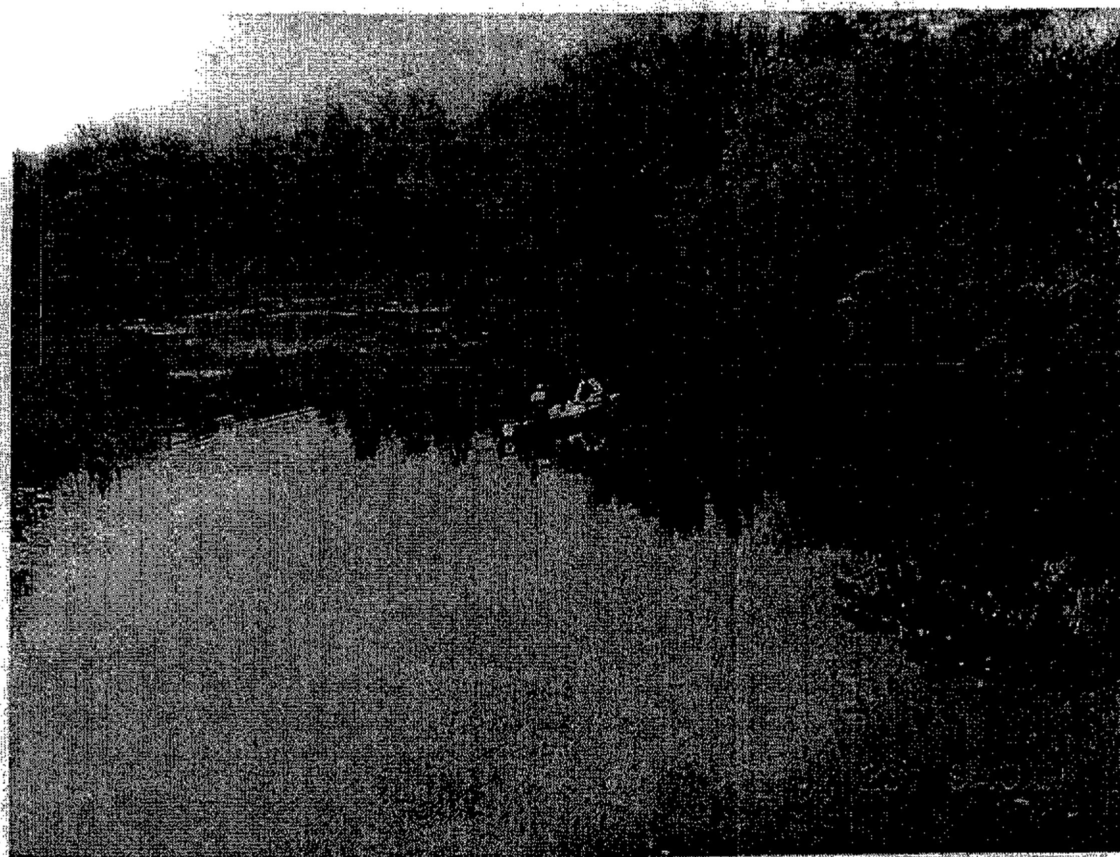
Section 7
Sediment Oxygen Demand Report

Measurement of Sediment Oxygen Demand in the Ashuelot River
US Environmental Protection Agency Report

Measurement of Sediment Oxygen Demand (SOD) in the Ashuelot River, New Hampshire



Prepared by:

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United States Environmental Protection Agency
Region I, New England
Office of Environmental Measurement and Evaluation
Ecosystem Assessment

Prepared for:

New Hampshire Department of Environmental Services
Watershed Management Bureau
Total Maximum Daily Load Program

January 2003

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APPENDICES

1.0 INTRODUCTION

The New Hampshire Department of Environmental Services, Water Quality Bureau, requested EPA's Office of Environmental Measurement and Evaluation assistance in conducting a Sediment Oxygen Demand Study (SOD) on the Ashuelot River in the area of southwestern, New Hampshire.

SOD is the total of biological and chemical processes in sediment that utilize oxygen. SOD studies are useful in the development of predictive mathematical models that will determine waste load allocations. They are also useful in measuring the depletion of oxygen in stratified waters when there are concerns about nutrient regeneration and the loss of aquatic life.

NHDES will reassess attainment/ non-attainment status of dissolved oxygen criteria and the trophic status of the Ashuelot River as well as complete the water quality model based on the results of the SOD study and the water quality survey conducted by NHDES in 2002.

This SOD project included monitoring seven sites along the Ashuelot River. The site selections were determined by NHDES from a previous water quality sampling survey in the summer of 2002. Sites chosen were behind impoundments and low-gradient areas where there is the best chance to find fine sediment. Site descriptions and locations are shown in Table 1. Sediment analyses included SOD and total organic carbon (TOC). The Work/QA Plan in Appendix B provides a detailed account of the methods, procedures and analyses conducted as part of the investigation.

2.0 MATERIALS

EPA, New England Office of Environmental Measurement and Evaluation's mobile laboratory was trailered to the Keene Wastewater Treatment Plant in Keene, New Hampshire. This site was chosen for the electric power and the water supply to the mobile laboratory. A canoe was used for collecting the samples with a Wildco KB Corer. Overlying water was grabbed at each site in four 300 ml BOD bottles at approximately 0.5 meters below the surface. SOD measurements were performed with YSI Model 5100 dissolved oxygen meters.

3.0 METHODS

3.1 Sampling Locations

The seven sampling locations were determined during a field reconnaissance, based on fine sediment availability and proximity to the NHDES water quality survey sites conducted during the summer of 2002. Stations were identified with the use of a Trimble GeoExplorer 3 GPS Unit. Station location GPS data can be found in Table I. Differentially corrected GPS locations were reported in datum NAD-83. Accuracy of the positions is less than 2 meters.

The stations below are identified using NHDES water quality station numbers for continuity. These stations extend from the city of Keene downstream to Winchester, New Hampshire near the Massachusetts border as seen on the map of station locations in Appendix C.

Table I. Station Descriptions and Locations

Station #	Station Description	[illegible]	
ASH-19A	*Upstream of footbridge*	42.933783	-72.288469
ASH-16D	*Upstream Keene WWTP*	42.893018	-72.281079
ASH-16	*Upstream Sawyers Crossing RD*	42.887554	-72.286372
ASH-15E	*Sawyer's Crossing*	42.881413	-72.325734
ASH-15	*Thompson's Bridge*	42.872308	-72.327688
ASH-14	*Village Road Bridge*	42.847115	-72.339714
ASH-12	*Upstream Coombs Bridge*	42.839775	-72.360293

3.2 Sediment Sampling

SOD samples were obtained by using a Wildco K-B Gravity Type Core Sampler. Five cores were grabbed and capped on the top and bottom with #11 stoppers at each site. A representative aliquot of the sediments was taken from the cores after the SOD analyses were complete for each site. These samples were stored in a cooler on ice and returned to the New England Regional Laboratory on September 26, 2002 for total organic carbon analyses. (See the Work/QA Plan in Appendix B for the sediment sampling method)

3.3 Dissolved Oxygen Ambient Water Collection

Ambient water was collected in four 300 ml capacity BOD bottles at each site by hand dipping the bottles 0.5 meters below the surface as described in the procedure in Appendix C. Initial and final dissolved oxygen measurements in each of these bottles are used to simulate production or respiration in the overlying water in the sediment core tubes. Once the bottles were read initially, they were put in the water bath and maintained at 20°C±1° until the end of the test, when the final readings were recorded. The results are used in the final SOD rate calculation. After each station analysis, the BOD bottles were cleaned with soapy water, rinsed with tap water three times and then rinsed with deionized water after each analysis was completed.

3.4 Sediment Oxygen Demand Determination

The method involves confining a measurable volume of water overlying a known area of sediment in a core tube and measuring the depletion of dissolved oxygen over a period of time.

The water column height (h) in each of the five cores is measured in meters and recorded in the logbook for the calculations. Sediment sample cores are then taken and transferred to a temperature controlled water bath and incubated at 20°C±1° for a 3 to 4 hour monitoring period. The dissolved oxygen concentration within these cores is measured every 30 minutes for the test duration. Following the monitoring period, SOD rates are calculated for each core sample and then averaged to produce a mean rate at each site. Standard Deviation is also examined to determine the variability of the sediment dedmand. See the Sediment Oxygen Demand calculation sheet in Appendix A for site specific SOD rates and standard deviations.

The formula for calculating SOD rates is as follows:

$$\text{SOD g } O_2/m^2\text{day} = \frac{((O_i - O_f) - (B_i - B_f))(h)}{(t)}$$

O_i = initial dissolved oxygen (DO) mg/ℓ
O_f = final DO mg/ℓ
B_i = initial DO in bottles mg/ℓ
B_f = final DO in bottles mg/ℓ
h = height of water column in meters
t = time in days

Dissolved oxygen and temperature measurements were recorded in a bound logbook for each station sampled. The meters were calibrated before analysis started and a post calibration check was also performed at the end of analysis. In the final calculation of the SOD rate, only data was used where oxygen depletion versus time is a constant. Often a 30-60 minute stabilization period is required for the core tube temperature to reach equilibrium with the water bath.

4.0 RESULTS AND DISCUSSION

4.1 Sediment Oxygen Demand

SOD results ranged from a low of 0.3 g/(m^2day) at the Foot Bridge in Keene (ASH-19A) to a high of 1.71 g/(m^2day) at the Coombs Bridge (ASH-12) in Winchester. The SOD rates for three of the seven sites (43 % of the sites) were between 0-1 g/m^2day, which is the low range. Four of the seven sites (57% of the sites) were in the medium SOD range of 1-2 g/(m^2day).

Only three replicates at 15E and 16D were used for the calculations due to air bubbles in the chambers. Standard deviation was highest at these sites because only three samples were calculated instead of five samples. For four of the five chambers at site ASH-19A, the oxygen values increased from the start of the test to the finish three hours later. As a result, only one SOD rate was able to be calculated at this site. See Appendix A for all of the stations worksheets with data and results.

Station # ***ASH-19A***

Description: Upstream Footbridge

Location: Keene, NH

Sample #	94868
Time	9:30
Date	9/23/02

Other Analytes	
TOC =	7500 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.422
2	0.430
3	0.415
4	0.418
5	0.485

INITIAL

	DO mg/l	Temp C
1	6.45	20.27
2	6.45	20.25
3	6.53	20.2

Bi ave = 6.48

FINAL

	DO mg/l	Temp C
1	6.43	20.21
2	6.42	20.28
3	6.46	20.4

Bf ave = 6.44

8(Bi-Bf) = 0.04

Water Bath

Time	Temp	Time	Temp
11:30	19.5	14:00	19.6
12:30	19.6		

SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5	Temperature (C) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
11:30	0	6.43	6.33	6.25	6.00	5.66	20.21	20.44	20.37	20.38	21.05
12:00	30	6.44	6.40	6.26	6.02	5.70	20.13	20.23	20.30	20.20	20.65
12:30	60	6.46	6.48	6.21	6.02	5.87	20.05	20.13	20.26	20.10	20.31
13:00	90	6.50	6.53	6.17	6.01	5.97	20.12	20.17	20.29	20.15	20.27
13:30	120	6.53	6.61	6.14	6.02	5.97	20.08	20.17	20.29	20.16	20.26
14:00	150	6.55	6.69	6.11	6.02	6.02	20.10	20.20	20.32	20.21	20.29
14:30	180	6.57	6.66	6.10	6.02	6.06	20.10	20.23	20.34	20.24	20.33
	210										

		SOD				
SOD Mean	n/a	-	-	0.30	-	-
Standard Deviation	n/a					

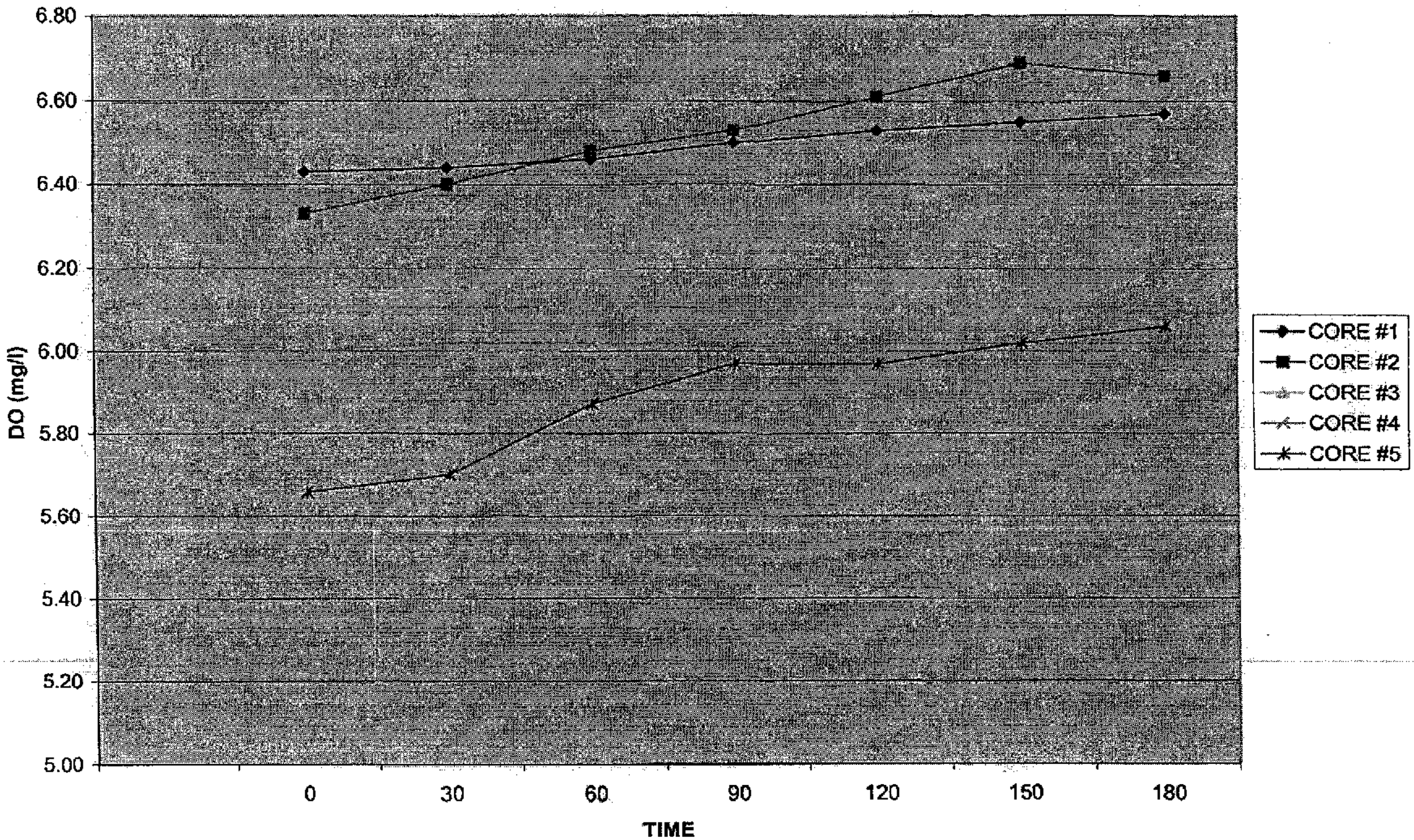
Barometric Pressure	755	752	735	753	754
YSI 5100 Unit #	1	2	3	4	5

Analyzed by: Tim Bridges

Samples collected by: Tom Faber, Melisa Graeble, Jennifer Aederman

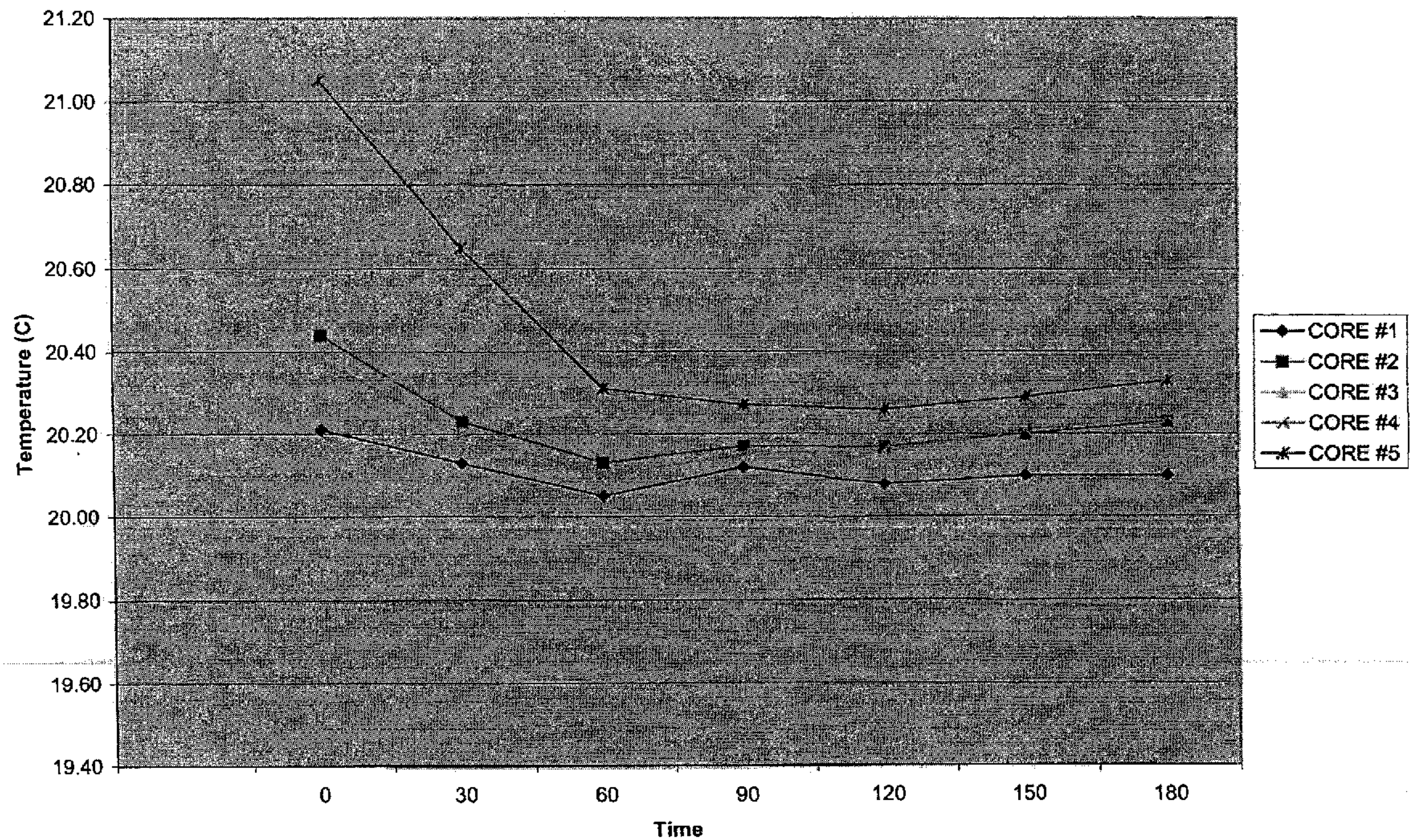
Note: Sediments collected upstream of foot bridge where water depth was betweem 1.5 - 3.0 meters. Sediment was sandy -TF

ASH-19A DO



6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
DO (mg/l)
0
30
60
90
120
150
180
TIME
CORE #1
CORE #2
CORE #3
CORE #4
CORE #5

Temperature ASH-19A



SOD SITE FORM

DRAFT

Station #	*Ash-12*
Description:	Upstream Coombs Bridge
Location:	Winchester, NH

Sample #	94869
Time	12:45
Date	9/23/02

Other Analytes

TOC= 5550 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.388
2	0.387
3	0.395
4	0.406
5	0.378

INITIAL

	DO mg/l	Temp C
1	8.35	20.32
2	8.29	20.32
3	8.41	20.2

Bi ave = 8.35

FINAL

	DO mg/l	Temp C
1	8.24	20.61
2	8.20	20.44
3	8.30	20.43

Bf ave = 8.25

B(Bi-Bf) = 0.10

SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	CORE #5	Temperature (C) CORE #1	CORE #2	CORE #3	CORE #5
1535	0	9.47	9.07	9.48	8.16	20.56	20.60	20.68	20.64
1605	30	9.33	8.98	9.36	8.00	20.36	20.43	20.44	20.47
1635	60	9.20	8.96	9.27	7.88	20.25	20.32	20.33	20.36
1705	90	9.09	8.91	9.17	7.77	20.24	20.33	20.32	20.36
1735	120	9.01	8.88	9.08	7.67	20.23	20.35	20.32	20.34
1805	150	8.90	8.82	8.98	7.59	20.30	20.42	20.39	20.41
1835	180	8.82	8.77	8.90	7.50	20.34	20.45	20.41	20.47
	210	8.68	8.69	8.83	7.40	20.38	20.48	20.45	20.51

SOD Mean	1.71	2.10	1.01	1.76	1.97
Standard Deviation	0.49	SOD			

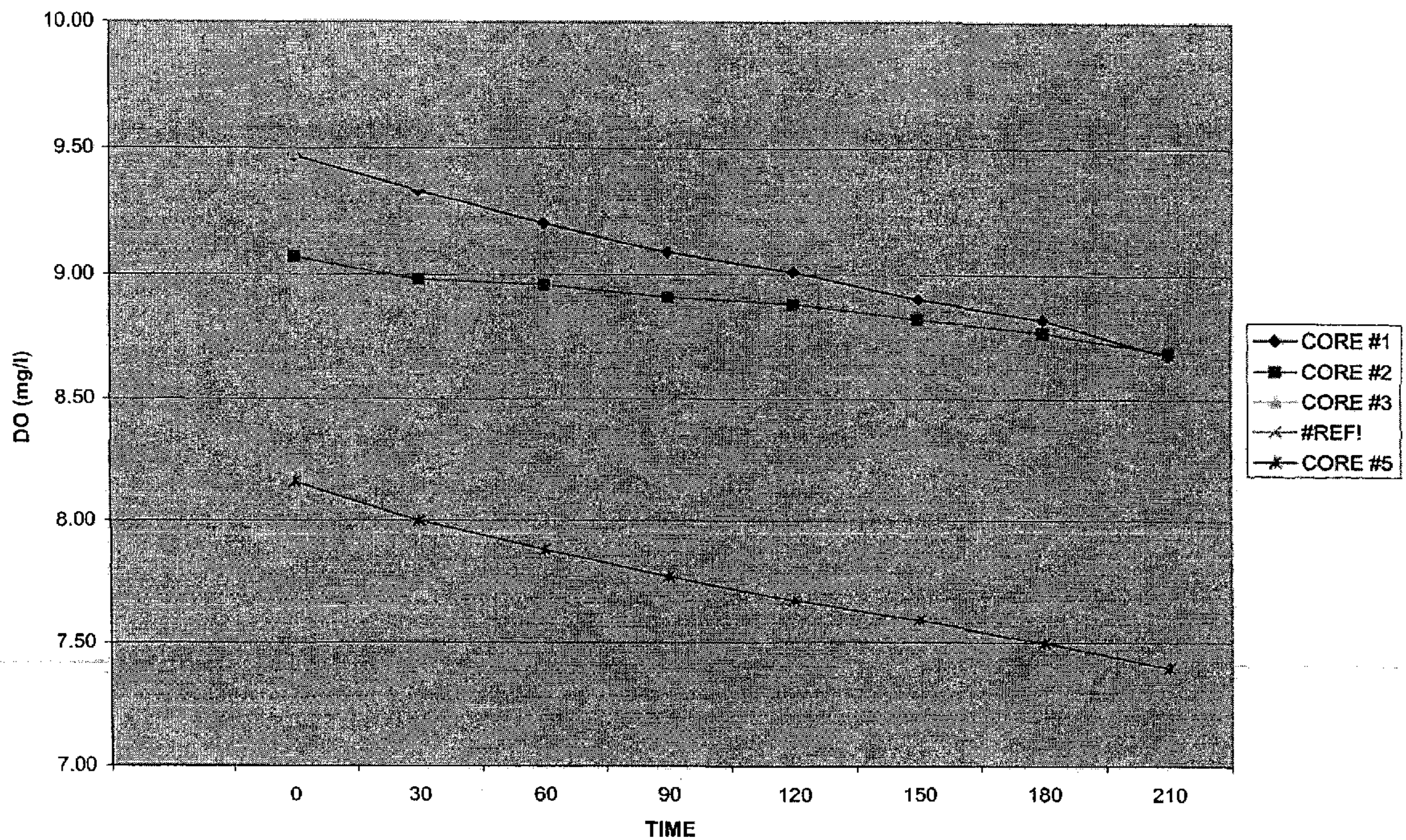
Analyzed by: Tim Bridges

Samples collected by Tom Faber, Melisa Graeble, Jennifer Aederman

Note: Samples were collected upstream of bridge. Sediment was sandy. Samples collected between 0.3 and 1 meter in water depth - TF

8/15/03

ASH-12 DO


10.00
9.50
9.00
8.50
8.00
7.50
7.00
DO (mg/l)
0
30
60
90
120
150
180
210
TIME
CORE #1
CORE #2
CORE #3
#REF!
CORE #5

Station # **ASH-16**
Description: Upstream Sawyers Crossing RD
Location: Swanzey, NH

Sample #	94870
Time	4:30 PM
Date	9/23/02

Other Analytes	
TOC=	3800 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.384
2	0.403
3	0.389
4	0.374
5	0.468

INITIAL

	DO mg/l	Temp C
1	7.32	21.06
2	7.35	20.93
3	7.32	21.28

BI ave = 7.33

FINAL

	DO mg/l	Temp C
1	7.30	20.61
2	7.32	20.52
3	7.32	20.47

Bf ave = 7.31

B(Bi-Bf) = 0.02

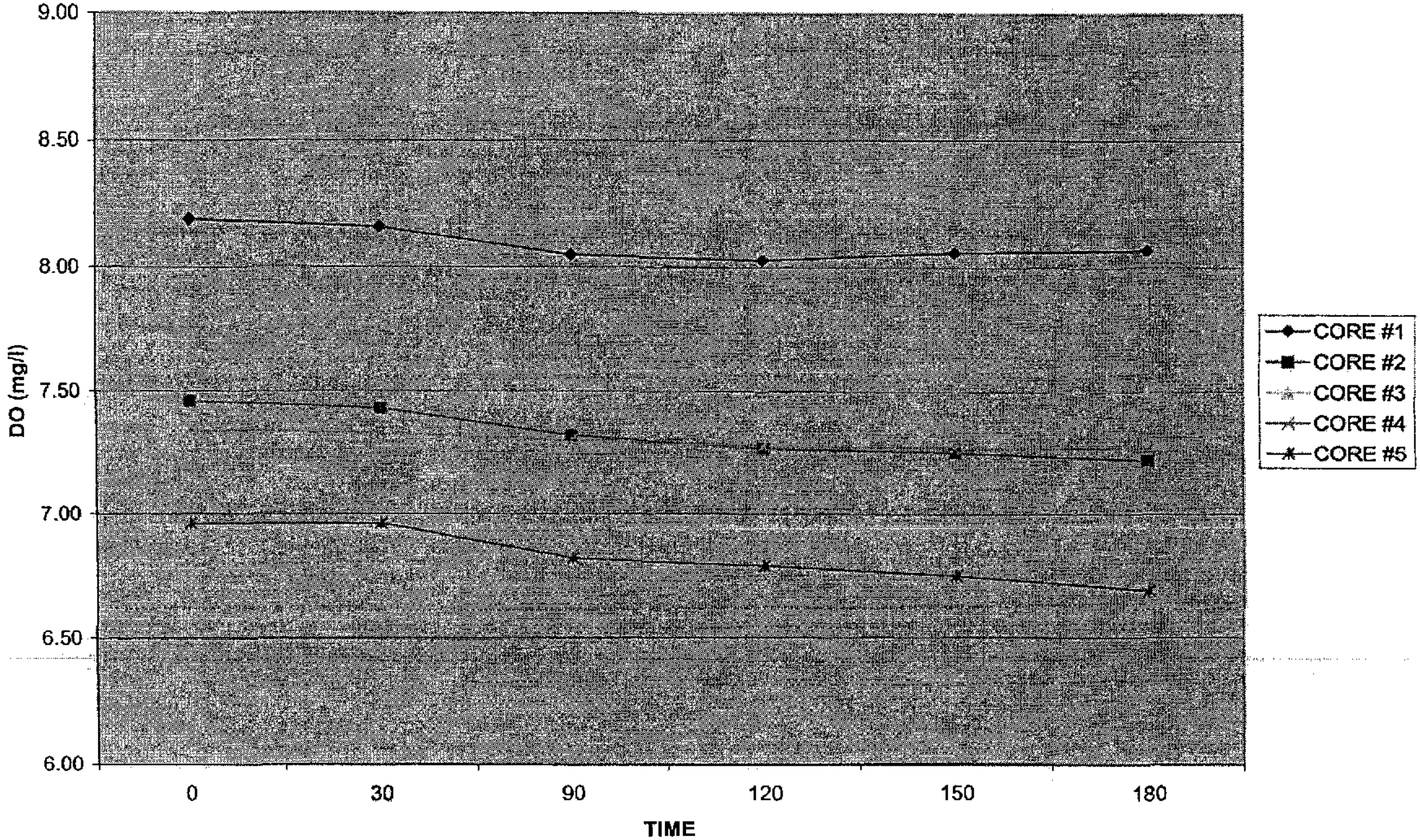
SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5	Temperature (C) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
19:15	0	8.19	7.46	7.64	7.34	6.96	20.39	20.50	20.66	20.48	20.49
19:45	30	8.16	7.43	7.64	7.33	6.96	20.38	20.39	20.54	20.41	20.46
20:45	90	8.05	7.32	7.57	7.30	6.82	20.37	20.32	20.46	20.35	20.43
21:15	120	8.03	7.27	7.53	7.28	6.79	20.38	20.34	20.46	20.36	20.45
21:45	150	8.06	7.25	7.52	7.27	6.75	20.39	20.35	20.46	20.36	20.46
22:15	180	8.07	7.22	7.49	7.27	6.69	20.35	20.34	20.44	20.34	20.47
22:45	210										

		CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
SOD Mean	0.61	0.33	0.74	0.78	0.21	1.01
Standard Deviation	0.33	SOD				

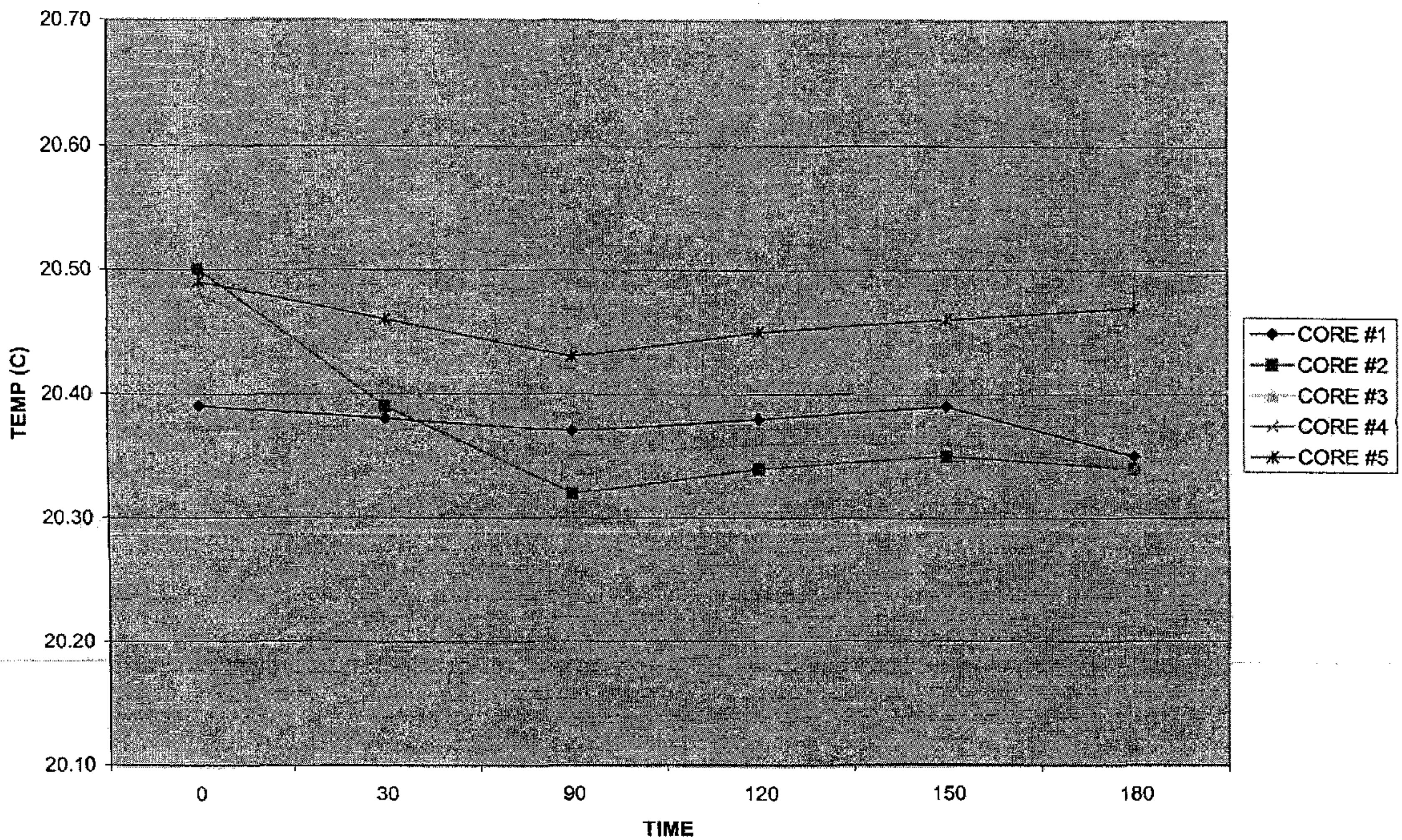
Analyzed by: Melisa Graeble, Jen Aederman, Tim Bridges
Samples collected by Tom Faber, Melisa Graeble, Jennifer Aederman
Note: Samples were collected upstream of bridge #6. Sediment was sandy. Samples collected between 0.3 and 1 meter in water depth.

ASH-16 DO



9.00
8.50
8.00
7.50
7.00
6.50
6.00
DO (mg/l)
0
30
90
120
150
180
TIME
CORE #1
CORE #2
CORE #3
CORE #4
CORE #5

ASH-16 TEMPERATURES



Station # ASH-15

Description:

Location: Swansea, NH

Sample #	94871
Time	8:30
Date	9/24/02

Other Analytes

TOC= 9400 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.396
2	0.375
3	0.395
4	0.394
5	0.490

INITIAL

	DO mg/l	Temp C
1	6.70	20.41
2	6.70	20.40
3	6.71	20.42

Bi ave = 6.70

B(Bi-Bf) = 0.00

FINAL

	DO mg/l	Temp C
1	6.71	20.35
2	6.72	20.36
3	6.67	20.39

Bf ave = 6.70

SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5	Temperature (C) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
10:15	0	6.75	6.63	6.66	6.65	5.95	19.43	19.45	19.55	19.46	19.25
10:45	30	6.69	6.54	6.50	6.59	5.87	20.15	20.16	20.20	20.10	19.93
11:15	60	6.66	6.46	6.32	6.56	5.83	20.24	20.25	20.36	20.21	20.12
11:45	90	6.63	6.40	6.16	6.53	5.78	20.24	20.25	20.38	20.22	20.20
12:15	120	6.59	6.35	6.15	6.49	5.7	20.25	20.28	20.42	20.27	20.28
12:45	150	6.57	6.30	6.10	6.45	5.67	20.28	20.32	20.46	20.33	20.35
13:15	180	6.54	6.25	5.94	6.42	5.65	20.28	20.34	20.48	20.36	20.40
	210										

		SOD CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
SOD Mean	1.05	0.66	1.14	1.80	0.72	0.94
Standard Deviation	0.46					

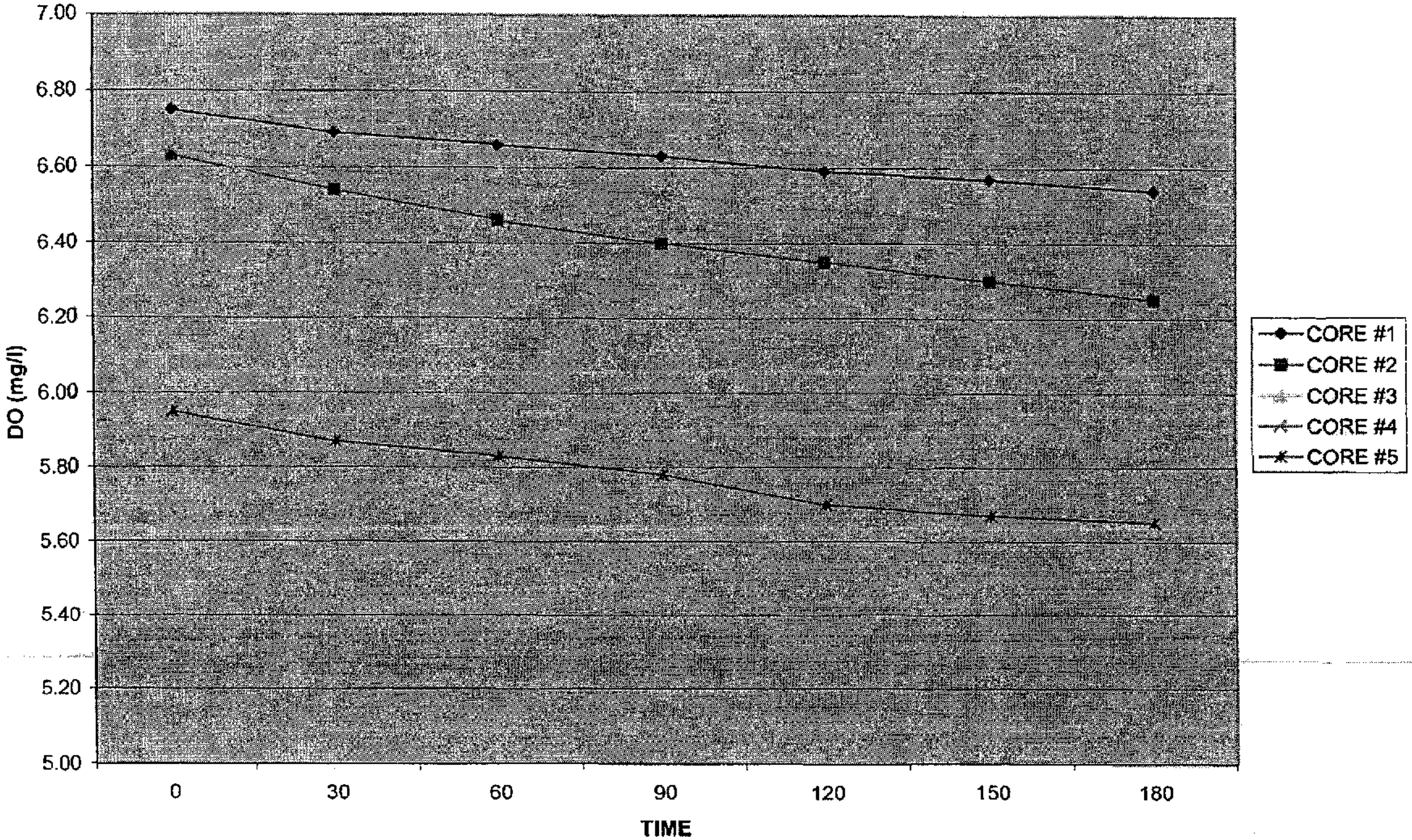
Analyzed by: Tim Bridges, Melissa Graeble, Jen Aederman

Samples collected by Tim Bridges, Melissa Graeble, Jen Aederman

Samples collected between).3 and 1 meter in water depth. Cores 1-3 collected from west bank. Cores 1-2 had oily sheen on the water when sediment was disturbed.

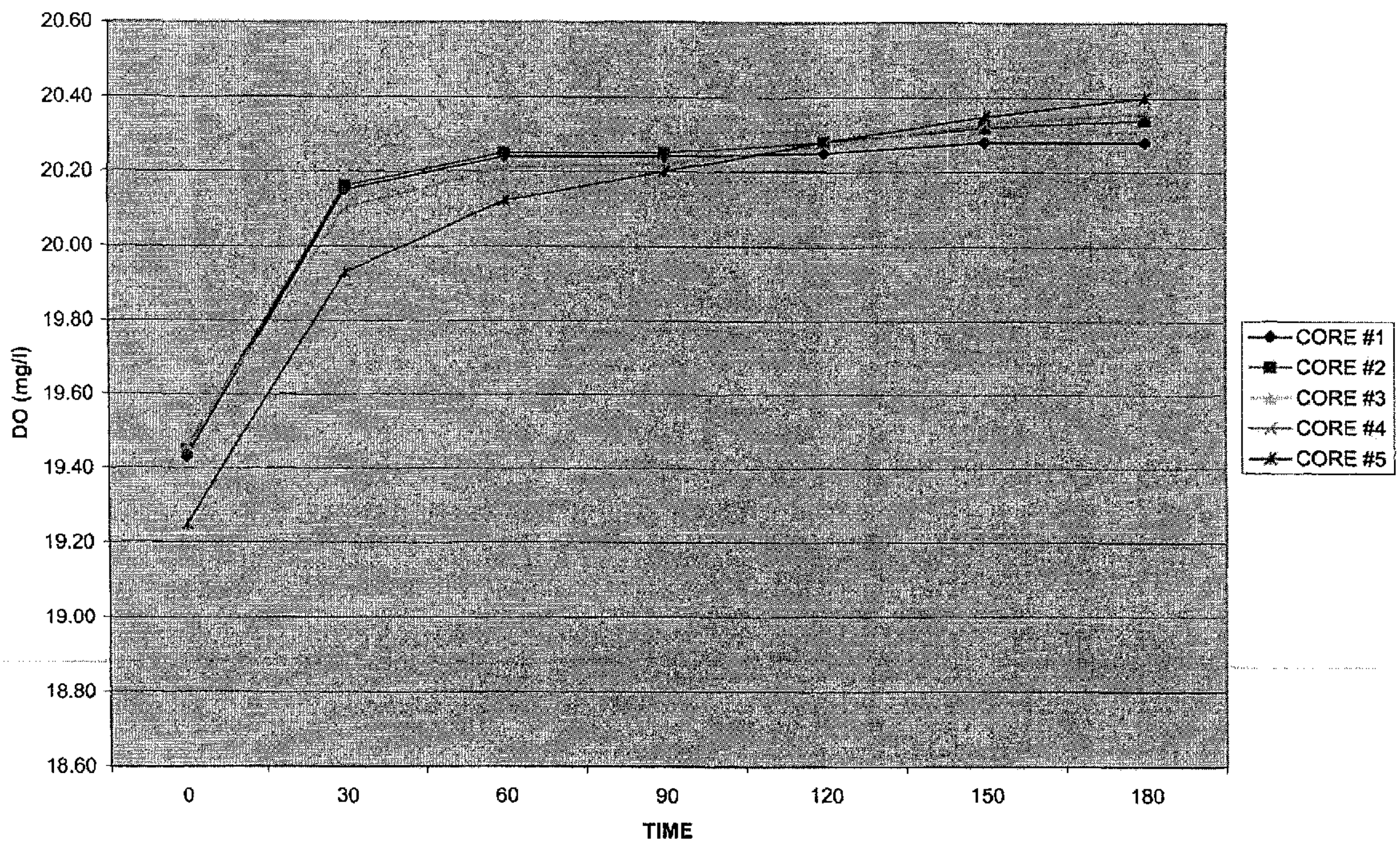
Cores 4-5 collected from east bank, sediment sandy.

ASH-15 DO



7.00
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
DO (mg/l)
0
30
60
90
120
150
180
TIME
CORE #1
CORE #2
CORE #3
CORE #4
CORE #5

ASH-15 TEMPERATURES



Station # ASH-14
Description:
Location:

Sample #	94872
Time	10:30
Date	9/24/02

Other Analytes

TOC= 4800 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.390
2	0.390
3	0.396
4	0.410
5	0.400

INITIAL

	DO mg/l	Temp C
1	7.55	20.37
2	7.53	20.33
3	7.56	20.36

Bi ave = 7.55

FINAL

	DO mg/l	Temp C
1	7.39	20.81
2	7.45	20.48
3	7.51	20.42

Bf ave = 7.45

B(Bi-Bf) = 0.10

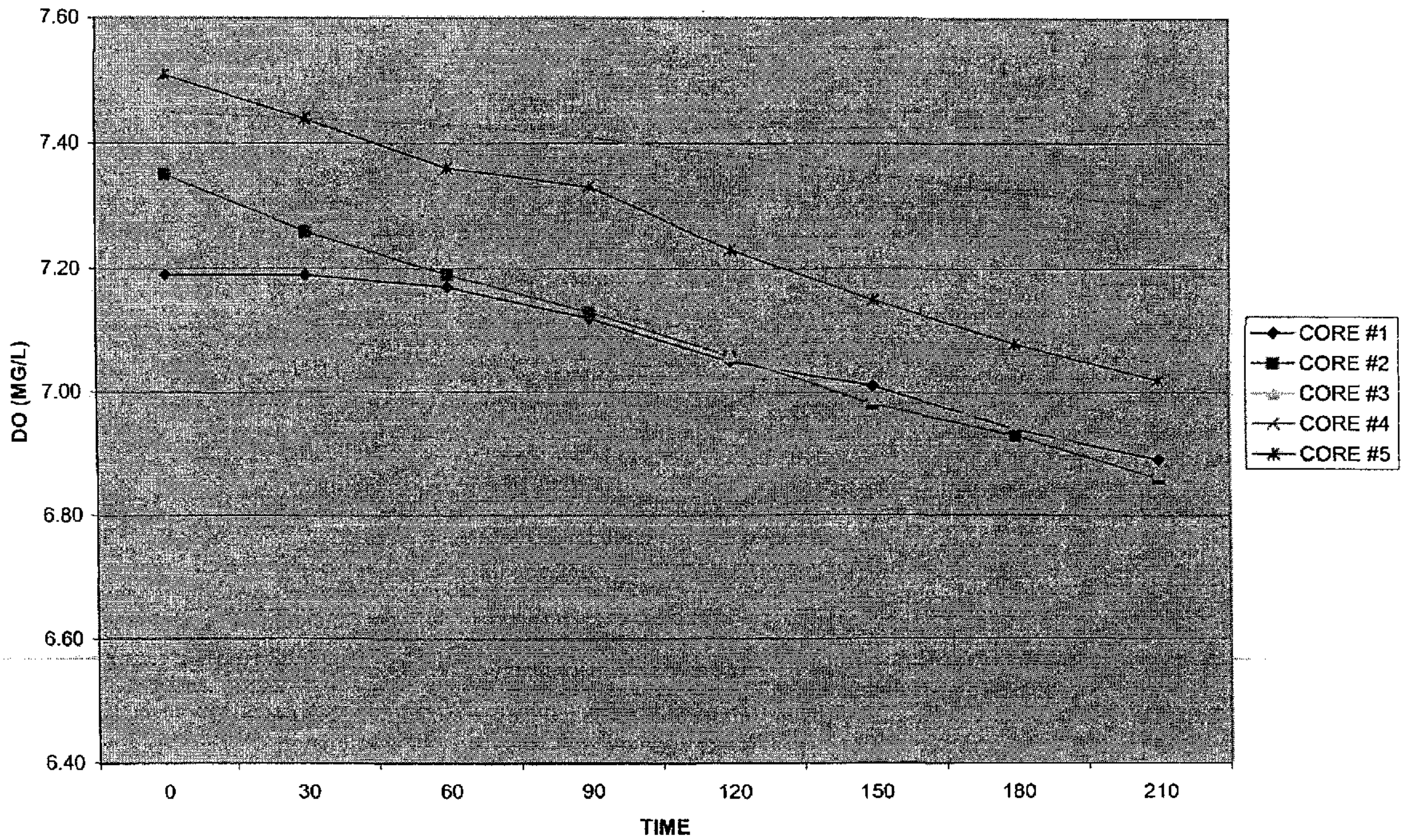
SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5	Temperature (C) CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
13:30	0	7.19	7.35	7.46	7.45	7.51	19.92	20.13	20.10	19.87	19.95
14:00	30	7.19	7.26	7.35	7.44	7.44	20.22	20.29	20.30	20.18	20.23
14:30	60	7.17	7.19	7.25	7.43	7.36	20.26	20.30	20.32	20.26	20.29
15:00	90	7.12	7.13	7.17	7.41	7.33	20.28	20.33	20.33	20.29	20.30
15:30	120	7.05	7.06	7.06	7.38	7.23	20.38	20.43	20.44	20.40	20.39
16:00	150	7.01	6.98	6.99	7.35	7.15	20.44	20.50	20.52	20.49	20.46
16:30	180	6.94	6.93	6.95	7.32	7.08	20.46	20.51	20.53	20.52	20.52
17:00	210	6.89	6.86	6.87	7.30	7.02	20.51	20.55	20.57	20.57	20.53

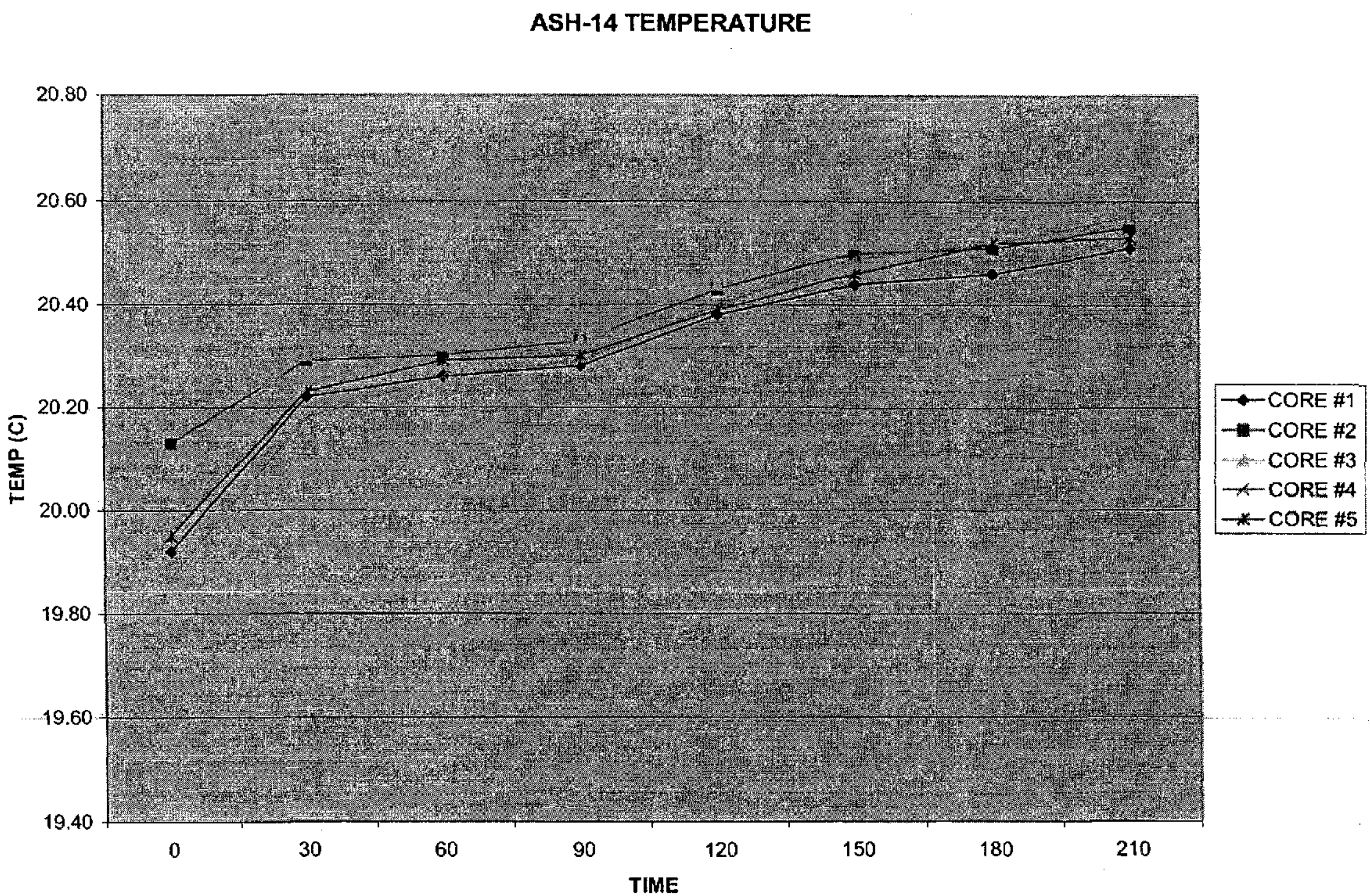
		CORE #1	CORE #2	CORE #3	CORE #4	CORE #5
SOD Mean	1.13	1.05	1.31	1.45	0.51	1.34
Standard Deviation	0.38	SOD				

Analyzed by: Tim Bridges, Melissa Graeble, Jen Aederman
Samples collected by Tim Bridges, Melissa Graeble, Jen Aederman

ASH-14 DO



7.60
7.40
7.20
7.00
6.80
6.60
6.40
DO (MG/L)
0
30
60
90
120
150
180
210
TIME
CORE #1
CORE #2
CORE #3
CORE #4
CORE #5


ASH-14 TEMPERATURE
20.80
20.60
20.40
20.20
20.00
19.80
19.60
19.40
TEMP (C)
0
30
60
90
120
150
180
210
TIME
CORE #1
CORE #2
CORE #3
CORE #4
CORE #5

Station # **16D**

Description: Upstream Keene WWTP

Location: Keene, NH

Sample #	94873
Time	16:30
Date	9/24/02

Other Analytes	
TOC=	6000 mg/kg
TOC DUP =	6400 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.385
2	0.370
3	0.467
4	
5	

INITIAL

	DO mg/l	Temp C
1	7.55	20.77
2	7.54	20.58
3	7.56	20.53

Bi ave = 7.55

FINAL

	DO mg/l	Temp C
1	7.53	20.72
2	7.53	20.61
3	7.51	20.6

Bf ave = 7.52

B(Bi-Bf) = 0.03

SOD ANALYSIS

TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #3	Temperature (C) CORE #1	CORE #2	CORE #3
17:35	0	6.56	7.71	7.18	20.02	19.92	19.83
18:05	30	6.45	7.62	7.13	20.35	20.33	20.13
18:35	60	6.35	7.52	7.10	20.65	20.52	20.54
19:05	90	6.31	7.42	7.12	20.79	20.64	20.68
20:35	180	6.27	7.18	7.13	20.73	20.66	20.68
21:05	210	6.27	7.15	7.15	20.57	20.66	20.72

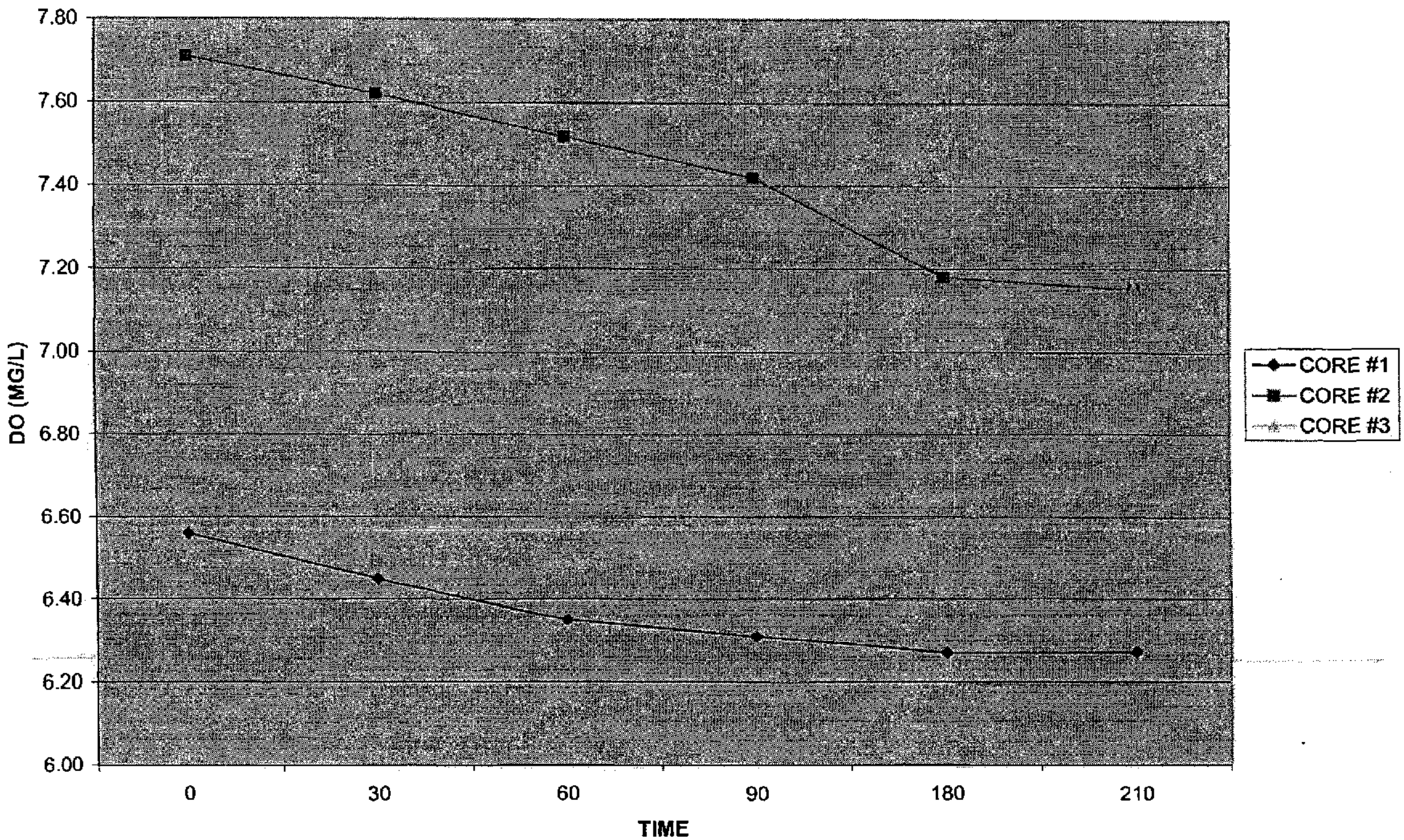
		CORE #1	CORE #2	CORE #3
SOD Mean	1.23	0.66	1.79	0.89
Standard Deviation	0.80	SOD		

Analyzed by: Tim Bridges, Melissa Graeble, Jen Aederman

Samples collected by Tim Bridges, Melissa Graeble, Jen Aederman

Cores #4 and #5 had air bubbles and test was rejected.

ASH-16D



7.80
7.60
7.40
7.20
7.00
6.80
6.60
6.40
6.20
6.00
DO (MG/L)
0
30
60
90
180
210
TIME
CORE #1
CORE #2
CORE #3

Station #	ASH-15E
Description:	Christian Campground
Location:	Swansea, NH

Sample #	94875
Time	8:20
Date	9/25/02

Other Analysis
TOC= 3100 mg/kg

AMBIENT WATER

	Water Column Height (meters)
1	0.392
2	0.377
3	
4	0.395
5	

INITIAL

	DO mg/l	Temp C
1	6.28	20.15
2	6.24	20.16
3	6.3	20.18
Bi ave =	6.27	

FINAL

	DO mg/l	Temp C
1	6.22	20.3
2	6.17	20.3
3	6.19	20.3
Bf ave =	6.19	

B(Bi-Bf) = 0.08

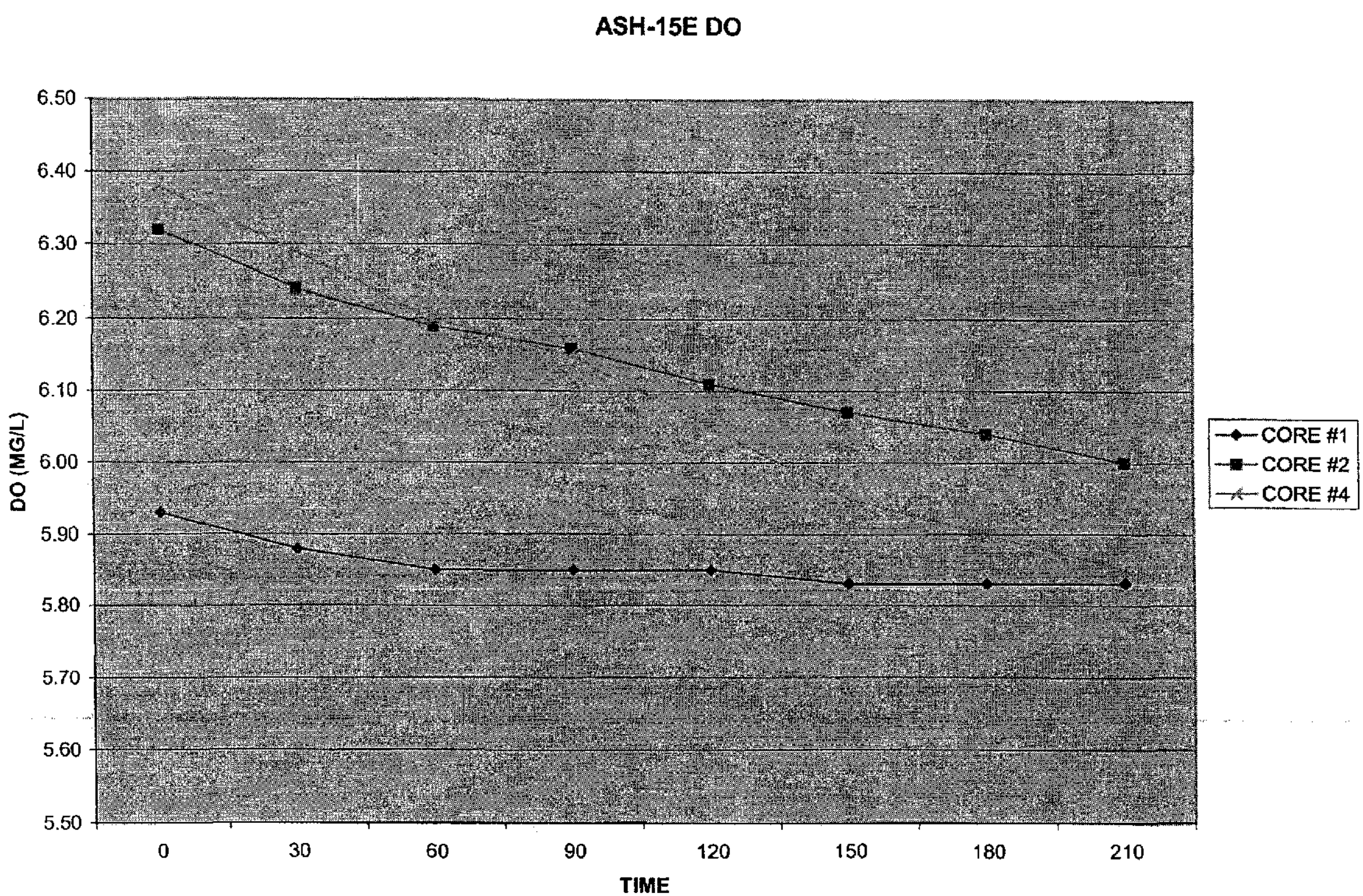
SOD ANALYSIS

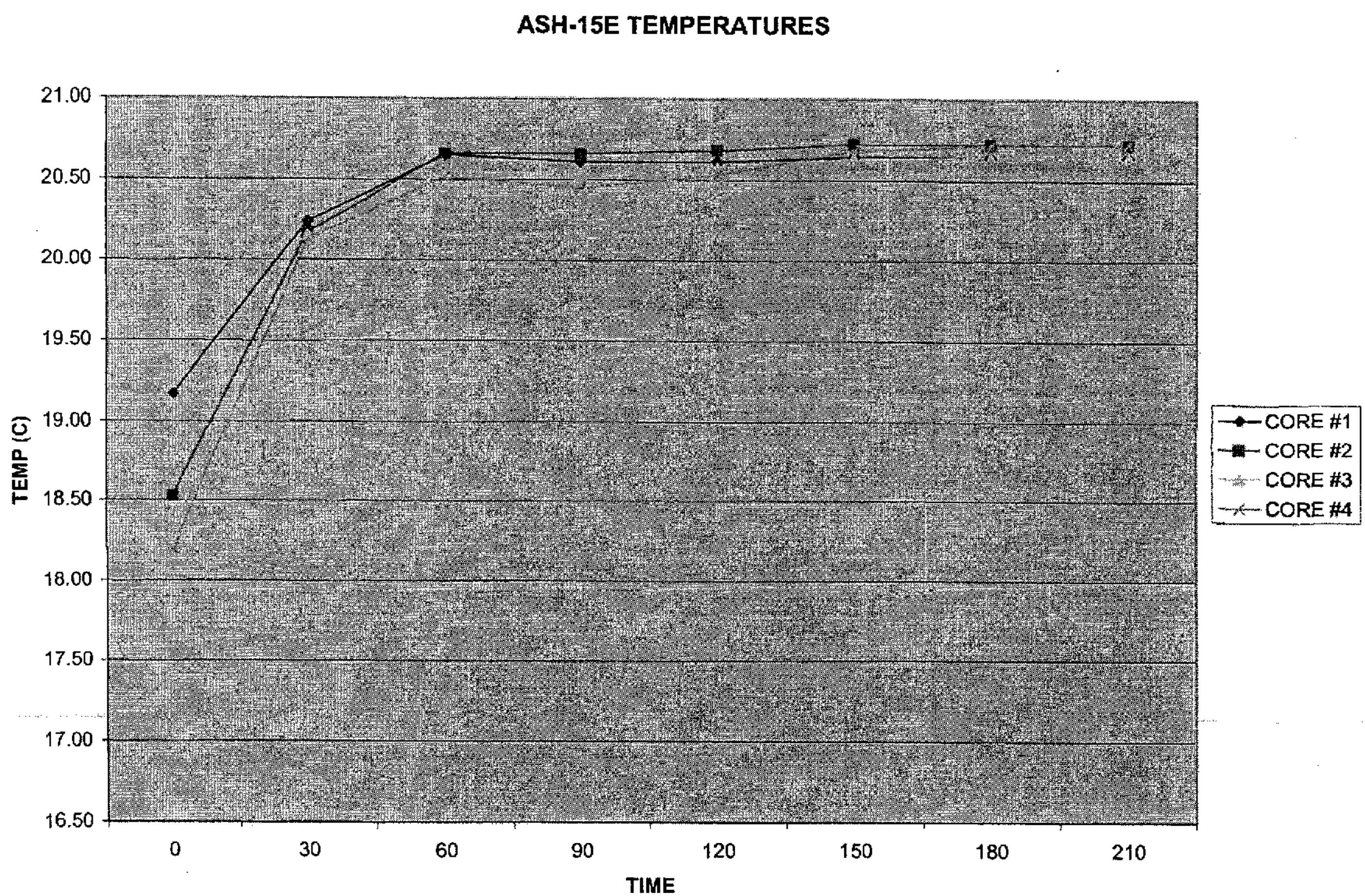
TIME		Dissolved Oxgen (mg/l) CORE #1	CORE #2	CORE #4	Temperature (C) CORE #1	CORE #2	CORE #4
9:15	0	5.93	6.32	6.38	19.17	18.53	18.20
9:45	30	5.88	6.24	6.29	20.24	20.17	20.13
10:15	60	5.85	6.19	6.20	20.65	20.66	20.52
10:45	90	5.85	6.16	6.15	20.61	20.66	20.45
11:15	120	5.85	6.11	6.05	20.61	20.68	20.53
11:45	150	5.83	6.07	5.95	20.64	20.72	20.68
12:15	180	5.83	6.04	5.90	20.64	20.72	20.71
12:45	210	5.83	6.00	5.85	20.64	20.72	20.72

		CORE #1	CORE #2	CORE #4
SOD Mean	0.80	0.16	0.84	1.39
Standard Deviation	0.62	SOD		

Analyzed by: Tim Bridges, Melissa Graeble, Jen Aederman

Samples collected by: Tim Bridges, Melissa Graeble, Jen Aederman


ASH-15E DO
DO (MG/L)
6.50
6.40
6.30
6.20
6.10
6.00
5.90
5.80
5.70
5.60
5.50
0
30
60
90
120
150
180
210
TIME
CORE #1
CORE #2
CORE #4


ASH-15E TEMPERATURES
21.00
20.50
20.00
19.50
19.00
18.50
18.00
17.50
17.00
16.50
TEMP (C)
0
30
60
90
120
150
180
210
TIME
CORE #1
CORE #2
CORE #3
CORE #4

3/24/2000

STATE OF NEW HAMPSHIRE

INTRA-DEPARTMENT COMMUNICATION

FROM: Michael Racine

TO: David Neils

DATE: 8/8/03

SUBJECT: Impact of the Wastewater Treatment Facility on the Ashuelot River, Swanzey, New Hampshire. Summer 2001.

Introduction

This study was conducted by the New Hampshire Department of Environmental Services Biomonitoring Program (NHDES). The purpose of the study was to assess the potential effects by the city of Keene's treated effluent discharge into the Ashuelot River, Swanzey, New Hampshire on the biotic integrity of the aquatic community. The wastewater treatment facility (WWTF) has a history of NPDES permit violations relative to the effluent limits for copper.

Biotic integrity is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981). In short, biotic integrity can be equated to the existing relative "health" of the fish and macroinvertebrate communities. The major factors that affect biotic integrity include the food availability and type, water quality, habitat structure, flow regime, and biotic interactions. Since this study used a traditional upstream-downstream design for comparison purposes, all four sites, one upstream and three downstream of the discharge pipe, were subjected equally to the five factors aforementioned, with the exception of water quality. That is, as documented by NHDES, the downstream sites were historically subjected to decreased water quality. Thus, the upstream site will be used to assess the level of impact caused by the discharge pipe to ascertain whether the Department's Water Quality Standards (NHDES, 1999b) have been violated.

Biotic assessments supplement water chemistry data. In this study, the Biomonitoring Program used properties of the resident biota, specifically benthic macroinvertebrates, to assess the immediate and longitudinal severity of the impact. Macroinvertebrates have been used for decades to judge the health of aquatic systems. Advantages of using the macroinvertebrate community are (Barbour et al. 1999):

- they are relatively sessile organisms and thus good indicators of localized conditions;
- short-term environmental variations (perturbations) that may have been missed by chemical samples are integrated overtime in the community abundance and structure;
- they are easy to collect and identify;
- the taxa constitute a broad range of tolerances to pollution;
- the taxa integrate the effect of multiple stressors.

The report documents our findings from sampling conducted in the summer of 2001.

Study Area

The Ashuelot River is a tributary to the Connecticut River, entering it in the town of Hinsdale. The wastewater treatment facility in Swanzey lies approximately 20 miles upstream of the confluence with the Connecticut River and approximately 35 miles downstream of its source.

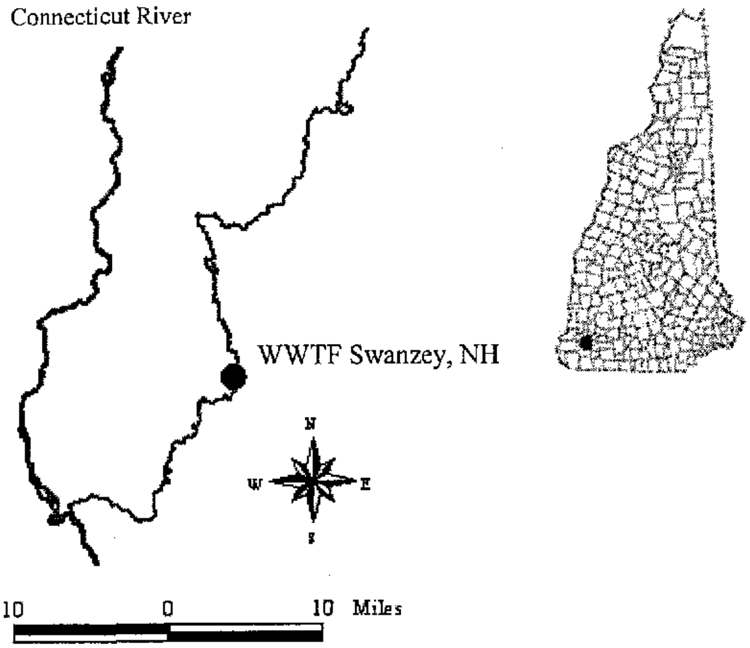


Figure 1. Locus map of the WWTF in Swanzey, New Hampshire and the location of this WWTF with respect to its source and confluence with the Connecticut River.

Methods

Chemical Sampling
Dissolved oxygen, pH, specific conductance, and temperature were measured at each site on 8/23/03 following NHDES (1999a) protocols.

Biological Sampling
Sampling was conducted upstream and downstream of the discharge pipe as depicted in Table 1. The upstream site, SP01C-01, was used as the reference site. Sites SP01C-02, -03, and -04 are progressively farther downstream at discrete distances from the discharge pipe.

Table 1.

Stations	Distance from WWTF discharge (meters)	
SP01C-01	30m	Upstream
SP01C-02	15m	Downstream
SP01C-03	50m	
SP01C-04	150m	

Variability among sites was minimized as water depth, substrate type, distance of the artificial substrate sampling devices above the substrate, horizontal distance of the sampling devices from the banks, and perpendicular orientation to flow of the sampling devices were all similar. Approximate water depth was 5 feet and all samplers were place one foot off the sand bottom substrate.

Equipment

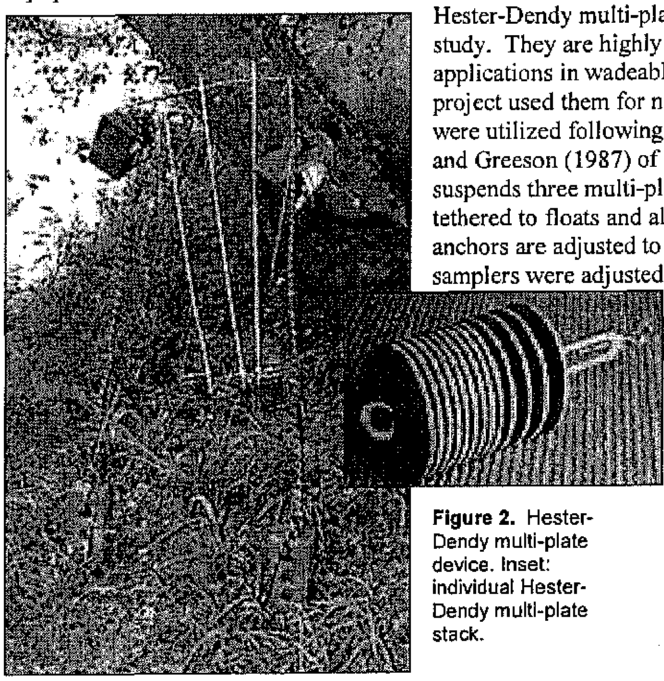


Figure 2. Hester-Dendy multi-plate device. Inset: individual Hester-Dendy multi-plate stack.

Hester-Dendy multi-plate samplers (Figure 2) were used in the study. They are highly portable and have a diversity of applications in wadeable and non-wadeable streams. This project used them for non-wadeable collections. These devices were utilized following the sampling design set forth by Britton and Greeson (1987) of the US Geological Survey. The device suspends three multi-plate stacks from a single top bar. The bar is tethered to floats and also to two anchors. The ropes on the anchors are adjusted to hold the entire device in place. The samplers were adjusted to rest just above the sediment-water interface.

Hester-Dendy units were set perpendicular to flow so that the plates would not interfere with each other and to ensure uniformity of conditions for all three stacks. The macroinvertebrate colonization period for the Hester-Dendy units was 6 weeks. They were set on 7/13/01 and retrieved on 8/23/01.

Setting Devices

1. Hester-Dendy devices were deployed perpendicular to flow using brick anchors. The anchor rope was adjusted so that there was a slight drift downstream to the entire unit.
2. Depths of individual multi-plate units were roughly one foot above the substrate. The threaded rods and the length of anchor rope were adjusted to obtain this height.
3. After depth adjustments were finalized, the apparatus was checked for its ability to remain stable and perpendicular to flow in the current, and it was also inspected for retention of proper depth placement.

Retrieving Devices

1. A dipnet was placed on the substrate immediately downstream of each unit.
2. The units were lifted just enough to be quickly placed into the dipnet and were then immediately brought to the water's surface.
3. Each Hester-Dendy multi-plate sampler was then detached, disassembled, and the spacers and plates were placed in a sieve bucket.
4. All pieces were gently scrubbed in sieve bucket to remove attached organisms.
5. Removed organisms were preserved in a sampling jar with 1/3 water and 2/3 ethanol.
6. Jars were labeled using an indelible marker with the following information: date, replicate number, and the site number.

Care was taken not to disturb the Hester-Dendy units before actual retrieval. Upon retrieval, all four Units were resting slightly on the substrate due to a water level drop.

Data Analysis
An independent taxonomic laboratory identified the benthic macroinvertebrates to the lowest possible resolution. Laboratory identification and enumeration quality control followed the 2001 New Hampshire Department of Environmental Services Standard Operating Procedures (NHDES 1999a). Three replicates per site were composited into one sample. One quarter of the sample was identified and enumerated. The total number of organisms ranged from 159 to 688 per site. The surrogate measures of stream health, termed metrics, are summarized below in Table 3 and Figures 3-6. Raw data is presented in Table 7.

Results

The results of chemical testing on 8/23/01 are presented in Table 2. All values are acceptable under the Department's Water Quality Standards (1999b). The lowest dissolved oxygen value of 6.88 mg/L was recorded at site SP01C-02 and the highest value of 7.62 mg/L was recorded at site SP01C-01. pH values ranged from 6.49 to 7.07 units. Specific conductance ranged from 228 to 249 uS/cm. Temperature ranged from 21.10 to 21.33°C.

Table 2. Chemical values recorded on 8/23/03 using a multi-parameter unit.

Stations	Chemical Parameter	Value
SP01C-26.1	DO (mg/L)	7.62
SP01C-26.1	pH (units)	7.07
SP01C-26.1	Specific Conductance (uS/cm)	228
SP01C-26.1	Temperature (°C)	21.10
SP01C-26.2	DO (mg/L)	6.88
SP01C-26.2	pH (units)	6.89
SP01C-26.2	Specific Conductance (uS/cm)	249
SP01C-26.2	Temperature (°C)	21.15
SP01C-26.3	DO (mg/L)	7.11
SP01C-26.3	pH (units)	6.51
SP01C-26.3	Specific Conductance (uS/cm)	248
SP01C-26.3	Temperature (°C)	21.27
SP01C-26.4	DO (mg/L)	7.18
SP01C-26.4	pH (units)	6.49
SP01C-26.4	Specific Conductance (uS/cm)	242
SP01C-26.4	Temperature (°C)	21.33

Table 3. Metric values per Site. SP01C-01 is upstream of the discharge pipe. Proceeding left to right, the other Sites represent increased distance downstream from the pipe.

	SP01C-01	SP01C-02	SP01C-03	SP01C-04
Biotic Index	4.92	6.04	6.13	5.5
%EPT	62	20	34	44
% Chironomids	32	48	36	49
%Insecta	97	67	71	95
Abundance	159	360	688	535

BIOTIC INDEX
This metric is based on the fact that benthic macroinvertebrate taxa have varying degrees of susceptibility to stressors. These varying degrees are referred to as tolerance values (i.e. describing, on a scale of 0-10, an organism's degree of tolerance to stressors). This metric was initially designed for the stress of organic pollution (Hilsenhoff, 1987), but has proven responsive to other anthropogenic impacts (Pinder and Farr, 1987; Barton and Metcalfe-Smith, 1992; Camargo, 1993; Resh and Jackson, 1993; Growns et al., 1995). The Biotic Index Score range associated with a narrative ranking are depicted below in Table 4. When the

Biotic Index scores for all sites are compared to the narrative Water Quality assignments of Hilsenhoff (1987), all sites ranked as "good" to "fair".

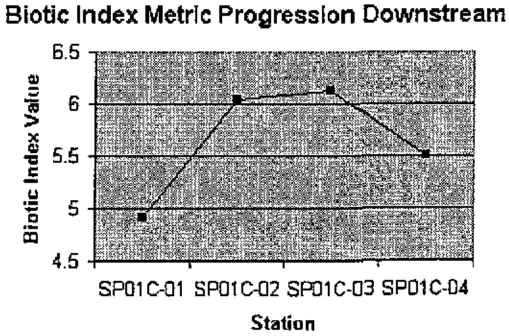
Table 4. Water Quality numeric to narrative ranking when using the Biotic Index (Hilsenhoff, 1987)

	*Biotic Index Range	*Water Qaulity
Based on Organic Pollution	0.00 - 3.50	Excellent
	3.51 - 4.50	Very Good
	4.51 - 5.50	Good
	5.51 - 6.50	Fair
	6.51 - 7.50	Fairly Poor
	7.51 - 8.50	Poor
	8.51 - 10.00	Very Poor

*Hilsenhoff (1987), BI range based on genus/species data.

Our expectations, if the discharge pipe was affecting the biotic integrity of the river, would be that site SP01C-01 would have the lowest value. Site SP01C-02 would have the highest value. Sites SP01C-03 and -04 would show progressive decreases in Biotic Index Scores from site SP01C-02. The data from Table 3 are graphically presented in Figure 3. Site SP01C-01 does have the lowest value of 4.92 indicating it has the best water quality. Site SP01C-02 shows decreased water quality as its Biotic Index score is 6.04. The Biotic Index score 150m downstream of the discharge pipe is 5.5.

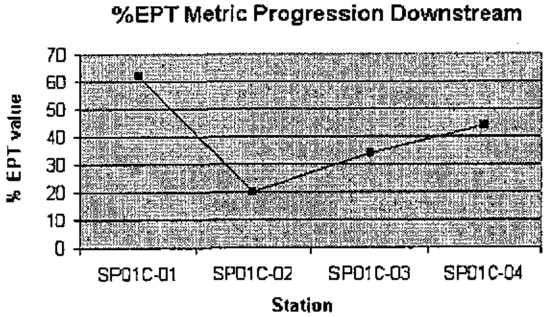
Figure 3. Biotic Index values for all Sites.



% EPT

This metric represents the proportion of the sample that is made up of organisms in the orders Ephemeroptera, Plecoptera, and Trichoptera. These taxa are all sensitive to various stressors, with Plecoptera being the most sensitive. Therefore, higher percentages of these orders indicate higher water quality. Our expectations and rationale for these expectations follow the trend explained with the Biotic Index. Site SP01C-01 would show the highest percentage of these sensitive taxa. Site SP01C-02 would show a decrease and sites SP01C-03 and -04 would should an increase over site SP01C-02, and thus an improvement in water quality. The graphical representation of our data (Figure 4) reveals this trend to be true with the four stations. Site SP01C-01 has the highest water quality, indicated by a score of 62 (Table 3). Site SP01C-2 has the lowest %EPT of 20, and thus the lowest water quality. Site SP01C-03 shows an increase in water quality over SP01C-02, and site SP01C-04 shows an increase in water quality over SP01C-03.

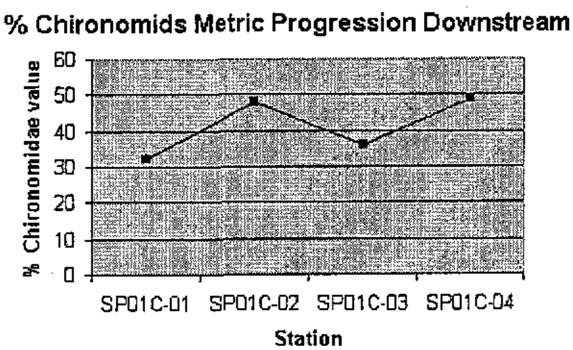
Figure 4. Percent sensitive taxa for all Sites.



%CHIRONOMIDAE

This metric represents the proportion of the sample comprised of organisms in the family Chironomidae, otherwise known as midges. This family is known to be tolerant of organic pollution (Johnson et al. 1993). Thus, the proportion (i.e. percent) of chironomids would be expected to increase at site SP01C-02 and gradually decrease through SP01C-03 to -04 to a proportion similar to the reference site above the discharge. Values ranged from 32-49% (Table 3, Figure 5) with the site upstream of the treatment plant having the lowest percent of the community comprised of chironomids (32%).

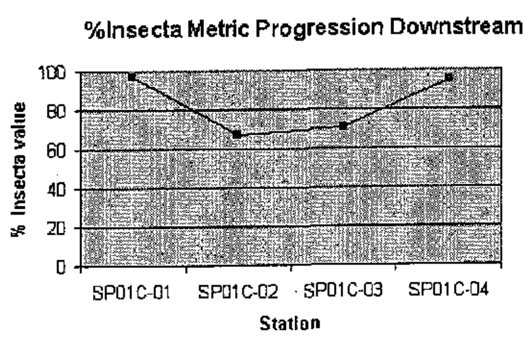
Figure 5. Percent Midges for all Sites.



% INSECTA

Percent Insecta represents the proportion of the sample that is composed of Insects. Conversely, the common non-insects are worms, snails, and water mites. Non-insect organisms have higher tolerances to pollution. Thus, lower proportions of insects in the aquatic community would indicate a perturbation. Our expectance and rationale, again, follow the trend set forth in the Biotic Index. We would expect site SP01C-02 to have a lower percentage of insects than site SP01C-01, and sites SP01C-03 and -04 to have increased percentages over SP01C-02 if the discharge pipe was affecting the biotic integrity of the river. Much like the %EPT metric, this trend was seen. Site SP01C-01 had the highest value of 97, and thus the highest water quality when using this metric (Table 3). The graphic representation below in Figure 6 displays the clear trend. Water quality decreases to its lowest immediately below the discharge pipe at site SP01C-02 and recovers to nearly its initial value at site SP01C-04.

Figure 6. Percent Class-Insecta for all Sites.



Discussion

Aquatic macroinvertebrate responses to organic pollution include a change in species composition, increased densities of taxa tolerant to enrichment, and decreased densities and/or extirpation of sensitive taxa (Hynes, 1960). Responses to heavy metal pollutants are similar, but tend to decrease the numbers and types of all taxa (Cairns and Dickson, 1971). Most surrogate metrics of stream health used in this study responded in a manner consistent with our expectations of perturbation effects on the biotic integrity of the aquatic community.

The %EPT and %Insecta declined below the discharge pipe and increased towards the values upstream of the discharge as seen at site SP01C-01 (Figures 4 & 6). The Biotic Index showed the inverse trend (Figure 3). It increased below the discharge pipe and then decreased at site SP01C-04. All three metrics reveal the same trend, decreased water quality immediately below the discharge pipe when compared to the site above the discharge pipe. The trend results from %Chironomidae (Figure 5) are inconclusive. The Chironomidae family is tolerant to organic enrichment and is expected to increase at SP01C-02 and then decrease gradually downstream to values similar to the reference site recorded upstream of the pollution source. This metric showed no trend, but rather fluctuated through the entire 180m sampling reach. However, when compared to 4th to 6th order streams of reference quality sampled by the NHDES Biomonitoring Program from 1997-1999 in the Connecticut River Drainage, the percent Chironomidae of all four sites on this 7th order river appear elevated. Percent Chironomidae at the fourteen reference sites had a mean of 17.0 ($\pm$ 19.5, range 0-55.7). This comparison should be viewed with caution as differences could be due to different sampling methods.

A clear longitudinal trend in biotic integrity exists when traveling from the site above the discharge pipe (SP01C-01) to the site farthest downstream (SP01C-04) at 150m from the pipe. This trend represents a decrease in biotic integrity, based on benthic macroinvertebrates, just below the discharge pipe and then a progressive recovery continuing downstream through SP01C-03 to SP01C-04. These trends were made evident by three of the four metrics (Figures 3, 4, & 6). The Biotic Index Score increased by 1.12, the percentage of the community made up of Ephemeroptera, Plecoptera, and Trichoptera dropped 42%, and the percentage of the community made up of Insects decreased 30% from SP01C-01 to SP01C-02.

The next logical question is 'Has this impairment violated the Department's Water Quality Standards (NHDES, 1999b)?' The pertinent Water Quality Standards as set forth in December 1999 read as follows:

Part Env-Ws 1703 Water Quality Standards

Env-Ws 1703.19 Biological and Aquatic Community Integrity

(a) *The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.*
(b) *Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.*

Under 1703.19 (a), the impacted downstream sites must be **comparable** to that SP01C-01. The surrogate measures of biological integrity as previously described provide the details to make this decision. Merely using the percent composition and community shifts to tolerant organisms provides clear evidence that SP01C-02 is not comparable to SP01C-01. Furthermore, section 1703.19 (b) states that if differences exist in sites, then the differences must by **non-detrimental to the community structure and function**. Based on the results gathered in this study, the observed changes in community composition indicate a shift away from a benthic community dominated by taxa that are predacious, prefer epilithic algae to a one that primarily suited for the processing of fine particulate organic matter (FPOM).

Section 3.2.4 Use: Aquatic Life of the *Consolidated Assessment and Listing Methodology and Comprehensive Monitoring Strategy* (CALM), December, 2002 describes how biological assessments are used for 305(b) and 303(d) reporting. The methodology uses a Modified "O'Brien Plot" of Index Values (Table 5), which is based on model designed by the New York Department of Environmental Conservation, to yield a Water Quality Score.

Table 5. Modified "O'Brien Plot" of Index Values

Water Quality Score	Total Taxa	EPT	PMA	Habitat
10	20	15	90	200
7.5	15	10	65	150
5.0	10	5	50	100
2.5	5.0	2.0	35	50
0	0	0	0	0

This score is then put into the following matrix to depict Use Support:
Table 6.

Mean Water Quality Score	Use Support
$\geq$ 7.5	FS
> 2.5 but < 7.5	INSUFFICIENT INFORMATION
$\leq$ 2.5	NS

As stated in the CALM, macroinvertebrate data is to be collected by "deployment and collection of rock baskets" and "is considered an interim method and is likely to change in the future when numeric water quality standards are adopted." Using the CALM, all of the sites would be reported as "not assessed" (i.e. the information collected is not definitive enough to make a decision as impaired or not; Table 7). This is

Table 7. Modified "O'Brien Plot" of Index Values for all sites

SITE ID	EPT TAXA (family level)	WQ Score	TOTAL TAXA	WQ Score	PMA VALUE	WQ Score
SP01C-26.1	8	5.8	15	7.5	[redacted]	
SP01C-26.2	9	6.5	[redacted]		47.6	4.4
SP01C-26.3	[redacted]				48.0	4.4
SP01C-26.4	10	7.2	[redacted]		49.9	4.7

FROM 305b/303d REPORTING CRITERIA

		TAXA richness			Percent Model Affinity	
WQ Score		Taxa richness	WQ scale score		PMA value	WQ scale score
[redacted]						
2.5-7.5	not assessed	5-15	2.5-7.5	not assessed	35-65	2.5-7.5
[redacted]						

IN ORDER TO ACHIEVE FULLY SUPPORTING STATUS ALL SITES MUST BE GREEN

a conservative evaluative procedure. Evaluation of water quality at these sites is best examined through the additional metrics which provide more detailed information.

Table 7. Raw abundance and percent composition taxonomic data for all sites.

CLASS	ORDER	FAMILY	GENUS	SPECIES	FinalID	Station1 Abundance	Station1 %	Station2 Abundance	Station2 %	Station3 Abundance	Station3 %	Station4 Abundance	Station4 %
					Nemertea - (PHYLUM)			3	<1	3	<1		
ARACHNIDA	TROMBIDIFORMES	HYGROBATIDAE	Hygrobates		Hygrobates					2	<1	1	<1
ARACHNIDA	TROMBIDIFORMES	HYGROBATIDAE			Hygrobatidae			6	2				
ARACHNIDA	TROMBIDIFORMES	LEBERTIIDAE	Lebertia		Lebertia			1	<1				
ARACHNIDA	TROMBIDIFORMES	MIDEOPSIDAE	Mideopsis		Mideopsis					1	<1		
ARACHNIDA	TROMBIDIFORMES	SPERCHONIDAE	Sperchonopsis		Sperchonopsis					1	<1		
ARACHNIDA	TROMBIDIFORMES	TORRENTICOLIDAE	Torrenticola		Torrenticola	3	2	1	<1	7	1	7	1
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Chaetogaster	diaphanus	Chaetogaster diaphanus			3	<1	1	<1		
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Dero	digitata	Dero digitata			2	<1				
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Nais	bretscheri	Nais bretscheri			62	17	7	1		
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Nais	communis	Nais communis			13	4	4	<1	2	<1
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Ripistes	parasita	Ripistes parasita			6	2	164	24	13	2
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Slavina	appendiculata	Slavina appendiculata			12	3	3	<1	1	<1
CLITELLATA	HAPLOTAXIDA	NAIDIDAE	Vejdovskyella	comata	Vejdovskyella comata			3	<1				
GASTROPODA					Gastropoda					2	<1	2	<1
GASTROPODA	BASOMMATOPHORA	ANCYLIDAE	Ferrissia		Ferrissia			4	1	3	<1		
GASTROPODA	BASOMMATOPHORA	PHYSIDAE	Physa		Physa			3	<1				
INSECTA	COLEOPTERA	ELMIDAE	Ancyronyx		Ancyronyx							1	<1
INSECTA	COLEOPTERA	ELMIDAE	Dubiraphia		Dubiraphia			2	<1			2	<1
INSECTA	COLEOPTERA	ELMIDAE	Macronychus		Macronychus	1	<1						
INSECTA	DIPTERA	CERATOPOGONIDAE	Bezzia/Palpomyia		Bezzia/Palpomyia	1	<1	1	<1	2	<1	2	<1
INSECTA	DIPTERA	CHIRONOMIDAE			Chironomidae	7	4	17	5	23	3	25	5
INSECTA	DIPTERA	CHIRONOMIDAE			Chironominae	28	18	130	36	182	26	194	36
INSECTA	DIPTERA	CHIRONOMIDAE	Orthocladiinae		Orthocladiinae	4	2	6	2	14	2	4	<1
INSECTA	DIPTERA	CHIRONOMIDAE			Tanypodinae	12	8	21	6	28	4	38	7
INSECTA	DIPTERA	CULICIDAE	Anopheles		Anopheles					2	<1		
INSECTA	DIPTERA	EMPIDIDAE	Hemerodromia		Hemerodromia					5	<1	1	<1
INSECTA	EPHEMEROPTERA	BAETIDAE	Baetis		Baetis					11	2	5	<1
INSECTA	EPHEMEROPTERA	BAETIDAE	Procloeon		Procloeon	1	<1	5	1				
INSECTA	EPHEMEROPTERA	BAETISCIDAE	Baetisca		Baetisca					2	<1		
INSECTA	EPHEMEROPTERA	CAENIDAE	Caenis		Caenis					1	<1		
INSECTA	EPHEMEROPTERA	EPHEMERELLIDAE			Ephemerellidae			1	<1			3	<1
INSECTA	EPHEMEROPTERA	EPHEMERIDAE	Hexagenia		Hexagenia							1	<1
INSECTA	EPHEMEROPTERA	HEPTAGENIIDAE			Heptageniidae	21	13					3	<1
INSECTA	EPHEMEROPTERA	HEPTAGENIIDAE	Stenonema		Stenonema	29	18	4	1	42	6	47	9
INSECTA	EPHEMEROPTERA	LEPTOPHLEBIIDAE			Leptophlebiidae	10	6	15	4	14	2	22	4
INSECTA	MEGALOPTERA	CORYDALIDAE	Nigronia	serricornis	Nigronia serricornis	1	<1	1	<1			1	<1
INSECTA	ODONATA	AESHNIDAE	Boyeria	vinosa	Boyeria vinosa							1	<1
INSECTA	ODONATA	CALOPTERYGIDAE	Calopteryx		Calopteryx	1	<1	1	<1				
INSECTA	ODONATA	COENAGRIONIDAE	Argia		Argia	2	1			1	<1	2	<1
INSECTA	ODONATA	CORDULIIDAE			Corduliidae					1	<1		
INSECTA	ODONATA	GOMPHIDAE			Gomphidae			1	<1				
INSECTA	PLECOPTERA	PERLIDAE	Acroneuria		Acroneuria			1	<1				
INSECTA	TRICHOPTERA	BRACHYCENTRIDAE	Brachycentrus		Brachycentrus					3	<1		
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	Cheumatopsyche		Cheumatopsyche	5	3	3	<1	85	12	108	20
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	Hydropsyche		Hydropsyche			1	<1				
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE			Hydropsychidae					1	<1		
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	Macrostemum		Macrostemum					1	<1	1	<1
INSECTA	TRICHOPTERA	HYDROPTILIDAE	Hydroptila		Hydroptila							2	<1
INSECTA	TRICHOPTERA	HYDROPTILIDAE			Hydroptilidae			1	<1	2	<1	4	<1
INSECTA	TRICHOPTERA	HYDROPTILIDAE	Oxyethira		Oxyethira	4	2	1	<1	8	1	4	<1
INSECTA	TRICHOPTERA	LEPTOCERIDAE			Leptoceridae			5	1	3	<1	2	<1
INSECTA	TRICHOPTERA	LEPTOCERIDAE	Mystacides		Mystacides					2	<1	1	<1
INSECTA	TRICHOPTERA	LEPTOCERIDAE	Nectopsyche		Nectopsyche					2	<1	2	<1
INSECTA	TRICHOPTERA	LEPTOCERIDAE	Oecetis		Oecetis	2	1	13	4	21	3	4	<1
INSECTA	TRICHOPTERA	POLYCENTROPODIDAE	Nyctiophylax		Nyctiophylax	2	1	1	<1	2	<1	6	1
INSECTA	TRICHOPTERA	POLYCENTROPODIDAE			Polycentropodidae			1	<1				
INSECTA	TRICHOPTERA	POLYCENTROPODIDAE	Polycentropus		Polycentropus	21	13	9	2	23	3	19	4
INSECTA	TRICHOPTERA	PSYCHOMYIIDAE	Lype	diversa	Lype diversa	4	2			9	1	4	<1
					Total Individuals	**169**		**360**		**688**		**536**	

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