50-390/391

Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

September 14, 2001

Mr. Philip Stewart, Manager
Tennessee Department of Environment & Conservation
Division of Water Pollution Control
Environmental Assistance Center
540 McCallie Avenue, Suite 550
Chattanooga, Tennessee 37402-2013

Dear Mr. Stewart:

WATTS BAR NUCLEAR PLANT (WBN) - NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT NO. TN0020168-HYDROTHERMAL DATA FOR SCCW OUTFALL

Enclosed are two copies of the Hydrothermal Data for Watts Bar Nuclear Plant SCCW Outfall report. Parts I-A and III-B of the National Pollutant Discharge Elimination System Permit requires monitoring and surveying the impact of the thermal effluent from Outfall 113 on the Tennessee River.

If you should have any questions or need additional information, please contact Robert J. Crawford at (423) 365-8005 or me at (423) 365-1846 at Watts Bar.

Sincerely,

Edward R. Robinson
Radwaste/Environmental Superintendent

Enclosures
cc: U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

C001

Printed on recycled paper

TENNESSEE VALLEY AUTHORITY
River System Operations & Environment
River Operations

Hydrothermal Data For Watts Bar Nuclear Plant SCCW Outfall

WR2001-4-85-145

Prepared by

Brennan T. Smith
Paul N. Hopping
Walter L. Harper
Meihuei Lee

Norris, Tennessee

September 2001

Executive Summary

Parts I-A and III-B of the National Pollutant Discharge Elimination System Permit for the Watts Bar Nuclear Plant summarize requirements for monitoring and surveying the impact on the Tennessee River of the thermal effluent from Outfall 113. This outfall includes the discharge from the Supplemental Condenser Cooling Water System. This report includes a summary of the monitoring and survey data and is provided in fulfillment of the requirement that "A report of the surveys will be submitted to the Division within nine months of the end of survey completion." The monitoring data are provided for the months of December 1999 through August 2001. The survey data includes the results from six field tests conducted between February 23, 2000 and December 14, 2000.

Table of Contents

Executive Summary i

List of Figures iii

List of Tables vi

1.0 INTRODUCTION 1

2.0 MONITORING DATA 2

- 2.1 Timeline 2
- 2.2 Station 34 and Station 35 9
- 2.3 NPDES Monitoring Data 9
- 2.4 Comparison of 1-Hour Averaging and 24-Hour Averaging 11

3.0 SURVEY DATA 11

- 3.1 Survey No. 1 12
- 3.2 Survey No. 2 13
- 3.3 Survey No. 3 13
- 3.4 Survey No. 4 13
- 3.5 Survey No. 5 14

4.0 References 14

List of Figures

		Page
2.3.1a	SCCW Monitoring Data, December 1999	15
2.3.1b	SCCW Monitoring Data, December 1999	16
2.3.2a	SCCW Monitoring Data, January 2000	17
2.3.2b	SCCW Monitoring Data, January 2000	18
2.3.3a	SCCW Monitoring Data, February 2000	19
2.3.3b	SCCW Monitoring Data, February 2000	20
2.3.4a	SCCW Monitoring Data, March 2000	21
2.3.4b	SCCW Monitoring Data, March 2000	22
2.3.5a	SCCW Monitoring Data, April 2000	23
2.3.5b	SCCW Monitoring Data, April 2000	24
2.3.6a	SCCW Monitoring Data, May 2000	25
2.3.6b	SCCW Monitoring Data, May 2000	26
2.3.7a	SCCW Monitoring Data, June 2000	27
2.3.7b	SCCW Monitoring Data, June 2000	28
2.3.8a	SCCW Monitoring Data, July 2000	29
2.3.8b	SCCW Monitoring Data, July 2000	30
2.3.9a	SCCW Monitoring Data, August 2000	31
2.3.9b	SCCW Monitoring Data, August 2000	32
2.3.10a	SCCW Monitoring Data, September 2000	33
2.3.10b	SCCW Monitoring Data, September 2000	34
2.3.11a	SCCW Monitoring Data, October 2000	35
2.3.11b	SCCW Monitoring Data, October 2000	36
2.3.12a	SCCW Monitoring Data, November 2000	37
2.3.12b	SCCW Monitoring Data, November 2000	38
2.3.13a	SCCW Monitoring Data, December 2000	39
2.3.13b	SCCW Monitoring Data, December 2000	40
2.3.14a	SCCW Monitoring Data, January 2001	41
2.3.14b	SCCW Monitoring Data, January 2001	42
2.3.15a	SCCW Monitoring Data, February 2001	43
2.3.15b	SCCW Monitoring Data, February 2001	44
2.3.16a	SCCW Monitoring Data, March 2001	45
2.3.16b	SCCW Monitoring Data, March 2001	46
2.3.17a	SCCW Monitoring Data, April 2001	47
2.3.17b	SCCW Monitoring Data, April 2001	48
2.3.18a	SCCW Monitoring Data, May 2001	49
2.3.18b	SCCW Monitoring Data, May 2001	50

List of Figures
(Continued)

		Page
2.3.19a	SCCW Monitoring Data, June 2001	51
2.3.19b	SCCW Monitoring Data, June 2001	52
2.3.20a	SCCW Monitoring Data, July 2001	53
2.3.20b	SCCW Monitoring Data, July 2001	54
2.3.21a	SCCW Monitoring Data, August 2001	55
2.3.21b	SCCW Monitoring Data, August 2001	56
2.4.1	Comparison of 1-Hour and 24-Hour Averaging, December 1999	57
2.4.2	Comparison of 1-Hour and 24-Hour Averaging, January 2000	58
2.4.3	Comparison of 1-Hour and 24-Hour Averaging, February 2000	59
2.4.4	Comparison of 1-Hour and 24-Hour Averaging, March 2000	60
2.4.5	Comparison of 1-Hour and 24-Hour Averaging, April 2000	61
2.4.6	Comparison of 1-Hour and 24-Hour Averaging, May 2000	62
2.4.7	Comparison of 1-Hour and 24-Hour Averaging, June 2000	63
2.4.8	Comparison of 1-Hour and 24-Hour Averaging, July 2000	64
2.4.9	Comparison of 1-Hour and 24-Hour Averaging, August 2000	65
2.4.10	Comparison of 1-Hour and 24-Hour Averaging, September 2000	66
2.4.11	Comparison of 1-Hour and 24-Hour Averaging, October 2000	67
2.4.12	Comparison of 1-Hour and 24-Hour Averaging, November 2000	68
2.4.13	Comparison of 1-Hour and 24-Hour Averaging, December 2000	69
2.4.14	Comparison of 1-Hour and 24-Hour Averaging, January 2001	70
2.4.15	Comparison of 1-Hour and 24-Hour Averaging, February 2001	71
2.4.16	Comparison of 1-Hour and 24-Hour Averaging, March 2001	72
2.4.17	Comparison of 1-Hour and 24-Hour Averaging, April 2001	73
2.4.18	Comparison of 1-Hour and 24-Hour Averaging, May 2001	74
2.4.19	Comparison of 1-Hour and 24-Hour Averaging, June 2001	75
2.4.20	Comparison of 1-Hour and 24-Hour Averaging, July 2001	76
2.4.21	Comparison of 1-Hour and 24-Hour Averaging, August 2001	77
3.1.1a	SCCW Survey of 2/23/2000–Hydrothermal Data	78
3.1.1b	SCCW Survey of 2/23/2000–Meteorological Data	79
3.1.2a	SCCW Survey of 2/23/2000–River Temperature, Pass 1	80
3.1.2b	SCCW Survey of 2/23/2000–River Temperature, Pass 2	81
3.1.2c	SCCW Survey of 2/23/2000–River Temperature, Pass 3	82
3.1.2d	SCCW Survey of 2/23/2000–River Temperature, Pass 4	83
3.1.2e	SCCW Survey of 2/23/2000–River Temperature, Pass 5	84
3.1.3a	SCCW Survey of 2/23/2000–River Temperature Rise, Pass 1	85

List of Figures
(Continued)

		Page
3.1.3b	SCCW Survey of 2/23/2000–River Temperature Rise, Pass 2	86
3.1.3c	SCCW Survey of 2/23/2000–River Temperature Rise, Pass 3	87
3.1.3d	SCCW Survey of 2/23/2000–River Temperature Rise, Pass 4	88
3.1.3e	SCCW Survey of 2/23/2000–River Temperature Rise, Pass 5	89
3.2.1a	SCCW Survey of 3/8/2000–Hydrothermal Data	90
3.2.1b	SCCW Survey of 3/8/2000–Meteorological Data	91
3.2.2a	SCCW Survey of 3/8/2000–River Temperature, Pass 1	92
3.2.3a	SCCW Survey of 3/8/2000–River Temperature Rise, Pass 1	93
3.3.1a	SCCW Survey of 5/18/2000–Hydrothermal Data	94
3.3.1b	SCCW Survey of 5/18/2000–Meteorological Data	95
3.3.2a	SCCW Survey of 5/18/2000–River Temperature, Pass 1	96
3.3.2b	SCCW Survey of 5/18/2000–River Temperature, Pass 2	97
3.3.2c	SCCW Survey of 5/18/2000–River Temperature, Pass 3	98
3.3.3a	SCCW Survey of 5/18/2000–River Temperature Rise, Pass 1	99
3.3.3b	SCCW Survey of 5/18/2000–River Temperature Rise, Pass 2	100
3.3.3c	SCCW Survey of 5/18/2000–River Temperature Rise, Pass 3	101
3.4.1a	SCCW Survey of 8/1/2000–Hydrothermal Data	102
3.4.1b	SCCW Survey of 8/1/2000–Meteorological Data	103
3.4.2a	SCCW Survey of 8/1/2000–River Temperature, Pass 1	104
3.4.2b	SCCW Survey of 8/1/2000–River Temperature, Pass 2	105
3.4.3a	SCCW Survey of 8/1/2000–River Temperature Rise, Pass 1	106
3.4.3b	SCCW Survey of 8/1/2000–River Temperature Rise, Pass 2	107
3.5.1a	SCCW Survey of 12/14/2000–Hydrothermal Data	108
3.5.1b	SCCW Survey of 12/14/2000–Meteorological Data	109
3.5.2a	SCCW Survey of 12/14/2000–River Temperature, Pass 1	110
3.5.2b	SCCW Survey of 12/14/2000–River Temperature, Pass 2	111
3.5.2c	SCCW Survey of 12/14/2000–River Temperature, Pass 3	112
3.5.3a	SCCW Survey of 12/14/2000–River Temperature Rise, Pass 1	113
3.5.3b	SCCW Survey of 12/14/2000–River Temperature Rise, Pass 2	114
3.5.3c	SCCW Survey of 12/14/2000–River Temperature Rise, Pass 3	115

List of Tables

Page

2.1.1 Correspondence Related to the Hydrothermal Monitoring System for WBN Outfall 113 4

2.1.2 SCCW Hydrothermal Monitoring System per TVA Letter of September 28, 1999 5

2.1.3 SCCW Hydrothermal Monitoring System as of February 2, 2001 8

3.1 Basic Field Conditions for SCCW Surveys 12

HYDROTHERMAL DATA FOR
WATTS BAR NUCLEAR PLANT SCCW OUTFALL

1.0 INTRODUCTION

The purpose of this report is to summarize hydrothermal data collected as required by National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for the Watts Bar Nuclear (WBN) Plant, for the permit cycle from July 17, 1999 to September 28, 2001. The data includes that for Outfall 113, the Supplemental Condenser Cooling Water (SCCW) System. The specific data requirements for this outfall are as found primarily in the following sections of the permit:

- Part I-A, Permit Limits, Outfall 113

Effluent Characteristics	*Effluent Limitations Daily*	*Monitoring Requirements*	
	Max. Conc.	*Msrmnt. Frqncy.*	*Sample Type*
Flow	*Report*	*Continuous*	*Recorder*
Temperature, Effluent	*Report*	*Hourly*	*Recorder*
Temperature, Edge of mixing zone	*30.5°C* (86.9°F)	*Hourly*	*Recorder*
Temperature, Rise upstream to downstream	*3.0 C°* (5.4 F°)	*Hourly*	*Calculated*
Temperature, Rate-of-change	*2.0 C°/hour* (3.6 F°/hour)	*Hourly*	*Calculated*
Temperature, Receiving stream bottom	*33.5°C* (92.3°F)	*Hourly*	*Recorder*
Stream Flow Direction	*Report data on flow status*	*Hourly*	*Recorder*

- Part III-B

TVA shall conduct routine temperature monitoring of the bottom of the discharge zone of the river along the periphery of the mussel relocation zone. Monitoring will be made by four thermistors wired to a data logger. Temperature data will be recorded for each thermistor on an hourly basis and will be available as unaggregated data for analysis. ··· Flow direction of the water near the Outfall 113 discharge shall be monitored by automatic equipment. Any instream monitoring equipment failures shall be remedied as soon as reasonably practical. Record of the flow direction instream and of the bottom temperatures shall be used to assess the mixing zone and to further characterize the impacts on bottom dwelling organisms within the mixing zone.

TVA shall conduct four separate temperature surveys during the first year of full operation of the Supplemental Condenser Cooling Water project. These surveys are intended to better define the mixing zone and reflect seasonal changes in the mixing zone at Outfall 113. The plant should be operating at the time of the survey and the SCCW be thermally loaded. ··· Each survey shall consist of determining vertical temperature profiles that allow assessment of the predicted mixing zone. The survey area shall include the width of the river and the downstream extent of the predicted mixing zone. The goal of the surveys is to determine the actual effects of the water releases from the dam and periods of no release from the dam upon the predicted mixing zone. The proposal for temperature survey shall be submitted to the division and be approved prior to start of the survey.

A report of the surveys will be submitted to the Division within nine months of the end of survey completion. The report shall summarize all data from the continuous monitoring system as well as the survey results. The assessment must compare 1-hour averaging of temperatures with 24-hour averaging.

As required in the above, TVA submitted a proposal for separate temperature surveys in early 2000 (Smith et al., January 2000). The Tennessee Department of Environment and Conservation (TDEC) accepted the proposal on February 24, 2000. The last of the surveys was completed December 14, 2000. The data given herein, therefore, is in fulfillment of the nine-month reporting requirement for the surveys and monitoring data. It is emphasized that this presentation is solely a data report. Although some minor discussions are provided, no detailed analyses of these data are given in support of establishing specific temperature criteria or monitoring requirements for the SCCW effluent.

The data provided in this report are organized into the two major categories found in Parts I-A and III-B of the NPDES permit—monitoring data and survey data. The monitoring data refers to the continuous and hourly measurements made to monitor compliance with the SCCW effluent limitations. The survey data is that of the separate temperature surveys of the SCCW mixing zone.

2.0 MONITORING DATA

2.1 Timeline

The system used to monitor the SCCW effluent limitations of the NPDES permit changed significantly during the first year of operation of the SCCW system. This is because, when the NPDES permit was issued and the SCCW system commenced operation, the design and installation of the hydrothermal monitoring system were incomplete. Other unforeseen problems with the monitoring system also spurred changes. Under these conditions, and before presenting any data, it is considered valuable to give a timeline summary of the SCCW monitoring system. This summary will be presented with the help of Table 2.1.1, which gives a list of correspondence pertinent to the hydrothermal monitoring system for Outfall 113.

TDEC transmitted the NPDES permit to TVA on July 16, 1999. The basic measurements required to monitor the effluent limitations of the SCCW, given in Part I-A of the permit, include the following:

- River temperature upstream of the SCCW outfall (i.e., ambient temperature),
- River temperature at the downstream edge of the mixing zone of the SCCW outfall,
- River bottom temperature at the SCCW outfall,
- River bottom velocity at the SCCW outfall,

- SCCW effluent flow at the SCCW outfall, and
- SCCW effluent temperature at the SCCW outfall.

The permit specified that *"installation, testing, calibrating and adjusting of the monitoring equipment and system"* should be complete 90 days from the effective date of the permit (Part I-E). Based on the effective date, July 17, 1999, the hydrothermal monitoring system was to be complete by October 15, 1999.

To allow operation of the SCCW system prior to completion of the hydrothermal monitoring system, TDEC specified that the effluent temperature should be monitored continuously, on an hourly basis, and that the maximum effluent temperature shall be limited to 92.3°F. With this, TVA placed the SCCW system in operation on July 19, 1999. The effluent flow and temperature were measured by an annubar in the SCCW system discharge conduit at a station located in an underground concrete vault about 2100 feet from the Unit 1 cooling tower basin. This station is known as Station 31 of the hydrothermal monitoring system.

Table 2.1.1. Correspondence Related to the Hydrothermal Monitoring System for WBN Outfall 113

Date	From	To	Summary
7/16/99	Saya A. Qualls Manager, Permit Section TDEC—DWPC	George E. Vickery Chemistry Superintendent TVA—WBN	TDEC transmittal of NPDES permit, which contained the SCCW hydrothermal monitoring requirements for the permit cycle from 7/17/01 to 9/28/01. Part I-E of the NPDES permit specified that the permittee shall have 90 days from the effective date of the permit to comply with the monitoring requirements. The transmittal letter specified that the SCCW system could be operated with the following minimum operating requirements: • The temperature of the SCCW effluent shall be monitored continuously on an hourly basis. • The maximum SCCW effluent temperature shall be 92.3°F. • The maximum SCCW effluent temperature can be exceeded if the river bottom temperature is measured for at least one site in the mussel relocation zone (MRZ) (i.e., immediate zone of SCCW impact) and monitored on an hourly basis. Note—per the NPDES permit, the maximum MRZ bottom temperature is 92.3°F.
9/28/99	Steven O. Casteel Manager, Radiological & Chem Control TVA—WBN	Philip L. Stewart Manager, DWPC Chattanooga Field Office TDEC—DWPC	TVA submittal of design for SCCW upstream temperature monitoring, and changes in the proposed designs for monitoring the river bottom (MRZ) temperature, monitoring the downstream temperature, and monitoring the effluent discharge and temperature. This letter also summarized the following phases of installation: • Phase 1—Installation of all equipment to allow local data collection of all river monitoring required by the NPDES permit. • Phase 2—Enhancement to radio-link all monitoring stations to one location and to provide access to this location via cell phone. • Phase 3—Enhancement to radio-link all monitoring stations to the WBN Environmental Data Station and Plant Integrated Computer System.
10/11/99	Philip L. Stewart Manager, DWPC Chattanooga Field Office TDEC—DWPC	Steven O. Casteel Manager, Radiological & Chem Control TVA—WBN	TDEC approval of the SCCW hydrothermal monitoring system as proposed in TVA letter of 9/28/99. This approval included some contingencies, the most significant of which included the right of TDEC to request a new location of the downstream monitor, if the proposed location did not provide suitable data.
1/21/00	Edward R. Robinson Environmental/Radwaste Superintendent TVA—WBN	Paul E. Davis Director, DWPC TDEC—DWPC	TVA submittal of proposed changes in SCCW monitoring. These included relocating the measurements for the effluent temperature and flow from the Annubar to the SCCW morning glory weir at Outfall 113.
2/24/00	Philip L. Stewart Manager, DWPC Chattanooga Field Office TDEC—DWPC	Edward R. Robinson Environmental/Radwaste Superintendent TVA—WBN	TDEC approval of a proposed change in the SCCW hydrothermal monitoring system as requested in TVA letter of 1/21/00.
6/6/00	Edward R. Robinson Environmental/Radwaste Superintendent TVA—WBN	Philip L. Stewart Manager, DWPC Chattanooga Field Office TDEC—DWPC	TVA submittal of proposed changes in SCCW monitoring. These included adding additional temperature sensors and a pressure (water level) sensor to the upstream monitoring station. With this arrangement, the upstream temperature will be assigned as that measured by the first temperature sensor below a water depth of 5 feet.
8/8/00	Cynthia M. Anderson Environmental Protection Specialists Chattanooga Field Office TDEC—DWPC	Edward R. Robinson Environmental/Radwaste Superintendent TVA—WBN	TDEC approval of a proposed change in the SCCW hydrothermal monitoring system as requested in TVA letter of 6/6/00.

The TDEC transmittal of July 16 also stipulated that the maximum effluent temperature of 92.3°F could be exceeded if the river bottom temperature at the SCCW outfall were measured for at least one site in the MRZ and monitored on an hourly basis. Since this allowed greater flexibility in operating the SCCW system, TVA installed a temporary temperature sensor on the river bottom on July 30, 1999. The sensor was located on the downstream edge of the MRZ about 75 feet from the river shoreline. The sensor was connected to a data acquisition unit that recorded the bottom temperature every 15 minutes. Temperature data could be viewed and retrieved from the data acquisition unit by cell phone. Later, on August 18, 1999, the data acquisition was upgraded with an alarm system to notify WBN personnel if the bottom temperature or other station parameters exceeded specific action levels.

The design of the "permanent" hydrothermal monitoring system, including the annubar and other stations for instream measurements, was developed in close consultation with TDEC personnel. TVA submitted the first significant summary of the design by letter on September 28, 1999. In this submittal, the monitoring system included four remote stations—the Upstream Monitoring Station (Station 30), the Effluent Monitoring Station (Station 31), the River Bottom or MRZ Monitoring Station (Station 32), and the Downstream Monitoring Station (Station 33). A brief description of these stations is given in Table 2.1.2. The system was approved by TDEC on October 11, 1999, with some minor contingencies.

Table 2.1.2. SCCW Hydrothermal Monitoring System per TVA Letter of September 28, 1999

Station	ID	Location	Sensors
Upstream	30	Watts Bar Hydro Plant at the outlet of the draft tube for Unit 3.	Temperature sensor at elevation 670 feet msl, which is 5 feet below the normal minimum tailwater at the Watts Bar Hydro Plant.
Effluent	31	SCCW discharge conduit, 2100 feet from the Unit 1 cooling tower basin.	Annubar, which contains sensors to measure both the effluent flow and effluent temperature.
MRZ	32	River bottom at the SCCW outfall.	MRZ temperature sensors at four locations and a velocity sensor at one location. The temperature sensors are situated on the periphery of the MRZ, which includes a square area, 150-foot on each side, centered on and directly next to the SCCW river outlet. One temperature sensor is located at the centers of both the upstream and downstream edges of the MRZ. The remaining two temperature sensors are located on the MRZ edge opposite of the SCCW outlet; one 50 feet upstream and one 50 feet downstream of the outlet centerline. The velocity sensor is located at the center of the upstream edge of the MRZ and is used to determine the stream flow direction.
Downstream	33	About 350 feet from the right bank of the river, 1000 feet downstream of the SCCW outfall.	Temperature sensors suspended from a floating buoy at depths 3, 5, and 7 feet below the water surface.

The hydrothermal monitoring system was installed in three phases. Phase 1 included the installation of all equipment to allow local collection of all the monitoring data required by the NPDES permit. The Phase 1 work was completed October 14, 1999, satisfying the 90-day requirement specified in the permit. Phase 2, completed shortly thereafter, included enhancements to radio-link all the monitoring stations to one location accessible by cell phone.

Phase 3 included enhancements to radio-link all the monitoring stations to the WBN Environmental Data Station (EDS). The EDS contains computers and software to record, analyze, and display all of the data in "real time" for all of the monitoring stations. The analyses include computations for the following thermal compliance parameters:

- Hourly average river temperature upstream of the SCCW outfall (Station 30),
- 15-minute SCCW effluent flow (Station 31),
- 15-minute SCCW effluent temperature (Station 31),
- MRZ maximum 15-minute bottom temperature (Station 32),
- MRZ 15-minute bottom velocity (Station 32),
- Hourly average river temperature downstream of the SCCW outfall (Station 33),
- Hourly average temperature rise, upstream to downstream (Station 30 to Station 33), and
- Hourly average temperature rate-of-change (Station 33).

The Phase 3 work was completed on November 19, 1999. On January 12, 2000, a callout system was implemented at the EDS to replace the alarm system installed in August 1999.

Shortly after the SCCW system began operation, problems were encountered with Station 31. First, sporadic losses of station power began causing data outages. Since the effluent temperature was of primary importance in the initial operation of the system, on July 28, 1999, a backup temperature probe was installed in the effluent at the morning glory weir (glory hole) located just before the river outlet for Outfall 113. Second, dye-dilution flow tests conducted in late July indicated that the annubar was not providing flow measurements of suitable accuracy (i.e., within ±10 percent of the true flowrate). In the months that followed it became clear that the annubar was not going to be reliable for measuring the effluent flowrate, primarily due to chronic fouling of pressure taps in the instrument. During the same period, dye-dilution flow tests showed that that the effluent flowrate could be accurately monitored by measuring the water level at the glory hole weir. As such, on November 10, 1999, a temporary water level sensor was installed at the glory hole to monitor the flowrate on a continuous basis. On January 21, 2000, TVA submitted a request to permanently move measurements for the effluent flow and temperature from Station 31 to the glory hole. TDEC approved this change on February 24, 2000. By March 20, 2000, the instrumentation for flow and temperature were upgraded with permanent equipment and incorporated as part of Station 32. Consequently, Station 31 was abandoned. Currently, therefore, Station 32 includes all instrumentation to monitor the effluent flow and temperature, as well as all MRZ parameters.

Beginning in May 2000, problems of a different kind began occurring at Station 30, which is located on the downstream face of the powerhouse at Watts Bar Dam. At that time the station included a single temperature sensor situated at elevation 670 feet msl, 5 feet below the normal minimum tailwater elevation at the dam. In late spring and early summer, stratification develops

in the forebay of Watts Bar Dam. During periods when the powerhouse was idle, cold bottom water from the forebay was found to be leaking through the hydroturbines, which caused artificial cooling of the temperature sensor. Since Station 30 serves as the upstream measurement for the Outfall 113, this, in turn, artificially increased the temperature rise for the SCCW discharge, sometimes threatening the NPDES limit. In late spring and summer the depth of the sensor at Station 30 is typically 12 feet or more below the water surface (e.g., the pool of Chickamauga Reservoir is well above the normal minimum tailwater elevation of 675 feet msl). Subsequent measurements in the tailrace appeared to indicate that the water temperature above the sensor, at the 5-foot depth, remained indicative of the ambient temperature when unaffected by leakage (e.g., when the hydroturbines were operating).

In an attempt to remedy this situation, on June 6, 2000, TVA proposed to TDEC to upgrade Station 30 with a series of additional temperature sensors and a pressure sensor. TDEC approved the request on August 8, 2000. The pressure sensor, installed at elevation 670 feet msl, was added to measure the water surface elevation. The additional temperature sensors were installed at elevations 674, 675, 676, 677, and 678 feet msl. With this arrangement, the upstream temperature for Outfall 113 is taken as the reading from the first temperature sensor at or below the 5-foot depth.

The modification to Station 30, to include multiple temperature sensors, was implemented on February 2, 2001. With this, a summary of the SCCW hydrothermal monitoring system as it exist today is presented in Table 2.1.3. Detailed aspects of the system are provided in TVA drawings, as listed below.

- HTMS-00-G-01, General Layout,
- HTMS-00-M-02, Antenna Mast Details,
- HTMS-00-M-03, Underwater Conduit Details,
- HTMS-30-E-01, Panel Wiring/Connections,
- HTMS-30-G-03, Equipment Locations,
- HTMS-32-E-01, Panel Wiring/Connections,
- HTMS-32-M-03, Thermistor Anchors,
- HTMS-32-M-04, Velocimeter Anchors,
- HTMS-32-M-05, Glory Hole Water Level Sensor Support,
- HTMS-33-E-01, Panel Wiring/Connections, and
- HTMS-33-M-02, Buoy and Anchor Details.

It is important to note that at Station 33 the downstream temperature is taken as the average of the readings of the sensors at the 3-, 5-, and 7-foot depths. If T_u and T_d denote the measured upstream and downstream temperatures, respectively, then the temperature rise for Outfall 113 is given by

$$\Delta T = T_d - T_u . \tag{1}$$

The temperature rate-of-change is given by

$$\frac{\delta T_d}{\delta t} = \frac{(T_d)_t - (T_d)_{t-\Delta t}}{\Delta t}, \tag{2}$$

where $(T_d)_t$ is the downstream temperature at time t and $(T_d)_{t-\Delta t}$ is the downstream temperature at time t-Δt. For the WBN hydrothermal monitoring system, Δt is 15 minutes.

The hourly average of any compliance parameter is computed as the average of the current and previous four values of the parameter.

Table 2.1.3. SCCW Hydrothermal Monitoring System as of February 2, 2001

Station	ID	Location	Sensors
Upstream	30	Watts Bar Hydro Plant at the outlet of the draft tube for Unit 3.	Temperature and pressure sensors at elevation 670 feet msl, and temperature sensors at elevations 674, 675, 676, 677, and 678 feet msl.
Effluent	32	Glory hole at the outlet for Outfall 113 .	Water temperature sensor and ultrasonic water level sensor.
MRZ	32	River bottom at the SCCW outfall.	MRZ temperature sensors at four locations, and a velocity sensor at one location. The temperature sensors are situated on the periphery of the MRZ, which includes a square area, 150-foot on each side, centered on and directly next to the SCCW river outlet. One temperature sensor is located at the centers of both the upstream and downstream edges of the MRZ. The remaining two temperature sensors are located on the MRZ edge opposite of the SCCW outlet; one 50 feet upstream and one 50 feet downstream of the outlet centerline. The velocity sensor is located at the center of the upstream edge of the MRZ and is used to determine the stream flow direction.
Downstream	33	About 350 feet from the right bank of the river, 1000 feet downstream of the SCCW outfall.	Temperature sensors suspended from a floating buoy at depths 3, 5, and 7 feet below the water surface.

Despite the modifications to Station 30, as summarized above, subsequent measurements in 2001 show that artificial cooling from leakage at Watts Bar Dam continues to persist, even at the 5-foot depth. It is speculated that this is due to the additional fact that Station 30 is installed next to a solid boundary at the most upstream end of the tailrace. Cold water leaking through the hydroturbines first fills the bottom areas of the tailwater, initially affecting the deepest sensors at Station 30. At the same time, peaking operations at Watts Bar Dam and Chickamauga Dam create small amplitude gravity waves that move back and forth in Chickamauga Reservoir. When such waves travel up the reservoir and strike the boundary created by the powerhouse at Watts Bar Dam, the cold water in the bottom of the tailrace is forced up the wall upon which Station 30 is installed. The entire temperature string thus becomes immersed in leakage water from the bottom. This likely was not detected in the original evaluations, conducted to determine the problem at Station 30, because of the dynamic character of the waves in Chickamauga Reservoir. The original evaluations included the collection of temperature profiles

only at a single point in time, which was likely away from the point in time when the crest of any peaking-induced gravity waves were striking the downstream face of the powerhouse.

To prevent artificial cooling at Station 30 from threatening the NPDES limit for the SCCW temperature rise, special operations currently are required at the Watts Bar Hydroplant (WBH) to flush cold water out of the tailrace. For example, when the temperature of leakage water is significantly cooler than the ambient water, and when the hydroturbines are scheduled to be idle for a long period of time, a special pulse of water must be provided about every five hours to prevent an excessive buildup of cold water in the bottom of the tailrace.

2.2 Station 34 and Station 35

To obtain additional data for the behavior of the thermal plume created by the SCCW outfall, TVA has installed two additional monitoring stations at the downstream end of the mixing zone. Both stations are situated in navigation zones, and thus are best classified as "expendable" study monitors. Station 34 is situated between Station 33 and the right bank of the river and was installed to obtain a better understanding of plume behavior when at least one hydroturbine is operating at Watts Bar Dam. Station 35 is situated on the left bank of the river and was installed to obtain a better understanding of plume behavior when there are no hydroturbines operating at Watts Bar Dam. Stations 34 and 35 are mentioned here only for information and completeness. They are not a formal part of the NPDES hydrothermal monitoring system. The analysis of data for Stations 34 and 35 currently is incomplete and hence is not included in this report.

2.3 NPDES Monitoring Data

The NPDES monitoring data presented herein encompasses the period from December 1999 through August 2001, a total span of twenty-two months. The starting month, December 1999, was selected primarily for convenience, as this is the first full month that EDS data collection and analysis commenced for the SCCW hydrothermal monitoring system. No data are presented for the temporary sensors, backup sensors, and partially established data collection systems used between July 1999, when the SCCW system commenced operation, and November 1999. It is noted that, within the span of this data, changes were yet taking place with the hydrothermal monitoring system—in particular, the previously discussed modifications for Stations 30, 31, and 32.

Plots of the monitoring data are given in Figures 2.3.1 through 2.3.21. Each figure encompasses one month of data and includes two parts, a and b. Plots contained in each part are as follows:

Part a Plots

- Instream water temperatures (°F), including:
  - Intake temperature for WBN Unit 1,
  - Hourly average temperature upstream of the SCCW outfall, T_u,
  - MRZ maximum 15-minute bottom temperature, and
  - Hourly average temperature downstream of the SCCW outfall, T_d.
- Hourly average temperature rise, ΔT, upstream to downstream (F°).
- Hourly average temperature rate-of-change, $\delta T_d/\delta t$ (F°/hour).
- Discharge from Watts Bar Hydroplant (cfs).

Part b Plots

- 15-minute SCCW effluent temperature (Outfall 113, °F) and 15-minute plant diffuser effluent temperature (Outfall 101, °F).
- Plant yard holding pond elevation (feet msl).
- 15-minute SCCW effluent flow (Outfall 113, gpm) and 15-minute plant diffuser effluent flow (Outfall 101, gpm).
- 15-minute MRZ bottom velocity (feet/second, positive=velocity in downstream direction).

Some general observations in the behavior of the data include the following:

- No temperature violations occurred within the span of the data.
- The MRZ, downstream, and Unit 1 temperatures usually are lower when WBH is on, because of dilution by the turbine releases, and higher when WBH is off. The upstream temperature can behave differently depending on the temperature of water in the forebay of Watts Bar Dam and/or leakage through the hydroturbines.
- The temperature rise ΔT is usually lower when WBH is on, because of dilution by the turbine releases, and higher when WBH is off. Leakage of cold water through the hydroturbines at WBH can, at times, reverse this trend.
- The temperature rate-of-change usually exhibits a positive spike when WBH ceases operation, because instream temperatures increase, and exhibits a negative spike when WBH resumes operation, because instream temperatures decrease.
- The effluent temperature for the plant diffusers is measured in the blowdown pipe before entering the diffusers. An interlock from Watts Bar Dam ensures that the diffusers are closed when WBH is off, which diverts the WBN cooling tower blowdown to the yard holding pond (e.g., see plot of diffuser and SCCW effluent flowrates). During these times, even though there is no diffuser discharge, the temperature of the effluent is yet recorded, and represents the temperature of the blowdown flowing to the yard holding pond. When the SCCW system is operating in summertime mode (i.e., with the bypass

closed), the temperature of the SCCW effluent is about the same as the temperature of the blowdown flowing to the yard holding pond. However, when WBH is on and the diffusers are in service, the diffuser discharge includes effluent from both the cooling tower blowdown and the yard holding pond. During these times, since water in the yard holding pond is usually cooled, the temperature of the diffuser discharge will be lower than that of the SCCW discharge.

- Except for short-term events when WBH is off, the MRZ bottom velocity is usually in the downstream direction.
- Due to an outage of the SCCW system in earch November 2000, no data are available for the effluent temperature and flowrate (Figure 2.3.12b).

2.4 Comparison of 1-Hour Averaging and 24-Hour Averaging

Plots of the instream compliance parameters for Outfall 113, including the downstream temperature T_d, temperature rise ΔT, and temperature rate-of-change $\delta T/\delta t$, are given in Figures 2.4.1 through 2.4.21. As before, these include the months of December 1999 through August 2001. In fulfillment of Part III-B of the permit, data are shown for both 1-hour averaging and 24-hour averaging. Note that a 24-hour average is not presented for the temperature rate-of-change. This is because by nature of its definition, a temperature change *per hour*, it is somewhat ambiguous to average this parameter over any period longer than one hour.

3.0 SURVEY DATA

As required in Part III-B of the permit, TVA has conducted instream temperature surveys of the SCCW thermal discharge. To obtain data showing significant seasonal changes in the mixing zone, if any, the surveys were conducted with ambient conditions indigenous of the winter, spring, summer, and fall. In all of the surveys the SCCW system was thermally loaded and included measurements across the full width of the river from Outfall 113 to the end of the mixing zone. The plan for the surveys is summarized by Smith et al. (2000) and includes a description of the survey rationale and measurement specifications. The data presented herein focuses on surface temperature transects obtained using a sidearm array of fixed RTD sensors at 0.5, 1.0, 1.5, and 2.0 meters below the water surface. The RTD array was mounted on a survey vessel that passed through the study area approximately every two hours. Each pass included measurements along multiple transects of sufficient number to define the full lateral and longitudinal extent of the SCCW thermal plume. Analyses of other data containing full depth temperature profiles were taken in the surveys, but currently are not available for this report.

A summary of basic field conditions for each survey is given in Table 3.1. A brief description of each survey follows.

Table 3.1. Basic Field Conditions for SCCW Surveys

Survey No.	Date	Approximate Ambient Water Temperature	Approximate Ambient Air Temperature	River Conditions
1	2/23/2000	46.5°F	67°F	Period of no flow for about 8 hours
2	3/8/2000	51.0°F	66°F	Hydro operation at WBH providing about 7000 cfs
3	5/18/2000	64.4°F	85°F	Period of no flow for about 11 hours
4	8/1/2000	80.6°F	80°F	Period of no flow for about 12 hours
5	12/14/2000	48.5°F	45°F	Period of no flow for about 9 hours

3.1 Survey No. 1

Survey No. 1 was conducted on February 23, 2000. The survey was performed to measure the evolution of the SCCW thermal mixing zone under wintertime conditions with no flow in the river. The ambient water temperature during the test was about 46.5°F. The SCCW system was operating with the bypass open. With an air temperature approaching 67°F, the Outfall 113 effluent temperature was between 10 F° to 15 F° warmer than the ambient water temperature. These types of conditions contribute to a large temperature rise in the river. Five passes were made through the study area during the survey.

Plots of the survey data are given in Figures 3.1.1 through 3.1.3. Each figure contains a series of plots as follows:

Figure 3.1.1a Plots

- WBH discharge (cfs).
- WBH tailwater elevation (feet msl).
- SCCW effluent discharge (gpm).
- MRZ bottom velocity (ft/s).
- Water temperature obtained by temporary study monitors (°F).
- Water temperature obtained by the SCCW hydrothermal monitoring system (°F).

Figure 3.1.1b Plots

- Solar radiation (g-cal/cm^2/min).
- Rainfall (inches).
- Air temperature (°F).
- Wind speed (mph) and direction (azimuth).

Figure 3.1.2a through 3.1.2e Plots

- River temperatures at 0.5-, 1.0-, 1.5-, and 2.0-meter depths for passes 1, 2, 3, 4, and 5, respectively (°F).

Figure 3.1.3a through 3.1.3e Plots

- River temperature *rises* at 0.5-, 1.0-, 1.5-, and 2.0-meter depths for passes 1, 2, 3, 4, and 5, respectively (°F).

3.2 Survey No. 2

Survey No. 2 was conducted on March 8, 2000. The survey was performed to measure the SCCW thermal mixing zone under wintertime conditions with a flow in the river of about 7000 cfs, produced by one hydroturbine at Watts Bar Dam. The ambient water temperature during the test was about 51.0°F. The SCCW system was operating with the bypass open. With an air temperature approaching 67°F, the Outfall 113 effluent temperature was about 16 F° warmer than the ambient water temperature. Since the ambient flow was somewhat steady, only one pass was made through the study area during the survey.

Plots of the survey data are given in Figures 3.2.1 through 3.2.3 in a fashion similar to that of Survey No. 1.

3.3 Survey No. 3

Survey No. 3 was conducted on May 18, 2000. The survey was performed to measure the SCCW thermal mixing zone under springtime conditions. The survey first examined the mixing zone after a long period of no flow, and then with a flow in the river of about 25,000 cfs, produced by four hydroturbines at Watts Bar Dam. The ambient water temperature during the test was about 64.4°F. The SCCW system was operating with the bypass closed. With an air temperature approaching 85°F, the Outfall 113 effluent temperature was between 17 F° to 21 F° warmer than the ambient water temperature. These types of conditions contribute to a large temperature rise in the river. Three passes were made through the study area during the survey, two with essentially no flow and one with a river flow of about 25,000 cfs.

Plots of the survey data are given in Figures 3.3.1 through 3.3.3 in a fashion similar to that of the previous surveys.

3.4 Survey No. 4

Survey No. 4 was conducted on August 1, 2000. The survey was performed to measure the SCCW thermal mixing zone under summertime conditions after a long period of no river flow. The ambient water temperature during the test was about 80.6°F. The SCCW system was operating with the bypass closed. With an air temperature approaching 80°F, the Outfall 113 effluent temperature was only about 7 F° warmer than the ambient water temperature. Two passes were made through the study area during the survey, both with essentially no flow in the river.

Plots of the survey data are given in Figures 3.4.1 through 3.4.3 in a fashion similar to that of the previous surveys.

3.5 Survey No. 5

Survey No. 5 was conducted on December 14, 2000. The survey was performed to measure the SCCW thermal mixing zone under fall conditions. The survey first examined the mixing zone with a river flow of about 16,000 cfs—equivalent to that produced by two hydroturbines at Watts Bar Dam. After this, the survey examined the evolution of the mixing zone with no flow in the river. The ambient water temperature during the test was about 48.5°F. The SCCW system was operating with the bypass open. With an air temperature of only about 45°F, the Outfall 113 effluent temperature was about 12 F° warmer than the ambient water temperature. Three passes were made through the study area during the survey, one with a river flow of 16,000 cfs and two with no river flow.

Plots of the survey data are given in Figures 3.5.1 through 3.5.3 in a fashion similar to that of the previous surveys.

4.0 References

Smith, Brennan T., Paul N. Hopping, and Walter L. Harper, "Instream Temperature Survey Plan for the Watts Bar Nuclear Plant SCCW System Outfall," Report No. WR2000-3-85-144, Tennessee Valley Authority, January 2000.

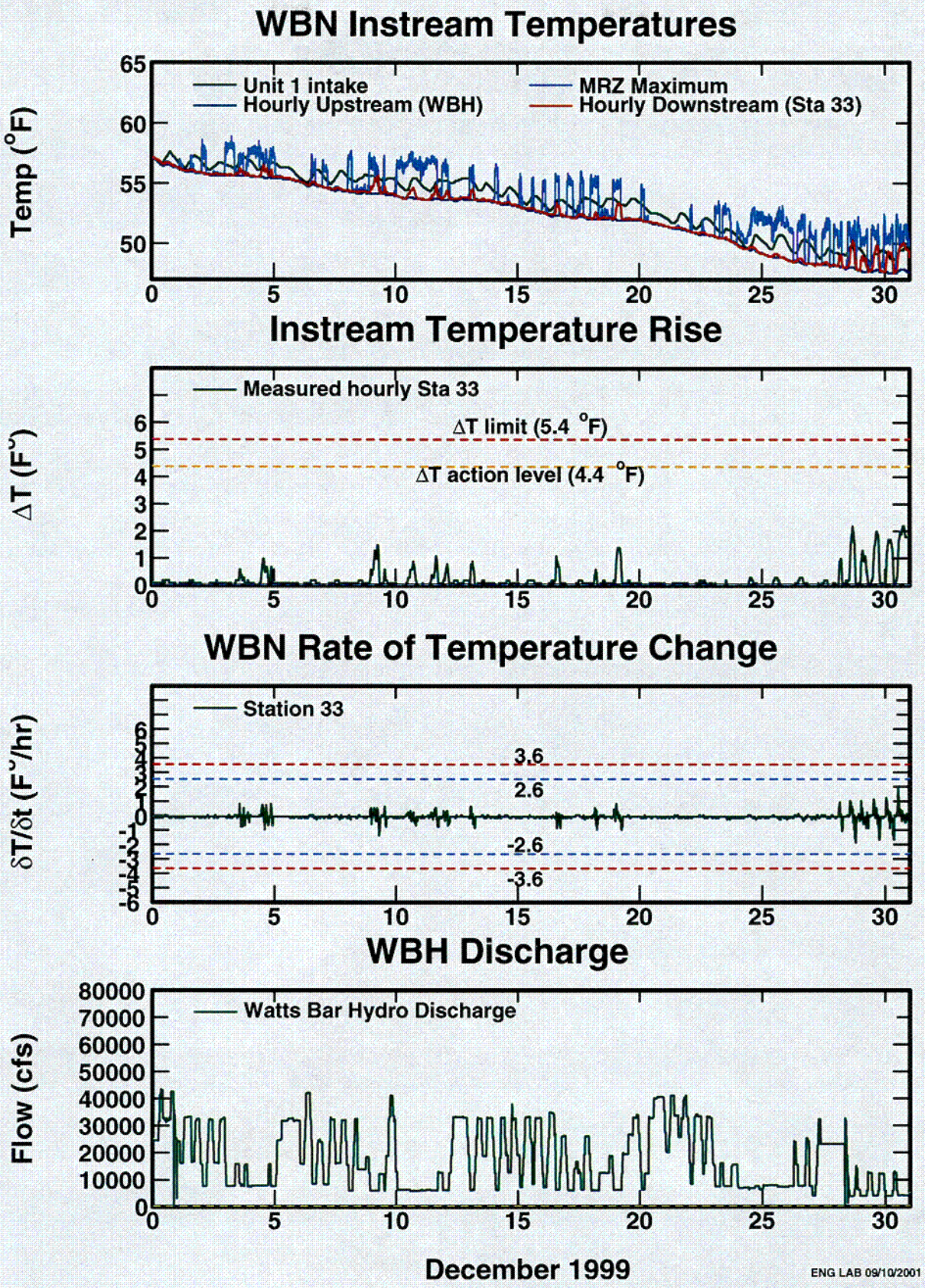

Figure 2.3.1a. SCCW Monitoring Data, December 1999

C01

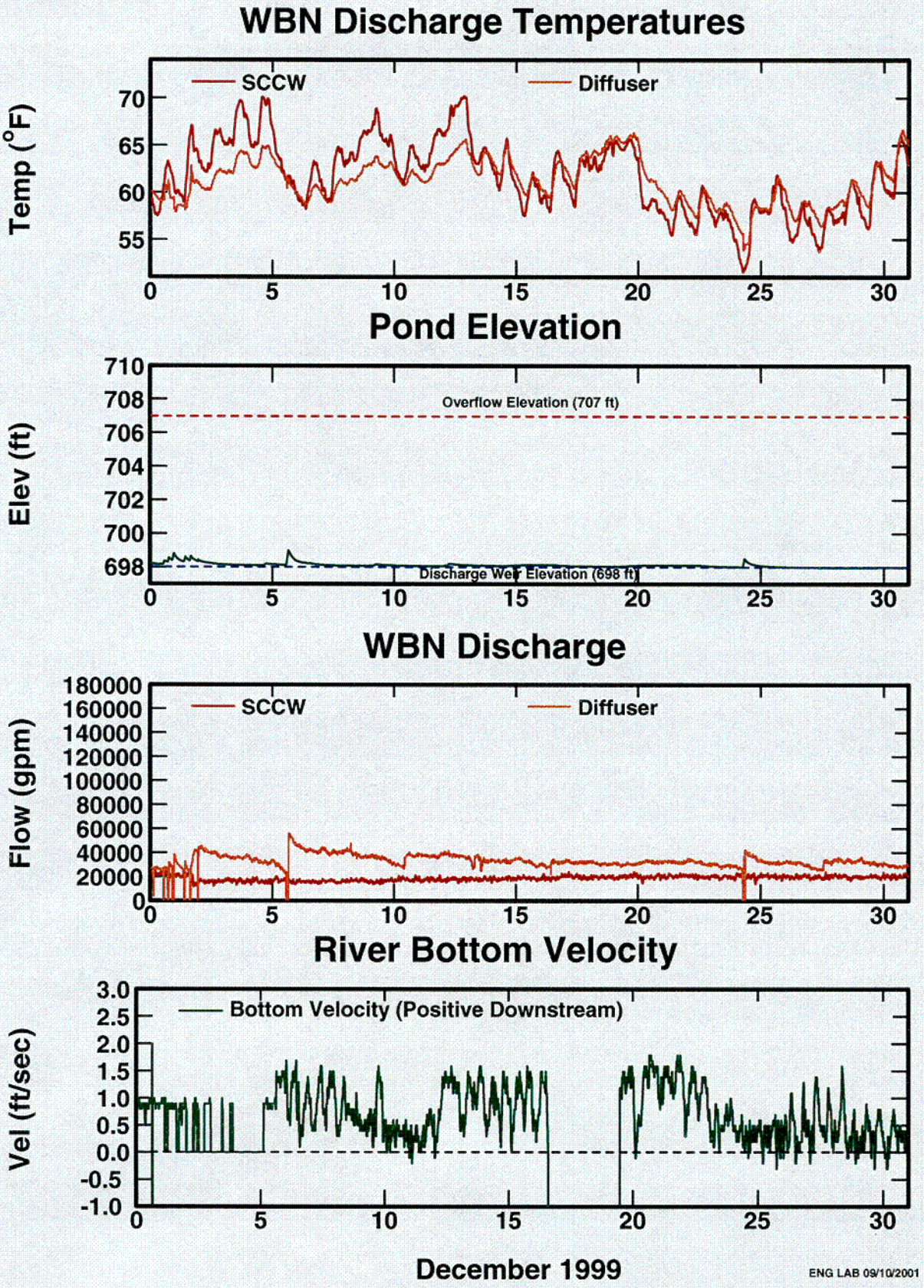

Figure 2.3.1b. SCCW Monitoring Data, December 1999

C02

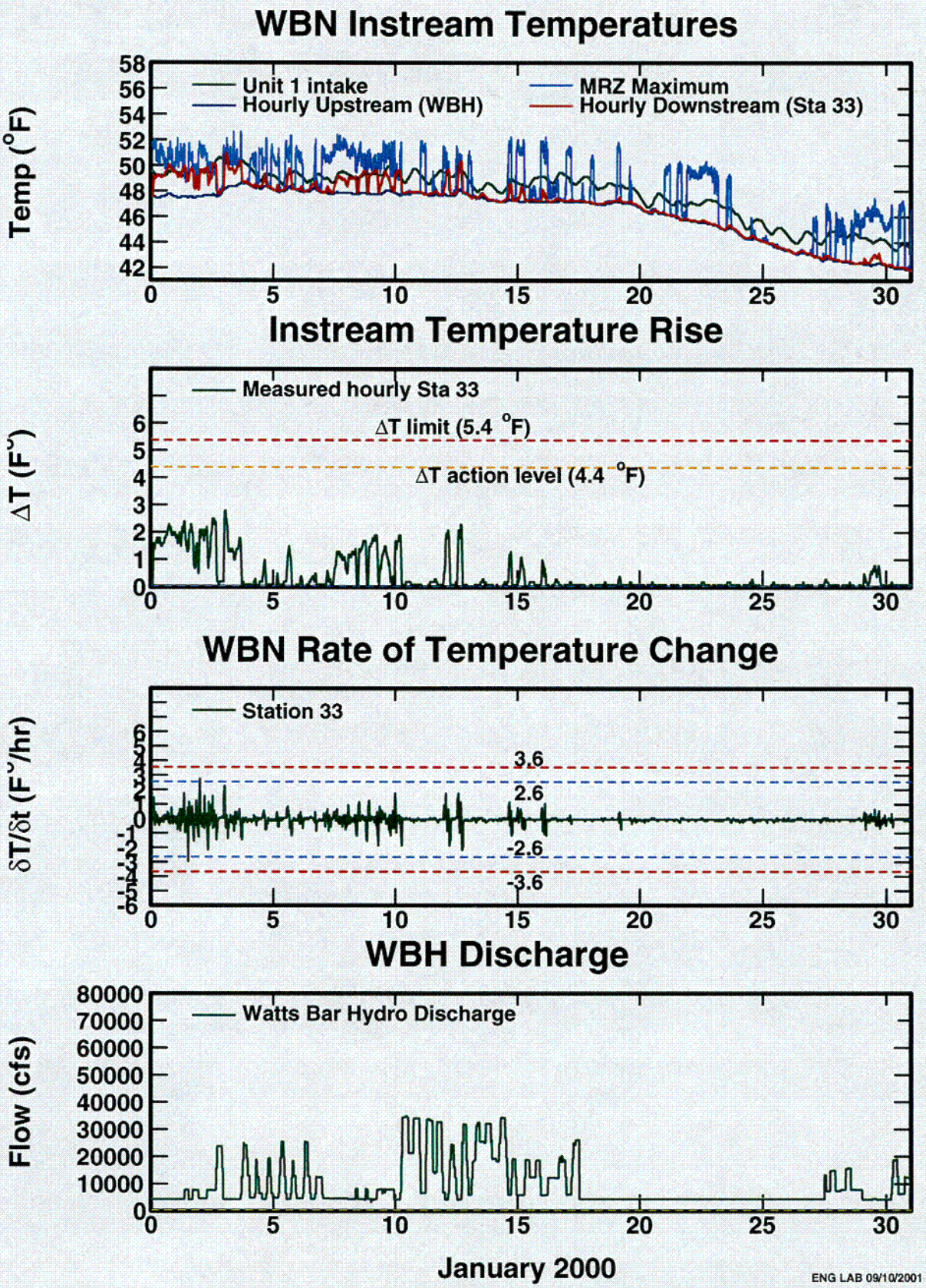

Figure 2.3.2a. SCCW Monitoring Data, January 2000

C03

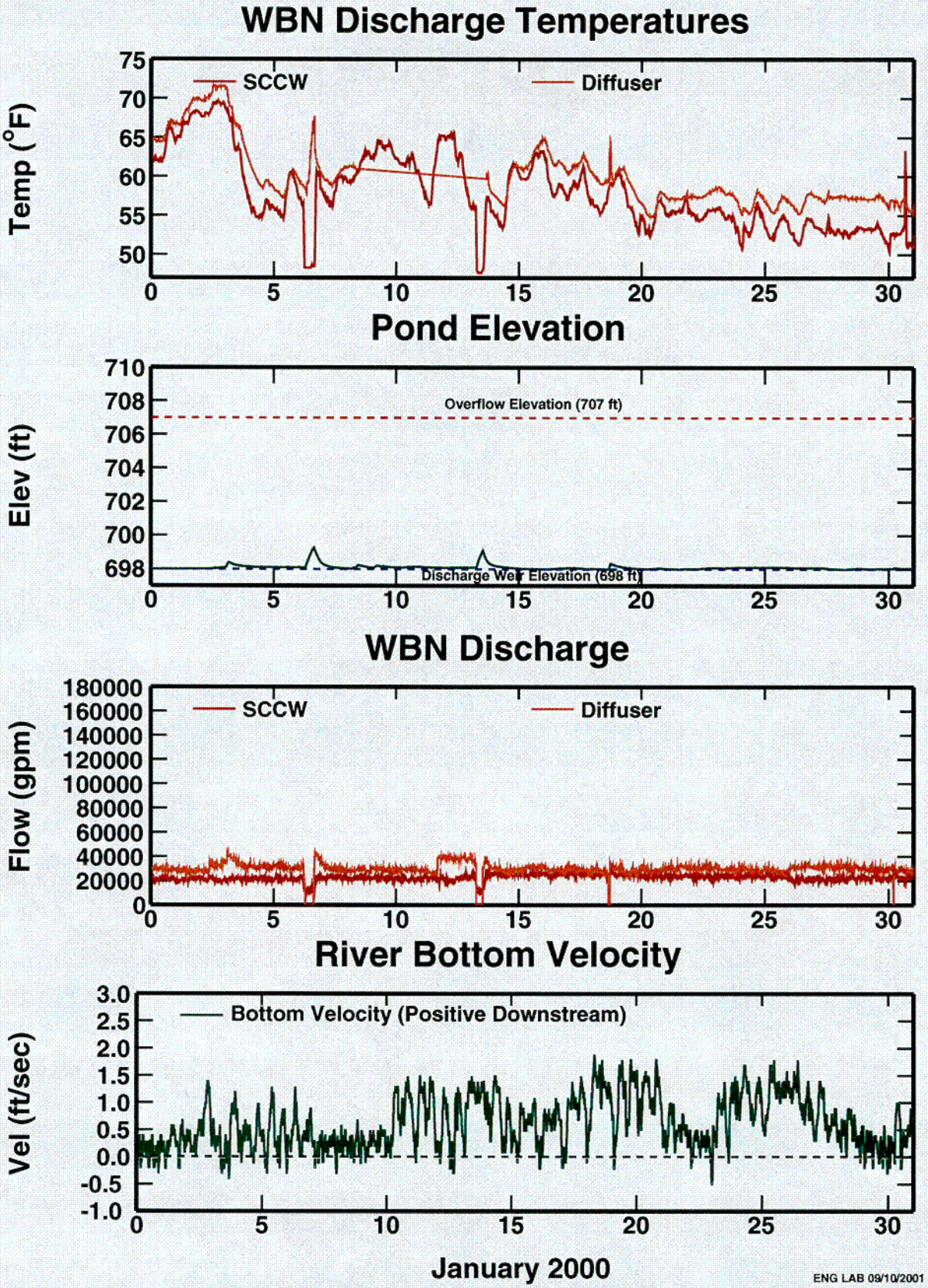

Figure 2.3.2b. SCCW Monitoring Data, January 2000

C04

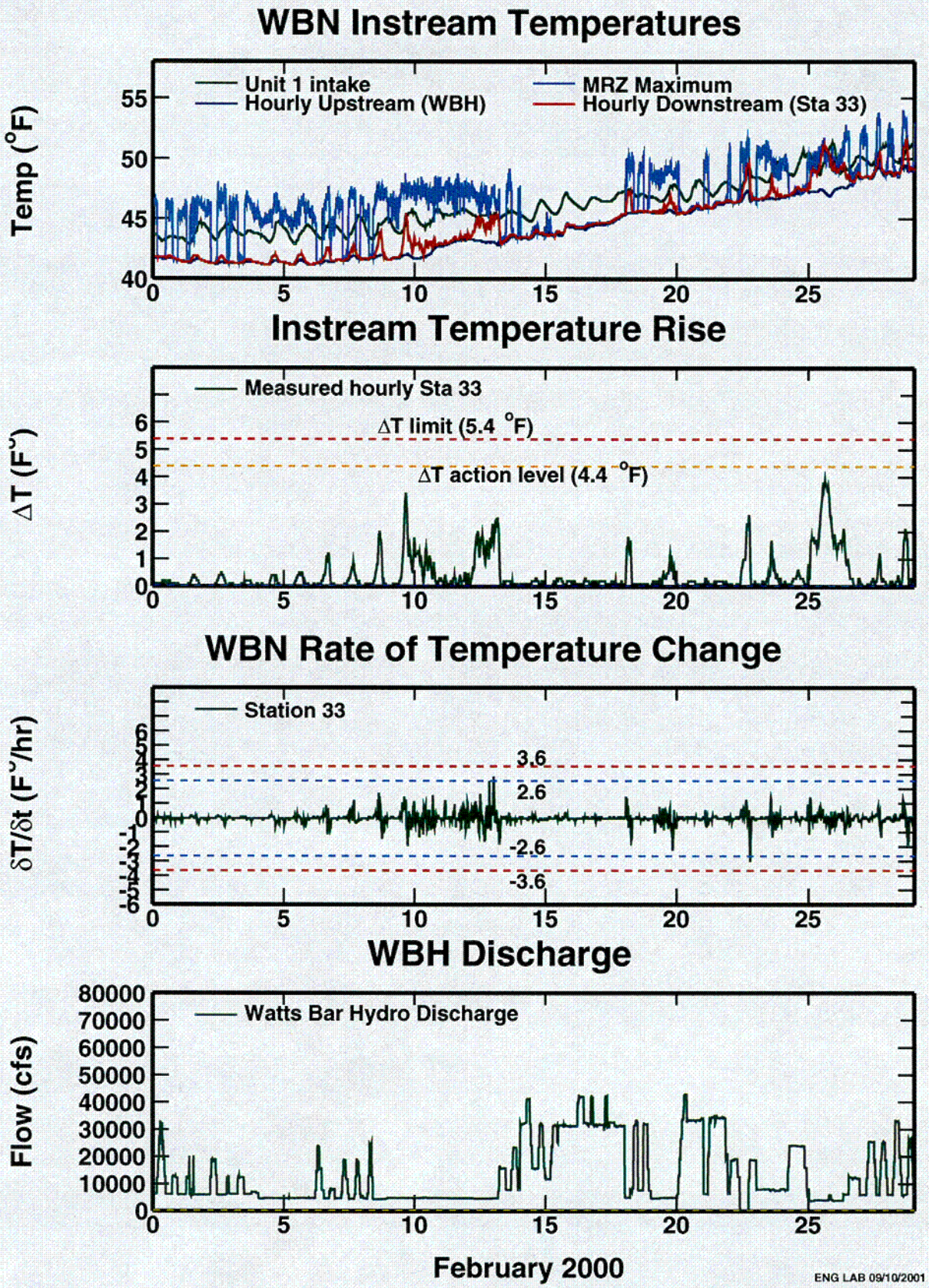

Figure 2.3.3a. SCCW Monitoring Data, February 2000

C05

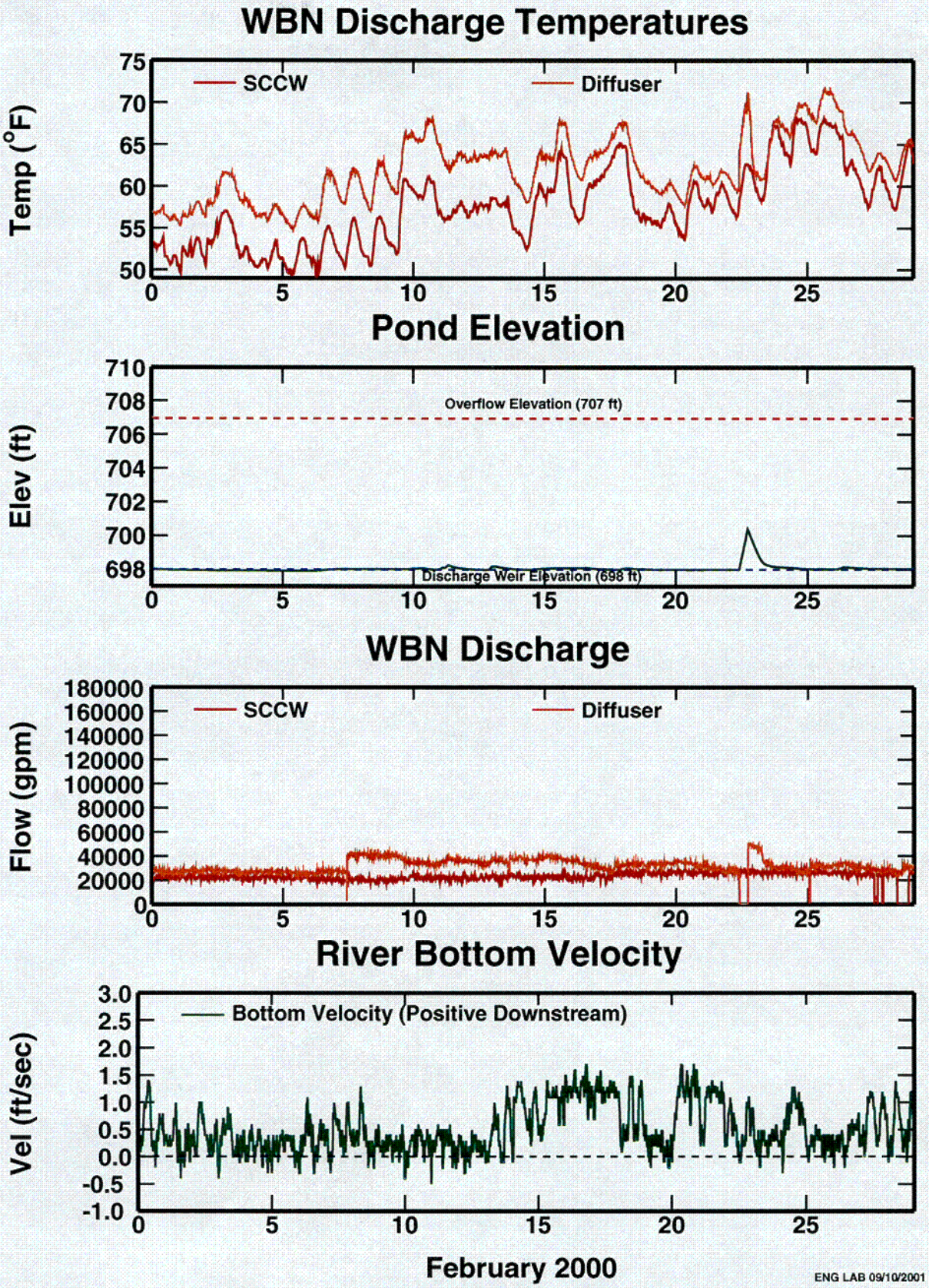

Figure 2.3.3b. SCCW Monitoring Data, February 2000

C06

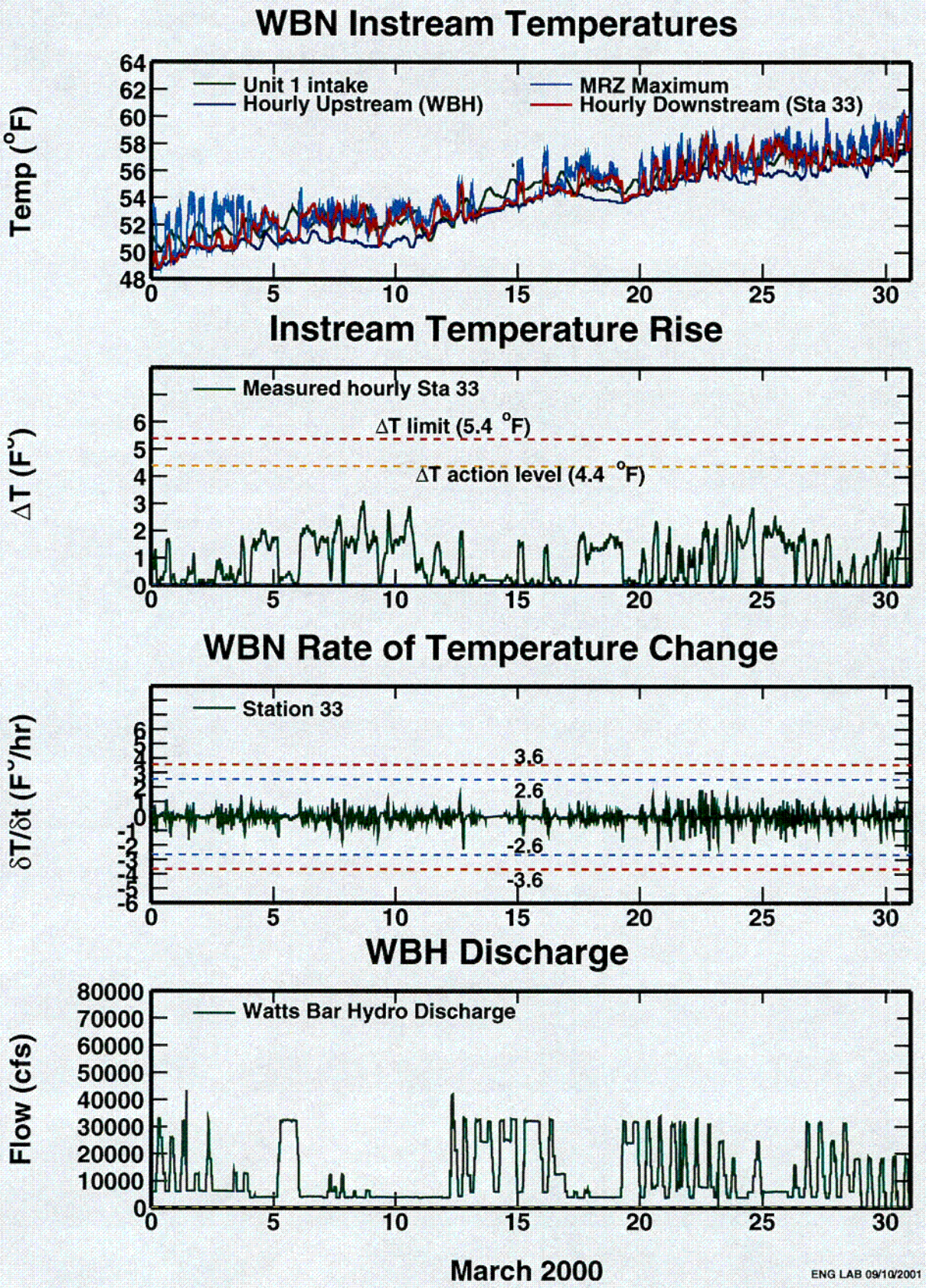

Figure 2.3.4a. SCCW Monitoring Data, March 2000

C07

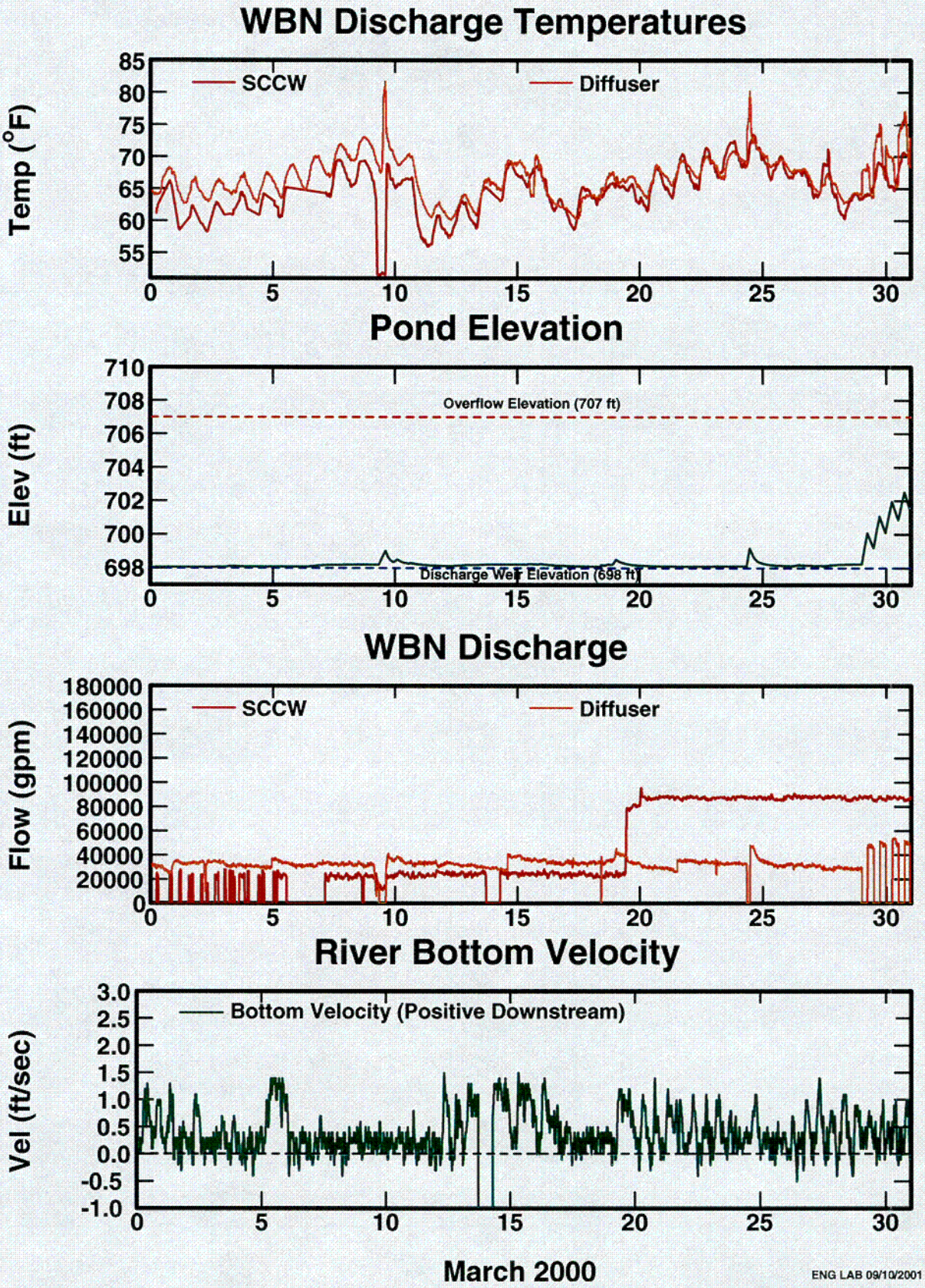

Figure 2.3.4b. SCCW Monitoring Data, March 2000

C08

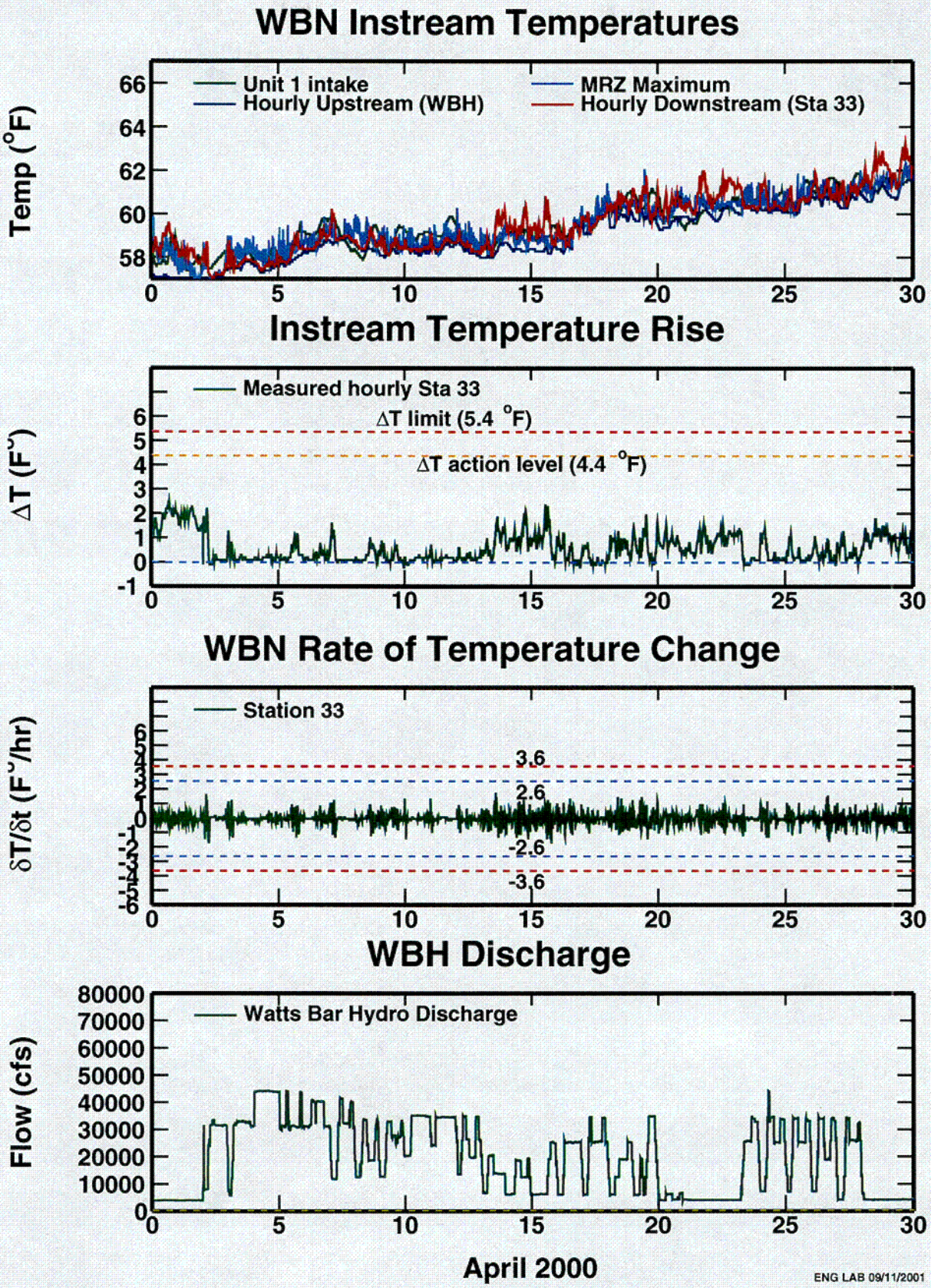

Figure 2.3.5a. SCCW Monitoring Data, April 2000

C09

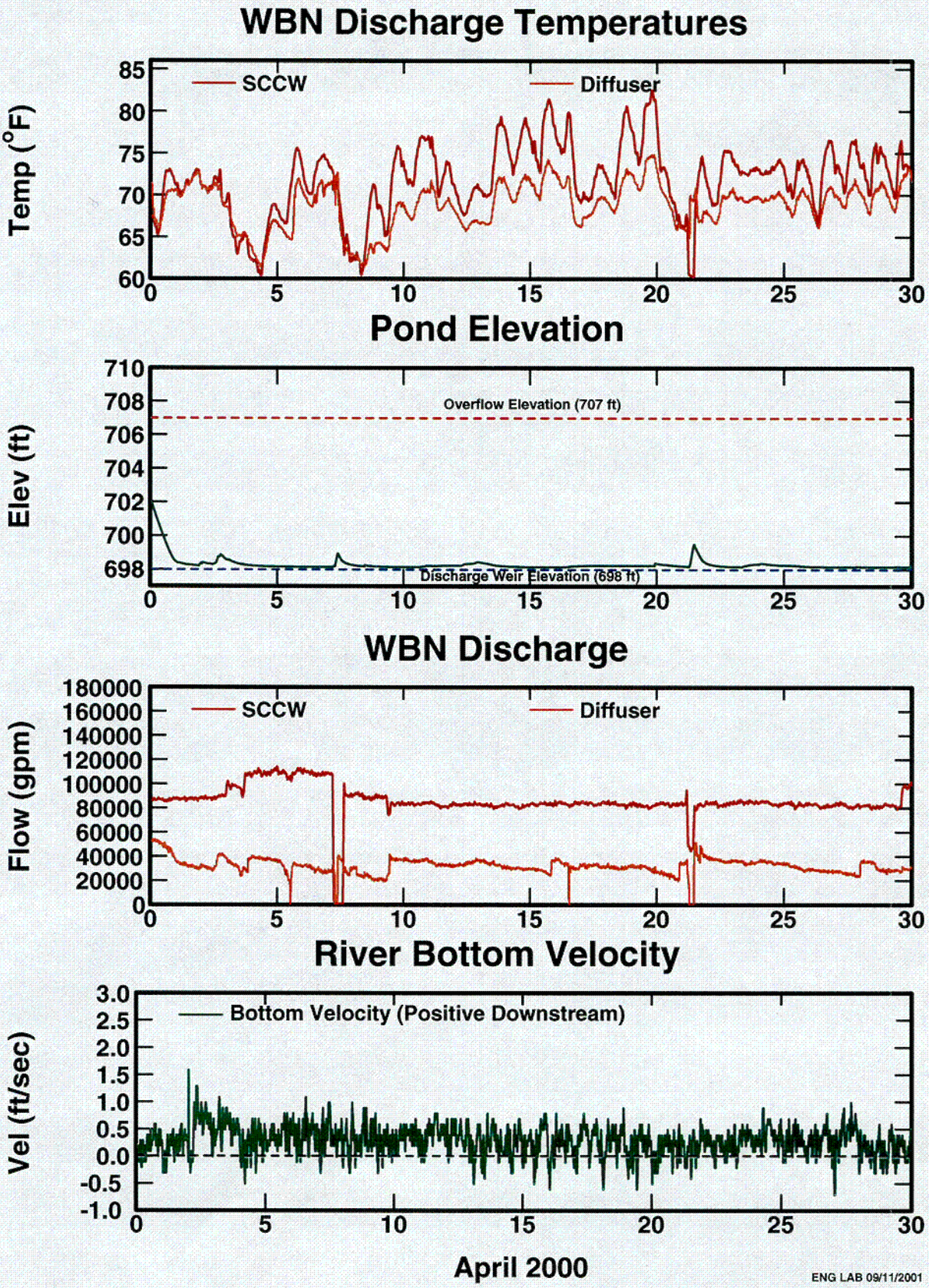

Figure 2.3.5b. SCCW Monitoring Data, April 2000

C10

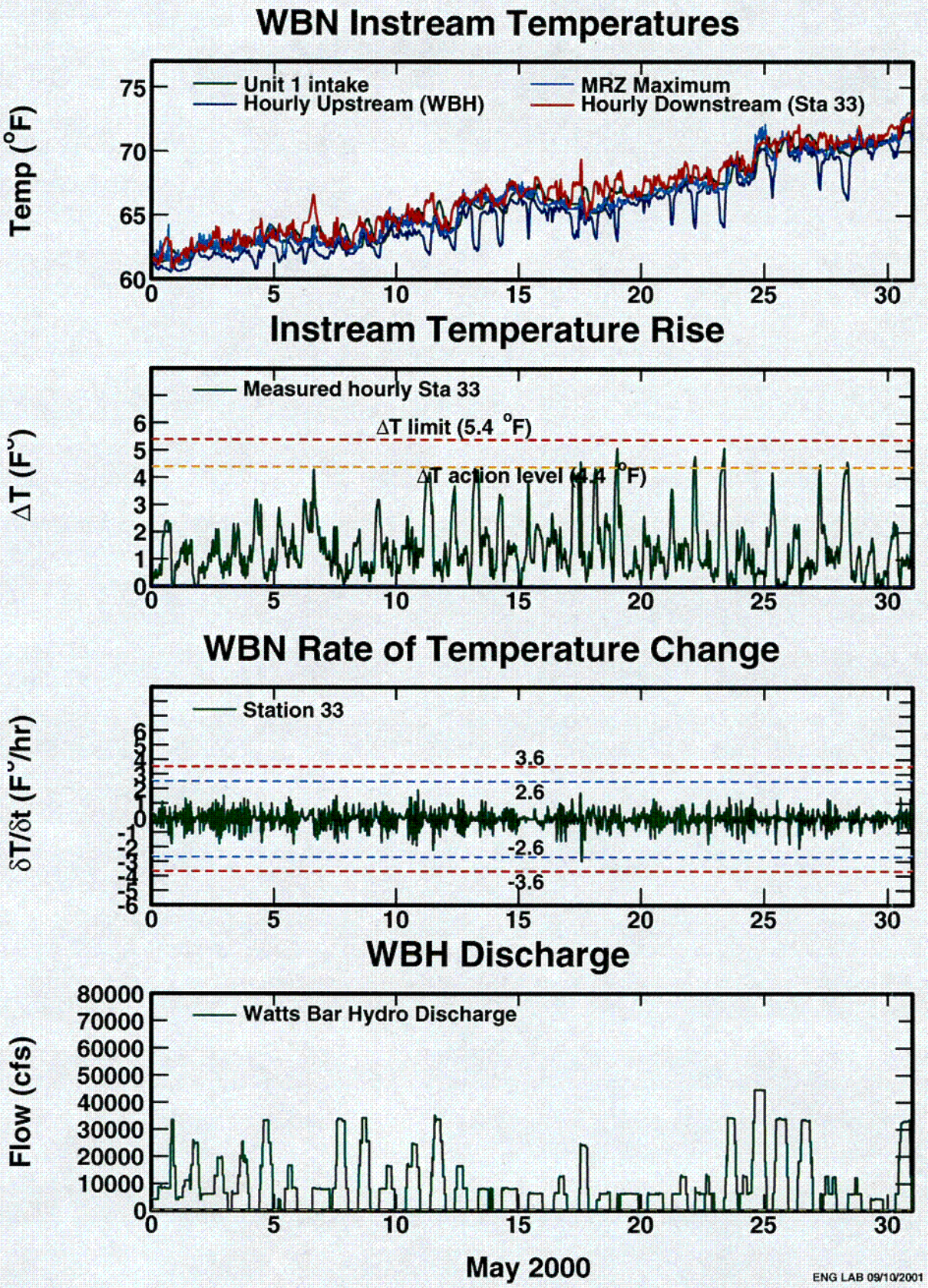

Figure 2.3.6a. SCCW Monitoring Data, May 2000

C11

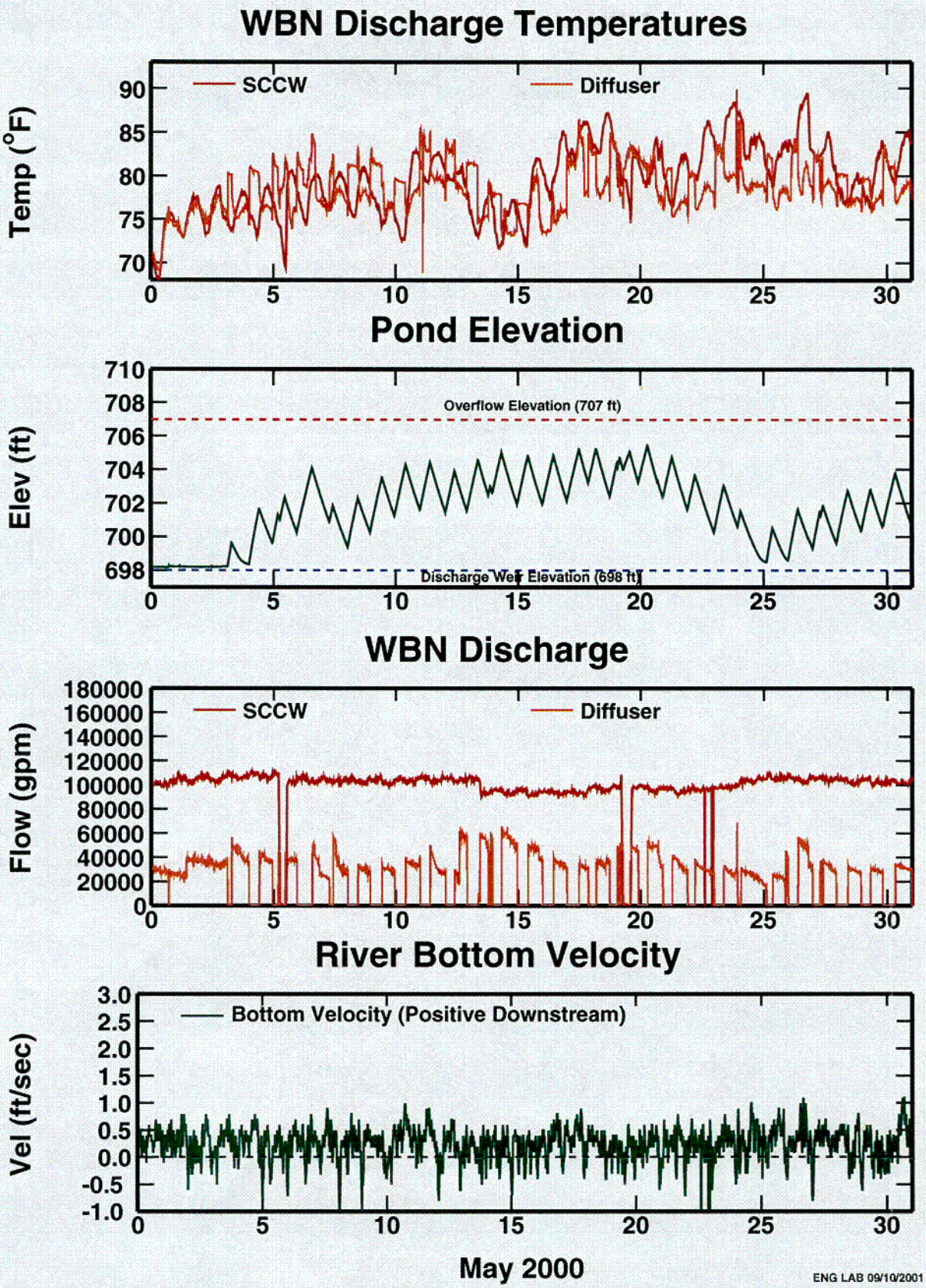

Figure 2.3.6b. SCCW Monitoring Data, May 2000

C12

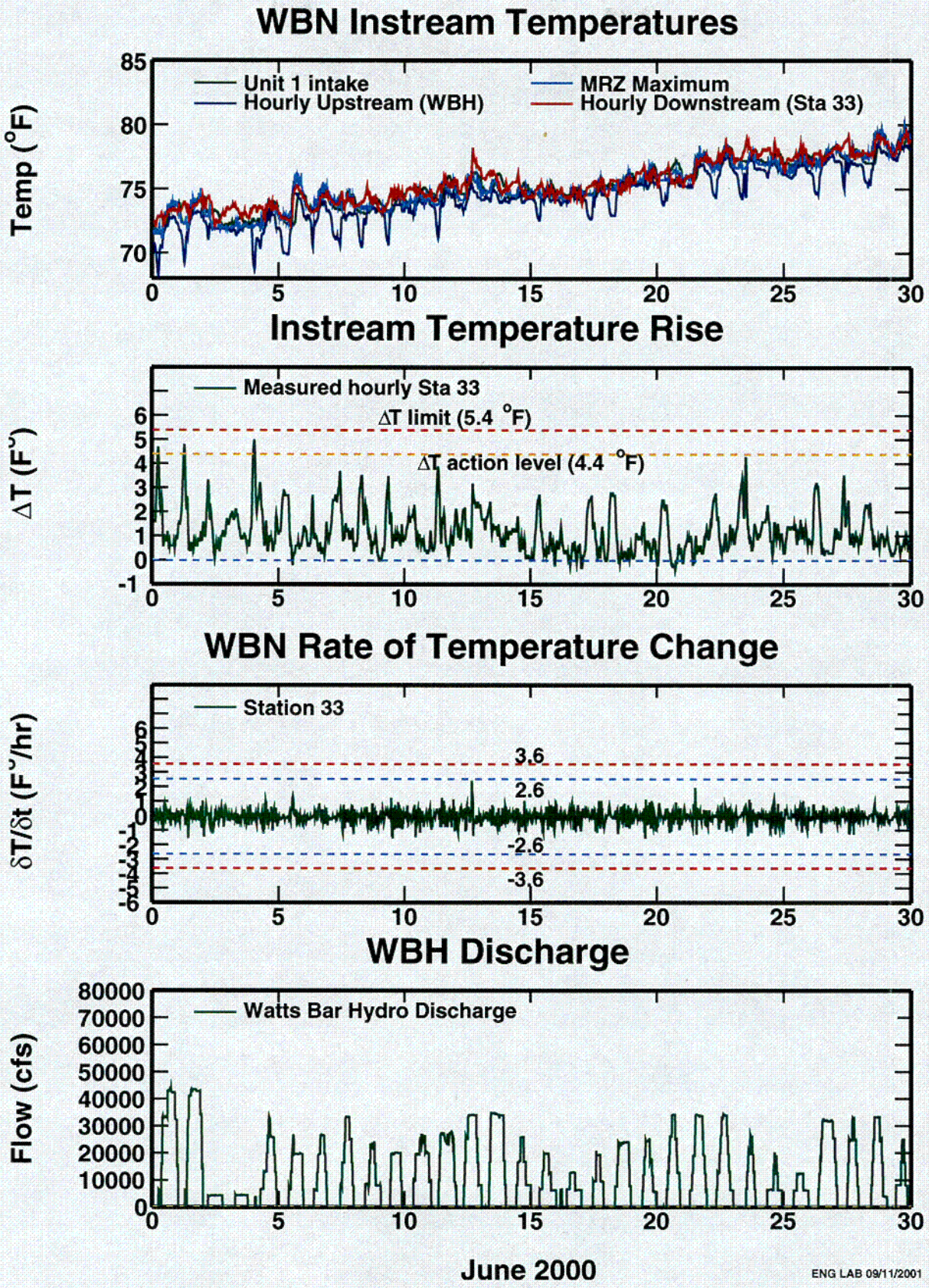

Figure 2.3.7a. SCCW Monitoring Data, June 2000

C13

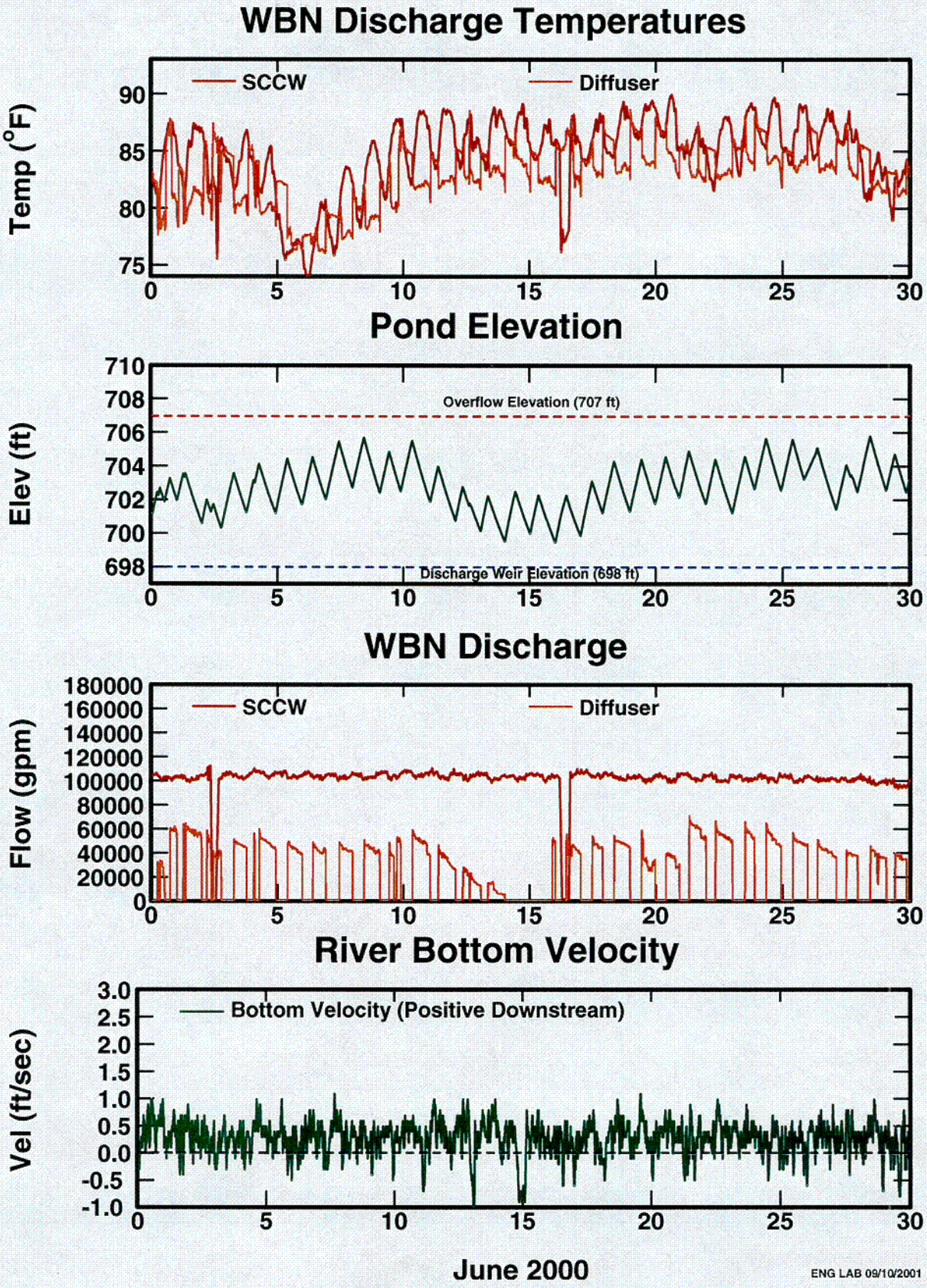

Figure 2.3.7b. SCCW Monitoring Data, June 2000

C14

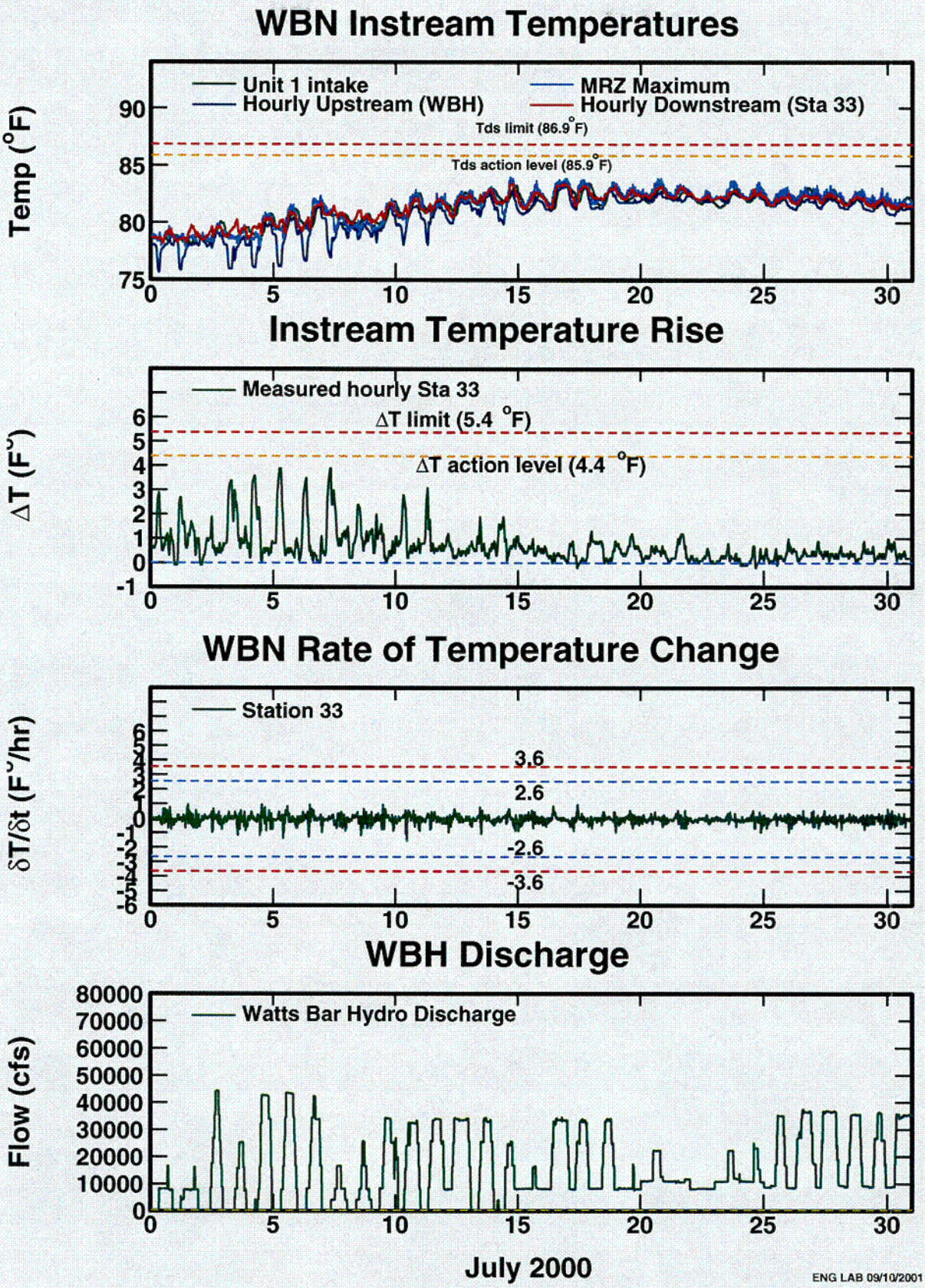

Figure 2.3.8a. SCCW Monitoring Data, July 2000

C15

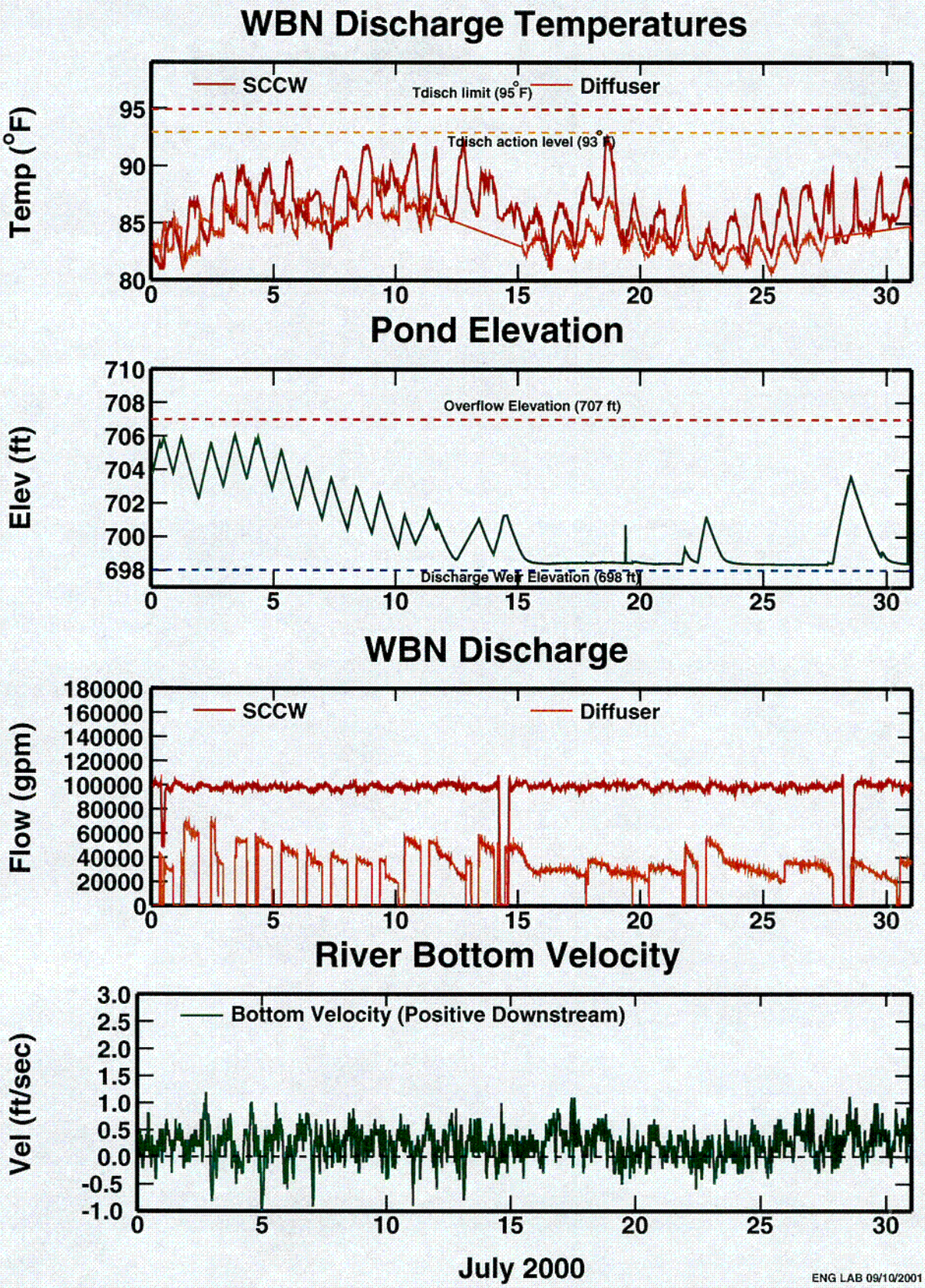

Figure 2.3.8b. SCCW Monitoring Data, July 2000

C16