A Department of Ecology Report

Green River and Newaukum Creek Temperature and Dissolved Oxygen Total Maximum Daily Load Study: Data Summary Report

Abstract

As part of the *Green River and Newaukum Creek Temperature and Dissolved Oxygen Total Maximum Daily Load Study*, the Washington State Department of Ecology (Ecology), King County Department of Natural Resources, Muckleshoot Indian Tribe, and others participated in a cooperative effort to conduct a series of short-term water quality studies from June through September 2006. This report presents data collected during these studies, including field and laboratory water quality data and flow data. The quality assurance and quality control analysis of the data is also provided.

Ecology will use the data to conduct a detailed scientific analysis and to recommend pollutant loading limits for the Green/Newaukum system.

Field data include pH, conductivity, dissolved oxygen, temperature, relative humidity, flow, periphyton biomass, and riparian shade. Laboratory data include total nitrogen, total phosphorus, dissolved nutrients (nitrate+nitrite, ammonia, nitrogen, orthophosphorus), chlorophyll a, total organic carbon, dissolved organic carbon, and alkalinity.

Subsequent reports will summarize (1) how these data are used to develop predictive temperature and dissolved oxygen models, and (2) how the models are applied to establish pollutant load reduction targets for the Green/Newaukum system.

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August 2007

Publication Number: 07-03-001
Waterbody Numbers: WA-09-1020, -1030

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Publication Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0703001.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, MROB003.

Ecology's Study Tracker Code for this project is 05-065-02 (data summary only)

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List of Acronyms and Abbreviations

AFDW	Ash free dry weight
Alk	Alkalinity
Chl a	Chlorophyll a
DO	Dissolved oxygen
DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
NH_3	Ammonia
NO_2	Nitrite
NO_3	Nitrate
NO_2NO_3	Nitrite-nitrate
OP	Orthophosphorus
RPD	Relative percent difference
RSD	Relative standard deviation
TMDL	Total Maximum Daily Load (Water Cleanup Plan)
TOC	Total organic carbon
TPN	Total persulfate nitrogen
USGS	U.S. Geological Survey

Background

Data collected by the Washington State Department of Ecology (Ecology), King County, and the Muckleshoot Indian Tribe indicate that segments of the Green River, Hill (Mill) Creek, Mullen Slough, and Newaukum Creek do not meet Washington State water quality standards for temperature and dissolved oxygen (DO). On the basis of those data, Ecology placed these segments on the 2004 federal Clean Water Act section 303(d) list of impaired waters.

Ecology, King County, the Muckleshoot Tribe, and others initiated a cooperative effort to develop water quality cleanup plans for temperature and DO in the Green/ Newaukum system. King County has monitored water quality in local lakes, rivers, and streams for over 30 years.

The cooperative effort supplemented existing data collection programs to provide water quality model input and output data. The models will be used to (1) evaluate factors contributing to elevated temperature and low DO in the system, and (2) develop load reduction targets necessary to bring stream segments into compliance with the water quality standards. King County supported this investigation through in-kind laboratory analysis and field activities performed in Newaukum Creek. This report summarizes the short-term data collection and modeling efforts.

Project Description

This project aimed to collect data and to develop temperature and DO models for the Green/Newaukum system during critical low-flow conditions. The data supplemented the ambient monitoring programs conducted by Ecology, King County, U.S. Army Corps of Engineer, City of Kent, and others. Specific tasks were to (1) characterize stream temperatures and the processes governing the thermal regime in Green River and Newaukum Creek, and (2) survey the physical, chemical, and biological measures relevant to DO levels in the system. Ongoing work will develop predictive temperature and DO models to establish pollutant load reduction targets for the Green/Newaukum system.

The Green/Newaukum watershed study area (Figure 1), consisting of about 1253 km^2 (310,000 acres), includes portions of King County as well as the cities of Auburn, Covington, Maple Valley, Kent, Sea-Tac, Tukwila, Black Diamond, Enumclaw, and Renton.

The headwaters of the Green River originate about 1,220 meters (4,000 ft) above sea level and discharge to the Duwamish Waterway. Major streams draining to the Green River within the study area include Soos, Springbrook, Mill, and Newaukum Creeks. Newaukum Creek is the only major subbasin in this TMDL targeted for its own modeling and analysis.

The headwaters of Newaukum Creek originate about 920 m (3,000 ft) above sea level and discharge to the Green River near river mile 40.7 at an elevation of 55 m (180 ft). The Green River flows about 86 km (53.5 miles) from the outlet of Howard Hanson Dam to the confluence with Duwamish Waterway. Newaukum Creek runs about 23 km (14.4 miles) from its headwater to the confluence with the Green River. Basin land use consists of high-density development, agriculture/pasture, and forest/forestry practices.

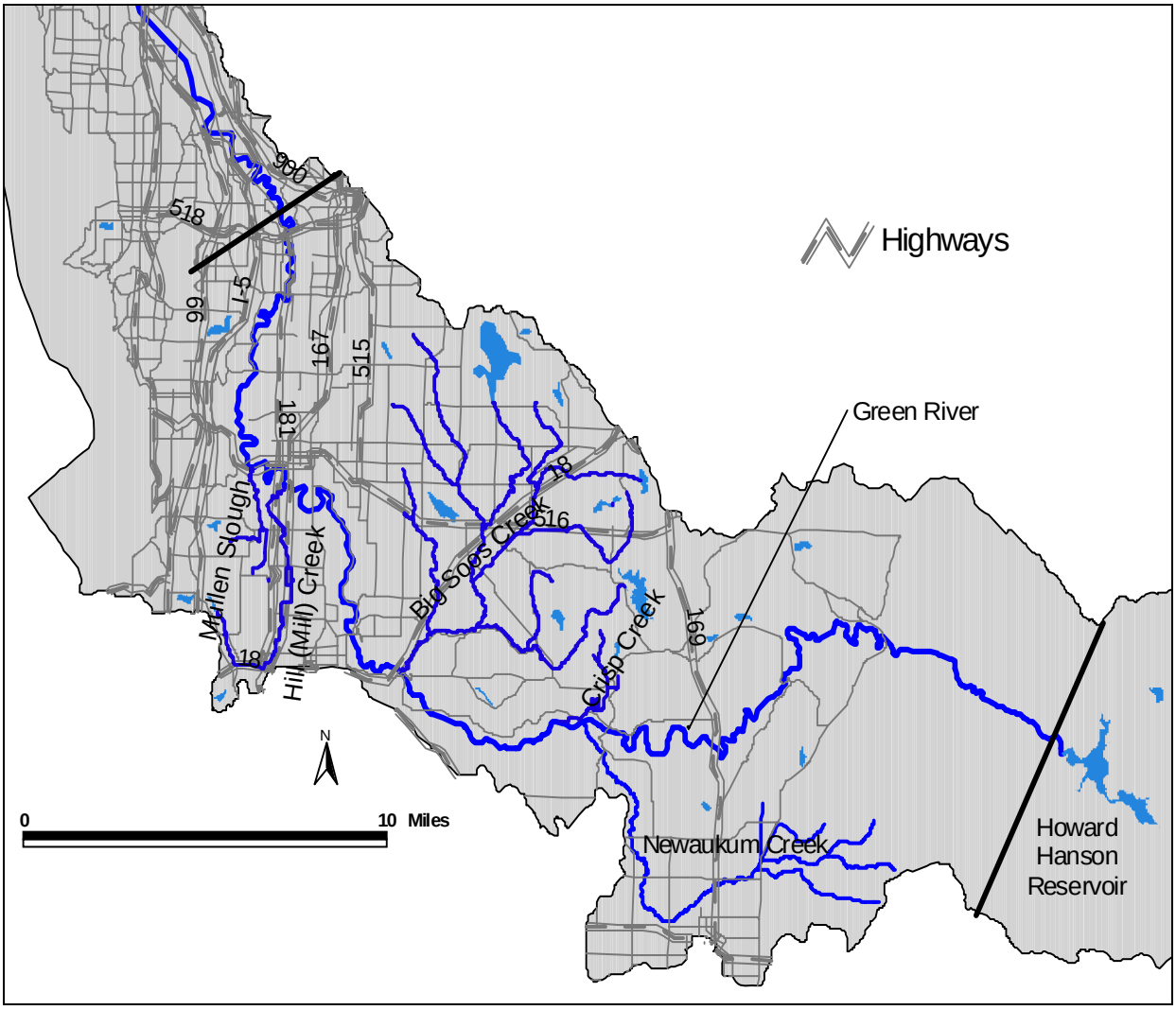

Figure 1. Green River watershed study area.

During the summer low-flow conditions from June through September 2006, several water quality monitoring programs were conducted to collect short-term data on continuous temperature, continuous DO, synoptic productivity, and synoptic flow and travel time as outlined in the Green/Newaukum Dissolved Oxygen and Temperature Sampling and Analysis Plan and Quality Assurance Project Plan. Monitoring included *in situ* continuous data and instantaneous values as well as grab samples collected for laboratory analysis. Table 1 summarizes the experimental design. Appendix A describes specific monitoring locations.

Table 1. Station summary by monitoring program.

Program	Parameter	Type	Equipment	Number of Stations	
				Green River	Newaukum Creek
Continuous Temperature and Dissolved Oxygen	Water temperature	Continuous	TidBit/Hobo	19	8
	Air temperature	Continuous	TidBit/Hobo	8	1
	Relative humidity	Continuous	RH probe	4	1
	DO, pH, temperature, conductivity	Continuous	YSI	8	7
Synoptic Productivity	DO, pH, temperature, conductivity	Instantaneous *in situ*	YSI and Hydrolabs	20*	8
	Total nitrogen and total phosphorus	Grab samples, unfiltered	(laboratory)	20*	8
	Dissolved nutrients (nitrate+nitrite, ammonia nitrogen, orthophosphorus)	Grab samples, filtered	(laboratory)	20*	8
	Chlorophyll a	Grab samples	(laboratory)	20*	8
	TOC, DOC, alkalinity	Grab samples	(laboratory)	20*	8
	Periphyton	Grab samples	(see *Methods*)	8	6
Synoptic Flow	Discharge	Instantaneous *in situ*	Flow meter and wading rod	16	8
Shade	Riparian shade	Instantaneous *in situ*	HemiView camera	11	4

*Includes the mouth of Newaukum Creek split sample with King County Environmental Laboratory

Results

Continuous Temperature

Ecology's water and air temperature loggers collected 30-minute temperature data from June 20 and July 5, respectively, to September 6, 2006 when all instruments were retrieved. The four relative humidity loggers were deployed from July 5 to September 6, 2006. Ecology also placed a water temperature logger in the mouth of Newaukum Creek from July 20 to September 6, 2006. King County's instruments collected water temperature data from August 18 to September 28, 2006 and air temperature data from August 3 to October 24, 2006. Eighteen of 19 locations in the Green River, and two of eight locations in Newaukum Creek, violated state water quality standards for temperature. Except for Ecology's water temperature logger at the mouth, temperature loggers in Newaukum Creek were not deployed during the hottest period of the summer.

For locations of loggers, see Appendix A. Graphs of 30-minute continuous data, daily maximums and minimums, and seven-day averages are presented in Appendix E.

Productivity Monitoring

During the synoptic survey, Ecology and King County sampled nutrients, alkalinity, instream chlorophyll a, and periphyton ash free dry weight and chlorophyll a. For sampling locations, dates, and times, see Appendix A. Results are listed in Appendix B, Table B-1.

Ecology recorded HemiView images at the left, right, and center of stream reaches to determine *in situ* riparian shade levels for comparison with predicted values. Calculated shade percentages are listed by site in Appendix F, and unprocessed HemiView photos are located in Appendix G.

Continuous and In Situ Dissolved Oxygen, pH, and Conductivity

Ecology calibrated and deployed eight Hydrolab® dataloggers in the Green River watershed from August 1 to 4, 2006. King County staff calibrated and deployed nine YSI dataloggers at eight key sites throughout the Newaukum subbasin from July 31 to August 3, 2006. An additional probe recorded replicate data. The Hydrolabs and YSIs logged continuous DO, pH, temperature, and conductivity data every 15 minutes. For locations of Hydrolab and YSI deployment, see Appendix A. Appendix D contains plotted continuous data. The mouth of Mill Creek and two locations in Newaukum Creek did not meet water quality standards for DO.

In situ DO, pH, and conductivity were recorded while sampling nutrients and other laboratory parameters. Results are presented in Appendix C, Table C-1.

Streamflows

Ecology measured instantaneous streamflows at all wadeable sites during the synoptic sampling event. Discharge was calculated by measuring velocities and depths in 20 or more divisions of a cross-section (Ecology, 1993). Fewer divisions were measured if necessary on small streams. Ecology also collected USGS flow data. During the productivity and synoptic flow studies, discharge at the USGS gage in Auburn was 310 cubic feet per second (cfs). For flow locations, see Appendix A. Streamflow results are in Appendix C, Table C-2.

Quality Control Analysis

Replicates and Duplicates

Manchester Environmental Laboratory performed laboratory duplicate analyses of 6 to 13 percent of all samples (Table 2), which was within the range required by the Quality Assurance Project Plan (Roberts and Jack, 2006). The results for laboratory duplicates provide an estimate of analytical precision, including homogeneity of the sample matrix (Manchester Laboratory, 2005).

Table 2. Measurement quality objectives and results of laboratory duplicates performed by Manchester Laboratory. Data quality was found to be adequate to use for the purposes of this study.

Parameter	Median RSD%	Average RSD%	Combined RPD	Precision Standard (RSD%)	Number of duplicates taken	Total number of samples (less duplicates)	Percent of total samples duplicated*
Alk	0.2	0.2	1.2	5	5	84	6
DOC	0.0	2.5	1.4	5	5	84	6
NH3	0.0	0.0	1.1	5	4	84	5
NO2/NO3	0.0	0.1	1.1	5	5	84	6
OP	2.3	2.7	1.9	5	6	84	7
TOC	0.0	0.0	0.0	5	4	84	5
TP	2.8	2.4	3.1	5	5	84	6
TPN	0.4	0.5	0.8	5	5	84	6
Instream Chl a	3.6	4.5	2.8	5	12	84	14
Periphyton-AFDW	4.9	19.1	4.0	5	5	47	11
Periphyton-Chl a	3.7	4.2	1.9	5	6	47	13

*Quality Assurance Project Plan required at least 5% of samples be duplicated in the laboratory.

Ecology took replicate field samples for laboratory parameter analyses. Field replicates are two samples collected from the same location at the same time. Ecology collects field replicates to check the precision of the entire process of sampling and analysis. The percentages of replicates taken per parameter are presented in Table 3. These percentages meet Quality Assurance Project Plan objectives.

Table 3. Measurement quality objectives and results of field replicates collected and analyzed by Ecology.

Parameter	Median RSD%	Average RSD%	Combined RPD	Precision Standard* (RSD%)	Number of replicates taken	Total number of samples (less replicates)	Percent of total samples replicated*
Alk	0.4	0.3	1.3	10	8	76	11
DOC	0.0	0.6	1.6	10	8	76	11
NH3	3.2	5.9	1.8	10	8	76	11
NO2/NO3	0.3	0.4	1.3	10	8	76	11
OP	1.0	2.3	4.5	10	8	76	11
TOC	0.0	1.9	1.7	10	8	76	11
TP	2.4	5.2	5.2	10	8	76	11
TPN	2.0	2.4	1.4	10	8	76	11
Chl a	5.9	7.4	1.1	20	8	76	11

*Quality Assurance Project Plan required at least 10% of samples be replicated in the field.

Ecology calculated median and average relative standard deviation (RSD) and average relative percent difference (RPD), expressed as percent, to compare against each parameter's precision target set forth in the Quality Assurance Project Plan for both field replicates and laboratory duplicates. All parameters fell within their respective precision targets.

Continuous Temperature

Ecology field staff checked the data loggers with a hand-held alcohol thermometer checked against a National Institute of Standards and Technology (NIST) certified reference thermometer at all Ecology sites upon installation and removal.

The temperature loggers were pre- and post-calibrated by Ecology in accordance with standard Ecology protocols (Ward et al., 2001) to document instrument bias and performance at representative temperatures. A NIST certified reference thermometer was used for the calibration.

Continuous and In Situ Dissolved Oxygen, pH, and Conductivity

Ecology and King County calibrated all field monitoring equipment according to agency protocols or manufacturer's specifications, and pre-calibrated and post-checked *in situ* and continuous Hydrolab® and YSI® meters with certified standards. Ecology and King County checked continuous loggers with another calibrated meter.

Ecology compared Hydrolab® DO measurements with Winkler DO measurements. Hydrolab data were corrected using Winkler DO values (Appendix D). The correction of datalogger DO minimizes bias and improves the relationship between datalogger and Winkler DO data, giving a more accurate picture of the sites' diel DO characteristics. Hydrolab® and YSI® *in situ* DO data reported in this publication have not been corrected (Appendix C, Table C-1).

Laboratory Data Qualifiers

Manchester Laboratory and King County Environmental Laboratory performed all laboratory analyses within specified holding times using appropriate quality assurance measures, unless noted with qualifier codes (Table 4). Qualifiers place specific conditions on the laboratory data. Data reported with qualifiers should be used with caution, and data variability must be taken into consideration when interpreting results and applying data to other analyses. All other data reported by Manchester Laboratory may be used without qualification.

Table 4. Data qualifier codes.

Qualifier	Definition
J	The analyte was positively identified. The associated numerical result is an estimate. Often denotes samples analyzed past their holding time (mostly bacteria samples).
U	The analyte was not detected at or above the reported result.
UJ	The analyte was not detected at or above the reported estimated result.
G	Value is greater than result reported.
E	Reported result is an estimate.

Schedule

As described in the Quality Assurance Project Plan, model development will follow data collection described in the present report. All analyses will be presented in the technical study report, which will include heat and nutrient load reduction targets necessary for the Green River and Newaukum Creek to meet water quality standards for temperature and DO. Table 5 presents the schedule.

Table 5. Data, model, and report schedule.

Environmental Information System (EIM) Data Set (if applicable)	
EIM Data Engineer	Teizeen Mohamedali
EIM User Study ID	MROB003
EIM Study Name	Green/Newaukum Temperature and DO TMDL
EIM Completion Due	June 2007
Modeling	
Temperature Model Development	Fall 2006 through spring 2007
Dissolved Oxygen Model Development	Fall 2006 through spring 2007
Final Report	
Draft to Supervisor	December 2007
Draft to Client/Peer	January 2008
External Draft	February 2008
Report Final Due (original)	June 2008

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Ward, W., B. Hopkins, D. Hallock, C. Wiseman, R. Plotnikoff, and W. Ehinger, 2001. Stream Sampling Protocols for the Environmental Monitoring and Trends Section. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-036. www.ecy.wa.gov/biblio/0103036.html

Appendices

A. Site Descriptions and Monitoring Locations
B. Laboratory Results
C. Field Measurements
D. Datalogger Results
E. Temperature and Relative Humidity Figures
F. Calculated Shade Values
G. Unprocessed HemiView Photos

Appendix A. Site Descriptions and Monitoring Locations

Table A-1. Site identification codes and descriptions. "x" indicates that monitoring occurred.

Station ID	River Mile	Description	Water temp	Air temp	RH	Hemi/ shade	Periphyton	Continuous DO/pH	Nutrients	Flow
Green River										
09-GRE-DAM	60.9	below Tacoma Water Headworks Diverson Dam	x		x	x	x	x	x	x
09-GRE-KAN	57.6	at Cumberland-Kanaskat Rd	x	x		x	x	x	x	x
09-GRE-GOR		at Green River Gorge Rd							x	
09-GRE-FLA	43.1	at Flaming Geyser Park, near end of SE Flaming Geyser Rd.	x			x			x	x
09-GRE-WHI	41.4	at 212th Way SE (Whitney Bridge)	x		x	x	x	x	x	x
09-GRE-GRE	35.0	at Green Valley Rd.	x		x	x	x	x	x	x
09-GRE-8TH		at 8th St. NE in Auburn	x	x		x			x	
09-GRE-277	27.9	off Green River Rd. under 277th St. bridge	x			x	x		x	x
09-GRE-167	24.0	upstream of Mill Ck. under HWY 167 bridge	x	x		x		x	x	x
09-GRE-OLD	21.5	at Meeker St. near the "Old Fishin' Hole"	x			x			x	x
09-GRE-212		at S 212th St.	x	x		x			x	
09-GRE-180	14.4	at SE 180th St. (SW 43rd St.)	x			x	x		x	x
09-GRE-FOR		under Interurban Ave. bridge near Fort Dent	x		x	x		x	x	
09-GRE-COM		under 42nd Ave. S bridge at Tukwila Community Center	x			x			x	
09-GRE-BOE		downstream of 102nd Ave. at Boeing foot bridge	x			x			x	
Green River Tributaries										
09-CRI-GRE	40.1*	Crisp Ck. at Green Valley Rd.	x			x			x	x
09-SOO-USG	33.8*	Soos Ck. at USGS gaging station upstream of hatchery	x			x	x	x	x	x
09-MIL-WAS	23.9*	Mill Ck. at Washington Ave.	x			x	x	x	x	x
09-FRA-FRA	21.7*	Mullen Slough at Frager Rd.	x			x			x	x
Newaukum Creek (King County stations)										
X322	40.7*	Newaukum Ck. near the mouth off of 358th SE	x				x	x	x	x
E322		Newaukum Ck. at SE 400 St. bridge	x				x	x	x	
AC322		Trib. upstream of confluence with Newaukum Ck.at 236th St. SE	x				?	x	x	
AN322		Newaukum Ck. just upstream of confluence with trib. at 236th St.	x				x	x	x	
G322		Newaukum Ck at bridge on SE 424th St.	x				x	x	x	
R322		Newaukum Ck. off 416th St., down pipeline trail	x				x	x	x	
N322		Newaukum Ck. at Veazie Cumberland Rd. crossing	x	x			x	x	x	
Q322		Newaukum trib. off Veazie Cumberland Rd., ditch north of TPU trail	x				?	x	x	

* Green River river mile where creek enters.
Trib = tributary

Appendix B. Laboratory Results

Table B-1. Results for nutrients and other productivity related parameters.

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)	NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll *a* (ug/L)
8/1/2006 - Morning (5:55 to 9:30)											
Mainstem Green River											
09-GRE-DAM	8:25		22.8	0.13	0.014	0.072	0.0059	0.0073	1.0 U	1.0 U	1.1
09-GRE-KAN	8:00		24.0	0.346	0.019	0.096	0.0054	0.0073	1.0 U	1.0 U	0.8
09-GRE-GOR	7:25		28.7	0.302	0.01 U	0.193	0.0045	0.0067	1.0 U	1.0 U	0.9
09-GRE-FLA	6:30		32.6	0.357	0.01 U	0.294	0.0033	0.0061	1.0 U	1.0 U	0.9
09-GRE-WHI	9:30		32.5	0.342	0.01 U	0.278	0.0037	0.0055	1.0 U	1.0 U	1.0
09-GRE-WHI	9:30	Y	32.5	0.333	0.01 U	0.276	0.0048	0.0057	1.0 U	1.0 U	0.9
09-GRE-GRE	8:45		36.3	0.438	0.01 U	0.37	0.0074	0.0087	1.0 U	1.0 U	0.9
09-GRE-8TH	8:05		41.2	0.573	0.013	0.479	0.0127	0.011	2.0 U	1.0 U	0.9
09-GRE-277	7:45		41.4	0.486	0.013	0.422	0.0148	0.011	1.0 U	1.0 U	0.9
09-GRE-167	7:00		43.1	0.501	0.023	0.408	0.0255	0.015	1.0 U	1.0 U	0.9
09-GRE-OLD	7:55		45.0	0.527	0.03	0.413	0.0313	0.015	1.0 U	1.0 U	0.9
09-GRE-212	7:30		48.4	0.547	0.041	0.43	0.0388	0.017	1.0 U	1.0 U	1.5
09-GRE-212	7:30	Y	48.3	0.506	0.039	0.422	0.0391	0.017	1.0 U	1.2	1.6
09-GRE-180	7:05		51.8	0.572	0.05	0.429	0.0439	0.014	1.0	1.1	2.6
09-GRE-FOR	6:45		51.9	0.525	0.034	0.422	0.0506	0.016	1.0	1.2	2.5
09-GRE-COM	6:25		52.9	0.514	0.026	0.4	0.0409	0.015	1.2	1.2	1.8
09-GRE-BOE	5:55		59.9	0.521	0.031	0.394	0.0478	0.017	1.2	1.3	1.4
Green River tributaries											
09-CRI-GRE	9:10		52.0	0.741	0.01 U	0.667	0.0214	0.022	1.0 U	1.0 U	0.8
09-SOO-USG	8:30		56.7	1.2	0.023	1.06	0.0238	0.022	1.2	1.3	1.2
09-MIL-WAS	8:30		126.0	0.663	0.03	0.315	0.0753	0.0436	5.6	6.2	1.5
09-FRA-FRA	8:10		73.4	0.578	0.055	0.339	0.196	0.0957	2.9	3.2	2.7

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)	NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll *a* (ug/L)
Mainstem Newaukum Creek											
X322	7:05		57.0	1.92	0.01 U	1.8	0.0598	0.0437	2.9	2.9	1.3
E322	7:20		56.5	1.95	0.01 U	1.77	0.0493	0.0255	3.0	2.8	1.3
AN322	7:53		52.7	1.84	0.01 U	1.71	0.0406	0.0201	2.4	2.4	0.7 J
G322	8:05		50.6	2.01	0.01 J	1.95	0.0387	0.0211	1.5	1.6	0.8 J
G322	8:06	Y	51.3	2.04	0.015 J	1.97	0.0391	0.0219	2.0	1.9	0.9 J
N322	8:38		41.9	1.47	0.01 U	1.42	0.0301	0.0157	1.6	1.5	1.7 J
Newaukum Creek tributaries											
AC322	7:46		75.4	0.732	0.01 U	0.563	0.0667	0.0311	3.6	4.1	0.7 J
R322	8:21		66.8	2.23	0.0436	2.07	0.0983	0.0764	2.1	2.4	0.8 J
Q322	8:45		52.8	1.6	0.0621	1.44	0.0487	0.0267	1.7	2.0	1.2
8/1/2006 - Afternoon (15:45 to 18:00)											
Mainstem Green River											
09-GRE-DAM	17:45		22.5	0.12	0.011	0.062	0.0061	0.0068	1.0 U	1.0 U	1.4
09-GRE-KAN	17:15		23.3	0.14	0.01 U	0.074	0.0055	0.0065	1.0 U	1.0 U	1.1
09-GRE-KAN	17:15	Y	23.3	0.14	0.012	0.074	0.0056	0.0065	1.0 U	1.0 U	1.2
09-GRE-GOR	16:35		28.4	0.25	0.012	0.169	0.0045	0.0057	1.0 U	1.0 U	0.9
09-GRE-FLA	15:45		31.9	0.386	0.066	0.236	0.0047	0.0058	1.0 U	1.0 U	1.2
09-GRE-WHI	18:15		32.2	0.252	0.01 U	0.231	0.0047	0.0061	1.0 U	1.0 U	1.0
09-GRE-GRE	17:55		35.9	0.4	0.01 U	0.318	0.0079	0.0088	1.0 U	1.0 U	0.8
09-GRE-8TH	16:55		40.7	0.552	0.01 U	0.467	0.0119	0.011	1.0 U	1.0 U	0.6
09-GRE-277	16:25		41.6	0.515	0.01 U	0.434	0.0139	0.011	1.0 U	1.0 U	0.6
09-GRE-167	16:00		43.6	0.503	0.021	0.408	0.0263	0.015	1.0 U	1.0 U	0.7
09-GRE-OLD	18:00		45.3	0.51	0.027	0.401	0.0321	0.016	1.0 U	1.0 U	0.7
09-GRE-212	17:35		48.3	0.505	0.038	0.382	0.0392	0.017	1.0 U	1.0 U	1.4
09-GRE-180	17:20		51.8	0.532	0.051	0.39	0.048	0.015	1.1	1.2	6.0
09-GRE-FOR	16:50		54.3	0.533	0.039	0.4	0.047	0.014	1.1	1.2	4.0
09-GRE-COM	16:30		65.6	0.504	0.024	0.375	0.0437	0.016	1.4	1.6	2.3
09-GRE-BOE	16:15		61.4	0.513	0.021	0.369	0.0442	0.017	1.2	1.5	2.0

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)	NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll *a* (ug/L)
Green River tributaries											
09-CRI-GRE	18:30		52.5	0.755	0.01 U	0.602	0.0935	0.0737	1.0	1.1	3.3
09-SOO-USG	17:35		56.2	1.21	0.035	1.03	0.0239	0.022	1.6	1.9 J	1.1
09-MIL-WAS	18:40		126.0	0.697	0.032	0.29	0.111	0.0775	7.0	6.7	0.5
09-FRA-FRA	18:20		75.5	0.643	0.044	0.394	0.185	0.0953	2.8	3.0	1.6
09-FRA-FRA	18:20	Y	75.8	0.647	0.047	0.394	0.181	0.0949	3.0	3.1	1.9
Mainstem Newaukum Creek											
X322	16:21		56.6	1.89	0.01 U	1.78	0.0575	0.042	2.3	2.4	1.6
E322	16:34		53.6	1.9	0.01 U	1.77	0.0521	0.0298	2.4	2.5	1.8
AN322	17:05		52.5	1.88	0.01 U	1.71	0.0426	0.0223	2.0	1.9	0.5 U
G322	17:21		50.1	1.95	0.01 U	1.92	0.0422	0.0215	1.7	1.6	0.5 U
N322	17:50		42.2	1.45	0.01 U	1.4	0.0296	0.0156	1.3	1.4	1.3
N322	17:55	Y	42.1	1.44	0.01 U	1.41	0.0322	0.0157	1.4	1.3	1.2
Newaukum Creek tributaries											
AC322	16:57		60.2	0.773	0.01 U	0.54	0.0729	0.033	3.0	3.2	1.0 U
R322	17:40		64.3	2.3	0.0232	2.14	0.0902	0.0676	2.2	2.0	0.5 U
Q322	18:00		52.9	1.66	0.0482	1.4	0.051	0.0302	1.7	1.7	0.5 U

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)		NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)		TOC (mg/L)		Chlorophyll *a* (ug/L)	
8/2/2006 - Morning (05:55 to 8:44)															
Mainstem Green River															
09-GRE-DAM	8:35		23	0.14	0.014		0.065	0.0064	0.007	1.0	U	1.0	U	1.3	
09-GRE-DAM	8:35	Y	22.8	0.13	0.014		0.066	0.0061	0.0076	1.0	U	1.0	U	1.2	
09-GRE-KAN	8:05		24	0.14	0.01	U	0.083	0.0054	0.0067	1.0	U	1.0	U	1.1	
09-GRE-GOR	7:25		27.9	0.256	0.01	U	0.167	0.0045	0.0058	1.0	U	1.0	U	1.1	
09-GRE-FLA	6:45		32.4	0.337	0.01	U	0.26	0.0038	0.0059	1.0	U	1.0	U	1.1	
09-GRE-WHI	8:44		32.2	0.326	0.01	U	0.251	0.0042	0.0072	1.0	U	1.0	U	1.1	
09-GRE-GRE	8:15		36.6	0.437	0.01	U	0.343	0.0077	0.0085	1.0	U	1.0	U	1.2	
09-GRE-GRE	8:15	Y	36.3	0.431	0.01	U	0.342	0.0075	0.0083	1.0	U	1.0	U	1.1	
09-GRE-8TH	7:15		40.7	0.546	0.01	U	0.456	0.0124	0.011	1.0	U	1.0	U	0.9	
09-GRE-277	6:50		41.4	0.513	0.012		0.401	0.0152	0.011	1.0	U	1.0	U	1.0	
09-GRE-167	6:25		43.4	0.492	0.022		0.397	0.0261	0.015	1.0	U	1.0	U	0.9	
09-GRE-OLD	7:45		45	0.53	0.027		0.401	0.0306	0.015	1.0	U	1.0	U	0.9	
09-GRE-212	7:25		48.4	0.545	0.039		0.408	0.0378	0.017	1.0	U	1.0		1.5	
09-GRE-180	7:00		51.9	0.54	0.044		0.403	0.0429	0.014	1.0		1.2		3.2	
09-GRE-FOR	6:25		52.8	0.535	0.033		0.399	0.0443	0.016	1.1		1.2		3.0	
09-GRE-COM	6:40		54.6	0.5	0.022		0.379	0.0425	0.014	1.2		1.2		2.3	
09-GRE-BOE	5:55		59.6	0.493	0.03		0.376	0.0474	0.016	1.3		1.4		1.7	
Green River tributaries															
09-CRI-GRE	8:55		52.4	0.766	0.012		0.632	0.0487	0.0353	1.0	U	1.0	U	2.4	
09-SOO-USG	7:40		56.2	1.2	0.025		1.01	0.0236	0.021	1.1		1.3		0.9	
09-MIL-WAS	8:15		128	0.662	0.029		0.285	0.0789	0.0503	6.1		6.2		1.2	
09-FRA-FRA	7:55		74	0.601	0.048		0.346	0.191	0.0998	3.0		3.0		2.4	
Mainstem Newaukum Creek															
X322	7:14		56.9	2.09	0.01	U	1.81	0.0566	0.0422	2.1		2.6		1.0	J
X322	7:15	Y	56.9	1.96	0.01	U	1.8	0.0545	0.0417	2.1		2.4		1.2	
E322	7:31		54.3	2.03	0.01	J	1.76	0.0468	0.0247	2.2		2.6		1.1	
AN322	7:53		53.1	1.86	0.01	U	1.73	0.0358	0.0198	2.0		1.8		1.0	U
G322	8:18		51.0	2.11	0.01	U	1.97	0.0353	0.0203	1.4		1.6		0.7	U
N322	8:55		42.0	1.48	0.01	U	1.42	0.0277	0.0151	1.3		1.2		1.1	

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)	NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll *a* (ug/L)
Newaukum Creek tributaries											
AC322	7:45		61.3	0.761	0.01 U	0.55	0.0579	0.0324	2.9	2.9	0.5 U
R322	8:46		63.5	2.37	0.0324	2.21	0.0789	0.0618	1.9	1.9	0.5 U
Q322	9:01		53.1	1.59	0.0488	1.44	0.0455	0.0296	1.6	1.8	0.9 J
8/2/2006 - Afternoon (16:10 to 18:45)											
Mainstem Green River											
09-GRE-DAM	17:55		22.7	0.12	0.012	0.058	0.0063	0.0063	1.0 U	1.0 U	1.0
09-GRE-KAN	17:30		23.1	0.14	0.01 U	0.067	0.0055	0.0059	1.0 U	1.0 U	1.1
09-GRE-GOR	16:55		28	0.22	0.01 U	0.15	0.0046	0.0051	1.0 U	1.0 U	0.9
09-GRE-FLA	16:10		31.7	0.313	0.014	0.215	0.0052	0.0056	1.0 U	1.0 U	1.0
09-GRE-FLA	16:10	Y	31.5	0.299	0.01 U	0.215	0.0044	0.005	1.0 U	1.0 U	1.0
09-GRE-WHI	18:10		31.8	0.291	0.01 U	0.208	0.0051	0.0053	1.0 U	1.0 U	1.0
09-GRE-GRE	17:30		35.5	0.361	0.01 U	0.287	0.0075	0.0081	1.0 U	1.0 U	0.8
09-GRE-8TH	16:45		40.5	0.529	0.01 U	0.427	0.0115	0.01	1.0 U	1.0 U	0.6
09-GRE-277	16:20		39.5	0.468	0.01 U	0.401	0.0137	0.011	1.0 U	1.1	0.7
09-GRE-167	16:00		43.3	0.495	0.02	0.386	0.0242	0.014	1.0 U	1.0 U	0.9
09-GRE-OLD	18:15		44.8	0.48	0.024	0.381	0.03	0.015	1.0 U	1.0 U	0.8
09-GRE-OLD	18:15	Y	44.5	0.494	0.025	0.379	0.0313	0.015	1.0 U	1.0 U	0.6
09-GRE-212	17:55		47.6	0.496	0.033	0.371	0.038	0.016	1.0 U	1.1 J	1.3
09-GRE-180	17:30		51.5	0.51	0.04	0.377	0.0436	0.014	1.0 U	1.2	3.4
09-GRE-FOR	17:15		53.4	0.5	0.038	0.387	0.0423	0.013	1.0	1.2	6.3
09-GRE-COM	16:55		62.5	0.511	0.025	0.351	0.0423	0.015	1.4	1.4	2.0
09-GRE-BOE	16:35		63.1	0.498	0.022	0.35	0.0458	0.015	1.3	1.4	2.4
Green River tributaries											
09-CRI-GRE	18:30		51.4	0.792	0.027	0.639	0.0354	0.0308	1.0 U	1.0 U	1.0
09-SOO-USG	17:15		55.8	1.23	0.03	0.998	0.023	0.021	1.1	1.4	1.2
09-MIL-WAS	18:45		127	0.544	0.022	0.258	0.075	0.0483	5.9	5.9	0.4
09-FRA-FRA	18:30		76.1	0.642	0.045	0.375	0.187	0.0957	2.8	2.9	1.6

Station	Time	Rep.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)		NO_2NO_3 (mg/L)	TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll *a* (ug/L)	
Mainstem Newaukum Creek													
X322	16:04		55.7	1.97	0.01	U	1.76	0.0561	0.0406	2.5	2.4	1.7	
E322	16:24		53.3	1.92	0.01	U	1.74	0.0466	0.0275	2.3	2.4	1.5	
AN322	16:50		51.4	1.87	0.01	U	1.68	0.041	0.0216	2.1	2.4	0.8	J
G322	17:05		49.3	2.04	0.01	U	1.91	0.0395	0.0219	1.7	1.6	0.6	J
N322	17:44		41.1	1.5	0.01	U	1.36	0.0292	0.0135	1.4	1.5	1.3	
Newaukum Creek tributaries													
AC322	16:42		58.7	0.78	0.01	U	0.533	0.0687	0.0333	3.0	3.6	0.6	J
R322	17:25		61.7	2.45	0.019	J	2.17	0.097	0.0596	1.9	2.3	2.2	
Q322	17:52		51.8	1.6	0.0424		1.35	0.048	0.0321	1.8	2.4	0.8	J

Rep = replicate

Table B-2. Periphyton chlorophyll *a* and ash free dry weight (AFDW) summary data.

Station*		PERIPHYTON			
		Chlorophyll *a* (mg/m^2)	average	AFDW (g/m^2)	average
Collected 7/24 and 7/27 2006					
Mainstem Green River					
09-GRE-DAM	R	12.8		4.2	
09-GRE-DAM	C	26.7		9.3	
09-GRE-DAM	L	18.3	**19.3**	4.7	**6.1**
09-GRE-KAN	R	16.4		3.8	
09-GRE-KAN	C	25.1		6.9	
09-GRE-KAN	L	42.7	**28.1**	12.1	**7.6**
09-GRE-WHI	R	81.2		8.2	
09-GRE-WHI	C	50.6		8.0	
09-GRE-WHI	L	40.4	**57.4**	6.0	**7.4**
09-GRE-WHI***	R	34.8		10.6	
09-GRE-WHI***	C	17.1		6.7	
09-GRE-WHI***	L	11.9	**21.3**	5.3	**7.5**
09-GRE-GRE	R	11.2		5.9	
09-GRE-GRE	C	2.5		1.9	
09-GRE-GRE	L	4.0	**5.9**	1.6	**3.1**
09-GRE-277	R	4.4		5.6	
09-GRE-277	C	1.9		3.7	
09-GRE-277	L	6.6	**4.3**	4.4	**4.6**
09-GRE-180	R	25.2		50.2	
09-GRE-180	L	21.4	**23.3**	8.5	**29.4**

Station*		PERIPHYTON			
		Chlorophyll *a* (mg/m^2)	average	AFDW (g/m^2)	average
Green River Tributaries					
09-SOO-USG	R	16.0		18.3	
09-SOO-USG	C	34.4		16.6	
09-SOO-USG	L	27.7	26.0	6.8	13.9
09-MIL-WAS	R	18.6		57.3	
09-MIL-WAS	C	54.7		47.5	
09-MIL-WAS	L	32.6	35.3	74.4	59.7
Collected 8/1 and 8/2 2006					
Mainstem Newaukum Creek					
X322	R	34.3		53.3	
X322	C	33.6		51.0	
X322	L	46.7	**38.2**	57.9	**54.1**
E322	R	20.6		9.1	
E322	C	5.0		NAF**	
E322	L	6.7	**10.8**	3.3	**6.2**
AN322	R	2.9		0.6	
AN322	C	4.8		0.9	
AN322	L	1.1	**3.0**	0.4	**0.6**
AN322***	R	4.9		1.1	
AN322***	C	13.8		1.6	
AN322***	L	1.5	**6.7**	0.4	**1.0**
G322	R	61.9		164.1	
G322	C	62.2		108.5	
G322	L	54.2	**59.4**	52.2	**108.3**
N322	R	5.1		2.5	
N322	C	12.2		4.7	
N322	L	8.5	**8.6**	2.9	**3.3**

Station*		PERIPHYTON			
		Chlorophyll *a* (mg/m^2)	average	AFDW (g/m^2)	average
Newaukum Creek tributaries					
R322	R	32.8		5.0	
R322	C	57.8		10.0	
R322	L	76.7	**55.8**	10.1	**8.4**

* Indicates if the pebble was taken from the right bank (R), center of stream (C), or left bank (L).
** Not analyzed for.
*** Replicate.

Appendix C. Field Measurements

Table C-1. Ecology's and King County's *in situ* multi-probe field measurements. Highlighted values indicate possible errors due to a faulty DO membrane.

Station	Time	Temp (°C)	Cond (uS/cm)	pH	DO* (mg/L)
8/1/2006 - Morning					
Mainstem Green River					
09-GRE-DAM	8:25	14	43.2	7.22	9.91
09-GRE-KAN	8:00	13.71	45.7	7.85	10.2
09-GRE-GOR	7:25	15.08	59.1	7.87	9.85
09-GRE-FLA	6:30	13.25	68.1	7.85	10.34
09-GRE-WHI	9:30	13.73	69.1	8.22	0.99
09-GRE-GRE	8:45	13.76	78.9	7.96	3.11
09-GRE-8TH	8:05	14.56	90.1	7.85	7.83
09-GRE-277	7:45	15.81	91.8	7.86	8.59
09-GRE-167	7:00	16.41	96.3	7.95	8.45
09-GRE-OLD	7:55	16.19	108.1	7.37	8.6
09-GRE-212	7:30	16.06	130.8	7.32	8.37
09-GRE-180	7:05	15.94	155	7.28	8.13
09-GRE-FOR	6:45	16.28	154	7.39	7.86
09-GRE-COM	6:25	17.54	248	7.54	8.15
09-GRE-BOE	5:55	18.2	1158	7.57	8.7
Green River tributaries					
09-CRI-GRE	9:10	10.9	114	8.21	3.07
09-SOO-USG	8:30	12.72	133.3	8.1	5.87
09-MIL-WAS	8:30	15.39	280	7.5	6.93
09-FRA-FRA	8:10	16.81	180	7.36	6.7

Station	Time	Temp (°C)	Cond (uS/cm)	pH	DO* (mg/L)
Mainstem Newaukum Creek					
X322	7:05	12.2	161	8.2	10.2
E322	7:20	11.7	152	8.0	10.0
AN322	7:53	11.6	145	7.5	8.7
G322	8:05	10.5	143	7.5	8.8
N322	8:38	9.8	108	7.9	10.4
Newaukum Creek tributaries					
AC322	7:46	10.9	160	7.5	4.2
R322	8:21	11.2	193	7.5	7.1
Q322	8:45	10.4	134	7.7	9.0
8/1/2006 - Afternoon					
Mainstem Green River					
09-GRE-DAM	17:45	16.36	43.2	7.93	9.13
09-GRE-KAN	17:15	16.76	44.7	8.02	9.41
09-GRE-GOR	16:35	16.1	58.2	8.13	9.57
09-GRE-FLA	15:45	17.88	68.4	8.56	10.66
09-GRE-WHI	18:15	19.67	69.9	8.55	8.53
09-GRE-GRE	17:55	18.09	78.8	8.02	8.45
09-GRE-8TH	16:55	16.61	90.1	7.82	8.19
09-GRE-277	16:25	16.86	92	7.86	9.12
09-GRE-167	16:00	17.44	97.2	7.76	8.68
09-GRE-OLD	18:00	17.82	108.6	7.45	9.4
09-GRE-212	17:35	18.49	133.1	7.4	9.76
09-GRE-180	17:20	18.83	160	7.52	9.67
09-GRE-FOR	16:50	18.81	165	7.4	9.93
09-GRE-COM	16:30	18.25	205	7.58	8.75
09-GRE-BOE	16:15	18.69	6250	7.29	8.35
Green River tributaries					
09-CRI-GRE	18:30	14.74	116.2	8.25	8.95
09-SOO-USG	17:35	16.29	155	8.21	9.24
09-MIL-WAS	18:40	17.77	282	7.6	6.84
	18:20	17.37	184	7.36	6.74

Station	Time	Temp (°C)	Cond (uS/cm)	pH	DO* (mg/L)
Mainstem Newaukum Creek					
X322	16:21	15.4	159	8.1	9.4
E322	16:34	14.0	150	8.2	10.0
AN322	17:05	13.1	145	7.5	9.5
G322	17:21	12.6	139	7.2	9.8
N322	17:50	12.7	108	7.9	9.7
Newaukum Creek tributaries					
AC322	16:57	12.6	157	7.1	4.2
R322	17:40	14.2	190	7.5	8.8
Q322	18:00	15.8	135	7.7	9.0
8/2/2006 - Morning					
Mainstem Green River					
09-GRE-DAM	8:35	14.25	43	7.64	9.65
09-GRE-KAN	8:05	13.87	44.9	7.77	9.54
09-GRE-GOR	7:25	14.68	56.3	7.88	9.46
09-GRE-FLA	6:45	13.63	66.2	7.69	9.92
09-GRE-WHI	8:44	13.86	68.8	8.07	9.18
09-GRE-GRE	8:15	14.24	78.8	7.81	8.33
09-GRE-8TH	7:15	15.34	90.2	7.72	7.35
09-GRE-277	6:50	16.33	92	7.78	7.79
09-GRE-167	6:25	16.5	98.2	7.84	7.54
09-GRE-OLD	7:45	16.14	108.7	7.37	8.61
09-GRE-212	7:25	16.12	131.1	7.35	8.57
09-GRE-180	7:00	16.44	159	7.46	7.94
09-GRE-FOR	6:25	16.91	158	7.63	7.75
09-GRE-COM	6:40	17.99	263	7.36	8.12
09-GRE-BOE	5:55	17.87	1400	7.51	8.95
Green River tributaries					
09-CRI-GRE	8:55	11.29	113	8.06	9.38
09-SOO-USG	7:40	13.02	132.2	8.02	9.1
09-MIL-WAS	8:15	15.54	281	7.51	6.81
09-FRA-FRA	7:55	17.01	180	7.32	6.7

Station	Time	Temp (°C)	Cond (uS/cm)	pH	DO* (mg/L)
Mainstem Newaukum Creek					
X322	7:14	12.4	163	8.0	10.4
E322	7:31	11.9	154	7.8	10.1
AN322	7:53	11.7	147	7.4	8.8
G322	8:18	10.7	143	7.4	9.0
N322	8:55	10.1	109	7.7	10.3
Newaukum Creek tributaries					
AC322	7:45	11.0	158	7.3	4.3
R322	8:46	11.2	185	7.4	7.7
Q322	9:01	10.9	134	7.6	9.6
8/2/2006 - Afternoon					
Mainstem Green River					
09-GRE-DAM	17:55	16.87	43.4	7.88	9.09
09-GRE-KAN	17:30	17.53	44.6	8.01	9.23
09-GRE-GOR	16:55	16.1	57	8.13	9.41
09-GRE-FLA	16:10	17.72	66.4	8.46	9.8
09-GRE-WHI	18:10	18.39	68.5	8.55	8.6
09-GRE-GRE	17:30	17.76	77.4	8.03	8.53
09-GRE-8TH	16:45	16.59	89.4	7.76	8.46
09-GRE-277	16:20	16.75	91.3	7.8	9.17
09-GRE-167	16:00	17.17	96	7.71	8.66
09-GRE-OLD	18:15	17.69	108.2	7.14	9.5
09-GRE-212	17:55	18.26	135.2	7.53	9.68
09-GRE-180	17:30	18.31	154	7.75	9.85
09-GRE-FOR	17:15	18.37	160	7.74	10.15
09-GRE-COM	16:55	18.64	198	7.61	8.66
09-GRE-BOE	16:35	19.12	5210	7.51	8.94
Green River tributaries					
09-CRI-GRE	18:30	14.04	114.5	8.3	8.41
09-SOO-USG	17:15	15.72	132.5	8.29	8.96
09-MIL-WAS	18:45	17.5	284	7.53	7.05
09-FRA-FRA	18:30	17.47	184	7.61	7

Station	Time	Temp (°C)	Cond (uS/cm)	pH	DO* (mg/L)
Mainstem Newaukum Creek					
X322	16:04	15.3	162	8.1	9.8
E322	16:24	13.9	151	8.1	10.0
AN322	16:50	13.1	147	7.4	9.4
G322	17:05	12.6	142	7.4	9.8
N322	17:44	12.7	109	7.7	9.7
Newaukum Creek tributaries					
AC322	16:42	12.5	158	7.2	3.8
R322	17:25	14.1	185	7.0	8.3
Q322	17:52	15.7	136	7.6	9.1

*Dissolved oxygen values for Newaukum Creek and its tributaries were backcalculated from the percent saturation and should be considered estimates.

Table C-2. Green/Newaukum flow measurement summary from July and August 2006.

Ecology and King County Flow Measurements										
Site	Rep.	Date Time	River Mile	Wet Width (ft)	Wet Perimeter (ft)	Cross-sectional area (ft^2)	Avg. Depth (ft)	Avg. Velocity (ft/s)	Discharge (cfs)	Description
09-GRE-DAM		080106 1050	60.9	39.1	41.8	40.9	1.0	1.5	**60.9**	Below Tacoma headworks dam, in rapids
09-GRE-KAN		080106 1220	57.6	79.1	81.0	119.5	1.4	1.3	**160**	Downstream of Cumberland Kanaskat Road
09-GRE-FLA		080106 1440	43.1	94.2	95.9	194.1	1.7	1.0	**200**	Flaming Geyser State Park, upstream of bridge
09-GRE-WHI		080106 1250	41.4	140.0	140.2	133.1	0.9	1.7	**219**	At Whitney Bridge (212th Way SE)
Newaukum Ck			40.7							
09-CRI-GRE		080106 1340	40.1	13.2	13.9	12.3	1.0	0.5	**5.7**	Crisp Creek
09-CRI-GRE	Y	080106 1400	40.1	13.1	14.0	12.5	1.0	0.4	**5.3**	Crisp Creek, duplicate
09-GRE-GRE		080106 1115	35.0	131.4	131.7	162.4	1.1	1.5	**242**	At SE Green Valley Road crossing
09-GRE-DAM		080206 1420	60.9	62.2	68.7	108.3	1.6	0.6	**59.6**	Below Tacoma headworks dam, in pool
09-GRE-KAN		080206 1230	57.6	66.8	69.2	122.1	1.6	1.3	**162**	Downstream of Cumberland Kanaskat Road
09-GRE-WHI		080206 1050	41.4	142.1	142.3	133.7	0.9	1.6	**219**	At Whitney Bridge (212th Way SE)

Ecology and King County Flow Measurements										
Site	Rep.	Date Time	River Mile	Wet Width (ft)	Wet Perimeter (ft)	Cross-sectional area (ft^2)	Avg. Depth (ft)	Avg. Velocity (ft/s)	Discharge (cfs)	Description
Newaukum Ck			40.7							
09-CRI-GRE		080206 1130	40.1	13.0	14.3	12.7	1.0	0.4	**4.4**	Crisp Creek
09-GRE-GRE		080206 1220	35.0	134.2	128.1	173.6	1.2	1.4	**251**	At SE Green Valley Rd crossing
09-GRE-GRE	Y	080206 1245	35.0	134.3	128.2	176.5	1.2	1.4	**249**	At SE Green Valley Rd crossing
Soos Ck			33.8							
09-GRE-277		080206 1350	27.9	118.2	114.2	143.4	1.1	2.0	**292**	At S 277th St.
09-GRE-167		080206 1515	24.0	84.0	84.6	199.3	2.2	1.6	**310**	At Hwy 167
09-MIL-WAS		080206 1500	23.9	6.1	6.4	1.9	0.3	0.1	**0.2**	Mill Ck, enters downstream of Hwy 167
09-FRA-FRA		080206 1430	21.7	5.5	5.5	1.3	0.3	0.6	**0.8**	Mullen Slough near Frager Rd upstream of Old Fishing Hole Park
09-GRE-OLD		080206 1000	21.5	96.6	98.9	277.6	2.7	1.0	**275**	At Old Fishing Hole Park in Kent
09-GRE-180		080206 1130	14.4	80.0	81.0	212.9	2.4	1.4	**301**	At S 180th St in Tukwila

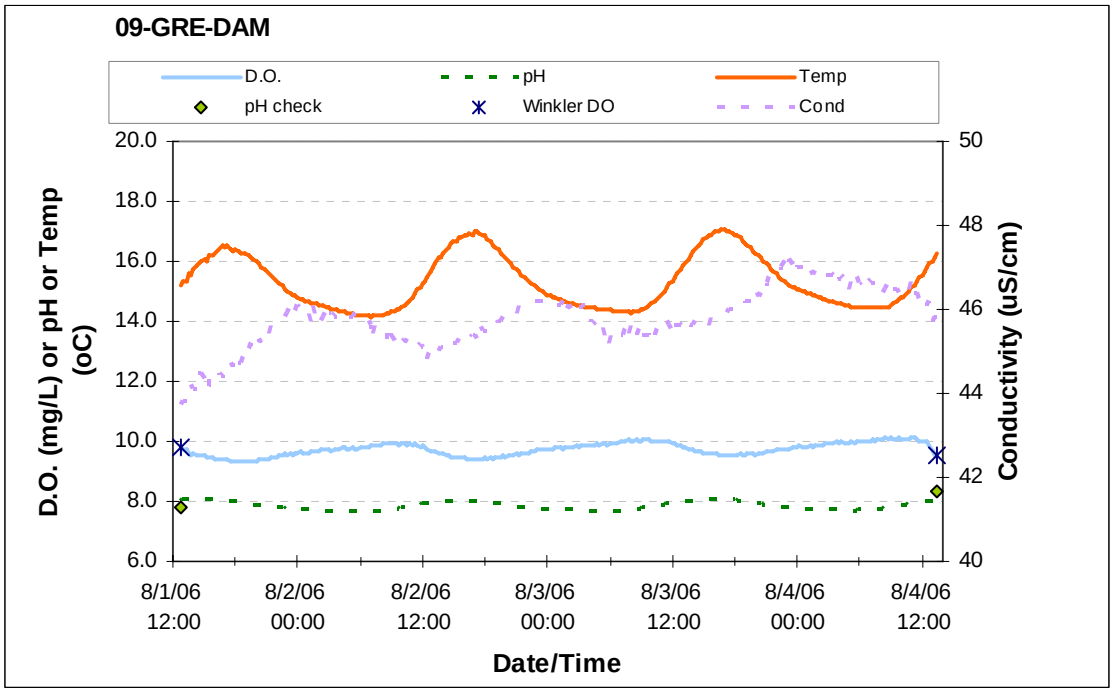
USGS Flow Measurements										
Site	Rep.	Date Time	River Mile	Wet Width (ft)		Cross-sectional area (ft^2)		Avg. Velocity (ft/s)	Discharge (cfs)	Description
USGS 12105900		073106 1106	63.8	80		183		1.23	**226**	Green River below Howard A. Hanson Dam
USGS 12106700		073106 1405	60.3	95		156		0.92	**143**	Green River at Purification Plant near Palmer
USGS 12108500		080906 1247	40.7	23		10.9		1.58	**17.2**	Newaukum Creek near Black Diamond
USGS 12112600		080906 0904	33.8	31		24		1.35	**32.3**	Big Soos Creek above Hatchery near Auburn
USGS 12113000		080206 1027	32	135		184		1.68	**310**	Green River near Auburn

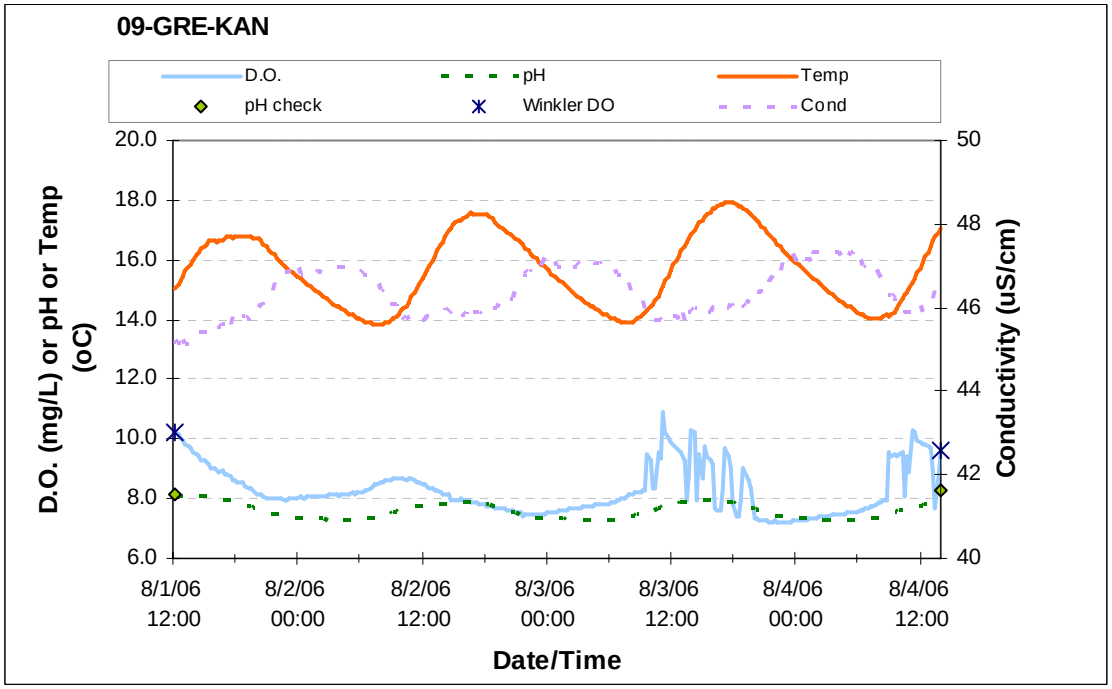
Rep = replicate

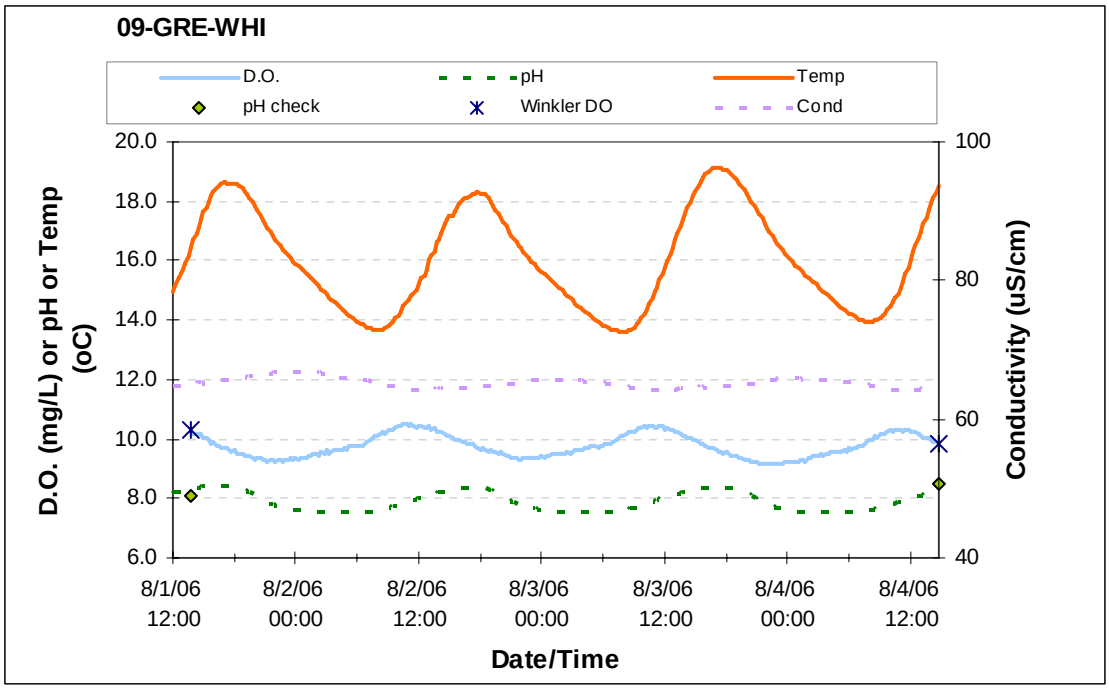
Appendix D. Datalogger Results

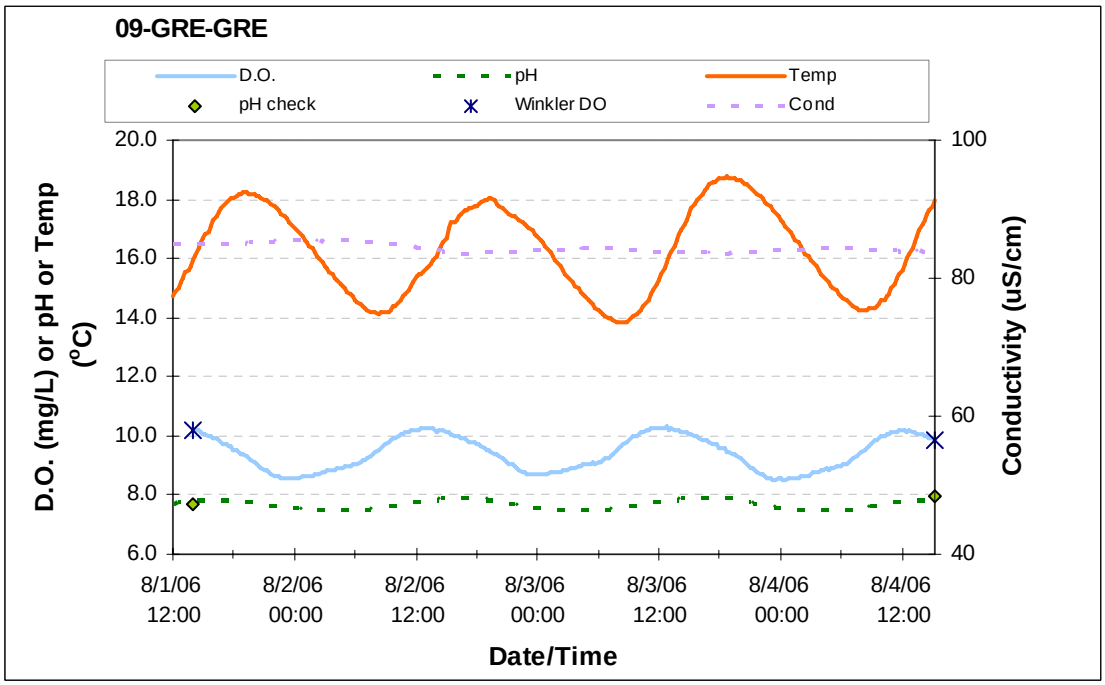
Figure D-1. Hydrolab DataSonde® pH, DO, temperature, and conductivity taken every 15 minutes from August 1 to 4, 2006.

DO measurements were corrected to match Winkler checks. pH comparisons were taken with another calibrated DataSonde®. Site identifications are provided on the graphs. Continuous DO data at 09-GRE-KAN did not meet quality control expectations and will not be used.






09-GRE-WHI
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
100
80
60
40
8/1/06 12:00
8/2/06 00:00
8/2/06 12:00
8/3/06 00:00
8/3/06 12:00
8/4/06 00:00
8/4/06 12:00
Date/Time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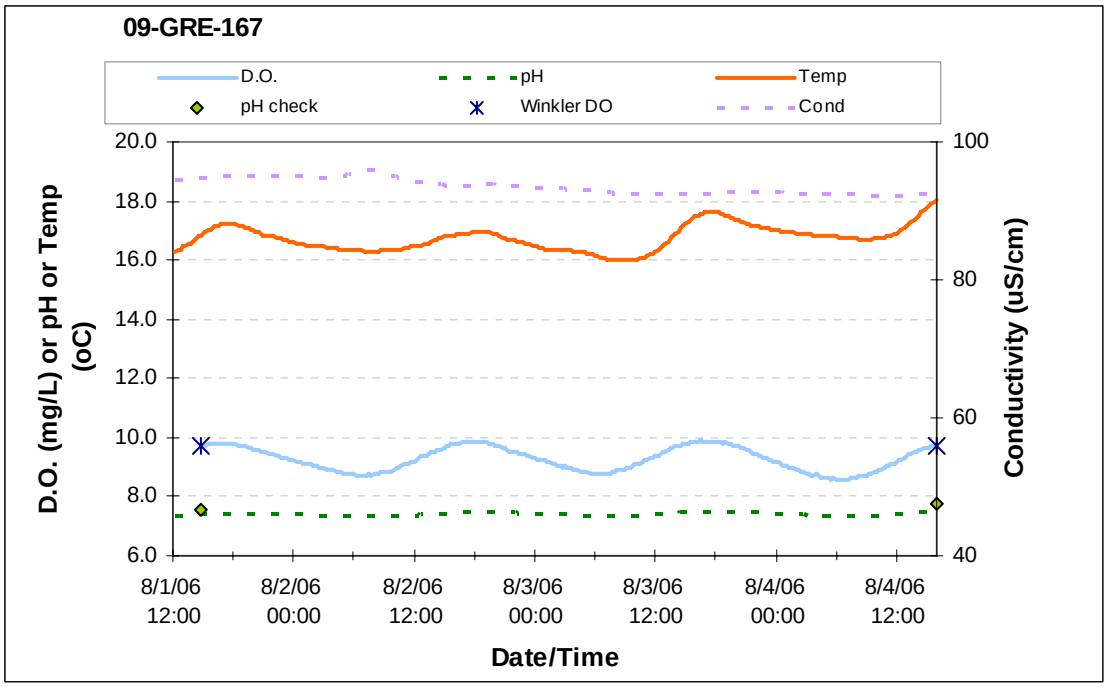
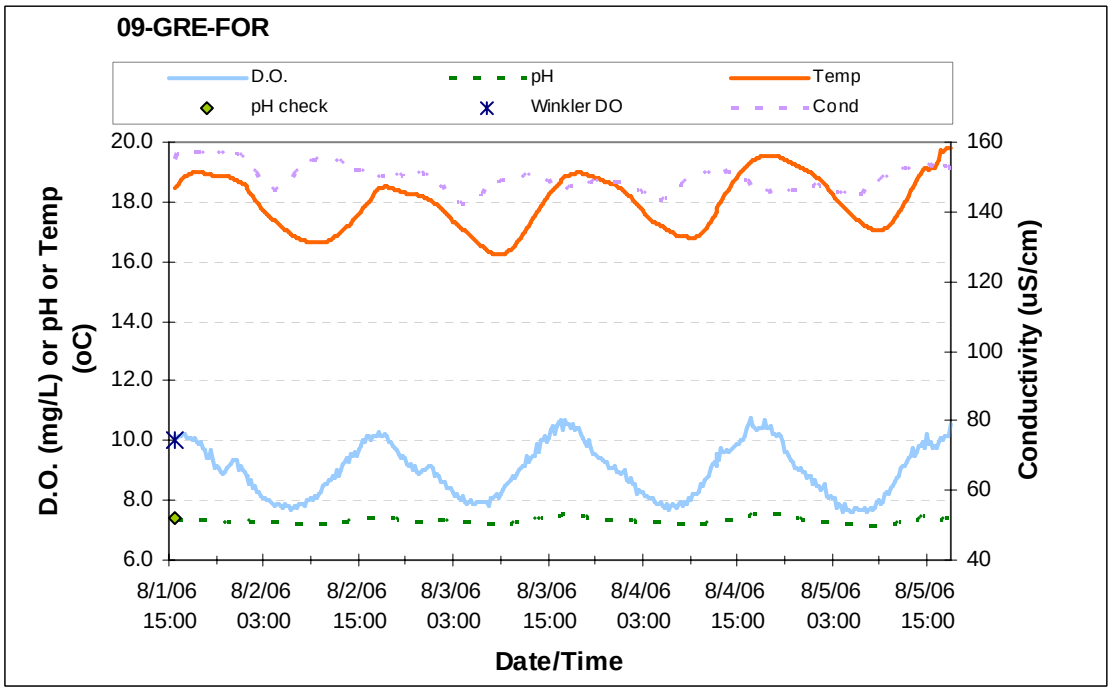
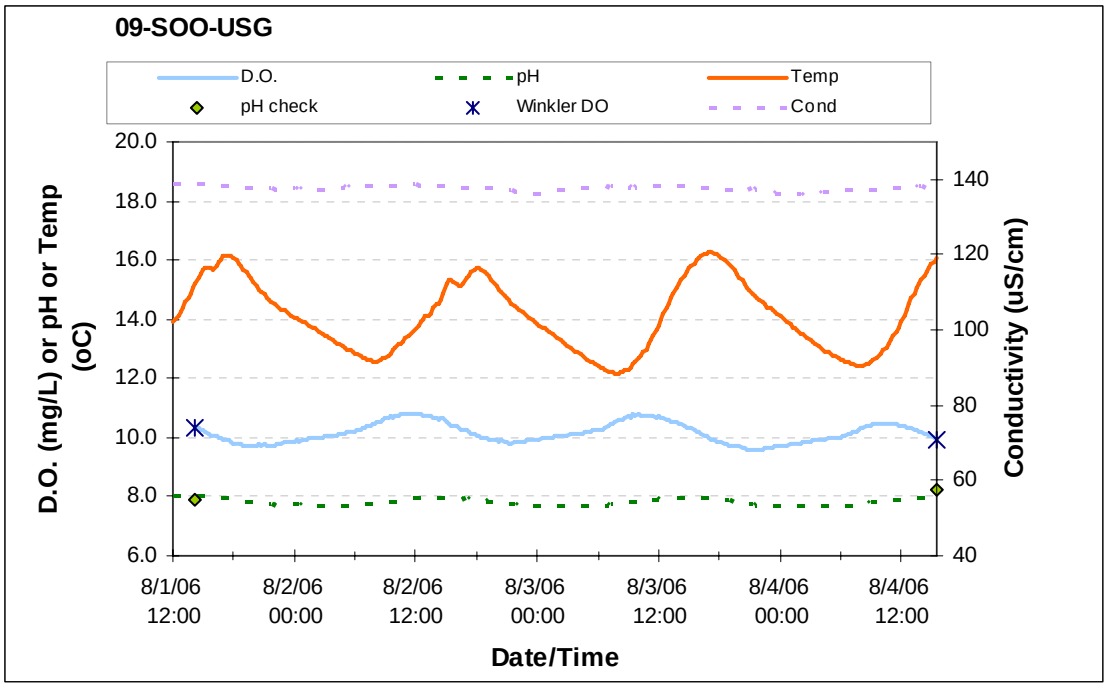
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (°C)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
100
80
60
40
8/1/06 12:00
8/2/06 00:00
8/2/06 12:00
8/3/06 00:00
8/3/06 12:00
8/4/06 00:00
8/4/06 12:00
Date/Time


09-GRE-167
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
100
80
60
40
8/1/06 12:00
8/2/06 00:00
8/2/06 12:00
8/3/06 00:00
8/3/06 12:00
8/4/06 00:00
8/4/06 12:00
Date/Time


09-GRE-FOR
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
160
140
120
100
80
60
40
8/1/06 15:00
8/2/06 03:00
8/2/06 15:00
8/3/06 03:00
8/3/06 15:00
8/4/06 03:00
8/4/06 15:00
8/5/06 03:00
8/5/06 15:00
Date/Time


09-SOO-USG
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
140
120
100
80
60
40
8/1/06 12:00
8/2/06 00:00
8/2/06 12:00
8/3/06 00:00
8/3/06 12:00
8/4/06 00:00
8/4/06 12:00
Date/Time

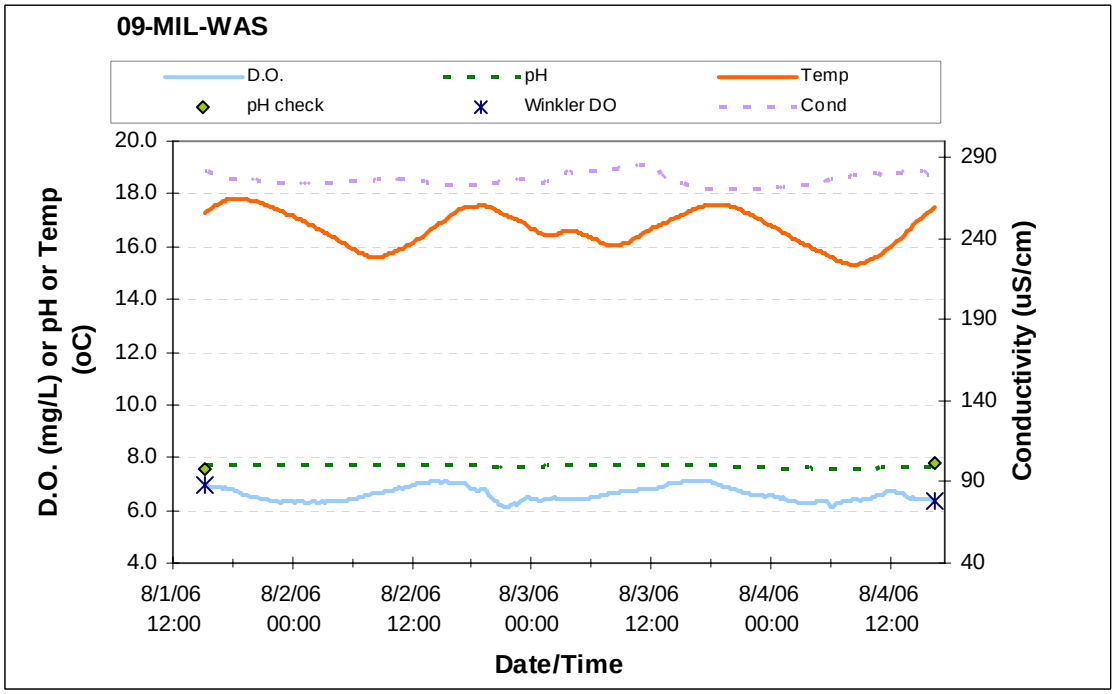
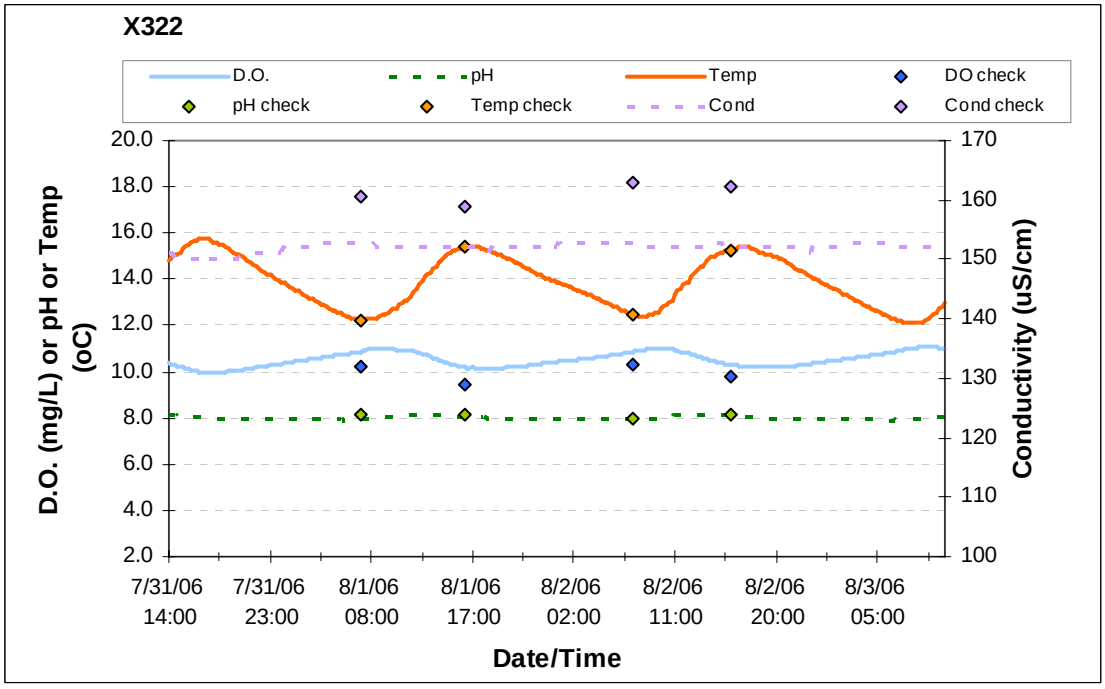
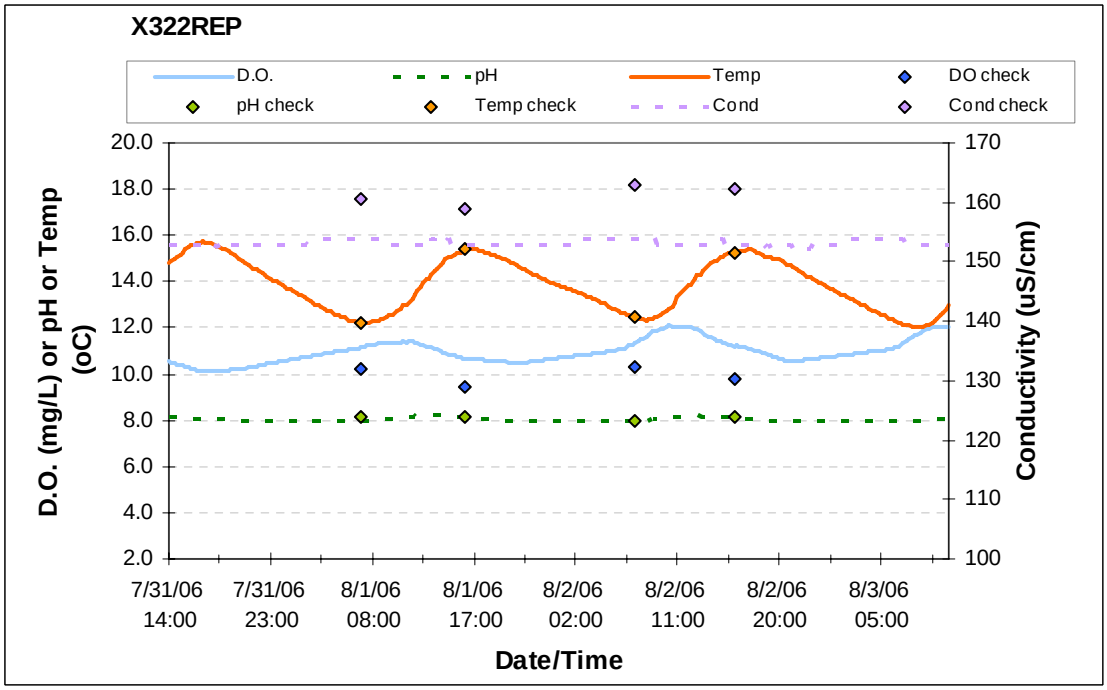
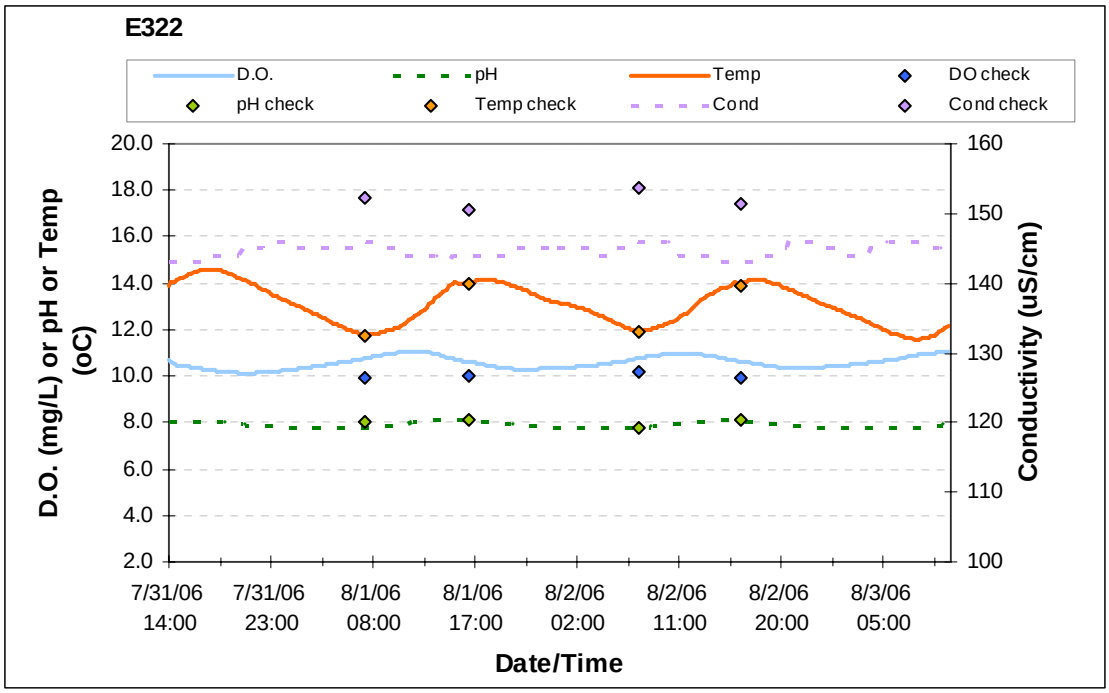

09-MIL-WAS
D.O.
pH
Temp
pH check
Winkler DO
Cond
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
290
240
190
140
90
40
8/1/06 12:00
8/2/06 00:00
8/2/06 12:00
8/3/06 00:00
8/3/06 12:00
8/4/06 00:00
8/4/06 12:00
Date/Time

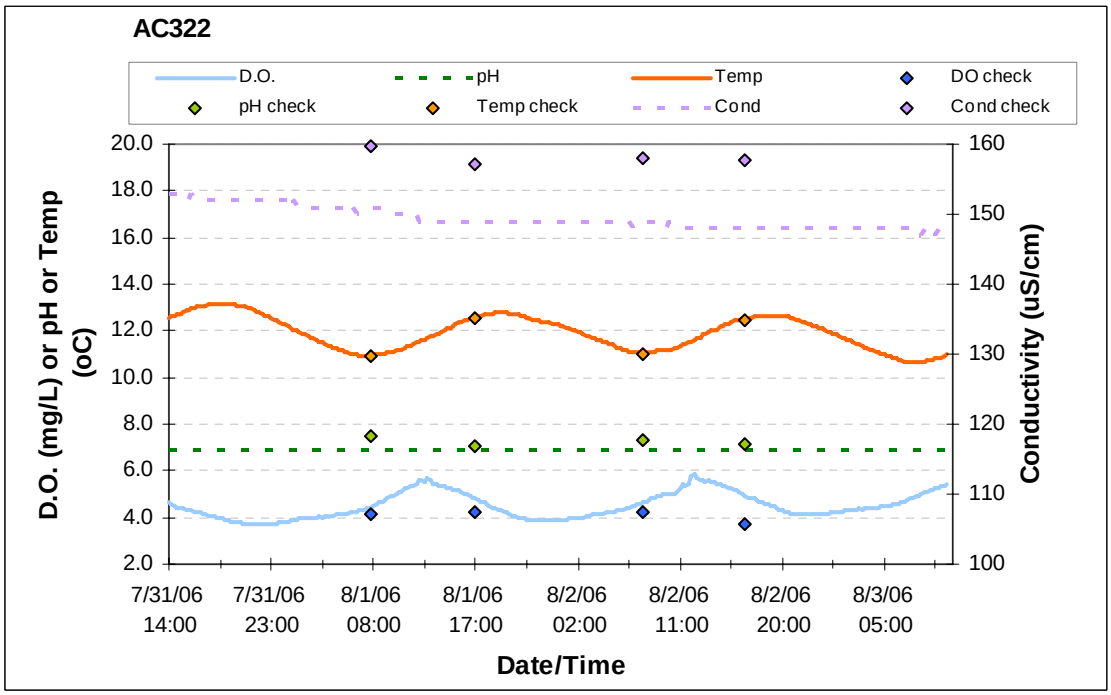
Figure D-2. King County YSI® pH, DO, temperature, and conductivity taken every 15 minutes from July 31 to August 3, 2006.

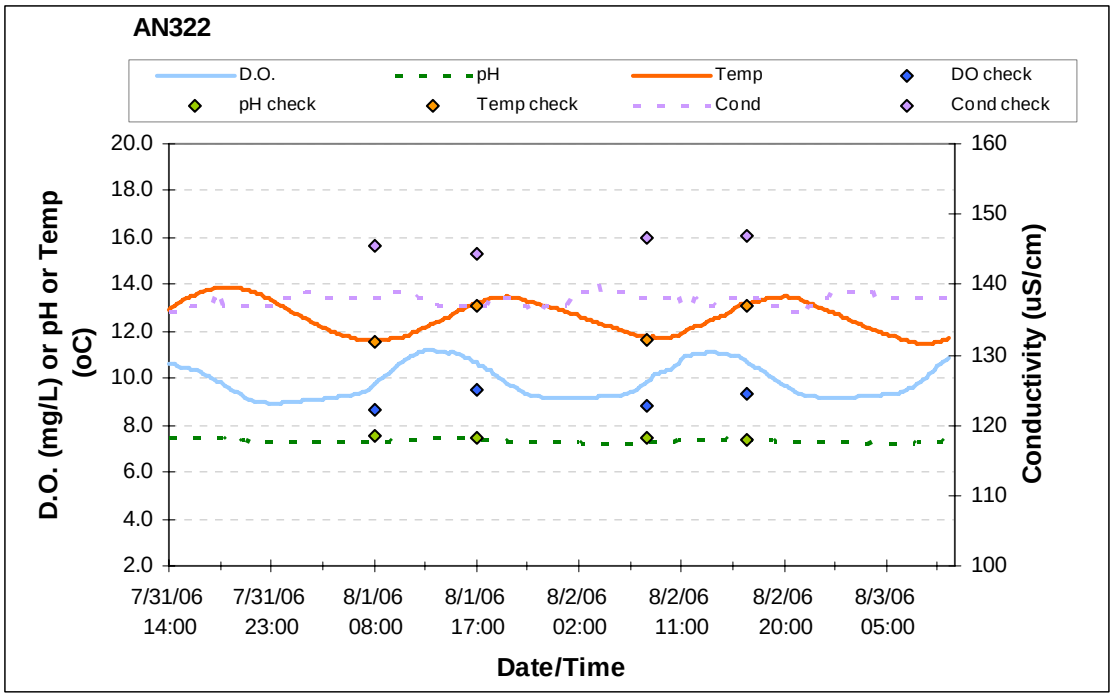
Data were checked with another calibrated YSI®. Site identifications are provided on the graphs.

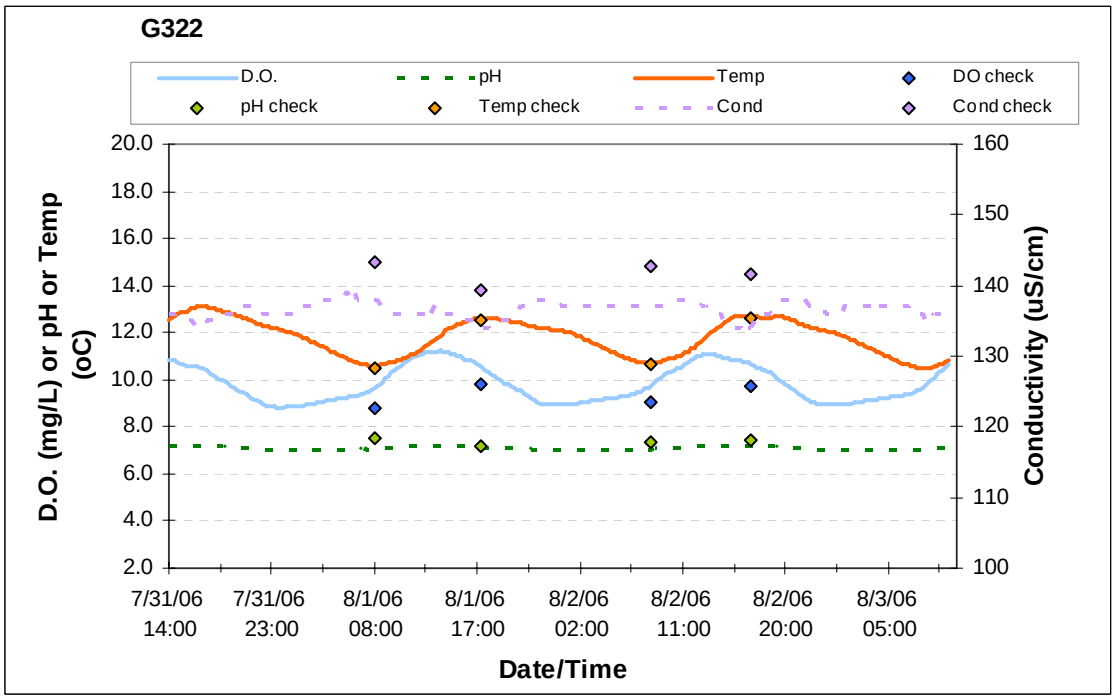


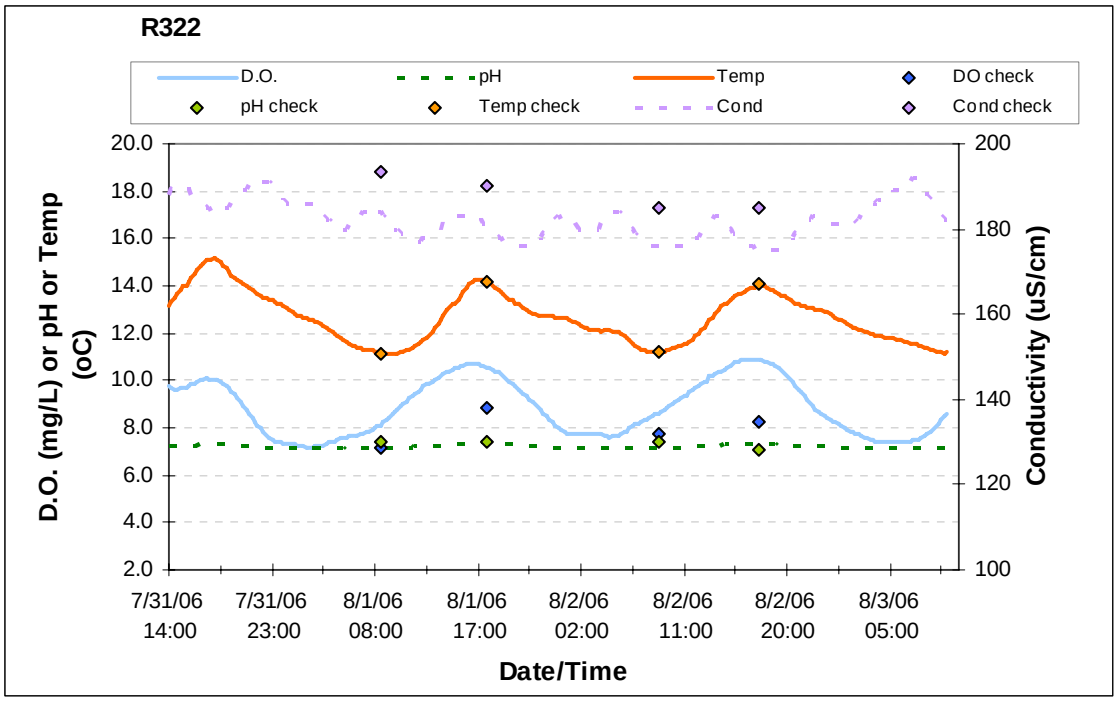


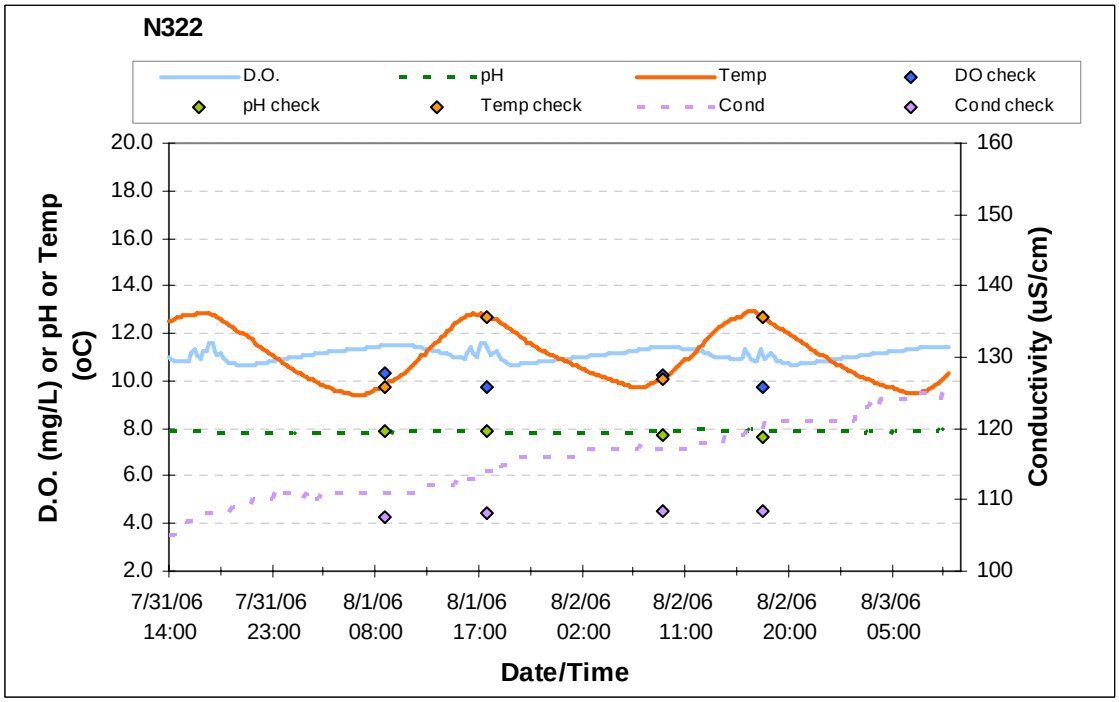

E322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time

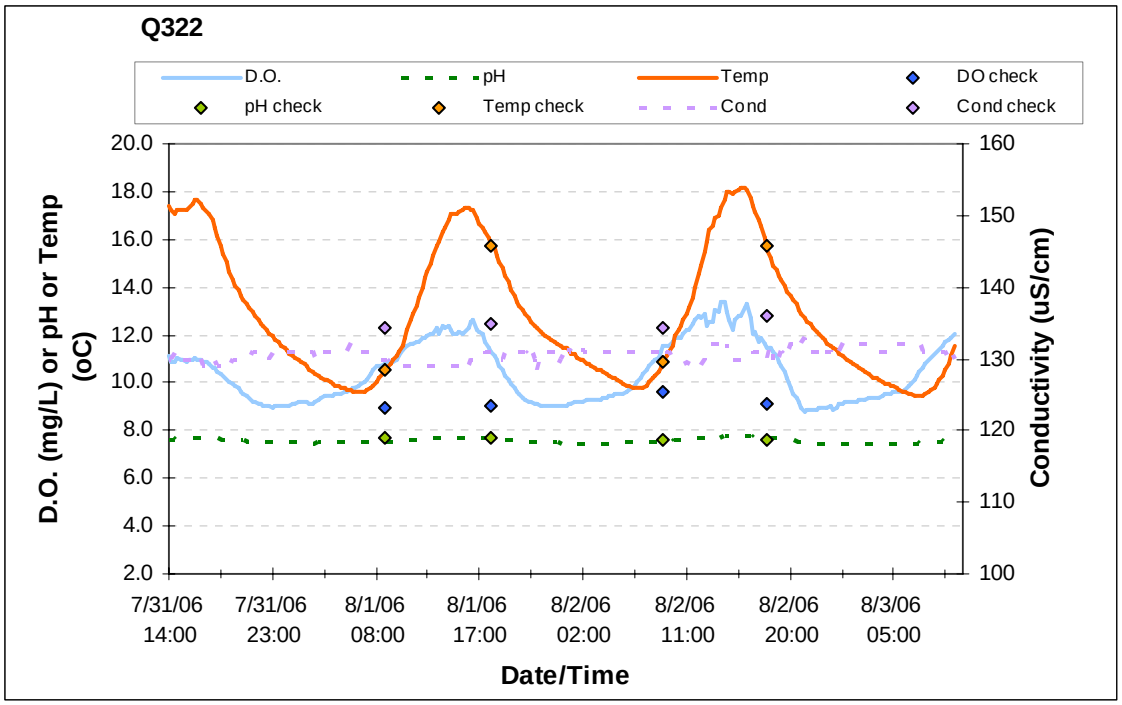

AC322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time


AN322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time


G322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time

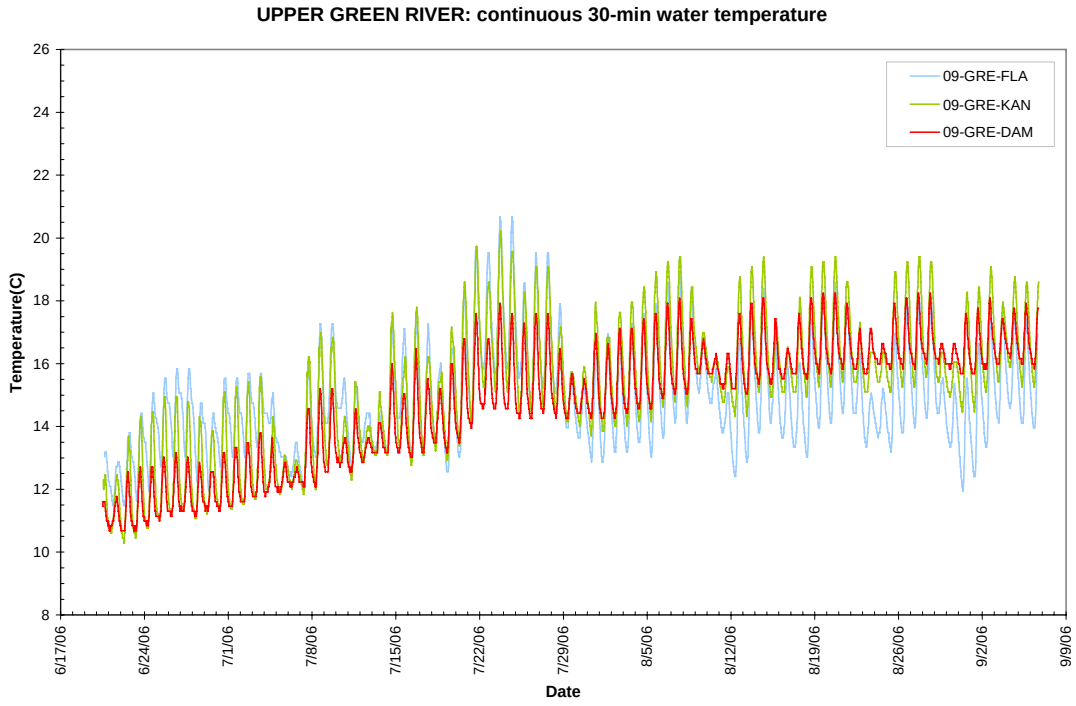

R322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
200
180
160
140
120
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time

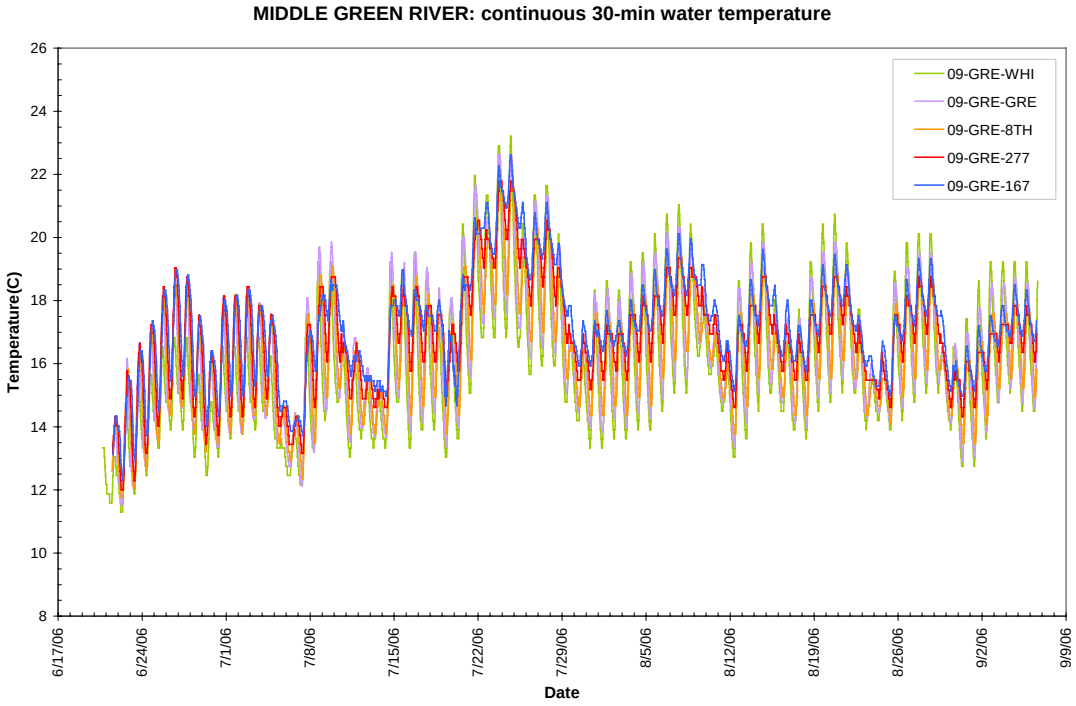

N322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time


Q322
D.O.
pH
Temp
DO check
pH check
Temp check
Cond
Cond check
D.O. (mg/L) or pH or Temp (oC)
Conductivity (uS/cm)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
160
150
140
130
120
110
100
7/31/06 14:00
7/31/06 23:00
8/1/06 08:00
8/1/06 17:00
8/2/06 02:00
8/2/06 11:00
8/2/06 20:00
8/3/06 05:00
Date/Time

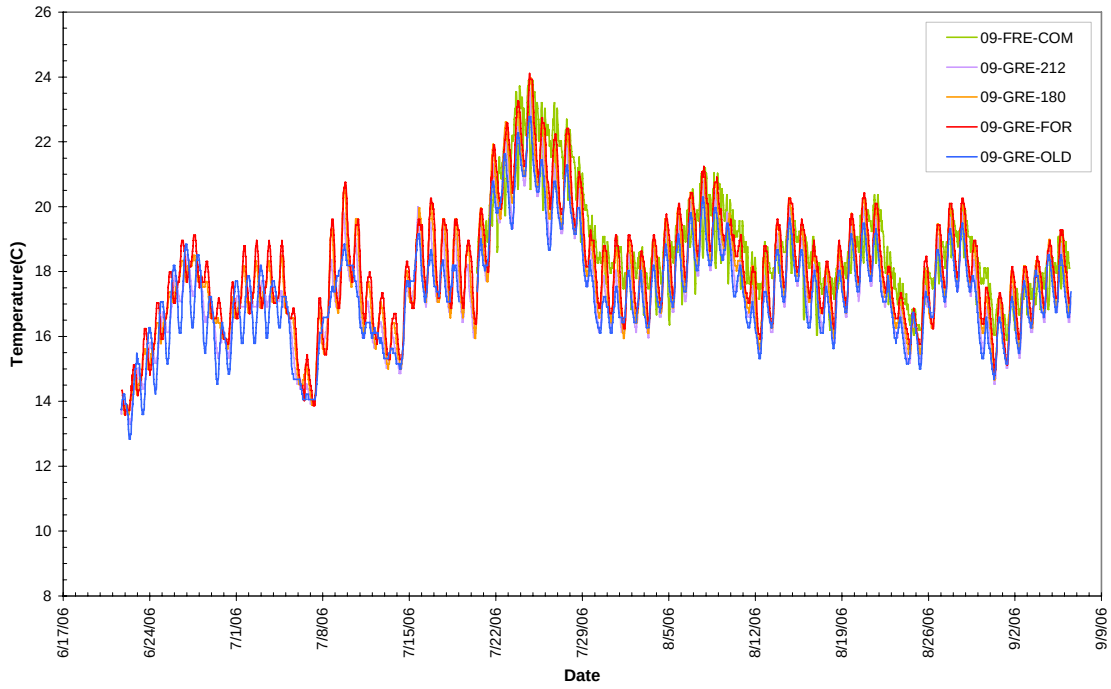
Appendix E. Temperature and Relative Humidity Figures

Figure E-1. Continuous 30-minute water temperature measurements.

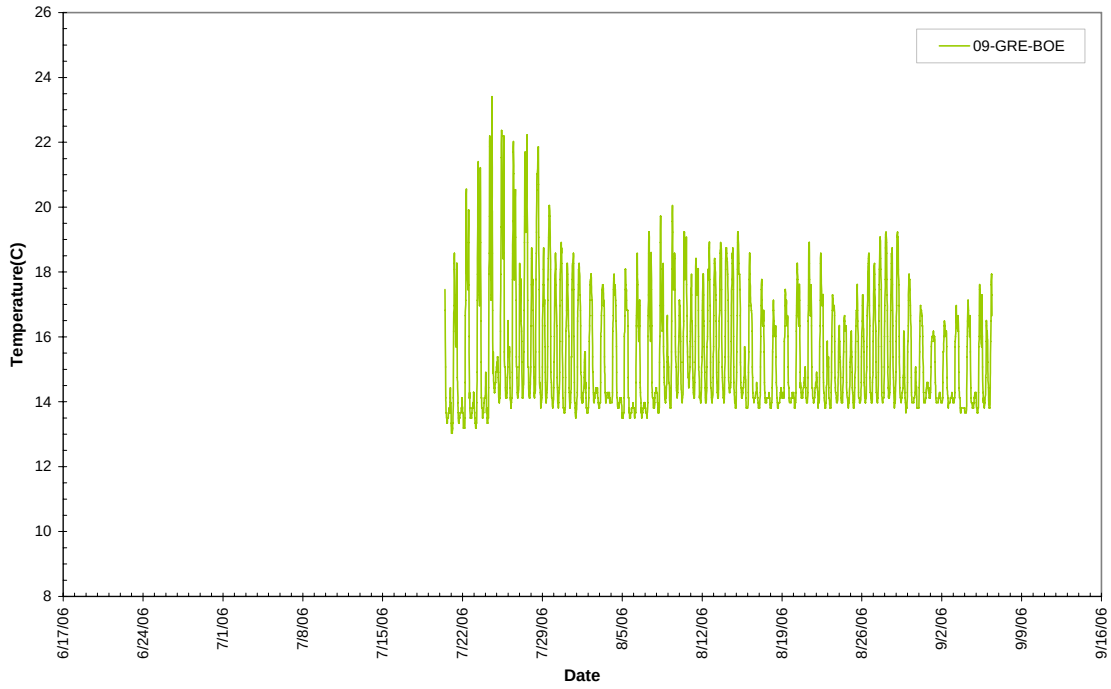




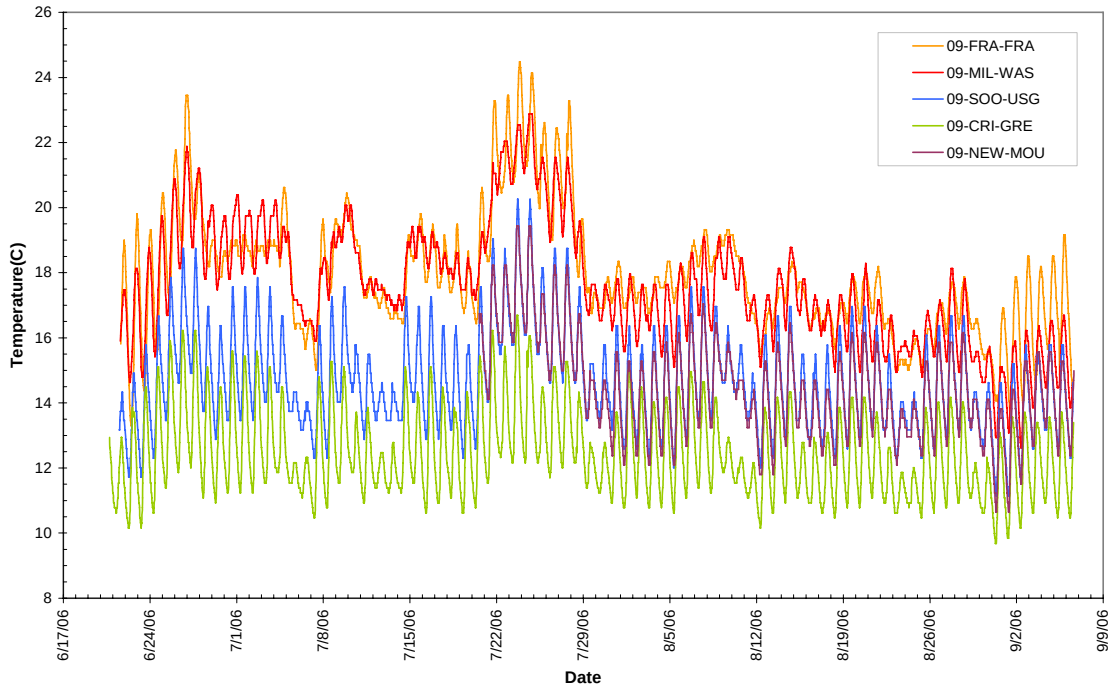
LOWER GREEN RIVER: continuous 30-min water temperature



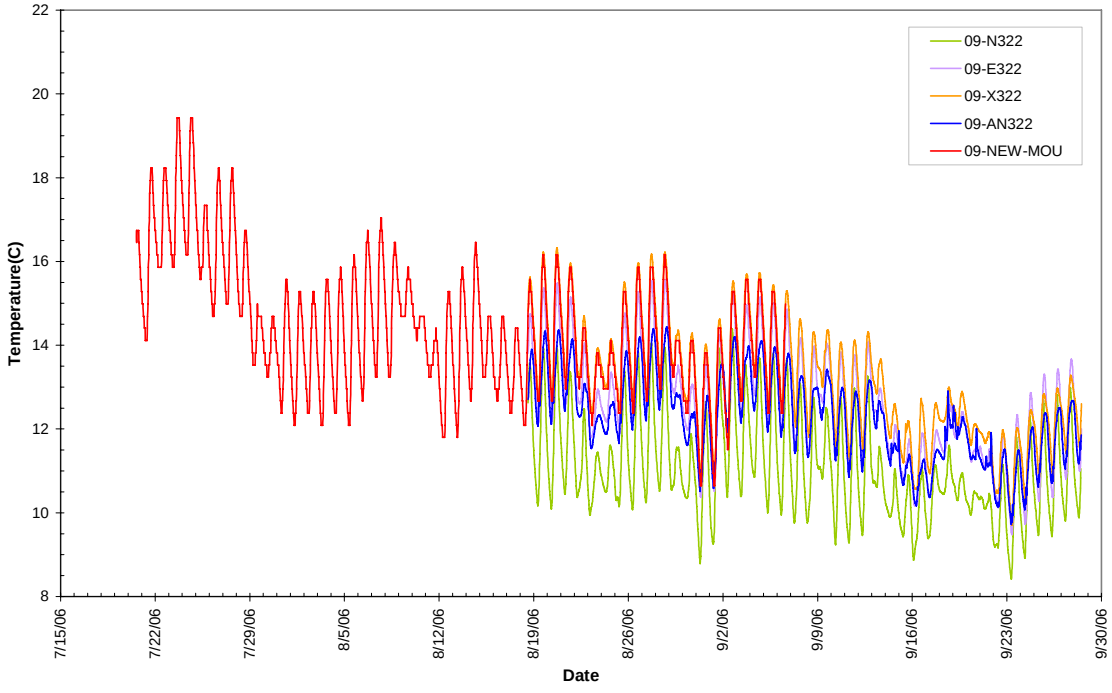
09-GRE-BOE: continuous 30-min water temperature



GREEN RIVER TRIBUTARIES: continuous 30-min water temperature



NEWAUKUM CREEK: continuous 30-min water temperature



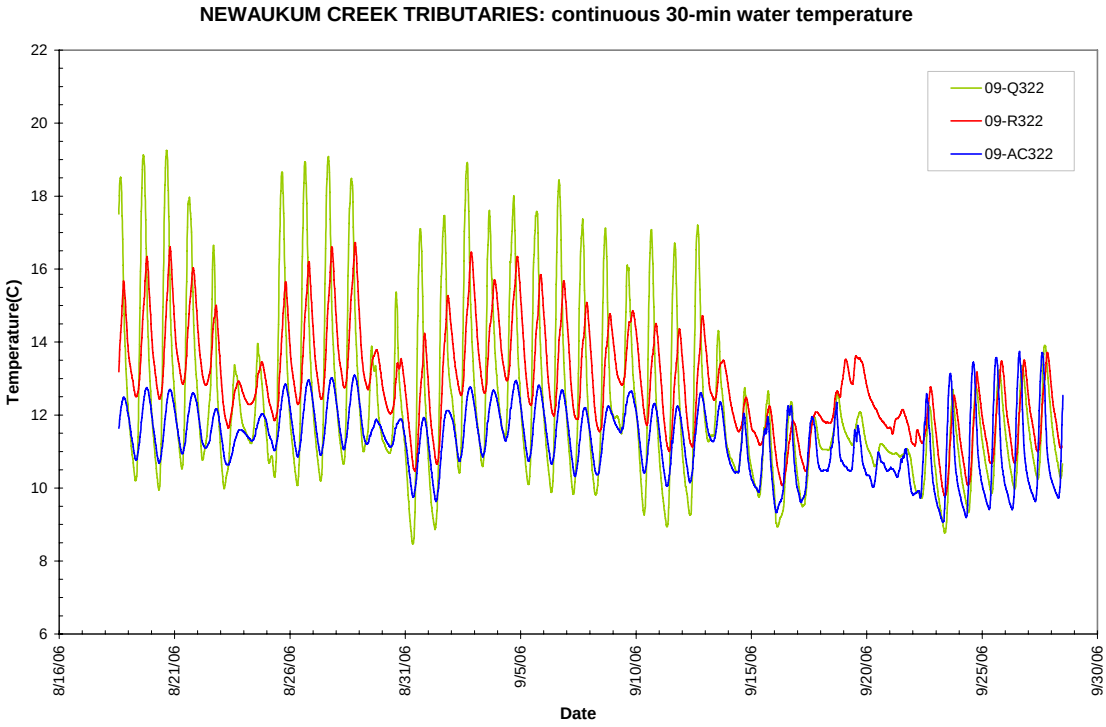
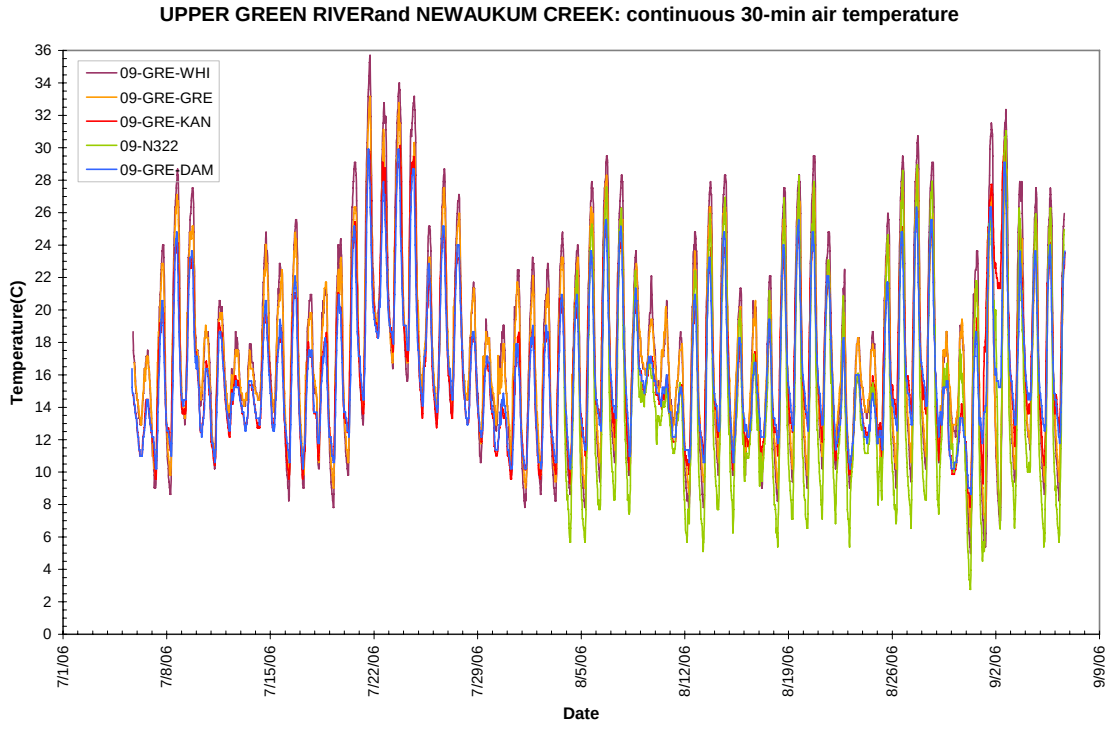

NEWAUKUM CREEK TRIBUTARIES: continuous 30-min water temperature
Temperature(C)
22
20
18
16
14
12
10
8
6
8/16/06
8/21/06
8/26/06
8/31/06
9/5/06
9/10/06
9/15/06
9/20/06
9/25/06
9/30/06
Date
09-Q322
09-R322
09-AC322

Figure E-2. Continuous 30-minute air temperature measurements.



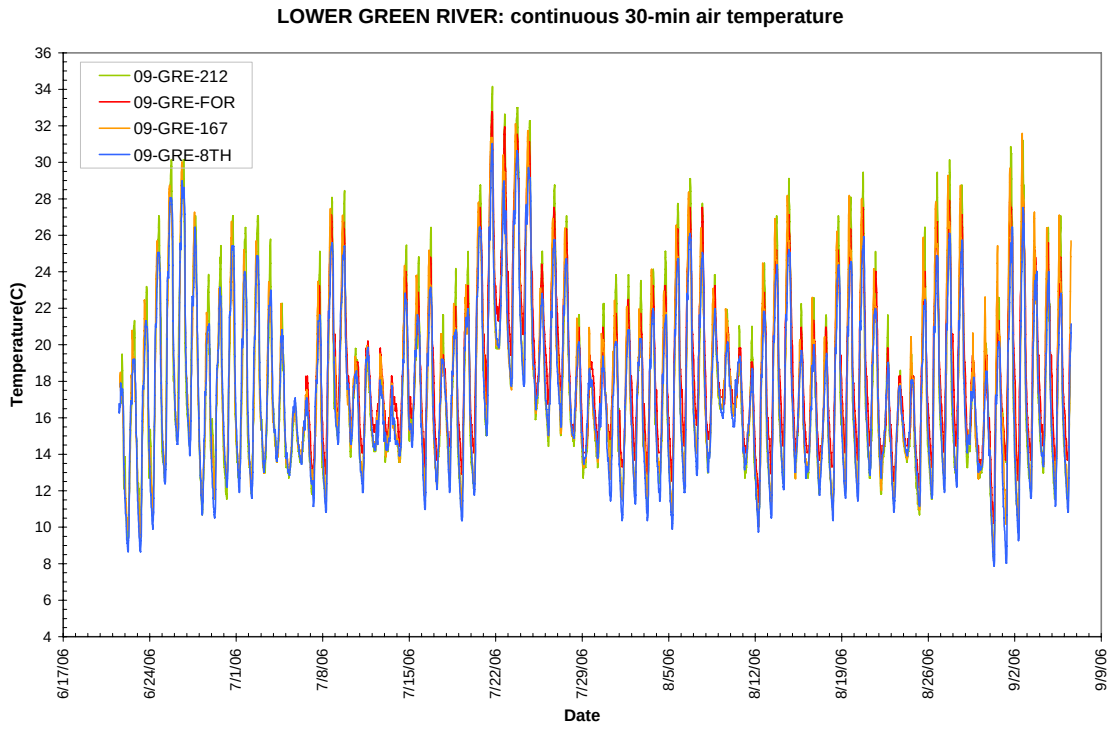
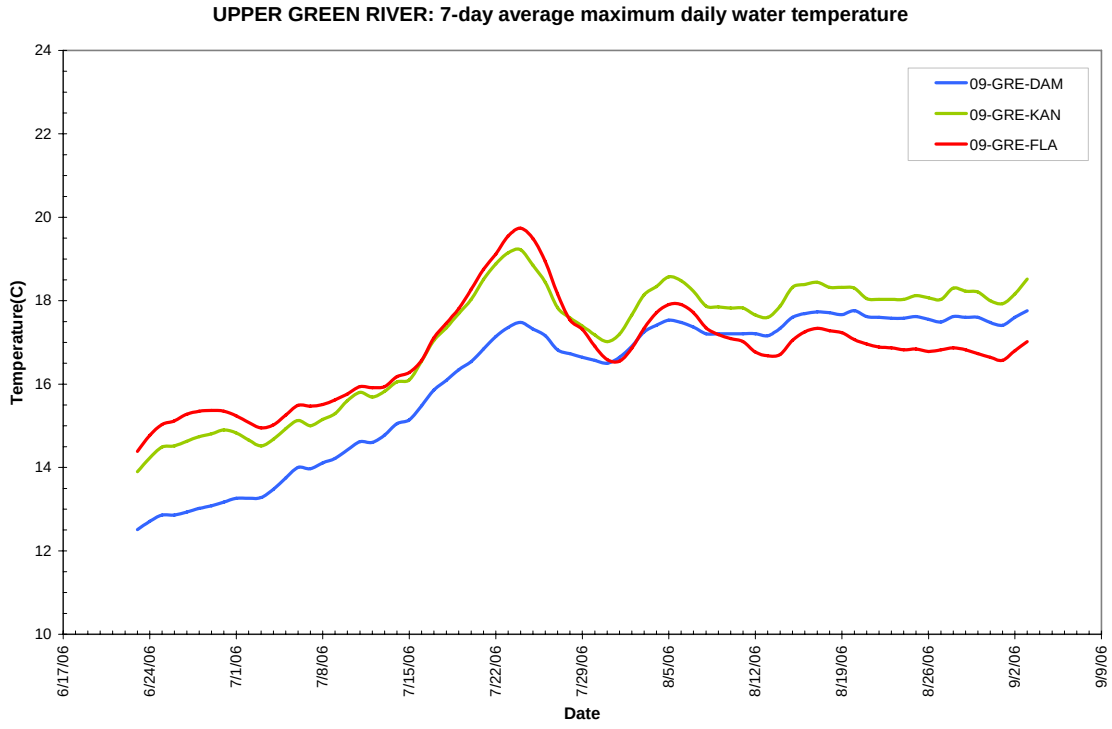
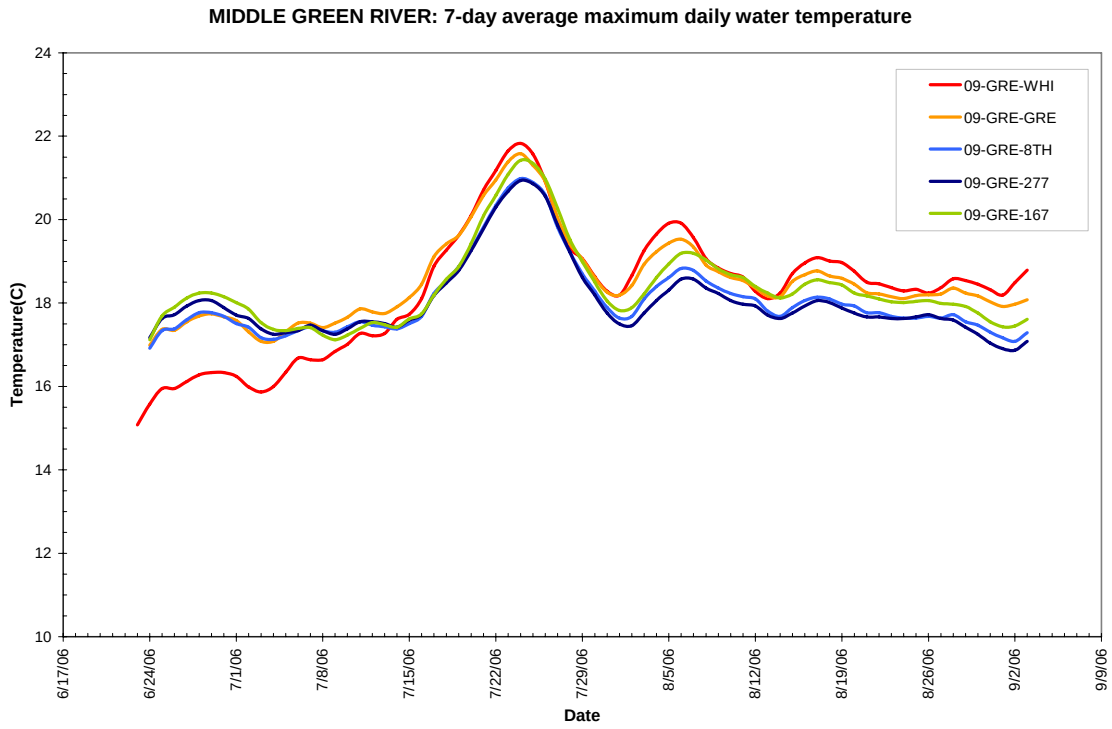
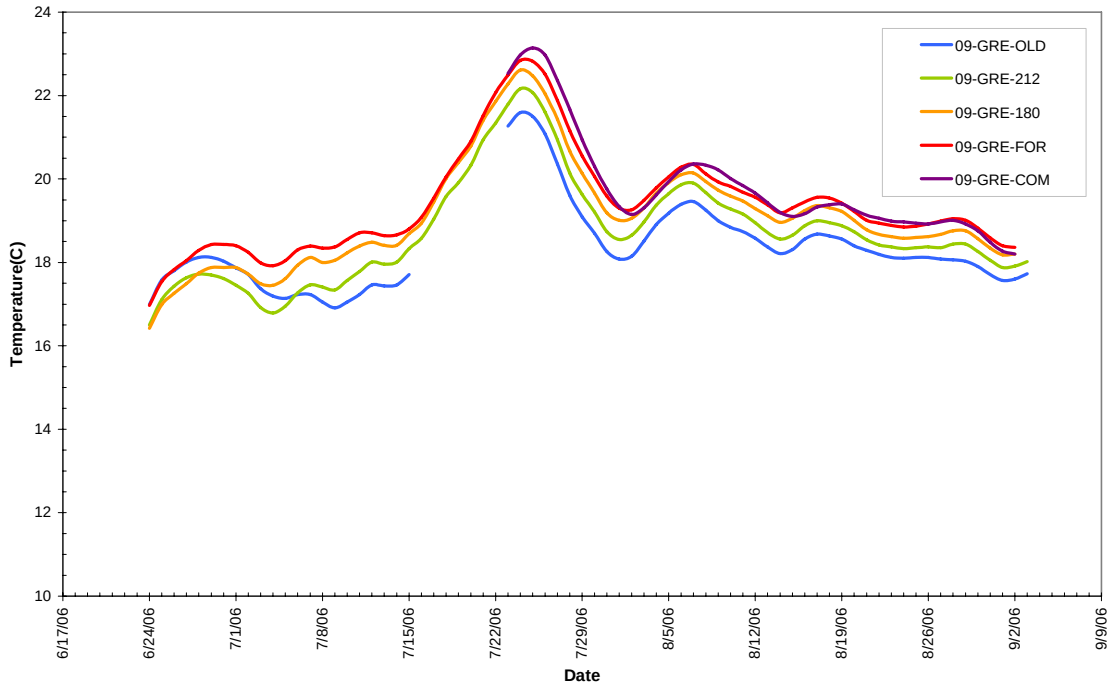


Figure E-3. 7-day averages of maximum daily water temperature.

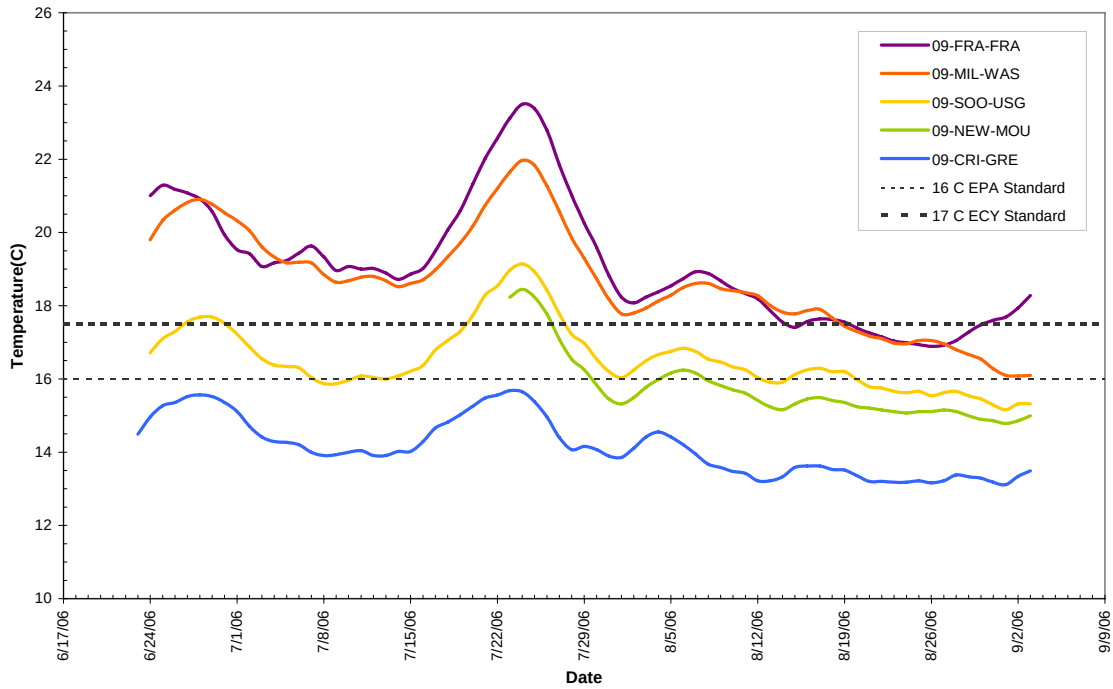




LOWER GREEN RIVER: 7-day average maximum daily water temperature



GREEN RIVER TRIBUTARIES: 7-day maximum daily average water temperature



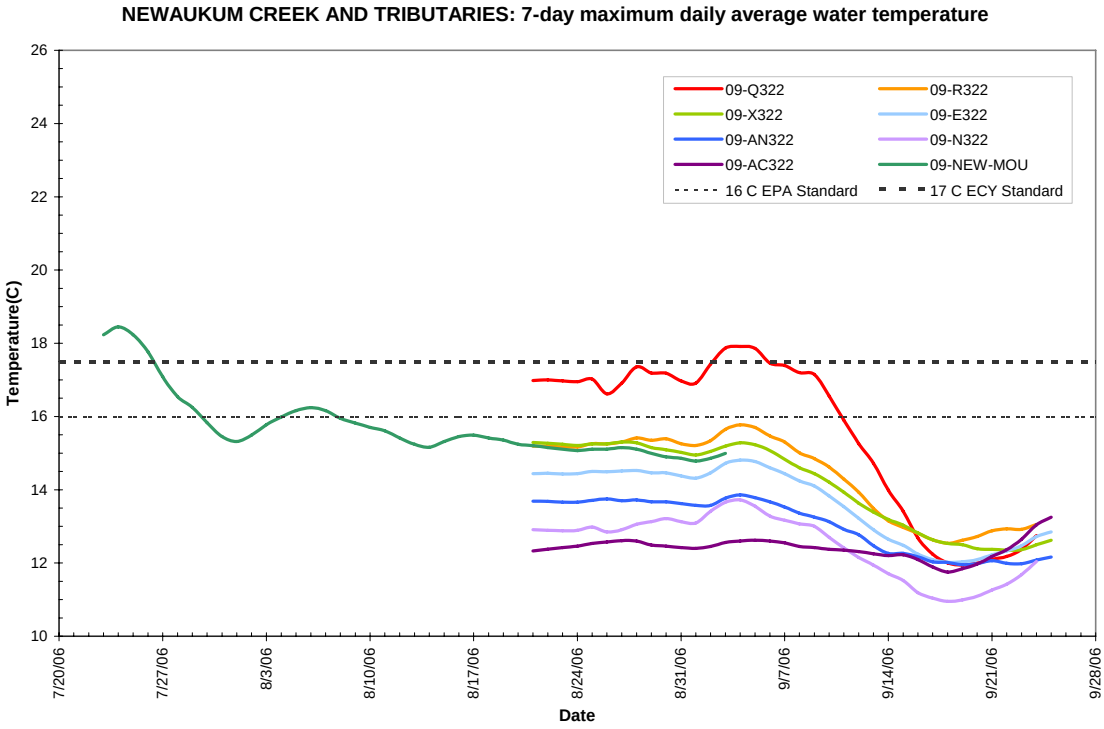

NEWAUKUM CREEK AND TRIBUTARIES: 7-day maximum daily average water temperature
Temperature(C)
26
24
22
20
18
16
14
12
10
7/20/06
7/27/06
8/3/06
8/10/06
8/17/06
8/24/06
8/31/06
9/7/06
9/14/06
9/21/06
9/28/06
Date
09-Q322
09-R322
09-X322
09-E322
09-AN322
09-N322
09-AC322
09-NEW-MOU
16 C EPA Standard
17 C ECY Standard

Figure E-4. 7-day average maximum air temperature measurements.

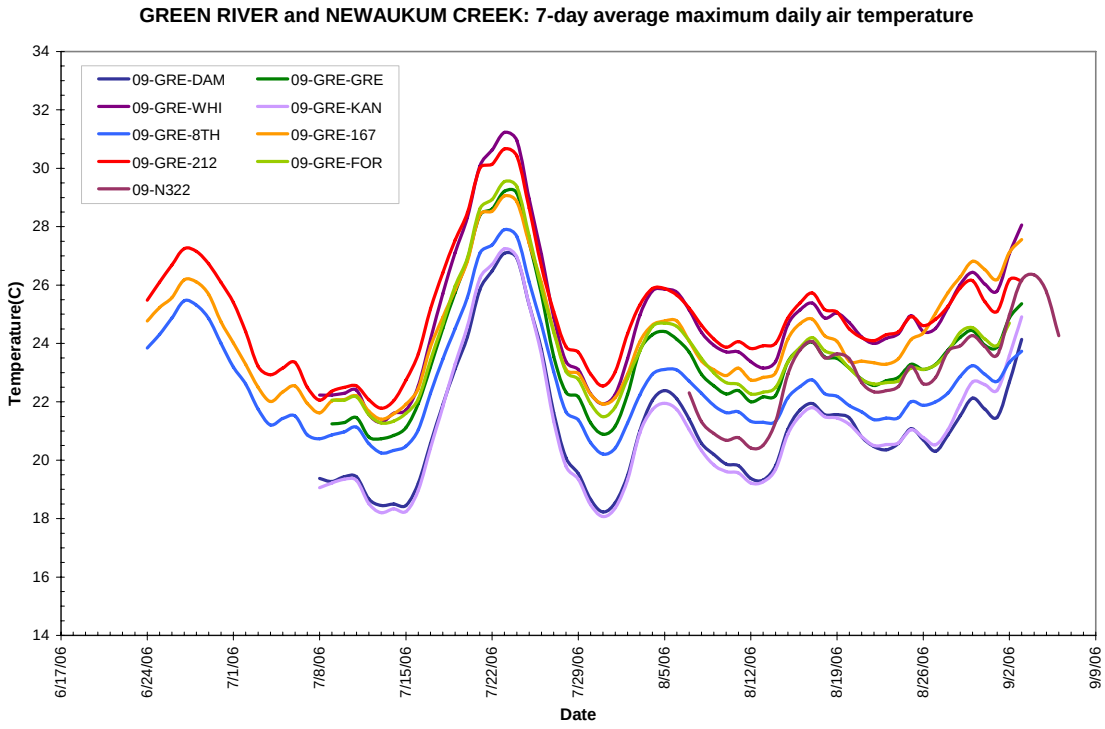
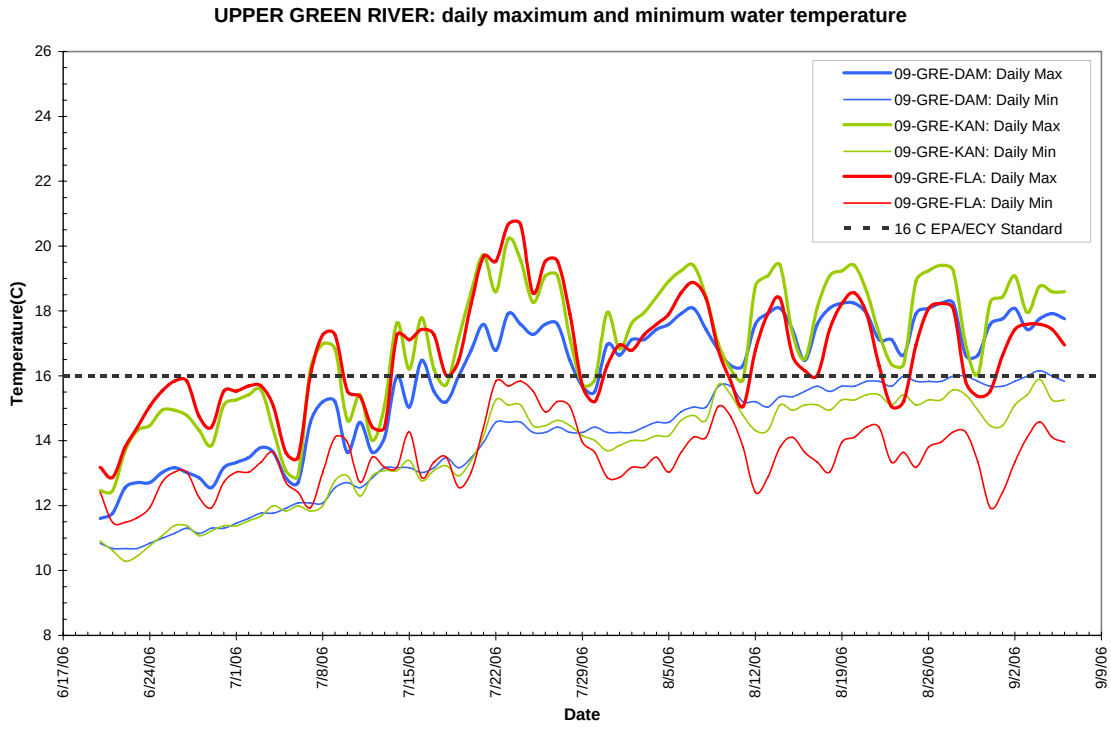
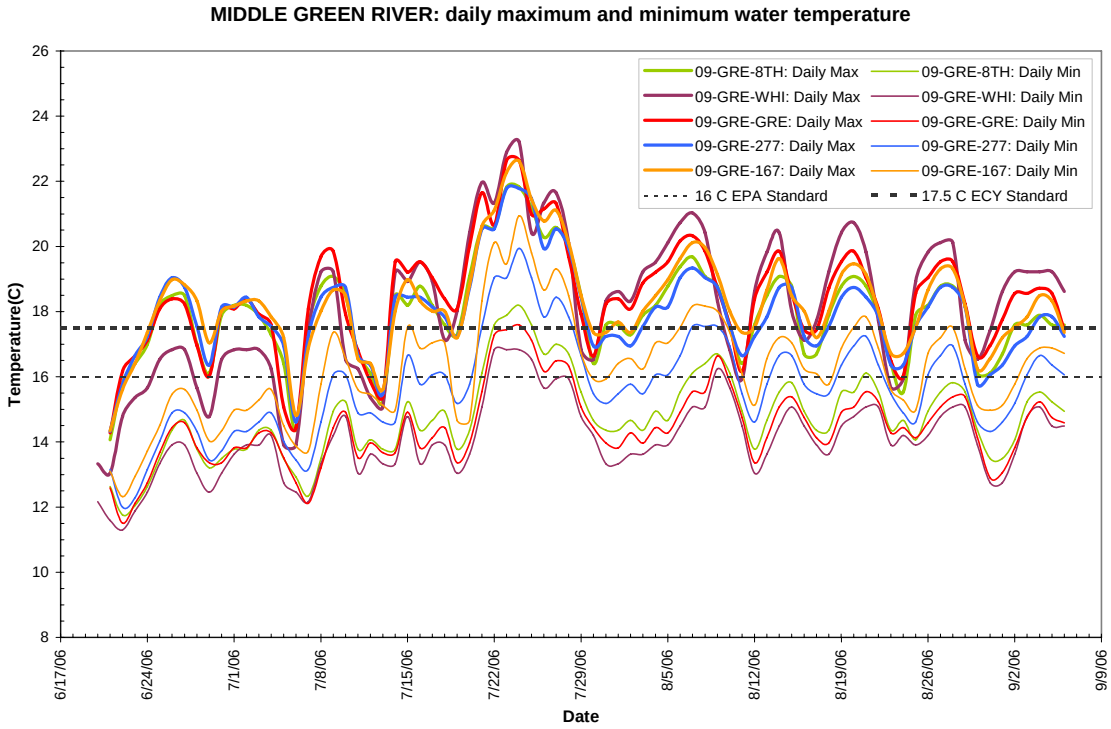
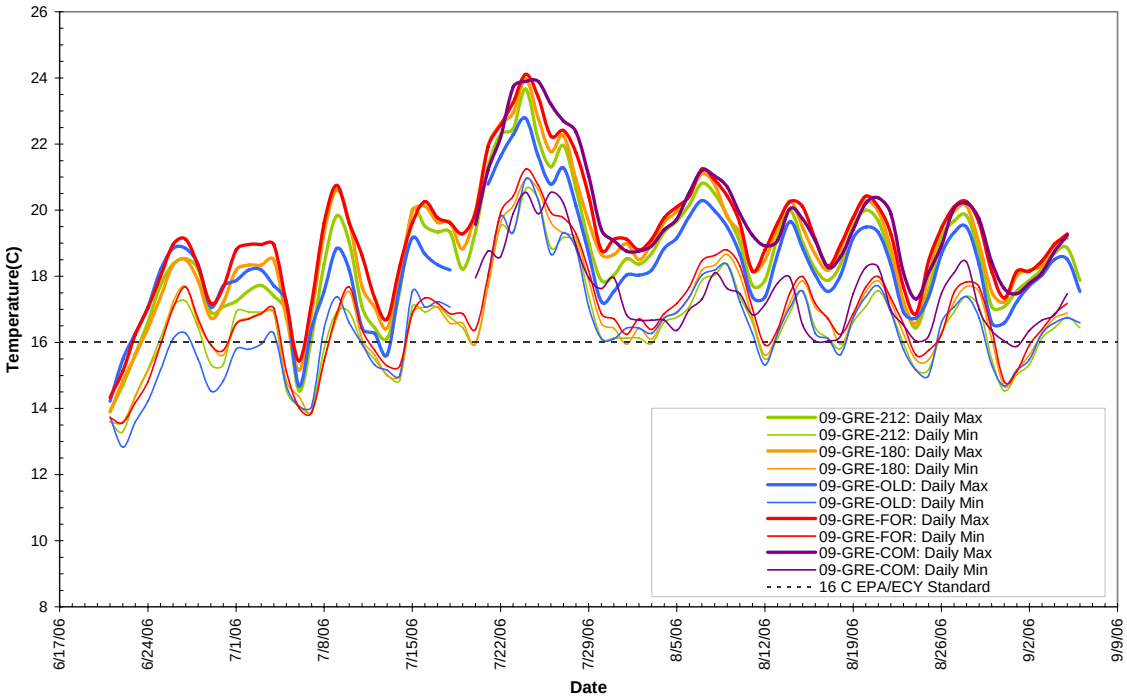


Figure E-5. Daily maximum and minimum water temperature measurements.

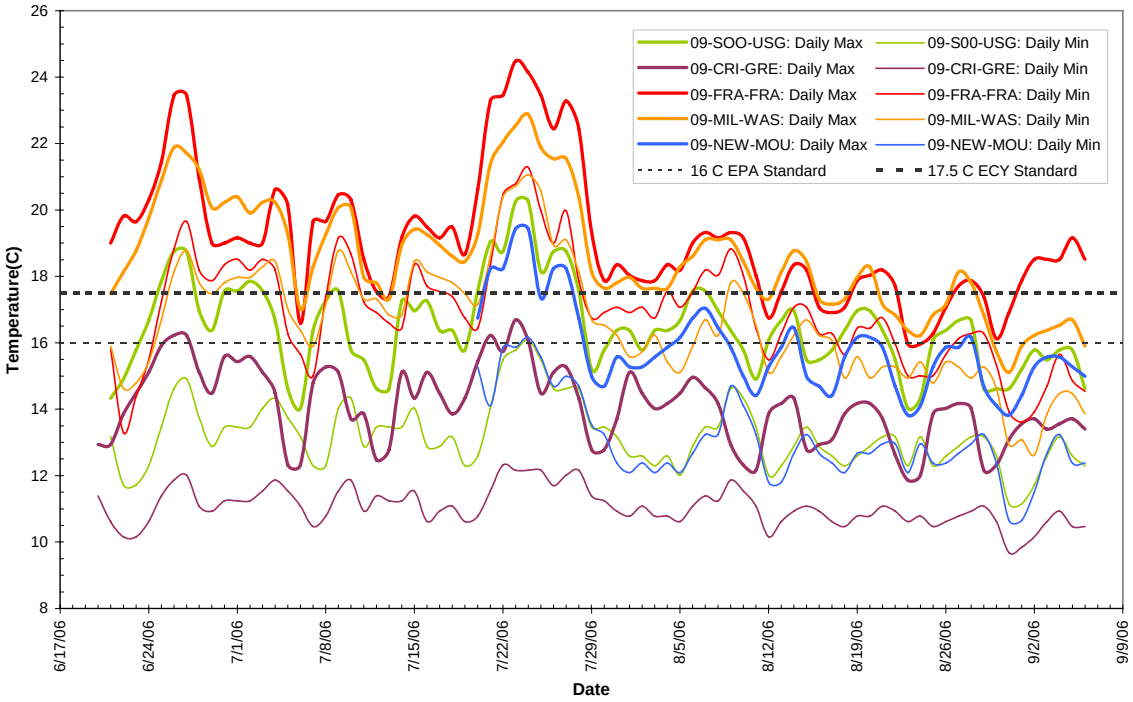




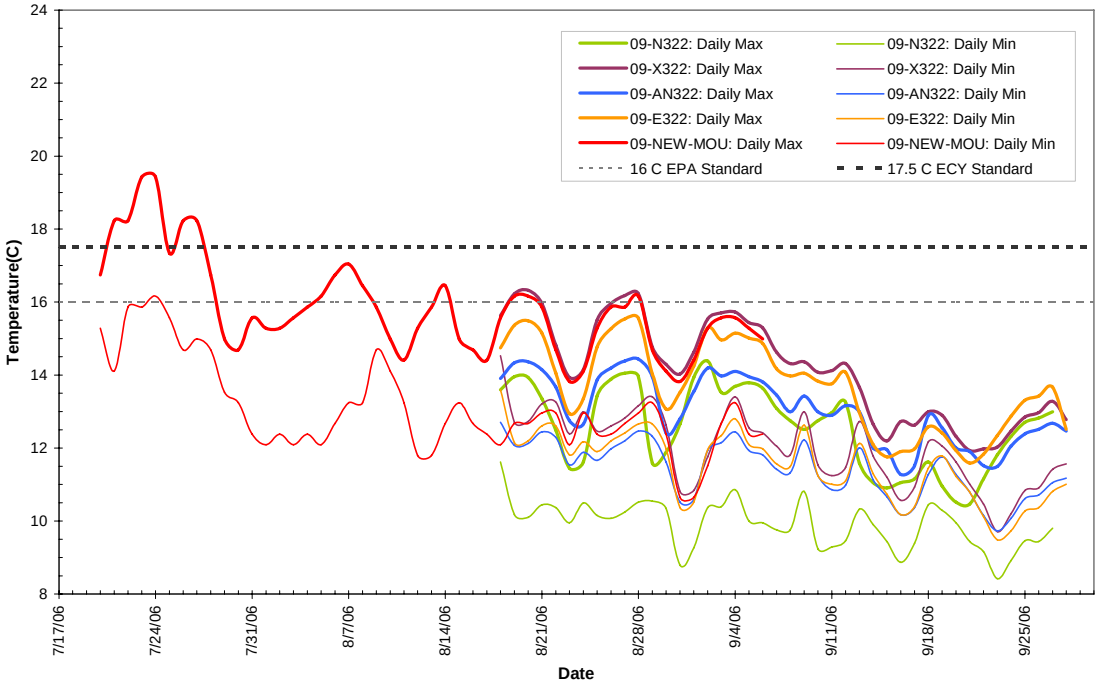
LOWER GREEN RIVER: daily maximum and minimum water temperature



GREEN RIVER TRIBUTARIES: daily maximum and minimum water temperature



NEWAUKUM CREEK: daily maximum and minimum water temperature



NEWAUKUM CREEK TRIBUTARIES: daily maximum and minimum temperature

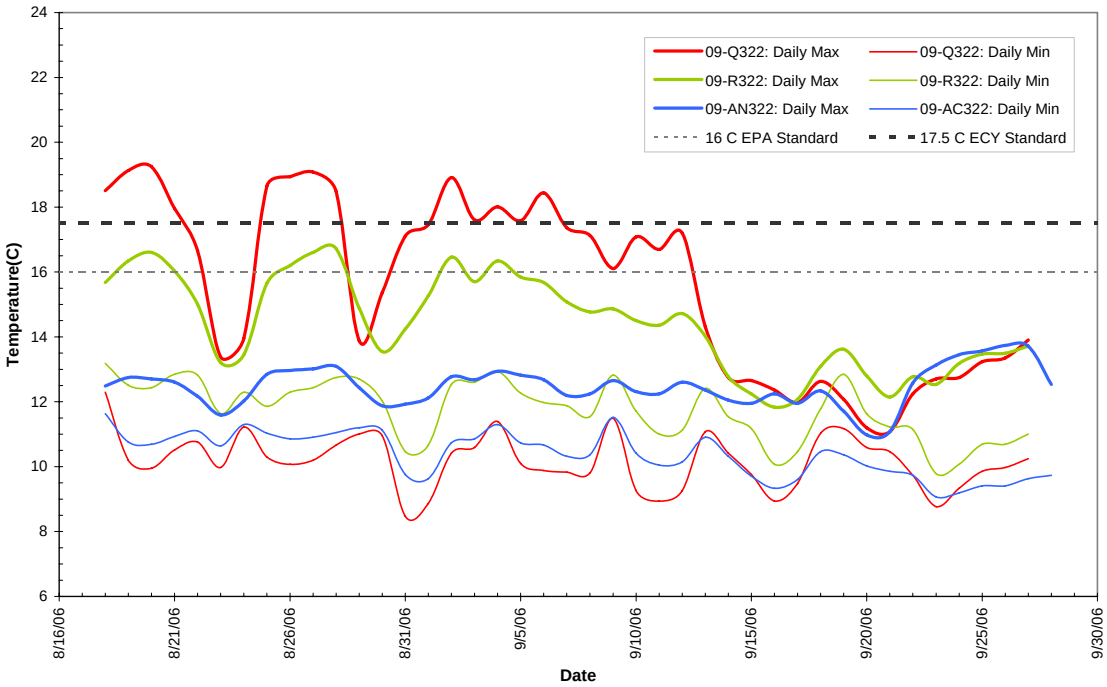
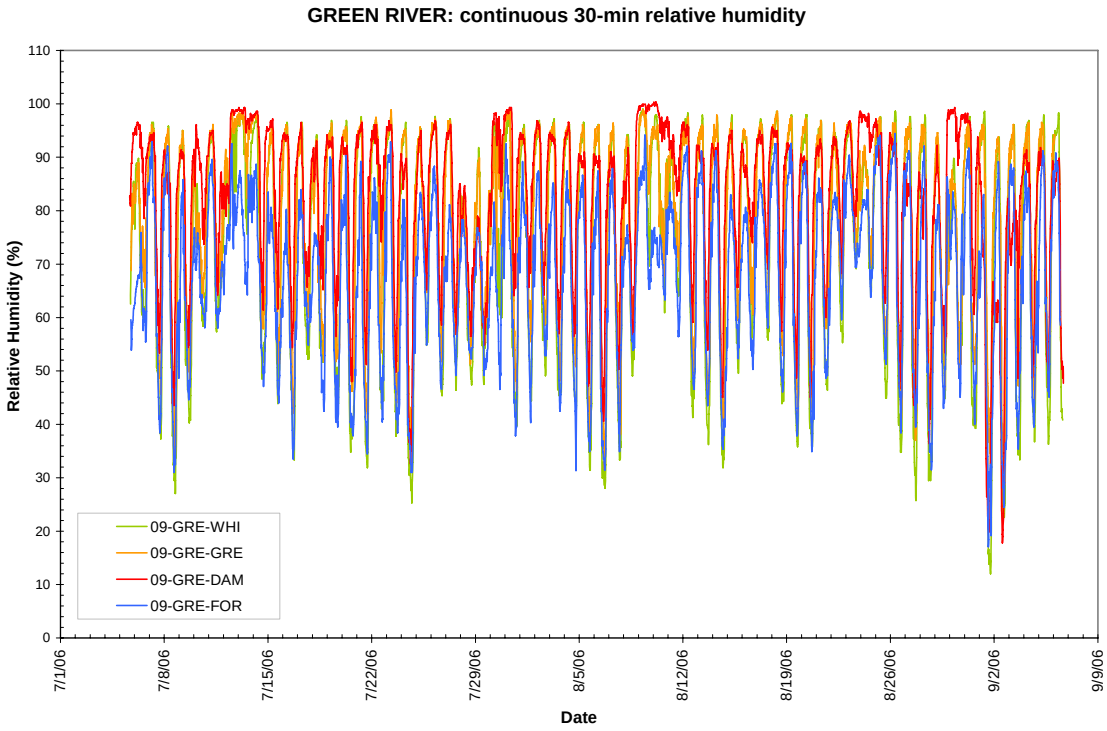


Figure E-6. Continuous 30-minute relative humidity measurements.



Appendix F. Calculated Shade Values

Table F-1. Effective riparian shade calculated from HemiView images.

Station	Effective Shade		
	Left Bank	Center	Right Bank
Mainstem Green River			
09-GRE-DAM	93%	73%	49%
09-GRE-KAN	86%	34%	33%
09-GRE-FLA	94%	44%	62%
09-GRE-WHI	28%	6%	39%
09-GRE-GRE	91%	8%	61%
09-GRE-8TH	54%	-	65%
09-GRE-277	87%	51%	40%
09-GRE-167	-	-	22%
09-GRE-OLD	28%	21%	-
09-GRE-212	18%	15%	76%
09-GRE-180	68%	12%	-
09-GRE-FOR	20%	-	29%
09-GRE-COM	-	-	15%
09-GRE-BOE	37%	-	-
Green River tributaries			
09-CRI-GRE	-	86%	-
09-SOO-USG	-	77%	-
09-MIL-WAS	-	79%	-
09-FRA-FRA	-	93%	-

*gaps in data are due to site inaccessibility

Appendix G. Unprocessed HemiView Images

Figure G-1. 09-GRE-DAM (Green River below Tacoma Water Headworks Diversion Dam)

Left Bank

Center

Right Bank

Figure G-2. 09-GRE-KAN (Green River at Cumberland-Kanaskat Rd)

Left Bank

Center

Right Bank

Figure G-3. 09-GRE-WHI (Green River at 212th Way SE (Whitney Bridge))

Left Bank

Center

Right Bank

Figure G-4. 09-GRE-FLA (Green River at Flaming Geyser Park, near end of SE Flaming Geyser Rd)

Left Bank

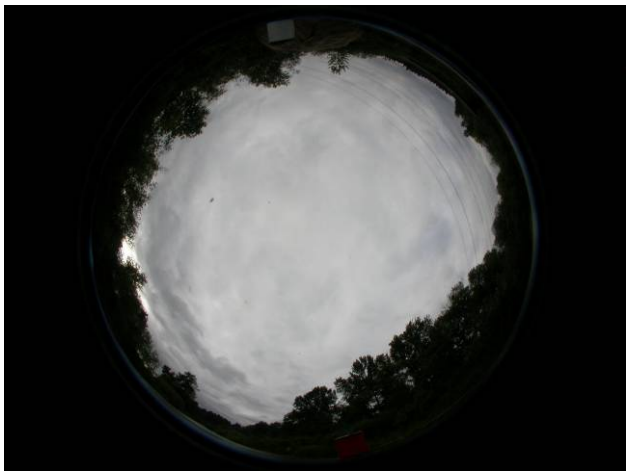
Center

Right Bank

Figure G-5. 09-GRE-GRE (at Green Valley Rd)

Left Bank

Center



Right Bank

Figure G-6. 09-GRE-8TH (at 8th St. NE in Auburn)

Left Bank

Right Bank

Figure G-7. 09-GRE-277 (off Green River Rd. under 277th St. bridge)

Left Bank

Center

Right Bank

Figure G-8. 09-GRE-212 (at S 212th St)

Left Bank

Center

Right Bank

Figure G-9. 09-GRE-167 (upstream of Mill Ck. under Hwy 167 bridge)

Right Bank

Figure G-10. 09-GRE-OLD (at Meeker St. near the "Old Fishin' Hole")

Left Bank

Center

Figure G-11. 09-GRE-180 (at SE 180th St. (SW 43rd St.))

Left Bank

Center

Figure G-12. 09-GRE-FOR (under Interurban Ave. bridge near Fort Dent)

Left Bank

Right Bank

Figure G-13. 09-GRE-COM (under 42nd Ave. S bridge at Tukwila Community Center)

Right Bank

Figure G-14. 09-GRE-BOE (downstream of 102nd Ave. at Boeing foot bridge)

Left Bank

Figure G-15. 09-CRI-GRE (Crisp Ck. at Green Valley Rd)

Center

Figure G-16. 09-SOO-USG (Soos Ck. at USGS gaging station upstream of hatchery)

Center

Figure G-17. 09-FRA-FRA (Mullen Slough at Frager Rd)

Center

Figure G-18. 09-MIL-WAS (Mill Ck. at Washington Ave)

Center