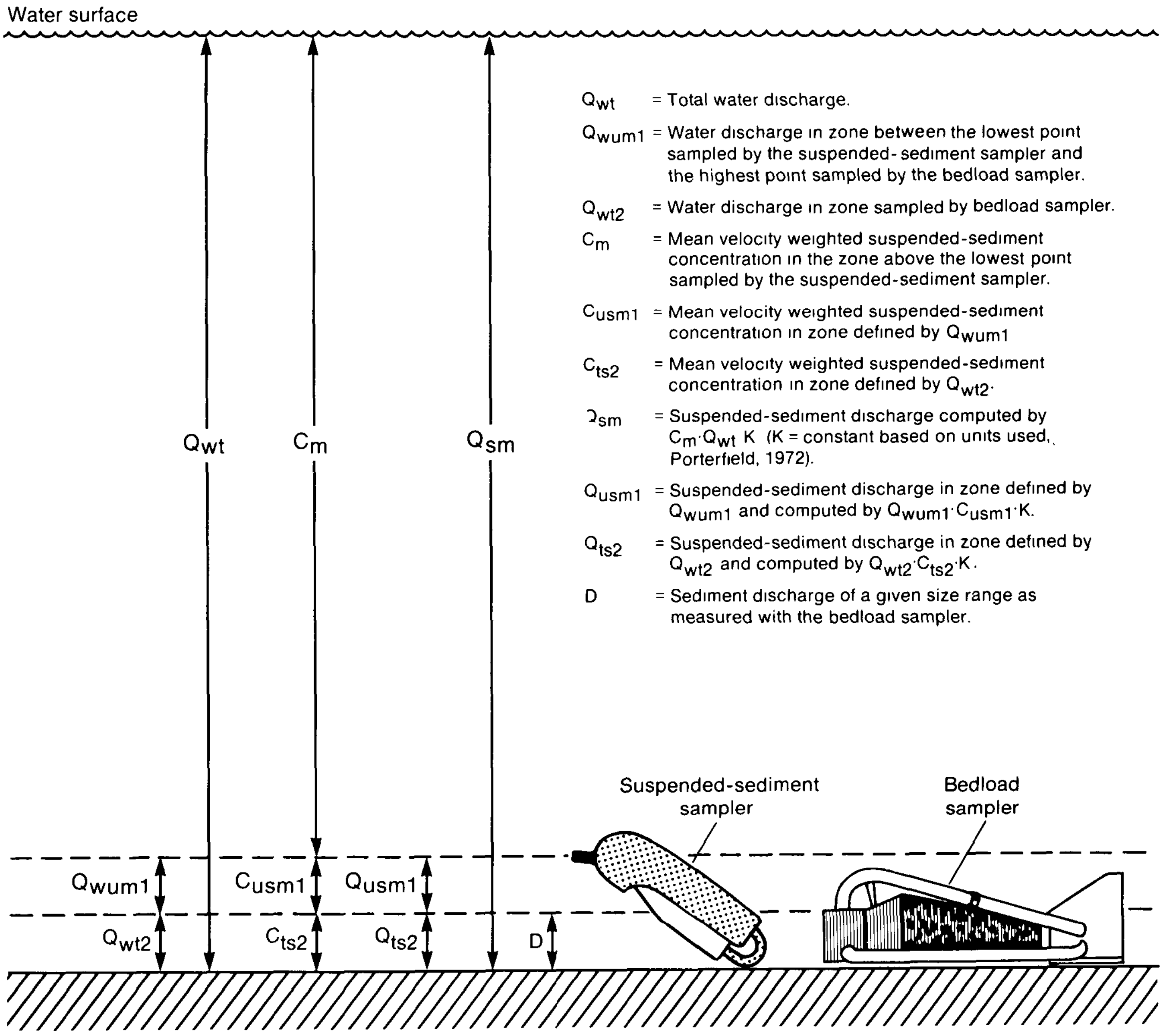
1. Stream width, average depth, and mean velocity.
2. Average concentration of suspended sediment from depth-integrated samples.
3. Size analyses of the suspended sediment included in the average concentration.
4. Average depth of the verticals where the suspended-sediment samples were collected.

5. Size analyses of the bed material.
6. Water temperature.

Stevens (1985) has developed two computer programs for the computation of total sediment discharge by the modified Einstein procedure. One program is written in FORTRAN 77 for use on the PRIME computer; the other is in BASIC and can be used on most microcomputers.

Hubbell (1964) gives the following formula for determining the total sediment discharge of a given size range from the measured suspended-sediment discharge and the discharge measured with any type of bedload apparatus (see fig. 57).

$$Q_T = \frac{Q_D}{eff} + Q_{sm} + Q_{usm1} - FQ_{sm} + (1 - E/e)Q_{ts2} \quad (9)$$



Q_{wt} = Total water discharge.

Q_{wum1} = Water discharge in zone between the lowest point sampled by the suspended-sediment sampler and the highest point sampled by the bedload sampler.

Q_{wt2} = Water discharge in zone sampled by bedload sampler.

C_m = Mean velocity weighted suspended-sediment concentration in the zone above the lowest point sampled by the suspended-sediment sampler.

C_{usm1} = Mean velocity weighted suspended-sediment concentration in zone defined by Q_{wum1}

C_{ts2} = Mean velocity weighted suspended-sediment concentration in zone defined by Q_{wt2}.

Q_{sm} = Suspended-sediment discharge computed by $C_m \cdot Q_{wt}$ K (K = constant based on units used, Porterfield, 1972).

Q_{usm1} = Suspended-sediment discharge in zone defined by Q_{wum1} and computed by $Q_{wum1} \cdot C_{usm1} \cdot K$.

Q_{ts2} = Suspended-sediment discharge in zone defined by Q_{wt2} and computed by $Q_{wt2} \cdot C_{ts2} \cdot K$.

D = Sediment discharge of a given size range as measured with the bedload sampler.

Figure 57. Zones sampled by suspended-sediment and bedload samplers and the unmeasured zone.

where

Q_T = total sediment discharge of the size range,

Q_D = discharge of the size range as measured with the bedload apparatus. If the apparatus measures more than the bedload discharge, as does the Helley-Smith, Q_D includes some of the suspended-sediment discharge,

e = efficiency of the bedload apparatus in measuring bedload discharge of the size range,

Q_{sm} = measured suspended-sediment discharge of the size range,

Q_{usm1} = unmeasured suspended-sediment discharge of the size range in the depth between the lowest point measured by the suspended-sediment sampler and the highest point measured by the bedload apparatus,

F = the fraction of the total depth represented by the flow in the depth measured by the bedload apparatus,

E = the efficiency of the bedload apparatus in measuring the suspended-sediment discharge of the size range transported through the vertical sampled by the apparatus, and

Q_{ts2} = total suspended-sediment discharge of the size range through the depth measured by the bedload apparatus.

A more detailed explanation of how to compute the total sediment discharge from measured suspended-sediment discharge and bedload discharge measured with a bedload measuring apparatus is given by Hubbell (1964, p. 7–9). If the efficiency of the bedload sampler is 100 percent for both bedload and suspended-sediment load and if the bedload sampler samples the entire unsampled zone, then the above equation is much simpler.

Reservoir-Trap Efficiency

The efficiency with which a reservoir traps sediment depends mostly on its size with respect to the rate of inflow. Other factors may include the reservoir shape, its operation, the water quality, and the size and kind of inflowing sediment. Except for small detentions with bottom outlets, all of the sand-sized and much of the silt-sized particles would be expected to be trapped. An evaluation of reservoir-trap efficiency must involve measurements of the quantity and size characteristics of the sediment entering and leaving the reservoir (Mundorff, 1964, 1966). Sometimes measurements of sediment accumulation in the reservoir plus the sediment output are used as a practical method of evaluating the sediment yield of the drainage basin.

Inflow Measurements

On many reservoirs, trap efficiency cannot be evaluated in sufficient detail from measurements of accumulation and sediment outflow. For such reservoirs, it is necessary to measure the sediment discharge and particle size entering the reservoirs. This measurement requires that stations be operated daily or continuously on streams feeding into the reservoir. Trap efficiency on a storm-event basis can be determined if several samples adequately define the concentration of the inflow and outflow hydrographs. For small detention reservoirs, it may be difficult or impractical to measure the inflow on a daily basis. If a continuous record is not possible, the objective should be to obtain observations sufficient to define the conditions for several inflow hydrographs so that a storm-event sediment rating curve can be constructed for use in estimating the sediment moved by the unsampled storms (Guy, 1965).

If it is impractical to obtain sufficient data to define the sediment content of several storm events, the least data for practical analysis should include 10 or 15 observations per year so that an instantaneous sediment rating curve can be constructed (Miller, 1951). It is expected that the instantaneous curve will yield less accurate results than the storm-event curve, which in turn will be less accurate than the continuous record. Each of the rating-curve methods may require data for a range of conditions so that adjustments can be determined for the effect of time of year, antecedent conditions, storm intensity, and possibly for the storm location in the basin (Colby, 1956; Jones, 1966).

As for most new sediment stations, particle-size analysis should be made on several of the inflow observations during the first year. These particle-size analyses will form a data base, which may make it possible to reduce the number of analyses required in future years.

Outflow Measurements

The outflow from a reservoir is drastically different from the inflow because of the attenuating effect of the flow through the reservoir or because of possible willful control in the release of water (Carter and Godfrey, 1960; Mitchell, 1962). Logically, the smaller reservoirs, which are likely to have fixed outlets and the poorest trap efficiencies, require the most thorough outflow measurement schedules. If an inflow-outflow relation for sediment discharge can be constructed, such a relation may change considerably in the direction of greater sediment output (lower trap efficiency) as the reservoir fills with sediment.

Normally, the particle size of sediment outflow is expected to be finer than for the inflow; and, therefore, the concentration of outflowing sediment should not fluctuate as rapidly as that of the inflow. The normal slowly changing outflow concentration may not occur if the outflow is from the vicinity of the interface involving a density current.

A desirable sampling schedule for outflow may vary from once a week for the large reservoir to several observations during a storm event for a small reservoir. The need for outflow particle-size data also will depend on the scale of the stream and reservoir system, the trap efficiency, and how well the inflow is defined. With respect to quality control, if the trap efficiency of a reservoir is expected to be more than 95 percent and if the sediment inflow can only be measured to the nearest 10 or 15 percent of its expected true value, it is not necessary to measure the sediment outflow in great detail unless there is a need to accurately define the amount of sediment in the flow downstream from the reservoir.

Sediment Accumulation

The small reservoir or detention basin can be used—if trap efficiency can be estimated or measured—to provide a measure of the average annual sediment yield of a drainage basin. This method is useful in very small basins where the inflow is difficult to measure and where the amount of water-inflow and sediment-concentration data is not important.

For small catchment basins or reservoirs on ephemeral streams (those that are dry most of the time), the determination of sediment accumulation involves a detailed survey of the reservoir from which stage-capacity curves can be developed—usually 1-foot contours for the lower parts of the reservoirs and 2- to 5-foot contours for the upper parts, depending on the terrain and size of the reservoir (Peterson, 1962). The accretion of sediment then can be measured either by monumented range lines in the reservoir or by resurvey for a new stage-capacity curve.

For reservoirs not dry part of the time, the sediment accumulation is usually measured by sounding on several monumented range lines spaced to provide a representative indication of the sediment accumulation between measurements. Methods for reservoir surveys are described by Heinemann (1961), Porterfield and Dunnam (1964), and Vanoni (1975). A summary of reservoir sediment deposition surveys made in the United States through 1975 was compiled by Dendy and Champion (1978). The period from 1976 to 1980 has been covered by the Inter-Agency Advisory Committee on Water Data's Subcommittee on Sediment (1983).

In order to convert the measurements of sediment volume found in reservoirs to the usual expression of mass of sediment yield, it is necessary that the sedimentation surveys of reservoirs include information on the volume-mass of sediment. Heinemann (1964) reports that this was accomplished in Sebetha Lake, Kansas, using a gamma probe and a piston sampler. From his data, obtained at 41 locations, he found that the best equation for predicting volume-mass is

$$V_M = 1.688d - 0.888c + 98.8 \qquad (10)$$

where

V_M = the dry unit volume-mass, in pounds per cubic foot;

d = the depth of sample from the top of the deposit; and

c = the percentage of clay smaller than 0.002 mm.

On the basis of 1,316 reservoir deposit samples, Lara and Pemberton (1965) found the unit volume-mass to vary according to changes in reservoir operation and to the fraction of clay, silt, and sand. The Office of Water Data Coordination (1978) reported that refinements based on reservoir operation, sediment size, and compaction could be made to the estimates made by Lara and Pemberton (1965) and Lane and Koelzer (1943). The following formula, along with factors listed in table 4, may be used to estimate dry unit volume-mass:

$$V_M = V_{tc}P_c + V_{tm}P_m + V_{ts}P_s \qquad (11)$$

where

V_M = dry unit volume-mass, in pounds per cubic foot;

V_t = dry unit volume-mass as computed in equation 12, in pounds per cubic foot;

c = clay-size material;

m = silt-size material;

s = sand-size material;

P = percent of total sample, by weight, in size class (clay, silt, sand); and

$$V_t = V_i + 0.43K\left[\frac{T}{T-1}(\log T) - 1\right] \qquad (12)$$

where

V_i = initial unit volume-mass, in pounds per cubic foot from table 4;

K = Lane and Koelzer (1943) factors from table 4, in pounds per cubic foot; and

T = time after deposition, in years.

Table 4. Initial dry unit volume-mass (V_1) and K factors for computing dry unit volume-mass of sediment deposits in pounds per cubic foot (Office of Water Data Coordination, 1978)

	V_1			K		
Type of reservoir operation	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**
1. Sediment submerged	26	70	97	16	5.7	0
2. Moderate to considerable annual drawdown	35	71	97	8.4	1.8	0
3. Normally empty	40	72	97	0	0	0
4. River sediment	60	73	97	0	0	0

OTHER SEDIMENT DATA-COLLECTION CONSIDERATIONS

In retrospect, it must be emphasized that field methods for fluvial-sediment measurements must be coordinated with methods for other hydrologic and environmental measurements. With the ever-increasing requirements of a thorough data-acquisition system, together with advances in technology, it must be expected that methods will continue to change in the future. For example, because there is a foreseeable need for increasing water-pollution surveillance studies with respect to stream-quality standards, it is apparent that a continuous recording of some indicator of sediment conditions is badly needed at a large number of sites. Consequently, the F.I.S.P. has undertaken the development of sensors and automatic pumping-type samplers with a view toward continuously recording the concentration of sediment that moves in streams. The development of such automatic equipment is likely to enhance rather than detract from the need for conventional manual observations.

The authors sincerely hope that the material regarding the equipment and techniques for sampling presented herein will stimulate the ongoing development of better equipment and techniques for the future and, at the same time, help to standardize and make more efficient the day-to-day operations.

The opportunity certainly exists at the field level for many innovations for improving the end product or the sediment record. Some field people, for example, may like to carry a copy of the station stage-discharge rating curve, on which all particle-size analyses are recorded, showing date and kind of sample for each measuring site. As communications and river forecasting become more sophisticated, it may be possible to have better dialogue between the office and the field people or local observers, who are trying to obtain the maximum information at many sampling sites. Such communication is especially critical during periods of flooding, when timely data are most important.

In addition to increasing coordination of sediment-data activities with other related measurements, it is important to stress that adequate notes be obtained (including pictures) so that those involved in the laboratory analysis of the samples, those responsible for preparing the record, and especially those responsible for interpreting the data can properly read what happened at the sample site. The amount of new information to be obtained from data interpretation is seriously affected by the quality of the information with respect to timing and representativeness of the sediment measurements.

The authors further emphasize the need for a concerted and continuing effort with respect to safety in the measurement program. Aside from the hazards of highway driving, the work usually involves the use of heavy equipment during floods or other unusual natural events, often in darkness and under unpleasant weather conditions. Even though the hazards of working from highway bridges and cableways are mostly self-evident, there are many opportunities for the unusual to happen and, therefore, a great deal of effort must be expended to ensure safety. Such effort, of course, must be increased when it is necessary to accomplish the work in a limited amount of time and with a reduced work force.

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Appendix B – Flow Schedules

Included herein:

1. Trinity River Pulse Flow Schedule

Project: Lewiston Dam

Please make the following release changes
to the Trinity River:

DATE	TIME	RELEASE (cfs) FROM	TO
24 Aug 03	1400	450	550
24 Aug 03	1600	550	650
24 Aug 03	1800	650	900
24 Aug 03	2000	900	1,150
24 Aug 03	2200	1,150	1,400
24 Aug 03	2400	1,400	1,650
26 Aug 03	0900	1,650	1,575
26 Aug 03	1300	1,575	1,500
28 Aug 03	0900	1,500	1,450
30 Aug 03	0900	1,450	1,400
1 Sep 03	0900	1,400	1,350
3 Sep 03	0900	1,350	1,300
5 Sep 03	0900	1,300	1,250
7 Sep 03	0900	1,250	1,200
9 Sep 03	0900	1,200	1,150
11 Sep 03	0900	1,150	1,100
13 Sep 03	0900	1,100	1,050
15 Sep 03	0900	1,050	1,000
16 Sep 03	0001	1,000	900
16 Sep 03	0400	900	800
16 Sep 03	0800	800	700
16 Sep 03	1200	700	600
16 Sep 03	1600	600	500
16 Sep 03	2000	500	450

Comment: Flows for Hoopa Boat Dance ceremony and fishery purposes.

Issued By: Tom Patton

Appendix C – Synoptic Surveys

Included herein:

1. Synoptic Survey for June, 2003
2. Synoptic Survey for August, 2003

Klamath River Technical Memorandum 1

Topic: Klamath River Water Quality Synoptic Survey: June 2003

Date: 7/21/03

Abstract: Data collection along the Klamath River began June 9, 2003 and ended June 12, 2003. Within this period, measurements of dissolved oxygen, water temperature, pH and specific conductance were recorded at sub-daily intervals (one-hour or half hour) at multiple sites along the Klamath River between Iron Gate Dam and Klamath River at Turwar with water quality probes – a distance of approximately 180 river miles. In addition to these automated measurements, grab samples were collected once daily along the Klamath River between Iron Gate Dam and Martins Ferry – a distance of approximately 160 river miles. The grab samples were analyzed for ammonia, nitrate-nitrite, total Kjeldahl nitrogen and total phosphorus. On the last day of the survey, grab samples were also collected to be analyzed for ortho-phosphate, total suspended solids, volatile suspended solids, turbidity and chlorophyll-a. On each day of the survey additional samples were collected to perform field analysis for dissolved oxygen, ortho-phosphate and turbidity. Data from all measurement devices was retrieved successfully except for a partial loss of data at one site. All grab samples scheduled for collection were collected and delivered to the CH2MHill Applied Sciences Laboratory in Corvallis, OR with the exception of one bottle set, which was sent to another lab due to an oversight. This report is solely intended to present field data and a summary of field conditions and notes.

Introduction

As part of the PacifiCorp funded water quality monitoring program along the Klamath River, a synoptic survey was made June 9, 2003 through June 12, 2003. With the cooperation of E&S Environmental, the North Coast Regional Water Quality Control Board (NCRWQCB), the Karuk tribe and the Yurok tribe, Watercourse Engineering, Inc. conducted daily grab sampling during the survey as well as recorded data using several water quality probes (sondes) in the Klamath River and selected tributaries from the Iron Gate Dam to Klamath River at Turwar. The grab sampling sites and the sonde sites are shown in Table 1.

Table 1 Synoptic survey locations

Location	Site	River Mile	Elevation, ft	Grab Sampling?	Sonde location?
1	Klamath River below Irongate Dam	190	2200	Yes	Yes
2	Klamath River above Shasta River	177	2002	Yes	Yes
3	Shasta River	0.5	2002	Yes	Yes
4	Klamath River above Scott River	144	1560	Yes	Yes
5	Scott River	0.1	1560	Yes	Yes
6	Klamath River at Seiad Valley	129	1320	Yes	Yes
7	Klamath River at Clear Creek	99	933	Yes	No
8	Klamath River above Salmon River	67	491	Yes	Yes
9	Salmon River at Somes Bar	1.0	500	Yes	Yes
10	Klamath River at Aikens Hole	49	310	No	Yes
11	Klamath River at Weitchpec (above Trinity River)	44	302	Yes	Yes
12	Trinity River	0.25	302	Yes	Yes
13	Klamath River at Martins Ferry	40	273	Yes	Yes
14	Klamath River at Turwar Creek	6	6	No	Yes

Sampling

Grab Samples

Grab samples were collected at twelve sites for four consecutive days. Each day, samples were collected in bottles pre-preserved with sulfuric acid (H2SO4) for lab analysis of ammonia, total Kjeldahl nitrogen (TKN), nitrate-nitrite, and total phosphorus concentrations. Separate bottles were collected for field analysis of dissolved oxygen (DO), turbidity and orthophosphate (OPO4). On the last day of the survey, June 12, 2003, additional samples were collected for lab analysis of OPO4, total suspended solids (TSS), volatile suspended solids (VSS), turbidity, and chlorophyll-a concentrations. Each day, one set of external quality assurance samples (duplicate, spike and blank) was included with the bottles for lab analysis. Quality assurance sample sets were collected using a churn splitter. Samples collected for field analysis did not include an external quality assurance set of samples.

All lab analysis samples were kept chilled in ice or refrigerated until packed in ice for transport by Richard Raymond of E&S Environmental to the CH2MHill Applied Sciences Laboratory in Corvallis, OR on Friday, June 13, 2003. All lab analysis samples were received by Richard Raymond by 3 pm Thursday, June 12, 2003.

On Thursday, June 12, 2003, one set of bottles (Klamath River above the Trinity River site) sampled by the Yurok crew was inadvertently left behind when samples were delivered to Watercourse personnel. These samples were sent to North Coast Labs in Arcata, CA by the Yurok crew for analysis.

There were no grab samples which were not collected or which were lost after collection during this synoptic survey. Both tabulated data and graphs of grab sample results are presented in Appendix A. For visual interpretation, grab sample results are connected with lines. This does not indicate that the system was acting in a linear manner between grab samples.

Field analysis

There were three field analysis tests performed during the synoptic survey: the Winkler DO test, the turbidity test and the OPO4 test.

DO analysis

The Winkler DO test is a modified Winkler dissolved oxygen titration, performed with a Hach digital titration kit. This field analysis was performed approximately every other site each day, with each site having the test done at least twice during the synoptic survey. The Winkler DO test is the portion of a site visit which takes the longest to perform and thus the test was not performed at each site due to time constraints. Also, the Winkler test was not performed at some sites due to time constraints on Monday, June 9, 2003. At the three site which were sampled by the Yurok tribe crew, a Winkler was performed every day as a substitute for a DO sensor in the field measurement probe which was not working. Results of the Winkler DO tests are presented in Appendix B, and also along with the sonde DO results in Appendix C.

Turbidity and OPO4 analysis

Neither the turbidity nor the OPO4 field analysis was performed onsite. The samples collected for those tests were chilled along with the lab analysis samples and analyzed at the end of the day. Samples collected Monday were held until Tuesday evening due to time constraints, but were analyzed within the proper hold times for both turbidity and OPO4 analysis. Samples collected Thursday were given to Richard Raymond of E&S Environmental for analysis on Friday.

Because a single bottle was collected for use with both the turbidity and OPO4 field analysis, the turbidity analysis was performed first. For samples collected Monday, Tuesday and Wednesday, turbidity tests were performed by Watercourse three times on each sample and the average turbidity was reported. The turbidimeter used was an older meter with no make or model number indicated on the machine. However, reported it as being similar in function to VWR Model 800 turbidimeter. Samples collected on Thursday were analyzed by Richard Raymond from E&S Environmental once, though some repeat analysis was performed to confirm results. The turbidimeter used was the same machine mentioned above. Field turbidity data are presented in Appendix B. Field turbidity is also presented in the graphs in Appendix A.

Once turbidity analysis was completed, the remaining sample water was given to Richard Raymond from E&S Environmental to perform the OPO4 field analysis. OPO4 field analysis was performed using the Hach Model 2400 portable spectrophotometer, using the PhosVer II powder pillow test (#490). The samples were analyzed once, though selected reanalysis was performed to confirm results. Field OPO4 data are presented in Appendix B. Field OPO4 is also presented in the graphs in Appendix A.Field measurements

Several field measurements were taken during site visits in June. As there were effectively three sampling crews (Watercourse 1, Watercourse 2, and Yurok) during this synoptic, the specific measurements taken per site visit were determined by the equipment available to each crew. The Watercourse 1 crew, was able to measure water temperature and dissolved oxygen using a YSI DO 200 probe. Watercourse 1 was also able to measure pH using an Oakton waterproof pH TestR 3. However, Watercourse 1 was not able to measure specific conductance during this synoptic survey. The Watercourse 2 crew was not able to take any field measurements. The Yurok sampling crew was able to measure water temperature, pH and specific conductance using a Hydrolab Quanta. The dissolved oxygen probe on the Quanta was not functional during this survey. Field measurements are presented in Appendix B.

YSI DO 200 probe

A YSI DO 200 probe was used to measure DO at sampling locations. It was determined on the first day of the synoptic survey that the probe should be re-calibrated at elevations that were more closely associated with the sampling locations. On Monday of the sampling event the probe was calibrated to elevation and barometric pressure at the Klamath River below Irongate Dam site in the morning, but not calibrated again during the rest of the day – readings deviated from those determined by Winkler titrations and sonde data. On subsequent days the probe was recalibrated at different sites in an attempt to address this issue and the instrument to perform better. However, due to time constraints, recalibration was not done at each site; specifically, recalibration was not performed when there were no large elevation changes between adjacent sites.

pH TestR 3

The pH tester was calibrated once in the morning at the first site visited by Watercourse 1. A two point calibration was done using two buffers: pH 7.0 and pH 10.0. Starting Tuesday, the pre-calibration reading for each buffer was recorded as a method of determining instrument drift. The pH tester maintained its calibration throughout each day. There was very little instrument drift recorded each morning.

Meteorological Conditions

The meteorological conditions during the synoptic survey at Montague, CA and Arcata, CA are illustrated in Table 2 and Table 3 , respectively. While Montague, CA meteorological conditions can be considered representative for upper river sites, there were local variations along the river. The meteorological conditions at Arcata, CA are representative of coastal conditions. While most of the sites were well away from the coastline, Klamath River at Turwar is located at river mile six. Further, the influence of the Pacific Ocean was evident on Thursday, June 12, 2003 when a marine layer was present as far upriver as the Klamath-Salmon River confluence.

Table 2 Meteorological conditions during the synoptic survey at Montague, CA

Date	Temperature, F			Dew Point, F	Mean Wind Speed, mph	Precipitation, inches
	Mean	Maximum	Minimum			
6/9/2003	66.0	87.0	45.0	38.4	7.1	0.00
6/10/2003	66.5	86.0	47.0	35.6	7.3	0.00
6/11/2003	64.5	84.0	45.0	35.6	8.0	0.00
6/12/2003	62.5	81.0	44.0	41.5	6.4	0.00

Table 3 Meteorological conditions during the synoptic survey at Arcata, CA

Date	Temperature, F			Dew Point, F	Mean Wind Speed, mph	Precipitation, inches
	Mean	Maximum	Minimum			
6/9/2003	53.5	55.9	51.1	50.9	19.6	0.02
6/10/2003	53.6	57.2	50.0	50.7	6.1	0.00
6/11/2003	53.5	55.9	51.1	51.7	5.6	0.02
6/12/2003	51.4	55.9	46.9	50.5	4.9	0.01

Sondes

Sonde Deployment

Seven sondes, five borrowed from the NCRWQCB and two rented from US Environmental Rental Corp., were deployed for the synoptic survey. Deployment sites are listed in Table 4. Sondes were deployed starting the morning of Monday, June 9, 2003. Sondes were retrieved starting the morning of Thursday, June 12, 2003. Three types of sondes were deployed during this survey: Hydrolab Datasonde 3, YSI 6600, and YSI 600 sondes. All sondes were set to log water temperature, dissolved oxygen, specific conductance and pH hourly. All sensors for the borrowed sondes, except DO, were calibrated at the NCRWQCB lab on Friday June 6, 2003. The sensors for the rented sondes were calibrated by US Environmental Rental Corp. before being shipped to Watercourse Engineering, Inc. DO sensors were calibrated in the field at each site before deployment except at the Klamath River above the Shasta River and the Klamath River above the Scott River sites. DO sensors deployed at these sites were calibrated at the Shasta River and Scott River sites, respectively.

Table 4 Sonde locations and information

Location	Site	Deployed / Maintained	Agency	Logging Interval	Type
1	Klamath River below Irongate Dam	Deployed	Watercourse	1 hour	YSI 6600
2	Klamath River above Shasta River	Deployed	Watercourse	1 hour	Hydrolab DS3
3	Shasta River	Deployed	Watercourse	1 hour	YSI 6600
4	Klamath River above Scott River	Deployed	Watercourse	1 hour	YSI 6600
5	Scott River	Deployed	Watercourse	1 hour	Hydrolab DS3
6	Klamath River at Seiad Valley	Deployed	Watercourse	1 hour	YSI 600
8	Klamath River above Salmon River	Deployed	Watercourse	1 hour	YSI 600
9	Salmon River at Somes Bar	Maintained	Karuk	0.5 hour	Hydrolab DS4A
10	Klamath River at Aikens Hole	Maintained	Yurok	0.5 hour	Hydrolab DS4A
11	Klamath River at Weitchpec (above Trinity River)	Maintained	Yurok	0.5 hour	Hydrolab DS4A
12	Trinity River	Maintained	Yurok	0.5 hour	Hydrolab DS4A
13	Klamath River at Martins Ferry	Maintained	Yurok	0.5 hour	Hydrolab DS4A
14	Klamath River at Turwar Creek	Maintained	Yurok	0.5 hour	Hydrolab DS4A

Sondes were deployed by attaching the sonde to a cable secured on or near shore. At two sites the cable was attached to a tree trunk as a method of fixing the sonde to the bank, in other cases metal stakes were employed. The Hydrolab DS3 sondes were wrapped in black plastic garbage bags prior to deployment to decrease visibility by concealing the white sonde casing. The YSI sondes were not wrapped because their casings are dark gray and were deemed of low visibility during deployment. All sondes were deployed with sensor guards and placed into the rivers at locations with good flow.

There were two incidents of sondes becoming exposed to air during the course of the synoptic survey. At the Klamath River at Seiad site, exploration of the sonde deployment site on Tuesday, June 10, 2003 determined that the sonde had become lodged in some tree branches with the sonde sensors out of the water. The sonde was redeployed immediately upon discovery and there was no indication in the data record of the air exposure. It is concluded that exposure occurred between hourly readings and lasted less than an hour. The sensors themselves did not appear to have been affected by the air exposure.

The second incident of air exposure occurred in the Scott River. The sonde was deployed near a bridge pile on the right bank of the river on Monday, June 9, 2003. At the time of deployment there were approximately 6 inches of water above the sonde sensors and water surrounding the sonde was fast moving. On Tuesday, June 10, 2003, the sonde was still submerged, and did not appear to have been moved, but there were approximately only 2 to 3 inches of water above the sonde sensors. The water surrounding the sonde was still fast moving. By the site visit on Wednesday, June 11, 2003, the sonde appeared to be in the same location but had become exposed to air. The sonde was redeployed approximately four feet further from the bank, with approximately 5 inches of water above the sensors. Upon data retrieval, an air exposure period from 6/10/03 17:00 to 6/11/03 9:00 was determined by examining the recorded specific conductivity. All data recorded by this sonde within this period were discarded.

All data were successfully retrieved from all deployed sondes. Sonde data are presented in Appendix C.

Existing Sondes

Karuk Sonde

The Karuk sonde was deployed on June 9, 2003 for purposes of environmental monitoring in the Salmon River. The sonde did not begin recording until June 11, 2003. Sonde memory was full by June 13, 2003. The sonde was retrieved on June 19, 2003.

Yurok Sondes

The Yurok sondes were deployed on June 5, 2003, prior to the synoptic survey for the purposes of environmental monitoring in the Yurok reservation at Weitchpec, CA. The sondes' dissolved oxygen sensors were cleaned on Monday, June 9, 2003, so the data could be applied to the synoptic survey. The sondes were retrieved on Thursday, June 12, 2003.

Other Notes

During the synoptic survey period, Monday June 9, 2003 through Thursday, June 12, 2003, there were noticeable changes in the Klamath River and some of its tributaries.

Over the course of the survey, water level decreases of at least six inches were noticed at the Scott River site, as well as at the Klamath River above the Salmon River site. The changes were not observable within the length of a daily site visit, but were observable on a day-to-day basis. Water level decreases were noted because of observable water level changes relative to sonde deployment equipment (the sonde at the Scott River, and the attachment stake at the Klamath River above Salmon River site). Recorded flow in the Klamath and some of its tributaries both prior to and during the synoptic survey is presented in Appendix D. All flow data were downloaded from CDEC as reported, in 15-minute intervals.

Also noticeable over the course of the survey was a change in turbidity and color in both the Scott and Salmon Rivers. The Scott River was visibly turbid during the site visit on Monday, June 9, 2003, and with each successive day became noticeably less turbid. The Salmon River appeared slightly turbid and colored on the Monday site visit, but by the Thursday site visit was remarkably clear.

Acknowledgements

This project was a part of a larger WQ project sponsored by PacifiCorp with support from the North Coast Regional Water Quality Control Board (loaning of sondes), the Karuk Tribe and the Yurok Tribe. Instrumental in the success of this effort was the direct involvement of Peter Otis from the North Coast Region Water Quality Control Board, Ken Fetcho from the Yurok Tribe, Scott Quinn from the Karuk Tribe, and Richard Raymond of E&S Environmental, as well as those personnel who assisted in the collection of field information.

Appendix A - Laboratory analysis results of grab samples

Table 5 Water quality results from grab sample analysis

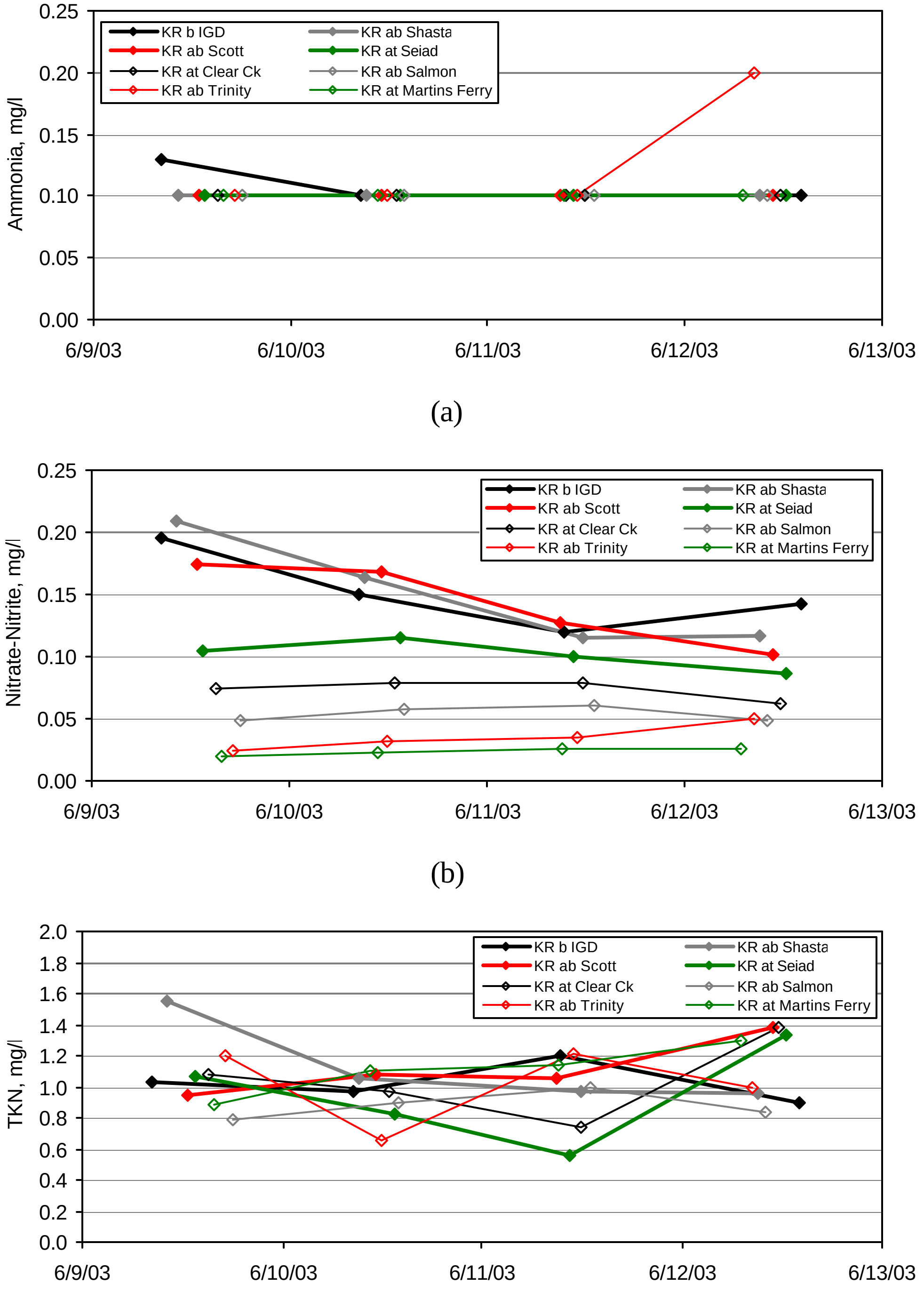
Date Sampled	Time	Site Name	Ammonia as N mg/L	Nitrate+Nitrite as N mg/L	Ortho Phosphate as P mg/L	Total Phos-phorous as P mg/L	Total Kjeldahl Nitrogen mg/L	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Turbidity NTU
6/9/2003	1242	KLAMATH RIVER ABOVE SCOTT RIVER	<0.1	0.17		0.16	0.95			
6/9/2003	820	KLAMATH RIVER BELOW IRON GATE DAM	0.13	0.20		0.15	1.03			
6/9/2003	1015	KLAMATH RIVER U/S SHASTA RIVER	<0.1	0.21		0.13	1.55			
6/9/2003	910	SHASTA RIVER AT MOUTH	0.14	<0.01		0.21	1.00			
6/9/2003	1200	SCOTT RIVER NEAR MOUTH	<0.1	0.070		<0.05	0.82			
6/9/2003	1325	KLAMATH RIVER NEAR SEIAD VALLEY	<0.1	0.10		0.053	1.07			
6/9/2003	1505	KLAMATH R AT CLEAR CREEK	<0.1	0.074		<0.05	1.08			
6/9/2003	1805	KLAMATH R AB SALMON RIVER	<0.1	0.049		<0.05	0.79			
6/9/2003	1640	SALMON RIVER AT SOMES BAR	<0.1	<0.01		<0.05	0.96			
6/9/2003	1547	KLAMATH R AT MARTINS FERRY	<0.1	0.019		<0.05	0.89			
6/9/2003	1627	TRINITY R AT WEITCHPEC	<0.1	<0.01		<0.05	0.85			
6/9/2003	1702	KLAMATH R AB TRINITY RIVER	<0.1	0.025		<0.05	1.20			
6/10/2003	1105	KLAMATH RIVER ABOVE SCOTT RIVER	<0.1	0.17		0.11	1.08			
6/10/2003	825	KLAMATH RIVER BELOW IRON GATE DAM	<0.1	0.15		0.13	0.97			
6/10/2003	910	KLAMATH RIVER U/S SHASTA RIVER	<0.1	0.16		0.11	1.06			
6/10/2003	910	SHASTA RIVER AT MOUTH	<0.1	<0.01		0.23	1.21			
6/10/2003	1150	SCOTT RIVER NEAR MOUTH	<0.1	0.11		<0.05	0.89			
6/10/2003	1320	KLAMATH RIVER NEAR SEIAD VALLEY	<0.1	0.12		0.095	0.82			
6/10/2003	1245	KLAMATH R AT CLEAR CREEK	<0.1	0.079		<0.05	0.97			
6/10/2003	1345	KLAMATH R AB SALMON RIVER	<0.1	0.058		<0.05	0.90			
6/10/2003	1355	SALMON RIVER AT SOMES BAR	<0.1	<0.01		<0.05	0.75			
6/10/2003	1145	KLAMATH R AB TRINITY RIVER	<0.1	0.032		<0.05	0.66			
6/10/2003	1124	TRINITY R AT WEITCHPEC	<0.1	<0.01		<0.05	0.87			
6/10/2003	1035	KLAMATH R AT MARTINS FERRY	<0.1	0.023		<0.05	1.10			
6/11/2003	900	KLAMATH RIVER ABOVE SCOTT RIVER	<0.1	0.13		0.12	1.05			
6/11/2003	930	KLAMATH RIVER BELOW IRON GATE DAM	<0.1	0.12		0.15	1.20			
6/11/2003	1150	KLAMATH RIVER U/S SHASTA RIVER	<0.1	0.12		0.12	0.97			
6/11/2003	1235	SHASTA RIVER AT MOUTH	<0.1	<0.01		0.20	0.88			
6/11/2003	935	SCOTT RIVER NEAR MOUTH	<0.1	0.13		0.13	0.46			
6/11/2003	1030	KLAMATH RIVER NEAR SEIAD VALLEY	<0.1	0.10		<0.05	0.56			
6/11/2003	1150	KLAMATH R AT CLEAR CREEK	<0.1	0.079		0.059	0.74			
6/11/2003	1300	KLAMATH R AB SALMON RIVER	<0.1	0.061		0.054	0.99			
6/11/2003	1400	SALMON RIVER AT SOMES BAR	<0.1	<0.01		<0.05	0.91			
6/11/2003	1105	KLAMATH R AB TRINITY RIVER	<0.1	0.035		<0.05	1.21			
6/11/2003	1018	TRINITY R AT WEITCHPEC	<0.1	0.007		<0.05	1.11			
6/11/2003	920	KLAMATH R AT MARTINS FERRY	<0.1	0.026		<0.05	1.14			
6/12/2003	1410	KLAMATH RIVER BELOW IRON GATE DAM	<0.1	0.14	0.082	0.12	0.90	4	2	2.88

Date Sampled	Time	Site Name	Ammonia as N	Nitrate+Nitrite as N	Ortho Phosphate as P	Total Phos-phorous as P	Total Kjeldahl Nitrogen	Total Suspended Solids	Volatile Suspended Solids	Turbidity
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/l	mg/l	NTU
6/12/2003	1050	KLAMATH RIVER ABOVE SCOTT RIVER	<0.1	0.10	0.073	0.11	1.38	6	3	4.60
6/12/2003	905	KLAMATH RIVER U/S SHASTA RIVER	<0.1	0.12	0.080	0.13	0.96	5	3	3.69
6/12/2003	825	SHASTA RIVER AT MOUTH	<0.1	<0.01	0.17	0.22	1.35	2	2	1.30
6/12/2003	1135	SCOTT RIVER NEAR MOUTH	<0.1	0.14	<0.05	<0.05	1.38	22	2	9.00
6/12/2003	1225	KLAMATH RIVER NEAR SEIAD VALLEY	<0.1	0.086	<0.05	0.057	1.33	11	3	5.50
6/12/2003	1140	KLAMATH R AT CLEAR CREEK	<0.1	0.063	<0.05	0.054	1.38	8	2	5.53
6/12/2003	825	SALMON RIVER AT SOMES BAR	<0.1	<0.01	<0.05	<0.05	1.20	2	<2.0	1.45
6/12/2003	1005	KLAMATH R AB SALMON RIVER	<0.1	0.049	<0.05	<0.05	0.84	9	4	5.35
6/12/2003	800	TRINITY R AT WEITCHPEC	<0.1	<0.01	<0.05	<0.05	0.92	5	2	3.30
6/12/2003	830	KLAMATH R AB TRINITY RIVER	<0.2	<0.05	<0.05	0.079	<1.0	7.3	<10	6.1
6/12/2003	700	KLAMATH R AT MARTINS FERRY	<0.1	0.026	<0.05	<0.05	1.30	6	<2.0	4.27

Notes:

For graphing purposes, results which were below the reporting limit were replaced with the reporting limit.

Sample collected on 6/12/03 at Klamath River above Trinity River was analyzed by North Coast Laboratory in Arcata, CA, and has different reporting limits than the other samples. All other samples were analyzed by CH2MHill Applied Sciences Laboratory in Corvallis, OR.

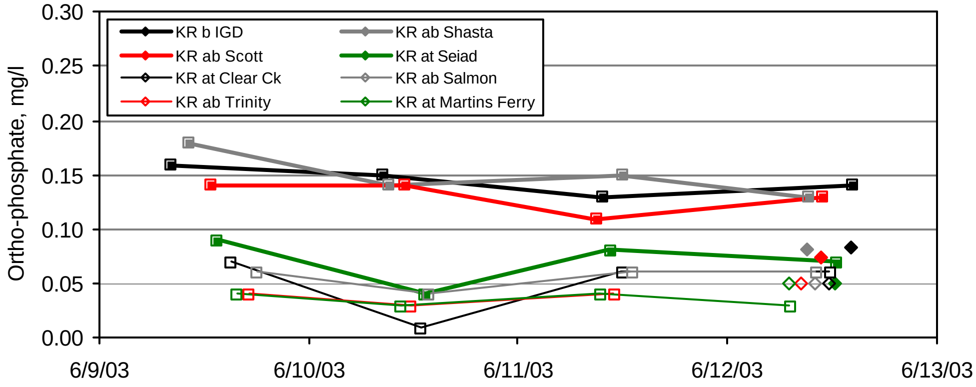


(a)

(b)

(c)

Figure 1 KR 2000 synoptic grab sample results for different locations in the Klamath River: (a) ammonia, (b) nitrate -nitrite, (c) TKN



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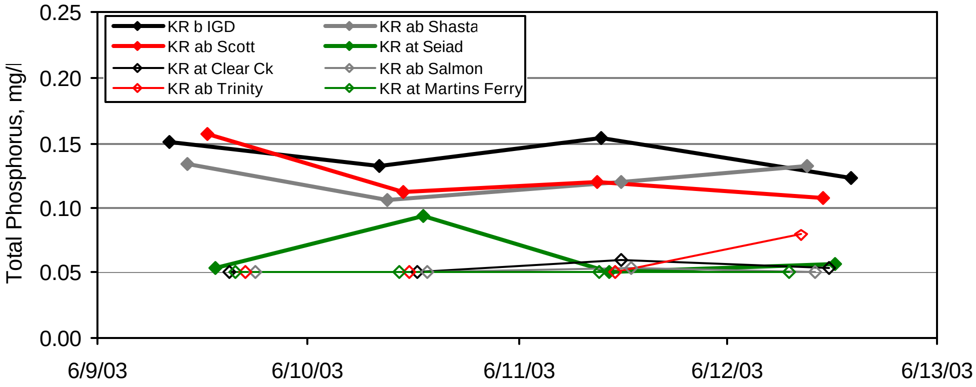

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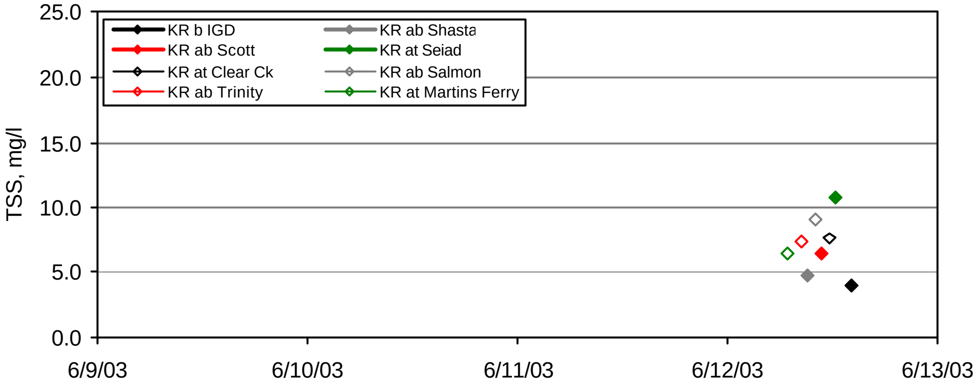
Figure 2 KR 2000 synoptic grab sample results for different locations in the Klamath River: (a) ortho-phosphate, (b) total phosphorus. Note that there are both field results (squares) and lab results (diamonds) on the ortho-phosphate graph.



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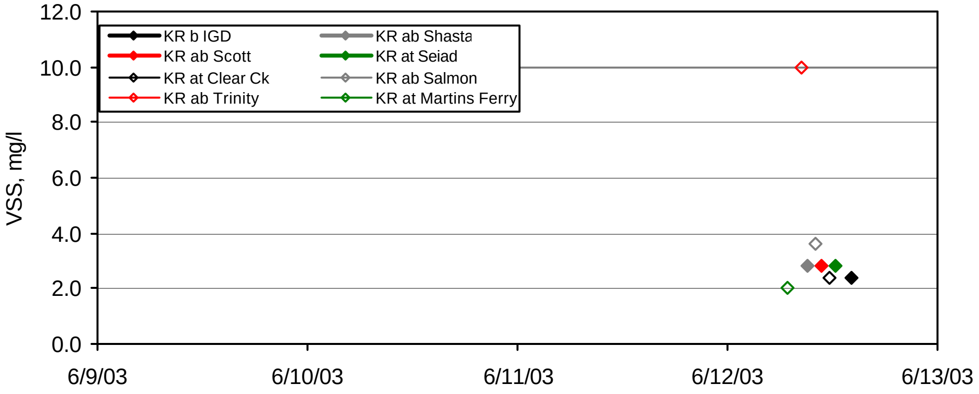

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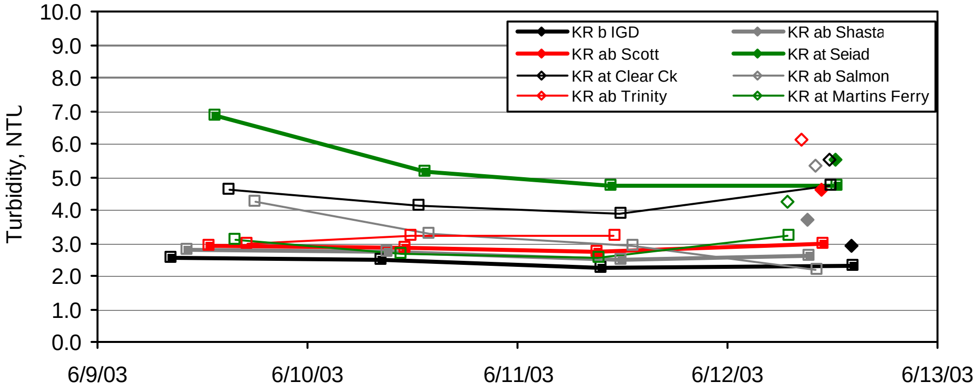
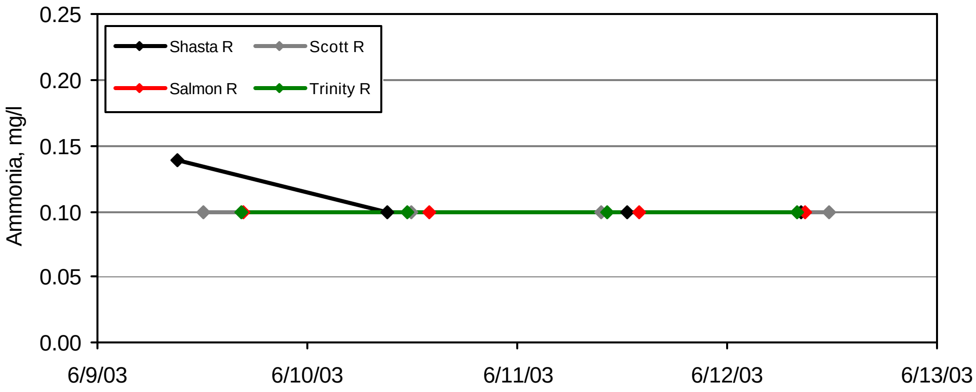


(c)

Figure 3 KR 2000 synoptic grab sample results for different locations in the Klamath River: (a) TSS, (b) VSS, (c) turbidity. Note that there are both field results (squares) and lab results (diamonds) on the turbidity graph.



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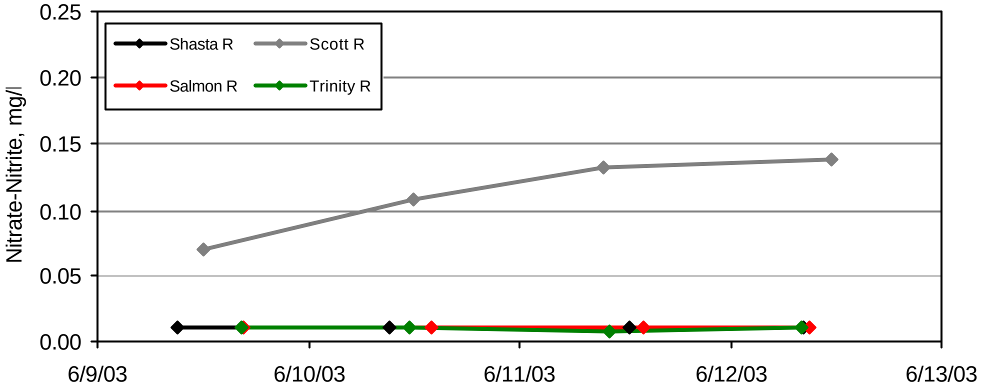

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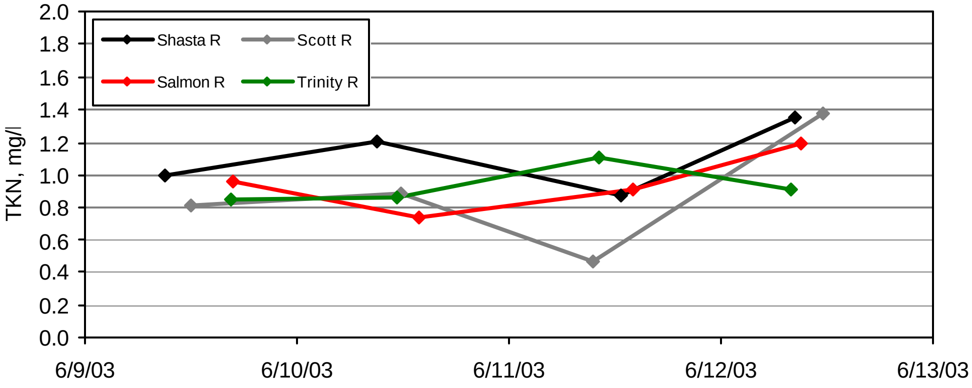
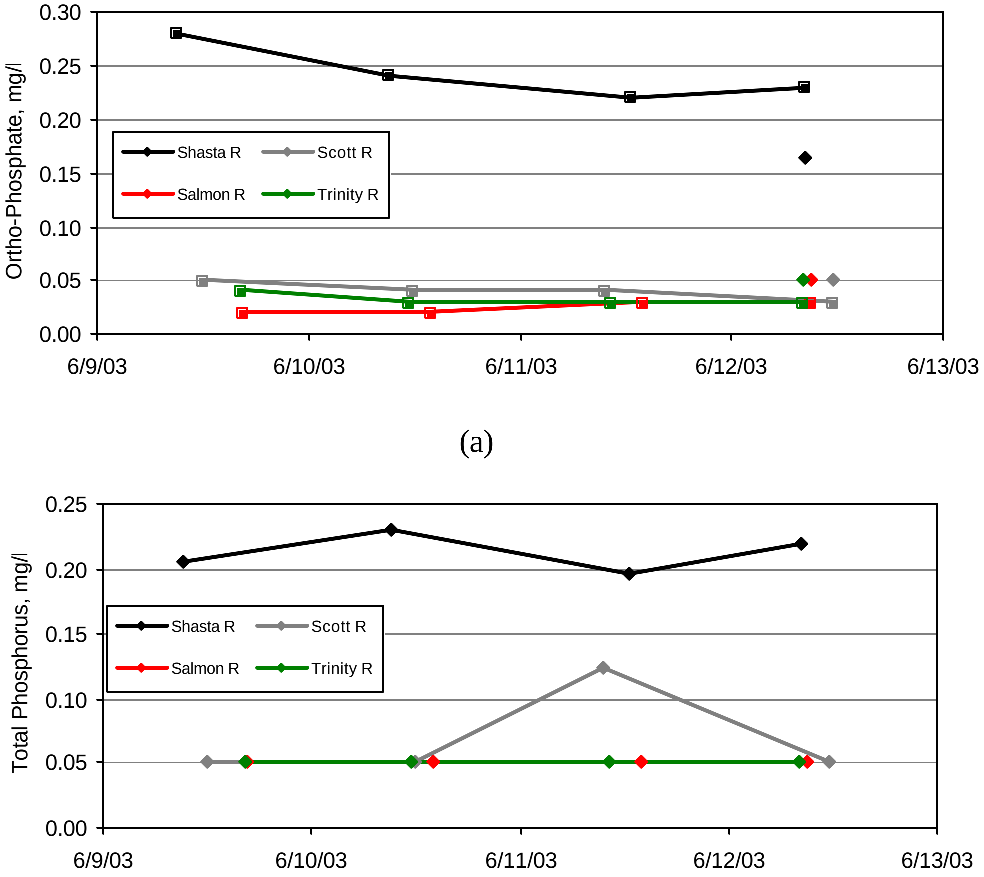


(c)

Figure 4 KR 2000 synoptic grab sample results for different tributaries along the Klamath River: (a) ammonia, (b) nitrate-nitrite, (c) TKN.



(a)

(b)

Figure 5 KR 2000 synoptic grab sample results for different tributaries along the Klamath River: (a) ortho-phosphate, (b) total phosphorus. Note that there are both field results (squares) and lab results (diamonds) on the ortho-phosphate graph.

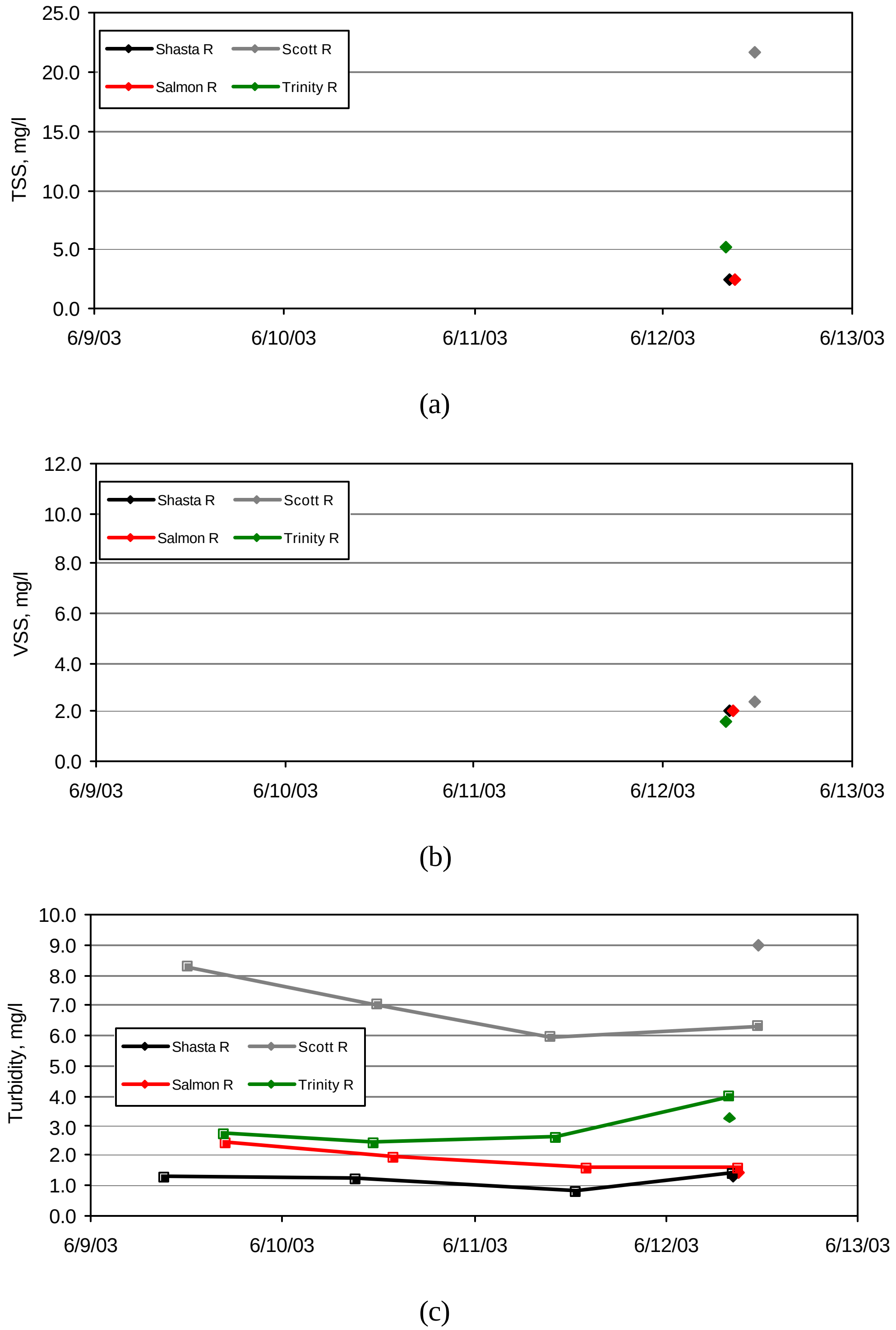


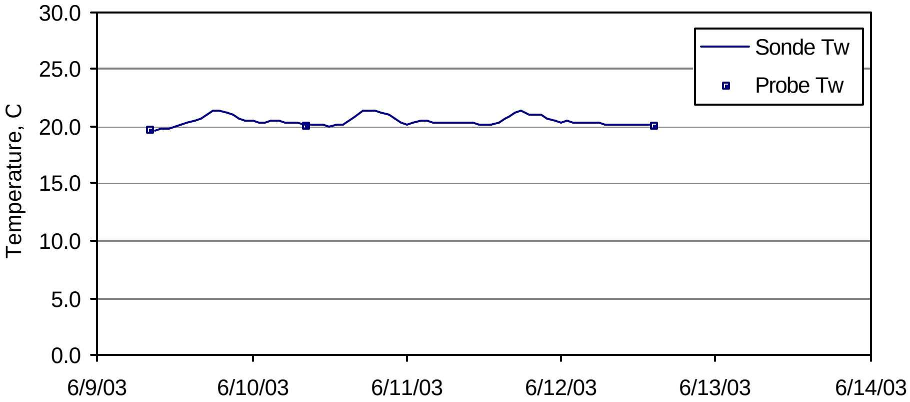
Figure 6 KR 2000 synoptic grab sample results for different tributaries along the Klamath River: (a) TSS, (b) VSS, (c) turbidity. Note that there are both field results (squares) and lab results (diamonds) on the turbidity graph.

Appendix B - Field Measurements

Table 6 Field measurements and field analysis results

Date	Site Name	Tw, °C	DO, mg/l	Spec Cond, uS/cm	pH	Field Turb, NTU	Field OPO4, mg/l	Winkler DO, mg/l
6/9/2003	KLAMATH RIVER ABOVE SCOTT RIVER	19.50	9.70		8.25	2.9	0.14	
6/9/2003	KLAMATH RIVER BELOW IRON GATE DAM	19.80	8.40		8	2.6	0.16	6.86
6/9/2003	KLAMATH RIVER U/S SHASTA RIVER	19.60	9.00		8.15	2.8	0.18	8.18
6/9/2003	SHASTA RIVER AT MOUTH	19.60	8.70		8.4	1.3	0.28	8.06
6/9/2003	SCOTT RIVER NEAR MOUTH	15.20	10.61		8.12	8.3	0.05	8.96
6/9/2003	KLAMATH RIVER NEAR SEIAD VALLEY	18.10	10.52		8.25	6.9	0.09	
6/9/2003	KLAMATH R AT CLEAR CREEK	18.60	10.30		8.16	4.6	0.07	8.44
6/9/2003	KLAMATH R AB SALMON RIVER	19.60	10.38		8.28	4.3	0.06	
6/9/2003	SALMON RIVER AT SOMES BAR	15.30	10.65		8.06	2.5	0.02	9.48
6/9/2003	KLAMATH R AT MARTINS FERRY	18.26		106	7.49	3.1	0.04	
6/9/2003	TRINITY R AT WEITCHPEC	18.15		109	7.58	2.7	0.04	
6/9/2003	KLAMATH R AB TRINITY RIVER	18.58		99	7.69	3.0	0.04	
6/10/2003	KLAMATH RIVER ABOVE SCOTT RIVER	19.10	9.76		8.26	2.8	0.14	8.08
6/10/2003	KLAMATH RIVER BELOW IRON GATE DAM	20.20	9.36		8.29	2.5	0.15	
6/10/2003	KLAMATH RIVER U/S SHASTA RIVER	19.40	9.40		8.1	2.7	0.14	7.62
6/10/2003	SHASTA RIVER AT MOUTH	18.80	9.08		8.46	1.2	0.24	
6/10/2003	SCOTT RIVER NEAR MOUTH	15.30	11.40		8	7.0	0.04	
6/10/2003	KLAMATH RIVER NEAR SEIAD VALLEY	18.20	11.00		8.11	5.2	0.04	8.68
6/10/2003	KLAMATH R AT CLEAR CREEK					4.1	0.01	
6/10/2003	KLAMATH R AB SALMON RIVER	19.20				3.3	0.04	
6/10/2003	SALMON RIVER AT SOMES BAR	13.90				2.0	0.02	
6/10/2003	KLAMATH R AB TRINITY RIVER	17.23		103	7.45	3.2	0.03	8.94
6/10/2003	TRINITY R AT WEITCHPEC	16.35		109	7.46	2.5	0.03	9.37
6/10/2003	KLAMATH R AT MARTINS FERRY	16.72		104	7.37	2.7	0.03	8.72
6/11/2003	KLAMATH RIVER ABOVE SCOTT RIVER	18.70	7.91		8.11	2.7	0.11	
6/11/2003	KLAMATH RIVER BELOW IRON GATE DAM					2.2	0.13	7.82
6/11/2003	KLAMATH RIVER U/S SHASTA RIVER					2.5	0.15	7.82
6/11/2003	SHASTA RIVER AT MOUTH					0.8	0.22	9
6/11/2003	SCOTT RIVER NEAR MOUTH	14.40	7.91		8.11	6.0	0.04	
6/11/2003	KLAMATH RIVER NEAR SEIAD VALLEY	17.30	9.65		8.05	4.7	0.08	
6/11/2003	KLAMATH R AT CLEAR CREEK	17.50	9.40		7.97	3.9	0.06	8.8
6/11/2003	KLAMATH R AB SALMON RIVER	18.80	12.42		8.07	2.9	0.06	9.04
6/11/2003	SALMON RIVER AT SOMES BAR	14.50	12.50		7.89	1.6	0.03	9.3
6/11/2003	KLAMATH R AB TRINITY RIVER	17.12		108	7.55	3.2	0.04	8.70
6/11/2003	TRINITY R AT WEITCHPEC	15.76		112	7.4	2.6	0.03	9.34
6/11/2003	KLAMATH R AT MARTINS FERRY	16.50		109	7.35	2.5	0.04	9.14
6/12/2003	KLAMATH RIVER BELOW IRON GATE DAM	20.20	9.05		8.31	2.3	0.14	7.98
6/12/2003	KLAMATH RIVER ABOVE SCOTT RIVER	19.20	8.72		8.48	3.0	0.13	8.24
6/12/2003	KLAMATH RIVER U/S SHASTA RIVER	19.00	8.00		8.07	2.6	0.13	7.6
6/12/2003	SHASTA RIVER AT MOUTH	18.20	8.40		8.4	1.4	0.23	
6/12/2003	SCOTT RIVER NEAR MOUTH	15.50	9.86		8.16	6.3	0.03	
6/12/2003	KLAMATH RIVER NEAR SEIAD VALLEY	17.90	10.00		8.35	4.7	0.07	8.26
6/12/2003	KLAMATH R AT CLEAR CREEK					4.7	0.06	
6/12/2003	SALMON RIVER AT SOMES BAR					1.6	0.03	
6/12/2003	KLAMATH R AB SALMON RIVER	17.77	10.30		7.99	2.2	0.06	8.94
6/12/2003	TRINITY R AT WEITCHPEC	15.99		120	7.93	4.0	0.03	9.24
6/12/2003	KLAMATH R AB TRINITY RIVER	16.80		117	7.83			9.02
6/12/2003	KLAMATH R AT MARTINS FERRY	16.75		119	7.89	3.2	0.03	8.96

Appendix C – Sonde Data



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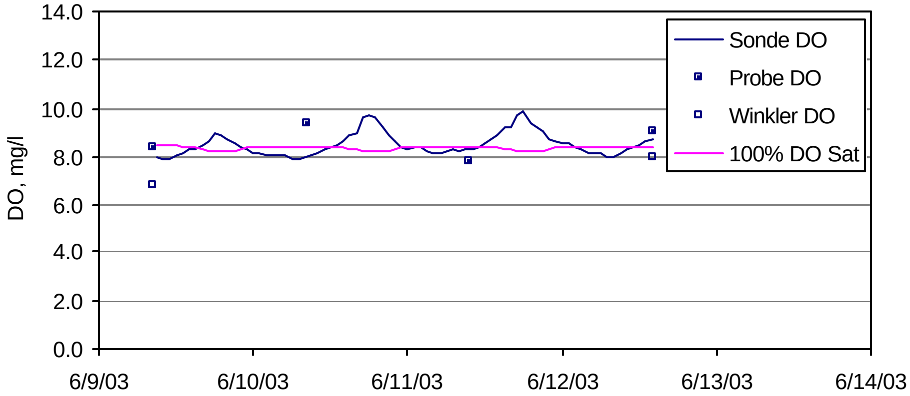

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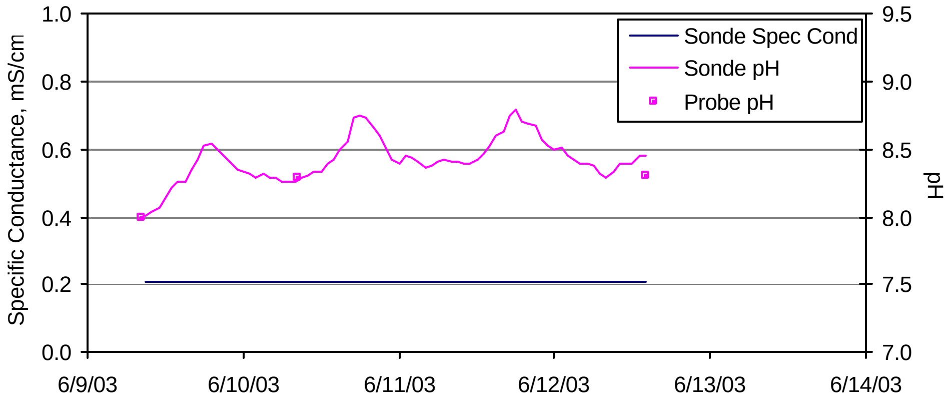
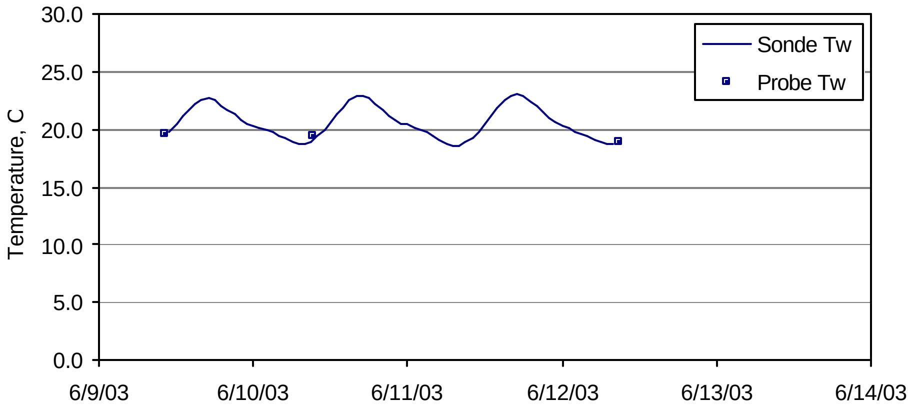


(c)

Figure 7 Sonde data and field measurements for Klamath River below Irongate Dam: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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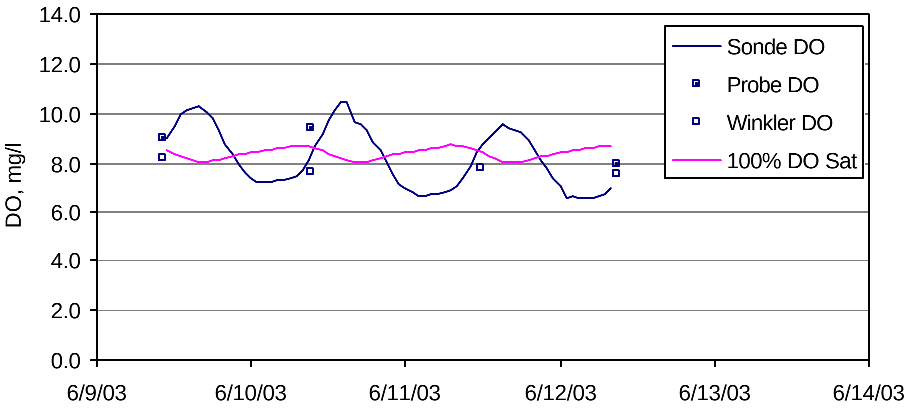

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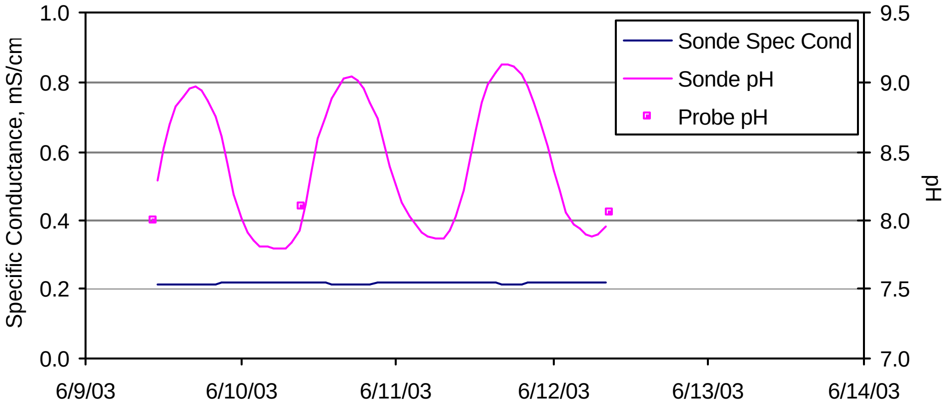
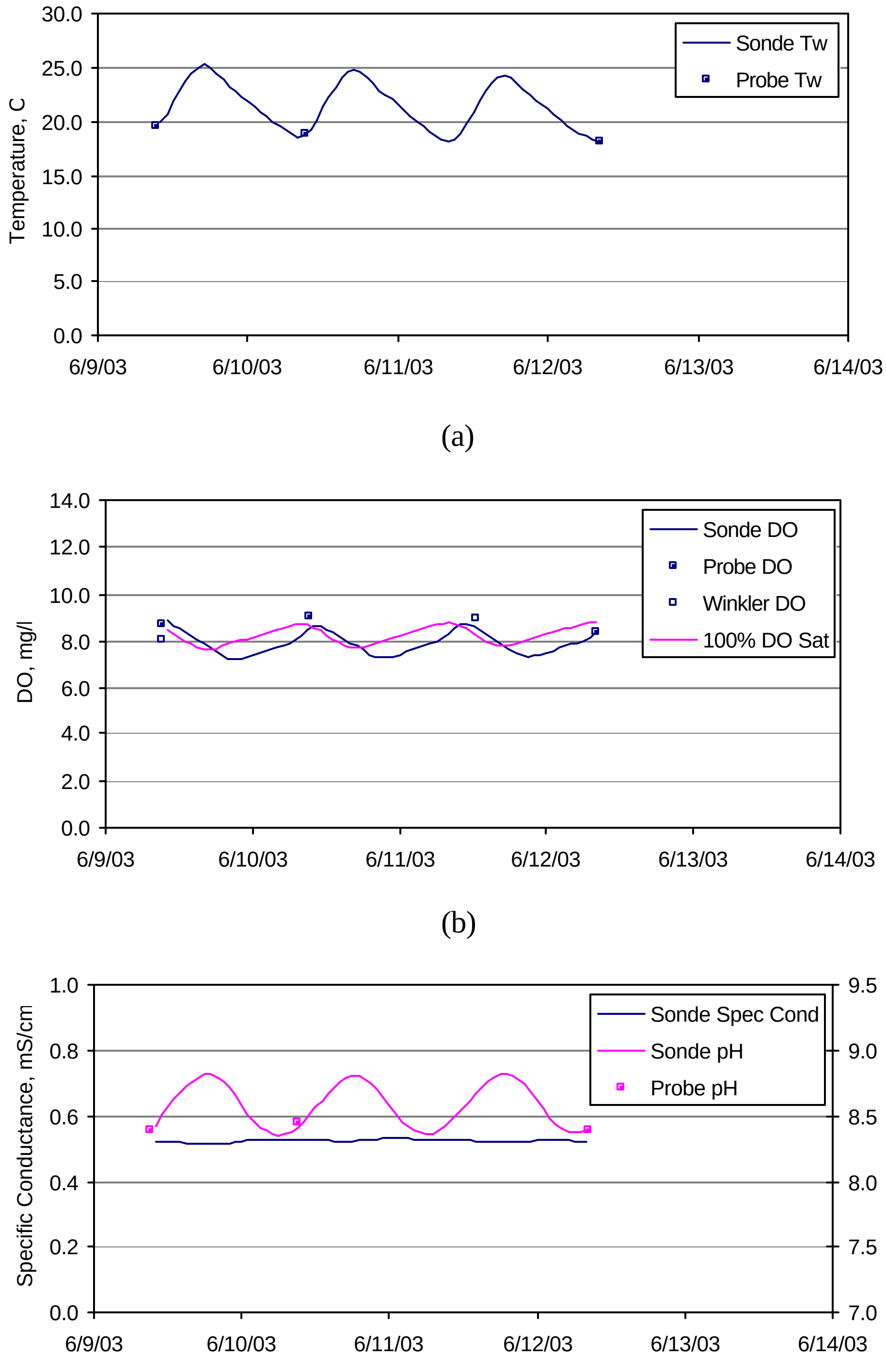


(c)

Figure 8 Sonde data and field measurements for Klamath River above Shasta River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

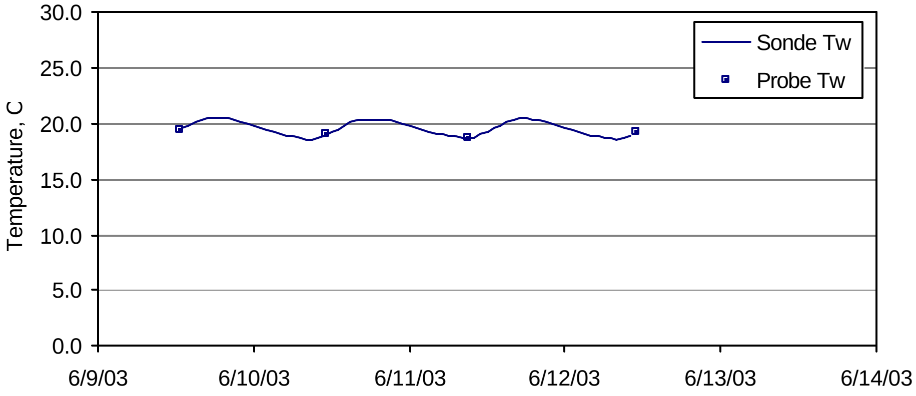


(a)

(b)

(c)

Figure 9 Sonde data and field measurements for Shasta River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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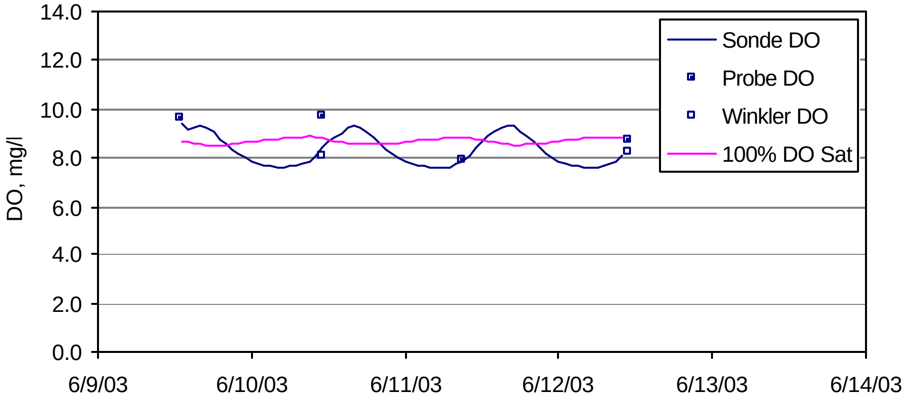

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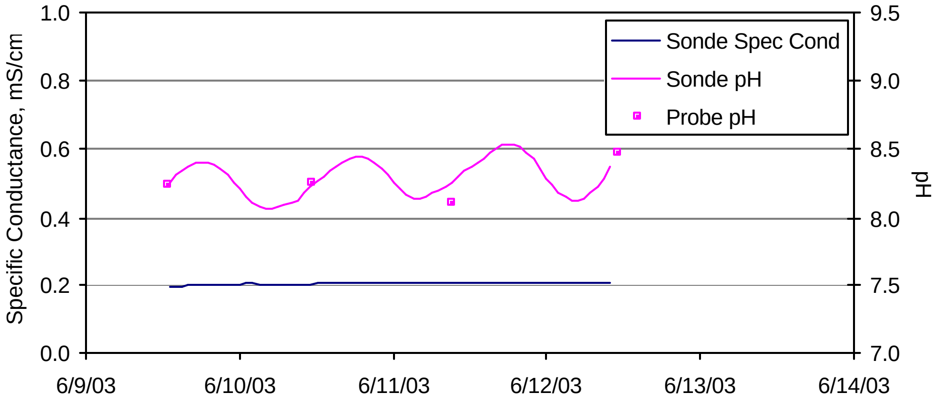


(c)

Figure 10 Sonde data and field measurements for Klamath River above Scott River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

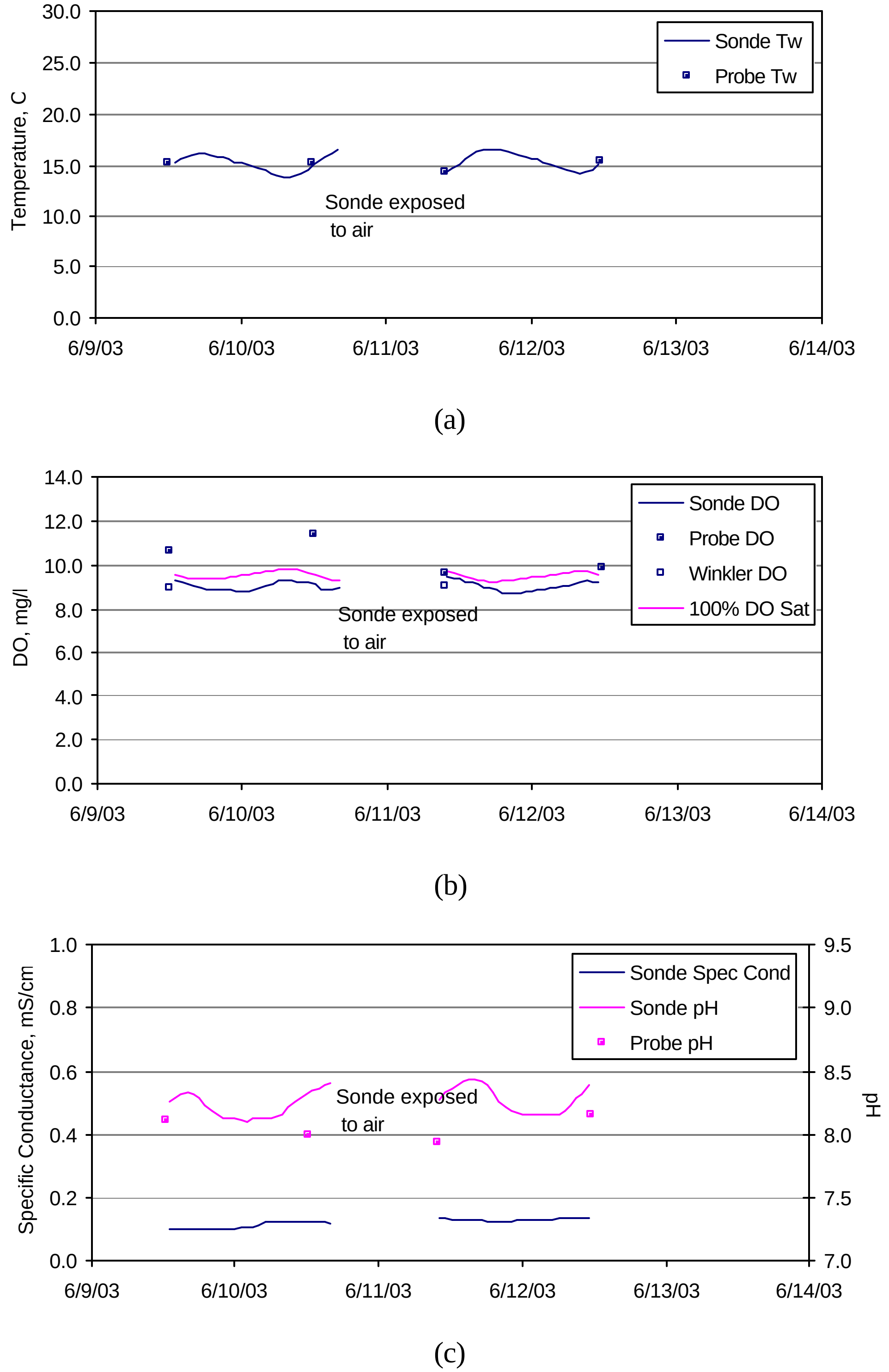
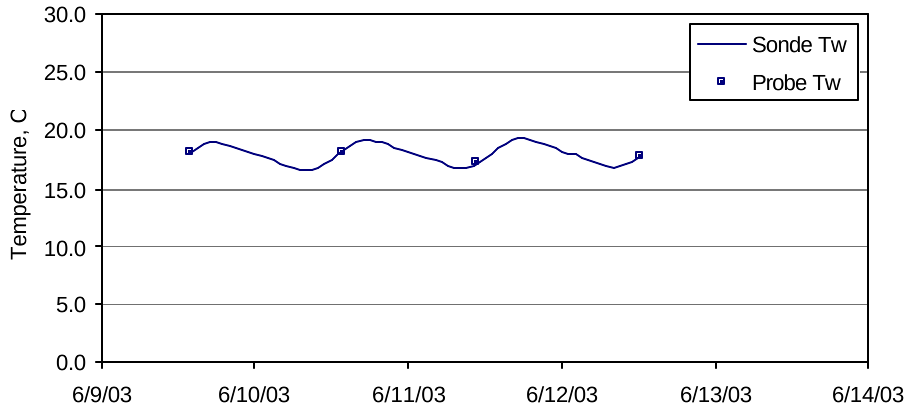


Figure 11 Sonde data and field measurements for Scott River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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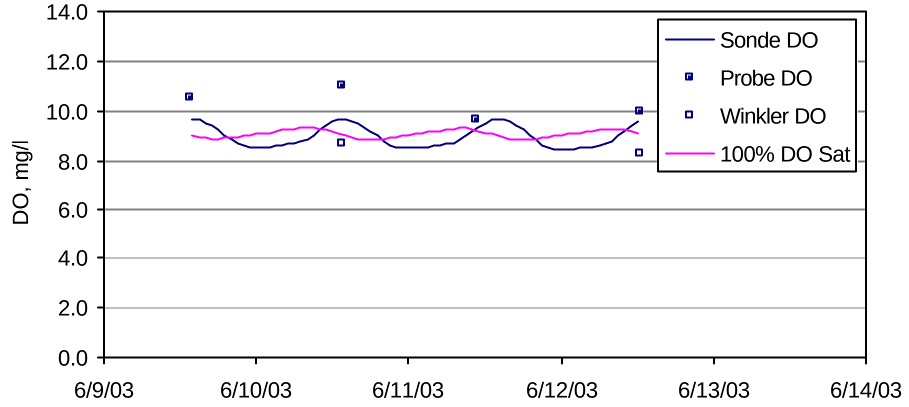

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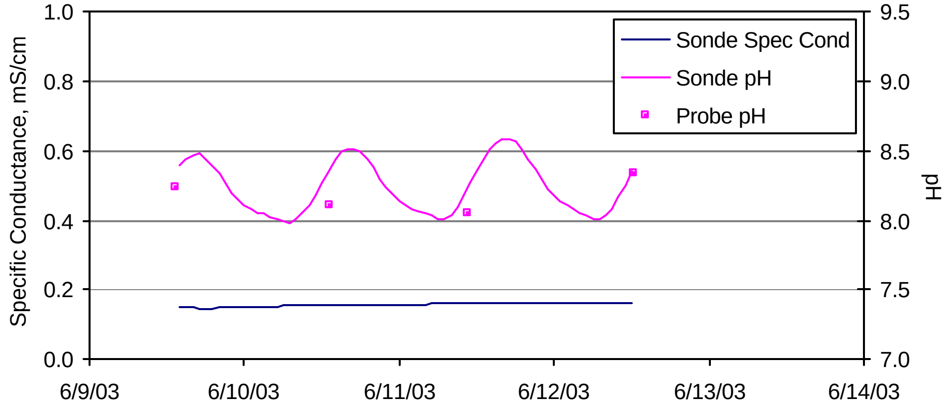
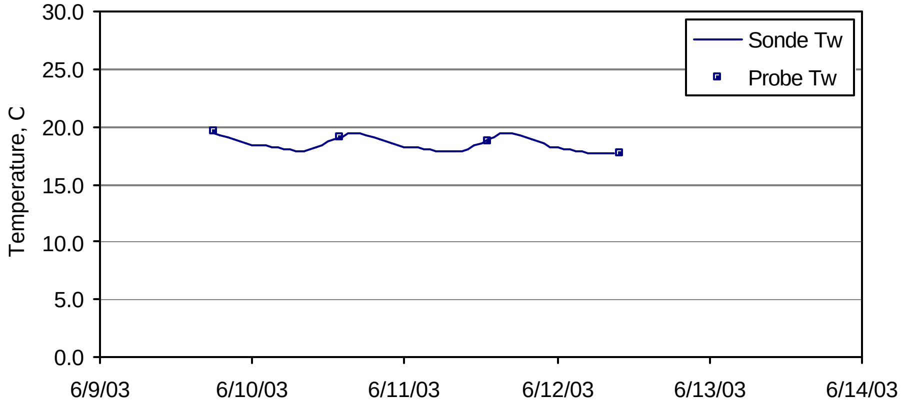


(c)

Figure 12 Sonde data and field measurements for Klamath River at Seiad Valley: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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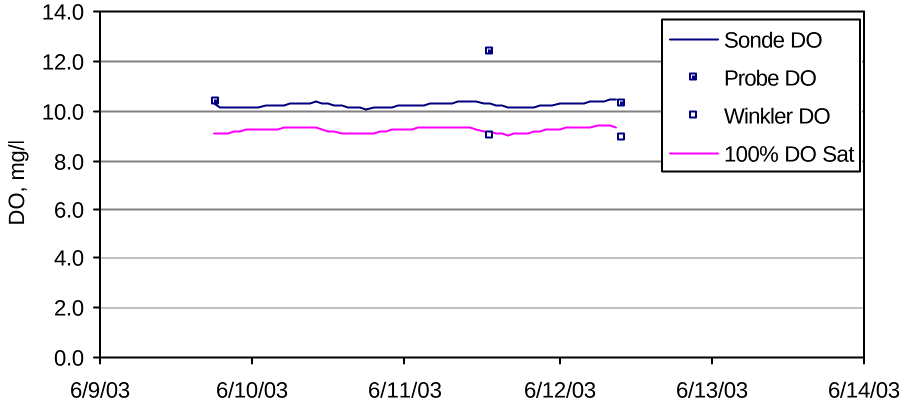

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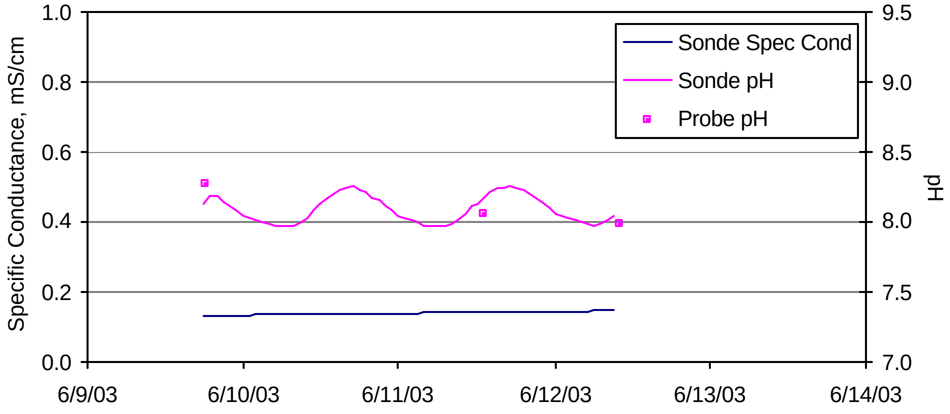


(c)

Figure 13 Sonde data and field measurements for Klamath River above Salmon River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

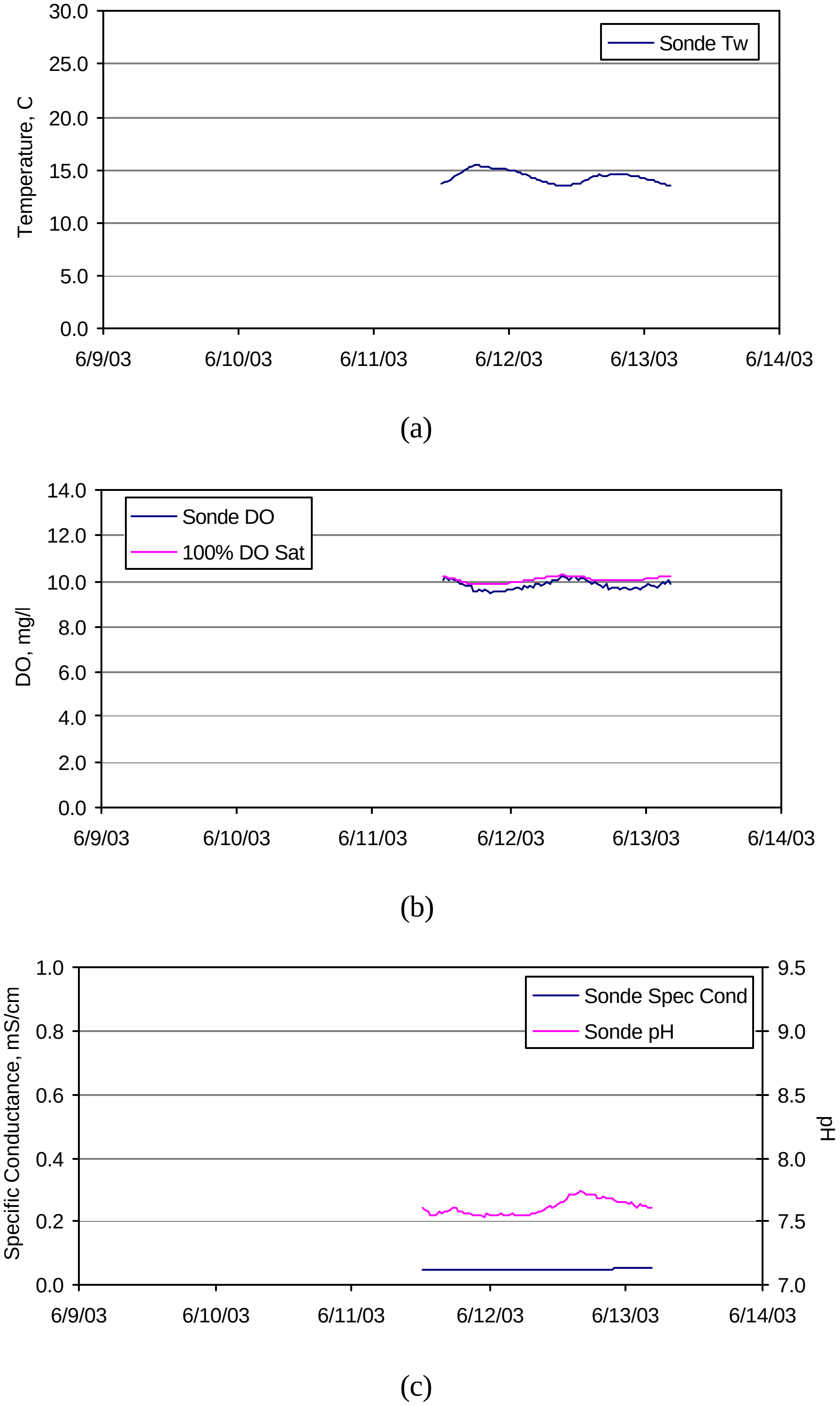
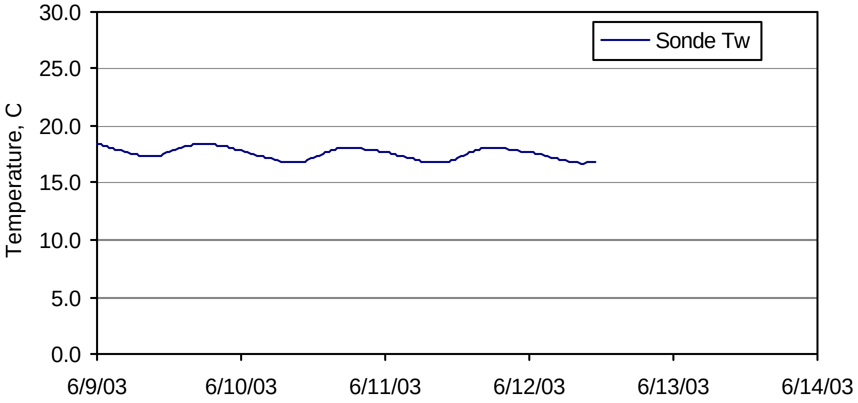


Figure 14 Sonde data for Salmon River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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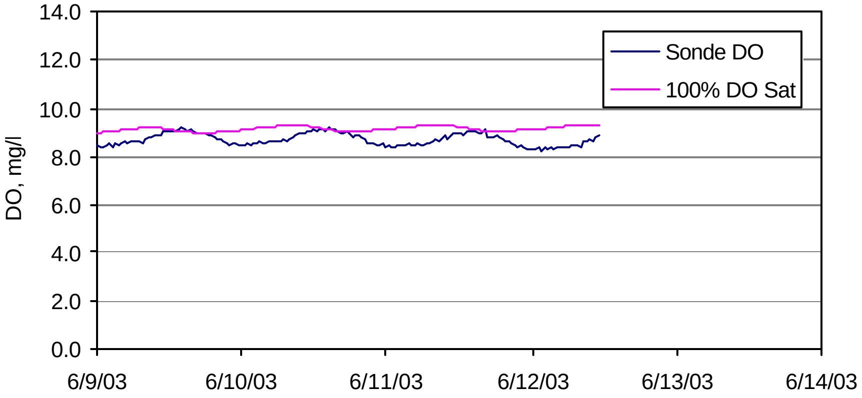

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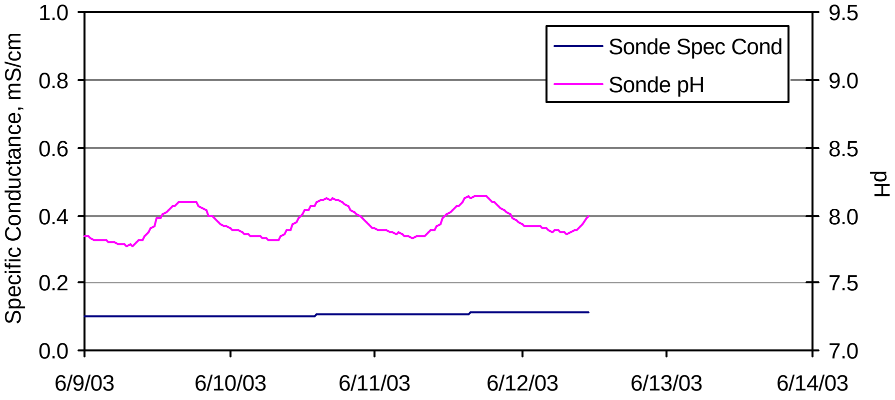


(c)

Figure 15 Sonde data for Klamath River at Aikens Hole: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

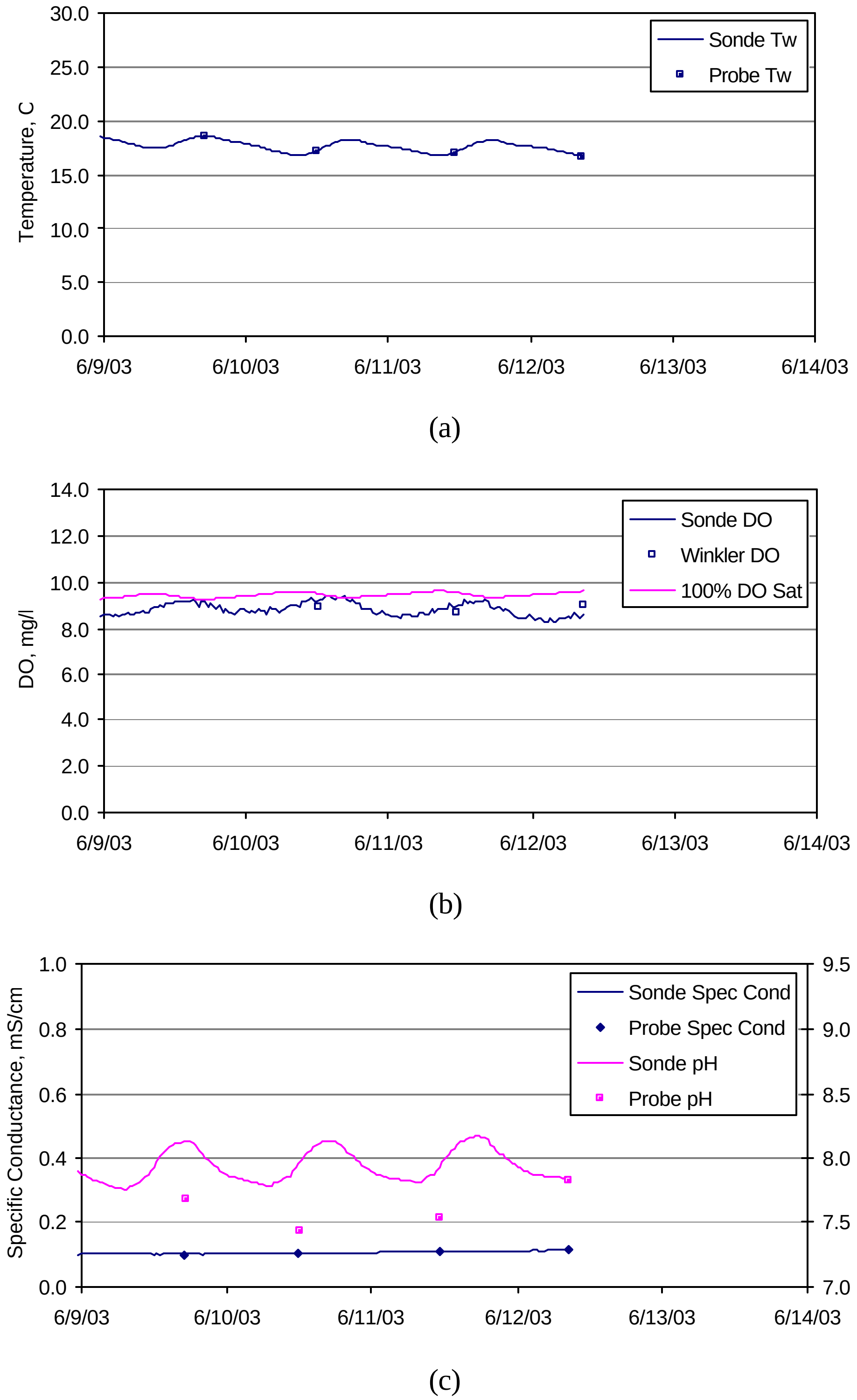
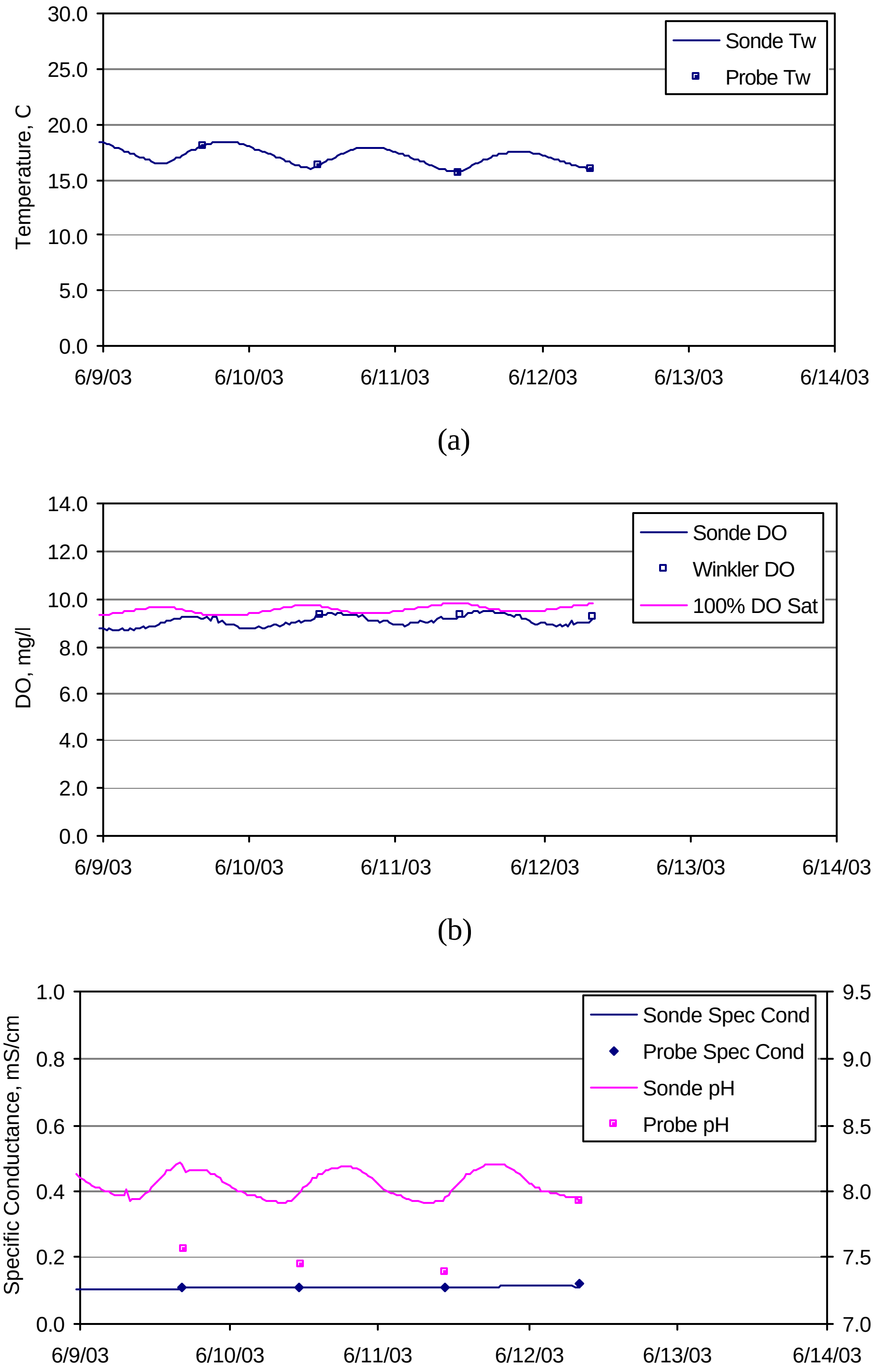


Figure 16 Sonde data and field measurements for Klamath River at Weitchpec (above Trinity River): (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

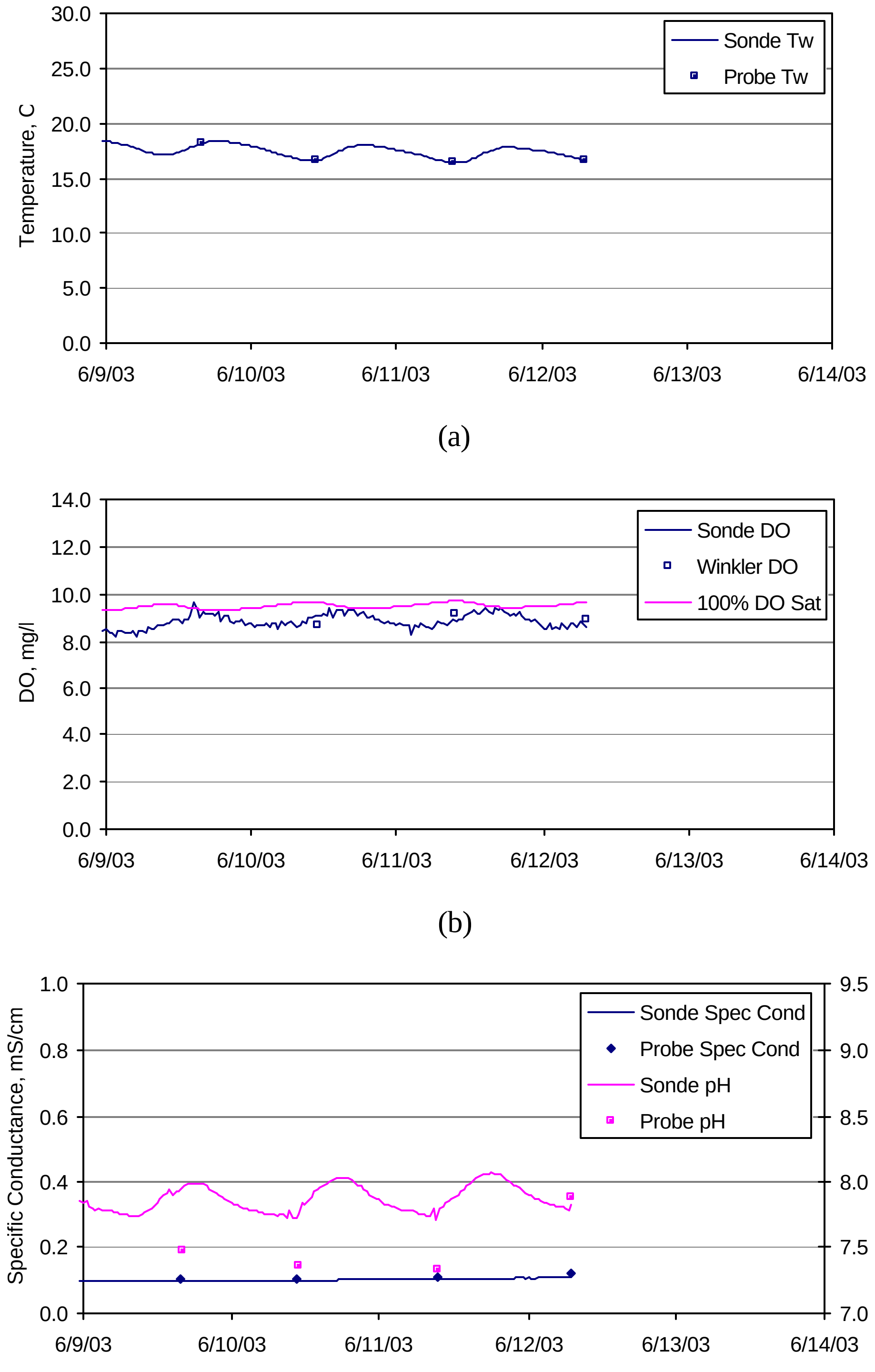


(a)

(b)

(c)

Figure 17 Sonde data and field measurements for Trinity River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

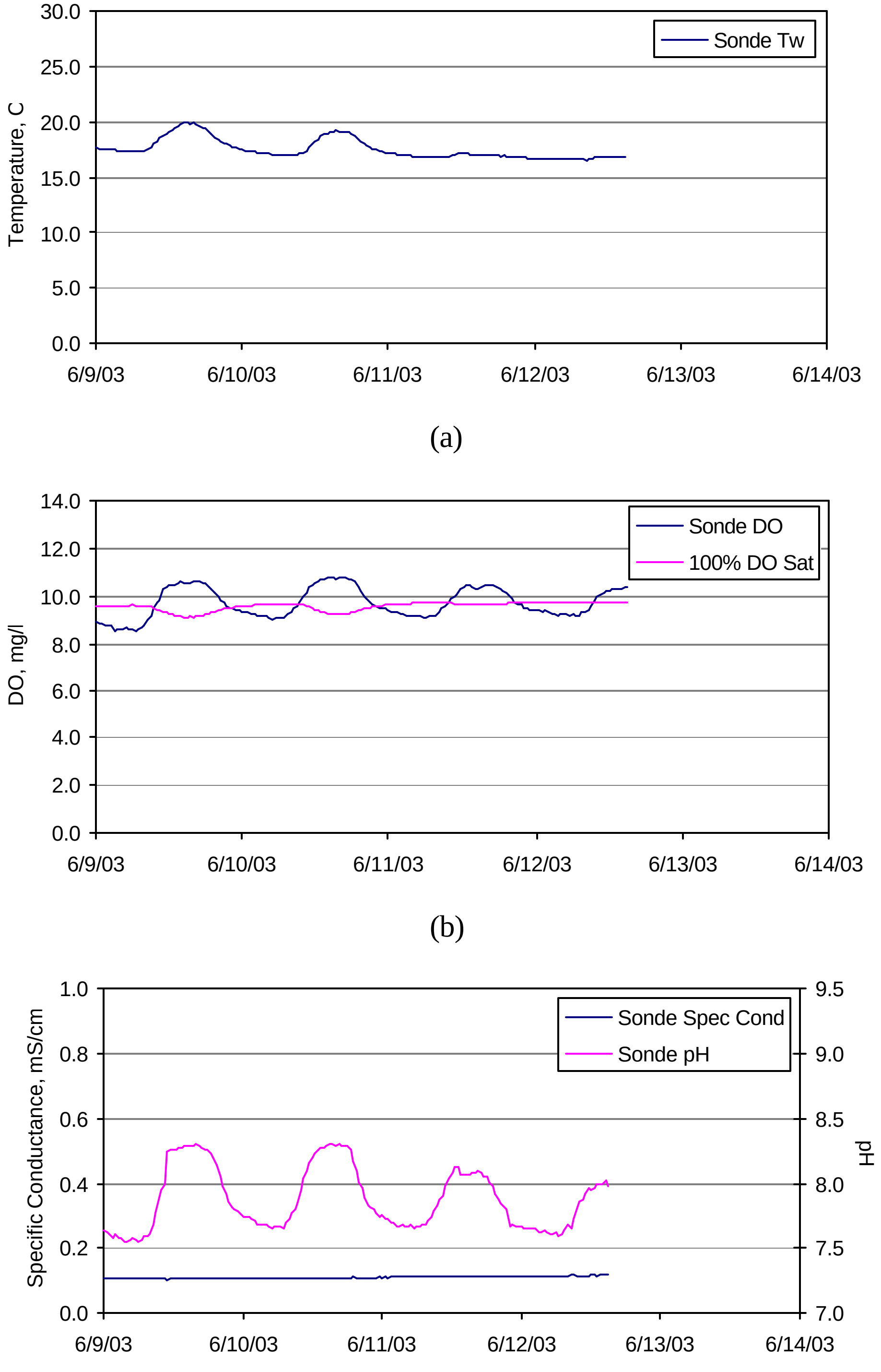


(a)

(b)

(c)

Figure 18 Sonde data and field measurements for Klamath River at Martins Ferry: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



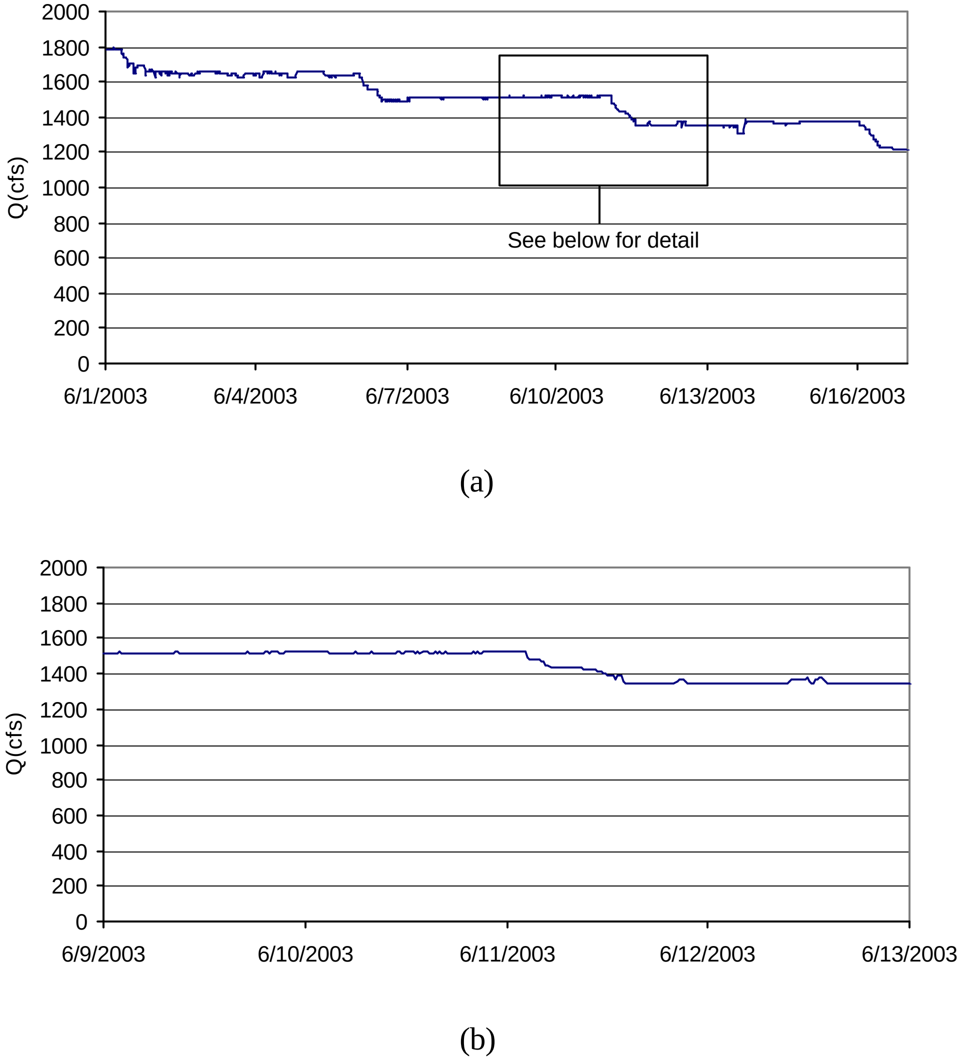
(a)

(b)

(c)

Figure 19 Sonde data for Klamath River at Turwar: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

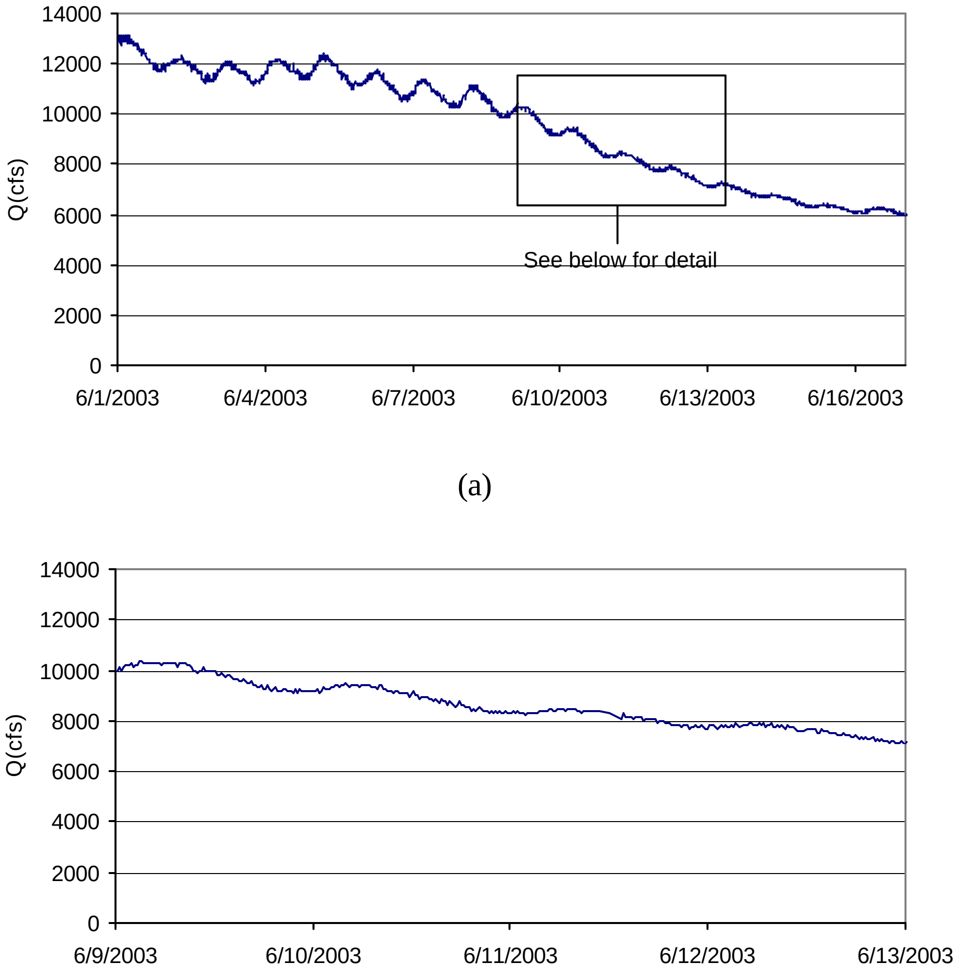
Appendix D - Flow prior to and during the synoptic survey



(a)

(b)

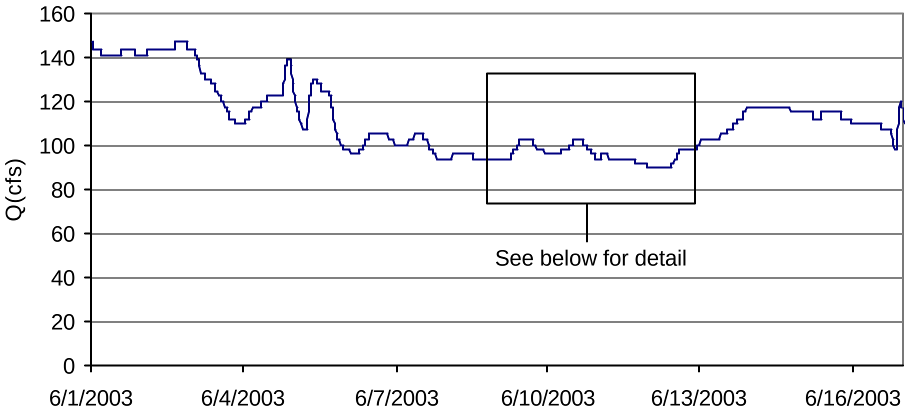
Figure 20 Flow in the Klamath River below Irongate Dam: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003



(a)

(b)

Figure 21 Flow in the Klamath River at Orleans: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003



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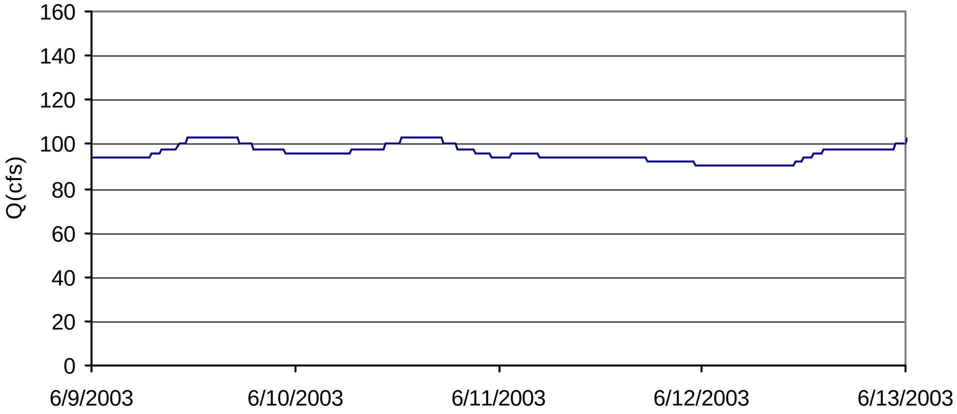
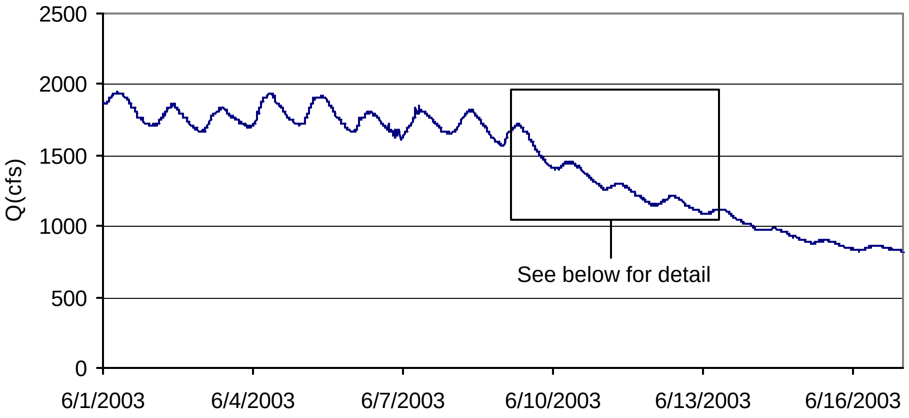


(b)

Figure 22 Flow in the Shasta River near Yreka: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003



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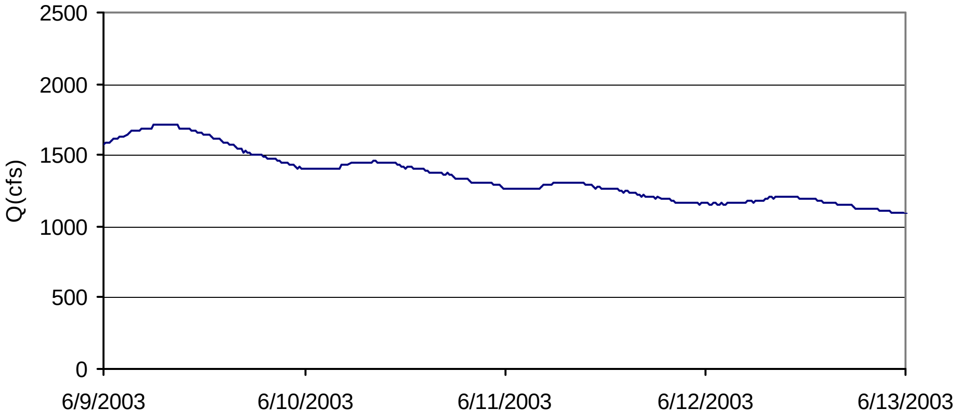
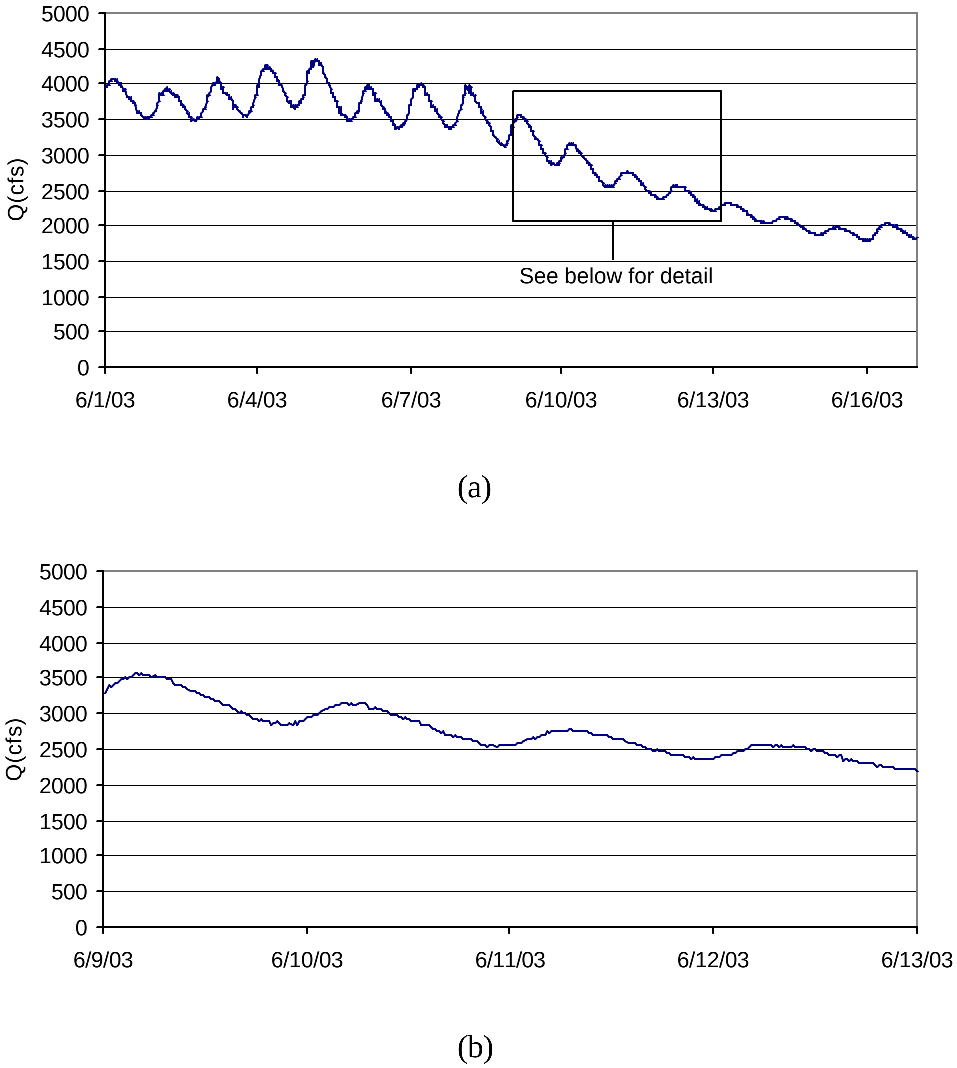


(b)

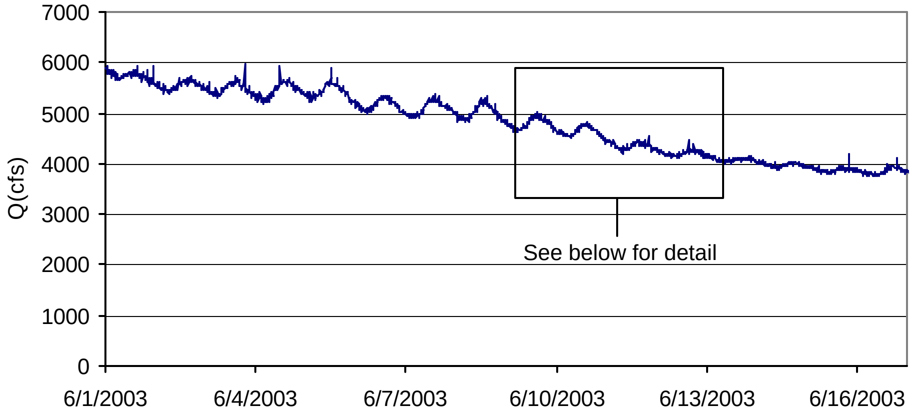
Figure 23 Flow in the Scott River near Fort Jones: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003



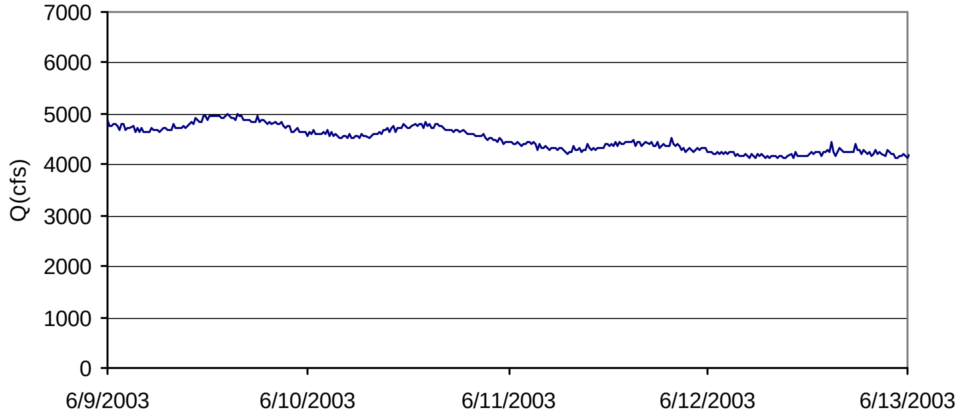
(a)

(b)

Figure 24 Flow in the Salmon River at Somes Bar: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003



(a)



(b)

Figure 25 Flow in the Trinity River at Hoopa: (a) June 1, 2003 through June 17, 2003, (b) June 9, 2003 through June 12, 2003

Klamath River Technical Memorandum 6

Topic: Klamath River Water Quality Synoptic Survey: August 2003

Date: 10/7/2003

Abstract: Data collection along the Klamath River began August 18, 2003 and ended August 21, 2003. During this period, measurements of dissolved oxygen, water temperature, pH and specific conductance were recorded at half-hour intervals at multiple sites along the Klamath River between Iron Gate Dam and Blue Creek – a distance of approximately 180 river miles – with water quality probes (sondes). In addition to these automated measurements, grab samples were collected for laboratory analysis once daily along the Klamath River between Iron Gate Dam and Tully Creek – a distance of approximately 160 river miles. The grab samples were analyzed for ammonia, nitrate-nitrite, total Kjeldahl nitrogen and total phosphorus. On the last day of the survey, grab samples for analysis of ortho-phosphate, total suspended solids, volatile suspended solids, turbidity and chlorophyll-a. On each day of the survey additional samples were collected to perform field analysis for dissolved oxygen, ortho-phosphate and turbidity. Data from all remote measurement devices (sondes) was retrieved successfully. All grab samples scheduled for collection were collected and delivered to the CH2MHill Applied Sciences Laboratory in Corvallis, Oregon or North Creek Analytical in Beaverton, Oregon. This report is solely intended to present field data and a summary of field conditions and notes.

Introduction

As part of the PacifiCorp funded water quality monitoring program along the Klamath River, a synoptic survey was made August 18, 2003 through August 21, 2003. Watercourse Engineering, Inc. conducted daily grab sampling during the survey as well as recorded data using several water quality probes (sondes) in the Klamath River and selected tributaries from the Iron Gate Dam to Blue Creek. This field work was completed with the cooperation of E&S Environmental, the North Coast Regional Water Quality Control Board (NCRWQCB), the Karuk tribe, and the Yurok tribe. The grab sampling sites and the sonde sites are shown in Table 1. The Klamath River at Martins Ferry site from the June 2003 synoptic survey was moved downstream approximately two miles to the Klamath River at Tully Creek site due to safety concerns in accessing the site and past site vandalism. Sonde data was available in June at Klamath River at Turwar but that site was not available during the August sampling period. Information for Klamath River at Blue Creek (approximately 10 miles upstream of Turwar Creek) was available for the August sampling period and is presented in this document.

Table 1 Synoptic survey locations

Location	Site	River Mile	Elevation, ft	Grab Sampling	Sonde location
1	Klamath River below Irongate Dam	190	2200	Yes	Yes
2	Klamath River above Shasta River	177	2002	Yes	Yes
3	Shasta River	0.5	2002	Yes	Yes
4	Klamath River above Scott River	144	1560	Yes	Yes
5	Scott River	0.1	1560	Yes	Yes
6	Klamath River at Seiad Valley	129	1320	Yes	Yes
7	Klamath River at Clear Creek	99	933	Yes	Yes
8	Klamath River above Salmon River	67	491	Yes	Yes
9	Salmon River at Somes Bar	1.0	500	Yes	Yes
10	Klamath River at Weitchpec (above Trinity River)	44	302	Yes	Yes
11	Trinity River	0.25	302	Yes	Yes
12	Klamath River at Tully Creek	40	273	Yes	Yes
13	Klamath River at Blue Creek	15	100	No	Yes

Sampling

Grab Samples

Grab samples were collected at twelve sites for four consecutive days. Each day, samples were collected in bottles pre-preserved with sulfuric acid (H_2SO_4) for lab analysis of ammonia, total Kjeldahl nitrogen (TKN), nitrate-nitrite, and total phosphorus concentrations. Separate bottles were collected for field analysis of dissolved oxygen (DO), turbidity and orthophosphate (PO_4^{3-}). On the last day of the survey, August 21, 2003, additional samples were collected for lab analysis of PO_4^{3-}, total suspended solids (TSS), volatile suspended solids (VSS), turbidity, and chlorophyll-a concentrations. Each day, one set of external quality assurance samples (duplicate, spike and blank) was included with the sample set for lab analysis. Quality assurance samples were collected using a churn splitter. Samples collected for field analysis did not include an external quality assurance set of samples.

All lab analysis samples were kept chilled in ice or refrigerated until packed in ice for transport by Richard Raymond of E&S Environmental to the CH2MHill Applied Sciences Laboratory in Corvallis, Oregon (for ammonia, nitrate-nitrite, total phosphorus, lab turbidity, TSS and VSS analysis) or to the North Creek Analytical Lab in Beaverton, Oregon (for TKN analysis) on Friday, August 22, 2003. Richard Raymond received all lab analysis samples by 5 pm Thursday, August 21, 2003. Chlorophyll-a samples were packed in ice and shipped from Yreka to Aquatic Analysts in Hubbard, Oregon.

All scheduled grab samples for lab analysis were successfully collected and delivered to the lab or field processed. One grab sample for turbidity and ortho-phosphate field analysis collected on Wednesday, August 20, 2003 at Trinity River was could not be located on Wednesday, although it was collected, and was found on Thursday, August 21, 2003 and was analyzed with the other turbidity and ortho-phosphate samples for

Thursday, August 21, 2003. Both tabulated data and graphs of grab sample results are presented in Appendix A. For visual interpretation, grab sample results are connected with lines; however, these lines do not suggest that intermediate locations or times can be interpolated from these graphs.

Field analysis

There were three field analysis tests performed during the synoptic survey: the Winkler DO test, the turbidity test and the PO_4^{3-} test.

DO analysis

The Winkler DO test is a modified Winkler dissolved oxygen titration, performed with a Hach digital titration kit. This field analysis was performed at approximately every other site each day, each site having the test done at least twice during the synoptic survey, with the exception of the Klamath River at Weitchpec, Trinity River and Klamath River at Tully Creek sites, at which no Winkler titrations were performed by the Yurok crew who sampled these sites. The Winkler DO test is the portion of a site visit that takes the longest to perform and thus the test was not performed at each site due to time constraints. Results of the Winkler DO tests are presented in Appendix B, and also along with the sonde DO results in Appendix C.

Turbidity and PO_4^{3-} analysis

The turbidity and PO_4^{3-} field analysis samples collected were chilled and analyzed at the end of each day. However, samples collected by the Yurok tribe on Tuesday, August 19, 2003 were not delivered to the Watercourse staff until Wednesday, August 20, 2003, and thus were not analyzed until Wednesday evening. Samples collected Thursday, August 21, 2003 were given to Richard Raymond of E&S Environmental for analysis on Friday, August 22, 2003.

Because a single bottle was collected for use with both the turbidity and PO_4^{3-} field analysis, the turbidity analysis was performed first. For samples collected Monday, Tuesday and Wednesday, turbidity tests were performed by Watercourse three times for each sample and the average turbidity was reported. The turbidimeter used was an ICM Model #11520. Richard Raymond from E&S Environmental analyzed samples collected on Thursday, August 21, 2003 three times each, and the average turbidity was reported. The same turbidimeter was used for all analysis. Field turbidity data are presented in Appendix B. Field turbidity is also presented in the graphs in Appendix A.

Once turbidity analysis was completed, the remaining sample water was used (by Richard Raymond from E&S Environmental, Corvallis Oregon) to perform the PO_4^{3-} field analysis. PO_4^{3-} field analysis was completed using the Hach Model 2400 portable spectrophotometer and the PhosVer II powder pillow test (#490). The samples were analyzed once, though selected reanalysis was performed to confirm results. Due to an inadequate supply of reagent chemicals for this test, the samples collected on Thursday, August 21, 2003 were frozen and processed in Corvallis, Oregon on September 22, 2003. Field PO_4^{3-} data are presented in Appendix B. Field PO_4^{3-} is also presented in the graphs in Appendix A. Field PO_4^{3-} concentrations were consistently elevated when compared with the laboratory analyzed PO_4^{3-} concentrations. Field PO_4^{3-} also did not have any external quality assurance, unlike the laboratory analyzed PO_4^{3-}.

Field measurements

Several field measurements were taken during site visits in August. As there were effectively three sampling crews (Watercourse 1, Watercourse 2, and Yurok) during this synoptic, the specific measurements taken per site visit were determined by the equipment available to each crew. The Watercourse 1 crew was able to measure water temperature, dissolved oxygen, pH and specific conductivity using a Horiba U-10 probe Tuesday, August 19, 2003 through Thursday, August 21, 2003. On Monday, August 18, 2003, Watercourse 1 crew measured water temperature and dissolved oxygen with a YSI DO200 probe and an Oakton pH TestR. Watercourse 1 did not measure specific conductivity on Monday, August 18, 2003. The Watercourse 2 crew was able to measure water temperature, dissolved oxygen, pH and specific conductivity using a Horiba U-10 probe all four days of sampling. The Yurok sampling crew was able to measure water temperature, dissolved oxygen, pH and specific conductance using a Hydrolab Quanta on Wednesday, August 20, 2003 and Thursday, August 21, 2003. Field measurements are presented in Appendix B.

Horiba U-10

Two Horiba U-10 multi-parameter probes were rented by Watercourse from US Environmental Rental Corporations. The Horiba U-10 instruments were pre-calibrated before being shipped to Watercourse by the rental company. None of the sensors were recalibrated in the field. However, all dissolved oxygen measurements taken using the probes were corrected for elevation once the survey was completed. The corrected data are presented in this document.

YSI DO 200 probe

A YSI DO 200 probe was used to measure DO at sampling locations on Monday, August 18, 2003 by the Watercourse 1 crew. The probe’s DO sensor was recalibrated at the Klamath River below Irongate site, the Shasta River near mouth site, the Scott River near mouth site and the Klamath River at Seiad site. The Klamath River above Shasta and the Klamath River above the Scott sites were estimated to be approximately the same elevations as the Shasta River and Scott River sites, respectively, and thus the probe was not recalibrated at those sites, since the visits to those sites either preceded or followed the visit to the tributaries associated with them.

pH TestR 3

The pH tester was calibrated once in the morning at the first site visited by Watercourse 1 on Monday, August 18, 2003. A two-point calibration was done using two buffers: pH 7.0 and pH 10.0. The Watercourse 1 crew only used the pH TestR 3 on Monday, August 18, 2003.

Meteorological Conditions

The meteorological conditions during the synoptic survey at Montague, CA and Arcata, CA are illustrated in Table 2 and Table 3 , respectively. While Montague, CA meteorological conditions can be considered representative for upper river sites, there were local variations along the river. The meteorological conditions at Arcata, CA are representative of coastal conditions. While most of the sites were well away from the coastline, Klamath River at Blue Creek is located at river mile fifteen.

Table 2 Meteorological conditions during the synoptic survey at Montague, CA

Date	Temperature, F			Dew Point, F	Mean Wind Speed, mph	Precipitation, inches
	Mean	Maximum	Minimum			
8/18/2003	78.0	100.0	55.0	45.7	-	0.00
8/19/2003	90.0	97.0	63.0	49.2	-	0.00
8/20/2003	76.0	95.0	57.0	46.0	-	0.00
8/21/2003	71.0	85.0	57.0	48.3	-	0.00

Table 3 Meteorological conditions during the synoptic survey at Arcata, CA

Date	Temperature, F			Dew Point, F	Mean Wind Speed, mph	Precipitation, inches
	Mean	Maximum	Minimum			
8/18/2003	60.0	66.0	54.0	57.4	6.1	0.00
8/19/2003	55.5	61.0	50.0	55.9	5.2	0.00
8/20/2003	55.5	61.0	50.0	53.7	4.1	0.00
8/21/2003	56.9	62.1	51.8	54.7	2.3	0.02

Sondes

Sonde Deployment

Eight sondes, two Hydrolab DS3 sondes on loan from the NCRWQCB and six YSI 600 XLM sondes rented from US Environmental Rental Corporation, were deployed by Watercourse for the synoptic survey. Deployment sites are listed in Table 4. Sondes were deployed starting the morning of Monday, August 18, 2003. Sondes were retrieved starting the morning of Thursday, August 21, 2003. All sondes were set to log water temperature, dissolved oxygen, specific conductance and pH every half hour. All sensors for the borrowed sondes, except DO, were calibrated at the NCRWQCB lab on Friday, August 15, 2003. The sensors for the rented sondes were calibrated by US Environmental Rental Corporation before being shipped to Watercourse. DO sensors for both types of sondes were calibrated in the field at each site before deployment except at the Klamath River above the Shasta River and the Klamath River above the Scott River sites. DO sensors deployed at these sites were calibrated at the Shasta River and Scott River sites, respectively.

Table 4 Sonde locations and information

Location	Site	Deployed / Maintained	Agency	Logging Interval	Type
1	Klamath River below Irongate Dam	Deployed	Watercourse	½ hour	YSI 600
2	Klamath River above Shasta River	Deployed	Watercourse	½ hour	Hydrolab DS3
3	Shasta River	Deployed	Watercourse	½ hour	Hydrolab DS3
4	Klamath River above Scott River	Deployed	Watercourse	½ hour	YSI 600
5	Scott River	Deployed	Watercourse	½ hour	YSI 600
6	Klamath River at Seiad Valley	Deployed	Watercourse	½ hour	YSI 600
7	Klamath River at Clear Creek	Deployed	Watercourse	½ hour	YSI 600
8	Klamath River above Salmon River	Deployed	Watercourse	½ hour	YSI 600
9	Salmon River at Somes Bar	Maintained	Karuk	½ hour	Hydrolab DS4A
10	Klamath River at Weitchpec (above Trinity River)	Maintained	Yurok	½ hour	Hydrolab DS4A
11	Trinity River	Maintained	Yurok	½ hour	Hydrolab DS4A
12	Klamath River at Tully Creek	Maintained	Yurok	½ hour	Hydrolab DS4A
13	Klamath River at Blue Creek	Maintained	Yurok	½ hour	Hydrolab DS4A

Sondes were deployed by attaching the sonde to a cable secured on or near shore. At two sites the cable was attached to a tree trunk as a method of fixing the sonde to the bank, in other cases metal stakes were employed. The Hydrolab DS3 sonde deployed at the Klamath River above the Shasta River was wrapped in black plastic garbage bags prior to deployment to decrease visibility by concealing the white sonde casing. The Shasta River site was deemed secure enough not to require such action. The YSI sondes were not wrapped because their casings are dark gray and were deemed of low visibility during deployment. All sondes were deployed with sensor guards and placed into the rivers at locations with good flow. There were no incidents of sondes becoming exposed to air during the course of the synoptic survey.

All data were successfully retrieved from all deployed sondes. Sonde data are presented in Appendix C.

Existing Sondes

Karuk Sonde

The sonde at the Salmon River was previously deployed by the Karuk tribe. The sonde was serviced on Monday, August 18, 2003. The sonde probes were inspected and cleaned, the dissolved oxygen membrane was replaced and the temperature, specific conductivity and pH sensors were calibrated. The dissolved oxygen sensor was calibrated on August 19, 2003 after the sensor's new membrane had been in place for approximately twenty-four hours. The sonde was downloaded on August 25, 2003. Examination of the dissolved oxygen record did not show any signs of biofouling, so an adjustment of dissolved oxygen concentrations due to biofouling was not performed for this sonde.

Yurok Sondes

The Yurok sondes were previously deployed by the Yurok crew. The sondes deployed at Klamath River at Weitchpec, Trinity River, and Klamath River at Tully Creek were serviced on August 13, 2003: the sonde probes were inspected and cleaned, the dissolved oxygen membrane was replaced and the temperature, specific conductivity and pH sensors were calibrated. The dissolved oxygen sensor was calibrated on August 14, 2003 after the sensor's new membrane had been in place for approximately twenty-four hours. These sondes were downloaded on August 21, 2003. The sonde deployed at Klamath River at Blue Creek was serviced on August 18, 2003: the sonde probes were inspected and cleaned, the dissolved oxygen membrane was replaced and the temperature, specific conductivity and pH sensors were calibrated. The dissolved oxygen sensor was calibrated on August 19, 2003 after the sensor's new membrane had been in place for approximately twenty-four hours.

The DO sensors on the sondes located at Klamath River at Weitchpec, Trinity River and Klamath River at Tully Creek experienced bio-fouling during the synoptic survey. Biofouling adjustments were made to the DO concentrations of those sondes. The original and adjusted DO concentrations are presented graphically in Appendix C. The adjustment to the DO concentrations was calculated in the following manner. First, the data collected by the Yurok tribe for the period after the synoptic survey was procured. The time of day of the last biofouled DO concentration was determined and the DO concentration at that time identified ($DO_{fouled\text{-}final}$). Then the DO concentration from the newly installed and clean DO membrane (in the second set of sonde data) at the same time of day as the last biofouled DO concentration was identified ($DO_{clean\text{-}matched}$). The total number of data points in the biofouled data set was determined (n) and the data points were numbered ($Count$). A correction factor of Delta was calculated as:

$$Delta = \frac{DO_{clean-matched} - DO_{fouled-final}}{DO_{fouled-final}} \tag{1}$$

Then the adjusted DO ($DO_{adjusted}$) is calculated for each time in the set as:

$$DO_{adjusted} = Delta\left(\frac{Count}{n}\right)DO_{fouled} + DO_{fouled} \tag{2}$$

Other Notes

Water levels during the August synoptic appeared to remain constant during the course of the survey. Recorded flow in the Klamath and some of its tributaries both prior to and during the synoptic survey is presented in Appendix D. All flow data were downloaded from the USGS website and are daily mean discharges reported in cubic feet per second.

A notable difference between the August survey and the June survey was the lower turbidity of all water during the August survey when compared to the June survey.

Acknowledgements

This project was a part of a larger WQ project sponsored by PacifiCorp. Watercourse Engineering, Inc. would like to especially acknowledge the support of the North Coast Regional Water Quality Control Board (loaning of sondes), the Karuk Tribe and the Yurok Tribe. Instrumental in the success of this effort was the direct involvement of Peter Otis from the North Coast Region Water Quality Control Board, Ken Fetcho from the Yurok Tribe, Scott Quinn from the Karuk Tribe, and Richard Raymond of E&S Environmental, as well as those personnel who assisted in the collection of field information.

Appendix A - Laboratory analysis results of grab samples

Table 5 Water quality results from grab sample analysis

Date Sampled	Time	Site Name	Ammonia as N mg/l	Nitrate+Nitrite as N mg/l	Ortho Phosphate as P mg/l	Total Phos-phorous as P mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Turbidity mg/l	Total Kjeldahl Nitrogen mg/l
8/18/2003	840	KLAMATH RIVER BELOW IRON GATE DAM	<0.10	0.24		0.13				0.79
8/18/2003	1110	KLAMATH RIVER U/S SHASTA RIVER	<0.10	0.22		0.13				0.65
8/18/2003	1015	SHASTA RIVER AT MOUTH	<0.10	<0.01		0.11				0.60
8/18/2003	1250	KLAMATH RIVER ABOVE SCOTT RIVER	<0.10	0.08		0.10				0.61
8/18/2003	1350	SCOTT RIVER NEAR MOUTH	<0.10	0.13		<0.05				<0.5
8/18/2003	1500	KLAMATH RIVER NEAR SEIAD VALLEY	<0.10	0.03		0.08				0.55
8/18/2003	1314	KLAMATH R AT CLEAR CREEK	<0.10	<0.01		0.10				0.51
8/18/2003	1600	KLAMATH R AB SALMON RIVER	<0.10	<0.01		0.07				<0.5
8/18/2003	1505	SALMON RIVER AT SOMES BAR	<0.10	<0.01		<0.05				<0.5
8/18/2003	1225	KLAMATH R AB TRINITY RIVER	<0.10	<0.01		<0.05				<0.5
8/18/2003	1205	TRINITY R AT WEITCHPEC	<0.10	<0.01		<0.05				<0.5
8/18/2003	1124	KLAMATH R AT TULLY CREEK	<0.10	<0.01		<0.05				<0.5
8/19/2003	800	KLAMATH RIVER BELOW IRON GATE DAM	<0.10	0.27		0.14				0.58
8/19/2003	940	KLAMATH RIVER U/S SHASTA RIVER	<0.10	0.29		0.13				0.90
8/19/2003	915	SHASTA RIVER AT MOUTH	<0.10	<0.01		0.17				0.51
8/19/2003	1105	KLAMATH RIVER ABOVE SCOTT RIVER	<0.10	0.12		0.10				0.62
8/19/2003	1145	SCOTT RIVER NEAR MOUTH	<0.10	0.15		<0.05				0.84
8/19/2003	1220	KLAMATH RIVER NEAR SEIAD VALLEY	<0.10	0.06		0.11				0.59
8/19/2003	1530	KLAMATH R AT CLEAR CREEK	<0.10	<0.01		0.08				0.56
8/19/2003	1325	KLAMATH R AB SALMON RIVER	<0.10	<0.01		0.05				<0.5
8/19/2003	1235	SALMON RIVER AT SOMES BAR	<0.10	<0.01		<0.05				<0.5
8/19/2003	1149	KLAMATH R AB TRINITY RIVER	<0.10	<0.01		0.05				<0.5
8/19/2003	1130	TRINITY R AT WEITCHPEC	<0.10	<0.01		0.05				<0.5
8/19/2003	1049	KLAMATH R AT TULLY CREEK	<0.10	<0.01		<0.05				<0.5
8/20/2003	855	KLAMATH RIVER BELOW IRON GATE DAM	<0.10	0.31		0.18				0.86
8/20/2003	1035	KLAMATH RIVER U/S SHASTA RIVER	<0.10	0.25		0.09				0.75
8/20/2003	1005	SHASTA RIVER AT MOUTH	<0.10	0.01		0.27				0.57
8/20/2003	1155	KLAMATH RIVER ABOVE SCOTT RIVER	<0.10	0.13		0.12				0.93
8/20/2003	1220	SCOTT RIVER NEAR MOUTH	<0.10	0.14		<0.05				<0.5
8/20/2003	1320	KLAMATH RIVER NEAR SEIAD VALLEY	<0.10	0.07		0.08				0.82
8/20/2003	1325	KLAMATH R AT CLEAR CREEK	<0.10	<0.01		0.05				0.50
8/20/2003	1210	KLAMATH R AB SALMON RIVER	<0.10	<0.01		0.06				0.58
8/20/2003	1105	SALMON RIVER AT SOMES BAR	<0.10	<0.01		<0.05				<0.5

Date Sampled	Time	Site Name	Ammonia as N mg/l	Nitrate+Nitrite as N mg/l	Ortho Phosphate as P mg/l	Total Phos-phorous as P mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Turbidity mg/l	Total Kjeldahl Nitrogen mg/l
8/20/2003	910	KLAMATH R AB TRINITY RIVER	<0.10	<0.01		<0.05				<0.5
8/20/2003	850	TRINITY R AT WEITCHPEC	<0.10	0.01		<0.05				<0.5
8/20/2003	820	KLAMATH R AT TULLY CREEK	<0.10	<0.01		<0.05				<0.5
8/21/2003	1250	KLAMATH RIVER BELOW IRON GATE DAM	<0.10	0.27	0.12	0.12	<2	<2	1.85	0.77
8/21/2003	1120	KLAMATH RIVER U/S SHASTA RIVER	<0.10	0.28	0.11	0.13	2	<2	1.54	0.61
8/21/2003	1050	SHASTA RIVER AT MOUTH	<0.10	<0.01	0.20	0.20	2	<2	1.20	<0.5
8/21/2003	930	KLAMATH RIVER ABOVE SCOTT RIVER	<0.10	0.14	0.10	0.11	4	2	2.28	0.76
8/21/2003	910	SCOTT RIVER NEAR MOUTH	<0.10	0.16	<0.05	<0.05	<2	<2	0.45	<0.5
8/21/2003	805	KLAMATH RIVER NEAR SEIAD VALLEY	<0.10	0.10	0.09	0.12	<2	<2	2.14	0.67
8/21/2003	1300	KLAMATH R AT CLEAR CREEK	<0.10	<0.01	0.07	0.09	2	<2	1.18	<0.5
8/21/2003	1115	KLAMATH R AB SALMON RIVER	<0.10	<0.01	0.06	0.07	4	2	0.88	<0.5
8/21/2003	1035	SALMON RIVER AT SOMES BAR	<0.10	<0.01	<0.05	<0.05	2	<2	0.26	<0.5
8/21/2003	915	KLAMATH R AB TRINITY RIVER	<0.10	<0.01	<0.05	<0.05	<2	<2	0.72	<0.5
8/21/2003	900	TRINITY R AT WEITCHPEC	<0.10	<0.01	<0.05	<0.05	<2	<2	0.30	<0.5
8/21/2003	730	KLAMATH R AT TULLY CREEK	<0.10	<0.01	<0.05	<0.05	<2	<2	0.90	<0.5

Notes:

For graphing purposes, results which were below the reporting limit were replaced with the reporting limit.

All samples were analyzed by CH2MHill Applied Sciences Laboratory in Corvallis, OR, except TKN samples, which were analyzed by NCA labs in Beaverton, OR.

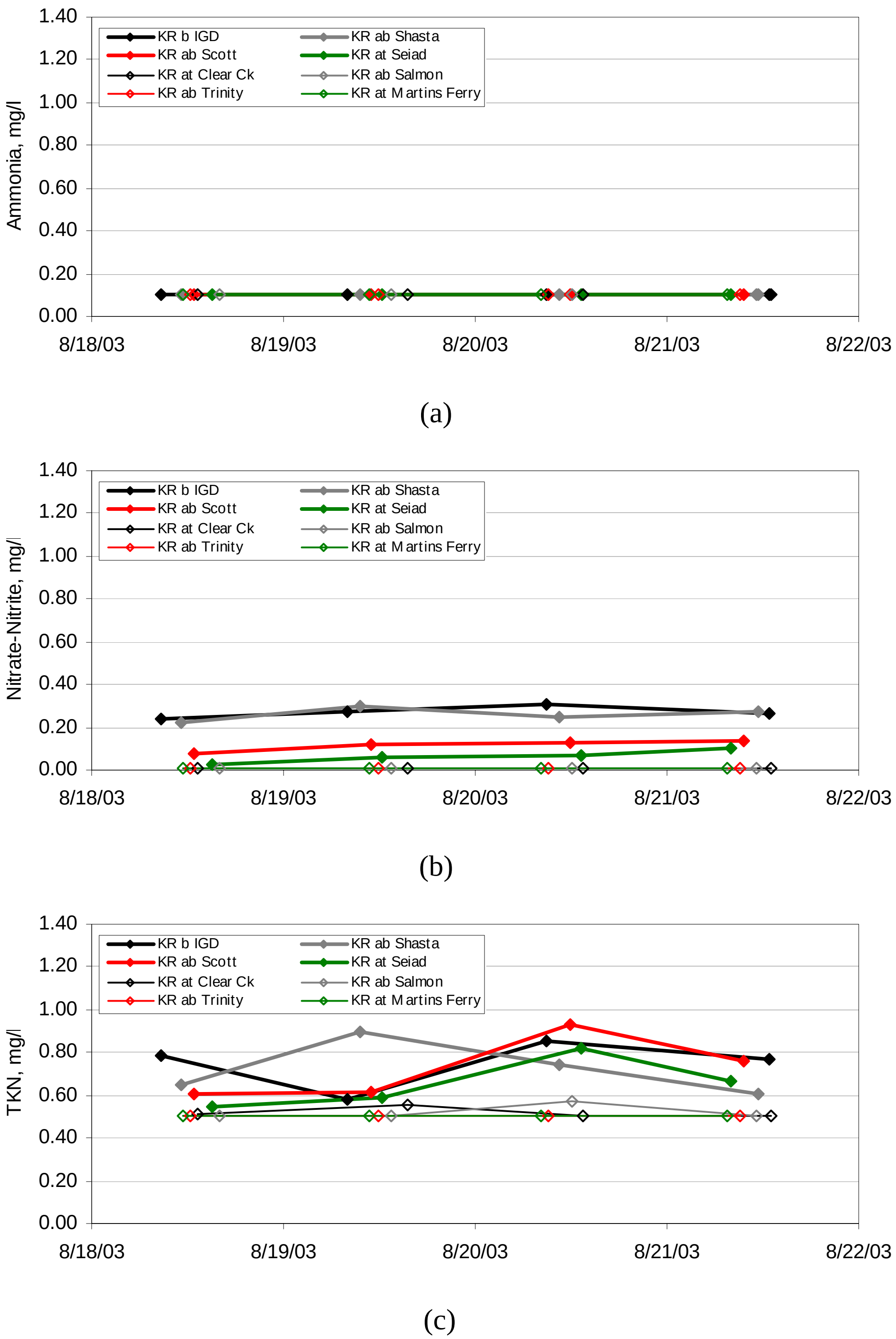
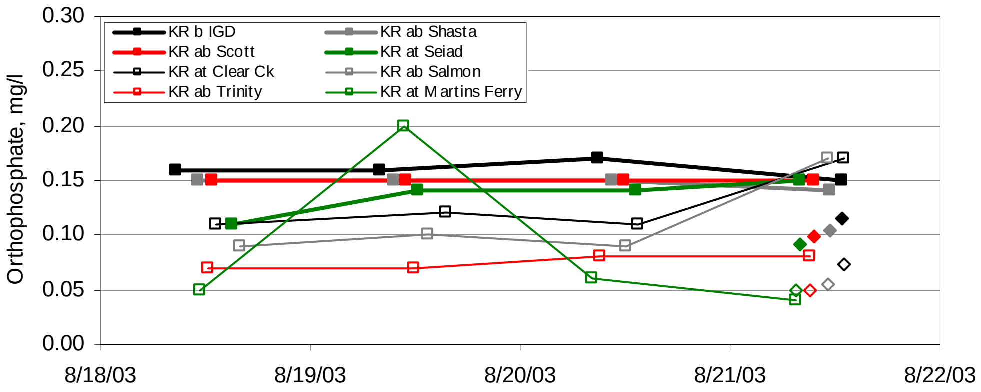
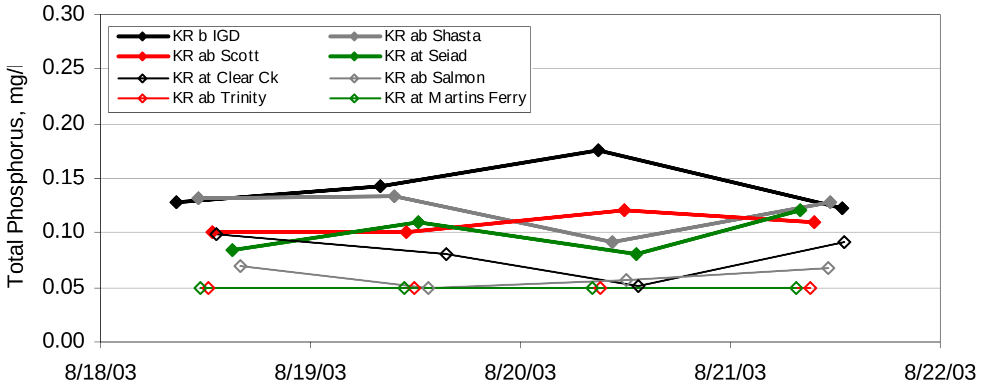


Figure 1 KR 2003 synoptic grab sample results for different locations in the Klamath River: (a) ammonia, (b) nitrate-nitrite, (c) TKN

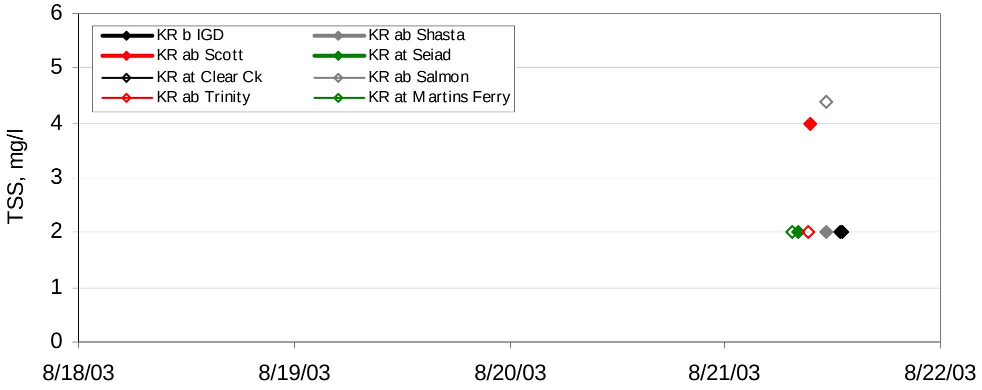


(a)

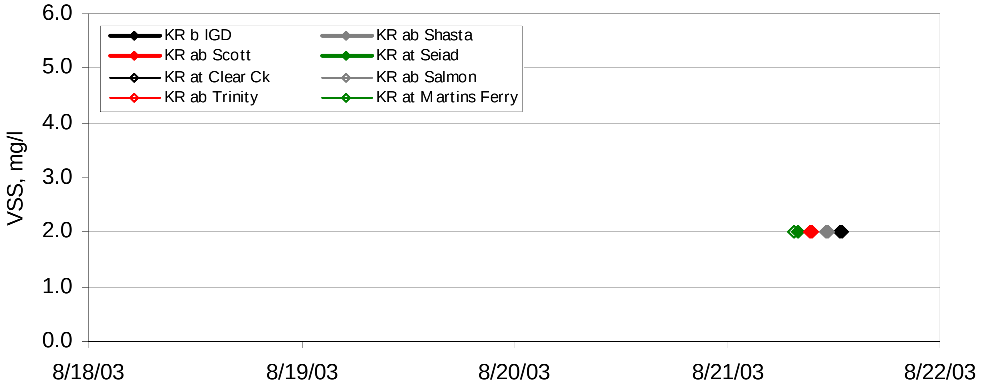


(b)

Figure 2 KR 2003 synoptic grab sample results for different locations in the Klamath River: (a) ortho-phosphate, (b) total phosphorus. Note that there are both field results (squares) and lab results (diamonds) on the ortho-phosphate graph.



(a)



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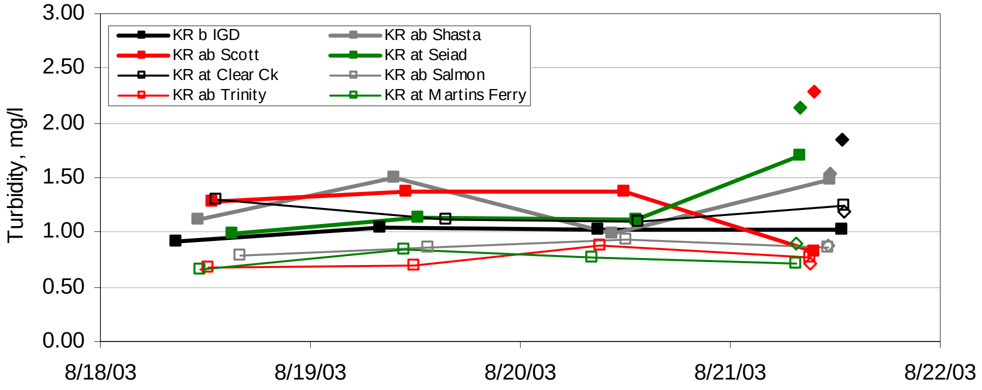
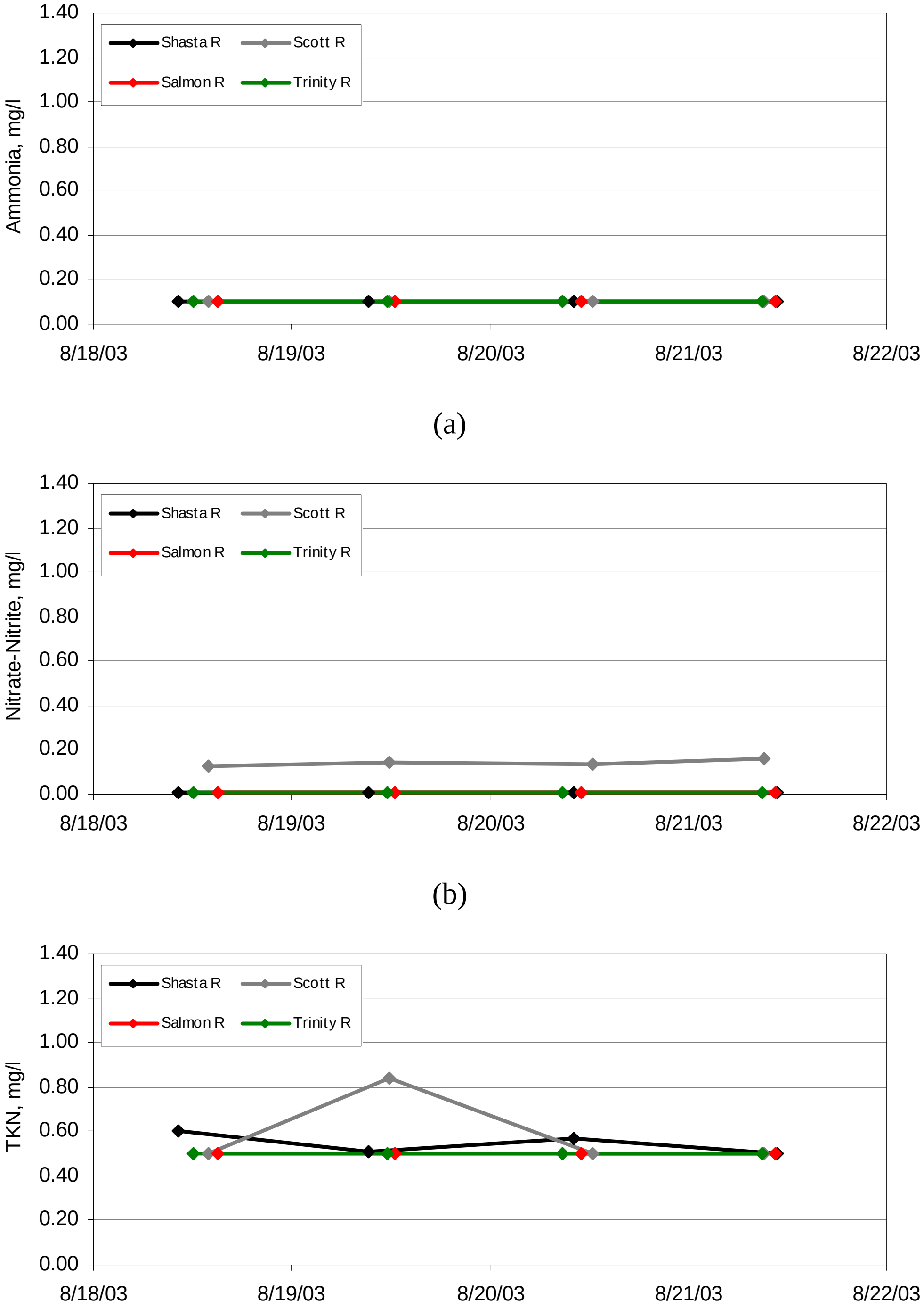


(c)

Figure 3 KR 2003 synoptic grab sample results for different locations in the Klamath River: (a) TSS, (b) VSS, (c) turbidity. Note that there are both field results (squares) and lab results (diamonds) on the turbidity graph.

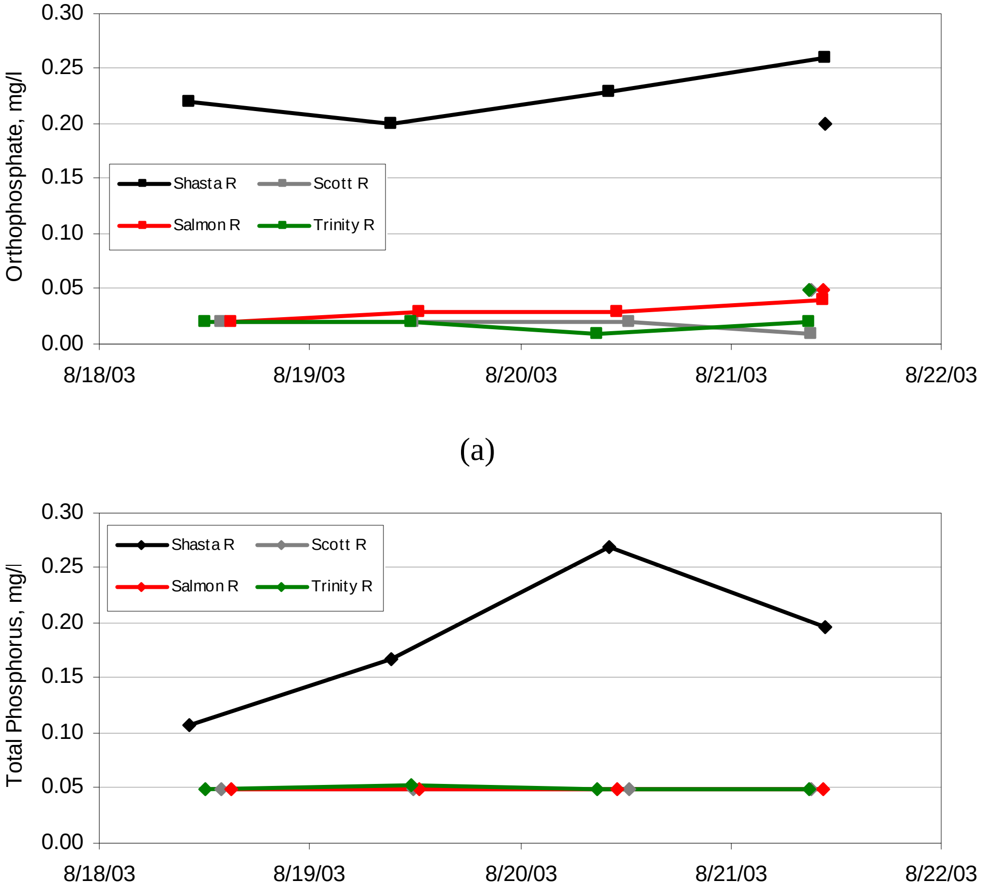


(a)

(b)

(c)

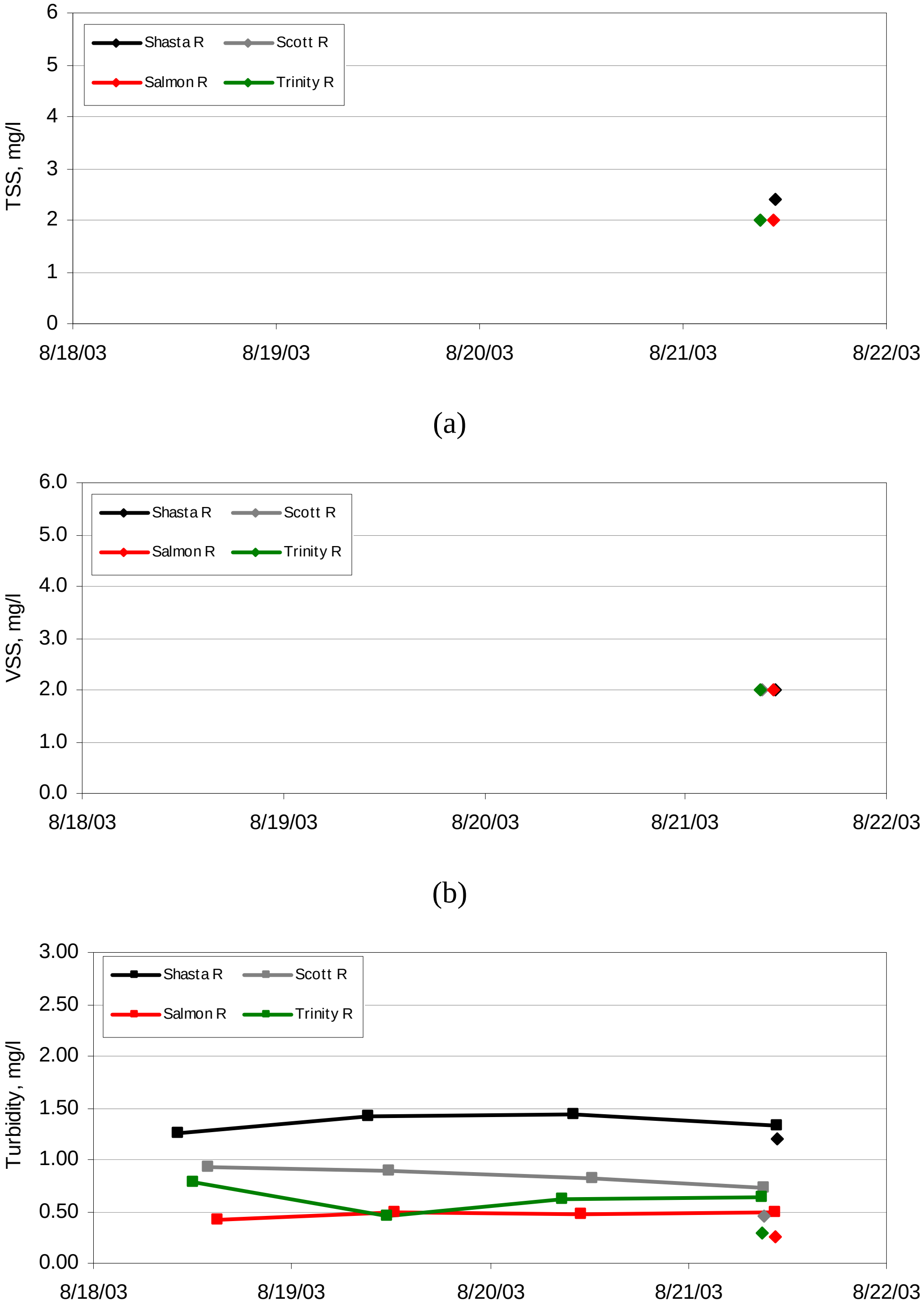
Figure 4 KR 2003 synoptic grab sample results for different tributaries along the Klamath River: (a) ammonia, (b) nitrate-nitrite, (c) TKN.



(a)

(b)

Figure 5 KR 2003 synoptic grab sample results for different tributaries along the Klamath River: (a) ortho-phosphate, (b) total phosphorus. Note that there are both field results (squares) and lab results (diamonds) on the ortho-phosphate graph.



(a)

(b)

(c)

Figure 6 KR 2003 synoptic grab sample results for different tributaries along the Klamath River: (a) TSS, (b) VSS, (c) turbidity. Note that there are both field results (squares) and lab results (diamonds) on the turbidity graph.

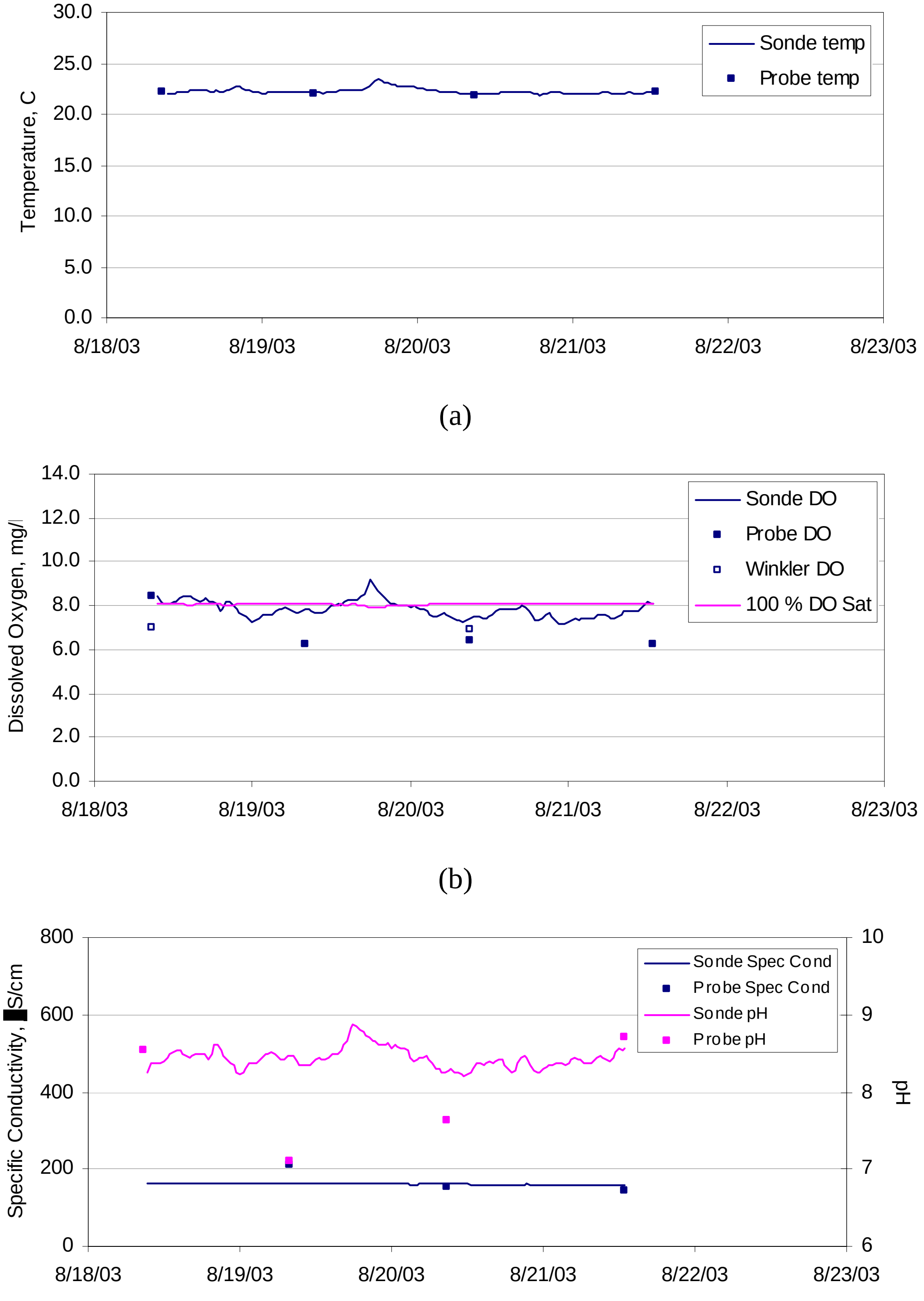
Appendix B - Field Measurements

Table 6 Field measurements and field analysis results

Date	Site Name	Tw, °C	DO, mg/l	Spec Cond, uS/cm	pH	Field Turb, NTU	Field PO_4^{3-}, mg/l	Winkler DO, mg/l
8/18/2003	KLAMATH RIVER BELOW IRON GATE DAM	22.1	8.42		8.54	0.9	0.16	6.96
8/18/2003	KLAMATH RIVER U/S SHASTA RIVER	21.4	8.8		8.21	1.1	0.15	
8/18/2003	SHASTA RIVER AT MOUTH	20.1	9.14		8.54	1.3	0.22	7.48
8/18/2003	KLAMATH RIVER ABOVE SCOTT RIVER	23	9.92		8.5	1.3	0.15	
8/18/2003	SCOTT RIVER NEAR MOUTH	23.6	8.66		8.6	0.9	0.02	7.8
8/18/2003	KLAMATH RIVER NEAR SEIAD VALLEY	24.3	10.8		8.78	1.0	0.11	
8/18/2003	KLAMATH R AT CLEAR CREEK	22.2	8.50	176	8.56	1.3	0.11	7.86
8/18/2003	KLAMATH R AB SALMON RIVER	23.9	9.03	164	8.92	0.8	0.09	
8/18/2003	SALMON RIVER AT SOMES BAR	22.1	7.44	112	8.57	0.4	0.02	8.84
8/18/2003	KLAMATH R AB TRINITY RIVER					0.7	0.07	
8/18/2003	TRINITY R AT WEITCHPEC					0.8	0.02	
8/18/2003	KLAMATH R AT TULLY CREEK					0.7	0.05	
8/19/2003	KLAMATH RIVER BELOW IRON GATE DAM	22	6.27	213	7.1	1.1	0.16	
8/19/2003	KLAMATH RIVER U/S SHASTA RIVER	20.8	5.97	166	7.2	1.5	0.15	7.16
8/19/2003	SHASTA RIVER AT MOUTH	20.8	6.33	523	8.07	1.4	0.20	
8/19/2003	KLAMATH RIVER ABOVE SCOTT RIVER	22.4	6.51	189	6.9	1.4	0.15	7.38
8/19/2003	SCOTT RIVER NEAR MOUTH	22.2	7.05	251	7.89	0.9	0.02	
8/19/2003	KLAMATH RIVER NEAR SEIAD VALLEY	24	5.82	190	7.66	1.1	0.14	8.4
8/19/2003	KLAMATH R AT CLEAR CREEK	24.5	8.76	170	8.85	1.1	0.12	
8/19/2003	KLAMATH R AB SALMON RIVER	23.6	8.47	164	8.74	0.9	0.10	8.08
8/19/2003	SALMON RIVER AT SOMES BAR	21.6	7.12	113	8.42	0.5	0.03	
8/19/2003	KLAMATH R AB TRINITY RIVER					0.7	0.07	
8/19/2003	TRINITY R AT WEITCHPEC					0.5	0.02	
8/19/2003	KLAMATH R AT TULLY CREEK					0.8	0.20	
8/20/2003	KLAMATH RIVER BELOW IRON GATE DAM	21.9	6.38	155	7.64	1.0	0.17	6.90
8/20/2003	KLAMATH RIVER U/S SHASTA RIVER	21.2	6.41	151	7.76	1.0	0.15	
8/20/2003	SHASTA RIVER AT MOUTH	20.6	6.24	473	7.97	1.4	0.23	7.18
8/20/2003	KLAMATH RIVER ABOVE SCOTT RIVER	22.9	6.34	179	7.59	1.4	0.15	
8/20/2003	SCOTT RIVER NEAR MOUTH	22.9	6.44	247	8.49	0.8	0.02	7.64
8/20/2003	KLAMATH RIVER NEAR SEIAD VALLEY	24.5	7.86	188	8.14	1.1	0.14	
8/20/2003	KLAMATH R AT CLEAR CREEK	24	8.69	169	8.77	1.1	0.11	6.64
8/20/2003	KLAMATH R AB SALMON RIVER	23.3	9.14	166	8.59	0.9	0.09	
8/20/2003	SALMON RIVER AT SOMES BAR	21	8.96	113	8.43	0.5	0.03	8.22
8/20/2003	KLAMATH R AB TRINITY RIVER	22.38	7.82	168	7.54	0.9	0.08	
8/20/2003	TRINITY R AT WEITCHPEC	21.67	7.13	146	7.53	0.6	0.01	
8/20/2003	KLAMATH R AT TULLY CREEK	22.56	7.58	160	8.23	0.8	0.06	
8/21/2003	KLAMATH RIVER BELOW IRON GATE DAM	22.2	6.22	145	8.7	1.0	0.15	

Date	Site Name	Tw, °C	DO, mg/l	Spec Cond, uS/cm	pH	Field Turb, NTU	Field PO_4^{3-}, mg/l	Winkler DO, mg/l
8/21/2003	KLAMATH RIVER U/S SHASTA RIVER	20.8	6.60	152	8.13	1.5	0.14	7.48
8/21/2003	SHASTA RIVER AT MOUTH	20.9	6.59	485	8.63	1.3	0.26	
8/21/2003	KLAMATH RIVER ABOVE SCOTT RIVER	21.8	5.63	179	8.22	0.8	0.15	6.84
8/21/2003	SCOTT RIVER NEAR MOUTH	20.2	6.83	251	7.99	0.7	0.01	
8/21/2003	KLAMATH RIVER NEAR SEIAD VALLEY	22.5	5.68	197	7.79	1.7	0.15	6.98
8/21/2003	KLAMATH R AT CLEAR CREEK	23.7	8.37	170	8.71	1.3	0.17	
8/21/2003	KLAMATH R AB SALMON RIVER	23	9.05	164	8.6	0.9	0.17	8.02
8/21/2003	SALMON RIVER AT SOMES BAR	20.7	6.98	114	8.41	0.5	0.04	
8/21/2003	KLAMATH R AB TRINITY RIVER	22.42	7.59	171	7.7	0.8	0.08	
8/21/2003	TRINITY R AT WEITCHPEC	21.49	7.75	147	7.72	0.6	0.02	
8/21/2003	KLAMATH R AT TULLY CREEK	22.78	6.54	159	7.75	0.7	0.04	

Appendix C – Sonde Data



(a)

(b)

(c)

Figure 7 Sonde data and field measurements for Klamath River below Irongate Dam: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

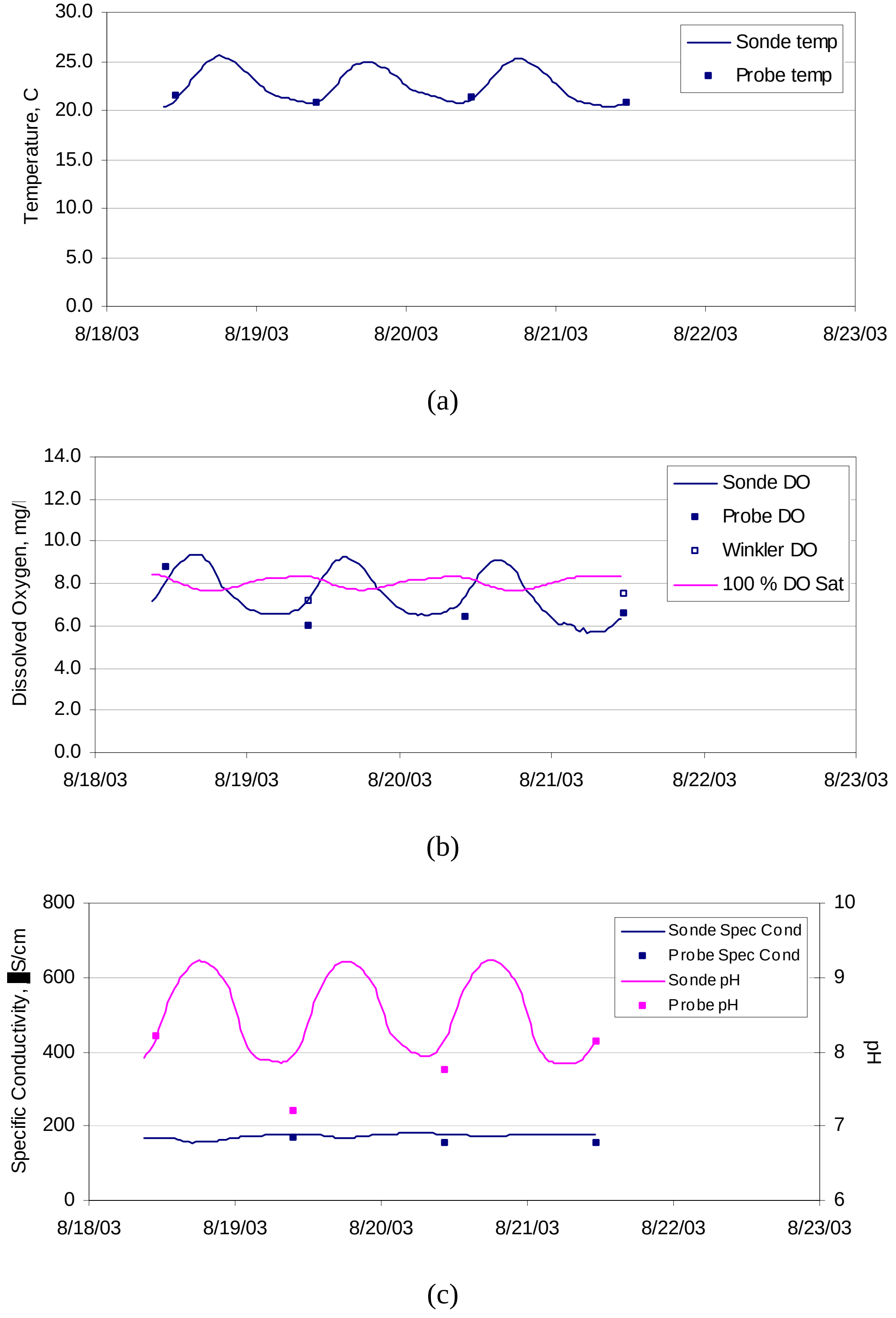
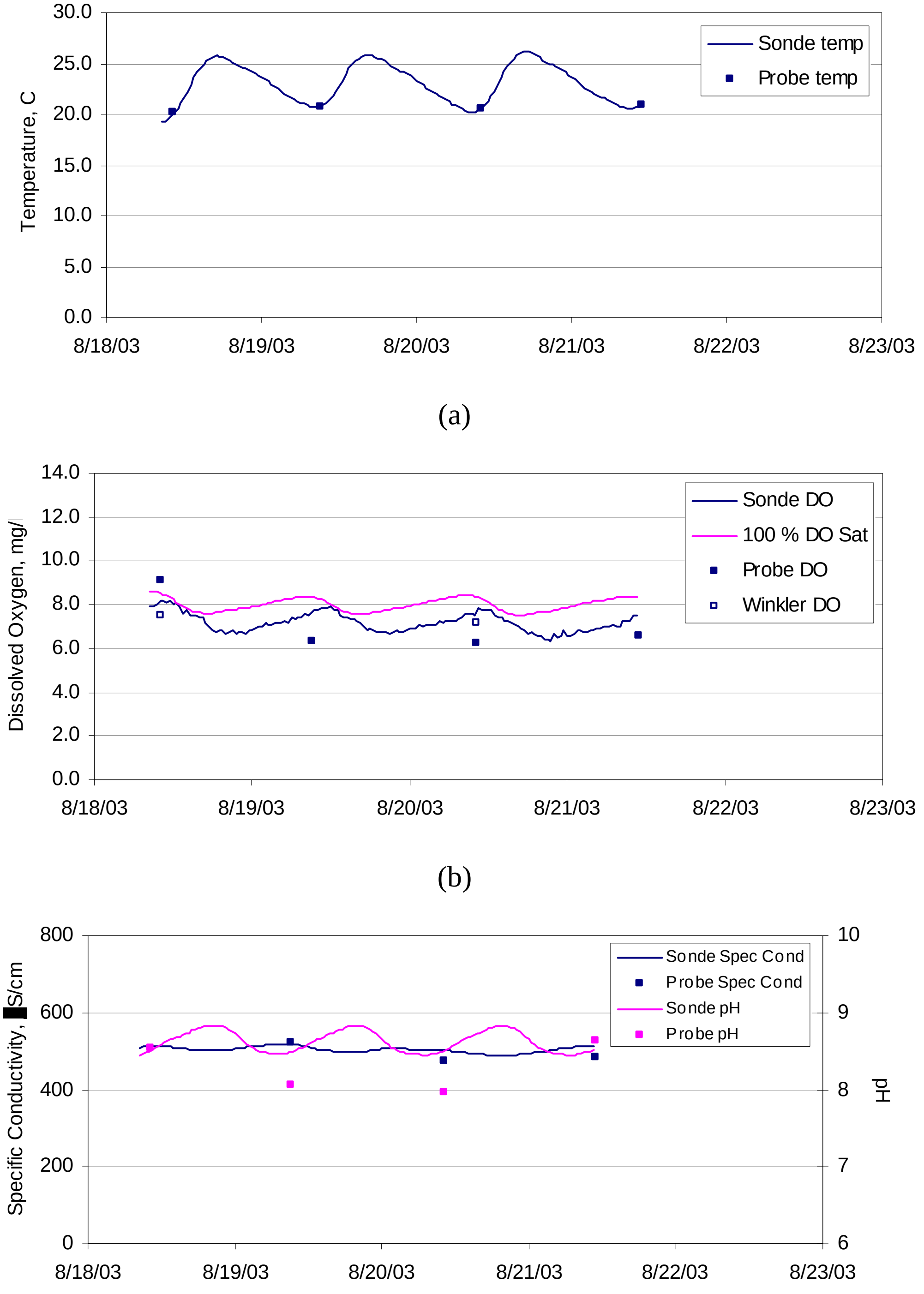


Figure 8 Sonde data and field measurements for Klamath River above Shasta River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

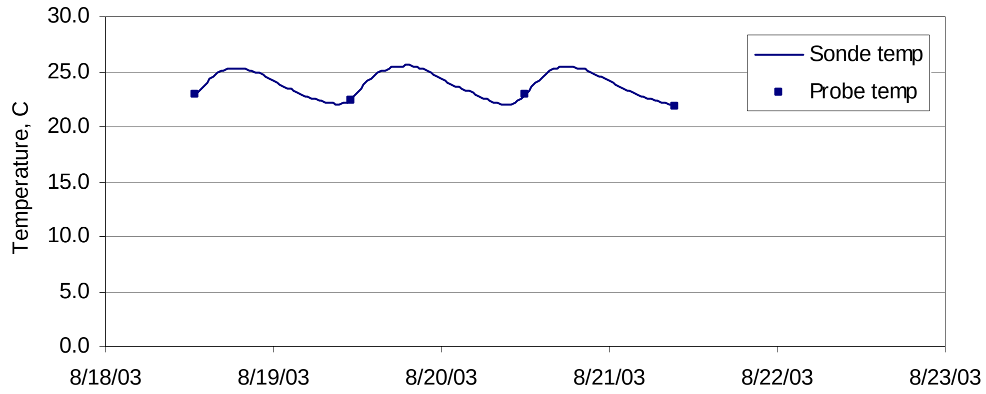


(a)

(b)

(c)

Figure 9 Sonde data and field measurements for Shasta River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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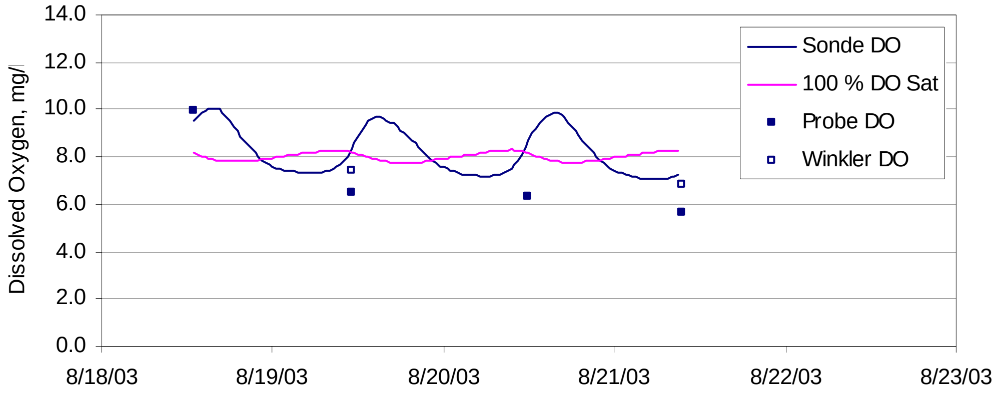

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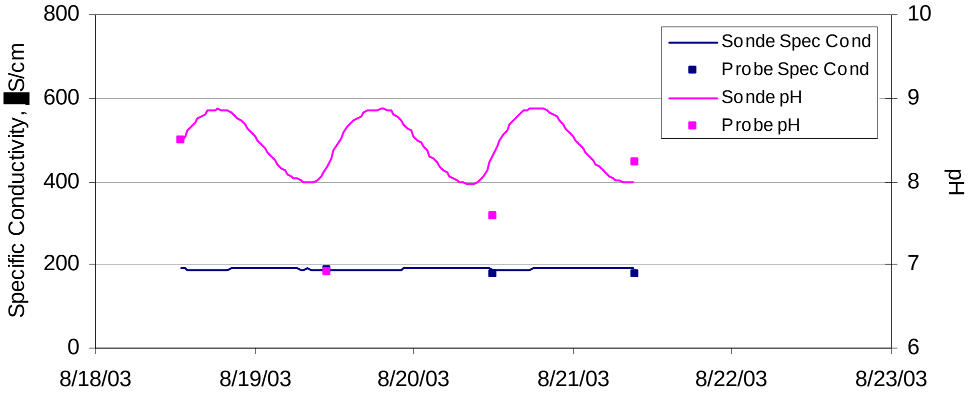


(c)

Figure 10 Sonde data and field measurements for Klamath River above Scott River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

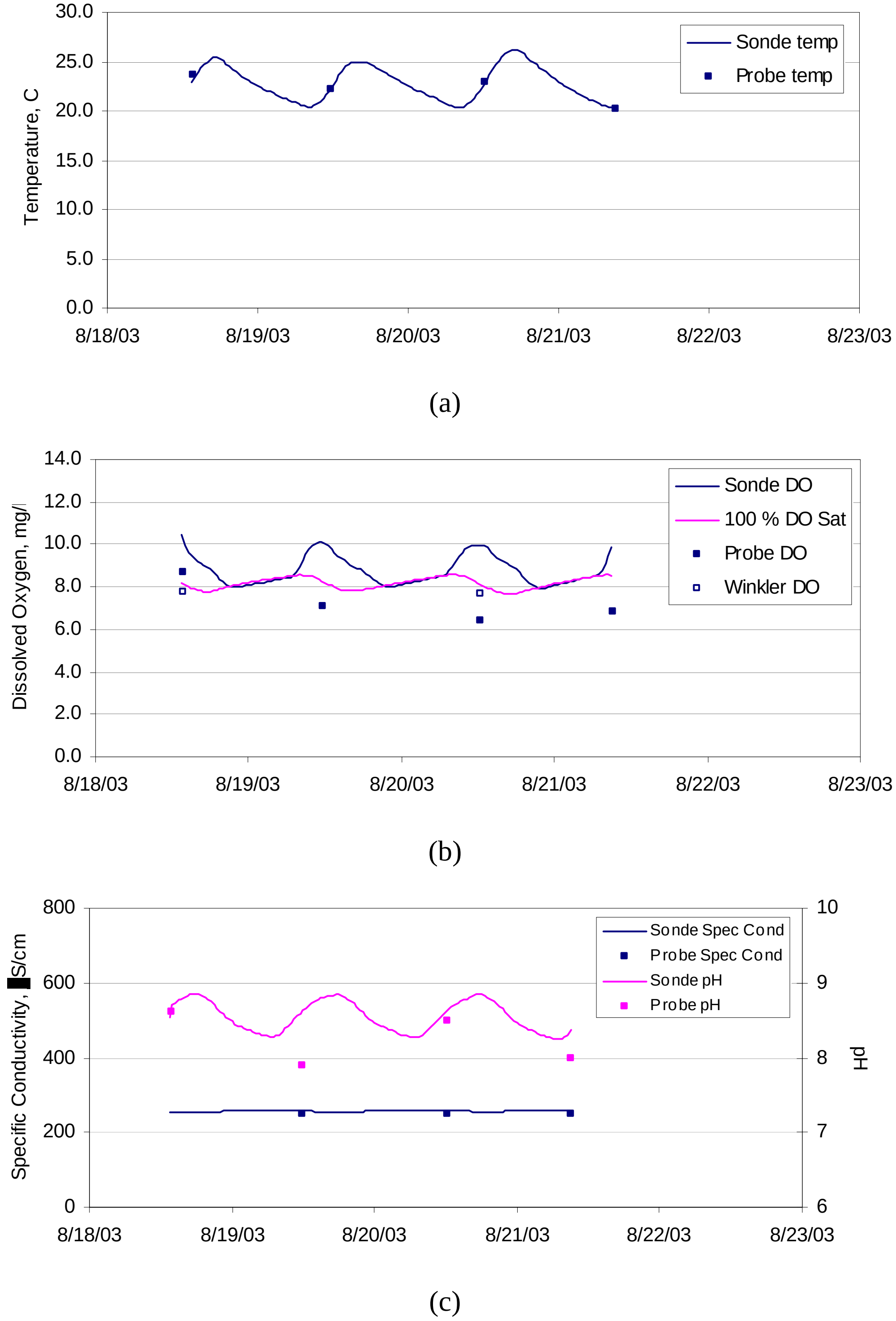
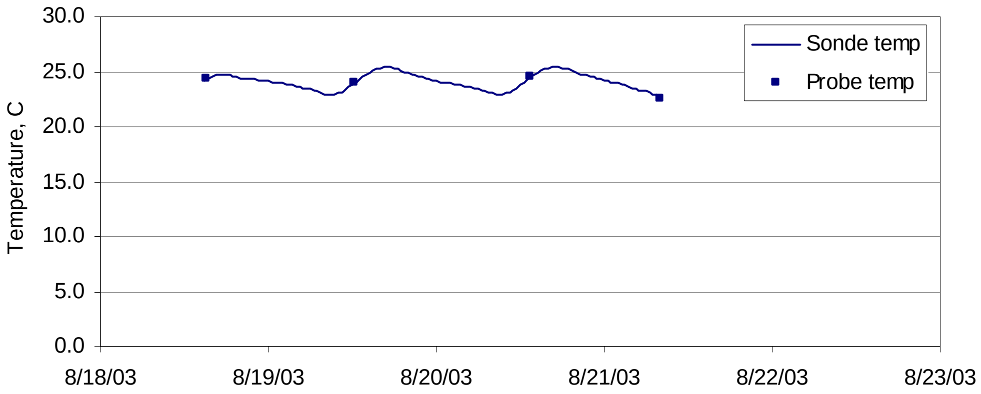


Figure 11 Sonde data and field measurements for Scott River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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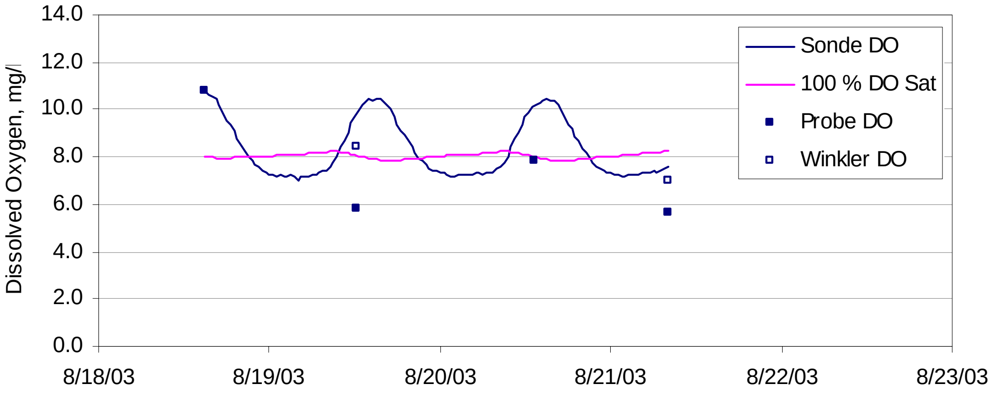

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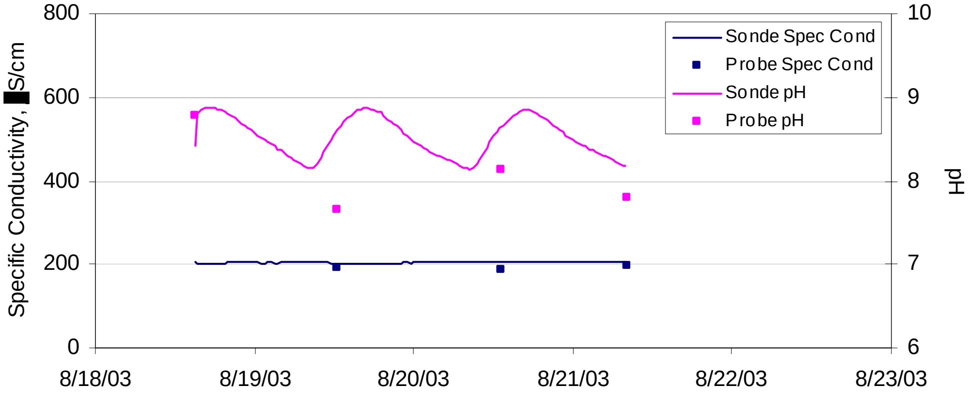
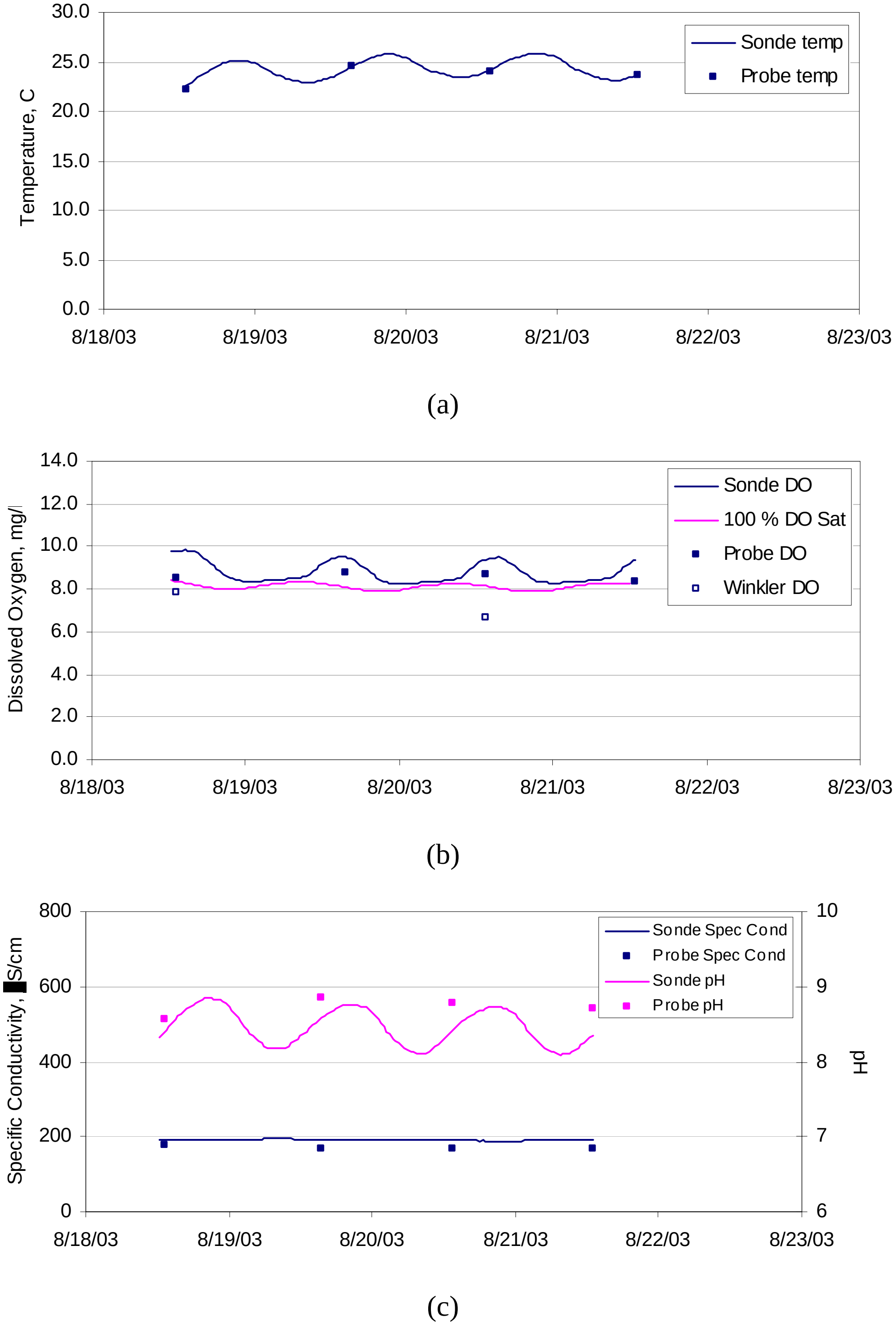


(c)

Figure 12 Sonde data and field measurements for Klamath River at Seiad Valley: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

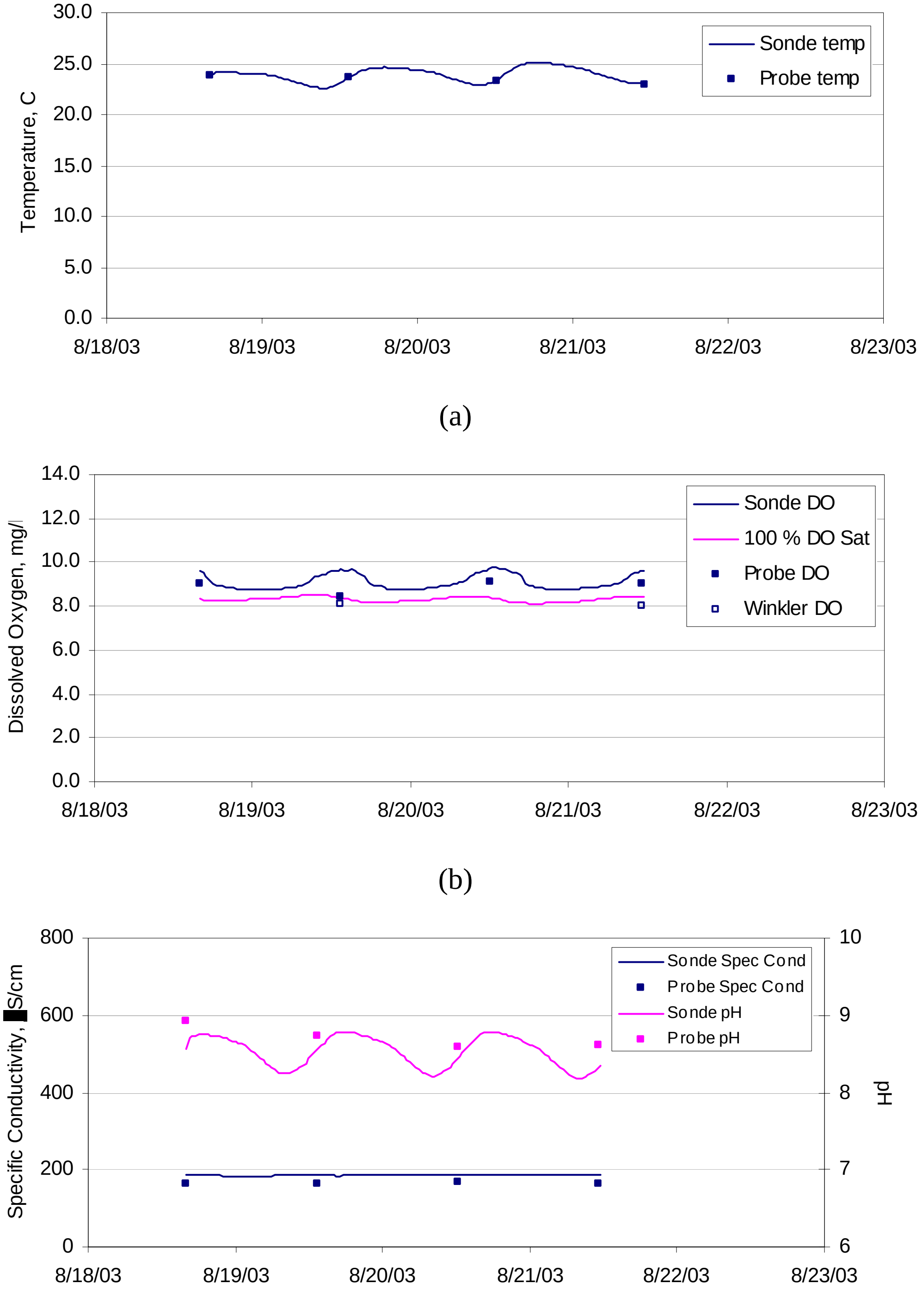


(a)

(b)

(c)

Figure 13 Sonde data and field measurements for Klamath River at Clear Creek: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

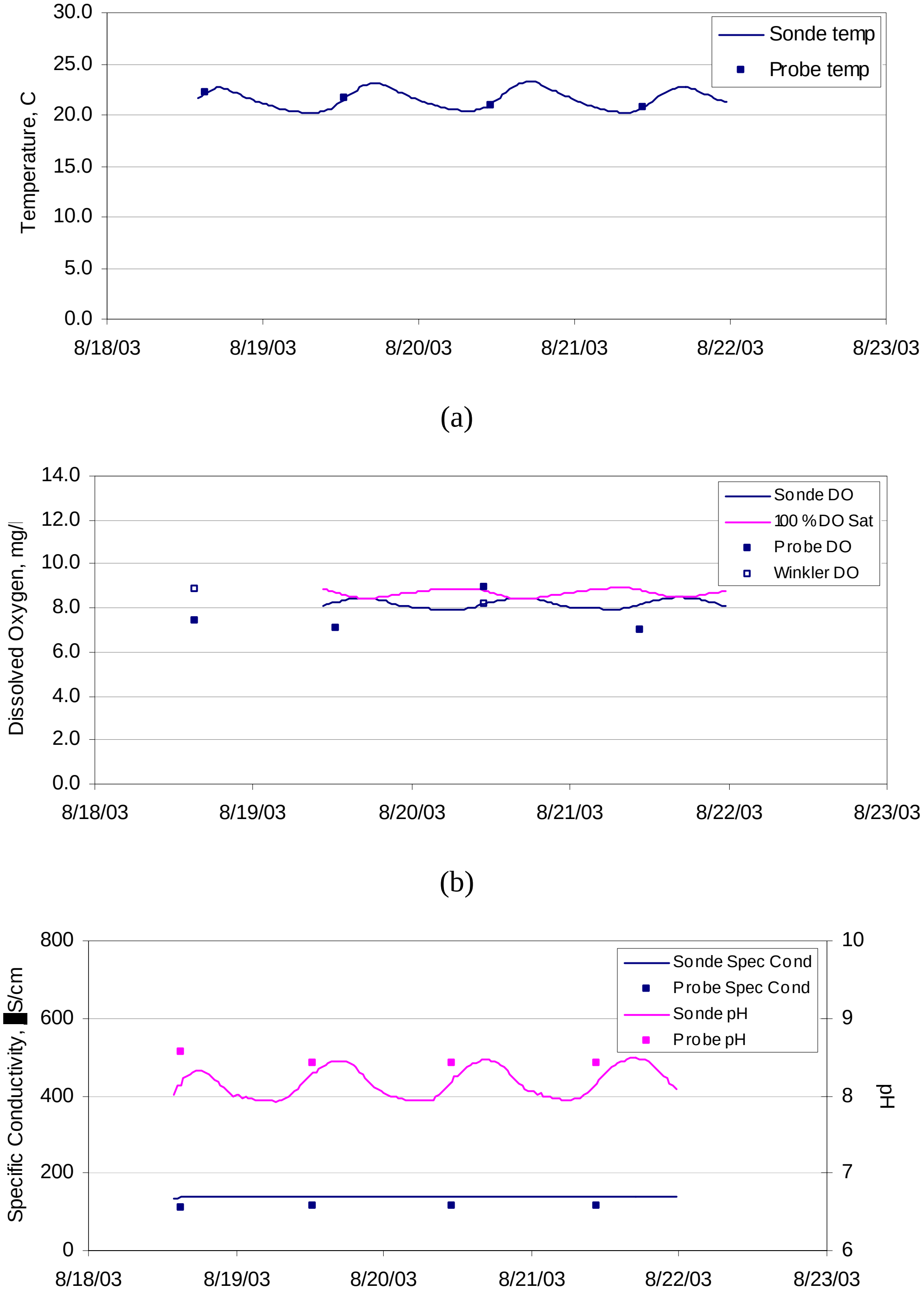


(a)

(b)

(c)

Figure 14 Sonde data and field measurements for Klamath River above Salmon River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

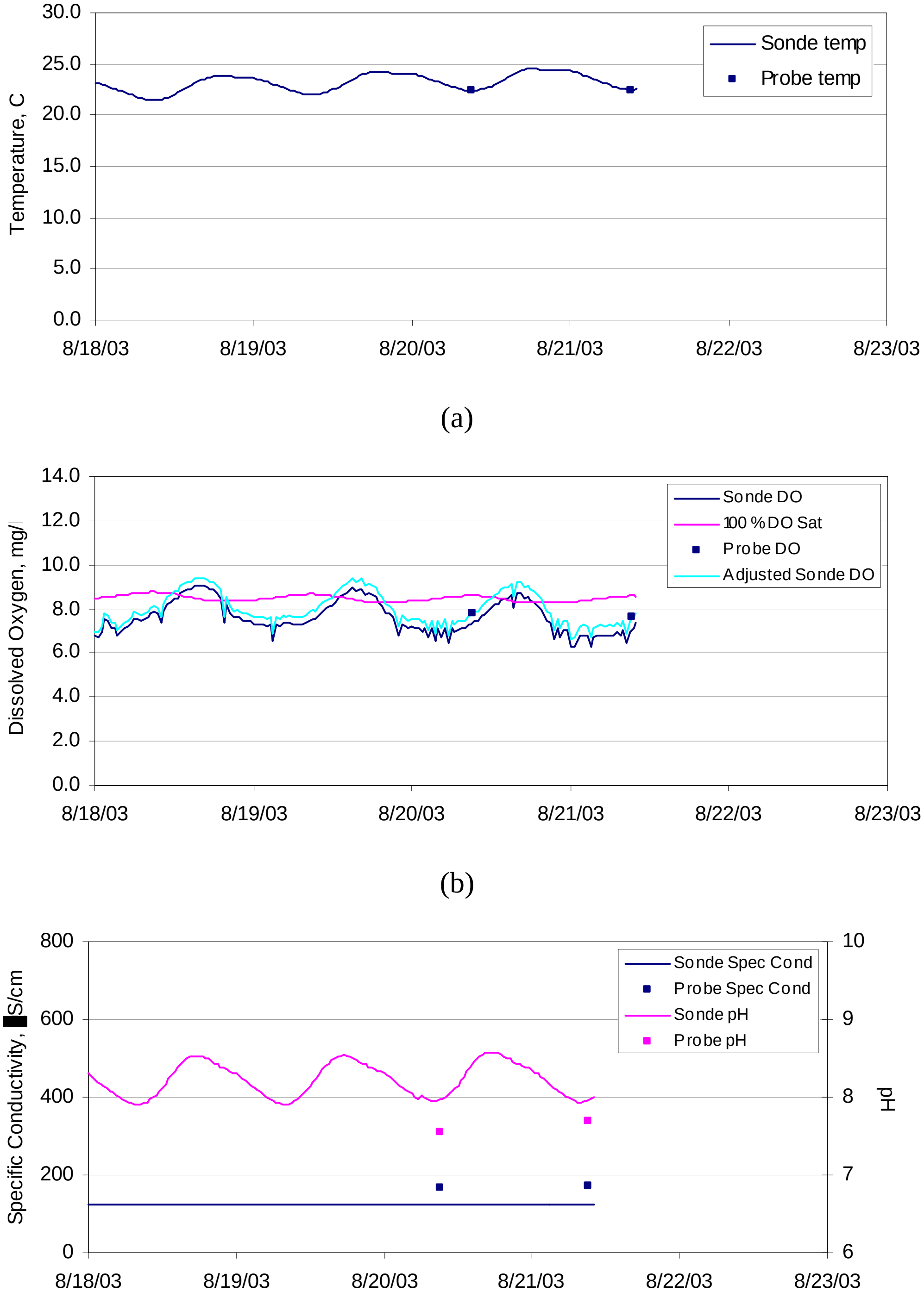


(a)

(b)

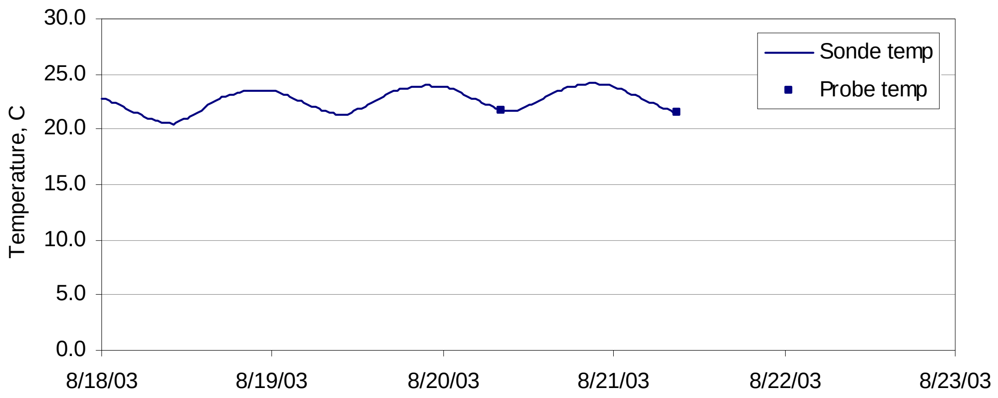
(c)

Figure 15 Sonde data for Salmon River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



(c)

Figure 16 Sonde data and field measurements for Klamath River at Weitchpec (above Trinity River): (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



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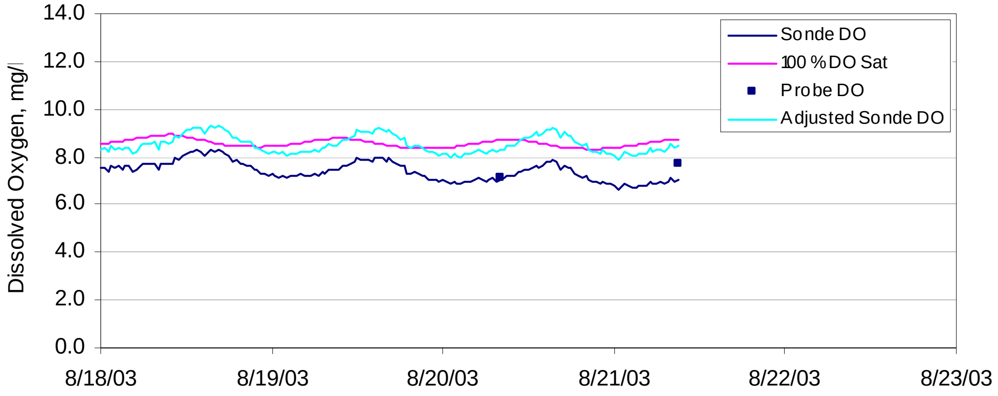

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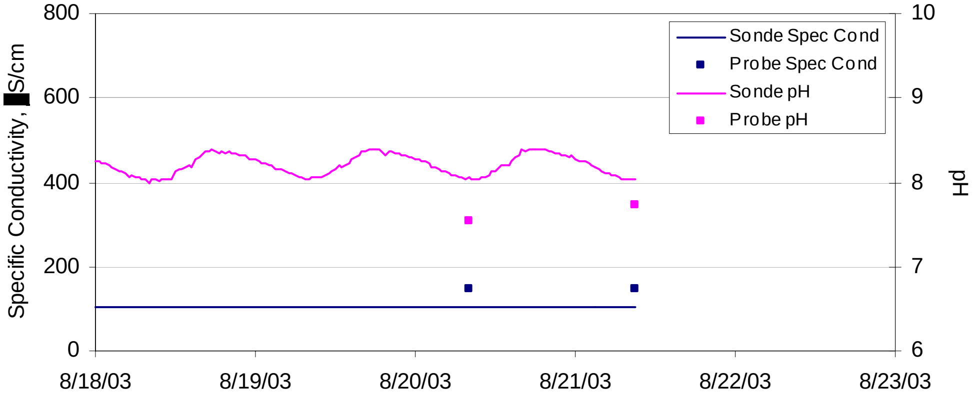
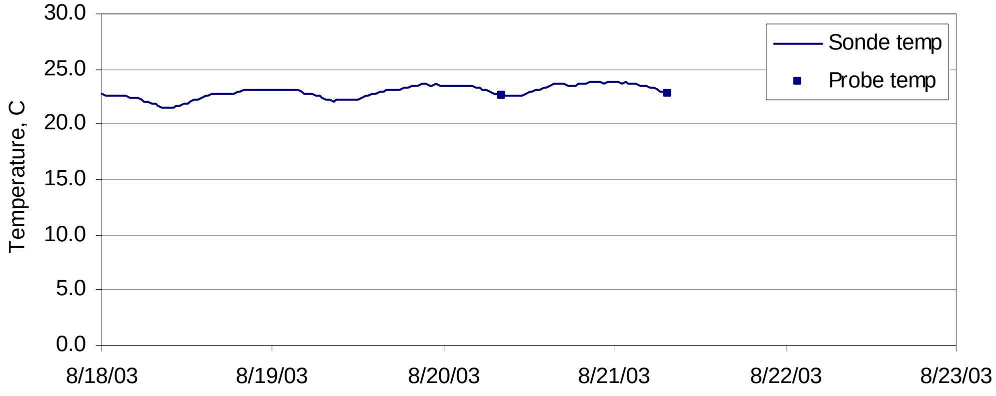
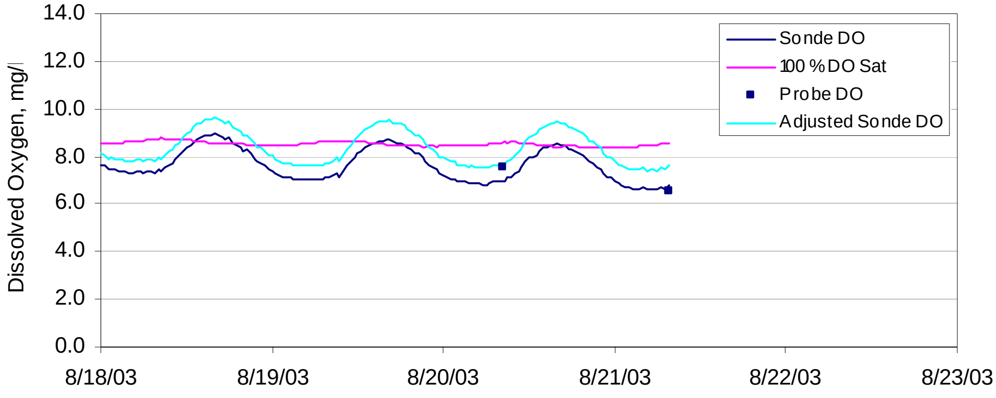


(c)

Figure 17 Sonde data and field measurements for Trinity River: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH



(a)



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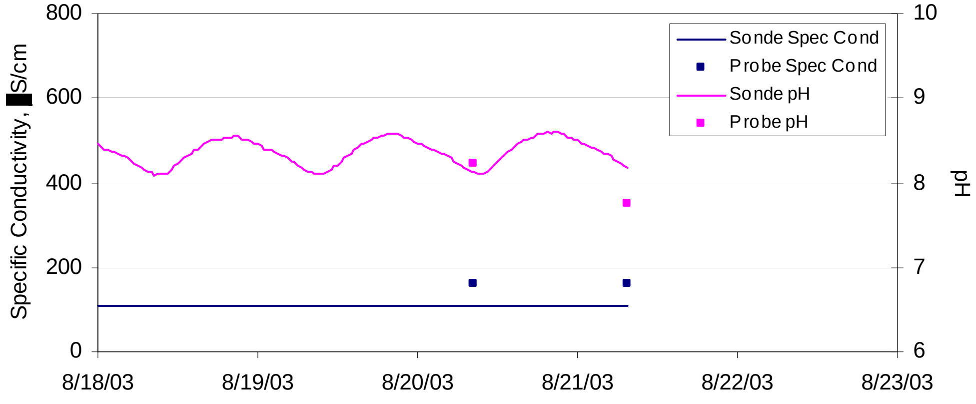


(c)

Figure 18 Sonde data and field measurements for Klamath River at Tully Creek: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

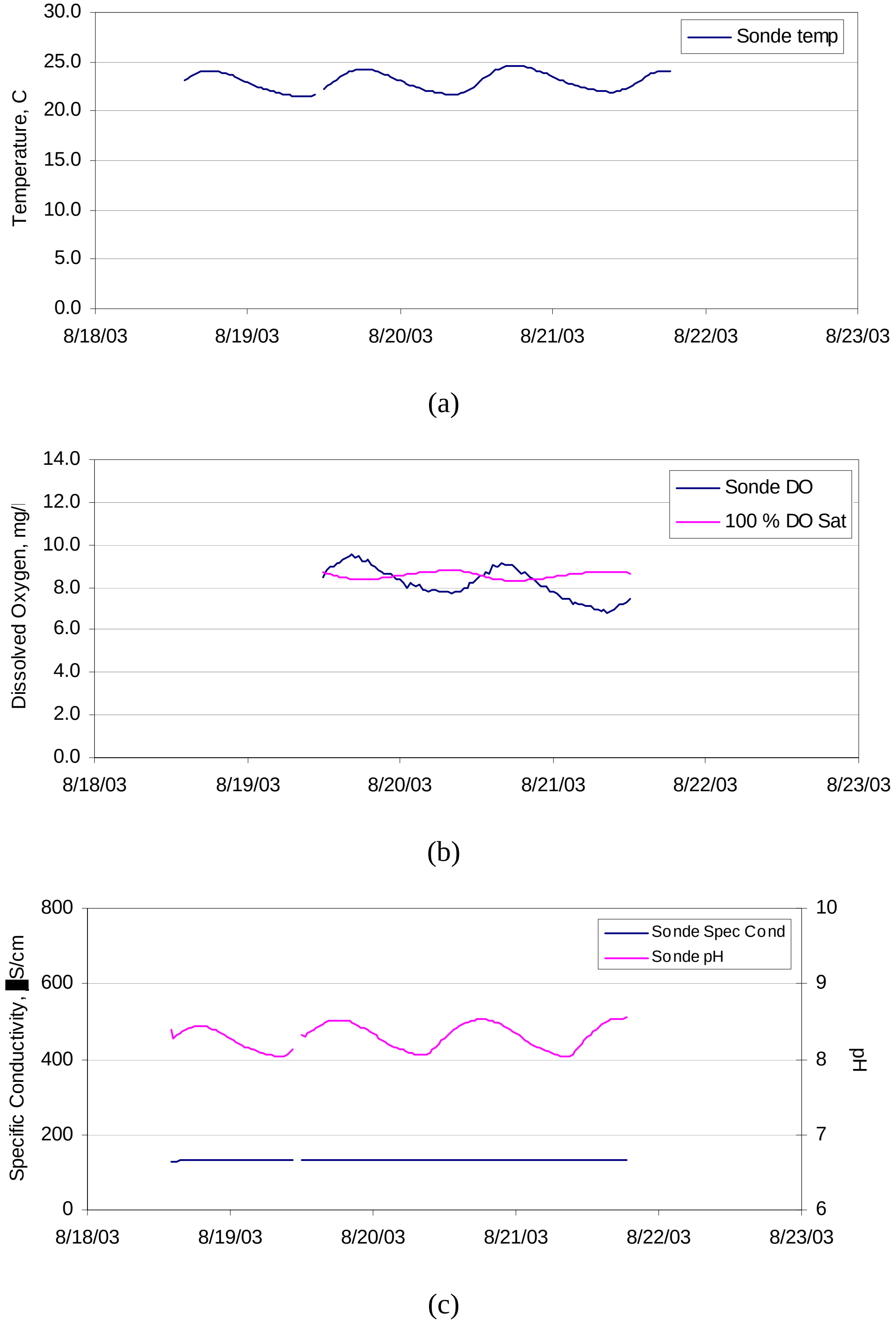


Figure 19 Sonde data for Klamath River at Blue Creek: (a) temperature, (b) dissolved oxygen, (c) specific conductance and pH

Appendix D - Flow prior to and during the synoptic survey

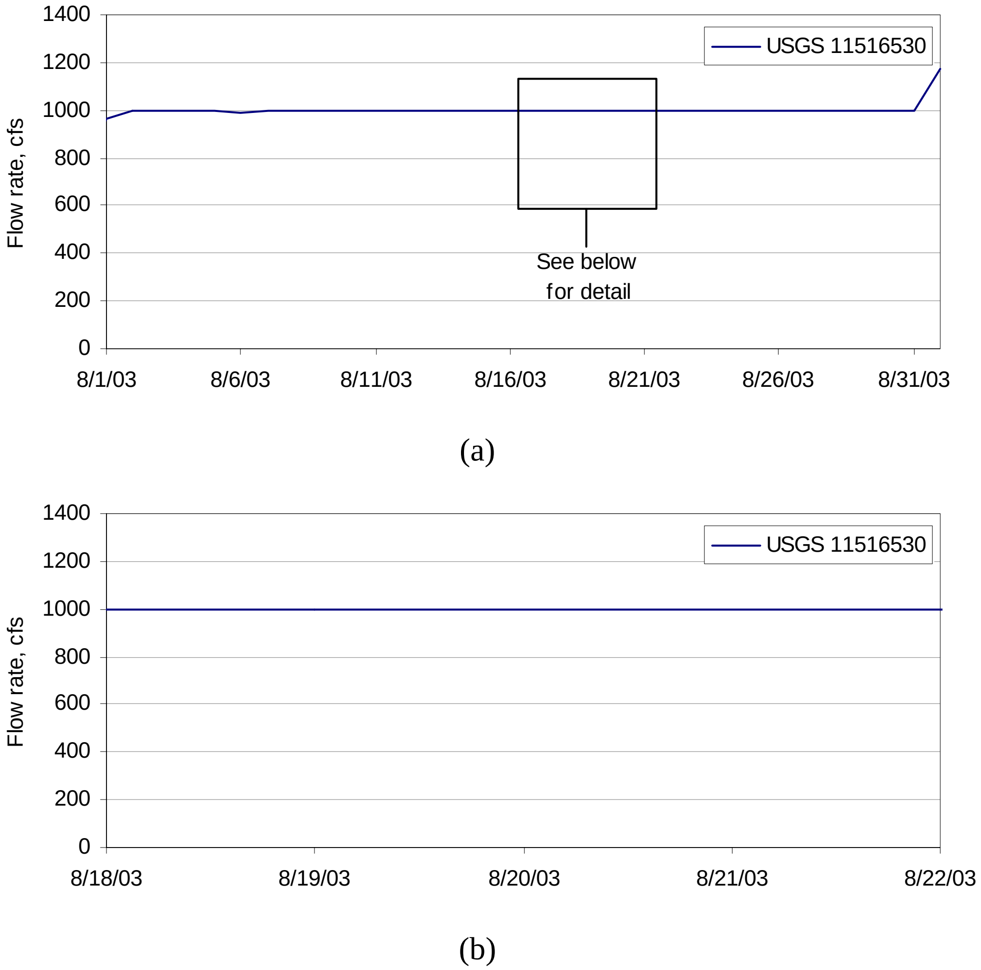
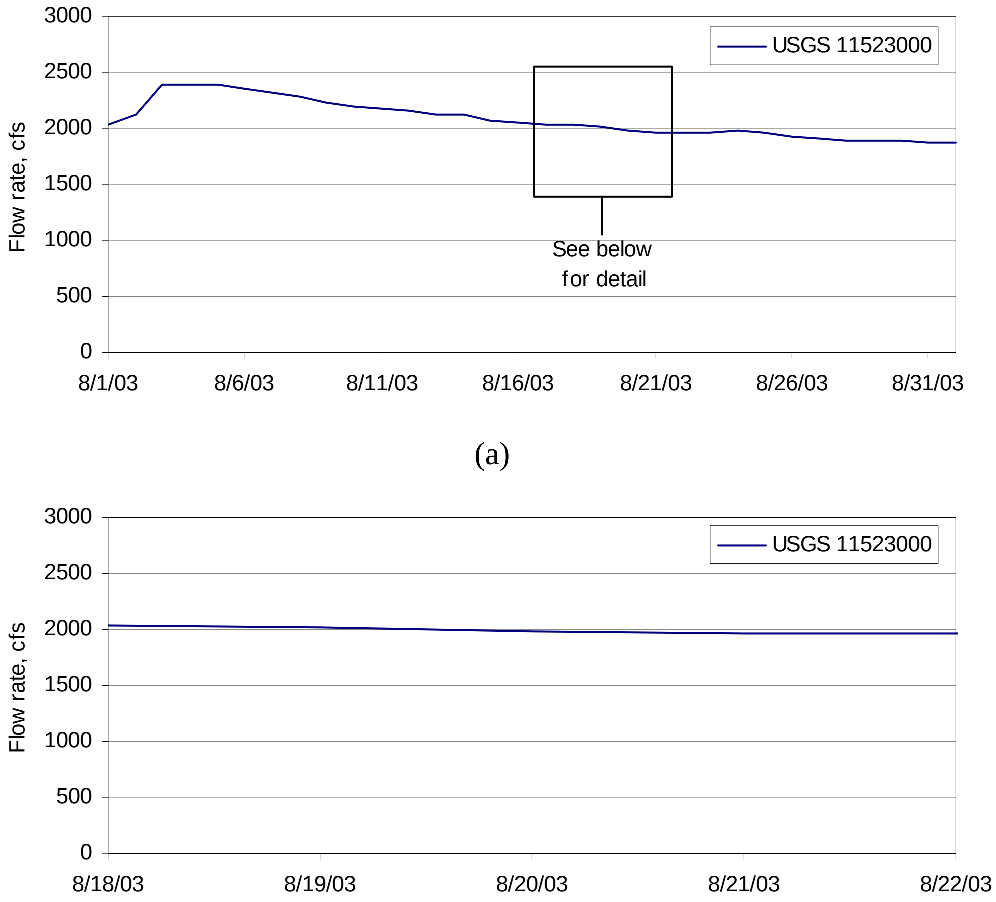


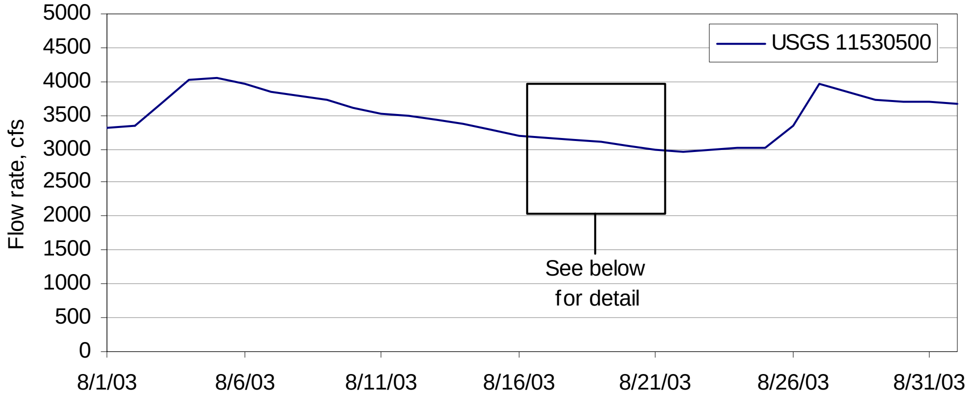
Figure 20 Flow in the Klamath River below Irongate Dam: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003



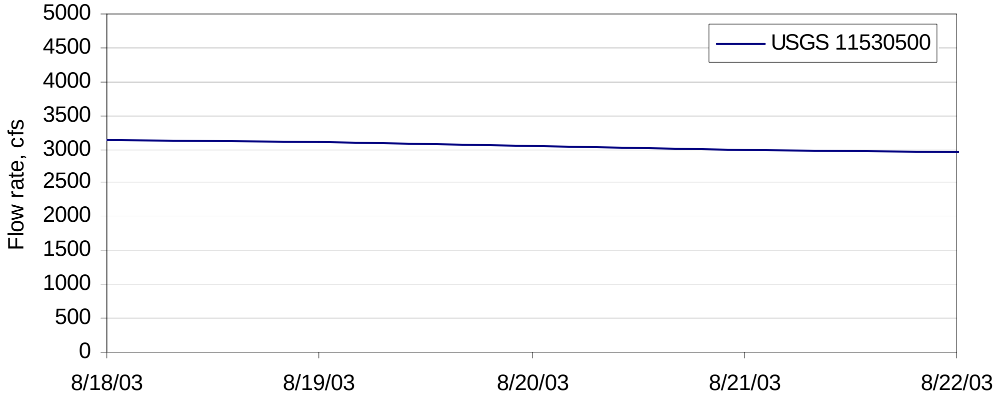
(a)

(b)

Figure 21 Flow in the Klamath River at Orleans: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003

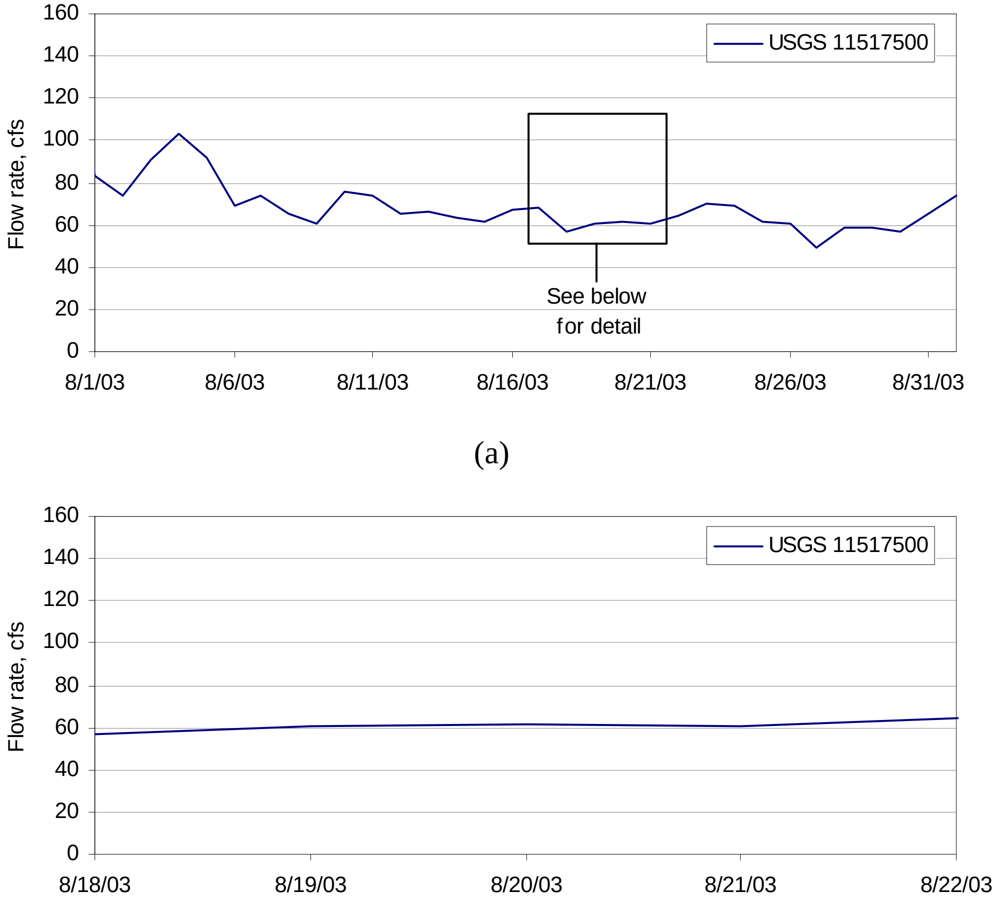


(a)



(b)

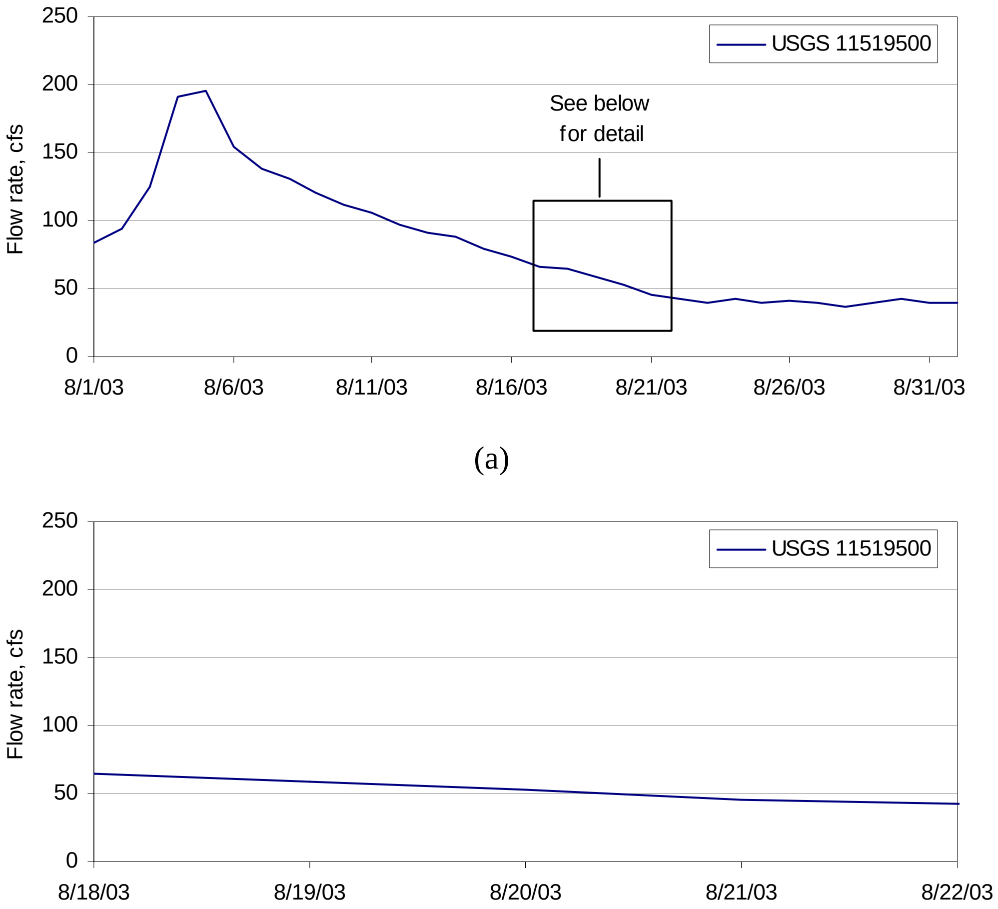
Figure 22 Flow in the Klamath River at Turwar: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003



(a)

(b)

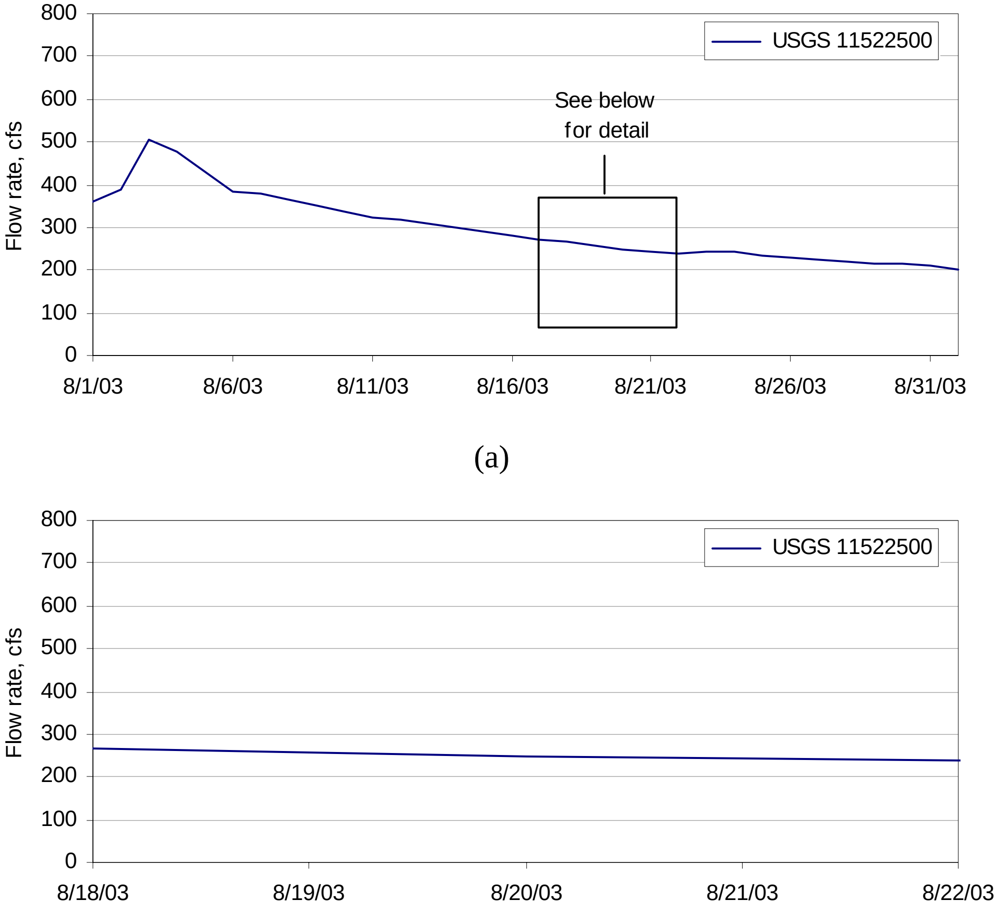
Figure 23 Flow in the Shasta River near Yreka: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003



(a)

(b)

Figure 24 Flow in the Scott River near Fort Jones: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003



(a)

(b)

Figure 25 Flow in the Salmon River at Somes Bar: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003

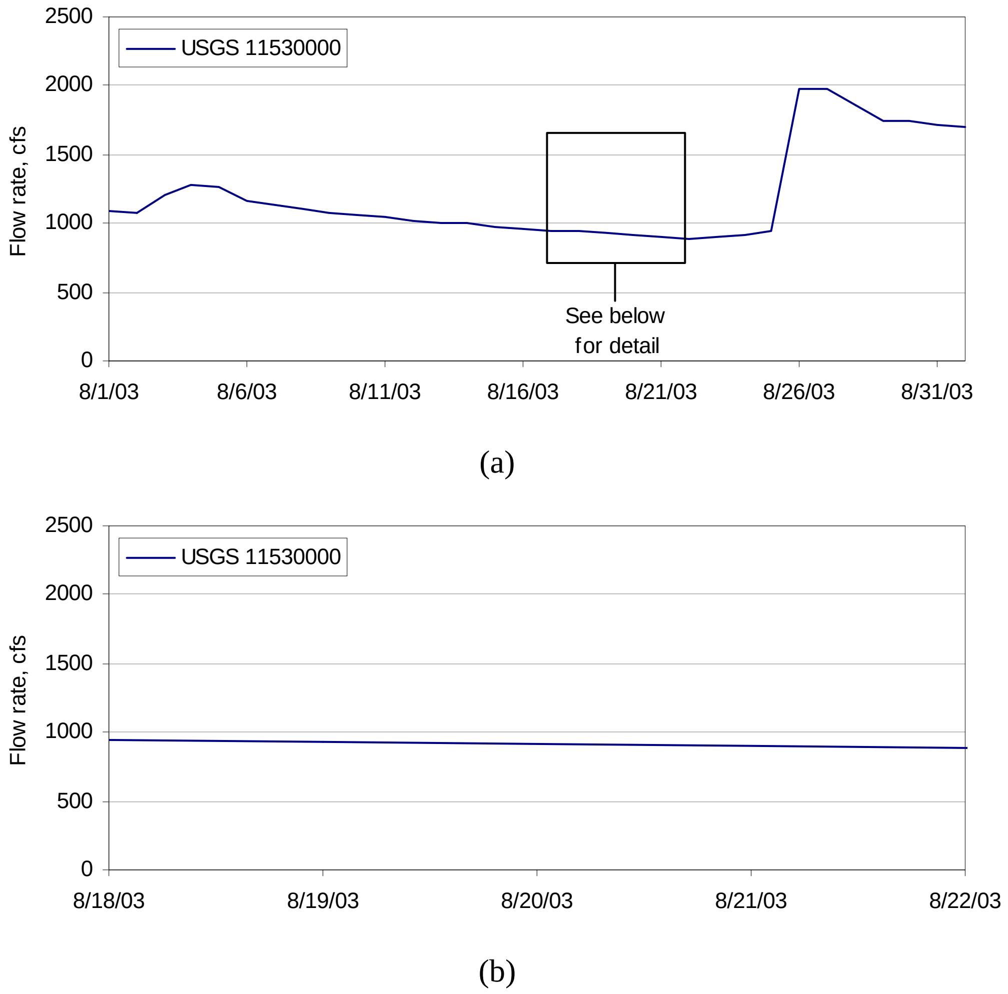


Figure 26 Flow in the Trinity River at Hoopa: (a) August 1, 2003 through August 31, 2003, (b) August 18, 2003 through August 21, 2003