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Environmental Services Monitoring

Long-Term Monitoring

Final

Annual Report
2002-2003 In-Stream Storm Flow Sampling
Puget Sound Naval Shipyard (PSNS)
Project Environmental Investment
(ENVVEST)

October 2003

The TEC LTM Team
The Environmental Company, Inc.
CH2MHILL

FINAL
ANNUAL REPORT

2002-2003 IN-STREAM STORM FLOW SAMPLING
PUGET SOUND NAVAL SHIPYARD (PSNS)
PROJECT ENVIRONMENTAL INVESTMENT (ENVVEST)

October 2003

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ACRONYMS AND ABBREVIATIONS

° F	degrees Fahrenheit
µs/cm	microseimens per centimeter
AC	Anderson Creek Storm Sampling Site
ADP	antecedent dry period
BA	Barker Creek Storm Sampling Site
BL	Blackjack Creek Storm Sampling Site
CC	Clear Creek Storm Sampling Site
CE	Clear Creek East Storm Sampling Site
CFU/100 mL	colony forming units per 100 milliliters
CH	Chico Creek Storm Sampling Site
CoC	Chain of Custody
CSO	combined sewer overflow
CT	Chico Creek Tributary Storm Sampling Site
CW	Clear Creek West Storm Sampling Site
CWA	Clean Water Act
DI	deionized
ENVVEST	Project Environmental Investment
EPA	U.S. Environmental Protection Agency
FC	fecal coliform
GC	Gorst Creek Storm Sampling Site
HSP	Health and Safety Plan
HSPF	Hydrological Simulation Program - FORTRAN
KPUD	Kitsap Public Utility District
MEL	Manchester Environmental Laboratory
mi^2	square mile
mL	milliliter
NPS	non-point source
NTU	Nephelometric Turbidity Unit
NWS	National Weather Service
OC	Olney (Karcher) Creek Storm Sampling Site
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PNNL	Pacific Northwest National Laboratory
PSNS	Puget Sound Naval Shipyard
QAPP	Quality Assurance Project Plan
RTD	Rapid Transfer Device
SAP	Sampling and Analysis Plan
SC	Strawberry Creek Storm Sampling Site
SSE	Storm Sampling Event
SSR	Storm Summary Report
TEC	The Environmental Company, Inc.
TMDL	Total Maximum Daily Load
WRCC	Western Regional Climate Center

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Executive Summary

The report describes in-stream storm flow sampling activities performed by The Environmental Company, Inc (TEC) during the 2002-2003 In-Stream Storm Sampling Season in the Puget Sound Naval Shipyard (PSNS) Project Environmental Investment (ENVVEST) study area, Washington. The sampling effort conducted by TEC constituted a component of the PSNS Project ENVVEST. A total of 11 storm flow sampling sites were sampled over 7 separate storms during the 2002-2003 In-Stream Storm Flow Sampling Season. The following list summarizes the major accomplishments of the sampling season:

- 7 discrete storm events were sampled;
- a minimum of 3 storms were sampled at each location;
- total rainfall for each event was greater than 0.25” (the minimum criteria);
- 137 fecal coliform (FC) samples were collected; and
- 193 composite sample bottles were collected for chemical analysis.

A discussion of composite sample data is not provided in this report. However, a preliminary analysis of FC and physio-chemical data collected by TEC during the 2002-2003 In-Stream Storm Flow Sampling Season has revealed the following:

- Season geometric mean storm flow FC concentrations at 7 of the 11 sampling sites (Barker Creek [BA], Clear Creek [CC], Clear Creek West [CW], Clear Creek East [CE], Strawberry Creek [SC], Blackjack Creek [BL], and Olney Creek [OC]) exceeded the Class A Part I or Part II surface water quality standards. Conversely, only 4 sampling sites (Chico Main [CH], Chico Tributary [CT], Gorst Creek [GC], and Anderson Creek [AC]) did not exceed the Class A Part I or Part II surface water quality standards.

- No clear correlation exists between storm flow FC concentrations and either cumulative rainfall, turbidity, or antecedent dry period (ADP) for the project area when analyzed as a whole. However, watershed-specific correlations do appear to exist.

- Storm flow FC concentrations generally increased during wetter storms and storm flow FC concentrations generally increased in storms with a longer ADP. While these two factors are major factors in influencing storm flow FC concentrations, the level of urbanization, or more specifically, the level of commercial development within the watershed appears to be the primary influence on storm flow FC concentrations.

- Watersheds with a higher percentage of urban high density land use had higher FC concentrations (geometric mean). Conversely, those watersheds with a higher percentage of forest had lower FC concentrations (geometric mean). Basically, watersheds with a higher percentage of urbanization (specifically urban high density) had higher FC concentrations and those watersheds with more forested (un-urbanized) watersheds had lower FC concentrations.

- Based on data collected during this study, the timing of peak FC concentrations appeared to vary from site to site during the sample events; peak FC concentrations did not occur at the same stage of the sample event at each site. However, some sites (AC, CH, GC, and OC) did display a first flush effect during some storms.

- The timing of the first sample round appears to be important. It appears that FC concentrations do not rise above what can be proposed as baseline concentrations until approximately 0.10” of cumulative rainfall. In light of this, it is recommended that future sampling efforts wait to take the first round of FC samples until after at least 0.10” of cumulative rainfall.

- It is also recommended that future sampling efforts increase the number of FC samples taken at each site per sample event (from 3 to perhaps 5 or 6) to provide additional data points for enhancing the ability for analyzing potential relationships between FC concentrations and physio-chemical and meteorological conditions.
- Physio-chemical data collected during the dry season revealed lower turbidity values, higher temperature readings, and higher conductivity readings as compared to data collected during storm events. Given the seasonal changes in the watersheds during this period, these changes were to be expected.

1.0 INTRODUCTION

The report describes In-Stream Storm Flow Sampling activities performed by The Environmental Company, Inc (TEC) during the 2002-2003 In-Stream Storm Flow Sampling Season in the Puget Sound Naval Shipyard (PSNS) Project Environmental Investment (ENVVEST) study area, Washington (Figure 1-1). This sampling effort conducted by TEC constituted a component of the PSNS Project ENVVEST, which is part of U.S. Environmental Protection Agency (EPA) Excellence and Leadership Program, developed to give communities, state and local agencies, federal facilities, and industry the opportunity to propose cleaner, cheaper, and smarter ways of protecting the environment.

This report consists of the following 7 sections: Section 1.0 provides an introduction, Section 2.0 describes the study area, Section 3.0 describes the methods used, Section 4.0 presents the sampling data, Section 5.0 discusses the data, Section 6.0 presents conclusions, and Section 7.0 contains the references. The Field Test Memo and Individual Storm Summary Reports from each of the 7 sample events are included in Appendices A – H.

1.1 BACKGROUND

On September 25, 2000, PSNS, Region X of the EPA, and the Washington State Department of Ecology signed a Final Project Agreement to initiate Phase I of PSNS Project ENVVEST. The goal of PSNS Project ENVVEST is to protect and improve the health of surface waters of Sinclair and Dyes Inlets by developing a more environmentally protective strategy for maintaining pollutant sources in the Inlets than the regulatory framework currently in place (Navy, EPA, and Ecology 2000).

Within the context of the goals for Impaired Water Bodies, ENVVEST will help ensure that water bodies will meet their beneficial uses under the Clean Water Act (CWA). This will require the development of a multi-parameter, multimedia Total Maximum Daily Load (TMDL) for Sinclair and Dyes Inlets, that will meet sediment and water quality targets, address contaminants on the CWA 303(d) list (chemical stressors), and implement Water Cleanup Plans. Assessing ecological risk at the watershed scale will define the components of the ecosystem at risk and identify the stressors causing risk (PSNS Project ENVVEST Technical Steering Committee 2002).

Successful achievement of these goals will result in developing efficient and effective approaches through TMDLs to increase the water quality of the Inlets and their watersheds. PSNS Project ENVVEST will provide valuable examples of how to partner with local stakeholders and how to develop innovative, cost-effective solutions to environmental problems, while meeting regulatory requirements, which may be applied elsewhere (PSNS Project ENVVEST Technical Steering Committee 2002).

1.2 SAMPLING GOALS

The objective of sampling the streams during storm events was to obtain an estimate of contaminant loading into the receiving waters during periods of storm flow. The goal of sampling was to sample a minimum of 3 discrete storm events at each stream location to: 1) characterize runoff from the surrounding watershed, and 2) provide data to calibrate and verify Hydrological Simulation Program-FORTRAN (HSPF) watershed models which have been developed for watersheds within the study area (Skahill et al 2003). Sampling events were targeted to capture storm events that resulted in more than 0.25” of rain within a 48-hour period preceded by a minimum of 24-hours of no or low rainfall.

The objective of the sampling effort was to obtain an estimate of contaminant loading into the receiving waters during storm events. Parameters analyzed included physical, biological, total metals, dissolved metals, and organic compounds including total polychlorinated biphenyls (PCBs). The analytical parameters are based on sediment management standards, contaminants on the 303(d) list for the study area, and screening for polycyclic aromatic hydrocarbons (PAHs), PCBs, and phthalates (Table 1-1).

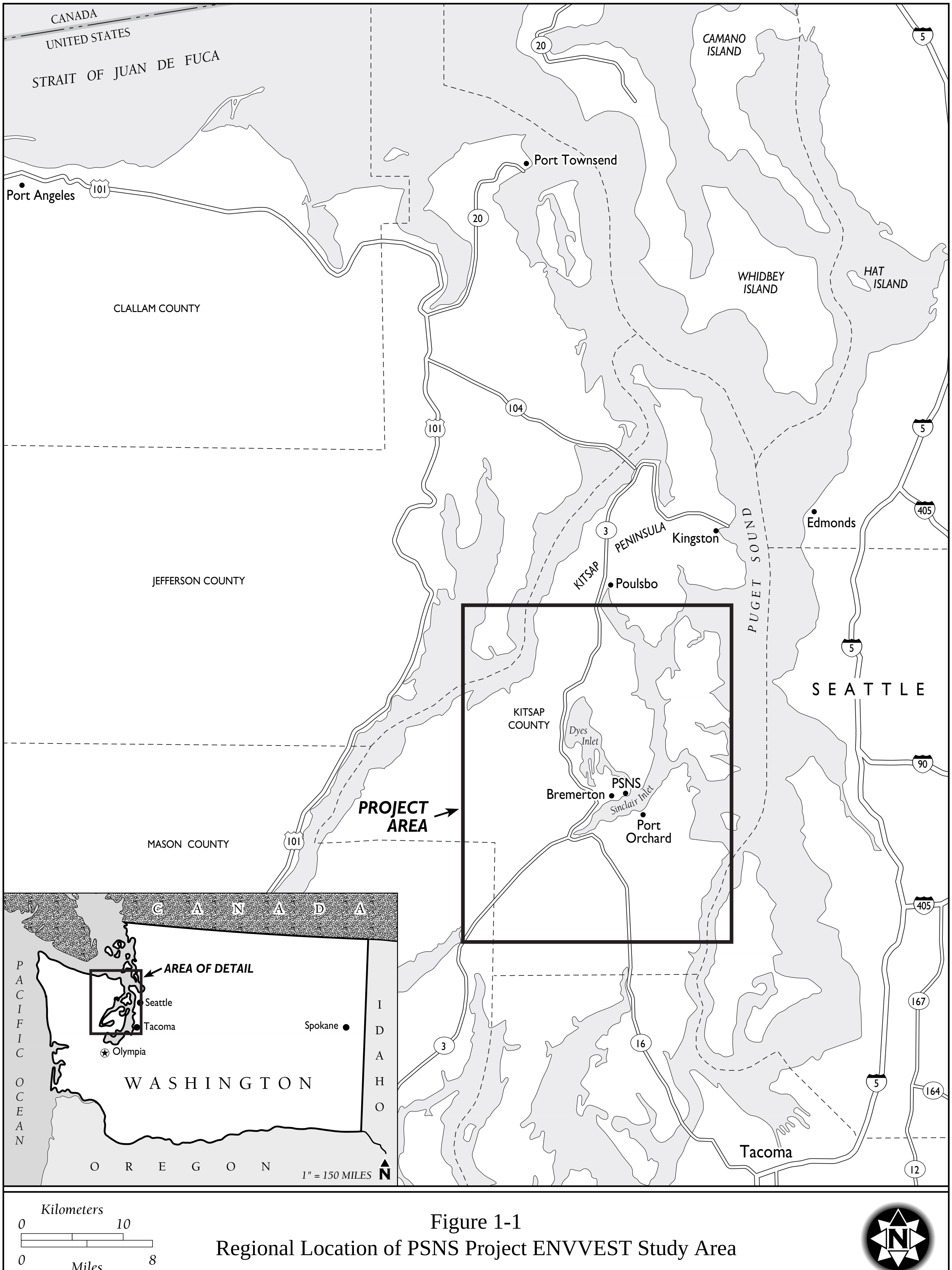

Figure 1-1
Regional Location of PSNS Project ENVVEST Study Area

Table 1-1. Analytical Parameters, Holding Times, and Detection Limits for Storm Flow Sampling

Analytical Parameter	*Holding Time*	*Detection Limit[1]*	
		Value	*Units*
Conventionals/Physicals			
YSI Probe			
Conductivity	-	-	µS/cm
pH	-	0 – 14	-
Temperature	-	0 – 100	C
Turbidity	-	0.01	NTU
Automatic Sampler			
Alkalinity, Total (as CaCO3)	14 days	1	mg/L, CaCO3
Hardness (as CaCO3)	6 months	2	mg/L, CaCO3
Total Solids	7 days	5	mg/L
Total Suspended Solids	7 days	1	mg/L
Total Organic Carbon (TOC)	28 days	250	ug/L
LISST Solids	6 months	-	-
Biological (Grab Sample)			
Fecal Coliform (membrane filtration)	24 hours	1	CFU/100 mL
Nutrients			
Automatic Sampler			
(Nitrate + Nitrite) Nitrogen	28 days	0.01	mg/L
Ammonia Nitrogen	28 days	0.1	mg/L
Total Nitrogen (TKN)	28 days	0.1	mg/L
Total Phosphorus	28 days	0.002	mg/L
Total Metals			
Automatic Sampler			
Aluminum	6 months	0.1	ug/L
Arsenic	6 months	0.01	ug/L
Cadmium	6 months	0.001	ug/L
Chromium	6 months	0.01	ug/L
Copper	6 months	0.001	ug/L
Lead	6 months	0.005	ug/L
Mercury	28 days	0.001	ug/L
Silver	6 months	0.005	ug/L
Zinc	6 months	0.005	ug/L
Dissolved Metals (0.45 um filter) – filtered within 24 hours			
Automatic Sampler			
Cadmium	6 months	0.001	ug/L
Copper	6 months	0.001	ug/L
Lead	6 months	0.005	ug/L
Silver	6 months	0.005	ug/L
Zinc	6 months	0.005	ug/L

Table 1-1. Analytical Parameters, Holding Times, and Detection Limits for Storm Flow Sampling (continued)

Organics			
Automatic Sampler			
2-methylnaphthalene	7 days / 40 days[2]	5	ug/L
Acenaphthene	7 days / 40 days[2]	5	ug/L
Acenaphthylene	7 days / 40 days[2]	5	ug/L
Anthracene	7 days / 40 days[2]	5	ug/L
Benz(a)Anthracene	7 days / 40 days[2]	5	ug/L
Benzo(a)pyrene	7 days / 40 days[2]	5	ug/L
Benzo(g,h,i)perylene	7 days / 40 days[2]	5	ug/L
Bis (2-ethylhexyl) phthalate	7 days / 40 days[2]	5	ug/L
Butyl benzyl phthalate	7 days / 40 days[2]	5	ug/L
Chrysene	7 days / 40 days[2]	5	ug/L
Dibenzo (a,h) Anthracene	7 days / 40 days[2]	5	ug/L
Di-n-butyl phthalate	7 days / 40 days[2]	5	ug/L
Fluoranthene	7 days / 40 days[2]	5	ug/L
Fluorene	7 days / 40 days[2]	5	ug/L
Indeno (1,2,3,-cd) pyrene	7 days / 40 days[2]	5	ug/L
Naphthalene	7 days / 40 days[2]	5	ug/L
PCB Congener (NOAA NS&T 20 congeners)	7 days / 40 days[2]	0.001	ug/L
Phenanthrene	7 days / 40 days[2]	5	ug/L
Pyrene	7 days / 40 days[2]	5	ug/L
Total benzofluoranthenes	7 days / 40 days[2]	5	ug/L
Total PCB'S	7 days / 40 days[2]	0.01	ug/L

Notes: [1] Method Detection Limit.
[2] Holding times are for "maximum holding time until extraction / maximum extract holding time," respectively.
CaCO3 = Calcium Carbonate, EPA = U.S. Environmental Protection Agency, g = grams, kg = kilograms, L = liter, CFU = colony forming units, ug = micrograms, mg = milligrams, mL = milliliters, µS/cm = micro Siemens per centimeter, NTU = Nephelometric Turbidity Unit, and LISST = laser induced suspended solids transmittance.

Storm flow quality data was obtained via 3 methods: (1) conducting automatic composite sampling with Isco automatic sampling units; (2) capturing grab samples for biological analysis (fecal coliform [FC]); and (3) obtaining physio-chemical data (conductivity, pH, temperature, and turbidity) continuously in the field with a YSI 6821 multi-parameter water quality meter.

1.3 PREVIOULSLY PREPARED DOCUMENTS

This report is the final document prepared by TEC as part of the 2002-2003 In-Stream Storm Sampling Season. Previously documents prepared by TEC in support of the sampling effort are available to interested readers on the PSNS Project ENVVEST website. These reports include the following:

- Sampling and Analysis Plan (SAP) (TEC 2002a). The SAP included: a description of the ENVVEST program, program goals, in-stream sampling objectives and data uses; a brief description of each basin/subbasin and stream characteristics; a general description of sampling locations, rationale, analyses, and frequency; a description of methods for conducting rain event monitoring, sampler and flow meter installation, site-specific sampler and flow meter setup; and a brief description of reporting requirements, project organizations, and schedule.
- Health and Safety Plan (HSP) (TEC 2002b). The HSP provided hazard information and safety guidelines for personnel involved in field operations and covered all activities associated with conducting In-Stream Storm Flow Sampling during the 2002-2003 sampling season.
- Quality Assurance Project Plan (QAPP) (TEC 2002c). The QAPP was prepared in accordance with the requirements outlined in EPA QA/R-5, "EPA Requirements for Quality Assurance Project Plans" and included: a description of quality control and instrument calibration requirements; instructions for undertaking assessment, response, and reporting mechanisms; a section on data validation and usability; and, procedures for data review and reconciliation.
- Field Test Tech Memo (TEC 2002d). This short deliverable detailed the results of the sampling station field test (8-10 December 2002) and recommendations for correcting problem areas. Refer to **Appendix A** to view this memo.
- Individual Storm Summary Reports (SSRs) (TEC 2002e, 2003a-f). At the conclusion of each individual Storm Sampling Event (SSE), TEC prepared a SSR which presented both a narrative of the sampling event (which included relevant meteorological data, a discussion of the sampling effort, and a discussion of any variances to the approved work plans), and a summary of the in situ analytical results for each site and chain of custody (CoC) copies. Refer to **Appendices B – H**, respectively, to view these reports.

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2.0 PSNS PROJECT ENVVEST STUDY AREA

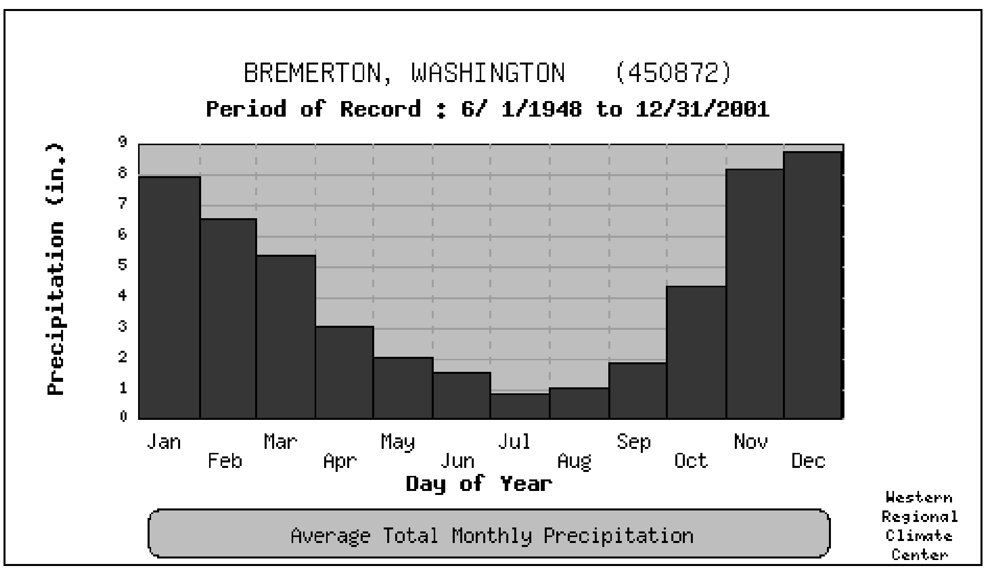
2.1 LOCATION

The PSNS Project ENVVEST study area includes the watersheds and receiving waters of Sinclair and Dyes Inlets (Figure 2-1). The 62,348 acre (25,231 hectare) Sinclair/Dyes Inlet Watershed is located entirely within Kitsap County and includes all or portions of the communities of Bremerton, Silverdale, Port Orchard, and Bainbridge Island, as well as land under the jurisdiction of the State of Washington Department of Natural Resources and the U.S. Department of the Navy. Outside of urbanized areas, the study area is generally characterized by scattered, small neighborhoods, homes on acreage, and large parcels of undeveloped land.

Sinclair and Dyes Inlets are two inter-connected sub-estuaries of the Puget Sound estuarine system. Tides enter through the mouth of the Puget Sound and propagate to both Inlets from Brownsville and Clam Bay, from the north and south, respectively. The Inlets receive freshwater inflow and land-based loadings from industrial and storm flow discharges, sewage treatment plants, and runoff from the surrounding watersheds.

Hydrologic conditions for the PSNS Project ENVVEST area have been approximated using a long-term data set (1948 – present) from Bremerton (Western Regional Climate Center [WRCC] 2002a). While annual rainfall in Bremerton averages 51.4”, annual rainfall throughout the study area ranges from approximately 40” in the lower reaches of Barker Creek to over 54” in the headwaters of Chico Creek (Kitsap Public Utility District [KPUD] 1997). The majority of precipitation occurs from October through March (Table 2-1).

Table 2-1. Average Monthly Rainfall at Bremerton (1948 -2001)



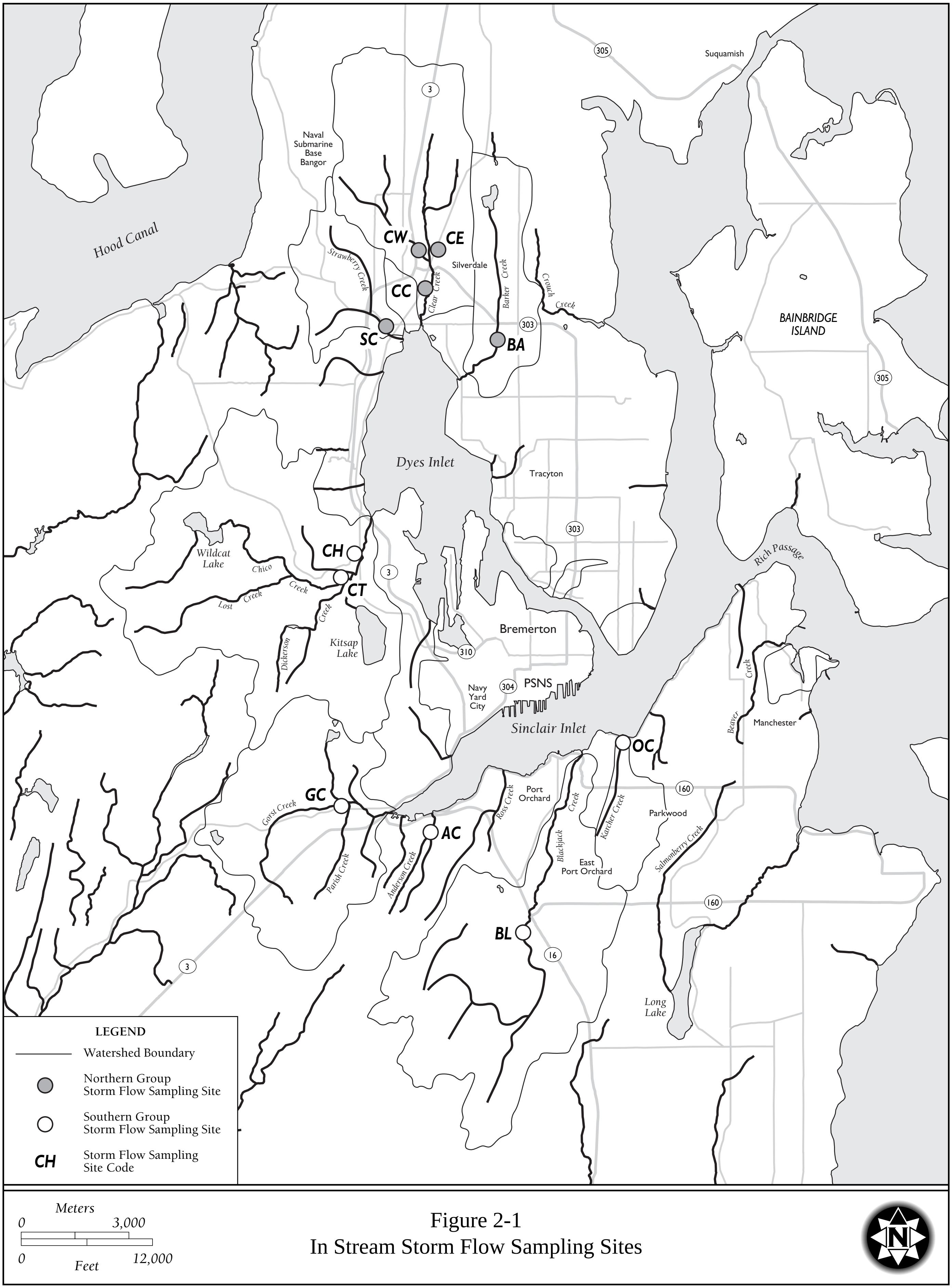


Figure 2-1
In Stream Storm Flow Sampling Sites

2.2 SAMPLING SITES

A total of 11 storm flow sampling sites, divided into 2 groups, were sampled in 2002-2003 (Figure 2-1). The Northern Group consisted of 6 sites which all flow into Dyes Inlet. The Southern Group consisted of 6 sites, the majority of which flow into Sinclair Inlet. Chico Creek was common to both groups. The sites were grouped as follows:

Northern Group (6): Chico Creek, Strawberry Creek, Clear Creek (West Tributary), Clear Creek (East Tributary), Clear Creek, and Barker Creek.

Southern Group (6): Chico Creek Tributary (at Taylor Road), Chico Creek, Gorst Creek, Anderson Creek, Blackjack Creek, and Olney Creek (Karcher).

2.2.1 Northern Group

2.2.1.1 Chico Creek (CH)

The Chico Creek Storm Flow Sampling Site is located at the downstream side of a culvert where the creek passes beneath NW Golf Club Road (Kitsap Golf and Country Club) (see CH on Figure 2-1). The majority of the 15.3 square mile (mi^2) Chico Creek Watershed consists of rural and forested land uses although the lower reaches of the watershed are urban residential (KPUD 1997).

2.2.1.2 Strawberry Creek (SC)

The Strawberry Creek Storm Flow Sampling Site is located in downtown Silverdale behind the former Silverdale Water Building (see SC on Figure 2-1). The majority of the 3.01 mi^2 Strawberry Creek Watershed consists of commercial and residential (urban) land uses (KPUD 1997).

2.2.1.3 Clear Creek - West Tributary (CW)

The Clear Creek West Tributary Storm Flow Sampling Site is located at the upstream side of a culvert passing beneath Schold Road (see CW on Figure 2-1). A tributary to Clear Creek, Clear Creek West begins at Submarine Base Bangor. The majority of the 3.68 mi^2 Clear Creek West Watershed consists of forested/open space land uses (KPUD 1997).

2.2.1.4 Clear Creek - East Tributary (CE)

The Clear Creek East Tributary Storm Flow Sampling Site is located at the upstream side of a culvert passing beneath Schold Road, approximately 1/8 mile north of CW (see CE on Figure 2-1). A tributary to Clear Creek, the majority of the 3.78 mi^2 Clear Creek East Watershed consists of low to medium density residential and forested/open space land uses (KPUD 1997).

2.2.1.5 Clear Creek (CC)

The Clear Creek Storm Flow Sampling Site is located at the downstream side of a culvert where the creek passes beneath Silverdale Way Northwest (see CC on Figure 2-1). The 8.08 mi^2 Clear Creek Watershed consists of a relatively equal mix of low to medium density residential and forested/open space land uses (KPUD 1997).

2.2.1.6 Barker Creek (BA)

The Barker Creek Storm Flow Sampling Site is located in the Barker Creek Watershed at the upstream side of a new culvert constructed over Barker Road (see BA on Figure 2-1). The majority of the 4.02 mi^2 Barker Creek Watershed consists of rural to low urban land uses (1 dwelling per 6-10 acres) (KPUD 1997).

2.2.2 Southern Group

2.2.2.1 Chico Creek Tributary at Taylor Road (CT)

The Chico Creek Tributary at Taylor Road Storm Flow Sampling Site is located at the foot of the upstream side of a new bridge on Northwest Taylor Road (see CT on Figure 2-1). As the main tributary to Chico Creek, the majority of the 9.28 mi^2 Chico Tributary Watershed consists of rural and forested land uses (KPUD 1997).

2.2.2.2 Gorst Creek (GC)

The Gorst Creek Storm Flow Sampling Site is located at the downstream side of a bridge on a dirt road leading off north of West Belfair Valley Road (GC on Figure 2-1). The majority of the 9.08 mi^2 Gorst Creek Watershed consists of forested land uses, as the watershed serves as the City of Bremerton's back-up water supply (KPUD 1997).

2.2.2.3 Anderson Creek (AC)

The Anderson Creek Storm Flow Sampling Site is located south of Highway 16 at Anderson Hill Road in the City of Bremerton's ground water well field (see AC on Figure 2-1). The majority of the 4.04 mi^2 Anderson Creek Watershed consists of low density residential forested/open space land uses (KPUD 1997).

2.2.2.4 Blackjack Creek (BL)

The Blackjack Creek Storm Flow Sampling Site is located in the Blackjack Creek Watershed at the upstream side of a culvert passing beneath Highway 16 at Exit 160 East (see BL on Figure 2-1). The majority of the 12.3 mi^2 Blackjack Creek Watershed consists of rural and forested land uses (KPUD 1997).

2.2.2.5 Olney (Karcher) Creek (OC)

The Olney Creek Storm Flow Sampling Site is located just behind the Karcher Creek Sewer District Sewage Treatment Plant south of Beach Drive East in Port Orchard (see OC on Figure 2-1). The majority of the 1.86 mi^2 Karcher Creek Watershed consists of low to medium density residential and forested/open space land uses (KPUD 1997).

3.0 METHODS

This section presents a discussion of the methods and materials used to obtain storm flow samples during the 2002-2003 sampling season.

3.1 PRE-SAMPLING ACTIVITIES

3.1.1 Equipment and Materials

To obtain composite samples from storm events, 7 automatic samplers (Isco Model 6700) and 7 rain gauges (Isco Model 674) and associated equipment (batteries, 3.7 liter clear glass jars, tubing, etc.) were used (TEC 2002a). FC samples were collected in 100 milliliter (mL) clean, sterilized plastic bottles provided by Manchester Environmental Laboratory (MEL). In addition, YSI 6820 multi-parameter probes were installed immediately downstream of the Isco sampler tube intake at each station to record physio-chemical data (conductivity, pH, temperature, and turbidity). Prior to each storm event the YSI water quality monitors were calibrated in the TEC field office in Poulsbo. Sampling equipment was stored at the TEC field office for quick mobilization before a targeted storm event.

3.1.2 Rinsate (Equipment Blank) Test

Once all of the sampling equipment was in TEC's possession, a rinsate (or equipment) test was conducted to evaluate the potential contamination from sample handling from sampling equipment and sampling procedures. Rinsate blanks (equipment blanks) were obtained by passing laboratory supplied deionized (DI) water through the each of the decontaminated Isco samplers at the TEC field office. The rinsate blank was analyzed for the same parameters as the storm samples.

3.1.3 Field Test

Prior to the start of the first SSE, TEC completed a field test of the sampling equipment at the 6 northern group sites (CH, SC, BA, CC, CW, and CW). The purpose of the field test was to ensure that the storm flow sampling equipment would perform properly over a 48-hour period (the maximum potential sampling period).

3.1.4 Storm Tracking

Throughout the sampling season, TEC monitored the weather forecast for candidate storms. When TEC identified a potential storm, coordination and discussion with the PSNS ENVVEST team followed, and, if the storm was predicted to meet the sampling criteria, the TEC field team mobilized to the project area and set up the sampling equipment. Once the sampling equipment was in place, the TEC field team continued to monitor the oncoming storm. TEC used near real-time meteorological data from a variety of local internet-accessible sites to monitor conditions in the project area (see TEC 2002d-2003f).

3.1.5 Mobilization

Once a candidate storm was identified and the decision was made to sample, TEC staff mobilized the sampling gear from the TEC field office to the sites. A rain gauge was installed at each site, and the samplers were programmed to begin sampling immediately once > 0.05" of rain fell within a 1 hour period. During site set-up, TEC staff calibrated the samplers to pull 140 mL aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 mL aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data. Once all the sites were mobilized ("armed"), TEC staff monitored the approaching storm via web-based weather forecasts (e.g., the National Weather Service [NWS] and University of Washington).

3.2 IN-STREAM STORM FLOW SAMPLING

3.2.1 Sampling

Once rain began, TEC staff went to each of the sites to make sure they had started in response to greater than 0.05” of rain within an hour. Time-paced composite samples were then collected at 15 minute intervals at each individual station. Composite samples were automatically collected for the duration of the storm event or 48 hours, which ever came first.

For each sampling event, 3 FC grab samples were collected at each station – 1 each at the beginning, middle, and end of the storm event. In addition, 1 field duplicate sample was taken for every 10 FC samples collected. Therefore, for most sample events, a minimum of 20 FC samples were obtained (18 + 2 duplicate = 20 total). FC samples were collected in accordance with accepted sampling protocols (Caltrans 2000, Lombard and Kirchmer 2001, Ward 2001).

Following initial activation, a 2-person team went from station to station and checked the samplers to make sure all components were operating properly. During each visit, the field team: checked the rain gauge and YSI probe data, ensured the sampler was collecting the programmed aliquots, checked the gauge height, took pictures as conditions warranted, changed 3.7 liter jars as needed, took FC samples when instructed, and downloaded physio-chemical and rainfall data every 24 hours. Throughout the sampling event TEC coordinated with the PSNS ENVVEST team on the progress of the sampling effort.

3.2.2 Sample Delivery

Immediately after samples were collected and labeled for off-site laboratory analysis, samples (FC and composite) were placed in coolers. Each sample holding cooler was filled with enough ice packs in order to meet the 4° Celsius preservative requirement. CoC forms for the samples were filled out and sent along with the coolers to their respective labs for analysis. Composite samples were delivered to Pacific Northwest National Laboratory (PNNL) by TEC within 48 hours of sample collection and FC grab samples were delivered to the MEL in Port Orchard within 24 hours of sample collection for FC analysis. Immediately following the conclusion of the sampling events, the physio-chemical data was sent to PSNS for preliminary analysis.

3.2.3 Demobilization

While the tubing was left in place, the automatic samplers were removed from the sites when not in use. The sample intake tubing remained inside the PVC pipe “housing” at the end of each sampling event. New, pre-cleaned sterilized bottles were delivered to TEC from a certified distributor. The batteries were charged the equipment was cleaned, accounted for, and stored at TEC’s field office. The internal tubing was removed from each Isco and bagged and sent to PNNL for cleaning. When samples were dropped off at PNNL, TEC picked up clean internal tubing. Similarly, clean FC sample bottles and CoC labels were obtained from MEL when samples were delivered.

3.2.4 Reporting

Following the conclusion of each SSE, TEC prepared individual storm sampling reports. These reports summarized each sampling event and contained: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the SSE; 3) storm sampling results; 4) variations to the sampling plan; and 5) follow-up action items. In addition, appendices containing satellite images, site photos, physio-chemical data, and chain of custody forms were included.

3.3 DRY SEASON PHYSIO-CHEMICAL DATA

After SSE #7, TEC suggested mobilizing the equipment to the sampling sites during the “dry” season to collect physio-chemical data, as sufficient resources remained on the contract to do so. The PSNS ENVVEST team agreed. This data would represent physio-chemical conditions within the study area during non-storm conditions as serve as an approximate baseline with which to compare storm data. With PSNS ENVVEST team concurrence, TEC installed the sampling equipment (Isco’s and YSI) at the following sites: BA, CC, CH, CT, OC, GC, and BL. In addition, TEC installed a rain gauge at GC to record rainfall in the project area during this period. GC was chosen as this site is the least likely to be vandalized due to its isolated location as well as its central location to the sampling sites.

TEC installed the samplers during the week of 14 May and continued sampling at the sites until 18 June, whereupon TEC demobilized and returned the sampling equipment to TEC’s field office for cleaning and storage.

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4.0 TEC 2002-2003
IN-STREAM STORM FLOW SAMPLING

4.1 SAMPLING SUMMARY

Sampling occurred during a variety of hydrological and watershed conditions - short duration, high-intensity events; long-duration medium intensity events; and long-duration, heavy intensity events. Table 4-1 presents a summary of rainfall and samples organized by storm event and Table 4-2 summarizes the sampling data by site. Table 4-3 presents the 2002-2003 In-Stream Storm Flow Sampling milestones and daily rainfall totals from the PSNS rain gauge.

Table 4-1: In-Stream Storm Flow Sampling Summary by Storm (2002-2003 Season)

Station Name (ID)	Total Rainfall (inches)	Total Fecal Grab Samples	Total Composite Sample Bottles
Storm #1 - 15/16 Dec 02			
BA	1.00*	4	4
CH	1.00*	4	4
CC	1.00*	3	4
CE	1.00*	3	4
CW	1.00*	3	4
SC	1.00*	3	4
**rainfall totals estimated from non-ENVVEST gauges*			
Subtotal	**6.00**	**20**	**24**
Storm Average (per station)	**1.00**	**NA**	**NA**
Storm #2 - 11/12 Jan 03			
BA	1.19	4	4
CH	1.31	4	4
CC	1.12	3	4
CE	1.11	3	4
CW	1.10	3	4
SC	1.03	3	4
Subtotal	**6.86**	20	24
Storm Average (per station)	**1.14**	**NA**	**NA**
Storm #3 - 22/23 Jan 03			
AC	1.56	3	4
BL	1.37	4	4
CH	1.69	3	4
CT	1.74	3	4
GC	1.45	3	4
OC	1.33	4	4
Subtotal	**9.14**	**20**	**24**
Storm Average (per station)	**1.52**	**NA**	**NA**

Table 4-1: In-Stream Storm Flow Sampling Summary by Storm (2002-2003 Season) (continued)

Storm #4 - 29/31 Jan 03			
AC	1.04	4	8
BL	0.97	5	8
CH	0.70	5	8
CT	0.76	4	8
GC	0.88	5	8
OC	0.77	4	8
Subtotal	**5.12**	**27**	**48**
Storm Average (per station)	**0.85**	**NA**	**NA**
Storm #5 - 15/17 Feb 03			
AC	0.93	0	3
BL	0.73	0	1
CH	0.83	0	3
CT	0.88	0	3
GC	0.89	0	4
OC	0.58	0	1
Subtotal	**4.84**	**0**	**15**
Storm Average (per station)	**0.81**	**NA**	**NA**
Storm #6 - 8/9 Mar 03			
BA	0.87	3	4
BL	0.83	3	4
CC	1.03	4	4
CE	1.00	3	4
CW	0.98	4	4
OC	0.72	3	4
SC	0.97	3	4
Subtotal	**6.40**	**23**	**28**
Storm Average (per station)	**0.91**	**NA**	**NA**
Storm #7 - 12/13 Mar 03			
BA	3.10	5	5
CH	3.09	4	5
CC	3.43	4	5
CE	3.40	5	5
CW	3.30	4	5
SC	3.19	5	5
Subtotal	**19.51**	**27**	**30**
Storm Average (per station)	**3.25**	**NA**	**NA**
Season Total	**57.87**	**137**	**193**
Season Average Storm Event	**8.27**	**NA**	**NA**
Season Average Storm Event (all stations)	**1.32**	**NA**	**NA**

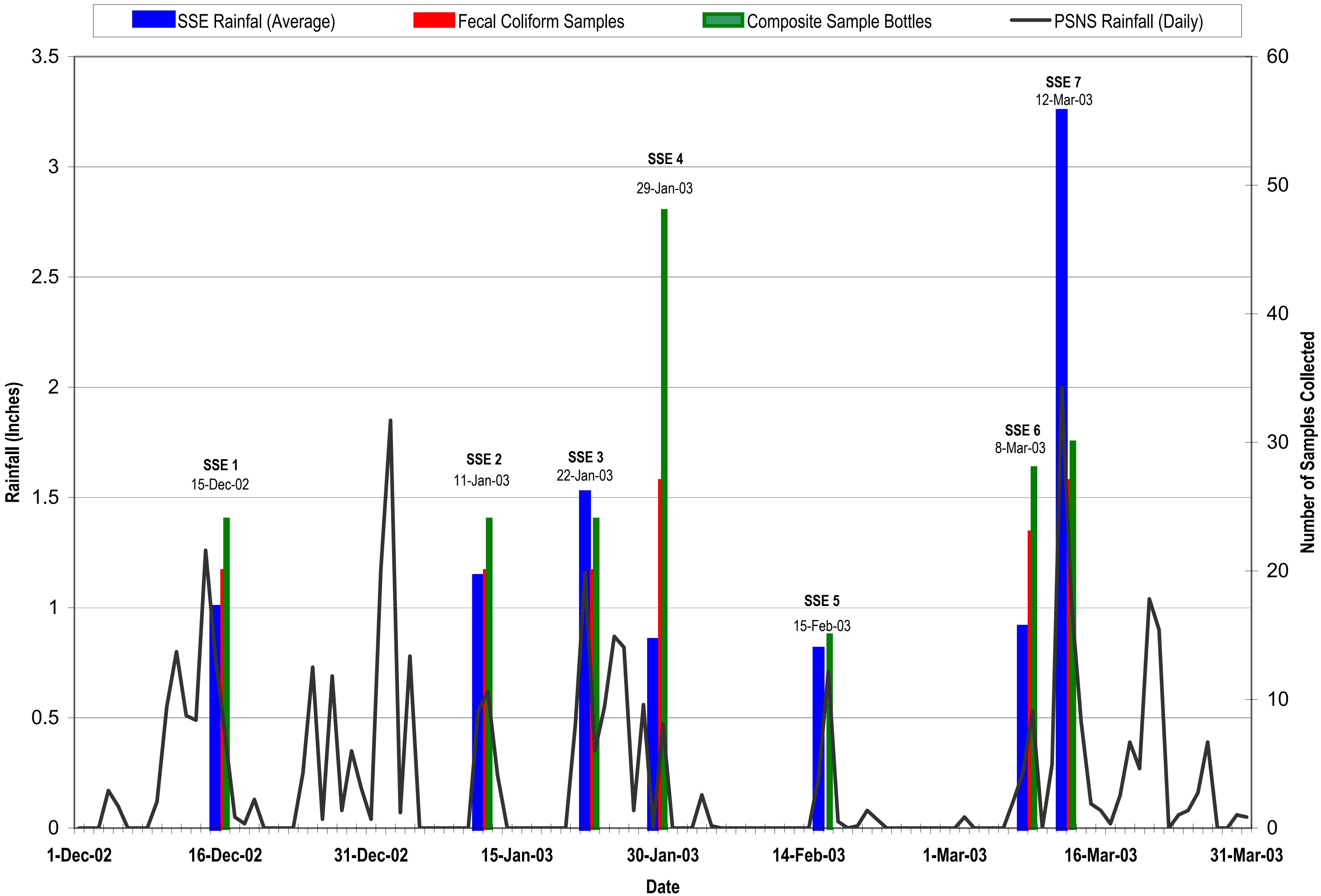
Table 4-2: In-Stream Storm Flow Sampling Summary By Site (2002-2003 Season)

Station	Storms Sampled	Total Rainfall (inches)	Average Rainfall per Event	Total Fecal Samples	Average Fecals Samples per Event	Total Composite Bottles	Average Composite Bottles per event
AC	3	3.38	1.13	7	2.3	15	3.7
BA	4	6.47	1.62	16	4.0	17	4.3
BL	4	3.94	0.99	11	2.8	17	3.3
CH	6	8.75	1.46	18	3.0	28	4.0
CT	3	3.07	1.02	9	3.0	15	3.7
CC	4	6.28	1.57	16	4.0	17	4.3
CE	4	6.03	1.51	13	3.3	17	4.3
CW	4	6.58	1.65	14	3.5	17	4.3
GC	3	3.22	1.07	8	2.7	16	4.0
OC	4	3.65	0.91	11	2.8	17	3.3
SC	4	6.50	1.63	14	3.5	17	4.3

A total of 11 storm flow sampling sites were sampled over 7 separate storms during the 2002-2003 In-Stream Storm Flow Sampling Season in a variety of hydrological and watershed conditions. The following list summarizes the major accomplishments of the sampling season:

- a minimum of 3 storms were sampled at each location;
- total rainfall for each event was greater than 0.25" (the minimum criteria);
- 7 discrete storm events were sampled;
- while the minimum ADP was not met on every occasion, it was met for 5 of 7 events;
- 137 FC samples were collected;
- 193 composite bottles were collected for chemistry analysis; and
- no equipment was destroyed or damaged and no injuries to staff participating in sampling activities occurred.

Table 4-3
In-Stream Storm Flow Sampling Milestones



4.2 EQUIPMENT TESTS

4.2.1 Rinsate (Equipment) Blank Test

On 3 December 2002, TEC staff performed the rinsate test at the TEC field office to determine if any of the equipment or procedures used during storm flow sampling activities would result in false positives in the samples. One, 3.7 liter composite sample from each of the 7 samplers (plus 1 blank of DI water) was delivered to PNNL later that same day.

4.2.2 Field Test

On 8-10 December 2002, TEC staff completed a field test of the in stream storm flow sampling equipment at the 6 northern group sites (BA, CC, CE, CW, SC, and CH) (TEC 2002d – **Appendix A**). Once the samplers were manually started, TEC staff visited each of the stations in order of activation to ensure that the samplers were operating correctly. Following this initial check, each station was monitored during the switch from Bottle 1 to Bottle 2 (6 hours from activation). Sampling stations were then periodically checked throughout the balance of the sampling event. On Monday, 9 December at the critical 24-hour juncture (i.e., when the first 4 bottles would be filled), TEC staff emptied the bottles and replaced them in the base on the sampler, thereby providing sufficient capacity for the subsequent 24-hours. On Tuesday, 10 December, each sampling station was de-mobilized 48-hours from their respective activation time. Samples were not collected for analysis.

The Isco samplers recorded the physio-chemical data logged by the YSI 6820 sonde; however the YSI sondes were not calibrated prior to installation and the data was therefore suspect. Rain gauges were not installed as a prior field test of the 2 Isco rain gauges proved they worked fine and the additional rain gauges lacked appropriate cable connectors. In addition, the YSI sonde data was not downloaded from the samplers as TEC did not yet have the Isco Rapid Transfer Device (RTD) or Flowlink software.

4.3 IN-STREAM STORM FLOW SAMPLING

4.3.1 Individual Storm Summaries

The following sections provide summaries of each individual SSE. These summaries represent condensed versions of the individual storm summary reports prepared following each SSE and include information on the storm number and date, ADP preceding the SSE, total rainfall, number of samples obtained, and any variances to the SAP. Refer to Appendices B through H to view the full storm summary reports.

For the most part, all SSEs were completed with little, if any variances to the approved SAP. When variations did occur, they are included with the individual SSE summary sections in which they occurred. While variations did occur, none of these variations affected the integrity of the samples or sampling effort.

4.3.1.1 Storm Sampling Event #1

<u>Storm Sampling</u>

SSE #1 was a 24-hour event sampled on 15-16 December 2002 at the 6 northern group sites (CH, SC, BA, CC, CW, and CE) (TEC 2002e – **Appendix B**). The ADP preceding SSE #1 was just less than 24 hours and the project area had been subject to several wet storms during the first couple of weeks in December. As a result, the level in each of the creeks rose visibly during the event and then slowly receded throughout the 16th. The quick response of the creeks to the rain is believed to have resulted from recent storms saturating the soils in the watershed, resulting in a large percentage of rainfall from this storm event transitioning directly to storm flow.

Sampling began at approximately 1400 hours on the 15th and continued until approximately 1400 hours on the 16th. Rain generally fell within 2 periods separated by a dry period. Moderate rain fell throughout the period of 1400 – 1800 on the 15th, and then again from 2130 on the 15th to 0100 on the 16th. Scattered light showers and periods of no rain occurred throughout the other hours. Nearby weather station data indicated that approximately 1" of rain fell within the 24-hour sampling period throughout the sampling area. A total of 20 FC grab samples and 24 composite bottles were collected.

Variances to the SAP

SSE #1 did not meet the defined sampling criteria in that it was not preceded by a 24-hour period of no or negligible rainfall. However, PSNS and TEC staff felt that the storm was a good storm to sample because it would produce a large amount of rain and it represented the first opportunity for sampling following sample site activation.

During a check at BA during the evening of 15 December, it became apparent that the sampler was not pulling appropriately sized aliquots as a visual check of Bottle 1 showed the bottle at less than one-half full (Bottle 2 had already began to fill). A quick calibration check showed that the sampler was pulling 65 mL aliquots, not the 140 mL aliquots as programmed. This problem was quickly solved by calibrating the sampler in the field. The balance of Bottle 2 and all of Bottles 3 and 4 were filled with appropriately sized aliquots. While the cause of this under sampling is not known, the problem was quickly fixed and did not occur again. In addition, even with the smaller sample volume there was sufficient volume to conduct laboratory analysis.

Calibration of the YSI sondes was not accomplished prior to the event as more important tasks needed to be completed to ready the sample sites for sampling. While data was obtained from the YSI sondes, they cannot be considered entirely accurate as the units were not calibrated.

As TEC was not in possession of RTDs to transfer rain data from the Isco's for this event, site-specific rainfall data was not available. Therefore, rainfall data from nearby non-PSNS gauges was used.

4.3.1.2 Storm Sampling Event #2

Storm Sampling

SSE #2 was a 24-hour event sampled on 11-12 January 2003 at the 6 northern group sites (CH, SC, BA, CC, CW, and CE) (TEC 2003a - **Appendix C**). After a moderate rain event on 4-5 January, the project area experienced a period of dry weather as high pressure dominated the Pacific Northwest, resulting in an ADP of 7 days prior to SSE #2. This relatively long dry period for this time of year allowed soil saturation levels in the watersheds to decrease.

Sampling began at approximately 1600 hours on the 11th and continued until approximately 1600 hours on the 12th. Rainfall was consistent at a moderate level throughout the entire event, interspersed with lighter and heavier showers. The 24-hour average rainfall total for each station was 1.14" and 20 FC samples and 24 composite bottles were collected.

Variances to the SAP

During a check at CH during the evening of 11 January, liquid (i.e., creek water) was discovered in the base of the sampler. In addition, Bottles 1 and 2 were filled to the top – it was quickly apparent that the sampler delivered more than the programmed aliquot on at least 2 occasions. A review of the sampling report shows that two things happened: 1) the sampler did not detect any liquid at intake, and subsequently, 2) the liquid detector temporarily malfunctioned. This resulted in the Isco not detecting any liquid, and therefore continued to pump creek water past the 140 mL sample size until the bottles filled. This is believed to have been caused by a hard angle in the intake tube which made it difficult for the Isco to detect liquid, and thereby not know when to stop sampling. The remainder of the storm event was sampled successfully.

While the YSI sondes were calibrated prior to SSE #2, several of the YSI sondes were not able to communicate with the Isco units when installed. This may have happened because some of the YSI sondes are set at a baud (communication) rate different than what the Isco uses. However, discrete data was obtained from the sites using the YSI 650 (hand-held data logger) when FC samples were taken.

4.3.1.3 Storm Sampling Event #3

Storm Sampling

SSE #3 was a 24-hour event sampled on 22-23 January 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003b – **Appendix D**). After a light rain event on 21 January (approximately 0.50"), the project area experienced a brief period of dry weather (approximately 7 hours). Previous to this moderate rain event, the NWS had predicted that the next system would be rather "wet" and potentially long-duration system. As such, it was decided that this event would be a good storm to sample, as the watersheds were near-saturated and runoff would be expected to mobilize any pollutants present.

Sampling began at approximately 0315 hours on the 22nd and continued until approximately 0300 hours on the 23rd. Rainfall was fairly consistent at a moderate level throughout the entire event, interspersed with lighter and heavier showers. The subtropical connection and Southwest/Northeast orientation of the storm resulted in generally high rainfall within the project area, as reflected in the 24-hour average rainfall total of 1.52" at each station. A total of 20 FC grab samples and 24 composite bottles were collected.

Variances to the SAP

SSE #3 occurred with an ADP of only approximately 7 hours. However, the preceding rain was generally light. Given that the event was forecast to result in a large amount of rain with high rainfall intensities, and the preceding rain event was light, the PSNS ENVVEST team decided it was more important to capture the runoff from the impending event.

4.3.1.4 Storm Sampling Event #4

Storm Sampling

SSE #4 was a 48-hour event sampled on 29-31 January 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003c – **Appendix E**). Together, Storm 4a and Storm 4b constitute SSE #4. Following the end of SSE #3, the PSNS Project ENVVEST study area experienced 3 consecutive days of moderate rain. However, by midday of 26 January, the study area began a period of several days of dry weather. The ADP for SSE #4a and #4b was approximately 3 days and 14 hours, respectively.

Storm 4a (Wednesday, 29 January – Thursday, 30 January)

Sampling began at approximately 0930 hours on the 29th and continued until approximately 0930 hours on the 30th. Rainfall associated with Storm 4a began to let up by mid-afternoon on the 29th. By the early evening hours the rain had transitioned to a light mist. By this time the bulk of the precipitation associated with Storm 4a had passed through the project area. The skies remained cloudy and the wind continued from the south – an indication that the next stronger, wetter system (Storm 4b) was approaching the area. By the late evening of the 29th the NWS had released a Flood Watch for most of Western Washington in anticipation of a heavy, prolonged rain event associated with Storm 4b.

Daybreak on the 30th revealed cloudy skies but no rain. A check of weather data revealed that no rain had fallen through the night. TEC staff went around to the sites and shut down the samplers, collected 24-

hours worth of samples (4 bottles), replaced the full bottles with empty bottles, and "re-armed" the samplers to start sampling when Storm 4b began.

The 24-hour average rainfall total for SSE #4a for each station was 0.32" and 7 FC samples and 24 composite bottles were collected. Per PSNS direction, only 7 FC samples (1 round) were collected during SSE #4a.

Storm 4b (Thursday, 30 January – Friday, 31 January)

Sampling began at approximately 1300 on the 30th and continued until approximately noon on the 31st. Rainfall was fairly consistent at a moderate level throughout the afternoon and early evening hours and was heaviest in the southern portion of the project area. By the early morning hours of the 31st, skies in the project area had begun to clear and the rain transitioned to a light mist then to nothing at all.

The bulk of the rain fell just south of the project area. Throughout the day on the 31st, rivers in West and Southwest Washington rose to or above flood stage in response to prodigious rainfall. While the project area missed out on the bulk of the precipitation associated with Storm 4b, the sites did receive enough rain to make for a qualifying sampling event. The 24-hour average rainfall total for SSE #4b for each station was 0.53" and 20 FC samples and 24 composite bottles were collected.

Variances to the SAP

In addition to the continuing communication issue between the some of the YSI sondes and Isco's, the Isco unit at CH did not achieve communication with the rain gauge. This lack of communication was discovered during the first round of FC sampling when TEC staff observed that the sampler had not started when more than 0.05" of rain had fallen in the area (CT had been sampling for over an hour at this point). So, TEC staff manually activated the sampler at 1115, approximately 3 hours after rainfall had started in the area. Rainfall at CH for SSE #4a was estimated using rainfall totals for CT. Prior to SSE #4b, communication at CH was established between the Isco and the rain gauge and sampling of SS #4b started when greater than 0.05" of rain fell within an hour.

A routine check of BL revealed that the top part of the sampler unit was not positioned correctly with the base of the unit and the first 10 samples of Bottle 5 had missed the bottle and had collected in the base of the Isco unit. Upon discovery the sampler unit was positioned correctly and subsequent samples were successfully obtained and the liquid in the base of the unit was drained out to the ground. However, as a result of the misalignment, Bottle 5 was 10 aliquots short (approximately 1.4 liters) of a full bottle (but enough water was collected to fulfill sampling objectives).

4.3.1.5 Storm Sampling Event #5

Storm Sampling

SSE #5 was a 24-hour event sampled on 15-16 February 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003d – **Appendix F**). Together, Storm #5a and Storm #5b constitute SSE #5. Following the end of SSE #4, the project area experienced 2 weeks of dry weather as a large, stationary dome of high pressure set up over the Pacific Northwest. This extended dry period during the typically wet month of February presented an appealing scenario for sampling the first rain event following this extended dry period. As such, the ADP for SSE #5 was approximately 15 days.

Storm #5a (Saturday, 15 February)

Sampling began at approximately 0800 hours on the 15th. However, by approximately 1200 the heaviest rain had fallen throughout the project area as the front had passed through. Following the frontal passage, skies began to clear in the project area. As approximately 0.20" of rain had fallen within a relatively short period and the forecast called for light and scattered precipitation for the next 18-24 hours, the PSNS ENVVEST team decided to halt sampling at the 6-hour mark (Bottle 1) as subsequent sampling would in theory be representative of base flow and not storm flow. Given that the morning's rain was the first significant rain in over 2 weeks, it was decided that the first 6-hours of sampling would have captured the first flush and therefore would be analyzed. Per this direction, TEC shut down the sampling effort at approximately 1330 hours and collected and iced down Bottle 1 from each of the 6 sites.

6-hour rainfall totals averaged 0.21" per site. While less than 0.25" of rain fell within the approximately 6-hour sampling period, based on data from other rain gauges in the area, it is highly likely that if sampling continued for 24-hours, rainfall totals would have exceeded 0.25"/24-hours. Per PSNS direction, no FC samples were collected during Storm #5a due to the President's Day Holiday weekend as holding times would have been exceeded. As previously noted, 6 composite bottles were collected.

Storm #5b (Sunday, 16 February)

Sunday morning presented with mostly sunny skies. However, the forecast for later that day called for mostly cloudy skies with scattered heavy showers and potential thunderstorms in the project area associated with the low-pressure system crossing inland through northern Washington later that afternoon. TEC staff met at the field office and organized the delivery of samples from Storm #5a to PNNL for later that morning. About this time, acting on the forecast, the project team activated the sample sites to sample if > 0.20" of rain fell within 1 hour – instead of the normal > 0.05"/hr. The theory behind this strategy was that as the forecast called for scattered heavy showers/thunderstorms, if a heavy shower set up over the project area, the resulting influx in storm flow associated with high rainfall intensities would present a good sampling scenario. By setting a high "trigger point" to begin sampling, this ensured that only a significant rainfall/runoff event would be sampled. The samplers were re-programmed accordingly and by approximately 1200 on the 16th, all 6 sites were re-programmed to sample only if > 0.20" of rain fell within 1 hour.

As forecast, heavy showers with a few imbedded thunderstorms began to form south of the project area and rotate slowly northeast towards the project area in the early afternoon. By 1400 hours, radar and satellite data indicated moderate to heavy rain falling throughout the Puget Sound region from south to north. Over the next few hours, several organized bands of heavy showers passed through the project area. The heaviest of these showers affected the project area from approximately 1400 to 1530 hours, whereupon 4 of the 6 sites were activated. Heavy rain (> 0.25"/hr at some sites) associated with these showers continued until approximately 1800 hours, at which time the rain intensity dropped dramatically and eventually ended. By the early morning hours of the 17th, skies in the project area were clear.

The heavy shower activity associated with the low-pressure system tracking across northern Washington was sufficient to trigger sampling at 4 sites – CH, CT, GC, and AC. However, due to the spatial distribution of the rainfall and the orographically unfavorable orientation of BL and OC, these sites did not receive sufficient rainfall to trigger sampling. 12-hour rainfall totals averaged 0.66" at each of the 4 sites. Per PSNS direction, no FC samples were collected during Storm #5a due to the President's Day Holiday weekend. A total of 9 composite bottles were collected and delivered to PNNL.

Variances to the SAP

During SSE #5a, the Isco unit at GC did not achieve communication with the rain gauge or the YSI sonde even though when the site was set up successful communication was established. This lack of communication was discovered at approximately 1030 on Saturday when TEC staff observed that the sampler had started when more than 0.05" of rain had fallen in the area (CT had been sampling for over an hour at this point). So, TEC staff manually activated the sampler at 1051, approximately 3 hours after rainfall had started in the area. A review of the sampling report indicates the Isco lost communication with the YSI sonde/rain gauge approximately 3 hours after site mobilization. Prior to SSE #5b, communication at GC was established between the Isco and the rain gauge and sampling of Storm #5b started when greater than 0.20" of rain fell within an hour. Rainfall at GC for SSE #5a was estimated using rainfall totals from AC.

Before this SSE TEC was able to achieve successful communication between all YSI sondes and the Isco's when tested at the field office. However, when placed in the field, 2 of the 6 Isco's (BL and OC) did not communicate with the YSI sondes.

4.3.1.6 Storm Sampling Event #6

Storm Sampling

SSE #6 was a 24-hour event sampled on 8-9 March 2003 (TEC 2003e – **Appendix G**). As described under SSE #5, OC and BL were not triggered for the second half of the 24-hour event, unlike the other 3 (AC, GC, and CT). Therefore, as 7 complete sets of sampling equipment were in TEC's possession, the decision was made to sample the 5 northern sites (BA, CC, CE, CW, and SC) and BL and OC, 1 more than the usual 6.

Following the end of SSE #5 the project area experienced nearly a full month of dry weather as a large, stationary dome of high pressure set up over the Pacific Northwest. This extended dry period during the typically wet period of late February into early March presented an appealing scenario for sampling the first rain event following this extended dry period. Thus, the ADP preceding SSE #6 was approximately 22 days.

Sampling began at approximately 1600 hours on the 8th and continued until approximately 1600 hours on the 9th. The strongest rainfall affected the region during the early morning hours on the 9th, from approximately 0600 to 0800, corresponding to the time the mid-point FC samples were collected. The nearby Silverdale gauge recorded rainfall intensities in excess of 0.25" per hour during this period. The 24-hour average rainfall total for each station was 1.06" and 20 FC samples and 24 composite bottles were collected.

Variances to the SAP

At approximately 0800 on the 9th, BA lost power when the battery ran out. Upon inspection, it was discovered that a slug of sediment had washed down the creek and clogged the intake. In trying to collect an aliquot, the Isco used an excessive amount of power, which drained the battery. Upon discovery, TEC switched out the battery with a new fully charged battery, cleared out the sediment at the intake, and resumed sampling. However, sampling was interrupted for approximately 3 hours, leading to the loss of samples in Bottles 3 and 4.

Before this SSE, TEC was able to achieve successful communication between all YSI sondes and the Isco's when tested at the field office. However, when placed in the field, 3 of the 7 Isco's were not able to communicate with the YSI sondes. While 4 sites provided all physio-chemical data during SSE #6, the other 3 did not. However, physio-chemical data at BL was recorded at 15 minute intervals using the YSI 650 data logger.

4.3.1.7 Storm Sampling Event #7

Storm Sampling

SSE #7 was a 30-hour event sampled on 12-13 March 2003 at the 6 northern sites (BA, CC, CE, CW, SC, and CH), the final Storm Flow Sampling Event for the 2002-2003 In-Stream Storm Flow Sampling Season (TEC 2003e – **Appendix H**). As the project area had received over an inch of rain from 8-9 March, the predicted wet nature of the storm would produce significant runoff due to the semi-saturated state of the watersheds. Furthermore, little rain was forecast before the storm arrived on the morning of the 12th. This was confirmed with no rainfall on Monday the 10th and less than 0.20" on Tuesday the 11th. As such, the ADP preceding SSE #7 was approximately 1 day.

Sampling began at approximately 0930 hours on the 12th as the rain generally worked its way south to north across the area, with pockets of heavier rain in some areas. The rain came on fast and strong. Moderate to heavy bands of rain worked their way from south to north through the project area, triggering the samplers. At several times during the day rainfall intensities exceeded 0.30" per hour.

Rainfall stayed at a moderate to occasionally high level throughout the sampling event and never really decreased. The strongest rainfall affected the region during the late morning hours and again during the evening hours of the 12th, corresponding to the time the 1st and 2nd round of FC samples were collected. During the storm, creeks in the project area rose quickly and reached heights higher than observed during the whole sample season. Sampling was halted at approximately 1600 hours on the 13th with the cessation of rainfall.

Rainfall totals within the project area were prodigious, ranging from 2.63" in Bremerton (Brownsville) to 4.35" in Silverdale (Newberry Hill) and generally increased from south to north. The 24-hour average rainfall total for each station was 3.25" and 27 FC samples and 30 composite bottles were collected.

Variances to the SAP

During the first round of FC sampling on the 12th, TEC staff discovered that the sampler at SC had not yet begun sampling, whereas all others had begun over an hour earlier. Upon discovery and inspection, it was discovered that the rain gauge did not achieve communication with the Isco. TEC staff immediately manually activated the sampler at 1139 by pouring water (0.05") in the rain gauge.

While 4 sites recorded all physio-chemical data via the Isco's during SSE #7, 2 did not. However, physio-chemical data at CC and SC was recorded at 15 minute intervals using the YSI 650 data loggers.

4.4 POST-SAMPLING ACTIVITIES

4.4.1 Dry Season Physio-Chemical Data

Dry season physio-chemical data was obtained from 14 May to 18 June for varying lengths of time from the following sites: BA, CC, CE, CW, CH, CT, BL, and OC. Following the initial site set-up, each site was visited once a week to make sure no vandalism had occurred, the equipment was operating properly, and to download the physio-chemical data with a RTD. In addition, the used batteries were replaced as necessary. Some batteries were used up quicker than others, resulting in different periods of data gathering (i.e., when the battery ran out, no data was collected until the battery was replaced). At the conclusion of the dry season physio-chemical sampling effort, all equipment was returned to TEC's field office where it was cleaned and stored for future use. All data was sent to PSNS in Flowlink format.

Successful communication between the YSI sondes and Isco's was finally obtained during the dry season physio-chemical data acquisition effort and are ready for use next season.

4.4.2 Data Management and Analysis

Following the conclusion of the storm sampling season, TEC in coordination with the PSNS ENVVEST team, incorporated the FC and composite sample data into Flowlink whereupon the data were integrated with the physio-chemical data associated with each storm and site (where available). A discussion of the data follows in Section 5. In addition, the data is also available for viewing in Flowlink format.

5.0 DISCUSSION

This section provides a discussion of FC pollution, the sampling events, hydrologic conditions, and physio-chemical results associated with each SSE during the 2002-2003 In-Stream Storm Flow Sampling Season. This section also discusses rainfall, physio-chemical, and storm flow FC data by individual SSE and also by storm sampling site. In addition, collected dry season physio-chemical data is also discussed. A discussion of composite sample data is not provided in this report.

5.1 FECAL COLIFORM POLLUTION

FC bacteria are commonly used indicators of domestic sewage and terrestrial runoff entering a body of water. FC bacteria themselves are not the main health concern, but their presence suggests the possible presence of other harmful, disease-causing bacteria and viruses. When predetermined FC concentration thresholds are reached, the affected area is considered unsafe for certain uses (Washington Administrative Code Chapter 173-204A-130).

The presence of FC bacteria in water can threaten public health through contact with water while fishing, swimming, or wading. In addition, consumption of shellfish contaminated with FC can cause health problems. Potential sources of FC include failing septic systems, leaky sewer systems, animals (e.g., dogs, foxes, other domesticated pets, raccoons, and waterfowl), and runoff from other non-point source (NPS) pollution such as farm manure.

Of particular interest to this discussion is FC pollution loading into coastal waters from point and NPS as a result of runoff flowing through areas where land use is comprised of a mix of urban, agricultural, and ranch lands. As storm flow moves through mixed land use watersheds containing agricultural fertilizers, cattle fecal matter, septic system effluents, and urban animal and waterfowl feces, it can acquire a variety of pollutants, including bacterial and viral pathogens originating in human or animal feces (Howell et al. 1996).

In most developed areas, aside from combined sewer overflows (CSO) and upsets in sanitary systems, the most significant source of FC input to the near shore environment is from storm flow or NPS pollution. This surface runoff can flow directly into estuaries or near shore waters from developed shoreline areas via storm drain outfalls or as overland flow. In addition, FC bacteria contamination and other NPS pollution can indirectly enter the near shore via streams that drain developed upland watersheds.

Recent studies indicate that levels of FC contamination in near shore areas is strongly correlated with human population, the level of watershed development, and the quantity of impervious surfaces within a drainage area (Weiskel et al. 1996; Young and Thackston 1999; Mallin et al. 2000). These studies also show that FC is often highly correlated with water column turbidity and nutrient concentration as well as being inversely correlated with salinity (Mallin et al., 2000).

Research has indicated that areas with large amounts of commercial and mixed urban land use land cover generally result in the highest FC concentrations (Tufford and Marshall 2002). Recent studies have shown that storm water runoff from impervious surfaces (roads, parking lots, etc.) and from storm water drainage networks (drain-inlets, storm water piping, and outfalls) are the most significant sources of FC contamination in urbanizing watersheds and near shore drainages (Weiskel et al., 1996; Young and Thackston, 1999; Mallin et al., 2000). As a result, streams that drain urbanizing watersheds can be significant sources of FC contamination to the near shore environment. However, it is not just the intensity or level of development that is important to downstream pollutant loading, but the type of land-use activity, the location of that development, the amount of impervious surface area, and the type of storm flow infrastructure present (White et al. 2000).

Research by Davies *et al*. (1995) has shown that FC can survive in sediment because the solid particles provide a favorable, “non-starvation” environment for the bacteria. When the sediment is re-suspended by storm events, bacteria are reloaded into the water (Marino and Gannon 1991). During storm events, FC bacteria sorbed on to sediment particles may desorb and partition into the water column when shear force is applied. FC has been shown to survive and multiply in moist sediments and urban ditches and catch basins. Such areas can be major FC sources during storm events (Schueler 1999). Experiments have shown that FC concentrations are significantly higher in samples with sediments than samples without sediments (Eustace et al 1999).

5.2 EQUIPMENT TESTS

5.2.1 Rinsate (Equipment) Blank Field Office Test

Samples analyzed from the rinsate blank field office test did not reveal analyte concentrations above acceptable background concentrations, meaning the sampling equipment and handling procedures were sufficiently clean and would not contaminate the samples. The results dictated that no cleaning or sterilization of the sampling equipment or evaluation of sampling procedures (including handling) was necessary. However, PNNL emphasized that care be taken to ensure that clean gloves be worn at all times when handling the composite bottles and sensitive components of the samplers (e.g., intake tubes and distributor arm) to minimize the potential for contamination. To this end, PNNL provided TEC with an “Ultra-Clean Sampling Techniques” brochure that was read by all TEC staff prior to storm sampling. The implementation of these techniques helped minimize the potential for sample contamination throughout the sampling season.

5.2.2 Field Test

During the field test, all sampling stations performed as expected. Each sampler filled the 3.7 liter bottles to a consistent level in all bottles – approximately 3.3 liters. There was no liquid observed in the base of the samplers, and the distributor arm rotated as designed and delivered aliquots as programmed. The batteries ran the entire 48-hours and had a fair amount of charge (30 - 40%) remaining at the conclusion of the field test. The sample sites and intake tubes were not damaged by the environment (e.g., stream flow debris) or vandalism.

5.3 SAMPLING SUMMARY BY STORM

This discussion focuses on those storms for which physio-chemical and storm flow FC data were both available by individual SSE, as opposed to each sampling location. A discussion of data by sampling location is provided in Section 5.4. As explained in Section 4, communication between the YSI sondes and Isco’s was an issue during every SSE. As a consequence, a complete data set was not obtained. Average, instead of geometric mean FC concentrations for each event are presented for each event as due to the small sample size (< 4), the geometric mean would be similar to the average values presented.

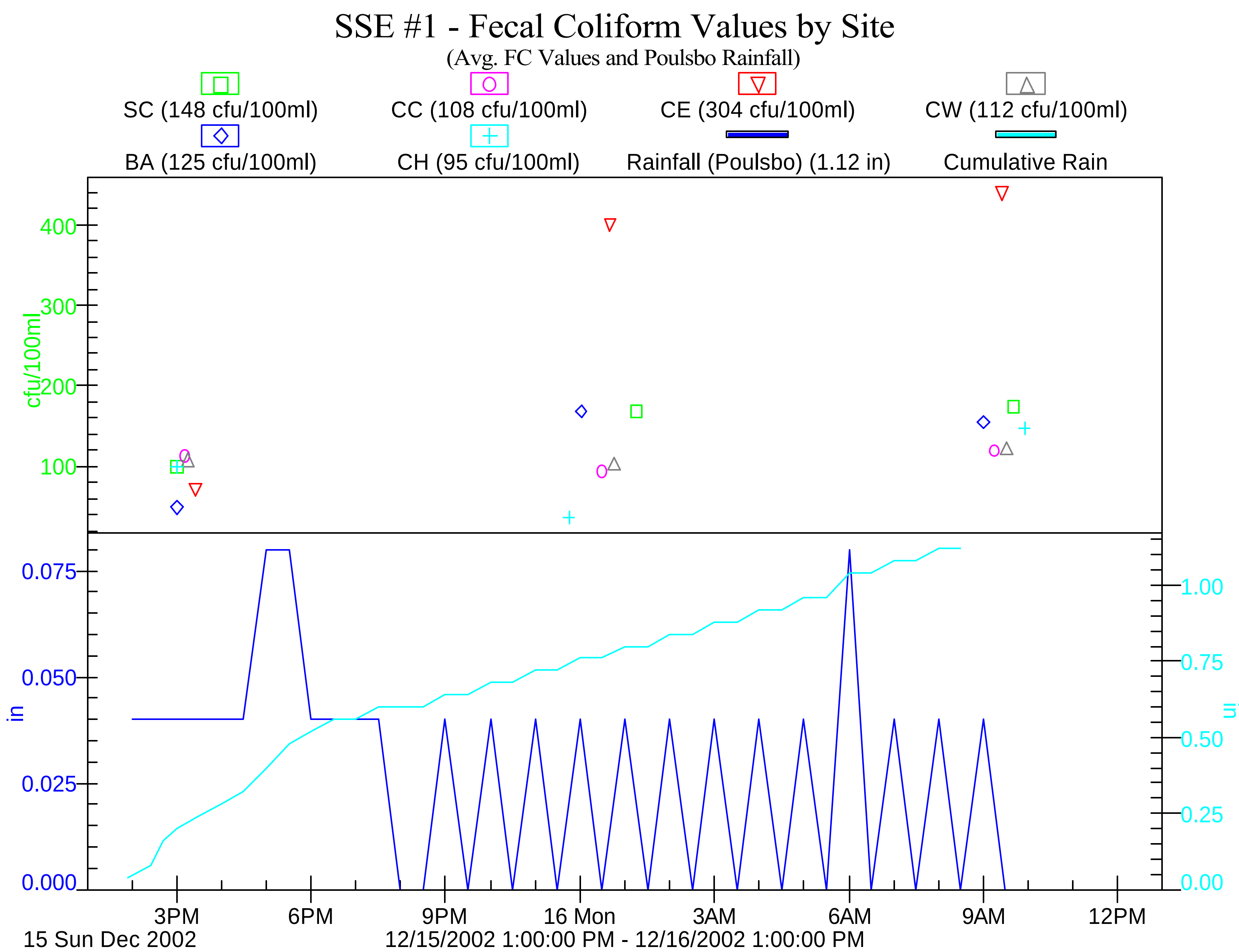
5.3.1 SSE #1

SSE #1 was a 24-hour event sampled on 15-16 December 2002 at the 6 northern group sites (CH, SC, BA, CC, CW, and CE) (TEC 2002d). As RTDs were not available to download rainfall and physio-chemical data for SSE #1, this data is not available for including in this discussion. Therefore, this discussion focuses on the FC concentrations only.

5.3.1.1 FC Data

Figure 5.3.1-1 presents storm flow FC data for each of the sites sampled during SSE #1. The 3 rounds of FC samples were taken after approximately 0.20”, 0.70”, and 1.10” of rainfall, respectively. Rainfall data was taken from the Poulsbo gauge (Weather Underground 2002). The ADP for SSE #1 was 1 day.

Figure 5.3.1-1


SSE #1 - Fecal Coliform Values by Site
(Avg. FC Values and Poulsbo Rainfall)
SC (148 cfu/100ml)
CC (108 cfu/100ml)
CE (304 cfu/100ml)
CW (112 cfu/100ml)
BA (125 cfu/100ml)
CH (95 cfu/100ml)
Rainfall (Poulsbo) (1.12 in)
Cumulative Rain
cfu/100ml
400
300
200
100
in
0.075
0.050
0.025
0.000
in
1.00
0.75
0.50
0.25
0.00
3PM
6PM
9PM
16 Mon
3AM
6AM
9AM
12PM
15 Sun Dec 2002
12/15/2002 1:00:00 PM - 12/16/2002 1:00:00 PM

Average storm flow FC concentrations were lowest at CH (95 colony forming units per 100 milliliters [CFU/100 mL]), and then increased to 108 CFU/100 mL at CC, 112 CFU/100 mL at CW, 125 CFU/100 mL at BA, and 148 CFU/100 mL at SC. CE had the highest average FC concentrations at 304 CFU/100 mL, more than twice that of the next highest value.

FC concentrations generally increased with each successive sample round and the majority of samples were less than 200 CFU/100 mL. However, storm flow FC concentrations at CE increased throughout the event and Round 2 and 3 concentrations were much higher than those of the other sites. FC concentrations at BA and SC generally track the same throughout the event. FC concentrations at CH actually decrease from Round 1 to 2, then increase again in Round 3.

Values at CC and CW remained in the same range throughout the event, with no real fluctuation in concentrations throughout the event. This is interesting in light of what happened at CE as not only were concentrations much higher at CE, but FC concentrations continued to increase with each successive round of sampling. Given that CE, CW, and CC are all within a quarter mile of each other, it is interesting to note how it appears that the elevated FC concentrations coming from CE are diluted by CW by the time storm flow reached CC in Rounds 2 and 3.

While rainfall records from each site are not available, it can be hypothesized that rainfall intensities may have been greatest between the Round 2 and 3 samples, as 4 of the 6 samples in Round 3 represented the highest FC concentrations for the event. A check of rainfall data available from the internet (Weather Underground 2002) reveals that rainfall intensity in the 8 hours preceding Round 3 sampling was in fact greater than in the 8 hours preceding Round 2 sampling. Therefore, the hydrological conditions between Rounds 2 and 3 may be the reason for the elevated concentrations in Round 3.

5.3.2 SSE #2

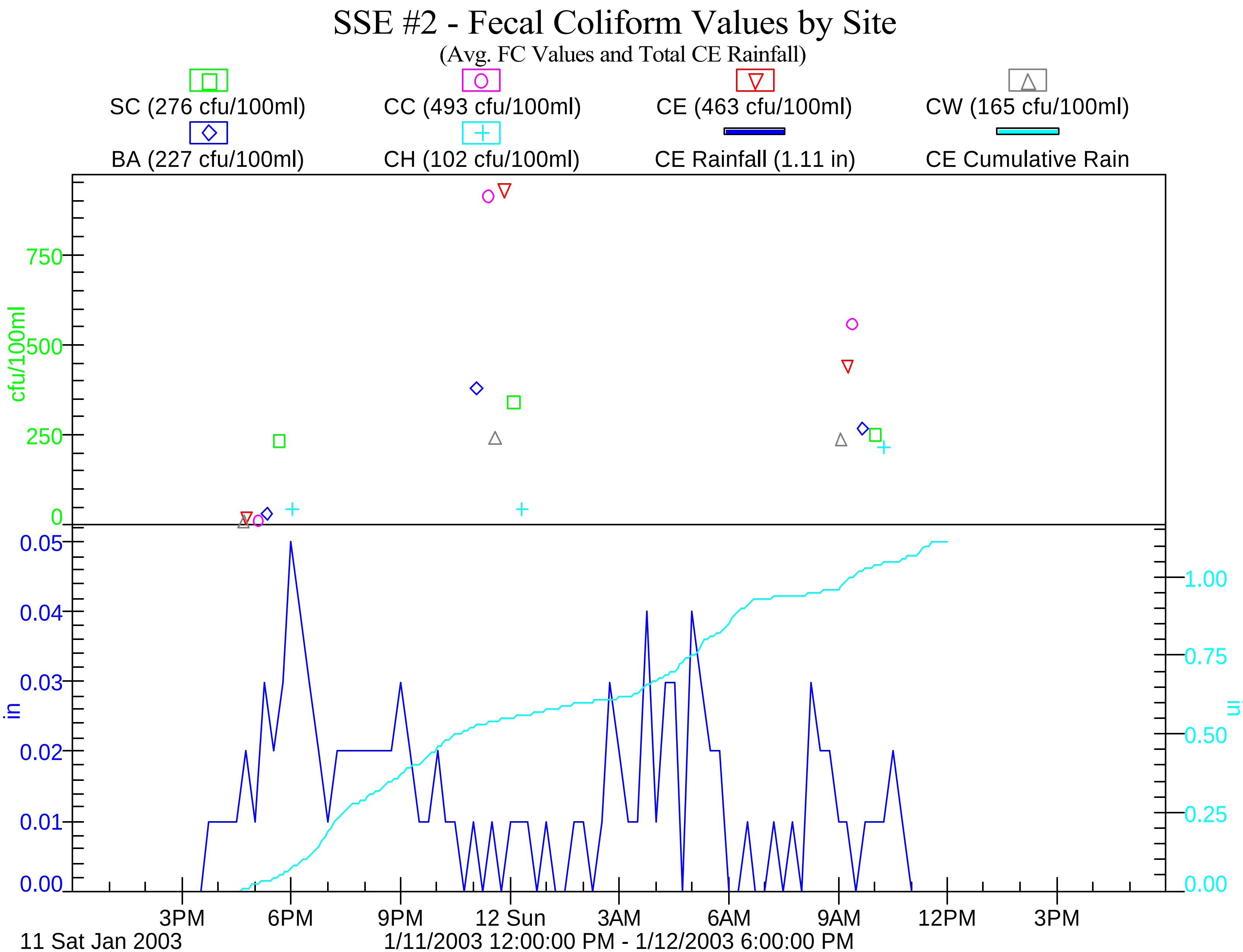
5.3.2.1 FC Data

SSE #2 was a 24-hour event sampled on 11-12 January 2003 at the 6 northern group sites (CH, SC, BA, CC, CW, and CE) (TEC 2003a). Figure 5.3.2-1 presents FC data for each for the sites as well as rainfall data for CC (which was chosen as the most representative rainfall record). The 3 rounds of FC samples were taken after approximately 0.05”, 0.50”, and 1.0” of cumulative rainfall, respectively. The ADP for SSE #2 was approximately 7 days.

Average storm flow FC concentrations were lowest at CH (102), and then increased to 165 CFU/100 mL at CW, 227 CFU/100 mL at BA, and 276 CFU/100 mL at SC. CE and CC had the highest average FC concentrations at 463 CFU/100 mL and 493 CFU/100 mL, respectively.

At each site (except CH), storm flow FC concentrations were lowest in the first round, highest during the mid-point of the storm, then second highest during the last round of samples. Conversely, CH had the highest FC concentration during the last round of sampling. However, while CH didn’t respond like the other streams, CH did have the overall lowest average FC concentration. CC and CE were both quite high, with CC having the highest average FC concentration and both sites recording the highest overall concentrations, at approximately 900 CFU/100 mL during the second round. SC and BA had similar, average FC concentrations and trend, at approximately 250 CFU/100 mL, although SC was much higher than BA at first where it had the highest concentration of all sites in the first round of sampling.

Figure 5.3.2-1


SSE #2 - Fecal Coliform Values by Site
(Avg. FC Values and Total CE Rainfall)
SC (276 cfu/100ml)
CC (493 cfu/100ml)
CE (463 cfu/100ml)
CW (165 cfu/100ml)
BA (227 cfu/100ml)
CH (102 cfu/100ml)
CE Rainfall (1.11 in)
CE Cumulative Rain
cfu/100ml
750
500
250
0
in
0.05
0.04
0.03
0.02
0.01
0.00
1.00
0.75
0.50
0.25
0.00
in
3PM
6PM
9PM
12 Sun
3AM
6AM
9AM
12PM
3PM
11 Sat Jan 2003
1/11/2003 12:00:00 PM - 1/12/2003 6:00:00 PM

It is interesting to note the significant increase in average storm flow FC concentrations from SSE #1 to SSE #2 (Table 5-1). For both of these storms, the total rainfall was nearly the same, at about 1.20". However, the ADP was different between the two – SSE #1 was less than 1 day while for SSE #2 it was 7 days. It can be hypothesized that all other factors being similar (total rainfall, rainfall intensity, sample site locations, sampling procedures, etc.) the greater ADP preceding SSE #2 was the primary factor for the significant increase in average FC concentrations at every site (except CH which was only 7%).

Table 5-1: Comparison of Average Storm Flow FC Concentrations Between SSE #1 and SSE#2

Sampling Station	*Average FC Concentrations (CFU/100 mL)*		*% Increase*
	Storm 1	*Storm 2*	
BA	125	227	82%
CC	108	493	356%
CE	304	463	52%
CH	95	102	7%
CW	112	165	47%
SC	148	276	86%

5.3.2.2 Physio-Chemical and FC Data

Figures 5.3.2-2 and 5.3.2-3 present physio-chemical and storm flow FC sample data for SC and CE. FC concentrations are similar at each location – they were initially low at the start of sampling, but then rose rapidly near the mid-point of the storm. Due to the low amount of rainfall the sampling site received prior to the FC sample time, it can be proposed that the first round of FC samples at SC and CE represent similar concentrations to those found during base flow conditions.

At the midpoint of the storm, storm flow FC concentrations are much higher than the first round. By this point, approximately 0.50" of rain had fallen throughout the project area. Turbidity values are at their peak for CE but not at SC. Towards the end of the storm the FC concentrations are lower than, but not as low as, the first round of samples. At CE the FC data points track the turbidity values whereas at SC the relationship is not as evident.

At both locations, it appears that the rainfall and associated runoff resulted in an increase in water temperature as water temperatures at both sites raised nearly 2 degrees Fahrenheit (˚ F) throughout the sampling event. Conversely, conductivity values decreased at SC during the event.

By viewing the two graphs, it appears that during the mid-point of the storm, runoff is near peak, as shown in the turbidity values and elevated FC concentrations. Following the peak, the turbidity and FC concentrations gradually decrease in response to less rainfall, runoff, and perhaps by this point, those pollutants and sediment that were able to be mobilized by this storm event have been flushed through the system. In time as the rainfall ends and runoff decreases, it can be expected that turbidity and FC concentrations would continue to decrease as well until reaching base flow concentrations.

Figure 5.3.2-2

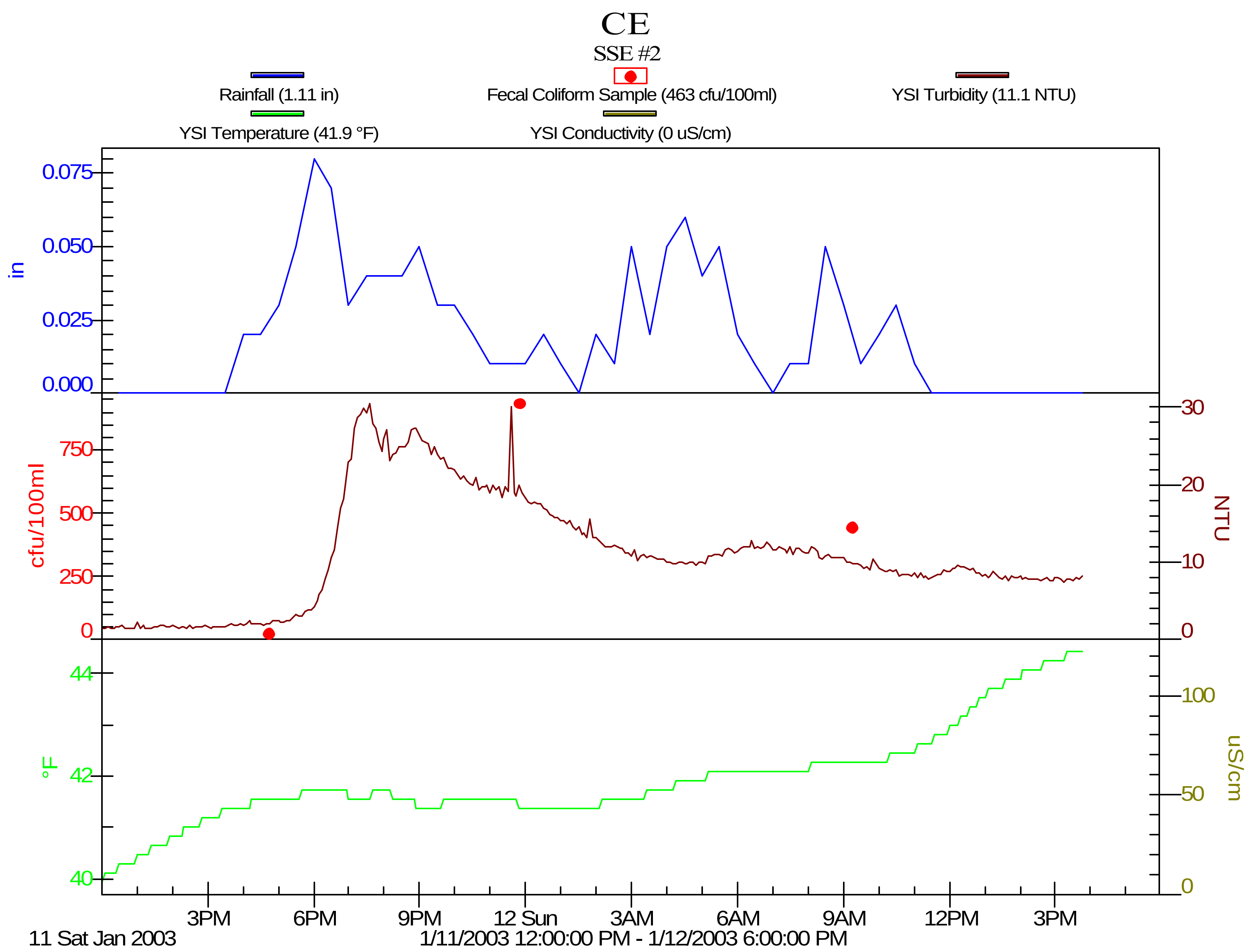
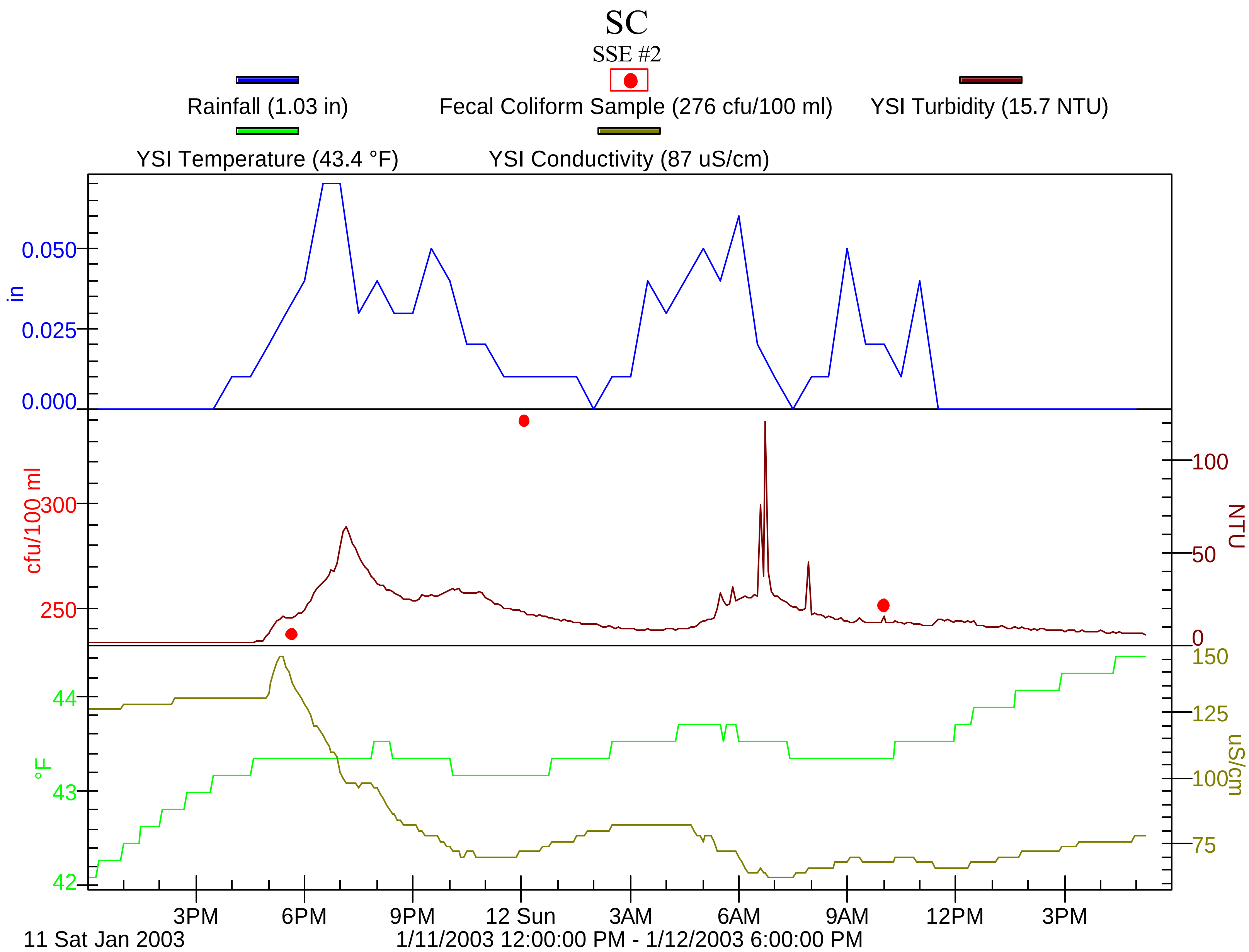

CE
SSE #2
Rainfall (1.11 in)
Fecal Coliform Sample (463 cfu/100ml)
YSI Turbidity (11.1 NTU)
YSI Temperature (41.9 °F)
YSI Conductivity (0 uS/cm)
in
0.075
0.050
0.025
0.000
cfu/100ml
750
500
250
0
NTU
30
20
10
0
°F
44
42
40
uS/cm
100
50
0
3PM
6PM
9PM
12 Sun
3AM
6AM
9AM
12PM
3PM
11 Sat Jan 2003
1/11/2003 12:00:00 PM - 1/12/2003 6:00:00 PM

Figure 5.3.2-3


SC
SSE #2
Rainfall (1.03 in)
Fecal Coliform Sample (276 cfu/100 ml)
YSI Turbidity (15.7 NTU)
YSI Temperature (43.4 °F)
YSI Conductivity (87 uS/cm)
in
0.050
0.025
0.000
cfu/100 ml
300
250
NTU
100
50
0
°F
44
43
42
uS/cm
150
125
100
75
3PM
6PM
9PM
12 Sun
3AM
6AM
9AM
12PM
3PM
11 Sat Jan 2003
1/11/2003 12:00:00 PM - 1/12/2003 6:00:00 PM

5.3.3 SSE #3

5.3.3.1 FC Data

SSE #3 was a 24-hour event sampled on 22-23 January 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003b). Figure 5.3.3-1 presents FC data for each for the sites as well as rainfall data for AC (which was chosen as the most representative rainfall record). The 3 rounds of FC samples were taken after approximately 0.40”, 1.1”, and 1.5” of cumulative rainfall, respectively. The ADP for SSE #3 was approximately 7 hours.

Average storm flow FC concentrations were less than 100 CFU/100 mL at CT, CH, and AC. GC averaged 112 CFU/100 mL while BL averaged 237 CFU/100 mL. However, the average FC concentration at OC was 807 CFU/100 mL, much higher than all other sites.

Perhaps due to the fact that the Round 1 samples were taken after approximately 0.40” of rain had already fallen throughout the area, Round 1 samples for all but 2 sites (BL and CT) were highest in Round 1, corresponding perhaps with the first flush. As can be seen in Figure 5.3.3-1, by the time the Round 2 samples were taken, the bulk of the precipitation associated with the storm had fallen. It is interesting to note that the storm flow FC values from Round 3 are similar to those taken during Round 2. This could be in response to the small amount of rainfall that occurred between the Round 2 and Round 3 samples. In effect, there was little change in hydrologic and physio-chemical conditions in the streams as shown in Figure 5.3.3-1 and as depicted in the individual site figures (Figure 5.3.3-2 and 5.3.3-3).

OC had by far the highest single storm flow FC concentration of any site, but by Rounds 2 and 3, OC had FC concentrations that were more similar to the other sites. This drastic reduction in concentration between Round 1 and Round 2 could represent a first flush phenomenon at OC, even though the ADP was less than 8 hours, the preceding rainfall perhaps was of low enough intensity to not mobilize FC in concentrations as measured during Round 1.

5.3.3.2 Physio-Chemical and FC Data

As shown on Figures 5.3.3-2 and 5.3.3-3, BL and GC are interesting to compare to one another as the storm flow FC concentrations follow an almost perfectly complementary (yet opposite) trend. At BL, FC concentrations start off low (around 50 CFU/100 mL), but then increase in Rounds 2 and 3 to around 320 CFU/100 mL. Note that the FC concentrations at BL do not generally track with the turbidity values. Conversely, FC concentrations at GC are initially high (around 300 CFU/100 mL), but then drop off to around 20 CFU/100 mL in Rounds 2 and 3. Note that unlike BL, FC concentrations at GC track generally well with the turbidity values. The change in FC concentrations at BL is interesting; these values do not track with typical FC concentration curves for similar rain events at other sites. FC concentrations at GC on the other hand, are consistent with other sites. Similar to SSE #2, stream temperatures increase slightly during the storm event and conductivity values decrease.

Figure 5.3.3-1

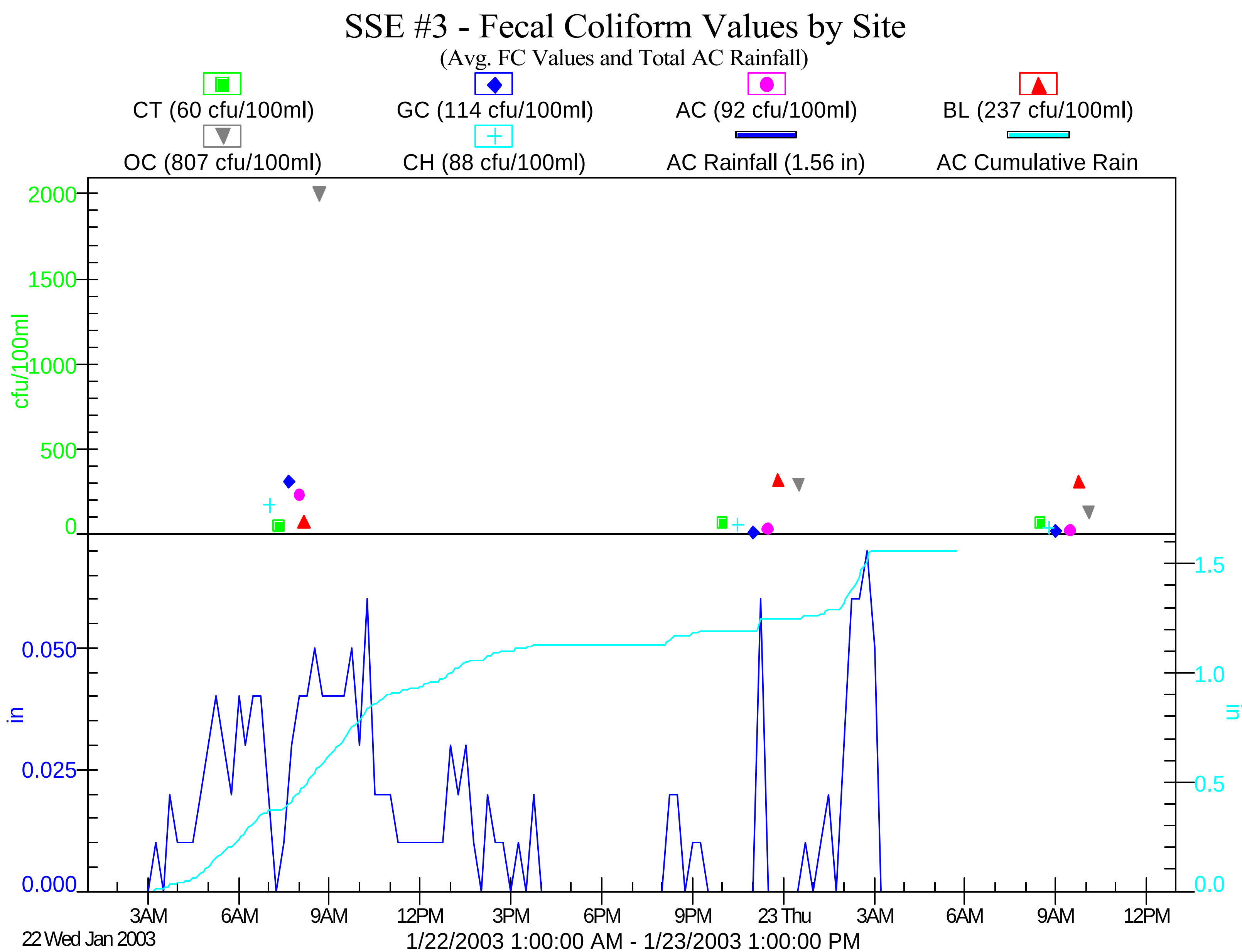

SSE #3 - Fecal Coliform Values by Site
(Avg. FC Values and Total AC Rainfall)
CT (60 cfu/100ml)
GC (114 cfu/100ml)
AC (92 cfu/100ml)
BL (237 cfu/100ml)
OC (807 cfu/100ml)
CH (88 cfu/100ml)
AC Rainfall (1.56 in)
AC Cumulative Rain
cfu/100ml
2000
1500
1000
500
0
in
0.050
0.025
0.000
1.5
1.0
0.5
0.0
in
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
12PM
22 Wed Jan 2003
1/22/2003 1:00:00 AM - 1/23/2003 1:00:00 PM

Figure 5.3.3-2

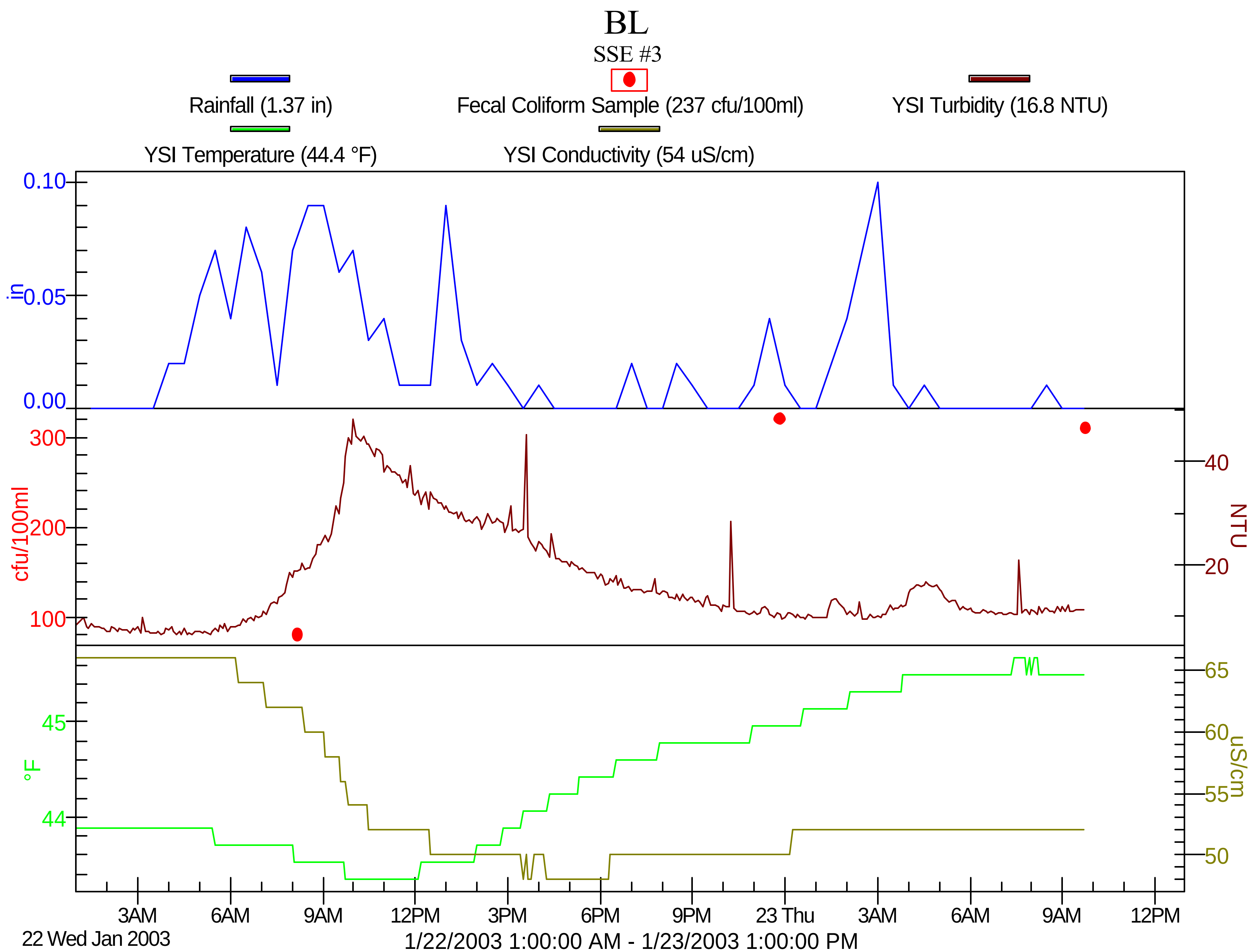
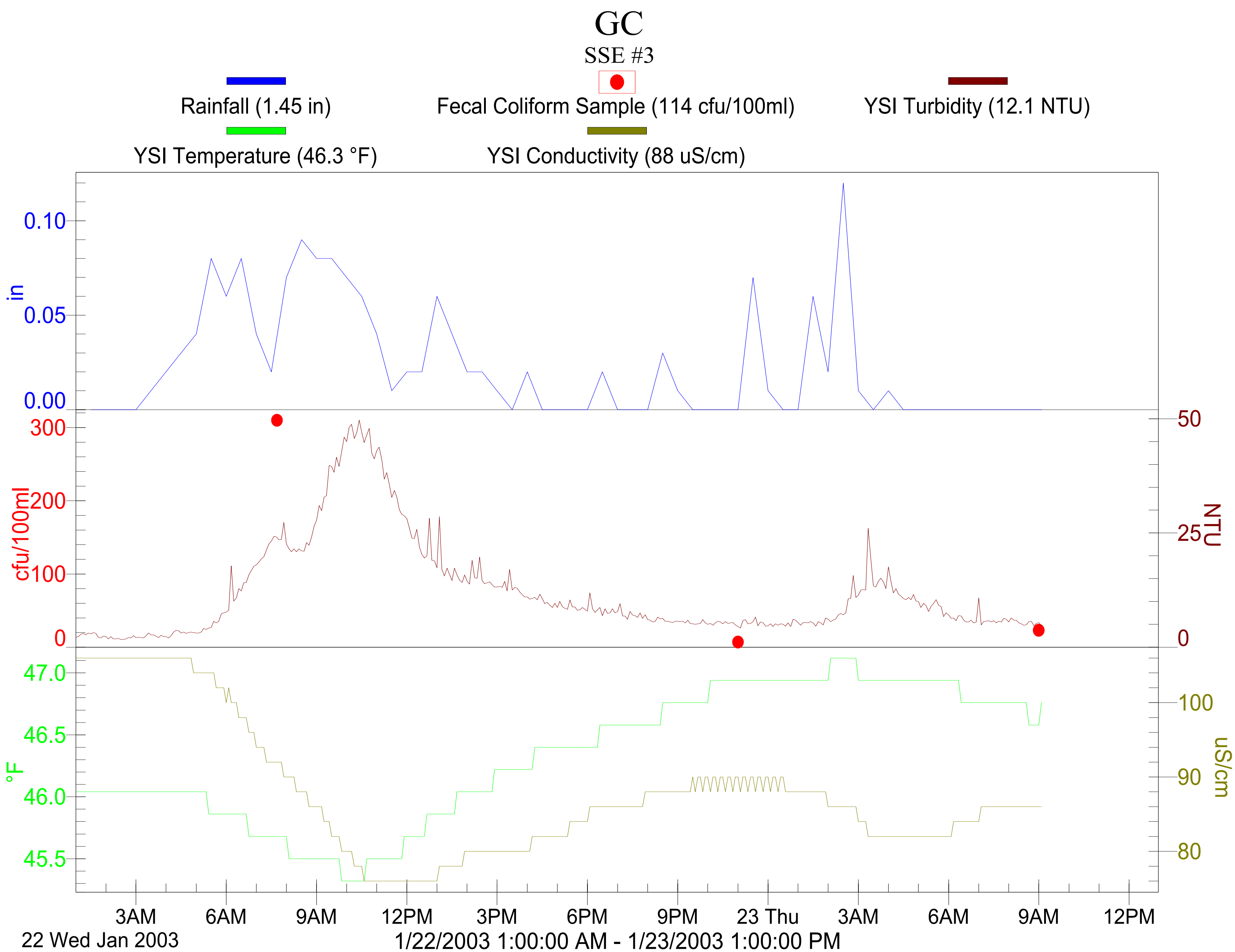

BL
SSE #3
Rainfall (1.37 in)
Fecal Coliform Sample (237 cfu/100ml)
YSI Turbidity (16.8 NTU)
YSI Temperature (44.4 °F)
YSI Conductivity (54 uS/cm)
0.10
0.05
0.00
in
300
200
100
cfu/100ml
40
20
NTU
45
44
°F
65
60
55
50
uS/cm
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
12PM
22 Wed Jan 2003
1/22/2003 1:00:00 AM - 1/23/2003 1:00:00 PM

Figure 5.3.3-3


GC
SSE #3
Rainfall (1.45 in)
Fecal Coliform Sample (114 cfu/100ml)
YSI Turbidity (12.1 NTU)
YSI Temperature (46.3 °F)
YSI Conductivity (88 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
300
200
100
0
NTU
50
25
0
°F
47.0
46.5
46.0
45.5
uS/cm
100
90
80
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
12PM
22 Wed Jan 2003
1/22/2003 1:00:00 AM - 1/23/2003 1:00:00 PM

5.3.4 SSE #4

5.3.4.1 FC Data

SSE #4 was a 48-hour event sampled on 29-31 January 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003c). Figure 5.3.4-1 presents storm flow FC data for each for the sites as well as rainfall data for GC (which was chosen as the most representative rainfall record). The 4 rounds of FC samples were taken after approximately 0.20", 0.50", 0.80", and 0.89" of cumulative rainfall, respectively. The ADP for SSE #4 was approximately 3 days.

Similar to SSE #3, CT, CH, AC, and GC had low average storm flow FC concentrations (less than 55 CFU/100 mL) with BL being a bit higher at 110 CFU/100 mL. However, FC concentrations at storm flow OC (1,091 CFU/100 mL) continued to be much higher than all other sites throughout the sample event, perhaps indicative of persistent storm flow FC pollution within the OC watershed.

Four rounds of FC samples were taken during SSE #4; however, 2 samples were not analyzed by the lab – the Round 4 samples for OC and AC. The greatest storm flow FC concentrations were from Round 3, which were collected right after the highest intensity rain affected the project area. Previous FC samples revealed concentrations less than 100 CFU/100 mL (except for OC). It is suspected that the rain that fell before Round 3 was not of sufficient intensity to mobilize material with higher FC content whereas the rain just prior to Round 3 was sufficient to do so. Round 4 samples had returned for most sites (except for BL) to lower FC concentrations.

5.3.4.2 Physio-Chemical and FC Data

Figures 5.3.4-2 and 5.3.4-3 present physio-chemical and storm flow FC sample data for GC and CT. Note that average FC concentrations are low at both locations. The highest FC concentration at CT was from Round 1 whereas the highest at GC was observed during Round 3. However, both sites had relatively low FC concentrations throughout the event.

In looking at GC, FC concentrations track well with the turbidity values throughout the storm event. This is consistent with the relationship between these two parameters during SSE #3. Conversely, FC concentrations do not track turbidity values as well at CT; however, turbidity values do not show a strong response to rainfall, unlike GC.

At both locations, it appears that the rainfall and associated runoff resulted in an increase in water temperature as water temperatures at both sites raised nearly 2˚ F throughout the sampling event. Conversely, conductivity values did not appear to be as strongly influenced by the rainfall and runoff.

5.3.5 SSE #5

SSE #5 was a 24-hour event sampled on 15-16 February 2003 at the 6 southern sites (CH, CT, GC, AC, BL, and OC) (TEC 2003d). Due to the Presidents Day holiday, per PSNS ENVVEST team coordination, it was decided that no FC samples would be collected as MEL would not be able to analyze the samples within the requisite holding time. Therefore, this discussion focuses on the available physio-chemical data.

Figures 5.3.5-1, 5.3.5-2, and 5.3.5-3 present physio-chemical data for GC, CH, and CT, respectively. Note that the time period associated with GC is shorter than the other 2 sites due to a communication error (as described in Section 4.4.1.5). As shown in Figure 5.3.5-1, given the correlation between FC concentrations and turbidity established with SSE #3 and #4 data, it can be proposed that FC concentrations would have followed a similar trend.

Figure 5.3.4-1

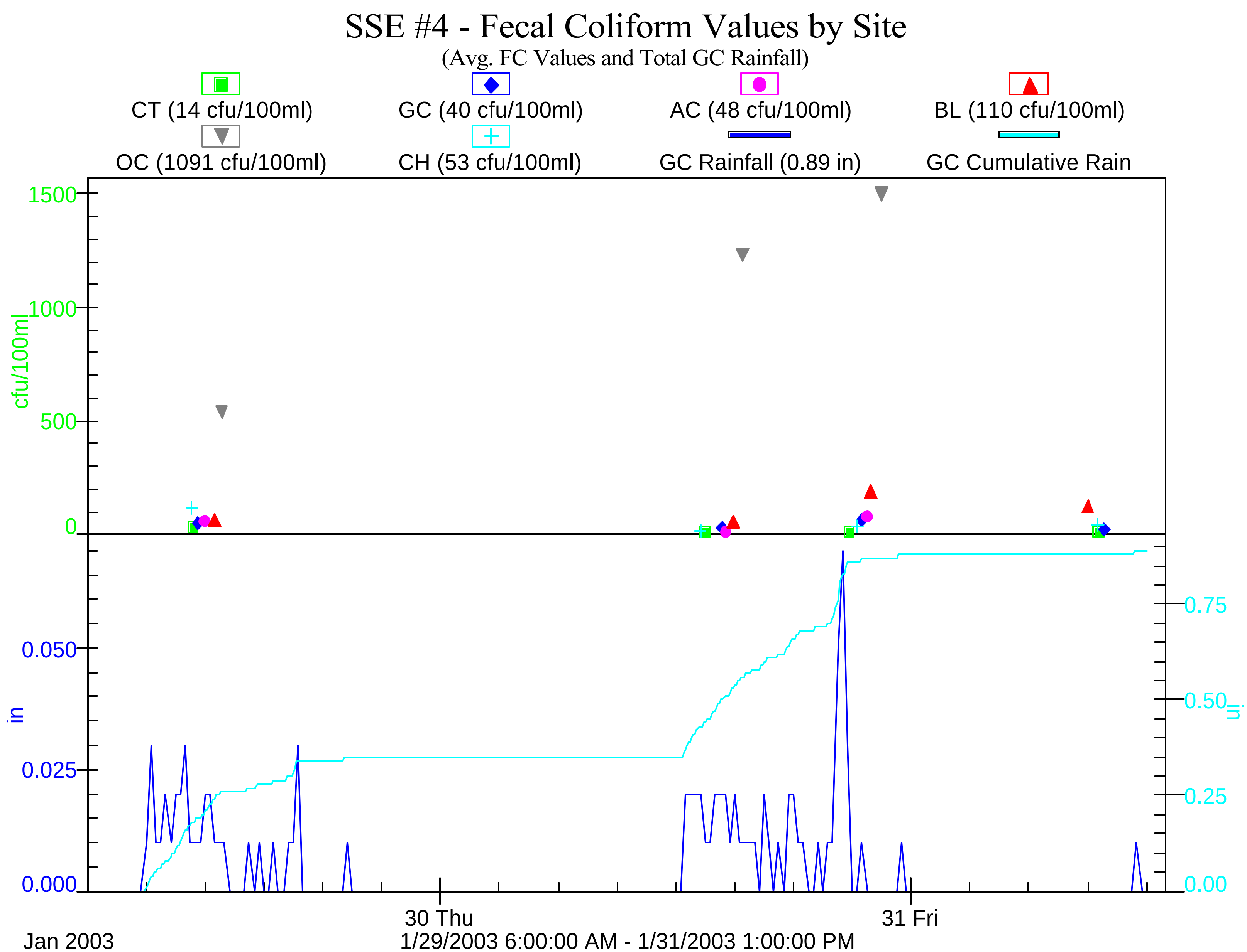
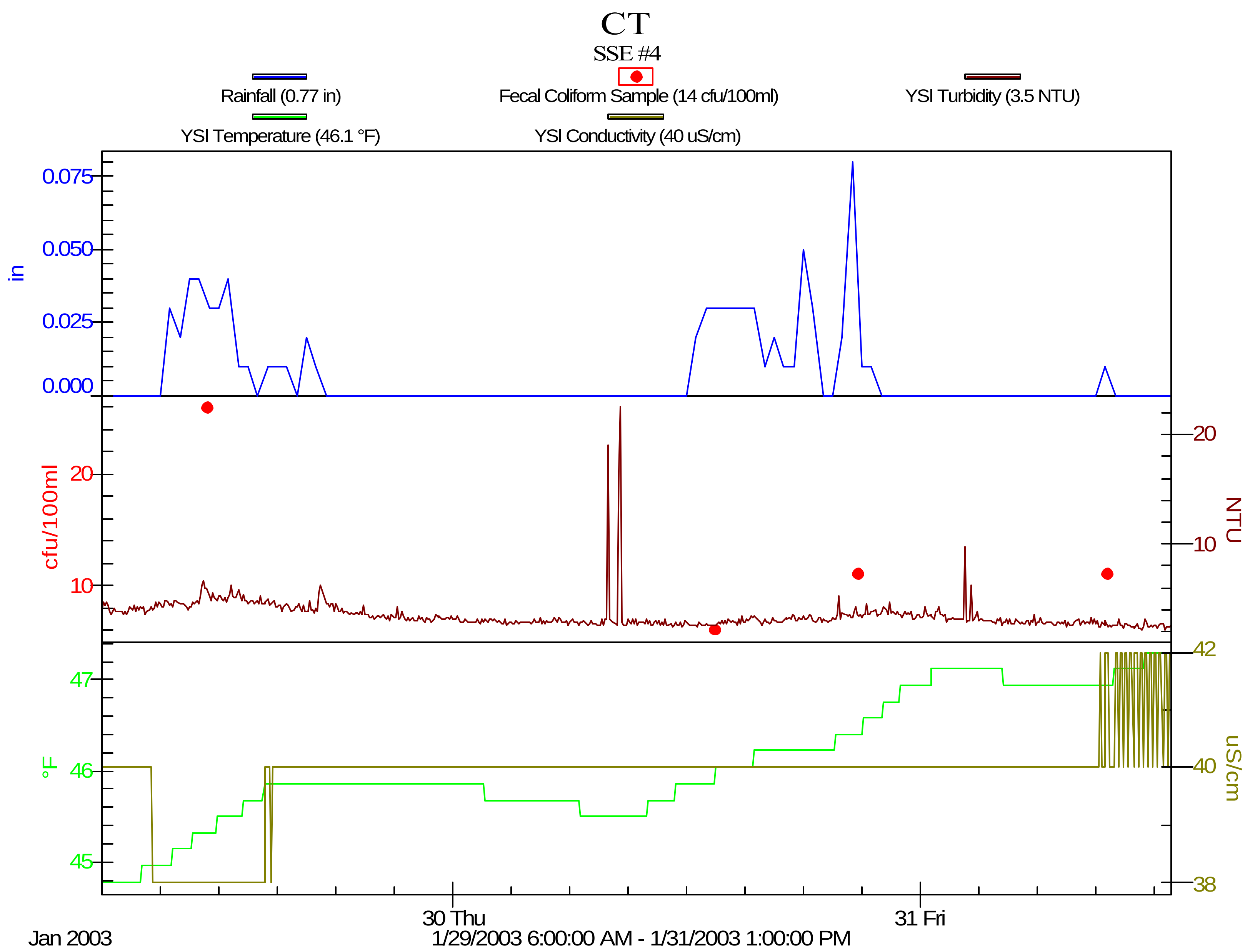

SSE #4 - Fecal Coliform Values by Site
(Avg. FC Values and Total GC Rainfall)
CT (14 cfu/100ml)
GC (40 cfu/100ml)
AC (48 cfu/100ml)
BL (110 cfu/100ml)
OC (1091 cfu/100ml)
CH (53 cfu/100ml)
GC Rainfall (0.89 in)
GC Cumulative Rain
cfu/100ml
1500
1000
500
0
in
0.050
0.025
0.000
0.75
0.50
0.25
0.00
in
30 Thu
31 Fri
Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 1:00:00 PM

Figure 5.3.4-2



CT
SSE #4
Rainfall (0.77 in)
Fecal Coliform Sample (14 cfu/100ml)
YSI Turbidity (3.5 NTU)
YSI Temperature (46.1 °F)
YSI Conductivity (40 uS/cm)
in
0.075
0.050
0.025
0.000
cfu/100ml
20
10
NTU
20
10
°F
47
46
45
uS/cm
42
40
38
30 Thu
31 Fri
Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 1:00:00 PM

Figure 5.3.4-3

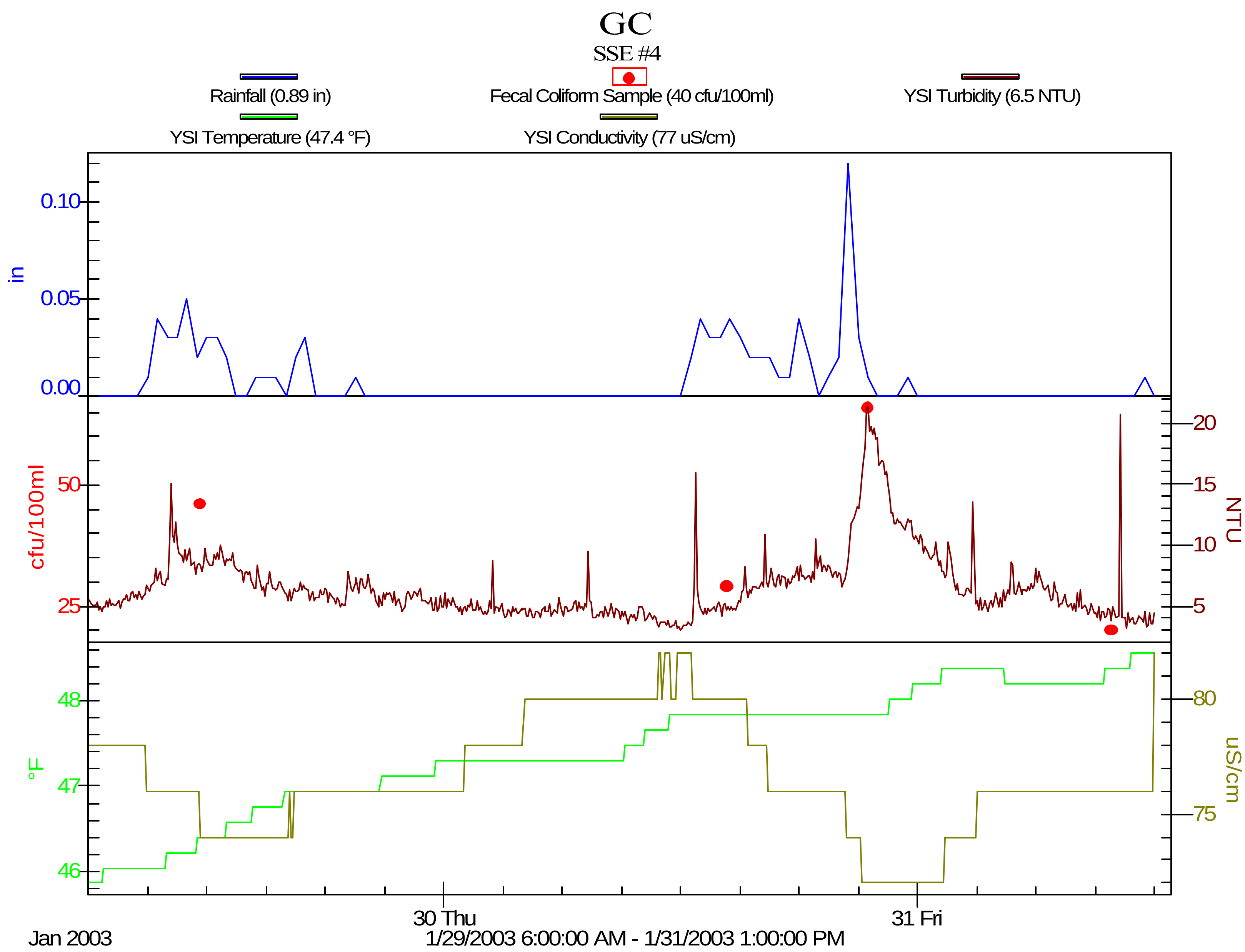
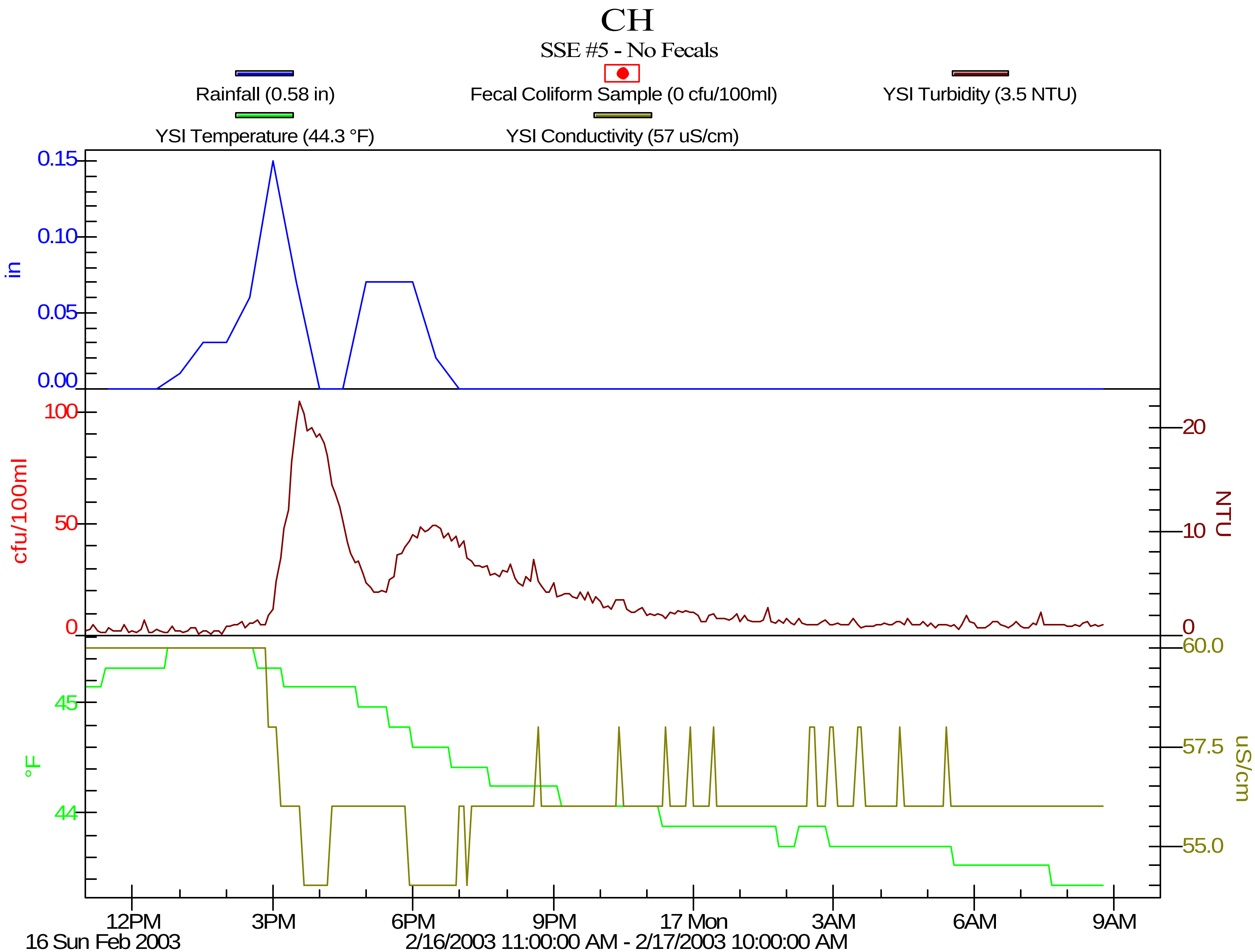

GC
SSE #4
Rainfall (0.89 in)
Fecal Coliform Sample (40 cfu/100ml)
YSI Turbidity (6.5 NTU)
YSI Temperature (47.4 °F)
YSI Conductivity (77 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
50
25
NTU
20
15
10
5
°F
48
47
46
uS/cm
80
75
30 Thu
31 Fri
Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 1:00:00 PM

Figure 5.3.5-1



CH
SSE #5 - No Fecals
Rainfall (0.58 in)
Fecal Coliform Sample (0 cfu/100ml)
YSI Turbidity (3.5 NTU)
YSI Temperature (44.3 °F)
YSI Conductivity (57 uS/cm)
in
0.15
0.10
0.05
0.00
cfu/100ml
100
50
0
NTU
20
10
0
°F
45
44
uS/cm
60.0
57.5
55.0
12PM
3PM
6PM
9PM
17 Mon
3AM
6AM
9AM
16 Sun Feb 2003
2/16/2003 11:00:00 AM - 2/17/2003 10:00:00 AM

Figure 5.3.5-2

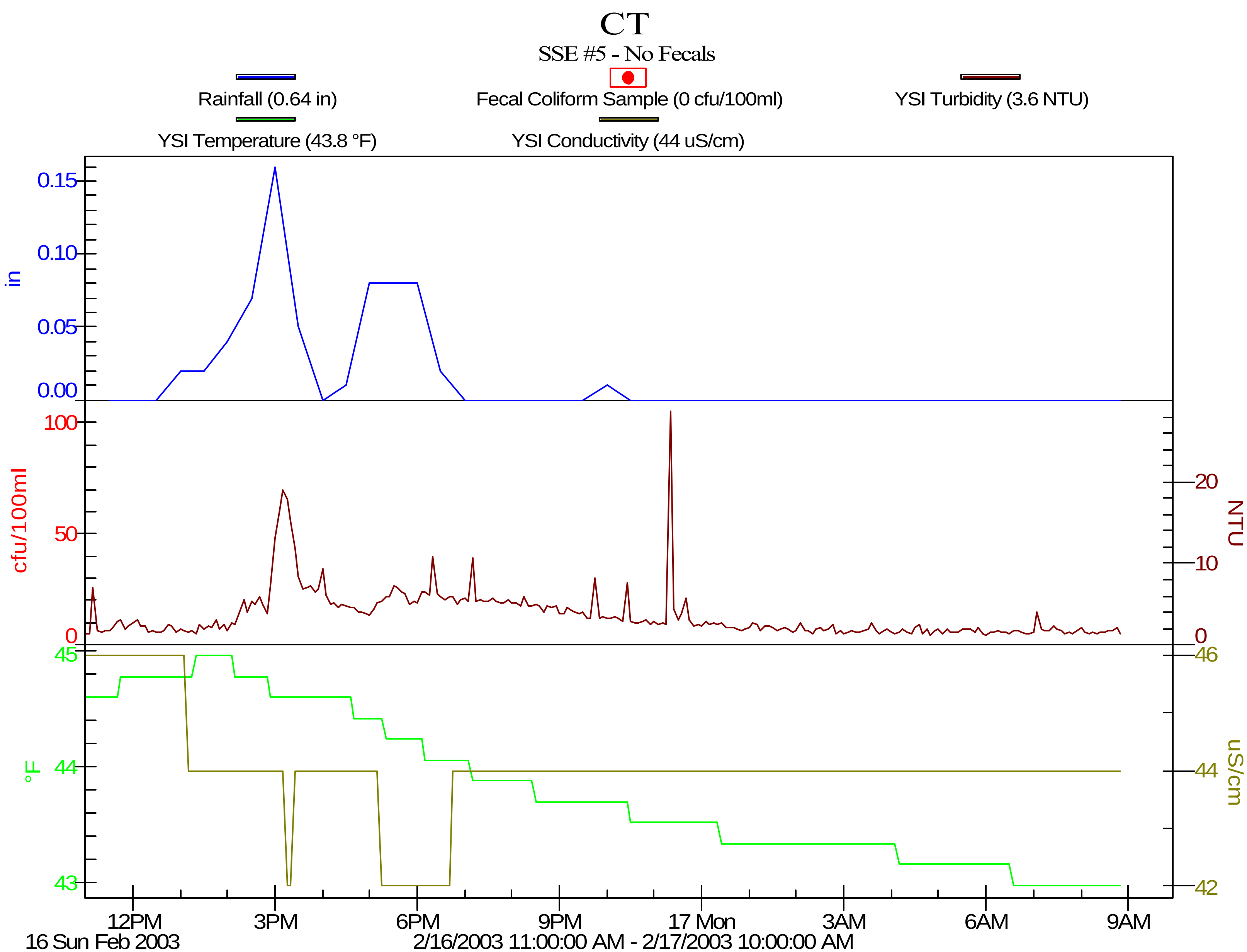
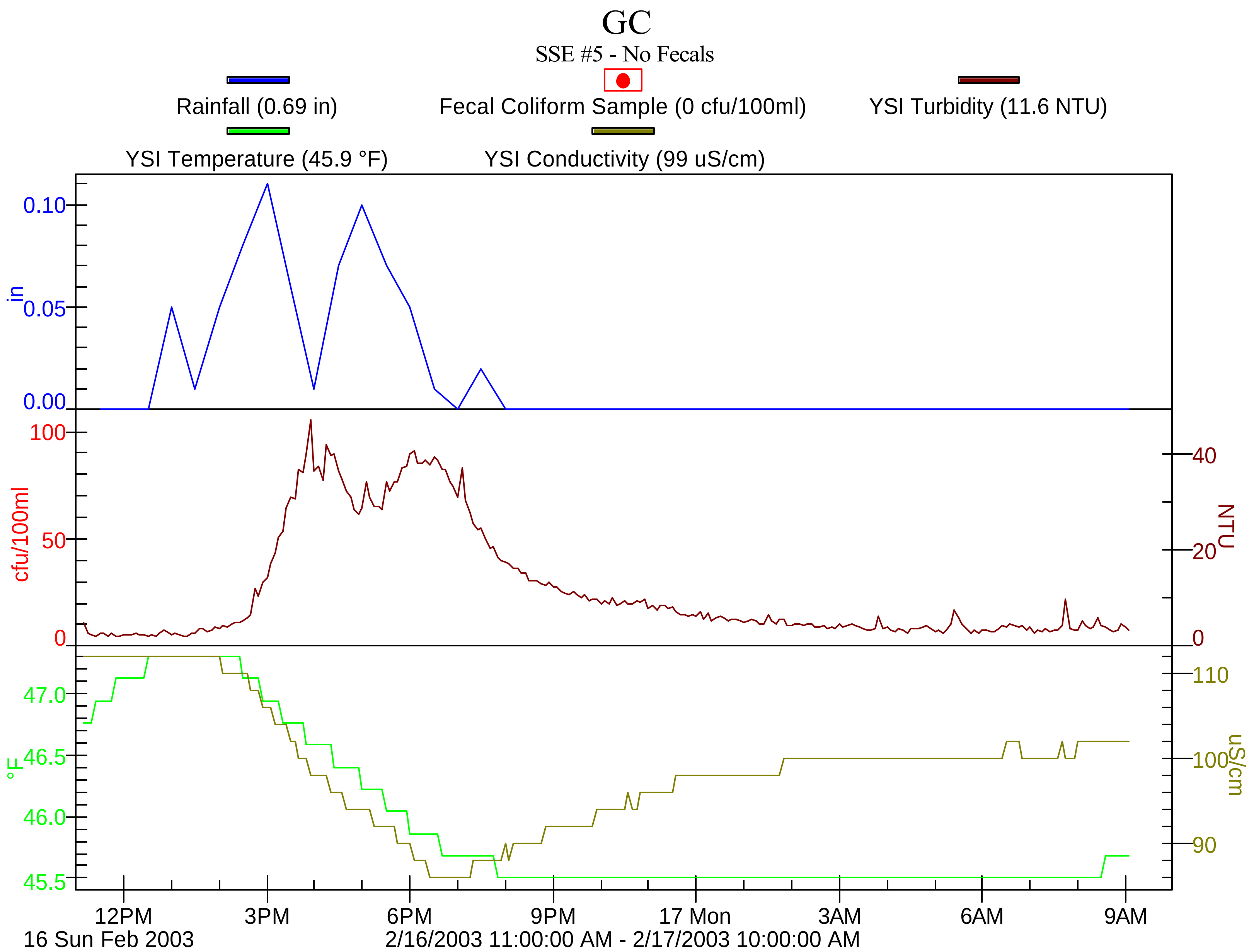

CT
SSE #5 - No Fecals
Rainfall (0.64 in)
Fecal Coliform Sample (0 cfu/100ml)
YSI Turbidity (3.6 NTU)
YSI Temperature (43.8 °F)
YSI Conductivity (44 uS/cm)
in
0.15
0.10
0.05
0.00
cfu/100ml
100
50
0
NTU
20
10
0
°F
45
44
43
uS/cm
46
44
42
12PM
3PM
6PM
9PM
17 Mon
3AM
6AM
9AM
16 Sun Feb 2003
2/16/2003 11:00:00 AM - 2/17/2003 10:00:00 AM

Figure 5.3.5-3


GC
SSE #5 - No Fecals
Rainfall (0.69 in)
Fecal Coliform Sample (0 cfu/100ml)
YSI Turbidity (11.6 NTU)
YSI Temperature (45.9 °F)
YSI Conductivity (99 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
100
50
0
NTU
40
20
0
°F
47.0
46.5
46.0
45.5
uS/cm
110
100
90
12PM
3PM
6PM
9PM
17 Mon
3AM
6AM
9AM
16 Sun Feb 2003
2/16/2003 11:00:00 AM - 2/17/2003 10:00:00 AM

It is interesting to compare CH to CT as the two sites are located within a third of mile of each other. Turbidity values at both sites show a response to rainfall; however, it's difficult to determine if temperature and conductivity were affected. Average temperature and conductivity values at CT were slightly lower than CH, where as total rainfall and average turbidity values at CT were slightly greater than those at CH.

SSE #5 provided a unique opportunity to sample 2 different hydrologic conditions within a short period of time. Sampling during #5a provided samples that represented a first flush of pollutants that had been building up over the 14-day dry period – an appealing condition for storm flow sampling. Similarly, the high rainfall intensities associated with #5b (greater than 0.20"/hr) resulted in a quick, high energy mobilization of pollutants, providing the opportunity to sample such a high intensity/short duration event. By examining the physio-chemical data it can be seen that turbidity levels jumped during #5b compared with #5a, as might be expected given the high rainfall intensity associated with #5b.

5.3.6 SSE #6

5.3.6.1 FC Data

SSE #6 was a 24-hour event sampled on 8-9 March 2003 (TEC 2003e). Figure 5.3.6-1 presents FC data for each for the sites as well as rainfall data for CW (which was chosen as the most representative rainfall record). The 3 rounds of storm flow FC samples were taken after approximately 0.10", 0.75", and 1.0" of cumulative rainfall, respectively. The ADP for SSE #6 was approximately 22 days. Sampling occurred at both northern and southern group sites, unlike the other events which were geographically grouped.

Average storm flow FC concentrations were lowest at BL (145 CFU/100 mL), and then increased to 185 CFU/100 mL at CW, 288 CFU/100 mL at SC, 314 CFU/100 mL at CC, 335 CFU/100 mL at CE, and 360 CFU/100 mL at BA. Once again, OC had the highest average storm flow FC concentration at 2,393 CFU/100 mL.

Samples from Round 1 contained low storm flow FC concentrations at all sites except for OC, which continued to have elevated FC concentrations. Round 2 concentrations were higher, and many sites reached their peak values. However, Round 3 concentrations were still similar to those from Round 2, except for OC which dropped dramatically. This may be due to the fact that high rainfall intensities occurred right before and immediately following Round 2. Given that Round 3 occurred approximately 6 hours after Round 2, streams may have still been running high. However, as storm flow FC concentrations at OC dropped off from Round 2 to Round 3, perhaps the stream flushed a large percentage of FC colonies prior to Round 3. When compared to preceding storm events and associated FC concentrations, the relatively high FC concentrations from SSE #6 can be perhaps attributed to the relatively long ADP of 22 days.

5.3.6.2 Physio-Chemical and FC Data

Figures 5.3.6-2, 5.3.6-3, and 5.6-4 present physio-chemical and FC data for BA, CW, and CE, respectively. FC concentrations at BA generally track well with turbidity throughout the event. Note the elevated turbidity values at BA starting around noon on the 9th – this was perhaps due to a large influx of sediment into the stream that took some time to pass through the system.

It is interesting to compare CE to CW - 2 tributaries to CC that are located a few hundred yards apart with watersheds of about the same size and similar physio-chemical parameter values. However, while the FC concentration trend for each location is similar, the concentrations are not. Perhaps an analysis of the land use/land cover differences between the two watersheds may shed some light as to why FC concentrations are so different between the two sites when all other measured physical parameters are so similar.

Figure 5.3.6-1

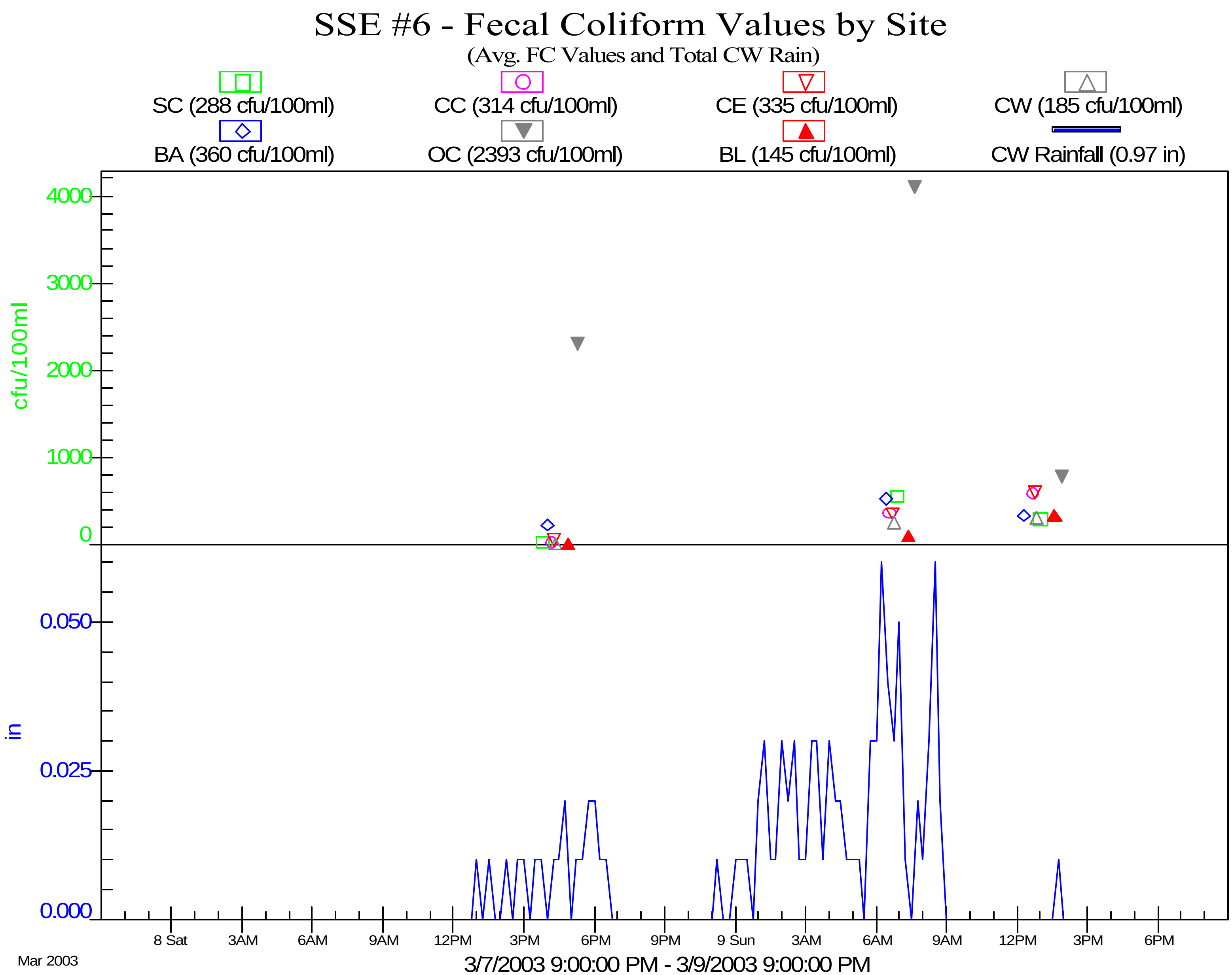

SSE #6 - Fecal Coliform Values by Site
(Avg. FC Values and Total CW Rain)
SC (288 cfu/100ml)
CC (314 cfu/100ml)
CE (335 cfu/100ml)
CW (185 cfu/100ml)
BA (360 cfu/100ml)
OC (2393 cfu/100ml)
BL (145 cfu/100ml)
CW Rainfall (0.97 in)
cfu/100ml
4000
3000
2000
1000
0
in
0.050
0.025
0.000
8 Sat
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
Mar 2003
3/7/2003 9:00:00 PM - 3/9/2003 9:00:00 PM

Figure 5.3.6-2

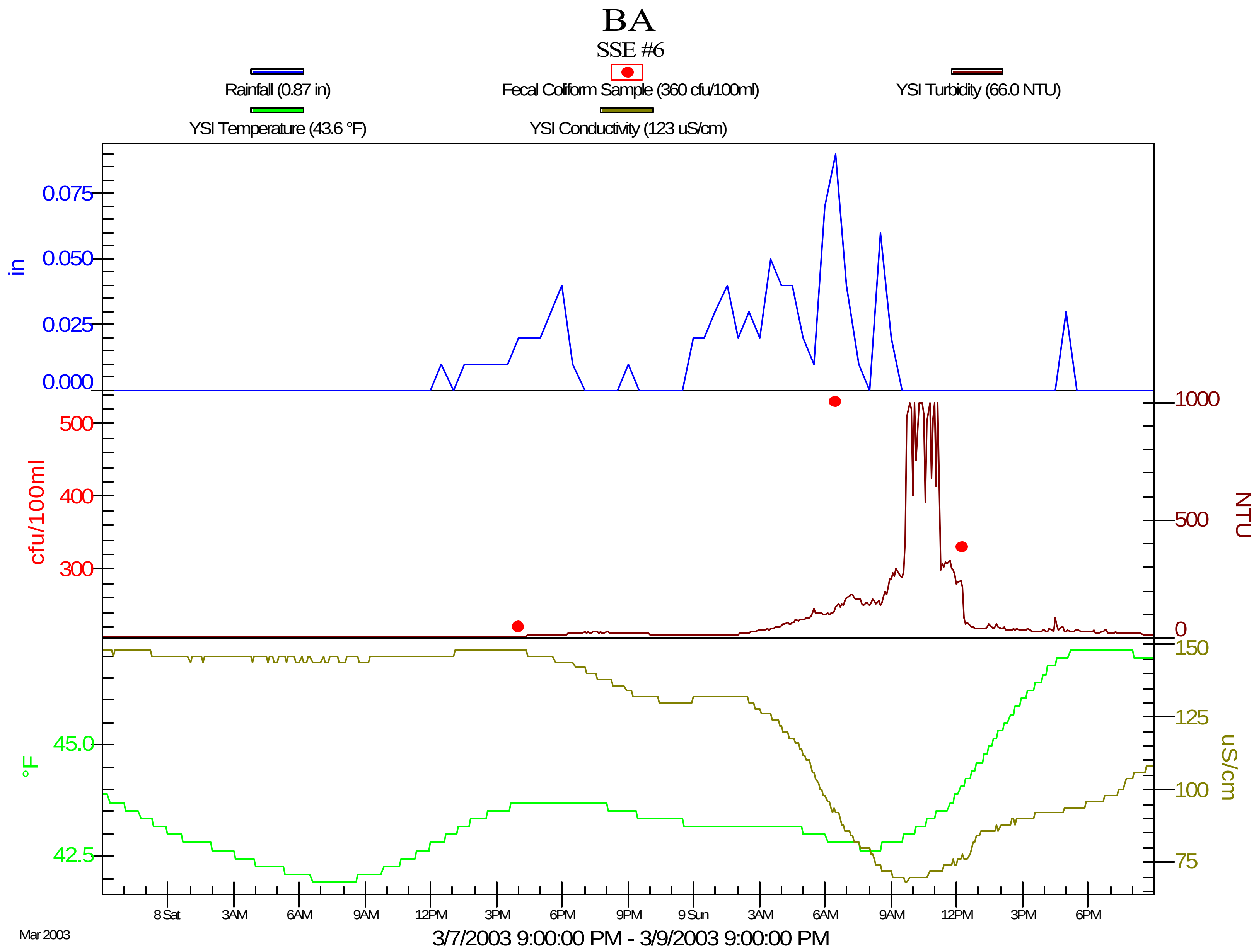

BA
SSE #6
Rainfall (0.87 in)
Fecal Coliform Sample (360 cfu/100ml)
YSI Turbidity (66.0 NTU)
YSI Temperature (43.6 °F)
YSI Conductivity (123 uS/cm)
in
0.075
0.050
0.025
0.000
cfu/100ml
500
400
300
NTU
1000
500
0
°F
45.0
42.5
uS/cm
150
125
100
75
8 Sat
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
Mar 2003
3/7/2003 9:00:00 PM - 3/9/2003 9:00:00 PM

Figure 5.3.6-3

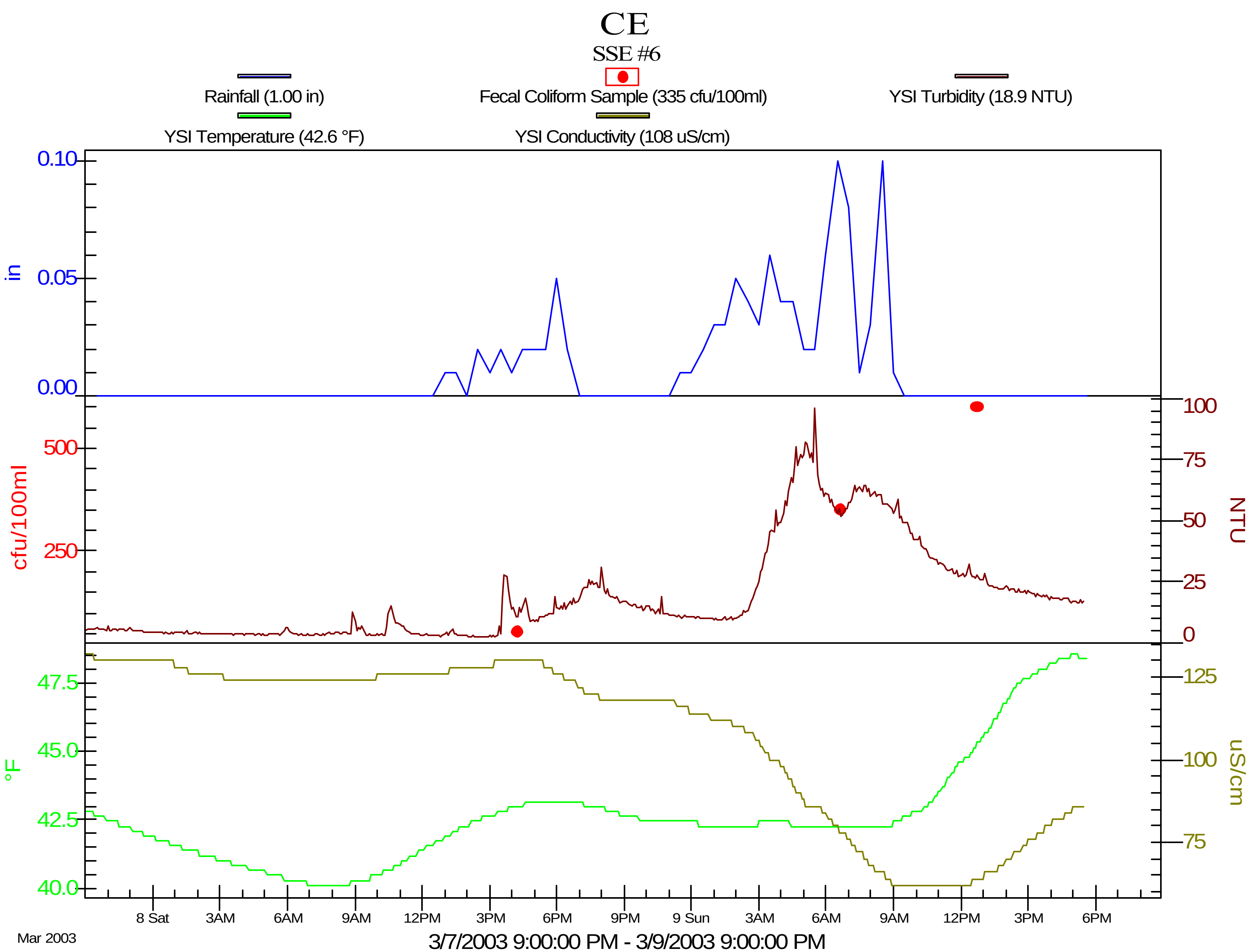
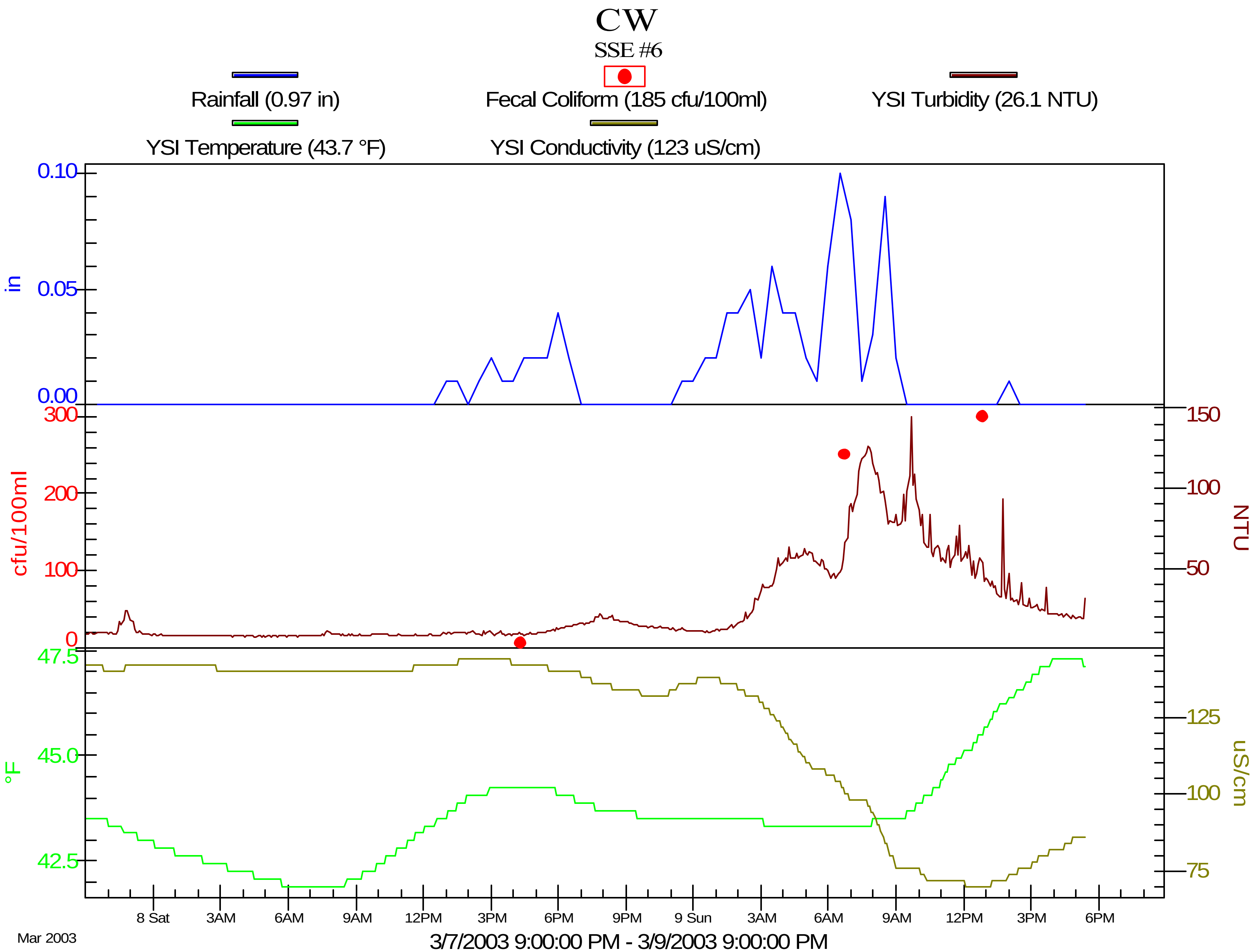

CE
SSE #6
Rainfall (1.00 in)
Fecal Coliform Sample (335 cfu/100ml)
YSI Turbidity (18.9 NTU)
YSI Temperature (42.6 °F)
YSI Conductivity (108 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
500
250
NTU
100
75
50
25
0
°F
47.5
45.0
42.5
40.0
uS/cm
125
100
75
8 Sat
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
Mar 2003
3/7/2003 9:00:00 PM - 3/9/2003 9:00:00 PM

Figure 5.3.6-4


CW
SSE #6
Rainfall (0.97 in)
Fecal Coliform (185 cfu/100ml)
YSI Turbidity (26.1 NTU)
YSI Temperature (43.7 °F)
YSI Conductivity (123 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
300
200
100
0
NTU
150
100
50
°F
47.5
45.0
42.5
uS/cm
125
100
75
8 Sat
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
Mar 2003
3/7/2003 9:00:00 PM - 3/9/2003 9:00:00 PM

5.3.7 SSE #7

5.3.7.1 FC Data

SSE #7 was a 30-hour event sampled on 12-13 March 2003 at the 6 northern sites (CH, SC, BA, CC, CW, and CW), the final In-Stream Storm Flow Sampling Event for the 2002-2003 Season (TEC 2003e). Figure 5.3.7-1 presents storm flow FC data for each of the sites as well as rainfall data for CW (which was chosen as the most representative rainfall record). The 4 rounds of FC samples were taken after approximately 0.50”, 1.75”, 2.75”, and 3.30” of cumulative rainfall, respectively. The ADP for SSE #7 was approximately 1 day.

Average storm flow FC concentrations were lowest at CH (102 CFU/100 mL), and then increased to 218 CFU/100 mL at CW, 233 CFU/100 mL at CC, 270 CFU/100 mL at BA, 310 CFU/100 mL at CE, and 640 CFU/100 mL at SC. FC concentrations generally increased from Round 1 to Round 2, and then slowly decreased with each successive round of samples. The notable exception to this was SC, which was highest during Round 1, then decreased with each successive round.

Rainfall associated with SSE #7 was prodigious. This rainfall resulted in copious runoff which raised the level of the streams to, at or above, bank full. Large woody debris and other materials (including large amounts of sediments) were mobilized. The high amount of rainfall and associated runoff can be considered as a major reason for the elevated FC concentrations as compared to previous SSEs.

Of particular note is to compare the average storm flow FC concentrations from SSE #7 to SSE #6. While SSE #6 had an ADP of 22 days, SSE #7 was only 1 day. However, total rainfall for SSE #7 was much greater than for SSE #6. Even with this short ADP, storm flow FC concentrations were comparable to those recorded during SSE #6. It can be hypothesized that therefore not only is the ADP an important factor in storm flow FC concentrations, but the amount and intensity of rainfall is as well.

5.3.7.2 Physio-Chemical and FC Data

Unlike previous events, due to high water and associated unsafe conditions, it was decided to not recover the physio-chemical equipment at each of the sites until it was safe to do so. As such, the following figures represent nearly a weeks worth of physio-chemical data for several sites, in addition to the FC data. Figures 5.3.7-2, 5.3.7-3, 5.3.7-4, 5.3.7-5, and 5.3.7-6 present physio-chemical and storm flow FC sample data for BA, CC, CH, CE, and CW.

Similar to what appeared to have happened during SSE #6, BA was subject to a large influx of sediment beginning at about noon on the 12^{th}, which corresponded to some of the highest rainfall intensities during the sampling event. Over the next several days, this sediment slowly worked its way through the system, eventually returning to near baseline levels. FC concentrations generally tracked with turbidity throughout the event. At CH, FC concentrations did not track well with turbidity values. The first value is much higher than all other FC readings, which gives credence to a strong first flush effect at CH. It is also interesting to pick out the individual turbidity peaks lagging just behind the individual rainfall peaks.

The relationship between recorded data at CE, CW, and CC is interesting. Unlike previous events (SSE #1, 2, and 6), FC concentrations at CC were more like CW than CE. Again, rainfall and physio-chemical conditions at CE and CW were similar throughout the event, yet average FC concentrations varied by more than 100 CFU/100 mL. Turbidity at CC was much higher than at CE and CW. This could have been due to either a sediment slug passing through the system (although this is not likely given the low upstream readings at CE and CW), or, perhaps, the sensor silted up with sediment during the course of the sampling event and then was cleaned out over the next few days by the stream action (although the YSIs have self-cleaning turbidity sensors that activate prior to each sample). At all 3 sites the FC trend generally tracked the same – FC concentrations peaked in the second round and then decreased thereafter in each successive round of sampling (although Round 3 at CC did not follow this pattern).

Figure 5.3.7-1

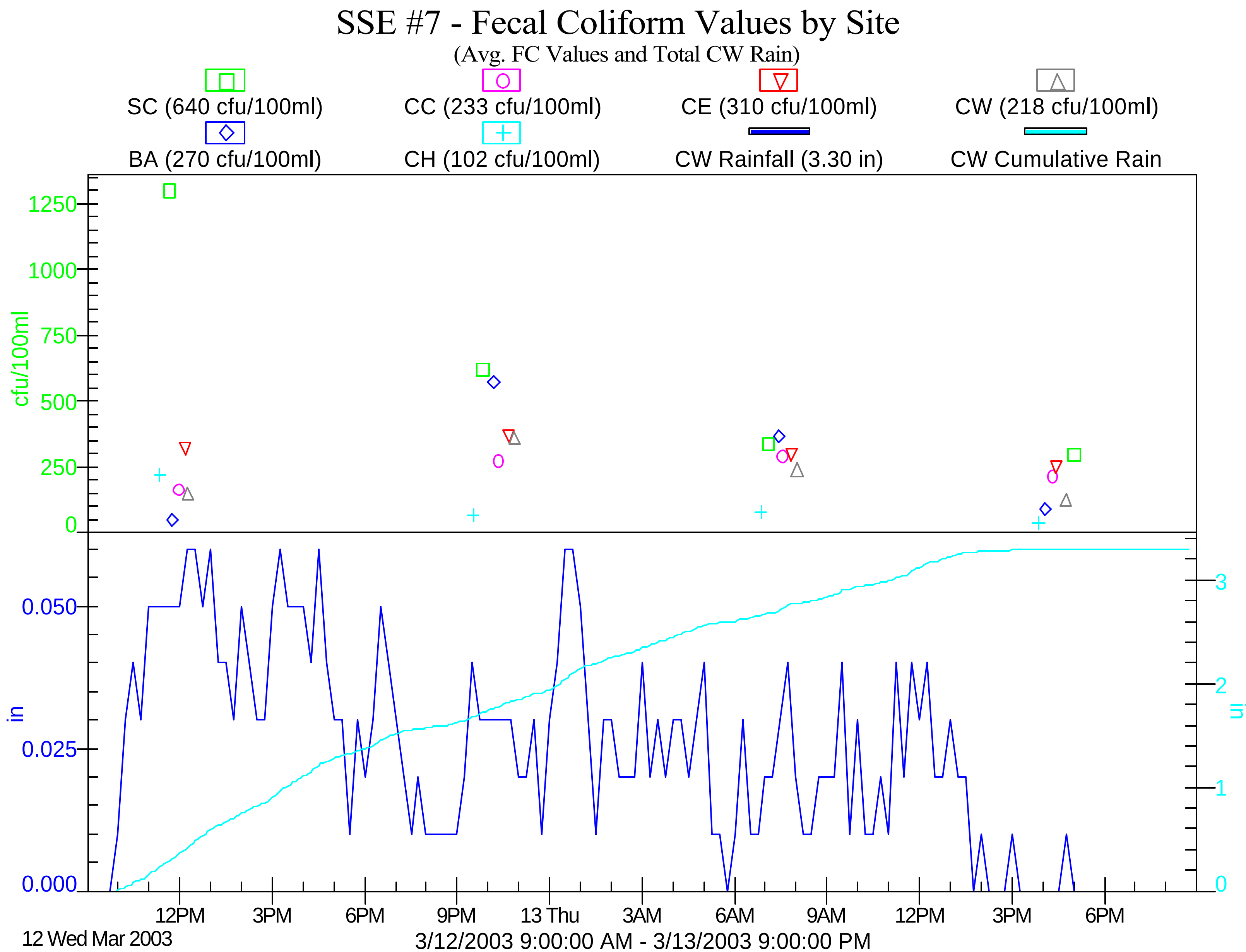
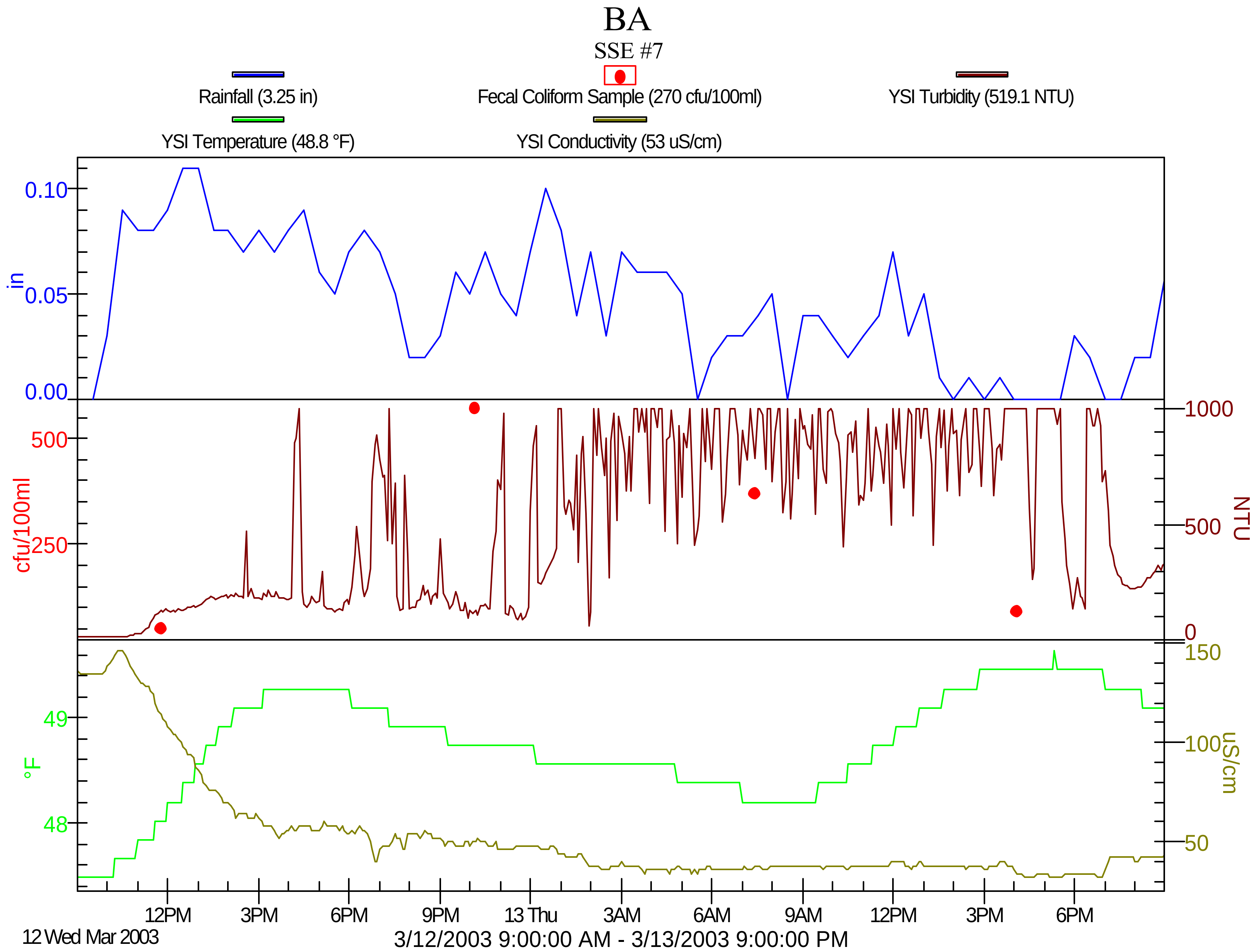

SSE #7 - Fecal Coliform Values by Site
(Avg. FC Values and Total CW Rain)
SC (640 cfu/100ml)
CC (233 cfu/100ml)
CE (310 cfu/100ml)
CW (218 cfu/100ml)
BA (270 cfu/100ml)
CH (102 cfu/100ml)
CW Rainfall (3.30 in)
CW Cumulative Rain
cfu/100ml
1250
1000
750
500
250
0
in
0.050
0.025
0.000
in
3
2
1
0
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/13/2003 9:00:00 PM

Figure 5.3.7-2



BA
SSE #7
Rainfall (3.25 in)
Fecal Coliform Sample (270 cfu/100ml)
YSI Turbidity (519.1 NTU)
YSI Temperature (48.8 °F)
YSI Conductivity (53 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
500
250
NTU
1000
500
0
°F
49
48
uS/cm
150
100
50
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/13/2003 9:00:00 PM

Figure 5.3.7-3

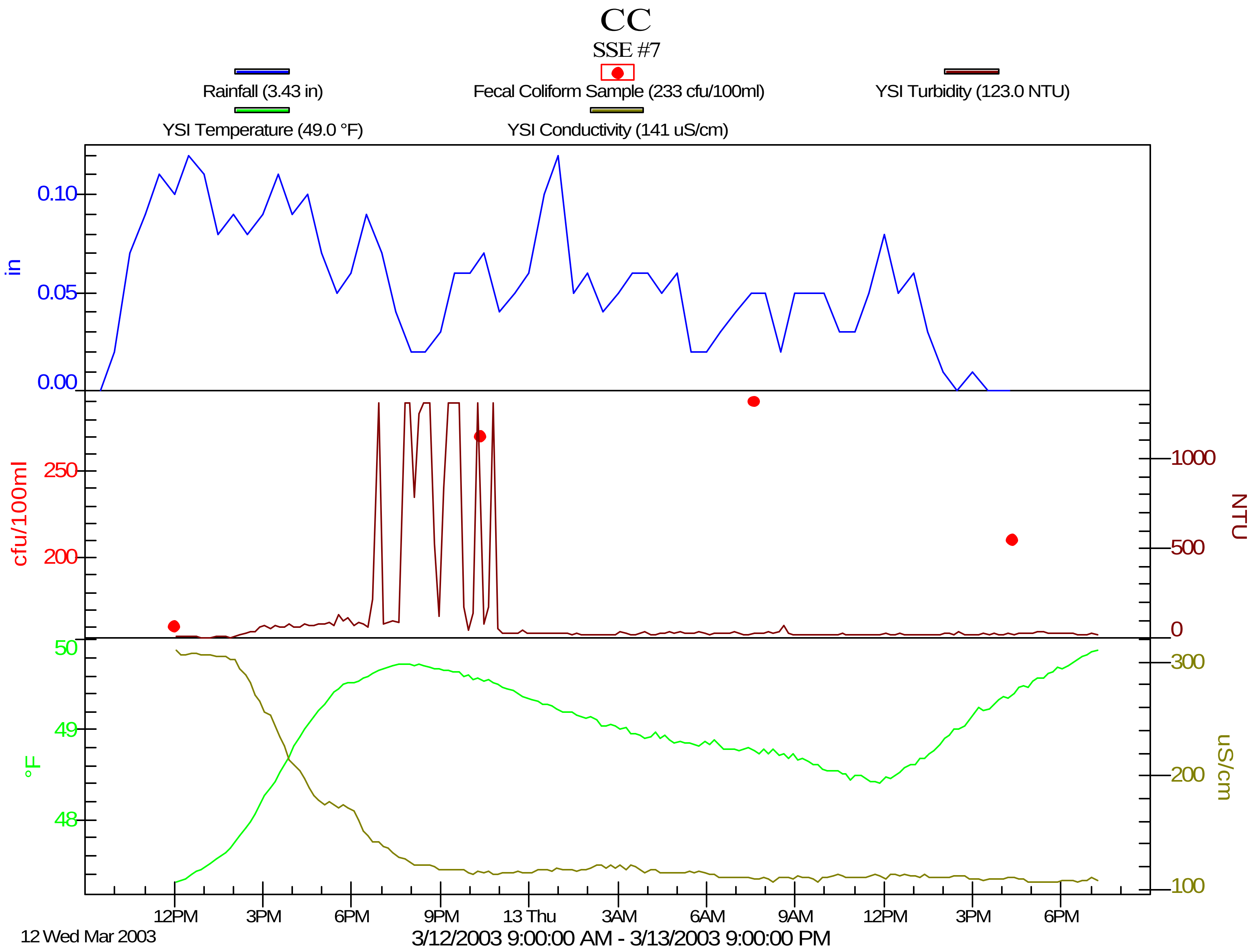

CC
SSE #7
Rainfall (3.43 in)
Fecal Coliform Sample (233 cfu/100ml)
YSI Turbidity (123.0 NTU)
YSI Temperature (49.0 °F)
YSI Conductivity (141 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
250
200
NTU
1000
500
0
°F
50
49
48
uS/cm
300
200
100
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/13/2003 9:00:00 PM

Figure 5.3.7-4

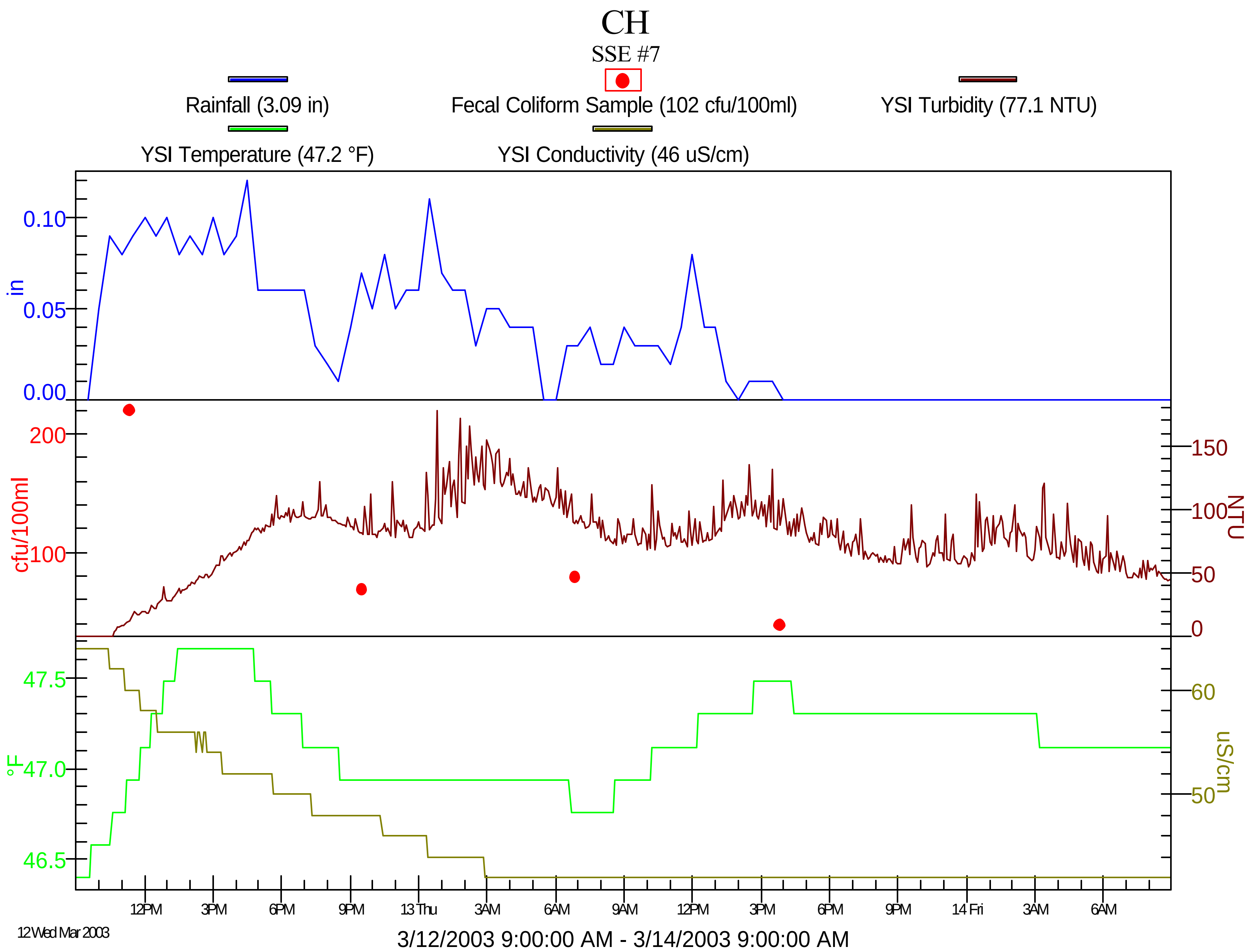

CH
SSE #7
Rainfall (3.09 in)
Fecal Coliform Sample (102 cfu/100ml)
YSI Turbidity (77.1 NTU)
YSI Temperature (47.2 °F)
YSI Conductivity (46 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
200
100
NTU
150
100
50
0
°F
47.5
47.0
46.5
uS/cm
60
50
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
14 Fri
3AM
6AM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/14/2003 9:00:00 AM

Figure 5.3.7-5

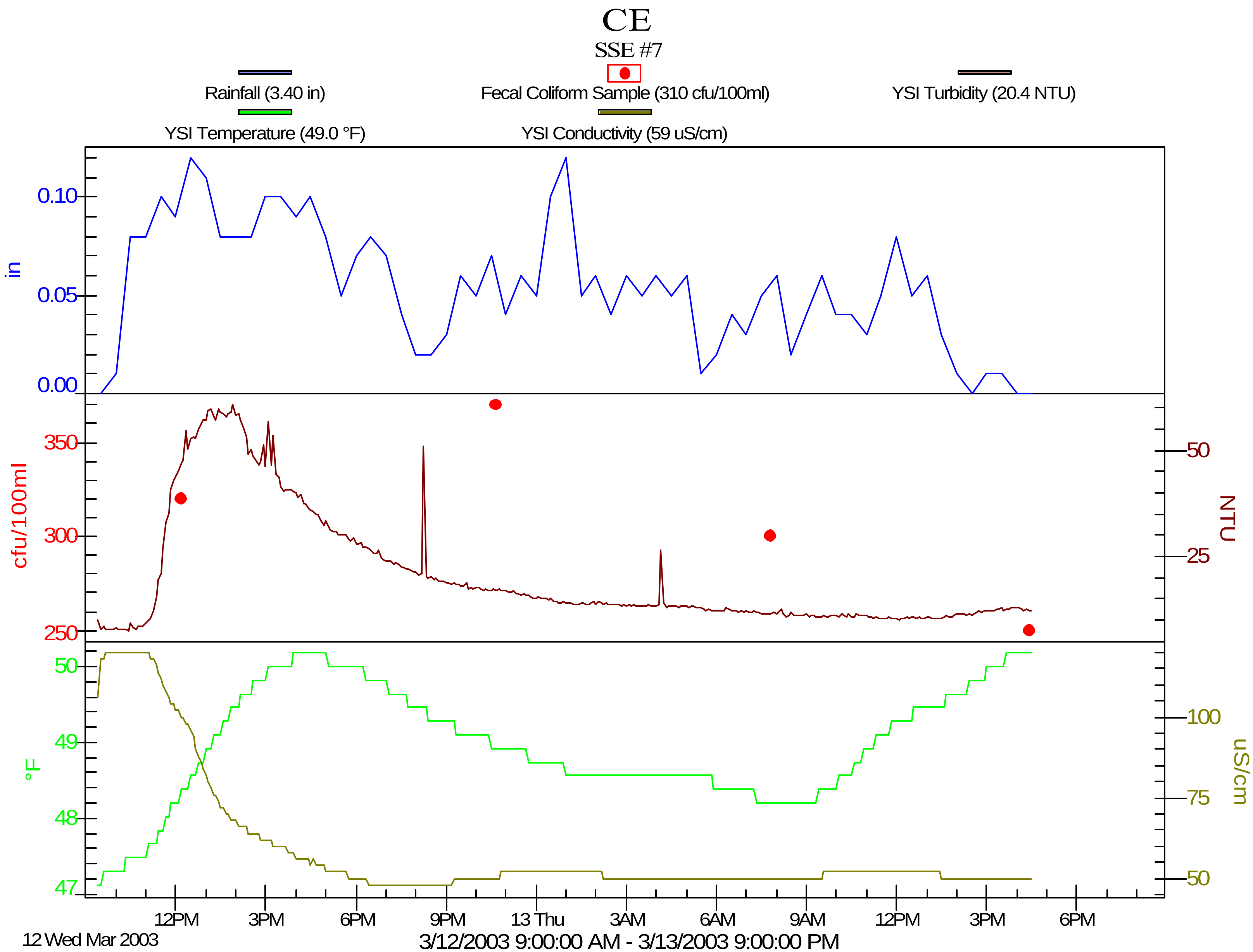
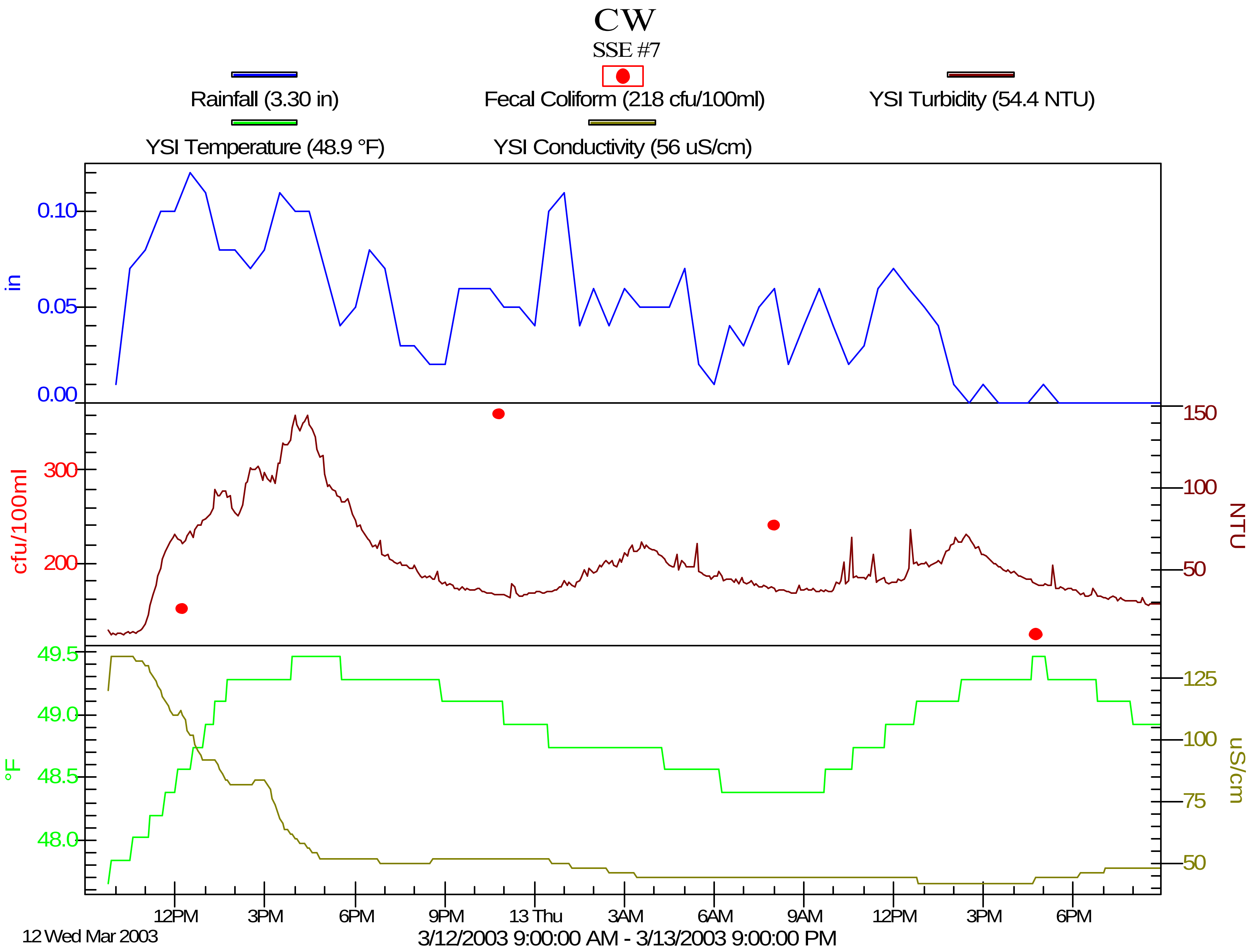

CE
SSE #7
Rainfall (3.40 in)
Fecal Coliform Sample (310 cfu/100ml)
YSI Turbidity (20.4 NTU)
YSI Temperature (49.0 °F)
YSI Conductivity (59 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
350
300
250
NTU
50
25
°F
50
49
48
47
uS/cm
100
75
50
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/13/2003 9:00:00 PM

Figure 5.3.7-6


CW
SSE #7
Rainfall (3.30 in)
Fecal Coliform (218 cfu/100ml)
YSI Turbidity (54.4 NTU)
YSI Temperature (48.9 °F)
YSI Conductivity (56 uS/cm)
in
0.10
0.05
0.00
cfu/100ml
300
200
150
100
50
NTU
°F
49.5
49.0
48.5
48.0
125
100
75
50
uS/cm
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 9:00:00 AM - 3/13/2003 9:00:00 PM

5.3.8 Summary Analysis by Storm

This discussion focuses on the response of storm flow FC concentrations to different hydrological conditions within the study area watersheds. The sampling sites have been grouped as follows to see if a relationship exists between average storm flow FC concentrations and average total rainfall and/or ADP:

- Group 1: SSE #1, SSE #2, and SSE #7 (all 6 northern group sites);
- Group 2: SSE #1, SSE #2, SSE #6, and SSE #7 (but excluding CH as it was not common to all SSEs); and
- Group 3: SSE #3 and SSE #4 (all 5 southern group sites and CH)

As shown in Table 5-2, average storm flow FC concentrations within Group 1 from SSE #1 were approximately half of those in SSE #2 and SSE #7. While the average total rainfall was similar for SSE #1 and SSE #2, the ADP for SSE #2 was 7 days, vs. 1 day for SSE #1. In this instance, it appears that when rainfall is similar, FC concentrations increase as ADP increases. Comparison of SSE #1 to SSE #7, both of which had a similar ADP, shows that average FC concentrations increased as a result of additional rainfall. As shown in Table 5-2, the average FC concentrations for both SSE #2 and SSE #7 were similar, leading to the conclusion that ADP and average total rainfall have a nearly equal effect on FC concentrations in storm flow.

Table 5-2: Comparison of SSEs by Group

Group	*Average FC Concentration (CFU/100 mL)*	*Average Total Rainfall (inches)*	*Antecedent Dry Period (days)*
Group 1			
SSE #1	149	1.00"	1
SSE #2	288	1.14"	7
SSE #7	295	3.25"	1
Group 2			
SSE #1	159	1.00"	1
SSE #2	325	1.14"	7
SSE #6	296	0.91"	22
SSE #7	334	3.25"	1
Group 3			
SSE #3	233	1.52"	1
SSE #4	227	0.85"	3

For Group 2, average storm flow FC concentrations for SSE #2, SSE #6, and SSE #7 are similar, even under a variety of rainfall and ADP conditions. However, all 3 are at least twice as great as the average FC concentration for SSE #1. As shown by the data, it appears that an ADP of either 7 or 22 days has the same effect on average storm flow FC concentrations as a high rain event at the Group 2 sites. However, once ADP reaches 7 days, it appears that the maximum loading has occurred; even with an ADP of 22 days for a similar storm, average FC concentrations do not greatly differ.

For the Group 3 sites, an ADP of 3 days results in nearly the same effect on average storm flow FC concentrations as does a doubling of rainfall. This is consistent with the other sites in that an ADP of 7 days resulted in nearly the same effect on average FC concentrations as a tripling of rainfall.

Therefore, it can be proposed that the watersheds within the project area reach their maximum storm flow FC concentrations after an ADP of approximately 7 days. It can also be proposed that more rain (wetter storms) result in higher storm flow FC concentrations. Therefore, it appears that maximum average FC concentrations would occur from a storm with at least 3" of rain and an ADP of approximately 7 days.

5.4 SAMPLING SUMMARY BY SAMPLING LOCATION

The following sections discuss the storm flow FC and turbidity data collected at each sampling location during the 2002-2003 In-Stream Storm Flow Sampling Season, and also includes dry season data, where available. In following pages, individual site data are discussed in alphabetical order. Three summary figures (a-c) are presented with each site comparing: a) FC concentrations vs. cumulative rainfall, b) FC concentrations vs. turbidity; and c) FC concentrations vs. ADP.

5.4.1 Anderson Creek

Table 5-3 presents storm flow FC and associated turbidity readings associated with each storm event sampled at AC (dry season data was not available) and Figures 5.4-1a-b present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Table 5-3: AC Storm Flow FC Concentrations and Turbidity

Storm/Sample Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #3			
	1	230	27.1
	2	26	36.8
	3	20	14.8
SSE #4			
	1	54	N/A
	2	11	13.0
	3	80	37.7

Storm flow FC concentrations at AC ranged from 11 CFU/100 mL to 230 CFU/100 mL and the average concentration was 70 CFU/100 mL. The lowest concentration was recorded during Round 2 of SSE #4. This sample was associated with approximately 0.57” of cumulative rainfall and a turbidity reading of 13 Nephelometric Turbidity Unit (NTU). Conversely, the highest concentration was recorded in Round 1 of SSE #3. This sample was associated with approximately 0.5” of cumulative rainfall, a turbidity reading of 27 NTU, and an ADP of less than 1 day (approximately 7 hours).

SSE #3 showed a strong first flush effect, as storm flow FC concentrations were initially high and then decreased dramatically in subsequent rounds of sampling. While FC concentrations decreased with each successive round of sampling during SSE #3, that same pattern did not hold true for SSE #4, as the highest concentration was found during the last round of sampling, corresponding to the highest turbidity reading during this event.

When viewed as a whole data set (n = 6), Figures 5.4-1a-b show no distinct relationship between the 3 physical parameters and FC concentrations; although it appears that storm flow FC concentrations generally decrease as the cumulative rainfall increases and increase as turbidity increases. The data set for ADP is too short to determine if a correlation exists. Overall, AC had low FC concentrations when compared to the other sites. This could potentially be a function of the relatively undeveloped nature of the 4.04 mi^2 AC Watershed, which consists primarily of low density residences and forested/open space. However, further analysis is necessary to determine the sources of FC in storm flow at AC.

Figure 5.4-1a
AC Fecal Coliform Concentrations and Cumulative Rainfall
(n = 6)

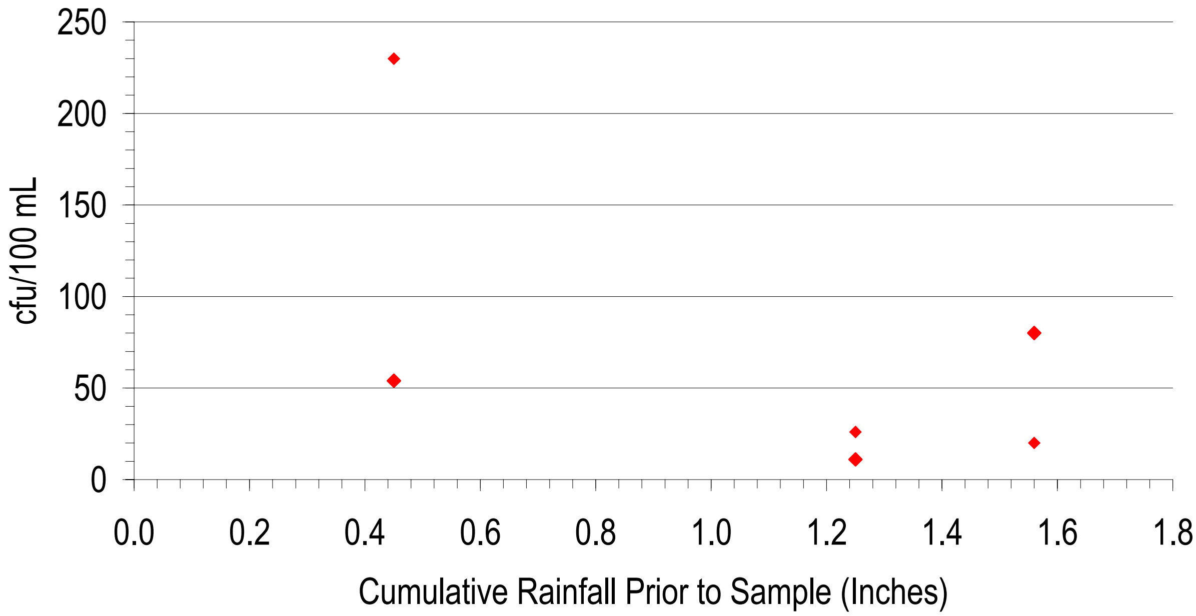
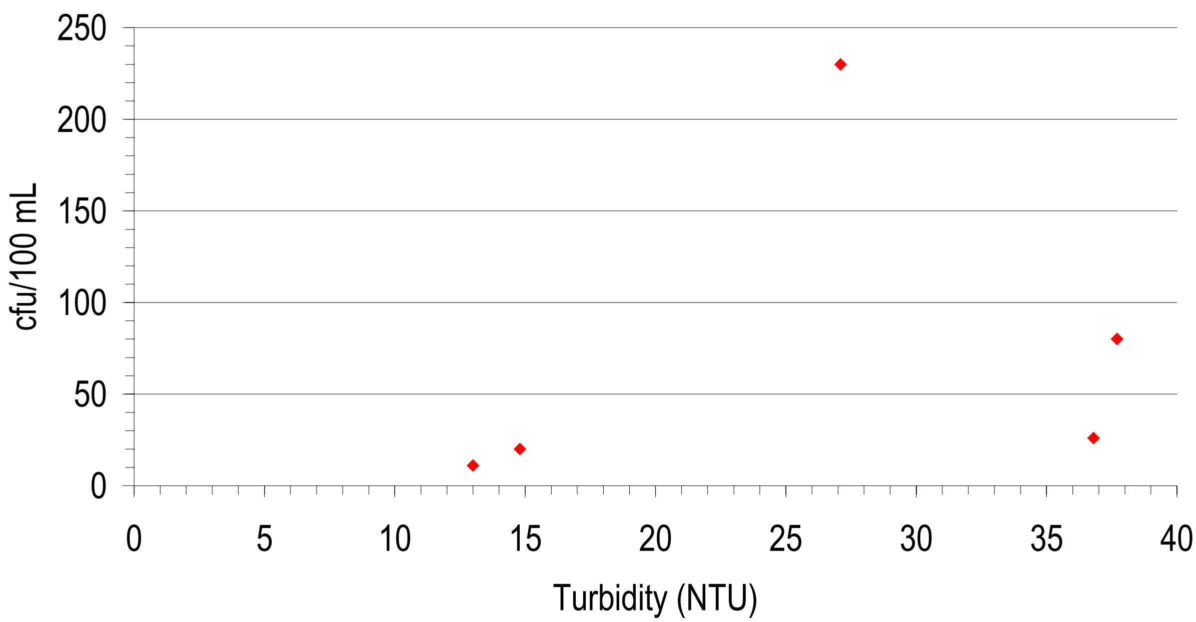


Figure 5.4-1b
AC Fecal Coliform Concentrations and Turbidity
(n = 6)



5.4.2 Barker Creek

Table 5-4 presents storm flow FC and associated turbidity readings associated with each storm event sampled at BA and Figures 5.4-2a-c present storm flow FC concentrations vs. cumulative rainfall and turbidity, respectively.

Table 5-4: BA Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	49	N/A
	2	160	N/A
	3	156	N/A
SSE #2			
	1	34	4.1
	2	380	55.2
	3	270	35.7
SSE #6			
	1	220	10.2
	2	530	108.0
	3	330	248.1
SSE #7			
	1	480	114.4
	2	570	104.2
	3	370	127.2
	4	92	1,011.0
Dry Season Average		N/A	2.8

Storm flow FC concentrations at BA ranged from 34 CFU/100 mL to 570 CFU/100 mL and the average concentration was 246 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #4. This sample was associated with approximately 0.47” of cumulative rainfall, a turbidity reading of 4.1 NTU, and an ADP of 7 days. Conversely, the highest concentration was recorded in Round 2 of SSE #7. This sample was associated with approximately 1.7” of cumulative rainfall and a turbidity reading of 104 NTU.

Throughout each sample event, storm flow FC concentrations generally behaved in the same manner: Round 1 samples were the lowest, Round 2 samples (corresponding to the peak runoff) were the highest, and then successive Rounds (3 and 4) were less than Round 2 but higher than Round 1 – corresponding to a slow decrease in FC concentrations. In short, storm flow FC concentrations at BA appear to mirror the unit hydrograph.

While the total rainfall for SSE #6 was similar to SSE #1 and SSE #2, the FC concentrations were much higher. A check of the ADP for each of the 3 events shows that SSE #6 had the longest ADP (22 days vs. 1 and 7 days, respectively). Therefore, it can be hypothesized that for similar storm events, FC concentrations will be higher when the ADP is longer. This hypothesis is strengthened when SSE #1 and SSE #2 are compared. Both events resulted in similar rainfall totals; however, storm flow FC concentrations from SSE #2 Rounds 2 and 3 were approximately double of those in SSE #1 and FC concentrations from SSE #6 Rounds 2 and 3 were higher than those from SSE #2.

Figure 5.4-2a
BA Fecal Coliform Concentrations and Cumulative Rainfall
(n = 13)

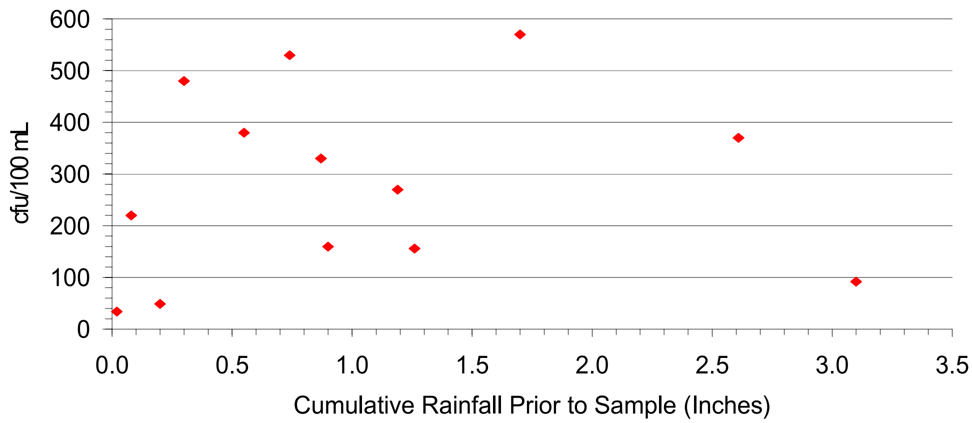


Figure 5.4-2b
BA Fecal Coliform Concentrations and Turbidity
(n = 13)

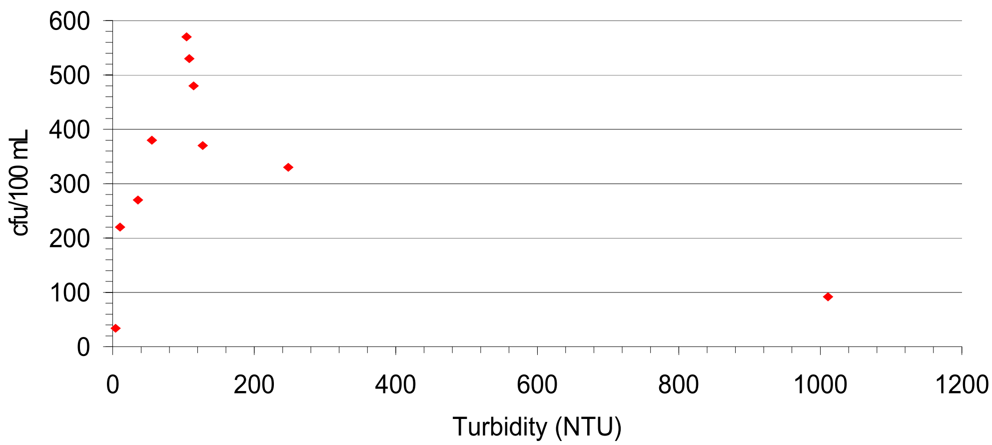
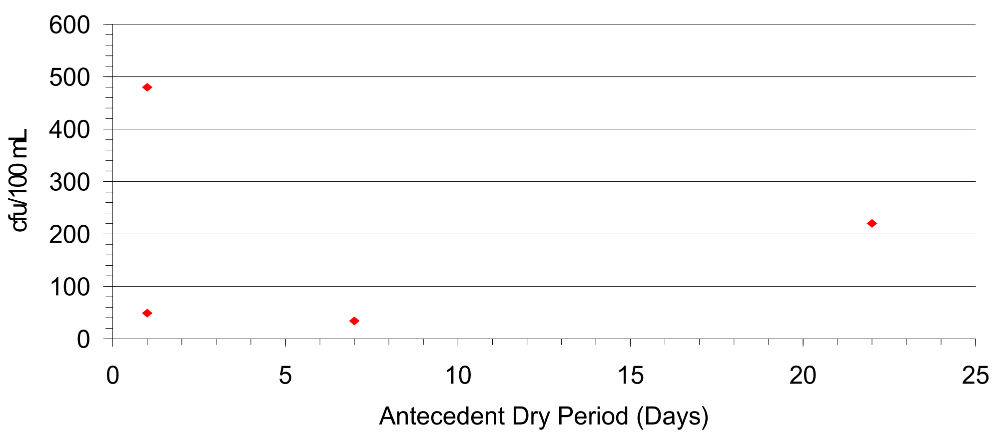


Figure 5.4-2c
BA Fecal Coliform Concentrations and Antecedent Dry Period
(n = 4)



SSE #1 and SSE #7 had a similar ADP – approximately 1 day. However, the rainfall totals were much different and the FC concentrations were much higher in SSE #7 and #1. Higher rainfall totals resulted in greater amounts of runoff and sediment mobilization. As FC can attach to sediment particles, increased sediment mobilization perhaps resulted in higher FC concentrations at BA during SSE #7.

When viewed as a whole data set (n = 13), Figures 5.4-3a-c show no distinct relationship between the 3 physical parameters and FC concentrations; although the consistent pattern of low to high to medium FC concentrations in each event is interesting and is apparent somewhat in Figure 5.4-3a.

Overall, BA had slightly higher storm flow FC concentrations when compared to the other sites. This could potentially be a function of the semi-developed nature (rural to low urban) of the 4.02 mi^2 BA Watershed. However, further analysis is necessary to determine the sources of FC in storm flow at BA.

5.4.3 Blackjack Creek

Table 5-5 presents storm flow FC and associated turbidity readings associated with each storm event sampled at BL and Figures 5.4-3a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Table 5-5: BL Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #3			
	1	120	17.7
	2	320	9.5
	3	310	9.4
SSE #4			
	1	57	13.5
	2	60	7.6
	3	188	37.5
	4	124	9.0
SSE #6			
	1	6	2.3
	2	100	20.9
	3	320	28.3
Dry Season Average		N/A	4.6

Storm flow FC concentrations at BL ranged from 6 CFU/100 mL to 320 CFU/100 mL and the average concentration was 161 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #6. This sample was associated with approximately 0.42" of cumulative rainfall, a turbidity reading of 2.3 NTU, and an ADP of 22 days. Conversely, the highest concentration was recorded in Round 2 of SSE #3. This sample was associated with approximately 1.05" of cumulative rainfall and a turbidity reading of 9.5 NTU.

Figure 5.4-3a
BL Fecal Coliform Concentrations and Cumulative Rainfall
(n = 10)

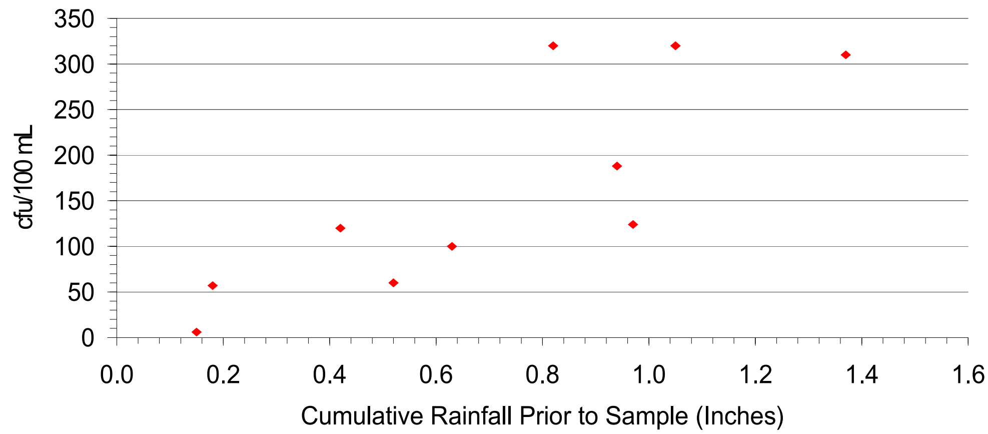


Figure 5.4-3b
BL Fecal Coliform Concentrations and Turbidity
(n = 10)

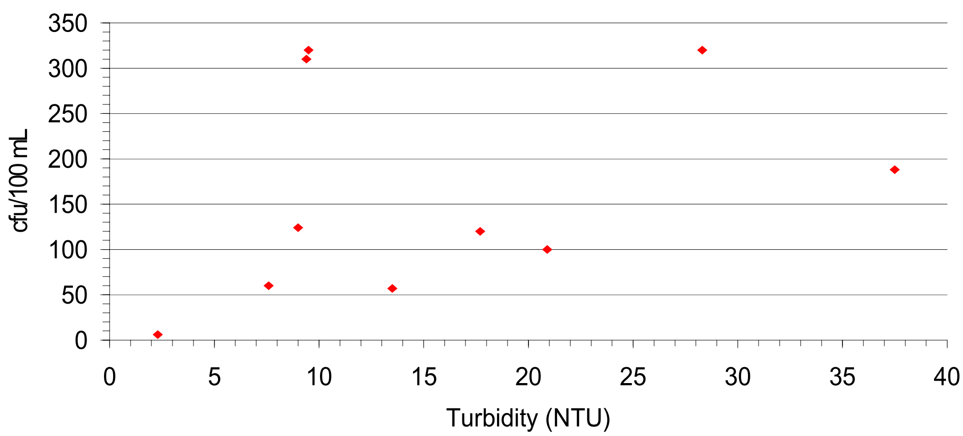
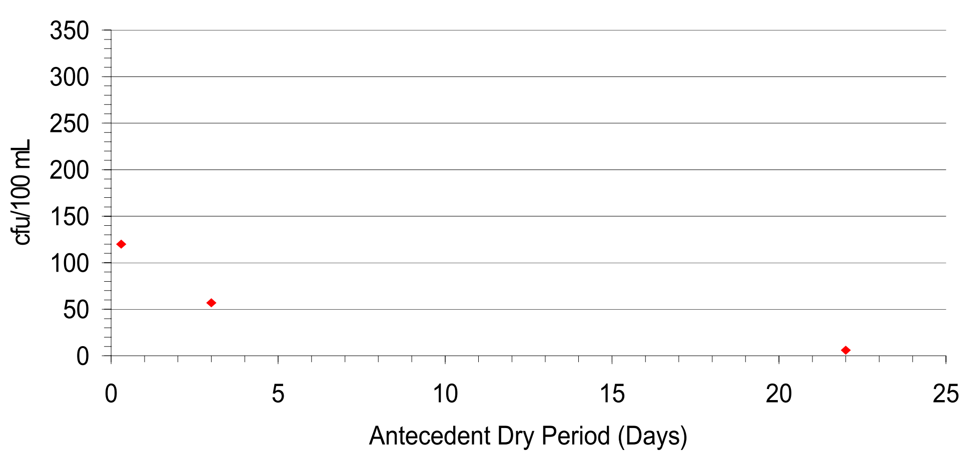


Figure 5.4-3c
BL Fecal Coliform Concentrations and Antecedent Dry Period
(n = 3)



During SSE #3 and SSE #4, storm flow FC concentrations appear to have changed in response to the hydrograph, similar to BA - FC concentrations were lowest during Round 1, then peaked during the peak runoff conditions (Round 2 and 3, respectively), and then decreased in concert with the receding limb of the hydrograph (Round 3 and 4, respectively). However, FC concentrations during SSE #6 increased exponentially with each successive round or sampling, unlike the previous 2 events.

SSE #3 had a shorter ADP than SSE #4 (7 hours vs. 3 days) but more rainfall (1.37" vs. 0.97"). As FC concentrations were higher from SSE #3 than from SSE #4, it therefore appears that cumulative rainfall and not ADP has more of an influence on FC concentrations at BL.

As shown in Figure 5.4-4a, there appears to be a correlation between cumulative rainfall and storm flow FC concentrations at BL; as rainfall increases, so do FC concentrations. However, there does not appear to be a relationship between FC concentrations and either turbidity or ADP.

Overall, BL had low storm flow FC concentrations when compared to the other sites. This could potentially be a function of the relatively undeveloped nature of the 12.3 mi^2 BL Watershed, which consists primarily of rural and forested areas. However, further analysis is necessary to determine the sources of FC in storm flow at BL.

5.4.4 Clear Creek

Table 5-6 presents storm flow FC and associated turbidity readings associated with each storm event sampled at CC and Figures 5.4-4a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Table 5-6: CC Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	112	N/A
	2	93	N/A
	3	120	N/A
SSE #2			
	1	9	2.2
	2	910	29.3
	3	560	11.6
SSE #6			
	1	11	8.7
	2	350	50.3
	3	580	30.3
SSE #7			
	1	160	50.0
	2	270	22.6
	3	290	19.0
	4	200	19.5
Dry Season Average		N/A	5.2

Figure 5.4-4a
CC Fecal Coliform Concentrations and Cumulative Rainfall
(n = 13)

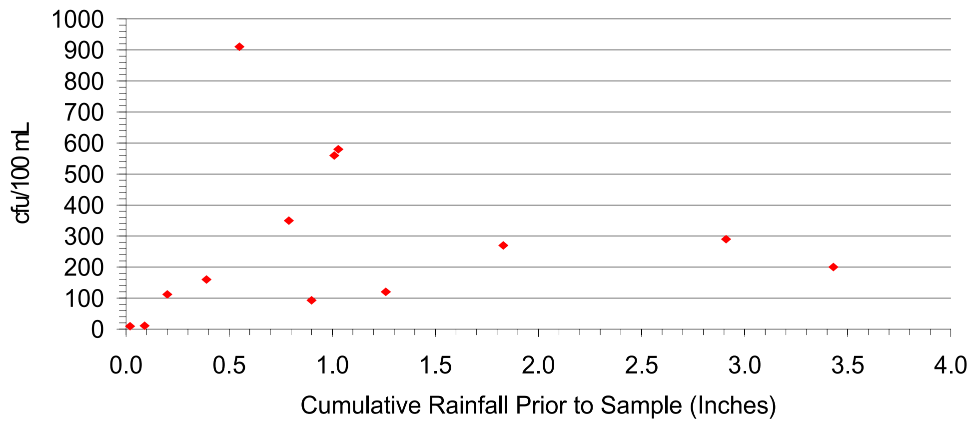


Figure 5.4-4b
CC Fecal Coliform Concentrations and Turbidity
(n = 13)

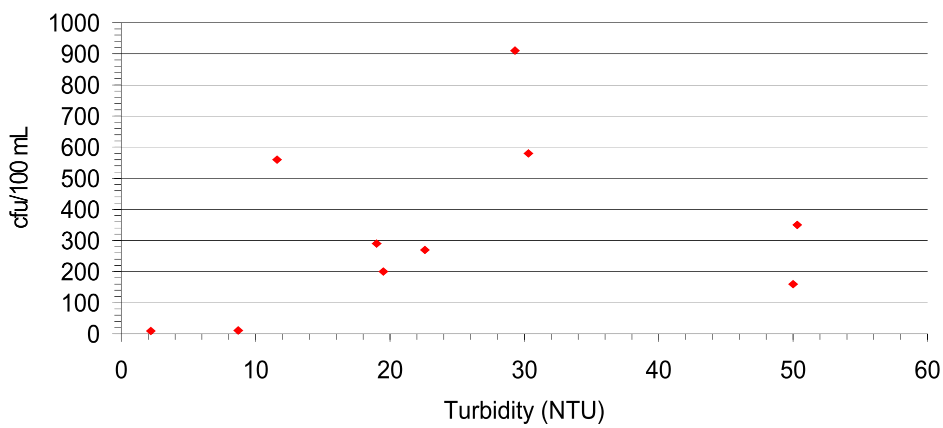
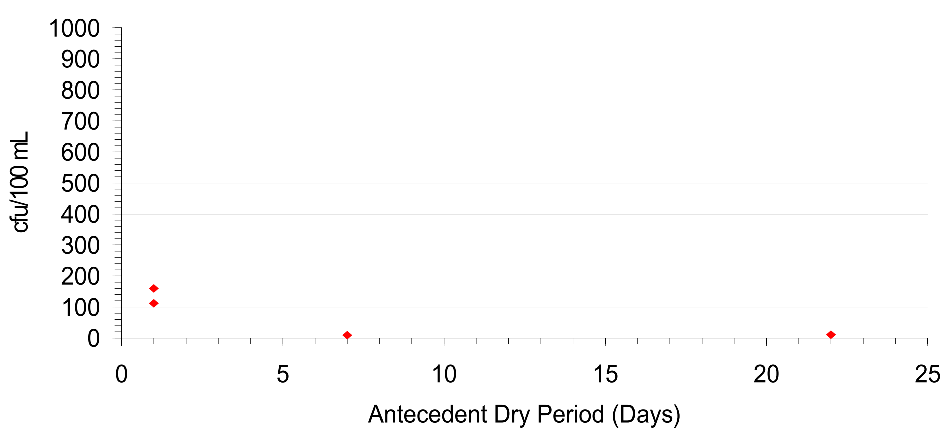


Figure 5.4-4c
CC Fecal Coliform Concentrations and Antecedent Dry Period
(n = 4)



Storm flow FC concentrations at CC ranged from 9 CFU/100 mL to 910 CFU/100 mL and the average concentration was 290 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #2. This sample was associated with approximately 0.02" of cumulative rainfall, a turbidity reading of 2.2 NTU, and an ADP of 7 days. The highest FC concentration was also recorded in SSE #2 during Round 2. This sample was associated with approximately 0.55" of cumulative rainfall and a turbidity reading of 29.3 NTU.

As shown in Table 5-6, storm flow FC concentrations were greater in SSE #2 than SSE #1. While the Round 1 sample from SSE #2 is much lower than the Round 1 sample from SSE #1, this is probably due to the fact that the Round 1 sample from SSE #2 was taken after only 0.02" of cumulative rainfall. Conversely, the Round 1 sample from SSE #1 was taken after 0.20" of cumulative rainfall.

The relationship between storm flow FC concentrations during SSE #1 and SSE #7 is similar to that presented at BA: while SSE #1 and SSE #7 had a similar ADP (approximately 1 day), the rainfall totals were greatly different, resulting in higher storm flow FC concentrations from SSE #7. Therefore, it also appears that the other hypothesis put forward in the BA discussion is also applicable at CC: for storms with similar ADPs, FC concentrations will be higher from the storm with higher rainfall totals (and perhaps rainfall intensity).

It is interesting to note, however, that unlike BA, storm flow FC concentrations from SSE #7 have lower peaks than those from the other SSEs. This response is therefore not consistent with BA, which had its highest FC concentrations during the wettest storm (SSE #7). It appears that at CC, FC concentrations are more likely to increase as ADP increases and are not as strongly affected by cumulative rainfall, unlike BA.

When viewed as a whole data set (n = 13), Figures 5.4-5a-c show no distinct relationship between the 3 physical parameters and storm flow FC concentrations. Although it appears that FC concentrations decrease with an increase in ADP, this appearance is misleading due to the times at which the samples were taken (i.e., the Round 1 samples from SSE #2 and SSE #6 were taken after only 0.02" and 0.09" of rain, respectively; basically base flow conditions).

Storm flow FC concentrations at CC appear to be most influenced by CE and to a lesser extent, by CW. As discussed in the following discussions for CE and CW, FC concentrations at CE are almost always higher than CC and lower at CW than CC. The confluence of CE and CW is just upstream of CC, east of Silverdale Road. While Silverdale Road can be considered a potential source of FC into CC, it appears that the FC-laden storm flow from CE is the main source of elevated FC concentrations at CC. Storm flow from CE is slightly diluted by the relatively "cleaner" storm flow from CW, resulting in FC concentrations at CC that are for the most part less than (but closer too) CE and greater than CW. However, an analysis of flow (and therefore flow-proportional loading) from each respective tributary to CC is necessary to investigate this potential relationship further.

Overall, storm flow FC concentrations at CC were slightly higher than FC concentrations at other sites. This could potentially be a function of the semi-developed nature of the 8.08 mi^2 CC Watershed, which consists primarily of a relatively equal mix of low to medium density residential and forested/open space land uses. However, further analysis is necessary to determine the sources of elevated FC concentrations in storm flow at CC.

5.4.5 Clear East

Table 5-7 presents storm flow FC and associated turbidity readings associated with each storm event sampled at CE (dry season data was not available) and Figures 5.4-5a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Table 5-7: CE Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	71	N/A
	2	400	N/A
	3	440	N/A
SSE #2			
	1	20	2.4
	2	930	19.1
	3	440	10.0
SSE #6			
	1	54	11.0
	2	350	52.1
	3	600	25.1
SSE #7			
	1	320	43.4
	2	360	16.3
	3	300	12.4
	4	250	12.2

Storm flow FC concentrations at CE ranged from 20 CFU/100 mL to 930 CFU/100 mL and the average concentration was 350 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #2. This sample was associated with approximately 0.06” of cumulative rainfall, a turbidity reading of 2.4 NTU, and an ADP of 7 days. The highest concentration was also recorded in SSE #2 during Round 2. This sample was associated with approximately 0.58” of cumulative rainfall and a turbidity reading of 19.1 NTU.

SSE #1 and SSE #2 were similar in that the total rainfall for each event was about the same. However, the ADP was longer for SSE #2 (7 days) than SSE #1 (1 day). As shown in Table 5-7, storm flow FC concentrations were greater in SSE #2 than SSE #1, but only slightly so. In addition, FC concentrations from SSE #6, which also had a similar rainfall total to SSE #1 and SSE #2 were not much higher, unlike those at BA and CC. In fact, throughout all 4 SSEs, FC concentrations are consistently high in all samples taken after Round 1.

It is interesting to note that storm flow FC concentrations from SSE #7 have lower peaks than those from the other SSEs. This response is therefore not consistent with BA, which had its highest FC concentrations during the wettest storm (SSE #7). This is however, consistent with the response of CC (for all SSEs except SSE #1). Thus, like CC, storm flow FC concentrations at CE appear to be most influenced by ADP and less influenced by the cumulative rainfall total. However, unlike CC, FC concentrations at CE were consistently higher from all SSEs, indicating that storm flow at CC has high FC concentrations during all storm events. As discussed in CC previously, it appears that the high FC concentrations present in the storm flow at CE serve to increase FC concentrations at CC.

Figure 5.4-5a
CE Fecal Coliform Concentrations and Cumulative Rainfall
(n = 13)

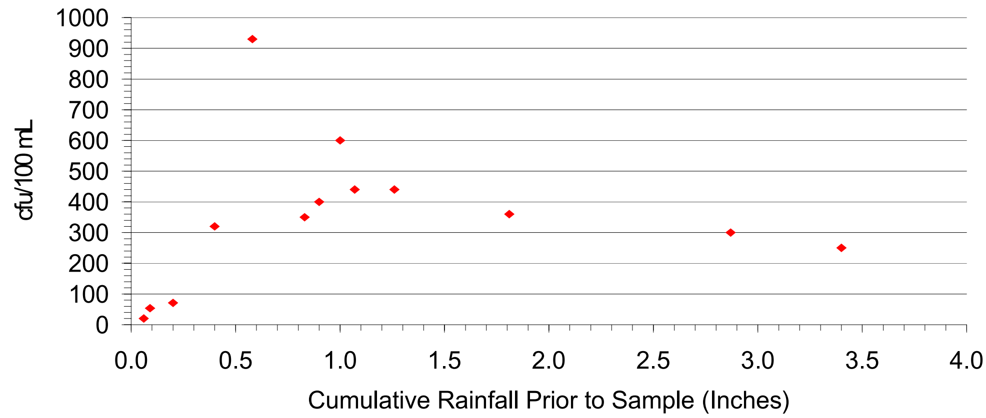


Figure 5.4-5b
CE Fecal Coliform Concentrations and Turbidity
(n = 13)

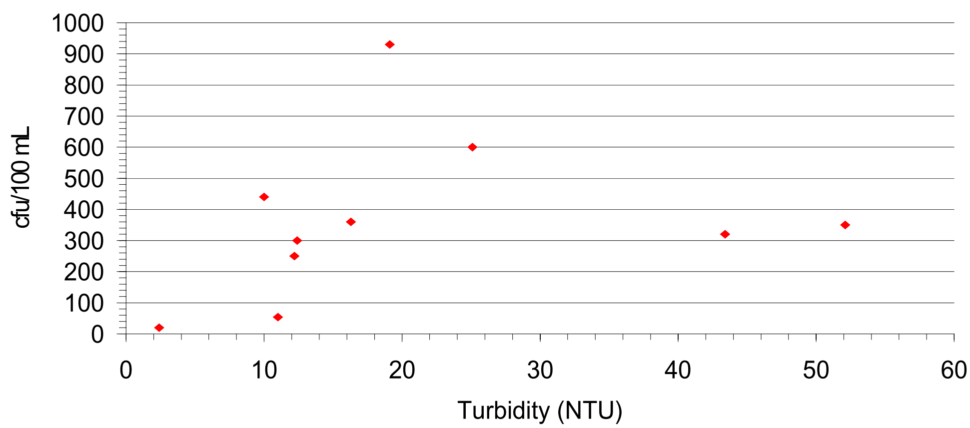
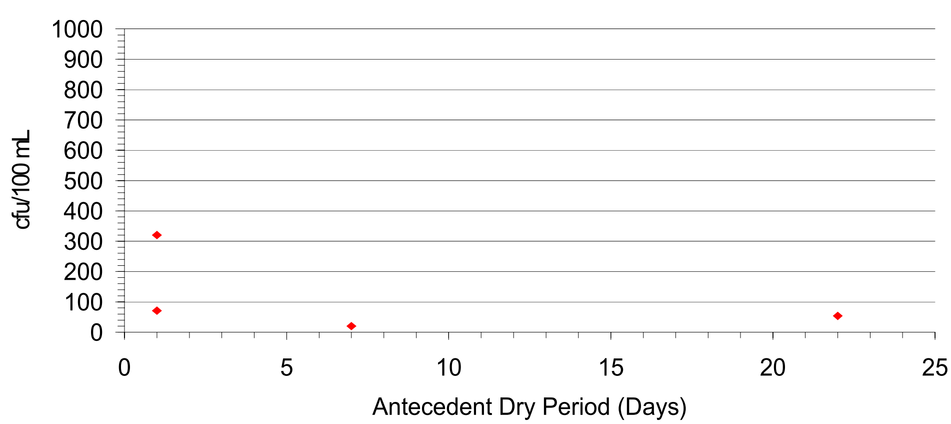


Figure 5.4-5b
CE Fecal Coliform Concentrations and Antecedent Dry Period
(n =4)



When viewed as a whole data set (n = 13), Figures 5.4-5a-c show no distinct relationship between the 3 physical parameters and storm flow FC concentrations. Although, similar to BA, the semi-consistent pattern of low to high to medium FC concentrations in each event is interesting and is apparent somewhat as shown in Figure 5.4-5a.

Overall, storm flow FC concentrations at CE are higher than most other sites. This could potentially be a function of the semi-developed nature of the 3.78 mi^2 CC Watershed, which consists primarily of low to medium density residential and forested/open space land uses. However, further analysis is necessary to determine the sources of elevated FC concentrations in storm flow at CE.

5.4.6 Chico Creek

Table 5-8 presents storm flow FC and associated turbidity readings associated with each storm event sampled at CH and Figures 5.4-6a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Table 5-8: CH Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	100	N/A
	2	37	N/A
	3	37	N/A
SSE #2			
	1	43	2.8
	2	51	3.2
	3	217	4.5
SSE #3			
	1	170	6.1
	2	54	9.7
	3	40	21.8
SSE #4			
	1	120	6.7
	2	14	2.0
	3	40	4.4
	4	40	2.5
SSE #7			
	1	69	85.6
	2	80	93.8
	3	38	87.5
	4	220	15.4
Dry Season Average		N/A	0.0

Figure 5.4-6a
CH Fecal Coliform Concentrations and Cumulative Rainfall
(n = 17)

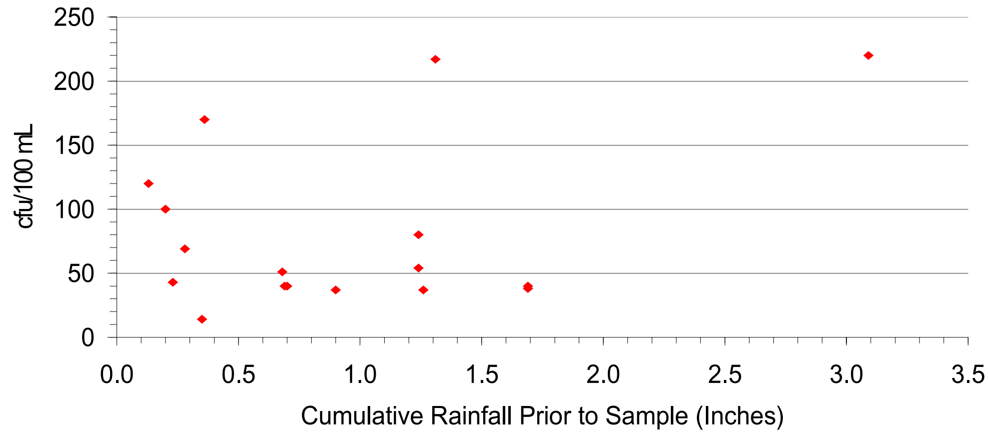


Figure 5.4-6b
CH Fecal Coliform Concentrations and Turbidity
(n = 17)

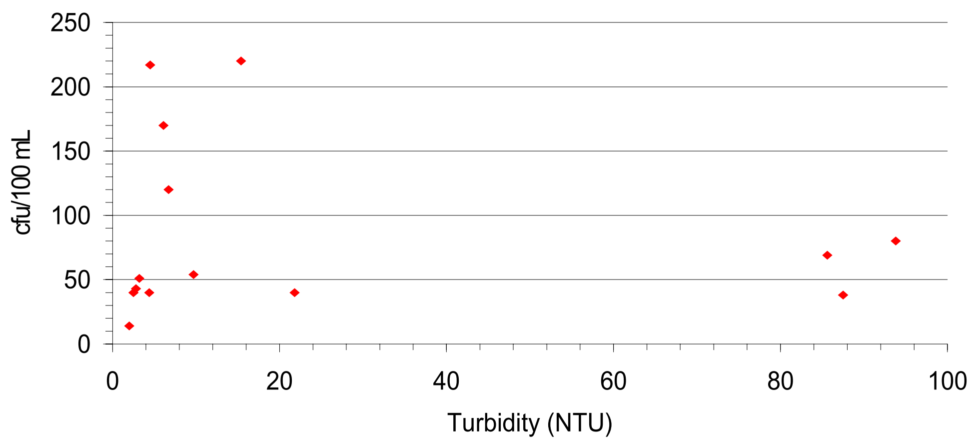
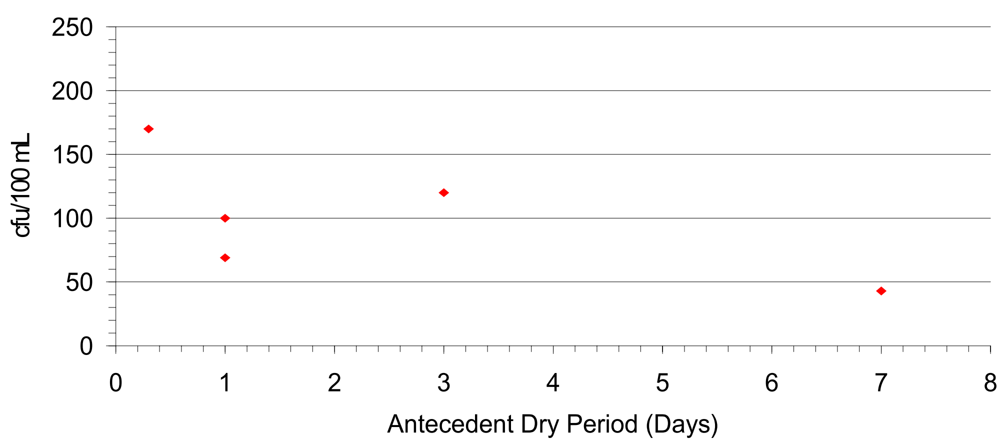


Figure 5.4-6c
CH Fecal Coliform Concentrations and Antecedent Dry Period
(n = 5)



CH was sampled on 5 different occasions, more than any other site. Storm flow FC concentrations at CH ranged from 14 CFU/100 mL to 220 CFU/100 mL and the average concentration was 80 CFU/100 mL. The lowest concentration was recorded during Round 2 of SSE #4. This sample was associated with approximately 0.35” of cumulative rainfall and a turbidity reading of 2.0 NTU. Conversely, the highest concentration was recorded in Round 4 of SSE #7. This sample was associated with approximately 3.09” of cumulative rainfall and a turbidity reading of 15.4.

For 3 of the 5 sampled storms (SSE #1, SSE #3, and SSE #4), storm flow FC concentrations were greatest during Round 1 and then much lower in later rounds. CH was the only site that exhibited this first flush data on more than one occasion. However, during SSE #2 and SSE #7, FC concentrations increased throughout the event and reached their peak during the last round, a trend directly opposite that of the other 3 storms.

SSE #1 and SSE #2 were similar in total rainfall but SSE #2 had a longer ADP (7 days vs. 1 day). Both Round 1 samples from each storm were taken at about the same cumulative rainfall total, yet given the longer ADP associated with SSE #2 and the observed first flush phenomenon from 3 of the events, the same first flush behavior would be expected for SSE #2 as well. Instead, there is a lag until near the end of the sample event when FC concentrations peaked.

Some of the highest storm flow FC concentrations were recorded when turbidity values were at their lowest and conversely, the highest turbidity values corresponded to only medium-high FC concentrations. While CH tends to show a first flush response, it also shows a “last flush” response, which makes it difficult to draw any conclusions as to what storm flow FC concentrations may be correlated with, if anything.

CH was one of the cleaner streams with respect to storm flow FC concentrations when compared to the other sites. This could potentially be a function of the relatively undeveloped nature of the 15.3 mi^2 CH Watershed, which consists primarily of rural and forested/open space areas. However, further analysis is necessary to determine the sources of FC in storm flow at CH.

5.4.7 Chico Tributary

Table 5-9 presents storm flow FC and associated turbidity readings associated with each storm event sampled at CT and Figures 5.4-7a-b present storm flow FC concentrations vs. cumulative rainfall and turbidity, respectively.

Table 5-9: CT Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #3			
	1	47	3.9
	2	69	17.7
	3	65	17.1
SSE #4			
	1	26	4.4
	2	6	3.0
	3	11	3.3
	4	11	2.3
Dry Season Average		N/A	0.1

Figure 5.4-7a
CT Fecal Coliform Concentrations and Cumulative Rainfall
(n = 7)

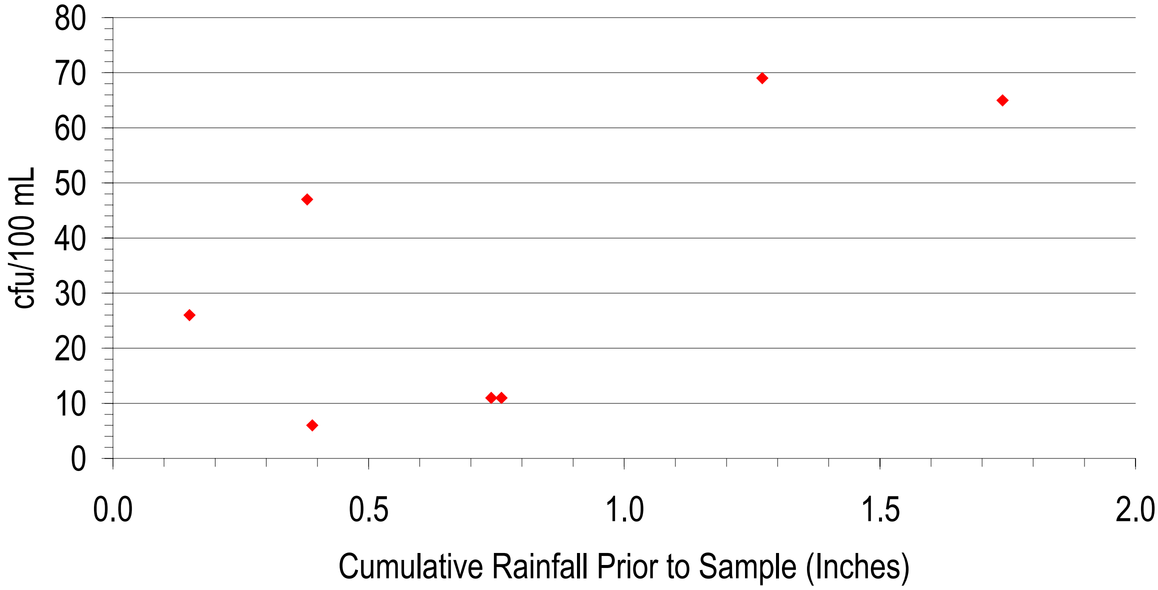
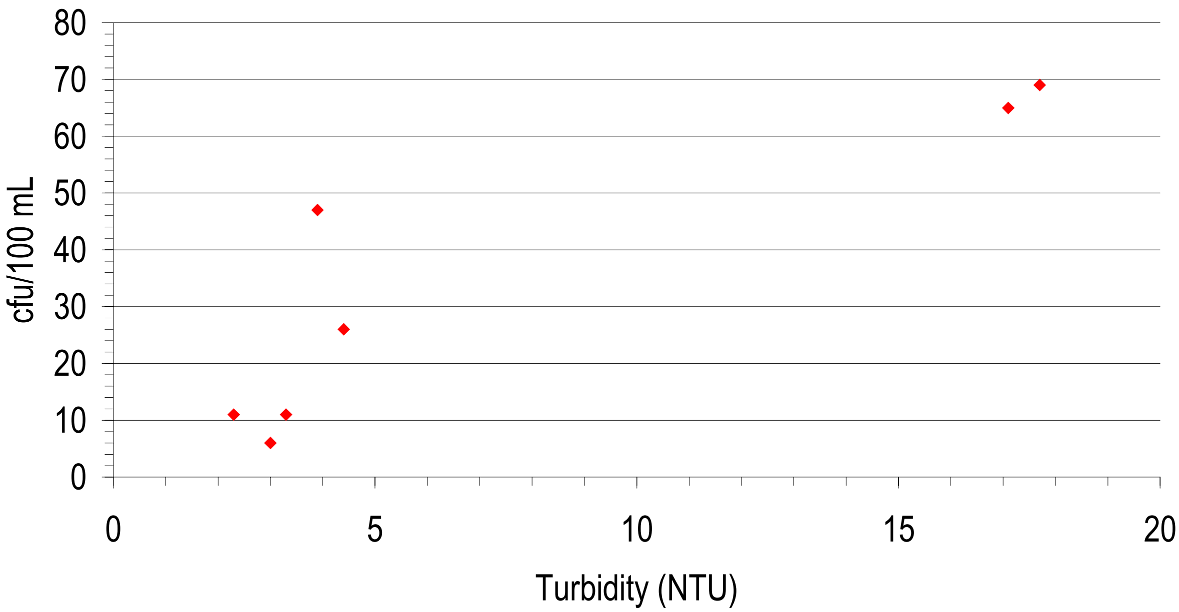


Figure 5.4-7b
CT Fecal Coliform Concentrations and Turbidity
(n = 7)



Storm flow FC concentrations at CT ranged from 6 CFU/100 mL to 69 CFU/100 mL and the average concentration was 34 CFU/100 mL, the lowest average of all 11 storm sampling sites. The lowest concentration was recorded during Round 2 of SSE #3. This sample was associated with approximately 0.39” of cumulative rainfall and a turbidity reading of 3.0 NTU. Conversely, the highest concentration was recorded in Round 2 of SSE #4. This sample was associated with approximately 1.27” of cumulative rainfall and a turbidity reading of 17.7.

CT exhibited a first flush effect for SSE #4, as did CH. In fact, storm flow FC concentrations from each of the 4 rounds trend much like CH, even so far as to have the same value repeated for the last 2 rounds of sampling. However, for SSE #3, CT did not exhibit a first flush effect, unlike CH, as FC concentrations increased from Round 1 to Round 2, then decreased from Round 2 to Round 3.

Storm flow FC concentrations were higher during SSE #3 than SSE #4. A check of the data reveals that the ADP for SSE #3 was 7 hours (vs. 3 days for SSE #4) and that the cumulative rainfall for SSE #3 was an inch greater than that for SSE #4. Therefore, the data suggest that storm flow FC concentrations at CT appear to be most influenced by cumulative rainfall rather than ADP (Figure 5.4-7a). Even stronger is the apparent relationship between storm flow FC concentrations and turbidity, as shown on Figure 5.4-7b. The data set for ADP is too short to determine if a correlation exists.

CT was the cleanest stream with respect to storm flow FC concentrations when compared to the other sites. This could potentially be a function of the relatively undeveloped nature of the 9.28 mi^2 CT Watershed, which consists primarily of rural and forested areas. However, further analysis is necessary to determine the sources of FC in storm flow at CT.

5.4.8 Clear West

Table 5-10 presents storm flow FC and associated turbidity readings associated with each storm event sampled at CW (dry season data was not available), and Figures 5.4-8a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Storm flow FC concentrations at CW ranged from 6 CFU/100 mL to 360 CFU/100 mL and the average concentration was 173 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #6. This sample was associated with 0.09” of cumulative rainfall, a turbidity reading of 9.2 NTU, and an ADP of 22 days. The highest concentration was recorded during SSE #7 in Round 2. This sample was associated with 1.77” of cumulative rainfall and a turbidity reading of 46.0 NTU.

Storm flow FC concentration data for CW are more similar to those collected at BA than those collected from CE and CC. Similar to BA, storm flow FC concentrations were twice as high during SSE #2 as during SSE #1 and only slightly higher during SSE #6 than during SSE #2. In addition, the highest FC concentrations at CW were recorded during SSE #7. Unlike CC and CE, it appears that the cumulative rainfall total has a greater influence on FC concentrations than ADP at CW. This observation is strengthened by observing Figure 5.4-8a. However, though cumulative rainfall appears to be the dominant factor, the ADP is also important, as shown by comparing the FC concentrations between SSE #1 and SSE #2.

Although it appears that storm flow FC concentrations decrease with an increase in the ADP (Figure 5.4-8c), this appearance is misleading due to the times at which the samples were taken (i.e., the Round 1 samples from SSE #2 and SSE #6 were taken after only 0.05” and 0.09” of rain, respectively; basically base flow conditions). As discussed in CC previously, it appears that the relatively lower FC concentrations (as compared to CE) present in the storm flow at CW serve to slightly decrease FC concentrations at CC.

Table 5-10: CW Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	108	N/A
	2	104	N/A
	3	124	N/A
SSE #2			
	1	11	0.0
	2	243	33.7
	3	240	12.6
SSE #6			
	1	6	9.2
	2	250	53.1
	3	300	40.0
SSE #7			
	1	150	56.0
	2	360	46.0
	3	260	38.7
	4	123	39.6

Overall, average storm flow FC concentrations at CW represent the median average storm flow FC concentration when compared with the other sites. The majority of the 3.68 mi^2 CW Watershed consists of forested/open space. While CE and CW have nearly identically-sized watersheds, the land use within each watershed is slightly different. Unlike CE, CW has less developed area, which could be the reason why FC concentrations are lower at CW than at CE. However, additional analysis is necessary to determine the sources of FC in storm flow at CW.

5.4.9 Gorst Creek

Table 5-11 presents storm flow FC and associated turbidity readings associated with each storm event sampled at GC and Figures 5.4-9a-b present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Storm flow FC concentrations at GC ranged from 8 CFU/100 mL to 310 CFU/100 mL and the average concentration was 71 CFU/100 mL. The lowest concentration was recorded during Round 2 of SSE #3. This sample was associated with approximately 1.15" of cumulative rainfall and a turbidity reading of 4.8 NTU. Conversely, the highest concentration was also during SSE #3, during Round 2. This sample was associated with approximately 0.40" of cumulative rainfall, an ADP of 7 hours, and a turbidity reading of 26.2.

GC exhibited a first flush effect for SSE #3 and a muted first flush effect during SSE #4. After the first round, storm flow FC concentrations decreased exponentially to low concentrations, as did turbidity. FC concentrations in SSE #4 decreased from Round 1 to Round 2, then increased from Round 2 to Round 3, then decreased again from Round 3 to Round 4. Turbidity readings were highest when storm flow FC concentrations were highest. This relationship is shown on Figure 5.4-9b. The data set for ADP is too short to determine if a correlation exists.

Figure 5.4-8a
CW Fecal Coliform Concentrations and Cumulative Rainfall
(n = 13)

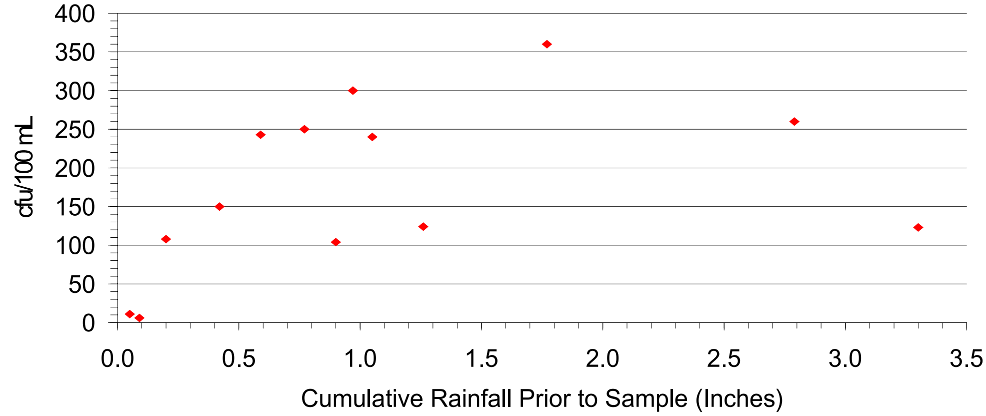


Figure 5.4-8b
CW Fecal Coliform Concentrations and Turbidity
(n = 13)

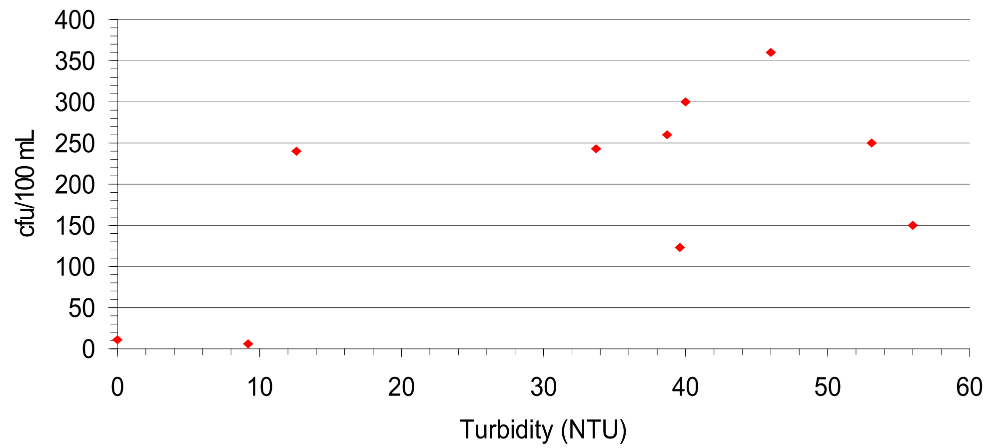


Figure 5.4-8c
CW Fecal Coliform Concentrations and Antecedent Dry Period
(n = 4)

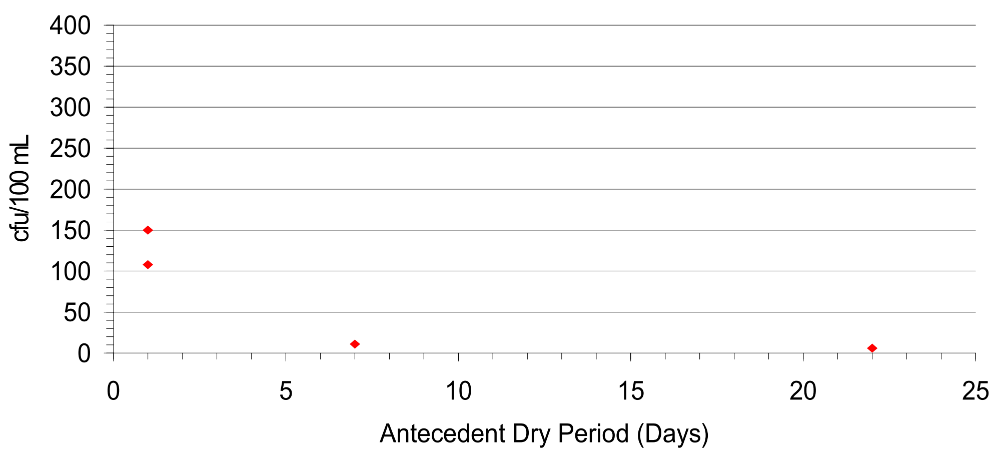


Table 5-11: GC Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #3			
	1	310	26.2
	2	8	4.8
	3	23	5.3
SSE #4			
	1	46	8.5
	2	26	5.1
	3	66	22.0
	4	20	3.7
Dry Season Average		N/A	0.5

The average storm flow FC concentration from SSE #3 was greater than that from SSE #4, which indicates that FC concentrations at GC appear to be most influenced by cumulative rainfall rather than the ADP. However, as shown in Figure 5.4-9a, this relationship is not fully developed.

The GC Watershed serves as the backup surface water supply for the City of Bremerton. As such, the 9.08 mi^2 watershed is almost entirely forested (i.e., undeveloped). Thus, the high initial FC concentration is not consistent with the undeveloped nature of the watershed. As noted by TEC staff during the sampling season, the area is habituated by a variety of wildlife. The abundance of wildlife in and around the sample site could be a contributing factor to elevated initial FC concentrations; however, further analysis is necessary to determine the sources of FC in storm flow at GC.

5.4.10 Olney Creek

Table 5-12 presents storm flow FC and associated turbidity readings associated with each storm event sampled at OC and Figures 5.4-10a-b present storm flow FC concentrations vs. cumulative rainfall and turbidity, respectively.

Table 5-12: OC Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #3			
	1	2,000	159.6
	2	200	24.3
	3	130	15.4
SSE #4			
	1	540	43.7
	2	1,233	34.3
	3	1,500	108.8
SSE #6			
	1	2,300	75.8
	2	4,100	90.1
	3	780	14.3
Dry Season Average		N/A	15.9

Figure 5.4-9a
GC Fecal Coliform Concentrations and Cumulative Rainfall
(n = 7)

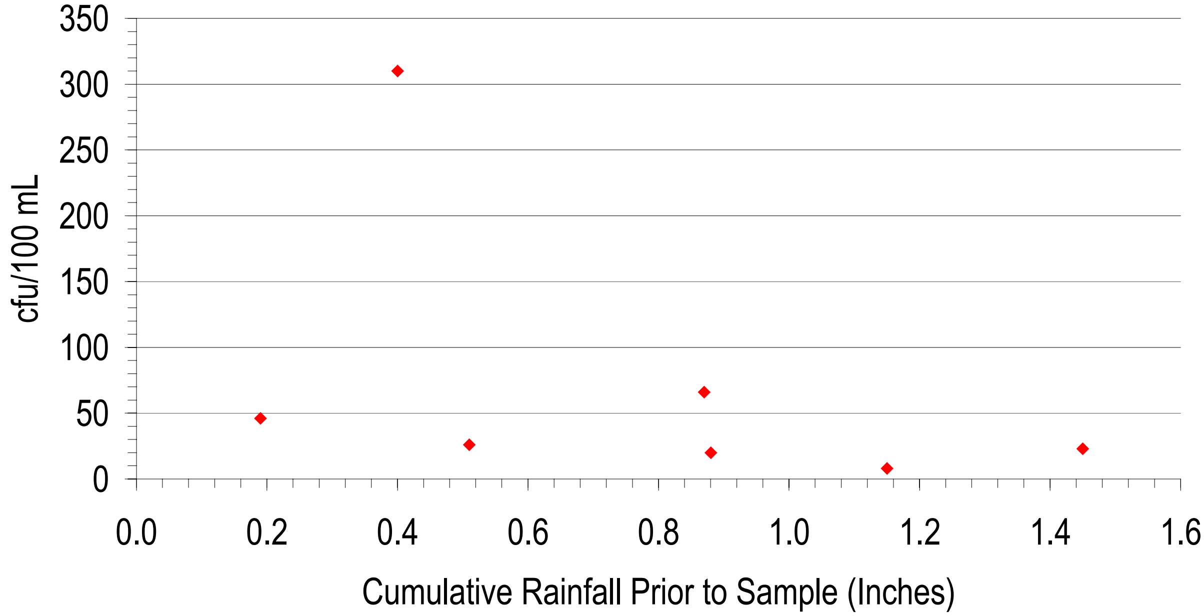


Figure 5.4-9b
GC Fecal Coliform Concentrations and Turbidity
(n = 7)

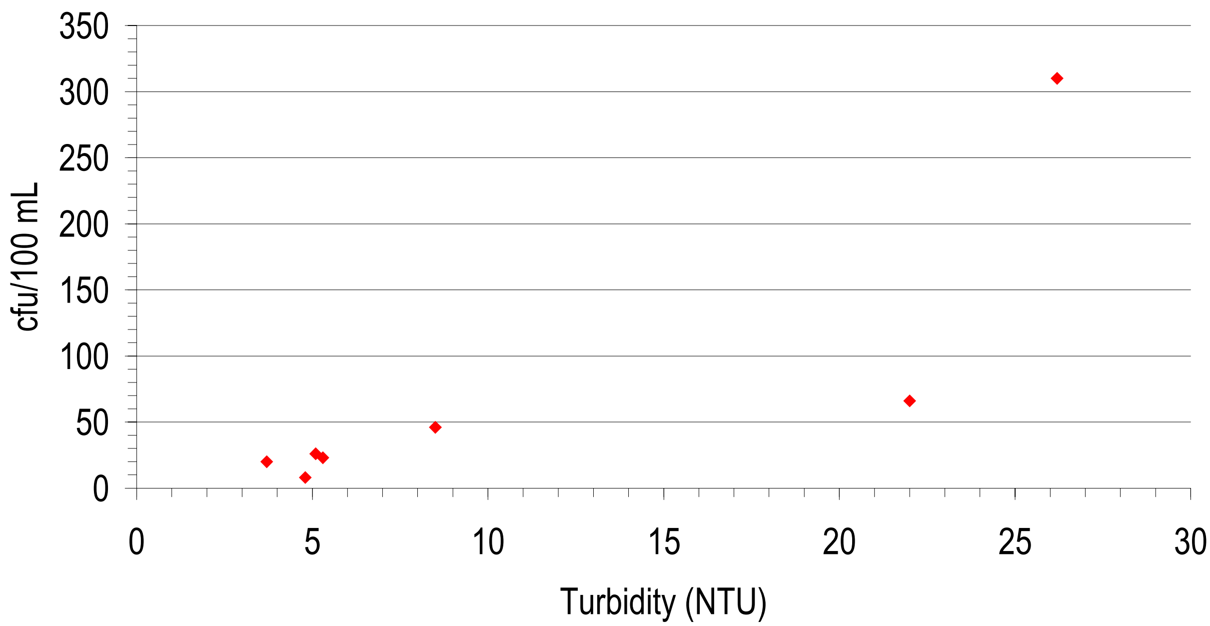


Figure 5.4-10a
OC Fecal Coliform Concentrations and Cumulative Rainfall
(n = 9)

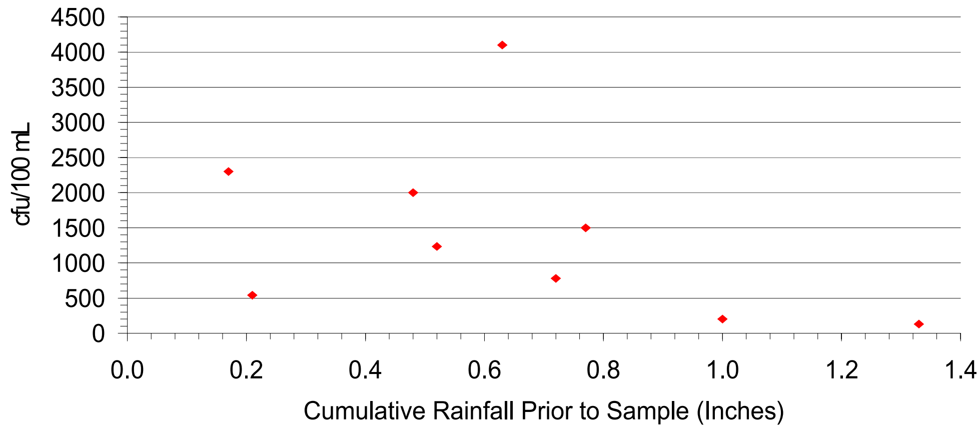


Figure 5.4-10b
OC Fecal Coliform Concentrations and Turbidity
(n = 13)

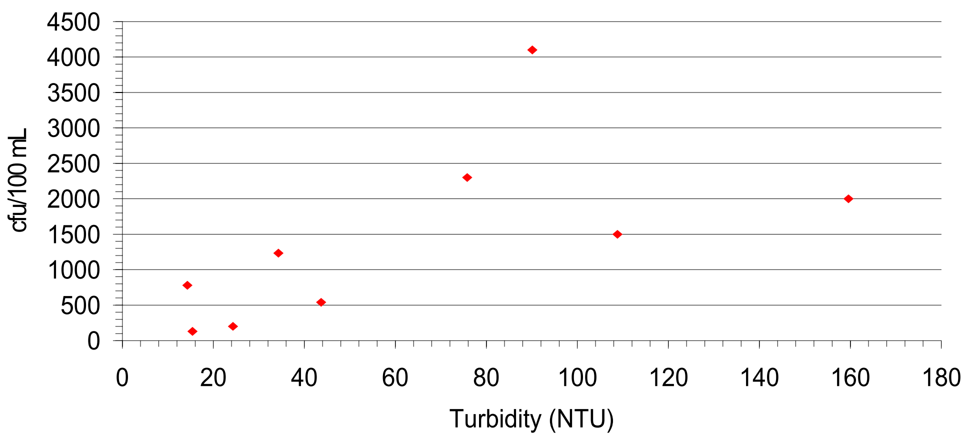
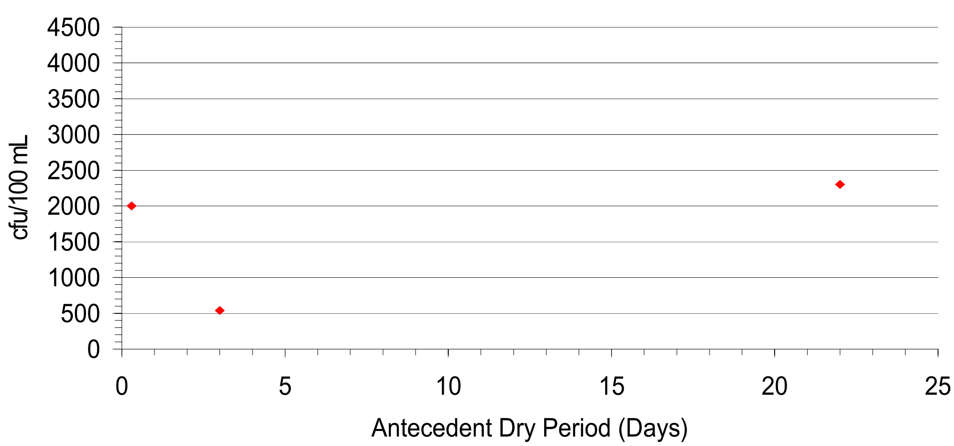


Figure 5.4-10c
OC Fecal Coliform Concentrations and Antecedent Dry Period
(n = 3)



Storm flow FC concentrations at OC ranged from 130 CFU/100 mL to 4,100 CFU/100 mL and the average concentration was 1,420 CFU/100 mL, by far the highest of all 11 sampling sites. The lowest concentration was recorded during Round 3 of SSE #3. This sample was associated with approximately 1.33" of cumulative rainfall and a turbidity reading of 15.4 NTU. Conversely, the highest concentration was recorded during Round 2 of SSE #6. This sample was associated with approximately 0.63" of cumulative rainfall and a turbidity reading of 90.1 NTU.

OC exhibited a near textbook first flush effect for SSE #3. After the first round of sampling, storm flow FC concentrations decreased exponentially to low concentrations, as did turbidity. FC concentrations in SSE #4 increased from Round 1 to Round 2 and from Round 2 to Round 3, as did turbidity. During SSE #6, FC concentrations increased from Round 1 to Round 2, then decreased from Round 2 to Round 3, as did turbidity. This correlation between FC concentrations and turbidity is shown on Figure 5.4-10b.

The OC Watershed is one of the most developed watersheds in the study area. As such, the 1.86 mi^2 watershed contains a large amount of commercial and residential development and therefore, impervious surfaces. Thus, the high storm flow FC concentrations at OC may be a function of the developed nature of the watershed; however, further analysis is necessary to determine the sources of FC in storm flow at OC.

5.4.11 Strawberry Creek

Table 5-13 presents storm flow FC and associated turbidity readings associated with each storm event sampled at SC (dry season data was not available) and Figures 5.4-11a-c present storm flow FC concentrations vs. cumulative rainfall, turbidity, and ADP, respectively.

Storm flow concentrations at SC ranged from 23 CFU/100 mL to 1,300 CFU/100 mL and the average concentration was 361 CFU/100 mL. The lowest concentration was recorded during Round 1 of SSE #6. This sample was associated with approximately 0.09" of cumulative rainfall, a turbidity reading of 22.9 NTU, and an ADP of 22 days. Conversely, the highest concentration was recorded in Round 1 of SSE #7. This sample was associated with approximately 0.28" of cumulative rainfall and a turbidity reading of 129 NTU.

Throughout the first 3 sample events, storm flow FC concentrations generally behaved in the same manner: Round 1 samples were the lowest, Round 2 samples (corresponding to the peak runoff) were the highest, and then successive Rounds (3 and 4) were less than Round 2 but higher than Round 1 – corresponding to a slow decrease in FC concentrations. In short, storm flow FC concentrations at SC appear to mirror the unit hydrograph. Unlike the previous 3 sampling events, SC exhibited a first flush effect for SSE #7. After the first round of sampling, storm flow FC concentrations decreased exponentially to low concentrations.

Table 5-13: SC Storm Flow FC Concentrations and Turbidity

Storm/Round #		*FC Concentration (CFU/100 mL)*	*Turbidity (NTU)*
SSE #1			
	1	100	N/A
	2	169	N/A
	3	174	N/A
SSE #2			
	1	237	42.1
	2	340	19.7
	3	251	11.2
SSE #6			
	1	23	22.9
	2	550	112.7
	3	290	10.4
SSE #7			
	1	1,300	129.0
	2	620	523.4
	3	340	297.0
	4	300	1,412.0

While the total rainfall for SSE #6 was similar to SSE #1 and SSE #2, storm flow FC concentrations were much higher (except for Round 1 which was taken after only 0.09" of cumulative rainfall, much less than the other 2 SSEs). A check of the ADP for each of the 3 events shows that SSE #6 had the longest ADP (22 days vs. 1 and 7 days, respectively). Therefore, it can be hypothesized that for similar storm events, FC concentrations will be higher at SC when the ADP is longer. This hypothesis is strengthened when SSE #1 and SSE #2 are compared. Both events resulted in similar rainfall totals; however, storm flow FC concentrations from SSE #2 were approximately double of those in SSE #1 and FC concentrations from SSE #6 Rounds 2 and 3 were higher than those from SSE #2.

SSE #1 and SSE #7 had a similar ADP – approximately 1 day. However, the rainfall totals were greatly different and the storm flow FC concentrations were much higher in SSE #7 and #1. Similar to BA, FC concentrations at SC appear to be higher during wetter storm events for similar ADPs.

When viewed as a whole data set (n = 13), Figures 5.4-11a-c show no distinct relationship between the 3 physical parameters and storm flow FC concentrations; although the consistent pattern of low to high to medium FC concentrations in each event is interesting and is apparent somewhat as shown in Figure 5.4-11a.

Overall, SC had the second-highest average storm flow FC concentration. As the 3.01 mi^2 SC Watershed consists primarily of commercial and residential land uses, the elevated FC concentrations are not surprising and are similar to those found at OC. Thus, the high FC concentrations at SC can be considered consistent with the developed nature of the watershed; however, site specific differences exist between the 2 watersheds and further analysis is necessary to determine the sources of FC in storm flow at SC.

Figure 5.4-11a
SC Fecal Coliform Concentrations and Cumulative Rainfall
(n = 13)

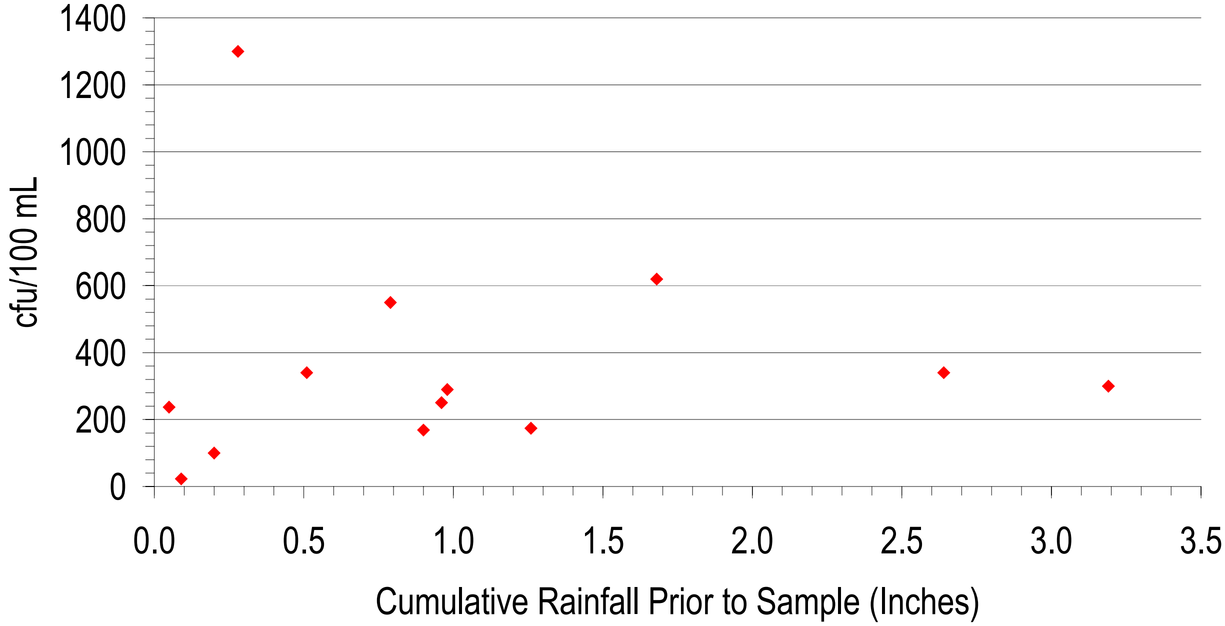
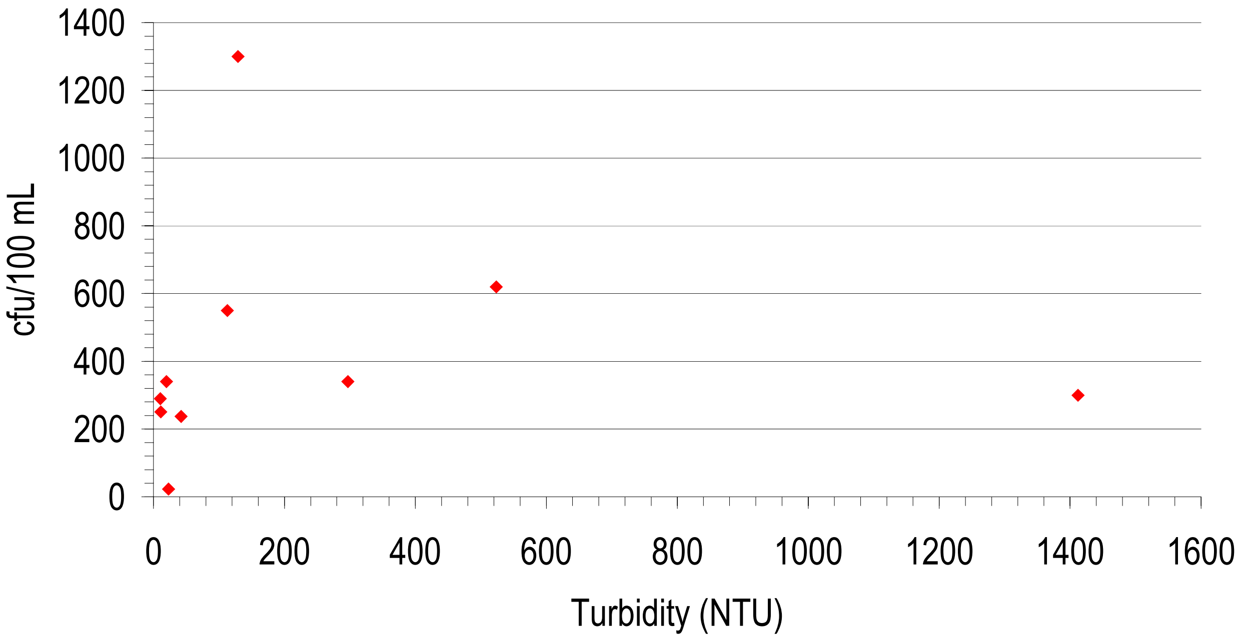


Figure 5.4-11b
SC Fecal Coliform Concentrations and Turbidity
(n = 13)



5.4.12 Summary Analysis by Site

Figures 5.4-12, 5.4-13, and 5.4-14 present storm flow FC data collected from all sites (not including duplicates) compared to cumulative rainfall, turbidity, and ADP, respectively. As shown in these figures, no noticeable trend or relationship between storm flow FC concentrations and these 3 physical-chemical/watershed parameters. However, while no generalizations can be applied to the project area as a whole, it is clear that site-specific relationships between storm flow FC concentrations and 1 or more of the 3 physical parameters in certain watersheds do exist. For example, FC concentrations at both BL and CT appear to increase with an increase in cumulative rainfall and FC concentrations at GC, CT, and OC appear to track well with turbidity. However, at other sites FC concentrations do not appear to be influenced more strongly by one condition or another, but rather, cumulative rainfall and ADP appear to have a near equal influence on FC concentrations when the project area is viewed as a whole. Specifically, the data show that storm flow FC concentrations generally increased during wetter storms and storm flow FC concentrations generally increased in storms with longer ADP. Clearly, these two factors are major factors in influencing FC concentrations.

While these two factors have proven to influence storm flow FC concentrations, they do not, however, appear to be as influential as the level of urbanization, or more specifically, the level of commercial development within the watershed. For example, OC and SC returned the highest average FC concentrations during the sampling season. The watersheds associated with these two sites are also the most developed, with high percentages of commercial development. Consistent with previously cited studies, it appears that storm flow FC concentrations at OC and SC are a function of the urbanized nature of the watersheds. Conversely, GC, AC, CH, and CT returned the lowest average FC concentrations, which have a low level of urbanization.

Based on data collected during this study, the timing of peak FC concentrations appeared to vary from site to site during the sample events; peak FC concentrations did not occur at the same stage of the sample event at each site. However, some sites (AC, CH, GC, and OC) did display a first flush effect during some storms. In summary, no general FC concentration response for the project area as a whole can be concluded from this data.

CE had consistently high storm flow FC concentrations during all sampled events, no matter what the cumulative rainfall total or ADP. While CC had lower peak and average storm flow FC concentrations than OC, the consistently high FC concentrations appear to indicate a persistent FC pollution problem at CC as FC concentrations were high during all rounds of sampling, whereas storm flow FC concentrations at OC exhibited a first flush effect during 3 storms.

The timing of the first sample round appears to be important. A check of the data reveals that a total of 10 samples were taken before 0.10” of cumulative rainfall. With 2 exceptions (SC and BA, which were consistently high throughout the sample season), these samples were found to contain comparatively low FC concentrations as compared to subsequent sample rounds during the same event. However, FC samples taken after 0.10” of rain were higher as it appears more storm flow is necessary to mobilize FC. Therefore, it appears that FC concentrations do not rise above what can be proposed as baseline concentrations until approximately 0.10” of cumulative rainfall.

While site specific differences may exist, it is possible that more sites would have exhibited a first flush response if the first sample round was taken after more rainfall had occurred. In light of this, it is recommended that future sampling efforts be sure to hold off taking the first round of FC samples until at least 0.10” of cumulative rainfall. It is also recommended that future sampling efforts increase the number of FC samples taken at each site per sample event (from 3 to perhaps 5 or 6) to provide additional data points for enhancing the ability for analyzing potential relationships between FC concentrations and physio-chemical and meteorological conditions.

Figure 5.4-12
Fecal Coliform Concentrations and Cumulative Rainfall
(n=121)

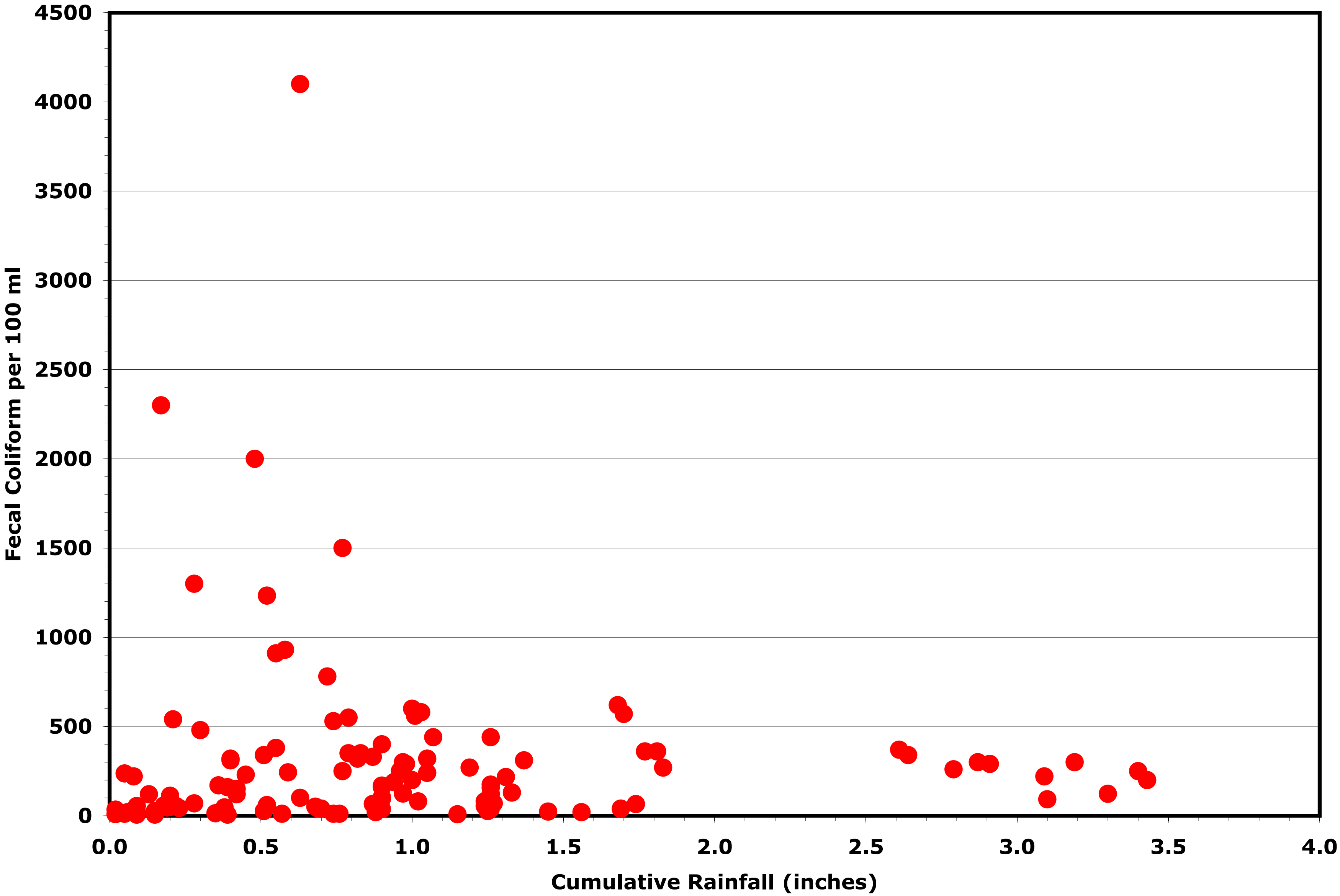


Figure 5.4-13
Fecal Coliform Concentrations and Antecedent Dry Period
(n = 37)

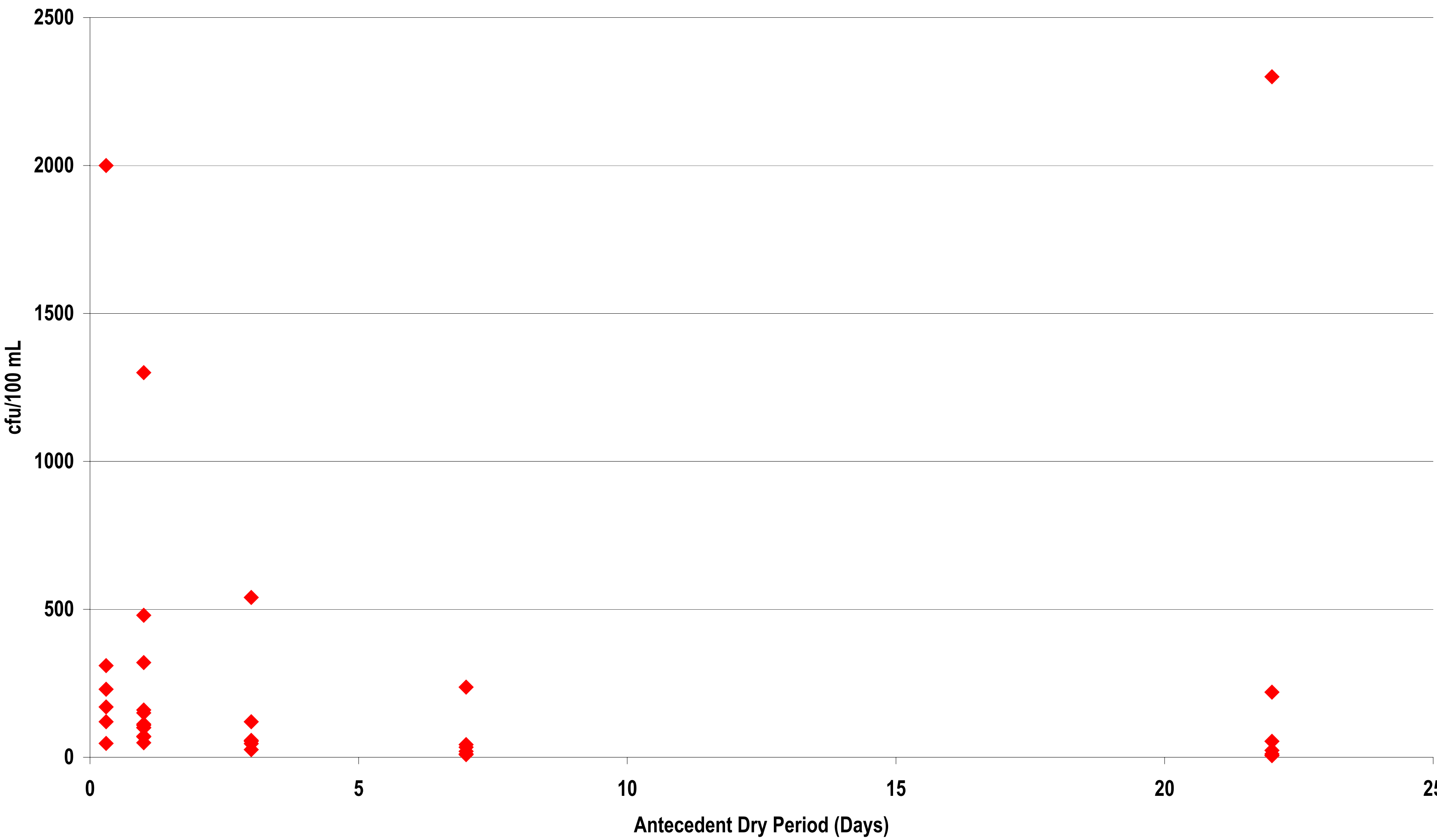
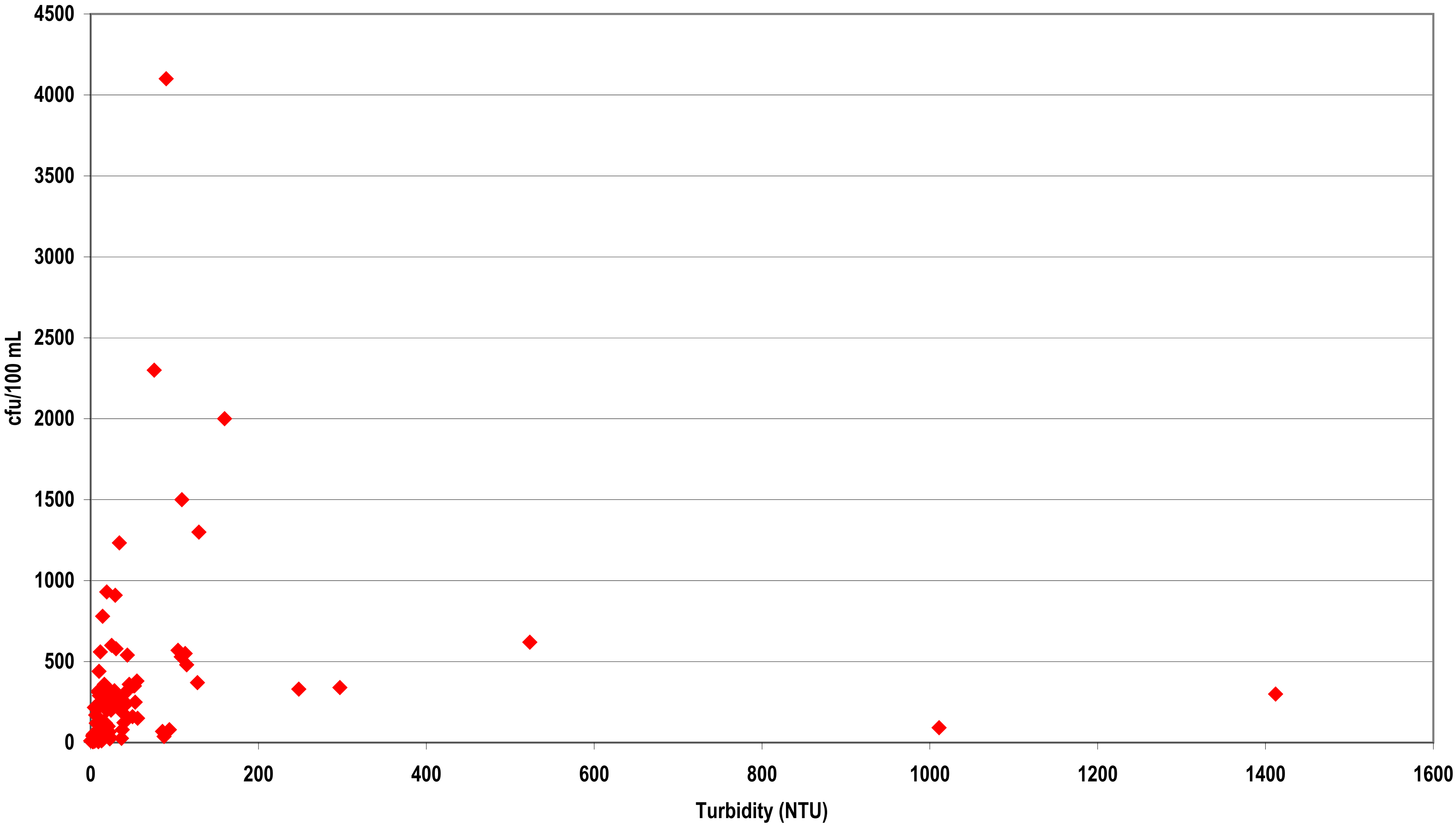


Figure 5.4-14
Fecal Coliform Concentrations and Turbidity
(n = 102)



5.5 STORM FLOW FECAL COLIFORM CONCENTRATIONS

This section explores the relationship between collected in-stream storm flow FC data and land use within the PSNS Project ENVVEST study area. Land use within the study area has been assigned the following categories: % urban high density, % urban, % total impervious area, road density, % urban-commercial-industrial, % suburban, % rural residential, % rural, % rural agricultural, and % forest. This land use data supplied by the PSNS ENVVEST team for each watershed has been plotted against the geometric mean FC concentrations for each sampling site.

Table 5-14 presents the geometric mean and average storm flow FC concentrations and the sample size (n) for each sample site (not including duplicates). The sample size for each site ranged from a high of 17 at CH to a low of 6 at AC. As shown in Table 5-14, OC had the highest geometric mean storm flow FC concentration at 899 CFU/100 mL, almost 4 times greater than the next highest site (SC). SC and CE were the next highest sites with average values of 254 CFU/100 mL and 242 CFU/100 mL, respectively. CC, BA, CW, and BL were near average, with average storm flow FC concentrations of 156 CFU/100 mL, 210 CFU/100 mL, 116 CFU/100 mL, and 106 CFU/100 mL, respectively. CH, AC, and GC had average storm flow FC concentrations of 62 CFU/100 mL, 42 CFU/100 mL, and 37 CFU/100 mL, respectively. CT had the lowest average storm flow FC value, at 24 CFU/100 mL.

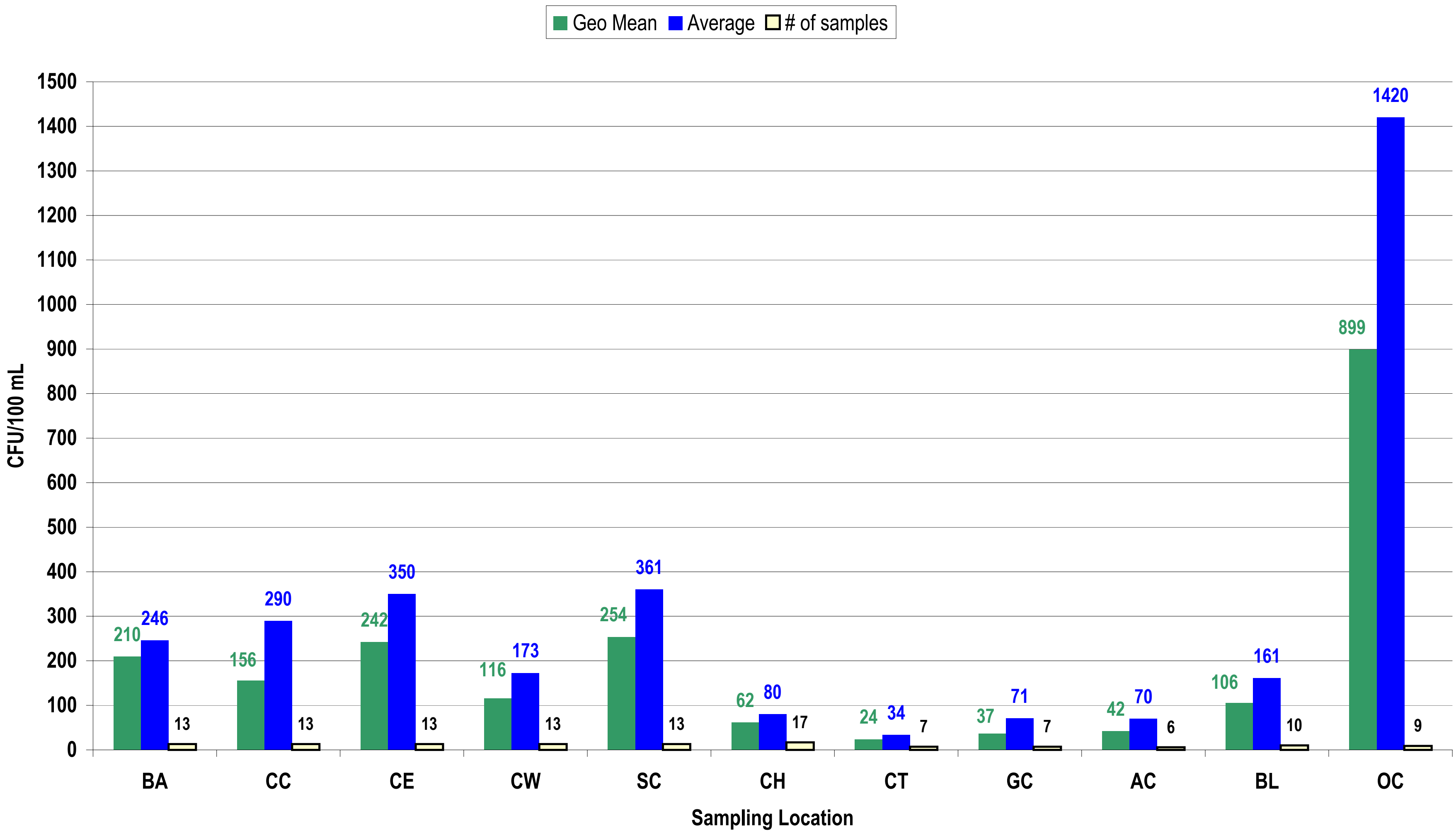
For comparison purposes, the fresh water quality standard (Class A Waters) for FC is geometric mean ≤ 100 CFU/100 mL. Using this standard, 7 of the 11 sampling sites (OC, SC, CE, CC, BA, CW, and BL) do not meet state surface water quality standards. Conversely, only 4 sampling sites (AC, GC, CH, and CT) meet state surface water quality standards.

Table 5-14 depicts the correlation between geometric mean FC concentrations and each of the land use types. As shown in the figure, the % of urban high density within a watershed has the greatest influence on increasing FC concentrations (positive correlation). Conversely, the percent of forest within a watershed has the greatest influence on decreasing FC concentrations (negative correlation). As also shown in the figure, the % of urban-commercial land use within a watershed also has an influence on FC concentrations. In fact, all "urban" land uses (except % suburban) are rather strongly correlated to storm flow fecal coliform concentrations. While the relationship is not as strong, derivatives of rural land use have a lesser influence on storm flow FC concentrations.

Table 5-15 shows that watersheds with a higher percentage of urban high density land use will have higher FC concentrations (geometric mean). Conversely, those watersheds with a higher percentage of forest will have lower FC concentrations (geometric mean). This data confirm the theories put forth earlier in this report – watersheds with a higher percentage of urbanization (specifically urban high density) will have higher FC concentrations and those watersheds that have more forested (un-urbanized) watersheds will have lower FC concentrations.

Table 5-16 presents the geometric mean FC concentration for each site for each storm event sampled. When flow data become available, this data can be used in conjunction with the flow data to approximate in-stream storm flow loading from the creeks during storm events.

Table 5-14
Geometric Mean and Average Storm Flow FC Concentrations by Site
2002-2003 In-Stream Storm Flow Sampling Season



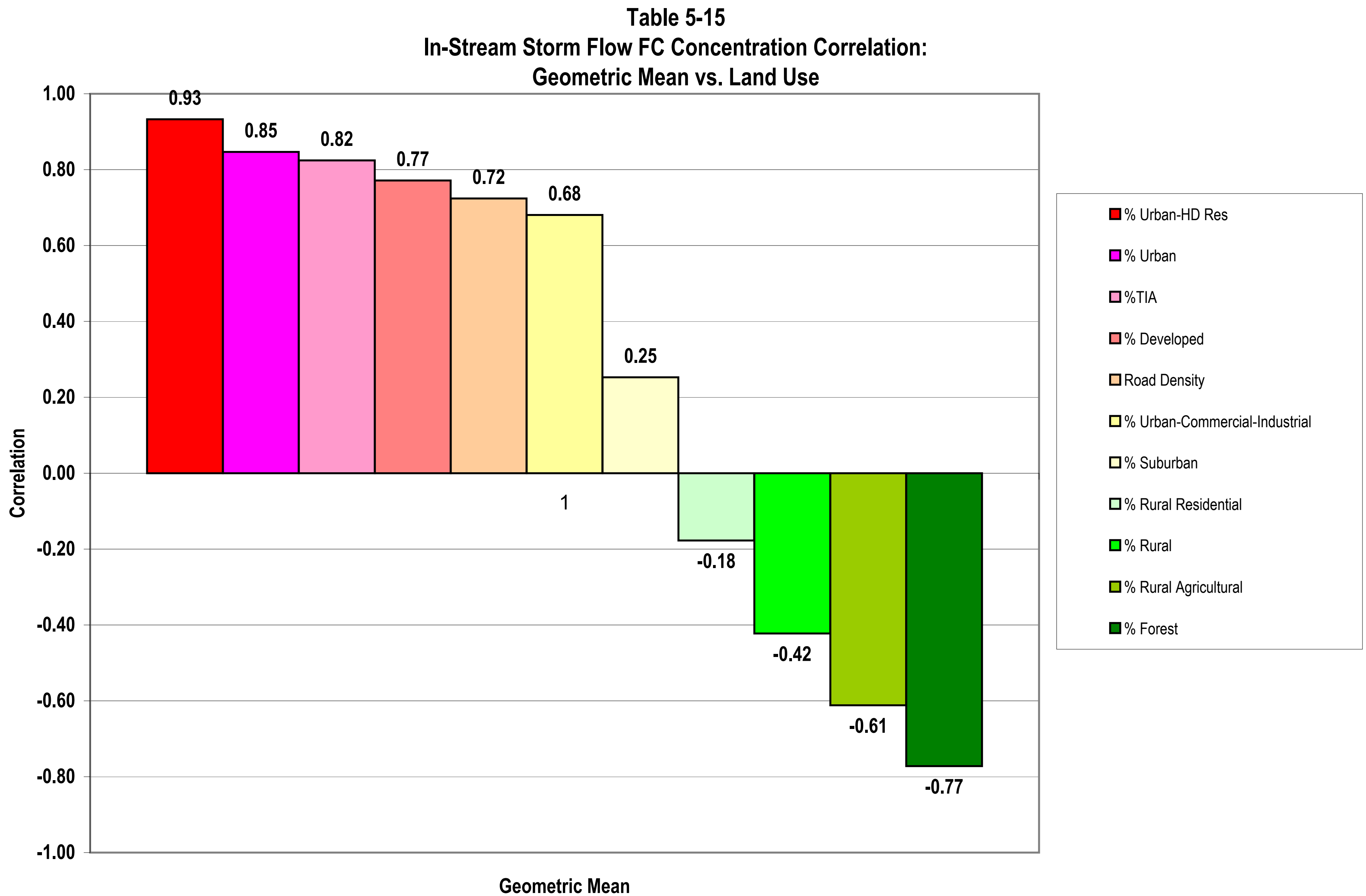


Table 5-15
In-Stream Storm Flow FC Concentration Correlation:
Geometric Mean vs. Land Use
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
Correlation
0.93
0.85
0.82
0.77
0.72
0.68
0.25
1
-0.18
-0.42
-0.61
-0.77
Geometric Mean
% Urban-HD Res
% Urban
%TIA
% Developed
Road Density
% Urban-Commercial-Industrial
% Suburban
% Rural Residential
% Rural
% Rural Agricultural
% Forest

Table 5-16: Storm Event Geometric Mean FC Concentrations by Site

Storm Event #	*Storm Event Geometric Mean FC Concentration by Site*										
	BA	CC	CE	CW	SC	CH	CT	GC	AC	BL	OC
1	**107**	**108**	**232**	**112**	**143**	**52**					
2	**152**	**166**	**94**	**86**	**272**	**78**					
3						**72**	**60**	**39**	**49**	**228**	**373**
4						**40**	**12**	**35**	**36**	**94**	**1,000**
6	**338**	**131**	**225**	**76**	**154**					**58**	**1,945**
7	**311**	**224**	**305**	**204**	**535**	**82**					

Note: No FC samples were taken during Storm Event #5 due to the Martin Luther King Holiday

5.6 DRY SEASON PHYSIO-CHEMICAL DATA

This discussion focuses in on the physio-chemical data collected during the dry season at BA, BL, CH, CT, CC, GC, and OC. Physio-chemical data was collected between 14 May and 28 June. Rainfall data is from GC, when available, as this was the only site with a rain gauge.

5.6.1 Barker Creek

Figure 5.6-1 presents dry season physio-chemical data collected from 28 May to 13 June at BA. Average physio-chemical values were 2.8 NTU, 55.4˚ F, and 152 microseimens/centimeter (µs/cm). Turbidity was low up until about 6 June whereupon turbidity increased. While the GC rainfall record stops prior to this date, a check of Weather Underground data reveals no rain fell within the area between 6 and 13 June. Therefore, the 2 spikes in turbidity were not a result of storm flow. Temperature shows a clear diurnal pattern and increases through the period. Conductivity values were initially high and then decreased.

5.6.2 Blackjack Creek

Figure 5.6-2 presents dry season physio-chemical data collected from 14 May to 6 June at BJ. Average physio-chemical values were 4.6 NTU, 52.7˚ F, and 166 µs/cm. Turbidity values were low up until about 4 June whereupon turbidity increased. As no rain fell within the area during this time, the increase in turbidity was not a direct result of storm flow. Temperature shows a clear diurnal pattern and increased throughout the period. Conductivity values were initially low and then generally increased.

5.6.3 Chico Main

Figure 5.6-3 presents dry season physio-chemical data collected from 20 to 28 June at CH. Average physio-chemical values were 0.0 NTU, 58.6˚ F, and 164 µs/cm. Turbidity values did not change throughout the period. As CH is relatively clear, turbidity values could have been at a low level throughout the period; however, it is more likely that the sonde was not calibrated properly and was therefore not able to pick up the subtle differences in turbidity values. When compared to CT, which had low turbidity values, turbidity values at CH were also likely low throughout the period. Both temperature and conductivity show a clear diurnal pattern and increased throughout the period.

Figure 5.6-1

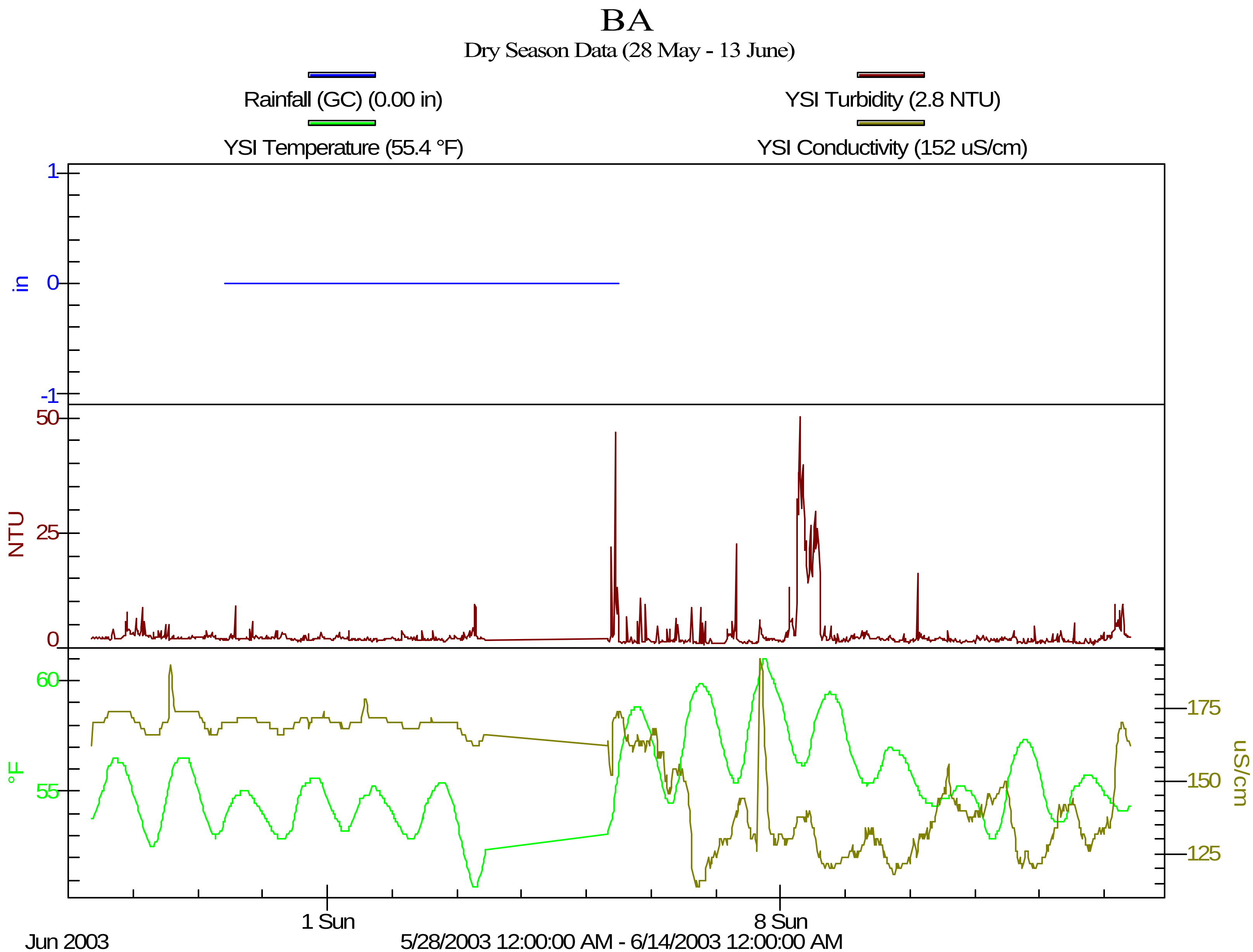

BA
Dry Season Data (28 May - 13 June)
Rainfall (GC) (0.00 in)
YSI Turbidity (2.8 NTU)
YSI Temperature (55.4 °F)
YSI Conductivity (152 uS/cm)
in
1
0
-1
NTU
50
25
0
°F
60
55
uS/cm
175
150
125
1 Sun
8 Sun
Jun 2003
5/28/2003 12:00:00 AM - 6/14/2003 12:00:00 AM

Figure 5.6-2

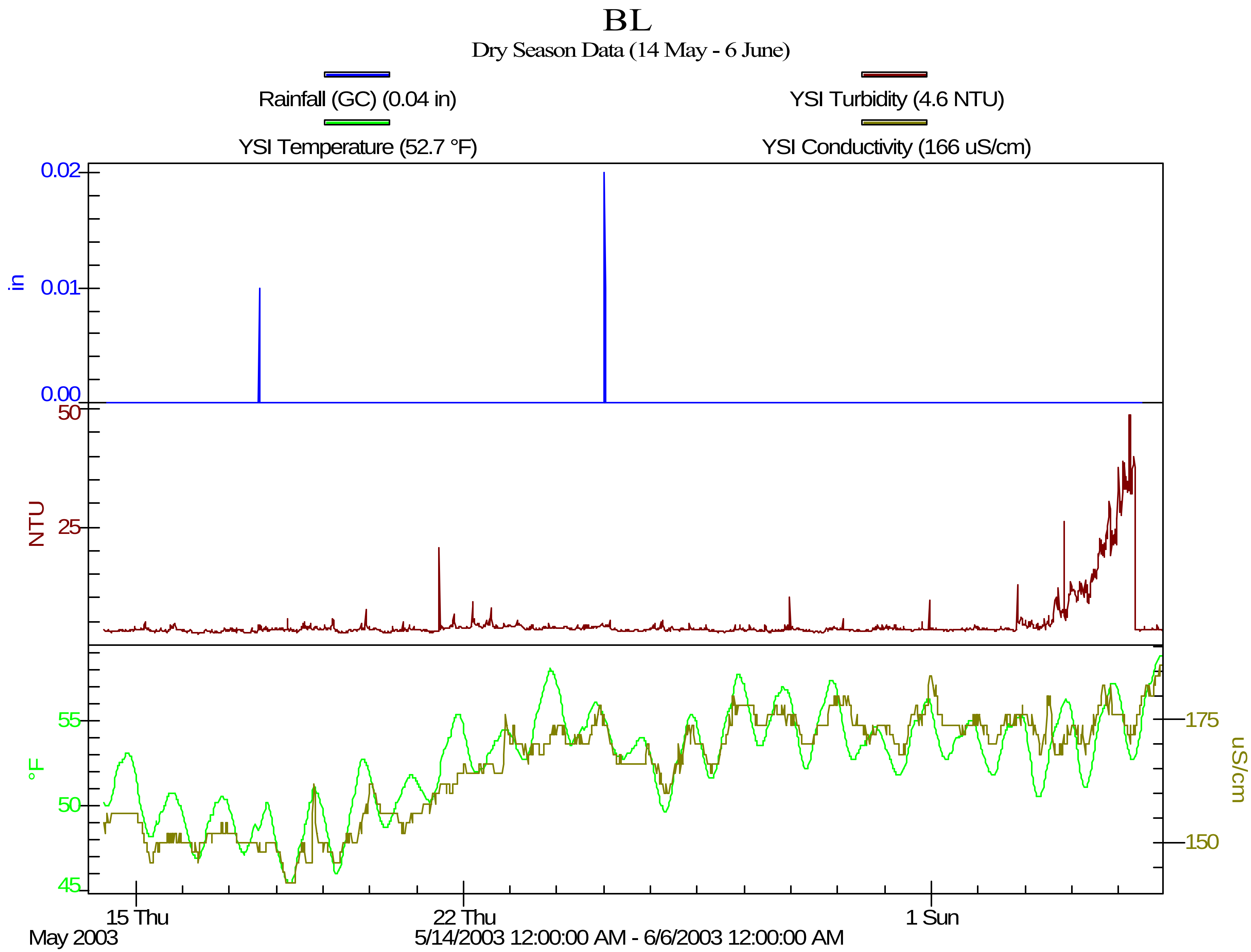
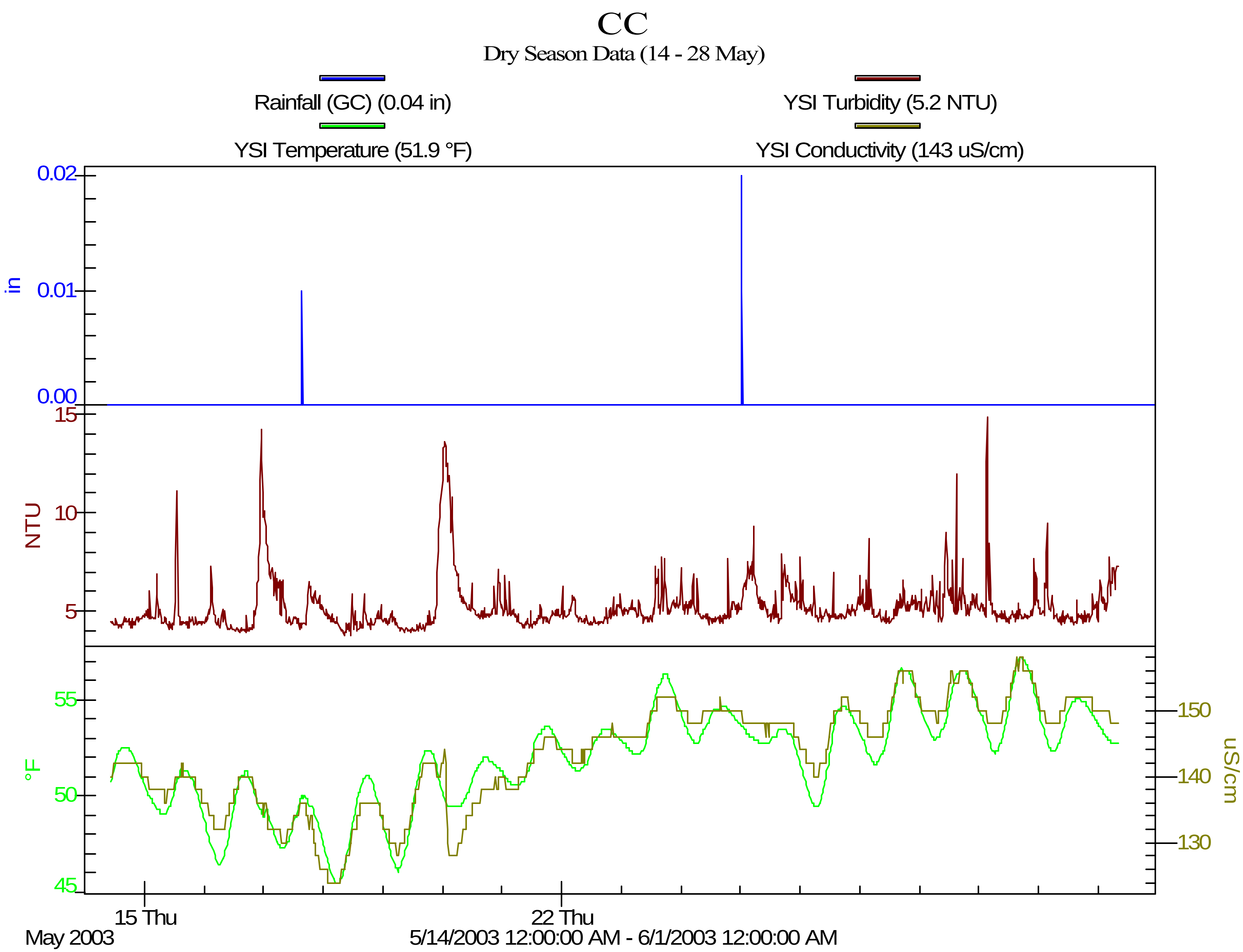

BL
Dry Season Data (14 May - 6 June)
Rainfall (GC) (0.04 in)
YSI Turbidity (4.6 NTU)
YSI Temperature (52.7 °F)
YSI Conductivity (166 uS/cm)
in
0.02
0.01
0.00
NTU
50
25
°F
55
50
45
uS/cm
175
150
15 Thu
22 Thu
1 Sun
May 2003
5/14/2003 12:00:00 AM - 6/6/2003 12:00:00 AM

Figure 5.6-3


CC
Dry Season Data (14 - 28 May)
Rainfall (GC) (0.04 in)
YSI Turbidity (5.2 NTU)
YSI Temperature (51.9 °F)
YSI Conductivity (143 uS/cm)
in
0.02
0.01
0.00
NTU
15
10
5
°F
55
50
45
uS/cm
150
140
130
15 Thu
22 Thu
May 2003
5/14/2003 12:00:00 AM - 6/1/2003 12:00:00 AM

5.6.4 Chico Tributary

Figure 5.6-4 presents dry season physio-chemical data collected from 14 May to 28 May at CT. Average physio-chemical values were 0.1 NTU, 51.4˚ F, and 56 µs/cm. Turbidity values fluctuated within a generally narrow range throughout the period with no significant spikes. Temperature followed a diurnal pattern and increased throughout the period after initially decreasing. Conductivity values were initially low and then generally increased. Throughout the data period, conductivity and temperature readings tracked with each other

5.6.5 Clear Creek

Figure 5.6-5 presents dry season physio-chemical data collected from 14 May to 28 May at CC. Average physio-chemical values were 5.2 NTU, 51.9˚ F, and 143 µs/cm. Turbidity values fluctuated within a generally narrow range throughout the period with no significant spikes. Temperature followed a diurnal pattern and increased throughout the period. Conductivity values were initially low and then generally increased. Throughout the data period, conductivity and temperature readings tracked with each other.

5.6.6 Gorst Creek

Figure 5.6-6 presents dry season physio-chemical data collected from 14 May to 6 June at GC. Average physio-chemical values were 0.5 NTU, 50.0 ˚ F, and 115 µs/cm. Turbidity values were low up until about 4 June whereupon turbidity increased dramatically. As no rain fell within the area during this time, the increase in turbidity was not a direct result of storm flow. Interestingly enough, this same increase in turbidity was detected at other sites (BA, BL, and OC) on or about the same day, a day with no rainfall. Temperature shows a clear diurnal pattern and increased throughout the period after an initial decrease. Conductivity values were initially low and then generally increased. Throughout the data period, conductivity and temperature readings tracked with each other.

5.6.7 Olney Creek

Figure 5.6-7a presents dry season physio-chemical data collected from 27 May to 13 June at OC. Average physio-chemical values were 2.8 NTU, 55.4˚ F, and 152 µs/cm. Turbidity values were low up until about 4 June whereupon turbidity increased dramatically. As shown, no rain fell within the area during this time. Temperature followed a clear diurnal pattern and increased throughout the period after an initial decrease. Conductivity values were initially stable and then generally decreased. Throughout the data period, conductivity and temperature readings did not track with each other.

Figure 5.6-7b presents dry season physio-chemical data collected from 20 – 28 June. Average physio-chemical values were 42.1 NTU, 52.6˚ F, and 148 µs/cm. Turbidity values were low up until about 21 June whereupon turbidity increased dramatically – probably due to approximately 0.25" of rain that fell within the Port Orchard area on the 21st. Temperature shows a clear diurnal pattern and increased slightly throughout the period.

5.6.8 Dry Season Summary

Physio-chemical data collected during the dry season revealed lower turbidity values, higher temperature readings, and higher conductivity readings as compared to the sampling season data. Given the changes in the watersheds during this period, these changes are to be expected. It is interesting to note the turbidity spike at BA, BL, GC, and OC, which began about 4 June – during a period when no rainfall occurred. Perhaps it is only a coincidence, but it is interesting nonetheless.

Figure 5.6-4

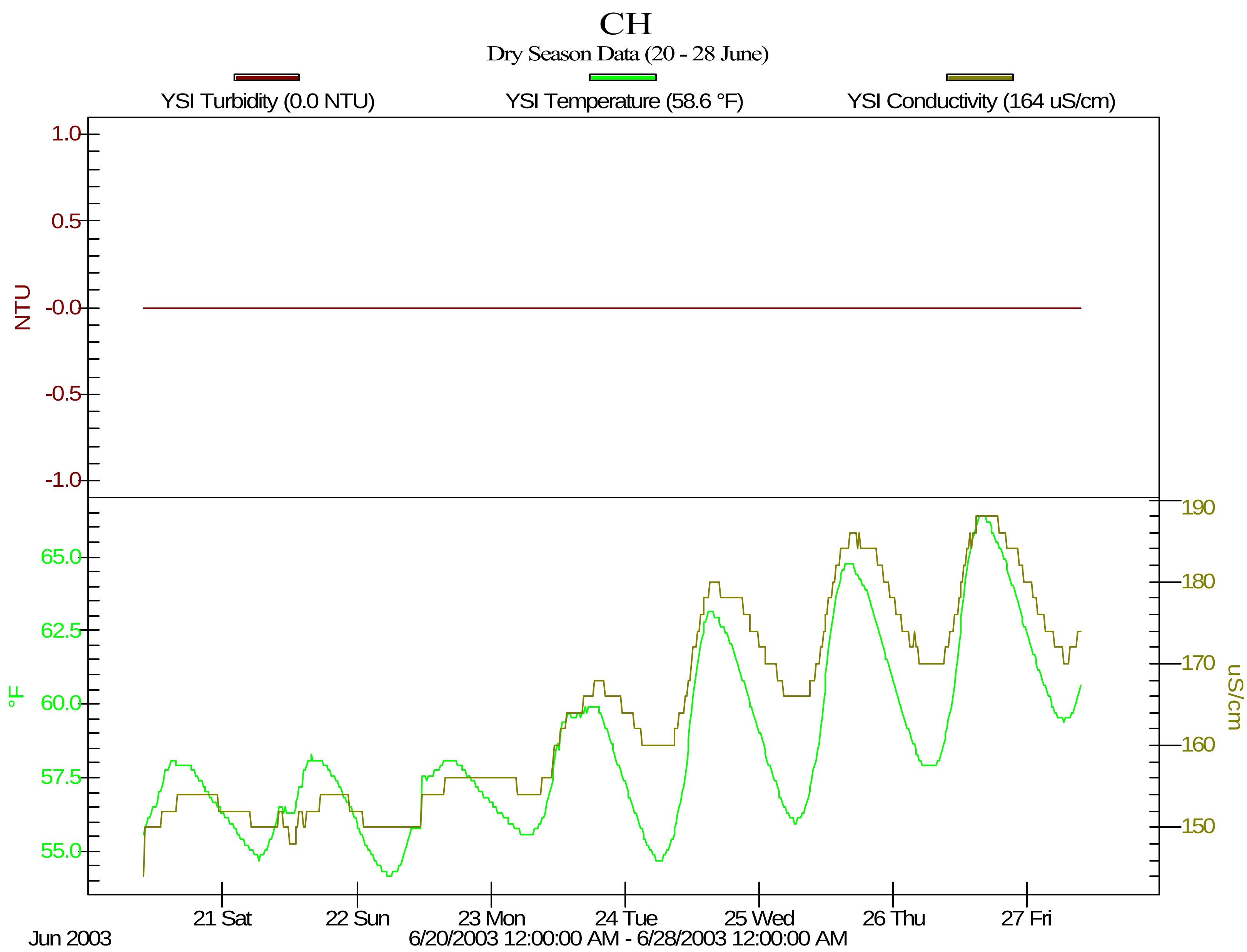

CH
Dry Season Data (20 - 28 June)
YSI Turbidity (0.0 NTU)
YSI Temperature (58.6 °F)
YSI Conductivity (164 uS/cm)
NTU
1.0
0.5
-0.0
-0.5
-1.0
°F
65.0
62.5
60.0
57.5
55.0
uS/cm
190
180
170
160
150
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
26 Thu
27 Fri
Jun 2003
6/20/2003 12:00:00 AM - 6/28/2003 12:00:00 AM

Figure 5.6-5

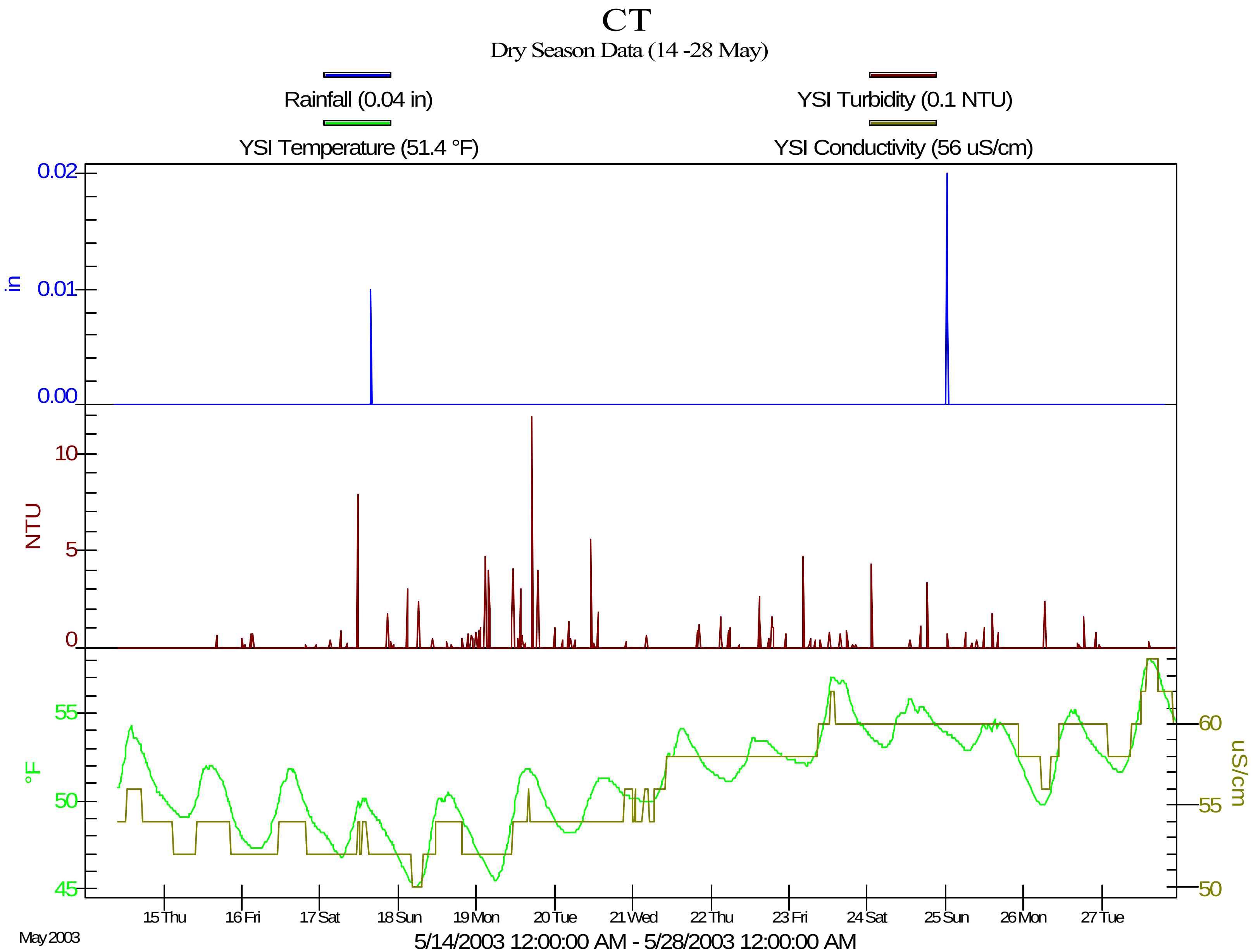

CT
Dry Season Data (14 -28 May)
Rainfall (0.04 in)
YSI Turbidity (0.1 NTU)
YSI Temperature (51.4 °F)
YSI Conductivity (56 uS/cm)
in
0.02
0.01
0.00
NTU
10
5
0
°F
55
50
45
uS/cm
60
55
50
15 Thu
16 Fri
17 Sat
18 Sun
19 Mon
20 Tue
21 Wed
22 Thu
23 Fri
24 Sat
25 Sun
26 Mon
27 Tue
May 2003
5/14/2003 12:00:00 AM - 5/28/2003 12:00:00 AM

Figure 5.6-6

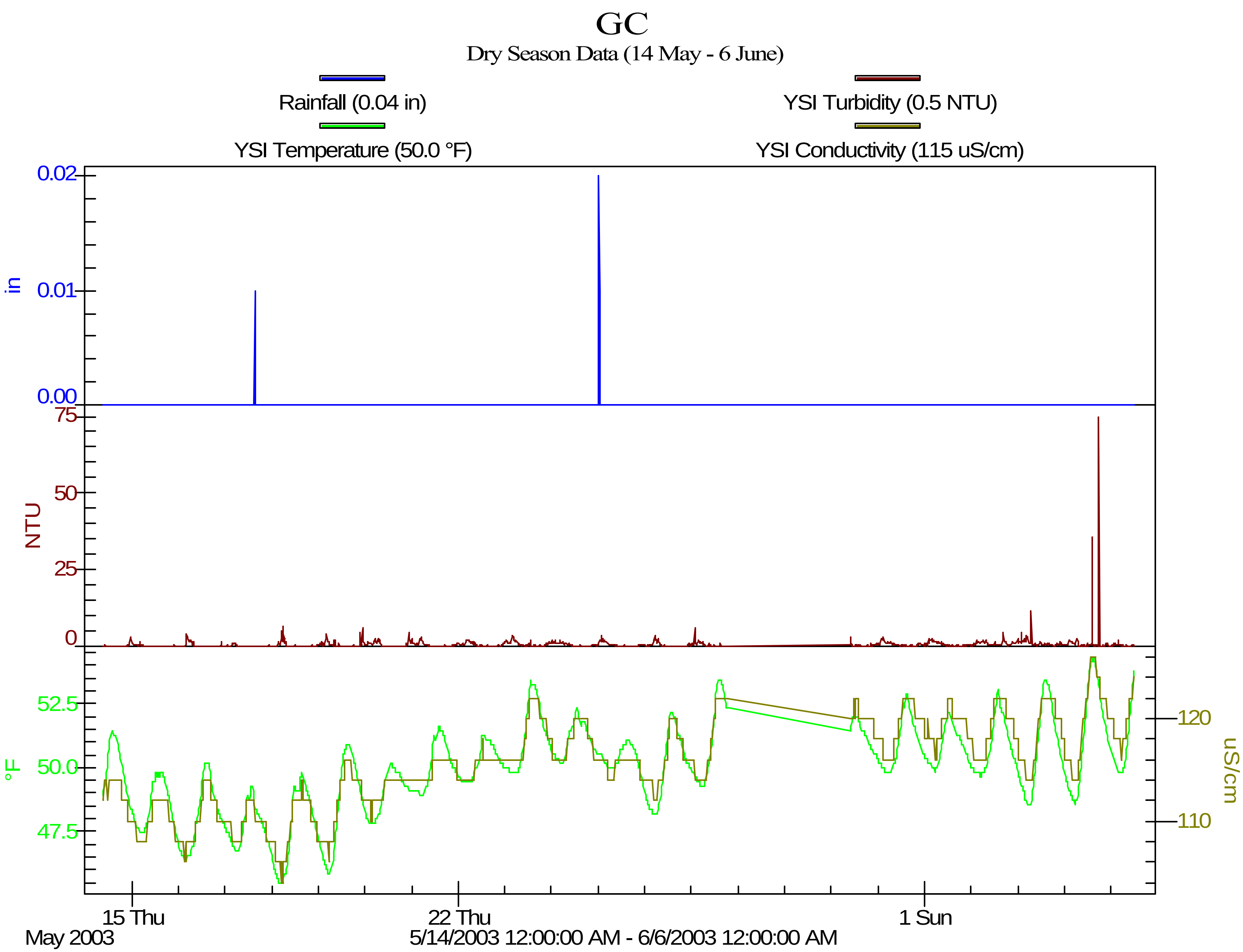
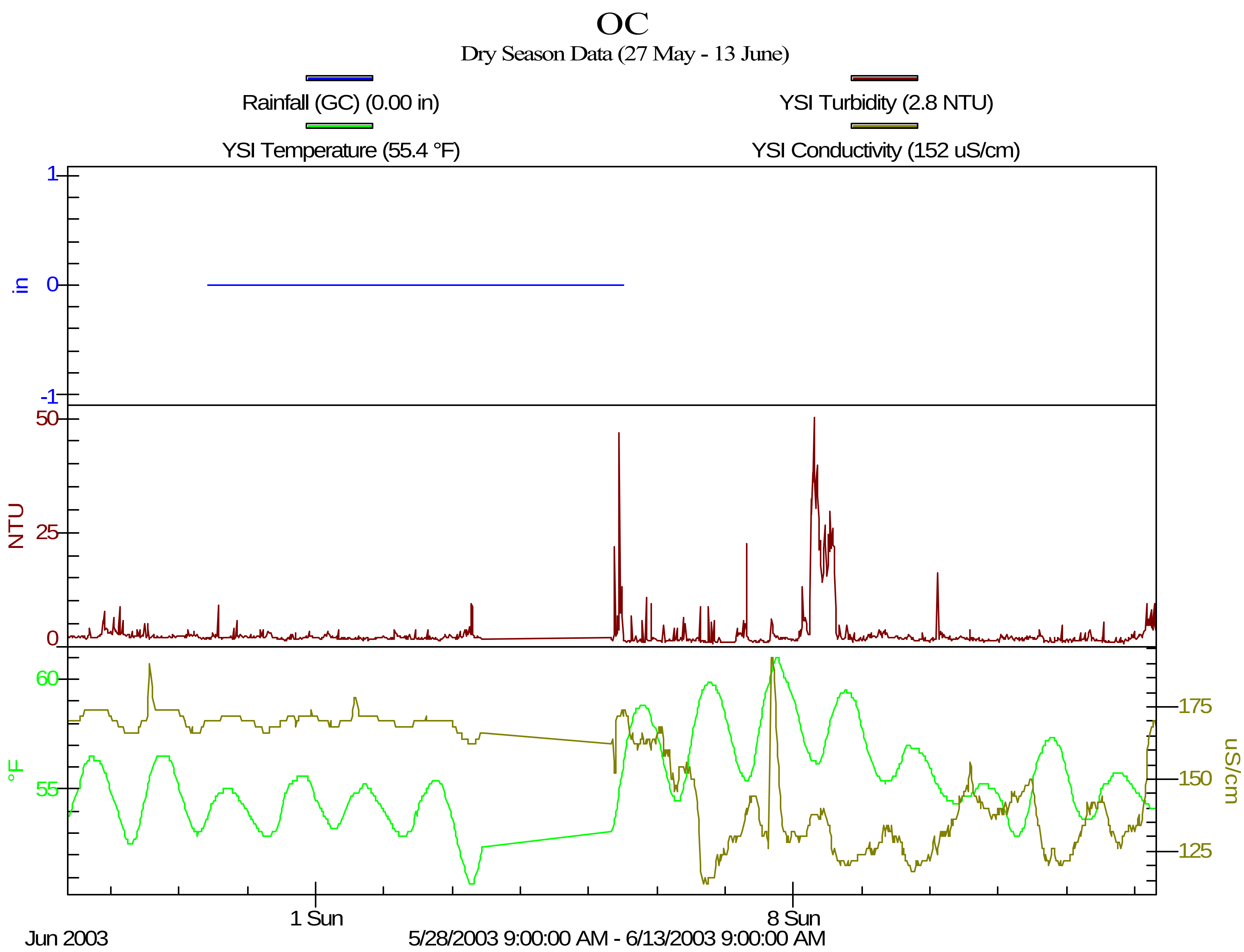
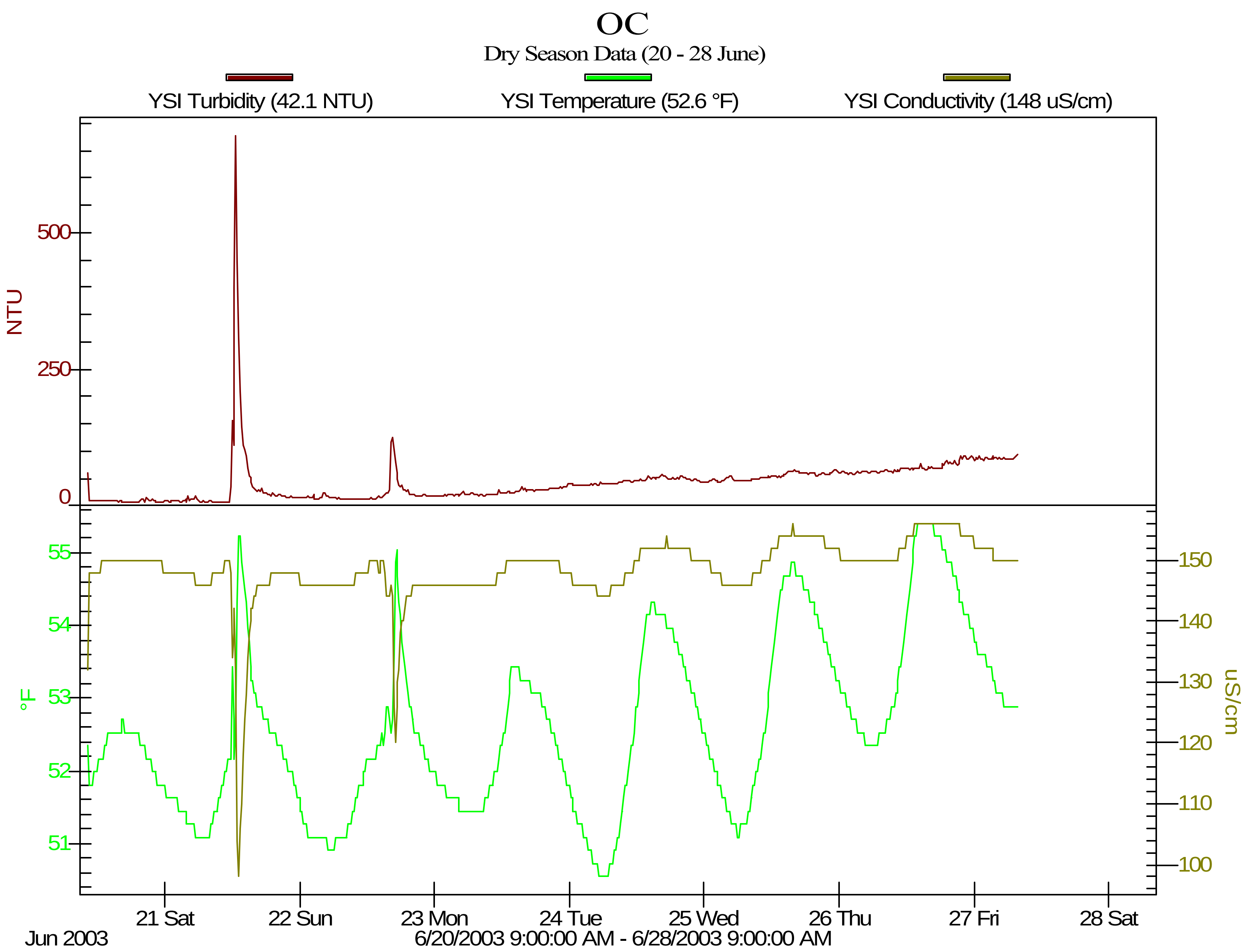

GC
Dry Season Data (14 May - 6 June)
Rainfall (0.04 in)
YSI Turbidity (0.5 NTU)
YSI Temperature (50.0 °F)
YSI Conductivity (115 uS/cm)
in
0.02
0.01
0.00
NTU
75
50
25
0
°F
52.5
50.0
47.5
uS/cm
120
110
15 Thu
22 Thu
1 Sun
May 2003
5/14/2003 12:00:00 AM - 6/6/2003 12:00:00 AM

Figure 5.6-7a



OC
Dry Season Data (27 May - 13 June)
Rainfall (GC) (0.00 in)
YSI Turbidity (2.8 NTU)
YSI Temperature (55.4 °F)
YSI Conductivity (152 uS/cm)
in
1
0
-1
NTU
50
25
0
°F
60
55
uS/cm
175
150
125
1 Sun
8 Sun
Jun 2003
5/28/2003 9:00:00 AM - 6/13/2003 9:00:00 AM

Figure 5.6-7b


OC
Dry Season Data (20 - 28 June)
YSI Turbidity (42.1 NTU)
YSI Temperature (52.6 °F)
YSI Conductivity (148 uS/cm)
NTU
500
250
0
°F
55
54
53
52
51
uS/cm
150
140
130
120
110
100
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
26 Thu
27 Fri
28 Sat
Jun 2003
6/20/2003 9:00:00 AM - 6/28/2003 9:00:00 AM

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6.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were developed based upon the 2002-2003 In-Stream Storm Flow Sampling Season data as presented in this report. As mentioned previously, this section will only focus on storm flow FC concentrations and physio-chemical and rainfall data.

A total of 11 storm flow sampling sites were sampled over 7 separate storms during the 2002-2003 In-Stream Storm Flow Sampling Season in a variety of hydrological and watershed conditions. The following list summarizes the major accomplishments of the sampling season:

- 7 discrete storm events were sampled;
- a minimum of 3 storms were sampled at each location;
- total rainfall for each event was greater than 0.25" (the minimum criteria);
- 137 FC samples were collected;
- 193 composite sample bottles were collected for chemical analysis; and
- no equipment was destroyed or damaged and no injuries to staff participating in sampling efforts occurred.

A preliminary analysis of data collected by TEC during the 2002-2003 In-Stream Storm Flow Sampling Season developed the following conclusions:

- Season geometric mean storm flow FC concentrations at 7 of the 11 sampling sites (BA, CC, CW, CE, SC, BL, and OC) exceeded the Class A Part I or Part II surface water quality standards. Conversely, only 4 sampling sites (CH, CT, GC, and AC) did not exceed the Class A Part I or Part II surface water quality standards.

- No clear correlation exists between storm flow FC concentrations and either cumulative rainfall, turbidity, or ADP for the project area when analyzed as a whole. However, watershed-specific correlations do appear to exist.

- Storm flow FC concentrations generally increased during wetter storms and storm flow FC concentrations generally increased in storms with a longer ADP. While these two factors are major factors in influencing storm flow FC concentrations, the level of urbanization, or more specifically, the level of commercial development within the watershed appears to be the primary influence on storm flow FC concentrations.

- While cumulative rainfall and ADP have proven to be important factors on storm flow FC concentrations, they do not; however, appear to be as influential as the level of urbanization, or specifically, the level of commercial development within the watershed.

- Watersheds with a higher percentage of urban high density land use had higher FC concentrations (geometric mean). Conversely, those watersheds with a higher percentage of forest had lower FC concentrations (geometric mean). Basically, watersheds with a higher percentage of urbanization (specifically urban high density) had higher FC concentrations and those watersheds with more forested (un-urbanized) watersheds had lower FC concentrations.

- Based on data collected during this study, the occurrence of peak FC concentrations varied from site to site during the sample events; peak FC concentrations did not occur at the same stage of the sample event at each site. However, some sites (AC, CH, GC, and OC) did display a first flush effect during some storms.

- The timing of the first sample round appears to be important. It appears that FC concentrations do not rise above what can be proposed as baseline concentrations until approximately 0.10" of cumulative rainfall. In light of this, it is recommended that future sampling efforts wait to take the first round of FC samples until after at least 0.10" of cumulative rainfall.

- It is also recommended that future sampling efforts increase the number of FC samples taken at each site per sample event (from 3 to perhaps 5 or 6) to provide additional data points for enhancing the ability for analyzing potential relationships between FC concentrations and physio-chemical and meteorological conditions.
- Physio-chemical data collected during the dry season revealed lower turbidity values, higher temperature readings, and higher conductivity readings as compared to data collected during storm events. Given the seasonal changes in the watersheds during this period, these changes were to be expected.

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APPENDICES

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Appendix A
Field Test Memo

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PSNS Project ENVVEST
In Stream Storm Flow Sampling
Field Test
8-10 December 2002

Introduction

As described in Task 3.5 of the SOW dated 28 October 2002, TEC is under contract to complete a field test of the in stream storm flow sampling equipment at the 6 northern group sites (Chico Main, Strawberry Creek, Barker Creek, Clear Creek Main, Clear West Tributary, and Clear Creek East Tributary). The purpose of the field test is to ensure that the storm flow sampling equipment will perform properly over a 48-hour period.

This report presents: the approach to conducting the field test; the results of the field test; follow-up action items; and a list of TEC staff and their roles participating in the field test.

Field Test

On Sunday, 8 December, TEC staff met at TEC Poulsbo field office and mobilized 6 Isco samplers and associated equipment to the 6 northern group sites. At each location the following equipment was installed: an Isco 6700 automatic sampler, 4, 3.7 liter clear glass bottles, an YSI 6820 Sonde, Teflon-lined intake tubing, and a PVC intake tube strainer. Power was provided to each station via a 12-volt deep-cycle marine battery.

Once the sites were set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6 hour period). Sampling sites were then activated from north to south at the following times:

Chico Main	1106
Strawberry Creek	1206
Barker Creek	1301
Clear Creek Main	1344
Clear Creek West Tributary	1428
Clear Creek East Tributary	1457

Following activation, TEC staff then visited each of the stations in order of activation to ensure that the samplers were operating correctly. Following this initial check, each station was monitored during the switch from bottle 1 to bottle 2 - 6 hours from activation. Sampling stations were then periodically checked throughout the balance of the sampling event. On Monday, 9 December at the critical 24-hour juncture (when the initial 4 bottles would be filled), TEC staff emptied the bottles and replaced them in the base on the sampler, thereby providing sufficient capacity for the subsequent 24-hours. On Tuesday, 10 December, each sampling station was de-mobilized 48-hours from their respective activation time. Equipment was then returned to the TEC field office.

Field Test Results

The field test was a success; all sampling stations performed as expected. The samplers filled the 3.7 liter bottles to a consistent level in all bottles at all stations – approximately 3.3 liters. There was no liquid observed in the base of the samplers; the distributor arm rotated as designed and delivered aliquots as programmed. The sample sites and intake tubes were not damaged by the environment (e.g., stream flow debris) or vandalism. The Isco samplers recorded the physio-chemical data logged by the 6820 YSI sonde; however the YSIs were not calibrated prior to installation and the data was therefore suspect. Rain gauges were not installed as a prior test in the field of the 2 Isco rain gauges proved they worked fine and the additional rain gauges lack appropriate cable connectors. In addition, the YSI data was not downloaded from the samplers as TEC does not yet have the Isco Rapid Transfer Device or Flowlink software.

In summary, the field test was a total success. The units can operate for periods up to 48-hours on the batteries and will deliver the appropriately-sized aliquots at the necessary intervals. In addition, the Isco samplers retained the YSI data and no damage to the sampling sites occurred.

Action Items

TEC is confident that the Isco samplers and associated equipment will meet the purpose and need for this project. However, several minor pieces of equipment need to be obtained to ensure that TEC performs the in stream storm water sampling in accordance with the provisions of the Sampling and Analysis Plan (SAP). Items still needed by TEC include:

Rapid Transfer Device	(2)
Flowlink Software	(1)
Isco Sample Bottle Cages	(5)
Isco Rain Gauges OR connectors for 5 older style bronze rain gauges	(5)
Rain Gauge/YSI Splitters “Y’s”	(5)

TEC will coordinate obtaining this additional equipment as soon as possible from PSNS.

Storm Sampling Readiness

TEC is ready to sample at the northern group sites once 1) the contract covering this phase of the project is finalized; 2) the additional equipment is acquired; and 3) a storm meeting the minimum sampling criteria materializes. That being said, the field test proved that the purpose and need for the project can be currently met with the existing equipment – storm water samples can be obtained successfully for analysis.

TEC is finishing the final ‘plumbing’ for the 5 southern group sites. This work is anticipated to be completed by 20 December. In addition, TEC will calibrate the YSIs prior to the first sample event. TEC expects the storm sampling ‘window’ to open on Monday, 16 December, assuming TEC is under contract at that time. Therefore, TEC has tentatively planned to be ready to initiate in stream storm water sampling at the 6 northern group sites on 16 December.

TEC Staff Participating in Field Test

Name	**Role**
Ryan Pingree	Project Manager
Dave Metallo	Field Team Leader
Jen Gaudette	Field Team Member
Brian Rupert	Field Team Member
Jason Strayer	Field Team Member
Rich Tremaglio	Field Team Member
Greg Whittaker	Field Team Member

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Appendix B

Storm Summary Report #1

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PSNS Project ENVVEST
In Stream Storm Flow Sampling

Storm Sampling Event #1
15-16 December 2002

Introduction

On 15-16 December 2002, TEC conducted in-stream storm flow sampling of 6 creeks within the PSNS Project ENVVEST study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the sampling plan; and 5) follow-up action items. In addition, Appendix A presents satellite images, Appendix B presents site photos, and Appendix C contains physio-chemical data for the fecal grab samples.

1. TEC Staff Participating in Storm Sampling Event #1

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Dave Metallo	Field Team Leader
Rusty Divine	Field Team Member
Jen Gaudette	Field Team Member
Rick Osgood	Field Team Member
Jason Strayer	Field Team Member
Rich Tremaglio	Field Team Member

2. Storm Sampling Event #1

Storm Identification

On Thursday, 12 December, PSNS staff and TEC identified via NWS Seattle weather forecasts a storm that appeared would meet the minimum storm sampling criteria. Subsequent coordination and updated weather forecasts in the days following confirmed the initial forecast. On Saturday, 14 December, PSNS and TEC agreed to begin preparations to sample the impending storm event. At this time TEC began mobilizing staff and equipment to sample the first storm event (Storm Sampling Event [SSE] #1) of the 2002/2003 PSNS Project ENVVEST In-Stream Storm Sampling Season.

Sampling Preparation

Early on the morning of Sunday, 15 December, TEC staff under the direction of R. Pingree mobilized sampling equipment to the 6 northern group sites (Chico Main [CM], Strawberry Creek [SC], Barker Creek [BA], Clear Creek Main [CC], Clear Creek West Tributary [CW], and Clear Creek East Tributary [CE]). As described in the Field Sampling Memo of 11 December, several pieces of supporting equipment were still pending from PSNS. However, the necessary components were in TEC's possession to conduct the sample event. As only 2 rain gauges were available, per coordination with PSNS, TEC set up 1 rain gauge at CM (as it was geographically separated from the other 5 sites) and CC (as it is a representative location for the CE, CW, and SC). These 2 sites were programmed to begin sampling when > 0.05 inches of rain fell within a 1 hour period. The other 4 sites would be manually started once sampling began at CC. Following site set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period).

In-Stream Storm Flow Sampling

The sampling sites were mobilized in the following order: BA, SC, CW, CE, CC, and CH. While the latest forecast called for rain to begin falling at approximately 1600 hours, moderate rain began to fall at approximately 1400 hours, while CE was being mobilized. All sites were not yet ready to begin sampling until 1445 hours, during which moderate rain continued to fall throughout the project area. Once CM was set-up, TEC staff then returned to the sites in the order in which they were mobilized and: 1) activated the samplers (except for CC which had self-started per the program) and 2) took a fecal grab sample. Throughout the storm sampling event, TEC staff routinely checked on the stations, took fecal grab samples, monitored weather conditions, coordinated with PSNS, MEL, and PNNL.

Table 1-1 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to Manchester Environmental Laboratory (MEL) and Pacific Northwest National Laboratory (PNNL).

Table 1-1. SSE #1: In-Stream Storm Flow Sampling Landmarks

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
Date	*12/15*	*12/15*	*12/16*	*12/16*	*12/16*	*12/16*	*12/17*
BA	1515	1500	0000	0900	1050	1500	0930
SC	1500	1500	0115	0940	1050	1445	0930
CW	1515	1515	0045	0930	1050	1500	0930
CE	1525	1525	0040	0925	1050	1510	0930
CC	1425	1511	0030	0915	1050	1410	0930
CH[1]	1638	1445	2345[2]	0955	1050	1623	0930

Notes: [1] CH started last as the rain generally began in the north and worked its way to the south.
[2] Sample taken on 12/15.

At approximately 2000 hours on 15 December, the storm sampling event officially became *Storm Sampling Event #1*, as rainfall totals from nearby rain gauges had surpassed 0.25 inches. Table 1-2 presents storm rainfall totals for nearby gauges and the gauges at CC and CM.

Table 1-2. SSE #1: Precipitation within the Project Area

Sampling Station	Total Rainfall[1]
Poulsbo	1.08"
Bremerton (Port of Brownsville)	0.87"
Bremerton (Airport)	0.96"
Silverdale	N/A
Clear Creek Main	0.25" [2]
Chico Main	0.27" [2]

Notes: [1] Storm event totals (12/15 – 12/16).
[2] CC and CH are lower than surrounding gauges. This is possibly due to the fact that rain began prior to set up and possible negative topography/vegetation effects on rainfall (i.e. screening).
Sources: Weather Underground, NWS Seattle.

Rainfall varied throughout the event. Rain generally fell within 2 periods separated by a 'dry' period. Moderate rain fell throughout the period of 1400 – 1800 on the 15th, and then again from 2130 on the 15th to 0100 on the 16th. Scattered light showers and periods of no rain occurred throughout the other hours. The level in each of the creeks rose visibly during the event and then slowly receded throughout the 16th. The quick response of the creek heights to the rain is believed to have resulted from recent storms saturating the soils in the watershed, resulting in a large percentage of rainfall from this storm event transitioning directly to storm flow.

Early on the morning of 16 December, it was apparent that the storm event was ending, as verified by satellite data and site conditions. At this time the last round of fecal samples was taken and TEC once again coordinated with MEL and PNNL. Shortly after the final fecal samples were taken TEC staff delivered 20 sample bottles to MEL. In addition, discussions between TEC, PSNS, and PNNL determined that due to the lateness of the hour the final samples would be collected, cooled, and organized (~1800 hours), TEC would hold the samples overnight and deliver them first thing in the morning of the 17th to PNNL.

Storm Sampling Event Demobilization

Once the last samples were collected from CH, the sites were demobilized and the composite samples and accompanying Chain of Custody (CoC) forms were taken to the TEC field office for delivery to PNNL the next morning.

3. Storm Sample Event #1 Results

At all stations except 1 (BA – see discussion below), all of the sampling stations performed as expected. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a consistent level in all bottles at all stations – approximately 3.3 liters. There was no liquid observed in the base of the samplers; the distributor arm rotated as designed and delivered aliquots as programmed. The sample sites and intake tubes were not damaged by the environment (e.g., stream flow debris) or vandalism. As occurred in the field test event, the Isco samplers recorded the physio-chemical data logged by the 6820 YSI sonde; however the YSIs were not calibrated prior to installation and the data is therefore suspect.

4. Variations to the Sampling and Analysis Plan (SAP)

Several minor variations to the approved SAP occurred during Storm Sampling Event #1 and are discussed as follows.

Storm Criteria

This storm event did not meet the sampling criteria in that it was not preceded by a 24-hour period of no or negligible rainfall. However, PSNS and TEC staff felt that the storm was a good storm to sample because it would produce a large amount of rain and it represented the first opportunity for sampling following sample site activation. For these reasons, PSNS and TEC decided to sample this storm event. Due to the capricious nature of storm events, strict adherence to the sampling criteria cannot always be met; however, attempts will be made to conduct future storm sampling events in accordance with the provisions of the SAP.

Barker Creek under Sampling

As mentioned above, all of the stations except BA performed as expected. During a check at BA during the evening of 15 December, it became apparent that the sampler was not pulling appropriately sized aliquots as a visual check of Bottle 1 showed the bottle at less than ½ full (Bottle 2 had already began to fill). A quick calibration check showed that the sampler was pulling 65 mL aliquots, not the 140 mL aliquots as programmed. This problem was quickly solved by calibrating the sampler in the field. The balance of Bottle 2 and all of Bottles 3 and 4 were filled with appropriately sized aliquots. While the cause of this under sampling is not fully understood, the problem was quickly fixed and did not occur again. In addition, even with the smaller sample volume there was sufficient volume to conduct laboratory analysis.

YSI 6820 Sondes

As mentioned previously, the YSI Sondes were not calibrated prior to mobilization to the field. Calibration was not accomplished prior to the event as more important tasks needed to be completed to ready the sample sites for sampling. While data was obtained from the YSI they cannot be considered entirely accurate as the units were not calibrated. Prior to future sampling events, the YSIs will be calibrated prior to installation. Furthermore, hand-held Horiba U-10 units will be used to confirm the YSI physio-chemical values.

Sampling Site Labeling

During the sample event, composite sample bottles from Clear Creek Main where incorrectly labeled "CM" instead of the "CC." This mistake was quickly realized and TEC coordinated with PNNL staff to let them know that "CM" was in fact "CC." Future sampling events will employ the 2-letter site codes as designated in the SAP.

Mobilization

This storm began raining earlier than anticipated and as such all sampling locations were not ready to start sampling when the rain began, although all stations were ready to go within the first hour of rainfall. Future mobilization efforts will be initiated earlier to allow for any changes in the timing of the storm system.

5. Action Items

Outstanding Equipment

Several minor pieces of equipment need to be obtained to ensure that TEC performs the in stream storm water sampling in accordance with the provisions of the SAP. Items still needed by TEC include:

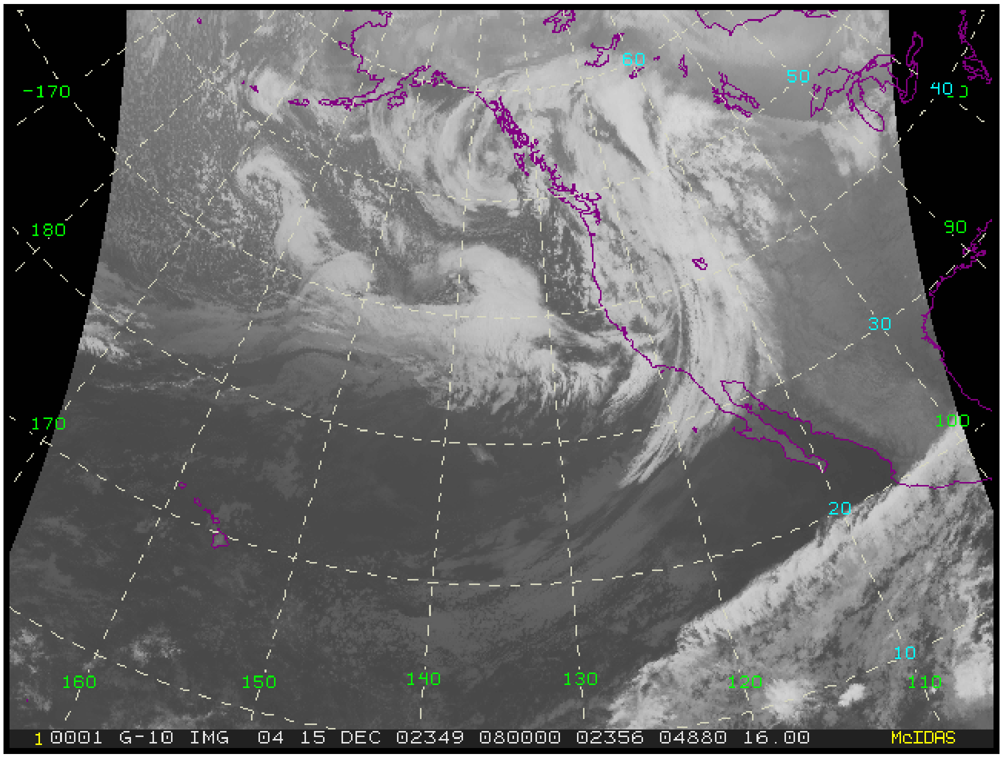
Rapid Transfer Device	(2)
Flowlink Software	(1)
Isco Sample Bottle Cages	(5)
Isco Rain Gauges OR connectors for 5 older style bronze rain gauges	(5)
Rain Gauge/YSI Splitters "Y's"	(5)

TEC will coordinate obtaining this additional equipment as soon as possible from PSNS.

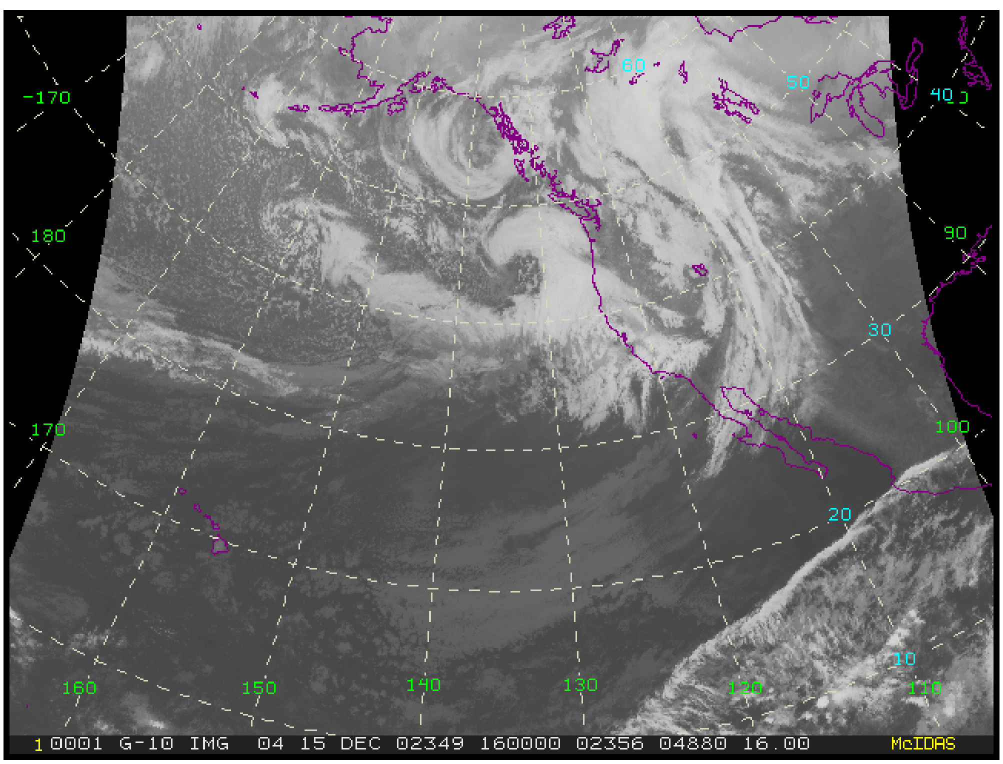
Storm Sampling Readiness

TEC is finishing the final 'plumbing' for the 5 southern group sites. This work was originally expected to be completed by 20 December. However, due to the storm sampling event and the upcoming Christmas Holiday, construction of the southern sites will not be completed until 10 January 2003. Therefore, should a storm meeting the sampling criteria materialize prior to this date, in-stream storm sampling could only occur for the same 6 northern sites.

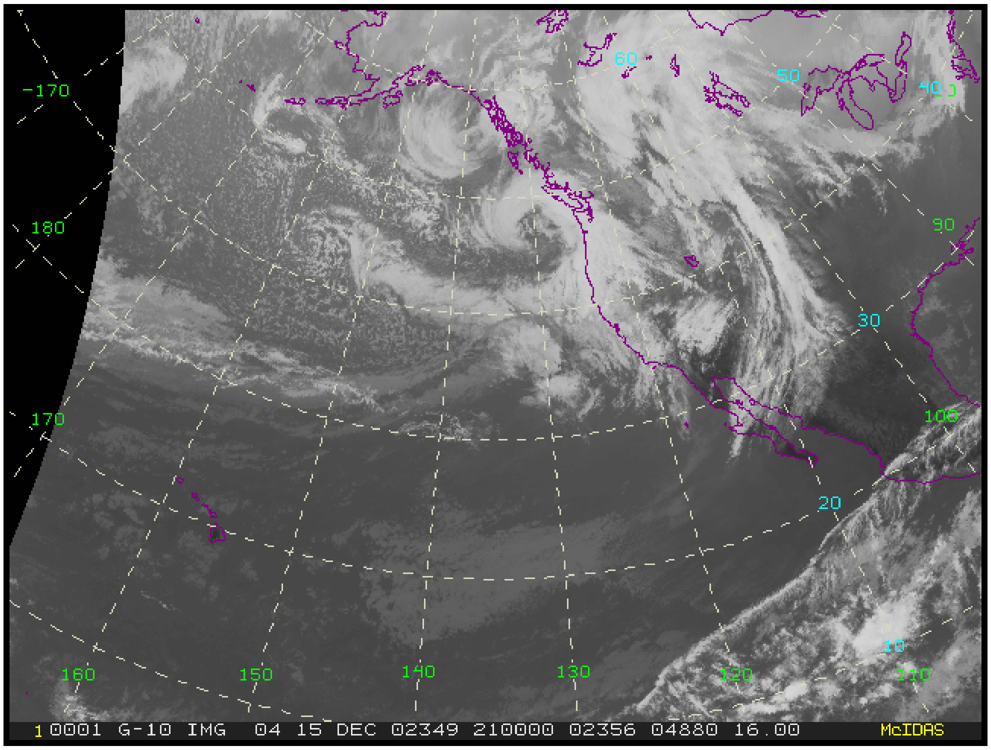
Appendix A
Satellite Data of Storm Event #1



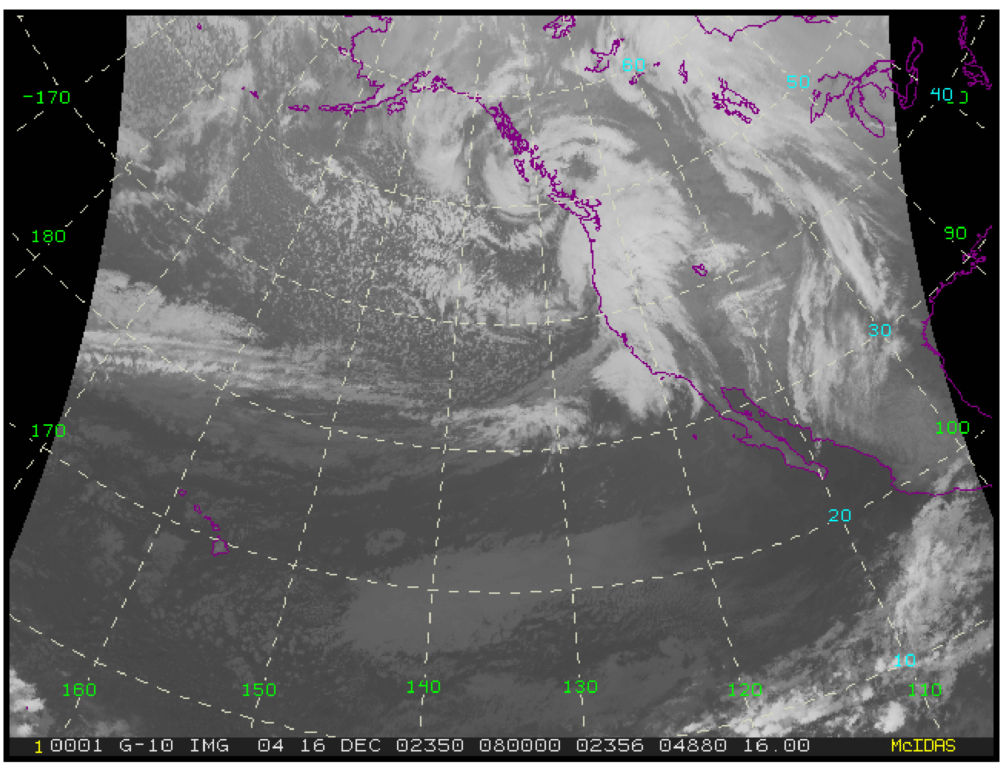
15 December 0000 (local time) - Storm Develops



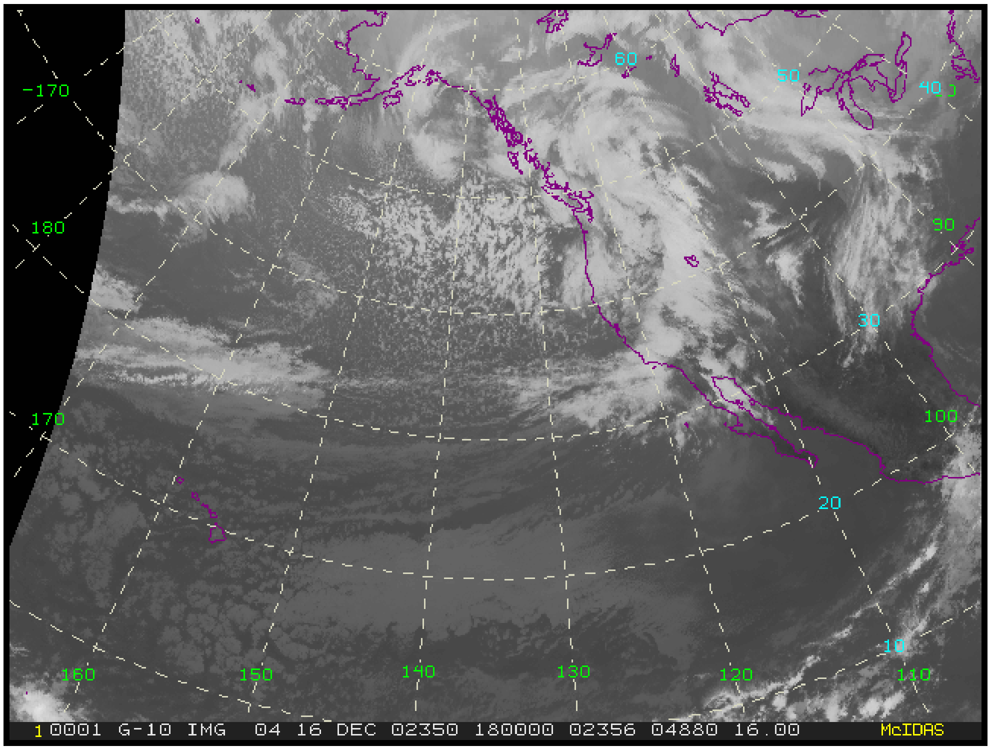
15 December 0800 (local time) - Storm Approaches



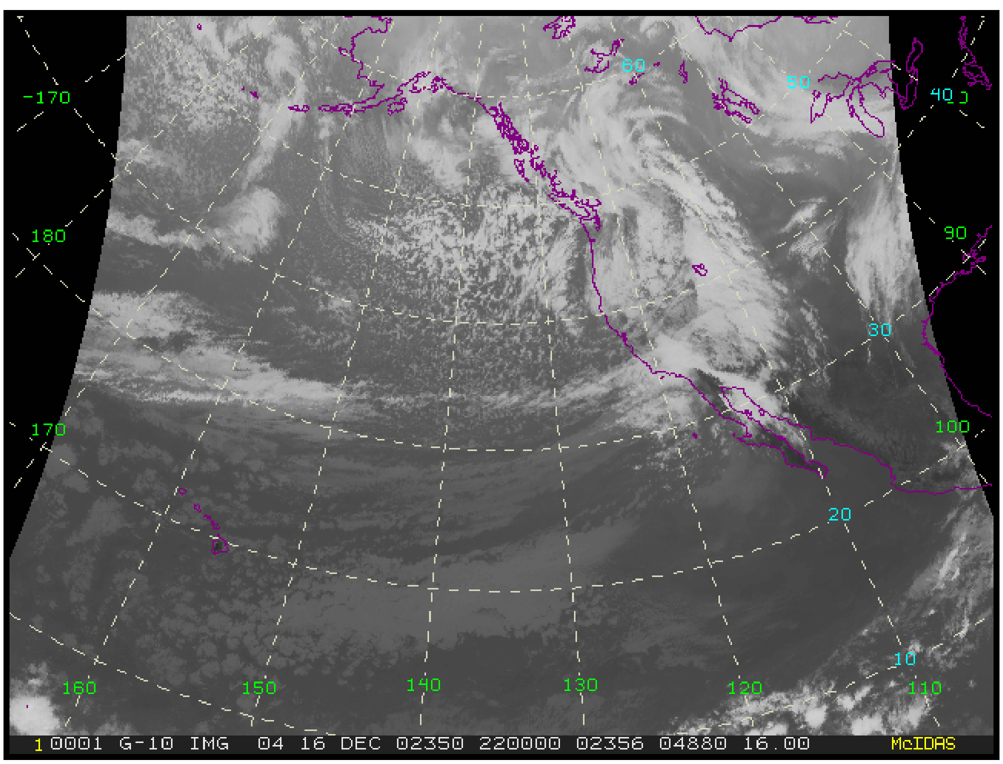
15 December 1300 (local time) - Rain Begins



16 December 0000 (local time) - 2nd Round of Rain



16 December 1000 (local time) - Storm Exits



16 December 1400 (local time) - Clear Skies

Appendix B
Photo Log

Clear Creek East Tributary 0900
Note high water level

Clear Creek East 0910
Note high water level

Appendix C
CoC Fecal Grab Samples and Physio-Chemical Data

Chain of Custody Form

Storm #1									PSNS Project ENVVEST
TEC									FC TMDL STUDY
Northern Group									
Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
02510455	BA	**12/15/2002**	1500	47.7	10	0.081	17	12	pH reading suspect
02510450	CH	**12/15/2002**	1500	44.1	7.2	0.073	17.3	12	
02510454	SC	**12/15/2002**	1500	47.3	10	0.081	17	12	pH reading suspect
02510453	CC	**12/15/2002**	1511	53.1	5.9	0.042	38.2	12	
02510451	CH	**12/15/2002**	1515	59.7	6.3	0.075	100.1	12	Temp and turbidity readings suspect
02510452	CE	**12/15/2002**	1525	47.3	7.8	0.117	10	12	
02510440	CM	**12/15/2002**	2345	44.1	7.2	0.073	17.3	12	
02510441	BA I	**12/16/2002**	0000	46.9	13.2	0.104	24.9	12	pH reading suspect
02510446	BA II (Dup)	**12/16/2002**	0000	46.9	13.2	0.104	24.9	12	pH reading suspect
02510442	CC	**12/16/2002**	0030	53.1	5.9	0.042	38.3	12	
02510444	CE	**12/16/2002**	0040	46.4	12.2	0.081	46.4	12	pH reading suspect
02510443	CW	**12/16/2002**	0045	59.7	6.3	0.075	100.1	12	Temp and turbidity readings suspect
02510445	SC	**12/16/2002**	0115	46.8	8.7	0.081	19.4	12	
02510431	BA	**12/16/2002**	0900	46.4	13.9	0.094	35.7	12	pH reading suspect
02510432	CC	**12/16/2002**	0915	53.1	5.9	0.042	38.3	12	
02510433	CE	**12/16/2002**	0925	45.9	26.5	0.081	9.6	12	pH reading suspect
02510434	CW	**12/16/2002**	0930	59.7	6.3	0.075	100.1	12	Temp and turbidity readings suspect
02510435	SC	**12/16/2002**	0940	46.4	12.7	0.081	11.6	12	pH reading suspect
02510430	CH I	**12/16/2002**	0955	44.1	7.2	0.073	17.3	12	
02510436	CH II (Dup)	**12/16/2002**	0955	44.1	7.2	0.073	17.3	12	

Preservatives Used:	None				Readings from uncalibrated YSIs
Relinquished By/Date:	Strayer 12/16	Method of Shipment:		Ground	YSI to be calibrated prior to next
Received By/Date:	K North	Airbill No.:			sample event and verified with
Relinquished By/Date:		Laboratory			hand-held units (Horibas)
Received By/Date:		Address:			
Relinquished By/Date:				Custody Seals Present? Yes No	
Received By Lab/Date:				Custody Seals Intact? Yes No	

Appendix C
Storm Summary Report #2

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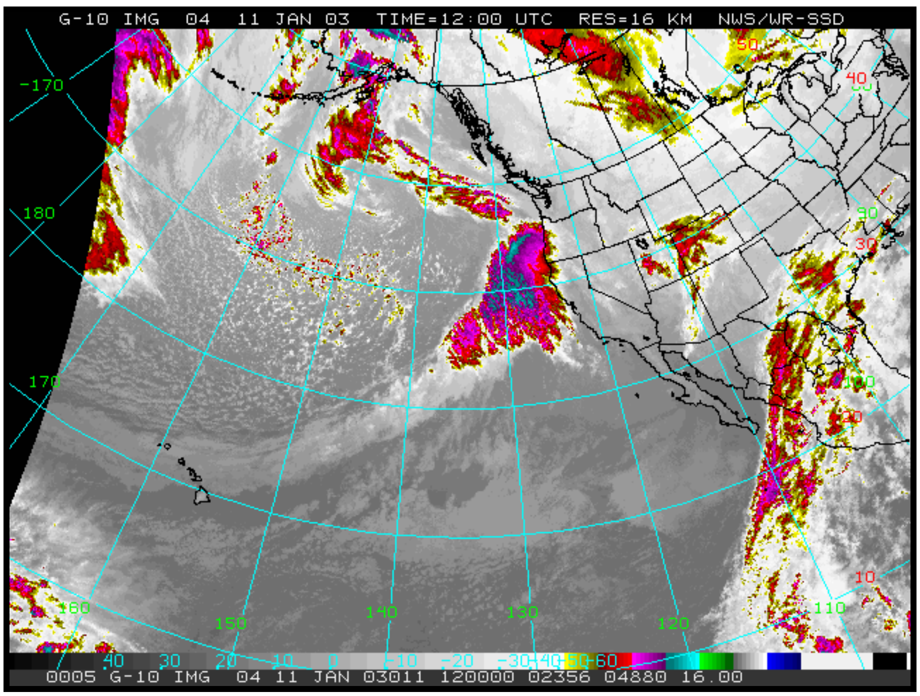
PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #2



(10 Jan 03 0400 local time – storm approaches)

11-12 January 2003
Northern Group Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

16 January 2003

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #2
11-12 January 2003

Introduction

On 11-12 January 2003, TEC conducted in-stream storm flow sampling of the 6 northern group creeks within the PSNS Project ENVVEST study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) follow-up action items. In addition, Appendix A presents satellite images and Appendix B contains physio-chemical and rainfall data.

1. TEC Staff Participating in Storm Sampling Event #2

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Dave Metallo	Field Team Leader
Rusty Divine	Field Team Member
JD Estes	Field Team Member
Jason Strayer	Field Team Member

2. Storm Sampling Event #2

Storm Identification

After a moderate rain event on 4-5 January, the project area experienced a period of dry weather as high pressure dominated the Pacific Northwest. Early during the week of 6 January, extended forecasts from the National Weather Service (NWS) Seattle predicted that the strong ridge of high pressure would shift east by the end of the week, thereby opening the 'storm door.' Throughout the week TEC and PSNS staff coordinated in anticipation of sampling the next event. While the extended forecast continued to be in flux (as the high pressure system continued to strengthen and low pressure systems swept south into northern California), TEC went ahead and made plans to go ahead and set up the northern sites and sample the event, should the forecast storm occur at sufficient intensity. As the week drew to a close, even short-term forecasts by NWS Seattle were unsure of the strength of the storm – on Thursday it appeared that any rain would be light and short lived. However, by Friday the forecast had been revised to reflect a better chance of moderate rain on Saturday night/Sunday morning. Satellite data from Friday night and early Saturday morning confirmed that the storm was intensifying as the ridge of high pressure which had produced dry, stable conditions for nearly a week, shifted east. The storm began to tap into a plume of subtropical moisture, directed at Northern Oregon/Southwest Washington. Within a short period of time the storm grew into a moderate system with a subtropical moisture connection. All indications were at this point (late Friday night/early Saturday morning) that the storm would produce sufficient rainfall (the UW model forecast 0.33" to 0.66") to qualify as a sampling event.

Continued coordination with PSNS and checking of weather and satellite data confirmed that while the storm was still strong, it had slowed somewhat and rain would not begin until late in the day on Saturday – but would continue for most of Sunday morning through midday. See Appendix A for a series of satellite images depicting the progression of the storm.

Preparation

Early on the morning of Saturday, 11 January, TEC staff mobilized sampling equipment to the 6 northern group sites (Chico Main [CM], Strawberry Creek [SC], Barker Creek [BA], Clear Creek Main [CC], Clear Creek West Tributary [CW], and Clear Creek East Tributary [CE]). As the outstanding equipment identified in Field Sampling Report #1 were now in TEC's possession, a full mobilization per the SAP was possible for this event.

A rain gauge was installed at each site, and the samplers were programmed to beginning sampling immediately once > 0.05 inches of rain fell within a 1 hour period. Following site set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSIs (which had been calibrated earlier in the week by TEC) were installed and began logging data.

In-Stream Storm Flow Sampling

The sampling sites were mobilized in the following order: CH, SC, BA, CW, CE, and CC. Mobilization was completed by approximately 1300. While some light rain did fall at approximately 0900, it only amounted to a trace – just enough to wet surfaces – and was not considered to be part of the approaching system. Following mobilization, the TEC team set up headquarters at the Silverdale Hotel and monitored the approaching storm. As shown in Table 1-1, rain began to fall after 1600 throughout the area and the samplers were activated shortly thereafter with 0.05" of rain. The rain generally worked its way south to north across the area, with pockets of heavier rain in some areas. The rain came on quickly - moderate to at times heavy rain occurred throughout the evening. Table 1-2 presents storm rainfall totals for nearby gauges and the gauges at CC and CM.

Table 1-1 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to Manchester Environmental Laboratory (MEL) and Pacific Northwest National Laboratory (PNNL). Throughout the storm sampling event, TEC staff routinely checked on the stations, took fecal grab samples, monitored weather conditions, and coordinated with PSNS, MEL, and PNNL. TEC arranged to deliver the fecal grab samples to MEL at noon on Sunday to meet the 24-hour holding time. Similarly, the composite samples were delivered to PNNL at 1000 on Monday, 13 January.

Table 1-1. SE #2: In-Stream Storm Flow Sampling Landmarks

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
Date	*1/11/03*	*1/11/03*	*1/11/03*	*1/12/03*	*1/12/03*	*1/12/03*	*1/13/03*
BA	1656	1720	2305	0940	1205	1626	1000
CH	1626	1800	0020[1]	1015	1205	1511	1000
CC	1648	1705	2325	0925	1205	1548	1000
CE	1644	1645	2350	0915	1205	1544	1000
CW	1631	1640	2335	0905	1205	1531	1000
SC	1657	1740	0005[1]	1000	1205	1612	1000

Notes: [1] Sample taken on 1/12/03.

Table 1-2. SE #2: Precipitation within the Project Area

Sampling Station	Total Rainfall[1]
PSNS Project ENVVEST Sampling Stations	
Barker Creek (BA)	1.19"
Chico Creek (CH)	1.31"
Clear Creek (CC)	1.12"
Clear Creek East (CE)	1.11"
Clear Creek West (CW)	1.10"
Strawberry Creek (SC)	1.03"
Other Rain Gauges in Vicinity	
Bremerton (Port of Brownsville)	0.93"
Poulsbo	1.08"
PSNS Building 427	1.15"
Silverdale	1.46"

Notes: [1] Storm event totals (12/15 – 12/16).
Sources: PSNS (B. Beckwith), Weather Underground:
Bremerton:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABREME3&month=1&day=11&year=2003
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&month=1&day=11&year=2003
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&month=1&day=11&year=2003

Rainfall was consistent at a moderate level throughout the entire event, interspersed with lighter and heavier showers. The rain did not stop until approximately noon on the 12th. Note that rainfall at the adjacent Clear Creek sites was nearly identical and that CH had the greatest rain of all the PSNS gauges. While the non-PSNS Silverdale site recorded nearly 1.50" of rain, this site is located approximately 3/5 mile west of SC on west side of Hwy 3 at an elevation of ~100' and it is theorized that it simply rained locally a bit harder in this area – which might be reflected in the higher total at CH.

By midday on 12 January, it was apparent that the storm event was ending, as verified by satellite data and site conditions. Like it began, the storm quickly ended and blue skies dominated the area. Sampling sites were turned off beginning shortly after 1500 and samples were collected and iced down for subsequent delivery to PNNL the next morning. Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco's to a laptop for analysis/viewing with Flowlink (see Appendix B).

The antecedent dry period preceding this storm was approximately 7 days, much greater than the 24-hour provision in the SAP. This relatively long dry period (for this time of year) allowed the watershed(s) to begin to "load up" with pollutants.

3. Storm Sample Event #2 Results

At all stations except 1 (CH – see discussion below), all of the sampling equipment performed as expected. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at CC and CW and therefore physio-chemical data was not recorded electronically. However, using the YSI 650 handheld logger, data was successfully obtained at each of these sites when fecal coliform samples were taken.

Variations to the Sampling and Analysis Plan (SAP)

Several minor variations to the approved SAP occurred during Sampling Event #2 and are discussed as follows.

Chico Creek Over-Sampling

As mentioned above, all of the stations except CH performed as expected. During a check at CH during the evening of 11 January, liquid (i.e., creek water) was discovered in the base of the sampler. In addition, bottles 1 and 2 were filled to the top – it was quickly apparent that the sampler delivered more than the programmed aliquot on at least 2 occasions. A review of the sampling report shows that 2 things happened: 1) first, the sampler did not detect any liquid at intake, and then subsequently, 2) the liquid detector temporarily malfunctioned. This resulted in the Isco not detecting any liquid, and therefore continued to pump creek water past the 140 mL sample size until the bottles filled.

A review of the sampling report and Isco 6700 Manual leads to the following hypothesis: After successfully filling sample 16 of 24 in bottle 1, the unit began sampling 17 of 24. While taking the sample, the liquid detector stopped detecting liquid. As no liquid was detected, the sampler didn't know when to stop pumping liquid into the bottle. This resulted in the bottle receiving a larger aliquot. This process appears to have continued for several more sample cycles until approximately sample 20 of 24, at which the bottle began to overflow, and continued to overflow for the next 4 samples. This process also continued on for the first several samples in bottle 2 (up until 8 of 24 in bottle 2). Upon the arrival of the TEC Team (just before 9 of 24), the team paused the program, emptied the tub, and calibrated the sampler to 140 mL. The field team leader decided to replace bottle 2 with a new bottle – thereby tossing out samples 1 – 8 (which had overflowed into the base of the tub). Therefore, bottle 2 only ended up with samples 9 – 14 of 24; not a complete spectrum but more than half. Therefore, bottle 1 from CH was filled higher than expected and bottle 2 was at a lower volume than expected.

As for what might have caused the error, it might have been a partial occlusion at the intake (perhaps a plastic bag wrapped around the PVC pipe) or the sample tube was twisted and/or pinched (creating a 'hard angle' which made it difficult for the liquid to pass though). In any event, the remainder of the storm event was sampled successfully as programmed. Continued checking of sites every few hours throughout the sampling event will ensure that challenges (when they do occur) can be dealt with quickly and fixed to minimize the potential loss of samples.

YSI 6820 Sondes

As mentioned previously, the YSI sondes were calibrated prior to mobilization to the field. However, several of the sondes were not able to communicate with the Isco units when installed. TEC believes that this may be because some of the YSI sondes are set at a baud (communication) rate different than what the Isco uses. TEC will investigate the problem and work to a solution, hopefully prior to the next sample event. In any event, good data was obtained from the sites using the YSI 650 (hand-held data logger) during the fecal grab samples.

Action Items

Storm Sampling Readiness

TEC has finished plumbing the 5 southern group sites. Per direction from PSNS, the next sampling event will occur at the 5 southern sites (and perhaps 1 northern site). Now that 2 storms have been sampled at the northern group sites, it is anticipated that the next 2 events (#3 and #4) will occur at the southern sites. TEC is ready to sample the next qualifying storm and will continue to monitor weather forecast for the next one.

YSI Sonde/Isco Communication

As described above, TEC will investigate as to why some of the YSI sondes are unable to communicate with some of the Isco samplers, while other seemingly identical sondes/Iscos are able to communicate properly.

Strawberry Creek Re-Plumb

On Monday, 13 January during de-mobilization, R. Pingree ran into Jim LeCuyer from Kitsap PUD at Barker Creek. Jim mentioned that the plumbing at Strawberry Creek was set in such a way that he felt it was creating an eddy which was slightly altering their data logger readings. While Jim understands why we placed our plumbing where we did (he initially agreed with the placement), he would like us to move the plumbing and intake downstream from his logger to reduce the interference. TEC will accomplish this task by the end of the month; however it will take a day's worth of labor and additional materials to accomplish this work.

RTD Error

The RTD successfully downloaded the rainfall and physio-chemical data from each of the sites, except for Barker Creek. Switching to the other RTD (in case the first one was full) resulted in the same result. However, rainfall data was retrieved via the Sampling Report, which was successfully downloaded from the Isco. TEC is investigating why this occurred will try to have the issue resolved in time for the next sample event.

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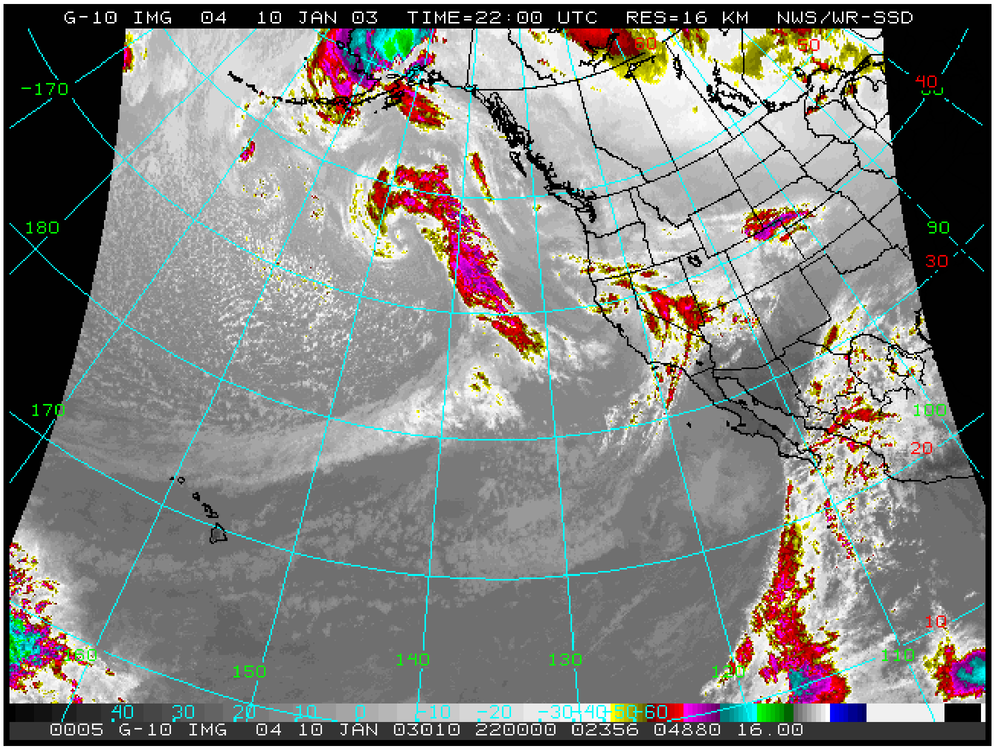
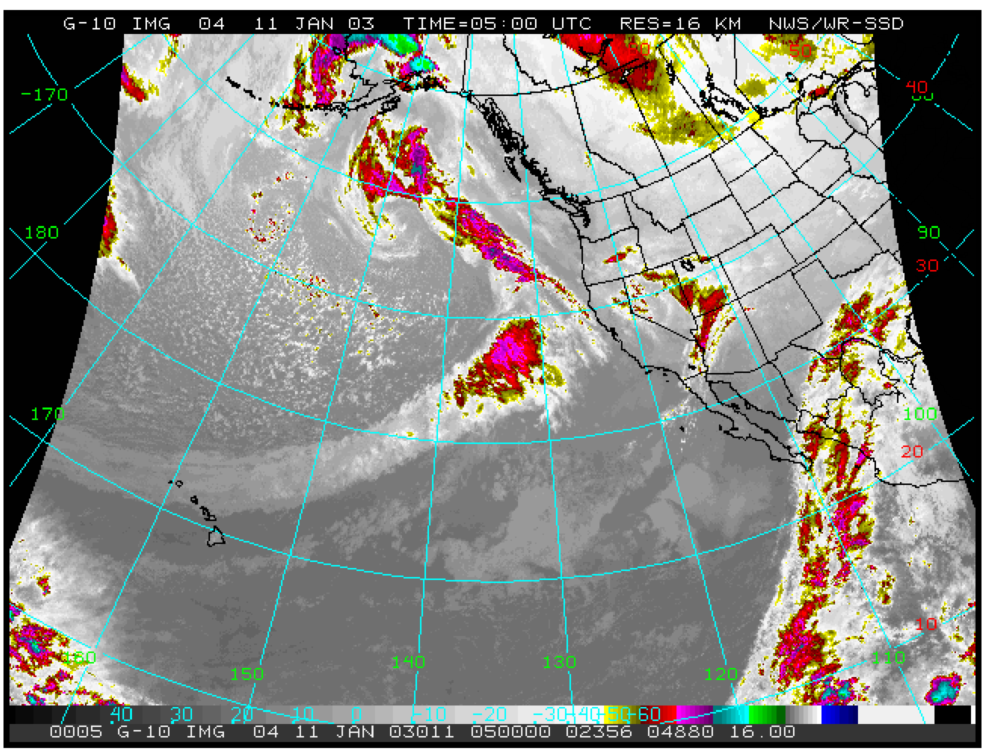
Appendix A

Satellite Data of Storm Event #2

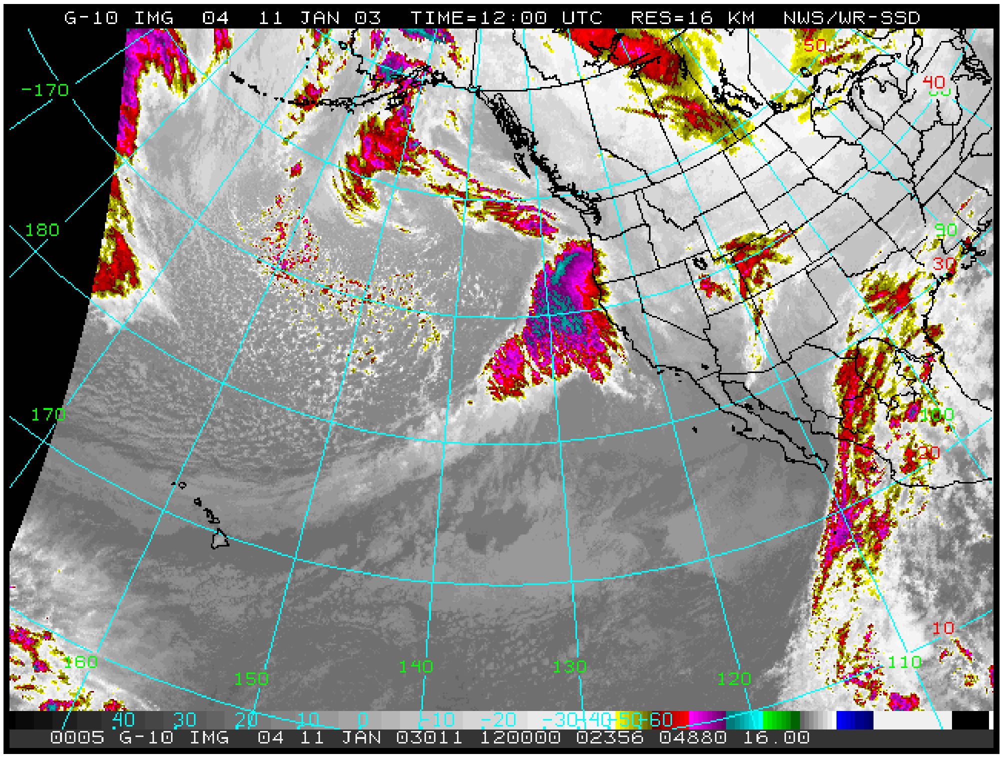
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



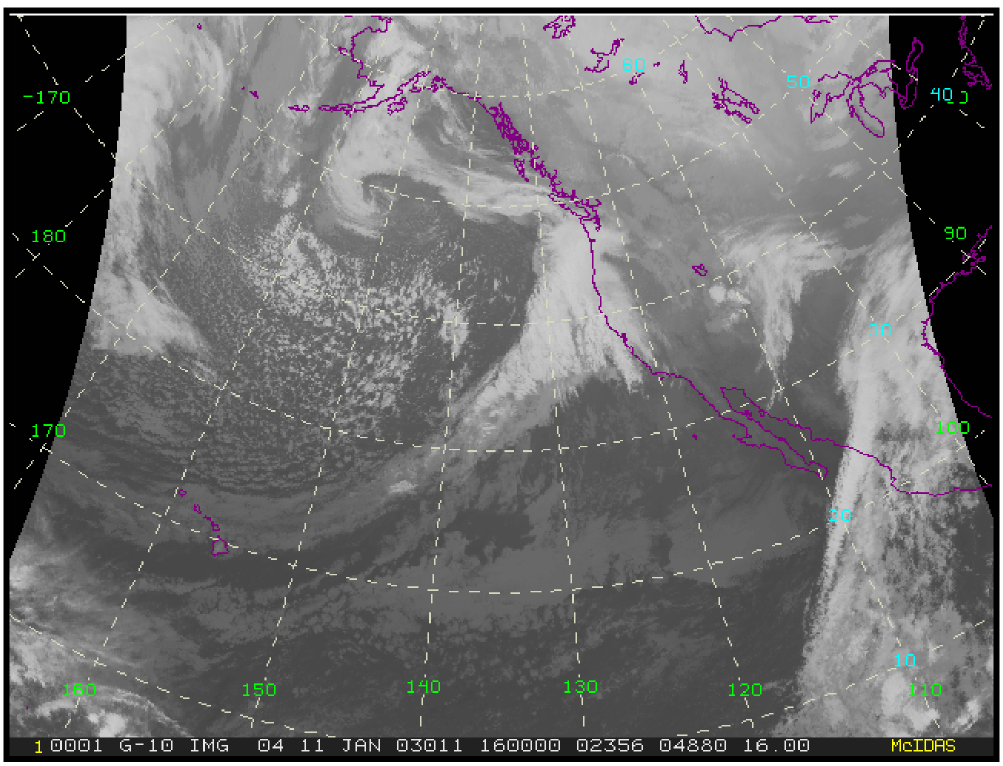
10 January 2003 1200 (local time) - Storm Develops



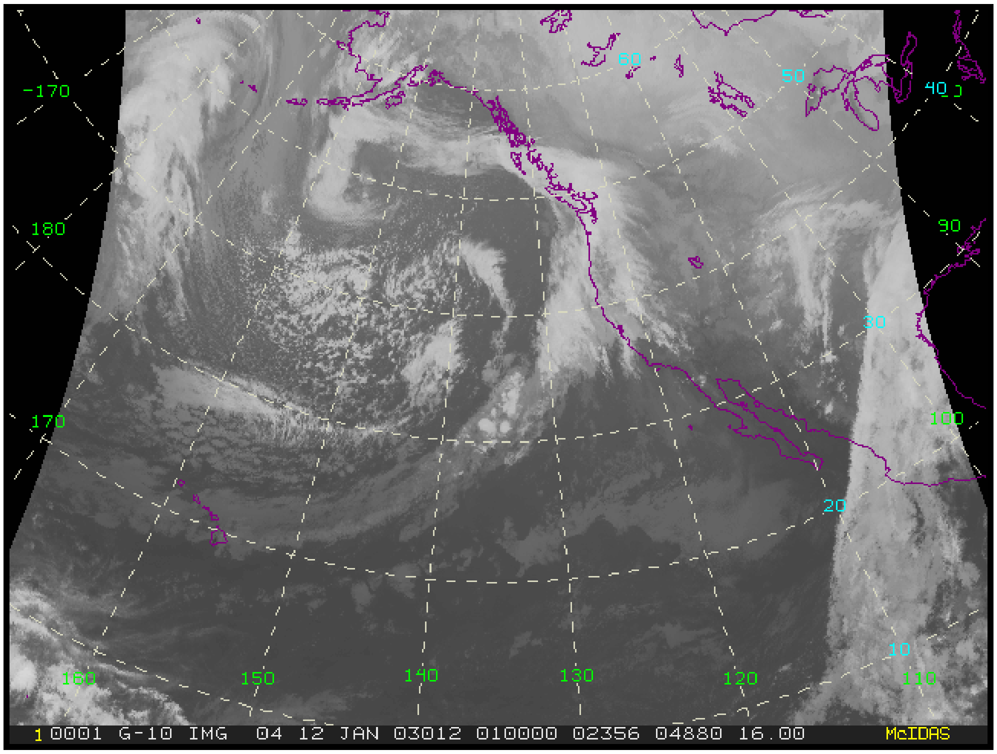
10 January 2003 2100 (local time) – "Alaskan low" develops. Note subtropical connection to front.



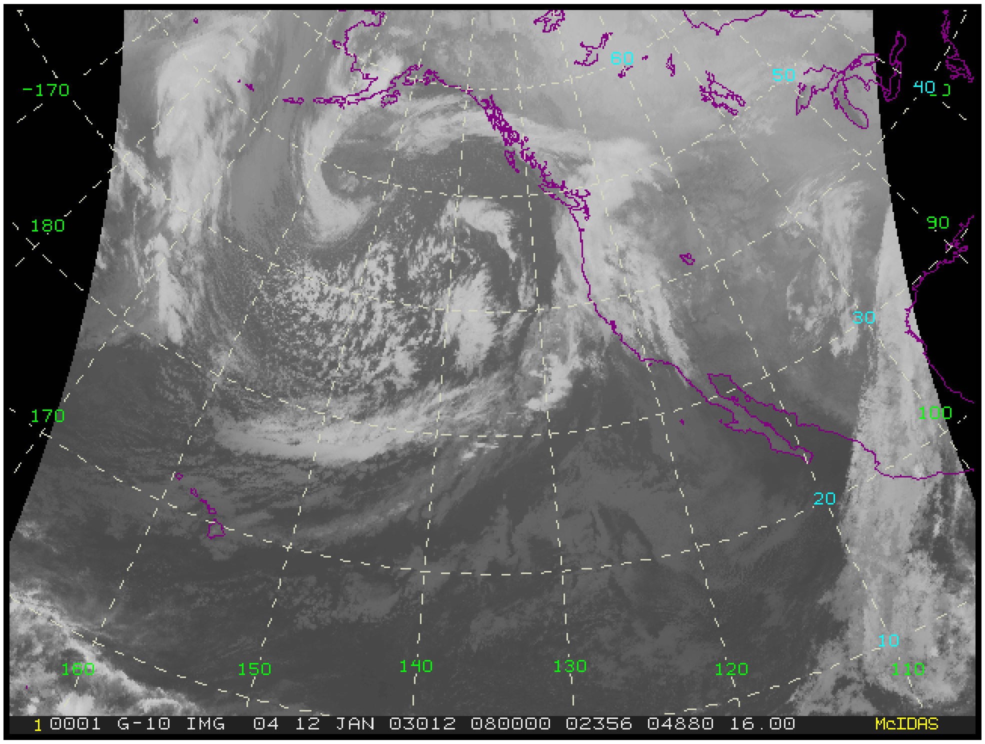
11 January 2003 0400 (local time) – Front begins to orient itself north/south, directed at Northern Oregon



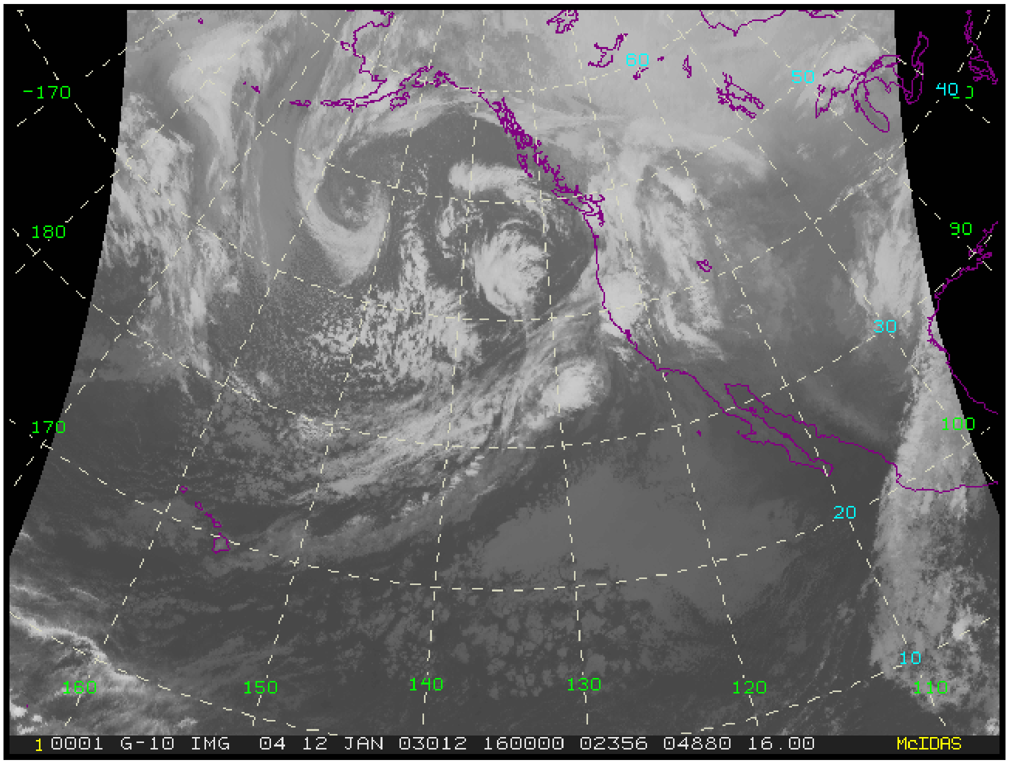
11 January 2003 0800 (local time) – Moisture plume moves into area; no rain yet.



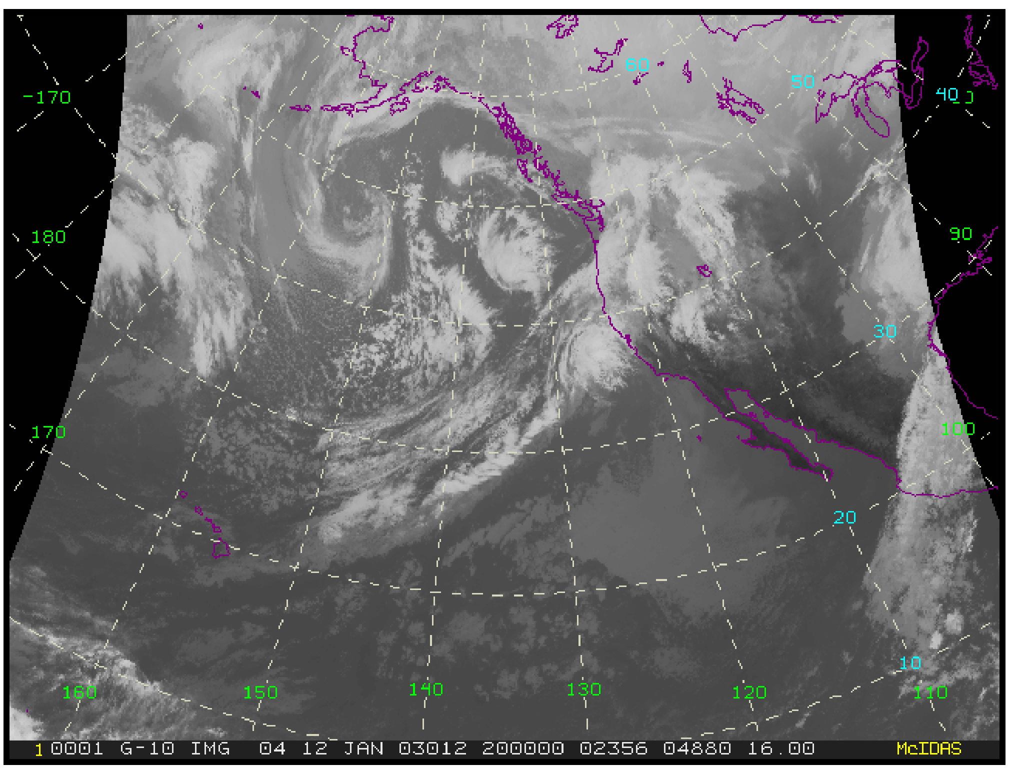
11 January 2003 1700 (local time) – Rain begins. Note N/S orientation of front – consistent with rainfall spreading in from south to north in project area.



12 January 2003 0000 (local time) – Midpoint of storm. Front stalls out over WA.



13 January 2003 0800 (local time) – Front begins to dissipate/pass through area.



13 January 2003 1200 (local time) – Clear skies; storm is over. Sampling continues for ~3-4 hours.

Appendix B
Flowlink Rainfall, Physio-Chemical Data, and Fecal Coliform CoC Form

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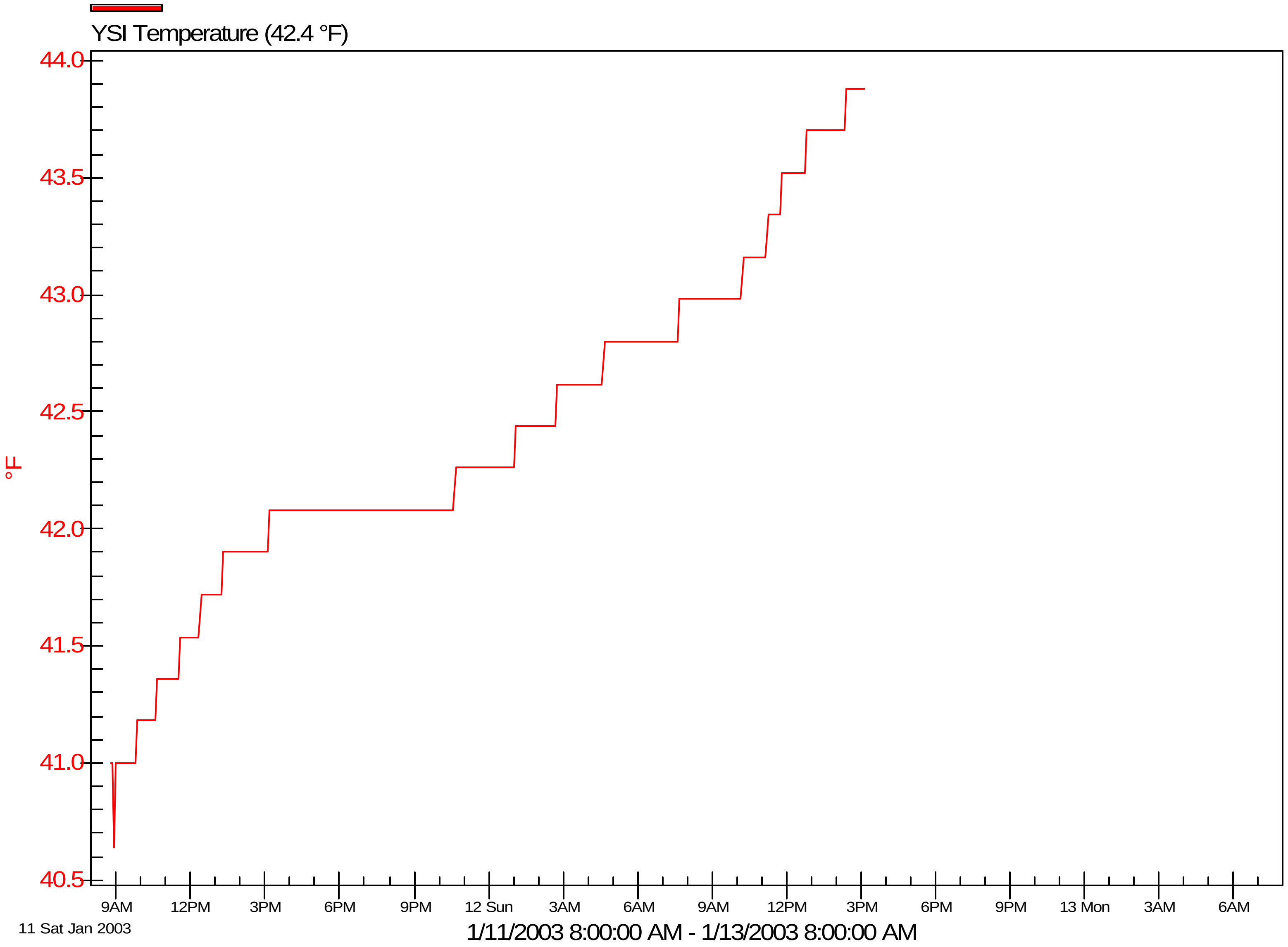
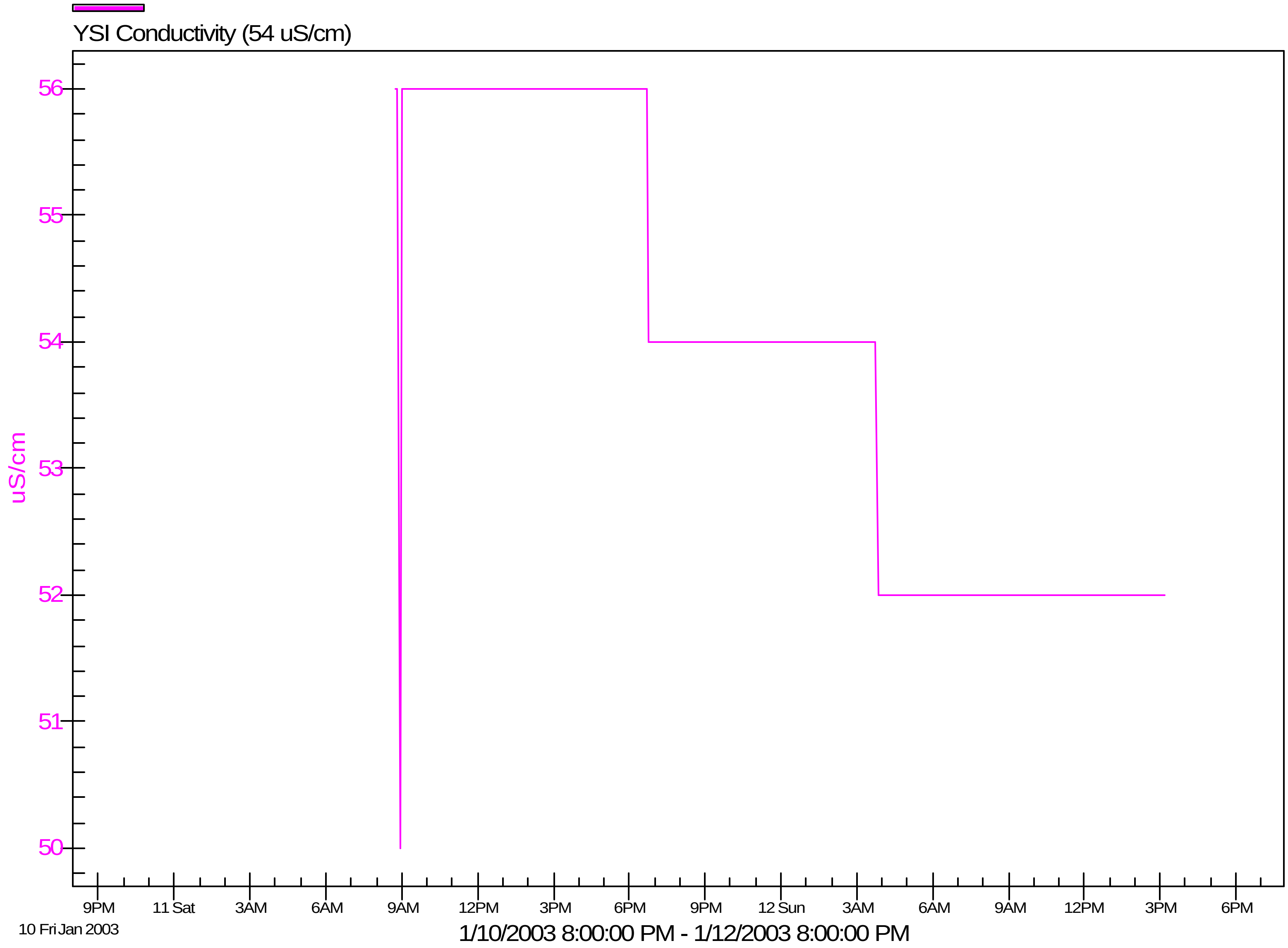
CH 002

Flowlink 4 for Windows



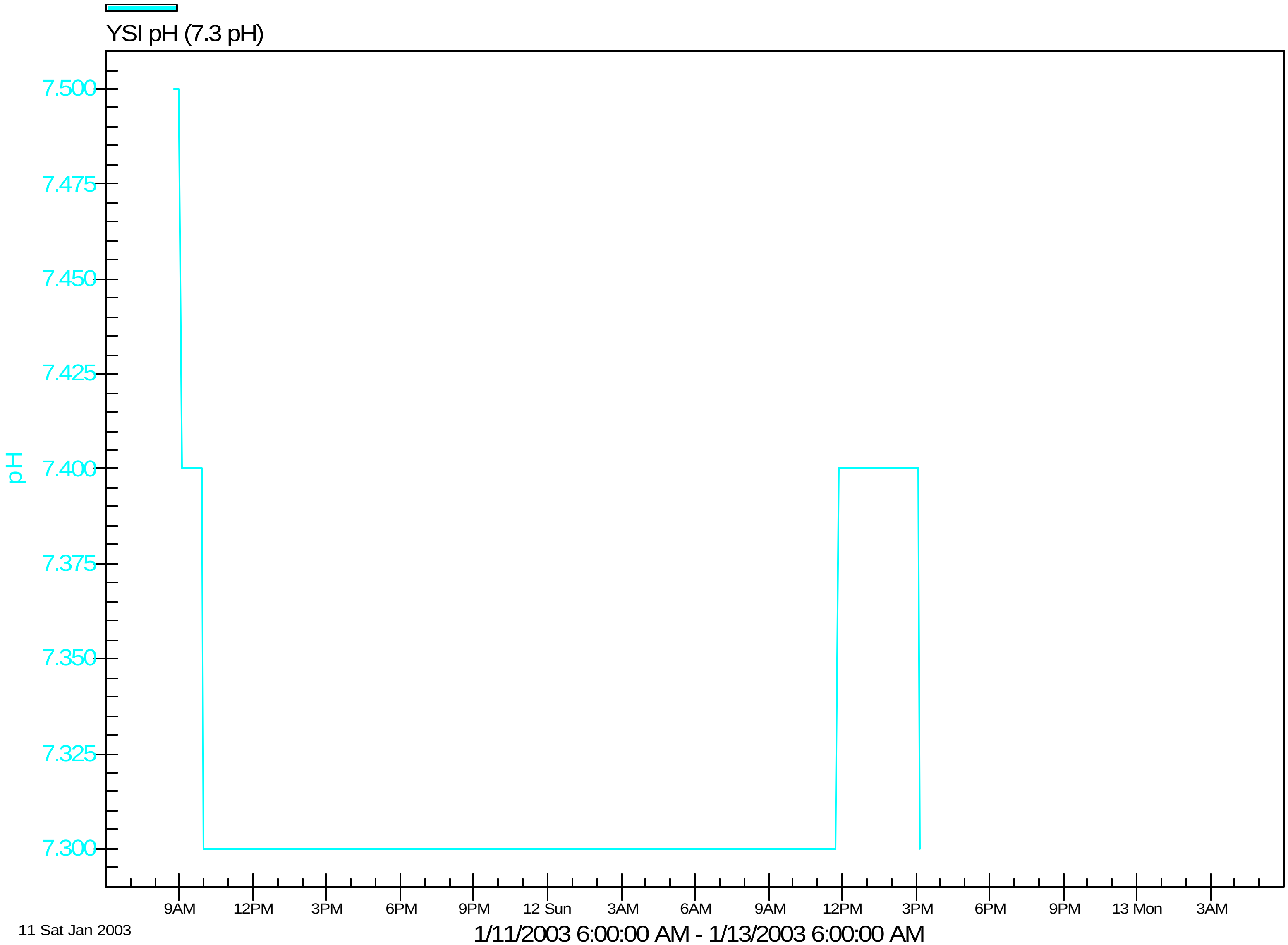
CH 002

Flowlink 4 for Windows



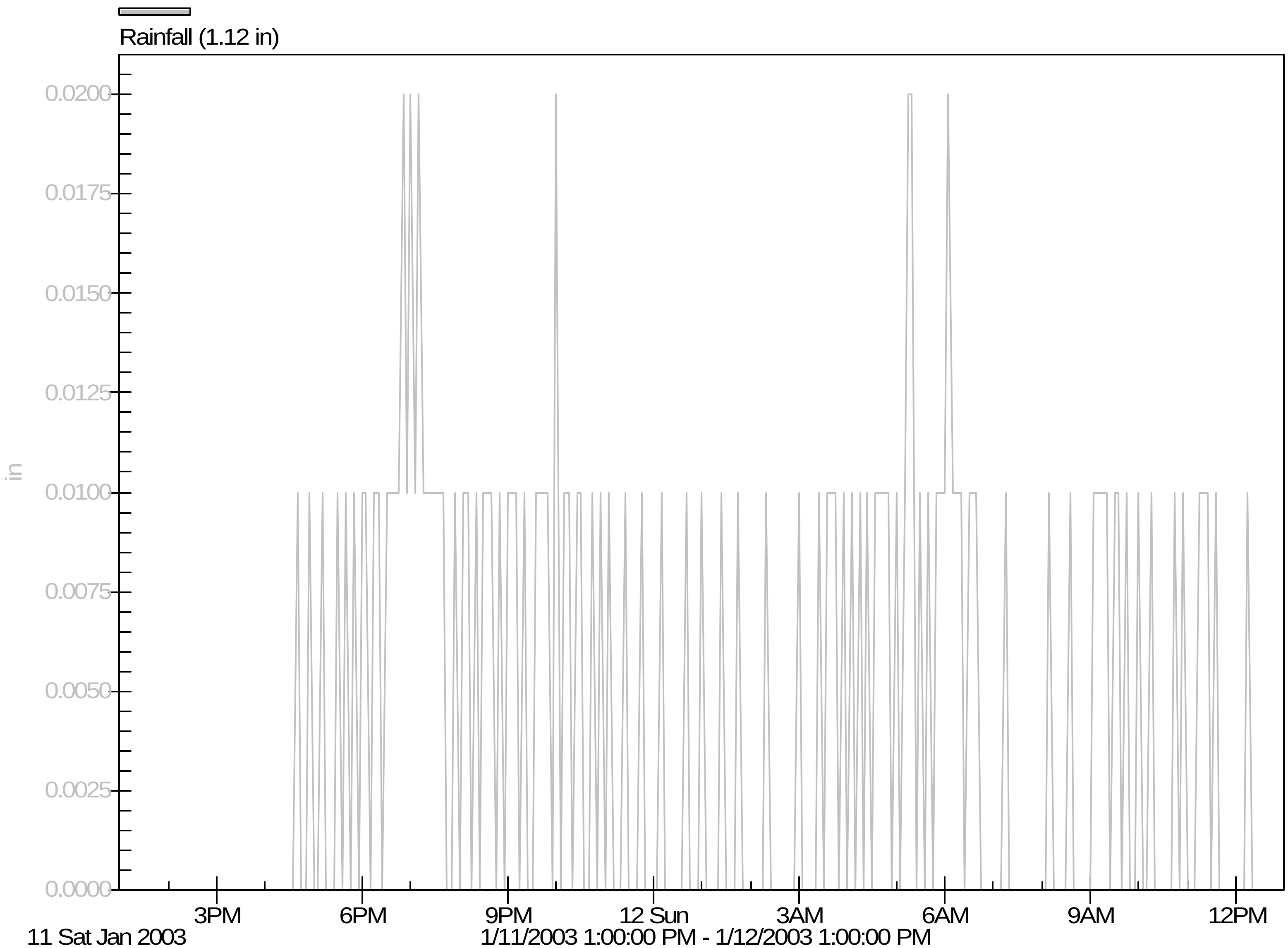
CH 002

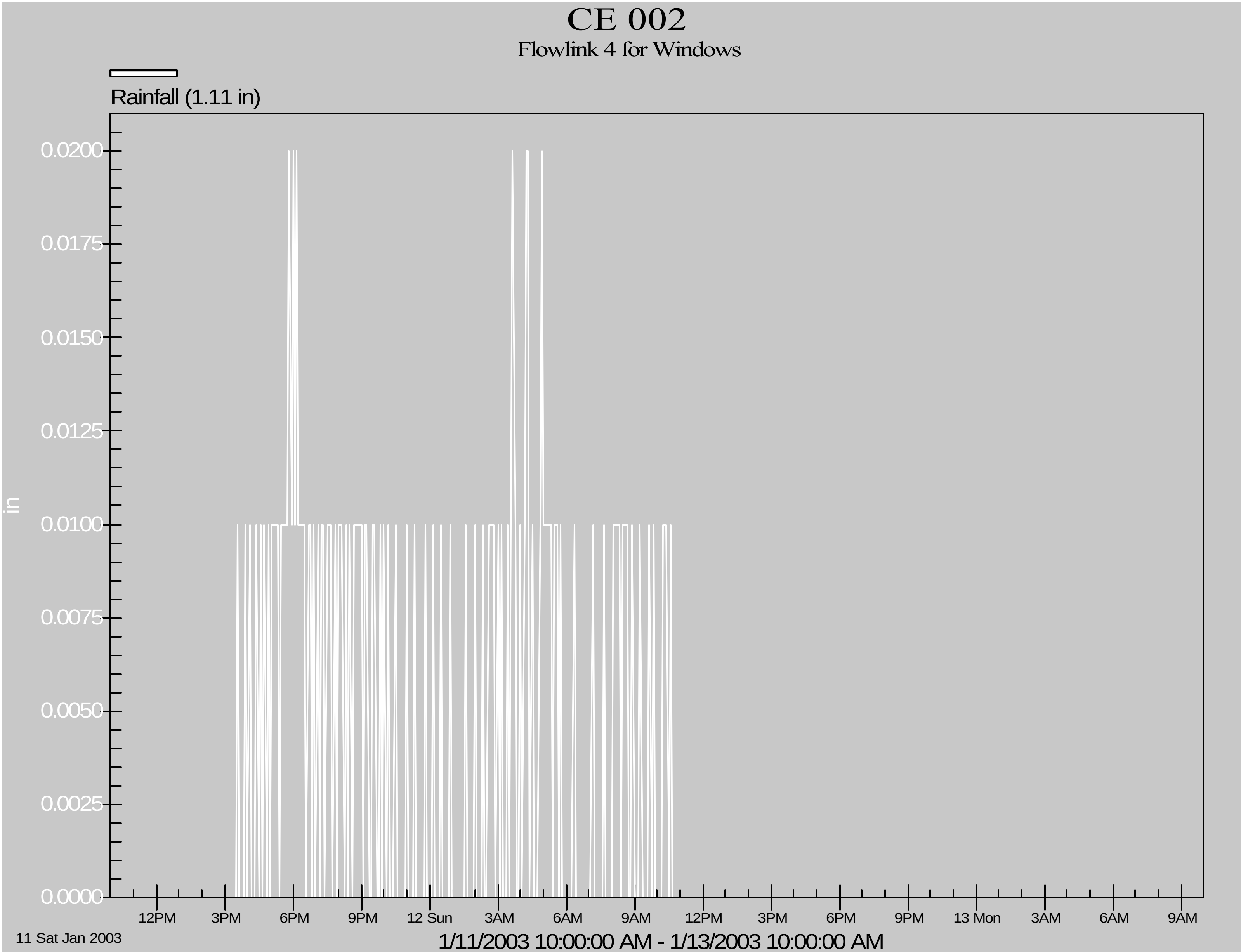
Flowlink 4 for Windows



CC 002

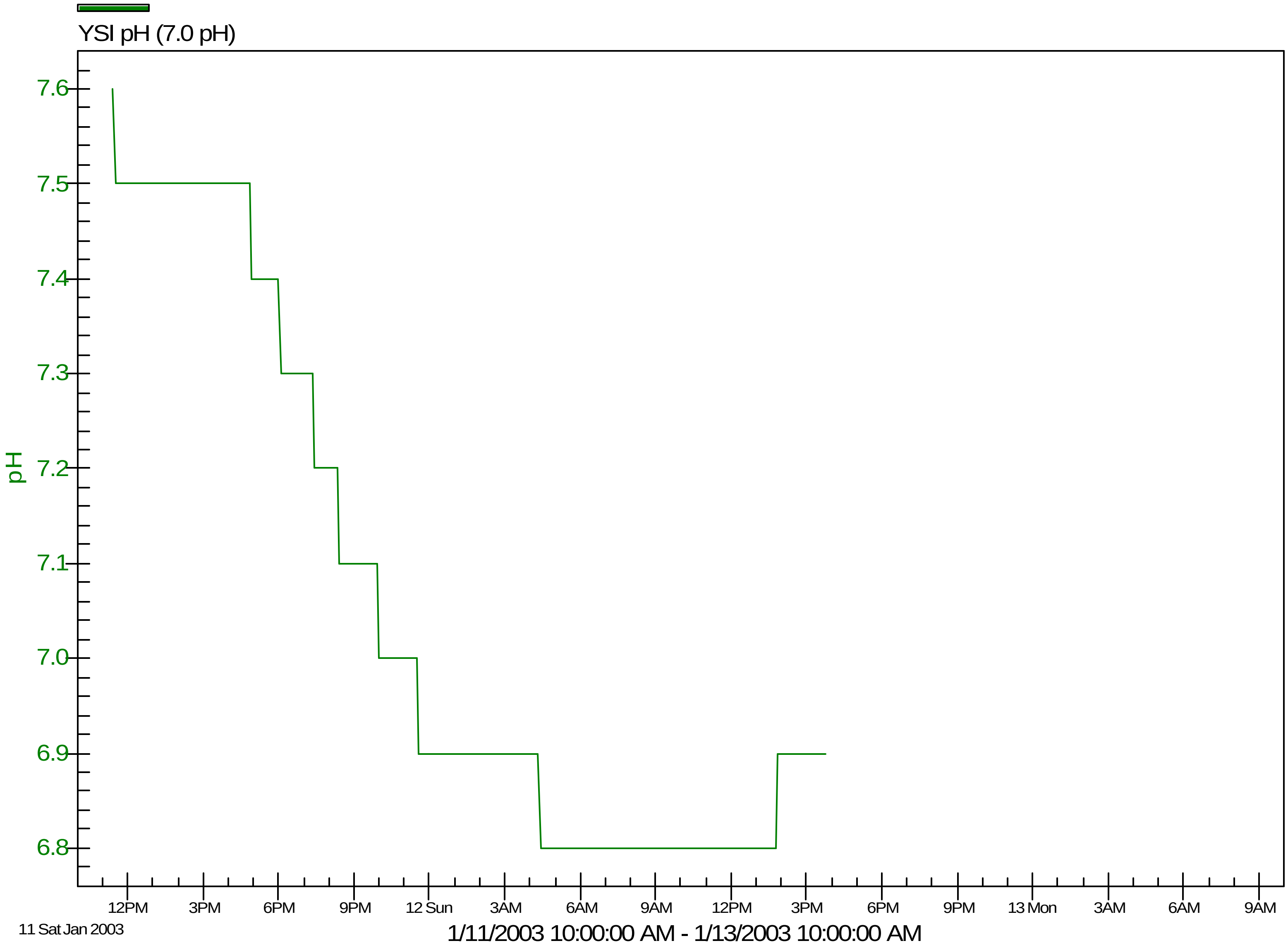
Flowlink 4 for Windows




CE 002
Flowlink 4 for Windows
Rainfall (1.11 in)
in
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
12PM
3PM
6PM
9PM
12 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
13 Mon
3AM
6AM
9AM
11 Sat Jan 2003
1/11/2003 10:00:00 AM - 1/13/2003 10:00:00 AM

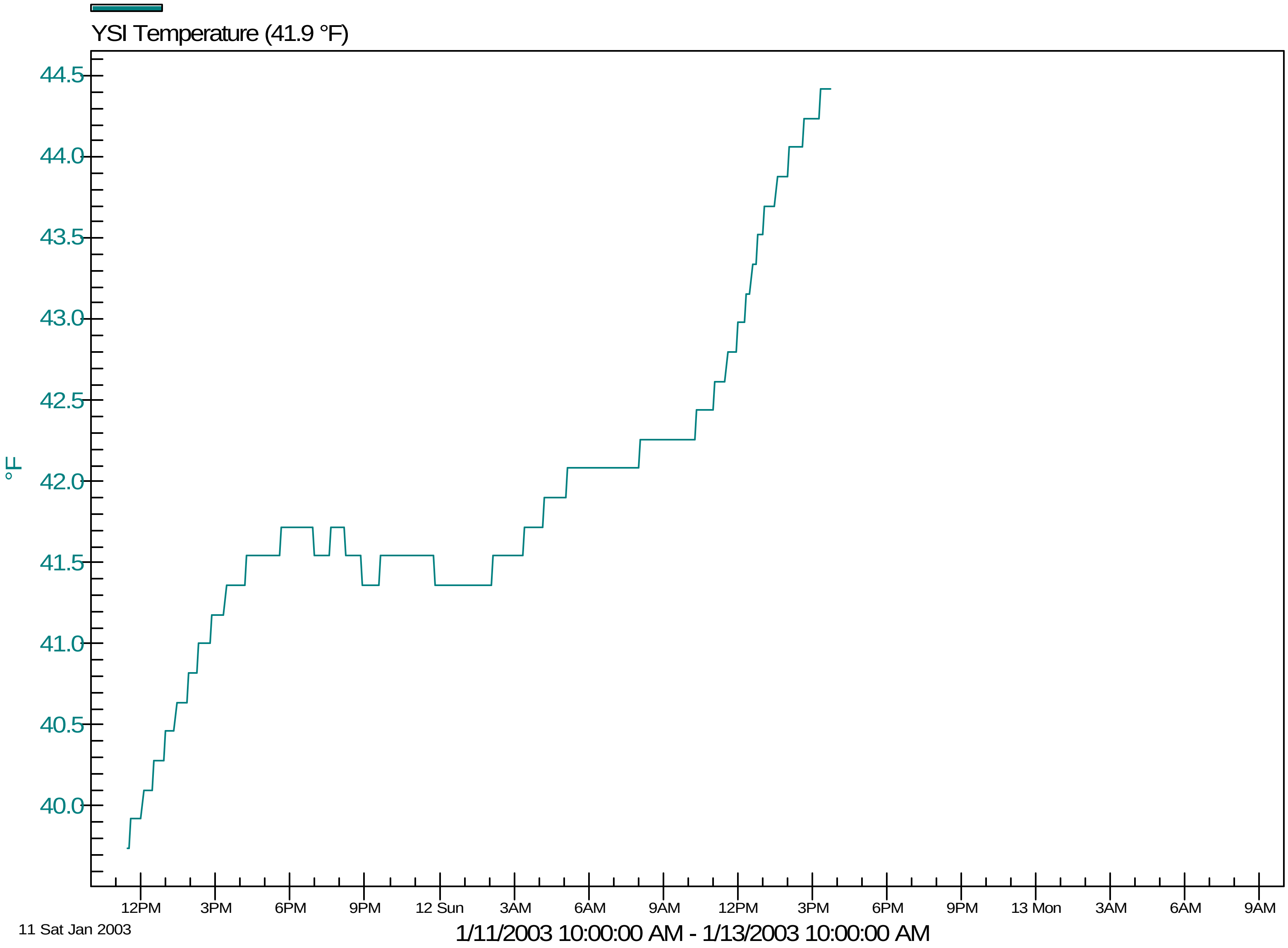
CE 002

Flowlink 4 for Windows



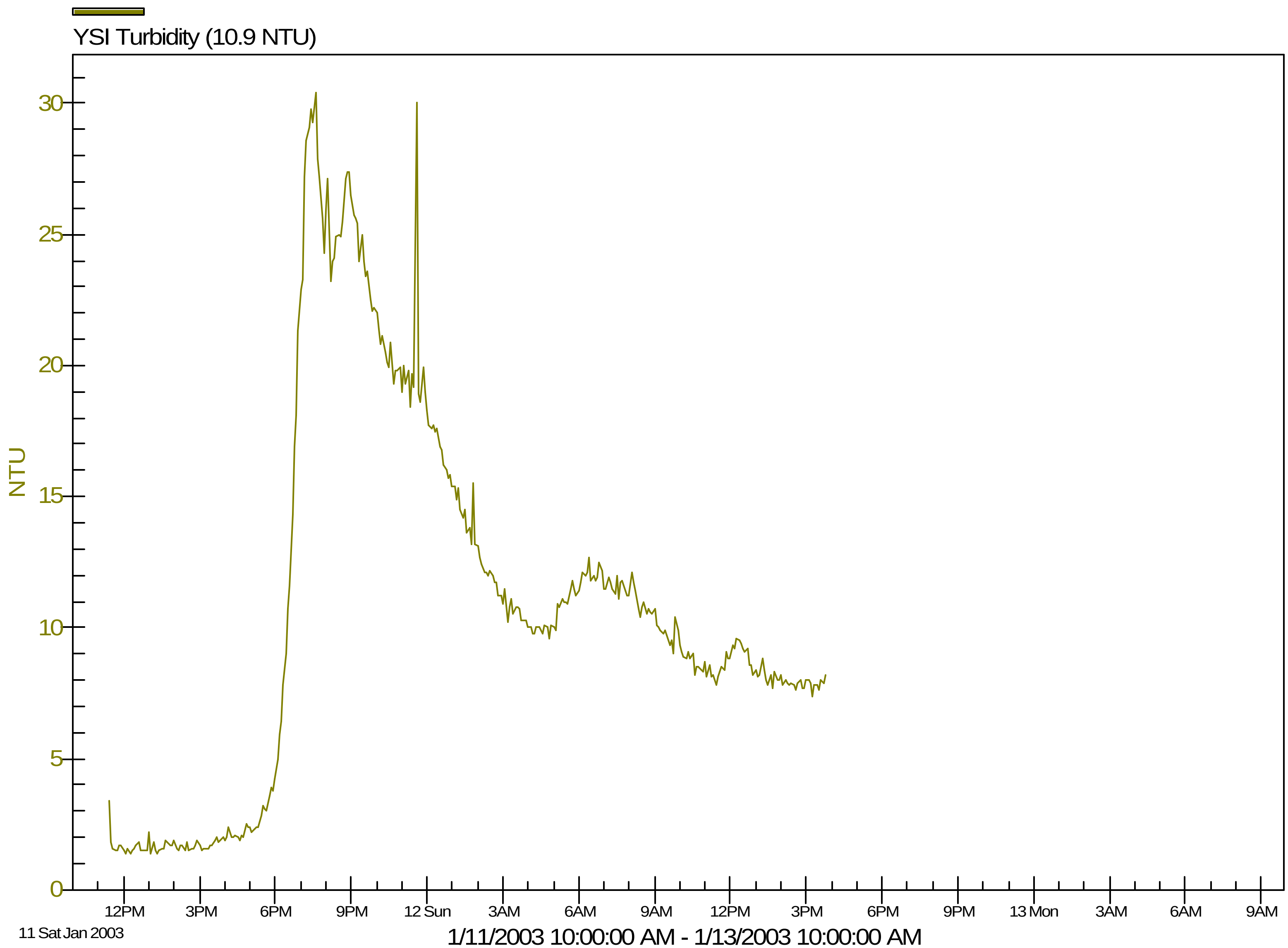
CE 002

Flowlink 4 for Windows



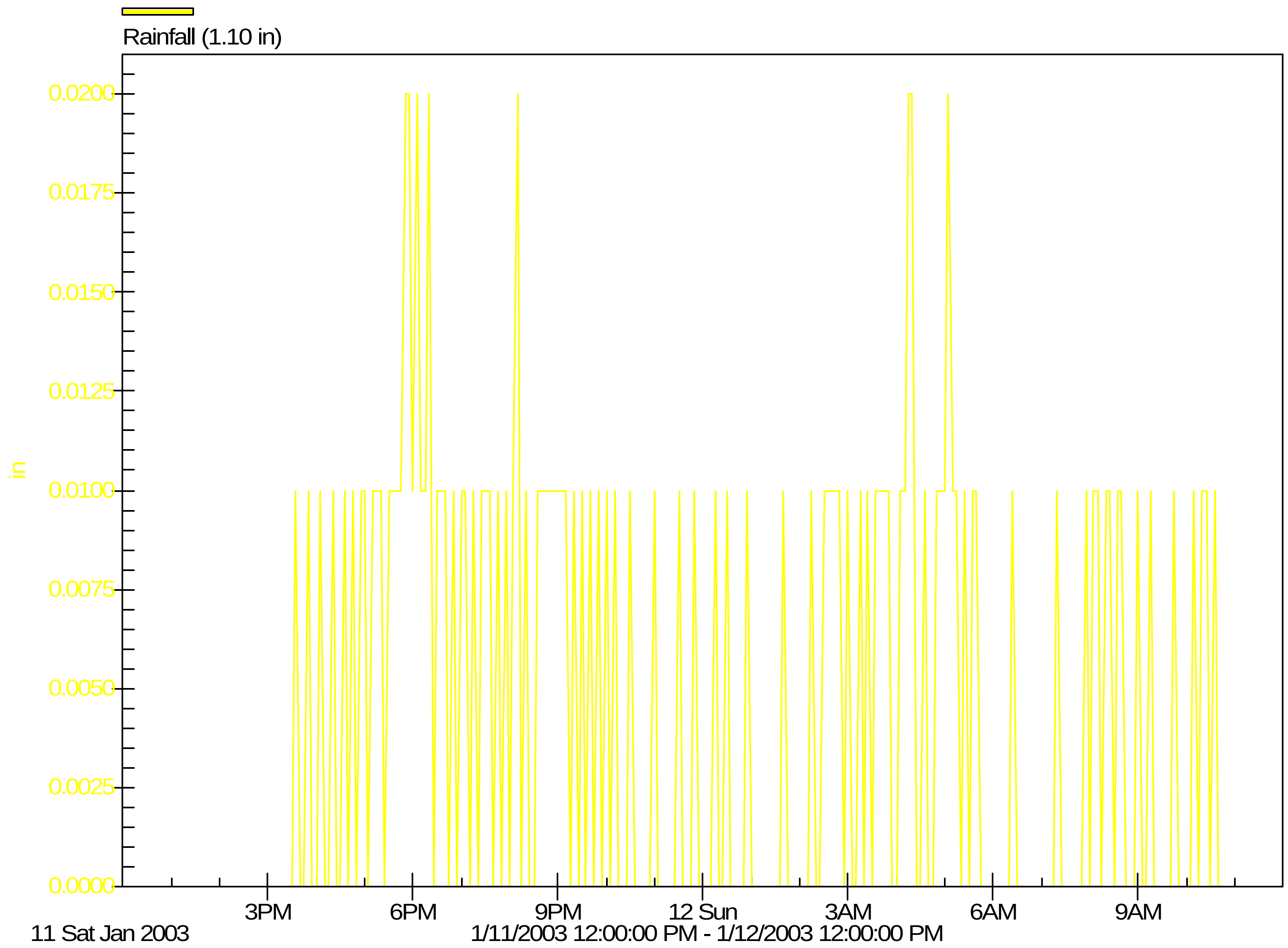
CE 002

Flowlink 4 for Windows



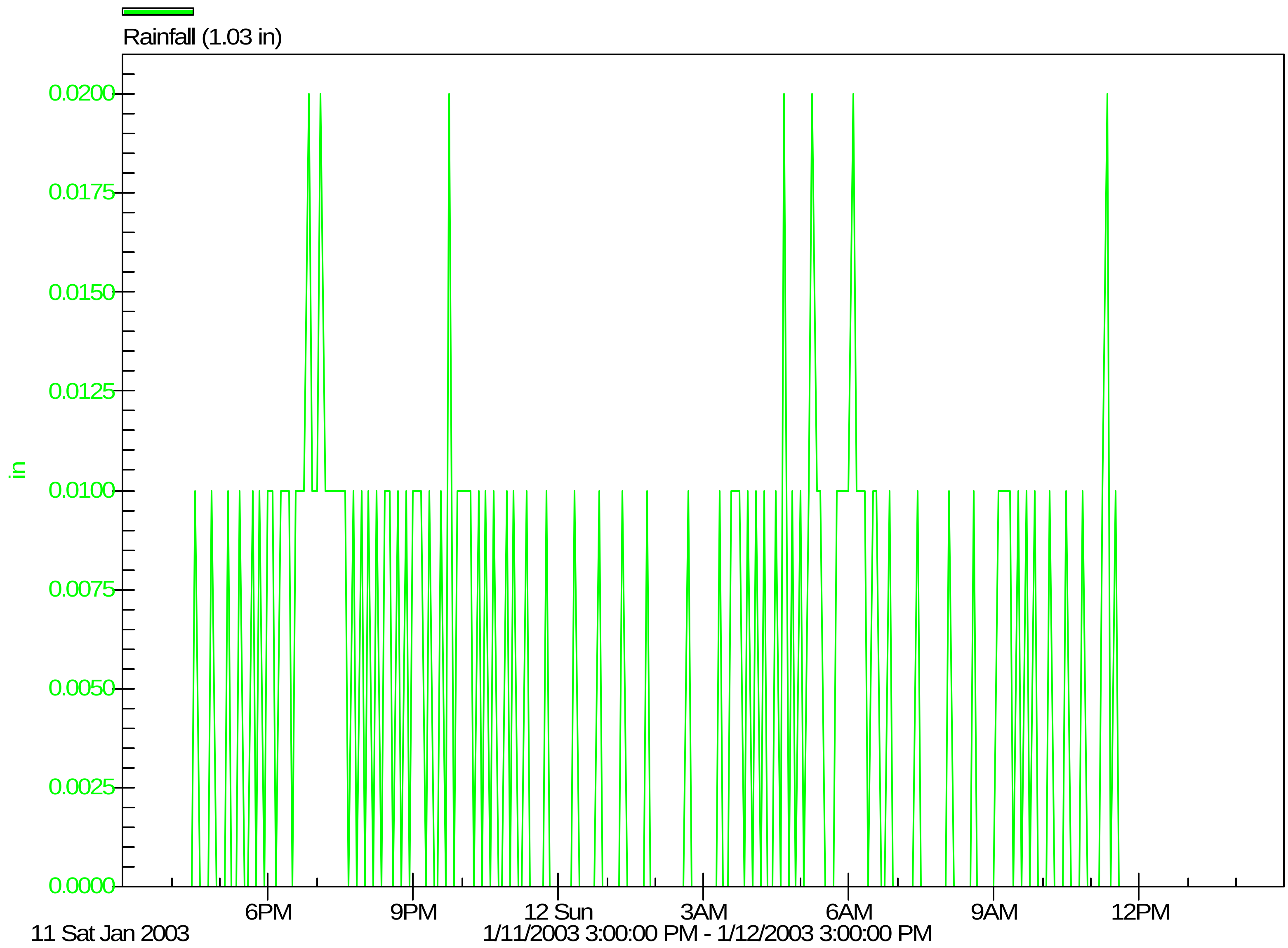
CW 002

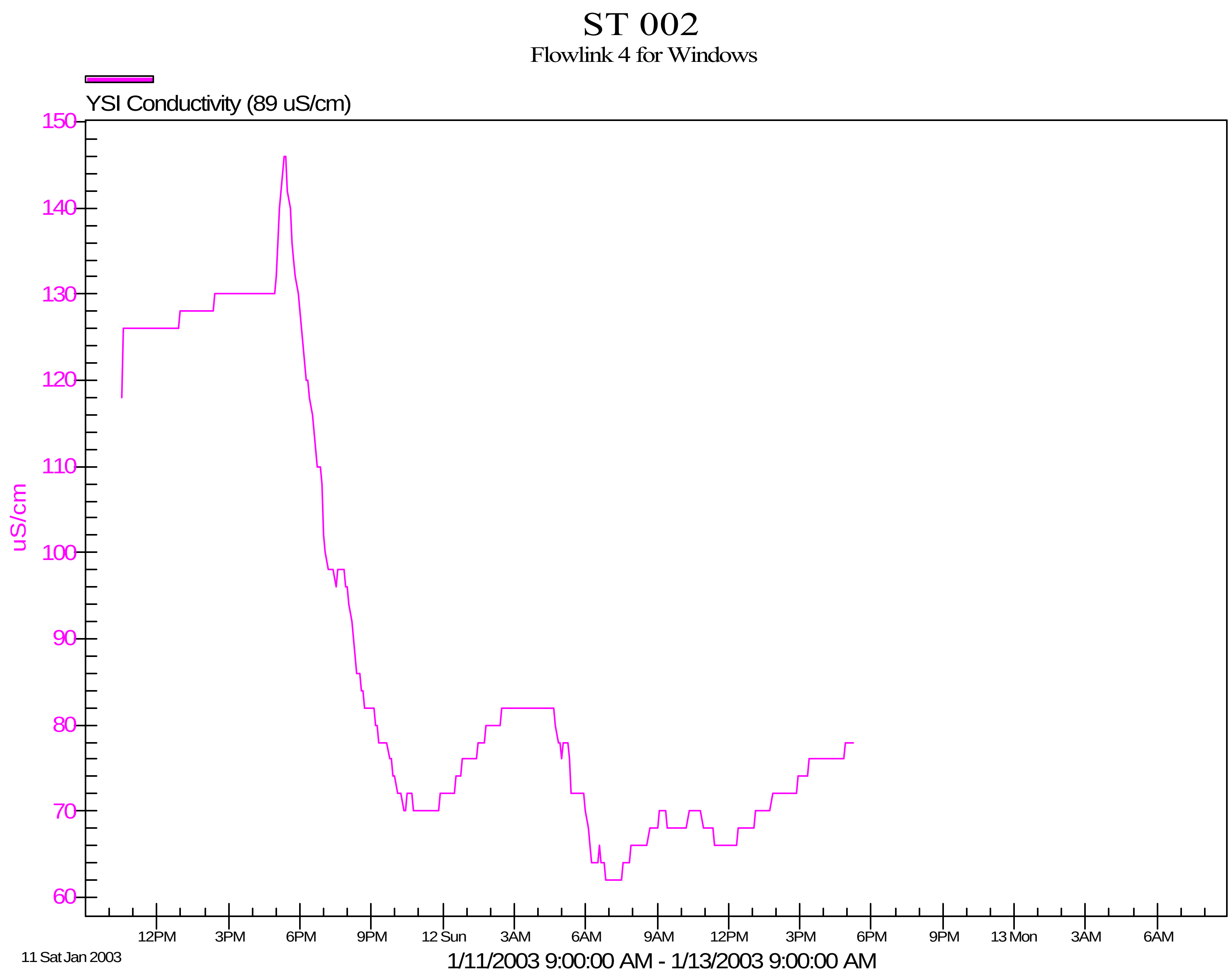
Flowlink 4 for Windows



ST 002

Flowlink 4 for Windows

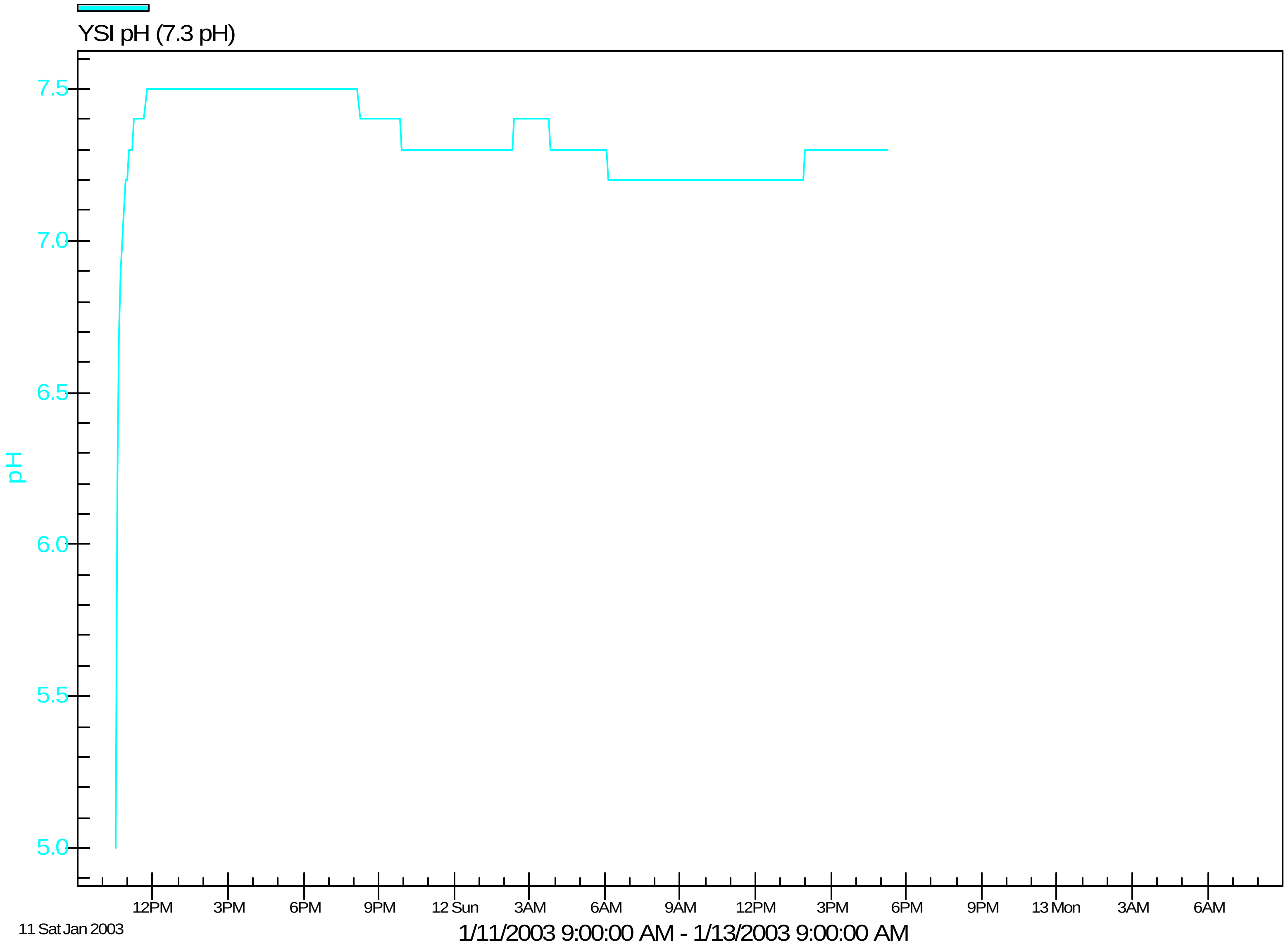




ST 002
Flowlink 4 for Windows
YSI Conductivity (89 uS/cm)
uS/cm
150
140
130
120
110
100
90
80
70
60
12PM
3PM
6PM
9PM
12 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
13 Mon
3AM
6AM
11 Sat Jan 2003
1/11/2003 9:00:00 AM - 1/13/2003 9:00:00 AM

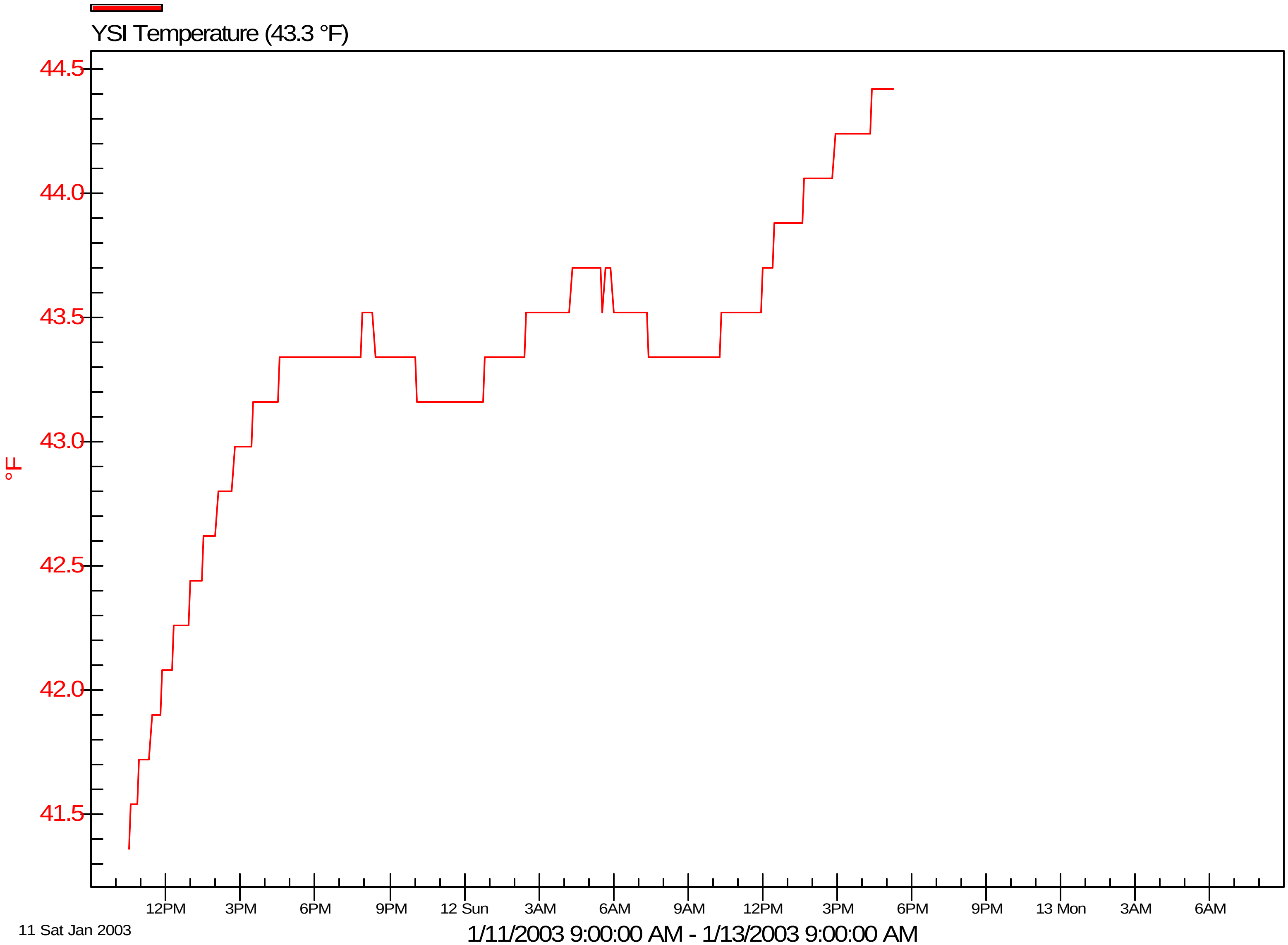
ST 002

Flowlink 4 for Windows



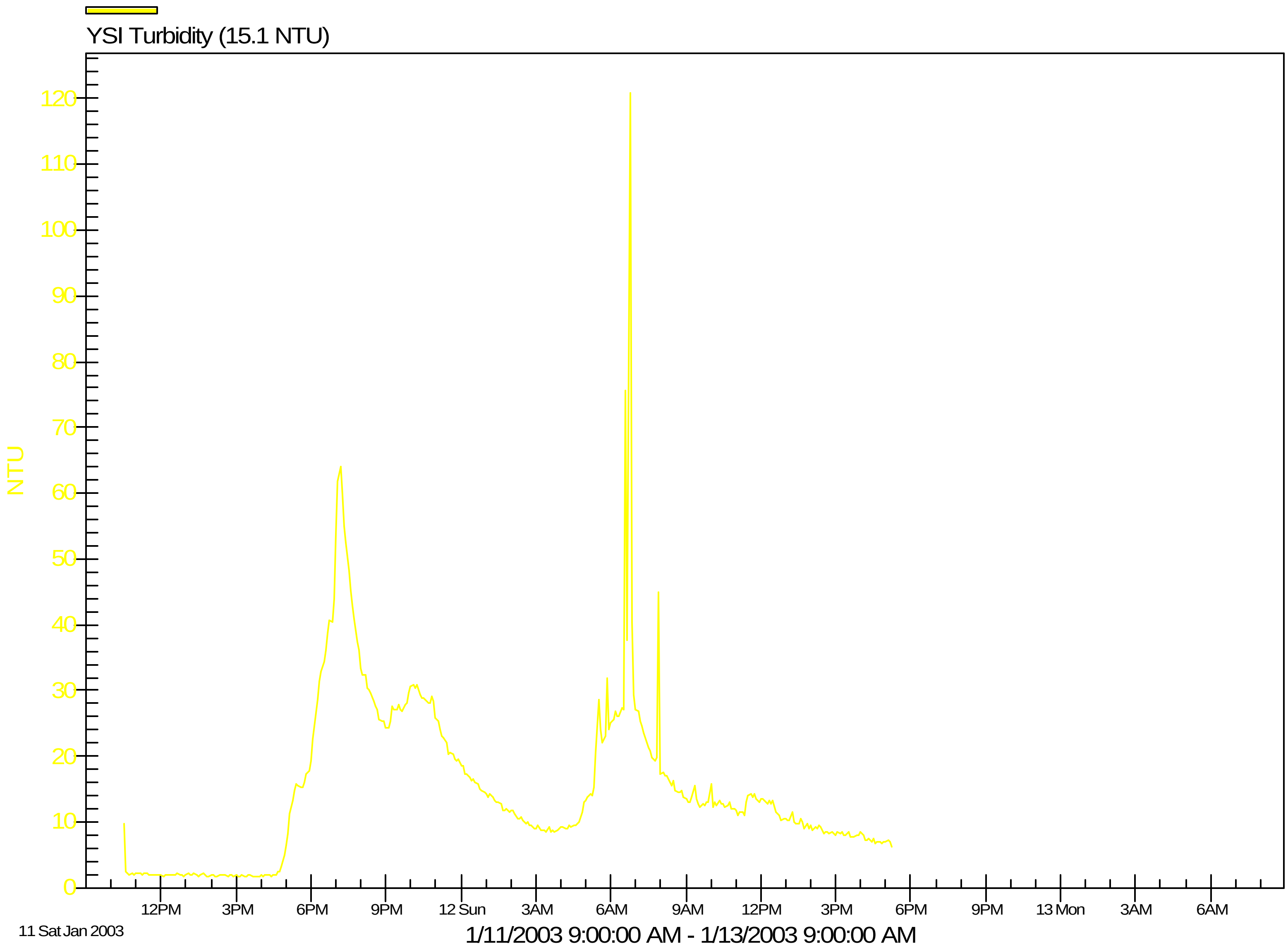
ST 002

Flowlink 4 for Windows



ST 002

Flowlink 4 for Windows



Chain of Custody Form

Sample Collectors	Pingree, Estes, Strayer	PSNS Project ENVVEST
Sampling Team	The Environmental Company (TEC)-Storm Event #2	FC TMDL STUDY
Organization	TEC	

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03020433	Clear West	1/11/2003	16:40	43.4	7.7	0.120	0.0	12	YSI 650 (Handheld) Reading
03020434	Clear East	1/11/2003	16:45	41.5	7.5	0.120	2.4	12	
03020435	Clear Main	1/11/2003	17:05	42.5	7.3	0.114	2.2	12	YSI 650 (Handheld) Reading
03020436	Barker Ck.	1/11/2003	17:20	42.6	7.5	0.119	4.1	12	
03020437	Barker Ck. (Dup)	1/11/2003	17:20	42.6	7.5	0.119	4.1	12	
03020438	Strawberry Ck.	1/11/2003	17:40	43.3	7.5	0.111	42.1	12	
03020439	Chico Main	1/11/2003	18:00	42.1	7.3	0.056	2.8	12	
03020440	Barker Ck.	1/11/2003	23:05	42.1	7.2	0.083	55.2	12	
03020441	Clear Main	1/11/2003	23:25	42.3	7.0	0.081	29.3	12	YSI 650 (Handheld) Reading
03020442	Clear West	1/11/2003	23:35	43.4	7.4	0.091	33.7	12	YSI 650 (Handheld) Reading
03020443	Clear East	1/11/2003	23:50	41.5	6.9	0.072	19.1	12	
03020444	Strawberry Ck.	1/12/2003	0:05	43.3	7.3	0.076	19.7	12	
03020445	Chico Main (Dup)	1/12/2003	0:20	42.3	7.3	0.054	3.2	12	
03020446	Chico Main	1/12/2003	0:20	42.3	7.3	0.054	3.2	12	
03020447	Clear West	1/12/2003	9:05	43.4	7.2	0.066	12.6	12	YSI 650 (Handheld) Reading
03020448	Clear East	1/12/2003	9:15	42.3	6.8	0.061	10.0	12	
03020449	Clear Main	1/12/2003	9:25	42.6	6.8	0.063	11.6	12	YSI 650 (Handheld) Reading
03020450	Barker Ck.	1/12/2003	9:40	42.8	7.0	0.067	35.7	12	
03020451	Strawberry Ck.	1/12/2003	10:00	43.5	7.2	0.068	11.2	12	
03020452	Chico Main	1/12/2003	10:15	43.3	7.4	0.054	4.5	12	

Preservatives Used:			
Relinquished By/Date:		Method of Shipment:	
Received By/Date:		Airbill No.:	
Relinquished By/Date:		Laboratory	
Received By/Date:		Address:	
Relinquished By/Date:			Custody Seals Present? Yes No
Received By Lab/Date:			Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

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Appendix D
Storm Summary Report #3

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #3

(22 January 2003 1200 – Chico Tributary at Taylor Road – Sampling Continues)

22-23 January 2003
Southern Group Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

4 February 2003

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #3
22-23 January 2003

Introduction

On 22-23 January 2003, TEC conducted in-stream storm flow sampling of the 5 southern group creeks (plus Chico Main) within the PSNS Project ENVVEST study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) follow-up action items. In addition, Appendix A presents satellite images, Appendix B contains physio-chemical and rainfall data, and Appendix C contains images taken during the sample event.

1. TEC Staff Participating in Storm Sampling Event #3

Name	Role
Ryan Pingree	Project Manager/Field Team Leader
Greg Whittaker	Field Team Leader
Rusty Divine	Field Team Member
JD Estes	Field Team Member
Jennifer Gaudette	Field Team Member

2. Storm Sampling Event #3

Storm Identification

After a light rain event on 21 January (a maximum of ~0.50 inches in the sampling area), the project area experienced a brief period of dry weather (~7 hours) as a temporary ridge of high pressure set up over the Pacific Northwest in between storm systems. Previous to this moderate rain event, the National Weather Service (NWS) had predicted that the next system would be rather "wet" and potentially long-duration system. As such, it was decided following discussion with the Project Team that this event would be a good storm to sample, as the watersheds were near-saturated and runoff would be expected to mobilize a large amount of pollutants - the preceding moderate event was forecast to not result in much rainfall or high rainfall intensities.

There was some discussion that this event may turn out to be a 48-hour sampling event, given the forecast by the NWS. As such, TEC mobilized to the field in anticipation of a 48-hour sampling event. As shown in the attached satellite images (see Appendix A), the storm system had a strong subtropical connection, thereby increasing precipitable water values (a metric used to approximate how much rain might fall from a system). Also, the Southwest/Northeast orientation of the storm was predicted to allow subtropical moisture 'train' north into the Pacific Northwest. This Southwest/Northeast orientation is not typical of storms in the region (usually fronts approach from the west). This atypical movement was expected to result in almost no "rain shadow" effect for the project area from the Olympic Mountains (i.e., moisture was able to stream unimpeded from the south and rain on the project area without first dropping a significant portion of its moisture in the Olympics). These 2 factors were the main reason why the Project Team decided to sample this storm event.

Preparation

Early on the morning of Tuesday, 21 January, TEC staff mobilized sampling equipment to the 5 southern sites (Chico Tributary at Taylor Road [CT], Gorst Creek [GC], Anderson Creek [AC], Blackjack Creek [BL], and Olney Creek [OC]). In addition, Chico Main (CM) was also included in the sampling event, bringing the total to 6 sites. This sampling event was the first one conducted at the 5 southern sites.

A rain gauge was installed at each site, and the samplers were programmed to begin sampling immediately once > 0.05 inches of rain fell within a 1 hour period. Following site set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data at sites where a connection between the Isco's and YSI was obtained.

In-Stream Storm Flow Sampling

Mobilization was completed and all 6 sites were "armed" by approximately 2000, at about the same time the last of the very light rain from the previous system ended. Following mobilization, the TEC team set up headquarters at the Holiday Inn Express in Port Orchard and monitored the approaching storm. As shown in Table 1-1, rain began to fall after 0400 on the morning of the 22nd. The rain generally worked its way south to north across the area, with pockets of heavier rain in some areas. The rain came on quickly - moderate to at times heavy rain occurred throughout the early and late morning hours.

Table 1-1 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to Manchester Environmental Laboratory (MEL) and Pacific Northwest National Laboratory (PNNL). Throughout the storm sampling event, TEC staff routinely checked on the stations, collected fecal grab samples, monitored weather conditions, and coordinated with PSNS, MEL, and PNNL. TEC delivered the fecal grab samples to MEL at 1100 on the 22nd and again at 1030 on the 23rd to meet the 24-hour holding time (samples were delivered on 2 occasions in case the storm turned out to be a 48-hour event). Similarly, the composite samples were delivered to PNNL at 1100 on 23 January.

Table 1-1. SE #3: In-Stream Storm Flow Sampling Landmarks

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
Date	*22 Jan*	*22 Jan*	*22 Jan*	*23 Jan*	*22 Jan/23 Jan*	*23 Jan*	*23 Jan*
GC	0310	0740	2300	0900	1100/1030	0310	1220
AC	0313	0800	2330	0930	1100/1030	0313	1220
CH	0314	0700	2230	0845	1100/1030	0314	1220
CT	0315	0720	2200	0830	1100/1030	0315	1220
BL	0330	0810	2350	0945	1100/1030	0330	1220
OC	0345	0840	0030[a]	1005	1100/1030	0345	1220

Notes: [a] Sample taken on 1/23/03.

Table 1-2. SE #3: Precipitation within the Project Area

Sampling Station	Total Rainfall[1]
PSNS Project ENVVEST Sampling Stations	
Chico Tributary at Taylor Road (CT)	1.74”
Chico Main (CH)	1.69”
Anderson Creek (AC)	1.56”
Gorst Creek (GC)	1.45”
Blackjack Creek (BL)	1.37”
Olney Creek (OC)	1.33”
Other Rain Gauges in Vicinity	
Silverdale	2.01”
Poulsbo	1.32”
Bremerton (Port of Brownsville)	0.89”

Notes: [1] Storm event totals (1/22 – 1/23).
Sources: Weather Underground: Bremerton:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABREME3&day=23&year=2003&month=1
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&day=23&year=2003&month=1
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&day=23&year=2003&month=1

Rainfall was fairly consistent at a moderate level throughout the entire event, interspersed with lighter and heavier showers. The area did experience a dry period following the passage of the cold front and passing of the center of the low pressure system. At times moderate to heavy showers affected the region – especially during the period from 0800 to 0930 on the 22nd (associated with the warm front), and again from 0000 to 0300 on the 23rd (corresponding to the low pressure system tracking across the area). During the storm, creeks in the project area rose noticeably and debris (e.g., medium-size woody debris) was mobilized. The rain did not stop until approximately 0300 on the 23rd, almost exactly 24 hours from when the rain first began.

During the evening of the 22nd following the passage of the cold front (and the bulk of the precipitation) TEC coordinated with PSNS and determined (based on the best available weather data) that the sample event should end at 24-hours, as no significant rain was forecast for the next 24-hours (beginning at approximately 0400 on the 23rd). By early morning on 23 January, it was apparent that the storm event was over, as verified by satellite data and site conditions. Sampling sites were turned off beginning shortly after 0300 and samples were collected and iced down for subsequent delivery to PNNL later that morning. Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco’s to a laptop for analysis/viewing with Flowlink (see Appendix B). The subtropical connection and Southwest/Northeast orientation of the storm resulted in generally high rainfall within the project area.

3. Storm Sample Event #3 Results

At all stations the sampling equipment performed as expected. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at CT and OC and therefore physio-chemical data was not recorded electronically. However, using the YSI 650 handheld logger, data was successfully obtained at each of these sites when fecal coliform samples were taken.

Variations to the Sampling and Analysis Plan (SAP)

Only 3 variations to the SAP occurred during Sampling Event #3. These minor variations are discussed below.

Antecedent Dry Period < 24 Hours

Sampling Event #3 occurred with an antecedent dry period of only approximately 7 hours. However, the preceding rain was generally light and did not result in a noticeable rise in creek levels. Given that the event that was sampled was forecast to result in a large amount of rain with high rainfall intensities, and the preceding rain event was light, per coordination with the Project Team it was decided to overlook the antecedent dry period in order to capture the runoff from the impending event.

Blackjack Creek Intake Tubing

During mobilization it was discovered that there was not enough Teflon-lined intake tubing to plumb Blackjack (2 feet short). Therefore, following coordination with PSNS, TEC went to Barker Creek and removed the tubing from the site. The tubing was then cut to length for Blackjack and installed. TEC has ordered additional Teflon tubing to replace the tubing at Barker Creek, as well as supply additional tubing for the Strawberry Creek re-plumb (see Field Sampling Report #2). Upon receipt of the tubing, it will be delivered to PNNL for sterilization prior to installation.

YSI 6820 Sondes

As mentioned previously, the YSI sondes were calibrated prior to mobilization to the field. However, several of the sondes were not able to communicate with the Isco units when installed. TEC believes that this may be because some of the YSI sondes are set at a baud (communication) rate different than what the Isco uses. TEC will investigate the problem and work to a solution, hopefully prior to the next sample event. In any event, data was obtained from the sites using the YSI 650 (hand-held data logger) during the fecal grab samples.

Action Items

Storm Sampling Readiness

Per direction from PSNS, the next sampling event will occur again at the 5 southern group sites (and probably Chico Main). TEC is ready to sample the next qualifying storm at the southern sites and will continue to monitor weather forecast for the next storm that is forecast to meet the provisions of the SAP.

YSI Sonde/Isco Communication

As described above, TEC will investigate as to why some of the YSI sondes are unable to communicate with some of the Isco samplers, while other seemingly identical sondes/Iscos are able to communicate properly.

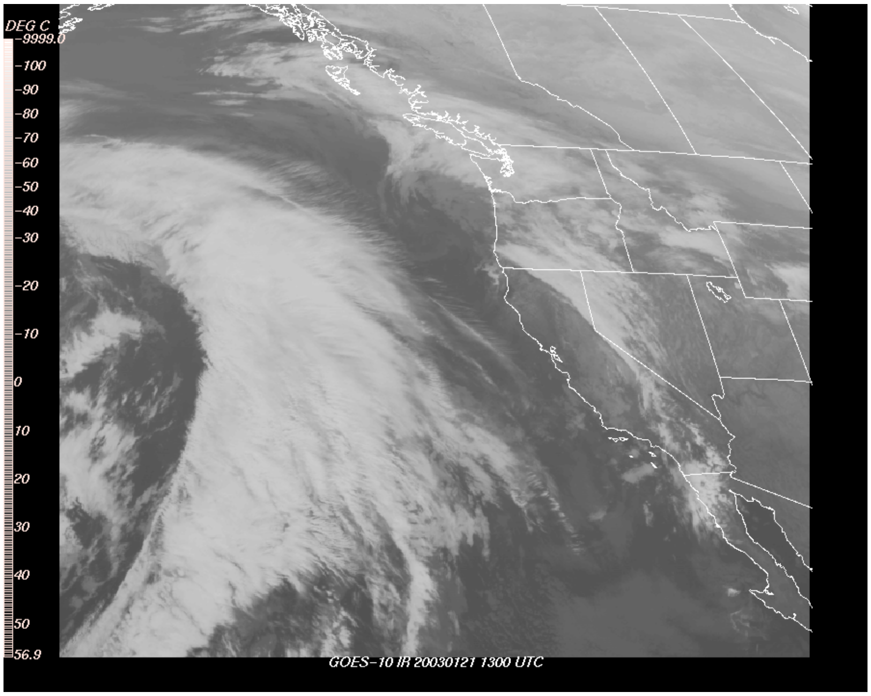
Strawberry Creek Re-Plumb

As described in Field Sampling Report #2, Strawberry Creek still needs to be re-plumbed per the KPUD's request. TEC will try and accomplish this task by early February.

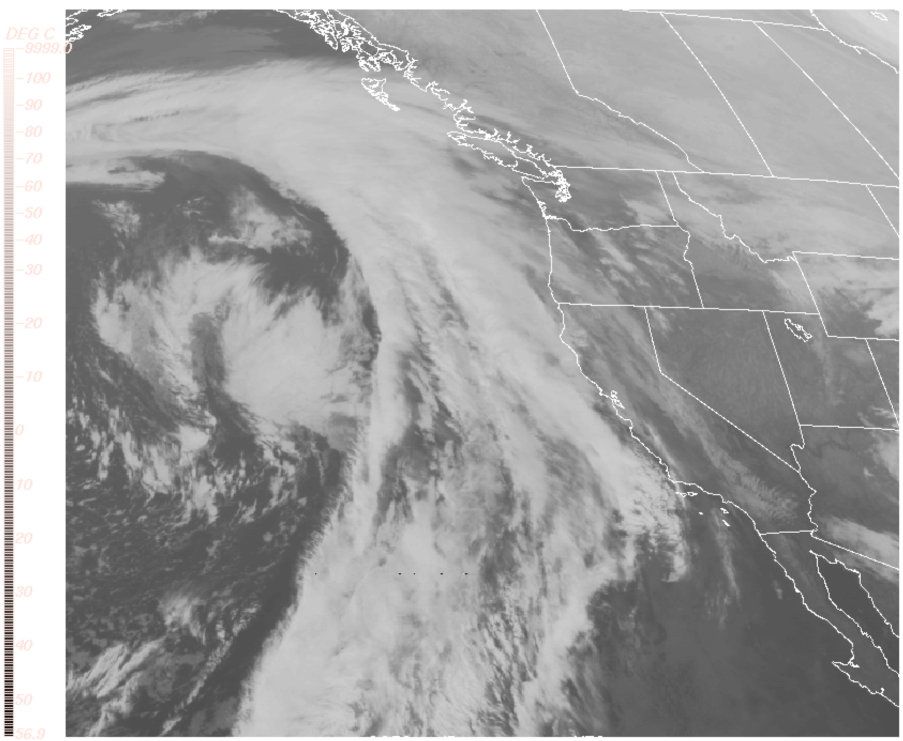
Appendix A

Satellite Data of Storm Event #3

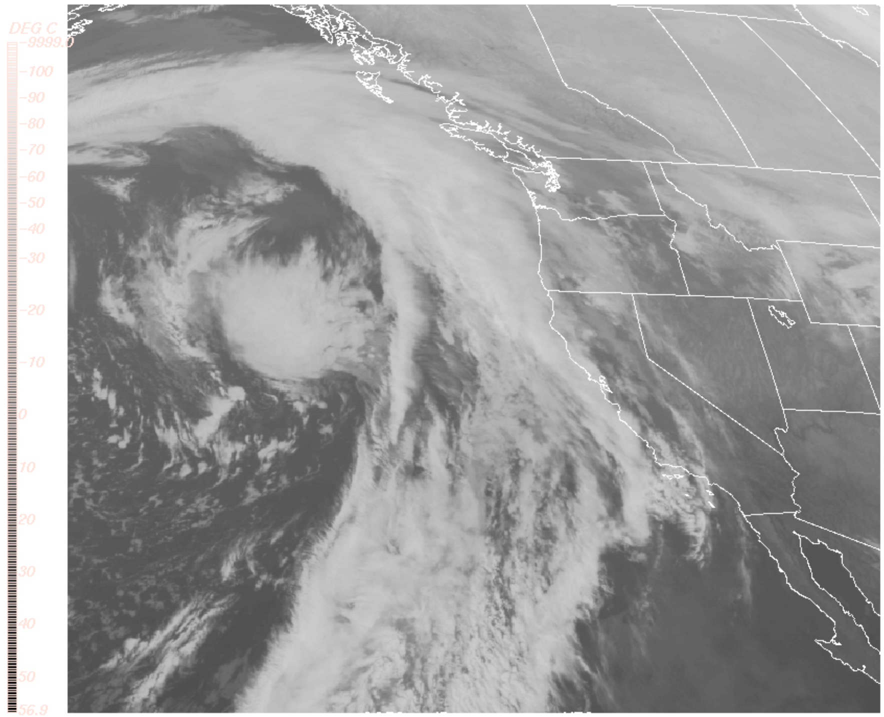
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



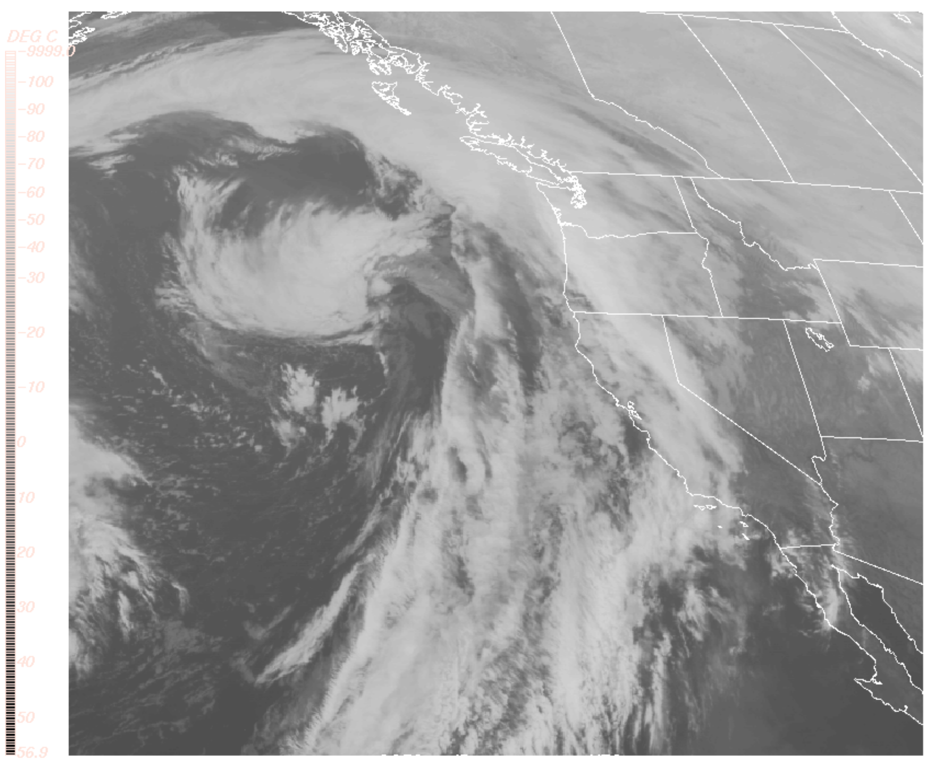
21 January 2003 0100 (local time) - Storm develops offshore while weaker system moves onshore



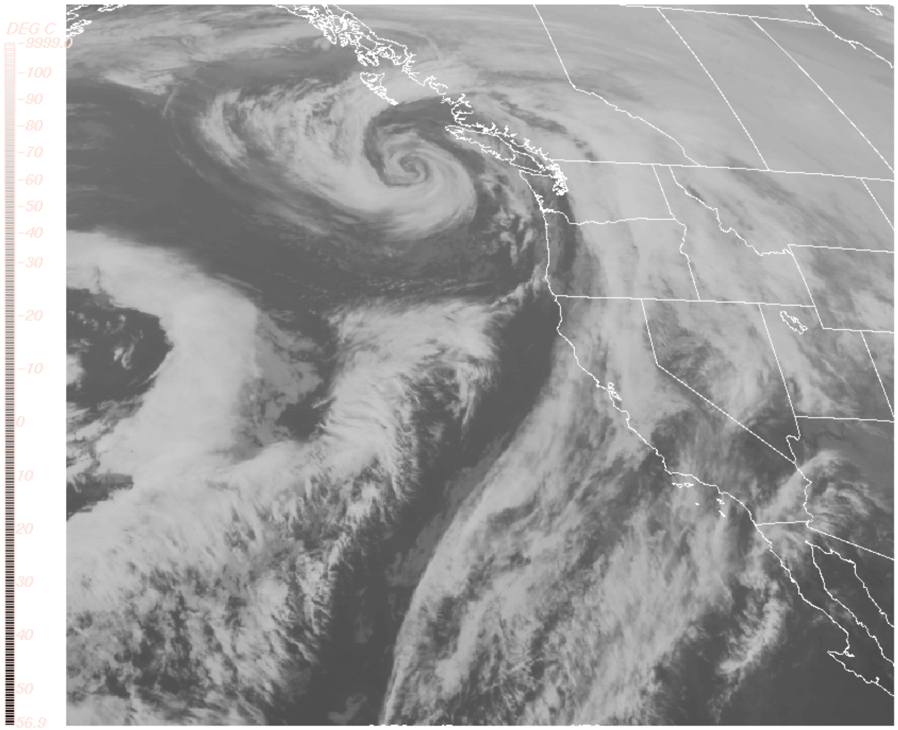
21 January 2003 1000 (local time) – Front approaches – Note southwest/northeast orientation and subtropical connection to front.



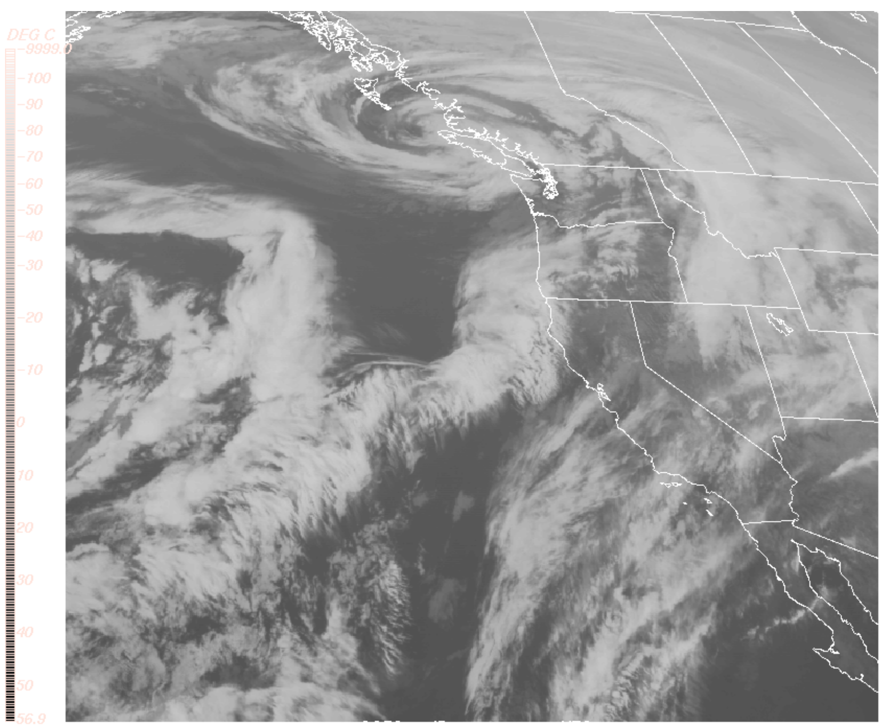
22 January 2003 0400 (local time) – Rain begins. Note copious moisture training from south to north.



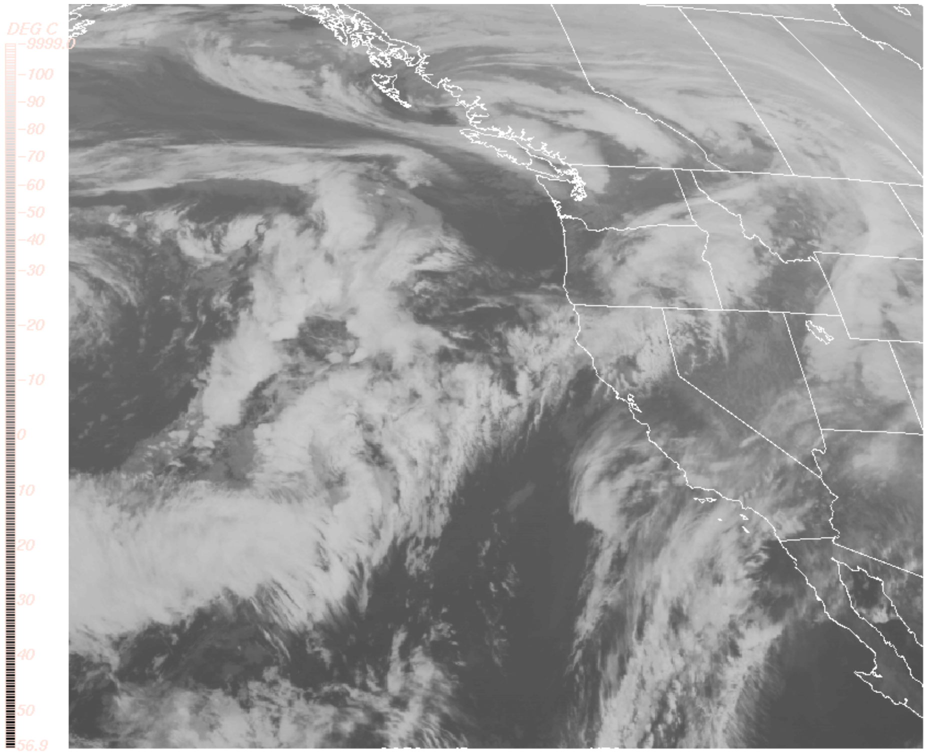
22 January 2003 1000 (local time) – Heavy rain associated with warm front moves through area.



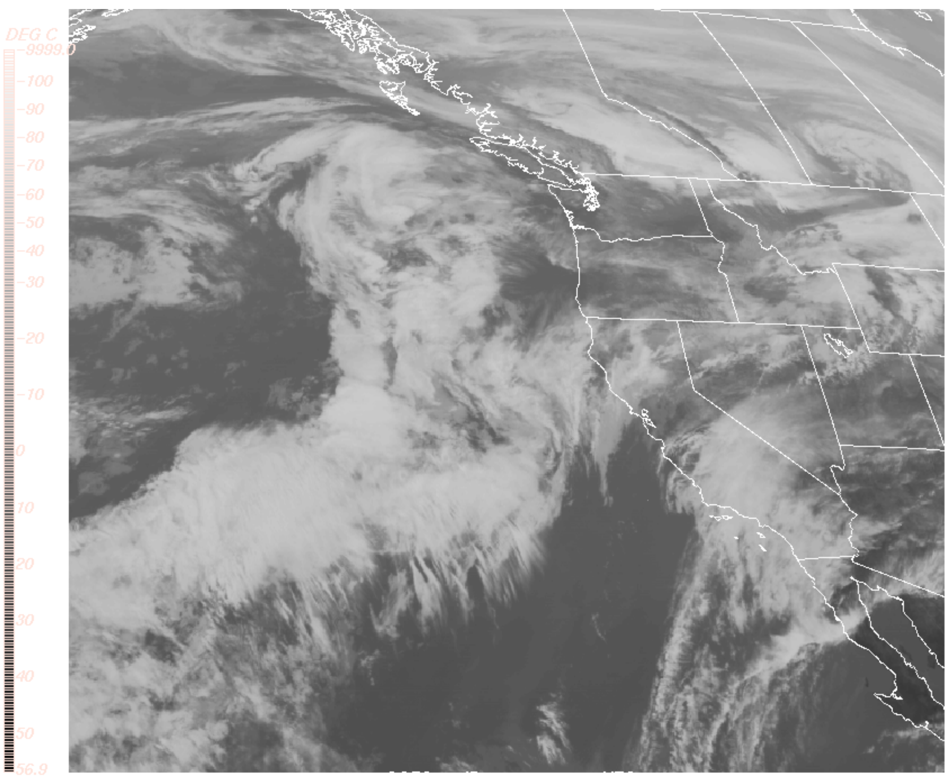
22 January 2003 1600 (local time) – Skies clear with cold front passage as rain ends. Note well-defined low pressure center due west of Victoria Island, tracking east.



23 January 2003 0100 (local time) – Low tracks just north of project area and produces round of heavy rain in project area.



23 January 2003 0600 (local time) – Low dissipates and moves east, skies begin to clear.



23 January 2003 1400 (local time) – Clear skies in project area.

Appendix B

Flowlink Rainfall, Physio-Chemical Data, and Fecal Coliform CoC Form

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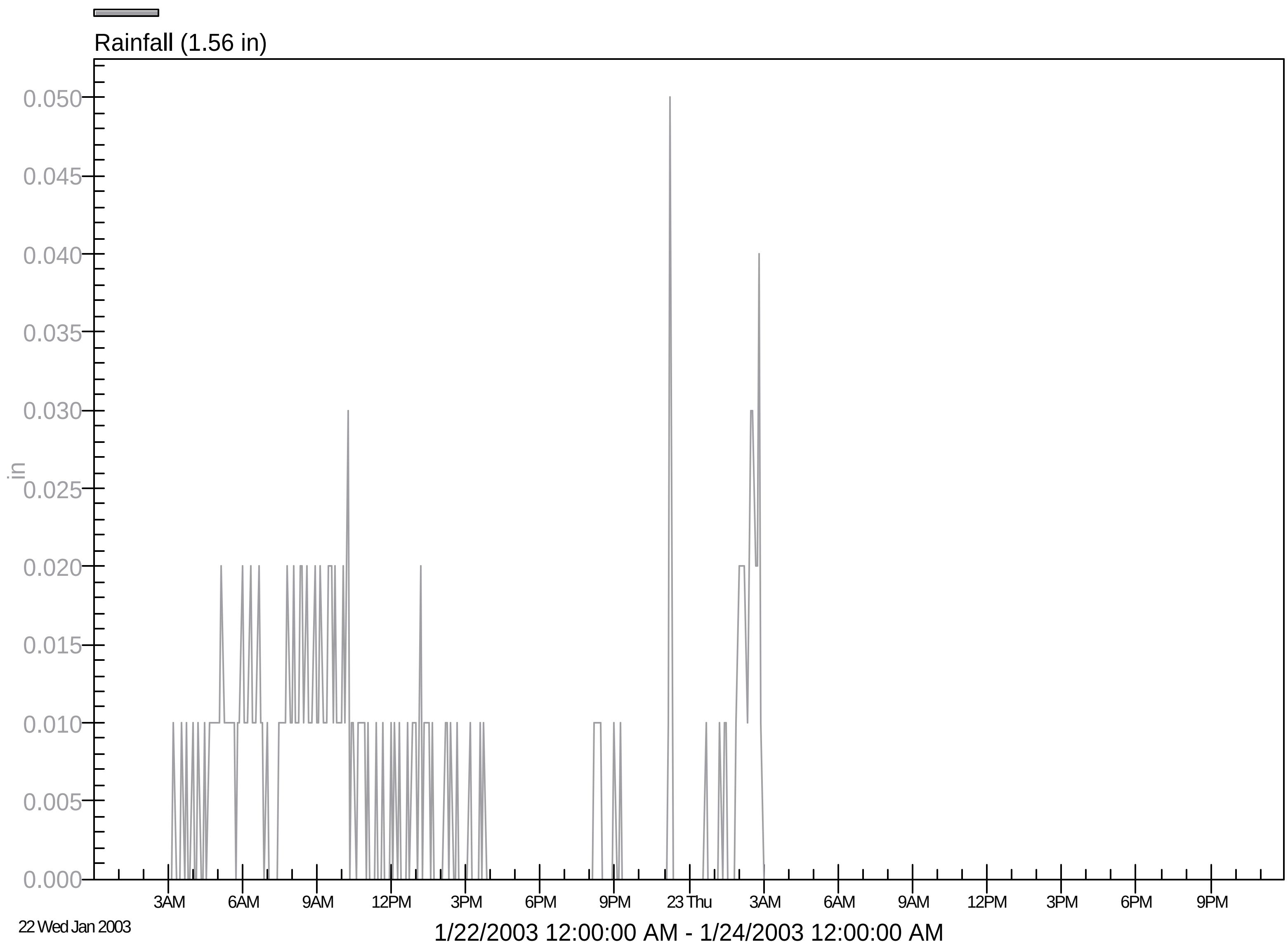
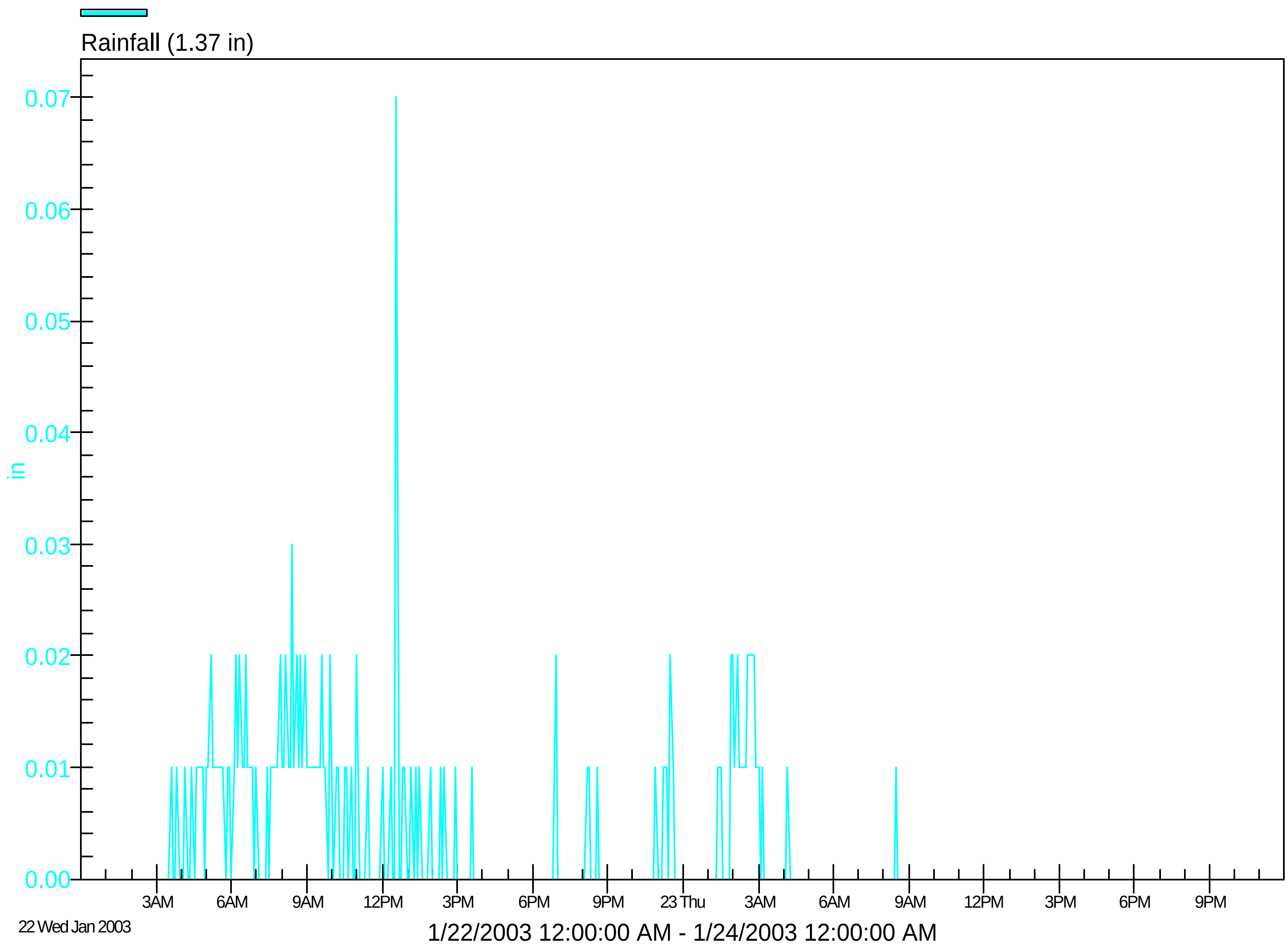
AC 03

Flowlink 4 for Windows



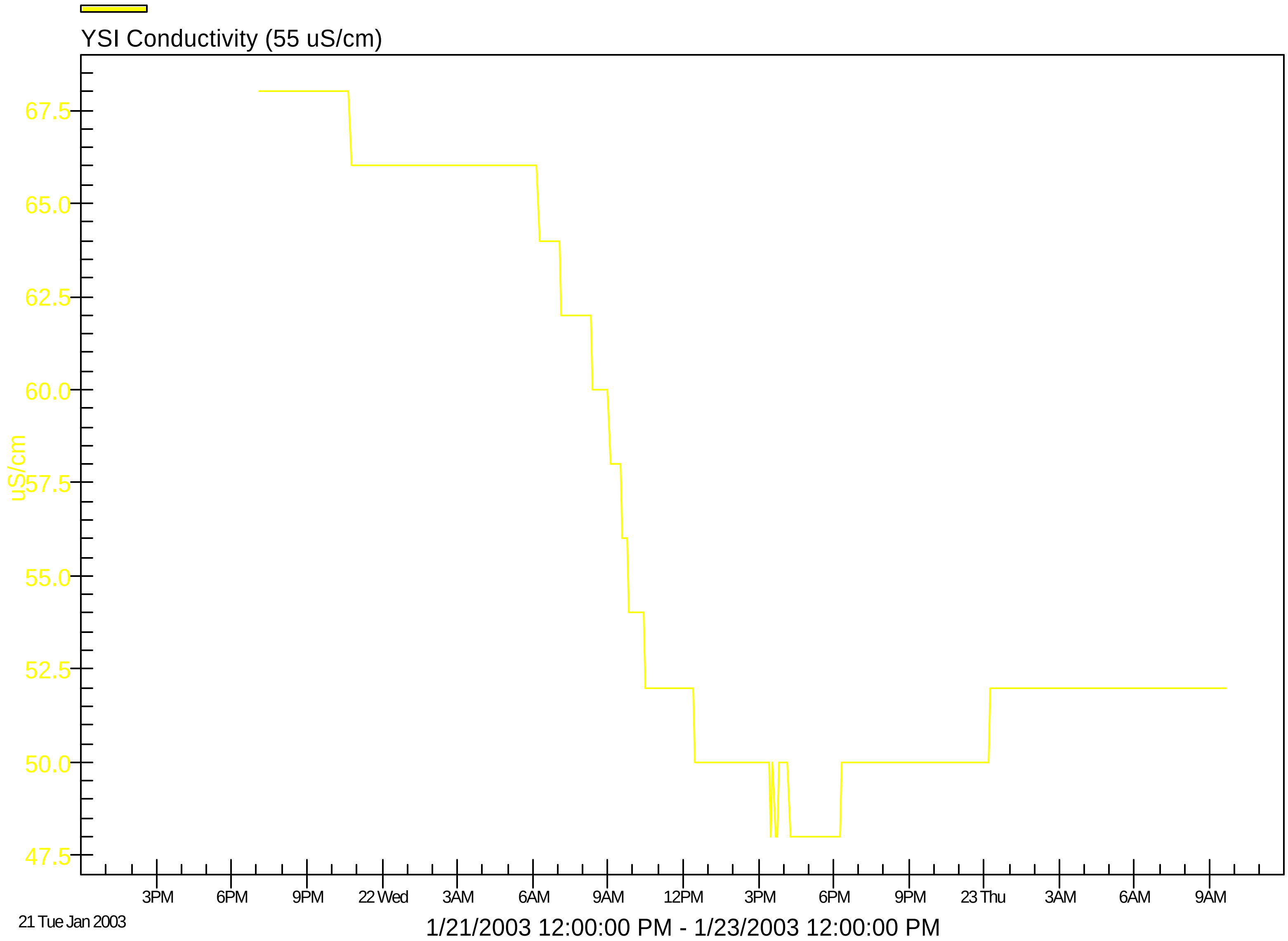
BL 03

Flowlink 4 for Windows



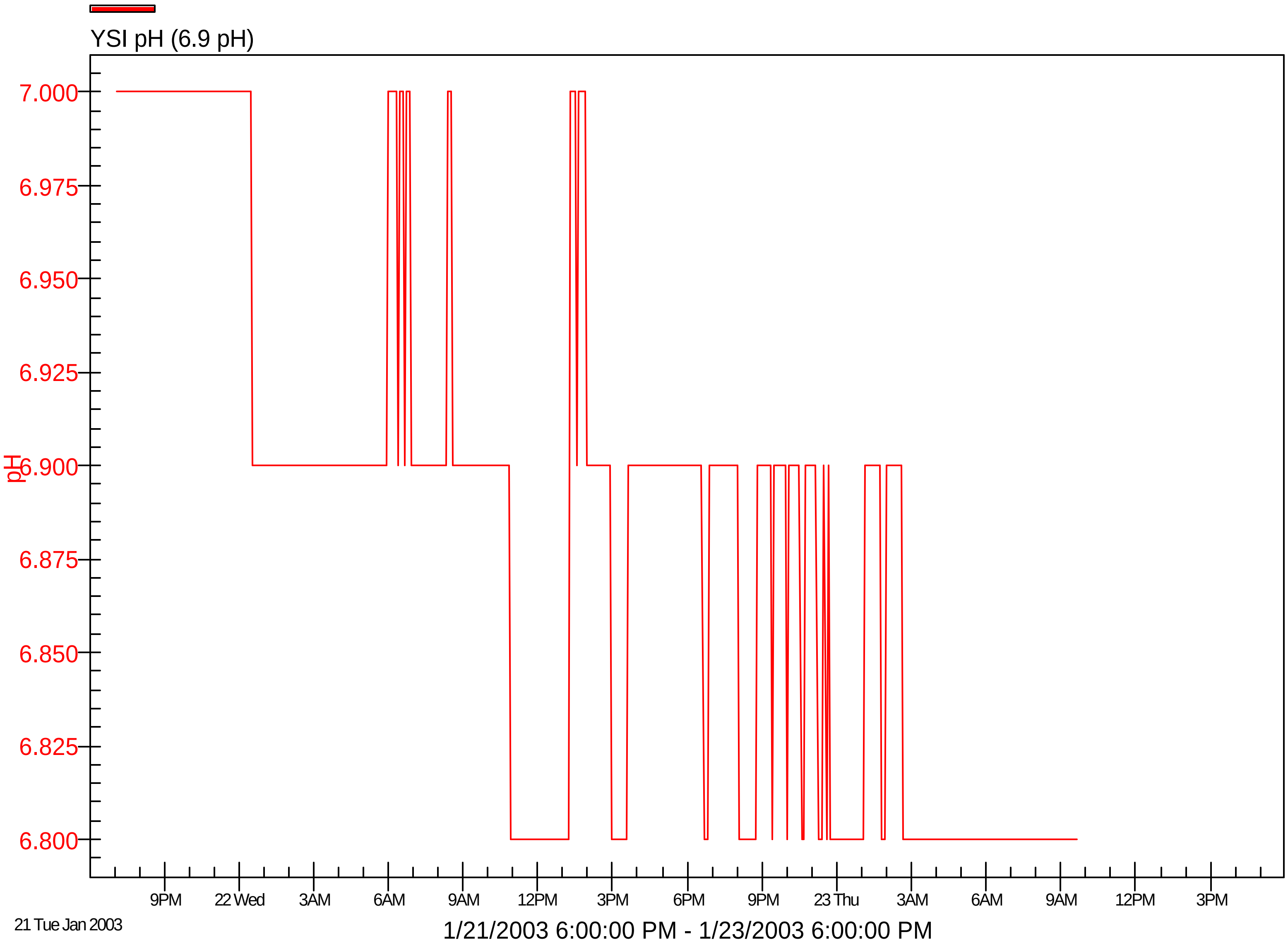
BL 03

Flowlink 4 for Windows



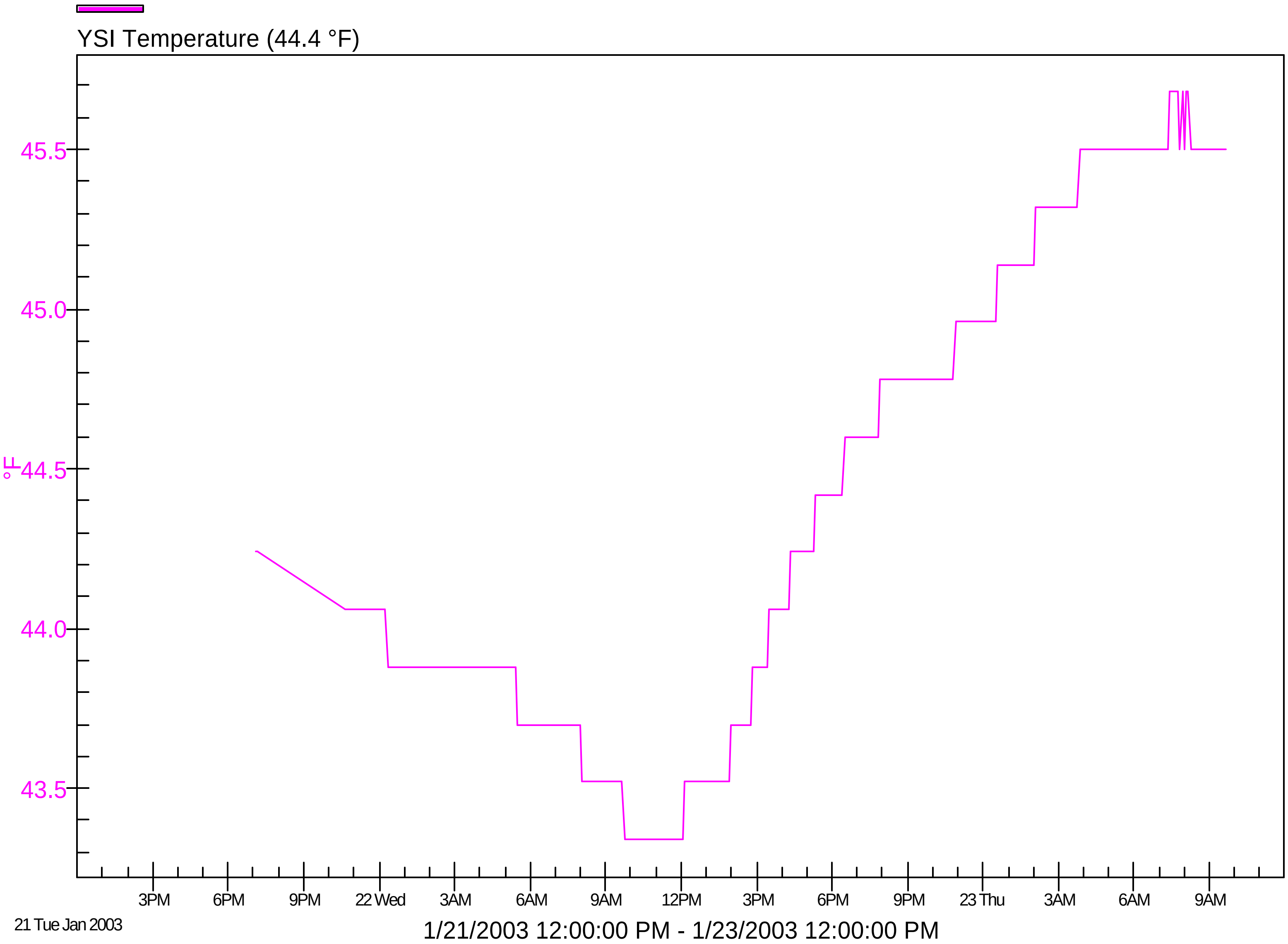
BL 03

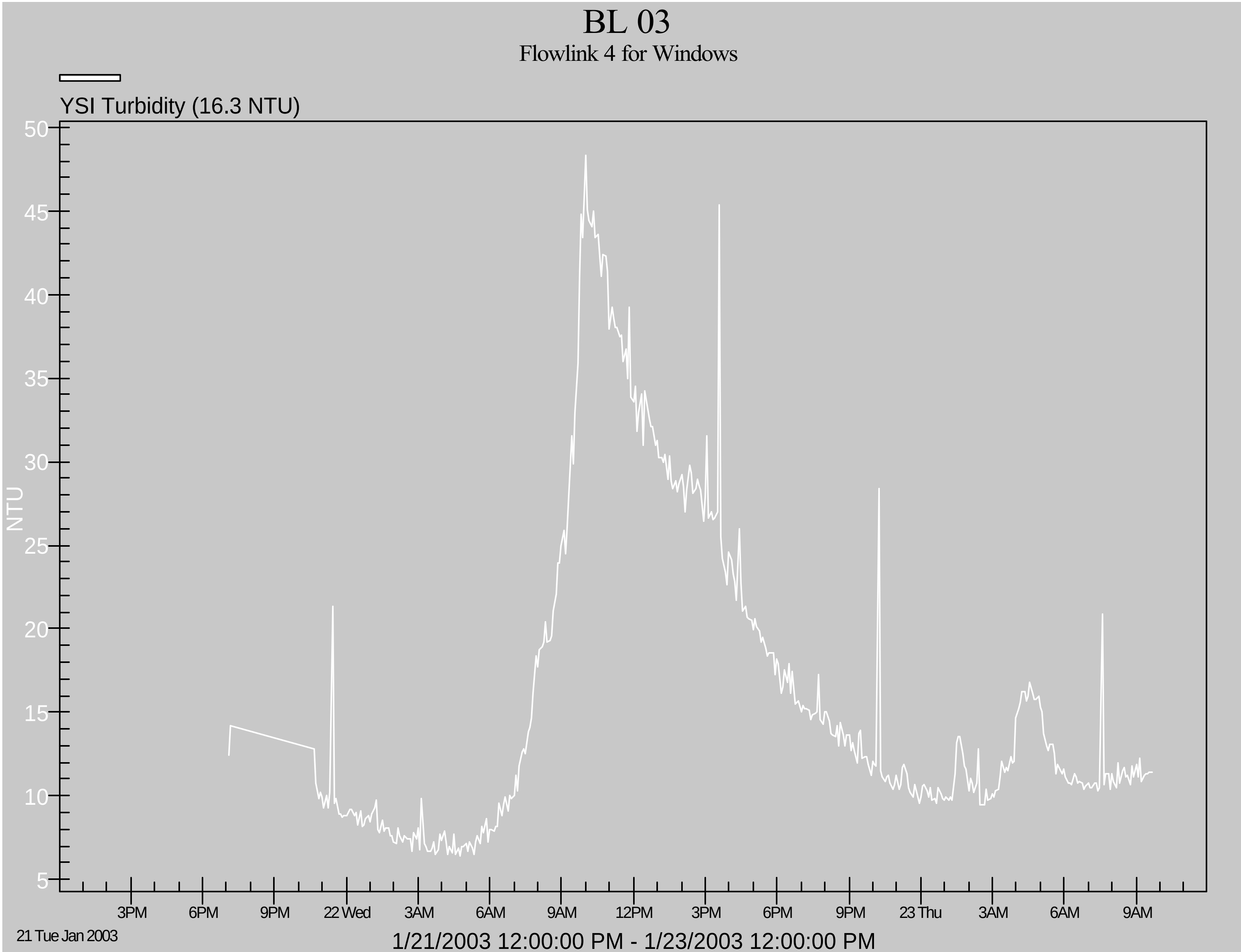
Flowlink 4 for Windows

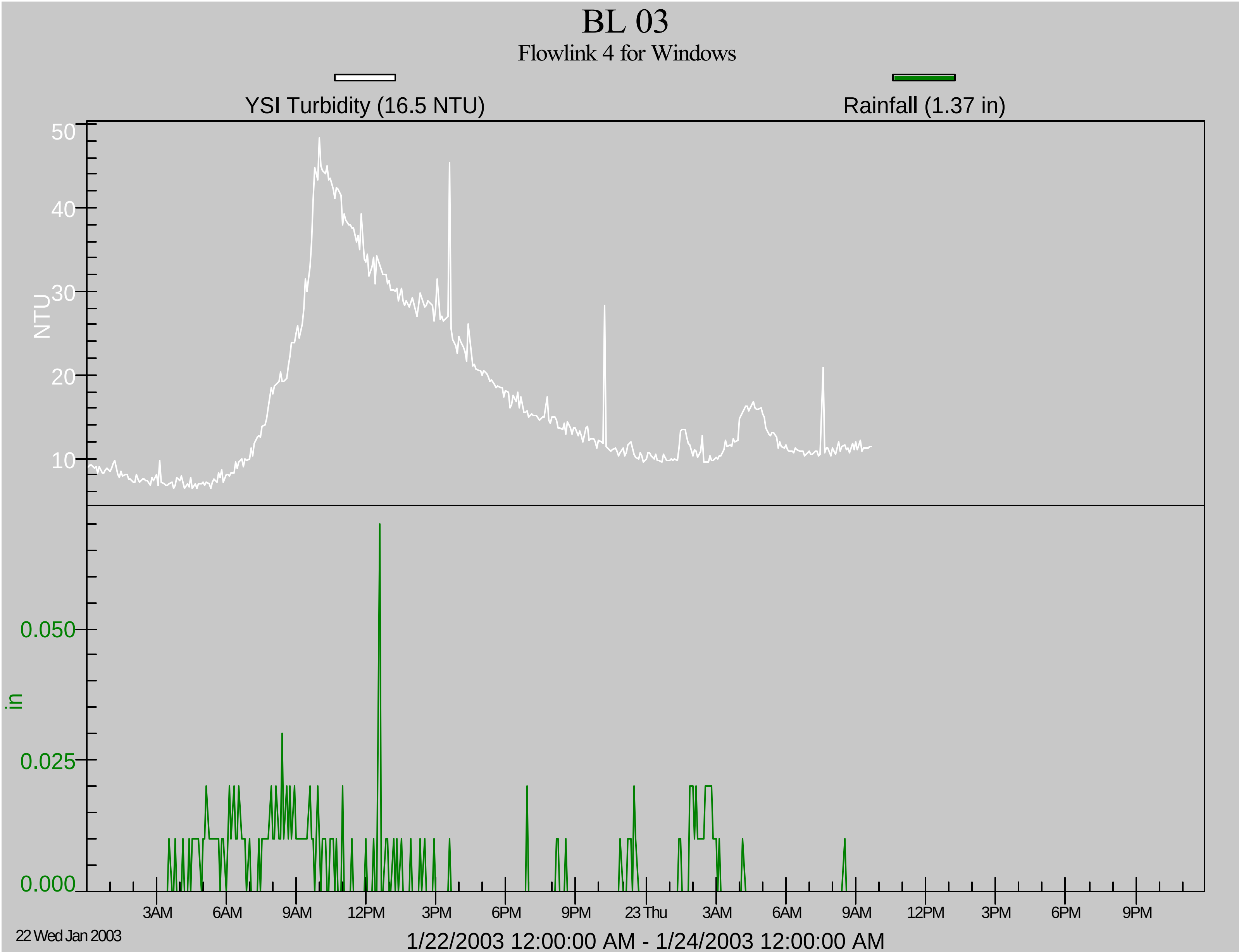


BL 03

Flowlink 4 for Windows

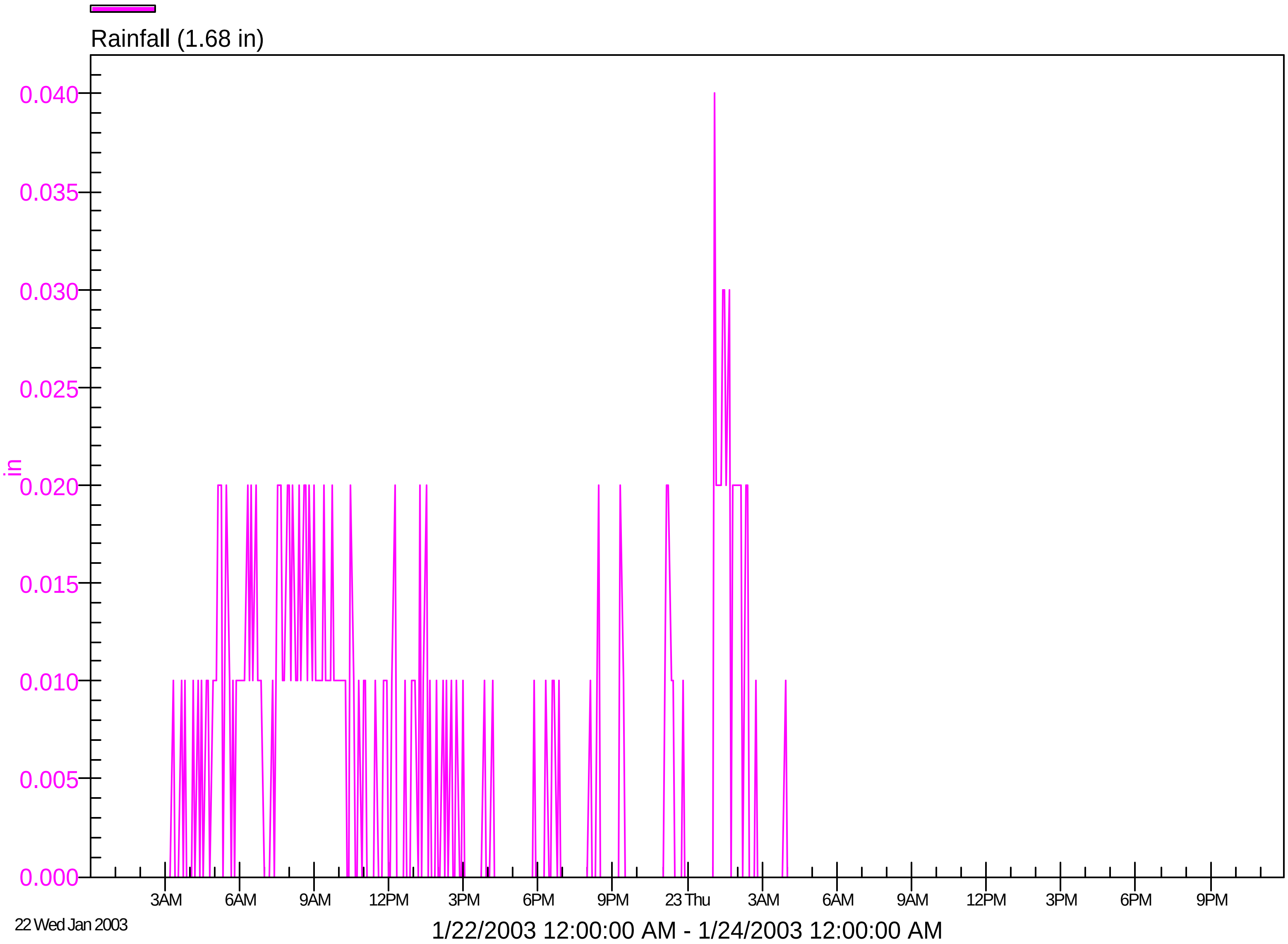



BL 03
Flowlink 4 for Windows
YSI Turbidity (16.3 NTU)
NTU
50
45
40
35
30
25
20
15
10
5
3PM
6PM
9PM
22 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
21 Tue Jan 2003
1/21/2003 12:00:00 PM - 1/23/2003 12:00:00 PM


BL 03
Flowlink 4 for Windows
YSI Turbidity (16.5 NTU)
Rainfall (1.37 in)
NTU
50
40
30
20
10
in
0.050
0.025
0.000
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
22 Wed Jan 2003
1/22/2003 12:00:00 AM - 1/24/2003 12:00:00 AM

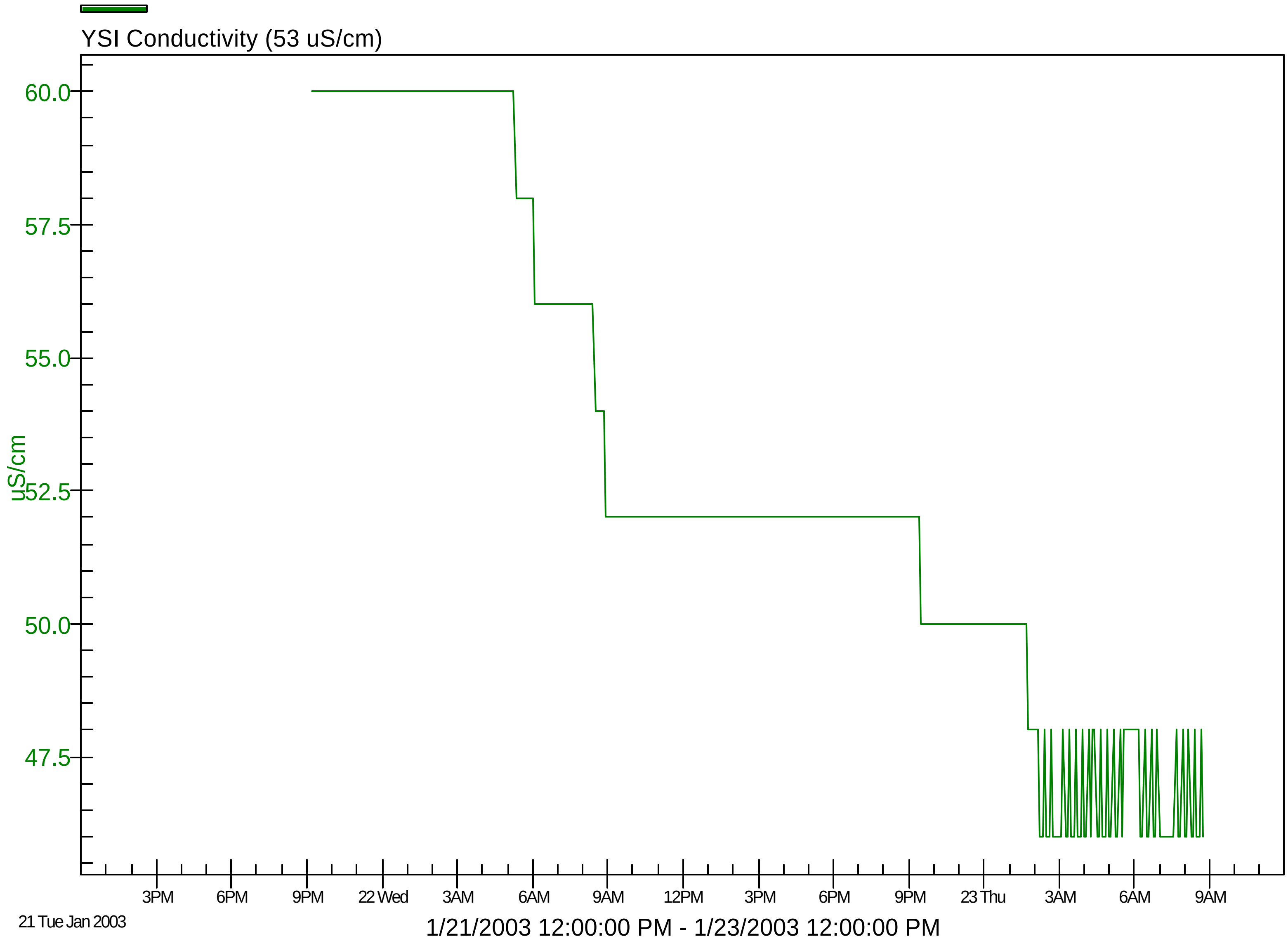
CH 03

Flowlink 4 for Windows



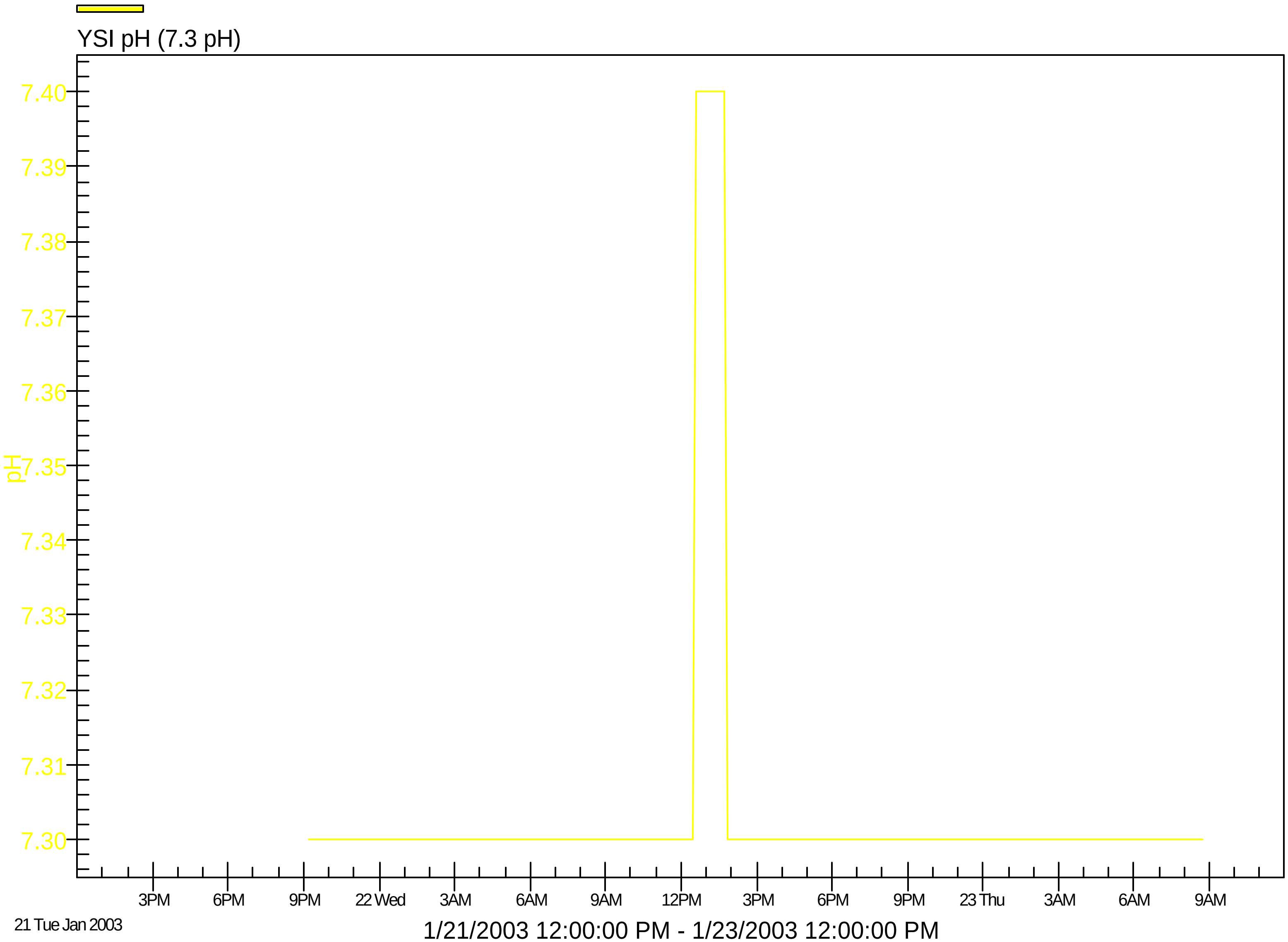
CH 03

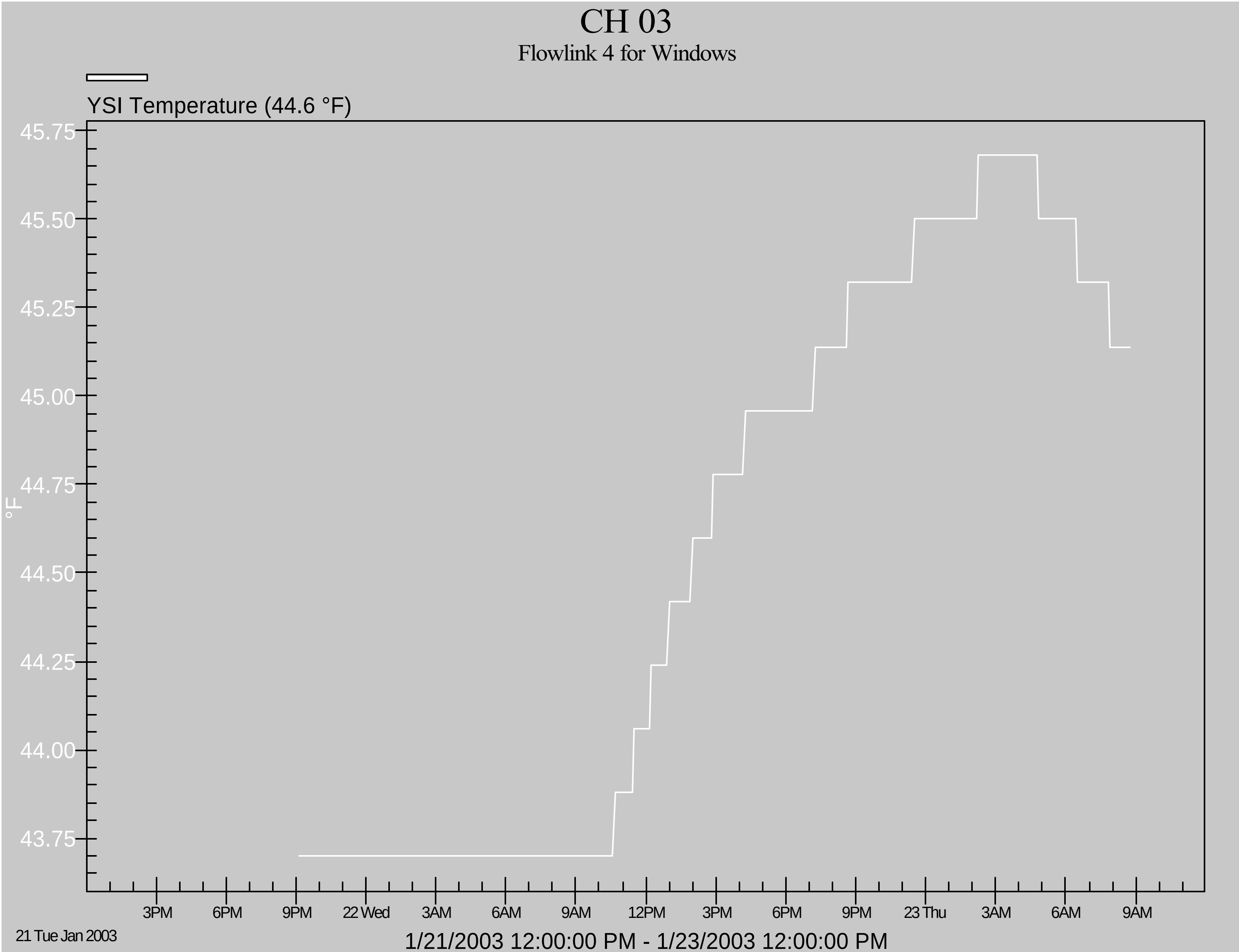
Flowlink 4 for Windows



CH 03

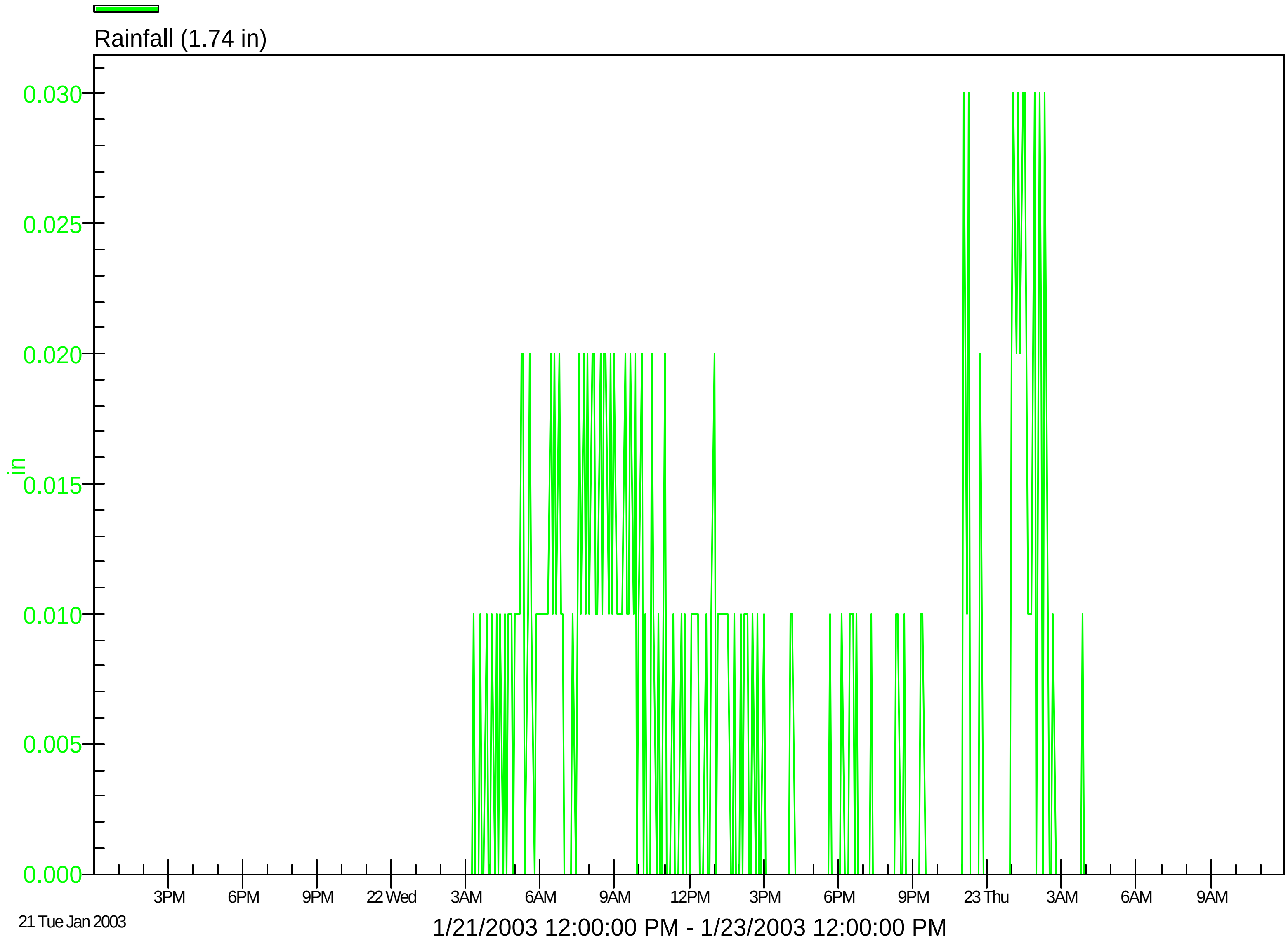
Flowlink 4 for Windows




CH 03
Flowlink 4 for Windows
YSI Temperature (44.6 °F)
°F
45.75
45.50
45.25
45.00
44.75
44.50
44.25
44.00
43.75
3PM
6PM
9PM
22 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
21 Tue Jan 2003
1/21/2003 12:00:00 PM - 1/23/2003 12:00:00 PM

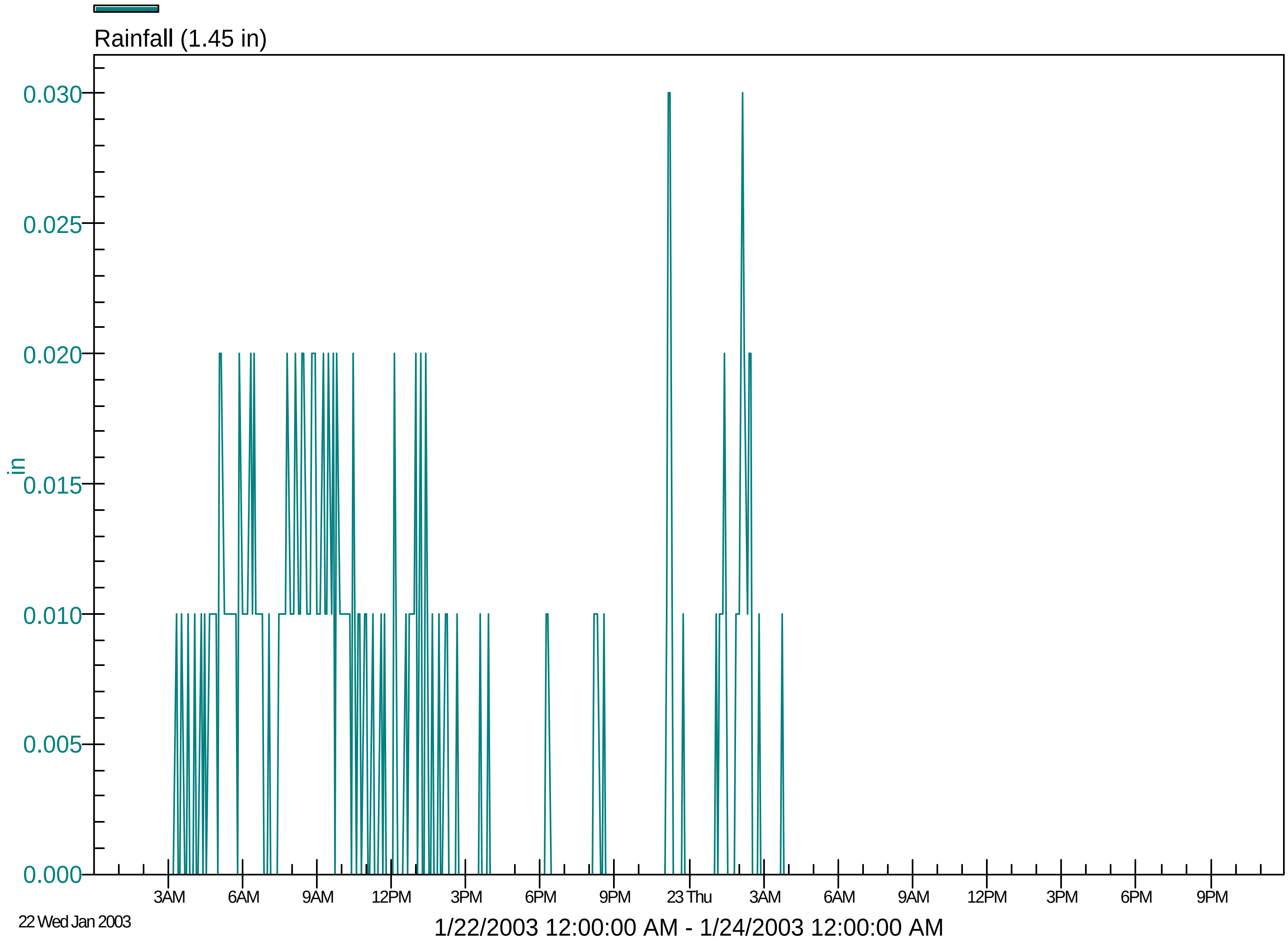
CT03

Flowlink 4 for Windows



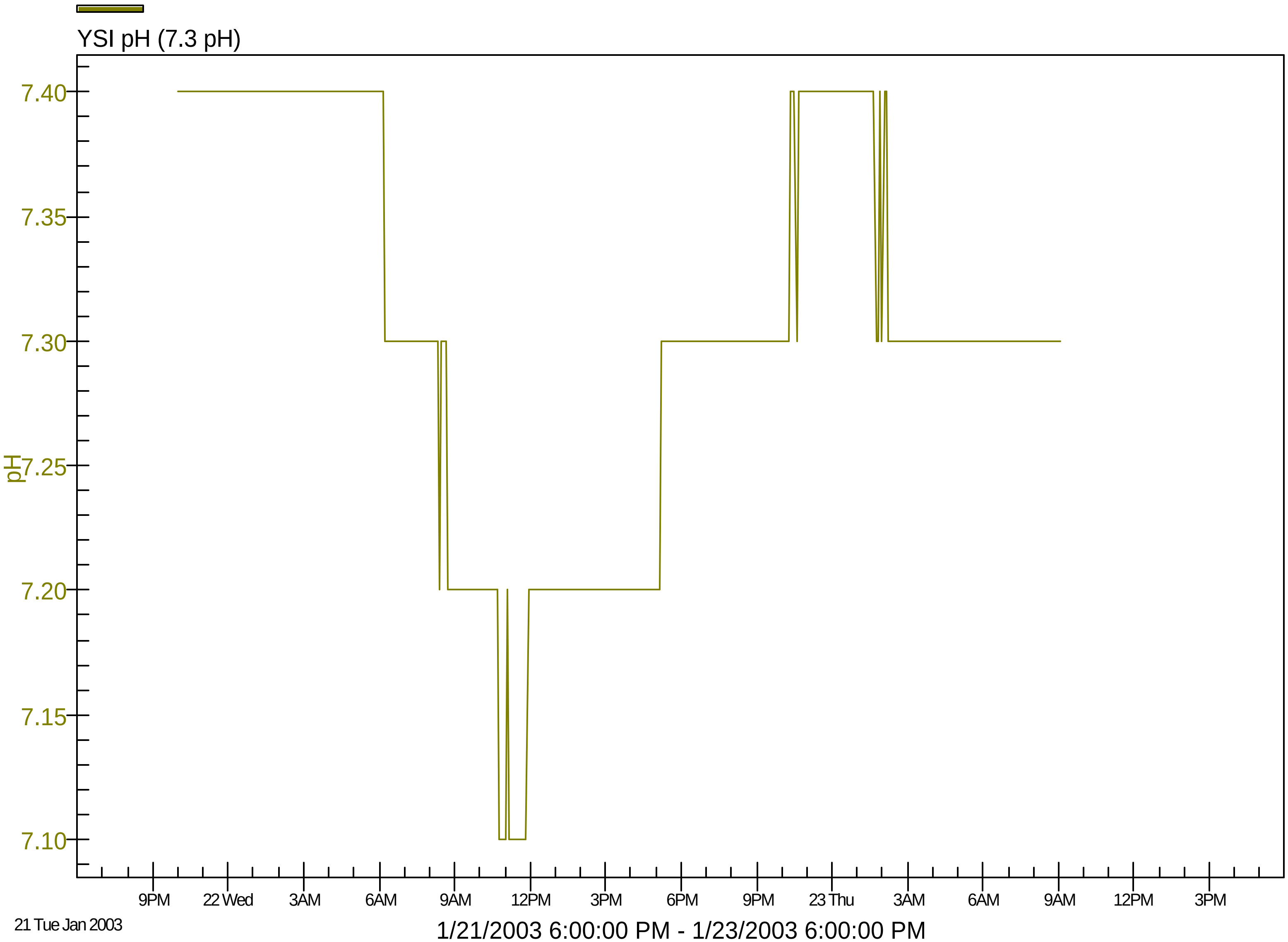
GC 03

Flowlink 4 for Windows



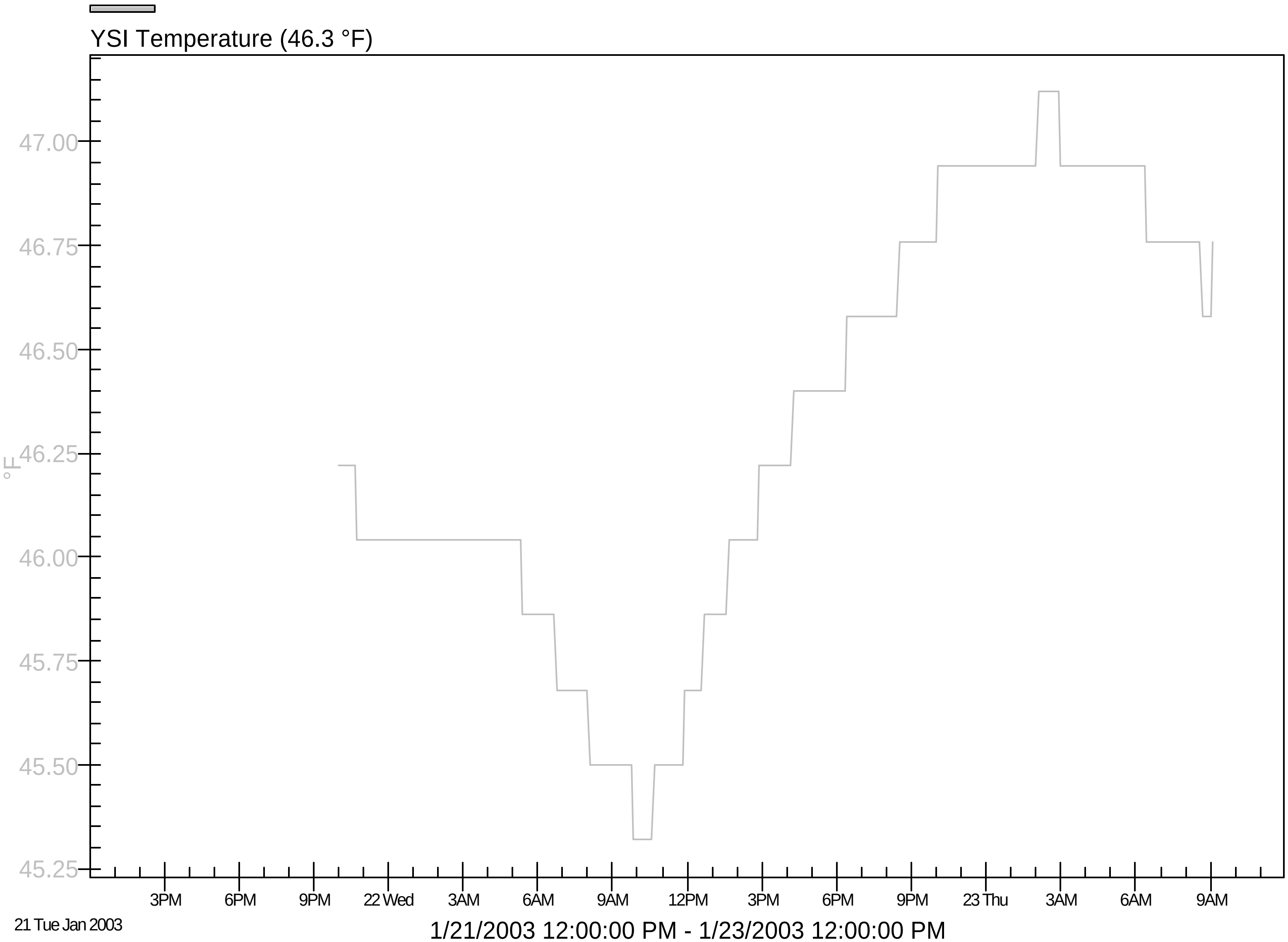
GC 03

Flowlink 4 for Windows



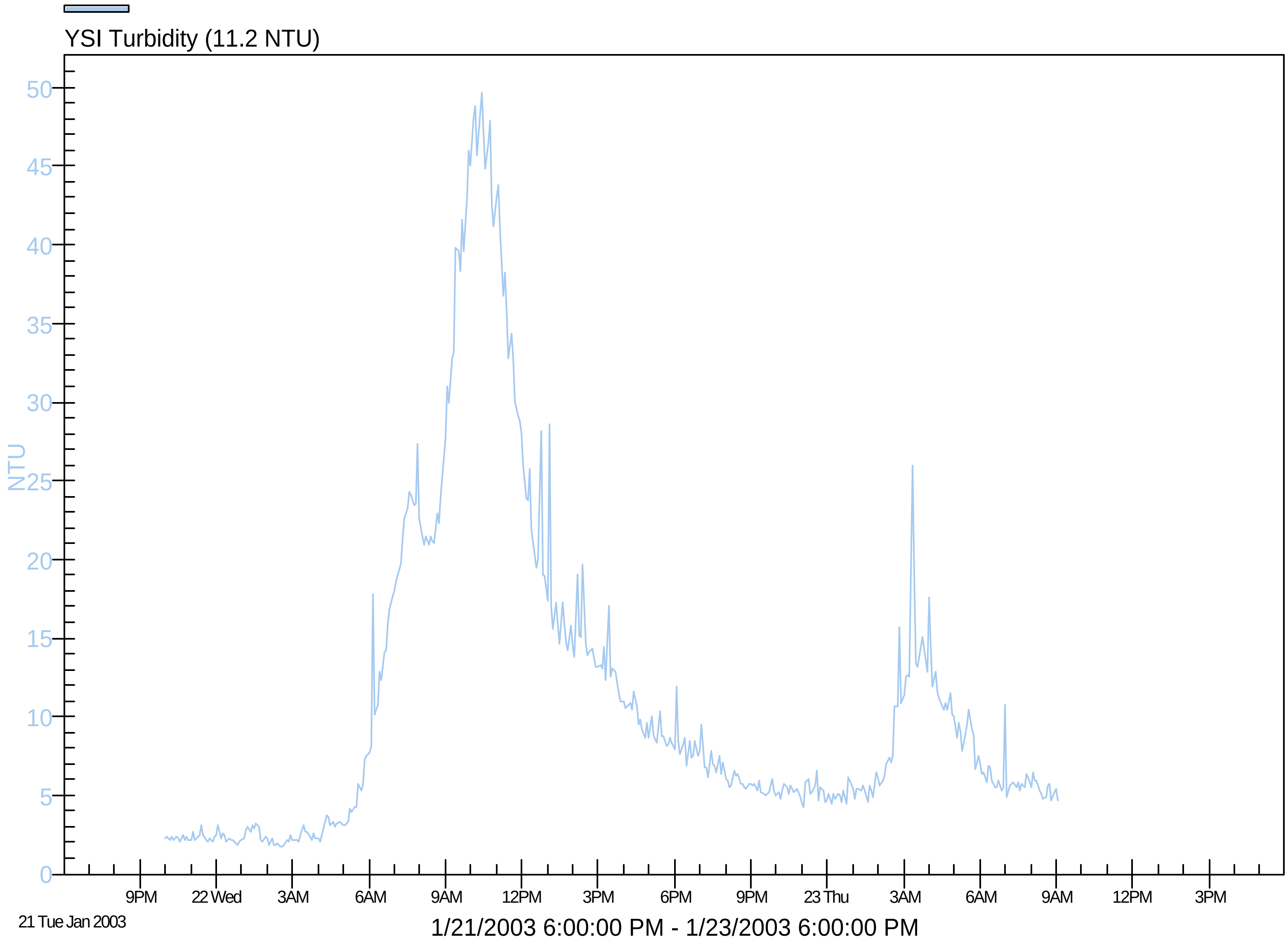
GC 03

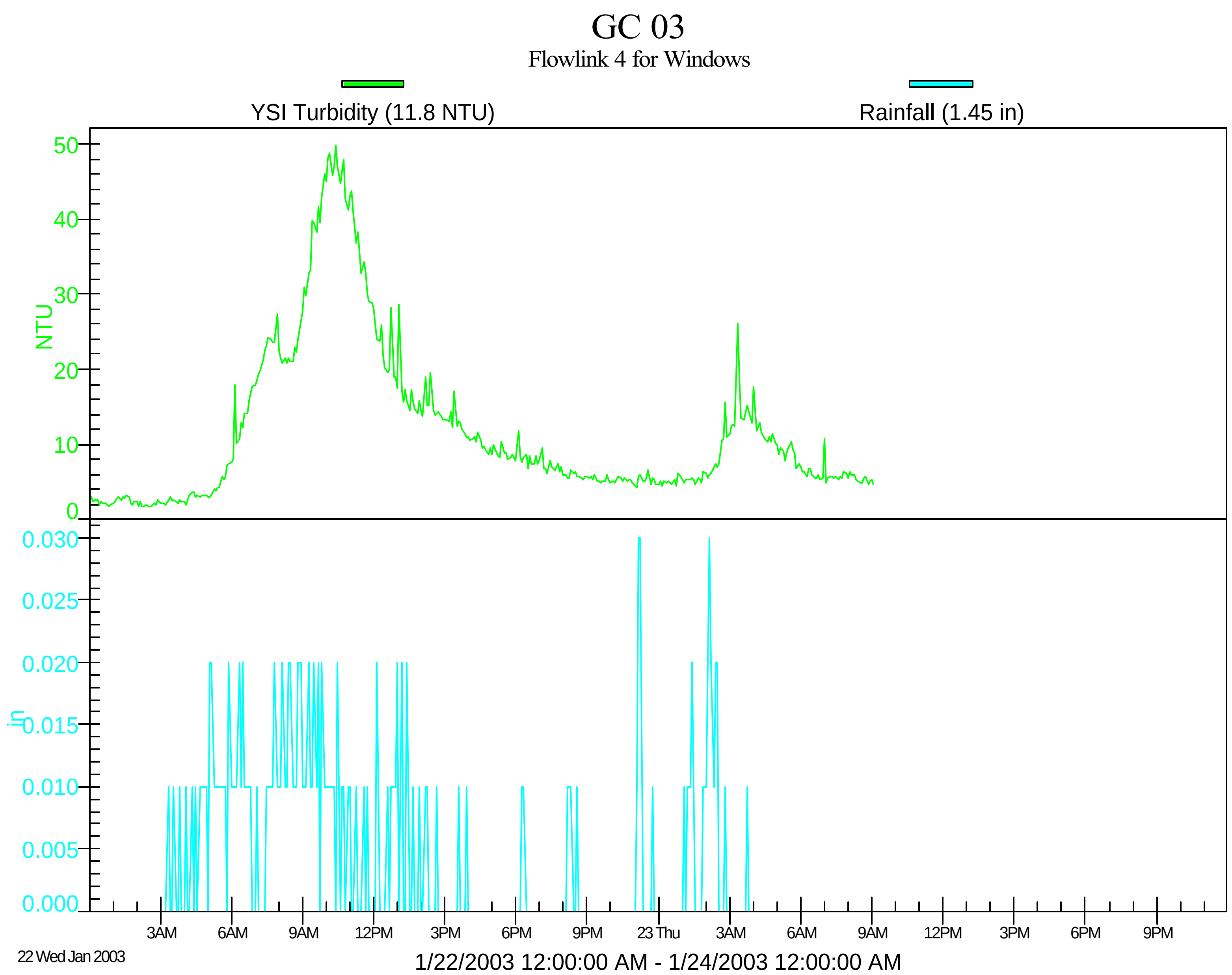
Flowlink 4 for Windows



GC 03

Flowlink 4 for Windows

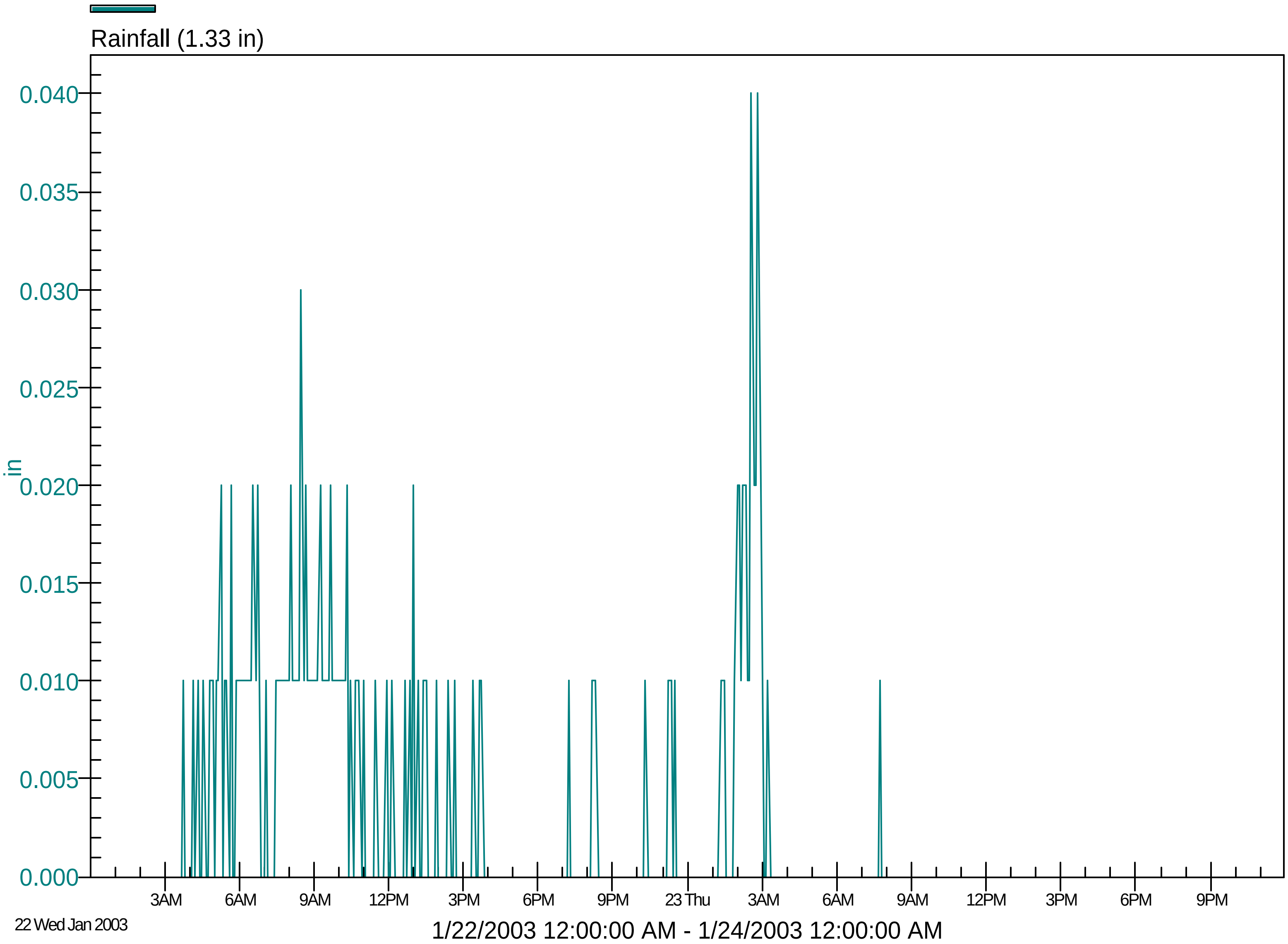




GC 03
Flowlink 4 for Windows
YSI Turbidity (11.8 NTU)
Rainfall (1.45 in)
NTU
50
40
30
20
10
0
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
3AM
6AM
9AM
12PM
3PM
6PM
9PM
23 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
22 Wed Jan 2003
1/22/2003 12:00:00 AM - 1/24/2003 12:00:00 AM

OC 03

Flowlink 4 for Windows



Chain of Custody Form

Sample Collector	Pingree, Estes, Whittaker, Gaudette	PSNS Project ENVVEST
Sampling Team	The Environmental Company (TEC) Storm Event #3	FC TMDL STUDY
Organization	TEC	

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03040430	Chico Main	1/22/2003	7:00	43.7	7.3	0.056	6.1	12	
03040431	Chico Trib	1/22/2003	7:20	43.8	7.4	0.045	3.9	12	YSI 650 (Handheld) Reading
03040432	Gorst Crk	1/22/2003	7:40	45.7	7.3	0.092	26.2	12	
03040433	Anderson Crk	1/22/2003	8:00	45.3	7.5	0.096	27.1	12	YSI 650 (Handheld) Reading
03040436	Blackjack Crk	1/22/2003	8:10	43.5	6.9	0.061	17.7	12	
03040437	Blackjack (Dup)	1/22/2003	8:10	43.5	6.9	0.061	17.7	12	
03040438	Olney Crk	1/22/2003	8:40	45.5	7.4	0.079	159.5	12	Muddy water/high suspended solids
03040439	Chico Trib	1/22/2003	22:00	45.5	7.3	0.042	17.7	12	YSI 650 (Handheld) Reading
03040440	Chico Main	1/22/2003	22:30	45.3	7.3	0.050	9.7	12	
03040441	Gorst Crk	1/22/2003	23:00	46.9	7.4	0.089	4.8	12	
03040442	Anderson Crk	1/22/2003	23:30	46.0	7.4	0.083	36.8	12	YSI 650 (Handheld) Reading
03040443	Blackjack Crk	1/22/2003	23:50	45.0	6.9	0.050	9.5	12	
03040444	Olney Crk	1/23/2003	0:30	47.7	7.6	0.120	24.3	12	
03040445	Olney (Dup)	1/23/2003	0:30	47.7	7.6	0.120	24.3	12	
03040446	Chico Trib	1/23/2003	8:30	45.2	7.3	0.040	17.1	12	YSI 650 (Handheld) Reading
03040447	Chico Main	1/23/2003	8:45	45.1	7.3	0.047	21.8	12	
03040448	Gorst Crk	1/23/2003	9:00	46.8	7.3	0.086	5.3	12	
03040449	Anderson Crk	1/23/2003	9:30	45.8	7.4	0.051	14.8	12	YSI 650 (Handheld) Reading
03040450	Blackjack Crk	1/23/2003	9:45	45.5	6.8	0.051	9.4	12	
03040451	Olney Crk	1/23/2003	10:05	47.3	7.6	0.116	15.4	12	

Preservatives Used:			
Relinquished By/Date:		Method of Shipment:	
Received By/Date:		Airbill No.:	
Relinquished By/Date:		Laboratory	
Received By/Date:		Address:	
Relinquished By/Date:			Custody Seals Present? Yes No
Received By Lab/Date:			Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

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Appendix C
Images Taken During Sampling Event #3

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Chico Tributary at Taylor Road – Isco and Rain Gauge

Gorst Creek

Gorst Creek

Anderson Creek

Inside of Sampling "Box" Depicting Isco, Tubing, Cables, and Battery

Appendix E

Storm Summary Report #4

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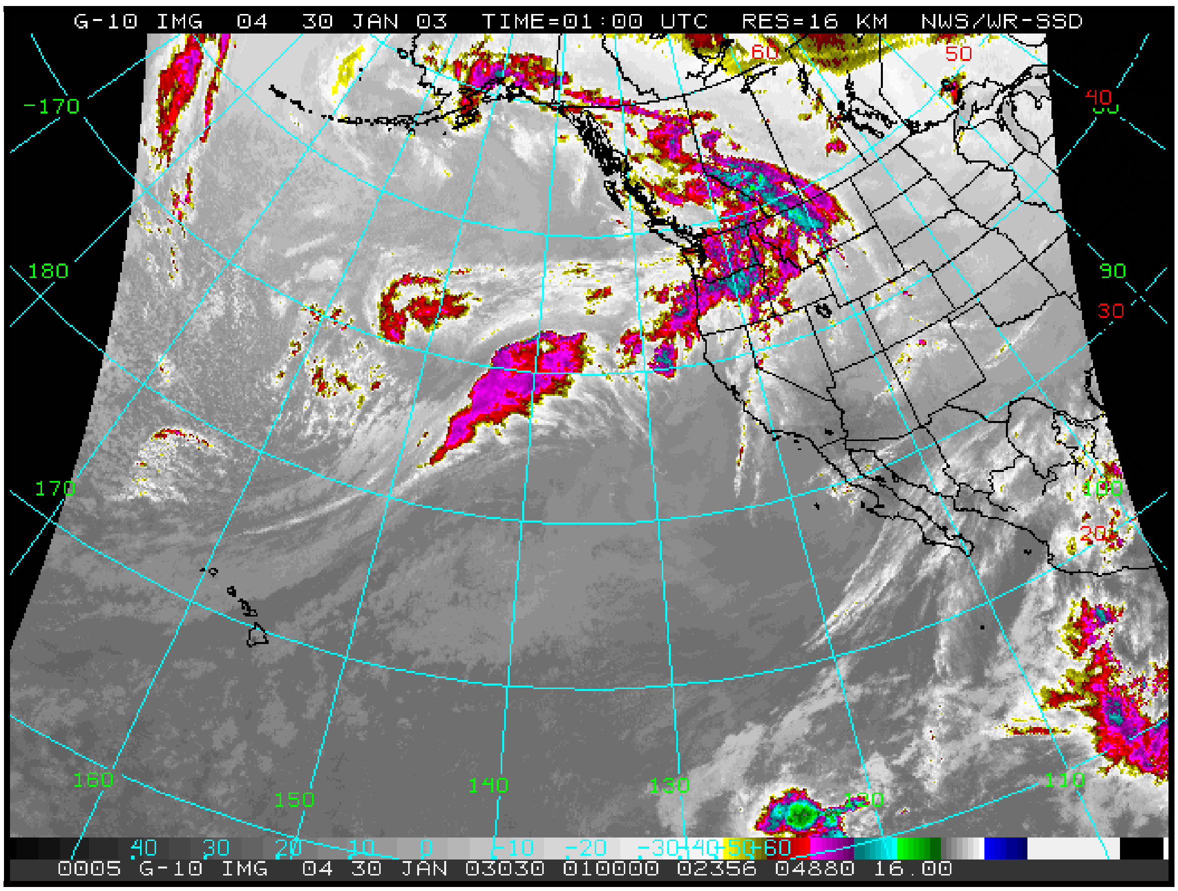
PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #4



(29 January 2003 1700 – Storm 4a exits as Storm 4b intensifies offshore)

29-31 January 2003
Southern Group Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

6 February 2003

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #4
29-31 January 2003

Introduction

On 29-31 January 2003, TEC conducted in-stream storm flow sampling of the 5 southern group creeks (plus Chico Main) within the PSNS Project ENVVEST study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) follow-up action items. In addition, Appendix A presents satellite images and Appendix B contains physio-chemical and rainfall data.

1. TEC Staff Participating in Storm Sampling Event #4

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Richard Tremaglio	Field Team Leader
Rusty Divine	Field Team Member
JD Estes	Field Team Member
Jennifer Gaudette	Field Team Member

2. Storm Sampling Event #4

Storm Identification

Following the end of Storm Event #3 (see Field Sampling Report #3), the PSNS Project ENVVEST study area experienced 3 consecutive days of moderate rain. However, by midday of 26 January, the study area began a period of several days of dry weather. This dry period was projected to last from the 26th until the 29th when a weak to moderate storm event was forecast to affect the study area, followed quickly by another much stronger, wetter storm. On the morning of Tuesday, 28 January, TEC and the Project Team discussed the forecast via conference call. The possibility of 2 storms passing through the project area in quick succession with the last storm forecast to be very wet presented an appealing opportunity to conduct a 48-hour sampling event. It was decided during the conference call to mobilize to the field that day (Tuesday) in anticipation of sampling both storms – forecast for Wednesday (Storm 4a) and Thursday/Thursday night (Storm 4b), with the later system forecast to bring heavy rain to the area.

Through the course of the mobilization effort on Tuesday, forecasts by the National Weather Service (NWS) and other outlets were revised to downgrade the strength of Storm 4a. Storm 4b, however, continued to be forecast as strong and wet. Through the course of the day, TEC coordinated with PSNS and discussed the changing forecast and the most appropriate sampling approach. It was decided late on Tuesday evening (the 29th) that Storm 4a (which continued to weaken) would not be sampled; however, the predicted wet system (Storm 4b) would be sampled, as the forecast for this system continued to indicate "heavy rain." Given that the watersheds were near saturation after almost a month of wet weather, the prospect of sampling an event that would produce a lot of runoff was attractive to the Project Team. Therefore, while it was decided that no attempt would be made to sample both storms (a 48-hour period), TEC prepared to sample the Thursday/Thursday night system (Storm 4b).

Preparation

For the second sampling event in a row, the 5 southern creeks (Chico Tributary at Taylor Road [CT], Gorst Creek [GC], Anderson Creek [AC], Blackjack Creek [BL], Olney Creek [OC]) and Chico Main (CM) would be sampled. By 1730 hours on the 28th, 4 of the 6 sites were mobilized. The last 2 sites were to be mobilized the next day in anticipation of sampling on Thursday/Thursday night. The 4 'ready' sites were not 'armed' as it was decided that TEC was not to sample the predicted light Storm 4a. The plan was to return to the field on Wednesday the 29th, mobilize the final 2 sites, and then activate all 6 sites once the rain associated Storm 4a ended, thereby making ready all 6 sites to sample once the rain associated with Storm 4b began on Thursday.

A rain gauge was installed at each site and the samplers were programmed to begin sampling immediately once > 0.05 inches of rain fell within a 1 hour period. However, the rain gauges were not connected to the Isco samplers. This ensured that the samplers would not be activated by rain from Storm 4a. TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data at sites where a connection between the Isco's and YSI was obtained.

In-Stream Storm Flow Sampling

Note: Together, Storm 4a and Storm 4b constitute "Sampling Event 4," a 48-hour sampling event.

Storm 4a (Wednesday 29 January – Thursday 30 January)

Early on the morning of the 29th the NWS forecast was once again revised, this time to reflect a strengthening of the system (Storm 4a) predicted to move onshore later that same morning. After receiving the revised update, TEC and PSNS coordinated and decided to activate all 6 sites and sample both Storm 4a as well as Storm 4b - in effect, a 48-hour event. TEC staff were in route to the project area when the decision was made to start sampling. Shortly thereafter (at approximately 0745) a light rain began to fall in the project area. As 2 sites had yet to be mobilized and all 6 sites needed to be 'armed,' TEC staff worked quickly to get the sites activated before much more rain fell in the project area. Four of the sites were activated by 1000; however the 2 remaining sites (Olney Creek and Chico Main) were not activated until 1030 and 1115, respectively. By looking at rainfall data from nearby sites (via the internet), it is estimated that approximately 2-3 hours worth of light to moderate rain fell before the sites were activated, totaling somewhere between 0.05 and 0.15 inches, depending upon the sampling site.

Rainfall associated with Storm 4a began to let up by mid-afternoon on the 29th. By the early evening hours the rain had transitioned to a light mist. By this time the bulk of the precipitation associated with Storm 4a had passed through the project area. The skies remained cloudy and the wind continued from the south – a sure sign that the next stronger, wetter system (Storm 4b) was approaching the area. By the late evening of the 29th the NWS had released a Flood Watch for most of Western Washington in anticipation of a heavy, prolonged rain event associated with Storm 4b. Rain was expected to begin in the project area by midday/early afternoon (on the 30th) and work its way from the south to the north. Rain was predicted to be heavy at times through Thursday afternoon and night, and then taper off slowly to scattered showers on Friday.

Daybreak on the 30th revealed cloudy skies but no rain. A quick check of weather data revealed that no rain had fallen through the night. TEC staff went around to the sites and shut down the samplers, collected 24-hours worth of samples (4 bottles), replaced the full bottles with new empty bottles, and 're-armed' the samplers to start sampling when rain from Storm 4b began later that day.

Table 1-1 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to Manchester Environmental Laboratory (MEL) and Pacific Northwest National Laboratory (PNNL). Throughout the storm sampling event, TEC staff routinely checked on the stations, collected fecal grab samples, monitored weather conditions, and coordinated with PSNS, MEL, and PNNL. Per PSNS direction, only 1 round of fecal coliform samples was collected during Storm 4a. TEC delivered samples to MEL and PNNL at 1400 and 1305, respectively.

Table 1-1. SE #4: In-Stream Storm Flow Sampling Landmarks – Storm 4a

Sampling Station	Sampling Begins	1st Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
	29 Jan	*29 Jan*	*29 Jan*	*30 Jan*	*30 Jan*
GC	0923	1140	1400	0908	1305
AC	0934	1200	1400	0919	1305
CT	0949	1125	1400	0934	1305
BL	0955	1230	1400	0955	1305
OC	1030	1250	1400	1015	1305
CH	1115	1120	1400	1100	1305

Table 1-2 presents rainfall totals for Storm 4a. Even though approximately 0.05" to 0.15" of rain were not recorded by the gauges, as shown by the ENVVEST gauge totals, Storm 4a was still considered a qualifying sampling event (> 0.25"/24-hrs).

Storm 4b (Thursday 30 January – Friday 31 January)

Rain from Storm 4b began in the project area shortly after noon on the 30th and moved from south to north over the area. Rainfall was fairly consistent at a moderate level throughout the afternoon and early evening hours and was heaviest in the southern portion of the project area. By the early morning hours of the 31st, skies in the project area had begun to clear and the rain transitioned to a light mist then to nothing at all. Sampling sites were turned off beginning shortly after 1200 and samples were collected and iced down for subsequent delivery to PNNL later that afternoon. Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco's to a laptop for analysis/viewing with Flowlink (see Appendix B).

Table 1-2 presents rainfall totals for Storm 4a and 4b, as well as the total for both systems. Rainfall was greatest to the south of the project area (see Portland, OR). This is consistent with the track of the storm system – the bulk of the rain associated with the storm ended up just south of the project area. Throughout the day on the 31st, rivers in West and Southwest Washington rose to or above flood stage in response to prodigious rainfall and melting snowfall (due to the warmth of the system). While the project area missed out on the bulk of the precipitation associated with Storm 4b, the sites did receive enough rain to make for a qualifying sampling event.

Table 1-2. SE #4: Precipitation within the Project Area

Sampling Station	Storm 4a[1]	Storm 4b	Total[2]
PSNS Project ENVVEST Sampling Stations			
Chico Main (CH)	0.28”[3]	0.42”	**0.70”**
Chico Tributary at Taylor Road (CT)	0.31”	0.45”	**0.76”**
Gorst Creek (GC)	0.35”	0.53”	**0.88”**
Anderson Creek (AC)	0.40”	0.64”	**1.04”**
Blackjack Creek (BL)	0.28”	0.69”	**0.97”**
Olney Creek (OC)	0.31”	0.46”	**0.77”**
Other Rain Gauges in Vicinity			
Poulsbo	0.32”	0.28”	**0.60”**
Silverdale	0.48”	0.43”	**0.91”**
Bremerton (Port of Brownsville)	0.32”	0.33”	**0.65”**
Gig Harbor	0.60”	1.12”	**1.72”**
Olympia	0.33”	0.47”	**0.80”**
Portland, OR	0.68”	2.71”	**3.39”**

Notes: [1] Rain started approximately 2 hours before ENVVEST samplers and gauges were activated.
[2] Storm event totals (1/29 – 1/31).
[3] Estimated from CT.

Sources: Weather Underground:
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&month=1&day=31&year=2003
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&month=1&day=31&year=2003
Bremerton:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABREME3&month=1&day=31&year=2003
Gig Harbor :
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAGIGHA2&month=1&day=31&year=2003
Olympia :
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAOLYMP2&month=1&day=31&year=2003
Portland, OR :
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KORPORTL6&month=1&day=31&year=2003

Table 1-3 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to MEL and PNNL. Throughout the sampling event, TEC staff routinely checked on the stations, collected fecal coliform samples, monitored weather conditions, and coordinated with PSNS, MEL, and PNNL. During Storm 4b, 3 rounds of fecal coliform samples were collected, bringing the total to 4 for both events. TEC delivered samples to MEL and PNNL at 1040 and 1515, respectively.

Table 1-3. SE #4: In-Stream Storm Flow Sampling Landmarks – Storm 4b

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
	30 Jan	*30 Jan*	*30 Jan*	*31 Jan*	*31 Jan*	*31 Jan*	*31 Jan*
BL	1235	1455	2155	0900	1040	1220	1515
AC	1242	1435	2145	1005	1040	1212	1515
GC	1245	1420	2130	0950	1040	1200	1515
CT	1258	1330	2050	0935	1040	1243	1515
CH	1300	1315	2115	0930	1040	1245	1515
OC	1302	1525	2230	1025	1040	1248	1515

3. Storm Sample Event #4 Results

At all stations the sampling equipment performed for the most part as expected for both storms. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at several sites; therefore, physio-chemical data was not recorded electronically. However, using the YSI 650 handheld logger, data was successfully obtained at each of these sites when fecal coliform samples were taken.

Variations to the Sampling and Analysis Plan (SAP)

Only 3 variations to the SAP occurred during Sampling Event #4. These minor variations are discussed below.

Chico Main Rain Gauge Malfunction

During Storm 4a, the Isco unit at Chico Main did not achieve communication with the rain gauge. This lack of communication was discovered during the first round of fecal samples when TEC staff observed that the sampler had not kicked off when obviously more than 0.05" of rain had fallen in the area (Chico Tributary had been sampling for over an hour at this point). So, TEC staff manually activated the sampler at 1115, approximately 3 hours after rainfall had started in the area Rainfall at Chico Main for Storm Event 4a was estimated using rainfall totals for Chico Tributary from Storms 4a and 4b. Prior to Storm 4b, communication at Chico Main had been established between the Isco and the rain gauge and sampling of Storm 4b started as programmed when greater than 0.05" of rain fell within an hour.

Blackjack Creek Under-Sampling (Bottle #5)

During Storm Event 4b a routine check of Blackjack Creek revealed that the top part of the sampler unit was not positioned correctly with the base of the unit and the first 10 samples of Bottle 5 had missed the bottle and had collected in the base of the Isco unit. Upon discovery the sampler unit was positioned correctly and subsequent samples were successfully obtained and the liquid in the base of the unit was drained out to the ground. However, as a result of the misalignment, Bottle #5 was 10 samples short (approximately 1.4 liters) of a full bottle.

YSI 6820 Sondes

As mentioned previously, the YSI sondes were calibrated prior to mobilization to the field. However, several of the sondes were not able to communicate with the Isco units when installed. TEC believes that this may be because some of the YSI sondes are set at a baud (communication) rate different than what the Isco uses. TEC will investigate the problem and work to a solution, hopefully prior to the next sample event. In any event, data was obtained from the sites using the YSI 650 (hand-held data logger) during the fecal grab samples.

Action Items

Storm Sampling Readiness

Per direction from PSNS, the next sampling event will occur again at the 5 southern group sites (and Chico Main). TEC is ready to sample the next qualifying storm at the southern sites and will continue to monitor weather forecast for the next storm that is forecast to meet the provisions of the SAP.

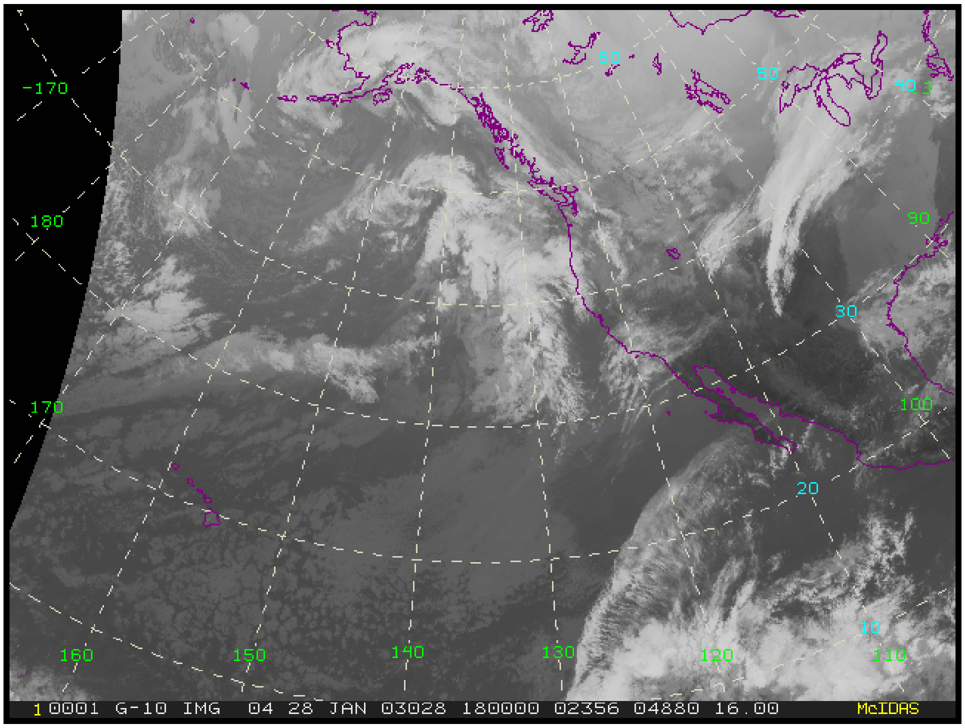
YSI Sonde/Isco Communication

As described above, TEC will investigate as to why some of the YSI sondes are unable to communicate with some of the Isco samplers, while other seemingly identical sondes/Iscos are able to communicate properly.

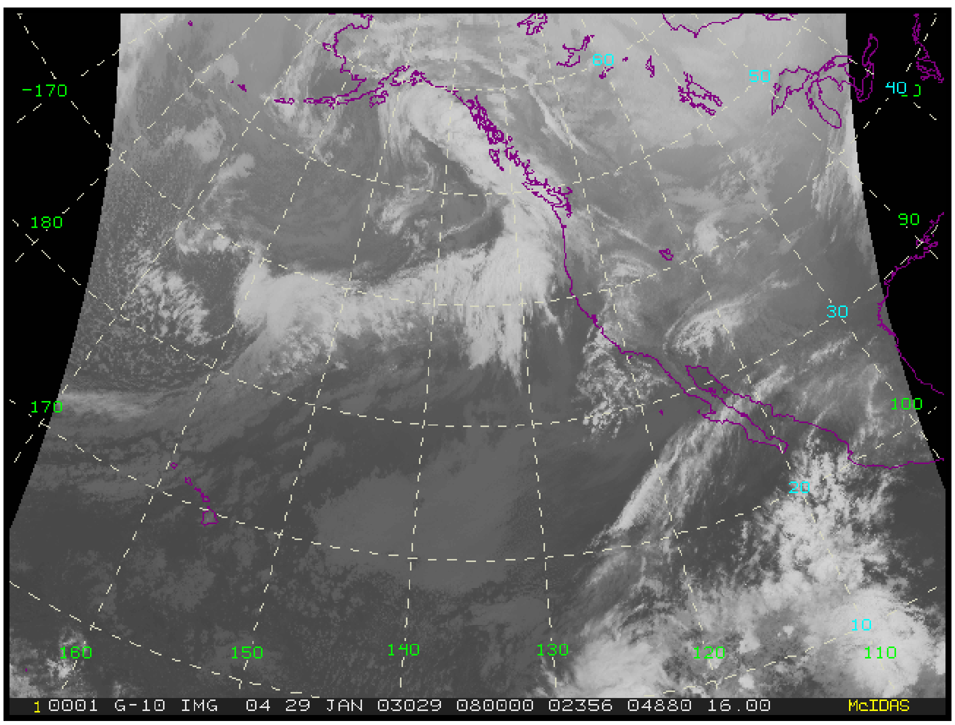
Strawberry Creek Re-Plumb

As described in Field Sampling Report #3, Strawberry Creek needs to be re-plumbed per the KPUD's request. TEC will try and accomplish this task by early February.

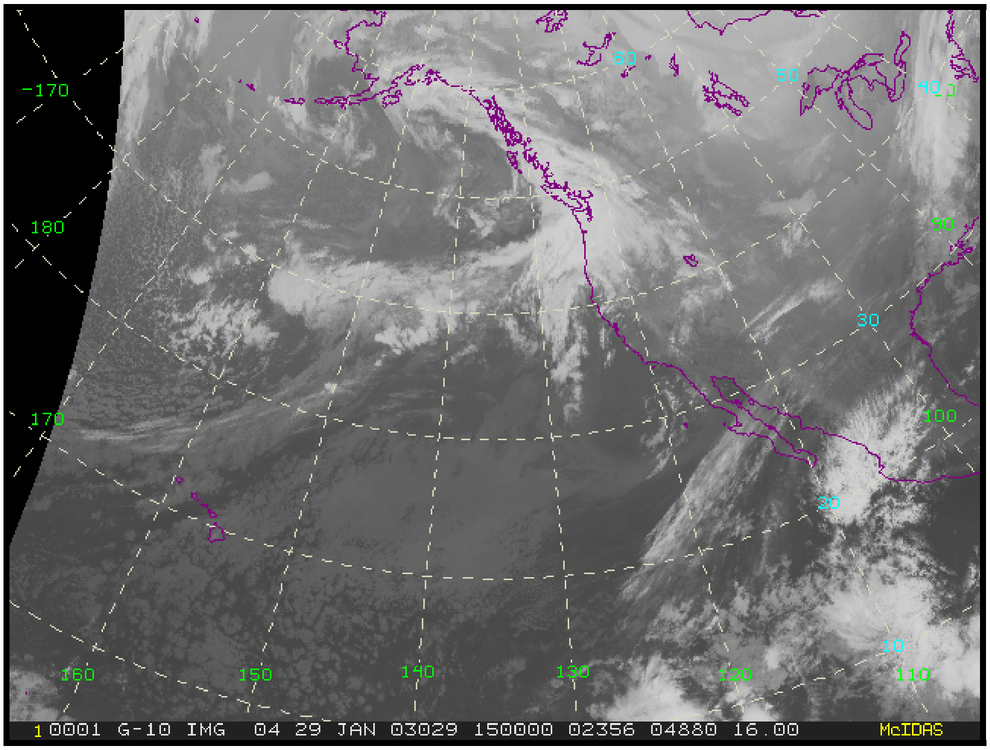
Appendix A
Satellite Data of Storm Event #4a and 4b
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



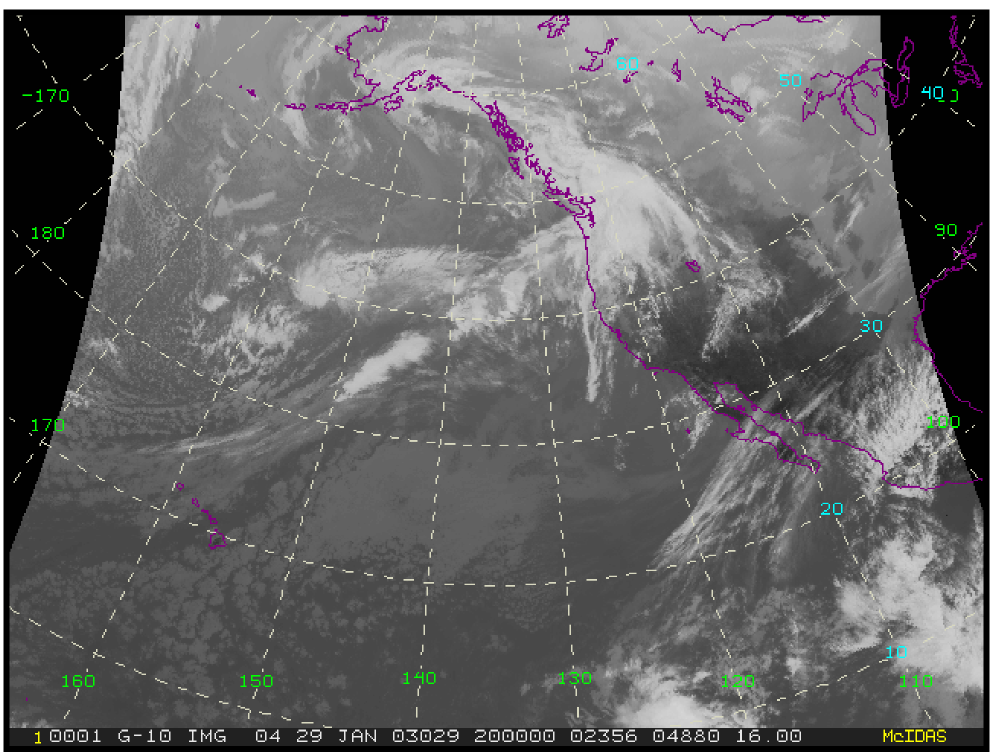
28 January 2003 1000 (local time) - Storm 4a approaches and Storm 4b develops at ~ 170 W/30N



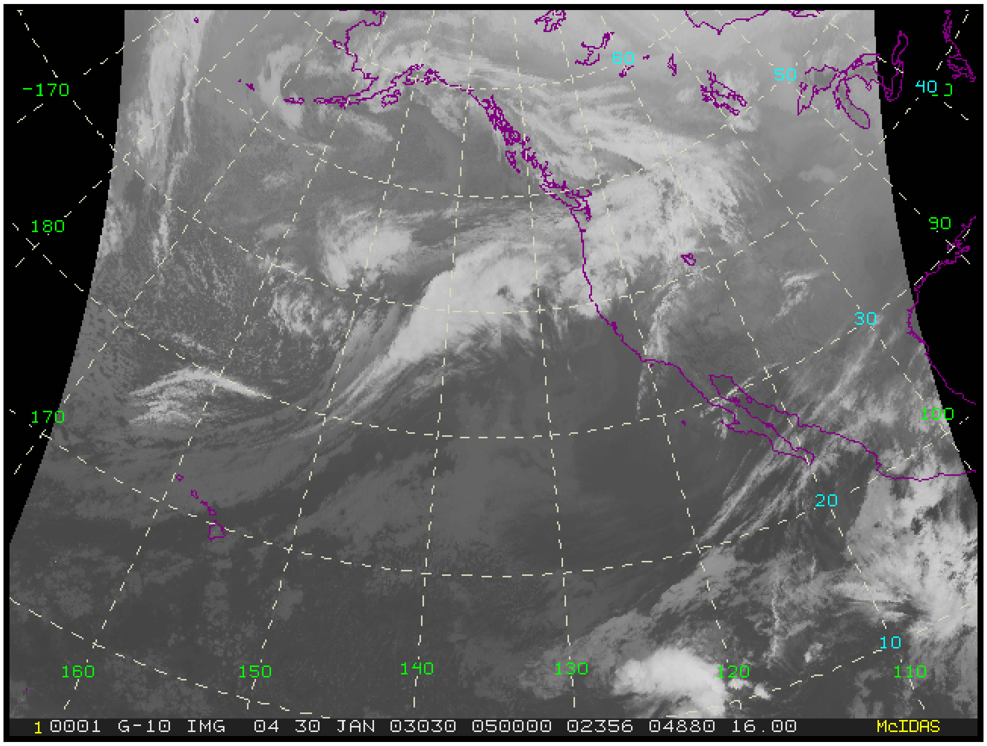
29 January 2003 0000 (local time) – Storm 4a – Note moisture trailing back to developing Storm 4b.



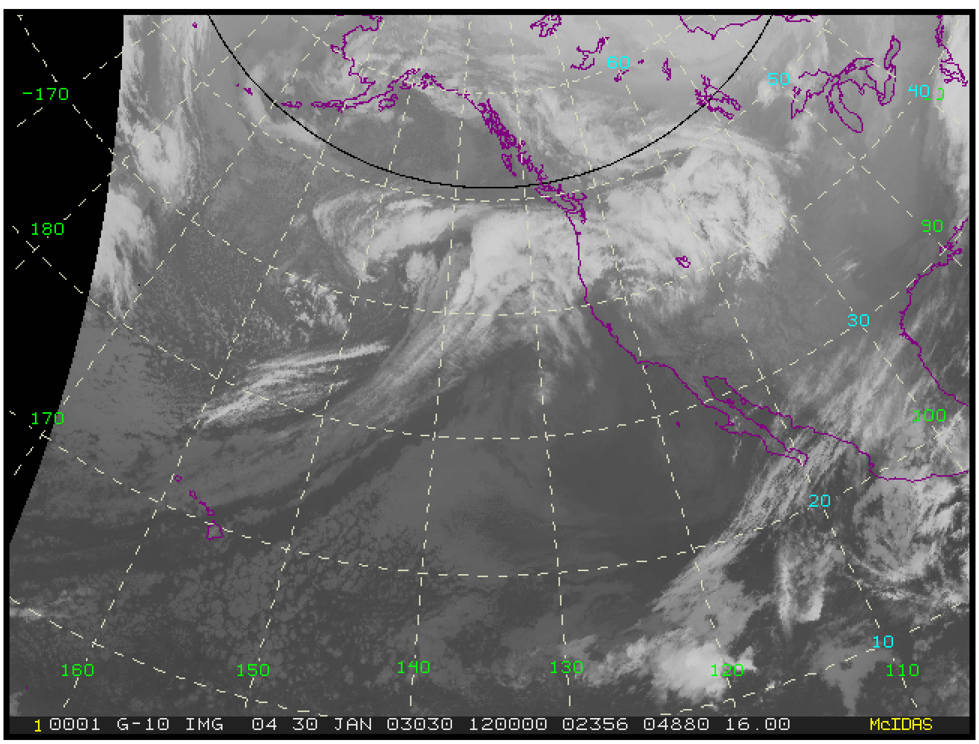
29 January 2003 0800 (local time) – Rain begins - Storm 4a. Storm 4b takes shape offshore.



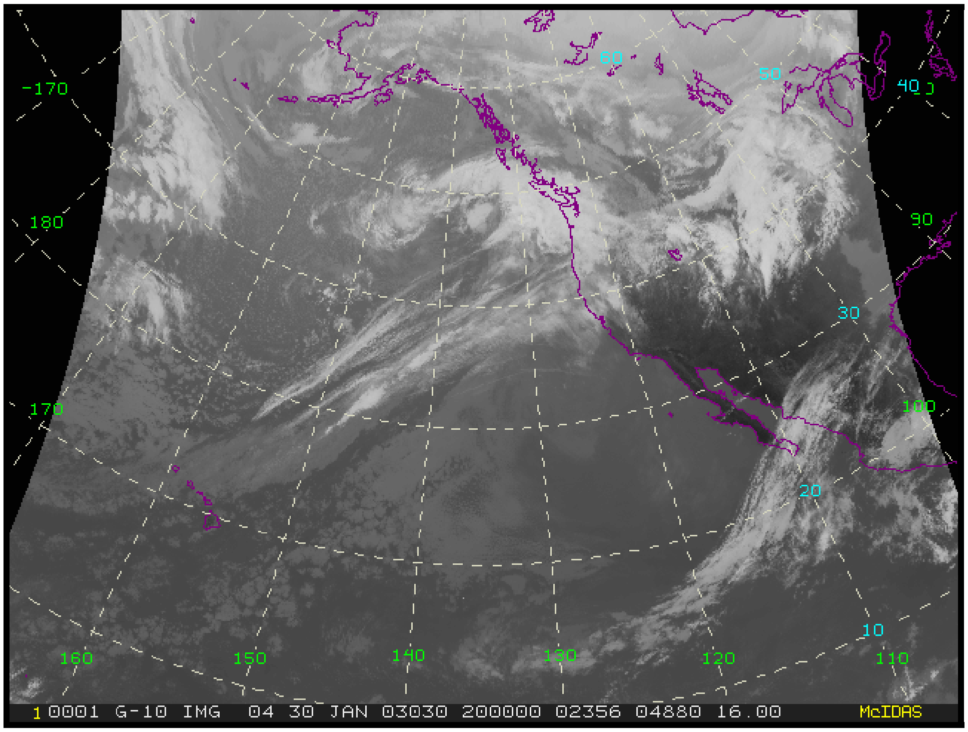
29 January 2003 1200 (local time) – Storm 4a front passes through project area.



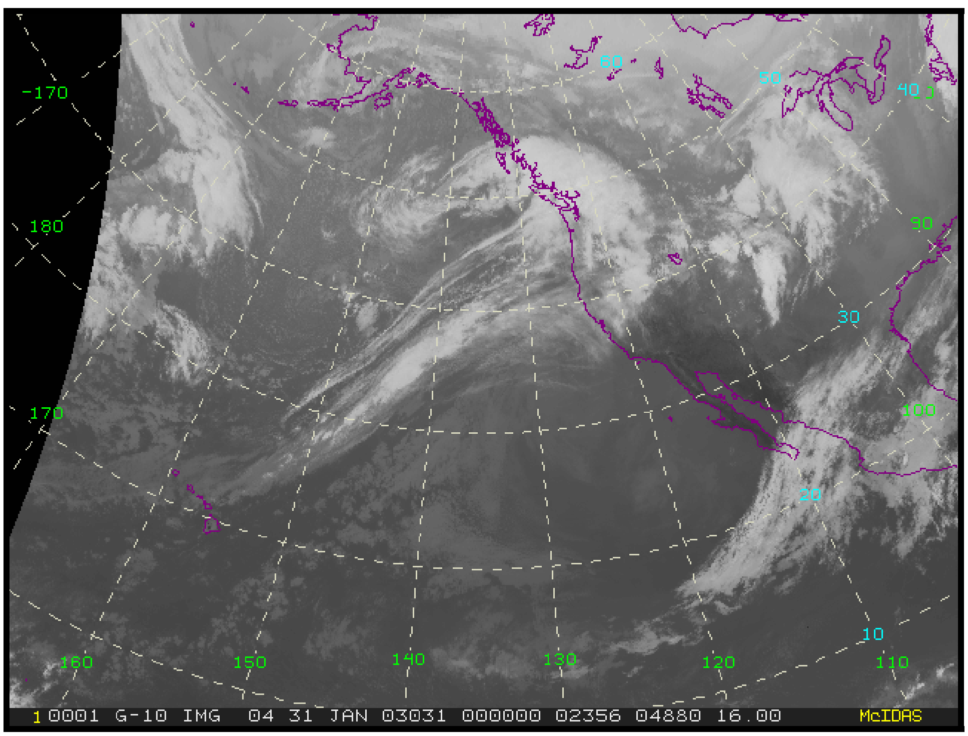
29 January 2003 2100 (local time) – Skies clear behind 4a; note baroclinic leaf from 4b offshore at ~140W/40N.



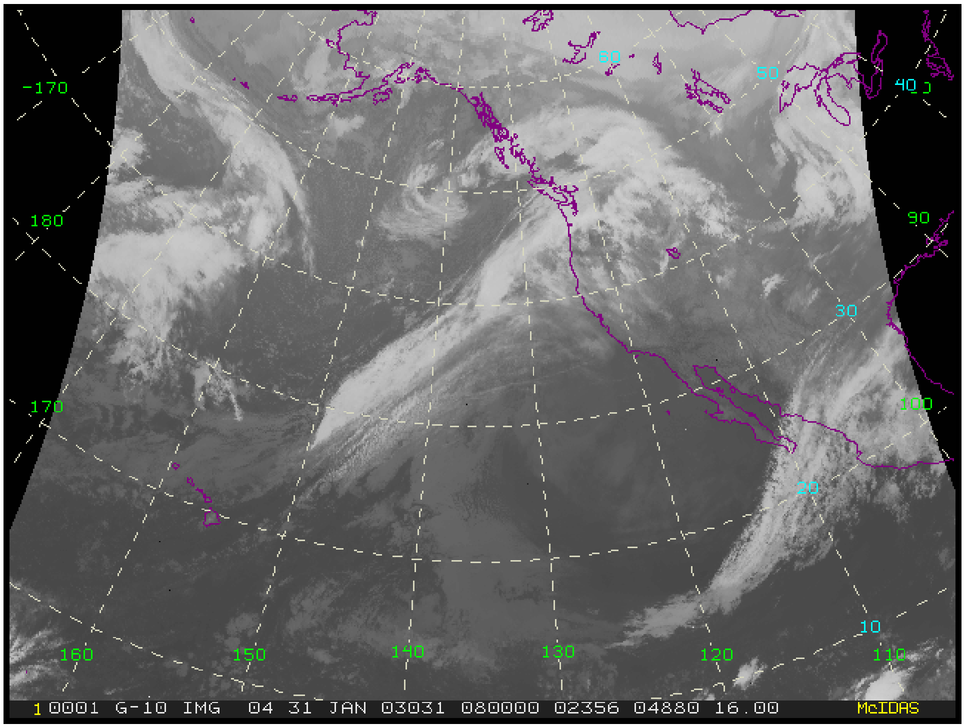
30 January 2003 0400 (local time) – Storm 4b approaches coast. Note extensive low-level moisture training back to Hawaii (light gray clouds).



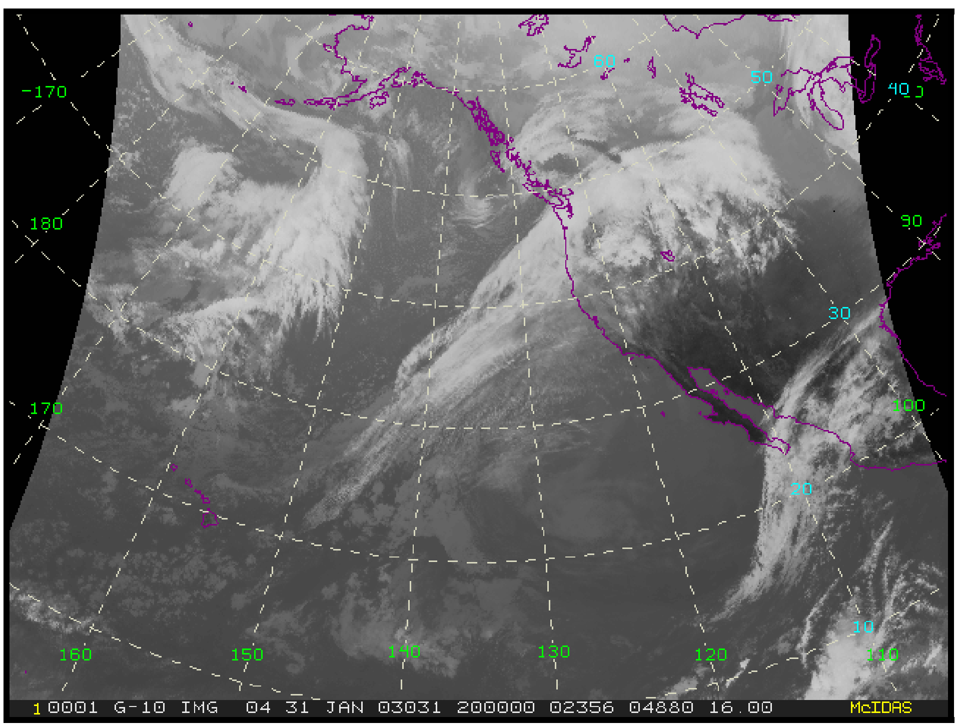
30 January 2003 1200 (local time) – Storm 4b moves onshore; rain begins from south to north.



30 January 2003 1600 (local time) – Storm 4b warm front passes through; cold front sags southward towards Oregon



31 January 2003 0000 (local time) – Storm 4b moves through local area; heavy rain moves south. Note moisture stream connection to subtropics still exists.



31 January 2003 1200 (local time) – Sampling ends yet high clouds stream over project area; rain continues south of project area.

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Appendix B
Flowlink Rainfall, Physio-Chemical Data, and Fecal Coliform CoC Form

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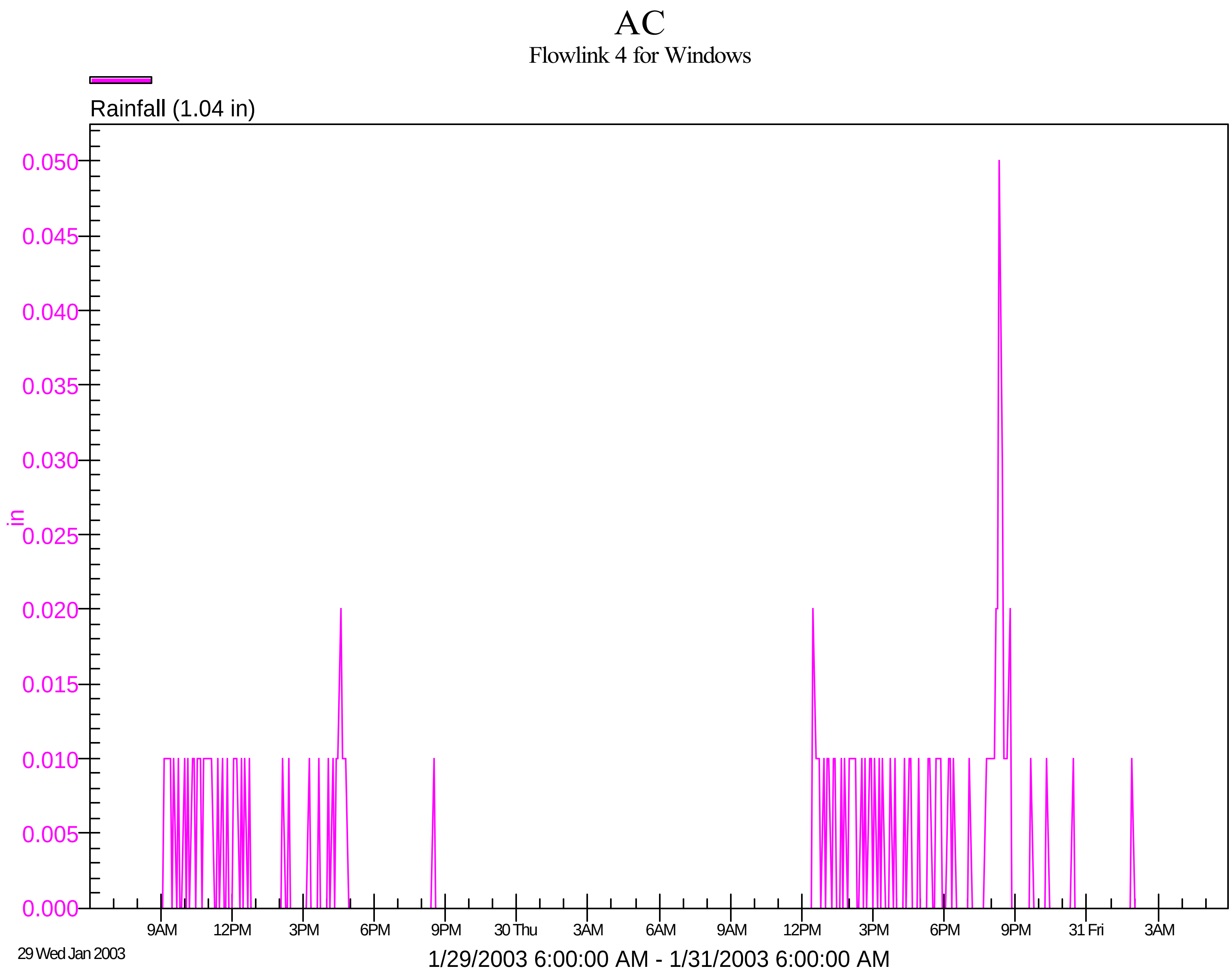
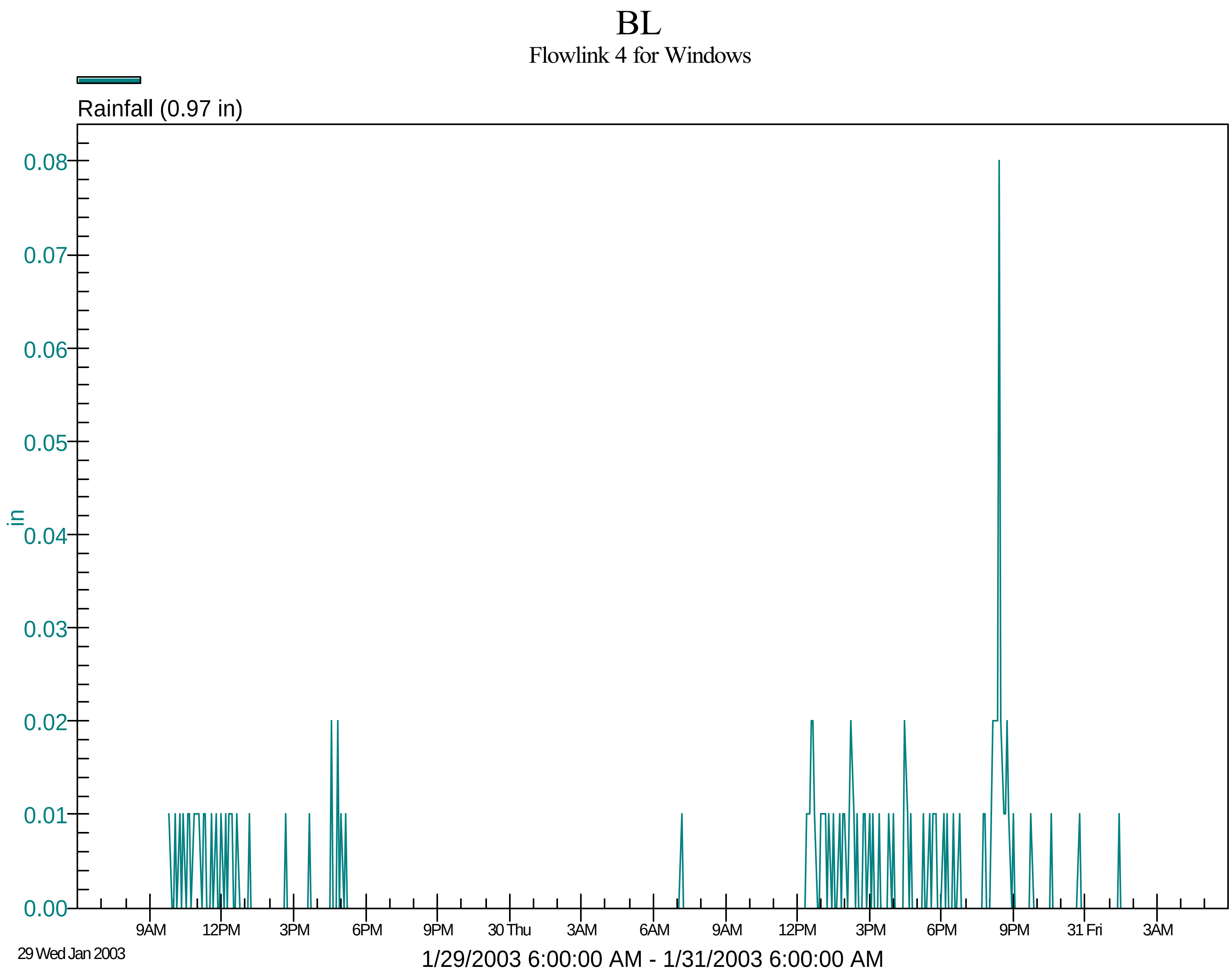
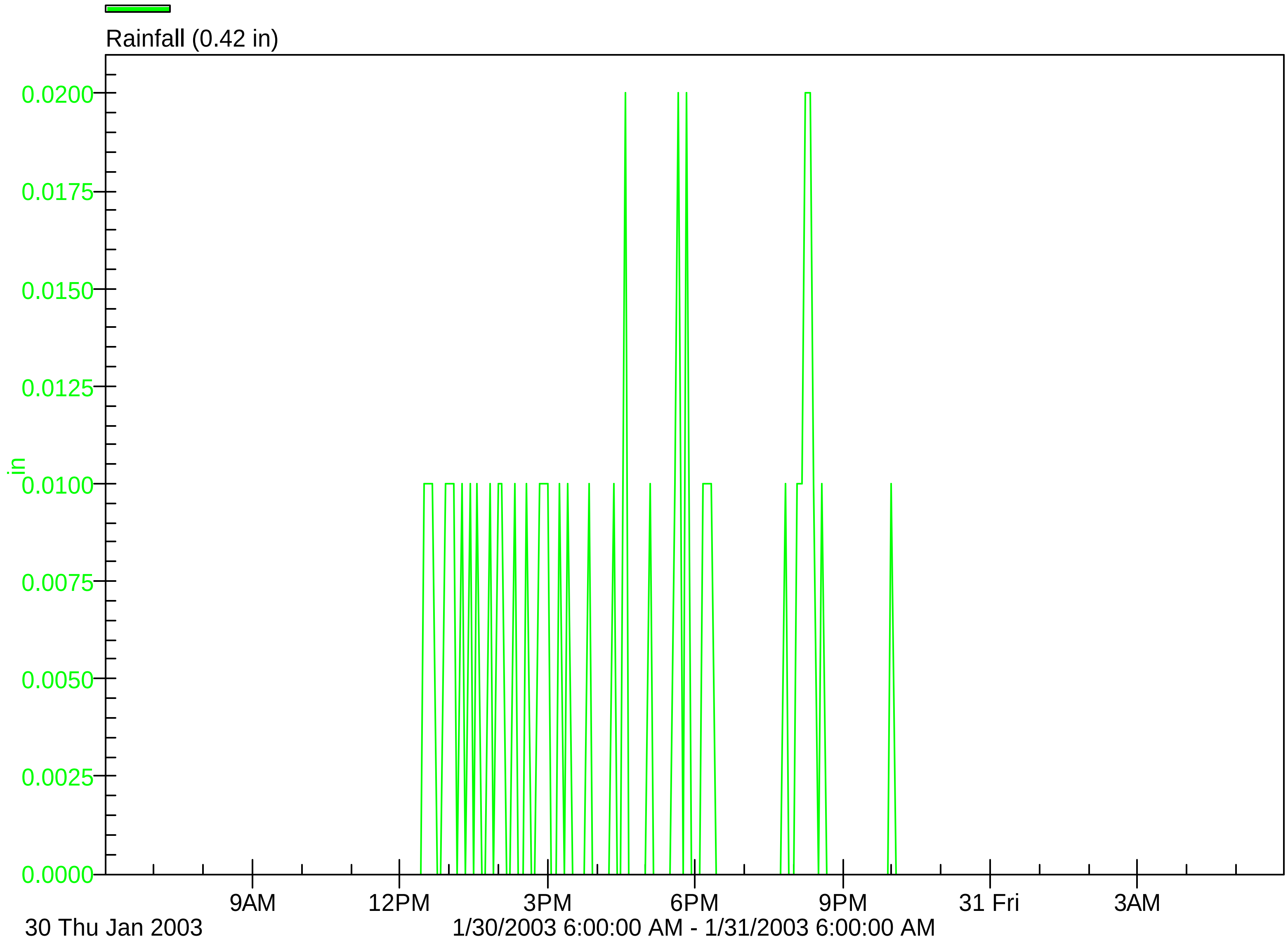
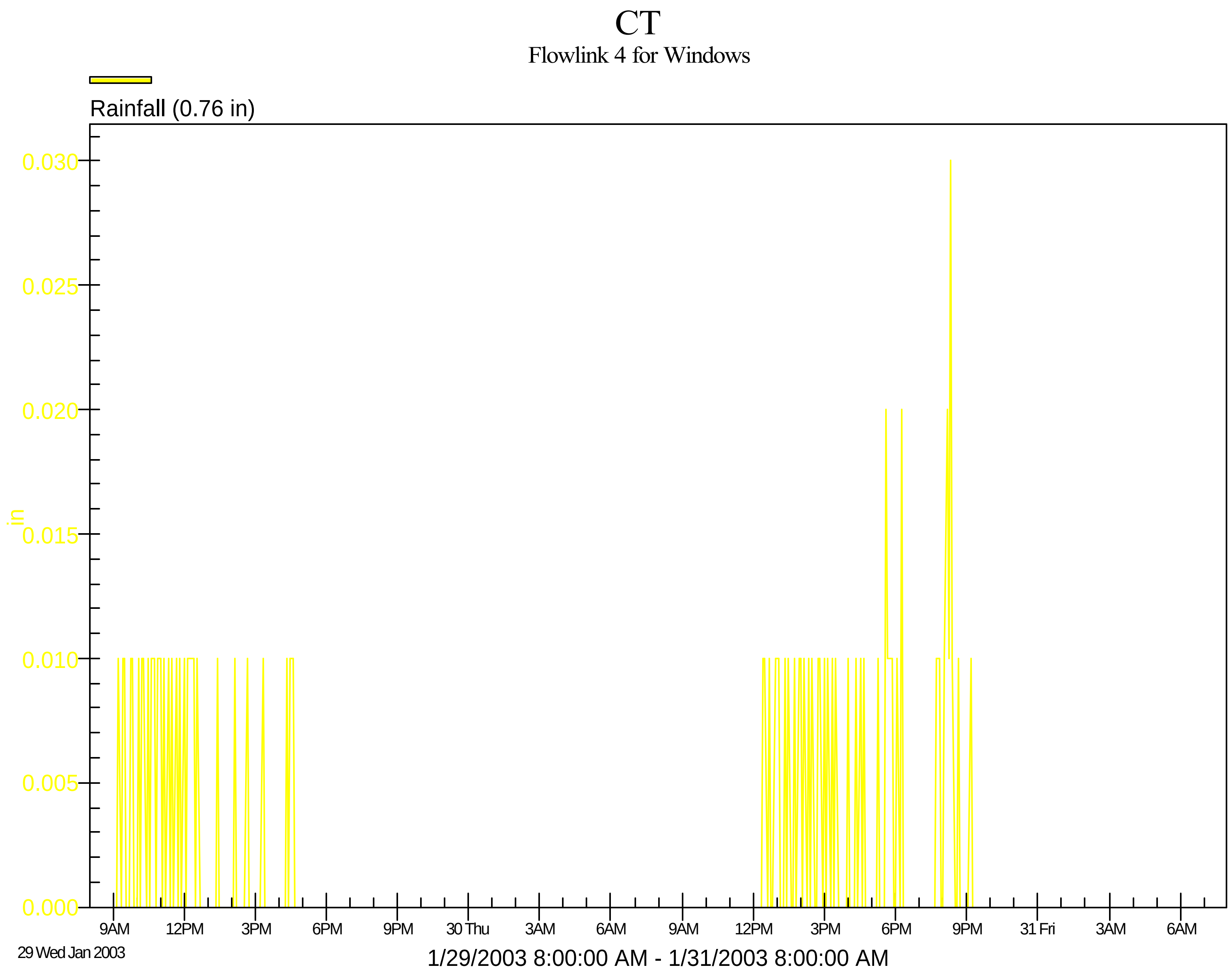

AC
Flowlink 4 for Windows
Rainfall (1.04 in)
in
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9AM
12PM
3PM
6PM
9PM
30 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
31 Fri
3AM
29 Wed Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 6:00:00 AM


BL
Flowlink 4 for Windows
Rainfall (0.97 in)
in
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
9AM
12PM
3PM
6PM
9PM
30 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
31 Fri
3AM
29 Wed Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 6:00:00 AM

CH

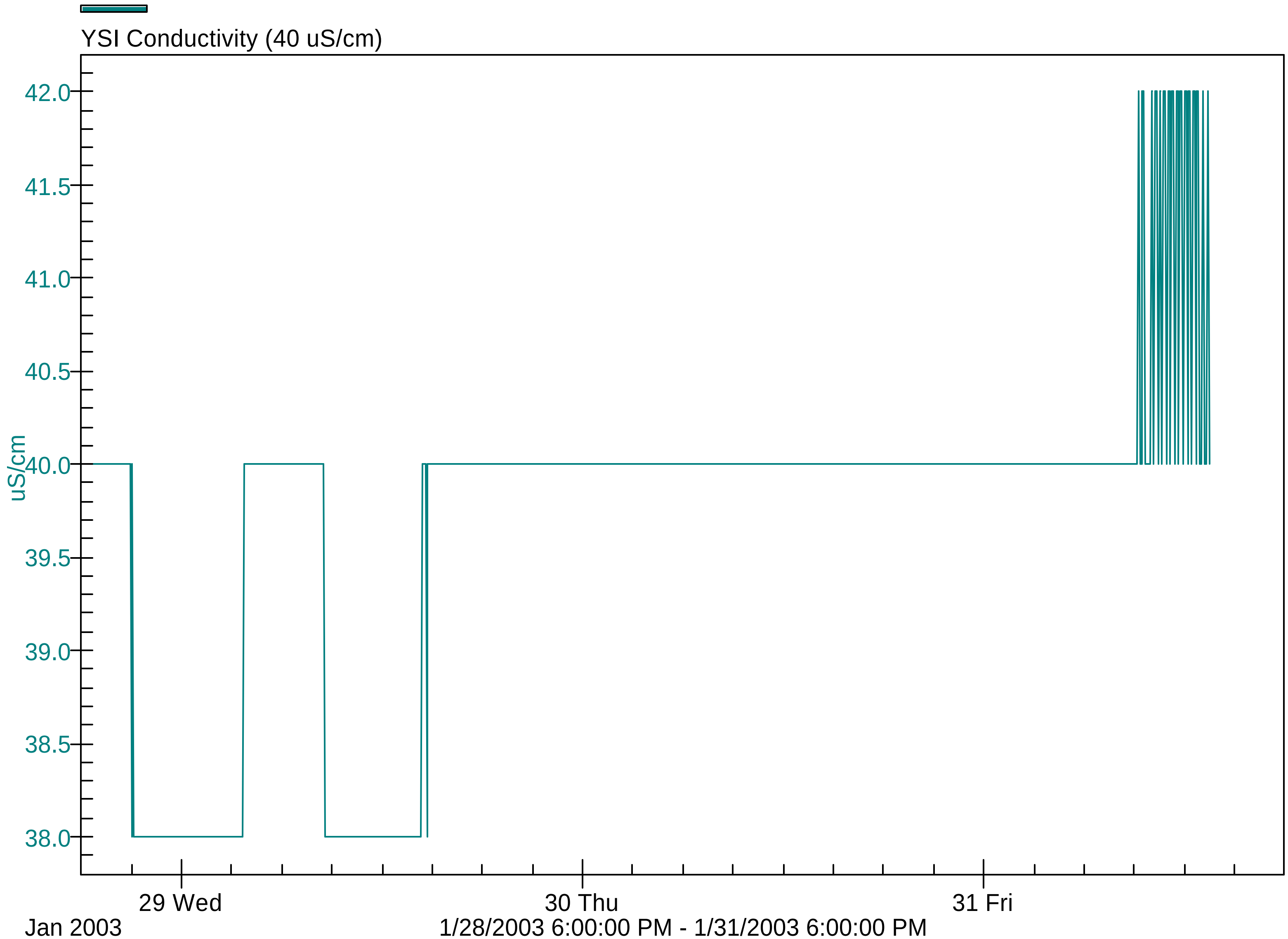
Flowlink 4 for Windows

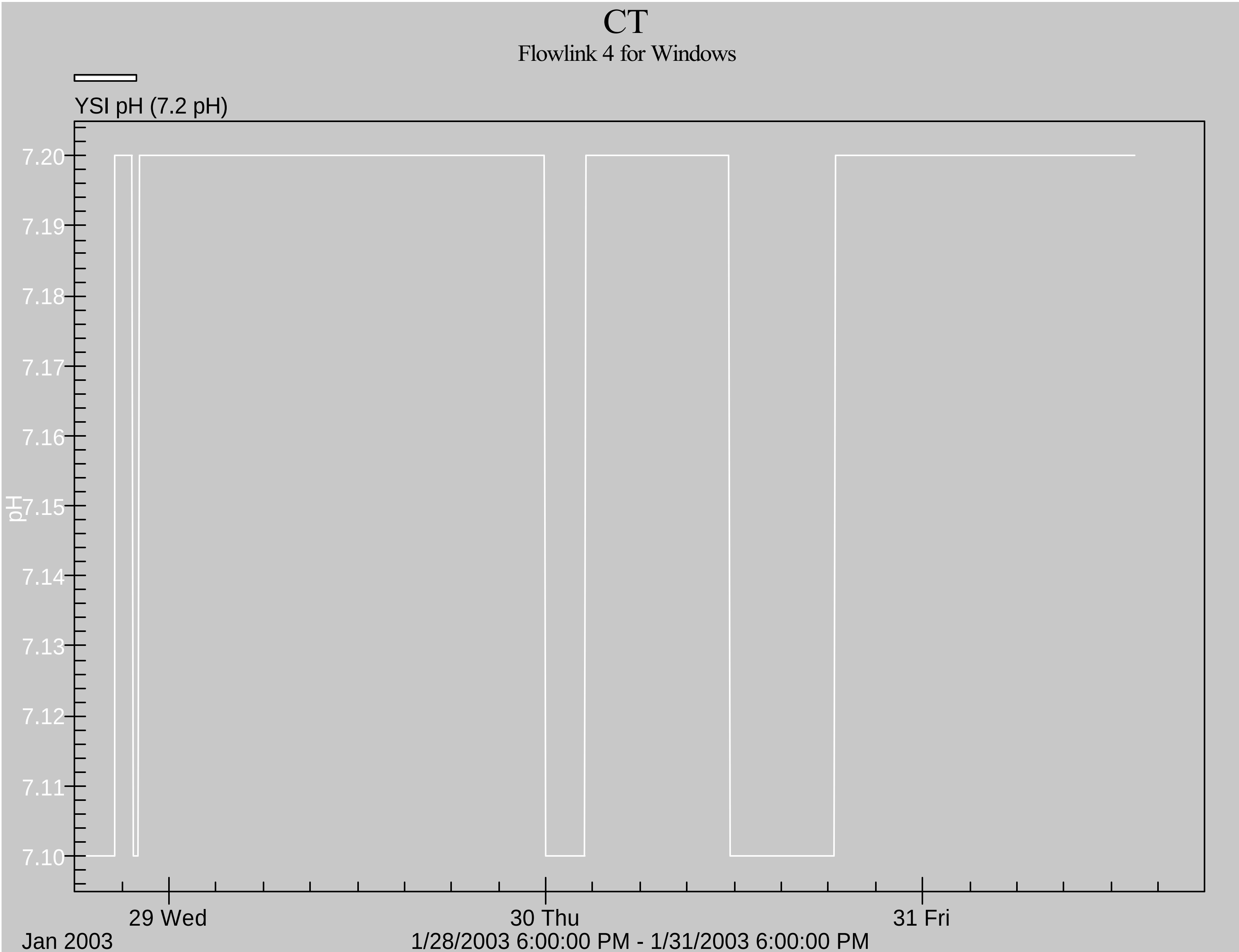


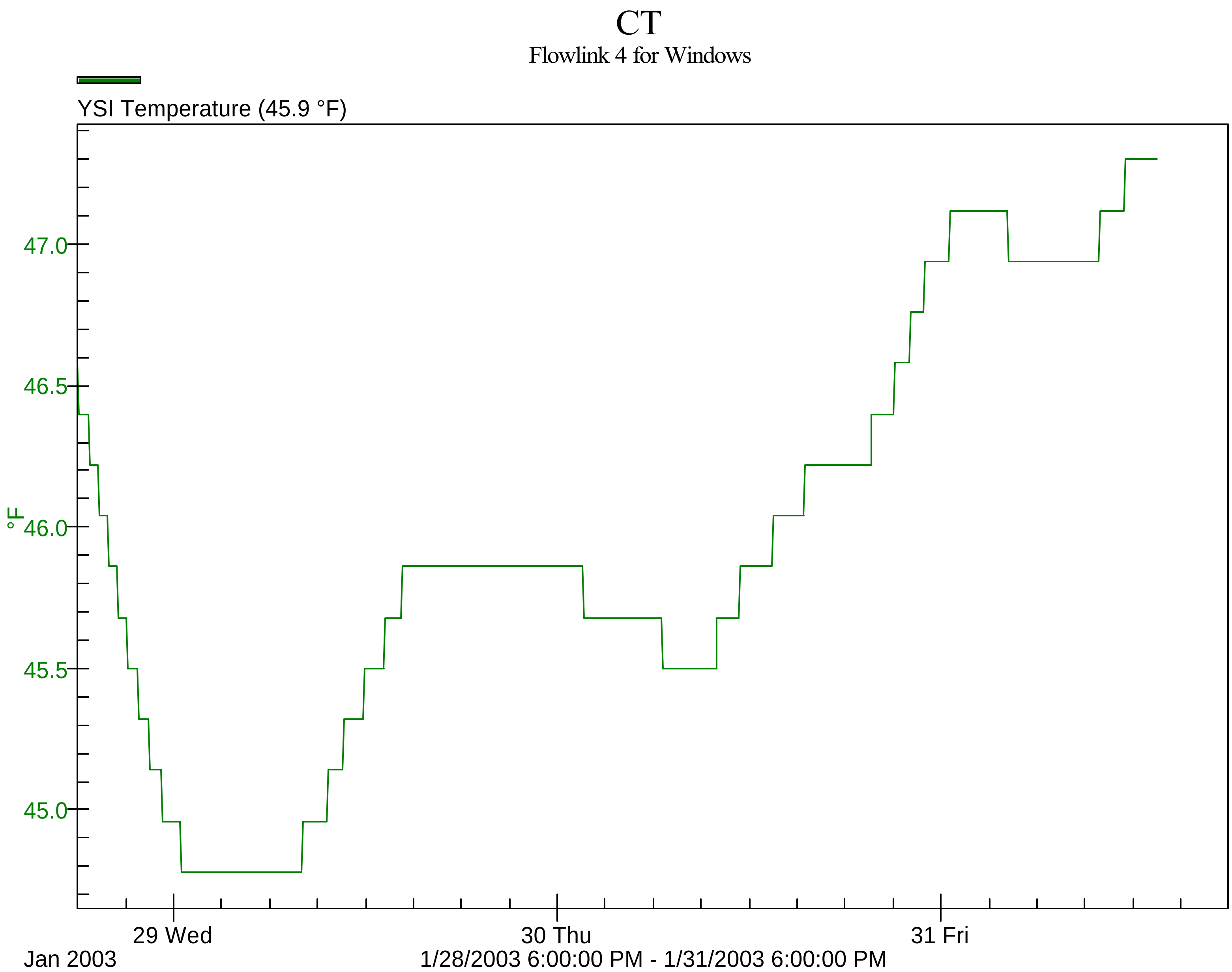

CT
Flowlink 4 for Windows
Rainfall (0.76 in)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9AM
12PM
3PM
6PM
9PM
30 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
31 Fri
3AM
6AM
29 Wed Jan 2003
1/29/2003 8:00:00 AM - 1/31/2003 8:00:00 AM

CT

Flowlink 4 for Windows

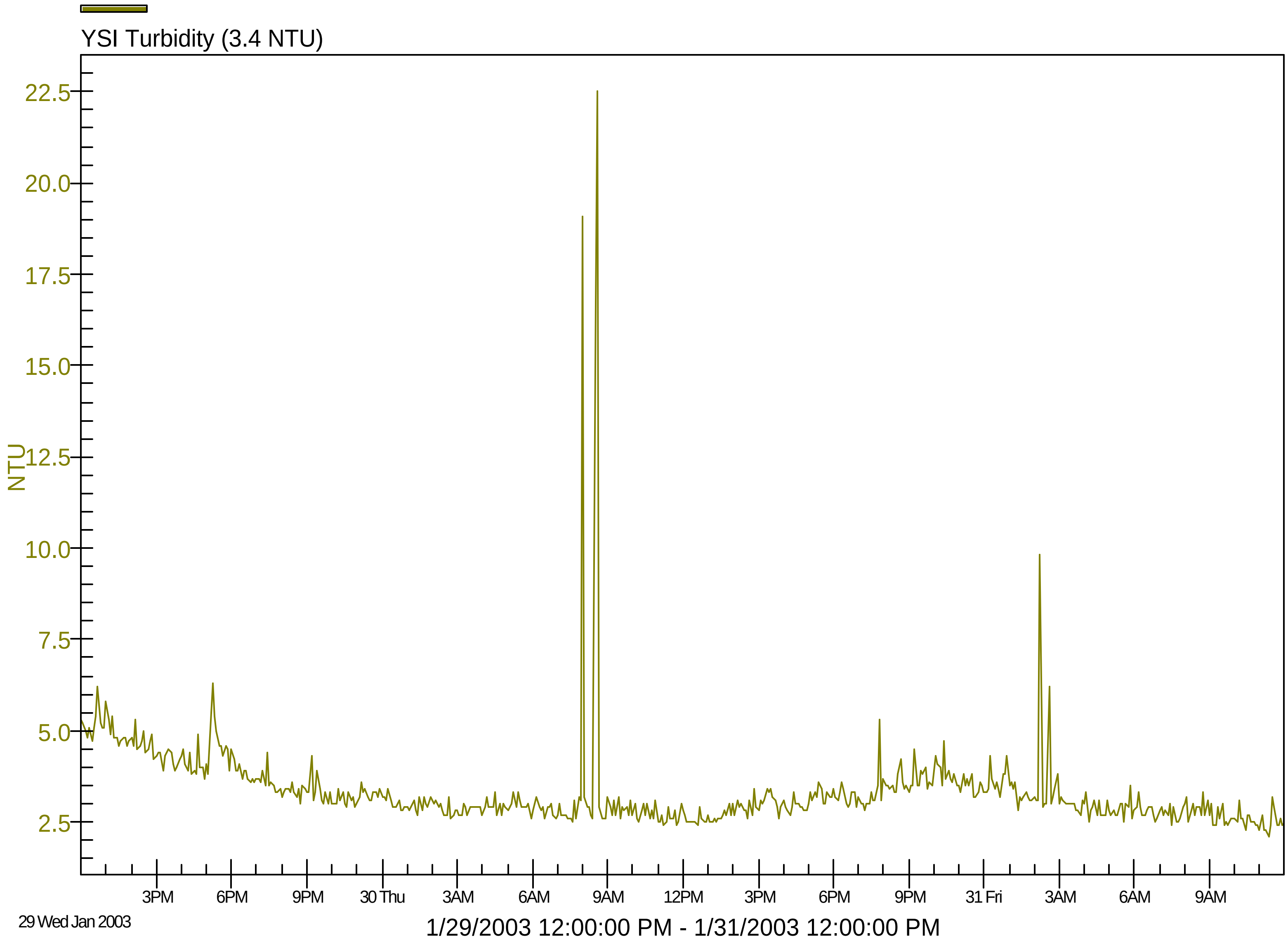


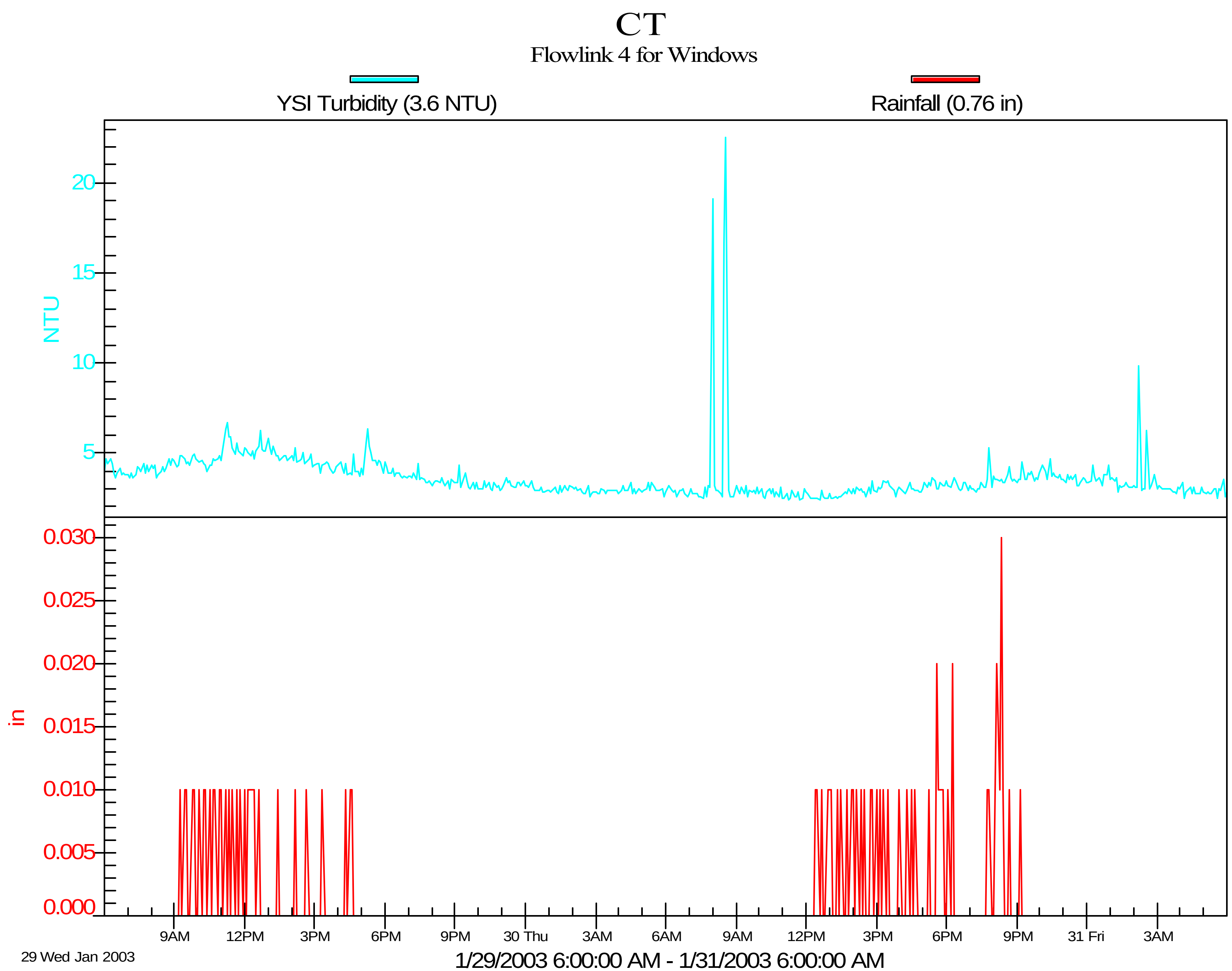

CT
Flowlink 4 for Windows
YSI pH (7.2 pH)
pH
7.20
7.19
7.18
7.17
7.16
7.15
7.14
7.13
7.12
7.11
7.10
29 Wed
30 Thu
31 Fri
Jan 2003
1/28/2003 6:00:00 PM - 1/31/2003 6:00:00 PM


CT
Flowlink 4 for Windows
YSI Temperature (45.9 °F)
°F
47.0
46.5
46.0
45.5
45.0
29 Wed
30 Thu
31 Fri
Jan 2003
1/28/2003 6:00:00 PM - 1/31/2003 6:00:00 PM

CT

Flowlink 4 for Windows

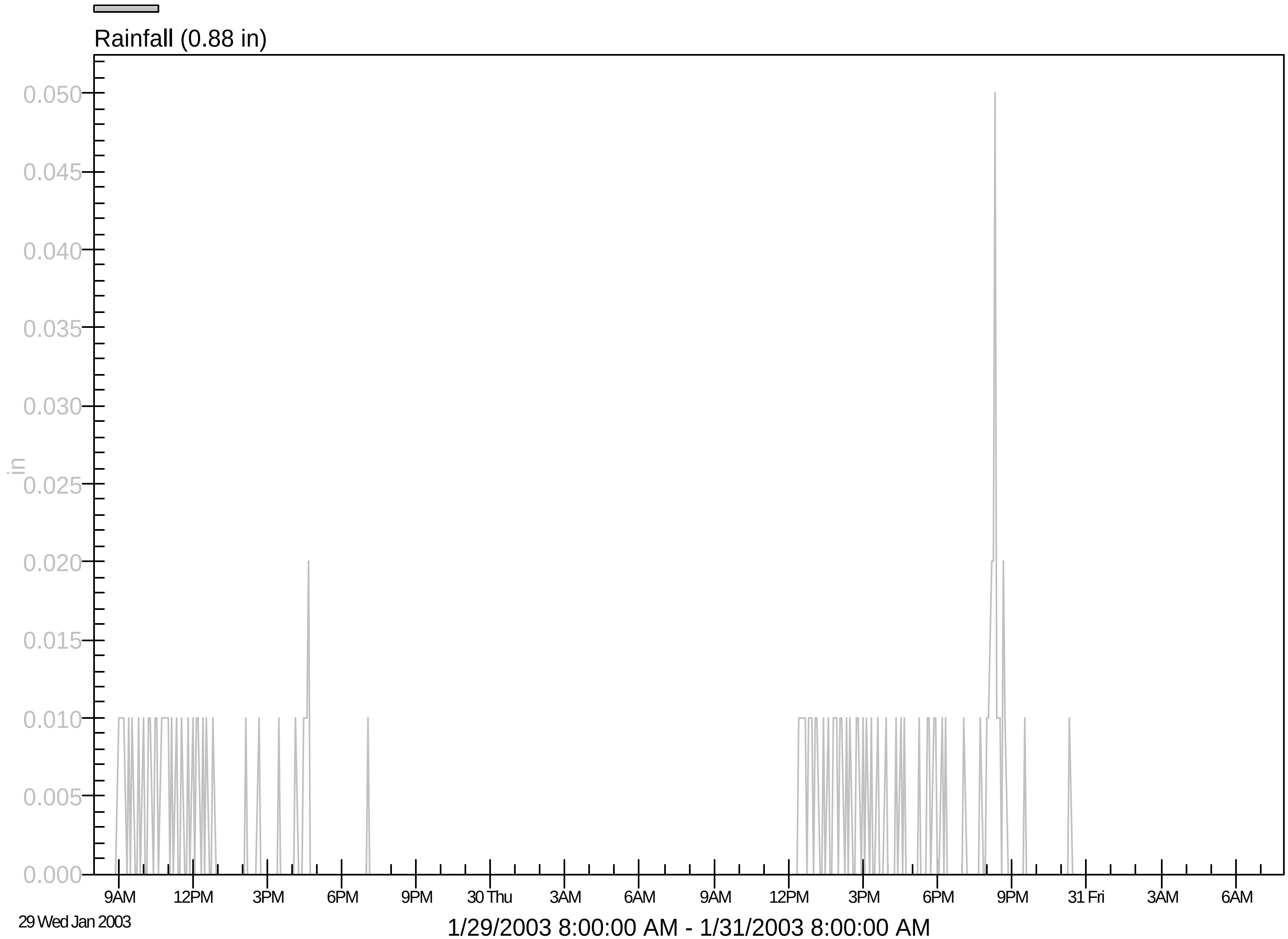




CT
Flowlink 4 for Windows
YSI Turbidity (3.6 NTU)
Rainfall (0.76 in)
NTU
20
15
10
5
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9AM
12PM
3PM
6PM
9PM
30 Thu
3AM
6AM
9AM
12PM
3PM
6PM
9PM
31 Fri
3AM
29 Wed Jan 2003
1/29/2003 6:00:00 AM - 1/31/2003 6:00:00 AM

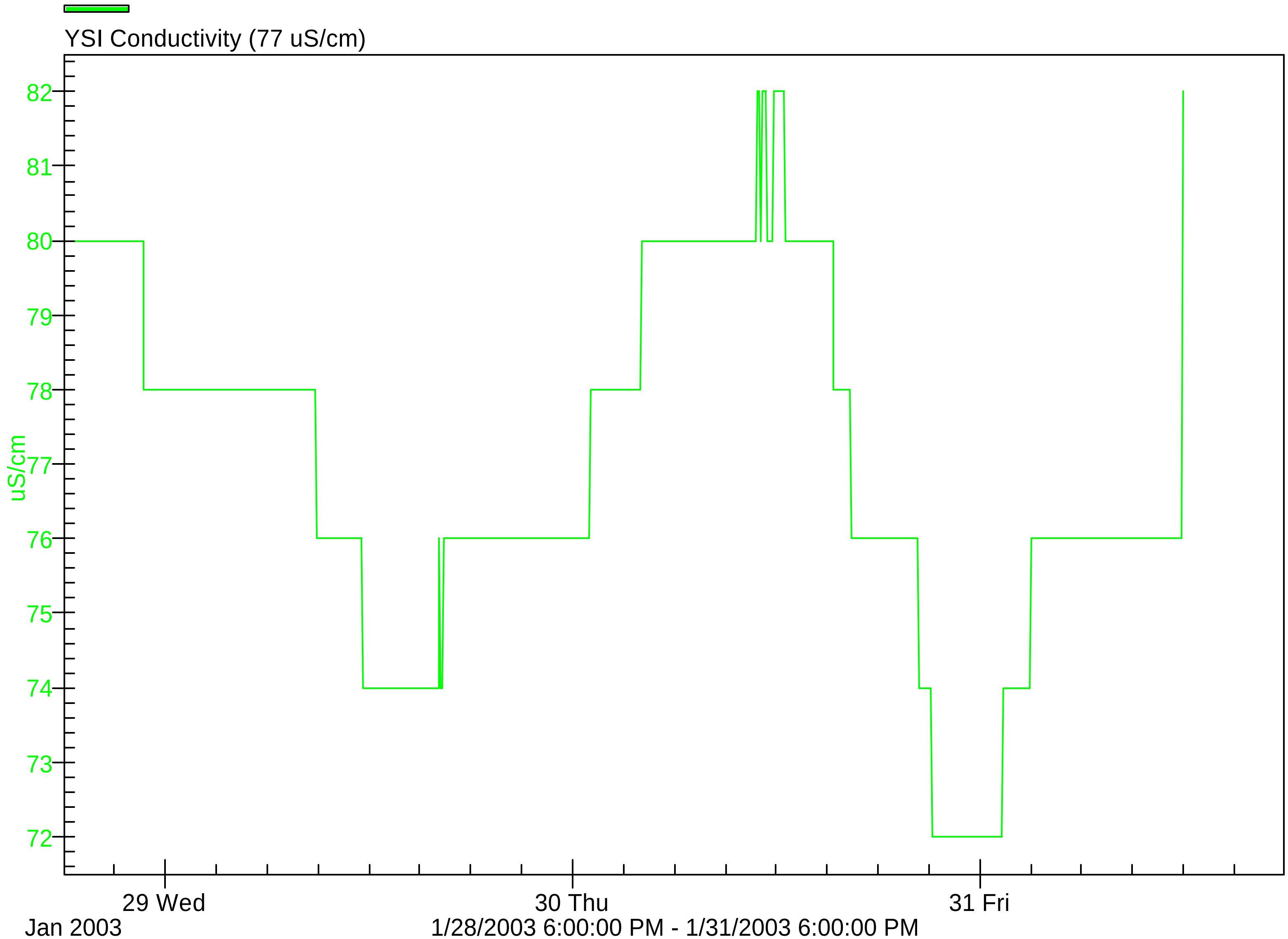
GC

Flowlink 4 for Windows



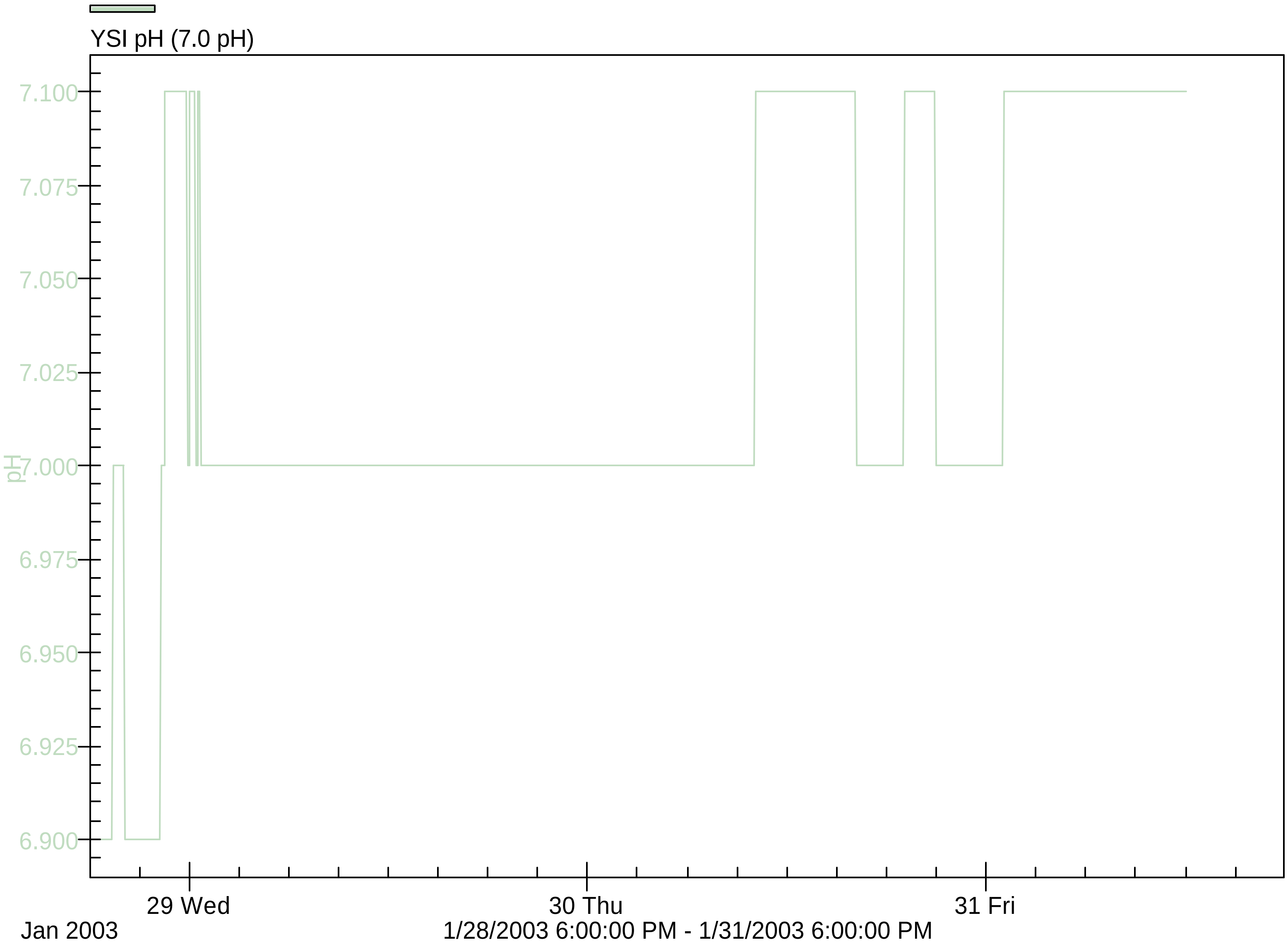
GC

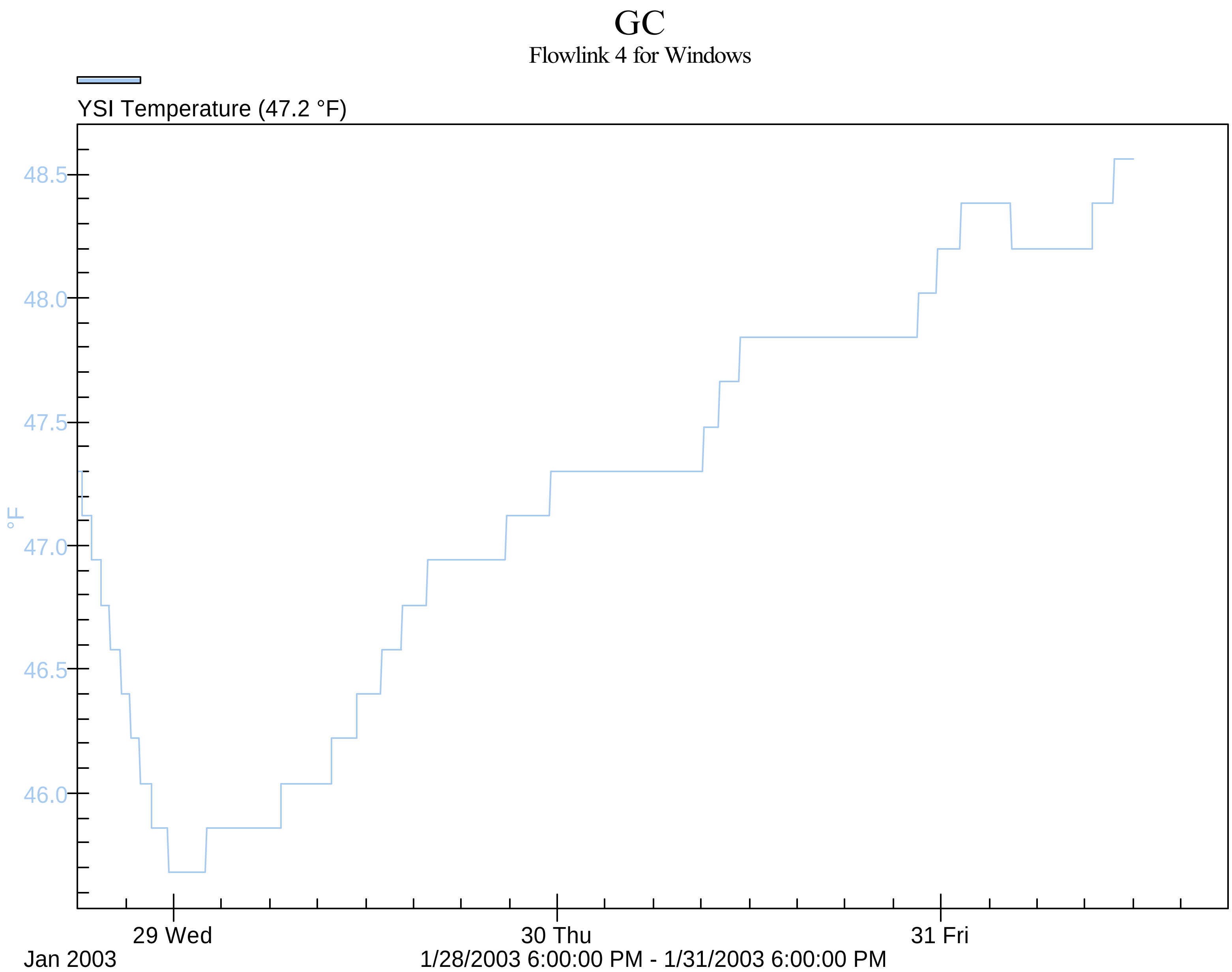
Flowlink 4 for Windows



GC

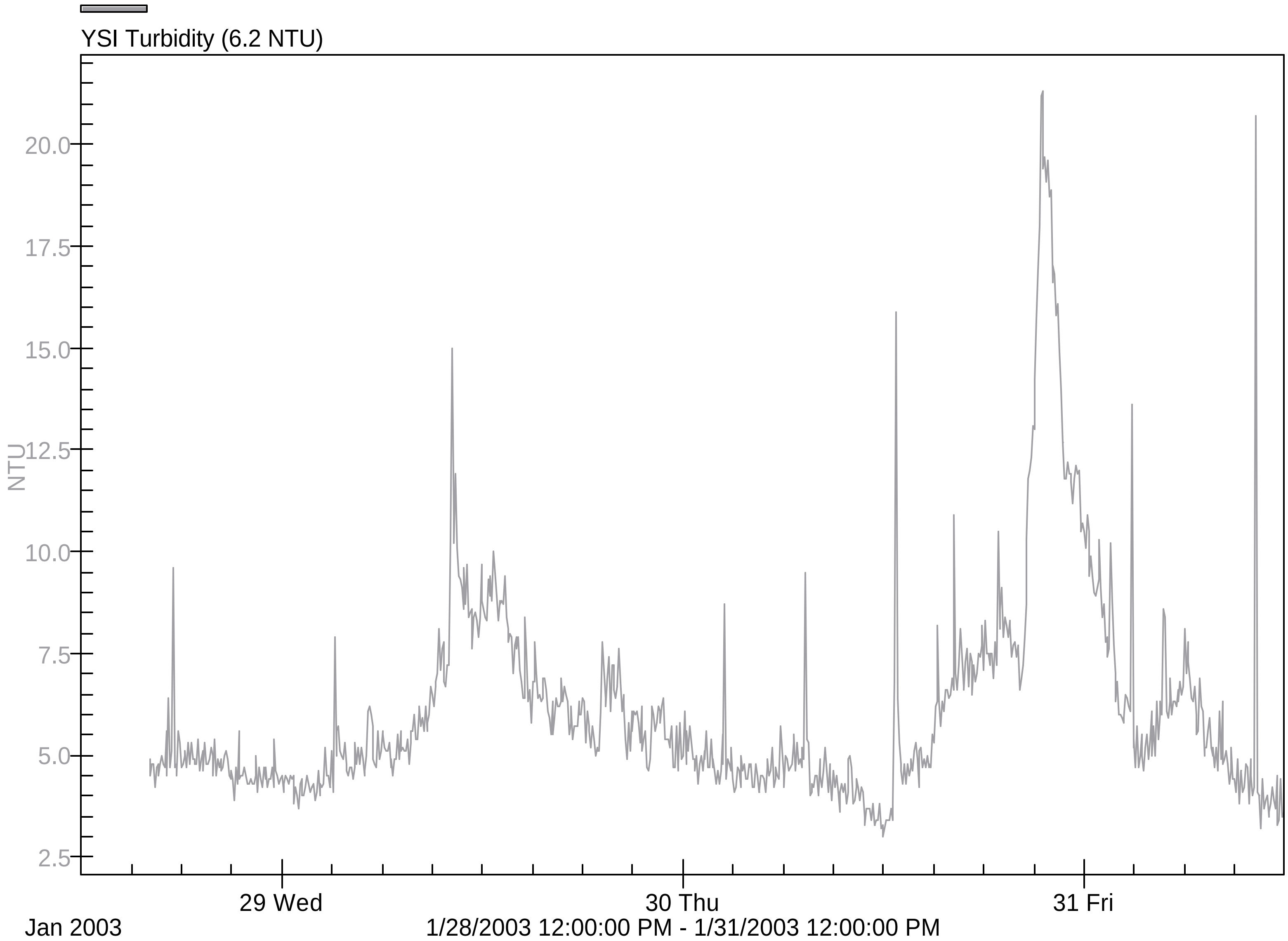
Flowlink 4 for Windows

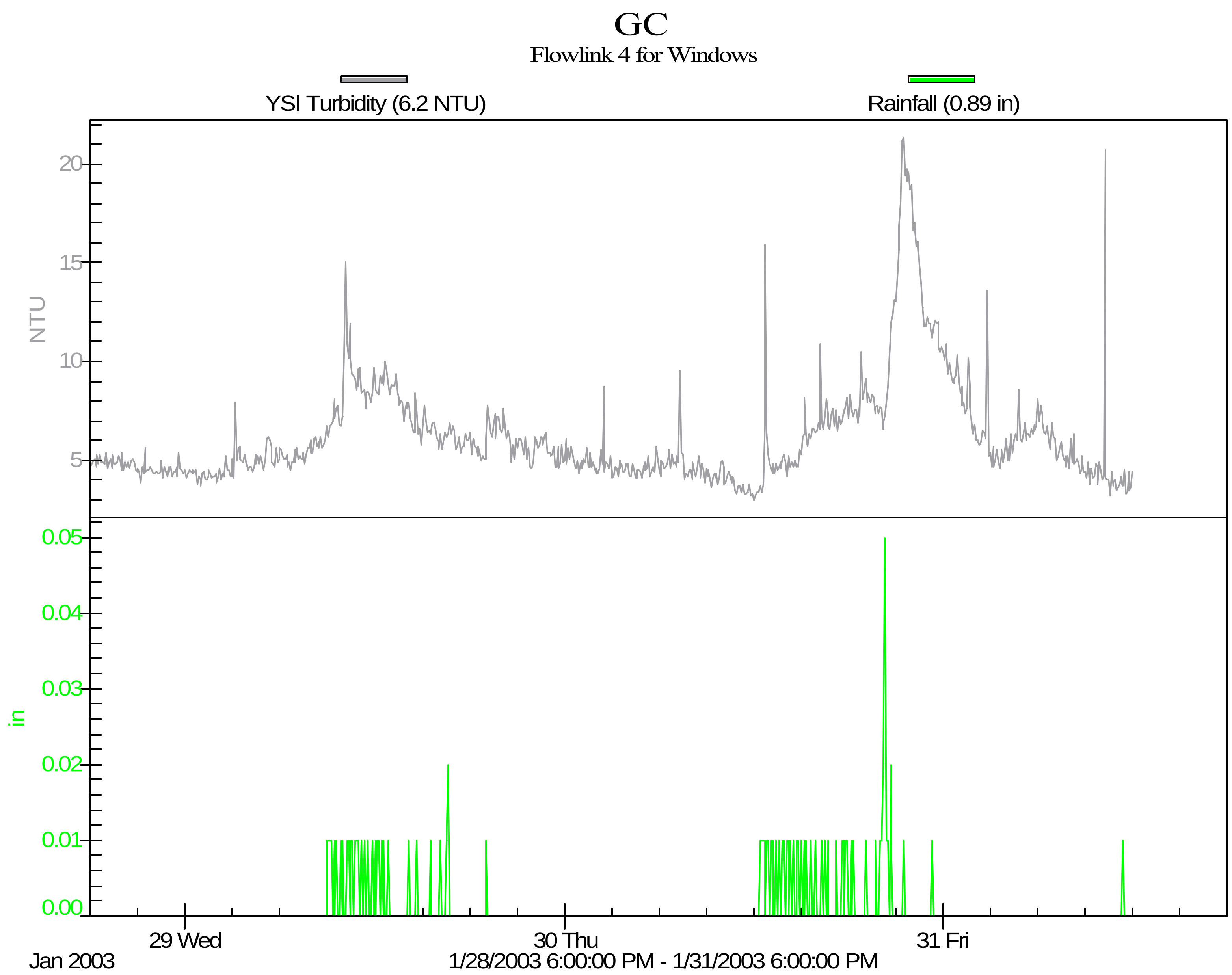



GC
Flowlink 4 for Windows
YSI Temperature (47.2 °F)
°F
48.5
48.0
47.5
47.0
46.5
46.0
29 Wed
30 Thu
31 Fri
Jan 2003
1/28/2003 6:00:00 PM - 1/31/2003 6:00:00 PM

GC

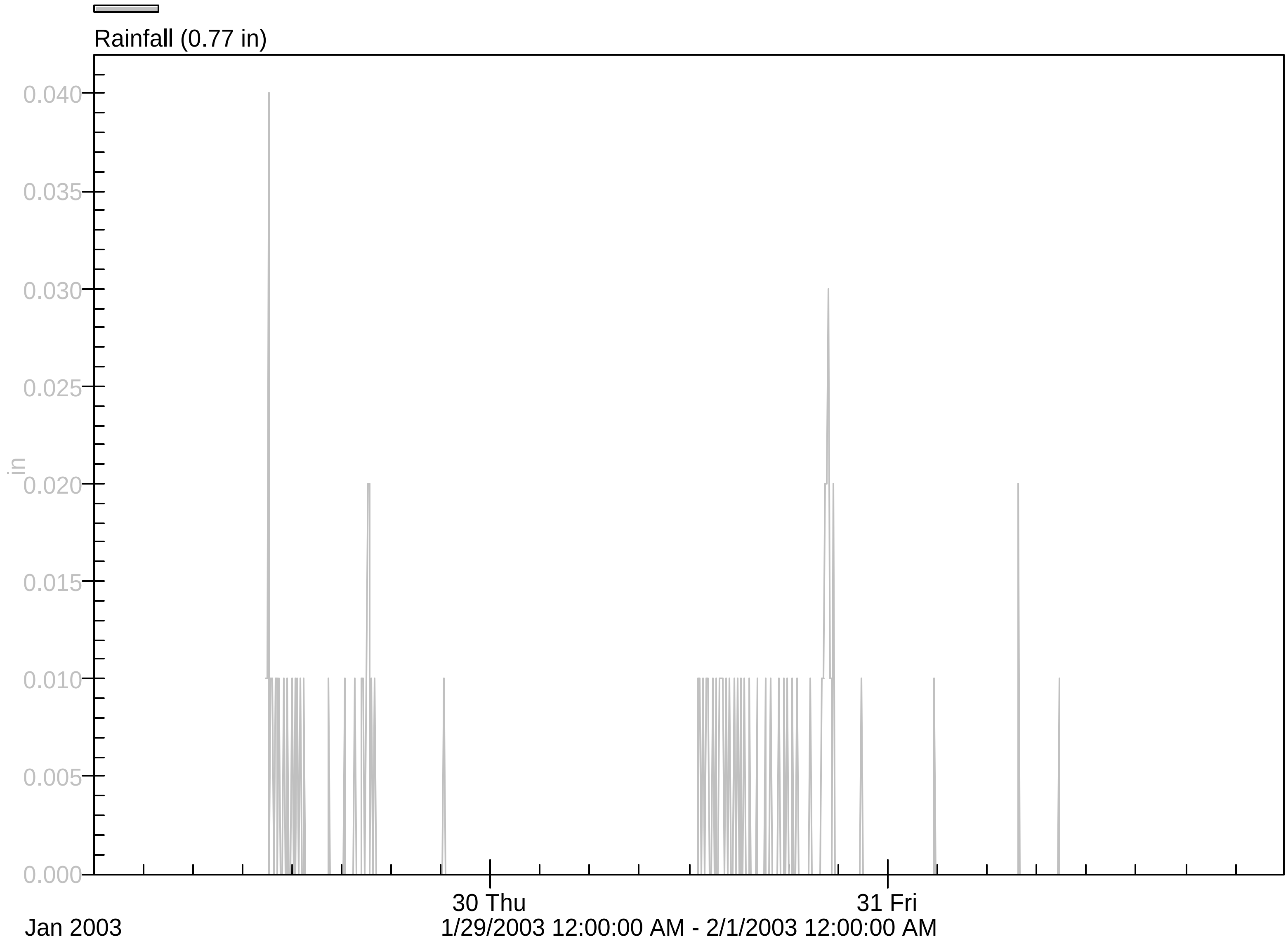
Flowlink 4 for Windows




GC
Flowlink 4 for Windows
YSI Turbidity (6.2 NTU)
Rainfall (0.89 in)
NTU
20
15
10
5
in
0.05
0.04
0.03
0.02
0.01
0.00
29 Wed
30 Thu
31 Fri
Jan 2003
1/28/2003 6:00:00 PM - 1/31/2003 6:00:00 PM

OC

Flowlink 4 for Windows



Sample Collector	Pingree, Estes, Tremaglio, Gaudette
Sampling Team	The Environmental Company (TEC)
Organization	Storm Event #4a

PSNS Project ENVVEST
FC TMDL STUDY

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03050430	Chico Main	1/29/2003	11:20	45.4	6.9	0.052	6.7	12	
03050431	Chico Trib	1/29/2003	11:25	45.3	7.2	0.038	4.4	12	
03050432	Gorst Crk.	1/29/2003	11:40	46.4	7.0	0.074	8.5	12	
03050433	Anderson Crk.	1/29/2003	12:00	46.3	7.5	0.049		12	No Turbidity Data Available
03050434	Blackjack Crk.	1/29/2003	12:30	44.6	6.8	0.054	13.5	12	
03050435	Blackjack Crk. (DUP)	1/29/2003	12:30	44.6	6.8	0.054	13.5	12	
03050436	Olney Crk.	1/29/2003	12:50	46.73	7.6	0.091	43.7	12	

Preservatives Used:
Relinquished By/Date:
Received By/Date:
Relinquished By/Date:
Received By/Date:
Relinquished By/Date:
Received By Lab/Date:

Method of Shipment:
Airbill No.:
Laboratory
Address:

Custody Seals Present? Yes No
Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Sample Collector	Pingree, Estes, Tremaglio, Gaudette
Sampling Team	The Environmental Company (TEC)
Organization	Storm Event #4b

PSNS Project ENVVEST
FC TMDL STUDY

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03050437	Chico Main	1/30/2003	13:15	46.1	6.9	0.054	2.0	12	
03050438	Chico Trib	1/30/2003	13:30	46.0	7.1	0.040	3.0	12	
03050439	Gorst Crk.	1/30/2003	14:20	47.8	7.1	0.080	5.1	12	
03050440	Gorst Crk. (DUP)	1/30/2003	14:20	47.8	7.1	0.080	5.1	12	
03050441	Anderson Crk.	1/30/2003	14:35	47.5	7.1	0.050	13.0	12	
03050442	Blackjack Crk.	1/30/2003	14:55	46.9	7.0	0.051	7.6	12	
03050443	Olney Crk.	1/30/2003	15:25	49.1	7.7	0.107	34.3	12	
03050444	Chico Trib	1/30/2003	20:50	46.4	7.2	0.040	3.3	12	
03050445	Chico Main	1/30/2003	21:15	46.6	7.0	0.053	4.4	12	
03050446	Chico Main (DUP)	1/30/2003	21:15	46.6	7.0	0.053	4.4	12	
03050447	Gorst Crk.	1/30/2003	21:30	47.8	7.0	0.072	22.0	12	
03050448	Anderson Crk.	1/30/2003	21:45	47.6	7.4	0.047	37.7	12	
03050449	Blackjack Crk.	1/30/2003	21:55	47.7	7.1	0.051	37.5	12	YSI 650 (Handheld) Reading
03050450	Olney Crk.	1/30/2003	22:30	49.2	7.5	0.077	108.8	12	YSI 650 (Handheld) Reading
03050451	Blackjack Crk.	1/31/2003	9:00	48.3	6.9	0.047	9.0	12	
03050452	Chico Main	1/31/2003	9:30	47.1	7.0	0.054	2.5	12	
03050453	Chico Trib	1/31/2003	9:35	46.9	7.2	0.041	2.3	12	
03050454	Gorst Crk.	1/31/2003	9:50	48.4	7.1	0.077	3.7	12	
03050455	Anderson Crk.	1/31/2003	10:05	47.9	7.2	0.044	18.6	12	
03050456	Olney Crk.	1/31/2003	10:25	47.4	7.8	0.128	6.3	12	

Preservatives Used:
Relinquished By/Date:
Received By/Date:
Relinquished By/Date:
Received By/Date:
Relinquished By/Date:
Received By Lab/Date:

Method of Shipment:
Airbill No.:
Laboratory
Address:

Custody Seals Present? Yes No
Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Appendix F

Storm Summary Report #5

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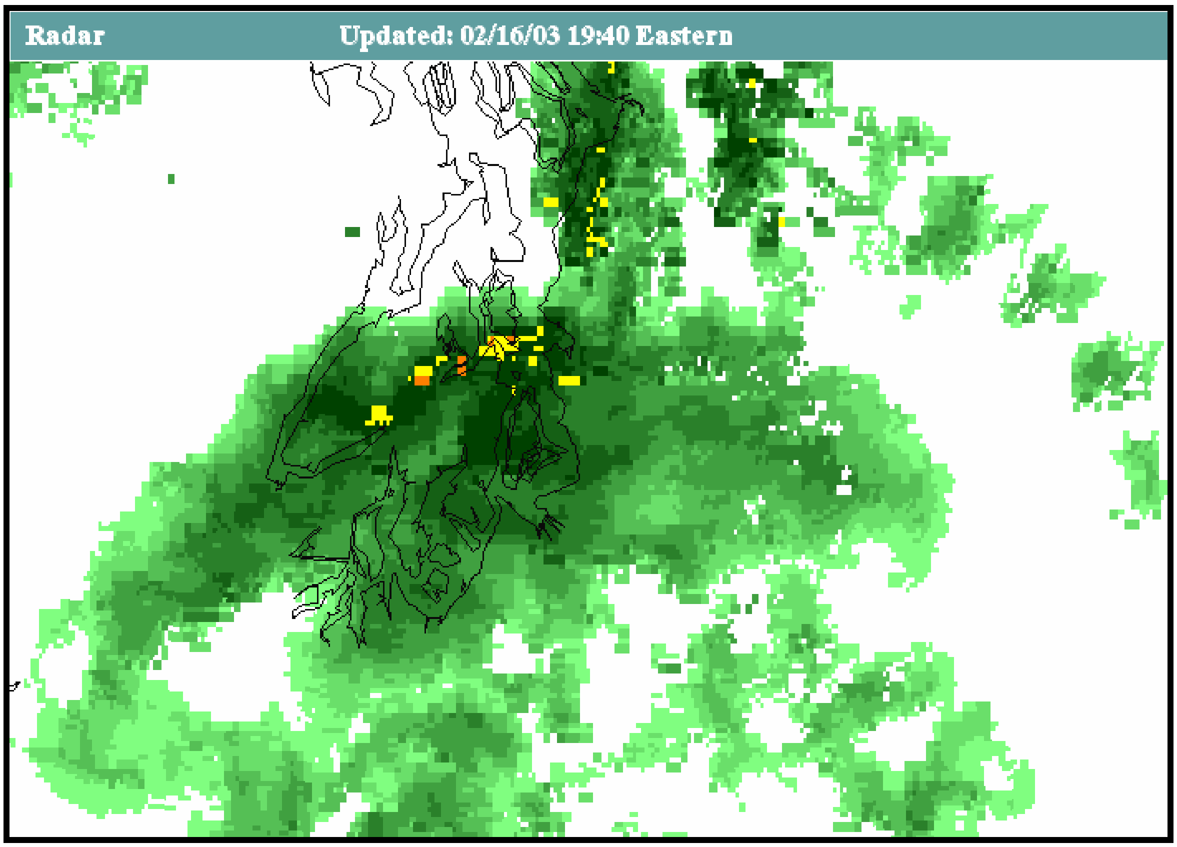
PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #5



(16 Feb 2003 1640 – Radar echoes from Storm 5b strongest over project area – we're sampling!)

15 - 17 February 2003
Southern Group Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

20 February 2003

PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #5
15-16 February 2003

Introduction

On 15-16 February 2003, The Environmental Company (TEC) conducted in-stream storm flow sampling of the 5 southern group creeks (plus Chico Main) within the Puget Sound Naval Shipyard (PSNS) Project Environmental Investment (ENVVEST) study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) action items. In addition, Appendix A presents satellite images and Appendix B contains physio-chemical and rainfall data.

1. TEC Staff Participating in Storm Sampling Event #5

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Dave Metallo	Field Team Leader
JD Estes	Field Team Member
Brian Rupert	Field Team Member

2. Storm Sampling Event #5

Storm Identification

Following the end of Storm Event #4 (see Field Sampling Report #4), the PSNS Project ENVVEST study area experienced 2 weeks of dry weather as a large, stationary dome of high pressure set up over the Pacific Northwest. This extended dry period during the typically wet month of February allowed the watersheds to 'load up' with pollutants and presented an appealing scenario for sampling the first rain event following this extended dry period. Weather forecasts by the NWS and other sources predicted that the strong ridge of high pressure would break down around 14 February, thereby allowing the region to be affected by storm systems that had been previously been shunted either north to Alaska, or south to California (both Alaska and California received near-record rainfall during the second week of February). Beginning on or about 14 February the weather pattern was forecast to change to a wet pattern, with storm systems of moderate strength to affect the region every few days. On Thursday, 13 February, per coordination with the Project Team, the decision was made to mobilize the southern sites in anticipation of sampling the "first flush" associated with the forecasted moderate storm event estimated to arrive on the morning of Saturday, 15 February. The cold front was forecast to sweep through the area on the morning of the 15th, followed by periods of sun breaks and heavy showers through the weekend as the low pressure center of the storm system tracked inland just north of the project area. Based on the forecast, this sample event was anticipated to be a 24-hour event.

Due to the President's Day Weekend (Monday, 17 February was a government holiday), per coordination with Manchester Environmental Laboratory (MEL) and PSNS, it was decided that no fecal coliform samples (which have a 24-hour holding time) would be collected over the weekend as no MEL staff would be available to process the samples until Tuesday 18 February. However, Pacific Northwest National Laboratory (PNNL) would be able to receive composite samples throughout the holiday weekend as necessary.

Preparation

For the 3rd sampling event in a row, the 5 southern creeks (Chico Tributary at Taylor Road [CT], Gorst Creek [GC], Anderson Creek [AC], Blackjack Creek [BL], Olney Creek [OC]) and Chico Main (CM) would be sampled. By 1600 hours on the 14th, all 6 sites were mobilized. A very light rain/mist in advance of Saturday's system fell at times during the day of the 14th but was not of sufficient intensity to mobilize pollutants (the nearby Silverdale rain gauge recorded only a trace of rain on the 14th). A rain gauge was installed at each site and the samplers were programmed to begin sampling immediately once > 0.05" of rain fell within a 1-hour period. TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data at sites where a connection between the Isco's and YSI was obtained.

In-Stream Storm Flow Sampling

Note: Together, Storm #5a and Storm #5b constitute "Sampling Event 5," a 24-hour sampling event.

Storm #5a (Saturday 15 February)

During the afternoon hours of the 14th, PSNS and TEC continued to coordinate and discuss the forecast for the anticipated storm. Throughout the day the forecast continued to evolve – at one point very light rain was predicted from Saturday's storm, however, at the end of the day on the 14th, the general consensus was that the project area would experience moderate rain on the morning of the 15th.

Rainfall associated with the cold front began in the project area at approximately 0700 on Saturday, 15 February. Shortly thereafter, the samplers were activated, generally from north to south. By approximately noon the heaviest rain had fallen throughout the project area as the front had passed through. A check of nearby gauges revealed that approximately 0.20" of rain had fallen throughout the project area over the morning hours with rainfall intensities below 0.10"/hr. Following the frontal passage, skies began to clear in the project area. Shortly thereafter, in response to clearing skies and a forecast for "partly cloudy skies with occasional showers," TEC and PSNS coordinated to discuss the updated forecast. As approximately 0.20" of rain had fallen within a relatively short period and the forecast called for light and scattered precipitation for the next 18-24 hours, TEC and PSNS decided to halt sampling at the 6-hour mark (Bottle #1) as subsequent sampling would in theory be representative of base flow and not storm flow. Given that the mornings' rain was the first significant rain in over 2 weeks, it was decided that the first 6-hours of sampling would have captured the "first flush" and therefore would be analyzed. Per this direction, TEC shut down the sampling effort at approximately 1330 hours and collected and iced down the first bottle (#1) from each of the 6 sites. While several showers did fall throughout the late evening and early morning hours, no significant precipitation fell in the project area.

Table 1-1 presents the times at which the samplers were activated, when the samplers were turned off, and when samples were delivered to PNNL. Throughout the storm sampling event, TEC staff routinely checked on the stations, monitored weather conditions, and coordinated with PSNS and PNNL. Per PSNS direction, no fecal coliform samples were collected during Storm #5a due to the President's Day Holiday weekend.

Table 1-1. SE #5: In-Stream Storm Flow Sampling Landmarks – Storm #5a

Sampling Station	Sampling Begins	Sampling Ends	Composites Delivered to PNNL
	15 Feb	*15 Feb*	*16 Feb*
CT	0808	1353	1100
CH	0810	1355	1100
AC	0815	1400	1100
BL	0825	1410	1100
OC	0830	1415	1100
GC	1051[a]	1636	1100

Note: [a] GC was not activated via the rain gauge due to a communication error; sampler was manually started by TEC staff.

Table 1-2 presents rainfall totals for Storm #5a. While less than 0.25" of rain fell within the approximately 6-hour sampling period, based on data from other rain gauges in the area, it is highly likely that if sampling continued for 24-hours, rainfall totals would have exceeded 0.25"/24-hours (see rainfall totals from "Other Rain Gauges" in Table 1-2.

Table 1-2. SE #5: Precipitation within the Project Area

Sampling Station	Storm #5a[1]	Storm #5b[2]	Total[3]
PSNS Project ENVVEST Sampling Stations			
Anderson Creek (AC)	0.22"	0.71"	**0.93"**
Gorst Creek (GC)	0.20"[4]	0.69"	**0.89"**
Chico Tributary at Taylor Road (CT)	0.24"	0.64"	**0.88"**
Chico Main (CH)	0.25"	0.58"	**0.83"**
Blackjack Creek (BL)	0.17"	0.56"	**0.73"**
Olney Creek (OC)	0.18"	0.40"	**0.58"**
Other Rain Gauges in Vicinity			
Bremerton (Airport)	0.51"	0.83"	**1.34"**
Silverdale	0.41"	0.56"	**0.97"**
Gig Harbor	0.08"	0.88"	**0.96"**
Poulsbo	0.32"	0.28"	**0.60"**

Notes: [1] Rainfall totals for ENVVEST sites are from ~0730 to 1400 hours; other totals are for 24-hrs ending 0000 16 Feb.
[2] Rainfall totals for ENVVEST sites are from ~1200 to 2359 hours; other totals are for 24-hrs ending 0000 17 Feb.
[3] Storm event totals.
[4] Estimated from AC.

Sources: Weather Underground, NOAA.
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&day=15&year=2003&month=2
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&day=16&year=2003&month=2
Bremerton:
http://www.wrh.noaa.gov/cgi-bin/Seattle/seaobs?site=KPWT&type=1&fmt=DEC&src=lcl&hh=168&gh=96&gy=1
Gig Harbor :
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAGIGHA2&day=16&year=2003&month=2

Storm #5b (Sunday 16 February)

Sunday morning presented with mostly sunny skies. However, the forecast for latter that day called for mostly cloudy skies with scattered heavy showers and potential thunderstorms in the project area associated with the low-pressure system crossing inland through northern Washington later that afternoon. TEC staff met at the Field Office and organized the delivery of samples from Storm #5a to PNNL for later that morning. About this time, acting on the forecast and an educated hunch, TEC staff suggested to PSNS that the sample sites be activated to sample if >0.20" of rain fell within 1 hour – instead of the normal >0.05"/hr. The theory behind this recommendation was that as the forecast called for scattered heavy showers/thunderstorms, if a heavy shower set up over the project area, the resulting influx in storm water associated with high rainfall intensities would present a good sampling scenario. By setting a high 'trigger point' to begin sampling, this ensured that only a significant rainfall/runoff event would be sampled. Per conversation with PSNS it was decided to re-program the samplers accordingly should this scenario play out. By approximately 1200 on the 16th, all 6 sites were re-programmed to sample only if > 0.20" of rain fell within 1 hour.

As predicted, heavy showers with a few imbedded thunderstorms began to form south of the project area and rotate slowly northeast towards Seattle in the early afternoon. By 1400 hours, radar and satellite data indicated moderate to heavy rain falling throughout the Puget Sound region from south to north. Over the next few hours, several organized bands of heavy showers passed through the project area. The heaviest of these showers affected the project area from approximately 1400 to 1530 hours, whereupon 4 of the 6 sites were activated (see cover image). Heavy rain (>0.25"/hr at some sites) associated with these showers continued until approximately 1800 hours, at which time the rain intensity dropped dramatically and eventually ended. By the early morning hours of the 17th, skies in the project area were clear.

The heavy shower activity associated with the low-pressure system tracking across northern Washington was sufficient to trigger sampling at 4 sites – CH, CT, GC, and AC. However, due to the spatial distribution of the rainfall and the orographically unfavorable orientation of BL and OC, rainfall intensity was not sufficient to activate these 2 sites.

Table 1-2 presents rainfall totals for Storm #5a and #5b, as well as the total for both systems. Rainfall was greatest at the northern sites. When compared to the rainfall totals and timing from other non-ENVVEST gauges, it can be safely assumed that the sampling associated with Storm #5a and #5b captured the bulk of the rainfall within the project area during this period of time (15-16 February).

On the morning of the 17th, TEC staff collected samples from those stations that had been activated and iced down the samples for subsequent delivery to PNNL later that afternoon. Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco's to a laptop for analysis/viewing with Flowlink (see Appendix B).

Table 1-3 presents the times at which the samplers were activated, when the samplers were turned off, and when samples were delivered to PNNL. Throughout the sampling event, TEC staff routinely checked on the stations, monitored weather conditions, and coordinated with PSNS and PNNL. Per PSNS direction, no fecal coliform samples were collected during Storm #5b due to the President's Day Holiday weekend.

Table 1-3. SE #5: In-Stream Storm Flow Sampling Landmarks – Storm #5b

Sampling Station[1]	Sampling Begins	Sampling Ends	Composites Delivered to PNNL
	16 Feb	*17 Feb*	*17 Feb*
AC	1429	0224	1300
CT	1447	0232	1300
CH	1452	0237	1300
GC	1504	0849	1300
Note: [1] BL and OC did not sample as sufficient rainfall for activation did not occur.			

Storm #5 Discussion

Storm Sampling Event #5 provided a unique opportunity to sample 2 different hydrologic conditions within a short period of time. Sampling during Storm #5a provided samples that represented a "first flush" of pollutants that had been building up over the 14-day dry period – an appealing condition for storm water sampling. Similarly, the high rainfall intensities associated with Storm #5b (greater than 0.20"/hr) resulted in a quick, high energy mobilization of pollutants, providing the opportunity to sample such a high intensity/short duration event. As shown in Appendix B – turbidity levels jumped significantly during Storm #5b as compared to Storm #5a, as might be expected given the high rainfall intensity. All in all, the approach to sampling Storm #5 during 2 different rainfall patterns and watershed conditions should provide interesting data for the sampled watersheds.

3. Storm Sample Event #5 Results

At all stations the sampling equipment performed for the most part as expected for both storms. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at several sites; therefore, physio-chemical data was not recorded electronically at these sites (BL and OC).

Variations to the Sampling and Analysis Plan (SAP)

Only 2 variations to the SAP occurred during Sampling Event #5. These minor variations are discussed below.

Gorst Creek Rain Gauge Malfunction

During Storm #5a, the Isco unit at Gorst Creek did not achieve communication with the rain gauge or the YSI even though when the site was set up successful communication was established. This lack of communication was discovered at approximately 1030 on Saturday when TEC staff observed that the sampler had not kicked off when obviously more than 0.05" of rain had fallen in the area (CT had been sampling for over an hour at this point). So, TEC staff manually activated the sampler at 1051, approximately 3 hours after rainfall had started in the area. A review of the sampling report indicates the Isco lost communication with the YSI/rain gauge approximately 3 hours after site mobilization.

Prior to Storm #5b, communication at GC had been established between the Isco and the rain gauge and sampling of Storm #5b started as programmed when greater than 0.20" of rain fell within an hour. While the reasons for this miscommunication are not fully known, when the "Y cable" was replaced with another and the Isco memory was cleared, all components worked properly for the duration of Storm #5b. Rainfall at GC for Storm Event #5a was estimated using rainfall totals from AC from Storms 4a and 4b.

YSI 6820 Sondes

Before this storm sampling event, TEC was able to achieve successful communication between all YSI sondes and the Isco's when tested at the field office. However, when placed in the field, 2 of the 6 Isco's (BL and OC) were not able to communicate with the YSI. While 4 sties provided all physio-chemical data during Storm #5 (2 more than previous events), TEC will investigate the problem further and work to a solution for the other 2 sites.

<u>Action Items</u>

Storm Sampling Readiness

Per coordination from PSNS, the next (and final [48-hr]) storm sampling event will occur at the 5 northern group sites (BA, CW, CE, CC, ST) and BL and OC. Since there are 7 complete Isco/YSI/Rain Gauge sets, sampling at all 7 sites is possible. While the final storm sampling event will be larger in scope than previous events, by sampling all 7 at once, all sites will have been sampled on a minimum of 3 occasions over 6 storms. TEC is ready to sample the next qualifying storm at the northern sites and will continue to monitor weather forecast for a storm that is forecast to meet the provisions of the SAP; however, per Project Team direction a "wet and long-duration" storm will be the preferred storm to sample (although sampling should occur before vegetation "leafs out," which could change runoff characteristics).

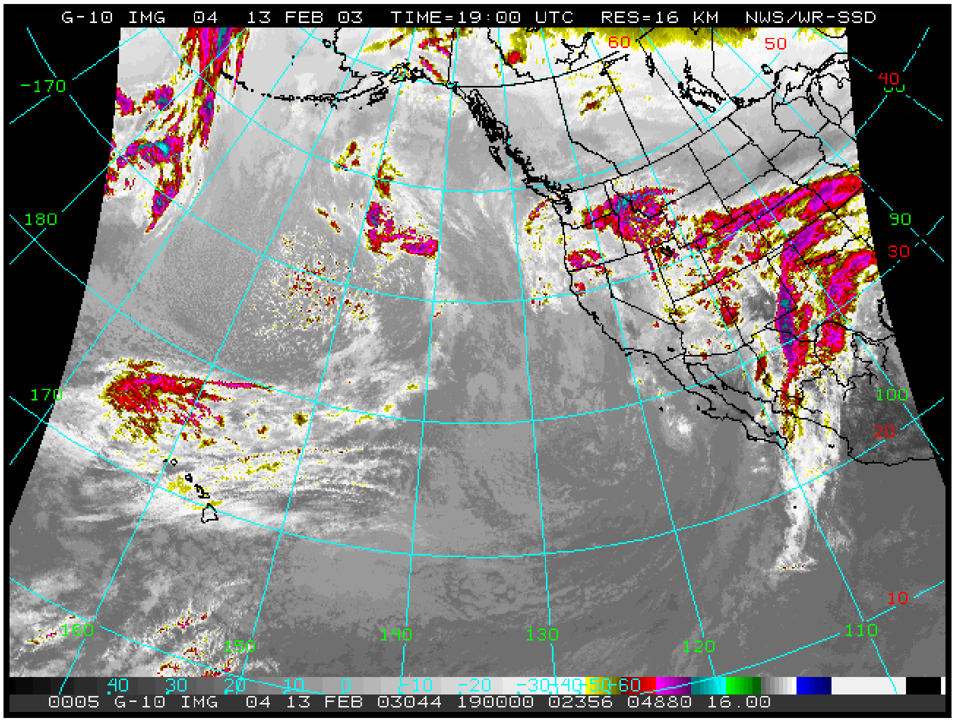
YSI Sonde/Isco Communication

As described above, TEC will investigate as to why some of the YSI sondes are unable to communicate with some of the Isco samplers in the field, while other seemingly identical sondes/Iscos are able to communicate properly.

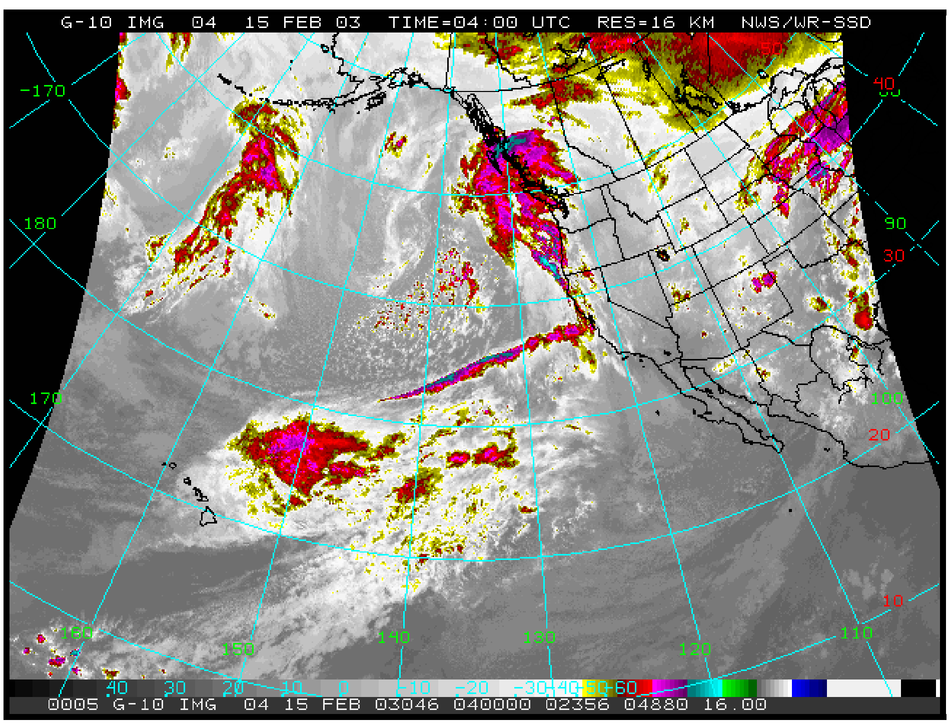
Strawberry Creek Re-Plumb

As described in Field Sampling Report #3, SC needs to be re-plumbed per the KPUD's request. However, per communication with KPUD (see email of 18 Feb with a cc to J. Sherrell), KPUD has agreed with waiting until storm sampling is complete at the northern sites. At that time TEC will remove all plumbing at SC.

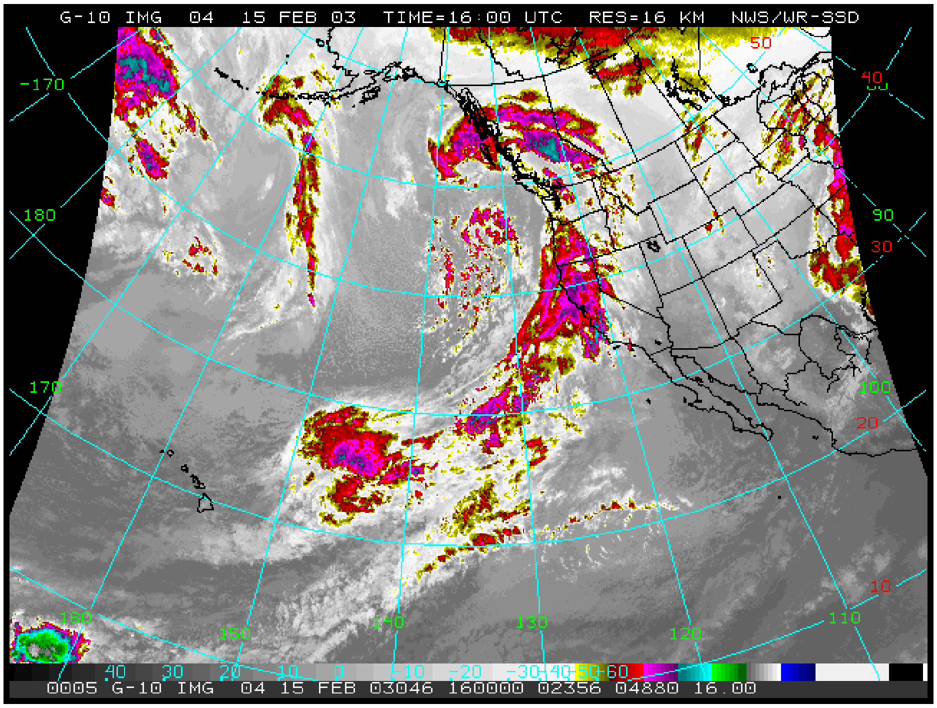
Appendix A
Satellite and Radar Data of Storm Event #5a and #5b
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



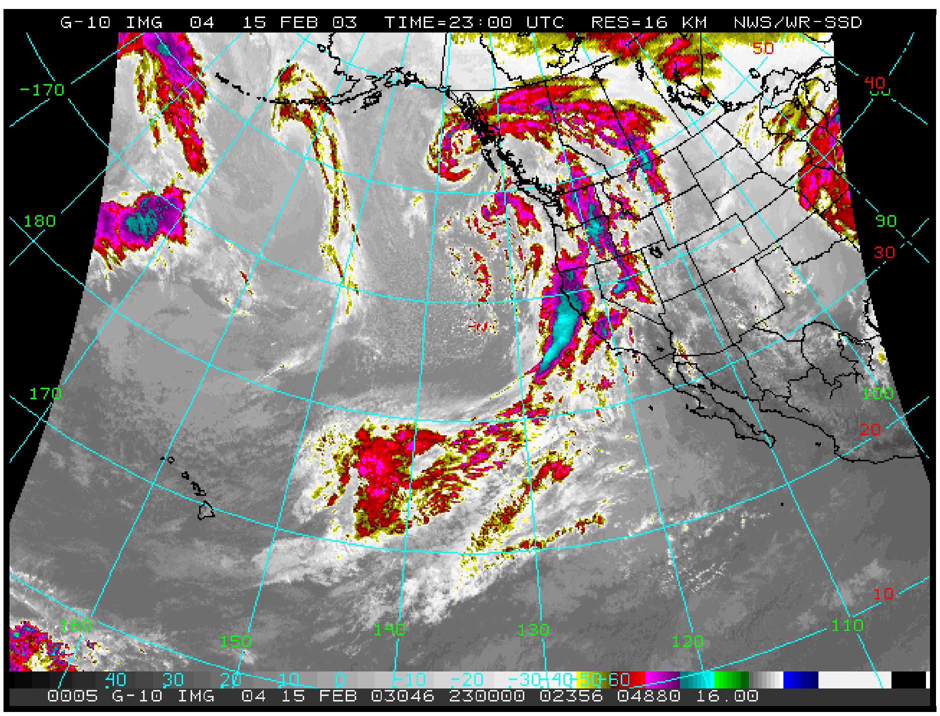
13 January 2003 1100 (local time) - Storm 5 develops at ~ 150W/40N.



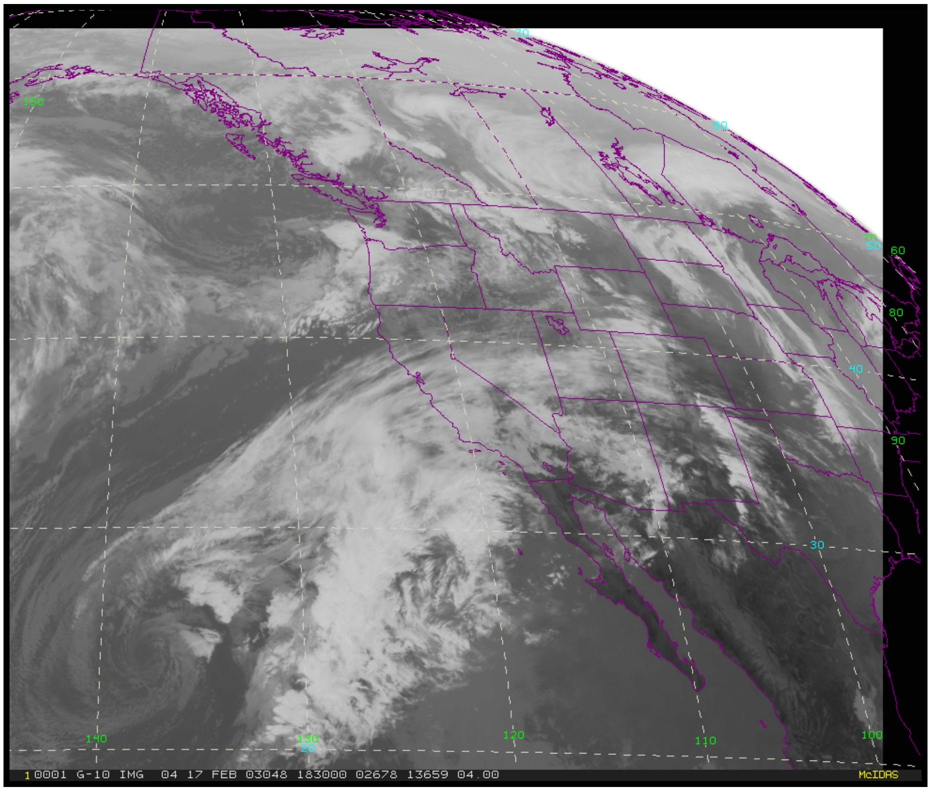
14 February 2003 2000 (local time) – Storm 5a (cold front) approaches coast. Note pool of cold, unstable air associated with low pressure center at ~140N/40N – this will become Storm 5b.



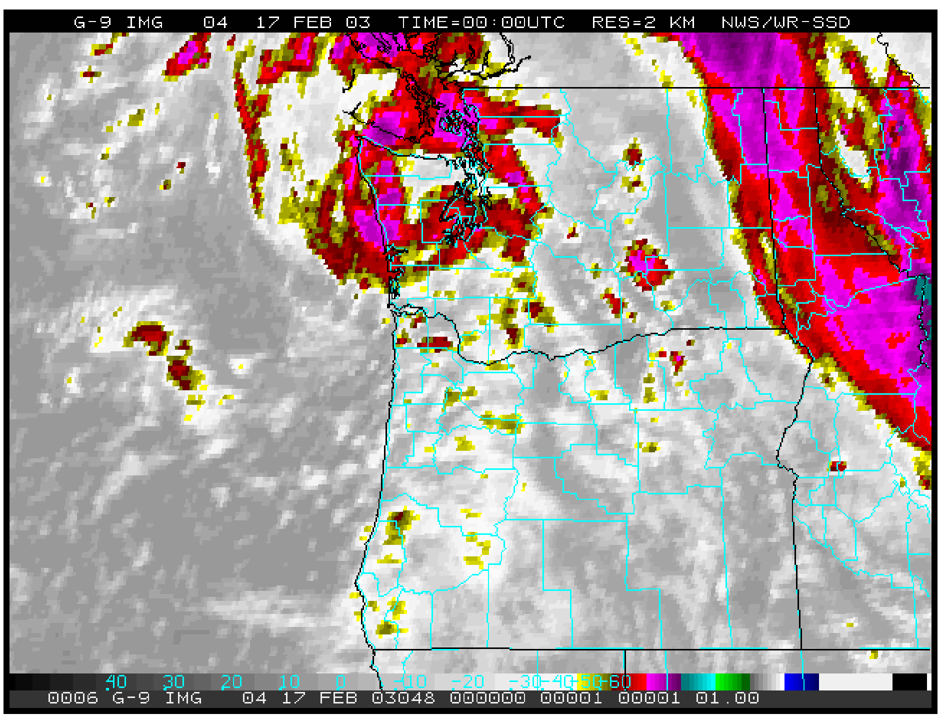
15 February 2003 0800 (local time) – Rain begins - Storm 5a. Storm 5b takes shape offshore.



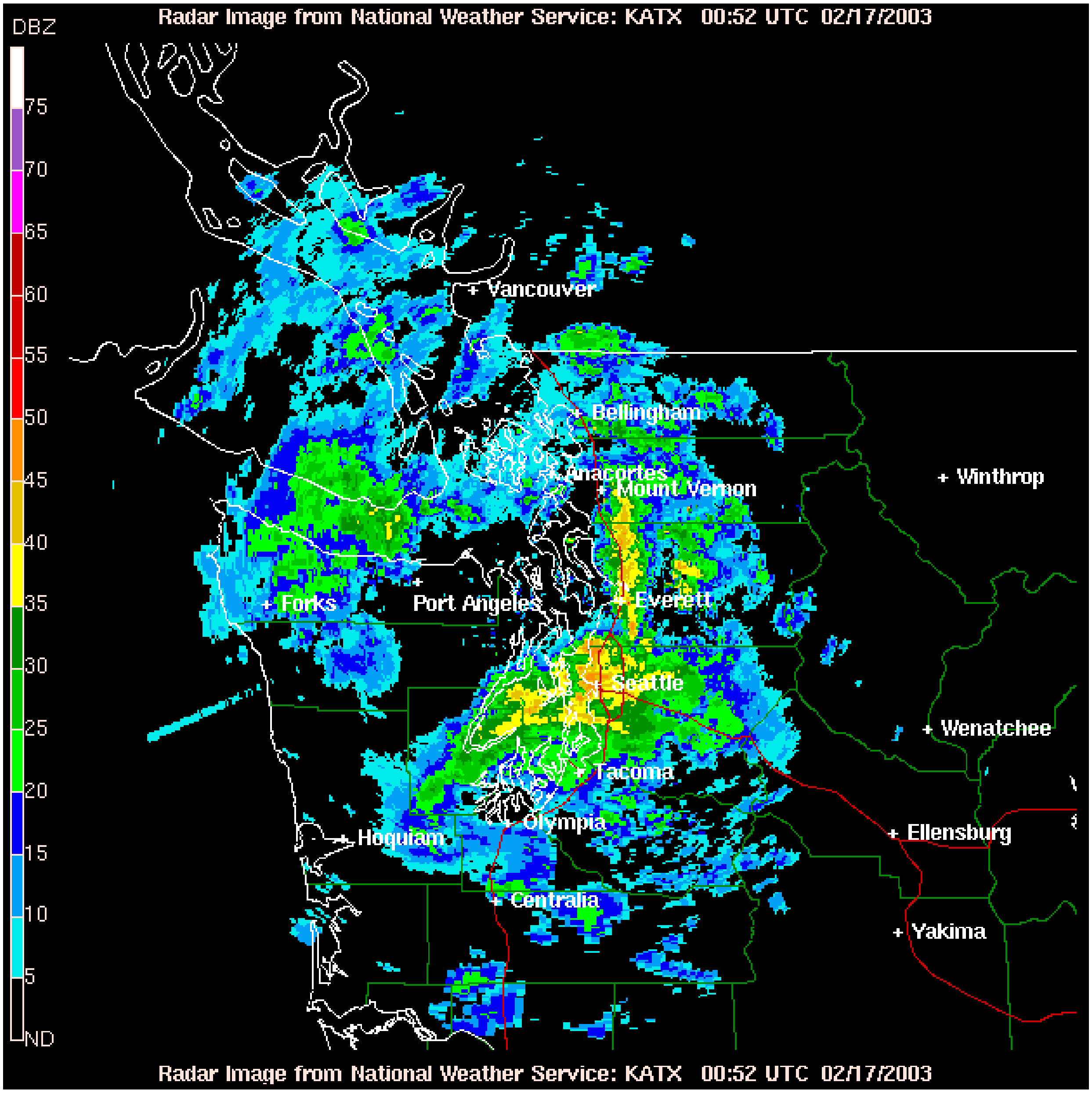
15 February 2003 1500 (local time) – Storm 4a front passes through project area and skies clear.



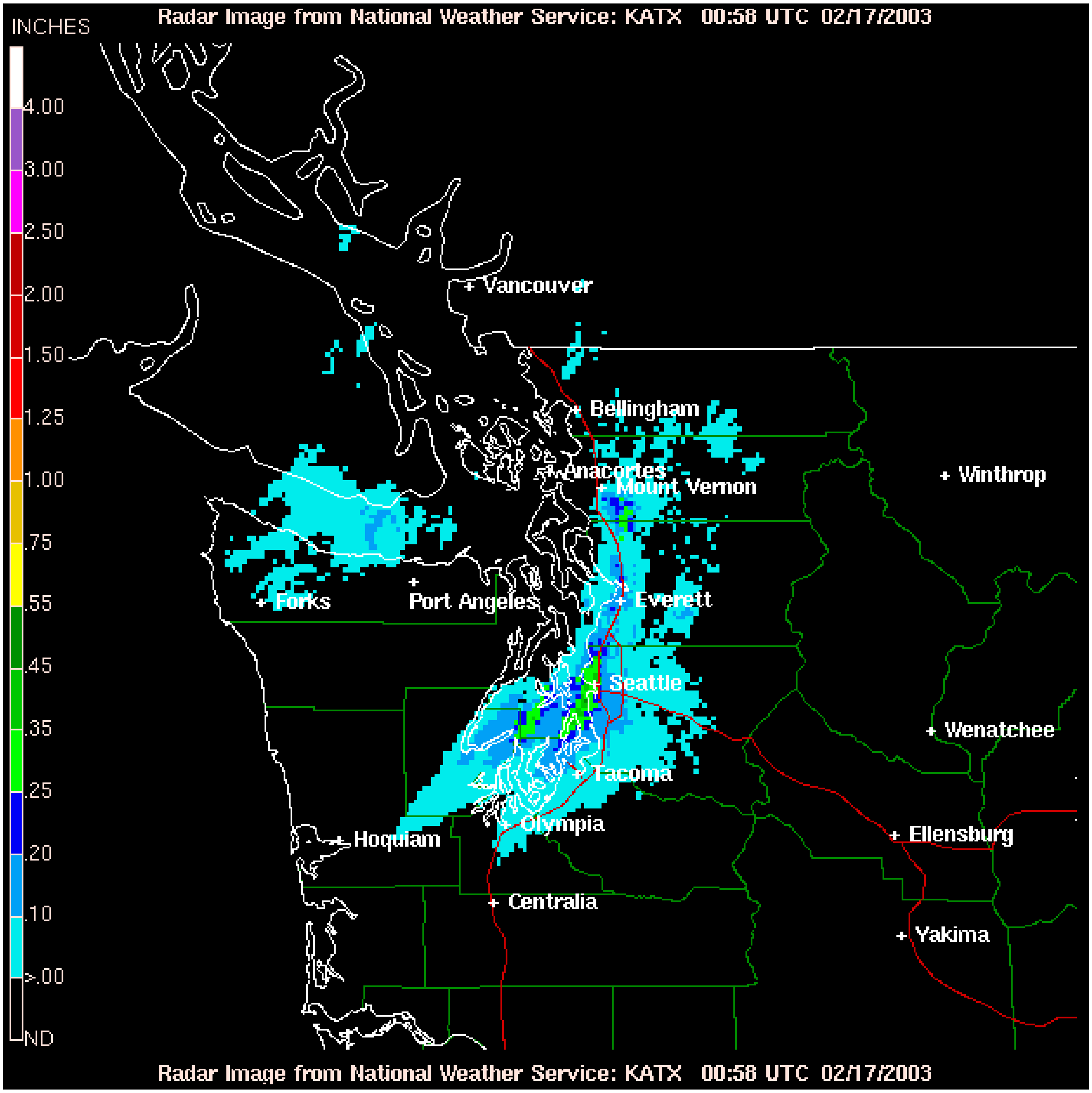
16 February 2003 0830 (local time) – Skies clear in project area but low-pressure center (Storm 5b) approaches NW WA – Storm 5b.



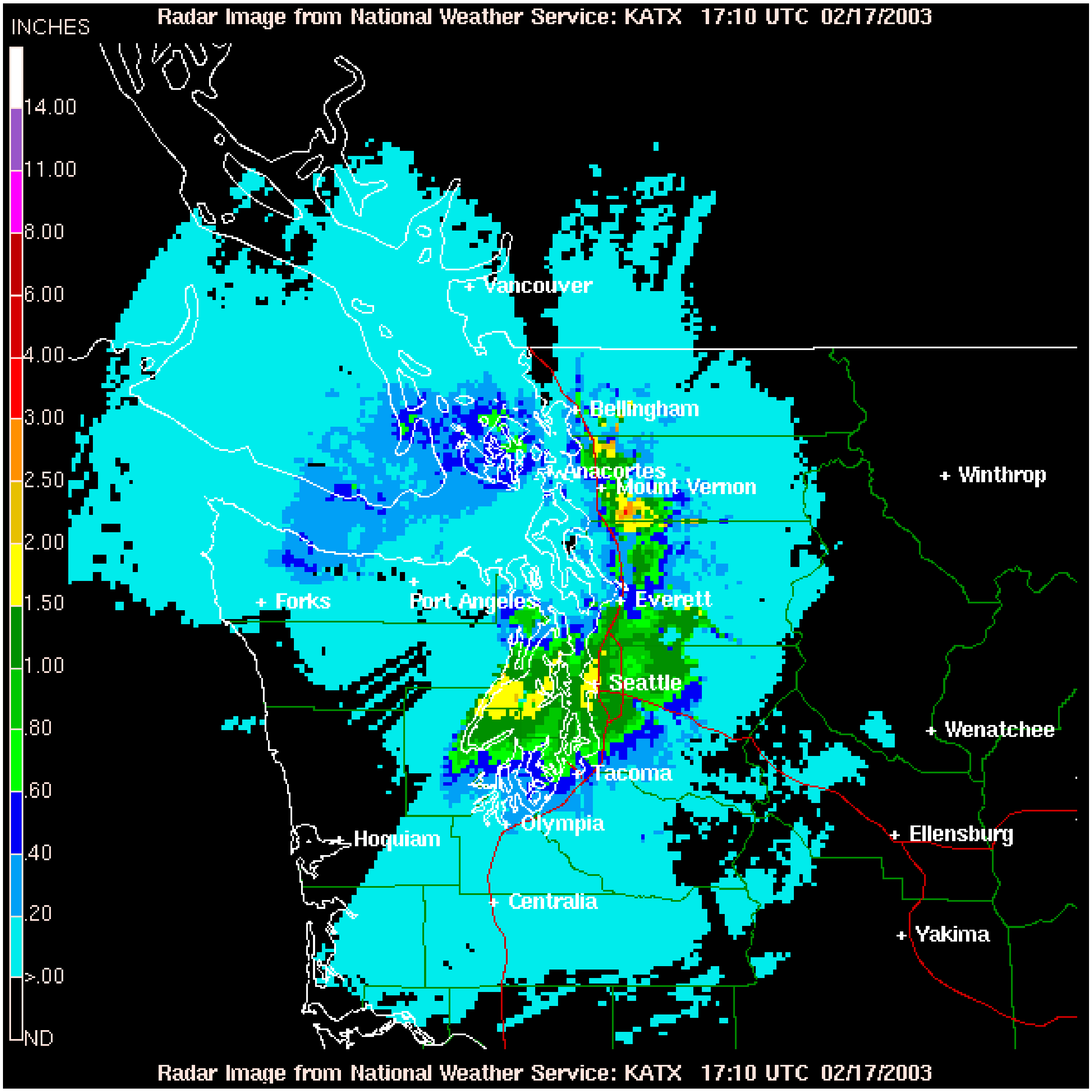
16 February 2003 1600 (local time) – Low-pressure center crosses through NW WA – Storm 5b. Note "bright" clouds in Puget Sound region – it's raining heavily at this point.



16 February 2003 1652 (local time) – Radar associated with Storm 5b. Note bright radar echoes/returns (which represent into heavier rainfall) over Kitsap County/Puget Sound region.



16 February 2003 1658 (local time) – 1-hour radar-generated rainfall totals (Storm 5b). Note 0.20" – 0.25" totals for project area (dark blue and green).



24-hour rainfall totals (radar-generated) ending 17 February 2003 0910 (local time) associated with Storm 5b. Note 1.00" – 1.50" totals for project area (greens and yellows).

Appendix B
Flowlink Rainfall and Physio-Chemical Data

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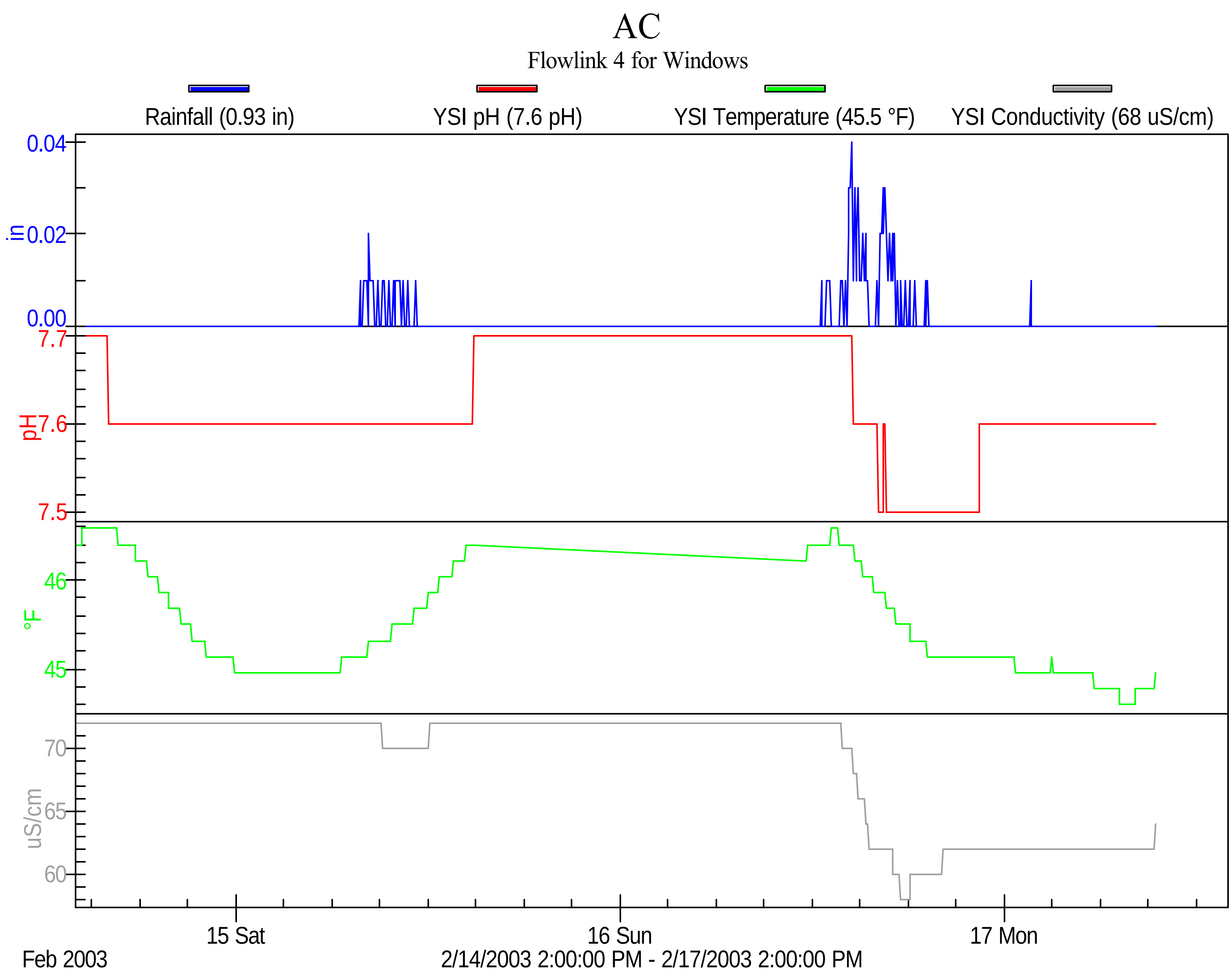
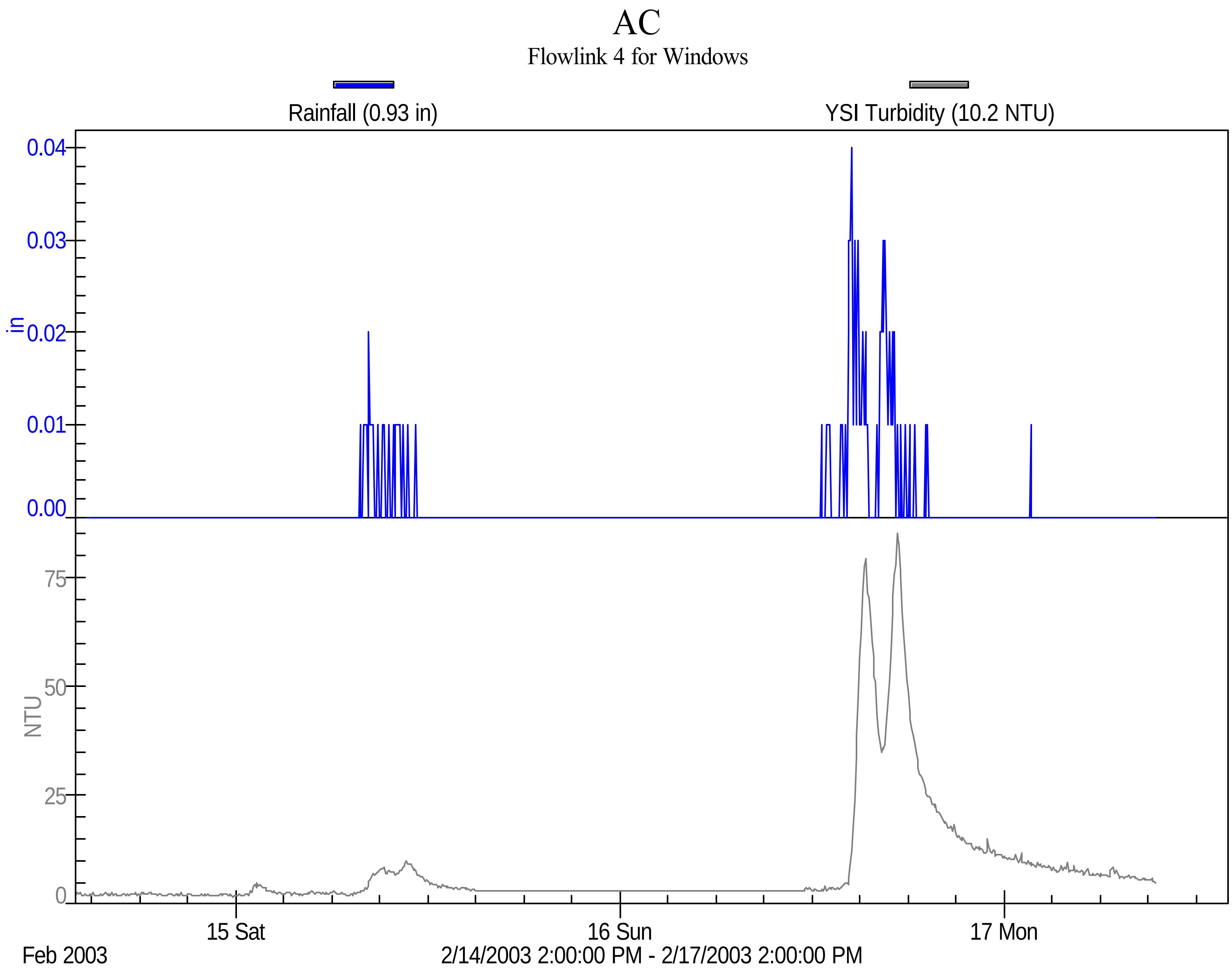
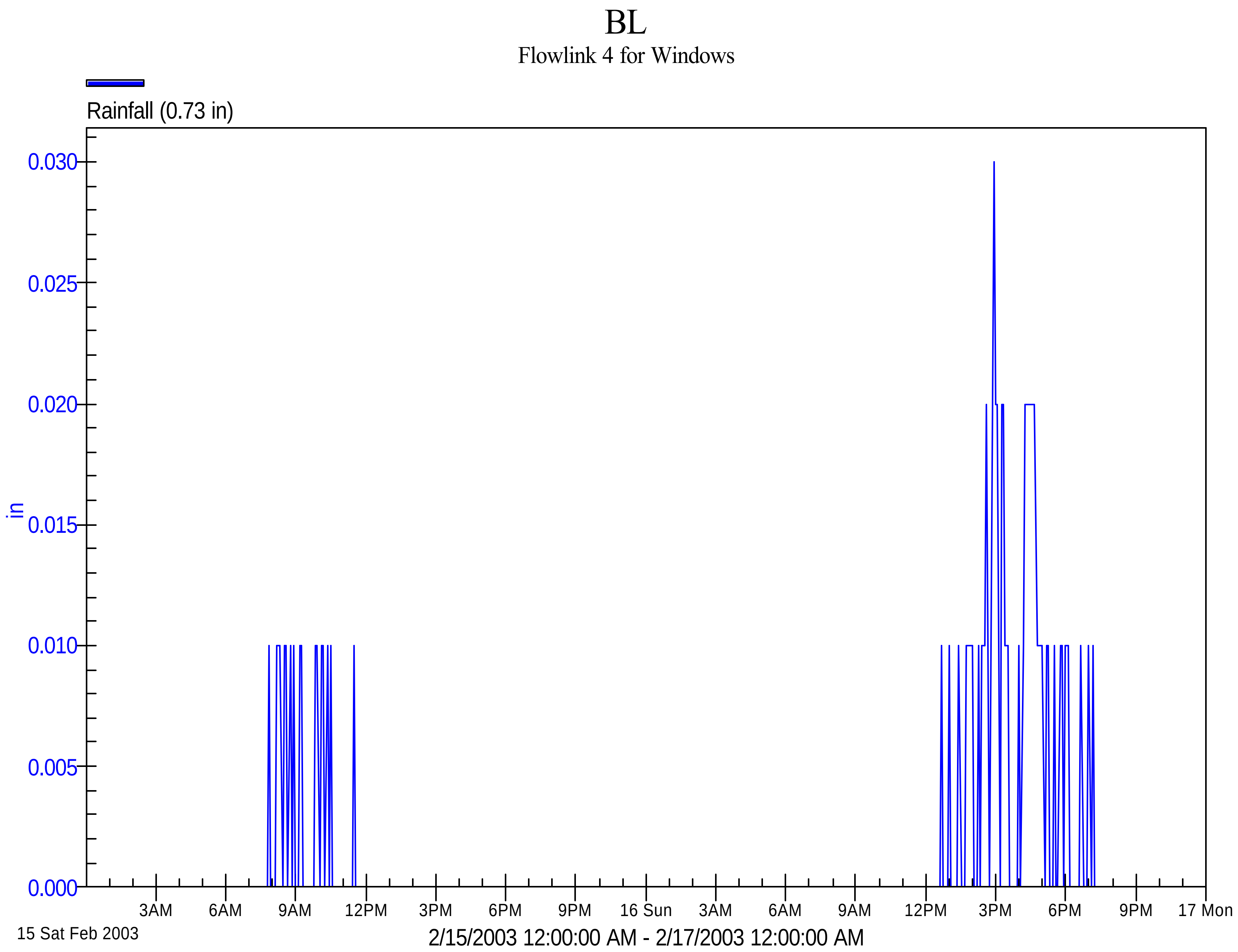

AC
Flowlink 4 for Windows
Rainfall (0.93 in)
YSI pH (7.6 pH)
YSI Temperature (45.5 °F)
YSI Conductivity (68 uS/cm)
0.04
0.02
0.00
in
7.7
7.6
7.5
pH
46
45
°F
70
65
60
uS/cm
15 Sat
16 Sun
17 Mon
Feb 2003
2/14/2003 2:00:00 PM - 2/17/2003 2:00:00 PM



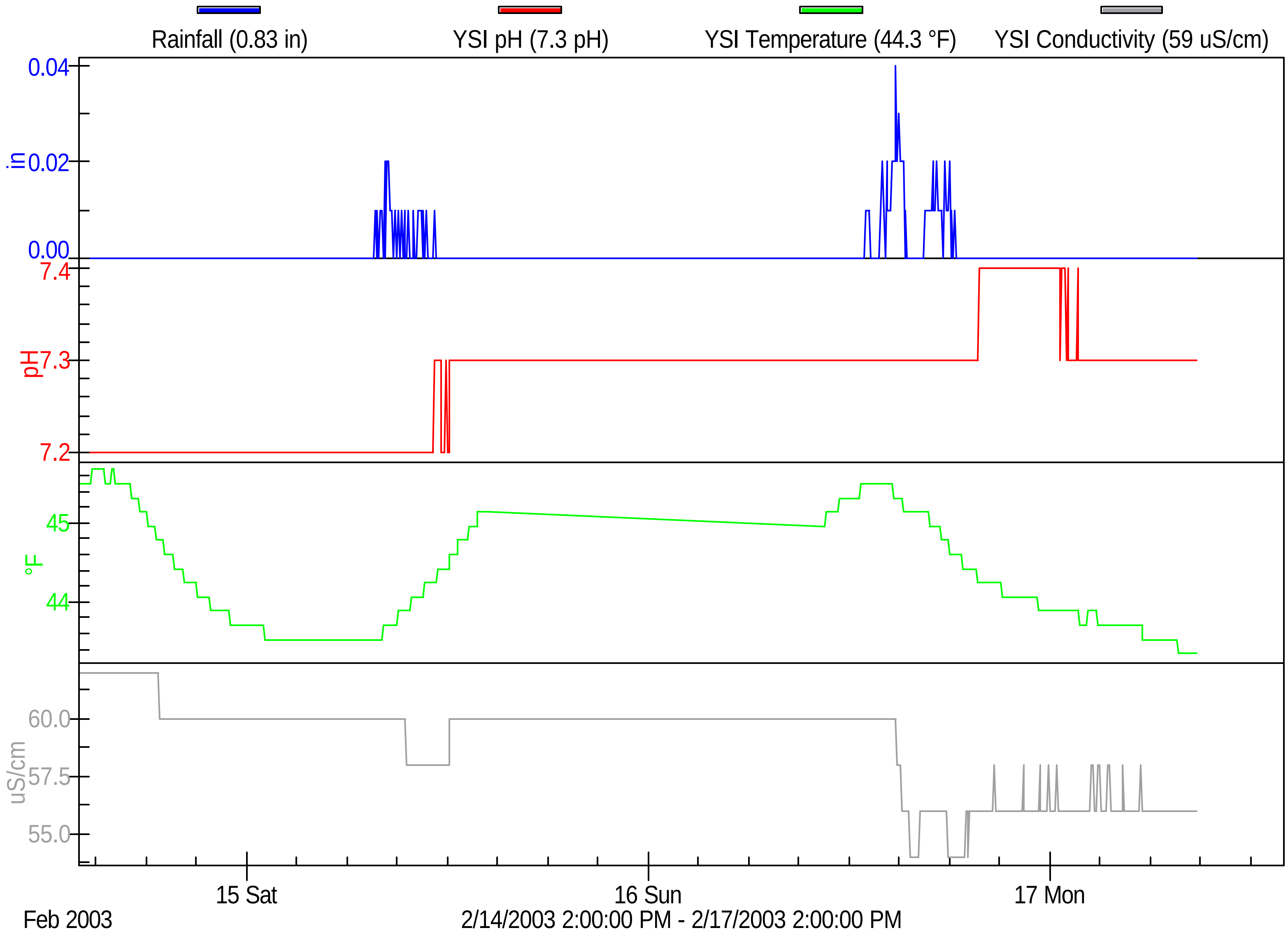
AC
Flowlink 4 for Windows
Rainfall (0.93 in)
YSI Turbidity (10.2 NTU)
in
0.04
0.03
0.02
0.01
0.00
NTU
75
50
25
0
15 Sat
16 Sun
17 Mon
Feb 2003
2/14/2003 2:00:00 PM - 2/17/2003 2:00:00 PM



BL
Flowlink 4 for Windows
Rainfall (0.73 in)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
3AM
6AM
9AM
12PM
3PM
6PM
9PM
16 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
17 Mon
15 Sat Feb 2003
2/15/2003 12:00:00 AM - 2/17/2003 12:00:00 AM

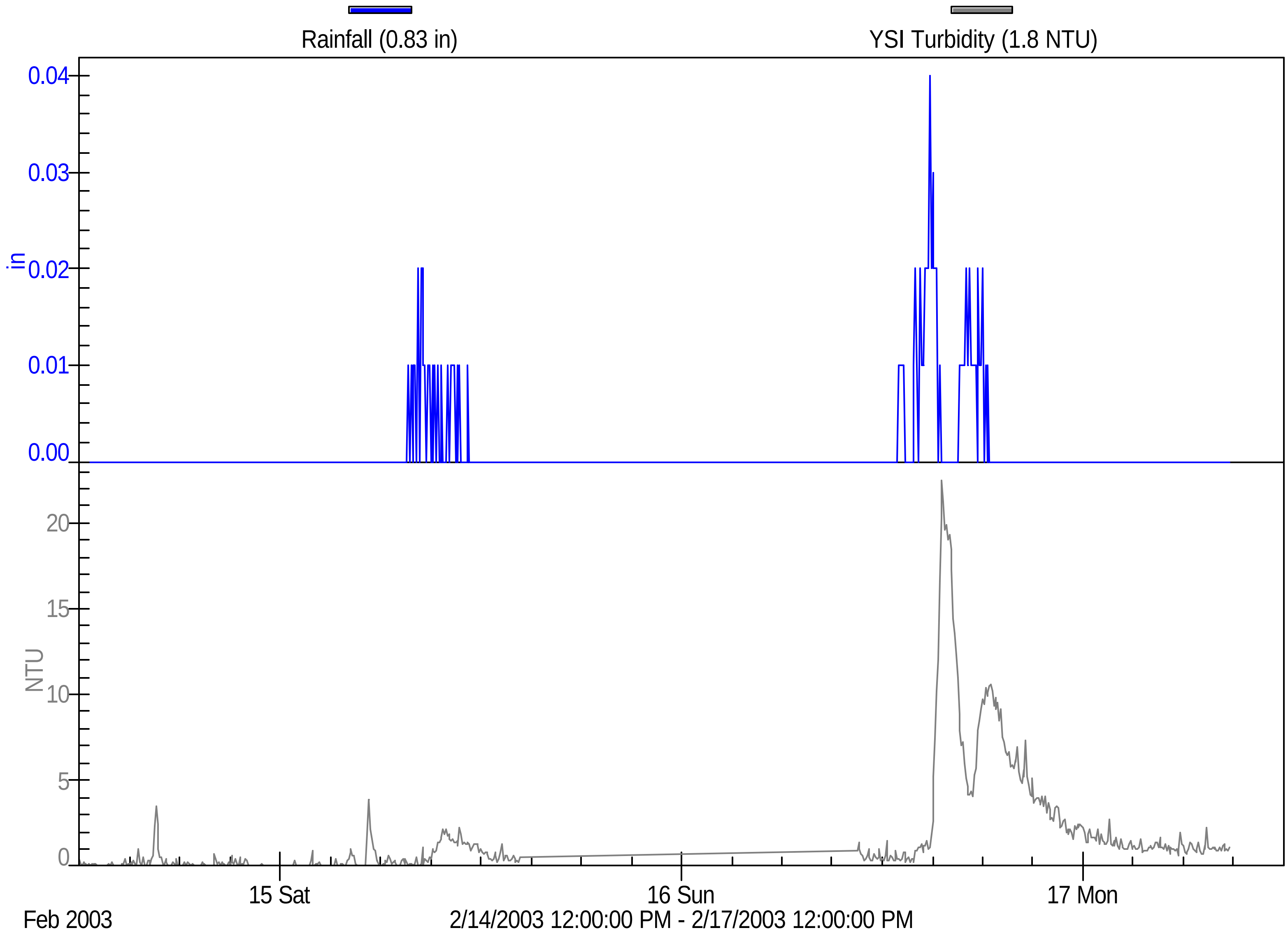
CH

Flowlink 4 for Windows



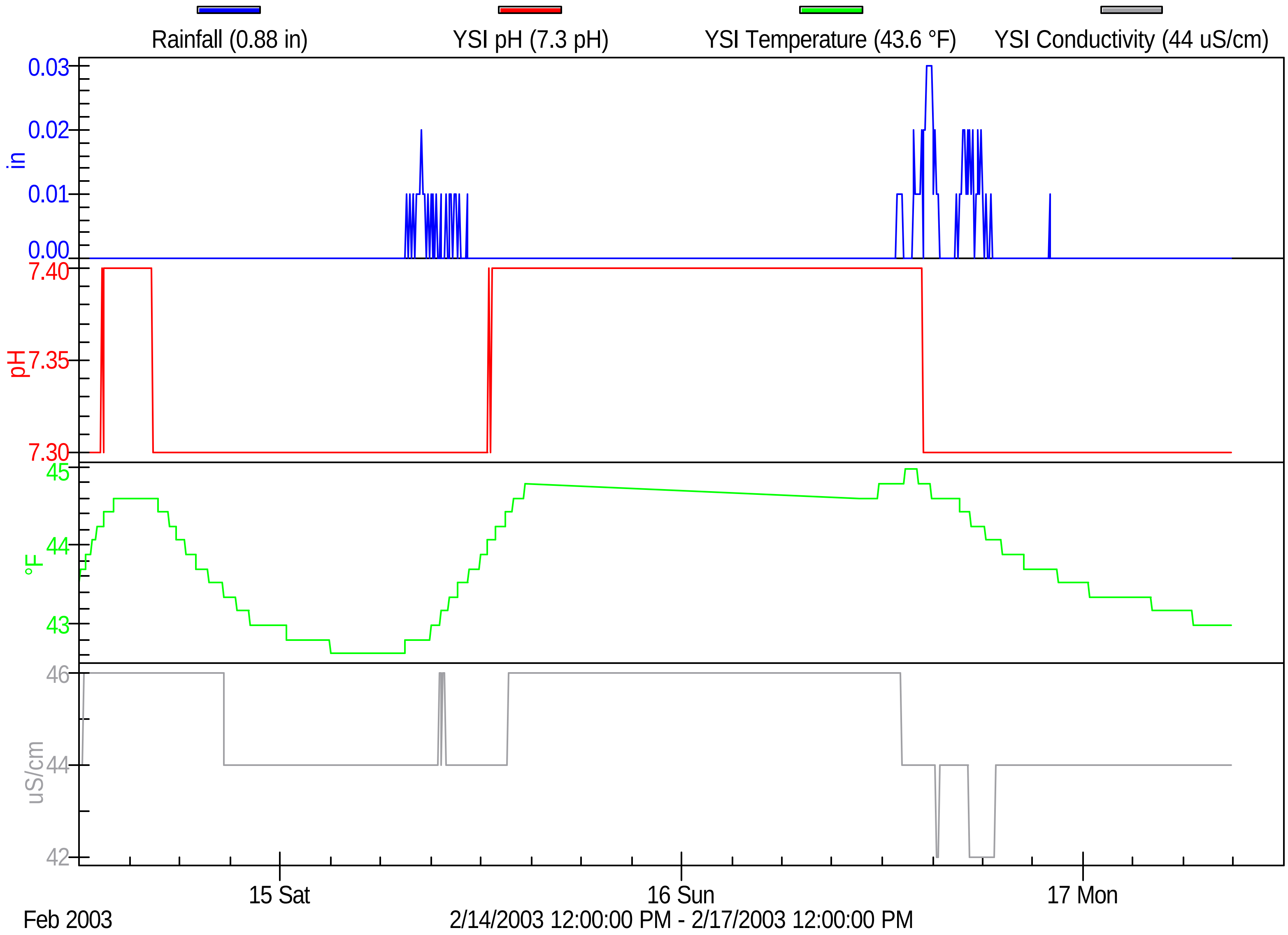
CH

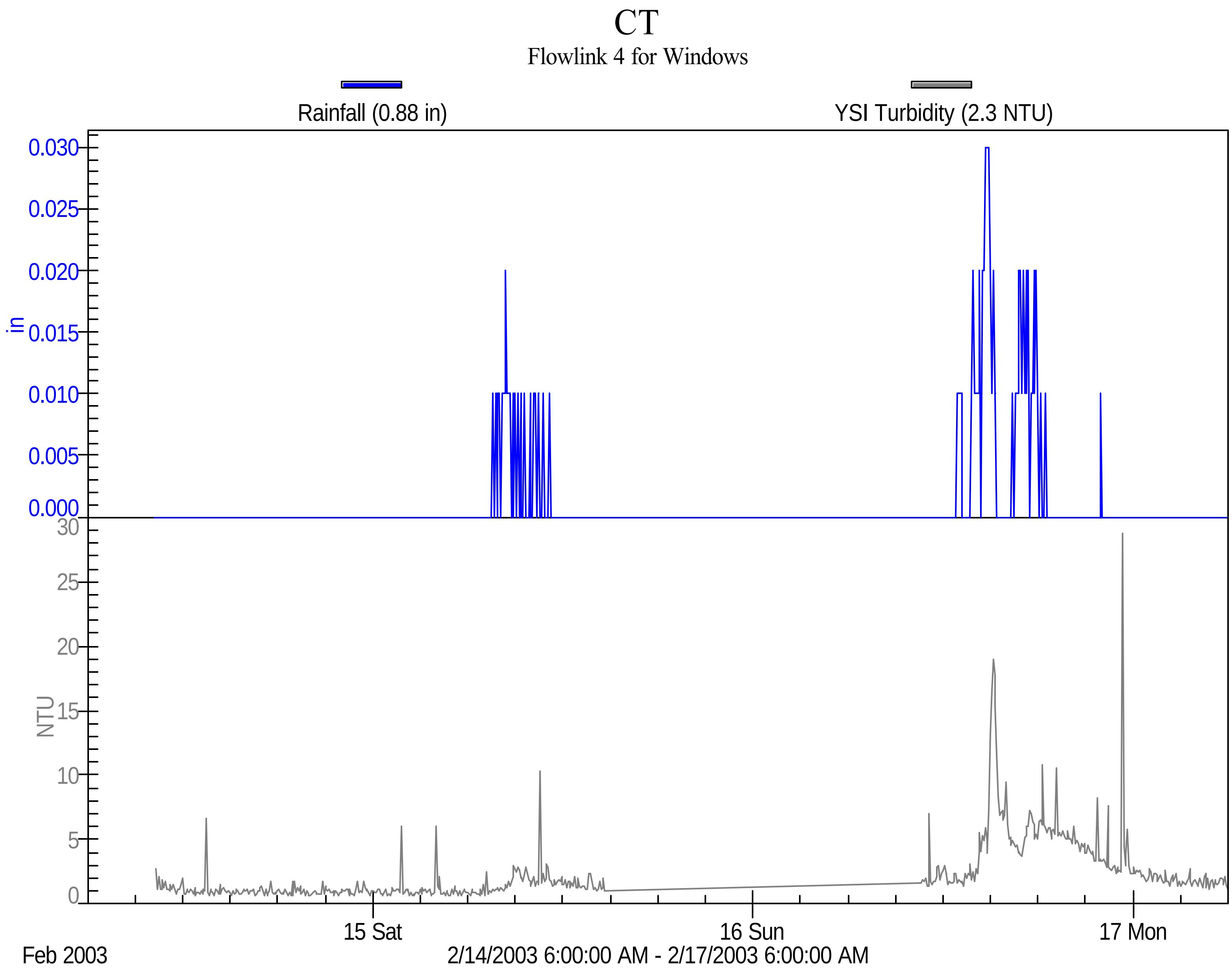
Flowlink 4 for Windows



CT

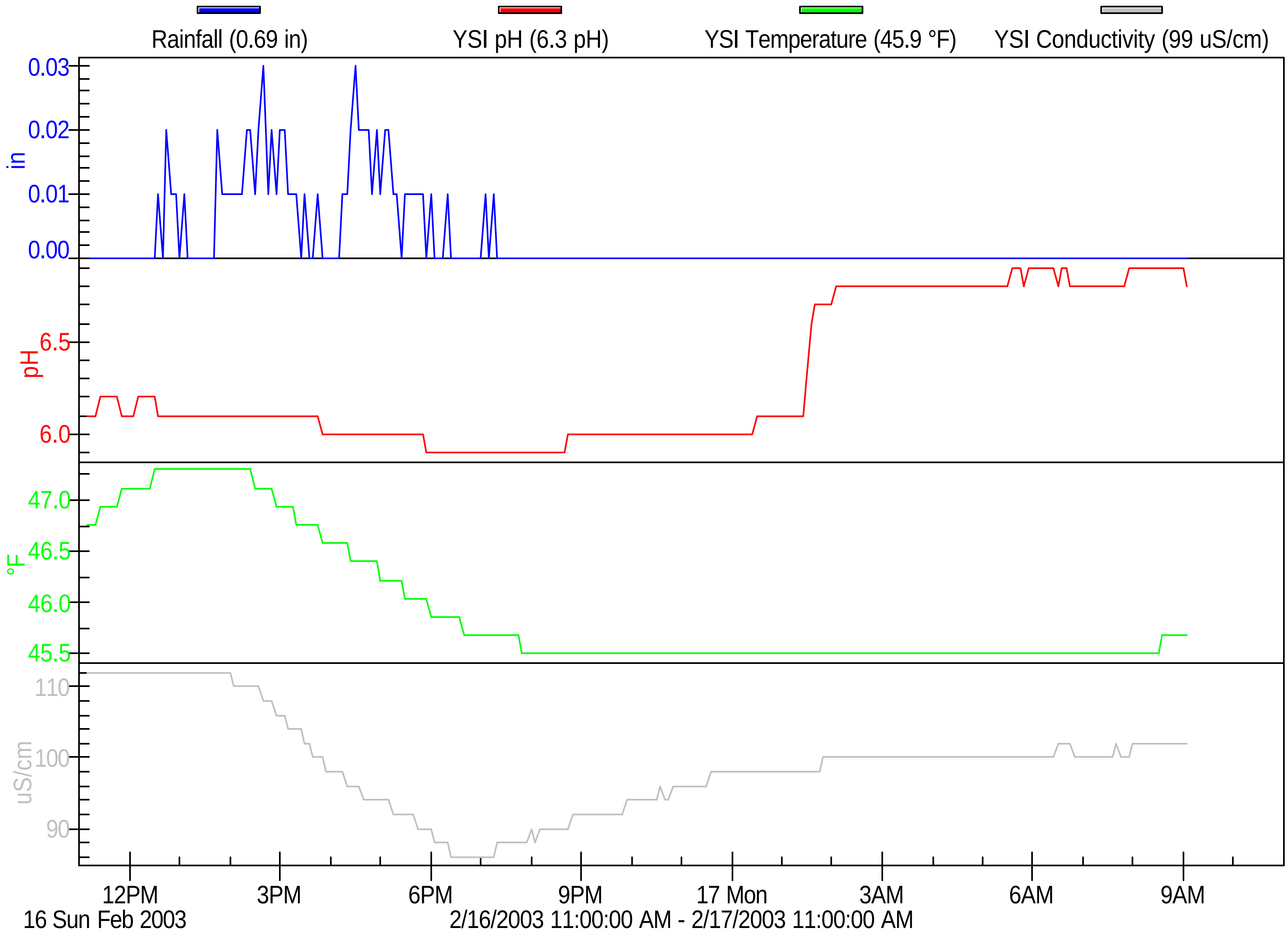
Flowlink 4 for Windows




CT
Flowlink 4 for Windows
Rainfall (0.88 in)
YSI Turbidity (2.3 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
30
25
20
15
10
5
0
15 Sat
16 Sun
17 Mon
Feb 2003
2/14/2003 6:00:00 AM - 2/17/2003 6:00:00 AM

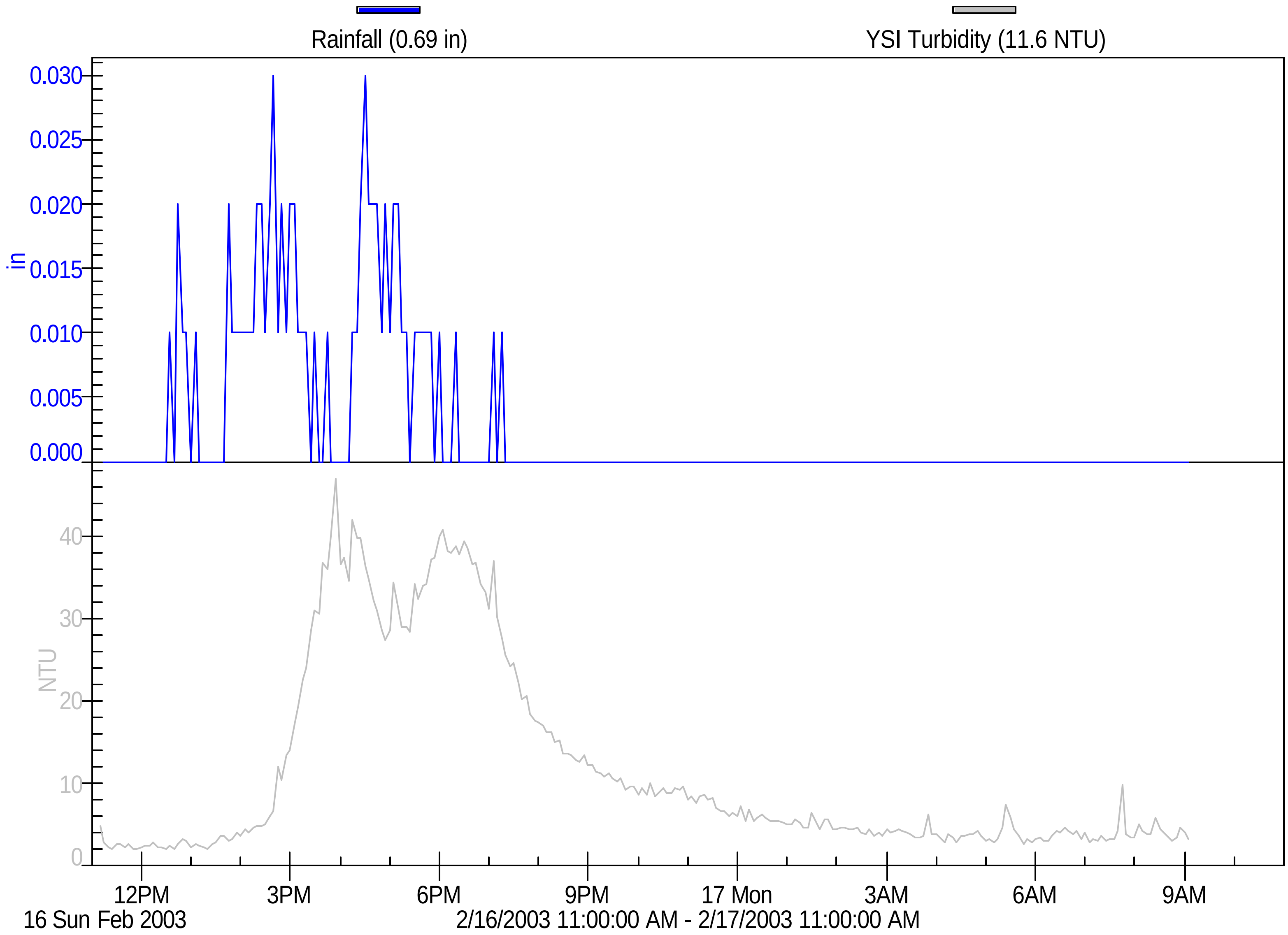
GC

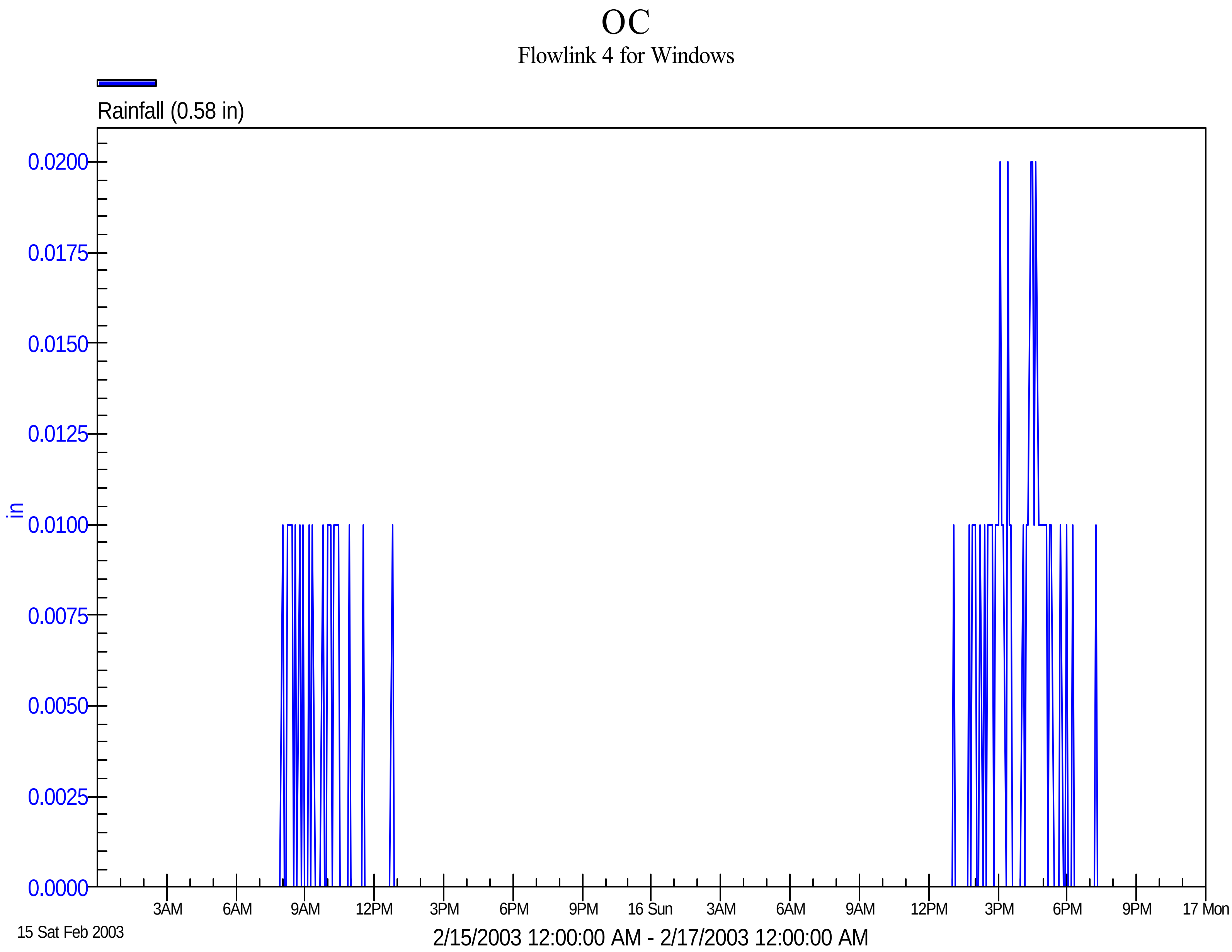
Flowlink 4 for Windows



GC

Flowlink 4 for Windows




OC
Flowlink 4 for Windows
Rainfall (0.58 in)
in
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
3AM
6AM
9AM
12PM
3PM
6PM
9PM
16 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
17 Mon
15 Sat Feb 2003
2/15/2003 12:00:00 AM - 2/17/2003 12:00:00 AM

Appendix G

Storm Summary Report #6

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #6a

(9 March 1500 – 4 Full Bottles at Olney Creek – 24 hours worth of composite samples)

8 - 9 March 2003
Northern Group and 2 Southern Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

17 March 2003

PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #6a
8-9 March 2003

Introduction

This is Field Sampling Report #6a, which describes Storm Sampling Event #6a. Field Sampling Report #6b describes Storm Sampling Event #6b, which occurred on 12-13 March. Together, Storm Sampling Events 6a and 6b constitute a 48+ hour sampling event, the final sampling event of the 2002-2003 In-Stream Storm Flow Sampling Season.

On 8-9 March 2003, The Environmental Company (TEC) conducted in-stream storm flow sampling of the 5 northern group creeks and 2 of the southern group sites within the Puget Sound Naval Shipyard (PSNS) Project Environmental Investment (ENVVEST) study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) action items. In addition, Appendix A presents satellite images, Appendix B contains physio-chemical and rainfall data, and Appendix C presents noteworthy images taken during the sample event.

1. TEC Staff Participating in Storm Sampling Event #6a

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Dave Metallo	Field Team Leader
JD Estes	Field Team Member
Brian Rupert	Field Team Member
Jen Gaudette	Field Team Member

2. Storm Sampling Event #6a

Storm Identification

Following the end of Storm Event #5 (see Field Sampling Report #5), the PSNS Project ENVVEST study area experienced nearly a full month of dry weather as a large, stationary dome of high pressure set up over the Pacific Northwest. This extended dry period during the typically wet period of late February into early March allowed the watersheds to 'load up' with pollutants and presented an appealing scenario for sampling the first rain event following this extended dry period. Weather forecasts by the NWS and other sources predicted that the strong ridge of high pressure would break down around the second week of March, thereby allowing the region to be affected by storm systems that had been previously been shunted north to Alaska,. Beginning on or about this time, the weather pattern was forecast to change to a wet pattern, with storm systems of moderate to strong strength to affect the region every few days.

On Thursday, 6 March, per coordination with the Project Team, the decision was made to mobilize the 5 northern group sites and OC and BL in anticipation of sampling the "first flush" associated with the forecasted moderate storm event estimated to arrive on the morning of Saturday, 8 March. The warm front was forecast to sweep through the area on the afternoon of the 8th, followed by the cold front on the morning of the 9th and a secondary cold front on the 10th. Based on the forecasts put forth by University of Washington and the National Weather Service, the sampling event might last 48 hours.

As detailed in Field Sampling Report #5, OC and BL were not triggered for the second half of the 24-hour event, unlike the other 3 (AC, GC, and CT). Therefore, as 7 complete sets of sampling equipment were in TEC's possession, the decision was made to sample the 5 northern sites (BA, SC, CC, CE, and CW) and OC and BL, bring the total to 7 sites, 1 more than the usual 6.

On Friday, 7 March, TEC staff mobilized sampling equipment to the 5 northern sites and the 2 remaining southern sites (BA, SC, CC, CE, CW, BL, and OC). A light rain fell throughout the project area on Friday; however, 24-hour rainfall totals did not exceed 0.20 inches and rainfall intensity was less than 0.05" per hour. As TEC was short a battery cable, the Karcher Creek Sewer District was kind enough to run a power line from a nearby outside outlet to the sampler, solving the potential power supply issue.

A rain gauge was installed at each site, and the samplers were programmed to begin sampling immediately once > 0.05 inches of rain fell within a 1 hour period. Following site set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data at sites where a connection between the Isco's and YSI was obtained.

In-Stream Storm Flow Sampling

Mobilization was completed on Friday and all 7 sites were "armed" by approximately 1200 on Saturday the 8th, at about the same time the first drops associated with the warm front started to fall. Following mobilization, the TEC team set up headquarters at the Silverdale Hotel in Silverdale and monitored the approaching storm. While the rain began around noon, it did not reach sufficient intensity to trigger the sampling until later in the afternoon. The rain generally worked its way south to north across the area, with pockets of heavier rain in some areas.

Rainfall was associated with the warm front ended by approximately 2000 hours on the 8th and amounted to approximately 0.33 inches in total. Little or no rain fell from approximately 2000 to 0000 on the 9th, whereupon the cold front approached and rainfall intensity quickly increased to moderate levels. The strongest rainfall affected the region during the early morning hours on the 9th, from approximately 0600 to 0800, corresponding to the time the mid-point fecal coliform samples were collected. The nearby Silverdale gauge recorded rainfall intensities in excess of 0.25 inches per hour during this period. Total rainfall within the project area ranged from 0.61" in Bremerton to 1.47" in Silverdale (Table 1-1). Throughout the storm sampling event, TEC staff routinely checked on the stations, collected fecal grab samples, monitored weather conditions, and coordinated with PSNS, Manchester Environmental Laboratory (MEL), and Pacific Northwest National Laboratory (PNNL).

Around midday on the 9th, following the passage of the cold front (and the bulk of the precipitation) TEC coordinated with PSNS and determined (based on the best available weather data) that the sample event should end at 24-hours, as no significant rain was forecast for the next 24-hours. In addition, the long-term forecast called for a strong, wet system to affect the region on or about Wednesday the 12th. Given the forecast, TEC and PSNS decided to stop the sampling event at 24-hours and conserve resources for potentially sampling later in the week.

Table 1-1. SE #6a: Precipitation within the Project Area

Sampling Station	Total Rainfall[1]
PSNS Project ENVVEST Sampling Stations	
Clear Creek Main (CC)	1.03"
Clear Creek East (CE)	1.00"
Strawberry Creek (SC)	0.98"
Clear Creek West (CW)	0.97"
Barker Creek (BA)	0.87"
Blackjack Creek (BL)	0.83"
Olney Creek (OC)	0.72"
Other Rain Gauges in Vicinity	
Silverdale	1.47"
Poulsbo	0.92"
Bremerton (Port of Brownsville)	0.61"

Notes: [1] Storm event totals (~1500 3/8 - ~1500 3/9).
Sources: Weather Underground: Bremerton:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABREME3&month=3&day=8&year=2003
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&month=3&day=8&year=2003
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&month=3&day=8&year=2003

During the storm, creeks in the project area rose noticeably and debris (e.g., medium-size woody debris) was mobilized, most noticeably during the rainfall associated with the cold front. The rain did not stop until approximately 1500 on the 9th, almost exactly 24 hours from when the rain first began. At this point the skies cleared except for occasional showers passing through the area. Sampling sites were turned off at 24-hours beginning shortly after 1500 on the 9th and samples were collected and iced down for subsequent delivery to PNNL and MEL the next day. Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco's to a laptop for analysis/viewing with Flowlink (see Appendix B).

Table 1-2 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to MEL and PNNL. TEC delivered the fecal grab samples to MEL at 1100 on the 8th and again at 1000 on the 9th to meet the 24-hour holding time (samples were delivered on 2 occasions in case the storm turned out to be a 48-hour event). Similarly, the composite samples were delivered to PNNL at 0930 on the 10th (Monday).

Table 1-2. SE #6a: In-Stream Storm Flow Sampling Landmarks

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	Grabs Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
Date	*8 Mar*	*8 Mar*	*9 Mar*	*9 Mar*	*9/10 Mar*	*9 Mar*	*10 Mar*
OC	1529	1715	0740	1355	0930/1000	1514	0950
BL	1537	1650	0720	1335	0930/1000	1522	0950
CC	1639	1610	0635	1240	0930/1000	1624	0950
SC	1649	1550	0655	1300	0930/1000	1634	0950
BA	1701	1600	0625	1215	0930/1000	1646	0950
CW	1740	1620	0645	1250	0930/1000	1725	0950
CE	1743	1615	0640	1245	0930/1000	1728	0950

3. Storm Sample Event #6a Results

At all stations the sampling equipment performed for the most part as expected (except for BA as explained below). Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at several sites; therefore, physio-chemical data was not recorded electronically at these sites.

Variations to the Sampling and Analysis Plan (SAP)

Only 2 variations to the SAP occurred during Sampling Event #6a. These minor variations are discussed below.

Barker Creek Battery Failure

At approximately 0800 on the 9^{th}, BA lost power when the battery ran out. Upon inspection, it was discovered that a slug of sediment had washed down the creek (see physio-chemical data) and clogged the intake. In trying to suck up and aliquot, the Isco used a lot of power, which drained the battery. Upon discovery, TEC switched out the battery with a new fully charged battery, cleared out the sediment at the intake, and re- initiated sampling. However, sampling was interrupted for approximately 3 hours, leading to the loss of samples in bottles 3 and 4. Members of the project team may walk the creek to search for the potential source of sediment.

YSI 6820 Sondes

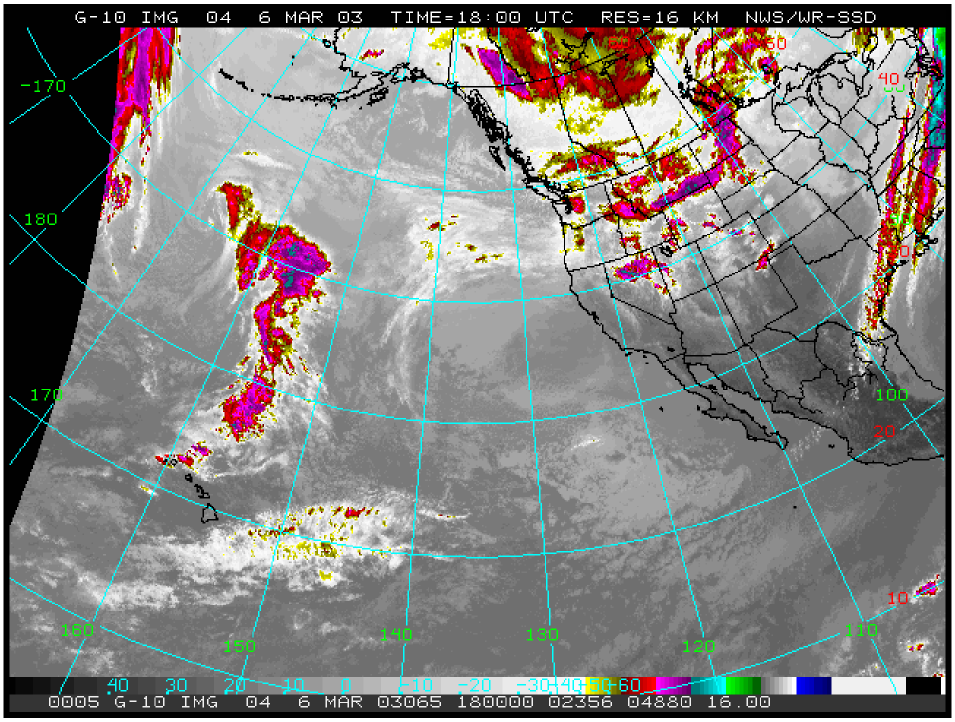
Before this storm sampling event, TEC was able to achieve successful communication between all YSI sondes and the Isco's when tested at the field office. However, when placed in the field, 3 of the 7 Isco's were not able to communicate with the YSI. While 4 sites provided all physio-chemical data during Storm #6, the other 3 did not. However, physio-chemical data at BL was recorded at 15 minute intervals using the 650 data logger. The data was then downloaded to EcoWatch for Windows.

Action Items

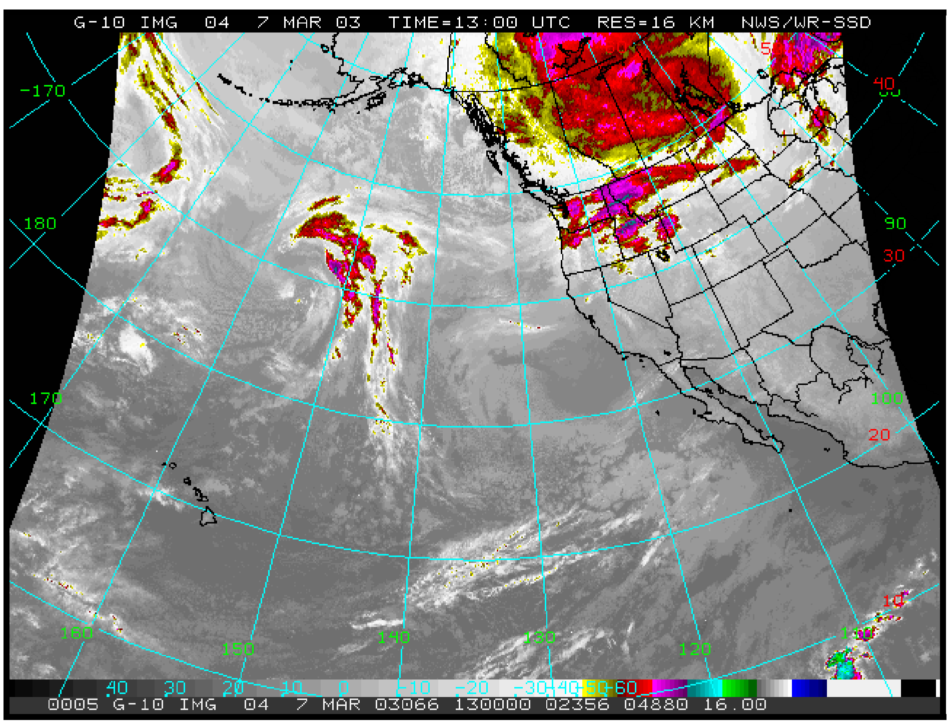
Anderson Creek Demobilization

Per the City of Bremerton's request, TEC will demolish the concrete pad at Anderson Creek and move the doghouse over the existing concrete pad/access port located immediately upstream from the current site. This work will be accomplished as soon as possible.

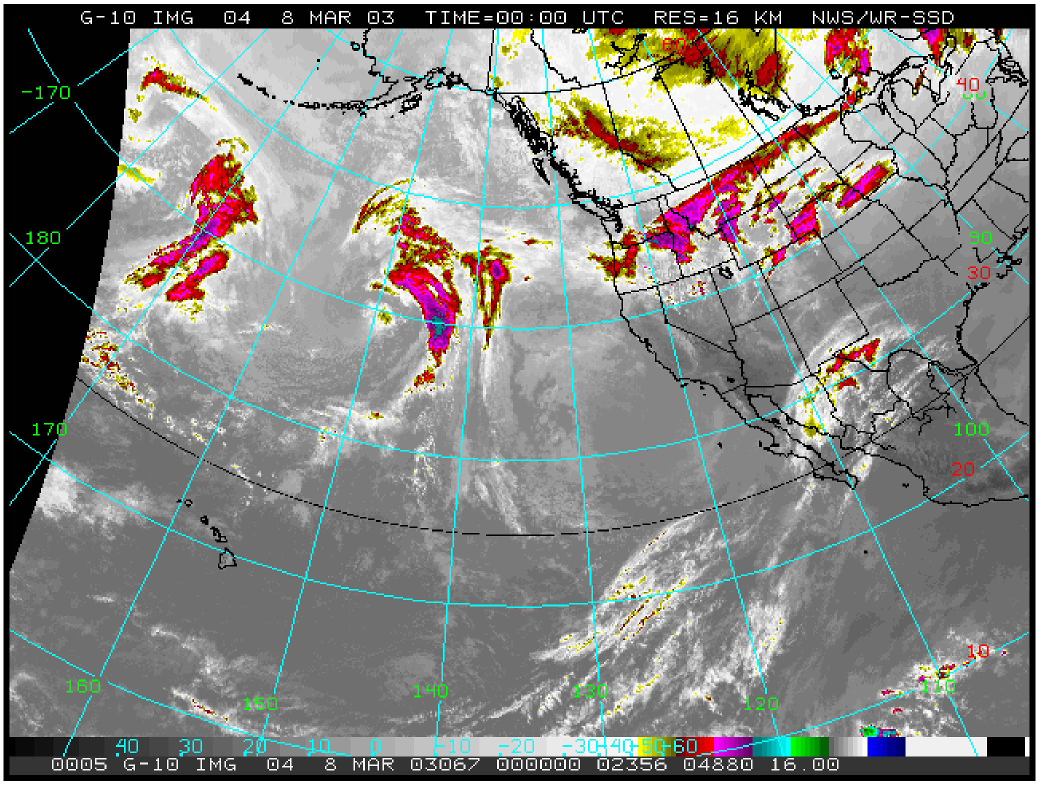
Appendix A
Satellite and Radar Data of Storm Event #6a
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



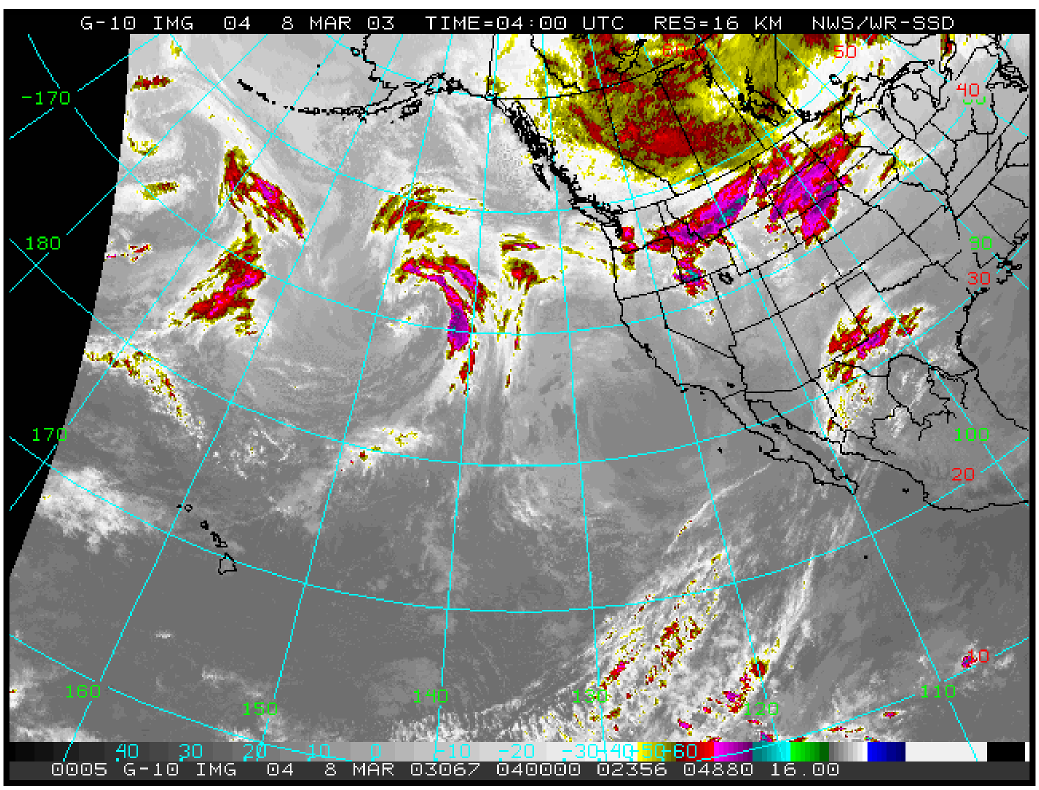
6 March 1000 (local time) - Storm 6a develops at ~ 160W/40N.



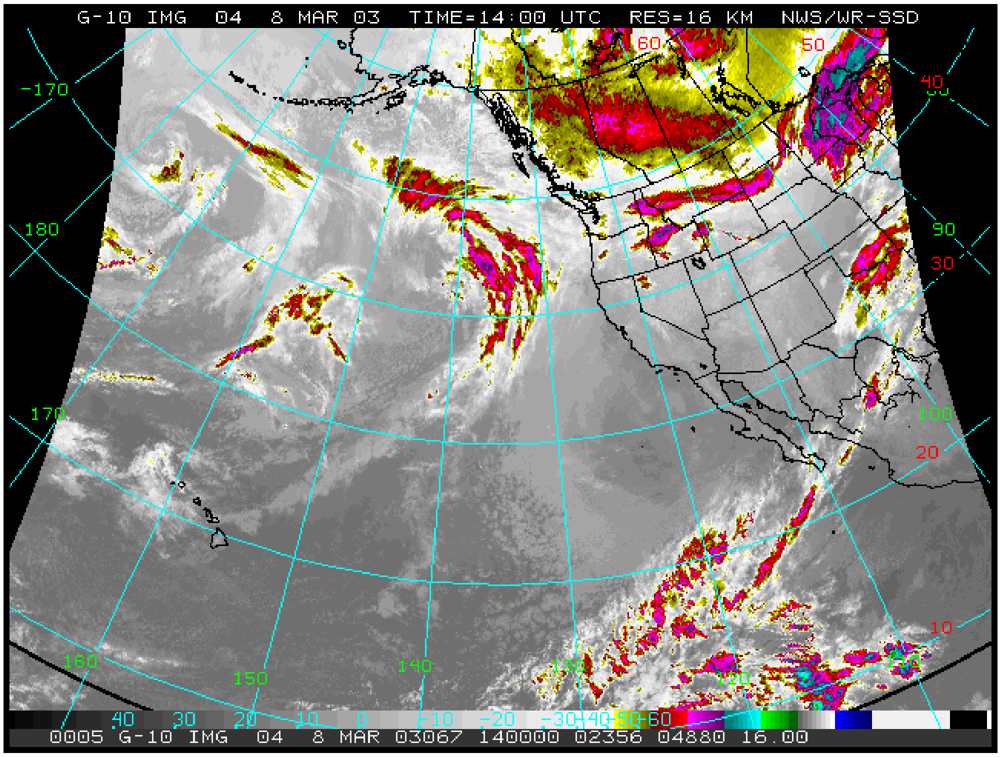
7 March 0500 – Storm 6a tightens up at ~155N/40N. Light rain from preceding system falls from clouds over project area.



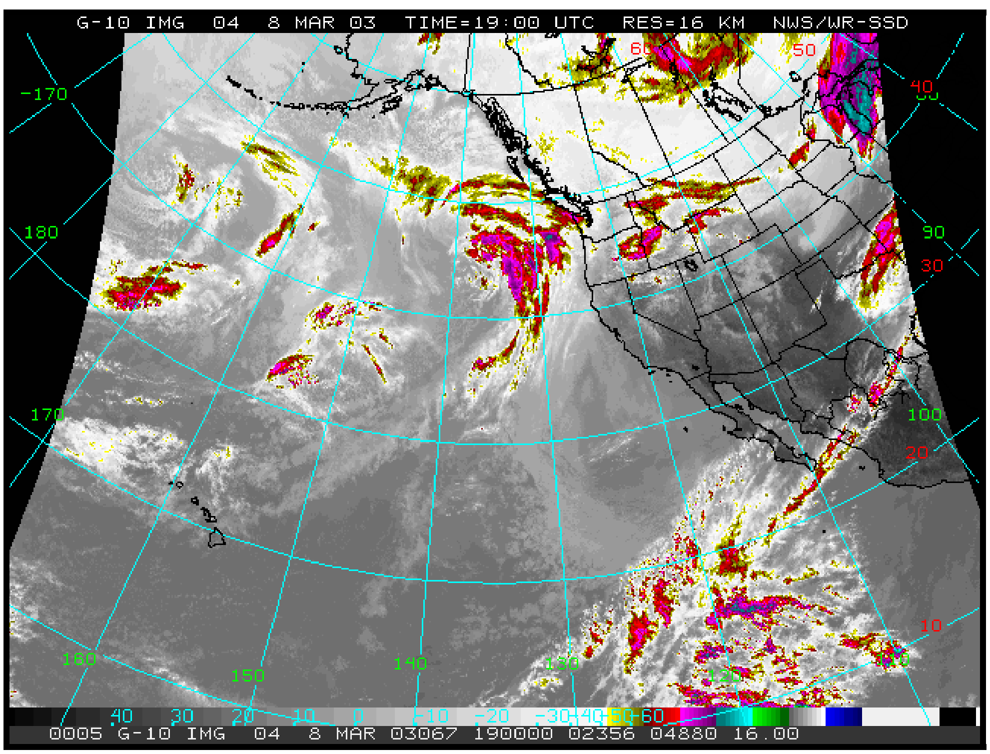
7 March 1600 – Warm front begins to take shape as storm strengthens.



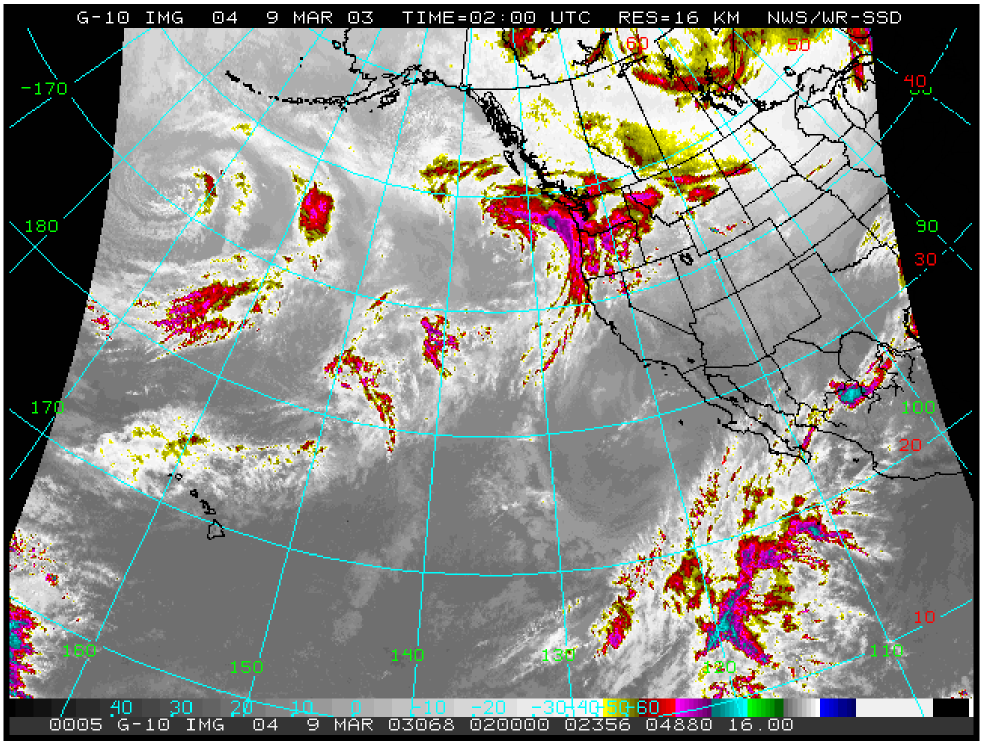
7 March 2000 – Now at ~ 145W/40N, storm taps some sub-tropical moisture and cold air.



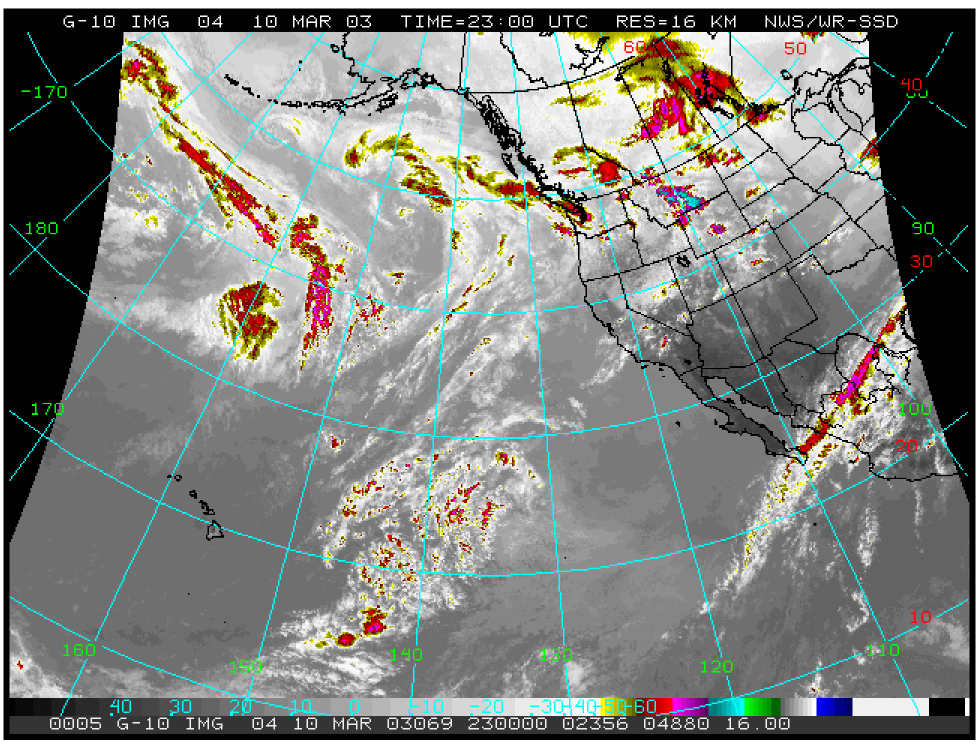
8 March 0600 – Skies clear in project area but low-pressure center and cold front (Storm 6a) approach.



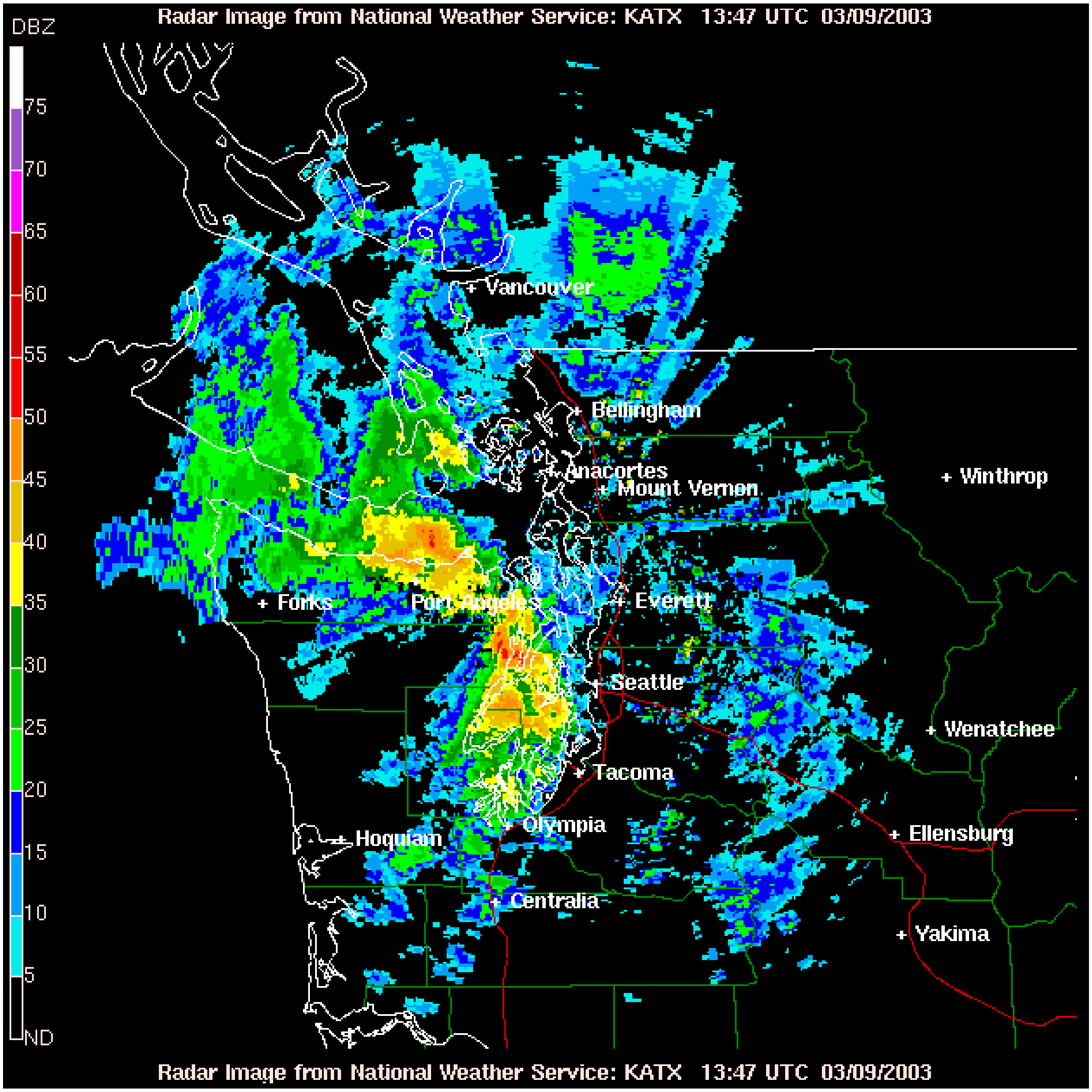
8 March 1100 – Warm front approaches and light rain begins in project area.



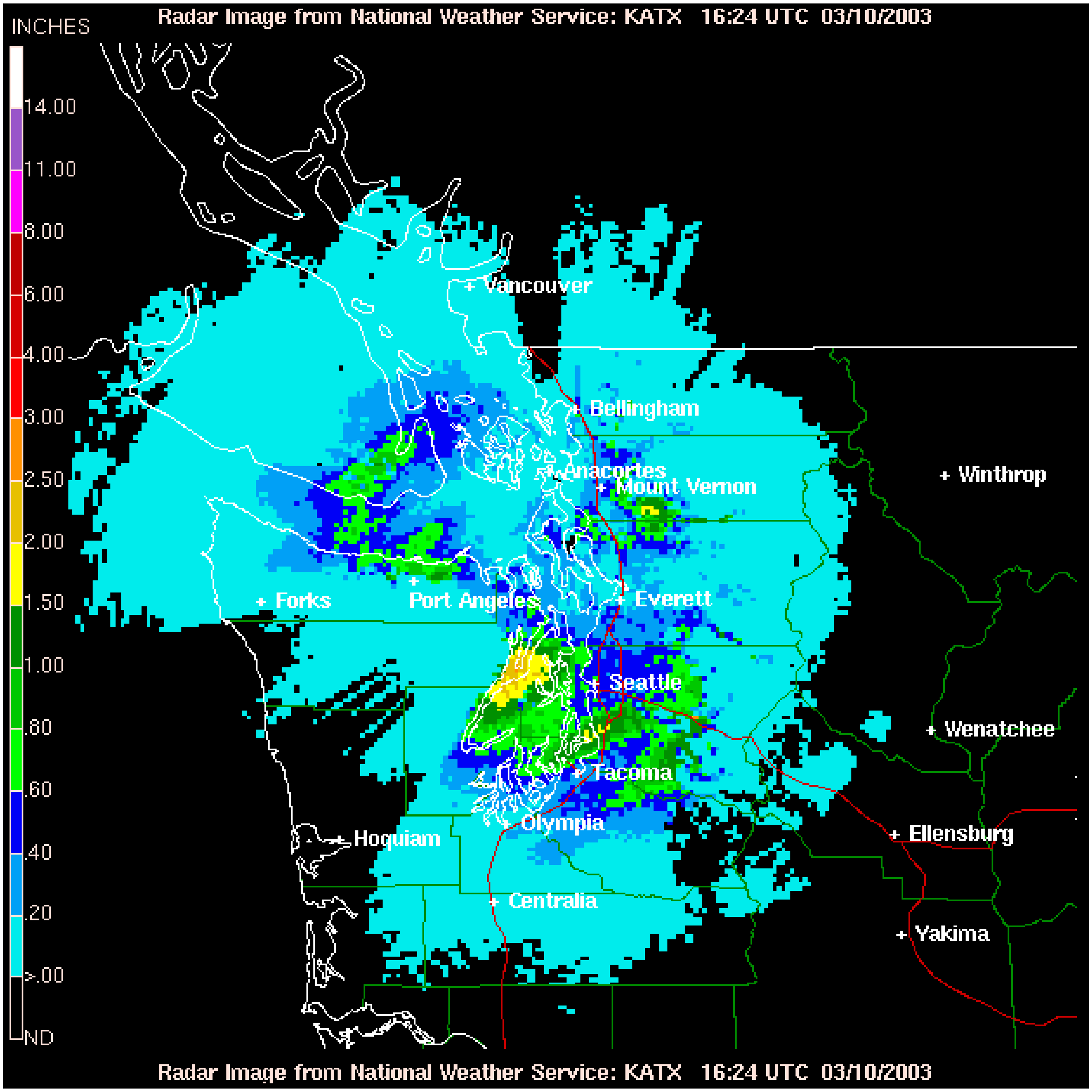
8 March 1800 – Warm front passes through as cold front approaches.



10 March 1500 – Storm is over and scattered showers affect region. Note developing system (Storm 6b) at ~160W/40N.



9 March 0547 – Radar image for W. WA – note heaviest rain over project area – 2nd round of fecals start now.

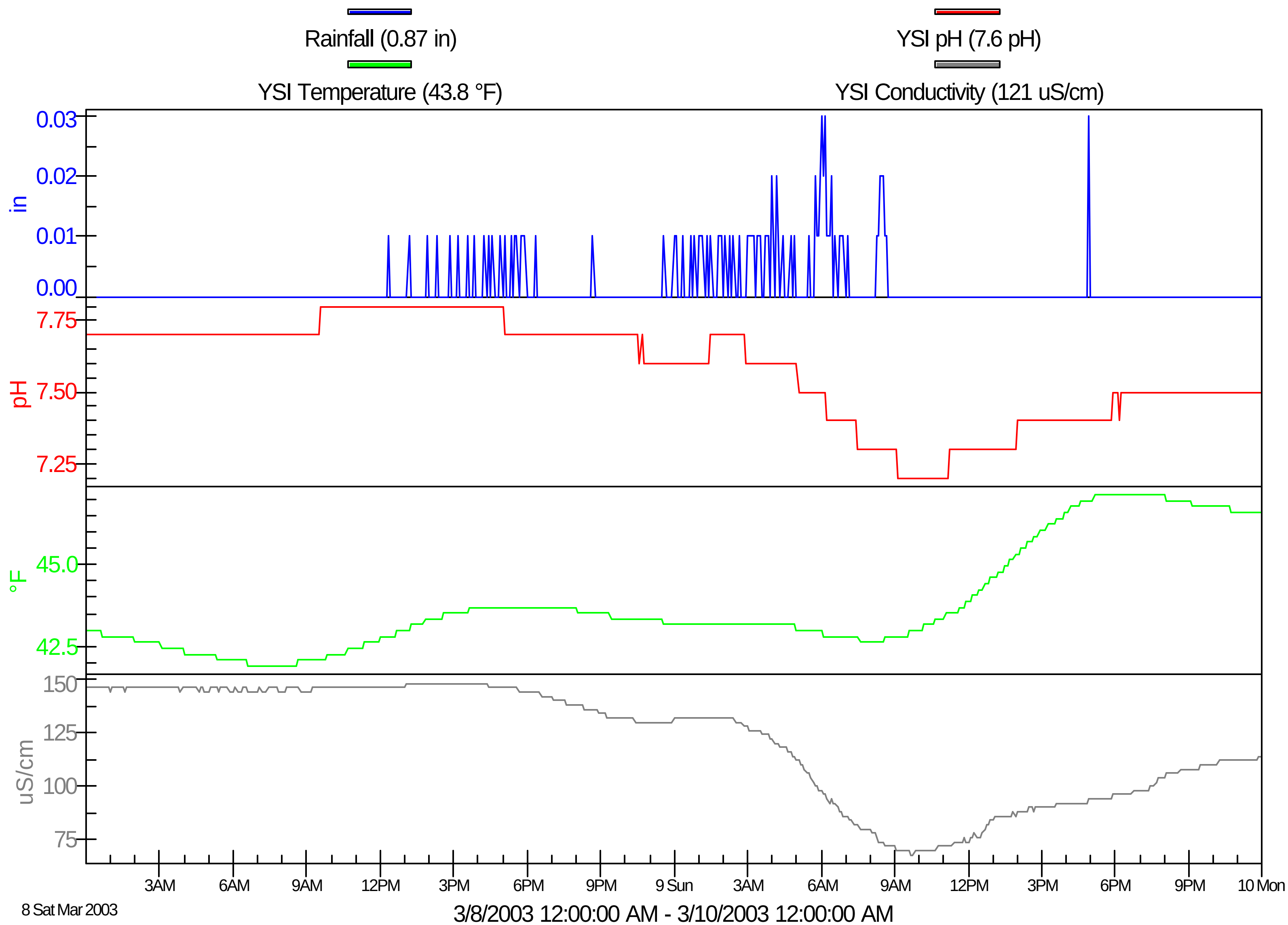


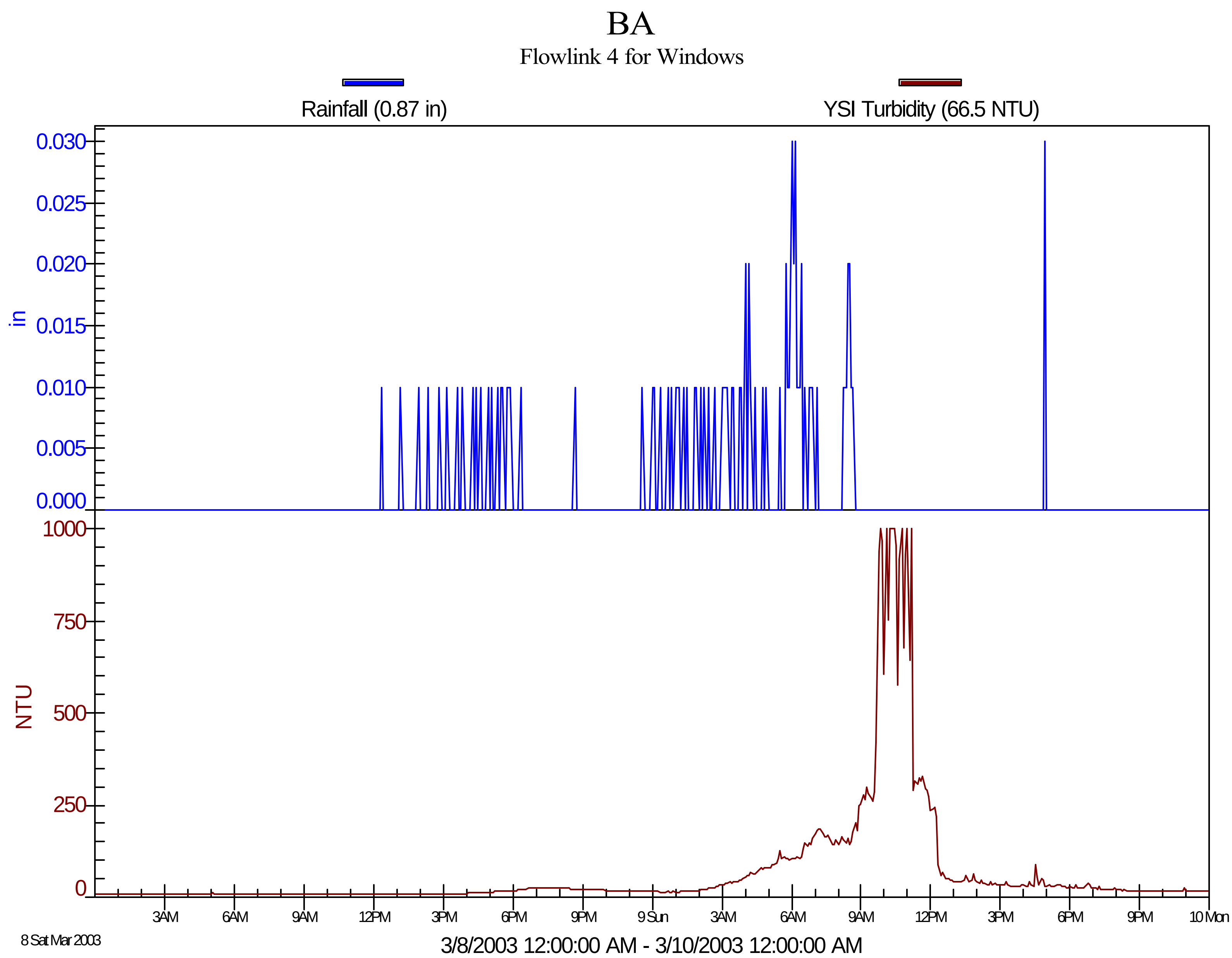
10 March 0824 – Storm totals. Note 1" totals for project area.

Appendix B
Flowlink Rainfall and Physio-Chemical Data

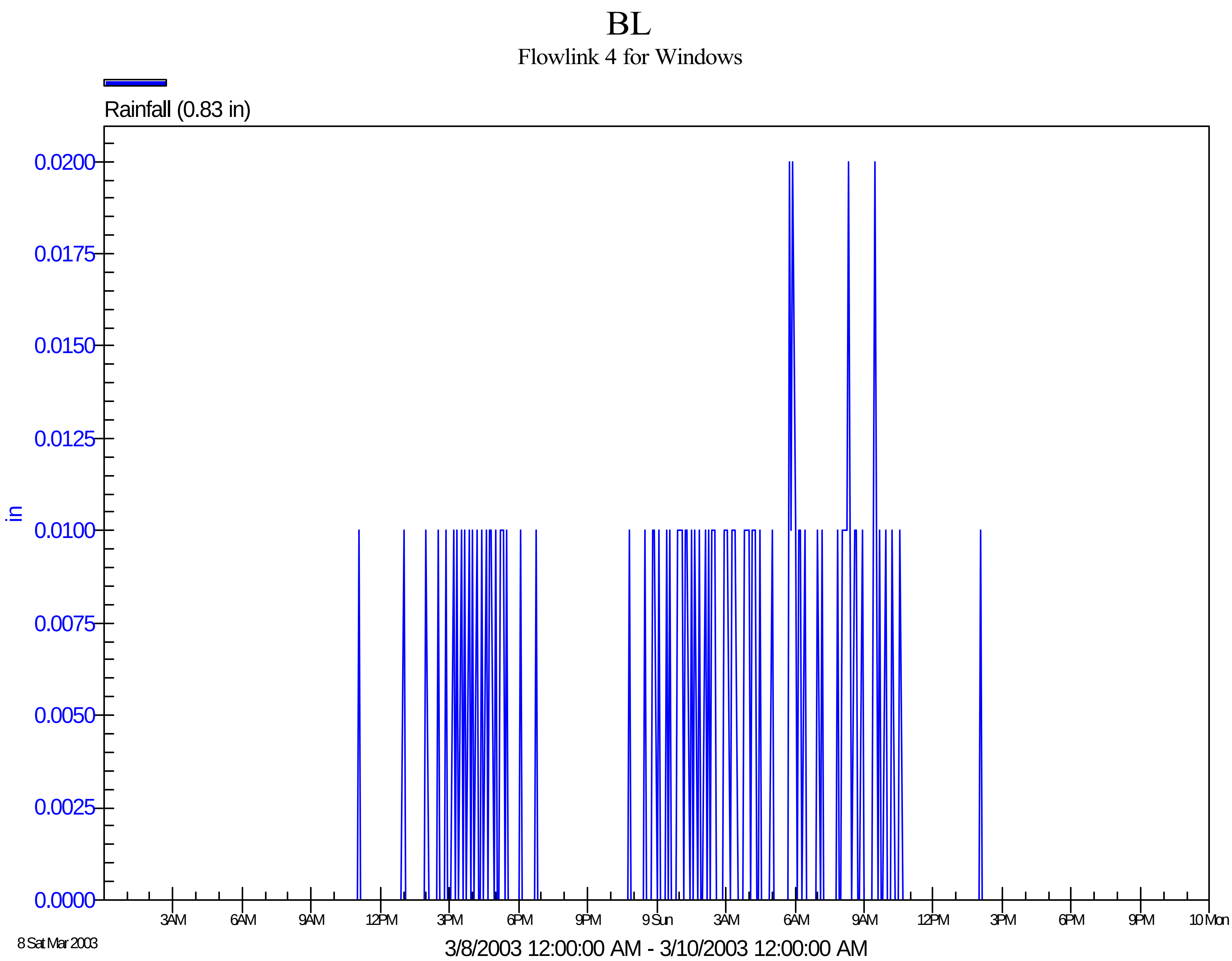
BA

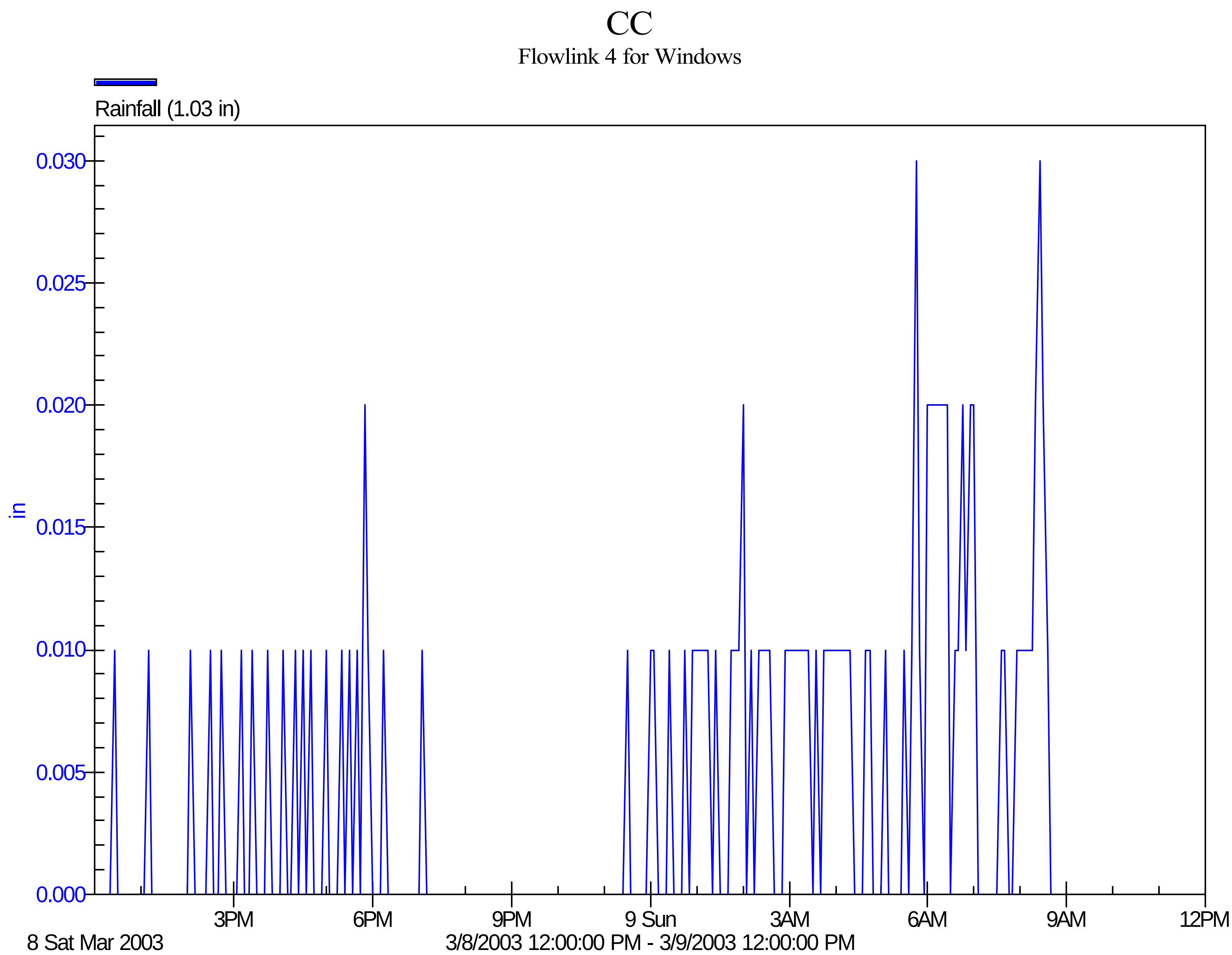
Flowlink 4 for Windows





BA
Flowlink 4 for Windows
Rainfall (0.87 in)
YSI Turbidity (66.5 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
1000
750
500
250
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
10 Mon
8 Sat Mar 2003
3/8/2003 12:00:00 AM - 3/10/2003 12:00:00 AM

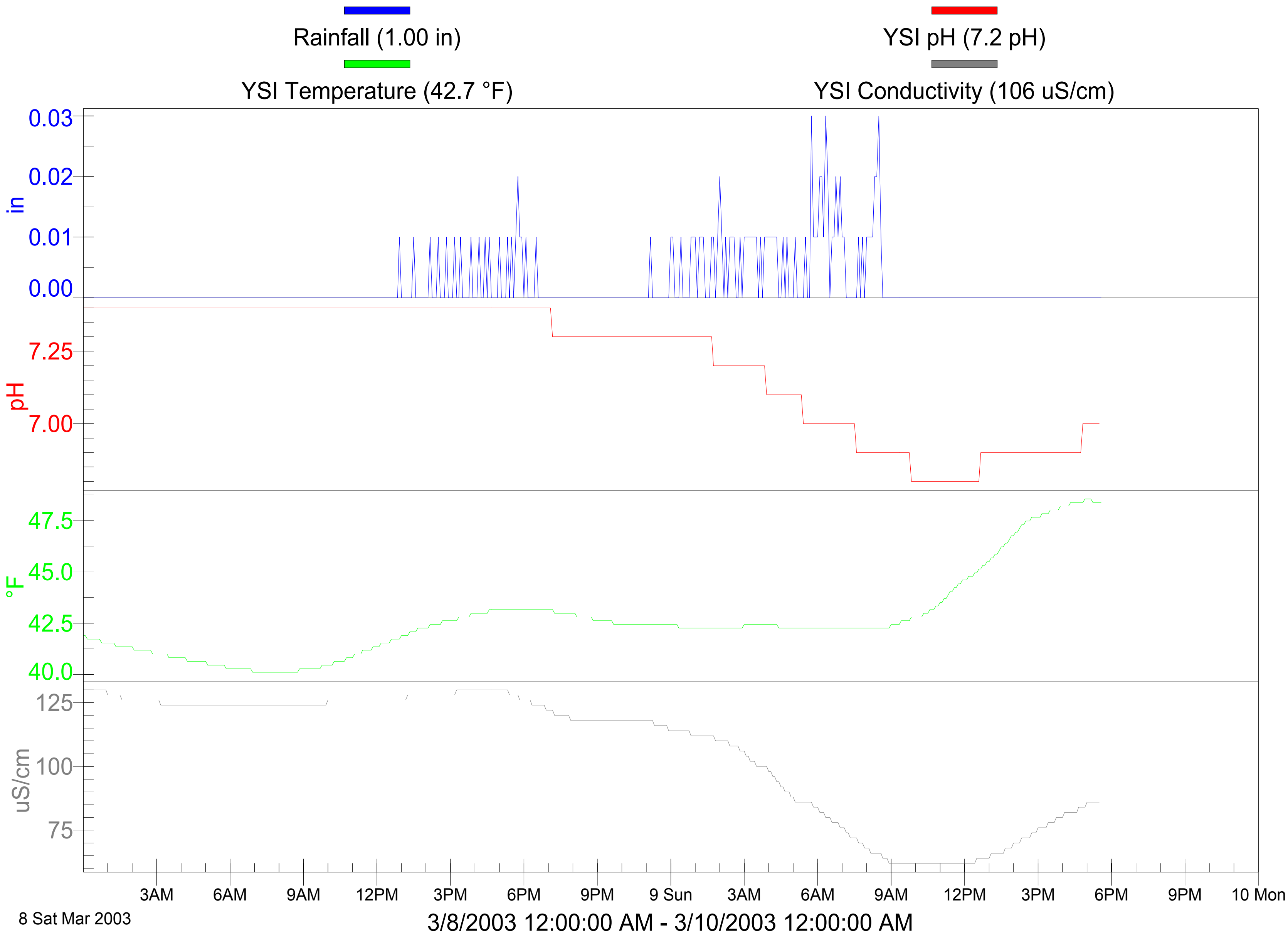

BL
Flowlink 4 for Windows
Rainfall (0.83 in)
in
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
10 Mon
8 Sat Mar 2003
3/8/2003 12:00:00 AM - 3/10/2003 12:00:00 AM

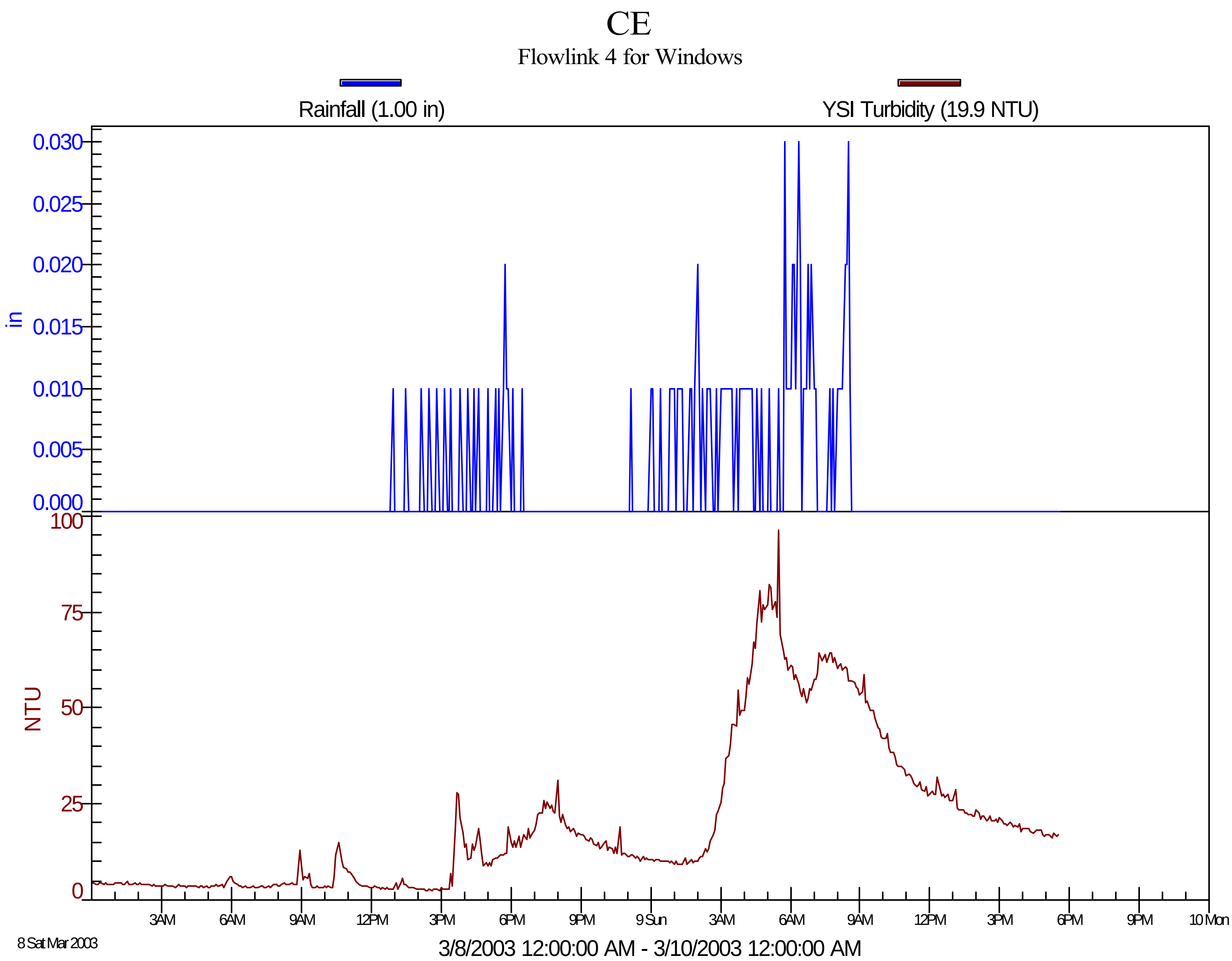


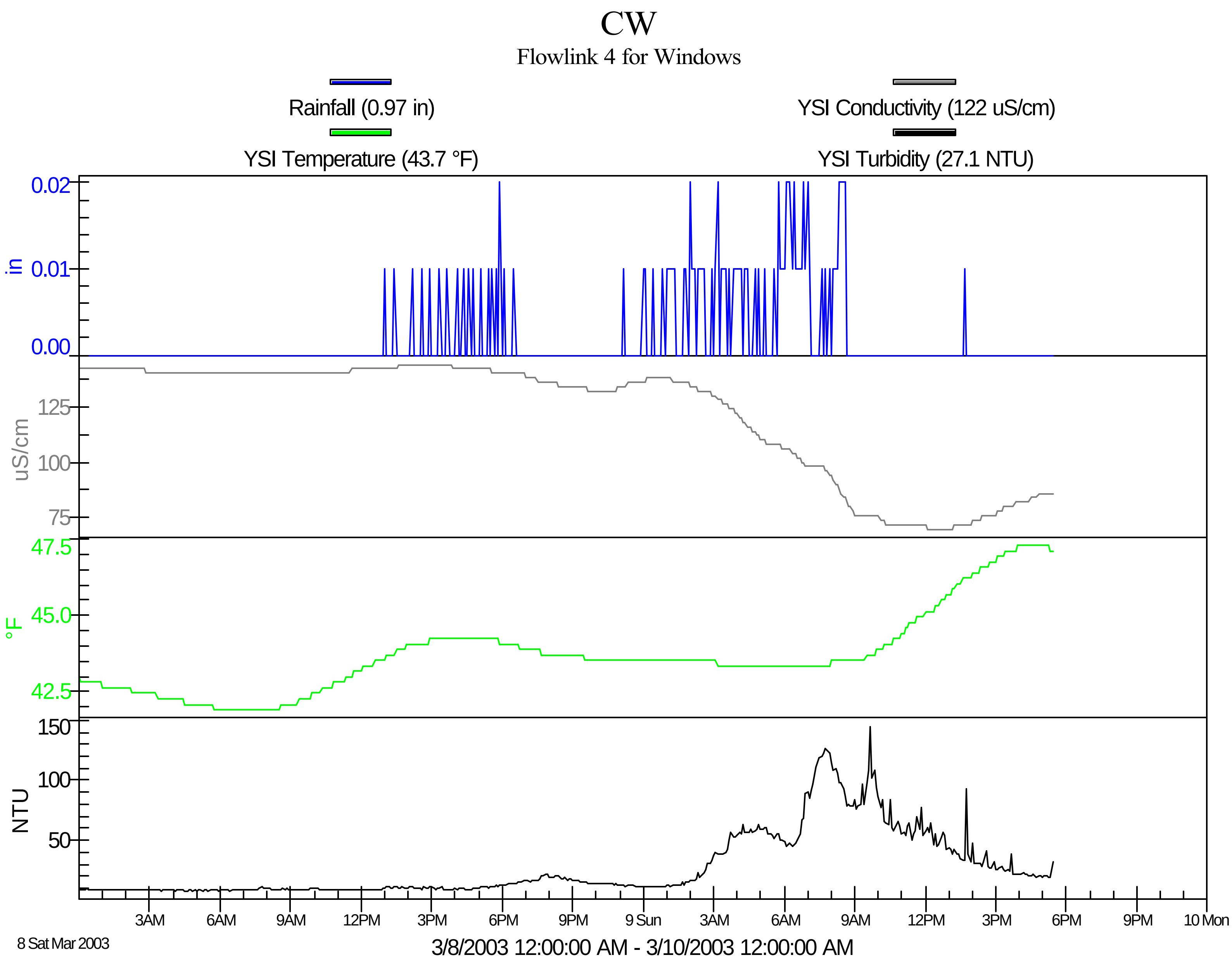
CC
Flowlink 4 for Windows
Rainfall (1.03 in)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
8 Sat Mar 2003
3/8/2003 12:00:00 PM - 3/9/2003 12:00:00 PM

CE

Flowlink 4 for Windows



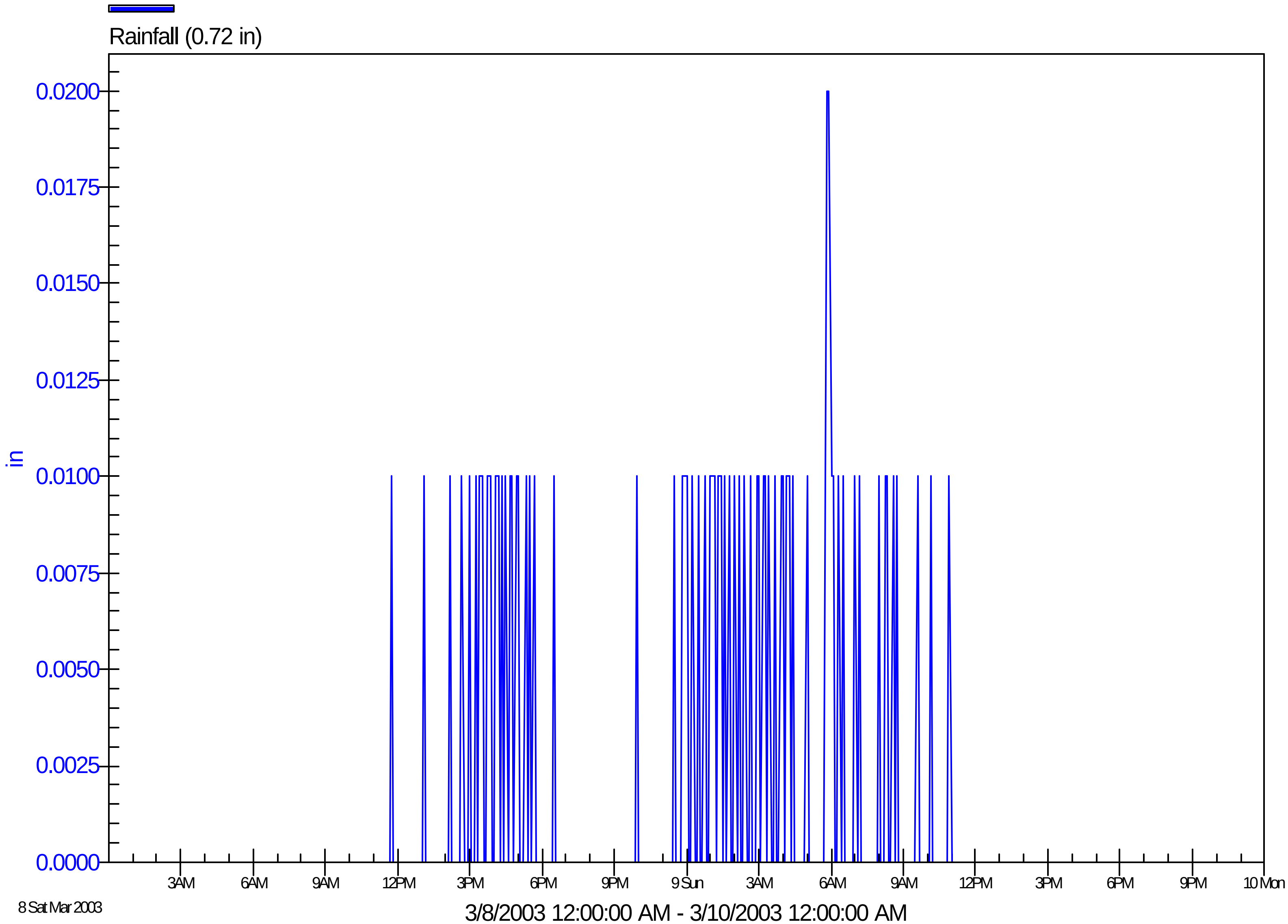

CE
Flowlink 4 for Windows
Rainfall (1.00 in)
YSI Turbidity (19.9 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
100
75
50
25
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
10 Mon
8 Sat Mar 2003
3/8/2003 12:00:00 AM - 3/10/2003 12:00:00 AM



CW
Flowlink 4 for Windows
Rainfall (0.97 in)
YSI Temperature (43.7 °F)
YSI Conductivity (122 uS/cm)
YSI Turbidity (27.1 NTU)
in
0.02
0.01
0.00
uS/cm
125
100
75
°F
47.5
45.0
42.5
NTU
150
100
50
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
10 Mon
8 Sat Mar 2003
3/8/2003 12:00:00 AM - 3/10/2003 12:00:00 AM

OC

Flowlink 4 for Windows



Chain of Custody Form

Sample Collector	Pingree, Estes	PSNS Project ENVVEST
Sampling Team	PSNS Project ENVVEST	FC TMDL STUDY
Organization	The Environmental Company, Inc.	Storm Event #6a

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03110430	Strwbry Crk	03/08/03	15:50	43.8	7.7	0.138	22.9	12	
03110431	Barker Crk	03/08/03	16:00	43.7	7.8	0.148	10.2	12	
03110432	Clear Crk Main	03/08/03	16:10	43.5	5.9	0.227	8.7	12	
03110433	Clear Crk East	03/08/03	16:15	43.0	7.4	0.129	11.0	12	
03110434	Clear Crk West	03/08/03	16:20	44.2	3.1	0.142	9.2	12	Suspect pH reading
03110435	Clear West (Dup)	03/08/03	16:20	44.2	3.1	0.142	9.2	12	Suspect pH reading
03110436	Blackjack Crk	03/08/03	16:50	42.8	7.2	0.134	2.3	12	
03110437	Olney Crk	03/08/03	17:15	45.7	7.8	0.125	75.8	12	
03110438	Barker Crk	03/09/03	6:25	42.8	7.4	0.093	108.0	12	
03110439	Strwbry Crk	03/09/03	6:55	43.1	7.2	0.066	112.7	12	
03110440	Clear Crk Main	03/09/03	6:35	42.6	6.2	0.151	50.3	12	
03110441	Clear Main (Dup)	03/09/03	6:35	42.6	6.2	0.151	50.3	12	
03110442	Clear Crk East	03/09/03	6:40	42.3	7.0	0.078	52.1	12	
03110443	Clear Crk West	03/09/03	6:45	43.3	3.1	0.100	53.1	12	Suspect pH reading
03110444	Blackjack Crk	03/09/03	7:20	42.2	7.0	0.124	20.9	12	
03110445	Olney Crk	03/09/03	7:40	44.2	7.6	0.093	90.1	12	

Preservatives Used:			
Relinquished By/Date:		Method of Shipment:	
Received By/Date:		Airbill No.:	
Relinquished By/Date:		Laboratory	
Received By/Date:		Address:	
Relinquished By/Date:			Custody Seals Present? Yes No
Received By Lab/Date:			Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Chain of Custody Form

Sample Collector	PSNS Project ENVVEST	PSNS Project ENVVEST
Sampling Team	Pingree, Estes	FC TMDL STUDY
Organization	The Environmental Company, Inc.	Storm Event #6a

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03110446	Barker Crk	03/09/03	12:15	44.1	7.3	0.076	248.1	12	
03110447	Clear Main	03/09/03	12:40	44.9	6.1	0.114	30.3	12	
03110448	Clear East	03/09/03	12:45	45.1	6.9	0.064	25.1	12	
03110449	Clear West	03/09/03	12:50	45.5	3.2	0.070	40	12	Suspect pH reading
03110450	Strwbry Crk	03/09/03	13:00	45.7	7.4	0.080	10.4	12	
03110451	Blackjack Crk	03/09/03	13:35	44.7	6.9	0.117	28.3	12	
03110452	Olney Crk	03/09/03	13:55	48.4	7.8	0.131	14.3	12	

Preservatives Used:			
Relinquished By/Date:		Method of Shipment:	
Received By/Date:		Airbill No.:	
Relinquished By/Date:		Laboratory	
Received By/Date:		Address:	
Relinquished By/Date:			Custody Seals Present? Yes No
Received By Lab/Date:			Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Appendix C
Storm 6a Images

Ryan takes a fecal coliform sample at CW

Ryan screws lid on fecal coliform sample at CW.

First (left) and Second Rounds (right) of Fecal Coliform Samples - Note second round samples are darker, corresponding to peak runoff period.

Downloading data from Isco using RTD – post sampling.

Snow! Morning of 7 March taken from van on freeway near Subase Bangor.

Appendix H

Storm Summary Report #7

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PSNS Project ENVVEST
In-Stream Storm Flow Sampling

Winter 2003

Field Sampling Report
for
Sampling Event #6b

(11/12 March – Before and after over 3" of rain at CC – note tip of green post in lower image - high water and we're sampling!)

12-13 March 2003
Northern Group Sites

Prepared by:
The Environmental Company, Inc.
Bellevue, WA

20 March 2003

PSNS Project ENVVEST
In-Stream Storm Flow Sampling

In-Stream Storm Flow Sampling Event #6b
12-13 March 2003

Introduction

This is Field Sampling Report #6b, which describes Storm Sampling Event #6b. Field Sampling Report #6a describes Storm Sampling Event #6a, which occurred on 8-9 March. Together, Storm Sampling Events 6a and 6b constitute a 48+ hour sampling event, the final sampling event of the 2002-2003 In-Stream Storm Flow Sampling Season. This is the final Field Summary Report for the 2002-2003 In-Stream Storm Flow Sampling Season.

On 12-13 March 2003, The Environmental Company (TEC) conducted in-stream storm flow sampling of the 5 northern group creeks and Chico Main (CH) within the Puget Sound Naval Shipyard (PSNS) Project Environmental Investment (ENVVEST) study area. This report presents: 1) a list of TEC staff and their roles in the sampling event; 2) a summary of the storm sampling event; 3) storm sampling results; 4) variations to the Sampling and Analysis Plan (SAP); and 5) action items. In addition, Appendix A presents satellite images, Appendix B contains physio-chemical and rainfall data, and Appendix C presents noteworthy images taken during the sample event.

1. TEC Staff Participating in Storm Sampling Event #6b

Name	**Role**
Ryan Pingree	Project Manager/Field Team Leader
Dave Metallo	Field Team Leader
JD Estes	Field Team Member
Brian Rupert	Field Team Member
Jen Gaudette	Field Team Member
Greg Whittaker	Field Team Member

2. Storm Sampling Event #6b

Storm Identification

Following the end of Storm Event #6a (see Field Sampling Report #6a), the PSNS Project ENVVEST study area was forecast to be subject to a series of strong, wet storms. This forecast presented an appealing sampling scenario with which to end the sampling season. With predictions of over 3” rainfall totals for the project area and flood warnings posted well in advance of the first storm, the decision was made per coordination with the PSNS Team on Monday, 10 March to sample the storm event predicted to start on Wednesday, 12 March.

As the project area had received over an inch of rain from 8-9 March, the predicted wet nature of the storm would produce a lot of runoff due to the semi-saturated state of the watersheds. Furthermore, little rain was forecast before the storm arrived on the morning of the 12th. This was confirmed with no rainfall on Monday the 10th and less than 0.20” on Tuesday the 11th. Based on the forecasts put forth by University of Washington and the National Weather Service, it appeared that the event might last 36 hours. A weak warm front was forecast to sweep through the area on the morning of the 12th, followed by the cold front approaching the project area during the midday hours. The cold front was then forecast to stall over the project area for the next 24-36 hours as moisture-laden waves within the front trained up from the south through the project area. By the night of Thursday the 13th, the rain was forecast to transition to scattered showers and then finally give way to clear skies on Friday morning (the 14th).

Preparation

As the 5 northern group sites were sampled during Storm Event #6a, little mobilization of these 5 sties was necessary. However, as Chico Main was not sampled, full mobilization was required at this site. On Tuesday, 11 March, TEC staff installed fresh batteries and new bottles at the 5 northern group sites (BA, SC, CC, CE, and CW) and mobilized Chico Main.

A rain gauge was installed at each site and samplers were programmed to begin sampling immediately once > 0.05 inches of rain fell within a 1 hour period. Following site set-up, TEC staff calibrated the samplers to pull 140 ml aliquots from the stream and the intake tubes were washed with DI water. The samplers were then programmed to pull 140 ml aliquots every 15 minutes and rotate to the next bottle in succession after 24 samples (a 6-hour period). The YSI sondes were installed and began logging data at sites where a connection between the Isco's and YSI was obtained.

In-Stream Storm Flow Sampling

Mobilization was completed on Wednesday morning and all 6 sites were "armed" by approximately 0900, at about the same time the first drops associated with the cold front started to fall. The weak warm front had passed through the area in the early morning hours and only produced light showers totaling approximately 0.15" in the project area. The rain generally worked its way south to north across the area, with pockets of heavier rain in some areas. The rain came on fast and strong. Moderate to heavy bands of rain worked there way from south to north through the project area, triggering the samplers. At several times during the day rainfall intensities exceeded 0.30 inches per hour.

Rainfall stayed at a moderate to occasionally high level throughout the sampling event and never really slacked off. The strongest rainfall affected the region during the late morning hours and again during the evening hours of the 12th, corresponding to the time the 1st and 2nd round of fecal coliform samples were collected. During the storm, creeks in the project area rose quickly and reached heights higher than observed during the whole sample season (see cover image and photo log – Appendix C). Rainfall totals within the project area were prodigious – a real "gully washer" – and ranged from 2.63" in Bremerton (Brownsville) to 4.35" in Silverdale (Newberry Hill) and generally increased from south to north, as shown in the PSNS gauge totals (Table 1-1). Throughout the storm sampling event, TEC staff routinely checked on the stations, collected fecal grab samples, monitored weather conditions, and coordinated with PSNS, Manchester Environmental Laboratory (MEL), and Pacific Northwest National Laboratory (PNNL).

On Thursday morning the 13th, TEC coordinated with the PSNS Team in Silverdale and determined (based on the best available weather data) that the sample event should end at 30 hours, as the forecast predicted that the steady moderate rain would turn to scattered showers by the evening hours and preliminary rainfall totals for non-PSNS gauges in the area had already recorded over 3" of rain within the preceding 24-hour period. Given the forecast, TEC and PSNS decided to stop the sampling event at 30 hours (approximately 1600 on Thursday the 13th).

Table 1-1. SE #6b: Precipitation within the Project Area

Sampling Station	Total Rainfall[1]
PSNS Project ENVVEST Sampling Stations	
Clear Creek Main (CC)	3.43”
Clear Creek East (CE)	3.40”
Clear Creek West (CW)	3.30”
Strawberry Creek (SC)	3.19”
Barker Creek (BA)	3.10”
Chico Main (CH)	3.09”
Other Rain Gauges in Vicinity	
Silverdale (Newberry Hill)	4.35”
Poulsbo (C. May’s House)	3.50”
Bremerton (Airport)	3.01”
Poulsbo (Viking Ave)	2.80”
Bremerton (Port of Brownsville)	2.63”

Notes: [1] 30 hour storm event totals (~1000 3/12 - ~1700 3/13).
Sources: Weather Underground: Bremerton:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWABREME3&month=3&day=12&year=2003
Poulsbo:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWAPOULS2&day=12&year=2003&month=3
Silverdale:
http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASILVE1&day=12&year=2003&month=3
NOAA: Bremerton Airport:
http://www.wrh.noaa.gov/cgi-bin/Seattle/seaobs?site=KPWT&type=1&fmt=DEC&src=lcl&hh=168&gh=96&gy=1

Sampling was stopped after 30 hours beginning at CH a little before 1600 on the 12th and a final round (4th round) of fecal samples was collected. Those samples not delivered the previous day were collected and iced down for subsequent delivery to PNNL and MEL early the next morning (the 14th). Using the Rapid Transfer Device (RTD), rainfall, physio-chemical, and sampling report data were downloaded from the Isco’s to a laptop for analysis/viewing with Flowlink (see Appendix B).

Table 1-2 presents the times at which the samplers were activated, fecal grab samples were taken, when the samplers were turned off, and when samples were delivered to MEL and PNNL. TEC delivered fecal grab samples to MEL at 0900 on the 13th and again at 0809 on the 14th to meet the 24-hour holding time (samples were delivered on 2 occasions in case the storm turned out to be a 48-hour event). Similarly, composite samples were delivered to PNNL at 1330 on the 13th and again at 1018 on Friday the 14th.

Table 1-2. SE #6b: In-Stream Storm Flow Sampling Landmarks

Sampling Station	Sampling Begins	1st Fecal Grab	2nd Fecal Grab	3rd Fecal Grab	4th Fecal Grab	Fecals Delivered to MEL	Sampling Ends	Composites Delivered to PNNL
Date	*12Mar*	*12 Mar*	*12 Mar*	*13 Mar*	*13 Mar*	*13/14 Mar*	*13 Mar*	*13/14 Mar*
CH	0959	1120	2130	0650	1550	0900/0807	1544	1330/1018
BA	1004	1145	2210	0725	1605	0900/0807	1549	1330/1018
CC	1011	1200	2220	0735	1620	0900/0807	1556	1330/1018
CE	1012	1210	2240	0750	1625	0900/0807	1557	1330/1018
CW	1016	1215	2250	0800	1645	0900/0807	1601	1330/1018
SC	1139	1140	2150	0705	1700	0900/0807	1724	1330/1018

As the water level in the creeks was too high to immediately recover the YSI Sondes, per PSNS direction they were left in place and continued to record physio-chemical data. TEC also left the rain gauge at BA up and connected to the Isco to record rainfall, to aid in the interpretation of the physio-chemical data. On 18 March, TEC staff recovered the sondes and downloaded the physio-chemical data. At some sites, almost a weeks worth of physio-chemical data was recorded. Upon de-mobilization, it was discovered that several of the sondes had collected small pieces of vegetation (e.g., leaves) and sediment in the base (cup), which may have affected readings.

3. Storm Sample Event #6b Results

At all stations the sampling equipment performed for the most part as expected. Following initial rain or manual activation, the samplers filled the 3.7 liter bottles to a more or less consistent level in all bottles at all stations – approximately 3.3 liters (minor variations in sample levels occurred due to the inherent liquid measurement resolution of the samplers). Physio-chemical data from the YSIs were logged at several locations - communication between the Isco and YSI was not achieved at several sites; therefore, physio-chemical data was not recorded electronically at these sites.

Variations to the Sampling and Analysis Plan (SAP)

Only 2 variations to the SAP occurred during Sampling Event #6b. These minor variations are discussed below.

Strawberry Creek Late Start

During the first round of fecal coliform sampling on the 12th, TEC staff discovered that the sampler at SC had not yet begun sampling, whereas all others had begun over an hour earlier. Upon discovery and inspection, it was discovered that the rain gauge did not achieve communication with the Isco. TEC staff immediately manually activated the sampler at 1139 by pouring water in the rain gauge.

YSI 6820 Sondes

While 4 sites recorded all physio-chemical data via the Isco's during Storm #6b, 2 did not. However, physio-chemical data at CC and SC was recorded at 15 minute intervals using the 650 data loggers. The data was then downloaded to EcoWatch for Windows.

Action Items

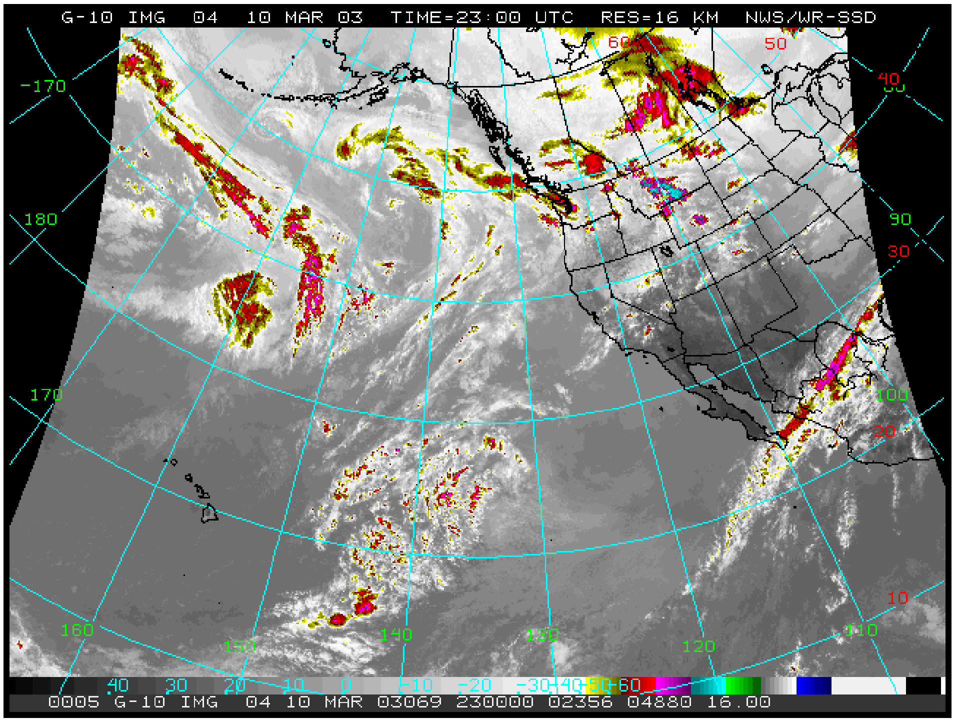
Storm Sampling Readiness

This was the last storm sampling event of the 2002-2003 In-Stream Storm Flow Sampling season. All equipment will be brought back to TEC's shop where it will be cleaned, inventoried, and stored for use next season.

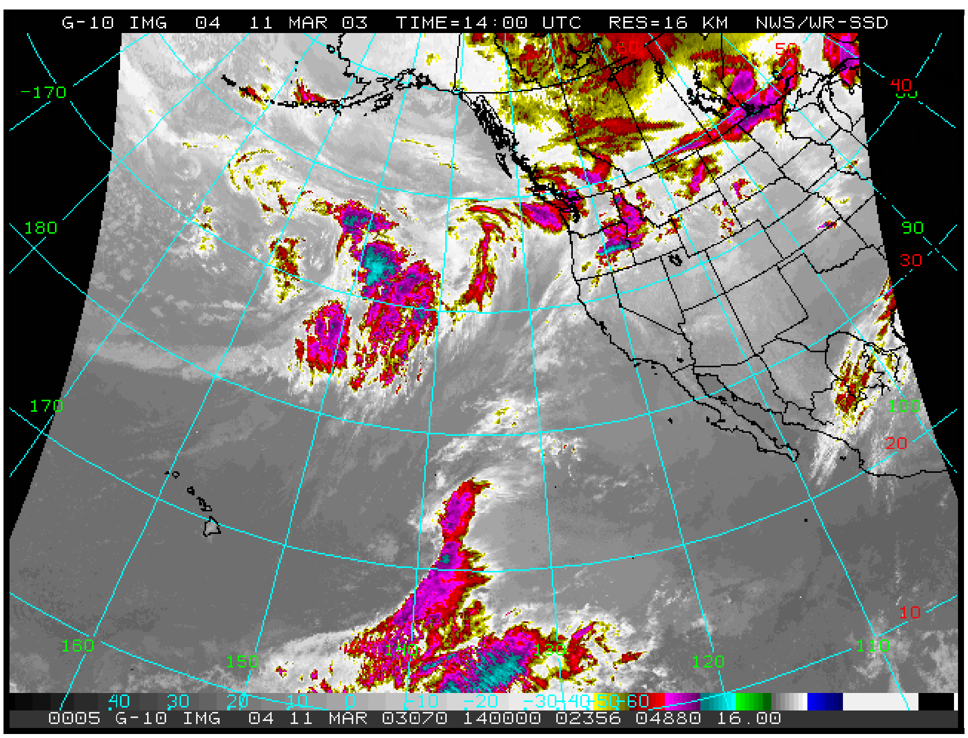
Strawberry Creek Demobilization

As described in Field Sampling Report #2, Strawberry Creek will be de-mobilized per KPUD's request. This task will be completed by 21 March 2003.

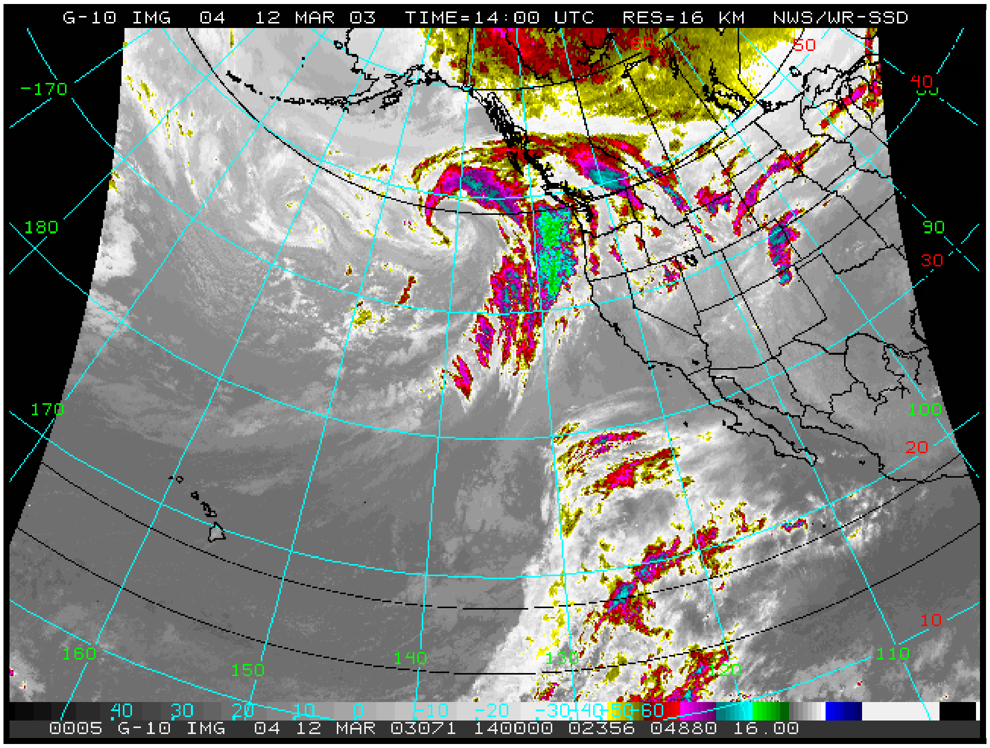
Appendix A
Satellite and Radar Data of Storm Event #6b
Source: http://www.atmos.washington.edu/cgi-bin/list.cgi?ir16km



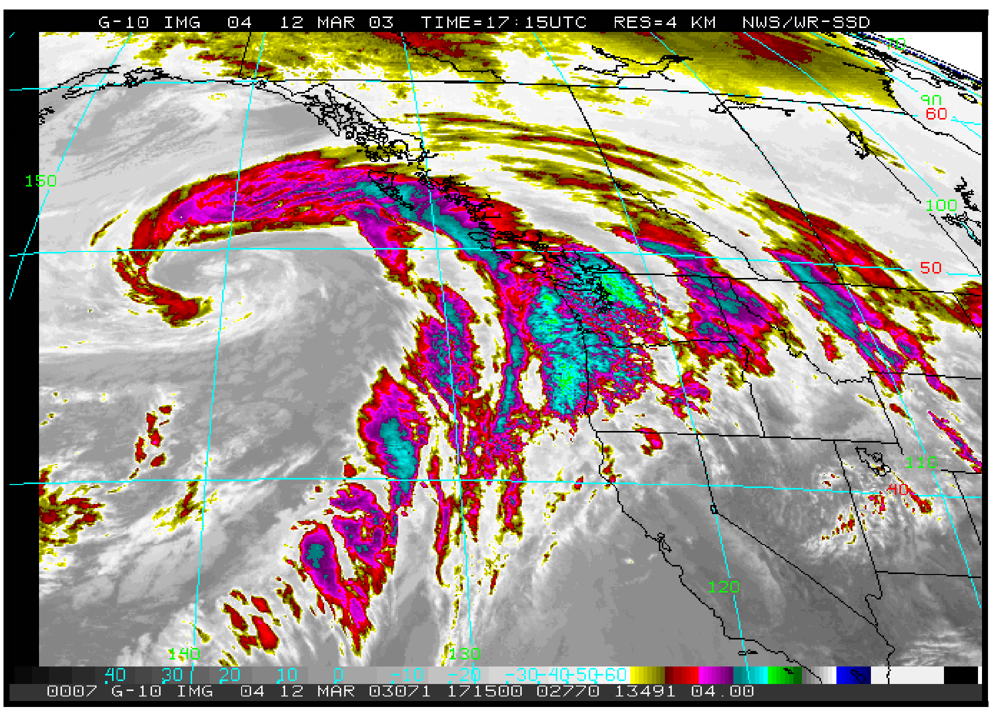
10 March 1500 – Storm #6b develops at ~160W/40N.



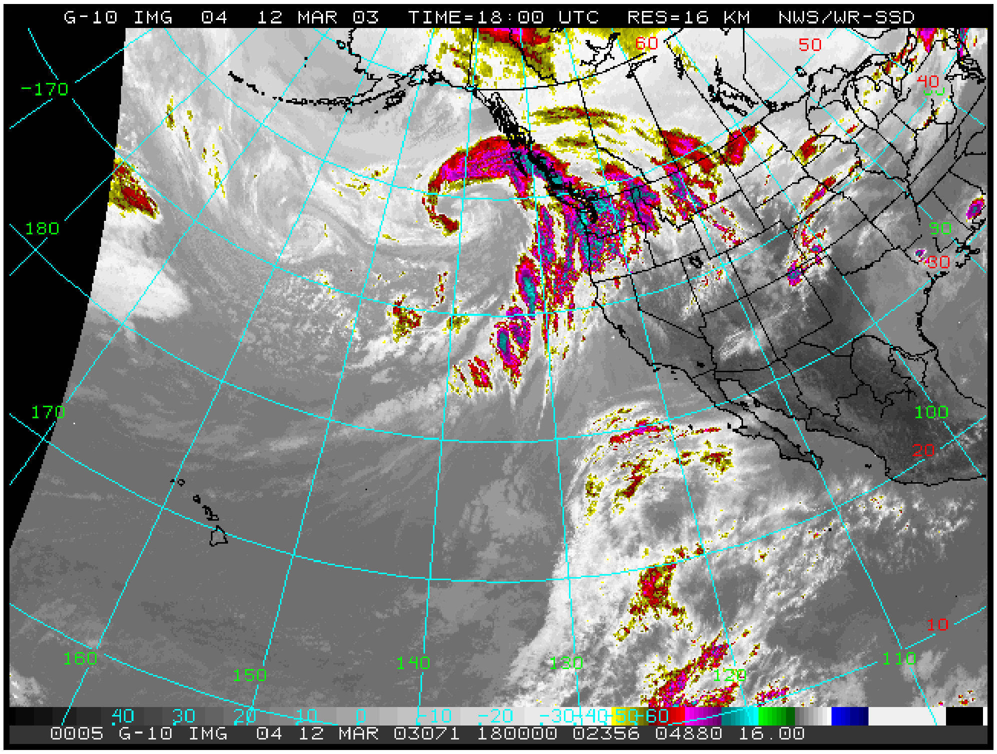
11 March 0600 - Storm #6b develops at ~ 160W/40N. Note copious moisture associated with system.



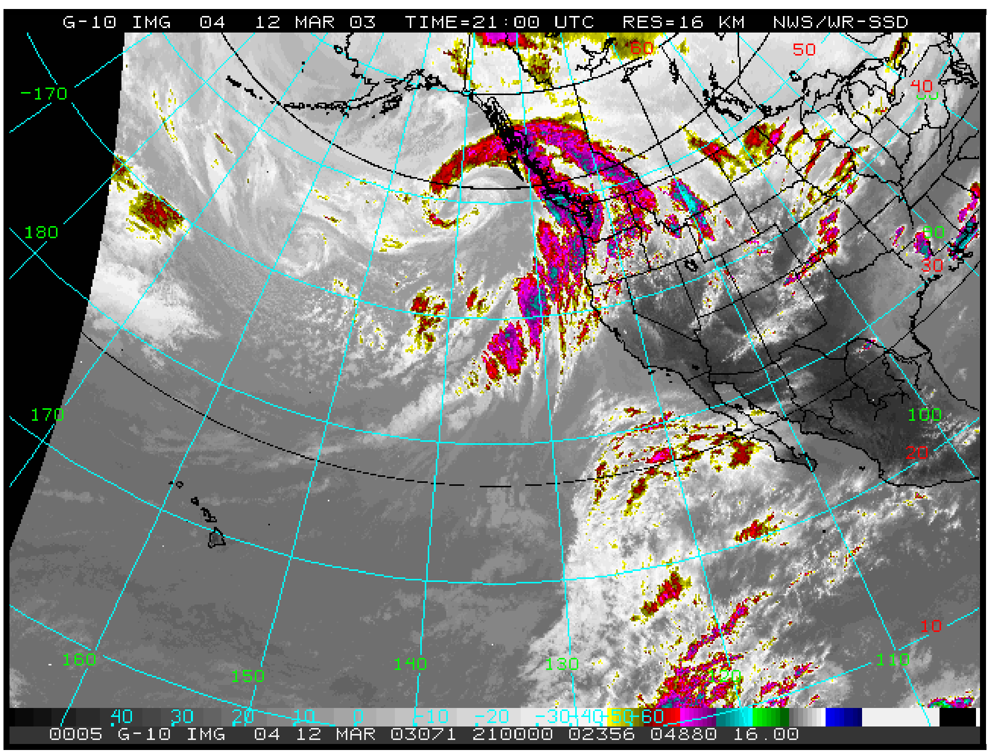
12 March 0600 – Storm #6b approaches the coast. Note thick band of moisture and high cloud tops (bright clouds) which translate into heavy rain at surface.



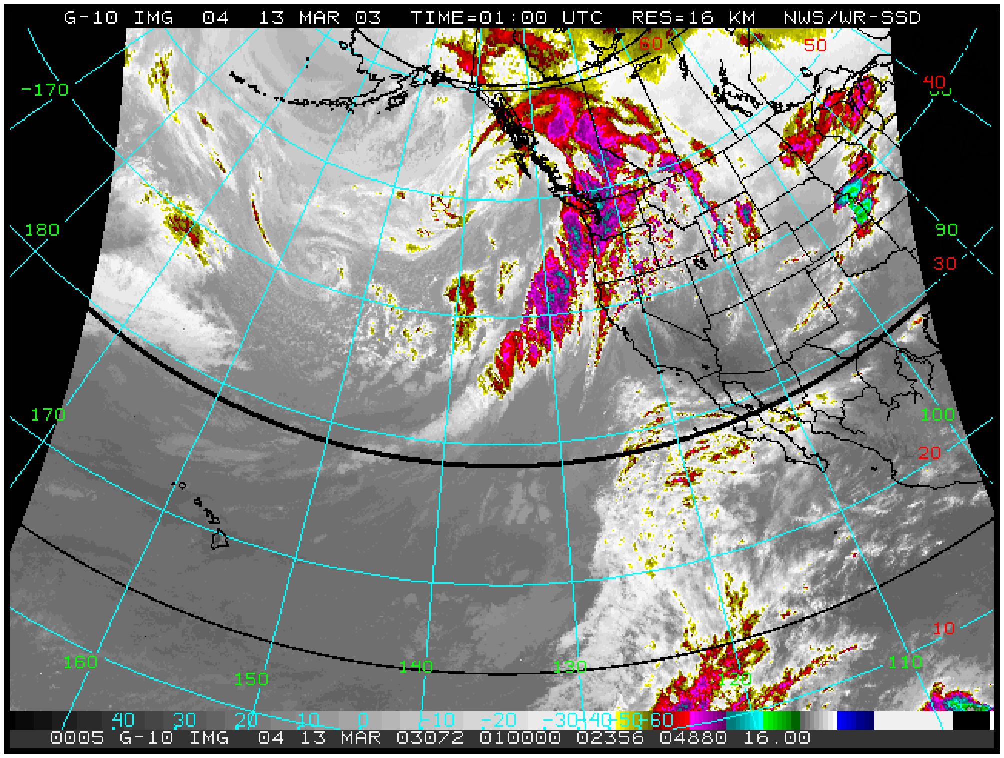
12 March 0915 – Close-up view of Storm 6b as it approaches the project area.



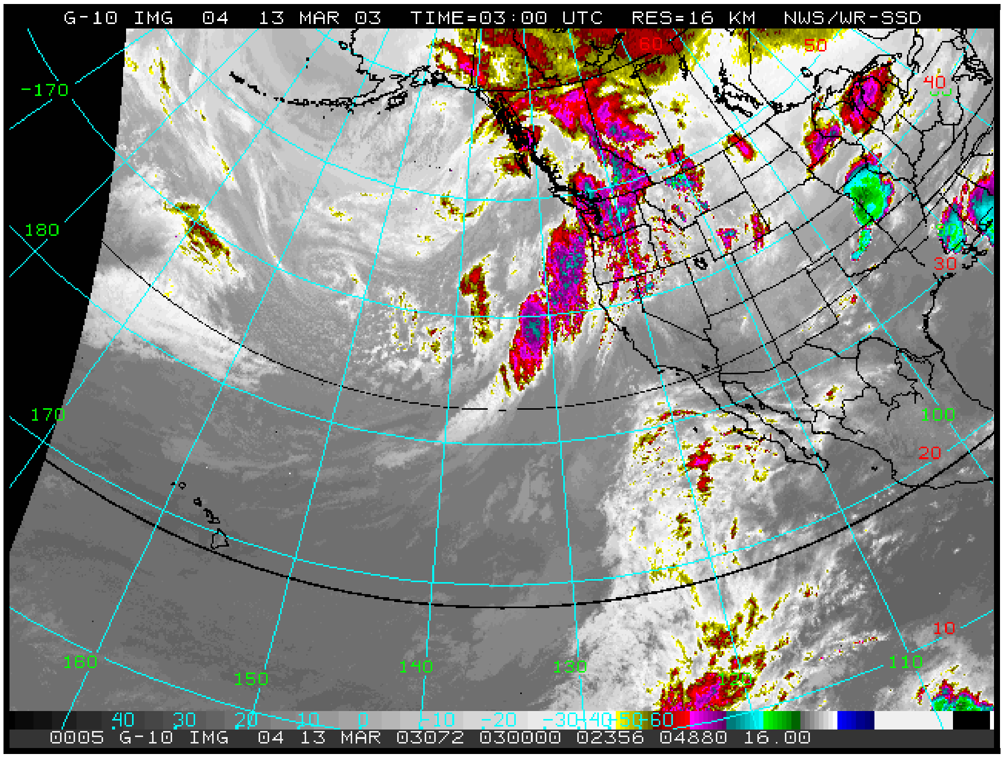
12 March 1000 – Cold front moves through project area as rain begins – we're sampling!



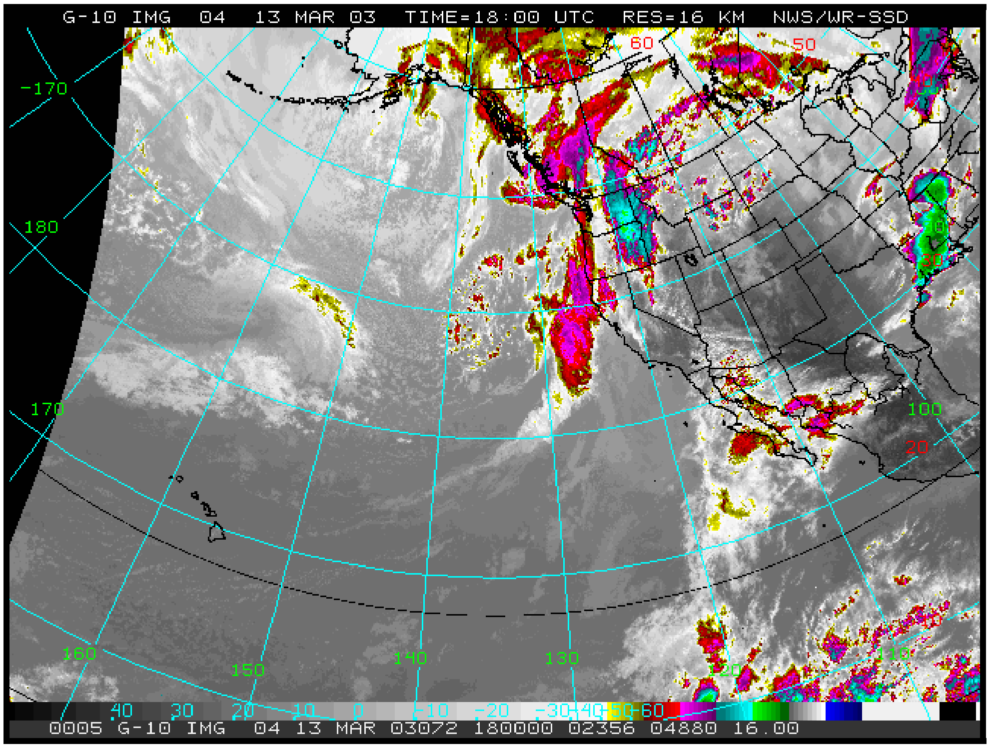
12 March 1300 – We've got a big, strong, wet storm pounding the area!



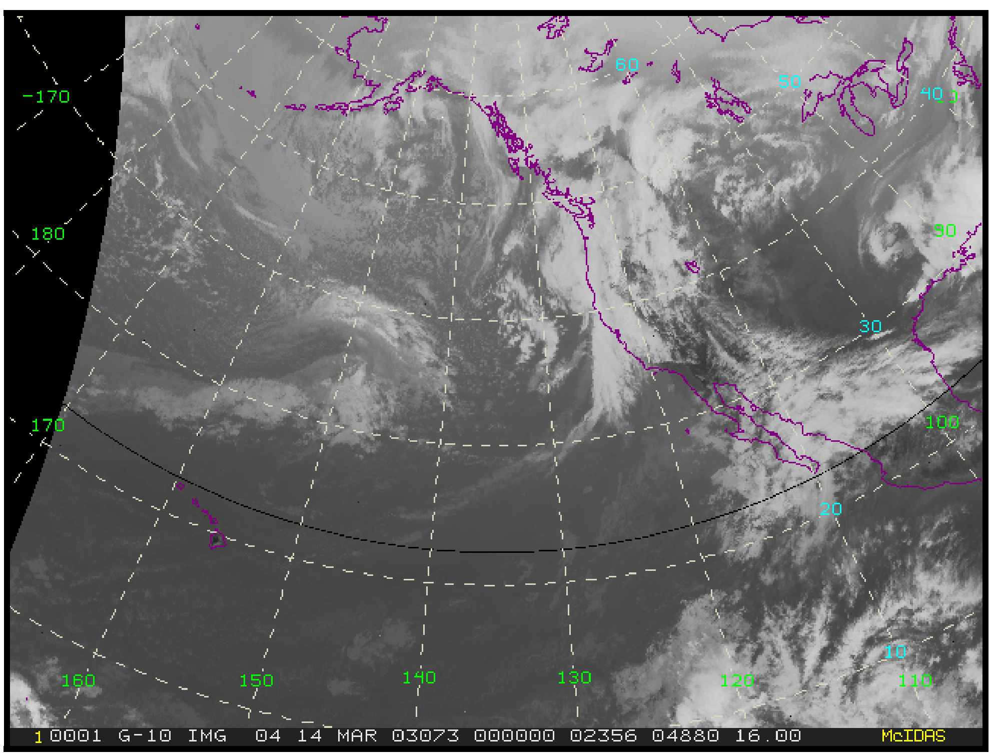
12 March 1700 – Storm stalls out of project area and waves of heavy rain sweep from south to north through the area.



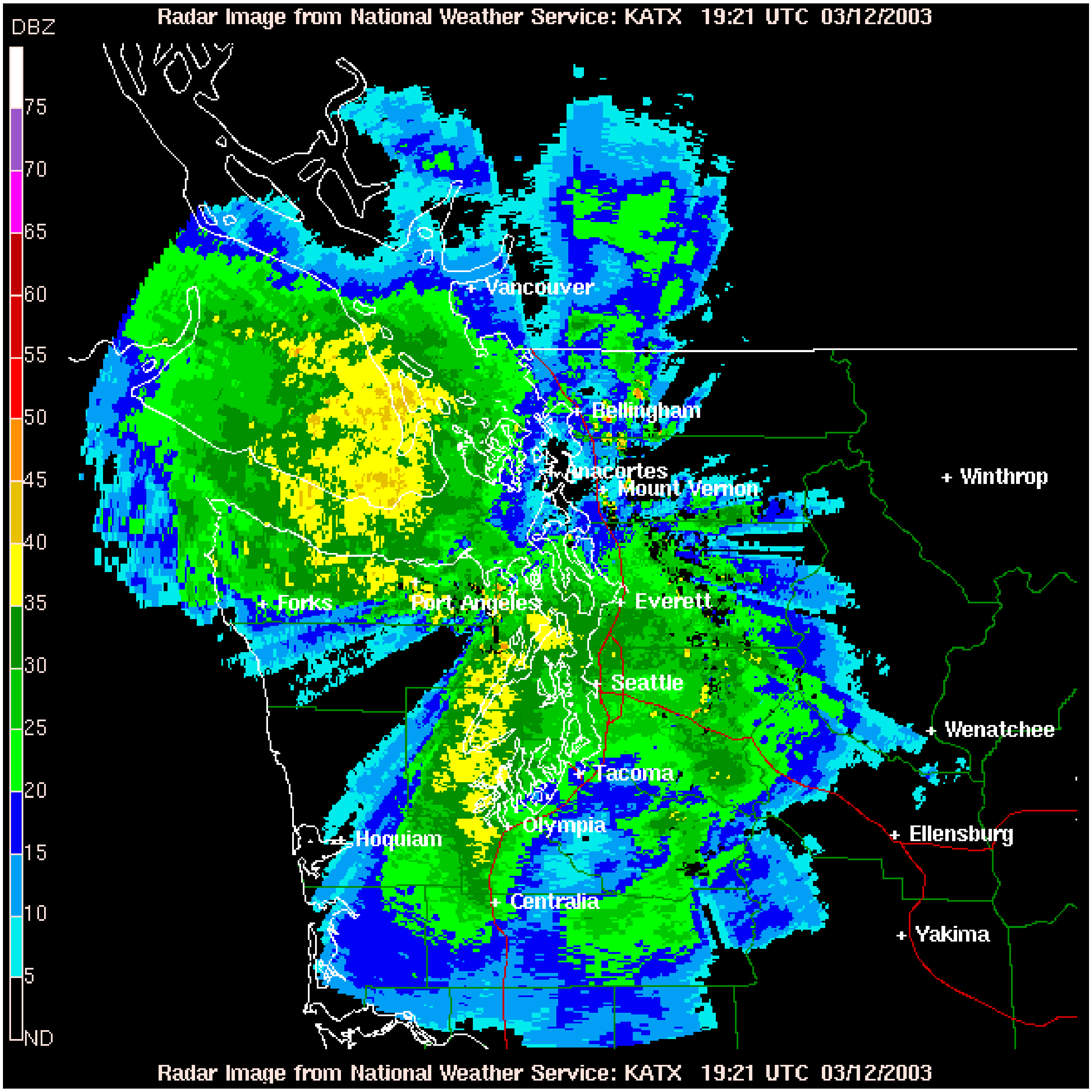
12 March 1900 – Storm has weakened but rain continues. 2nd round of fecals taken.



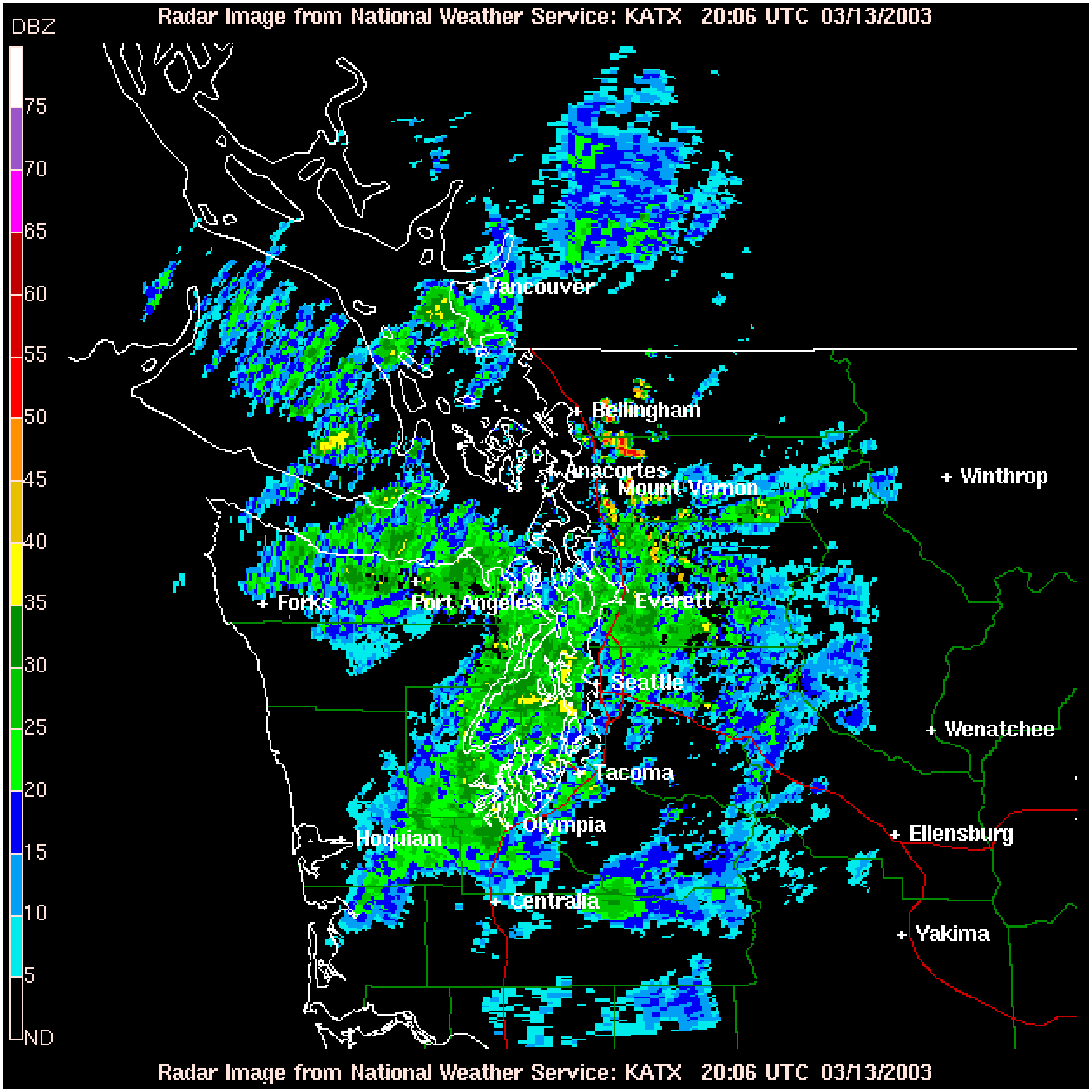
13 March 1000 – Secondary low forms off Northern CA as sampling continues in lighter rain.



13 March 1600 – Sampling ends as rain transitions to scattered showers in area and secondary low sweeps into CA. The 2002-2003 In-Stream Storm Sampling Season is complete!



12 March 1121 – Heavy rain begins in project area, 1st round of fecals taken.

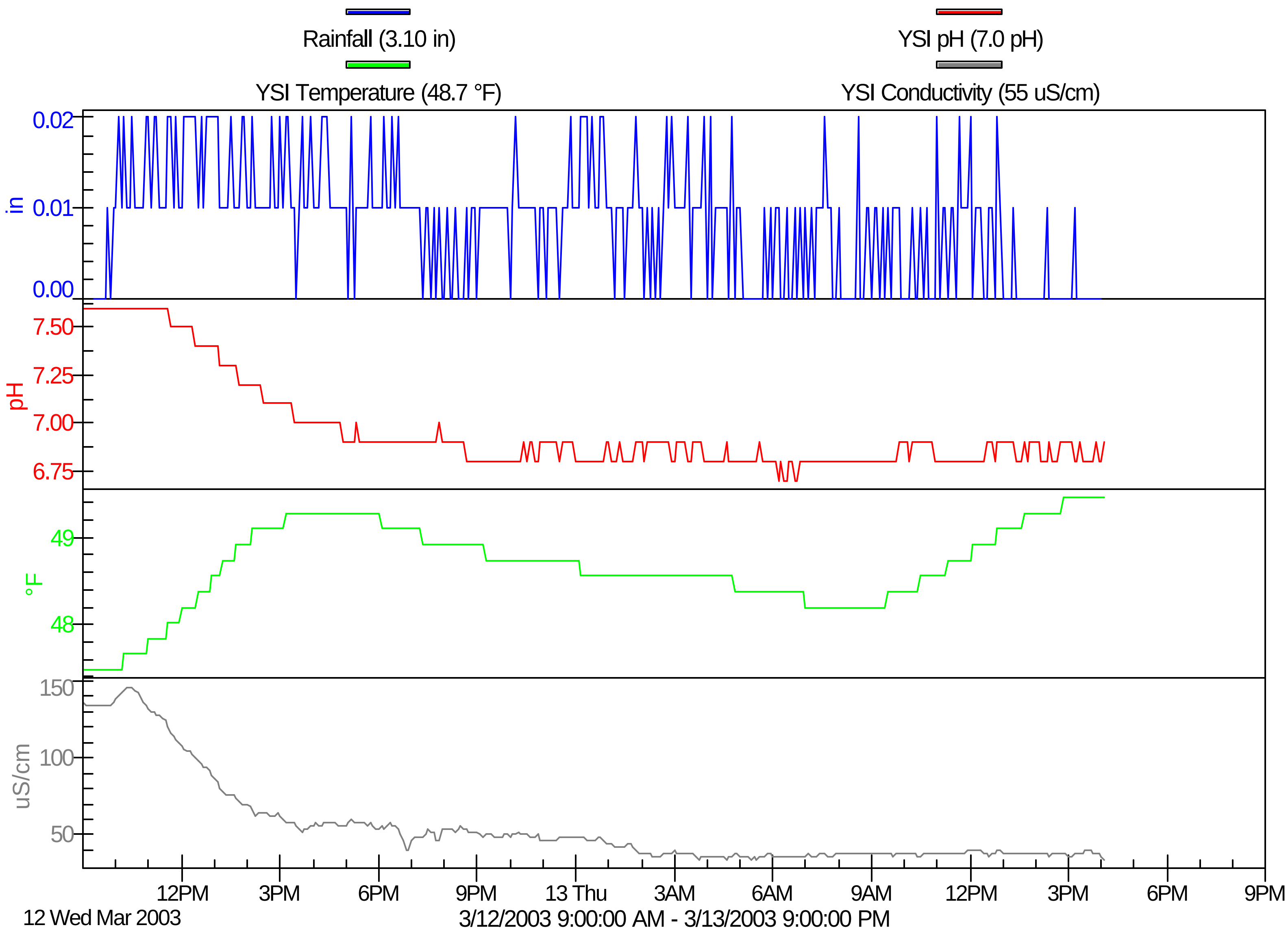


13 March 1206 – Radar image for W. WA – note heaviest rain (yellows) over project area.

Appendix B
Flowlink Rainfall and Physio-Chemical Data and Fecal Coliform CoC Forms

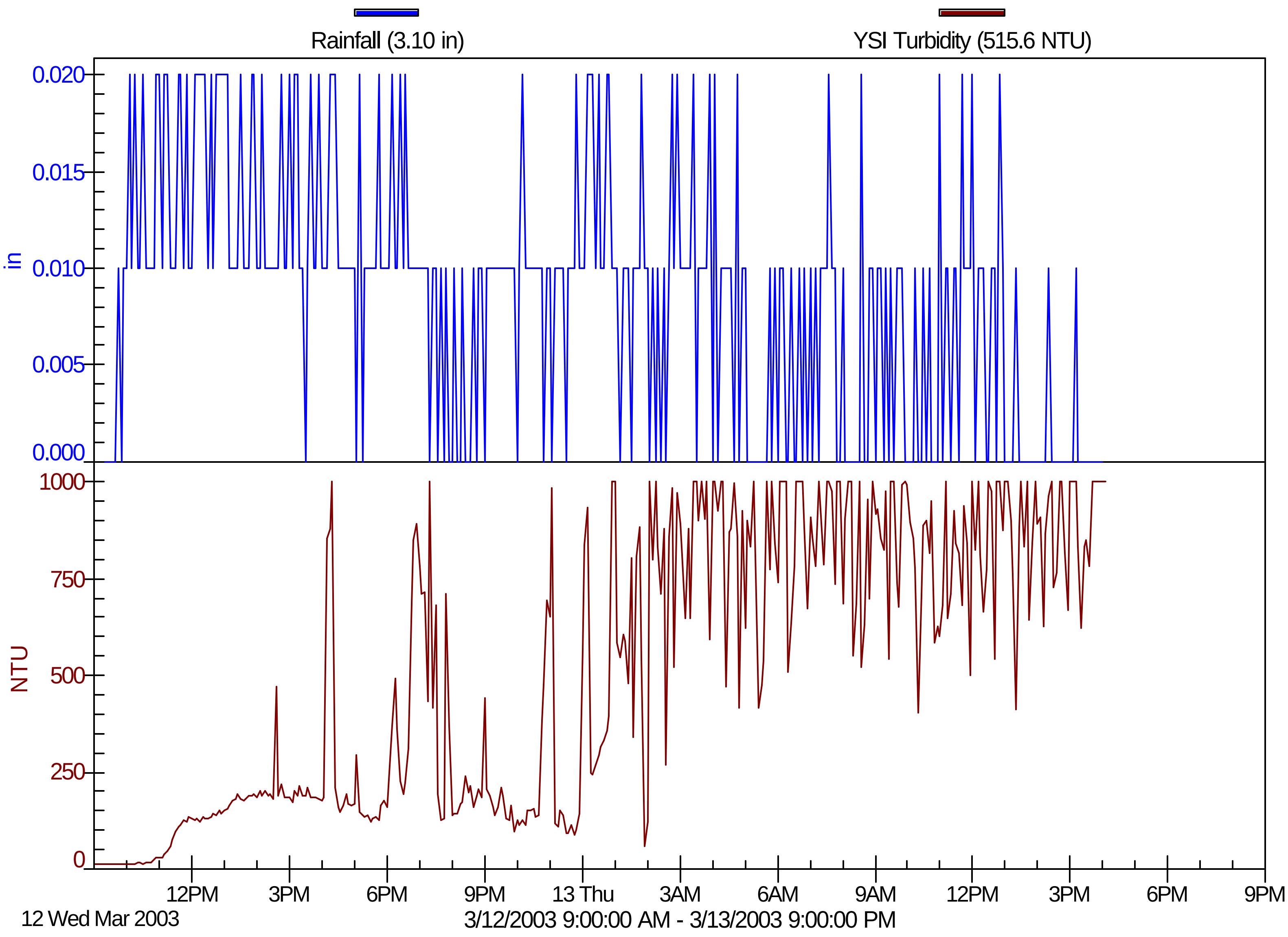
BA

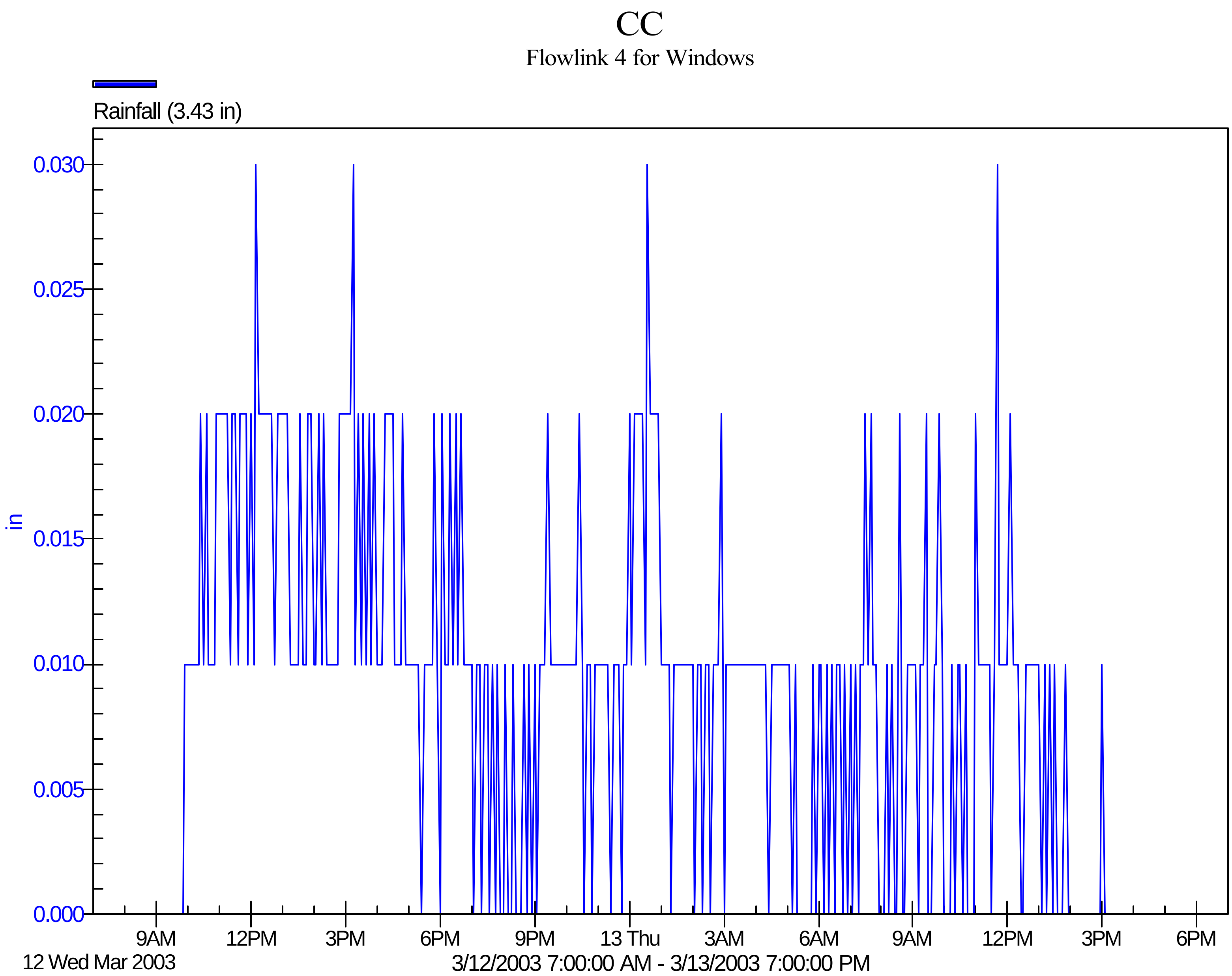
Flowlink 4 for Windows



BA

Flowlink 4 for Windows




CC
Flowlink 4 for Windows
Rainfall (3.43 in)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
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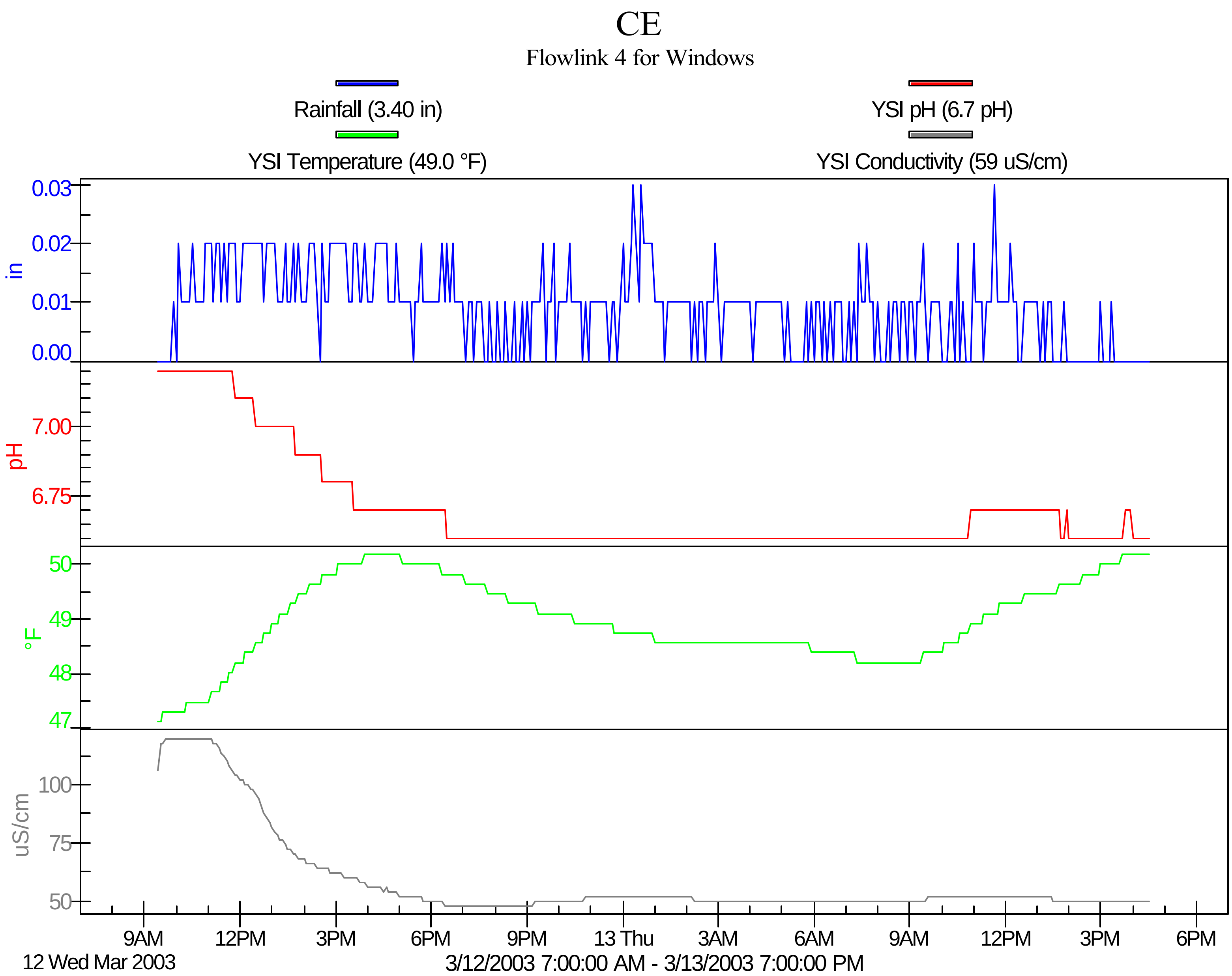
CE
Flowlink 4 for Windows
Rainfall (3.40 in)
YSI pH (6.7 pH)
YSI Temperature (49.0 °F)
YSI Conductivity (59 uS/cm)
in
0.03
0.02
0.01
0.00
pH
7.00
6.75
°F
50
49
48
47
uS/cm
100
75
50
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
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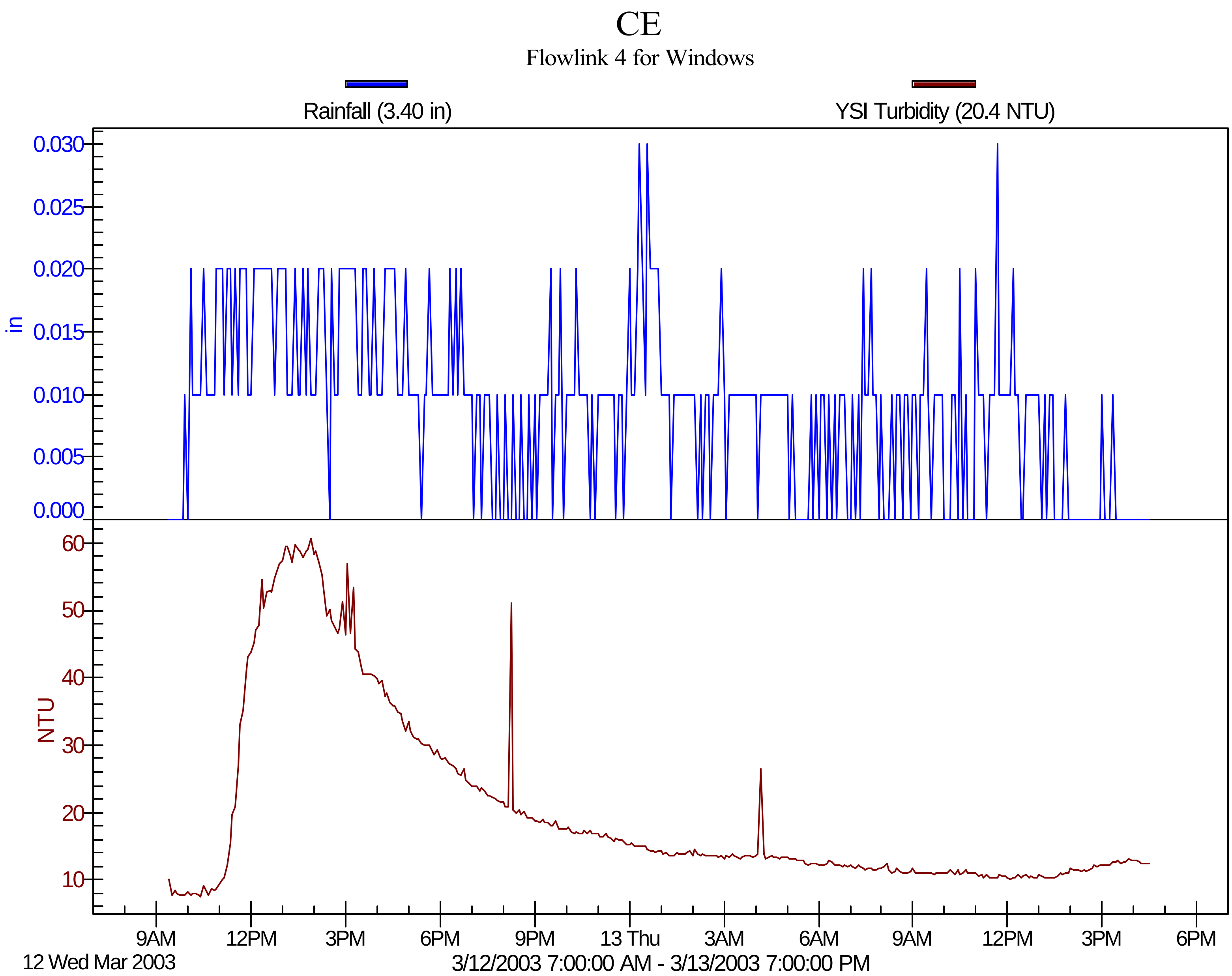
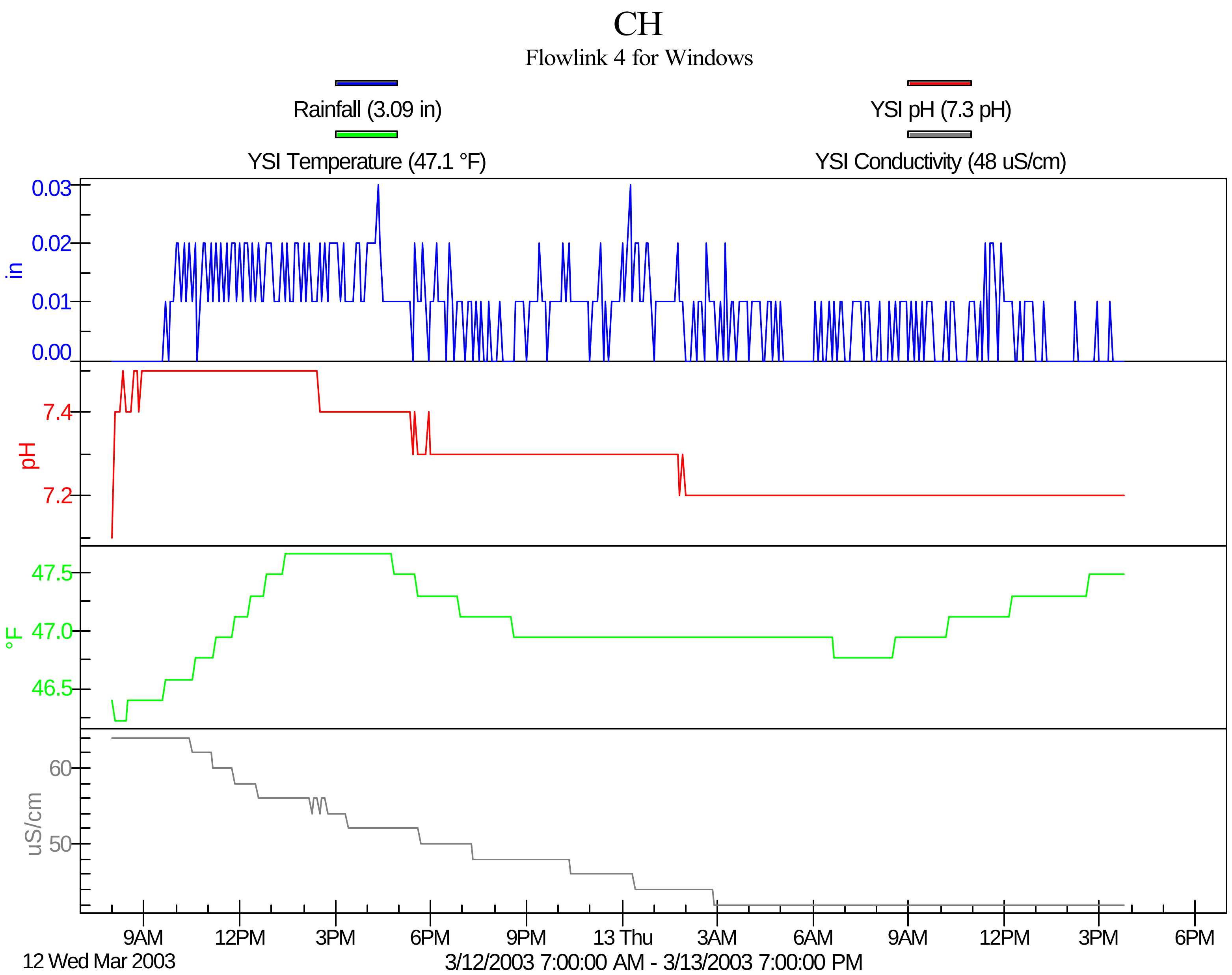
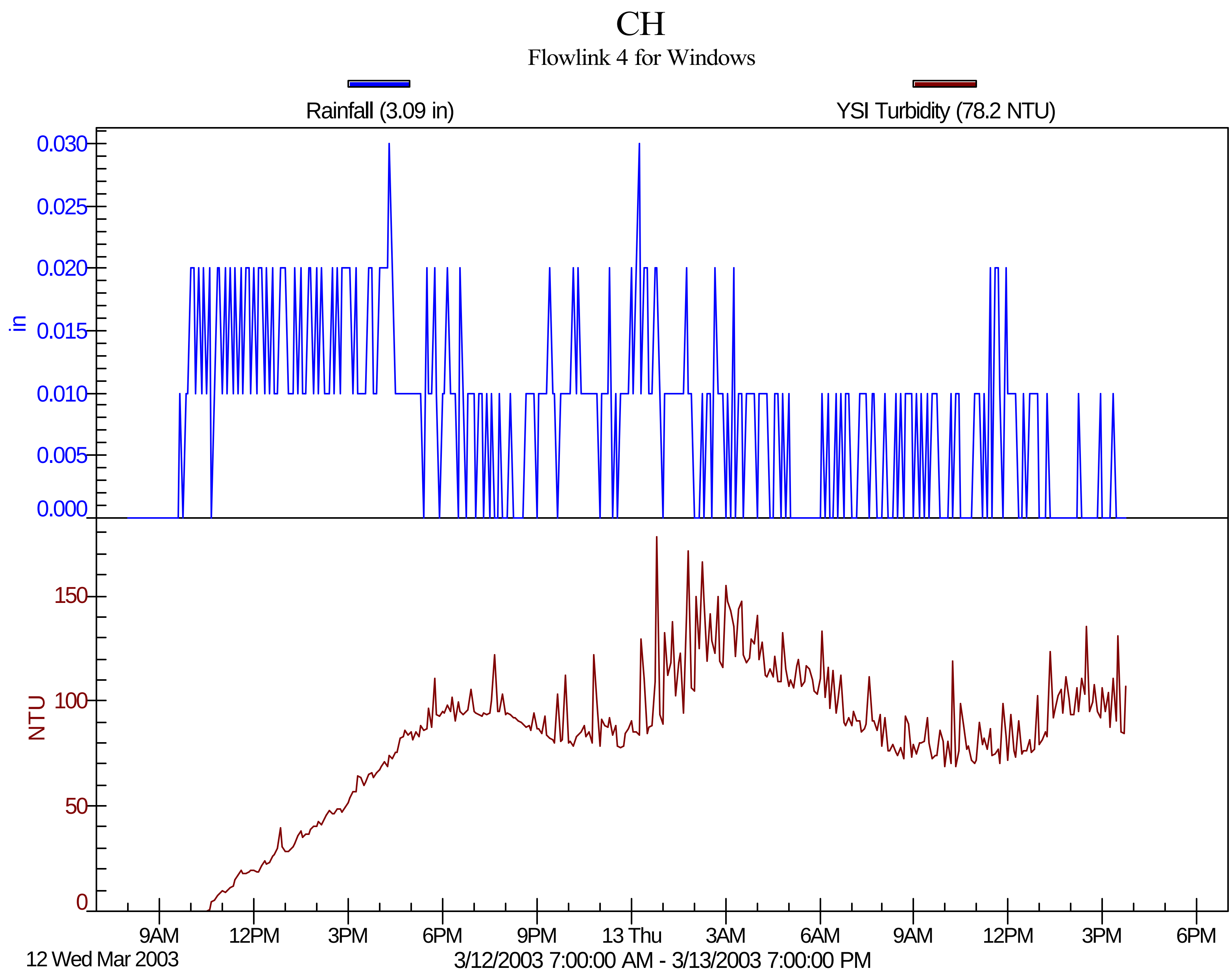
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM

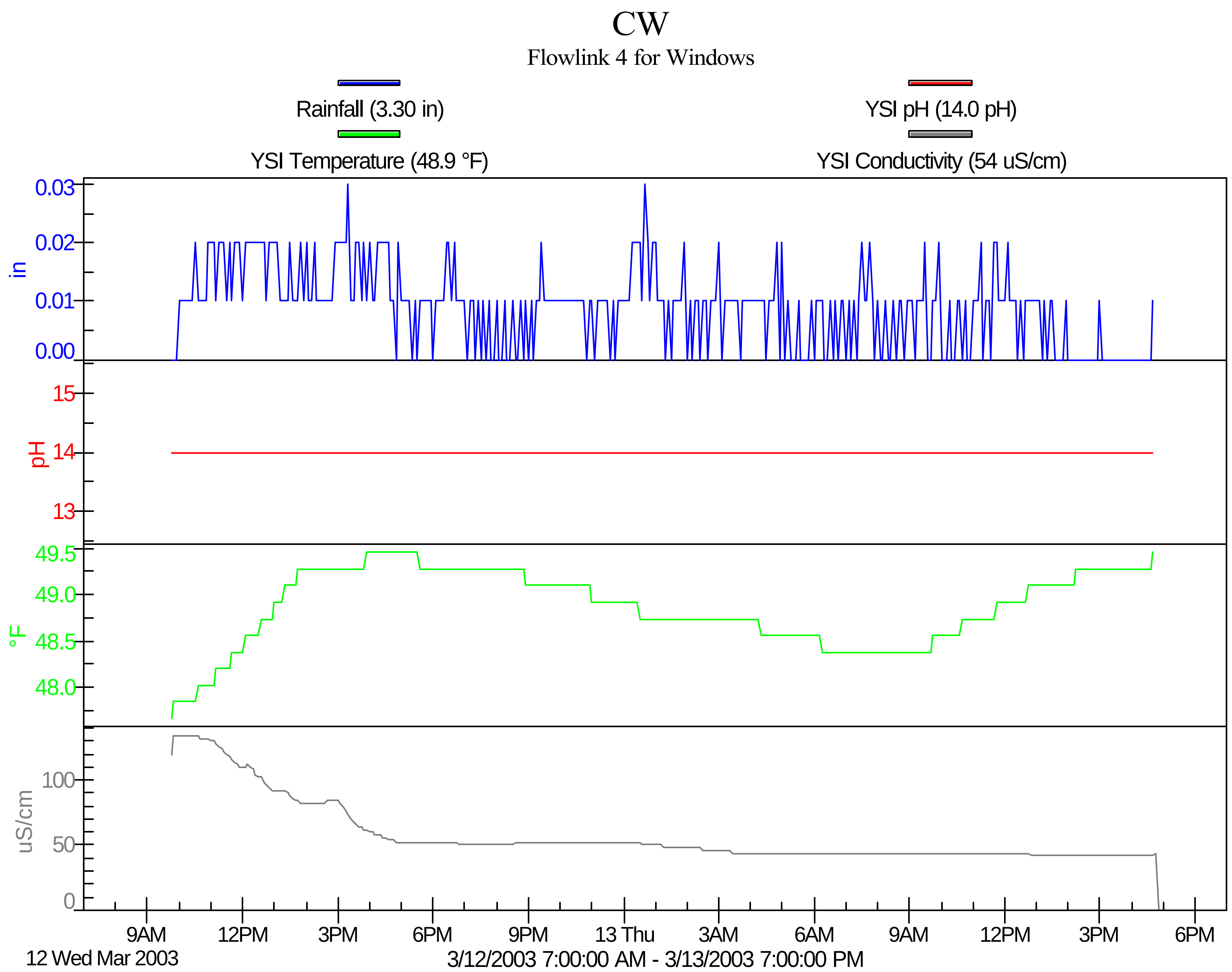


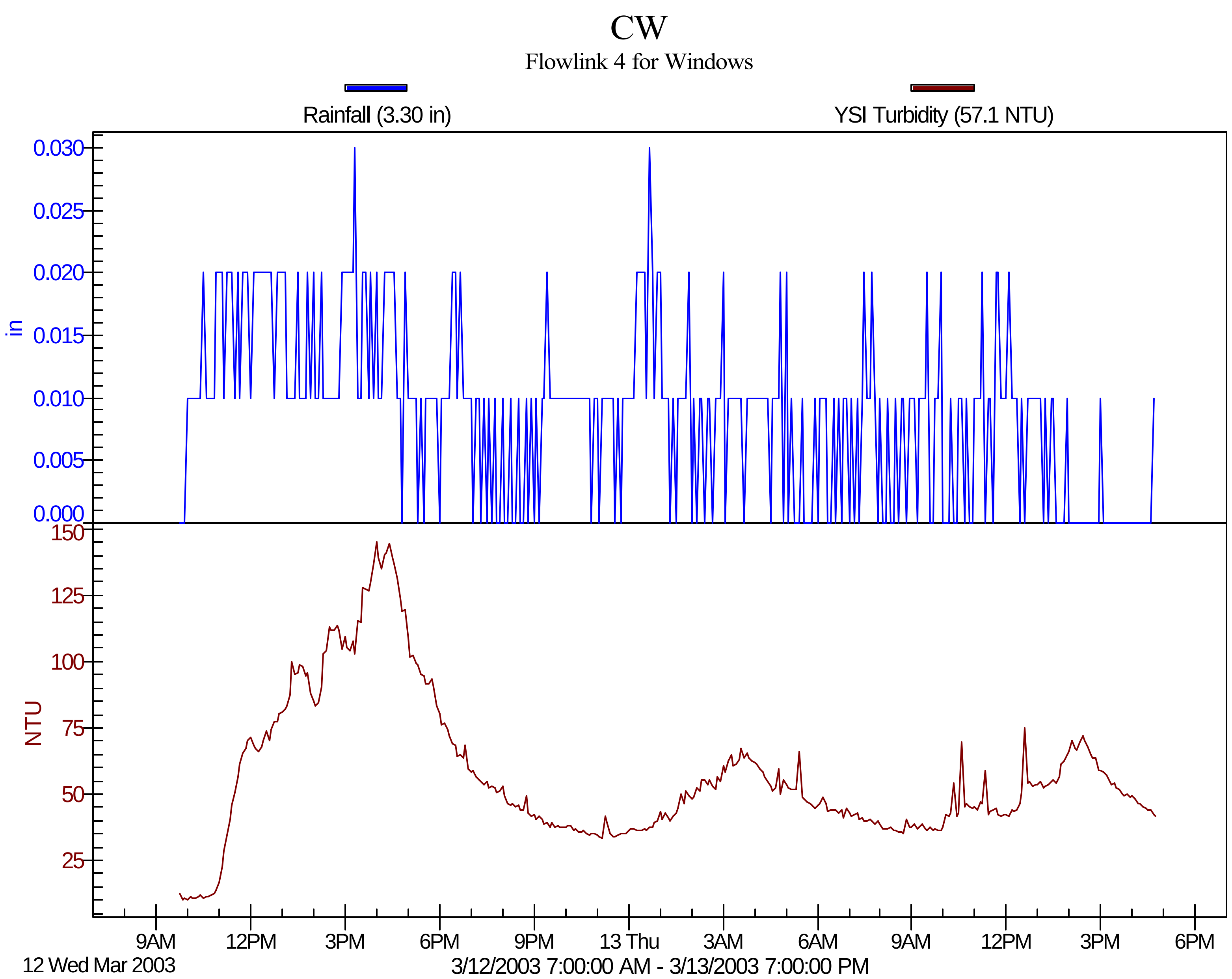
CE
Flowlink 4 for Windows
Rainfall (3.40 in)
YSI Turbidity (20.4 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
60
50
40
30
20
10
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM



CH
Flowlink 4 for Windows
Rainfall (3.09 in)
YSI pH (7.3 pH)
YSI Temperature (47.1 °F)
YSI Conductivity (48 uS/cm)
in
0.03
0.02
0.01
0.00
pH
7.4
7.2
°F
47.5
47.0
46.5
uS/cm
60
50
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM


CH
Flowlink 4 for Windows
Rainfall (3.09 in)
YSI Turbidity (78.2 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
150
100
50
0
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM


CW
Flowlink 4 for Windows
Rainfall (3.30 in)
YSI pH (14.0 pH)
YSI Temperature (48.9 °F)
YSI Conductivity (54 uS/cm)
in
0.03
0.02
0.01
0.00
pH
15
14
13
°F
49.5
49.0
48.5
48.0
uS/cm
100
50
0
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM


CW
Flowlink 4 for Windows
Rainfall (3.30 in)
YSI Turbidity (57.1 NTU)
in
0.030
0.025
0.020
0.015
0.010
0.005
0.000
NTU
150
125
100
75
50
25
9AM
12PM
3PM
6PM
9PM
13 Thu
3AM
6AM
9AM
12PM
3PM
6PM
12 Wed Mar 2003
3/12/2003 7:00:00 AM - 3/13/2003 7:00:00 PM

Chain of Custody Form

Sample Collector	Rupert, Estes, Gaudette, Whittaker	PSNS Project ENVVEST
Sampling Team	The Environmental Company (TEC)-Storm Event #6b	FC TMDL STUDY
Organization		

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03110453	Chico	3/12/2003	11:20	46.9	7.5	0.060	15.4	12	
03110454	Strawberry	3/12/2003	11:40	48.7	7.4	0.085	129.0	12	
03110455	Barker	3/12/2003	11:45	48.0	7.5	0.109	114.4	12	
03110456	Clear Main	3/12/2003	12:00	48.2	6.2	0.181	50.0	12	
03110457	Clear East	3/12/2003	12:10	48.4	7.1	0.101	43.4	12	
03110458	Clear East DUP	3/12/2003	12:10	48.4	7.1	0.101	43.4	12	
03110459	Clear West	3/12/2003	12:15	48.6	95.2*	0.108	56.0	12	*Suspect pH Reading
03110460	Chico	3/12/2003	21:30	46.9	7.3	0.047	85.6	12	
03110461	Strawberry	3/12/2003	21:50	48.6	6.9	0.055	523.4	12	
03110462	Barker	3/12/2003	22:10	48.7	6.8	0.051	104.2	12	
03110463	Barker DUP	3/12/2003	22:10	48.7	6.8	0.051	104.2	12	
03110464	Clear Main	3/12/2003	22:20	49.2	5.8	0.083	22.6	12	
03110465	Clear East	3/12/2003	22:40	48.9	6.6	0.050	16.3	12	
03110466	Clear West	3/12/2003	22:50	49.1	73.5*	0.052	46.0	12	*Suspect pH Reading

Preservatives Used:		
Relinquished By/Date:	Method of Shipment:	
Received By/Date:	Airbill No.:	
Relinquished By/Date:	Laboratory	
Received By/Date:	Address:	
Relinquished By/Date:		Custody Seals Present? Yes No
Received By Lab/Date:		Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Chain of Custody Form

Sample Collector	Rupert, Estes, Gaudette, Whittaker	PSNS Project ENVVEST
Sampling Team	The Environmental Company (TEC)-Storm Event #6b	FC TMDL STUDY
Organization		

Ecology ID	Station Code	Date	Time	Temp	pH	Cond	Turb	Source Code	Remarks/Comments
03110467	Chico	3/13/2003	6:50	46.9	7.2	0.043	93.8	12	
03110468	Strawberry	3/13/2003	7:05	48.0	6.7	0.052	297.0	12	
03110469	Strawberry DUP	3/13/2003	7:05	48.0	6.7	0.052	297.0	12	
03110470	Barker	3/13/2003	7:25	48.2	6.8	0.038	127.2	12	
03110471	Clear Main	3/13/2003	7:35	48.5	5.8	0.076	19.0	12	
03110472	Clear East	3/13/2003	7:50	48.2	6.6	0.050	12.4	12	
03110473	Clear West	3/13/2003	8:00	48.4	57.5*	0.045	38.7	12	*Suspect pH Reading
03110474	Chico	3/13/2003	15:50	47.5	7.2	0.042	87.5	12	
03110475	Barker	3/13/2003	16:05	49.5	6.8	0.033	1011.0	12	
03110476	Clear Main	3/13/2003	16:20	49.9	5.9	0.076	19.5	12	
03110477	Clear East	3/13/2003	16:25	50.2	6.6	0.051	12.2	12	
03110478	Clear West	3/13/2003	16:45	49.5	53.5*	0.044	39.6	12	*Suspect pH Reading
03110479	Strawberry	3/13/2003	17:00	49.0	6.8	0.052	1412.0	12	

Preservatives Used:		
Relinquished By/Date:	Method of Shipment:	
Received By/Date:	Airbill No.:	
Relinquished By/Date:	Laboratory	
Received By/Date:	Address:	
Relinquished By/Date:		Custody Seals Present? Yes No
Received By Lab/Date:		Custody Seals Intact? Yes No

Source Codes: 12 - Stream/River, 13 - Lake/Reservoir, 14 - Estuary/Ocean, 17 - Surface Runoff/Pond, 36 - Industrial Runoff/Pond

Appendix C
Storm #6b Images

11 March - CH – Low water level (~2.20') prior to storm.

13 March - CH – High water during storm (~3.60' – an increase of over 1.4'!)

13 March – CH – High water at Chico Main.

11 March – SC – Low water prior to storm (~0.6'). Note clarity of water.

12 March – SC – High water during storm (~1.0'). Note suspended sediment in water.

11 March – SC – Low water prior to storm.

12 March – SC – High water during storm.

11 March – CC – Low water prior to storm. Note leaves caught up in the "top" of the Sonde – high water mark from Storm #6a.

12 March – CC – High water during storm. Note that only the very top of the green post is above water.

11 March – CC – Low water prior to storm.

12 March – CC – High water during storm.

12 March – CE – Creek is rising…

13 March – CE – Creek level is up to "elbow" of sampling tube.

11 March – CE – Low water close up view of gauge.

12 March – CE – High water during storm – creek has risen over 1'.

13 March – Downstream from CE (looking northeast across road) – CE is running bank full.

11 March – CW – Low water prior to storm.

12 March – CW – Creek is rising…

13 March – CW – High water. Note green post is now underwater!

13 March – CW – Low water prior to storm – note green post.

13 March – CW – High water during storm – note green post is now underwater!