#3 WDWA

COSMOPOLITAN ENGINEERING GROUP

Civil, Environmental, and Recreational Consulting

Seattle-Tacoma International Airport

Dissolved Oxygen Deicing Study

Prepared for:

Port of Seattle
Sea-Tac International Airport
P.O. Box 1209
Seattle, Washington 98111

Prepared by:

Cosmopolitan Engineering Group
117 South 8th Street
Tacoma, Washington 98402

August 1999

AR 042698

8th & Pacific
117 South 8th Street
Tacoma, WA 98402
(253) 272-7220
Fax: (253) 272-7250

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Northwest Regional Office, 3190 - 160th Ave S.E. • Bellevue, Washington 98008-5452 • (425) 649-7000

October 21, 1999

Mr. Tom Hubbard
Surface Water Program
Port of Seattle
P.O. Box 68727
Seattle, WA 98168-0727

Dear Mr. ~~Hubbard~~ Tom:

Re: Port of Seattle, Sea-Tac International Airport
Dissolved Oxygen De-Icing Study (Final Draft)

Lisa Austin, Tom Luster and I have reviewed the draft final Dissolved Oxygen De-Icing Study submitted by the Port of Seattle on August 16, 1999 in responding to an anticipated 401 Certification monitoring requirement on the impacts of de-icing agents from airport storm water run-off to Miller and Des Moines Creeks. The comments provided below reflect a summary of concerns and criticisms of the study by the three reviewers listed above.

The data clearly show large BOD_5 discharges to both the NW Ponds and Lake Reba. Considering the relatively rapid transit time through and brief residence time in Des Moines and Miller Creeks, one would expect to see any impacts of BOD_5 discharges in Puget Sound and not in the stream systems. To support this conclusion, Streeter-Phelps analyses and modeling on both stream systems should have been conducted.

On page 4-9 of the study, there is a discussion of tributary sampling in the Des Moines Creek East Basin which revealed the highest concentration of BOD_5 (1,176 mg/l) detected in the study and led the Port to conclude that this was an indication that high BOD_5 producing chemicals were being used and discharged into stormwater from elsewhere in the basin. Ecology does not reach the same conclusion. Port of Seattle outfalls SDE4 and SDS1 also discharge into this basin and may be sources for high BOD_5 discharges, as well as any off-site contributions.

The Port should be mindful that glycols are applied to aircraft in some cases on a daily basis at the airport. Small amounts of glycols shear and drip from these aircraft and are introduced into the stormwater drainage system around the runways. This could well be a constant source of BOD_5 discharges to Lake Reba and the NW Ponds that contributes to the low DO levels found in both of these systems between storm events during this study. The Port should consider investigating this hypothesis further.

Creek Detention Facility and almost all the time at the downstream sampling points. These same trends are generally evident in Figures 7, 8, 10, & 11, showing conditions in Des Moines and Miller Creeks for about a two-week period around the December 98 deicing event.

Overall, this indicates that portions of both Miller and Des Moines Creeks were not meeting the applicable water quality criterion, at least in those locations and on those dates. It is difficult to determine, however, what this means as far as its effect on characteristic beneficial uses. Ecology believe this points more to the generally degraded conditions in the watersheds rather than one set of activities in the basins. Ecology believes that this finding is critical to a more complete understanding of Miller and Des Moines Creeks' ecosystems and it is a finding that should be shared with watershed planning authorities working on the restoration of these systems.

Should the Port of Seattle wish to re-submit this study with an addendum addressing the concerns and criticism of Ecology outlined in this letter, Ecology would be happy to re-evaluate the study. Unfortunately, given the deficiencies of the final draft study, Ecology can not make a fully informed decision as to whether or not the Port of Seattle is properly managing de-icing agents in use at Sea-Tac International Airport to prevent water quality impacts to Miller and Des Moines Creeks.

Please contact me at (425) 649-7037 to answer any questions on this letter or for further assistance on Port of Seattle's NPDES permit.

Sincerely,

Kevin C. Fitzpatrick
Supervisor
Industrial Wastewater Permit Unit
NWRO Water Quality

KCF:kcf:gm
cc: Elizabeth Leavitt, Port of Seattle
Tom Luster, Ecology SEA
Lisa Austin, Ecology WQ NWRO
Ray Hellwig, Regional Director NWRO

The study erroneously describes Des Moines and Miller Creeks as Class A waters and uses the Class A criterion for dissolved oxygen. Both the NPDES permit and last year's 401 describe them as Class AA waterbodies, and the Port's Natural Resource Mitigation Plan describes them as Class AA waters. Also, Lake Reba could be considered Lake Class. All narrative, figures, and tables should be corrected to compare the study's findings to the Class AA (9.5 mg/L) or Lake Class ("no measurable decrease from natural conditions") criterion.

Ecology is concerned that the findings of the study are based on only two de-icing events, which is a less than optimal sample size in developing robust and defensible statistical conclusions. In addition, background levels are based on samples taken on just one day, December 9, 1998. Given the highly variable D.O. levels in the creeks, it would have been helpful to have more background samples from a longer period of time.

This study used samples from Des Moines and Miller Creek tributaries as controls. Ecology believes that a more representative sampling plan would have included samples at points upstream and downstream from the Port's discharge points to more accurately assess Port-related effects in the receiving waters. Using the tributaries as controls does not serve this purpose.

The correction factors applied to the in-stream measurements of dissolved oxygen (D.O.) are puzzling and somewhat troubling to Ecology. The values of the correction factors ranged from –1.43 mg/l to +5.2 mg/l as detailed in the study's Appendix D. The study seemed content to work around this startling variability, rather than to have taken measures to reduce the variability through a more aggressive program of accurate in-stream D.O. measurement through timely maintenance and calibration of in-stream D.O. meters

Among the conclusions that Ecology draws from this draft final study is that some parts of both Des Moines and Miller Creeks do not meet the D.O. criterion for some time period. Samples taken in the upper watersheds did not meet the criterion for a majority of the sampling period.

This is pretty consistent throughout the study. The background sampling shows that D.O. levels in 5 of 18 samples (28%) were below the Class AA criterion (and in fact, that 4 were below Class A (22%), and 3 below Class B (17%)). Control samples taken during the various stages of the deicing events show a range of D.O. levels and a range of compliance with the D.O. criterion. Samples taken during all three stages of the December 11 event (Table 11) shows 2 of 31 samples not meeting the criterion (6%); the February event shows 4 of 14 samples not meeting the criterion (29%).

Figure 4 shows that in Des Moines Creek, the 9.5 mg/L D.O. criterion was generally not met during the 3-month sample time period upstream of the Golf Course Weir. The criterion was met about half the time at the weir, and was usually met downstream from the Des Moines Wastewater Treatment Plant. Figure 5 shows that, in Miller Creek, for the same sample time period, the 9.5 mg/L D.O. criterion was met about half the time at Lake Reba and the Miller

Agency Review Draft

Seattle-Tacoma International Airport

Dissolved Oxygen Deicing Study

Prepared for:

Port of Seattle
Sea-Tac International Airport
P.O. Box 1209
Seattle, Washington 98111

Prepared by:

Cosmopolitan Engineering Group
117 South 8th Street
Tacoma, Washington 98402

August 1999

TABLE OF CONTENTS

Page

AR 042703

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

AR 042705

ACKNOWLEDGEMENT

Cosmopolitan Engineering Group would like to acknowledge the assistance of the Port of Seattle personnel. Scott Tobiason of the Port of Seattle was a valuable resource in coordinating deicing notification and outfall sampling. Cosmopolitan would like to recognize the outfall sampling crew, Scott Tobiason of the Port of Seattle, and Curtis Nickerson and Diana Seales of Taylor and Associates. Cosmopolitan would also like to recognize Aquatic Research and University of Washington for their efforts in accepting and analyzing samples within accepted holding times.

AR 042706

EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

The Port of Seattle applies potassium acetate and sodium acetate as deicing chemicals to runways, taxiways, and other airport operations ground surface areas at Sea-Tac International Airport (STIA) for safety during periods of freezing temperatures. This is an FAA requirement for the protection of people and property. The Port of Seattle curtailed the use of urea and glycol for ground surface deicing in 1996 as a Best Management Practice for water quality protection.

When rainfall occurs following a deicing event, a portion of the deicing chemicals are discharged from STIA stormwater outfalls in runoff to the Des Moines Creek and Miller Creek watersheds in the vicinity of the airport. The purpose of this study was to assess the dissolved oxygen (DO) profiles in the downstream water courses after deicing events to determine if the application and subsequent discharge of the deicing chemicals had a negative effect on water quality in the receiving stream.

MONITORING PROGRAM

During the study period of December 1998 through March 1999 there were two separate deicing events. Neither of these events resulted in snow accumulations that required plowing. In terms of the amount of potassium acetate applied during different deicing events since the winter of 1995-96, the December 1998 and February 1999 deicing events ranked third and fourth, respectively, out of a total of nine events over a four-year period. This was the first winter where sodium acetate was applied as a deicing chemical.

Continuously recording DO meters were installed at five locations on Des Moines Creek and at four locations along Miller Creek during the study. During and immediately following deicing events, sampling for DO and other parameters was performed at the mainstem monitoring stations and at selected tributaries along both creeks. Samples were collected prior to the start of runoff; during initial runoff after deicing and the later stages of runoff.

AR 042707

GENERAL OBSERVATIONS

Continuous monitoring data showed that dissolved oxygen concentrations in the two detention ponds that receive runway/taxiway runoff (Northwest Ponds in Des Moines Creek and Lake Reba in Miller Creek) fluctuated widely over the course of the study. The trends in DO at these locations generally followed trends in rainfall. During periods of little or no rainfall, the pond DO concentrations decreased well below saturation. Conversely, DO increased during periods of rainfall.

The lowest DO concentrations were observed during the first two weeks of January 1999, which was the only period of extended dry weather during the study. During this two-week dry period, there was no deicing activity at STIA. The second-lowest DO concentrations occurred during dry weather prior to the first deicing event in December. Investigation of the causes for low DO corresponding to dry weather was not an objective of this study.

At the Golf Course weir monitoring station 0.3 miles downstream from NW Pond 3 on Des Moines Creek, the DO concentration was observed to generally follow the trends in upstream DO concentration, although substantial reaeration had occurred by that point. Further downstream near the Des Moines wastewater treatment plant and the Des Moines Creek mouth at Puget Sound, DO concentrations were not as variable and were typically greater than 90% of saturation. DO concentrations in lower Des Moines Creek always exceeded the Class A water quality standard by a 2 to 5 mg/L.

At the Miller Creek Detention Facility monitoring station about 0.4 miles downstream from the outlet of Lake Reba, the DO concentration did not follow the DO trends in the lake. This is because the discharge from Lake Reba is only a tributary to Miller Creek whereas the NW Ponds are part of the headwaters for Des Moines Creek. Downstream from the Miller Creek Detention Facility, DO concentrations at the Miller Creek WWTP and Miller Creek mouth stations were typically greater than 90% of saturation and always exceeded the water quality standard. DO concentrations downstream of the NW Ponds and Lake Reba rapidly reaerated under all conditions.

AR 042708

EFFECTS OF DEICING CHEMICALS ON DISSOLVED OXYGEN CONCENTRATIONS

Deicing chemicals passed rapidly through both Des Moines and Miller Creeks after rainfall and runoff began following deicing events. During the December 1998 deicing event, deicing chemicals were completely flushed through NW Pond 3 and Lake Reba within 20 hours and 16 hours, respectively. Travel time in the creeks from NW Pond 3 and Lake Reba to Puget Sound was approximately 2 hours. Therefore, the deicing chemicals were present in the Miller and Des Moines Creek watersheds for less than 24 hours.

The quantity of deicing chemicals and rainfall volumes in the February 1999 deicing event did not produce measurable effects on DO in the detention ponds.

There was no reduction in DO concentration within either watershed when deicing chemicals were present in runoff. Conversely, the DO increased during these periods as it did in response to all precipitation events producing runoff.

CONCLUSION

No reduction in DO concentration was observed in Miller or Des Moines Creeks as a result of deicing chemical applications in December 1998 and February 1999. The periods of lowest DO in the ponds can not be attributed to deicing activities at STIA, but rather were dry weather phenomena.

AR 042709

SECTION 1: INTRODUCTION

1.1 AIRFIELD DEICING OPERATIONS

For the last four winter seasons, the Port of Seattle (Port) has monitored runoff from selected outfalls after runway (ground surface) anti-icing/deicing (referred to herein as deicing) at Seattle-Tacoma International Airport (STIA) (RPA, 1995; Port of Seattle, 1996 and 1997b). A variety of ground surface deicing chemicals have been applied to runways and taxiways. Deicing chemical application resulted in concentrations of deicing chemicals in stormwater below toxic levels (Port of Seattle, 1997a). However, Ecology has expressed concern that the oxygen demand in STIA snowmelt and runoff after runway and taxiway deicing events could adversely affect dissolved oxygen levels in Miller Creek and Des Moines Creek. The locations of STIA, Miller Creek and Des Moines Creek are shown in Figure 1.

Anti-icing and deicing runways and taxiways is an FAA requirement for the protection of people and property. In the Seattle area, a typical runway/taxiway deicing event consists of several days of cold temperatures, with or without snow accumulations followed by a warming trend that produces runoff from snowmelt and rainfall.

The Port has implemented Best Management Practices (BMPs) by eliminating the use of two ground surface deicing chemicals, urea and glycols. In addition, the Port constructed four major snow storage facilities that prevent deicing chemicals from entering stormwater (Port of Seattle, 1997b). The snowmelt and runoff from these snow storage areas drain to the Industrial Waste System (IWS) and Industrial Waste Treatment Plant (IWTP), which discharge directly to Puget Sound. Aircraft deicing operations use glycol-based treatments that are applied by airlines or their contractors. Glycols are used only in IWS areas.

1.2 PURPOSE

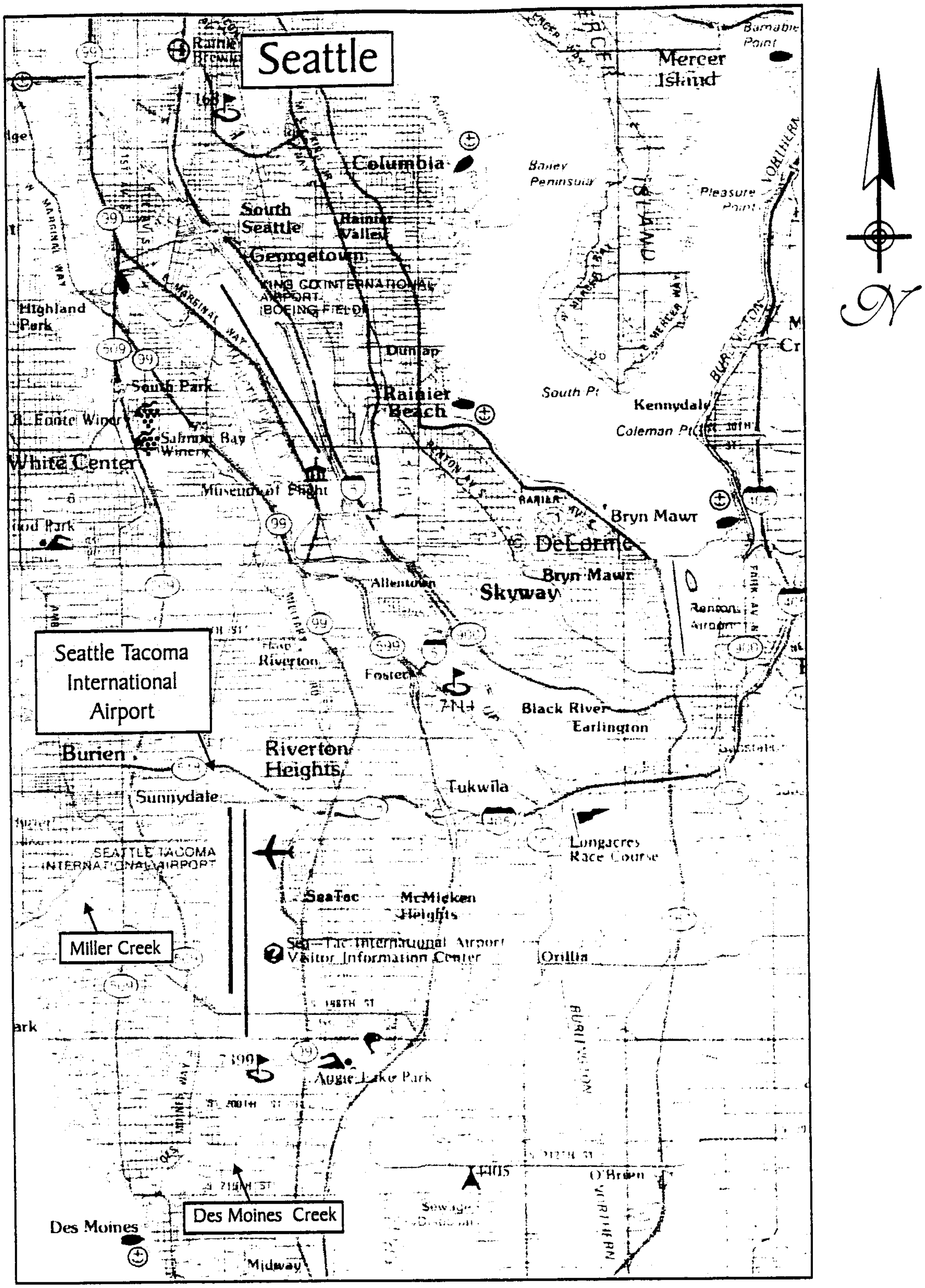
The purpose of this project is to determine if and to what degree adverse impacts exist in dissolved oxygen (DO) profiles in the downstream water courses of Miller Creek and Des Moines Creek after runway deicing events at STIA.

Because runway deicing occurs infrequently (typically two times per year), and only when temperatures are at or near freezing, the DO study was conducted during the period December 1998 through March 1999, when runway deicing was most probable. Because of recent concerns, Ecology requested that the Port also analyze metals in stormwater discharges concurrent with runway (ground surface) anti-icing/deicing events[1].

1.3 SCOPE

This study consisted of field measurements to assess the impact of runway/taxiway deicing on DO levels in Miller and Des Moines Creeks downstream of STIA stormwater outfalls. Flow, temperature, and DO were monitored at various locations in the creeks before, during, and after deicing events occurring in the 1998-99 winter season. BOD_5 concentrations and flow were also monitored for the STIA outfalls and other tributaries to Miller and Des Moines Creeks.

[1] In sample SDS3 112396 taken during runoff following a deicing event, the total recoverable copper value of 0.0388 was mistakenly entered as 0.388, an order of magnitude higher. This error was carried through in the November 1996 DMRs and the 1997 Annual Stormwater Monitoring Report (POS, 1997.) The Port brought this error to the attention of Ecology, but Ecology required sampling for and analyzing metals during the Dissolved Oxygen study.



File: MAP.CDR

ENGINEERING GROUP
COSMOPOLITAN
Civil, Environmental and Recreational Consulting

Figure 1:
Location of Study Area

SECTION 2: BACKGROUND

2.1 STIA STORMWATER SYSTEM

The Port owns approximately 2,500 acres of land at STIA. A total of 796 acres drain to Des Moines Creek through eight National Pollutant Discharge Elimination System[2] (NPDES)-permitted outfalls, three of which drain runways and taxiways subject to deicing (SDE4, SDS3, and SDS4). A total of 165 acres drain to Miller Creek through four permitted outfalls, two of which drain runways and taxiways subject to deicing (SDN3, and SDN4). There are 370 acres where aircraft fueling, aircraft deicing, servicing, and other activities take place that drain to the IWS. After treatment at the IWTP, the treated water is discharged via a deepwater outfall to Puget Sound (Port of Seattle, 1997b). These subbasins and their outfalls are shown in Figure 2, an excerpt from the Stormwater Pollution Prevention Plan (SWPPP) (POS, 1998).

2.2 MILLER AND DES MOINES CREEKS

Miller Creek drainage basin is approximately 5,200 acres. The Des Moines Creek drainage basin is approximately 3,700 acres. Table 1 lists estimates of relative area and storm flow volume that STIA contributes to these drainage basins. In the Miller Creek drainage, STIA generates less than 5 percent of the total flow to Miller Creek. STIA's annual average contribution to Des Moines Creek is approximately 24 percent of all streamflow (Port of Seattle 1997a).

Table 1 STIA Contribution to Miller and Des Moines Creeks

Creek Location	Airport Area of Watershed (%)		Annual Flow Volume (%)
	Total	Impervious	
Miller Creek Detention Facility	7.0	14	8.3
Miller Creek mouth	3.2	<5	2.8
Des Moines Creek mouth	21		24

Port of Seattle 1997a

AR 042713

[2] Washington State Department of Ecology (Ecology) issued NPDES Waste Discharge Permit No. WA-002465-1 to the Port of Seattle for the operation of Seattle-Tacoma International Airport IWS on June 30, 1994. The NPDES Permit was reissued March 1, 1998, for IWS and stormwater discharges.

Figures 1 and 3 show the locations of Miller and Des Moines Creeks and the tributaries discharging into each creek. Subbasins SDN3, SDN4, SDN1, the North Employee Parking Lot (NEPL), and non-STIA drainage from SR 518 drain into a detention pond identified as Lake Reba. Lake Reba discharges into Miller Creek, which flows through the Miller Creek Detention Facility (built in 1992) and 3.2 miles to Puget Sound.

A detention facility identified as the NW Ponds lie in the headwaters of the west branch of Des Moines Creek. NW Ponds was built in 1970 and consists of three cells. NW Pond inlet (non-STIA) and STIA Subbasins B, D, and SDW3 discharge into Cell 1 upstream of the other two cells. These subbasins rarely receive deicing chemicals. SDS3, the largest of the four runway subbasins, drains into NW Pond Cell 3. SDS4 discharges directly into Des Moines Creek just upstream of the Tyee Golf Course weir. Subbasins SDS1 and SDE4 drain to the east branch of Des Moines Creek (identified as East Basin) which passes through the Tyee Pond Detention Facility. SDS1 drains rooftops, parking lots and a small portion of ramp that receives little if any direct deicing chemical application. From the NW Pond outlet, Des Moines Creek flows 2 ½ miles to Puget Sound. One wastewater treatment plant (WWTP) is located adjacent to each creek, though the plants' discharges are piped directly to Puget Sound.

2.3 RUNWAY DEICING OPERATIONS

Deicing chemicals applied to the runways and taxiways include calcium-magnesium acetate (CMA), sodium acetate (NAC), and potassium acetate (PA). The Port generally applies only PA to runways and taxiways. CMA and NAC are usually applied only to vehicle traffic areas. Ground deicing chemicals are only applied to the runway and taxiways when temperatures approach freezing, which occurs infrequently and may occur with or without snowfall accumulation. Anti-icing refers to the application of deicing chemicals when taxiway and runway surfaces approach freezing temperatures. Deicing refers to the application of deicing chemicals to remove ice from taxiway and runway surfaces. Anti-icing and deicing runways and taxiways is an FAA requirement for the protection of people and property. In a typical year, deicing chemicals are applied to the runways and taxiways during two to three freezing periods in the winter months (POS, 1999).

AR 042714

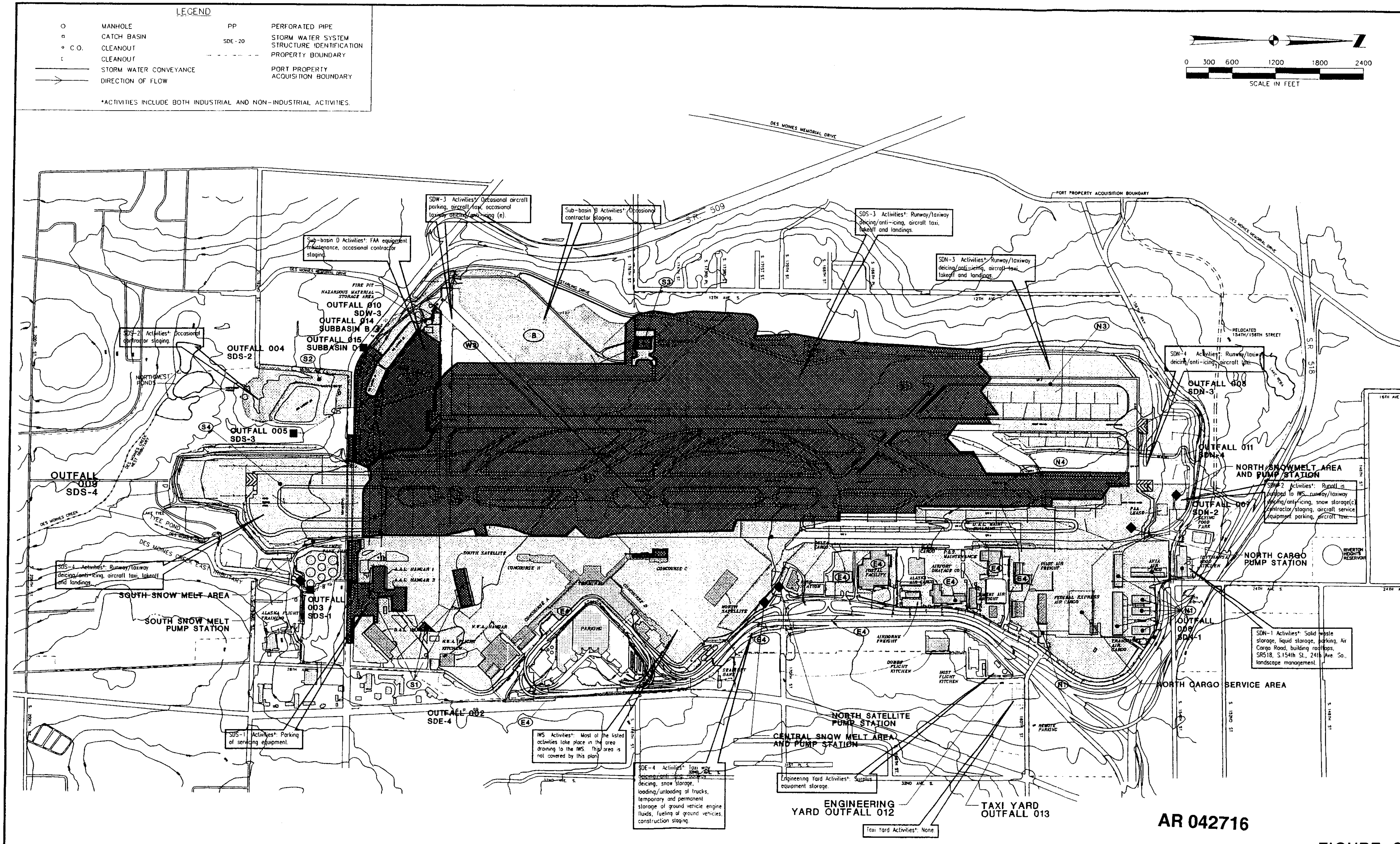
During periods of heavy snowfall, snow is removed from runways and taxiways and stored at four snow storage facilities. The snowmelt and runoff from these snow storage facilities drain to the IWS. Sampling runoff from these existing snowmelt facilities was not part of this study. Runoff from the runways and taxiways discharges to the outfalls SDN3, SDN4, SDS3, and SDS4. This project focused on these airfield outfall discharges that flow to Des Moines and Miller Creeks.

2.4 IMPACTS OF DEICING CHEMICALS

Deicing chemicals exert a biochemical oxygen demand (BOD_5) in water, consuming oxygen through biological and chemical oxidation. The rate of BOD_5 utilization (or uptake) is highly dependent on temperature, detention time, and other factors. The lower the temperature, the lower the BOD_5 utilization and oxygen consumption rate. DO is replenished throughout the length of the creeks by equilibration with atmospheric pressure and by reaeration from turbulence in the stream. Reaeration is a function of stream surface area, gradient and turbulence. Therefore, the overall effect of BOD_5 on DO levels is dependent primarily on stream temperature, reaeration, and atmospheric pressure.

2.5 WATER QUALITY STANDARD FOR DISSOLVED OXYGEN

Water quality standards for surface waters of Washington State are promulgated in WAC 173-201A. Des Moines and Miller Creeks are both unclassified streams under WAC 173-201A-130, and are not tributary to any classified freshwater stream or river. Both streams discharge to Puget Sound which is classified as Class AA marine water. WAC 173-201A-060(2) differentiates between fresh and marine water quality criteria. Under WAC 173-201A-120(6) these two undesignated streams are classified Class A. The freshwater dissolved oxygen standard for Class A surface waters is 8.0 mg/L.



AR 042716

FIGURE 2

STORMWATER DRAINAGE BASIN COLOR CODES:

N1 SDN1	S1 SDS1	W3 SDW3	IWS
N3 SDN3	S3 SDS3	S3 B	
N4 SDN4	S4 SDS4	S3 D	
	E4 SDE4	S2 SDS2	

■ OUTFALL LOCATION ◆ PUMPSTATION LOCATION

PROJECT ENGR./ARCH.	
DESIGNER:	
DRAWN BY:	
SCALE:	
DATE:	
FILE NAME:	P8SK001

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D
5	11/98	K/J	UPDATE FIGURE	
4	10/98	K/J	UPDATE FIGURE	
3	2/98	K/J	UPDATE FIGURE	
2	12/97	K/J	UPDATE FIGURE	
1	7/97	K/J	RELOCATED AND ADDED OUTFALL LOCATIONS	

PORT OF SEATTLE

SEA-TAC INTERNATIONAL AIRPORT

COMPREHENSIVE STORM DRAINAGE SYSTEM PLAN AND DESIGN

DRAINAGE BASINS AND ASSOCIATED SIGNIFICANT ACTIVITIES

CONSULTANT'S NO. 976079.23

FIGURE NO. FIGURE

SECTION G — SECTION T — SECTION B — SECTION N — DISCIPLINES — DWG

SECTION 3: METHODS

This study consisted of continuous DO and temperature monitoring in the mainstem of Miller Creek and Des Moines Creek coupled with targeted water quality sampling at STIA outfalls and other tributaries when deicing chemicals were applied to the airfield. The following subsections present the study design, including:

- Airfield deicing event criteria,
- Airfield outfall monitoring,
- Instream and pond monitoring, and
- Tributary monitoring.

This study was completed as part of a team effort by Cosmopolitan Engineering Group (Cosmopolitan) and the Port of Seattle. Cosmopolitan staff were responsible for tributary and mainstem monitoring and study analysis. Port of Seattle staff were responsible for airfield outfall monitoring and provided assistance with data preparation.

A *Sampling and Analysis Plan* was prepared by Cosmopolitan Engineering and approved by the Port of Seattle and Ecology (CEG, 1998).

3.1 AIRFIELD DEICING EVENT CRITERIA

An airfield deicing event (event) was defined as runway and/or taxiway (ground surface) deicing on the airfield followed by snowmelt and subsequent rainfall. Chemicals may be applied on multiple occasions during freezing conditions spanning several days in one event. The study intent was to monitor during one background (i.e., non-deicing) period and two runway deicing events occurring during the winter of 1998-99 (December 1998 through February 1999).

During each deicing event, three periods of sampling were targeted as goals to represent the following conditions in the creeks:

Condition 1. Antecedent conditions: discharges prior to warming trend or snowmelt/rainfall runoff (but after chemical application),

Condition 2. Rising limb: rising flows in the creeks caused by snowmelt/rainfall runoff resulting from the first 0.25 inches of precipitation, and

Condition 3. Falling limb: receding period of rainfall/runoff hydrograph following the first one to two inches of rainfall.

When ground deicing chemicals were applied to the runways/taxiways, the Port and Cosmopolitan were notified immediately by the STIA Snow Desk alphanumeric page system.

3.2 MONITORING STATIONS AND METHODS

A total of 24 sites were sampled. The sampling sites are listed in Tables 2 and 3 and shown on Figure 3. The sampling sites consist of:

- Four airfield outfalls serving airfield runways and taxiways (SDS3, SDS4, SDN3 and SDN4)
- Three other STIA outfalls (NEPL, SDN1 [includes a portion of SR 518], and BDW3 [combined inlet includes runoff from B, D, SDW3, non-STIA industrial area])
- Eight instream sites in Miller and Des Moines Creeks
- Four downstream tributaries to Miller and Des Moines Creeks
- Three ponds (two locations at NW Ponds detention facility in Cell 2 [NW Pond 2] and Cell 3 [NW Pond 3], and one location in Lake Reba detention pond)
- Two non-Port outfalls (SR 518, NW Pond inlet)

3.2.1 Runway/Taxiway Outfall Monitoring

Port personnel monitored the four airfield outfalls (SDN3, SDN4, SDS3, and SDS4) with ISCO automated samplers and flow meters. The automated samplers collected individual, sequential samples every hour over the duration of the entire event based on hydrographs. From these events, six samples were selected to represent initial runoff, rising limb, the peak, falling limb, and tail of the hydrographs.

Flow-weighted composite samples were also taken to obtain samples for metals analysis comparable with existing NPDES data. These samples were collected using separate samplers and protocols consistent with the *Procedure Manual for Stormwater Monitoring* (POS, 1998).

Table 2. Miller Creek Basin Sampling Locations

Sampling Site	Site ID	Location	Sampling Responsibility
		STIA Runway Outfalls	
SDN3	SDN3	STIA Outfall; Runway/Taxiway Runoff	POS
SDN4	SDN4	STIA Outfall; Runway/Taxiway Runoff	POS
		Miller Creek Major Tributaries	
NEPL	NEPL	STIA North Employee Parking Lot Outfall on SR 518, East of Des Moines Memorial Drive Exit	CEG
SR 518	SR 518	SR 518 Runoff, East of Des Moines Memorial Drive Exit	CEG
SDN1	SDN1	STIA Outfall; North of S 154th St, East of Lake Reba, **KC42G**	CEG
Miller Creek Upstream	MC1	**KC42F**, Miller Creek Upstream, double-culvert at SR 518 crossing, East of Des Moines Memorial Drive Exit	CEG
Lake Burien	MCLB	Elsie Creek (Outlet of Lake Burien) at 6th Ave. SW off of Sylvester Rd	CEG
2nd Tributary	MCT2	277 S 171st Pl., KC Miller Creek Tributary 0371A – sample at 1st Ave. and 174th, Westside.	CEG
		Miller Creek Instream Stations	
Lake Reba	MC3	15127 12th Ave. SW, Detection Facility - Lake Reba outlet to Miller Creek, **KC42L**, continuous lake level gage	CEG
Miller Creek Detention Facility	MC2	15127 12th Ave. SW, **KC42B** and KC Rain Gauge Instream location at detention structure	CEG
Miller Creek WWTP	MCSTP	Instream location adjacent to SW Suburban Wastewater Treatment Plant, SW 175th Place to SW Eastbrook, Bridge	CEG
Mouth at Puget Sound	MCPS	SW 175th Place and 17522 14th Ave. SW at Normandy Park **KC42A**, Miller Creek under SW 175th Place	CEG

POS – Port of Seattle CEG – Cosmopolitan Engineering Group

Table 3. Des Moines Creek Basin Sampling Locations

Sampling Site	Site ID	Location	Sampling Responsibility
		STIA Runway Outfalls	
SDS3	SDS3	STIA Outfall; Runway/Taxiway Runoff	POS
SDS4	SDS4	STIA Outfall; Runway/Taxiway Runoff	POS
		Des Moines Creek Tributaries	
NW Pond Inlet	DM7	Inlet to NW Pond Cell 1; 1505 S 192nd St, 16th Ave. S, near Office Parking Lot	CEG
B, D, W3 (combined)	BDW3	STIA Subbasins B, D and SDW3 and Non-STIA Industrial area combined outfall.	CEG
East Basin	DMEB	East fork of Des Moines Creek, which includes STIA outfalls SDE4 and SDS1. Includes City of SeaTac and Bow Lake runoff. Culvert at Tyee Golf Course, 2202 S 196th St, to Detention Facility - Tyee Pond Outlet, **KC11B** stage height only below Tyee Pond **KC11C** gage straight downhill from clubhouse above Tyee Pond	CEG
Tributary 1	DMT1	Des Moines Creek Tributary at 201st on east side of trail in City of Des Moines Park off of 200th	CEG
Tributary 2	DMT2	Des Moines Creek Tributary at Midway WWTP next to locked gate, sample instream	CEG
		Des Moines Creek Instream Stations	
NW2 Pond	DMNW2	West fork of Des Moines Creek, NW Ponds Detention Facility Cell 2 at Tyee Golf Course, 2202 S 196th St	CEG
NW3 Pond	DM5	NW Ponds Detention Facility Cell 3 at Tyee Golf Course, 2202 S 196th St. **KC11G**. stage height only	CEG
Golf Course Weir	DM3	Tyee Golf Course, 2202 S 196th St. **KC11F**; Downstream of East and West Fork confluence, downstream of first weir	CEG
Des Moines WWTP	DMSTP	Instream location adjacent to Midway Wastewater Treatment Plant, ½ mile upstream from KC11D; SR 509 to S 216th ,sign for WTP north of 216th , turn onto 12th Ave S	CEG
Mouth at Puget Sound	DM2	501 S 220th St in Des Moines Beach Park; **KC11D**, gage at old wooden bridge at end of public parking turn around	CEG

The samplers were initiated as soon as possible after ground deicing chemicals were applied. The samplers collected three samples per hour (one sample every 20 minutes) in one-liter polypropylene containers. These one-liter samples represent one-hour time composites. Plastic sample bottles were washed in the laboratory with detergent only. The one-gallon glass sample bottles used for the flow-weighted composites for metals analysis were similarly washed but with an acid rinse.

For each outfall, Cosmopolitan reviewed flow and precipitation data to select the six samples to be analyzed. The six samples were selected so that they represent peak concentrations and subsequent decreasing concentration in the precipitation runoff as ground deicing chemicals were "washed-off." Samples not selected to meet hydrograph conditions were frozen and subsequently analyzed as needed.

3.2.2 Instream and Pond Data Loggers

Cosmopolitan monitored the ponds and instream locations with continuous data loggers (HydroLabs or SeaBirds) deployed for three months. These loggers continuously measured DO and temperature every 15 to 30 minutes. The SeaBird data loggers include YSI oxygen sensors, which have ambient water pumped across the membranes, whereas the Hydrolabs only have stirring rods. Therefore, the SeaBirds were used in NW Pond 3 and Lake Reba, where water was relatively quiescent, ensuring proper DO measurement. However, a Hydrolab was installed in NW Pond 2 because there were only two SeaBird instruments available. Incidentally, the SeaBird instruments also measure and record conductivity, which served as a tracer for deicing chemicals.

In the ponds, the data loggers were suspended horizontally from marine floats at depths of 1-3 feet below the water surface depending on the pond depth. At the instream locations, the Hydrolabs were suspended vertically, six inches above the creek bottom and anchored in place in the main channel in slotted PVC pipe. The slotted PVC pipe provided protection from debris but was perforated to allow free flow water to pass the DO probe on the data logger. Photographs of each installation are shown in Appendix E.

3.2.3 Tributary Grab Samples

Cosmopolitan also monitored the other sources tributary to the instream stations including Miller Creek upstream, two major tributaries of each creek, plus six other outfalls. At each location, three grab samples were collected over the duration of the event. Samples were collected as close as possible to target Conditions 1, 2, and 3. When possible, personnel collected samples starting at the upstream tributaries and then proceeded downstream to other locations. These tributary grab samples were intended to identify water quality effects from discharge sources other than airfield runoff.

Tributary samples were collected directly into washed containers supplied by Aquatic Research and University of Washington Oceanographic Laboratory (UW).

3.3 ANALYTES

3.3.1 Laboratory and Field Data

Tables 5 and 6 list the water quality parameters monitored at the Miller and Des Moines Creek sampling stations, respectively. The STIA outfall samples were analyzed for BOD_5. The grab samples from the other tributaries were analyzed for BOD_5, DO, and temperature. Ammonia was analyzed at 20 percent of all outfall and grab sample locations. In addition, BOD_5 and ammonia samples were collected at instream locations during an event at a frequency of 20 percent of the total number of tributary samples. These samples were collected to measure BOD_5 concentrations in the receiving streams. For stations with continuous DO monitors and data loggers, samples were collected to verify DO concentrations measured by the instruments.

Field sampling and measurement protocols followed those described in Ecology's field sampling and measurement protocol manuals (WAS, 1993). The data quality objectives necessary to meet the objectives of the project are presented in Table 4. Laboratory analysis was provided by the UW and Aquatic Research, Inc.

Table 4 Field and Laboratory Specifications

Analyte	Detection Limit	Method
Field Measurements		
Flow		Direct, Float, Current, stage discharge (King County), ISCO flowmeter
Temperature	0.2 °C	Electronic thermometer and glass thermometer
Dissolved Oxygen	0.2 mg/L	Probe/Winkler Titration
Laboratory Analyses		
Ammonia nitrogen (NH3)	0.01 mg/L	EPA 350.1
BOD_5	4.0 mg/L	EPA 405.1

All samples were recorded on Chain of Custody forms, including sample number, location name, date and time of collection, and analyses requested. Samples were stored on ice and delivered to the laboratory within the 48-hour maximum holding times for BOD_5 and within the 5-day maximum holding time for DO samples fixed with Winkler reagents.

Table 5 Water Quality Parameters Monitored in the Miller Creek Basin

Sampling Site	Site ID	Description	Sampler	Field Measurements: Data Logger[1]	Field Measurements: Conductivity	Field Measurements: Flow	Field Measurements: Temp.	Field Measurements: DO	Laboratory Parameters: NH3[2]	Laboratory Parameters: BOD_5[3]
North End Drainage, Miller Creek										
SDN3	SDN3	Runway/Taxiway Runoff[4]	POS			ISCO			X	6
SDN4	SDN4	Runway/Taxiway Runoff[4]	POS			ISCO			X	6
QA samples[7]		Runway/Taxiway Runoff[4]	POS						X	X
NEPL	NEPL	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
SR 518	SR 518	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
SDN1	SDN1	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
Miller Creek	MC1	Tributaries Grab Samples[5]	CEG			King Co*	X	X	X	X
Lake Burien	MCLB	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
2nd Tributary	MCT2	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
Deicing QA samples[7]		Tributaries Grab Samples	CEG					X	X	X
Background QA samples[7]		Tributaries Grab Samples	CEG					X	X	X
Lake Reba	MC3	Mainstem, Continuous Samplers[6]	CEG	SeaBird	X	King Co* level only	X	X	X	X
Miller Creek Detention Facility	MC2	Mainstem, Continuous Samplers[6]	CEG	Hydrolab		King Co*	X	X	X	X
Miller Creek WWTP	MCSTP	Mainstem, Continuous Samplers[6]	CEG	Hydrolab			X	X	X	X
Mouth at Puget Sound	MCPS	Mainstem, Continuous Samplers[6]	CEG	Hydrolab		King Co*	X	X	X	X
Deicing QA samples[7]		Mainstem Grab Samples	CEG					X	X	X
Background QA samples[7]		Mainstem Grab Samples	CEG					X	X	X

* Stage-discharge was obtained from King County. POS – Port of Seattle CEG – Cosmopolitan Engineering Group

(1) Remote data collection of temperature and DO every hour starting December 1, 1998, through February 28, 1999.
(2) Only 20 percent of the samples collected were analyzed for ammonia.
(3) For the mainstem sites, only 20 percent of the deicing samples were analyzed for BOD_5.
(4) Samples were not collected from the runway/taxiway outfalls during the background-sampling event.
(5) For each deicing event, a total of three samples were to be collected at each site. Each sample represented one of the three target conditions as defined in Section 3.
(6) For each event, one sample was collected for verification (DO and temperature) of the data loggers and documentation of constituent concentrations (BOD_5 and ammonia) in the mainstem.
(7) The number of QA samples collected over the entire sampling program was ten percent.

Table 6 Water Quality Parameters Monitored in the Des Moines Creek Basin

Sampling Site	Site ID	Description	Sampler	Field Measurements					Laboratory Parameters	
				Data Logger[1]	Conductivity	Flow	Temp.	DO	NH3[2]	BOD_5[3]
South End Drainage, Des Moines Creek										
SDS3	SDS3	Runway/Taxiway Runoff[4]	POS			ISCO			X	6
SDS4	SDS4	Runway/Taxiway Runoff[4]	POS			ISCO			X	6
QA samples[7]		Runway/Taxiway Runoff[4]	POS						X	X
NW Pond Inlet	DM7	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
B, D, SDW3 (combined)	BDW3	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
East Basin	DMEB	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
Tributary 1	DMT1	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
Tributary 2	DMT2	Tributaries Grab Samples[5]	CEG			Swoffer	X	X	X	X
Deicing QA samples[7]		Tributaries Grab Samples	CEG					X	X	X
Background QA samples[7]		Tributaries Grab Samples	CEG					X	X	X
NW2 Pond	DMNW2	Mainstem, Continuous Samplers[6]	CEG	Hydrolab	X		X	X	X	X
NW3 Pond	DM5	Mainstem, Continuous Samplers[6]	CEG	Seabird	X	King Co level only	X	X	X	X
Golf Course Weir	DM3	Mainstem, Continuous Samplers[6]	CEG	Hydrolab		King Co	X	X	X	X
Midway STP	DMSTP	Mainstem, Continuous Samplers[6]	CEG	Hydrolab			X	X	X	X
Mouth at Puget Sound	DM2	Mainstem, Continuous Samplers[6]	CEG	Hydrolab		King Co	X	X	X	X
Deicing QA samples[7]		Mainstem Grab Samples	CEG					X	X	X
Background QA samples[7]		Mainstem Grab Samples	CEG						X	

POS – Port of Seattle CEG – Cosmopolitan Engineering Group

(1) Remote data collection of temperature and DO every hour starting December 1, 1998, through February 28, 1999.
(2) Only 20 percent of the samples collected were analyzed for ammonia.
(3) For the mainstem sites, only 20 percent of the deicing samples were analyzed for BOD_5.
(4) Samples were not collected from the runway/taxiway outfalls during the background-sampling event.
(5) For each deicing event, a total of three samples were to be collected at each site. Each sample represented one of the three target conditions as defined in Section 3.
(6) For each event, one sample was collected for verification (DO and temperature) of the data loggers and documentation of constituent concentrations (BOD_5 and ammonia) in the mainstem.
(7) The number of QA samples collected over the entire sampling program was ten percent.

Temperature was measured directly within the discharges. Tributary BOD_5 samples were collected directly into the plastic container. Tributary ammonia samples were field filtered, frozen, and delivered to UW after all samples were collected.

The Hydrolabs and Seabirds were pre-calibrated by the manufacturers. Before deployment, each Hydrolab's calibration was adjusted for barometric pressure in accordance with the manufacturer's instructions.

Field measurements of DO by Winkler titration methods were used to determine the accuracy of the instruments. DO samples were collected directly in glass DO bottles and fixed with appropriate reagents from the UW for the modified Winkler method. At the pond locations, DO samples were collected at the same depth as the instrument's intake or probe. The DO bottles were kept cool and in the dark. The samples were delivered to UW within twenty-four hours, when possible. The holding time for DO in samples fixed with Winkler reagents is five days.

3.3.2 Discharge (Flow) Data

Port personnel monitored flow at the four airfield outfalls (SDN3, SDN4, SDS3, and SDS4) using ISCO area-velocity and bubbler flow meters. Data from the ISCO flow meters were downloaded using OEM software and archived by the Port staff.

Tributary flow measurements were obtained using velocity measurement (Swoffer meter). When the velocity could not be properly measured using a Swoffer meter (i.e., low flow or high flows), flow measurements were obtained using other methods such as direct measurement or float method. Instantaneous flows from the tributaries were calculated using the measured velocities, the measured depth of flow and either the measured cross-sectional area of the stream or the diameter of the pipe discharging the flow.

King County operates and maintains several gages on the mainstems of Miller Creek and Des Moines Creek. The gages were listed in Tables 2 and 3 and shown in Figure 3. Cosmopolitan Engineering obtained continuous flow data from King County for these gages on the mainstem.

3.3.3 Precipitation Data

Cosmopolitan Engineering obtained rain data from King County, which operates and maintains two rain gages, one at the Miller Creek Detention Facility on the mainstem of Miller Creek and one at the Tyee Pond outlet, on the east branch of Des Moines Creek. In addition, Port personnel supplied rain data from a gage on the Air Cargo 4 Building rooftop and from the NWS gage at STIA. The gauge locations are shown in Figure 3.

3.4 REVISIONS TO THE SAMPLING AND ANALYSIS PLAN

After reviewing preliminary results of the December 1998 Deicing Event, the project team made several revisions to the *Sampling and Analysis Plan* (SAP) (CEG, 1998). After the December 1998 Deicing Event storm, it became evident that the DO probes were being fouled. The DO membrane on the data loggers were compromised from biological growth and/or sediment buildup. To properly monitor the effect of deicing events on DO levels in the streams, the following changes to the SAP were implemented in the second event:

- During target sample Conditions 1, 2, and 3, additional grab samples from Lake Reba and NW Pond 3 were collected for BOD_5 and DO analyses to verify BOD_5 flushing from the detention facilities and to verify DO levels during the target conditions.
- Conductivity was used as a conservative indicator of ions present in the water, and thus serves as a tracer for deicing chemicals. The Seabirds' conductivity measurements were used to verify flushing from the detention facilities.
- At Lake Reba and NW Pond 3, BOD_5 and DO samples were collected periodically over several days following the deicing event to verify DO levels at these locations.
- Replaced DO membranes in the Miller Creek Detention Facility, Golf Course weir, NW Pond 2, Lake Reba, and NW Pond 3 data loggers.
- Increased the maintenance frequency to every two weeks for the mainstem Hydrolabs.
- Increased DO calibration sampling frequency to every two weeks at the mainstem Hydrolab locations.

AR 042726

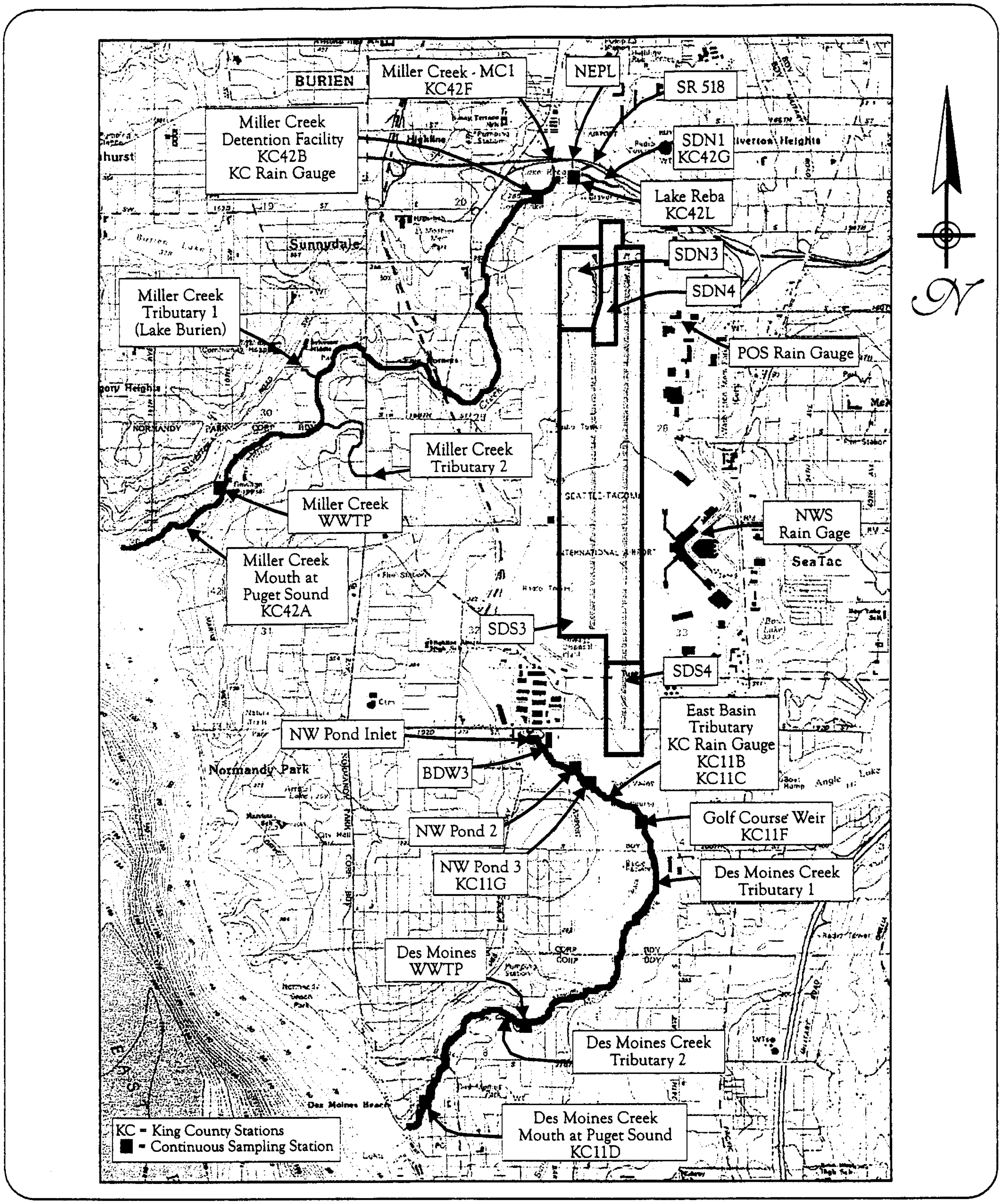
3.4.1 Pond Profiles

In addition to the increased monitoring in the mainstem, it was determined that DO and temperature profiles in NW Pond 3 and Lake Reba could be useful in determining other factors that affect DO in the ponds and Lake and if the ponds were stratified. Profiles were measured on January 22, 1999, by lowering and raising the Seabird the full depth of the ponds at a rate of approximately 1 feet per second. The electronic profile data are archived at the Cosmopolitan Tacoma Office.

3.4.2 Limited March Monitoring

Limited monitoring was continued at Northwest Pond 3 and Lake Reba through March 1999. This monitoring was to provide additional information on the DO concentrations in the pond and lake during colder temperatures and during periods of varying rainfall and dry conditions.

Two SeaBirds and two Hydrolabs were used to continue monitoring of Lake Reba, Northwest Pond 3 and the immediate downstream locations, Miller Creek Detention Facility and the Golf Course weir, respectively. These data loggers were deployed for the month of March, and DO calibration samples were collected twice.



File: seatac map.cdr

ENGINEERING GROUP
COSMOPOLITAN
Civil, Environmental and Recreational Consulting

Figure 3: Sampling Locations

AR 042728

SECTION 4: RESULTS

Continuous DO and temperature monitoring was conducted December 1998 through March 1999. The project team successfully collected all planned data during the period from December 4 through March 3 with only a few gaps in the data. The continuous data recorded for this period are presented in the appendices, including rainfall (Appendix A), instream flow (Appendix B), and instream DO and temperature (Appendix D), respectively. The stormwater outfall flow and BOD_5 concentration data for each deicing event are presented in Appendix C.

During this period, only two deicing events occurred. Relative to the amount of chemical applied in nine total ground deicing events in the past four years, the December 1998 event ranked third and the February 1999 event ranked fourth. Little to no snow accumulated in either event and no snow was plowed or moved to storage areas. The second event had only a trace of snow that melted immediately but froze again overnight.

The following sections present the data collected during the study. Detailed discussions of the data and the conclusions that can be drawn from it are presented in Section 5.

4.1 DATA QUALITY

Quality control procedures by the labs followed standard operating procedures described in their manuals. UW and Aquatic Research laboratories are Washington State Accredited Laboratories. Each laboratory has quality control manuals documenting their data quality objectives and quality control procedures in accordance with laboratory testing protocols, and are not provided herein.

The laboratory data reports indicated no difficulties were encountered in the preparation or analysis of the sample sets. Data variation and hydrolab data verification is assessed in the following subsections.

4.1.1 Data Variation

Total variation for field sampling was assessed by collecting replicate samples of all parameters at the rate of one in ten samples. These replicate pairs were analyzed for relative percent difference (RPD, difference divided by the mean, expressed as percent). The RPD results are presented in Table 7.

The average RPD for BOD_5, ammonia and DO is 5, 4, and 1 percent, respectively. This average RPD was deemed to be acceptable.

Table 7 Replicate Data

		BOD_5 (mg/L)			Ammonia (mg/L)			DO (mg/L)		
		Sample 1	Sample 2	RPD	Sample 1	Sample 2	RPD	Sample 1	Sample 2	RPD
Miller Creek Drainage Basin										
Miller Creek	12/9/98	<2	<2	0	0.0295	0.031	-5	10.9	10.88	0
	12/21/98	<2	<2	0	–	–	–	12.2	12.19	0
	12/24/98	5.48	4.36	23	–	–	–	11.67	11.63	0
Miller Creek Detention Facility	12/9/98	<2	<2	0	0.0447	0.047	-5	9.3	9.34	0
	12/24/98	<2	<2	0	–	–	–	–	–	–
SDN1	2/13/99	<2	<2	0	–	–	–	10.4	10.1	3
SDN3	12/25/99	47.9	54.6	-13	–	–	–	–	–	–
Des Moines Creek Drainage Basin										
NW Pond Inlet	12/9/98	<2	<2	0	0.0422	0.0437	-3	10.92	10.9	0
	12/24/98	6.26	6.2	1	–	–	–	11.79	11.69	1
	12/25/98	–	–	–	–	–	–	12.23	12.21	0
	2/13/99	<2	<2	0	–	–	–	11.39	11.27	1
Golf Course Weir	12/9/98	–	–	–	–	–	–	9.6	9.59	0
	12/24/98	852	774	10	–	–	–	–	–	–
SDS4	12/25/98	68.2	77.2	-12	–	–	–	–	–	–
Average Relative Percent Difference				5			4			1

Relative Percent Difference - difference divided by the mean, expressed as percent

0±: Flow was visible but not measurable.

4.1.2 Hydrolab and SeaBird Data Verification and Adjustment

The Hydrolabs and SeaBirds were deployed for three months at most locations. They were deployed one additional month in NW Pond 3 and Lake Reba and at the Golf Course weir and Miller Creek Detention Facility stations. The data were verified by the following QA checks:

1. Pre-calibration of DO prior to traveling to the site.

2. Field measurements of DO by Winkler titration methods in samples collected at the time of deployment, at the time of instrument maintenance and at the time of retrieval. Table 7 shows that the average RPD for the Winkler DO replicate samples was 1%, indicating that the DO grab samples were reliable.

3. Periodic maintenance of the instrument.

Nearly all of the DO concentrations measured by the in-stream instruments were lower than those measured in the samples that were collected. The average difference between the concentrations measured with Winkler titrations and the corresponding DO concentrations recorded by the instruments was 1.66 mg/L (sample concentration greater than recorded concentration). The recorded DO data were adjusted upward or downward to account for the differences. The recorded concentrations were not adjusted when they were equal to the measured sample concentrations or when the discrepancy between the two concentrations could not be reconciled. The value of the correction factor ranged from (-)1.43 mg/L to 5.2 mg/L. The methods and approximations used to adjust the DO data are described in detail in Appendix D.

Figures 4 and 5 present the corrected DO concentration data for the December through February study period at each sampling station on Des Moines Creek and Miller Creek.

4.2 BACKGROUND EVENT

To establish background conditions in the tributaries and in the mainstems, samples were collected December 9, 1998. There was no precipitation on this day, and it was 44°F at the time of sampling. The last measurable precipitation (0.36 inches on December 7-8) ended at 03:00 on December 8, 1998.

AR 042731

The data results are presented in Table 8. The flows at the tributary locations ranged from near zero to 3.6 cfs. BOD_5 was not detected in any samples from the tributary locations. Ammonia was detected at concentrations ranging from 0.02 to 0.05 mg/L.

DO concentrations ranged from 6 mg/L to 12 mg/L. At Lake Reba, NW Pond 3 and Des Moines Creek Tributary 1, the DO concentrations were around 6 mg/L, which are below the water quality standard of 8 mg/L. Water temperature ranged from 6°C to 10°C. These background data show adverse DO concentrations unrelated to STIA ground deicing activities.

Table 8 December 9, 1998 – Background Event Results

	BOD_5 (mg/L)	Ammonia (mg/L)	DO (mg/L)	Temp. (C)	Flow (cfs)
Miller Creek Drainage Basin					
Tributaries					
Miller Creek - MC1	<2.00	0.03	10.89	6.4	2.50
NEPL	<2.00	–	11.05	6.1	0±
SR 518	–	–	–	–	No flow
SDN1	<2.00	–	8.31	8.2	0±
Lake Burien - MCLB	<2.00	–	9.93	10	0±
Tributary 2 - MCT2	<2.00	–	10.34	8.4	3.60
Instream					
Lake Reba - MC3[(1)]	–	–	6.36[(2)]	–	2.43 ft
Miller Creek Detention Facility - MC2	<2.00	0.05	9.32	6	3.90
SW Suburban Sewer District WWTP	–	–	11.94	–	–
Miller Creek Mouth	–	–	11.79	–	8.90
Des Moines Creek Drainage Basin					
Tributaries					
NW Pond Inlet	<2.00	0.04	10.91	7.8	0.47
BDW3 (B, D, SDW3 combined)	<2.00	–	10.15	9.2	0±
East Basin	–	–	–	–	No flow
SDS4	<2.00	0.02	10.82	9.8	0±
Tributary 1	<2.00	–	6.3	8.9	0.78
Tributary 2	<2.00	–	11.32	8	0.67
Instream					
NW Pond 3[(1)]	–	–	5.98[(3)]	–	1.32 ft
Golf Course Weir	<2.00	0.04	9.595	7	3.30
Des Moines Creek Midway WWTP	–	–	12.04	–	–
Des Moines Creek Mouth	–	–	11.66	–	17

Weather conditions were 44°F and no rain. Last measurable precipitation ended at 03:00 on 12/8/98 (0.36" on 12/7 and 12/8/98).
No flow from the STIA outfalls SDS3, SDN3 and SDN4.
0±: Flow was visible but not measurable.
(1) Stage in feet, only.
(2) Collected at outlet from Lake Reba
(3) Collected at outlet from NW Pond 3

AR 042732

4.3 DECEMBER 1998 DEICING EVENT

Note: References to characteristics of the figures followed by a number, i.e. (①), are identified on the corresponding figure.

4.3.1 Weather Conditions

Based on NWS data, freezing temperatures began December 19, 1998, at 04:00 and persisted through December 24, 1998, at 09:00 (see Figure 6). During this 5 day period, a total of approximately three inches of snow fell in three different periods. The precipitation and air temperature for December 1998 Deicing Event are shown in Figure 6. The total precipitation for December 23-24 from 00:00 to 15:00 was 0.39 inches, comprised of 0.17 inches of water equivalent snowmelt followed by 0.25 inches of rainfall.

A trace of snow fell during two brief periods with no accumulations; December 19, 15:00-17:30 and December 21, 11:17-13:24. The only period where snow accumulated was during an 8-hour period from December 23, 23:56 to December 24, 08:00, after which the precipitation immediately changed to rain. Because of this rapid temperature change, the approximate 3-inches of snow (0.17 water equivalent) (NWS) did not require plowing as it melted rapidly with the ensuing 0.25-inch rainfall on December 24.

A much larger storm event followed on December 25 at 08:00 with initial runoff beginning around 10:00 (see Appendix C). The total precipitation of the December 25 event was 1.05 inches. The last measurable rainfall for this event ended 00:00 on December 26. The runoff for the north and south drainages continued until 12:00 and 09:00 on December 26, respectively.

4.3.2 Deicing Chemical Application

During the period from December 19-24, PA and NAC were applied to the airfield during three periods of precipitation. Table 9 lists the total amounts of chemical applied to the airfield.

Deicing chemicals may have been applied on other surfaces by other jurisdictions in the Miller and Des Moines Creek basins; however, this information is not included in this discussion.

AR 042733

Table 9 December 1998 Deicing Event Characteristics

December 18-24, 1998	
Type	Snow-Rain
Total Snow	3 inches
Rank based on snow	4
Total PA	15,850 gallons
Rank based on PA usage	3
Total NAC	6,800 lbs

Rank based on past 9 events during four seasons since winter 1995-1996.
Reference: Port of Seattle 3/25/99.

4.3.3 Airfield Outfall Monitoring

On December 26, the time composite samples and flowmeter data for December 1998 Event were collected from each of the four STIA airfield outfalls. Flow data were only available from SDN4 and SDS3[3]. The initial runoff for the north and south drainages began at 13:30 on December 24 and continued until around 00:00 on December 25 (see Appendix C). For the second precipitation event, the runoff for the north and south drainages continued until 12:00 and 09:00 on December 26, respectively.

Using the SDN4 and SDS3 flow data and the Port rain data (see Appendix C), Cosmopolitan selected six samples from each outfall (SDN4 and SDS3) that were representative of target Hydrograph conditions (initial runoff, rising limb, peak, falling limb and tail). For outfalls SDN3 and SDS4, samples were selected using the SDN4 and SDS3 flow data, respectively, assuming a 1-hour delay in the Hydrographs.

The results of the outfall sampling are presented in Table 10 and Appendix C. Generally, the peak BOD_5 concentrations were measured in the first runoff sample with decreasing BOD_5 concentrations in each of the following samples. During the December 1998 event, the BOD_5 concentrations ranged from 13.6 mg/L (SDN4) to 1,494 mg/L (SDS3). The peak BOD_5 concentrations were clearly associated with the initial snowmelt/rainfall runoff for this event. The ammonia concentrations ranged from 0.014 mg/L (SDN3) to 0.038 mg/L (SDS3).

[3] Data from the flow meter at SDN3 could not be retrieved while SDS4 flow meter stopped recording before the December 1998 event.

Table 10 December 1998 Deicing Event - STIA Outfall Results

	Start Date	Start Time	Compositing Period (hours)[1]	BOD_5 (mg/L)	Ammonia (mg/L)
Miller Creek Drainage Basin					
SDN3 - Pre Runoff Results, 12/19-23/98[2]	12/19/98	14:00	12	<4	
	12/21/98	12:00	8	<4	
	12/22/98	12:00	11	<4	
	12/23/98	19:00	19	95.7	
SDN3 – Runoff Results[3]	12/24/98	16:00	1	344	–
	12/24/98	22:00	1	181	0.014
	12/25/98	10:00	1	44.4	–
	12/25/98	13:00	1	51.25	–
	12/25/98	17:00	1	48.4	–
	12/25/98	22:00	1	119	–
SDN4 - Pre Runoff Results, 12/19-23/98[2]	12/20/98	12:30	9	<4	
	12/22/98	11:30	9	<4	
	12/23/98	18:30	19	<4	
SDN4 – Runoff Results[3]	12/24/98	15:30	1	723	–
	12/24/98	21:30	1	145	0.016
	12/25/98	9:30	1	51	–
	12/25/98	13:30	1	22.1	–
	12/25/98	16:30	1	13.6	–
	12/25/98	21:30	1	15.7	–
Des Moines Creek Drainage Basin					
SDS3 - Pre Runoff Results, 12/19-23/98[2]	12/20/98	15:30	24	<4	
	12/21/98	14:30	12	<4	
	12/22/98	15:00	6	<4	
	12/23/98	17:30	19	32.4	
SDS3 - Runoff Results[3]	12/24/98	1330	1	1494	0.038
	12/24/98	1730	1	672	0.02
	12/25/98	930	1	144	–
	12/25/98	1430	1	36.7	–
	12/25/98	1630	1	42.7	–
	12/25/98	2130	1	40.6	–
SDS4 - Pre Runoff Results, 12/19-23/98[2]	12/20/98	16:00	24	<4	
	12/21/98	11:00	12	<4	
	12/22/98	15:00	10	<4	
	12/23/98	15:00	21	<4	
SDS4 - Runoff Results[3]	12/24/98	1500	1	765	0.014
	12/24/98	1900	1	411	0.019
	12/25/98	1100	1	72.7	–
	12/25/98	1600	1	27.1	–
	12/25/98	1800	1	24.8	–
	12/25/98	2300	1	23.9	–

Airport Runways and Taxiways were deiced Dec. 19 at 17:21, Dec. 21 at 15:31, Dec. 23 at 20:00 and Dec. 24 at 04:30.

(1) Indicates duration of time composite sampling period.

(2) Samples were frozen upon collection and thawed 3/15/99 and composited for analysis.

(3) Samples are one-hour time composites.

AR 042735

4.3.4 Miller Creek and Lake Reba DO Data

Figure 7 plots corrected DO concentrations measured during the December deicing event from December 19 to December 31, 1998, in Miller Creek and Lake Reba. The figure shows that DO concentrations were relatively constant until mid-day on December 24. At this time, the air temperature increased above freezing, the precipitation changed from snow to rain and runoff to the creek began.

The DO concentration measured at the Miller Creek WWTP and the Miller Creek mouth station closely tracked each other until December 25 when the concentration at the mouth began to vary erratically. Based on field observations, it is likely that this was due to fouling of the meter housing and membrane during periods of increased flow in Miller Creek, when sediment would collect in and around the DO probe. If the drop in DO at the mouth had been due to BOD_5 exertion, the drop would have been mirrored by a similar drop in the DO at the WWTP station 0.3 miles upstream from the station at the mouth.

The erratic nature of the DO readings in Lake Reba and the Miller Creek Detention Facility is believed to be due to the heavy rainfall and resulting runoff into the creek of highly-aerated stormwater. Sharp increases in DO concentrations at the Miller Creek Detention Facility station (⑥) and at the Miller Creek Mouth station (③) on December 25 are due to changes in the correction factor applied to the recorded data. The other sharp increases shown during this period, including the 3.3 mg/L increase at Lake Reba on 12/24 (①), are due solely to fluctuations in recorded DO concentrations. The conclusions drawn from these data are discussed in detail in Appendix G.

4.3.5 Des Moines Creek and NW Ponds DO Data

Figure 8 presents the corrected DO concentrations measured during the December deicing event in the Des Moines Creek drainage. Similar to Miller Creek, DO concentrations at the downstream stations tended to increase during the sub-freezing weather period from December 19-24. The conclusions drawn from these data are discussed in more detail in Appendix G.

AR 042736

4.3.6 Tributary Grab Samples

The first sampling round (Condition 1 – prerunoff) was collected on December 21, 09:20-13:00, after the deicing chemical application at STIA and prior to snowmelt or rainfall runoff. The second sampling round (Condition 2 - rising limb) was collected on December 24 during the initial 0.39" combined snowmelt and rainfall from 12:15 to 14:45. This sampling period fell on or near the rising limb of the respective Hydrographs.

A much larger storm event followed on December 25 at 08:00 with initial runoff beginning around 10:00 (see Appendix C). The total precipitation of the December 25 event was 1.05 inches. The last measurable rainfall for this storm ended 00:00 on December 26. The runoff for the north and south drainages continued until 12:00 and 09:00 on December 26, respectively.

The third sampling round (Condition 3 – falling limb) was collected on December 25 from 08:20 to 11:30 during the first 0.28" of the second precipitation storm, 0.72 inches after airfield deicing. This nearly met the Condition 3 target of greater than 1.0 inches of rainfall.

The tributary sampling results are presented in Table 11. Condition 1 (prior to initial runoff) results show no BOD_5 from the other sources (low to no flow at the tributary sites with no BOD_5 detection) in the antecedent period. In most cases, the initial runoff (Condition 2) from other sources show the highest BOD_5 concentrations detected (1,176 mg/L at Des Moines Creek East Basin tributary and 528 mg/L at SDN1 Miller Creek tributary). This indicates that BOD-producing chemicals were likely used elsewhere in the watershed.

In Condition 3 (late runoff), the BOD_5 concentration abated with increasing total rainfall. Water temperatures ranged from –0.3° C (NEPL- Condition 2) to 7.3° C (Outfall B, D & SDW3 – Condition 2). In general, the temperatures were lower in the Condition 2 samples. Ammonia concentrations ranged from 0.07 mg/L to 4.3 mg/L (highest ammonia concentrations were 4. 3 mg/L at Des Moines Creek East Basin tributary and 3.1 mg/L at SDN1 Miller Creek tributary). These concentrations are all higher than the background concentrations (0.02 to 0.05 mg/L) as measured on December 9, 1998.

DO concentrations ranged from 6.8 mg/L (Des Moines Creek Tributary 1) to 13.1 mg/L (Tributary 2 – Condition 3). Only one tributary DO measurement (6.8 mg/L at Des Moines Creek Tributary 1) was below the water quality standard (8 mg/L).

AR 042737

Table 11. December Event, Tributary Sampling Results

	Time Sampled	BOD$_5$ (mg/L)	Ammonia (mg/L)	DO (mg/L)	Temp. (C)	Flow (cfs)
Miller Creek Drainage Basin						
[(1)] Condition 1 - Prior to Initial Runoff - December 21, 1998: below freezing temperatures and a trace of snow						
Miller Creek – MC1	11:35	<2	–	12.2	2	0.08
NEPL	11:50	<2	–	12.48	0	0.03
SR 518	–		–	–	–	No flow
SDN1	–		–	–	–	No flow
Lake Burien	12:30	<2	–	11.16	6.6	0.33
Tributary 2	13:00	<2	–	11.46	4	2.1
[(2)] Condition 2 – Initial Runoff - December 24, 1998: 3" of snow followed by 0.22" of rain						
Miller Creek – MC1	13:05	4.92	0.19	11.65	2.9	1.7
NEPL	13:17	19.7	0.27	12.65	-0.3	0.27
SR 518	13:25	50.2	0.67	12.66	1.4	0.04
SDN1	12:45	528	3.13	11.98	3.3	0.99
Miller Creek Detention Facility	12:15	<2	0.07	–	–	2.1
Lake Burien	14:10	8.94	–	11.24	3.9	1.12
Tributary 2	14:25	6.56	–	11.43	3.4	9.78
[(3)] Condition 3 - Runoff – December 25, 1998: 0.72" rainfall before 12:00						
Miller Creek – MC1	8:42	<2	–	11.14	3.9	0.55
NEPL	8:55	29.3	–	11.14	1.3	0±
SR 518	9:00	33.7	–	11.02	3.3	0.04
SDN1	8:20	20.3	–	9.22	5.3	0±
Lake Burien	11:06	2.52	–	11.44	4.9	4.09
Tributary 2	11:30	3.46	–	11.46	3.3	23.50
Des Moines Creek Drainage Basin						
[(1)] Condition 1 - Prior to Initial Runoff - December 21, 1998: below freezing temperatures and a trace of snow						
NW Pond Inlet	9:20	<2	–	11.73	4.5	0.47
BDW3 (B, D, SDW3 combined)	9:40	<2	–	10.5	2.4	0±
East Basin	10:10	<2	–	11.95	3.3	0±
Tributary 1	10:45	<2	–	6.83	5.9	1.05
Tributary 2	11:05	<2	–	13.17	2.3	0.31
[(2)] Condition 2 - Initial Runoff - December 24, 1998: 3" of snow followed by 0.22" of rain						
NW Pond Inlet	12:25	6.23	0.25	11.74	3.9	1.13
BDW3 (B, D, SDW3 combined)	12:15	<2	0.24	10.14	7.3	0±
East Basin	13:00	11761	4.29	10.53	1.7	11.00
Golf Course Weir	13:35	774	3.07	–	–	3.60
Tributary 1	14:15	15.8	–	10.79	1.1	3.20
Tributary 2	14:45	6.56	–	12.66	2.9	1.50
[(3)] Condition 3 - Runoff – December 25, 1998: 0.72" rainfall before 12:00						
NW Pond Inlet	10:20	5.56	–	12.22	3	6.60
BDW3 (B, D, SDW3 combined)	10:20	6.34	–	12.27	3	0±
East Basin	9:30	25.9	–	11.72	3.7	12.00
Tributary 1	9:41	5.04	–	10.82	3.3	3.30
Tributary 2	10:40	5.26	–	13.08	2.9	0.75

Airport Runways and Taxiways were deiced Dec. 19 at 17:21, Dec. 21 at 15:31, Dec. 23 at 20:00, and Dec. 24 at 04:3020:00.

0±: Flow was visible but not measurable.

[(1)] Condition 1 samples were collected on Dec. 21, 1998 between 0900 and 1300. Temperatures were below 32°F with a trace of snow.

[(2)] Condition 2 samples were collected on Dec. 24, 1998 between 1200 and 1500. Weather conditions were 3" of snow followed by 0.22" of rain and warming above freezing.

[(3)] Condition 3 samples were collected on Dec. 25, 1998 between 0800 and 1200 with an average rainfall intensity of 0.1" per hour.

4.4 FEBRUARY 1999 DEICING EVENT

4.4.1 Weather Conditions

Near-freezing temperatures (32-35°F) combined with clear skies at night on February 8 created radiational cooling, causing freezing surface conditions. The moisture remaining on the ground from light rain mixed with snow that fell earlier on the site and formed thin ice on these chilled ground surfaces. The precipitation and air temperature for February 1999 Deicing Event is provided in Appendix F.

There was no precipitation until February 13, 4 days after chemical application. Rainfall began February 13 at 02:00 and continued until 10:00. The total precipitation for the event was 0.26 inches. Thus, unlike the December Event, the February Event had an extended period of dry weather between chemical application and first rainfall runoff. Subsequent rain was also much less than in December, totaling 0.26 inches in the first 10 hours compared to 0.39 in 5 hours immediately following the December event.

4.4.2 Deicing Chemical Application

Though this is not a typical scenario for STIA, the resulting ice still posed a serious threat to aircraft safety, thus on February 8 and 9, PA was applied to the airfield at night. Table 12 lists the total amounts of chemical applied to the airfield.

Table 12 February 1999 Deicing Event Characteristics

February 8-9, 1999	
Type	Night Freeze of wet surfaces
Total Snow	Trace
Rank based on snow	7 (three-way tie for lowest)
Total PA	8,300 gallons
Rank based on PA usage	4
Total NAC	0 lbs

Rank based on 9 events in the past four seasons since winter 1995-1996.

Compared to the December event, the February event saw one-half the total PA and no NAC.

4.4.3 Airfield Outfall Monitoring

On February 14, the time composite samples and flow data for February 1999 Event were collected from each of the four STIA outfalls. Using the outfall flow data and the Port's rain data, Cosmopolitan selected six samples from each outfall that were representative of target Hydrograph conditions.

Flow weighted composite samples were collected for the period of February 8-11 from outfalls SDN4, SDS3 and SDS4. These composite samples represent the pre-runoff conditions that occurred during the chemical application period. Because BOD_5 in these composites was low (<4 to 11 mg/L), baseflow prior to initial runoff did not contain chemicals. At SDN4 and SDS4, the BOD_5 concentrations were not detected in the pre-runoff samples. At SDS3, the pre-runoff sample had a BOD_5 concentration of 10.9 mg/L, which is within typical ranges for this outfall (POS, 1998).

On February 13, a flow weighted composite sample was also collected at each outfall for BOD_5 analysis. The initial runoff for the STIA north drainage began at 04:00 on February 13 and continued until around 12:00. The runoff for the STIA south drainage began at 04:00 on February 13 and continued through midnight (see Appendix C).

The sampling results are presented in Table 13 and Appendix C. During the February 1999 Event, the BOD_5 concentrations ranged from <4 mg/L (SDS4) to 164 mg/L (SDN3). The peak BOD_5 concentrations were measured in the second sample between 05:00-06:00. BOD_5 concentrations decreased rapidly in each subsequent samples.

4.4.4 Miller Creek and Lake Reba DO Data

Figure 10 presents a plot of the DO concentrations (corrected) measured in the Miller Creek basin during the February deicing event from 2/8/99 to 2/18/99. The Hydrolab sampler at the Miller Creek Mouth station failed on 2/8 due to siltation and reliable readings were not available after that date and are not plotted. The DO concentration at the nearby Miller Creek WWTP station stayed nearly constant over this period, and was well above the water quality standard.

AR 042740

Table 13 February 1999 Deicing Event – STIA Outfall Results

	Start Date	Start Time	Compositing Period (hours)[1]	BOD_5 (mg/L)	Ammonia (mg/L)
Miller Creek Drainage Basin					
SDN3 - Runoff Results	2/13/99	3:40 4:40 5:40 6:40 8:40 10:00	1 1 1 1 1 1	32.5 146 38.8 13.7 15.4 22.8	– – – – – –
SDN3 – Runoff Flow Composite (3 subsamples)	2/13/99	5:46	2	17.6	–
SDN4 - Pre Runoff Results (9 subsamples)	2/9-11/99	0:35	34	<4	–
SDN4 - Runoff 2 Results	2/13/99	5:00 6:00 7:00 8:00 9:00 10:00	1 1 1 1 1 1	10.7 34.9 18.2 31.4 23.9 13.6	– – – – – –
SDN4 – Runoff Flow Composite	2/13/99	5:05	1	36	–
Des Moines Creek Drainage Basin					
SDS3 - Pre Runoff Results (12 subsamples)	2/8-11/99	23:50	26	10.9	–
SDS3 – Runoff Results	2/13/99	4:00 5:00 6:00 9:00 12:00 16:00	1 1 1 1 1 1	47.4 164 139 44.8 <4 45.5	– – – – – –
SDS3 - Runoff Flow Composite (8 subsamples)	2/13/99	5:16	7.75	80	–
SDS4 - Pre Runoff Results	2/9-11/99	21:20	34	<4	– –
SDS4 – Runoff Results	2/13/99	4:40 6:40 8:40 10:40 15:40 20:40	1 1 1 1 1 1	6.08 <4 <4 <4 <4 <4	– – – – – –
SDS4 – Runoff Flow Composite	2/13/99	4:40	8.5	10.5	–

Airport Runways and Taxiways were deiced Feb. 8 at 22:10 and Feb. 9 at 20:59.

(1) Indicates duration of time composite sampling period.

(2) Samples were frozen upon collection and thawed 3/15/99 and composited for analysis.

(3) Samples are one-hour time composites.

The figure shows that DO concentrations started to decline in Lake Reba on February 9 (before deicing chemicals were applied). This decline continued through February 15. Deicing chemicals were applied late on February 8 and again on February 9, with the first subsequent rainfall and runoff five days later on February 13. Compared to the December deicing event, only a small increase in DO at Lake Reba accompanied this rainfall and runoff. DO concentrations at the Miller Creek Detention Facility and Miller Creek WWTP stations remained well above the water quality standard of 8 mg/L throughout this period.

The sharp increase in DO at the Miller Creek Detention Facility shown on February 14 (③) is due to a 1.12 mg/L increase in the DO correction factor that was applied at this point. The conclusions drawn from these results are discussed in more detail in Appendix G.

4.4.5 Des Moines Creek and NW Ponds DO Data

Figure 11 presents the corrected DO concentrations measured in the Des Moines Creek drainage during the February deicing event from 2/8/99 to 2/18/99. DO concentrations at the Des Moines Creek WWTP and Des Moines Creek Mouth sites closely tracked each other throughout this period, and were at least 3 mg/L greater than the water quality standard of 8 mg/L.

The DO concentrations trends in NW Pond 2 and NW Pond 3 were also similar through most of this period. As was the case for the Miller Creek drainage, there was not enough rainfall and runoff on February 13 to affect the DO concentrations at the Golf Course weir to the degree that was observed following the first deicing event.

Changes to the correction factor applied to the data recorded at the Golf Course weir on February 11 and February 16 are noted on the figure (③ and ④, respectively). The conclusions drawn from these results are discussed in more detail in Appendix G.

4.4.6 Tributary Grab Samples

The first sampling round (Condition 1 – pre-runoff) was collected after the deicing chemical application at STIA on February 9, 1999, from 08:00 to 11:00. No precipitation followed the deicing application until February 13.

The second sampling round (Condition 2 – initial runoff period) was collected on February 13 during the first 0.26" precipitation from 03:00 to 10:00. No precipitation followed the second sampling round until late evening February 15 (only 0.03"), which produced little to no runoff.

Because of the low rainfall and protracted period, a third sampling round (Condition 3 – falling limb) was not conducted for the February 1999 Event. It was assumed that all chemical transport was completed with the second sampling round.

The sampling results are presented in Table 14. Results from the Condition 1 sampling (low- to no-flow periods) had low BOD_5 concentrations ranging from <2-8.2 mg/L. Condition 2 results show an increase in flow rates at most of the tributary sites, with yet even lower BOD_5 concentrations that were generally below detection limits. There appear to have been no other sources of BOD that coincide with Port of Seattle runoff.

Water temperatures ranged from 2.6° C to 8° C. Ammonia concentrations ranged from 0.014 mg/L to 0.102 mg/L. These concentrations were similar to those measured at background concentrations (December 9, 1998).

DO concentrations ranged from 7.9 mg/L (Lake Reba - Condition 1) to 12.1 mg/L (SR 518 – Condition 2). DO concentrations at Lake Reba (Condition 2), Miller Creek Detention Facility (Condition 1), and NW Pond 3 (Condition 2) were below the water quality standard of 8 mg/L.

4.5 LAKE REBA AND NW POND 3 CONDUCTIVITY AND DISSOLVED OXYGEN

Figures 12 and 13 present conductivity, corrected DO concentration, and precipitation data recorded in Lake Reba and NW Pond 3, respectively, over the course of the study. These figures show that there was a consistent trend in the relationship between dissolved oxygen concentration, conductivity and rainfall during background conditions and after deicing events. Dry periods exhibited increases in conductivity and decreases in DO concentration at both sampling locations. Conversely, the DO concentration increased during periods of rainfall and resultant runoff. This pattern is discussed in detail in Section 5.

The SeaBird instruments were also used to measure vertical DO and conductivity profiles through the water column in Lake Reba and NW Pond 3 on January 22, 1999. These profiles were measured during a period of moderate rainfall (see Appendix B) to determine if stratification was occurring in the ponds that could have resulted in erratic DO measurements. The profiles are presented in Appendix G and show that Lake Reba and NW Pond 3 were well mixed (not stratified) at the times and locations where the profile data were collected.

Table 14 February 1999 Sampling Results – Miller Creek and Des Moines Creek Tributaries and Other Grabs

	Time Sampled	BOD_5 (mg/L)	Ammonia (mg/L)	DO (mg/L)	Temp. (C)	Flow,(cfs) Stage,(ft)
Miller Creek Drainage Basin						
[(1)]*Condition 1 – Prior to Initial Runoff – February 9, 1999, Flash freeze (radiational cooling) overnight Feb. 8 to 9, Temperature 32°F at night and 40°F during day.*						
Lake Reba	8:18	3.62	–	8.79	4.1	3.07 ft
Miller Creek	8:40	3.26	–	10.89	4.1	3.79 ft
NEPL	–	–	–	–	–	No flow
SR 518	–	–	–	–	–	No flow
SDN1	–	–	–	–	–	No flow
Miller Creek Detention Facility	8:00	2.12	–	6.26[(5)]	4.0	NA
Lake Burien	9:00	2.52	–	10.94	7.9	0.98
Tributary 2	9:15	3.5	–	9.2	5.3	9.00
[(2)]*Condition 2 – Initial Runoff – February 13, 1999: 0.26" rain 02:00 to 10:00.*						
Lake Reba	8:20	<2	–	7.87		2.53 ft
Miller Creek	8:45	<2	0.10	10.81	5.40	4.12 ft
NEPL	–	–	–	–	–	No flow
SR 518	8:55	3.12	0.01	12.08	4.60	0.46
SDN1	10:00	<2	0.06	10.07	6.00	0 +/-
Miller Creek Detention Facility	8:00	<2	0.10	–	–	7.8
Lake Burien	9:10	<2	–	10.52	8.00	1.20
Tributary 2	9:20	<2	–	10.44	6.50	5.40
No Condition 3 Sampling – No subsequent rainfall						
POS Composite Samples[(3)]						
2/9 Miller Creek	02:00-22:22	<4	–	–	–	–
2/9 Miller Creek Detention Facility	01:34-21:45	<4	–	–	–	–
2/9-11 Miller Creek	22:00-12:01	<4	–	–	–	–
2/9-11 Miller Creek Detention Facility	21:58-12:30	<4	–	–	–	–
2/11-13 Miller Creek	13:34-5:25	<4	–	–	–	–
2/11-13 Miller Creek Detention Facility	18:04-11:12	<4	–	–	–	–
2/13-14 Miller Creek	06:08-08:30	<4	–	–	–	–
2/13-14 Miller Creek Detention Facility	12:13-07:23	<4	–	–	–	–
2/12/99 Lake Reba Grab[(4)]	11:55	<2	–	–	–	2.22 ft
2/14/99 Lake Reba Grab[(4)]	12:49	<2	–	–	–	2.99 ft
2/18/99 Lake Reba Grab[(4)]	9:15	<2	–	–	–	3.07 ft
2/23/99 Lake Reba Grab[(4)]	9:05	<2	–	–	–	1.65 ft
2/26/99 Lake Reba Grab[(4)]	13:10	<2	–	–	–	1.6 ft

Airport Runways and Taxiways were deiced Feb. 8, 1999 at 22:10 and February 9, 1999 at 20:59 during night freezes.

0±: Flow was visible but not measurable.

NA: not available – meter failed.

(1) Condition 1 samples were collected on February 9, 1999 between 0800 and 1200. Weather conditions were 32°F with no precipitation.

(2) Condition 2 samples were collected on February 13, 1999 between 0800 and 1200. Weather conditions were warming to 41°F-50°F with a light rain.

(3) Flow-weighted composites, also analyzed for total recoverable copper, lead, and zinc.

(4) Collected by Cosmopolitan Engineering Group

(5) Sample classified as an outlier, see discussion in Appendix D, Section D.7. Concentration measured with Hydrolab at this point was 9.33 mg/L.

Table 14 February 1999 Tributary Sampling Results (continued)

	Time Sampled	BOD_5 (mg/L)	Ammonia (mg/L)	DO. (mg/L)	Temp. (C)	Flow,(cfs) Stage,(ft)
Des Moines Creek Drainage Basin						
(1)Condition 1 - Prior to Initial Runoff – February 9, 1999, Flash freeze (radiational cooling) overnight Feb. 8 to 9, Temperature 32°F at night and 40°F during day.						
NW Pond Inlet	8:30	5.5	–	11.29	4.8	1.32 ft
BDW3 (B, D, SDW3 combined)	8:30	3.06	–	11.38	2.6	0±
NW Pond 3	9:30	8.18	–	8.38	3.9	5.1
East Basin	9:40	2.94	–	11.89	4.5	5.50
Golf Course Weir	10:00	3.13	–	10.43	4.5	10
Tributary 1	9:10	<2	–	8.53	5.6	0.84
Tributary 2	10:35	<2	–	11.9	5.5	2.41
(2)Condition 2 - Initial Runoff - February 13, 1999: 0.26" rain 02:00 to 10:00.						
NW Pond Inlet	10:25	<2	0.022	11.33	5.8	1.91 ft
BDW3 (B, D, SDW3 combined)	10:35	2.78	0.074	11.15	6.1	0±
NW Pond 3	11:10	<2	–	6.76	–	4.5
East Basin	11:20	<2	0.025	11.12	6.3	5.40
Golf Course Weir	11:30	<2	0.046	10.23	–	8.6
Tributary 1	11:00	<2	–	8.49	6.9	1.50
Tributary 2	11:45	<2	–	11.22	7.3	0.90
No Condition 3 Sampling – No subsequent rainfall						
NW Pond 3 Sampling						
POS Composite Samples(3)						
2/9 NW Pond Inlet	00:00-21:20	<4	–	–	–	–
2/9-11 NW Pond Inlet	21:23-11:00	5.64	–	–	–	–
2/8-11 NW Pond 3 Outlet	00:05-11:00	6.9	–	–	–	–
2/11-13 NW Pond Inlet	14:15-14:37	5.24	–	–	–	–
2/11-13 NW Pond 3 Outlet	11:15-07:05	<4	–	–	–	–
2/13-14 NW Pond 3 Outlet	08:01-08:42	13.5	–	–	–	–
2/12/99 NW Pond 3 Grab(4)	11:35	<2	–	–	–	2
2/14/99 NW Pond 3 Grab(4)	12:26	7.34	–	–	–	2.7
2/18/99 NW Pond 3 Grab(4)	10:50	2.24	–	–	–	3.1
2/23/99 NW Pond 3 Grab(4)	8:45	3.34	–	–	–	7
2/26/99 NW Pond 3 Grab(4)	13:30	<2	–	–	–	3

Airport Runways and Taxiways were deiced Feb. 8, 1999 at 22:10 and February 9, 1999 at 20:59 during night freezes.

0±: Flow was visible but not measurable.

(1) Condition 1 samples were collected on February 9, 1999 between 0800 and 1200. Weather conditions were 32°F with no precipitation.

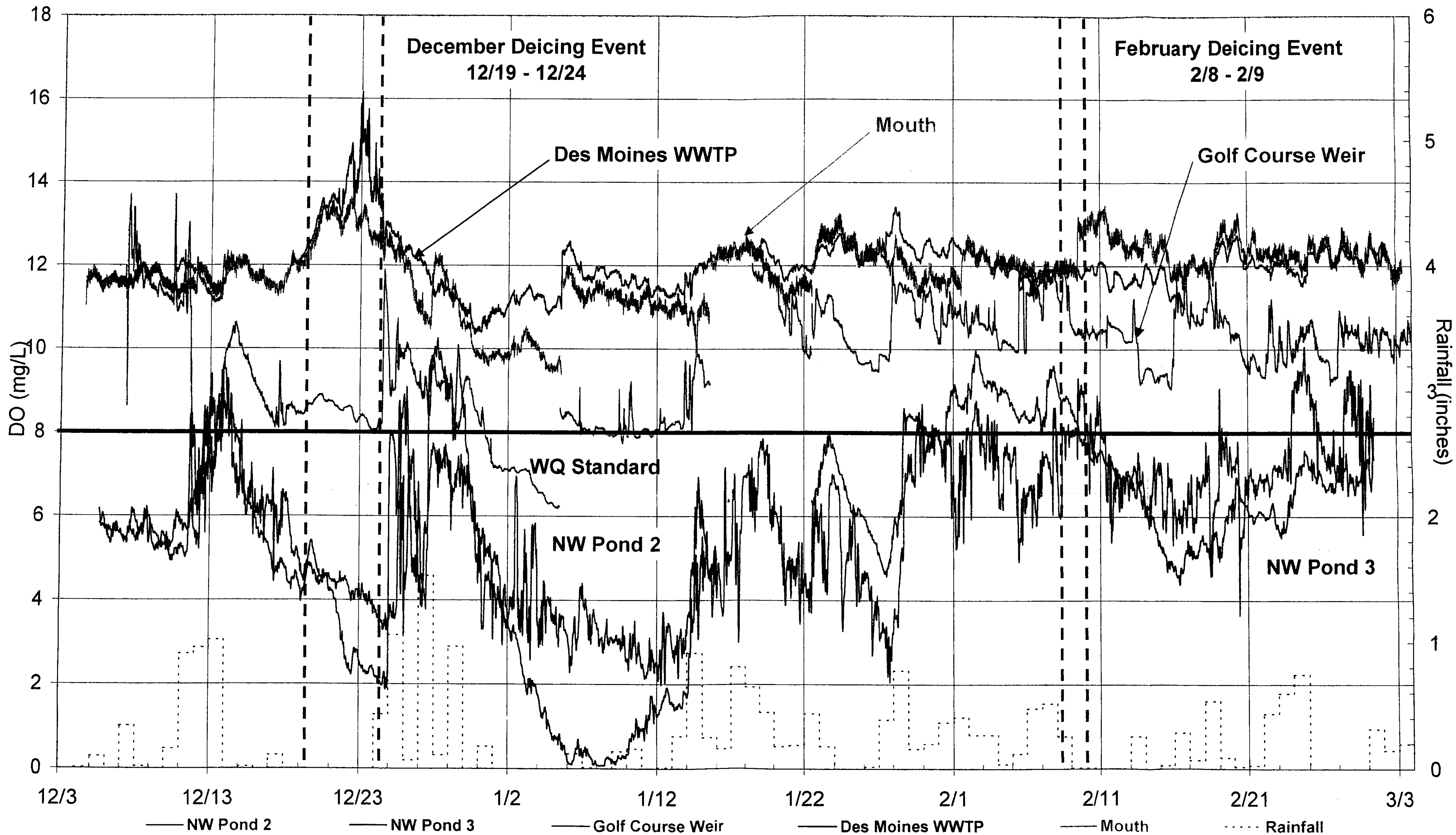
(2) Condition 2 samples were collected on February 13, 1999 between 0800 and 1200. Weather conditions were warming to 41°F-50°F with a light rain.

(3) Flow-weighted composites, also analyzed for total recoverable copper, lead, and zinc.

(4) Collected by Cosmopolitan Engineering Group

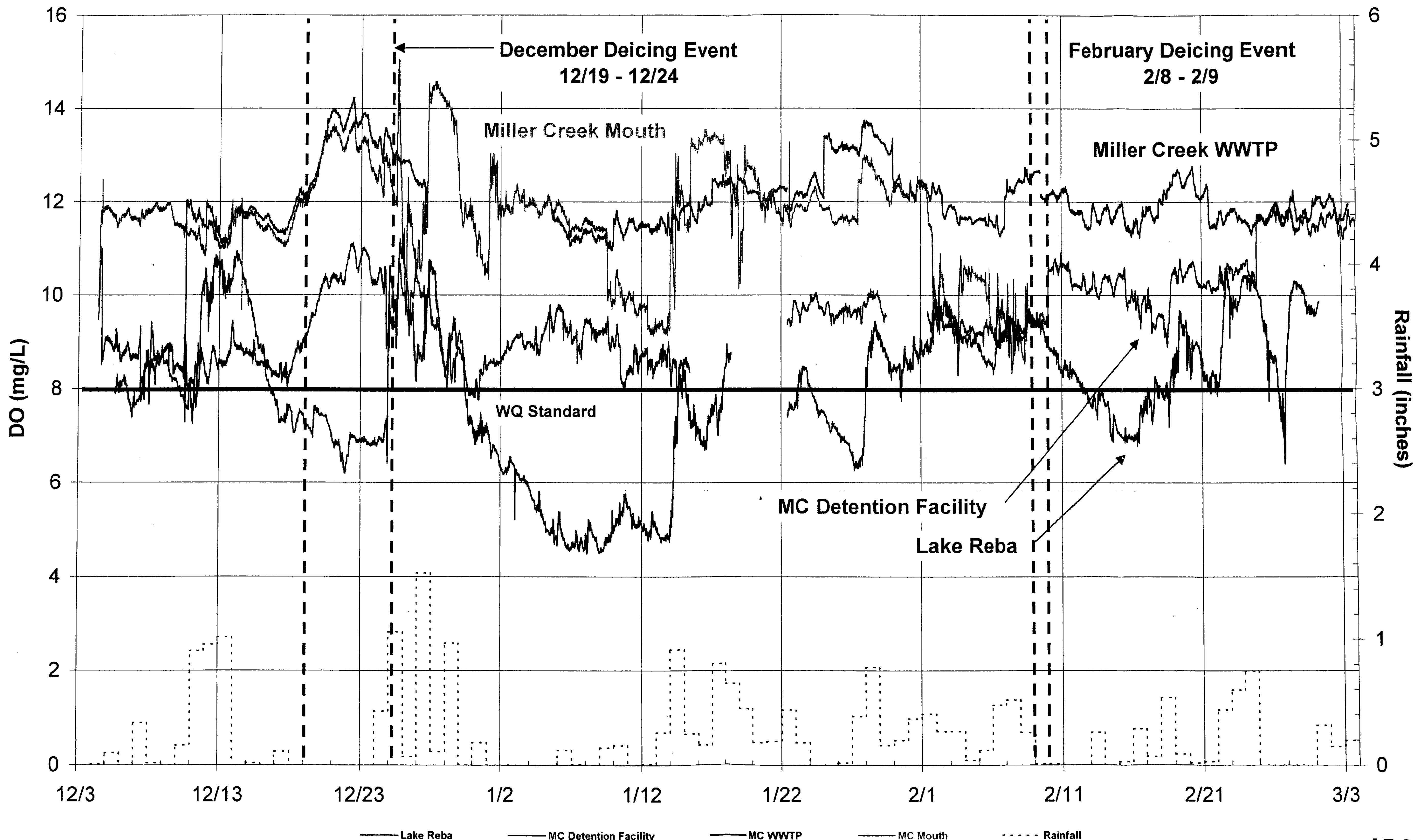
AR 042745

Figure 4
Des Moines Creek DO Monitoring Data



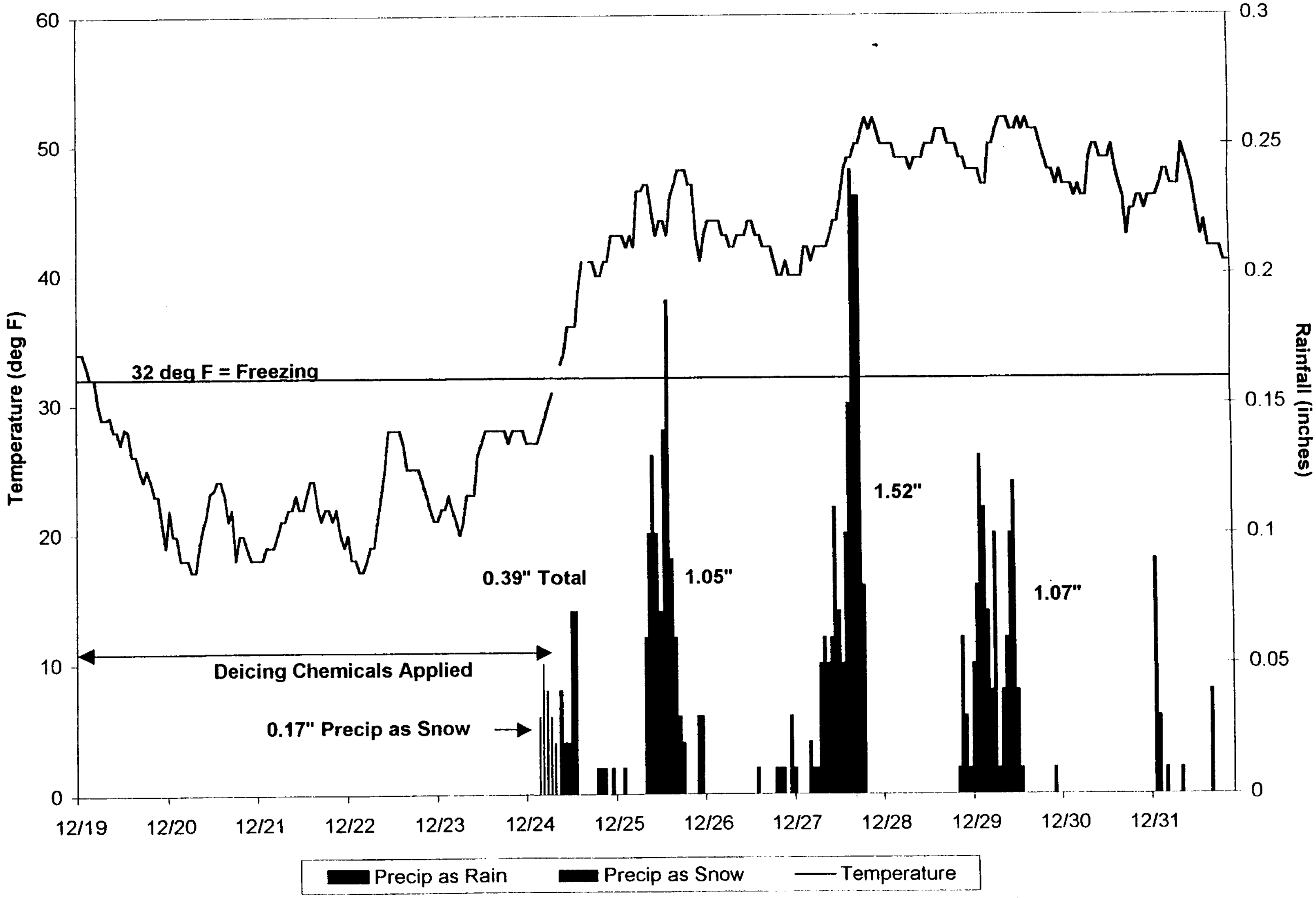
AR 042746

Figure 5
Miller Creek DO Monitoring Data



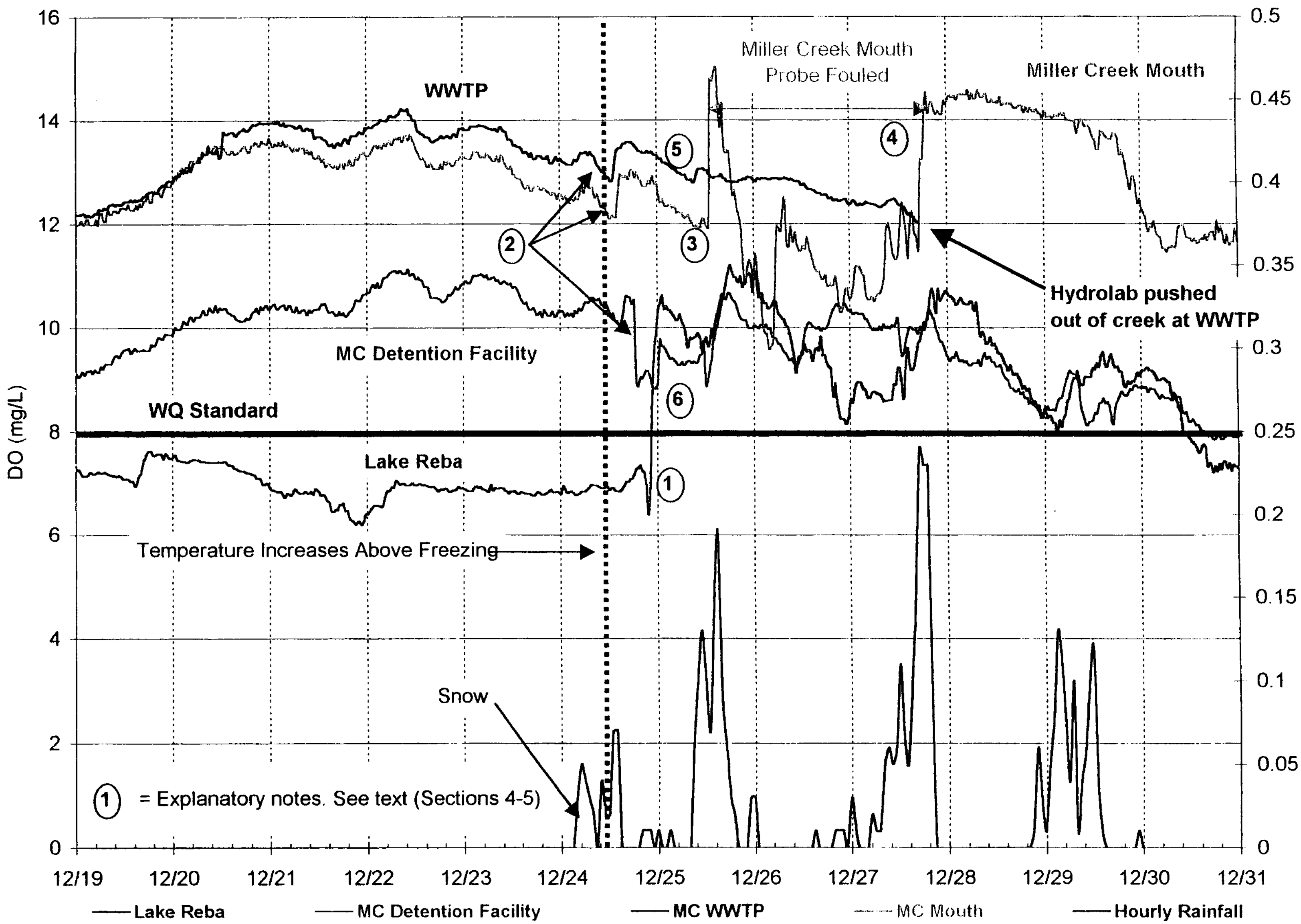
AR 042747

Figure 6
December '98 Deicing Event
STIA NWS HOURLY WEATHER DATA



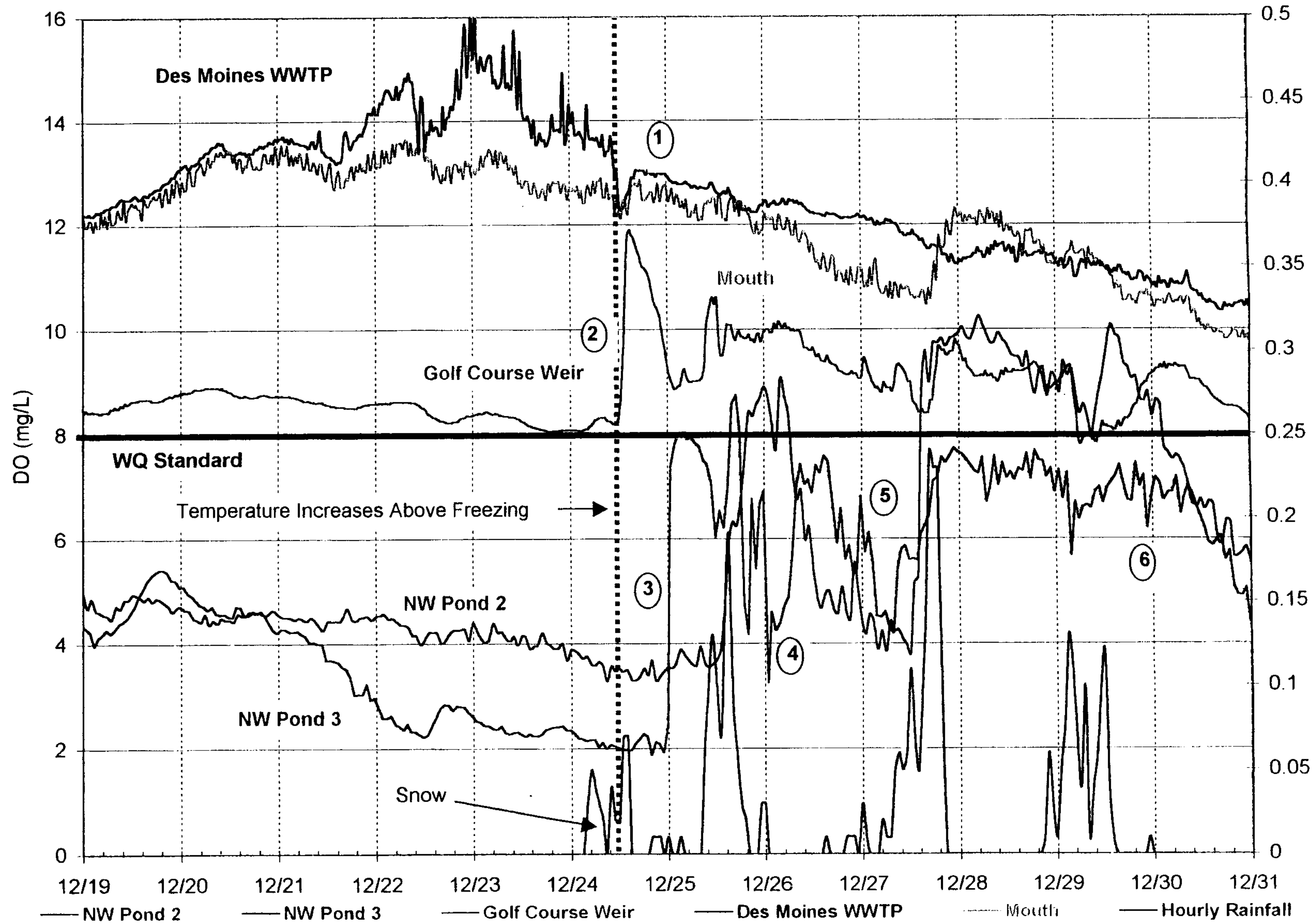
AR 042748

Figure 7
Miller Creek DO Monitoring Data
December 1998 Deicing Event



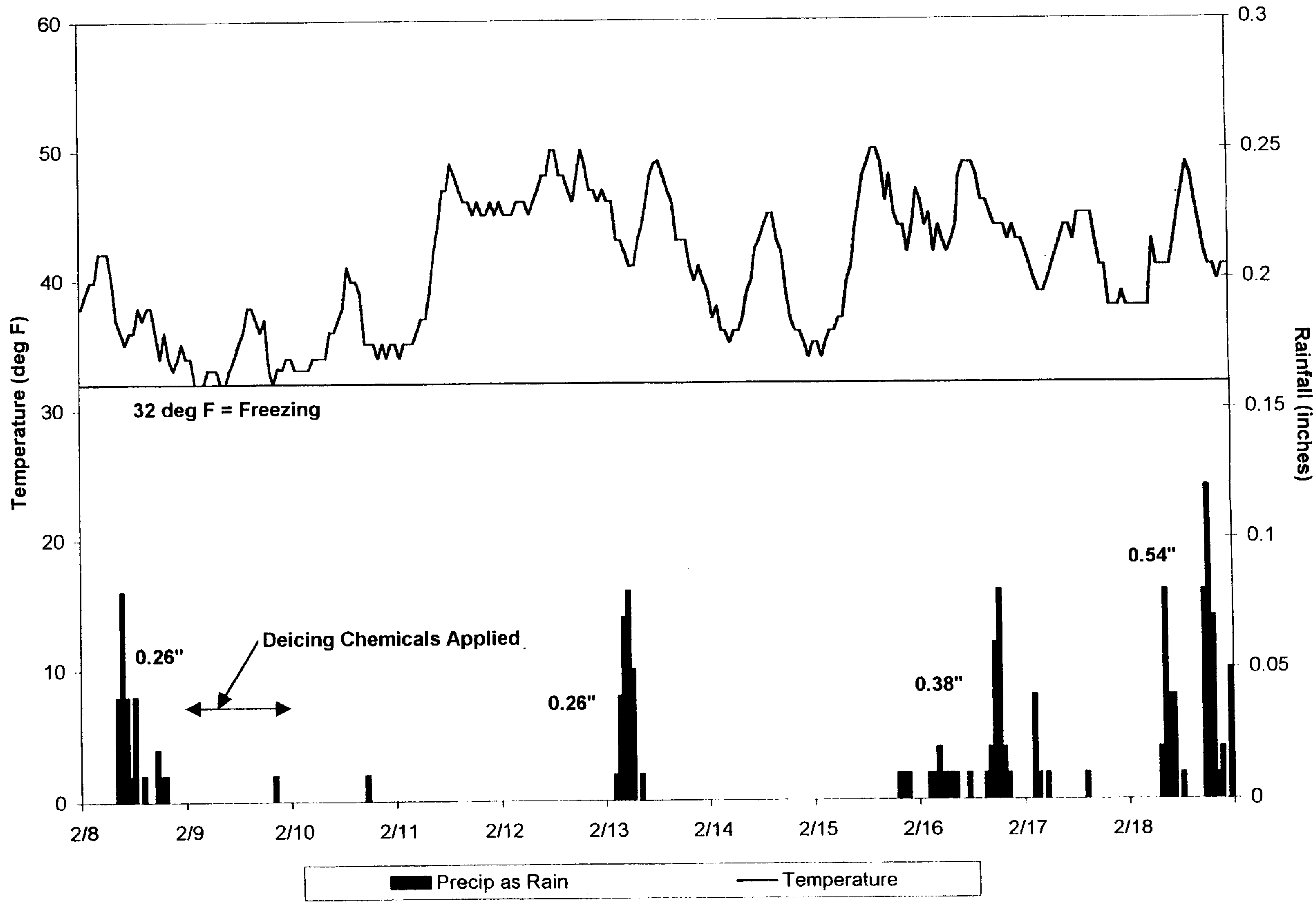
AR 042749

Figure 8
Des Moines Creek DO Monitoring Data
December 1998 Deicing Event



AR 042750

Figure 9
February '99 Deicing Event
STIA NWS HOURLY WEATHER DATA



AR 042751

Figure 10
Miller Creek DO Monitoring Data
Febuary 1999 Deicing Event

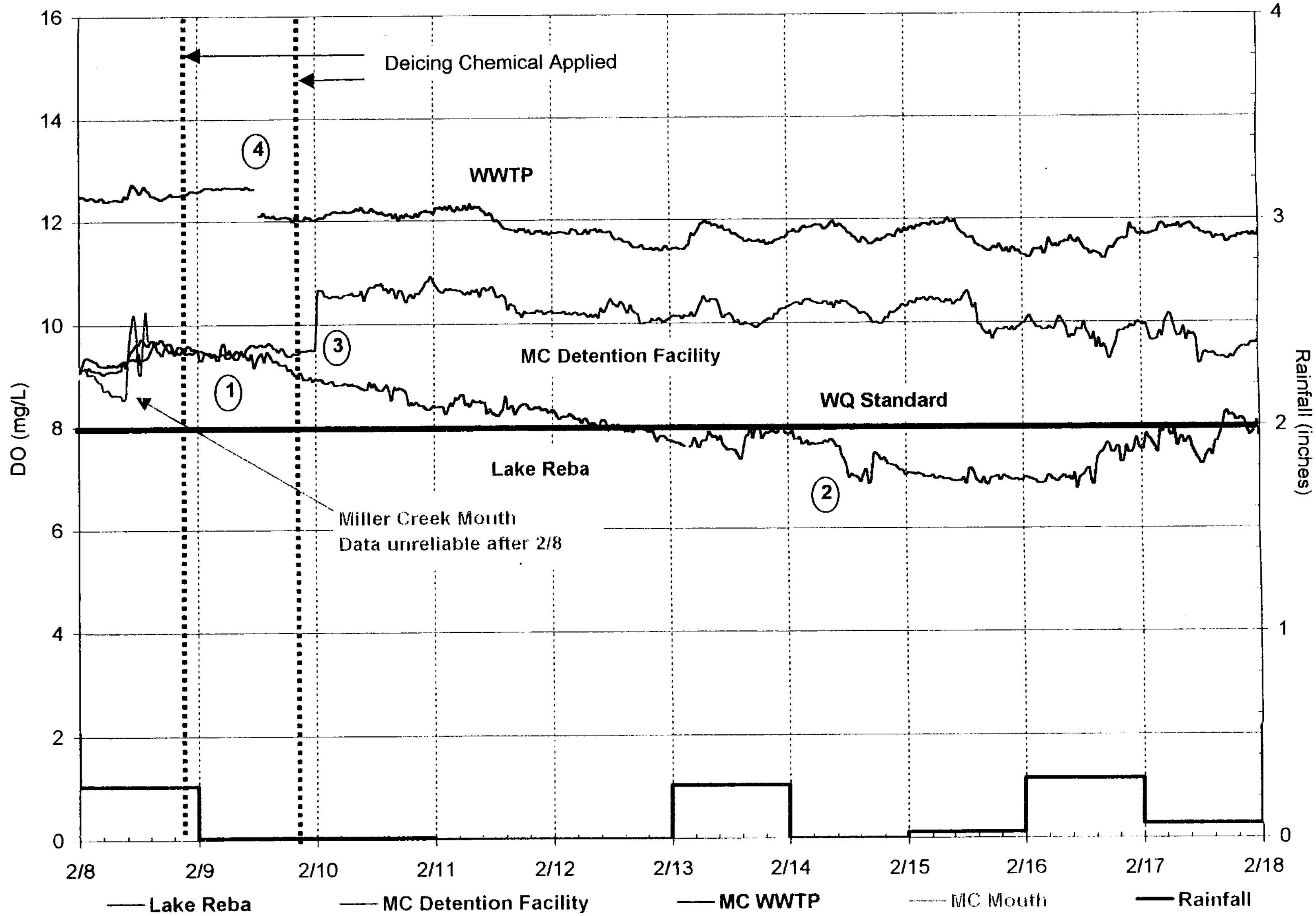


Figure 11
Des Moines Creek DO Monitoring Data
February 1999 Deicing Event

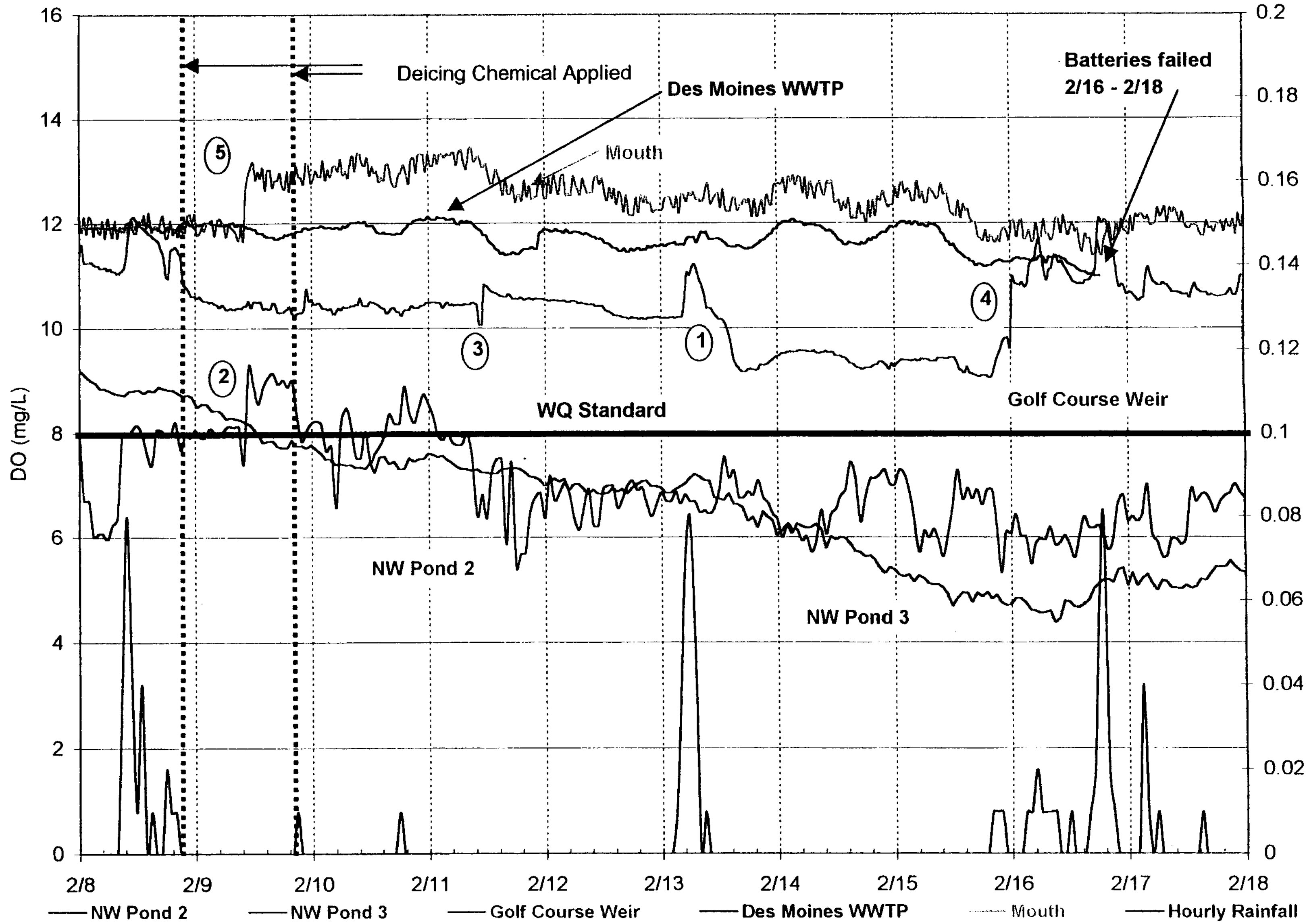
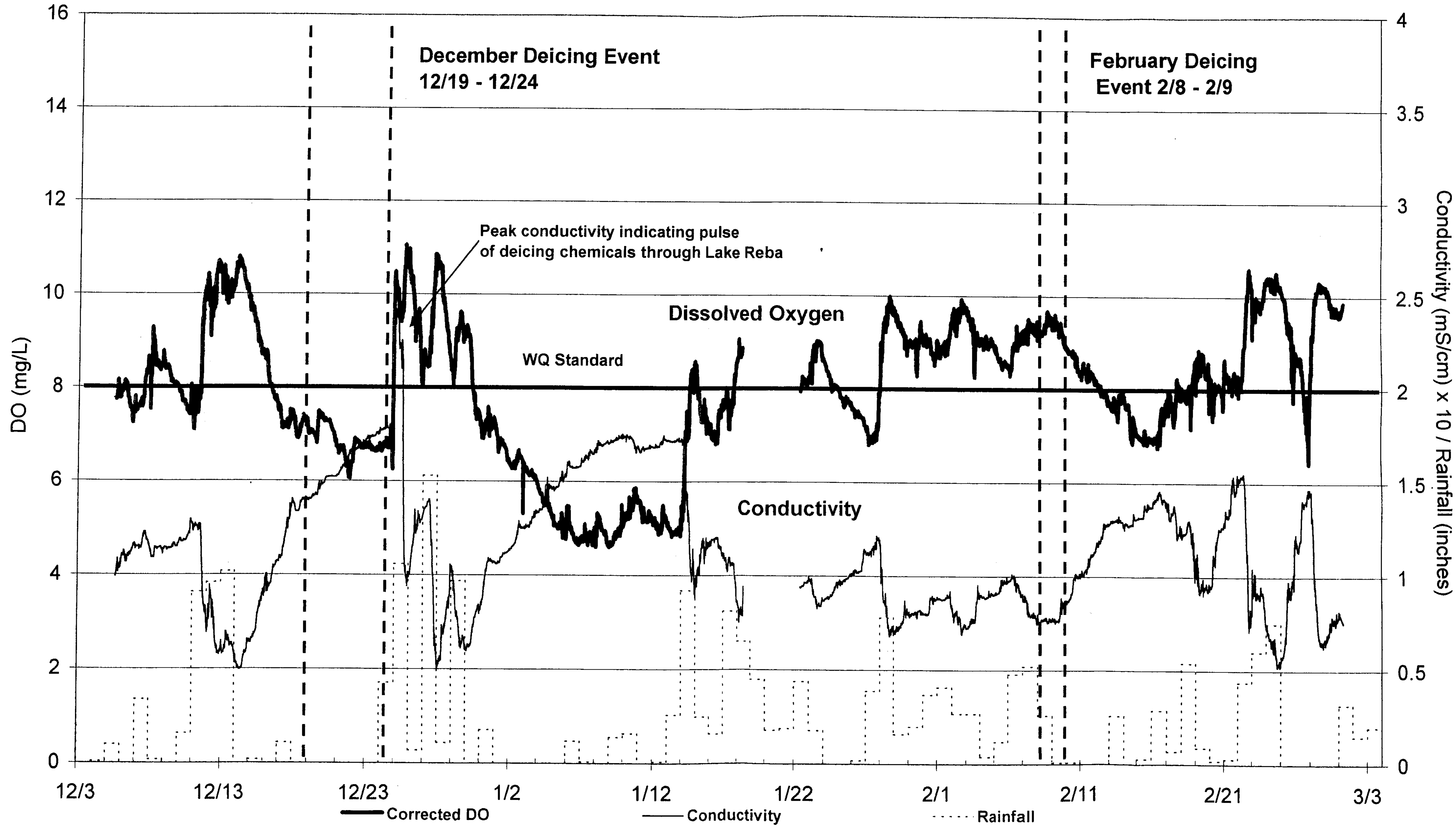
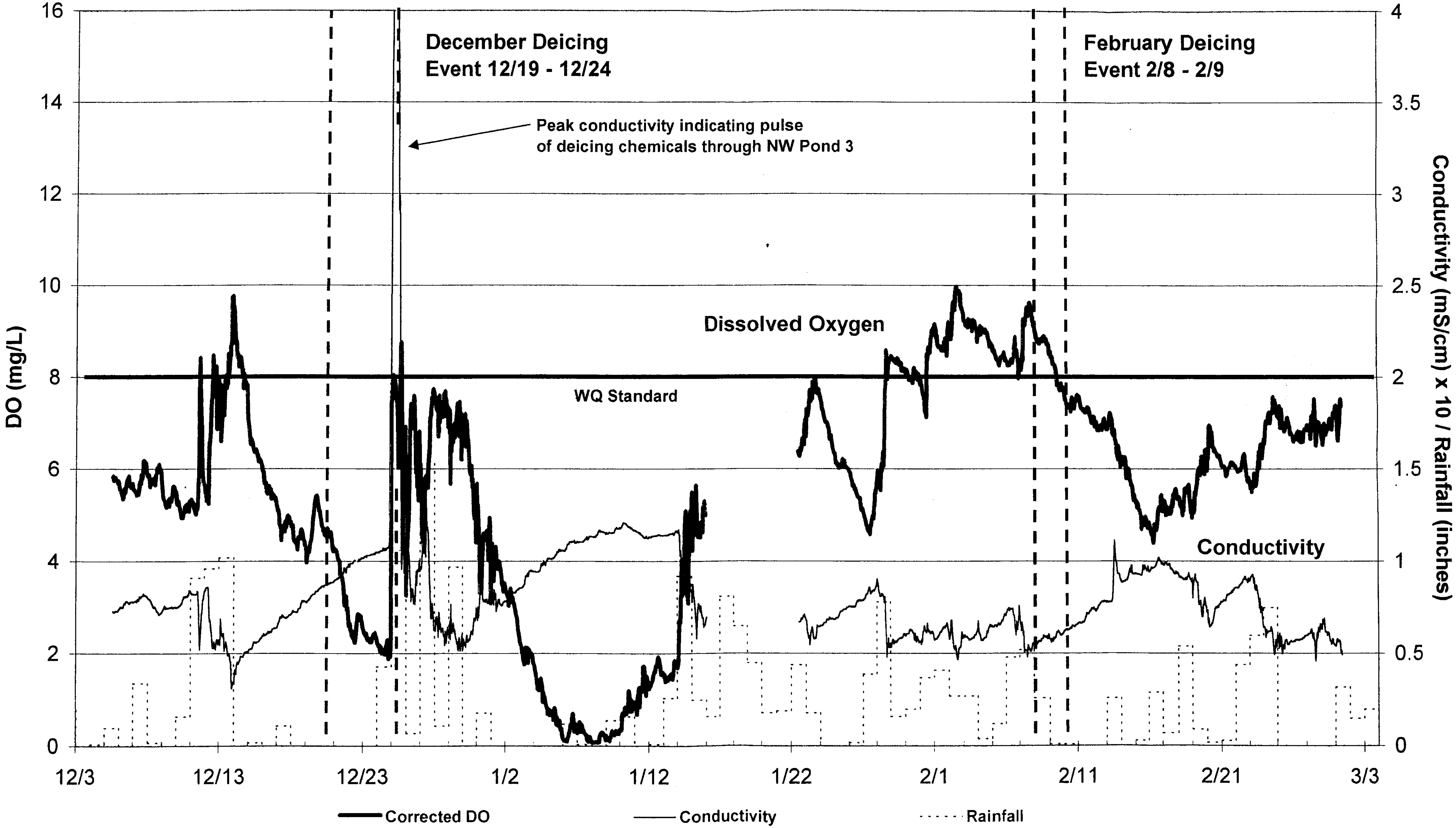


Figure 12
Lake Reba - DO Concentration and Conductivity



AR 042754

Figure 13
NW Pond 3 - DO Concentration and Conductivity



AR 042755

SECTION 5: DISCUSSION

This section of the report describes general relationships between dissolved oxygen concentrations observed in the ponds and other conditions that occurred during the study. More detailed observations of dissolved oxygen changes and relationships in the entire creek systems are provided in Appendix G.

5.1 GENERAL OBSERVATIONS

5.1.1 DO Versus Precipitation

The purpose of this study was to evaluate the impact on dissolved oxygen in Miller and Des Moines Creeks after application of deicing chemicals to STIA runways and taxiways. Since the instream DO monitors recorded data continuously, there are several key observations related to temporal trends that are important when interpreting results following deicing events. Figures 4 and 5 demonstrate the following:

1. Dissolved oxygen concentrations at the downstream stations (mouth of Miller and Des Moines Creeks, Miller and Midway WWTPs) were generally uniform and ranged from 3 to 5 mg/L above the water quality standard of 8.0 mg/L. The upstream variations in DO were greater than at the downstream stations.

2. Dissolved oxygen varied greatly in the detention ponds at the heads of Miller and Des Moines Creeks. DO was always lower in the detention ponds compared to downstream stations in the mainstream creek channel, and was usually below the water quality standard of 8.0.

3. The DO variations in Lake Reba and the NW Ponds clearly followed wet and dry weather patterns. The DO minima were observed during the periods of no precipitation, both at times before and well after deicing chemical application. The DO concentrations in Lake Reba and NW Ponds always increased at the onset of runoff from precipitation, regardless of whether deicing chemicals were present.

AR 042756

A notable example of the relationship between DO and precipitation is revealed in the graph of DO concentrations recorded for Des Moines Creek (Figure 4) in Northwest Pond 3 from January 3–13 (10 days and 4.5 inches of rain after the December deicing event). This was the longest period of the study with very little precipitation or runoff. Over this period, the DO concentration in NW Pond 3 fell below 2 mg/L. When precipitation and runoff began on January 13, DO concentrations quickly recovered to prior levels.

Similar low DO conditions were observed in the NW Ponds during dry weather conditions on December 16-24 (before deicing) and January 23-27 (one month after deicing). DO recovered quickly with the onset of precipitation runoff after all dry periods. The cause of the low DO during dry periods is unknown, but it is clear that suppressed DO conditions in the detention ponds occurred before deicing, and well after deicing chemicals were flushed from the system.

The DO concentration at the Golf Course weir (0.3 miles downstream of NW Pond 3) generally followed the trend of the ponds, though in all cases the water had reaerated substantially by that point. Except for a period in early December before any runway deicing had occurred, and in January when DO concentrations in the NW Ponds were at a minimum, DOs at the Golf Course weir exceeded the water quality standard.

5.1.2 DO Versus Conductivity

Figure 14 consolidates Figures 12 and 13 on a single graph. This figure shows that there was a consistent trend in the relationship between dissolved oxygen concentration, conductivity, and rainfall in NW Pond 3 and Lake Reba. Conductivity is a conservative indicator of ions present in the water and thus serves as a tracer for the deicing chemicals.

Until the middle of March, increases in conductivity and decreases in DO concentration at both sampling locations coincided with periods of minimal rainfall and runoff. In some cases a period of as little as 48-72 hours without rain resulted in a noticeable increase in conductivity and decrease in DO. For example, during the dry period from January 24 to January 26 (① on Figure 14) conductivity increased and dissolved oxygen decreased in both Lake Reba and NW Pond 3. Similar patterns are identified on Figure 14 for other points in the study (②,③,④).

Conversely, during periods of extended rainfall, the DO increased as the conductivity decreased. The pattern immediately following the dry period of January 24-26 is typical. From January 27-28, 1.17 inches of rain fell, the DO in NW Pond 3 increased from 4.9 to 8.4 mg/L, and the DO in Lake Reba increased from 7.0 to 10.0 mg/L. Conductivity in the two ponds also decreased over this same period. These variations occurred independent of deicing activities.

The peak conductivity concentrations shown on Figure 14 on 12/24 are due to the runoff of stormwater containing deicing chemicals. There was no distinct peak of similar magnitude for the February event. The other increases in conductivity that were observed during periods of minimal rainfall are due to the inflow of groundwater with a higher mineral content than the stormwater that enters the ponds[4]. During periods of heavier rainfall, well-aerated stormwater enters the ponds, increasing DO and diluting conductivity in the ponds. This theory is supported by the fact that the most extended drop in DO occurred in early January (③) during the longest dry period during the study. Again, this drop in DO occurred after 7 flushing cycles in Lake Reba and 21 flushing cycles in NW Pond 3. Therefore, it is highly unlikely that runway deicing caused the depressed DO conditions observed in the detention ponds.

5.2 RESIDENCE TIMES AND FLUSHING OF DEICING CHEMICALS IN PONDS

5.2.1 NW Pond 3

The travel time for deicing chemical-laden runoff to reach the NW Pond 3 outlet and enter Des Moines Creek can be determined from conductivity data for the pond relative to precipitation and measured runoff flow rates. Figure 15 presents a plot of the flow rate from outfall SDS3 (the outfall that discharges to the NW Ponds), precipitation, conductivity, and DO for NW Pond 3 for the period immediately following the December deicing event (12/24 0:00 to 12/26 12:00). Conductivity can be used as a tracer for the travel of the deicing chemicals.

Figure 15 shows that flow from the SDS3 outfall started to increase at approximately 12:00 on 12/24 and reached an initial peak at 14:00. A sharp increase in conductivity occurred in NW Pond 3 (near the outlet) about 12 hours later, with the maximum concentration of 0.33 ppt recorded between 1:00 and 3:00 on 12/25. An increase in the DO concentration in the pond closely followed the increase in conductivity. These observations indicate that the first runoff

AR 042758

containing deicing chemicals was discharged from NW Pond 3 to Des Moines Creek at approximately 0:00 on 12/25. Comparing the initial peak in flow from the SDS3 outfall to the peak in conductivity measured in NW Pond 3 leads to the following observations:

1. The time between the first rise in flow at the outfall and the initial rise in conductivity was approximately 8.5 hours.

2. The time between the peak flow from the outfall and the peak conductivity concentration at the NW Pond 3 station was about 12.5 hours.

3. The time between the approximate centroids of the flow and conductivity pulses was approximately 15 hours.

The precipitation and snowfall conditions during the December deicing event resulted in approximately 9-15 hours of retention time between the SDS3 outfall and the NW Pond 3 outlet. The width of the conductivity pulse shows that the deicing chemicals were completely flushed through NW Pond 3 in 20 hours from the time when the conductivity first started to increase (21:00 on 12/24) to the time when conductivity returned to its previous baseline level (approximately 17:00 on 12/25).

The estimated travel time down Des Moines Creek is four hours at winter baseflow conditions and one hour at routine storm runoff conditions (Horner, May 1996). Given the 1- to 4-hour travel time, the estimated travel time for deicing chemicals through NW Pond 3 and Des Moines Creek, combined, is 21 to 24 hours.

5.2.2 Lake Reba

Figure 16 presents a plot of the combined flow rate from outfalls SDN3 and SDN4, precipitation, conductivity, and DO for Lake Reba for the period immediately following the December deicing event (12/24 0:00 to 12/26 12:00).

---

[4] Conductivity is a function of the total dissolved solids in water after the organic matter has been oxidized. It includes calcium and potassium and other ions that are present in the deicing chemicals and are also present in groundwater.

Figure 16 shows that the discharge of runoff from SDN3 and SDN4 began at approximately 16:00 on 12/24. The first flow containing deicing chemicals was discharged from Lake Reba six hours later at approximately 22:00, based on sharp increases in both the DO concentration and conductivity at the Lake Reba outlet. The maximum conductivity concentration was 0.18 ppt at 0:10 on 12/25. Comparing the initial peak in flow from the combined SDN3 and SDN4 outfalls to the peak in conductivity measured in NW Pond 3 leads to the following observations:

1. The time between the first measured flow at the outfall and the first rise in conductivity near the Lake Reba outlet was approximately 6 hours.

2. The time between the peak flow from the outfalls and the peak conductivity concentration in Lake Reba was approximately 7.5 hours.

3. The time between the approximate centroids of the flow and conductivity pulse was approximately 11.5 hours.

The precipitation and snowfall conditions during the December deicing event, resulted in approximately 6-12 hours of retention time between the SDN3 and SDN4 outfalls and the Lake Reba outlet. Peak flow from the outfalls occurred at approximately 15:00 on 12/25, about the same time that conductivity returned to background levels. The graph shows that it took approximately 16 hours for the deicing chemicals to be flushed through Lake Reba.

The estimated travel time from Lake Reba to Puget Sound is 8 hours at winter base flow conditions and 2 hours at routine storm runoff conditions (Horner, May 1996). Given the 2- to 8-hour travel time, the estimated travel time for the deicing chemicals through the Miller Creek Drainage is 18 to 24 hours.

5.2.3 Effect on DO

The flow of deicing chemicals through NW Pond 3 and Lake Reba is relatively rapid. Deicing chemicals were completely flushed out of NW Pond 3 in 20 hours after the presence of chemicals was first indicated by an increase in conductivity. Deicing chemicals were flushed through Lake Reba in 16 hours.

There was no reduction in DO in the ponds during the period when deicing chemicals were present. Conversely, the DO concentrations were substantially higher than in the antecedent period. In NW Pond 3, the DO concentration quickly increased from 1.9 mg/L to 7.3 mg/L as the conductivity concentration started to increase, reflecting the highly aerated runoff. In Lake Reba, the DO concentration increased from 6.3 mg/L to 10.2 mg/L over a similar period of time.

5.2.4 February Deicing Event

During and immediately following the deicing event on February 8-9, Lake Reba and NW Pond 3 exhibited relatively slow increases in conductivity and slow decreases in DO concentration (Figure 14). There was little or no runoff from the airfield outfalls during this period. Dramatic spikes in conductivity and concentration similar to those observed immediately following the December deicing event did not occur during the dry period from 2/8 to 2/13.

The only spike in conductivity or DO concentration in either pond was a much smaller (compared to the December event) spike in conductivity measured in NW Pond 3 on 2/13 (from 0.08 mS/cm at 9:50 to 0.11 mS/cm at 12:50). This spike occurred approximately 6-7 hours after the first flow was discharged from outfall SDS3 (Appendix C, Figure C-5). After the spike in conductivity occurred on 2/13, the conductivity in NW Pond 3 resumed the slow upward trend begun previously on 2/9, before deicing chemicals were discharged from the outfalls.

The lack of rainfall following the February deicing event prevents the estimation of flushing times in the ponds for the February deicing event. Only 0.26 inches of precipitation fell on 2/13 and a total of only 0.4 inches was recorded between 0:00 2/9 and 12:00 2/16. In comparison, more than an inch of rain fell in the 24 hours immediately following the December deicing event. Heavier rainfall of 0.9 inches in the three day period beginning on 2/16 resulted in decreasing conductivity and increasing DO concentration in both ponds, similar to the pattern that was observed during similar conditions prior to and subsequent to both deicing events. In the following days, the previously described pattern of increasing DO and decreasing conductivity during periods of rainfall and runoff resumed.

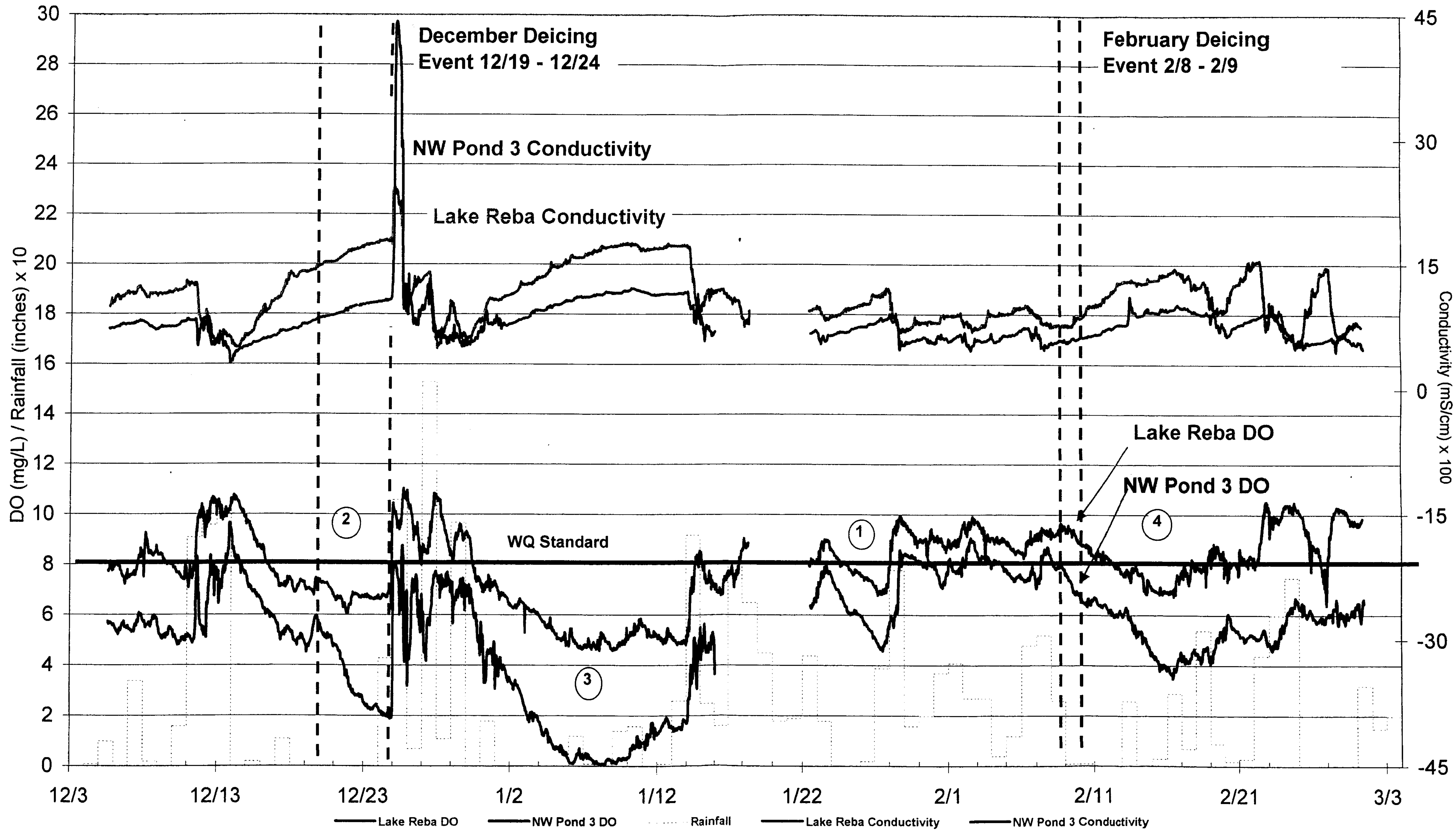
5.2.5 Flushing Rates

According to estimates (Ludwa, personal communication, 1999), approximately 0.6 inches of rain will completely flush Lake Reba and 0.2 inches of rain will flush the NW Ponds. Because this estimate represents flushing for the entire three cells of the NW Ponds, flushing for NW

Pond 3 should be even more rapid (requiring less rainfall) because SDS3, which serves the largest drainage area, flows into NW Pond 3, bypassing NW Ponds 1 and 2.

The minimum DO concentrations measured in NW Pond 3 and Lake Reba occurred in early January (<4 mg/L in NW Pond 3, <6 mg/L in Lake Reba). There was a total of 4.35 inches of precipitation between 12/24 (following the December deicing event) and 1/6. According to the above estimates, this amount of rainfall flushed the Northwest Ponds at least 21 times after the December deicing event before the minimum DO concentrations occurred. Lake Reba was flushed approximately seven times over this same period. These estimates indicate that it is unlikely that deicing chemicals were present when the low DO concentrations occurred.

Figure 14
Lake Reba and NW Pond 3 - DO and Conductivity



AR 042763

Figure 15
NW Pond 3 DO, Conductivity, and Flow - December Deicing Event

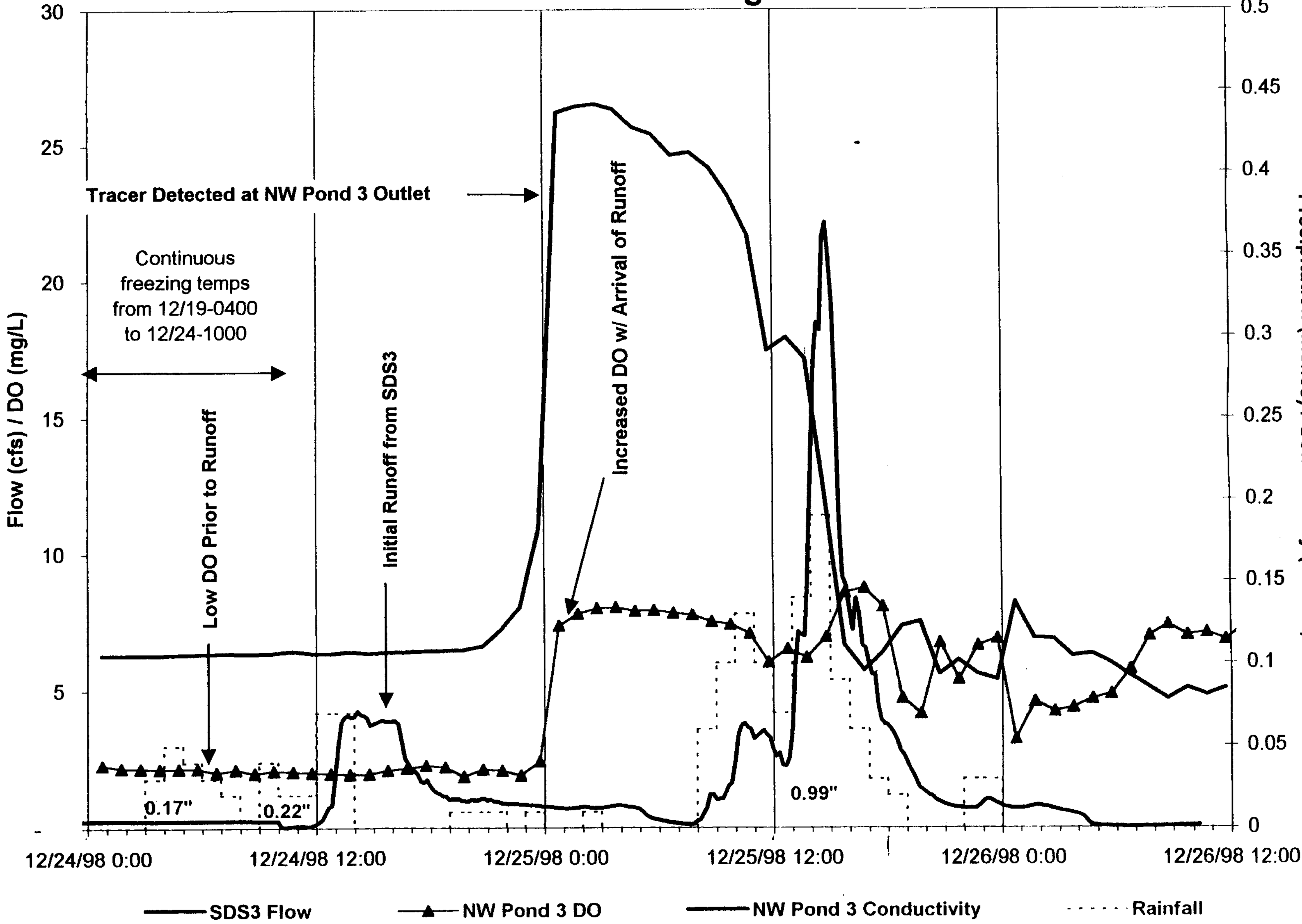
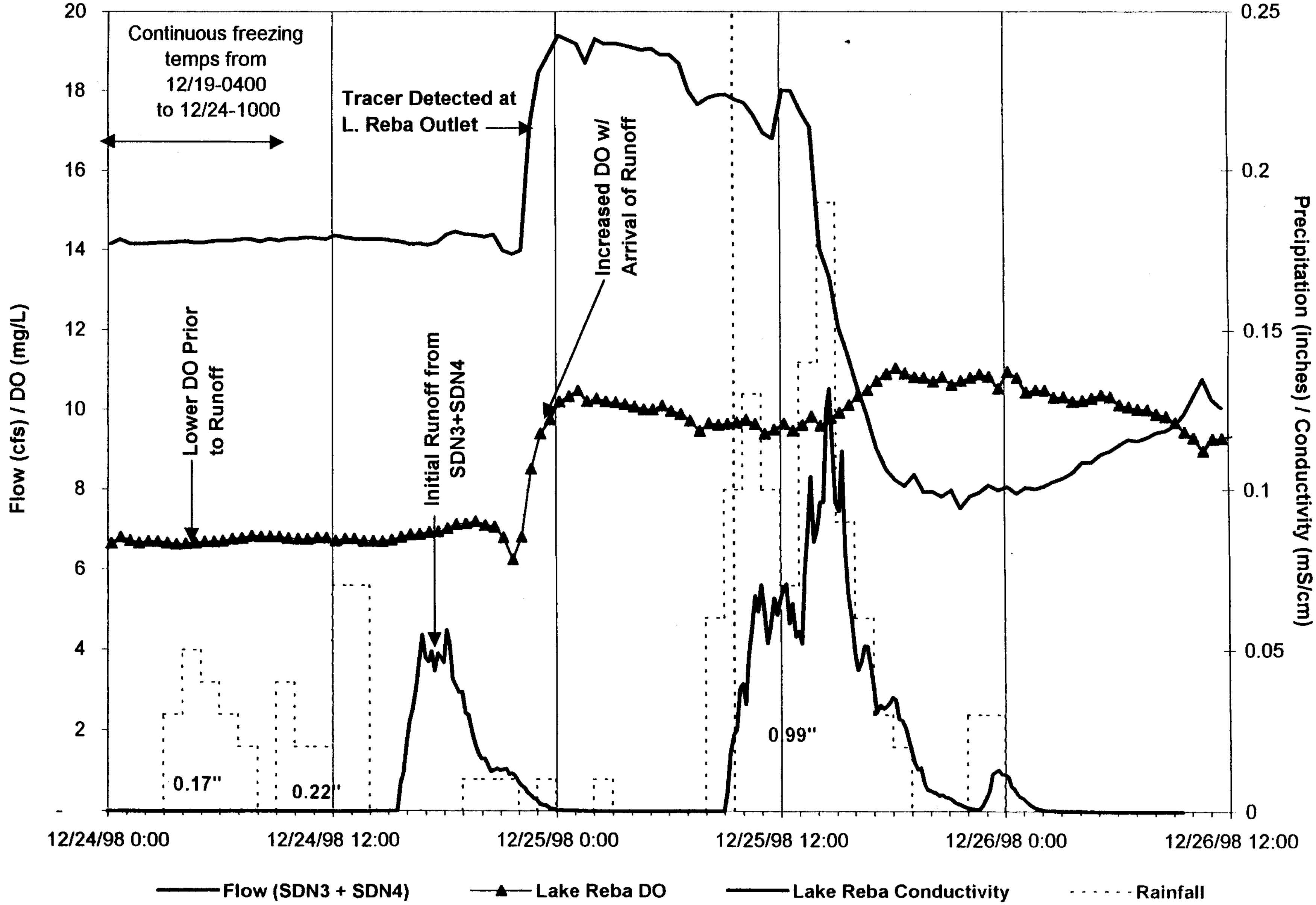


Figure 16
Lake Reba DO, Conductivity, and Flow - December Deicing Event



SECTION 6: METALS IN OUTFALL DISCHARGES AND INSTREAM LOCATIONS

Ecology verbally requested that the Port analyze metals in stormwater discharges concurrent with runway (ground surface) deicing/anti-icing events. The Port does not apply glycols as ground-surface deicers. Ecology also had a concern based upon what turned out to be an erroneous copper value[5] incorrectly reported from the November 1996 deicing event and concurrent NPDES storm sample.

During both events monitored this past winter, the Port analyzed metals in flow-weighted composite samples taken at four outfalls and in composite and discrete samples taken at select instream sampling stations. Tables 15 and 16 outline the samples and locations where they were taken. Because the December 1998 event also coincided with the only storm qualifying for monthly sampling for NPDES permit compliance (POS, 1999), other outfalls (SDE4 and SDN1) were also sampled in addition to those targeted specifically for this study. Both storm events sampled met NPDES sampling and reporting criteria (POS, 1999). Flow-weighted composite samples taken during these events by automatic sampler also met these NPDES criteria. Therefore, data from the two deicing events sampled are comparable to other NPDES samples in the Port's extensive stormwater database.

Overall, metals concentrations at outfalls were within ranges typically measured during non-deicing events sampled during the past 4 or more years. Table 15 summarizes metals data for outfall samples and compares ranks to the overall NPDES sampling history (June 1994 to June 1999) for each outfall. Only one value for total recoverable lead in the February 1999 SDN3 sample exceeded the historical maximum for this outfall. The result of 0.010 mg/L for this sample is less than one third of the receiving water criteria of 0.032 mg/L (calculated at 56 mg/L total hardness).

[5] In sample SDS3 112396, the total recoverable copper value of 0.0388 was mistakenly entered as 0.388, an order of magnitude higher and more than twice the historical maximum for this outfall. This error was carried through the 1997 and 1998 Annual Stormwater Monitoring Reports (POS, 1997 and 1998.) DMRs in November 1996, however, do report the correct value. The Port brought this error to the attention of Ecology, but Ecology requested on sampling for and analyzing metals during the Dissolved Oxygen study.

Table 15 STIA Outfalls Metals Results

Outfall	Event	Total Recoverable Metals, mg/L						Hard, mg/L
		Cu	Rank,%	Pb	Rank,%	Zn	Rank,%	
SDS3	Dec-98	0.047	65%	0.002	29%	0.134	91%	
SDS3 calc*	Dec-98	0.044	61%	0.004	62%	0.093	82%	51.3
SDS3	Feb-99	0.049	66%	0.001	0%	0.074	76%	53.6
SDS4	Dec-98	only discrete samples taken/analyzed, results calculated below						
SDS4 calc*	Dec-98	0.016	5%	0.001	26%	0.063	95%	58.1
SDS4	Feb-99	0.006	0%	0.001	26%	0.036	77%	94.2
SDN3	Dec-98	0.017	68%	0.001	28%	0.089	72%	
SDN3 calc*	Dec-98	0.012	45%	0.002	61%	0.056	52%	57.2
SDN3	Feb-99	0.020	84%	0.010	max	0.060	54%	33.5
SDN4	Dec-98	0.023	11%	0.001	32%	0.075	95%	
SDN4 calc*	Dec-98	0.018	0%	0.001	32%	0.034	75%	34.2
SDN4	Feb-99	0.036	48%	0.001	32%	0.026	61%	55.8
SDE4	Dec-98	0.005	4%	0.006	11%	0.151	43%	
SDN1	Dec-98	0.003	0%	0.004	14%	0.122	12%	

*Flow-weighted average of multiple discrete grab samples. All others are flow-weighted composites taken by auto sampler.

Table 16 Instream Metals Results

Instream Location	Event	Total Recoverable Metals, mg/L			Hard, mg/L
		Cu	Pb	Zn	
NWP in	Feb-99	0.003	0.001	0.035	58.7
NWP out	Feb-99	0.007	0.001	0.057	58.3
MC up	Feb-99	0.003	0.001	0.070	41.4
MC down	Feb-99	0.003	0.001	0.062	64.3
Acute*		**0.011**	**0.032**	**0.071**	**55.7**
NWP in	Dec-98	0.002	0.002	0.059	40.9
NWP out	Dec-98	0.005	0.001	0.032	74.5
MC up	Dec-98	0.008	0.017	0.147	46.9
MC down	Dec-98	sampling error			
Acute*		**0.010**	**0.037**	**0.070**	**54.1**

<MDL, value shown is ½ MDL

* Total metals criteria calculated (using Ecology's TSDCALC6.xls) at average of hardness values for each event.

Table 16 summarizes total recoverable metals data for instream samples and compares results to receiving water criteria calculated at average hardness values measured during this study. Metals concentrations were below criteria at all instream locations sampled downstream of Port outfalls.

Because virtually all metals data were within ranges of data recorded for non-deicing events, no correlation with deicing activities can be inferred. Therefore, the theory about metals being higher during these events did not manifest itself during the two events monitored.

AR 042768

SECTION 7: CONCLUSIONS

7.1 GENERAL OBSERVATIONS

The following conclusions are drawn from the continuous data loggers installed in Miller and Des Moines Creeks during the 1998-99 winter season:

- Dissolved oxygen in Miller and Des Moines Creeks were similar in the range of concentrations observed, and in their response to precipitation and runoff.
- DO concentrations were the highest in the lower reaches of both watersheds. The concentrations at the two lowest stations in both creeks were relatively stable and uniform, typically ranging between 3 to 5 mg/L above the water quality standard of 8 mg/L. Upstream variations in DO did not propagate down to the lower reaches of the creeks.
- The lowest DO concentrations observed during the study occurred in the NW Ponds, which were almost always below the water quality standard. Lake Reba concentrations were also typically below the water quality standard, but were usually higher than the NW Ponds.
- There were wide fluctuations in DO concentration in the ponds. These fluctuations followed a pattern linked to precipitation and revealed in conductivity data. The lowest DO concentrations occurred during dry weather periods when runoff rates were low. Conductivity in the ponds was also highest during these periods. Precipitation and runoff always increased DO and reduced conductivity in the ponds. When deicing chemicals were present, the conductivity increased during the initial runoff following the deicing event, indicating the passage of deicing chemicals through the ponds.
- The lowest DO occurred in NW Pond 3 during the longest dry period during the study, which occurred 2 to 3 weeks after the first deicing event. The second lowest DO occurred during the freezing temperatures prior to the first deicing event, in part due to the icing over of the ponds. Similar conditions occurred in Lake Reba. Neither low DO event can be attributed to the application of deicing chemicals.

- Explanation of the low DO during dry weather was not an objective of the field studies. This study makes no conclusions as to the cause of these conditions, other than that they are not linked to deicing activities.
- Reaeration occurs rapidly in the mainstem creeks. The Golf Course weir is only 0.3 miles downstream of the NW3 outlet. DO concentration there was typically 2 to 4 mg/L higher than in NW Pond 3, and was almost always above the water quality standard. Similar conditions were observed between the Lake Reba and Miller Creek Detention Facility stations.
- Metals in discharges associated with runway deicing chemical applications were similar to concentrations measured in many non-deicing events in the past five years. Instream concentrations downstream of the Port of Seattle outfalls were less than acute standards.

7.2 IMPACTS OF DEICING CHEMICALS ON DISSOLVED OXYGEN CONCENTRATIONS

The following conclusions are drawn from field study results prior to, during, and immediately following application and runoff of deicing chemicals from STIA taxiways and runways during the 1998-99 winter season.

- Deicing chemicals are not present in Lake Reba or the NW Ponds for very long. During the December deicing event, deicing chemicals were completely flushed through NW Pond 3 and Lake Reba within approximately 20 hours and 16 hours, respectively.
- Based on previous studies, the travel time in the creeks from the NW Pond 3 or Lake Reba to Puget Sound is approximately 1 to 2 hours for typical winter storm conditions. The deicing chemicals were present in the Miller and Des Moines Creek watersheds for less than 24 hours.
- There was no reduction in DO concentration within either watershed during the periods when deicing chemicals were present in runoff. Conversely, the DO increased during these periods, as it did in response to similar precipitation events that produced runoff.
- No reduction in DO concentration was observed as a result of deicing chemical applications in December 1998 and February 1999. The periods of lowest DO cannot be attributed to deicing activities at STIA.

SECTION 8: REFERENCES

Cancilla, 1998. *Personal Communication 7/9/98 during NPDES Permit Appeal Negotiations,* Scott Tobiason, Port of Seattle.

CEG, 1998. *Sampling and Analysis Plan – Miller Creek and Des Moines Creek Dissolved Oxygen Runway Deicing Events Sampling Program* prepared by Cosmopolitan Engineering Group, November 1998.

Horner, R.R. 1996. *Biochemical Oxygen Demand of Airplane and Airport Runway Deicing Chemicals: Laboratory Test Results and Recommendations for Impact Assessment.* Prepared for Port of Seattle.

Ludwa. 1999. *Personal Communication with Ken Ludwa, Parametrix, Inc.,* March 3, 1999.

POS, 1998. *Annual Stormwater Report for Sea-Tac International Airport for the Period of July 1, 1995 through June 30, 1996.* Prepared by Scott Tobiason, Port of Seattle Environmental Services, Seattle, Washington. November 18, 1996.

POS, 1996. *Annual Stormwater Monitoring Report for Sea-Tac International Airport for the Period of July 1, 1995 through June 30, 1996.* Prepared by Scott Tobiason, Port of Seattle Environmental Services, Seattle, Washington. November 18, 1996.

POS, 1997a. *Stormwater Receiving Environment Monitoring Report for NPDES Permit No. WA-002465-1.* Port of Seattle, June 1997.

POS, 1997b. *Annual Stormwater Monitoring Report for Sea-Tac International Airport for the Period of July 1, 1996 through May 31, 1997.* Prepared by Scott Tobiason, Port of Seattle Environmental Services, Seattle, Washington. September 29, 1997.

POS, 1997c. *Procedures Manual for Stormwater Monitoring, Sea-Tac International Airport.* Prepared by Scott Tobiason, Port of Seattle Environmental Services, Seattle, Washington. March 7, 1997.

POS, 1998. *Annual Stormwater Report for Sea-Tac International Airport for the Period of June 1, 1997, through May 31, 1998.* Prepared by Scott Tobiason, Port of Seattle Environmental Services, Seattle, Washington. November 1998.

POS, 1999. *Annual Glycol Usage Summary Report for Sea-Tac International Airport.* Prepared for Condition S2D of NPDES Permit WA-002465-1, May 25, 1999; May 2, 1998; April 30, 1997; May 17, 1996; April 27, 1995.

RPA, 1995. *Annual Stormwater Monitoring Report for Sea-Tac International Airport: Water Quality Data of the Discharges from the Storm Drainage System.* Prepared by Resource Planning Services for Port of Seattle, Seattle, Washington. August 30, 1995.

US EPA, 1983. *Methods for Chemical Analysis of Water and Wastes.* US Environmental Protection Agency, EPA-600/4-79-020. United States Environmental Protection Laboratory, Cincinnati, Ohio.

WAC 173-201A. *Surface Water Quality Standards for the State of Washington.*

WAS 1993. *Field Sampling and Measurement Protocols for the Watershed Assessments Section.* Washington Department of Ecology, Olympia, Washington.

COSMOPOLITAN

ENGINEERING

GROUP

Appendix A

NOAA Daily Rainfall

AR 042773

Civil, Environmental, and Recreational Consulting

Printed on Recycled Paper

December 1998

DT	A.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT	P.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT
1	----	----	T	T	----	T	T	0.01	T	T	T	0.01	1	T	T	T	0.06	0.11	0.06	0.03	0.07	0.1	0.12	0.1	0.02	1
2	T	T	0.01	0.03	----	----	----	0.04	----	T	0.04	0.01	2	T	----	----	0.07	----	----	----	----	----	----	----	----	2
3	----	----	----	T	----	----	----	----	----	----	----	----	3	----	----	----	----	----	----	----	----	----	----	----	----	3
4	----	----	----	----	----	----	----	----	----	----	T	T	4	----	----	----	----	----	----	----	----	----	----	0.01	T	4
5	----	----	----	T	----	----	----	----	T	T	T	0.03	5	0.01	T	T	0.01	0.04	0.01	----	----	----	----	----	----	5
6	----	----	----	----	----	----	----	----	----	----	----	----	6	----	----	----	----	----	----	----	T	T	T	T	T	6
7	T	0.01	T	T	T	0.01	0.03	0.04	0.03	0.01	0.01	0.01	7	0.01	----	0.03	0.05	0.02	0.01	0.04	T	T	T	0.03	T	7
8	0.01	T	0.01	----	----	----	----	----	----	----	----	----	8	----	----	----	----	----	----	----	----	----	----	----	----	8
9	----	----	----	----	----	----	----	----	----	----	----	T	9	T	----	----	----	----	----	----	----	----	----	----	----	9
10	T	T	0.01	T	T	T	0.01	T	T	0.07	0.06	0.01	10	T	----	----	----	----	----	----	----	----	----	----	----	10
11	T	0.02	0.02	0.03	----	----	----	0.02	0.07	0.09	0.11	0.13	11	0.09	0.07	0.06	0.06	0.06	0.03	0.03	T	0.01	T	0.01	T	11
12	T	0.01	0.03	0.06	0.06	0.05	0.02	0.08	0.08	0.05	0.05	0.06	12	0.06	0.06	0.02	T	0.04	0.01	0.02	0.03	0.04	0.05	0.05	0.03	12
13	0.03	0.02	T	0.01	0.04	0.01	0.04	0.07	0.02	0.06	0.06	0.04	13	0.02	0.03	T	----	----	0.4	0.09	0.06	T	T	0.01	0.01	13
14	----	----	----	----	----	----	----	----	----	----	----	----	14	----	----	----	----	----	----	T	T	----	----	----	----	14
15	----	----	----	----	T	T	T	----	----	----	----	----	15	----	----	----	----	----	----	----	T	0.02	T	T	----	15
16	----	----	----	----	----	----	----	----	----	----	----	----	16	----	----	----	----	----	----	----	----	----	----	----	----	16
17	----	----	----	----	----	----	0.01	0.01	T	----	0.01	T	17	T	0.05	0.02	T	T	0.01	T	----	----	----	----	----	17
18	----	----	----	----	----	----	----	----	----	----	----	----	18	----	----	----	----	----	----	----	----	----	----	----	----	18
19	----	----	----	T	----	----	----	----	----	----	----	----	19	----	----	T	T	T	T	----	----	----	----	----	----	19
20	----	----	----	----	----	----	----	----	----	----	----	----	20	----	----	----	----	----	----	----	----	----	----	----	----	20
21	----	----	----	----	----	----	----	----	----	----	----	T	21	T	T	----	----	----	----	----	----	----	----	----	----	21
22	----	----	----	----	----	----	----	----	----	----	----	----	22	----	----	----	----	----	----	----	----	----	----	----	----	22
23	----	----	----	----	----	----	----	----	----	----	----	----	23	----	----	----	----	----	----	----	----	----	----	----	T	23
24	T	T	T	0.03	0.05	0.04	0.03	0.02	M	0.04	0.02	0.02	24	0.07	0.07	T	----	M	T	T	0.01	0.01	0.01	T	0.01	24
25	T	T	0.01	T	T	----	----	----	0.06	0.1	0.13	0.1	25	0.07	0.14	0.19	0.09	0.06	0.03	0.02	T	T	----	0.03	0.03	25
26	----	----	----	----	----	----	----	----	----	----	----	----	26	----	----	0.01	----	----	----	----	0.01	0.01	0.01	T	0.03	26
27	0.01	T	----	T	0.02	0.01	0.01	0.05	0.06	0.05	0.06	0.11	27	0.07	0.05	0.1	0.15	0.24	0.23	0.23	0.08	T	----	----	----	27
28	----	----	----	----	----	----	----	----	----	----	----	----	28	----	----	T	----	----	----	----	T	0.01	0.06	0.03	0.01	28
29	0.05	0.08	0.13	0.11	0.07	0.04	0.1	0.01	0.04	0.06	0.1	0.12	29	0.04	0.01	T	----	T	----	----	----	----	----	0.01	T	29
30	----	----	----	----	----	----	----	M	M	----	----	----	30	----	----	----	----	----	----	----	----	----	----	----	----	30
31	----	----	T	0.09	0.03	T	0.01	T	----	----	0.01	----	31	----	----	----	T	T	T	0.04	T	----	----	----	----	31

AR 042774

January 1999

DT	A.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT	P.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT
1	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1
2	----	----	----	----	----	----	----	----	----	----	----	----	2	----	----	----	----	----	----	----	----	----	----	----	----	2
3	----	----	----	----	----	----	----	----	----	----	----	----	3	----	----	----	----	----	----	----	----	----	----	----	----	3
4	----	----	----	----	----	----	----	----	T	T	----	----	4	----	----	----	----	----	----	----	----	----	----	----	----	4
5	----	----	----	----	----	----	----	----	----	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----	----	5
6	----	----	----	----	----	----	----	T	T	T	T	T	6	T	0.01	T	----	0.01	0.06	0.02	0.02	T	----	T	T	6
7	----	0.01	T	T	----	----	----	----	----	----	----	----	7	----	----	----	----	----	----	----	----	----	----	T	T	7
8	T	T	----	----	----	----	----	T	----	T	----	----	8	T	----	----	----	----	----	----	----	----	----	----	----	8
9	T	T	----	----	----	T	T	----	0.02	0.04	0.03	0.01	9	T	T	----	T	0.03	T	0.01	T	----	T	----	----	9
10	----	0.04	0.02	0.04	0.04	0.01	0.01	T	T	----	----	----	10	----	----	----	----	----	----	----	----	----	----	----	----	10
11	----	----	----	----	----	----	----	----	----	----	----	T	11	T	----	T	----	----	----	----	----	----	----	----	----	11
12	----	----	T	0.01	T	----	T	T	T	T	----	----	12	----	----	----	----	----	----	----	----	----	----	----	----	12
13	----	T	----	T	T	----	----	----	----	----	----	----	13	----	----	----	----	----	T	0.09	0.09	0.05	0.01	T	0.02	13
14	0.01	----	0.04	0.2	0.05	0.05	0.05	0.05	0.1	0.06	0.07	0.05	14	0.08	0.09	0.02	----	----	----	----	----	----	----	----	----	14
15	----	----	----	----	----	----	0.01	T	----	----	----	0.01	15	----	----	----	----	----	----	T	T	0.04	0.05	0.1	0.04	15
16	----	----	----	T	T	0.01	0.01	T	0.01	0.03	0.02	0.02	16	0.04	----	----	----	0.01	T	0.01	T	T	T	T	T	16
17	----	----	----	----	----	----	----	----	----	----	0.03	0.1	17	0.06	0.05	0.07	0.06	0.02	0.07	0.15	0.05	0.02	0.01	T	0.12	17
18	0.01	T	0.01	0.02	0.05	T	0.02	0.04	0.02	0.01	0.01	0.01	18	T	0.01	0.03	0.04	0.02	T	0.01	0.05	0.09	0.05	0.09	0.06	18
19	0.03	0.16	0.02	----	----	----	T	0.05	0.03	0.01	T	0.02	19	0.03	0.02	0.02	0.02	0.04	T	T	----	----	----	T	T	19
20	T	0.01	T	0.01	T	T	T	T	----	T	T	----	20	----	----	T	0.01	0.02	0.05	0.05	0.03	----	T	T	T	20
21	T	T	T	0.06	T	0.02	T	0.02	0.01	0.03	0.03	T	21	0.02	T	----	T	T	----	----	----	----	----	----	----	21
22	T	T	T	T	T	----	----	T	0.03	T	0.01	T	22	T	T	0.02	0.02	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.06	22
23	0.05	0.03	0.01	0.01	0.01	----	T	0.02	0.01	0.01	0.01	0.01	23	0.01	T	----	----	----	----	----	----	----	----	----	----	23
24	----	----	----	----	----	----	----	----	----	----	----	----	24	----	----	----	----	----	----	----	----	----	----	----	----	24
25	----	----	----	----	----	----	----	----	----	----	----	----	25	----	----	----	----	----	----	----	----	----	----	----	----	25
26	----	----	----	----	----	T	T	0.02	T	T	----	T	26	T	T	T	T	T	T	T	----	----	----	----	T	26
27	----	----	----	----	0.01	----	----	----	----	T	T	T	27	T	T	T	0.01	0.01	0.03	0.04	0.07	0.06	0.1	0.03	0.03	27
28	0.04	0.06	0.05	0.03	0.01	0.01	0.02	0.05	0.05	0.06	0.05	0.04	28	0.04	0.04	0.03	0.01	0.01	0.03	0.07	0.01	0.02	0.03	0.02	T	28
29	T	T	T	----	----	----	----	----	----	----	----	----	29	T	T	T	0.02	0.01	T	0.02	0.02	T	0.02	0.04	0.03	29
30	0.01	0.01	T	0.01	0.02	0.01	0.02	0.02	0.02	0.03	0.03	T	30	T	0.01	0.01	----	----	----	----	T	T	----	----	T	30
31	0.01	0.02	T	0.02	0.07	0.02	T	0.01	T	T	----	T	31	0.01	0.05	0.01	0.06	T	0.07	0.01	T	0.01	----	----	----	31

February 1999

DT	A.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT	P.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT
1	T	0.02	----	T	----	0.01	T	T	T	0.02	----	T	1	T	----	T	T	0.04	0.05	0.08	0.1	0.05	0.02	0.02	T	1
2	----	----	T	0.02	0.05	0.1	0.08	0.02	T	----	T	----	2	----	----	----	----	----	----	----	----	----	----	----	----	2
3	----	----	----	----	----	----	----	----	----	----	----	----	3	----	----	T	0.02	0.05	0.06	0.06	0.01	0.04	0.02	T	0.01	3
4	0.01	T	T	T	T	T	T	0.02	0.01	----	----	----	4	----	----	----	----	----	T	T	----	----	----	T	T	4
5	----	----	----	----	----	----	----	----	----	----	T	0.03	5	0.01	T	T	T	0.01	----	0.07	T	----	----	T	----	5
6	----	----	T	T	0.04	0.01	T	0.03	0.14	0.1	0.02	T	6	----	T	0.03	0.02	0.03	0.06	T	T	T	T	----	T	6
7	----	0.01	0.08	0.16	0.04	T	0.03	0.02	0.04	T	T	0.01	7	T	0.06	0.01	----	0.03	0.03	----	----	----	T	----	----	7
8	----	----	----	----	----	----	----	T	0.04	0.08	0.04	0.01	8	0.04	----	0.01	T	----	0.02	0.01	0.01	T	----	----	----	8
9	----	----	----	----	----	----	----	----	----	----	----	----	9	----	----	----	----	----	----	----	T	0.01	T	T	T	9
10	----	----	----	T	----	----	----	----	----	----	----	----	10	----	----	----	----	T	0.01	----	----	----	----	----	----	10
11	----	----	----	----	----	----	----	----	----	----	----	----	11	----	----	----	----	----	----	----	----	----	----	----	----	11
12	----	----	----	----	----	----	----	----	----	----	----	----	12	----	----	----	----	----	----	----	T	T	----	----	----	12
13	----	----	0.01	0.04	0.07	0.08	0.05	T	0.01	T	----	----	13	----	----	----	----	----	----	----	----	----	----	----	----	13
14	----	----	----	----	----	----	----	----	----	----	----	----	14	----	----	----	----	----	----	----	----	----	----	----	----	14
15	----	----	----	----	----	----	----	----	----	----	----	----	15	----	----	----	----	----	T	T	0.01	0.01	0.01	T	T	15
16	----	T	0.01	0.01	0.02	0.01	0.01	0.01	0.01	T	----	0.01	16	T	T	T	0.01	0.02	0.06	0.08	0.02	0.01	----	T	T	16
17	T	T	0.04	0.01	----	0.01	T	----	----	----	T	----	17	T	T	0.01	----	----	----	----	----	----	----	----	----	17
18	----	----	----	----	----	----	----	0.02	0.08	0.04	0.04	T	18	0.01	T	----	T	T	0.08	0.12	0.07	0.01	0.02	T	0.05	18
19	0.05	0.03	----	----	----	----	----	----	----	T	----	T	19	----	T	T	0.01	----	T	T	----	----	----	----	----	19
20	----	----	----	----	----	----	----	----	----	----	----	----	20	----	----	----	----	----	----	----	T	T	----	T	0.02	20
21	----	----	----	----	----	----	----	----	----	----	----	----	21	----	----	T	T	0.02	0.01	T	----	----	T	T	T	21
22	T	T	0.01	T	0.01	0.02	0.01	0.01	0.02	0.03	0.03	T	22	0.02	0.08	0.16	0.03	----	----	----	----	----	----	----	0.01	22
23	0.01	0.03	0.04	T	----	0.04	----	----	----	----	----	T	23	0.01	T	0.04	0.06	0.08	0.06	0.06	0.06	0.02	0.03	0.03	0.03	23
24	0.04	0.02	0.04	0.06	0.04	0.06	0.02	0.03	0.03	0.01	0.02	0.02	24	T	T	0.03	0.17	0.14	0.02	----	T	----	----	----	----	24
25	M	M	M	M	M	M	M	M	M	M	M	M	25	M	M	M	M	M	M	M	M	M	M	M	M	25
26	M	M	M	M	M	M	M	M	M	M	M	M	26	M	M	M	M	M	M	M	M	M	M	M	M	26
27	M	M	M	M	M	M	M	M	M	M	M	M	27	M	M	M	M	M	M	M	M	M	M	M	M	27
28	M	M	M	M	M	M	M	M	M	M	M	M	28	M	M	M	M	M	M	M	M	M	M	M	M	28
29													29													29
30													30													30
31													31													31

AR 042776

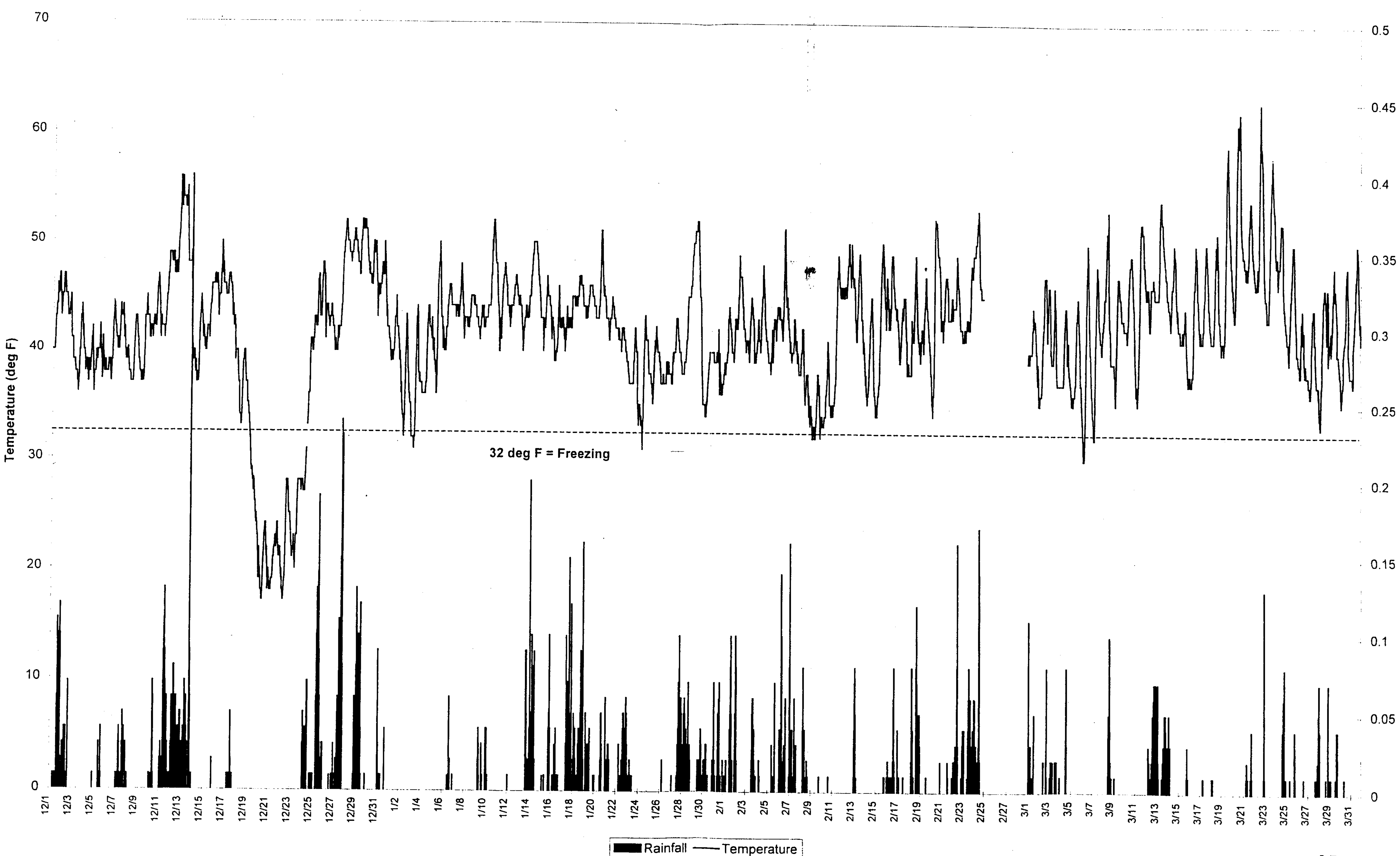
March 1999

UNEDITED HOURLY PRECIPITATION TABLE

DT	A.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT	P.M. HOUR (L.S.T) ENDING AT ---1---	---2---	---3---	---4---	---5---	---6---	---7---	---8---	---9---	---10---	---11---	---12---	DT
1	T	----	T	0.14	0.04	0.01	T	0.01	0.04	0.02	T	T	1	T	----	T	0.06	----	----	----	----	----	----	----	----	1
2	----	----	----	----	----	----	----	----	----	----	----	----	2	0.01	0.03	T	T	T	T	T	0.02	0.08	0.01	----	----	2
3	----	T	----	----	0.01	0.01	0.02	0.01	0.02	0.02	T	0.02	3	T	0.01	T	T	0.01	0.02	0.02	0.02	0.01	----	T	T	3
4	----	T	T	----	----	----	----	----	----	----	----	----	4	----	----	T	0.05	0.04	T	----	----	----	----	----	----	4
5	----	----	----	----	----	----	----	----	----	----	----	----	5	----	----	----	----	----	----	----	----	----	----	----	----	5
6	----	----	----	----	----	----	----	----	----	----	----	----	6	----	----	----	----	----	----	----	----	----	----	----	----	6
7	----	----	----	----	----	----	----	----	----	----	----	----	7	----	----	----	----	----	----	----	----	----	----	----	----	7
8	----	----	----	----	----	----	----	T	T	T	----	----	8	----	T	T	T	0.05	0.05	0.08	0.05	0.02	T	0.01	0.01	8
9	T	T	T	----	----	----	----	----	----	----	----	----	9	----	----	----	----	----	T	----	T	----	----	----	----	9
10	----	----	T	T	T	T	T	T	----	----	----	----	10	----	----	----	----	----	----	----	----	----	----	----	----	10
11	----	----	----	----	----	----	----	----	----	----	----	----	11	----	----	----	----	----	----	----	----	----	----	----	----	11
12	----	----	----	----	T	0.02	0.03	0.02	0.01	0.02	0.01	0.01	12	0.01	0.04	0.05	0.04	0.05	0.06	0.04	0.04	0.04	0.06	0.07	0.04	12
13	0.03	0.03	0.05	0.02	0.01	----	----	----	T	0.01	T	0.01	13	0.02	0.03	0.04	0.02	0.03	0.06	0.03	0.04	0.04	0.03	0.03	0.04	13
14	0.03	0.02	0.04	0.03	0.04	0.04	0.01	T	T	----	----	----	14	----	----	----	----	----	----	----	----	----	----	----	----	14
15	----	----	----	----	----	----	T	----	----	----	----	----	15	----	----	----	----	T	T	0.01	0.01	0.03	T	0.01	----	15
16	----	----	----	----	----	----	----	----	----	----	----	----	16	----	----	----	----	----	----	----	----	----	----	----	----	16
17	----	----	----	----	----	T	T	T	0.01	0.01	T	----	17	T	----	----	----	----	----	----	----	----	----	----	----	17
18	----	----	----	T	T	0.01	T	0.01	T	----	T	T	18	T	----	----	----	----	----	----	----	----	----	----	----	18
19	----	----	----	----	----	----	----	----	----	----	----	----	19	----	----	----	----	----	----	----	----	----	----	----	----	19
20	----	----	----	----	----	----	----	----	----	----	----	----	20	----	----	----	----	----	----	----	----	----	----	----	----	20
21	----	----	----	----	----	----	T	0.02	0.01	0.01	0.01	T	21	----	----	----	----	0.02	----	0.02	0.01	----	----	----	----	21
22	----	----	----	T	T	T	----	----	----	----	----	----	22	----	----	----	----	----	----	----	----	T	0.01	0.12	0.02	22
23	T	T	T	----	----	----	----	----	----	----	----	----	23	----	----	----	----	----	----	----	----	----	----	----	----	23
24	----	----	----	----	----	----	T	T	----	----	----	----	24	----	T	T	0.01	0.04	0.03	0.05	0.06	0.08	T	----	T	24
25	0.02	T	----	----	----	----	----	----	----	----	----	----	25	----	----	----	----	----	T	T	0.03	0.02	0.01	T	----	25
26	----	----	----	----	T	----	----	----	----	----	0.01	----	26	T	T	T	T	0.01	----	----	T	----	----	----	----	26
27	----	----	----	----	----	----	----	----	----	----	----	----	27	----	----	----	T	T	T	0.01	----	----	----	0.01	0.02	27
28	0.01	0.06	0.05	0.03	0.04	T	T	----	T	----	----	----	28	----	----	----	----	----	0.01	T	----	----	T	0.06	T	28
29	0.01	T	T	T	0.01	T	T	----	----	T	T	0.01	29	T	T	0.01	T	0.01	0.03	0.05	0.04	T	----	----	----	29
30	----	----	----	----	----	T	T	T	T	----	T	T	30	T	----	----	----	----	----	----	----	----	----	----	----	30
31	----	----	----	----	----	----	----	----	----	----	----	----	31	----	----	----	----	----	----	----	----	----	----	----	----	31

AR 042777

STIA NWS WEATHER DATA



AR 042778

COSMOPOLITAN
ENGINEERING
GROUP

Appendix B

King County Instream Flow Data

Civil, Environmental, and Recreational Consulting

APPENDIX B

King County Instream Flow Data Reference:

David Funke
Stream Monitoring Engineer
King County Department of Natural Resources
Water and Land Resources Division
700 5th AV Suite 2200
Seattle, WA 98104

(206) 296-8066
(206) 296-0192 fax
david.funke@metrokc.gov
http://splash2.metrokc.gov/hydrodat/

Stage-Discharge Curves Reference:

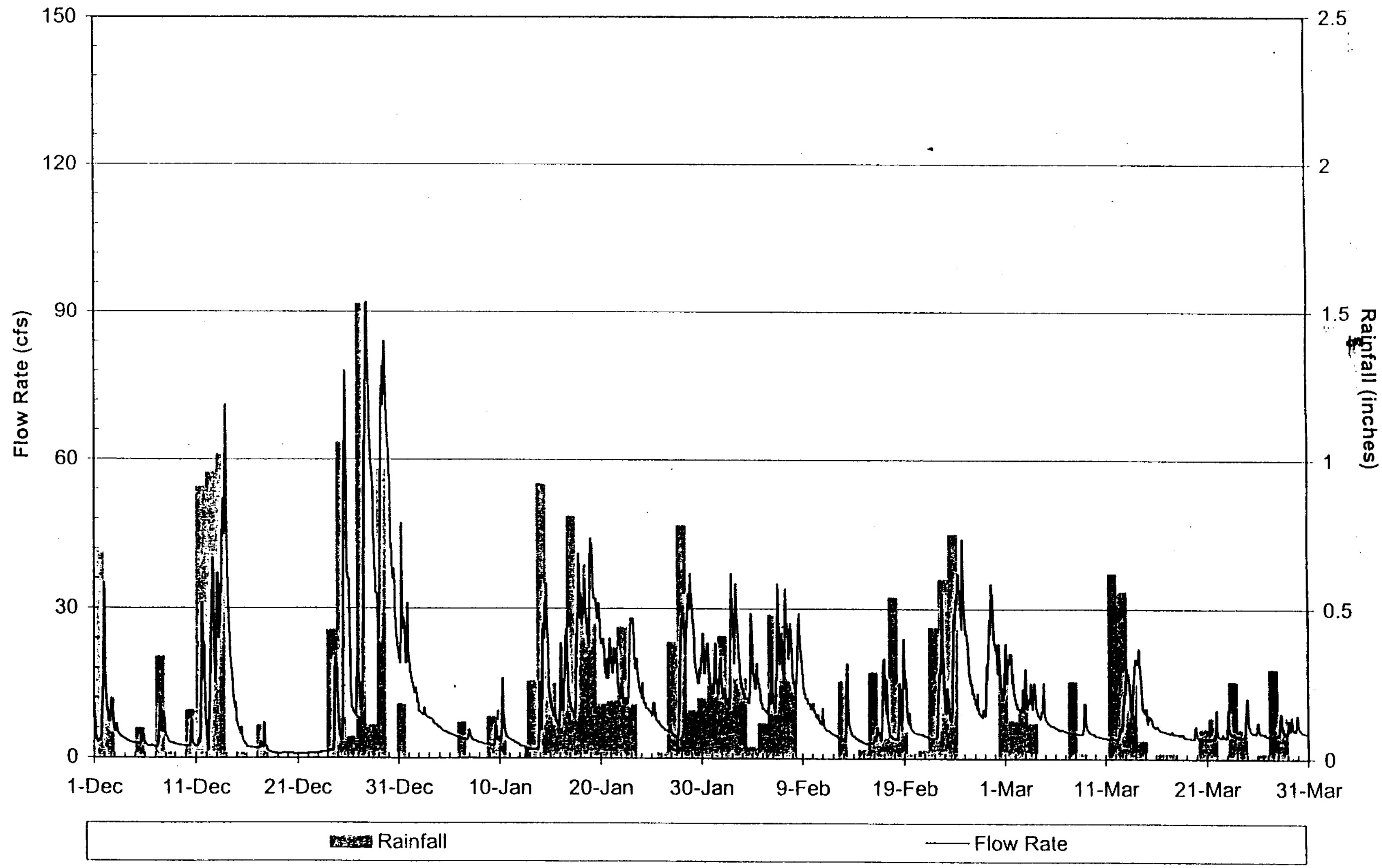
- Miller Creek at SR518: Stage (ft); Top of fence post = 6 ft.
- Miller Creek Detention Facility, 42B, Lake Reba Detention Outlet; Top of stilling well = 10.00 feet
- Gage 11G, NW Ponds Outlet; Top of 2" diameter steel well = 254.54 feet; Top of culvert = 249 feet
- Tyee Golf Course Weir; Stage (feet) above weir crest

Electronic data files are archived at:

Cosmopolitan Engineering Group
117 South 8th Street
Tacoma, WA 98402

(253) 272-7220
(253) 272-7250 fax

Figure B-1
Miller Creek Flow Rate at SR518 (MC1)



AR 042781

Figure B-2
Lake Reba Level (ft)

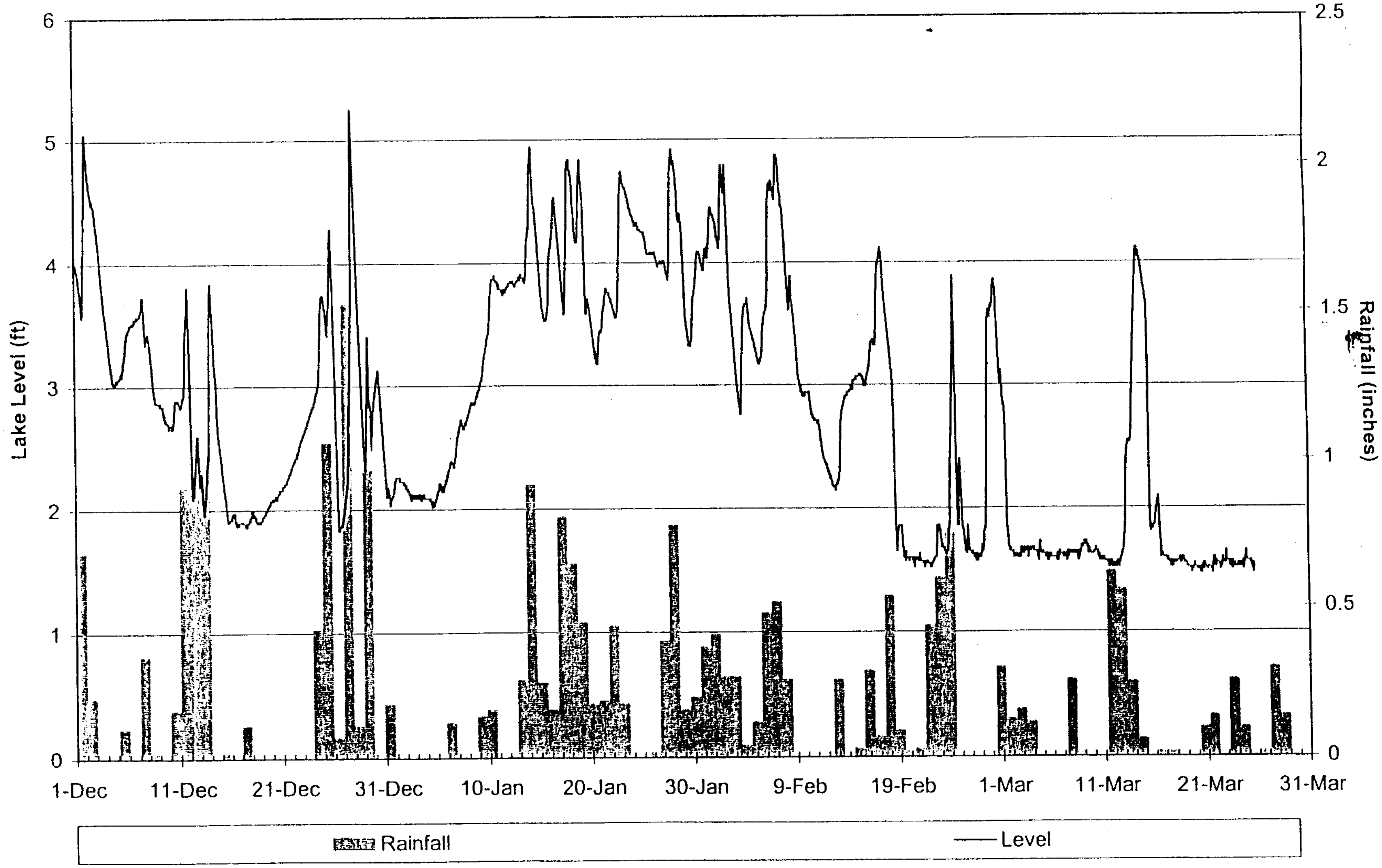
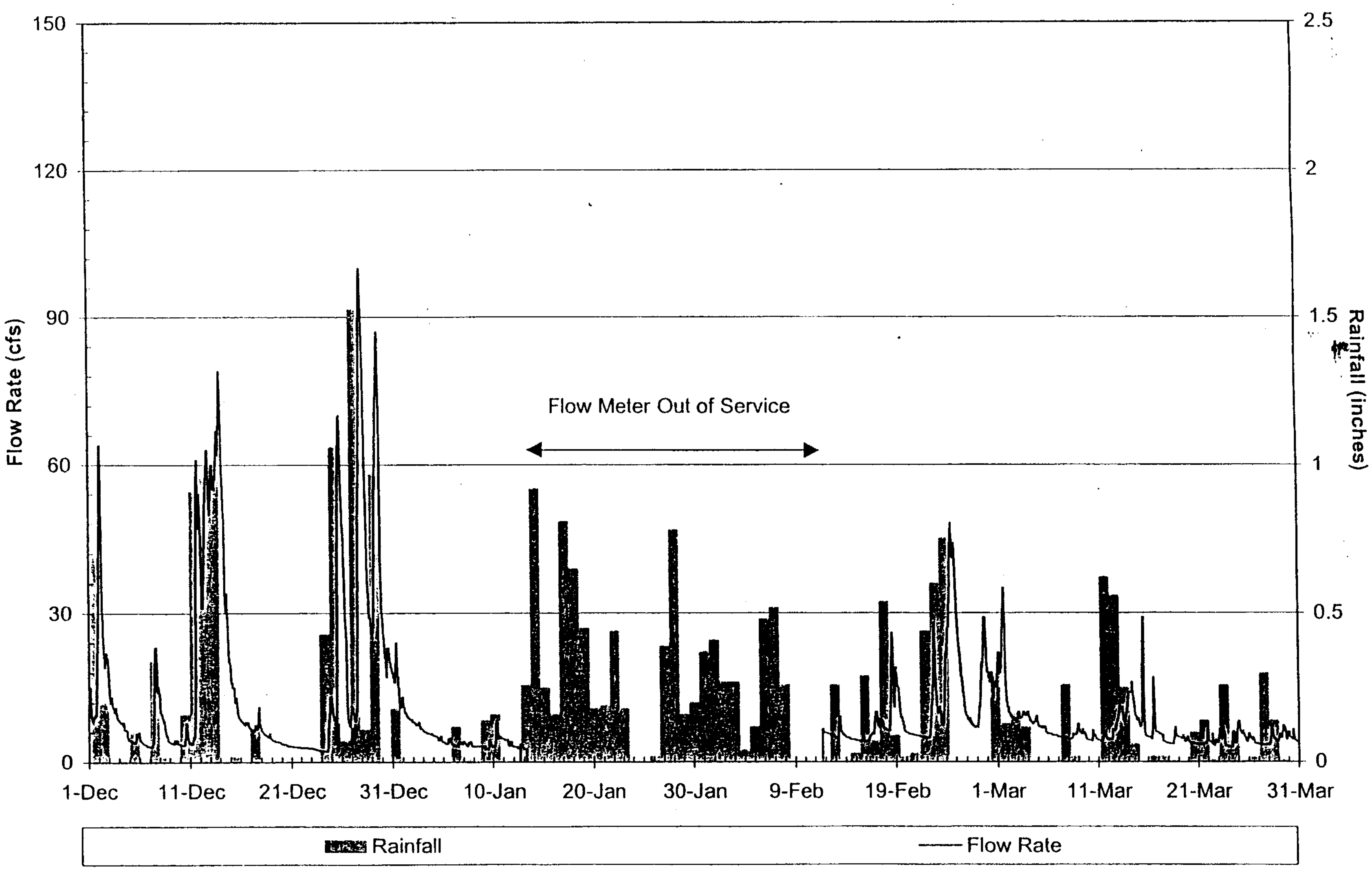
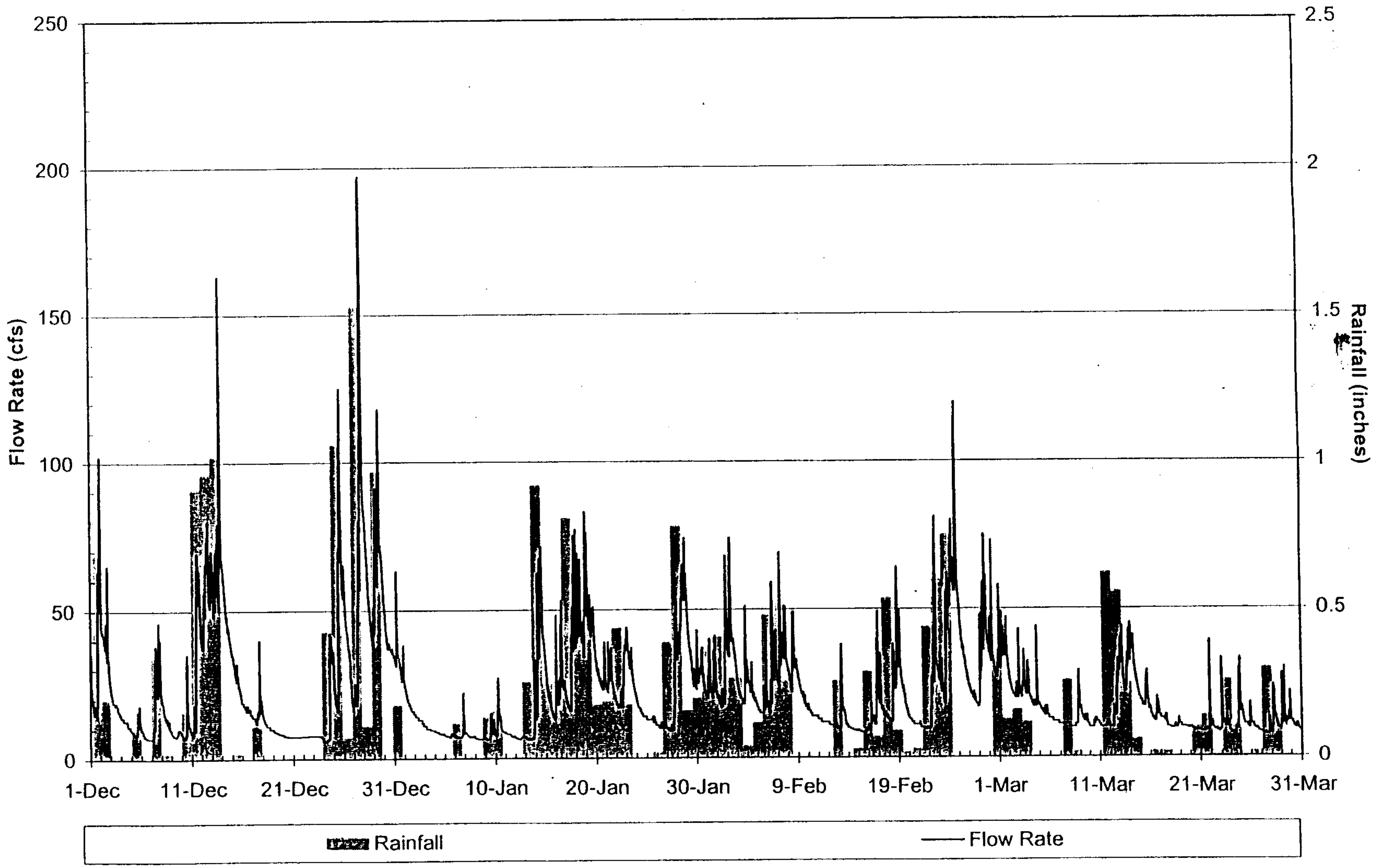


Figure B-3
Miller Creek Flow Rate at Miller Creek Detention Facility



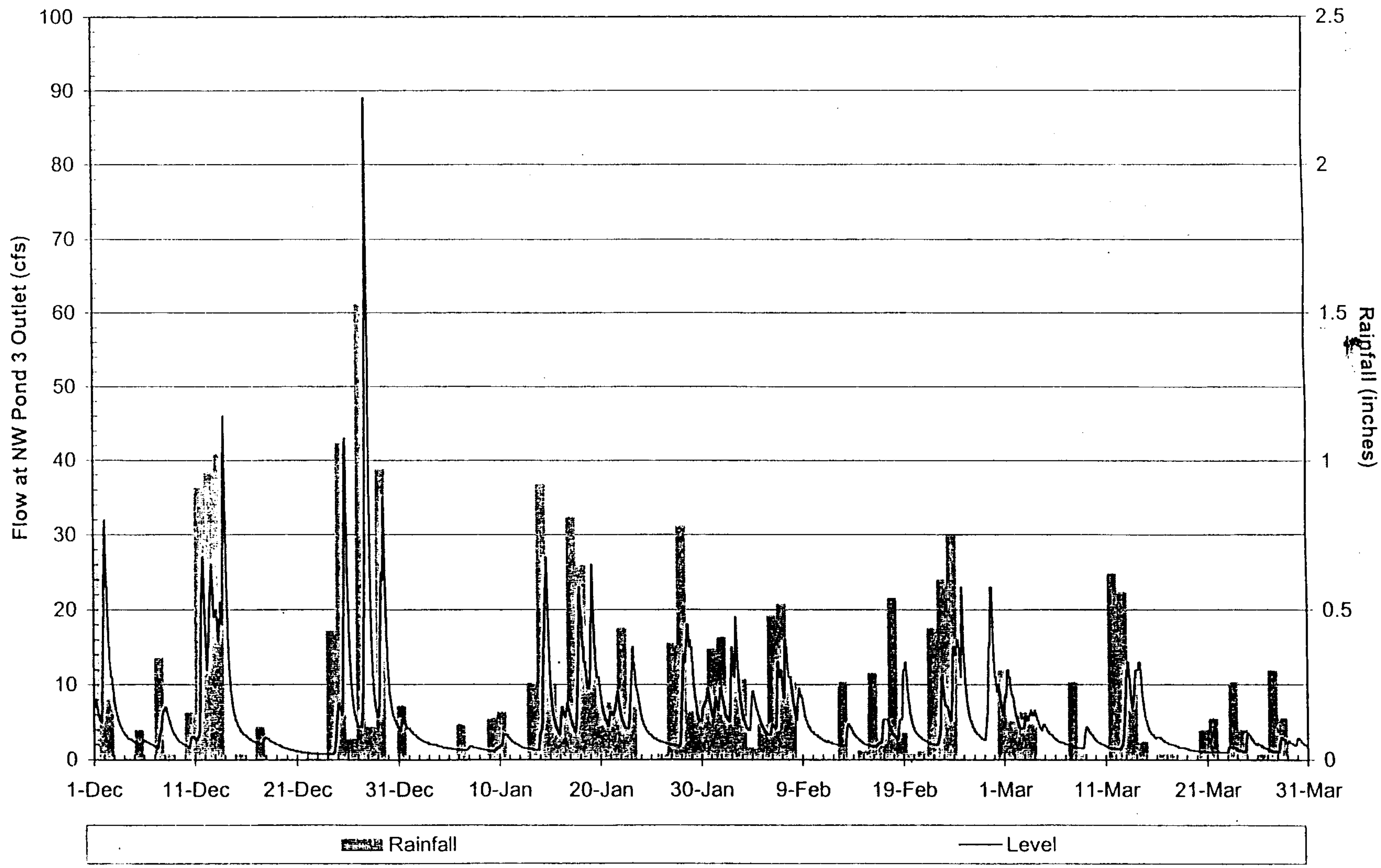
AR 042783

Figure B-4
Miller Creek Flow Rate at Mouth



AR 042784

Figure B-5
NW Pond 3 Outlet Flow Rate



AR 042785

Figure B-6
Des Moines Creek Flow Rate at Golf Course Weir

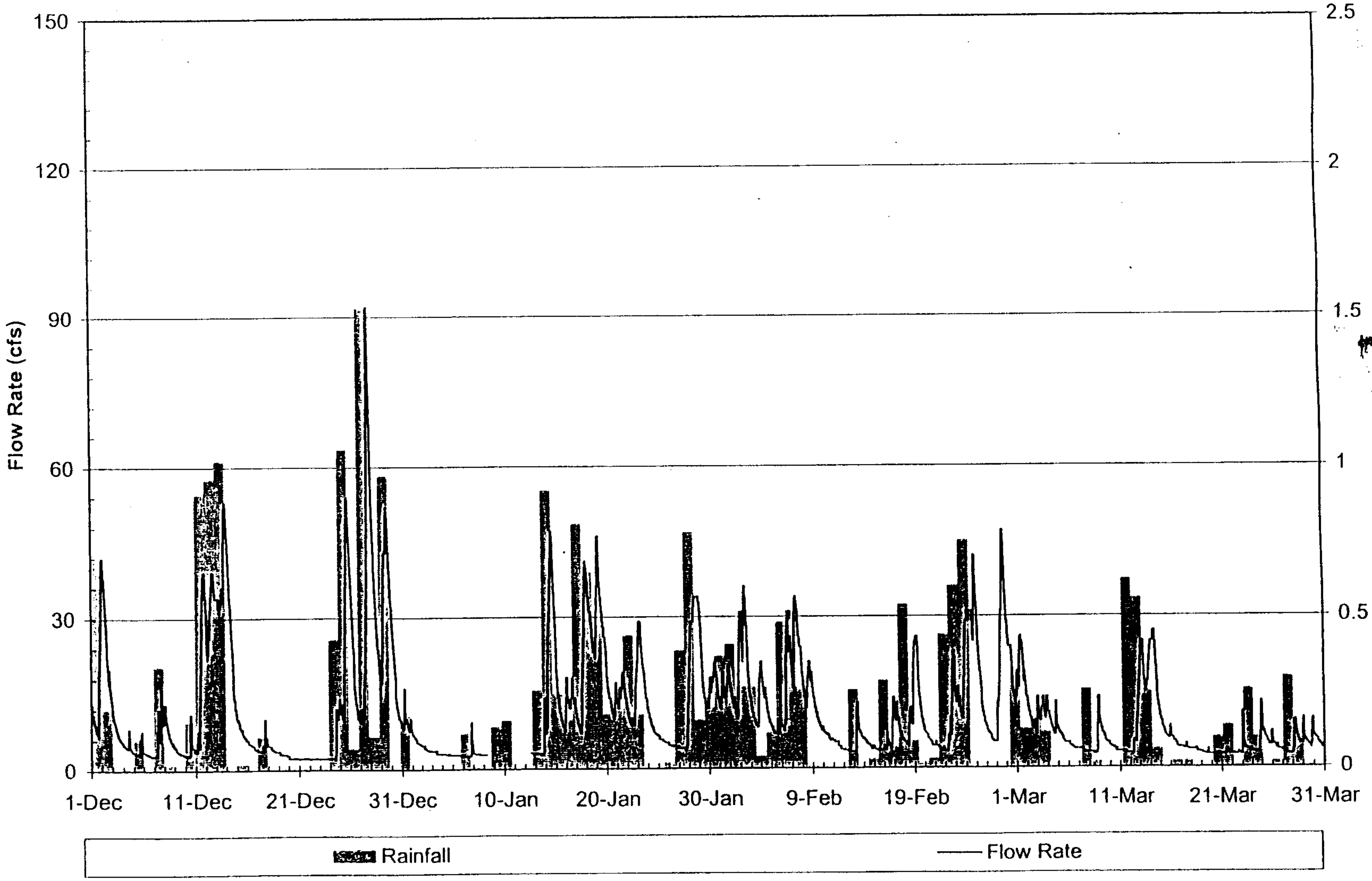
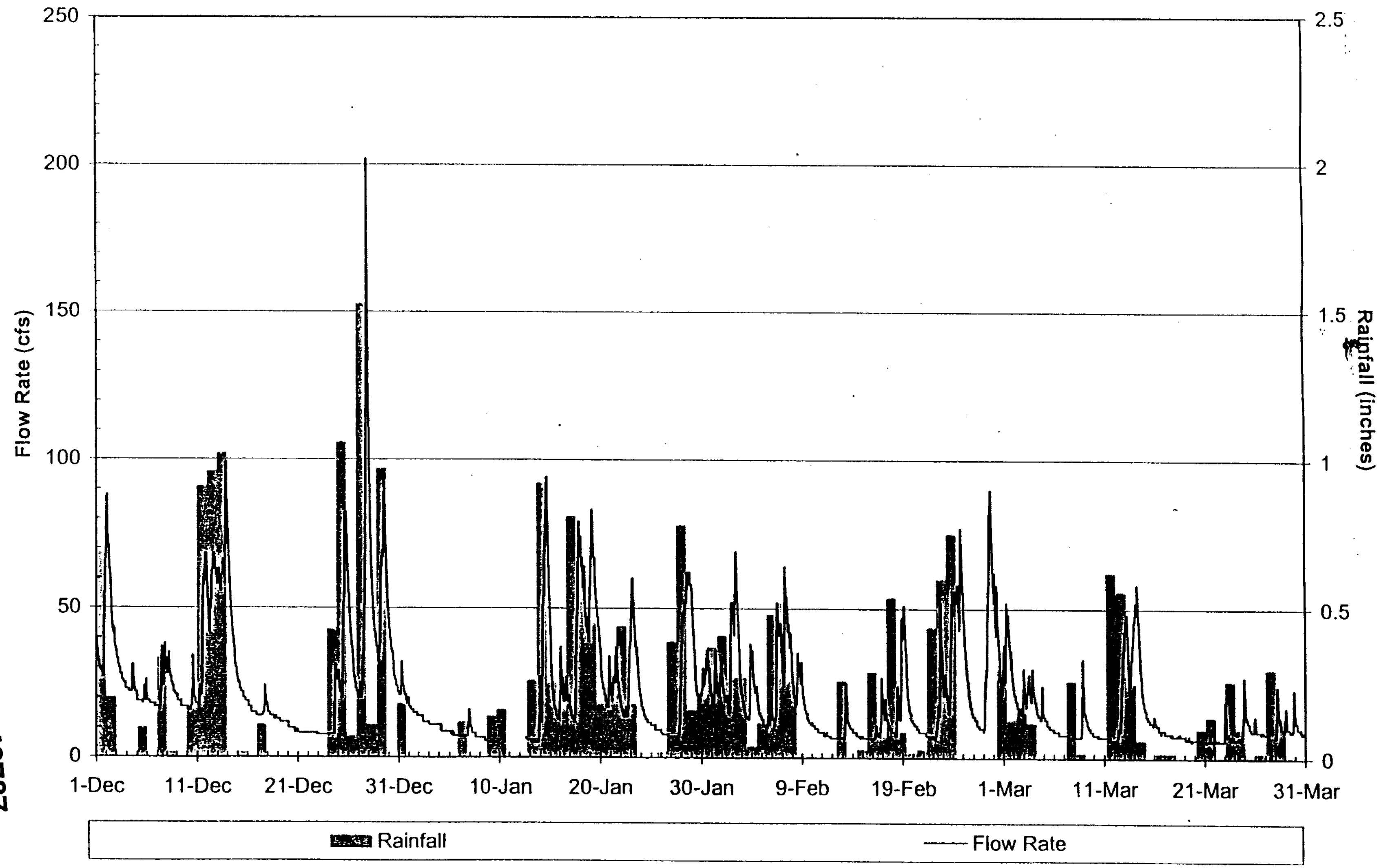
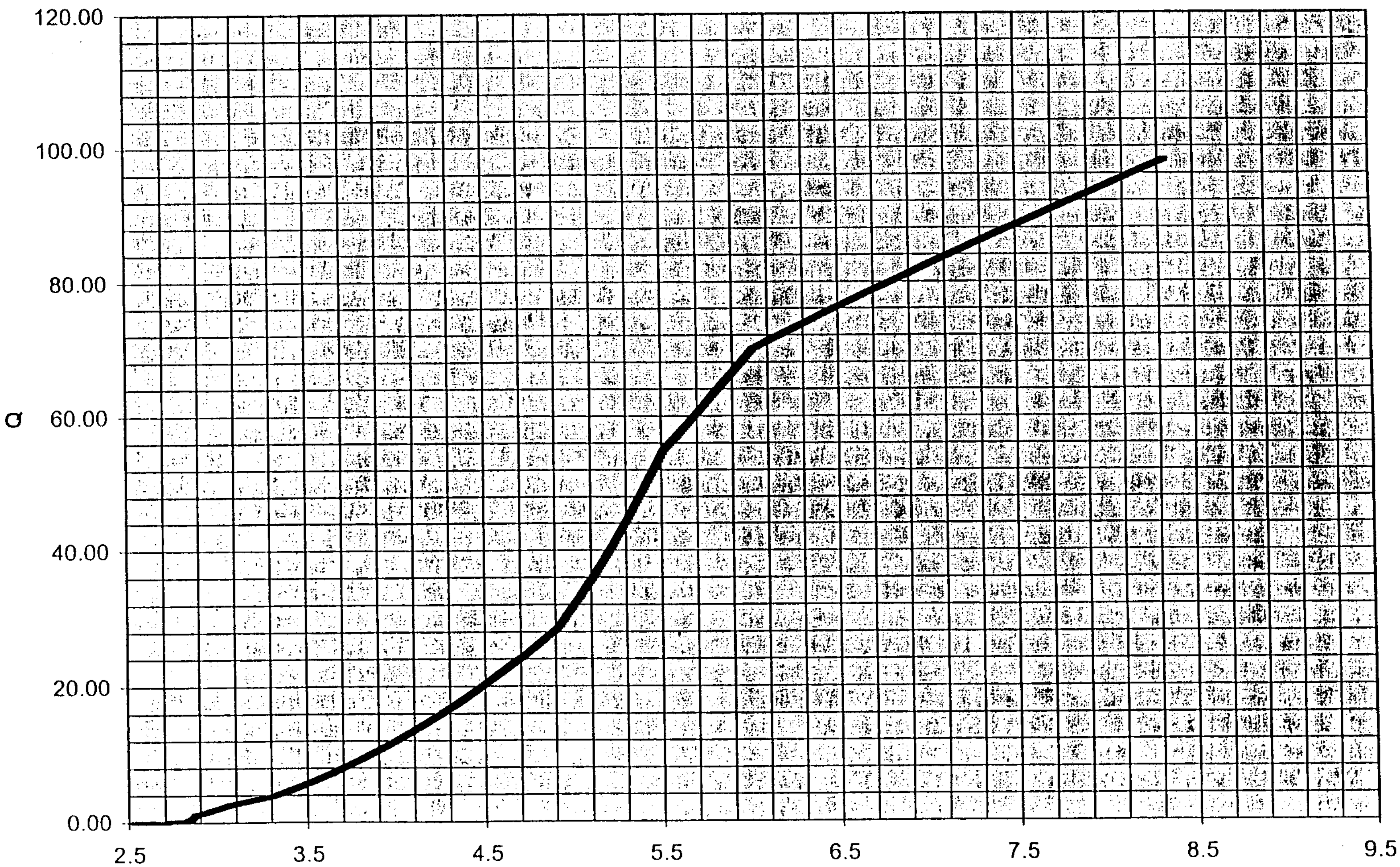


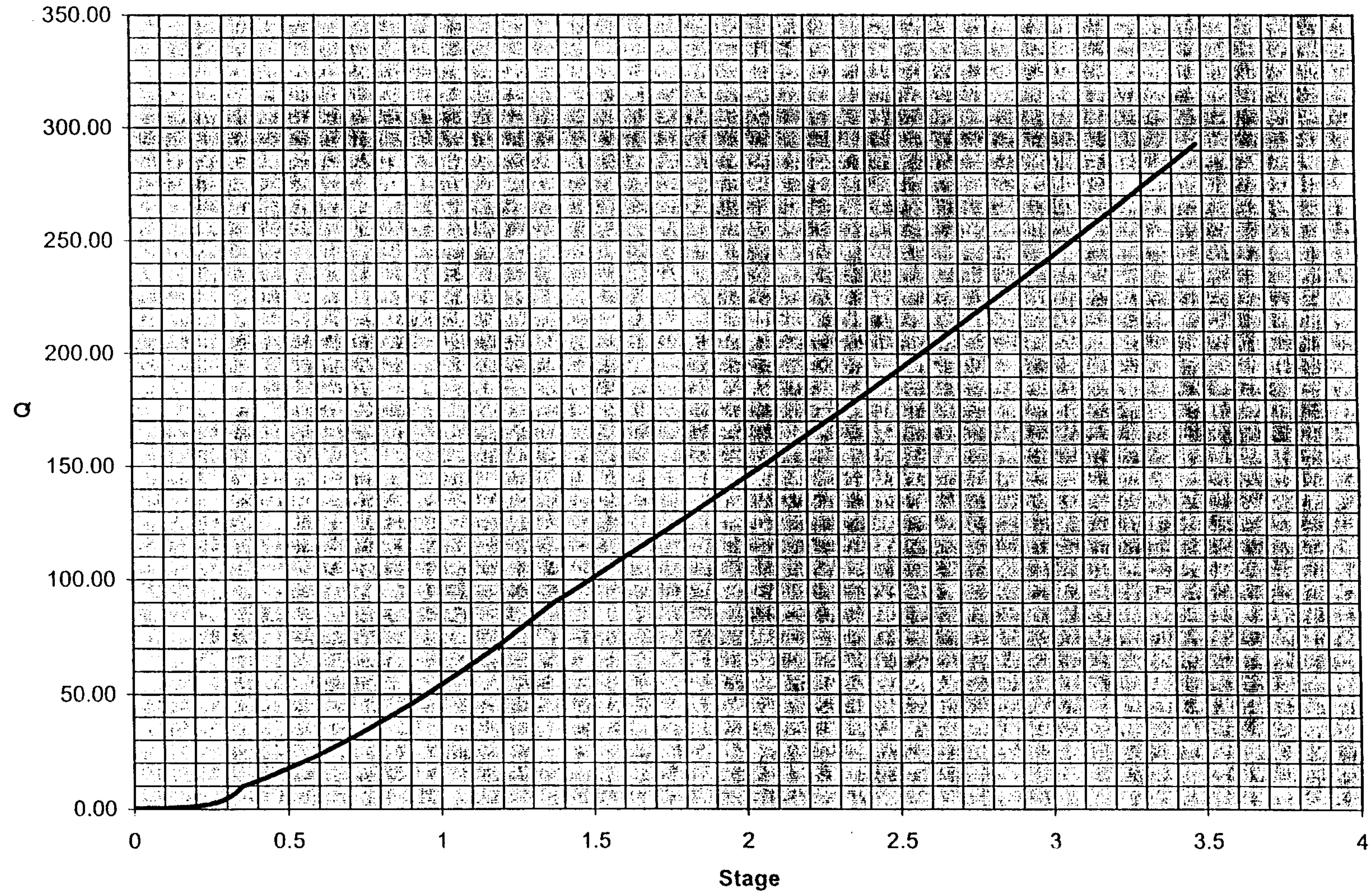
Figure B-7
Des Moines Creek Flow Rate at Mouth

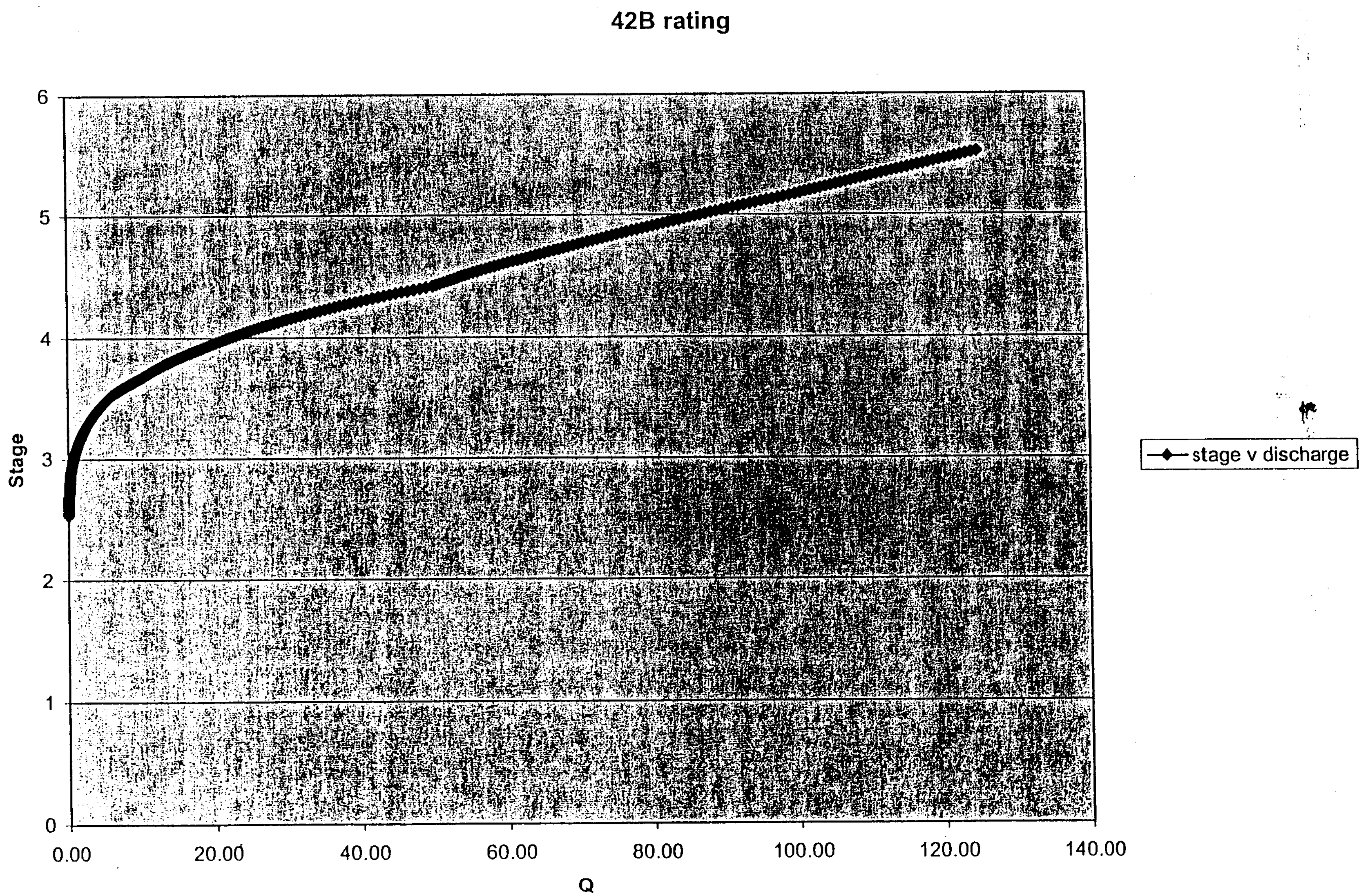


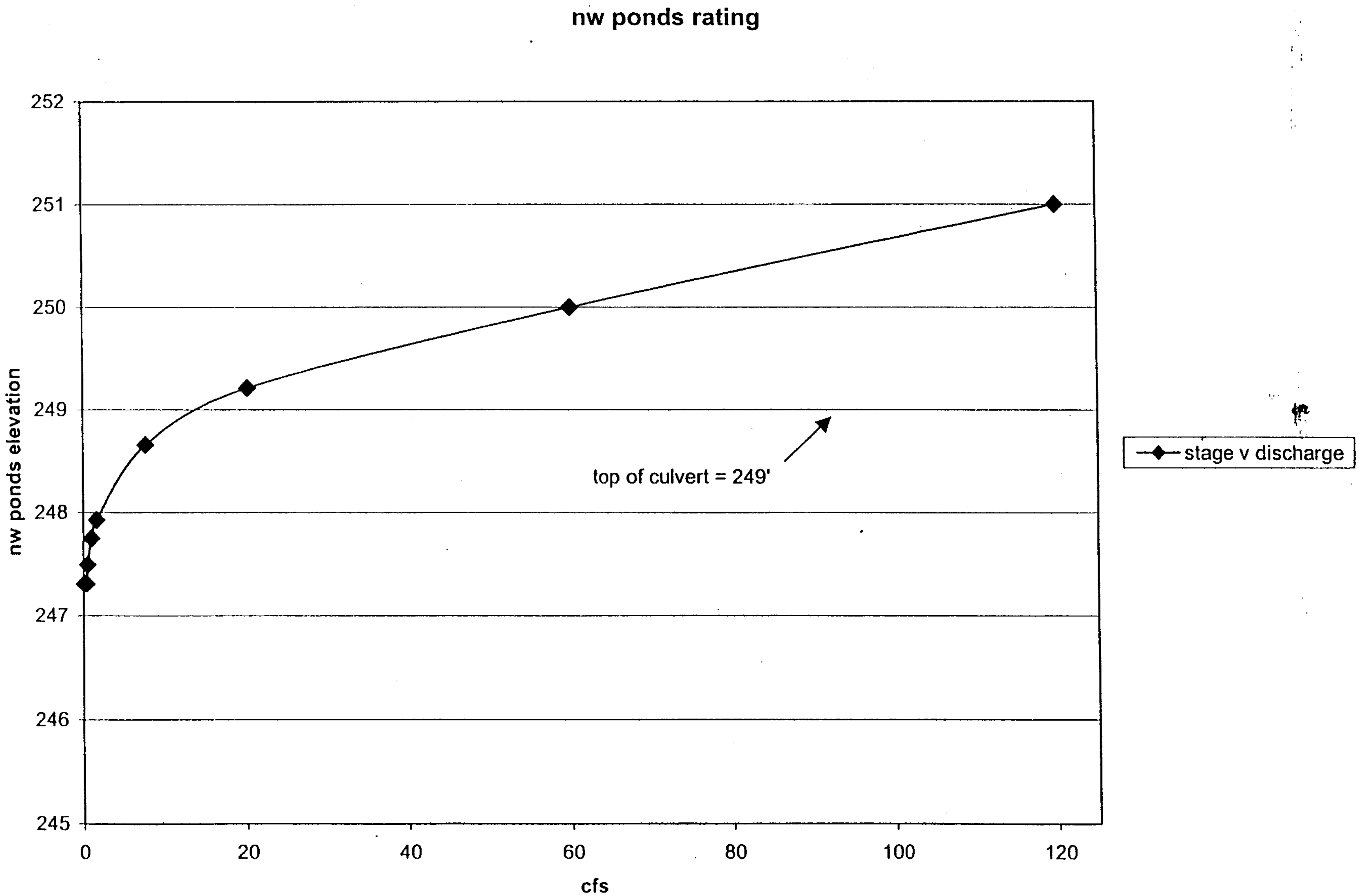
Stage-Discharge for Miller Creek d/s of SR518



Stage-Discharge for Des Moines Creek at Golf Course Weir



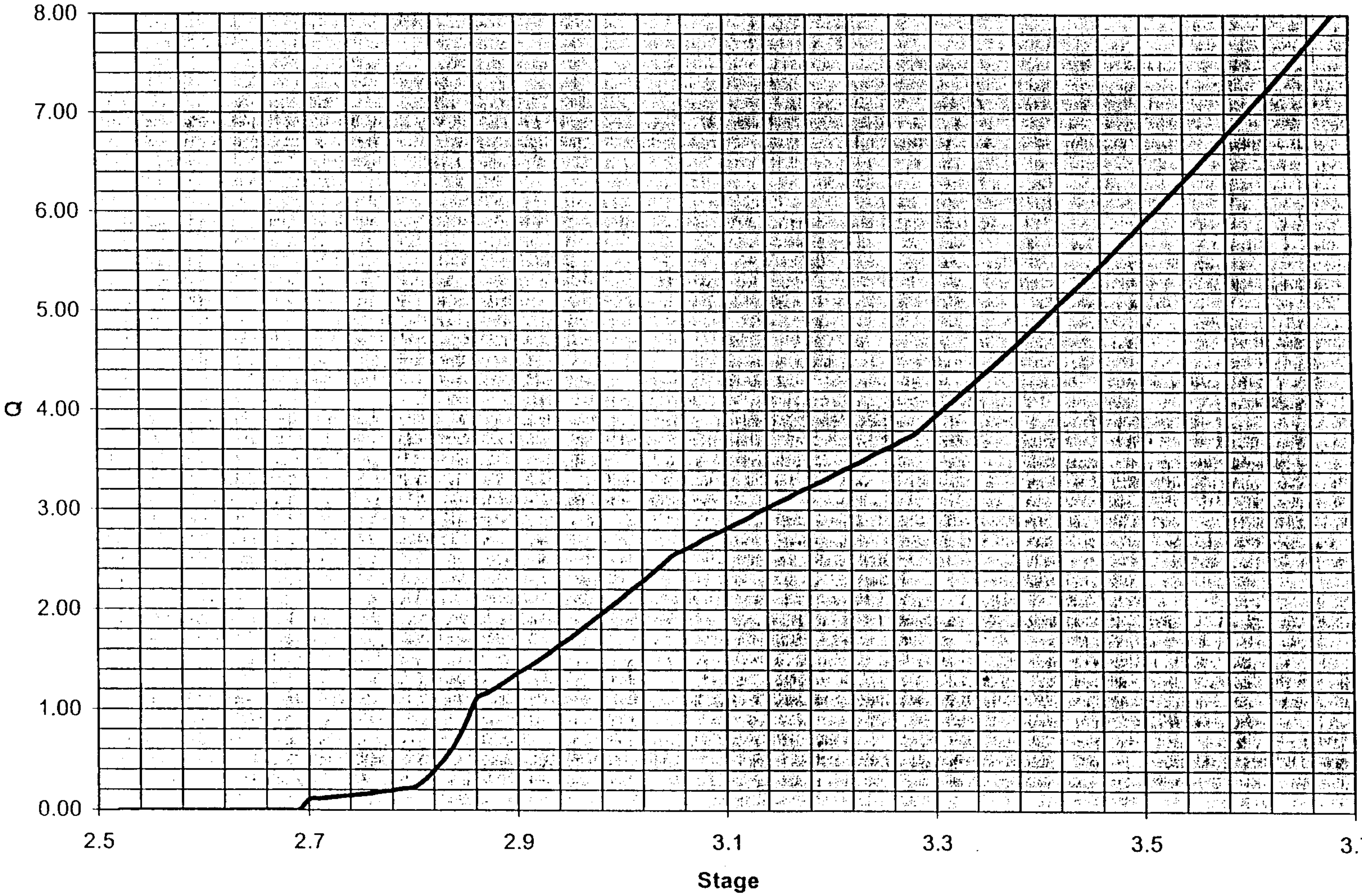

42B rating
Stage
6
5
4
3
2
1
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Q
stage v discharge


nw ponds rating
252
251
250
249
248
247
246
245
nw ponds elevation
0
20
40
60
80
100
120
cfs
top of culvert = 249'
stage v discharge

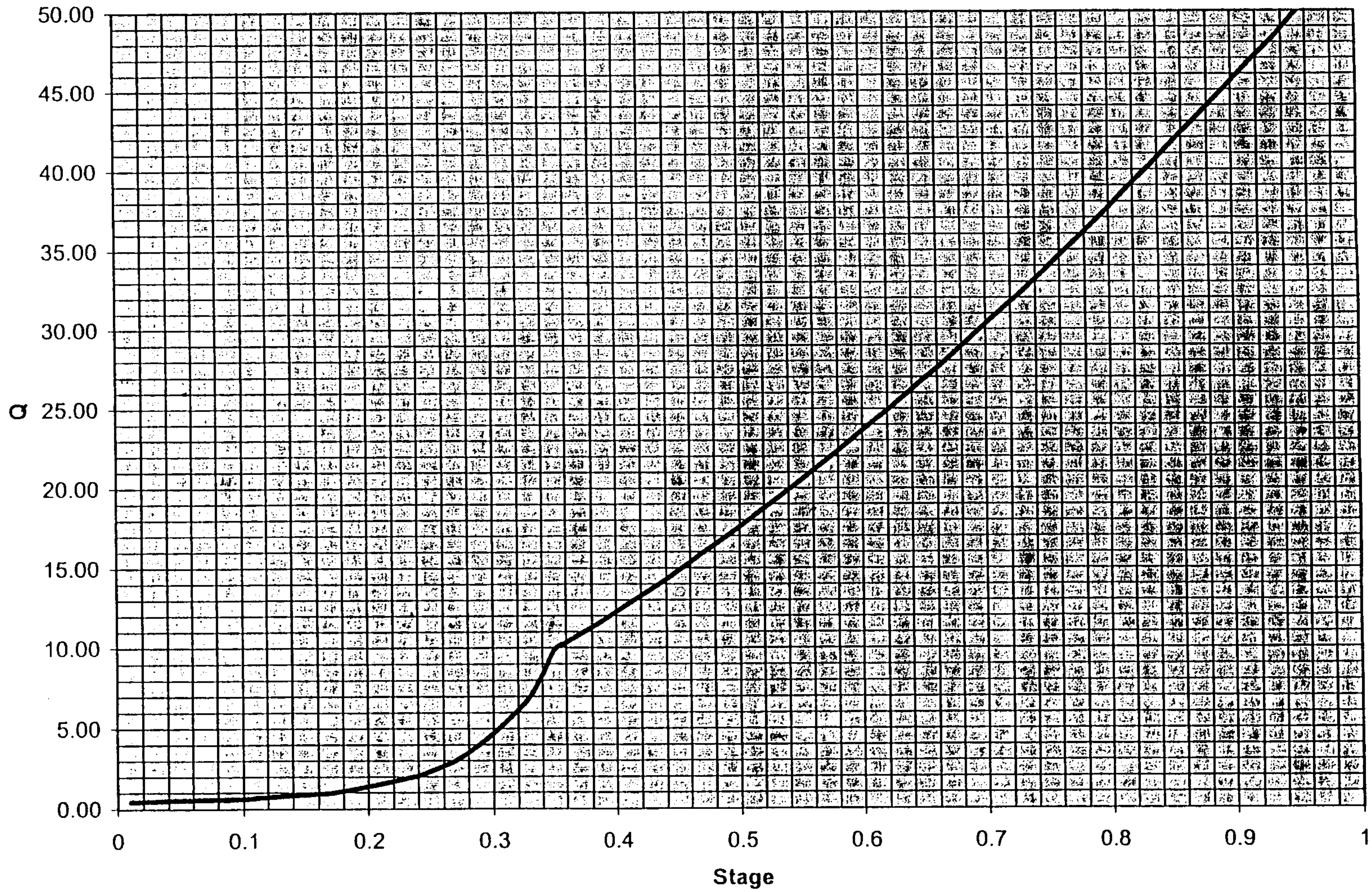
Gage 11G, NW Ponds Outlet
Top of 2" diameter steel well: 254.54'
Top of culvert = 249'

Q, cfs	Elevation
0.01	247
0.08	247.31
0.4	247.31
0.5	247.5
1	247.75
1.63	247.93
7.68	248.66
20.2	249.21
60	250
120	251

Stage-Discharge for Miller Creek d/s of SR518



Stage-Discharge for Des Moines Creek at Golf Course Weir



COSMOPOLITAN

ENGINEERING GROUP

Appendix C

Airport Outfall BOD_5 Concentrations and Hydrographs

Civil, Environmental, and Recreational Consulting

Printed on Recycled Paper

APPENDIX C

AIRPORT OUTFALL BOD_5 CONCENTRATIONS AND HYDROGRAPHS

BOD_5 – DECEMBER 1998 DEICING EVENT

This appendix contains BOD data plotted on hydrographs for the Port of Seattle airfield outfalls that were sampled, as described in Section 4.

SDS3

Figure C-1 presents the hydrograph for outfall SDS3. Also presented on this graph are the BOD_5 concentrations measured in the grab samples from this outfall and the precipitation recorded during the deicing event.

SDS4

Due to equipment malfunction, flow data from SDS4 were not available in December. The hydrograph for this outfall for the December 1998 deicing event was estimated by scaling SDS3 runoff according to the ratio of SDS4 to SDS3 pervious and impervious areas. Based on these known areas, the runoff from the SDS4 basin is estimated to be 11.2% of that measured from the SDS3 outfall.

Figure C-2 presents the estimated hydrograph for outfall SDS4 for the December 1998 deicing event. The experience of Port personnel in the past has been that the flows from outfall SDS4 are delayed by approximately 30 minutes relative to the flows from outfall SDS3. The estimated hydrograph shown for outfall SDS4 reflects this delay. Also presented on this graph are the BOD_5 concentrations measured in the grab samples from this outfall and the recorded precipitation during the deicing event.

SDN3

Figure C-3 presents the hydrograph and BOD_5 concentrations for outfall SDN3 for the December 1998 deicing event.

SDN4

The SDN4 hydrograph for December was estimated in the same manner as for SDS4 discussed above.

Figure C-4 presents the estimated hydrograph and measured BOD_5 concentrations for outfall SDN4 for the December 1998 deicing event.

BOD_5 – FEBRUARY 1999 DEICING EVENT

During the second deicing event the flow meters installed on all outfalls SDS3, SDS4, and SDN3 were functional. During this deicing event BOD_5 was also measured in flow-weighted composite samples that were collected during a portion of the time when stormwater was being discharged from the outfalls.

SDS3

Figure C-5 presents the hydrograph and BOD_5 concentrations for outfall SDS3 for the February 1999 deicing event.

SDS4

Figure C-6 presents the hydrograph and BOD_5 concentrations for outfall SDS4 for the February 1999 deicing event.

SDN3

Figure C-7 presents the hydrograph and BOD_5 concentrations for outfall SDN3 for the February 1999 deicing event.

SDN4

The SDN4 outfall flow meter was not functioning during this sampling period. Figure C-8 presents the estimated hydrograph and BOD_5 concentrations for outfall SDN4 for the February 1999 deicing event where the flow is estimated based on the hydrograph for the SDN3 outfall and the relative areas of pervious and impervious surface in the two drainage basins. A similar estimation is described above for the December 1998 deicing event.

Figure C-1
December 1998 Runway Deicing Event
SDS3 BOD Concentration and Hydrograph

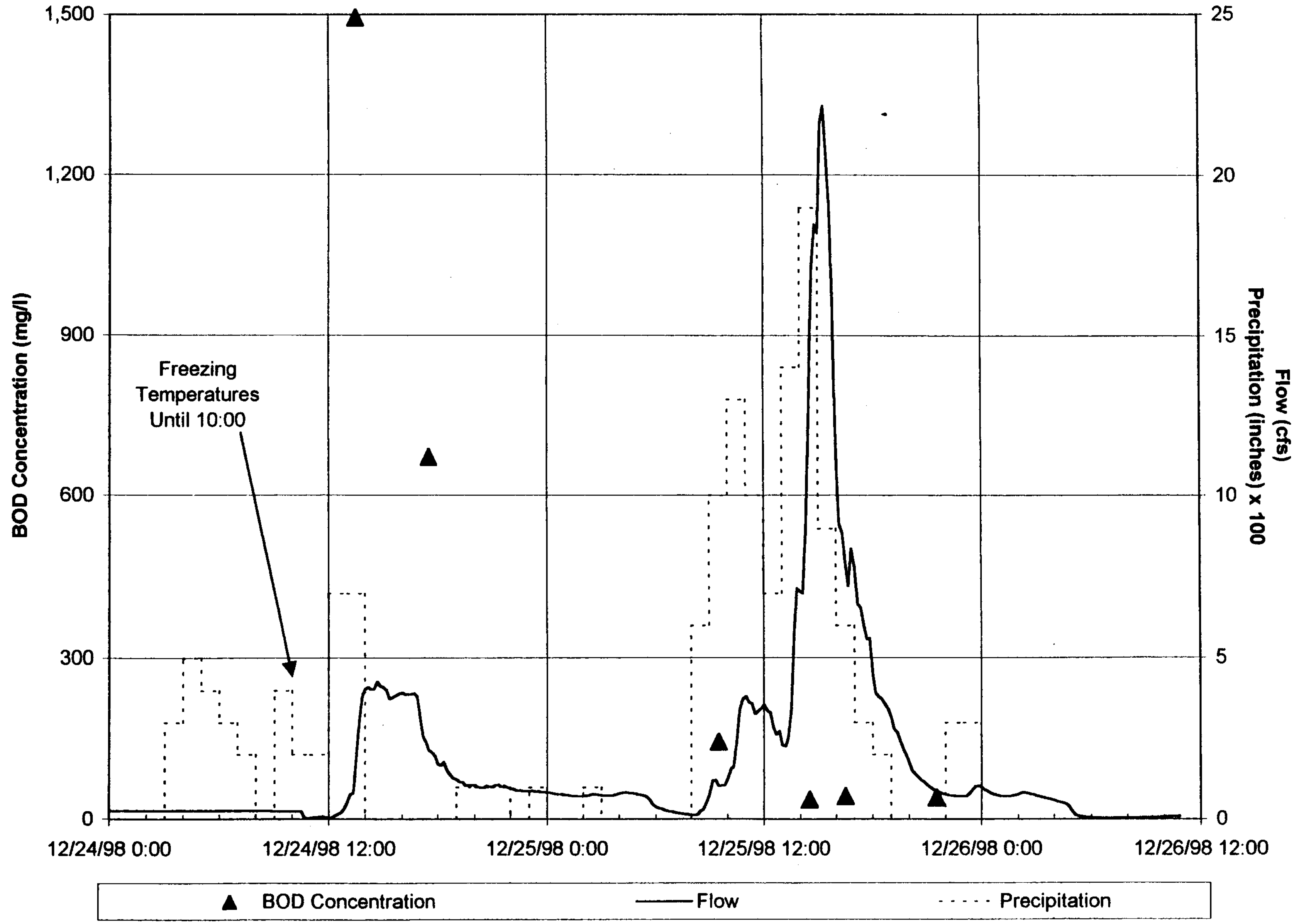
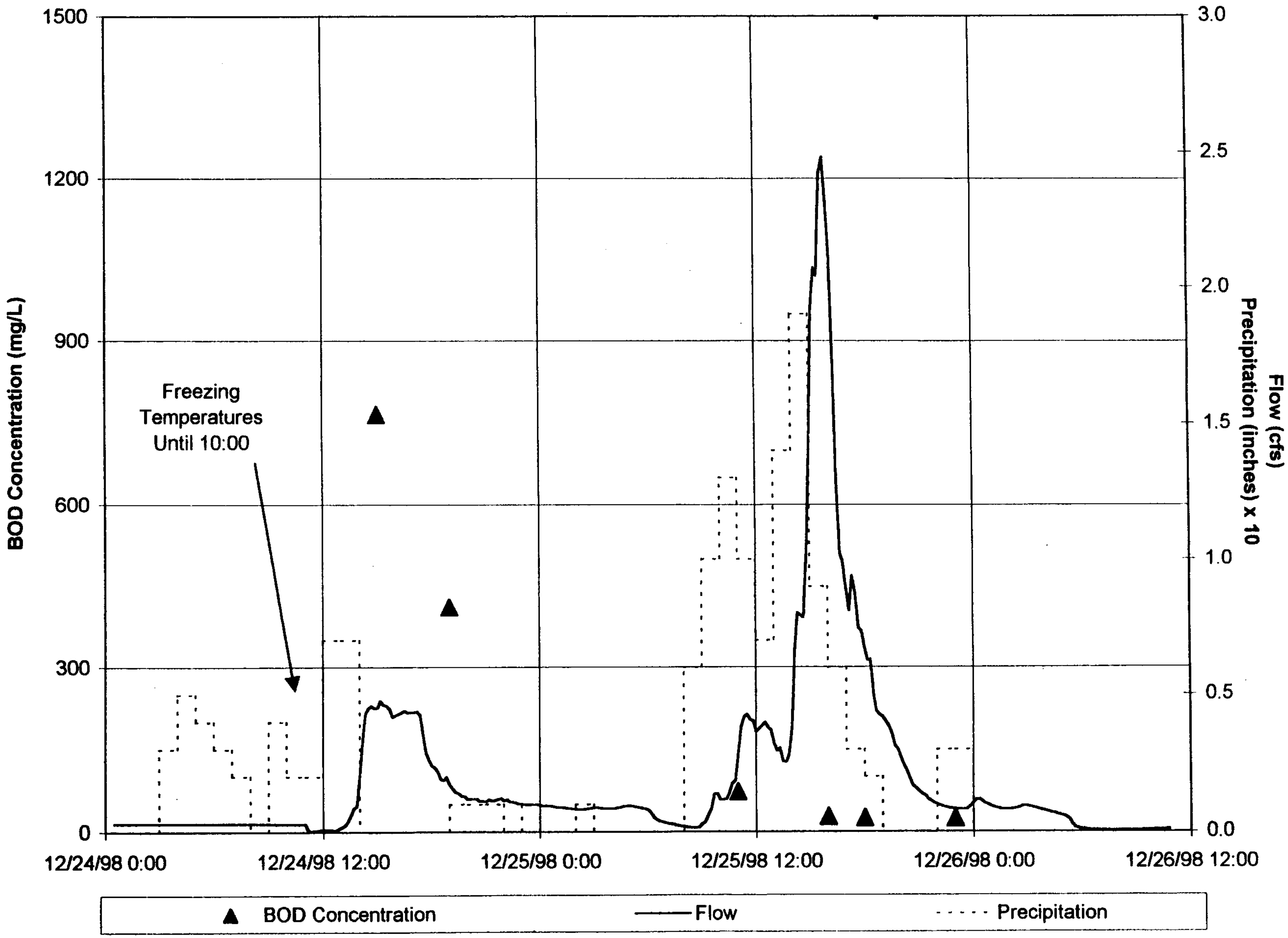


Figure C-2
December 1998 Runway Deicing Event
SDS4 BOD Concentration and Hydrograph



AR 042799

Figure C-3
December 1998 Runway Deicing Event
SDN3 BOD Concentration and Hydrograph

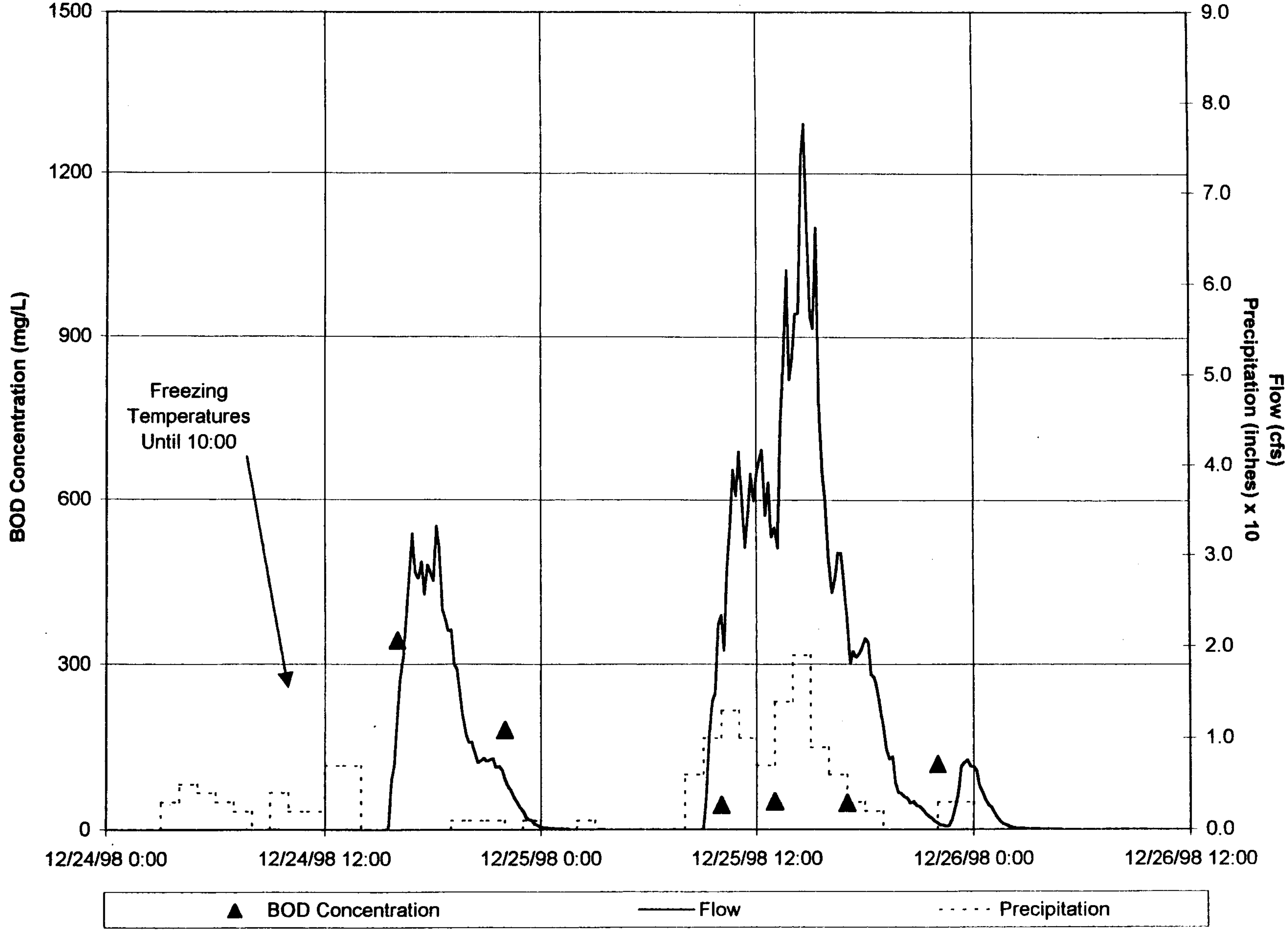


Figure C-4
December 1998 Runway Deicing Event
SDN4 BOD Concentration and Hydrograph

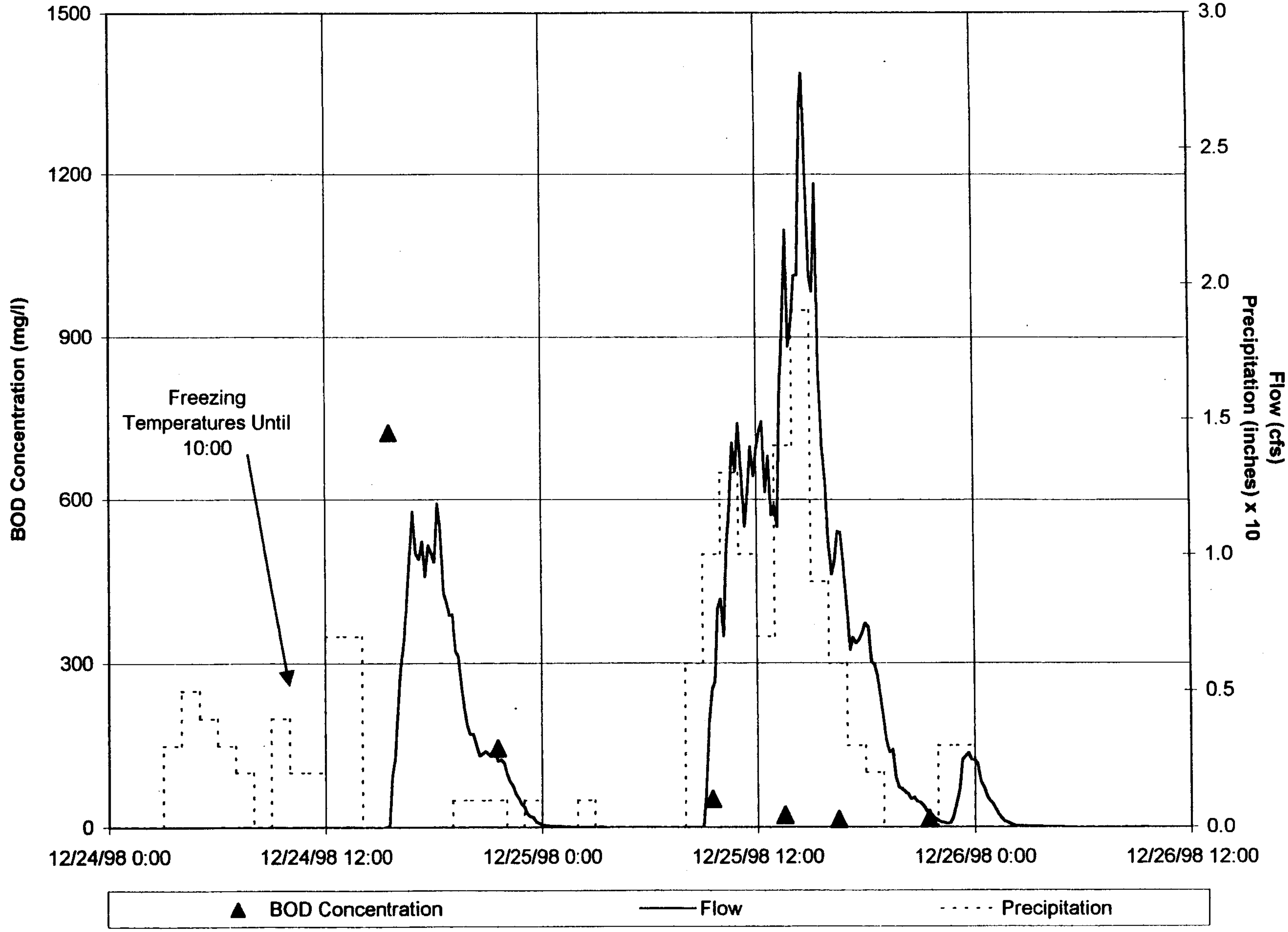


Figure C-5
February 1999 Runway Deicing Event
SDS3 BOD Concentrations and Hydrograph

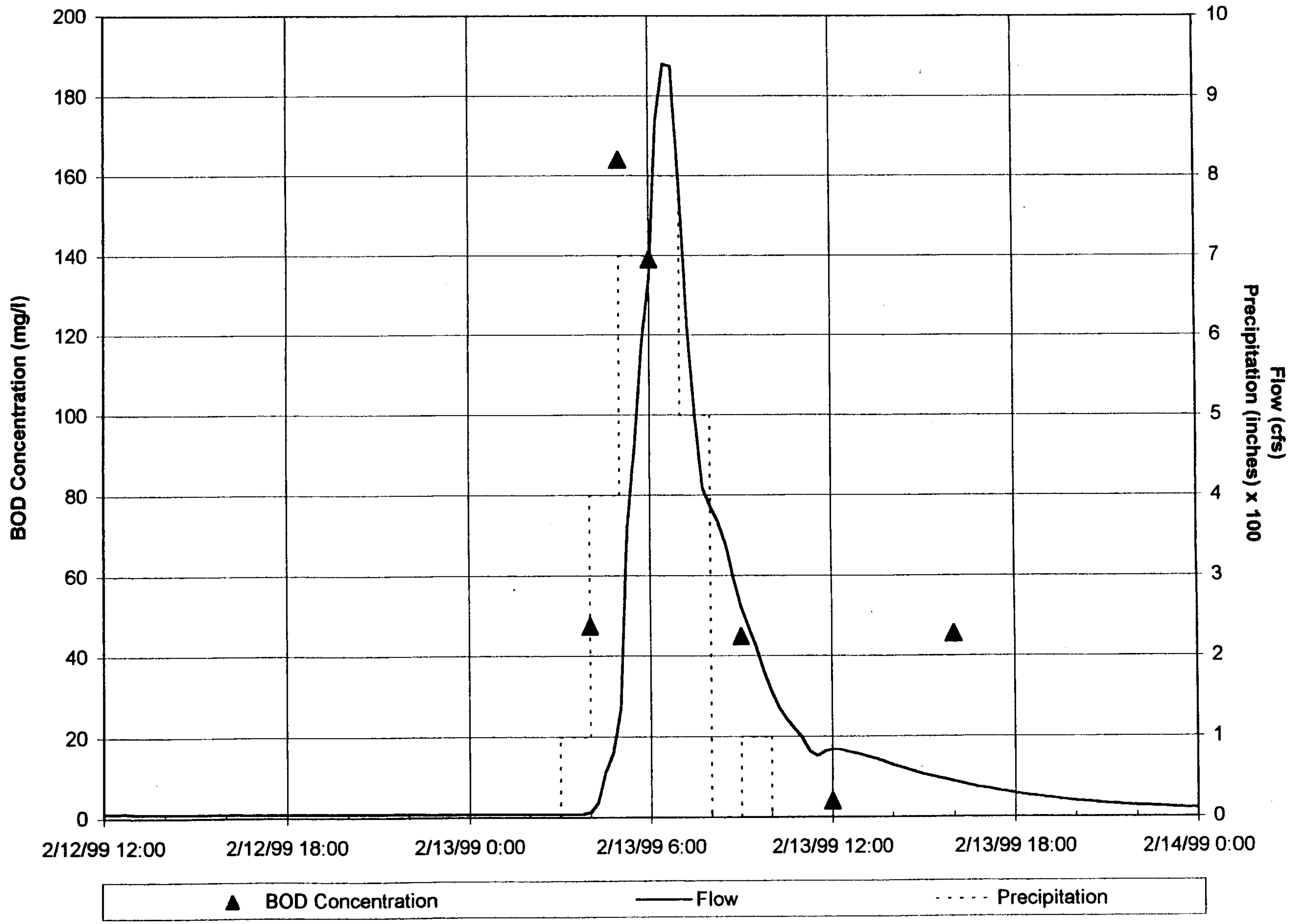


Figure C-6
February 1999 Runway Deicing Event
SDS4 BOD Concentrations and Hydrograph

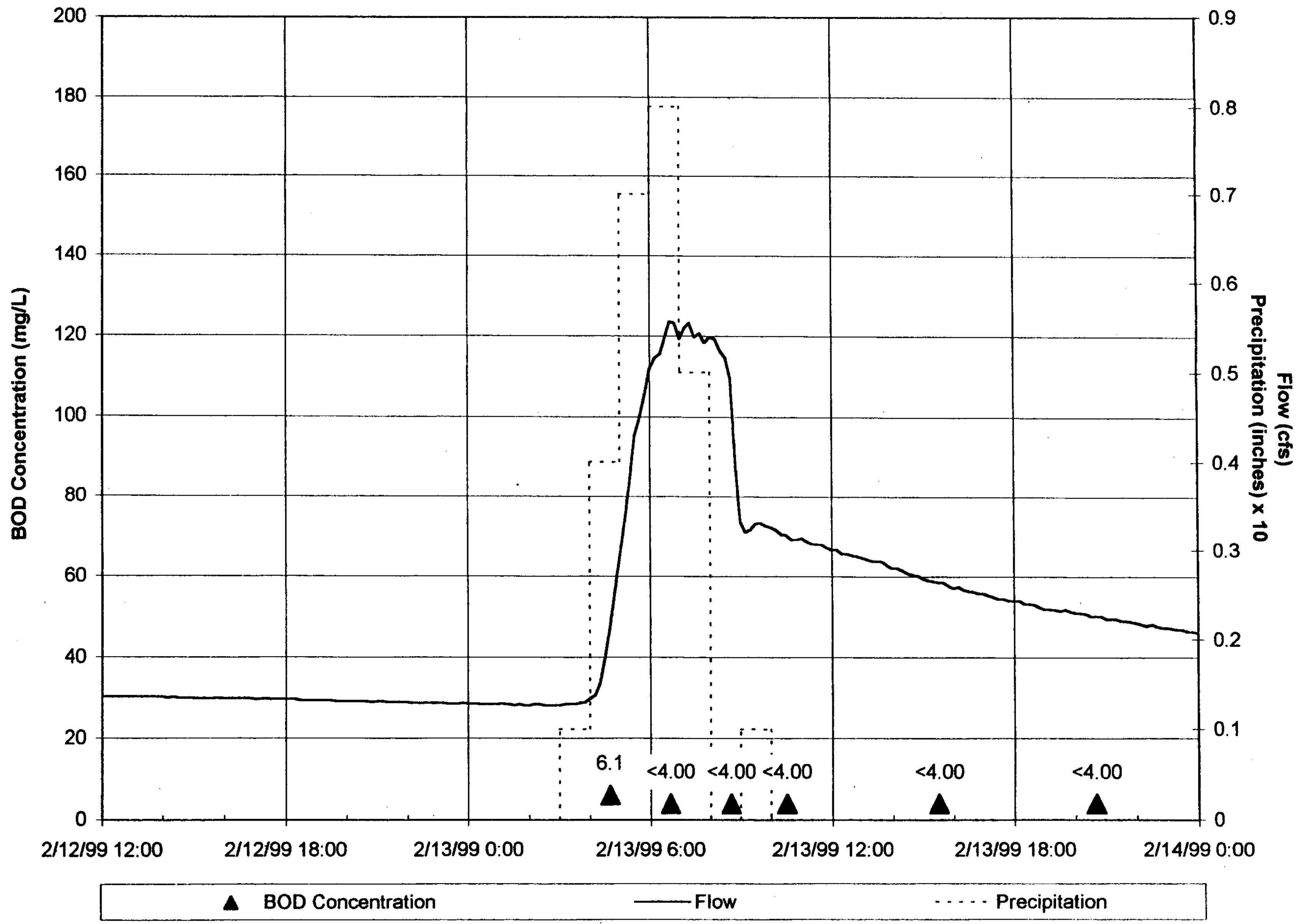
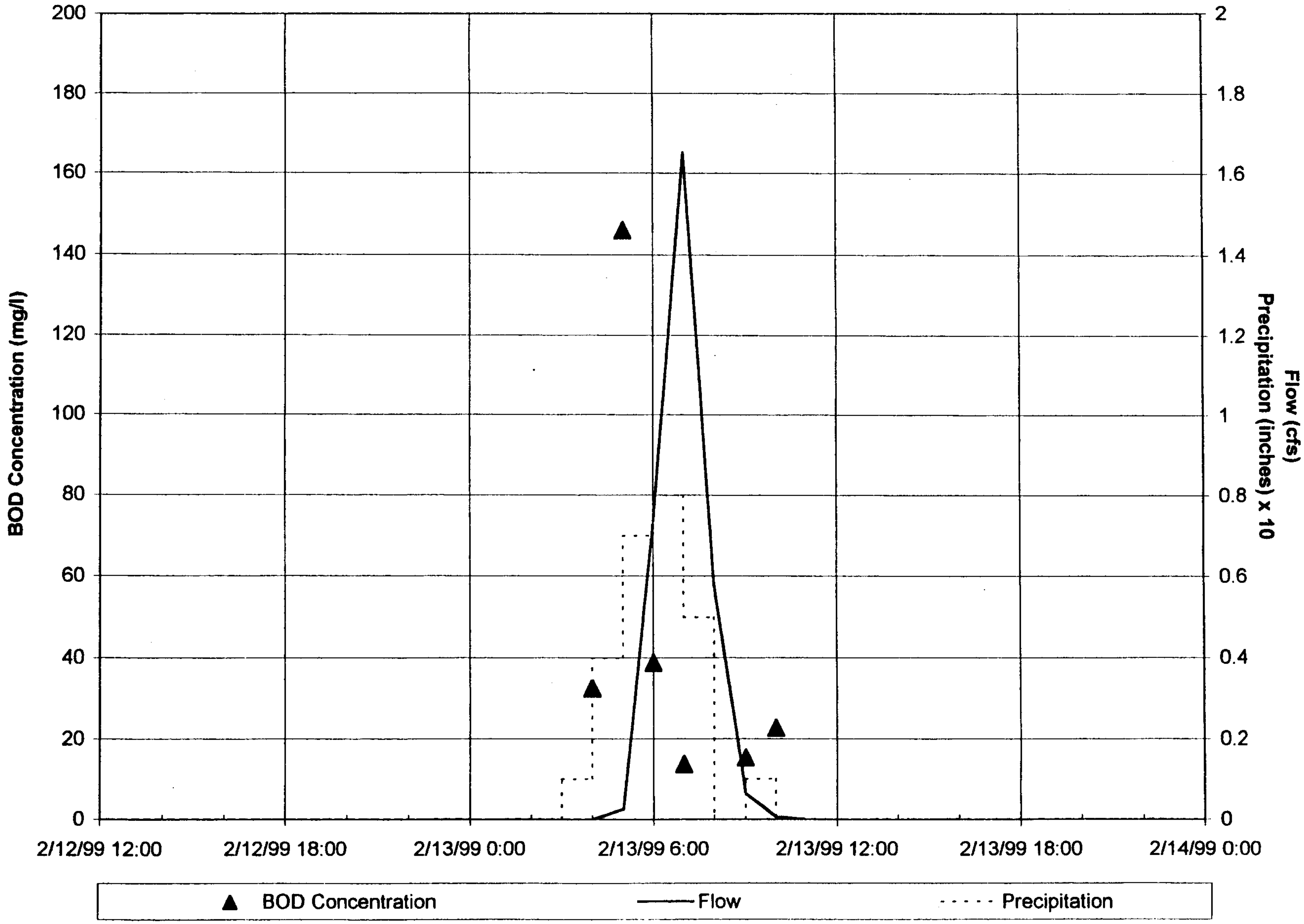
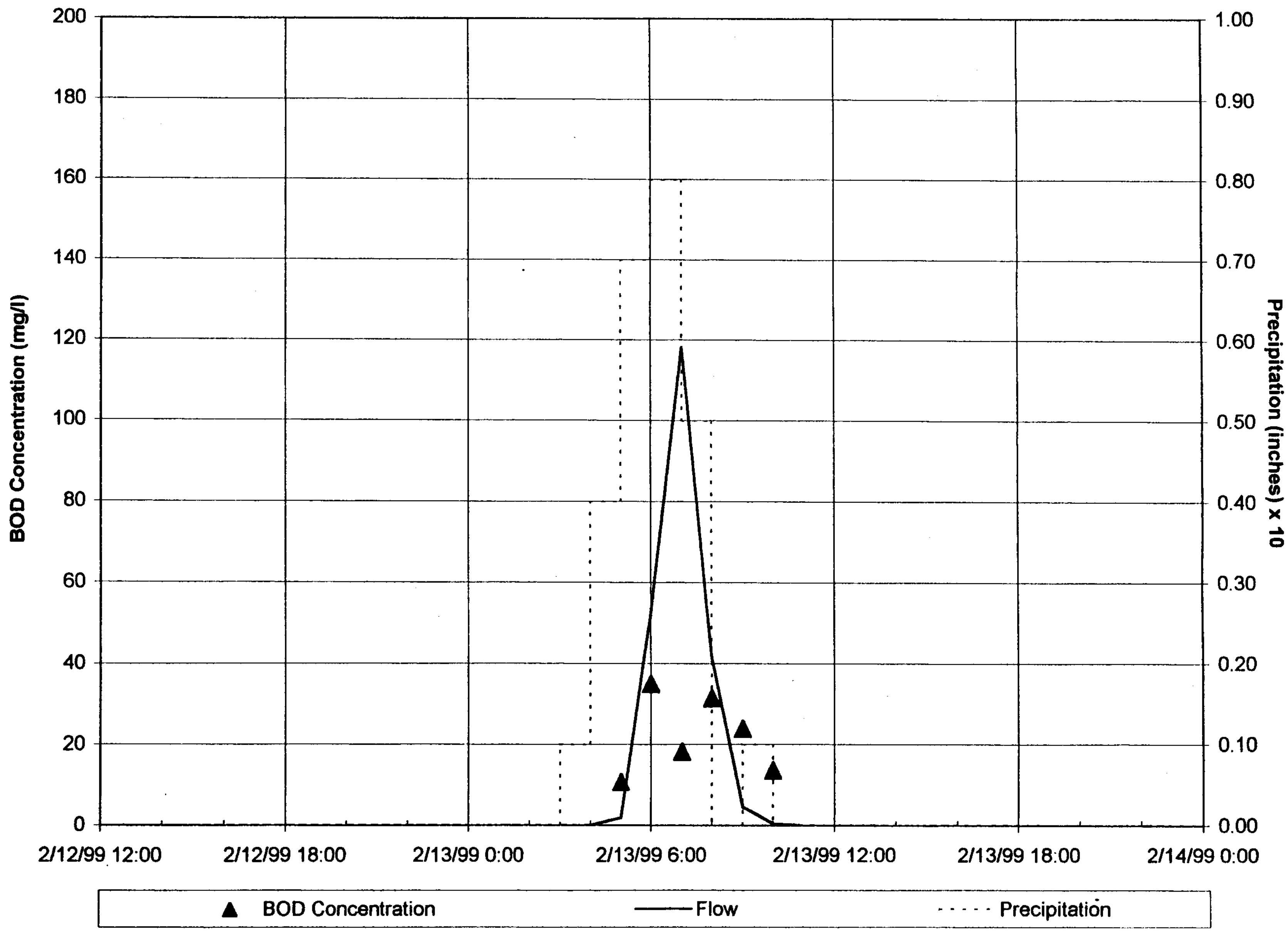


Figure C-7
February 1999 Runway Deicing Event
SDN3 BOD Concentrations and Hydrograph



AR 042804

Figure C-8
February 1999 Runway Deicing Event
SDN4 BOD Concentrations and Hydrograph



COSMOPOLITAN ENGINEERING GROUP

Appendix D

Continuous DO and Temperature Data

Civil, Environmental, and Recreational Consulting

Printed on Recycled Paper

APPENDIX D

DISSOLVED OXYGEN DATA CORRECTION

For each sampling station where a DO probe and data logger were installed, the discussion below presents a graph of the raw DO concentration data recorded by the instrument, the Winkler DO concentrations that were measured periodically to adjust the concentrations measured by the instruments, the adjusted DO concentrations, and the recorded temperature. Figures showing measured and adjusted (based on the adjusted DO concentrations) percent DO saturation for each station are also presented. Tables summarizing the Winkler DO data and the correction factors that were used to adjust the raw data are included in the discussion for each sampling station.

The corrected DO concentrations that are calculated and presented in the following graphs form the basis for the discussion of the DO concentrations observed in Miller Creek and Des Moines Creek during the study. The correction factors applied to the raw DO data were developed by comparing the DO concentrations measured by Winkler titrations to the concentrations recorded by the instruments at the times the Winkler DO samples were collected. A total of 75 Winkler DO analyses were performed during this study to validate the DO concentrations measured with the Hydrolab and Seabird instruments. (This total includes 13 samples collected at the Miller Creek WWTP that were analyzed by WWTP staff as part of their normal operations.) On 5 occasions the samples were less than those measured with the instruments. In the other 70 samples the measured DO concentration equaled or exceeded the concentration recorded by the instrument.

Nearly all of the DO concentrations measured by the in-stream instruments were lower than those measured in the samples that were collected. The degree to which the sample and recorded concentrations differed was found to vary from station to station. The DO probe membranes became fouled at different rates depending on the instrument's location. Cleaning the DO membrane reduced the bias in some cases. Where there was a noticeable change in DO concentration recorded after the membrane was cleaned, the following tables identify differences between sample and recorded concentrations before and after maintenance.

The average difference between the concentrations measured with Winkler titrations and the corresponding DO concentrations recorded by the instruments was 1.66 mg/L (sample concentration greater than recorded concentration). Thus the instruments tended to negatively bias the true values. Because of the magnitude of the bias (-34% to 49%) the recorded data were corrected to better reflect the actual concentrations.

The recorded DO data were adjusted upward or downward to account for the differences. The recorded concentrations were not adjusted when they were equal to the measured sample concentrations or when the discrepancy between the two concentrations could not be reconciled. The value of the correction factor ranged from (-)1.43 mg/L to 5.2 mg/L.

The methods used to develop the correction factors are described in the following sections. The estimation of these correction factors is an inexact process. Every effort was made to be conservative and not overstate, or overestimate, the required correction. Use of an interpolation method, where the correction to each individual data point was different, was considered. This would have eliminated the instantaneous increases in corrected concentrations that are the result of a sudden change in correction factor. However, there is not sufficient data available to be confident that the change in bias is a linear function. For example, if one sample shows a bias of 1 mg/L and another sample collected 10 days later shows a bias of 2 mg/L, an assumption that the bias increased at a rate of 0.1 mg/L/day would need to be made. For this situation, the methodology used in correcting DO concentrations in this report would result in a correction factor of 1 mg/L for the first five days of the period, and 2 mg/L for the next five days.

Using a linear interpolation method to correct the DO concentration data would also have the effect of causing the correction factor to change constantly when concentration trends were being evaluated for specific periods of interest, such as the period immediately following a deicing event. The use of a constant correction factor for a defined period of time is simpler and clearly shows what changes in DO trends are explicitly due to changes in correction factor.

D.1 DES MOINES CREEK NW POND 2 – DMNW2

The table below presents the concentrations measured in samples collected where the Hydrolab was installed in NW Pond 2 and the Hydrolab DO reading at the time the sample was taken. Samples were collected approximately 24 inches below the water surface from a boat moored next to the Hydrolab. Samples were collected in NW Pond 2 when the Hydrolab was installed on 12/5/98, when the first Hydrolab was replaced on 1/18/99, when maintenance to the Hydrolab was performed on 2/9/99, and when the Hydrolab was removed from service on 3/1/99.

Sample Summary				
Date	(1) Sample Concentration (mg/L)	(2) Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD[1] (%)
12/5/98 13:00	6.18	5.64	0.54	8.7
1/18/99 10:00	6.15	7.58	-1.43	-23
2/9/99 11:00	9.27	8.60	0.67	7.2
3/1/99 11:00	9.37	6.70	2.67	28

(1) RPD = Relative Percent Difference = [(1) – (2)]/(1)

The first Hydrolab installed in NW Pond 2 was replaced with a second one on 1/18/99 so that the batteries in the first Hydrolab could be changed and the membrane could be replaced . The sharper changes in DO in Pond 2 compared to those observed in Pond 3 are likely due in part to the different types of DO monitoring instruments installed in the two locations (a Seabird instrument was installed in NW Pond 3). Differences in the hydraulics and incoming flows to the two ponds may cause differences in the rate and degree of change in DO concentrations in the two ponds as well.

The concentrations recorded with the Hydrolab in NW Pond 2, while more variable than those recorded in Pond 3, exhibit a variability similar to that observed in the data recorded with the other Hydrolabs used in the study. Consequently, these data are evaluated in the same manner as those from other sampling locations.

The following table presents the method used to estimate the correction factors that are applied to the DO concentration data recorded in NW Pond 2.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
12/5/98 13:00	1/18/99 9:00	0.54	Difference between sample and recorded concentration 12/5. CF applied until Hydrolab maintained on 1/18.
1/18/99 10:00	1/29/99 10:00	-1.43	Difference between sample and recorded concentration on 1/18. CF applied for one half of period until next sample.
1/29/99 11:00	2/9/99 10:00	-.38	Average of differences calculated for 1/18 and 2/9. CF applied for second half of period until next sample on 2/9. Average applied because bias went from negative to positive.
2/9/99 11:00	2/18/99 23:00	0.67	Difference between sample and recorded concentration on 2/9. CF applied for one half of period until next sample on 3/1.
2/19/99 0:00	3/1/99 11:00	1.67	Average of differences measured on 2/9 and 3/1. Difference of 2.67 measured on 3/1 was not used to be conservative.

Figure D-1 presents the DO data that was recorded, the DO concentrations measured in the grab samples, the adjusted DO concentrations that were calculated using the correction factors described above, and the water temperature recorded by the instrument. Figure D-2 presents the same data in terms of % DO saturation.

D.2 DES MOINES CREEK NW POND 3 – DMNW3

Dissolved oxygen and salinity concentrations were measured in NW Pond 3 using a Seabird instrument equipped with dissolved oxygen and salinity probes and a data logger. The instrument was suspended from a float approximately three feet below the surface of the pond.

The instrument was out of service from 1/16/99 to 1/22/99 and again from 3/1/99 to 3/9/99 for cleaning and maintenance. The Seabird was removed from the pond on 4/20/99. A sample was collected on 12/22/98 during the first deicing event when ice had covered the pond. The presence of ice prevented the collection of a sample from NW Pond 2 at the same time because the boat used for sampling could not penetrate the ice to the upper pond.

Sample DO concentrations measured just before the instrument was maintained on 3/1/99, and again when the instrument was re-deployed on 3/9/99, were nearly double what was recorded by the Seabird. Dissolved oxygen concentrations measured with Winkler analyses on 3/24/99 and 4/1/99 were closer to those recorded by the Seabird but still higher by approximately 2.0 – 2.5 mg/L. Correction factors for DO for this location are estimated by classifying the results of the two analyses from 3/1/99 and 3/9/99, when the difference between the sample and recorded concentrations were greater than 3.3 mg/L, as outliers and neglecting the results. The other calculated differences were all less than 2.4 mg/L.

Figures D-3 and D-4 present recorded and adjusted DO concentration and % saturation data for this sampling station.

Sample Summary

Date	Sample Concentration (mg/L)	Seabird Concentration (mg/L)	Difference (mg/L)	RPD (%)
12/5/98 13:35	5.83	5.72	0.11	1.9
12/22/98 14:00	2.98	4.0	-1.02	-34
1/22/99 12:20	6.36	5.98	0.38	6.0
2/9/99 11:20	8.2	6.5	1.7	21
3/1/99 9:50	9.19(1)	5.83	3.36	--
3/9/99 12:00	10.05(1)	4.94	5.11	--
3/24/99 8:20	6.07	4.05	2.02	33
4/1/99 11:15	7.48	5.09	2.39	32

(1) Considered to be outlier. Differences and RPDs not included in statistics. Differences not considered in estimation of correction factors.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
12/5/98 13:30	12/14/98 0:00	0.11	Difference between sample and recorded concentration on 12/5. CF applied for half of period until next sample on 12/22
12/14/98 0:00	12/22/98 13:00	-0.55	Average of differences on 12/5 and 12/22. Average applied because bias went from negative to positive.
12/22/98 14:00	1/15/99 23:45	0	Difference measured on 12/22 is (–)1.02 mg/L. Application of a negative correction factor would result in negative DO concentrations from 1/4 to 1/11. Therefore, no correction factor is applied for the period from 12/22 – 1/15. Meter out of service 1/16 – 1/22
1/22/99 12:20	1/31/99 12:20	0.4	Difference recorded on 1/22. CF applied for half of period until next sample on 2/9
1/31/99 13:20	3/1/99 9:50	1.70	Difference recorded on 2/9. CF applied meter unit taken out of service on 3/1.
3/9/99 12:00	4/20/99 9:00	2.2	Average difference of samples collected on 3/24 and 4/1.

D.3 .DES MOINES CREEK GOLF COURSE WEIR – DM3

Sample Summary				
Date	Sample Concentration (mg/L)	Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD (%)
12/9/98 14:15	9.60	11.43	-1.83	-20
12/14/98 14:15	10.62	9.25/8.73[1]	1.37/1.89[1]	13/18[1]
1/5/99 10:45	8.59	4.35/5.24	4.24/3.35	49/39
1/22/99 11:30	9.88	6.67	3.21	32
2/1/99 14:00	10.64	7.04/8.71	3.6/1.93	34/18
2/9/99 10:00	10.43	6.95/7.58	3.48/2.85	33/27
2/13/99 11:30	10.23	6.56	3.67	36
2/18/99 17:00	10.53	5.34/7.64	5.19/2.89	49/27
3/3/99 11:00	10.49	7.32/8.49	3.17/2.00	30/19
3/16/99 11:00	10.18	7.94	2.24	22
3/24/99 8:00	8.98	6.4/7.38	2.58/1.6	29/18
		Average	2.81/2.36[(1),(2)]	32/24[(1),(2)]

(1) Before Maintenance/After Maintenance.

(2) Calculated averages consider differences shown when maintenance was not performed as being "Before Mainentenance."

The table above shows that the average Hydrolab meter readings were 2.9 mg/L lower than those measured by performing Winkler DO analyses.

The Hydrolab at this location was found to require more maintenance than those at other locations. On several occasions the instrument was found to be covered with an oily residue that coated the DO probe membrane. Once this condition was discovered, the frequency of maintenance and cleaning for this meter was increased to approximately every two weeks. The data above show that recorded DO concentrations typically increased after the DO membrane had been cleared (average RPD before cleaning = 32%, after cleaning = 24%). Since the DO probe membrane was cleaned more frequently than at the other sampling sites, with concurrent collection of Winkler DO titration samples, more frequent adjustments to the correction factors can be made, as shown in the following table. The DO correction factors shown in the following table were calculated using the differences shown above.

Data recorded before 12/7/98 were determined to be unreliable due to their unstable nature, as shown in Figure D-5 (①). Data recorded between 12/7/98 and 12/11/98 were not adjusted because the measured concentrations were significantly higher than those beginning on 12/11. A sharp decrease in DO beginning on 12/11 (②) may be indicative of a sudden fouling of the membrane. DO concentrations measured after this point were adjusted as shown in the following table.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
12/4/98 9:00	12/7/98 3:45	Data rejected	Data rejected due to extreme and rapid fluctuations in data. Data stabilized on 12/7.
12/7/98 4:00	12/11/98 15:15	0	Difference of (-)1.83 on 12/9, sharp decrease in measured concentration on 12/11. Difference of (+)1.37 on 12/14. Not possible to determine where bias goes from positive and negative.
12/11/98 15:30	12/14/98 14:15	1.37	Difference of 1.37 on 12/14. CF applied for half of period between 12/7 and sample on 12/14 up to time when meter was cleaned on 12/14.
12/14/98 14:30	12/24/98 23:45	1.89	Difference of 1.89 after probe cleaned on 12/14. CF applied for half of period between samples on 12/14 and 1/5. Coincidentally, change in CF on 12/25 corresponds to time between Condition 2 and Condition 3 sampling for December deicing event.
12/25/98 0:15	1/5/99 10:45	1.89	Difference of 4.24 on 1/5. However, to be conservative and remove possible artifical change in corrected concentration during period of deicing event, CF remains at 1.89 until 1/5.
1/5/99 11:00	1/15/99 12:30*	3.35	Difference of 3.35 after meter cleaned on 1/5. CF applied until Hydrolab removed from service on 1/15.
1/18/99 11:00	1/27/99 0:00	3.21	Difference of 3.21 on 1/22. CF applied from time when Hydrolab replaced on 1/18 for one half of period until next sample on 2/1.
1/27/99 0:30	2/1/99 14:00	3.6	Difference of 3.6 on 2/1 before meter was cleaned. CF applied for second half of period from 1/22 to 2/1, until meter cleaned.
2/1/99 14:30	2/5/99 12:00	1.93	Difference of 1.93 after meter cleaned on 2/1. CF applied from time meter cleaned for half of period until next sample on 2/9.
2/5/99 12:30	2/9/99 10:00	3.48	Difference of 3.48 on 2/9 before meter was cleaned. CF applied for second half of period from 2/1 to 2/9, until meter cleaned.
2/9/99 10:30	2/11/99 11:00	2.85	Difference of 2.85 after meter cleaned on 2/9. From time meter cleaned for half of period until next sample on 2/13.
2/11/99 11:30	2/16/99 0:00	3.67	Difference of 3.67 on 2/13. This sample was collected as part of the Condition 2 sampling for the February deicing event. CF applied for second half of period from 2/9 to 2/13 and for first half of period from 2/13 until next sample was collected on 2/18.
2/16/99 0:30	2/18/99 17:00	5.19	Difference of 5.19 on 2/18. CF applied for second half of period from 2/13 to 2/18 until meter was cleaned.
2/18/99 17:30	2/25/99 0:00	2.89	Difference of 2.89 after meter cleaned on 2/18. CF applied for half of period until next sample on 3/3.
2/25/99 0:30	3/3/99 11:00	3.17	Difference of 3.17 on 3/3 before meter was cleaned. CF applied for second half of period from 2/18 to 3/3, until meter was cleaned.
3/3/99 11:30	3/10/99 11:00	2.00	Difference of 2.0 after meter cleaned on 3/3. CF applied for half of period until next sample on 3/16.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
3/10/99 11:30	3/20/99 9:30	2.24	Difference of 2.24 on 3/16. CF applied for second half of period from 3/3 to 3/16 and for one half of period until next sample collected on 3/24.
3/20/99 10:00	3/24/99 8:00	2.58	Difference of 2.58 on 3/24 before meter was cleaned. CF applied for second half of period from 3/16 until 3/24.
3/24/99 8:30	4/13/99 12:00	1.6	Difference of 1.6 after meter cleaned on 3/24. CF applied until meter removed from service on 4/13.

*Meter out of service from 1/15/99 12:30 until 1/18/99 11:00

Figures D-5 and D-6 present recorded and adjusted DO concentration and % saturation data for this sampling station.

D.4 DES MOINES CREEK WWTP – DMSTP

Sample Summary				
Date	Sample Concentration (mg/L)	Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD (%)
1/5/99 13:30	12.11	10.88	1.23	10
1/22/99 12:00	11.94	10.60	1.34	11
2/1/99 13:00	12.31	10.25/11.22[(1)]	2.06/1.09[(1)]	17/8.8
2/18/99 17:30[(2)]	12.00	10.54	1.46	12
3/3/99 10:30	12.07	10.15	1.92	16

(1) Before Maintenance/After Maintenance.

(2) Out of service between 2/16/99 18:30 and 2/18/99 17:30 for membrane replacement.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
12/10/16:00	1/5/99 13:00	0	No samples collected prior to 1/5. Relatively low error between samples and concentrations measured by Hydrolab
1/5/99 13:30	1/22/99 11:30	1.23	Difference of 1.23 on 1/5. CF applied for period until next sample on 1/22.
1/22/99 12:00	1/27/99 12:00	1.34	Difference of 1.34 on 1/22. CF applied for one half of period until next sample on 2/1.
1/27/99 12:00	2/1/99 12:30	2.06	Difference of 2.06 on 2/1 before meter was cleaned. CF applied for second half of period between 1/22 and 2/1.
2/1/99 13:00	2/16/99 18:30	1.09	Difference of 1.09 on 2/1 after meter was cleaned. CF applied until battery failed on 2/16.
2/18/99 17:30	2/25/99 0:00	1.46	Difference measured when batteries replaced on 2/18. CF applied for half of period until sample on 3/3.
2/25/99 0:30	3/3/99 10:30	1.92	Difference measured when Hydrolab removed from service on 3/3. CF applied for second half of period between 2/18 and 3/3.

Figures D-7 and D-8 present recorded and adjusted DO concentration and % saturation data for this sampling station. The figure shows DO concentrations as high as 16 mg/L on 12/23. These high DO concentrations correspond to the lowest water temperatures that occurred during the period of freezing temperatures and reflect a supersaturated condition of approximately 110%. The Hydrolab at this location experienced a battery failure from 12/16/98 to 12/18/98.

AR 042816

D.5 DES MOINES CREEK MOUTH – DM2

Sample Summary				
Date	**Sample Concentration (mg/L)**	**Hydrolab Concentration (mg/L)**	**Difference (mg/L)**	**RPD (%)**
12/9/98 15:30	11.66	10.76	0.90	7.7
12/14/98 15:00	11.68	10.14	1.54	13
1/5/99 13:00	11.73	7.86/10.42[1]	3.87/1.31[1]	33/11
1/22/99 12:30	11.52	10.37	1.15	10
2/1/99 13:30	12.11	11.26	0.85	7.0
2/18/99 10:00	11.68	10.07	1.61	14
3/3/99 10:00	11.91	9.79	2.12	18

(1) Before Maintenance/After Maintenance.

Figures D-9 and D-10 present recorded and adjusted DO concentration and % saturation data for this sampling station. Figures D-9 and G-1 show that there was a downward drift in the meter, resulting in a difference of 3.87 mg/L before it was cleaned on 1/5. To avoid making a large change in the correction factor in the period immediately following the December deicing event, the CF is estimated without taking this difference into account. Neglecting this difference is a conservative assumption because the net effect is that the correction factor applied to the recorded data is reduced to 1.54 mg/L for the entire period between 12/14 and 1/5.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
12/4/98 9:00	12/12/98 0:00	0.9	Difference measured on 12/9. CF applied from time of initial installation and for half of period until next sample on 12/24.
12/12/98 0:15	12/24/98 23:30	1.54	Difference measured on 12/14. CF applied for second half of period between 12/9 and 12/14 and for first half of period between 12/14 and 1/5 .
12/25/98 0:00	1/5/99 13:00	1.54	Difference measured before meter cleaned on 1/5 was 3.87. To be conservative and to avoid making a change in CF during the December deicing period, a CF of 1.54 is maintained until the meter was cleaned on 1/5.
1/5/99 13:30	1/14/99 0:00	1.31	Difference measured after meter cleaned on 1/5. CF applied for half of period until next sample on 1/22.
1/14/99 0:30	1/27/99 13:00	1.15	Difference measured on 1/22. CF applied for second half of period from 1/5 to 1/22 and first half of period from 1/22 to 2/1 when next sample was collected.
1/27/99 13:30	2/9/99 10:00	0.85	Difference measured on 2/1. CF applied for second half of period from 1/22 to 2/1 and first half of period from 2/1 to 2/18.
2/9/99 10:30	2/25/99 0:00	1.61	Difference measured on 2/18. CF applied for second half of period from 2/1 to 2/18 and first half of period from 2/18 to 3/3.
2/25/99 0:30	3/3/99 10:00	2.12	Difference measured on 3/3 when meter was removed from service. CF applied for second half of period from 2/18 to 3/3.

D.6 MILLER CREEK – LAKE REBA

Sample Summary				
Date	**Sample Concentration (mg/L)**	**Seabird Concentration (mg/L)**	**Difference (mg/L)**	**RPD (%)**
12/5/98 14:10	7.93	6.38	1.55	20
1/18/99 10:10	8.77	7.47	1.30	15
1/22/99 10:30	7.44	6.98	0.46	6.2
2/9/99 9:00	9.43	8.40	1.03	11
3/1/99 10:30	9.87	7.98	1.89	19
3/9/99 10:30	10.04	7.35	2.69	27
4/1/99 10:15	10.94	10.02	0.92	8.4

Dissolved oxygen and salinity concentrations were measured in Lake Reba using a Seabird sampler. The instrument was suspended from a float approximately 1 foot below the surface. The instrument was out of service from 1/18/99 to 1/22/99 and again from 3/1/99 to 3/9/99 for cleaning and maintenance.

Figures D-11 and D-12 present recorded and adjusted DO concentration and % saturation data for this sampling station. The plot of measured and corrected DO concentrations for this site shows that after the middle of March, the DO in Lake Reba started to fluctuate on a regular diurnal cycle with peak concentrations during the day reaching as much as 150% of saturation. Possible reasons for this occurring are discussed in Section 5 of the report.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
12/5/98 14:40	12/27/98 12:10	1.55	Difference measured on 12/5. CF applied from time of initial installation and for half of period until next sample on 1/18.
12/27/98 12:40	1/18/99 10:10	1.3	Difference measured on 1/18. CF applied for second half of period from 12/5 to 1/18 when meter was removed for service.
1/22/99 10:30	1/31/99 10:30	0.46	Difference measured when meter reinstalled on 1/22. CF applied for half of period until next sample on 2/9.
1/31/99 11:00	2/19/99 9:30	1.03	Difference measured on 2/9. CF applied for second half of period from1/22 to 2/9 and first half of period from 2/9 to 3/1/99.
2/19/99 10:00	3/1/99 10:30	1.89	Difference measured on 3/1/99 when meter was removed for service. CF applied for second half of period from 2/9 to 3/1.
3/9/99 10:30	3/21/99 0:00	2.69	Difference measured on 3/9 when meter reinstalled. CF applied for half of period until 4/1.
3/21/99 0:30	4/20/99 9:30	0.92	Difference measured on 4/1. CF applied for second half of period from 3/9 to 4/1 and until meter removed on 4/20.

D.7 MILLER CREEK DETENTION FACILITY – MC2

Sample Summary				
Date	Sample Concentration (mg/L)	Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD (%)
12/9/98 9:45	9.32	8.88	0.44	4.7
12/14/98 11:45	8.64	8.93	-0.29	-3.3
1/5/99 9:45	9.49	8.67/8.94[(1)]	0.82/0.55[(1)]	8.6/5.8
1/22/99 9:30	9.37	9.41	-0.04	-0.4
2/1/99 10:00	9.58	9.56	0.02	0.2
2/9/99 8:00	6.26[(2)]	9.33	-3.07	--
2/18/99 9:30	9.25	8.13	1.12	12
3/3/99 13:30	11.69	9.06/8.36	2.63/3.33	22/28
3/16/99 11:30	8.67	7.04	1.63	19
3/24/99 9:00	9.47	6.19/7.67	3.28/1.80	35/19

(1) Before Maintenance/After Maintenance.

(2) Considered to be an outlier. Difference and RPD not included in statistics. Difference not included in estimation of correction factors.

The Hydrolab installed at the Miller Creek Detention Facility was out of service for maintenance from 1/15/99 9:00 to 1/22/99 9:30. The Hydrolab reinstalled on 1/22 was the unit previously installed in NW Pond 2. The Hydrolab experienced a power loss from 1/29/99 12:30 to 2/1/99 11:30.

The sample concentration measured on 2/9/99 of 6.26 mg/L was 3.07 mg/L less than the concentration of 9.33 mg/L measured with the Hydrolab. The RPD for this data pair is -49%, compared to RPDs of 12% or less for other samples collected from the time the meter was installed through 2/18. As shown in Table 14, the DO concentrations measured upstream in Miller Creek and at the Lake Reba outlet were 10.89 and 8.79 mg/L, respectively. The sample concentration measured of 2/9/99 is assumed to be inaccurate and is classified as an outlier. The DO correction factors for this station are calculated without taking this point into account.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
12/4/98 15:00	12/25/98 0:15	0	RPDs calculated based on samples collected on 12/9 and 12/14 were small and average difference was negligible. Apply CF of zero from meter installation and through half of period between12/14 and 1/5.
12/25/98 0:45	1/5/99 9:45	0.82	Difference measured on 1/5 before meter was cleaned. CF applied for second half of period between 12/14 and 1/5.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
1/5/99 10:30	1/15/99 9:00	0.55	Difference measured after meter was cleaned on 1/5. CF applied until meter removed for service on 1/15.
1/22/99 9:30	2/10/99 0:00	0	Difference measured on 1/22 and 2/1. CF applied from time meter was reinstalled through half of period between 2/1 and 2/18.
2/10/99 0:30	2/25/99 0:00	1.12	Difference measured on 2/18. CF applied for half of period between 2/18 and 3/3.
2/25/99 0:30	3/3/99 13:30	2.63	Difference measured on 3/3 before meter was cleaned. CF applied for second half of period between 2/18 and 3/3.
3/3/99 14:00	3/10/99 0:00	3.33	Difference measured on 3/3 after meter was cleaned. CF applied for half of period between 3/3 and 3/16.
3/10/99 0:30	3/20/99 12:00	1.63	Difference measured on 3/16. CF applied for second half of period between 3/3 and first half of period between 3/16 and 3/24.
3/20/99 12:30	3/24/99 9:00	3.28	Difference measured on 3/24 before meter was cleaned. CF applied for second half of period between 3/16 and 3/24.
3/24/99 9:30	4/13/99 10:30	1.80	Difference measured on 3/24 after meter was cleaned. CF applied until meter removed from service on 4/13.

Figures D-13 and D-14 present recorded and adjusted DO concentration and % saturation data for this sampling station.

AR 042820

D.8 MILLER CREEK AT WWTP – MCSTP

The DO concentration in Miller Creek is routinely measured each week by plant operations staff near the location where the Hydrolab was installed. Samples are analyzed in the plant laboratory using an Orion DO probe. Samples are collected by WWTP staff between 12:00 and 12:30. The table below presents a comparison of the Winkler DO measurements made as a part of this study, the weekly measurements made by the plant staff, and the corresponding DO concentrations recorded by the Hydrolab. All three sets of data are included in Figure D-15. On the two occasions where the collected sample and the sample analyzed by the WWTP staff were collected within a half hour of each other, the concentrations measured in the two samples were similar (max RPD = 2.2%).

The Hydrolab at this location did not record DO and temperature data from 12/27/98 16:45 until 1/5/99 12:30. During a period of high flows on 12/27 the mounting assembly for the unit was pushed up out of the channel so that once the flow decreased the unit was no longer submerged. When this condition was discovered, the mounting assembly was modified and the unit stayed submerged until the end of the study. On February 8 the batteries were changed, resulting in a missed reading at 12:00. When the Hydrolab was redeployed a drop of 0.5 mg/L was recorded in the DO concentration.

Figures D-15 and D-16 present recorded and adjusted DO concentration and % saturation data for this sampling station.

Sample Summary

Date	Sample Concentration (mg/L)	DO Concentration Measured by WWTP Staff (mg/L)	Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD (%)
12/9/98 12:30	11.94	12.1(1)	-(3)		
12/14/98 12:30	11.77		11.02	0.75	6.3
12/16/98 12:15		11.7	10.92	0.78	6.7
12/24/98 12:15		12.9	11.68	1.22	9.5
12/30/98 12:00		11.3	-(4)		
1/5/99 12:30	12.14		11.24	0.9	7.4
1/6/99 12:00		11.3	10.69	0.61	5.4
1/13/99 12:00		11.6	10.35	1.25	11
1/20/99 12:00		12.2	10.37	1.83	15
1/22/99 10:30	11.83		10.2	1.63	14
1/27/99 12:00		13.1	10.11	2.99	23
2/1/99 11:00	12.31		10.43	1.88	15
2/3/99 12:00		11.7	10.2	1.50	13
2/10/99 12:00		12.2	10.08	2.12	17
2/17/99 12:00		11.8	9.66	2.14	18
2/18/99 9:30	12.18		9.71	2.47	20
2/24/99 12:00		11.5	9.64	1.86	16
3/3/99 12:00	12.07	11.8(2)	9.84	2.10(5)	18

(1) RPD compared to sample = -1.3%
(2) RPD compared to sample = 2.2%
(3) Hydrolab not installed until 12/10
(4) DO meter out of service.
(5) Based on average of sample and WWTP-mesasured DO concentrations.

Correction Factors			
From	**To**	**Correction Factor (mg/L)**	**Determination of Correction Factor (CF)**
12/10/98 13:00	12/15/98 12:15	0.75	Difference measured on 12/14. CF applied from time meter installed through half of period from 12/14 to 12/16.
12/15/98 12:30	12/20/98 12:15	0.78	Difference measured on 12/16. CF applied for second half of period from 12/14 to 12/16 and first half of period from 12/16 to 12/24.
12/20/98 12:30	12/27/98 16:45	1.22	Difference measured on 12/24. CF applied for second half of period from 12/16 to 12/24 and until meter was pushed out of creek by high flows.
1/5/99 12:30	1/10/99 0:00	0.75	Average of differences measured on 1/5 and 1/6. CF applied from time meter returned to creek through one half of period from 1/6 to 1/13.
1/10/99 0:30	1/17/99 0:00	1.25	Difference measured on 1/13. CF applied for second half of period from 1/6 to 1/13 and first half of period from 1/13 to 1/20.
1/17/99 0:30	1/25/99 0:00	1.73	Average of differences on 1/20 and 1/22. CF applied for second half of period from 1/13 to 1/20 and first half of period from 1/22 to 1/27.
1/25/99 0:30	1/30/99 0:00	2.99	Difference measured on 1/27. CF applied for second half of period from 1/22 to 1/27 and first half of period from 1/27 to 2/1.
1/30/99 0:30	2/2/99 12:00	1.88	Difference measured on 2/1. CF applied for second half of period from 1/27 to 2/1 and first half of period from 2/1 to 2/3.
2/2/99 12:30	2/7/99 0:00	1.50	Difference measured on 2/3. CF applied for second half of period from 2/1 to 2/3 and first half of period from 2/3 to 2/10.
2/7/99 0:30	2/14/99 0:00	2.12	Difference measured on 2/10. CF applied for second half of period from 2/3 to 2/10 and first half of period from 2/10 to 2/17.
2/14/99 0:30	2/18/99 0:00	2.14	Difference measured on 2/17. CF applied for second half of period from 2/10 to 2/17 and first half of period from 2/17 to 2/18.
2/18/99 0:30	2/21/99 12:00	2.47	Difference measured on 2/18. CF applied for second half of period from 2/17 to 2/18 and first half of period from 2/18 to 2/24.
2/21/99 12:30	2/28/99 0:00	1.86	Difference measured on 2/24. CF applied for second half of period from 2/18 to 2/24 and first half of period from 2/24 to 3/3.
2/28/99 0:30	3/3/99 12:00	2.10	Difference measured on 3/3. CF applied for second half of period from 2/24 to 3/3 until meter removed from service on 3/3.

AR 042822

D.9 MILLER CREEK MOUTH AT PUGET SOUND – MCPS

Sample Summary				
Date	Sample Concentration (mg/L)	Hydrolab Concentration (mg/L)	Difference (mg/L)	RPD (%)
12/9/98 12:45	11.79	11.21	0.58	4.9
12/14/98 13:00	11.75	10.12/11.26(1)	1.63/0.49(1)	14/4.2
1/5/99 12:30	11.91	8.37/10.98	3.54/0.93	30/7.8
1/22/99 14:00	11.59	8.76/10.45	2.83/1.14	24
2/1/99 11:30	12.18	10.07/11.24	2.11/0.94	17/7.7
2/18/99 10:00	11.88	1.27	10.61	_(3)
2/19/99 9:00		5.63/11.18(1),(2)		
3/3/99 12:30	12.23	3.75	8.48	_(3)

(1) Before Maintenance/After Maintenance.

(2) Sample was collected on 2/18, but maintenance was not performed until 2/19/99 9:00. Once the meter was cleaned, recorded concentrations increased as shown.

(3) RPDs not calculated due to severity of meter fouling.

The Hydrolab installed at the downstream station in Miller Creek was susceptible to fouling due to the sediment in the creek at this location. Every time the meter was maintained in the field, sediment and sand had to be removed from the meter housing. The minimum concentration measured in the samples collected over the course of the study at this location was 11.59 mg/L. When the meter was cleaned, recorded concentration s returned to within 1 mg/L of the concentration measured in the corresponding sample.

The lower stream velocities observed at this location compared to the installation at the Miller Creek WWTP just 0.3 miles upstream allowed sediment and grit to accumulate inside the membrane housing to the point where DO concentrations that were recorded were not reliable after about February 8. Before this date the recorded DO concentrations were still observed to fluctuate sharply but the recorded concentrations also recovered more quickly, presumably due to more frequent high creek flows that would flush out the DO probe housing. DO concentration readings recorded after February 8 at this location were rejected as unreliable and are not used in the analyses of DO trends in the Miller Creek drainage in the report.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
12/4/98 11:00	12/12/98 0:00	0.58	Difference measured on 12/9. CF applied from time meter installed through half of period from 12/9 to 12/14.
12/12/98 0:15	12/14/98 13:00	1.63	Difference measured on 12/14. CF applied for second half of period from 12/9 to 12/14 until meter was cleaned.
12/14/98 13:15	12/25/98 13:00	0.49	Difference measured on 12/14 after meter was cleaned. CF applied for first half of period from 12/14 to 1/5.

Correction Factors			
From	To	Correction Factor (mg/L)	Determination of Correction Factor (CF)
12/25/98 13:30	1/5/99 12:30	3.54	Difference measured on 1/5 before meter was cleaned. CF applied for second half of period between 12/14 and 1/5.
1/5/99 13:00	1/14/99 0:00	0.93	Difference measured on 1/5 after meter was cleaned. CF applied for first half of period between 1/5 and 1/22.
1/14/99 0:30	1/22/99 14:00	2.83	Difference measured on 1/22 before meter was cleaned. CF applied for second half of period between 1/5 and 1/22.
1/22/99 14:30	1/27/99 12:00	1.14	Difference measured on 1/22 after meter was cleaned. CF applied for first half of period between 1/22 and 2/1.
1/27/99 12:30	2/1/99 11:30	2.11	Difference measured on 2/1 before meter was cleaned. CF applied for second half of period between 1/22 and 2/1.
2/1/99 12:00	2/8/99 14:00	0.94	Difference measured on 2/1 after meter was cleaned. CF applied for period after 2/1 until data determined to be unreliable on 2/8.
2/8/99 14:30	3/3/99 12:30	Data Rejected	See discussion above. Meter continually fouled with sediment and sand, making data unreliable.

Figures D-17 and D-18 present recorded and adjusted DO concentration and % saturation data for this sampling station.

AR 042824

Figure D-1
Comparison of Uncorrected and Corrected DO
Des Moines Creek NW Pond 2

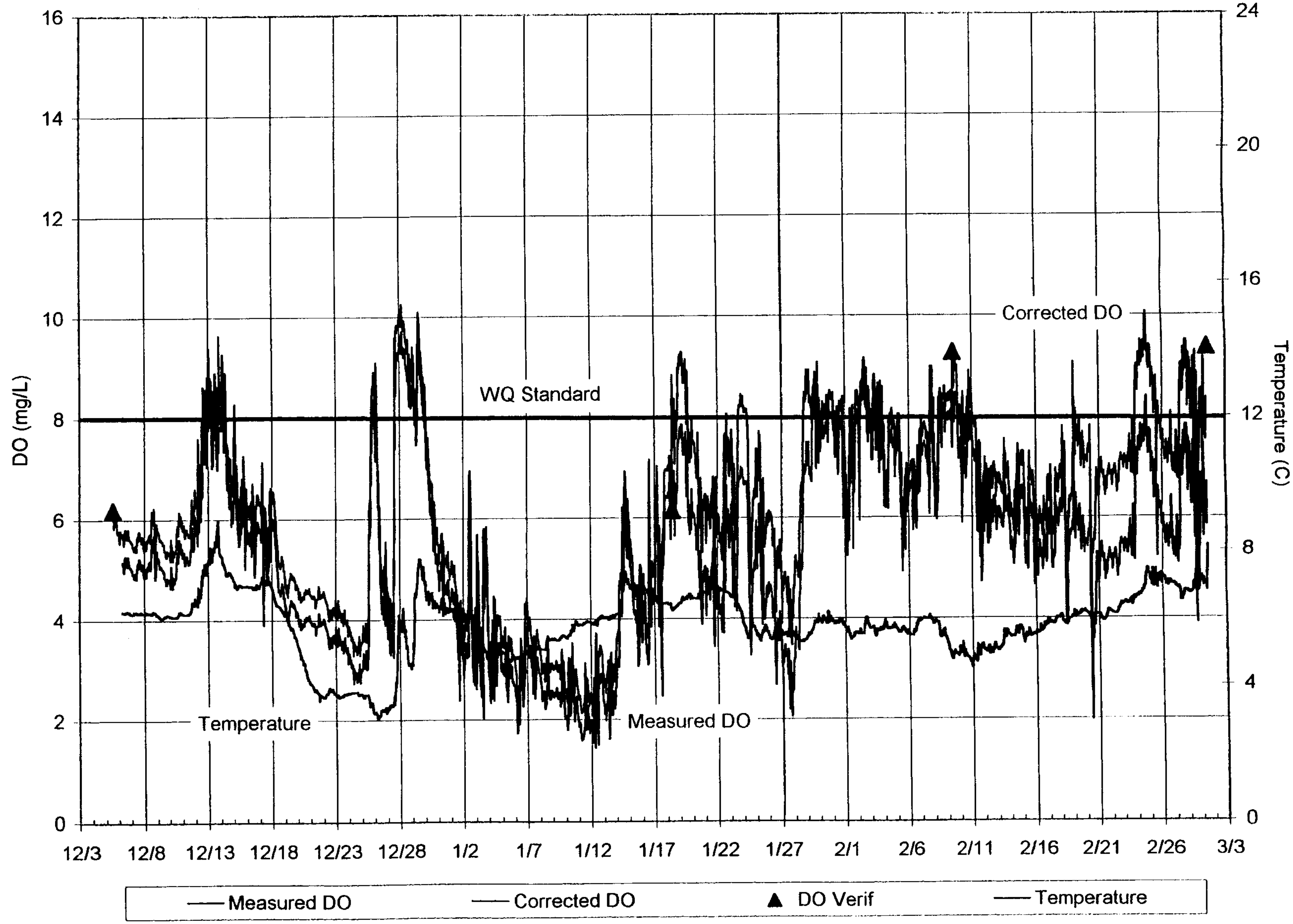


Figure D-2
Comparison of Uncorrected and Corrected DO Percent Saturation
Des Moines Creek NW Pond 2

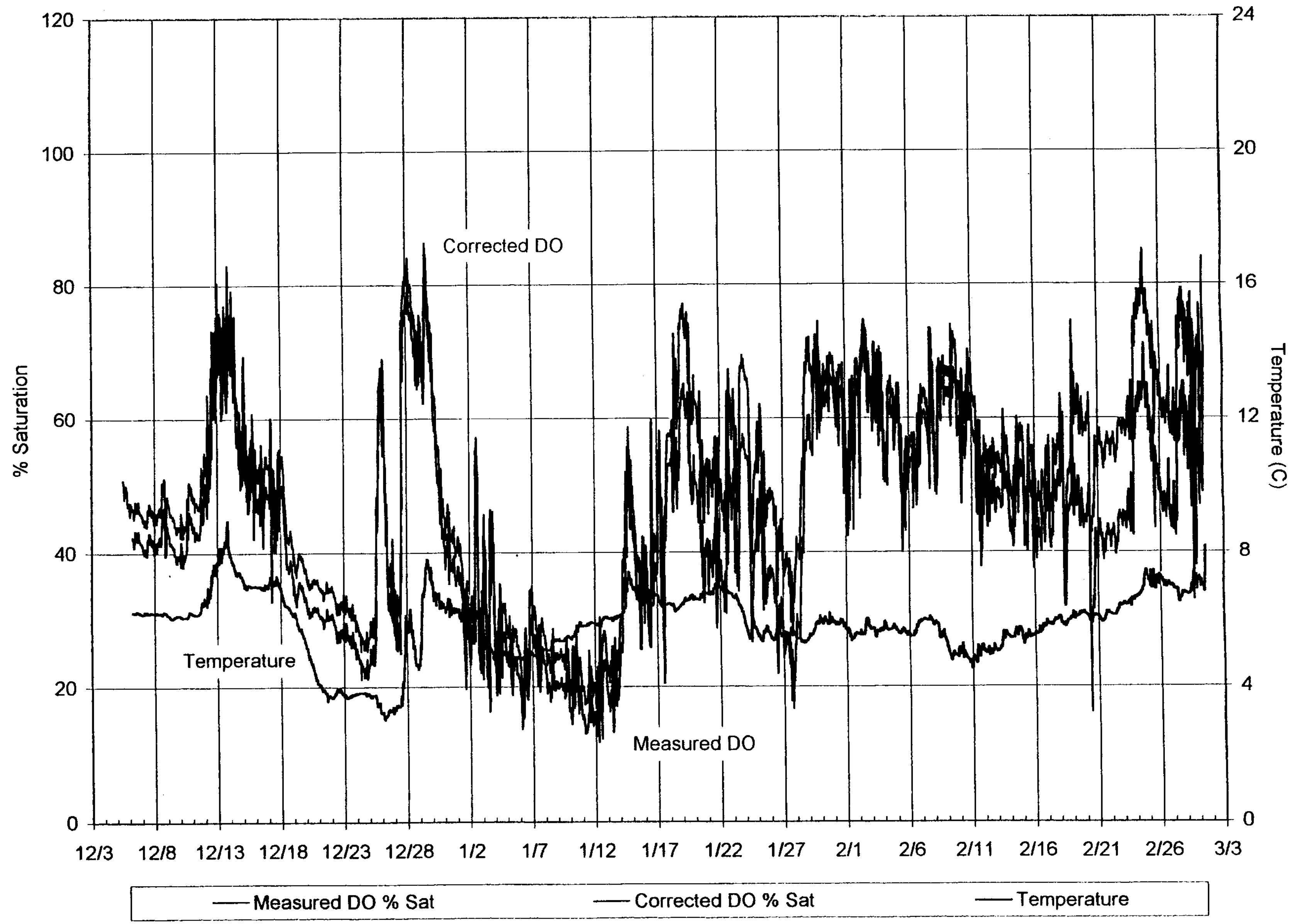


Figure D-3
Comparison of Uncorrected and Corrected DO
Des Moines Creek NW Pond 3

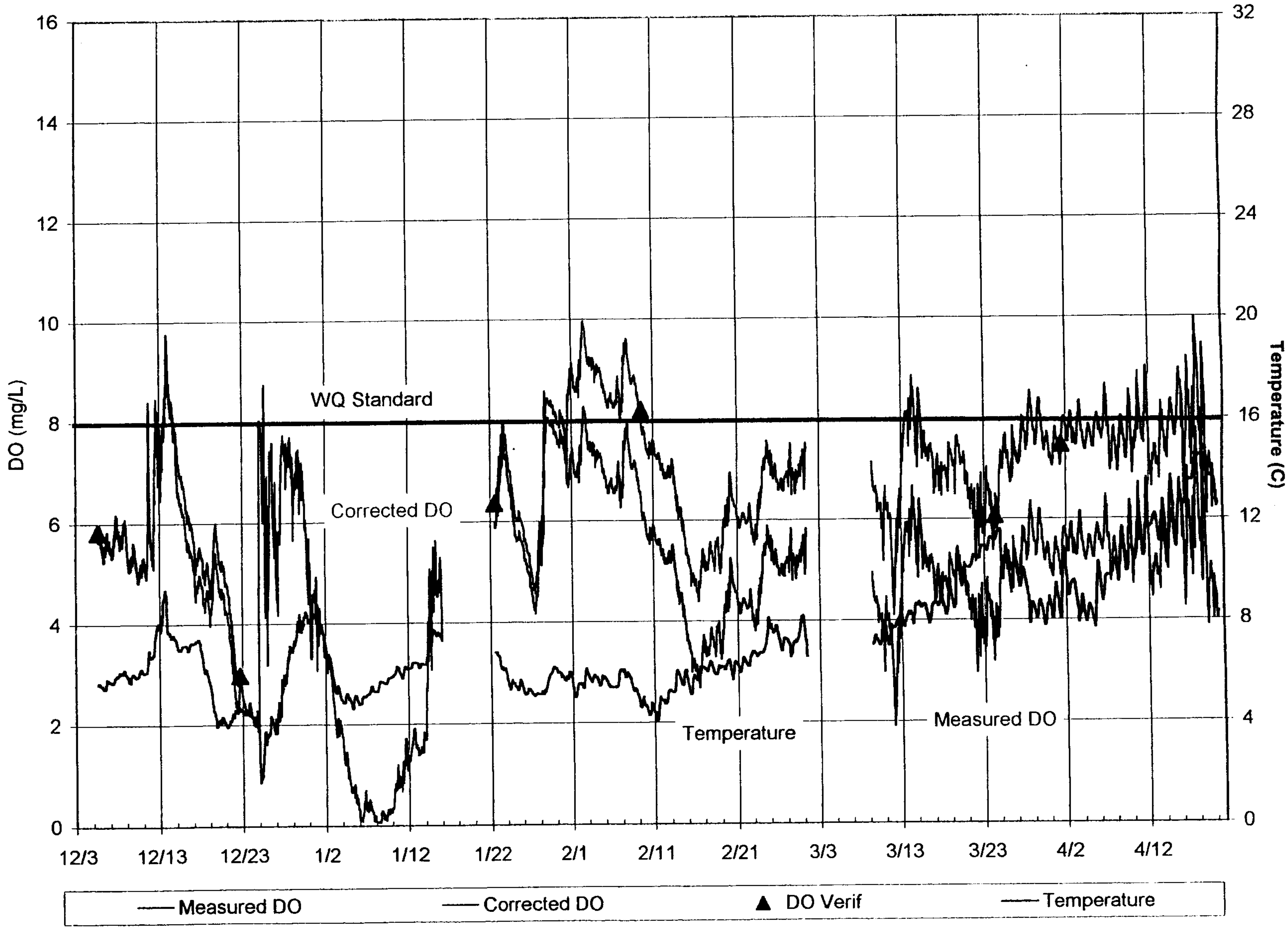
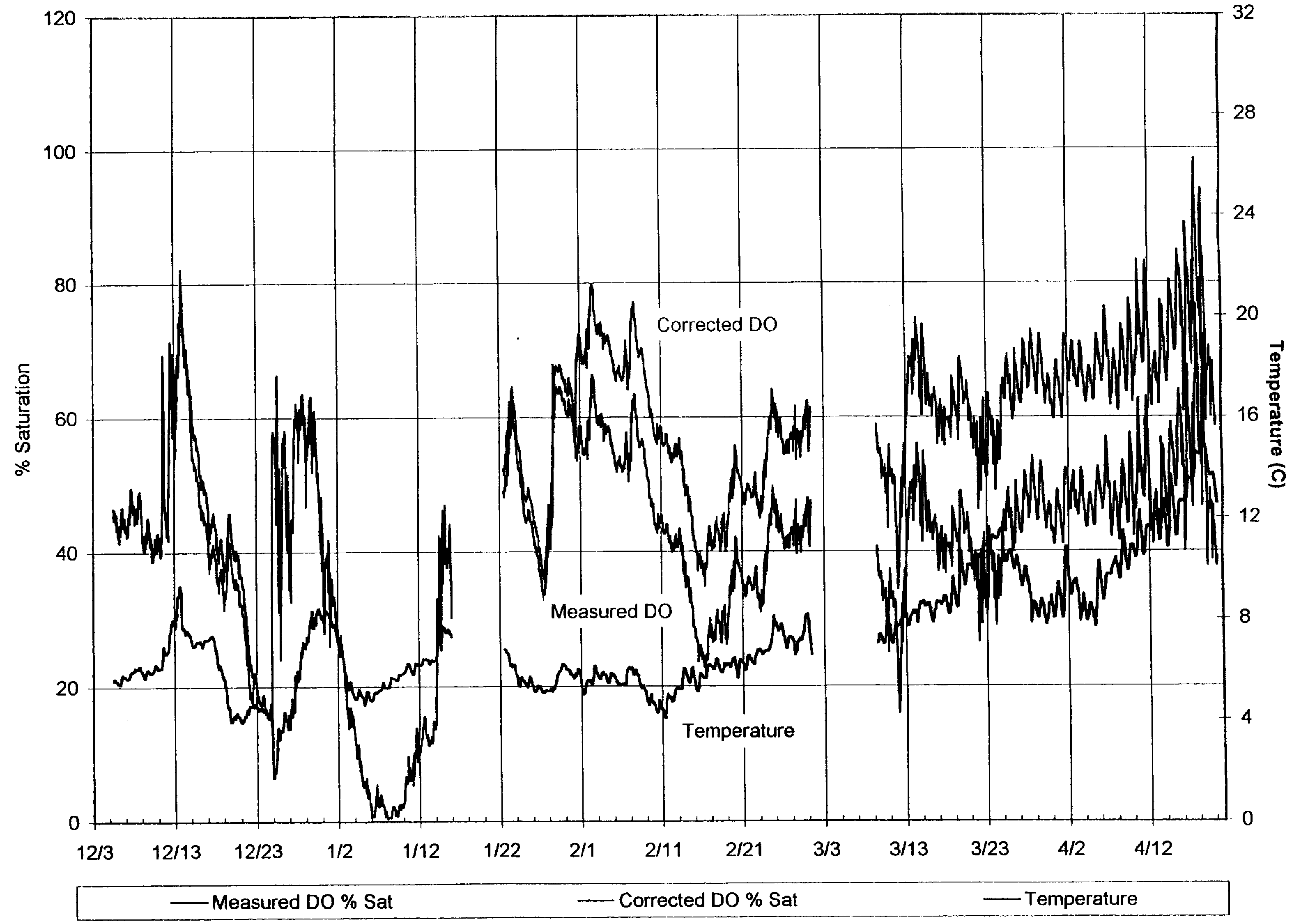


Figure D-4
Comparison of Uncorrected and Corrected DO Percent Saturation
Des Moines Creek NW Pond 3



AR 042828

Figure D-5
Comparison of Uncorrected and Corrected DO
Des Moines Creek Golf Course Weir

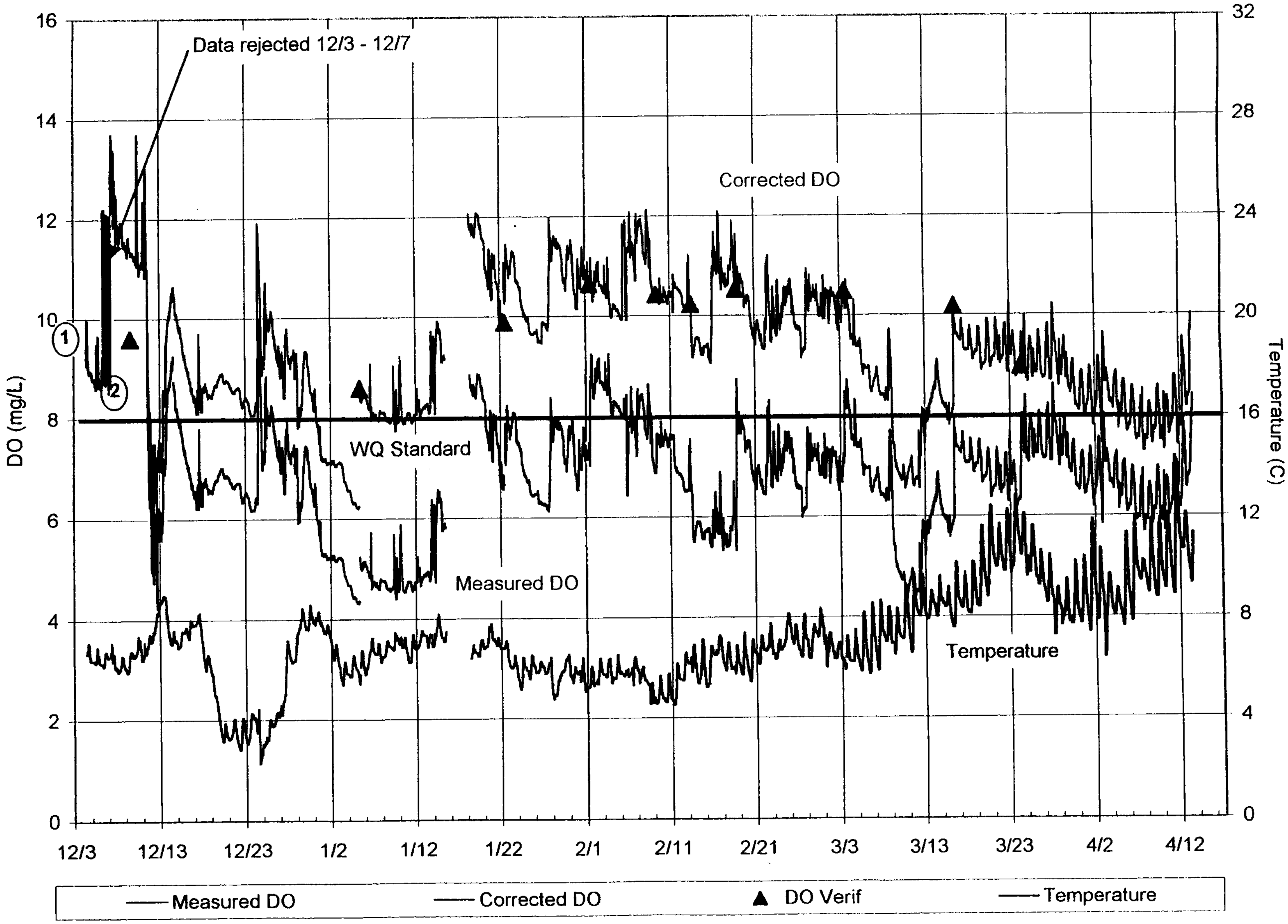
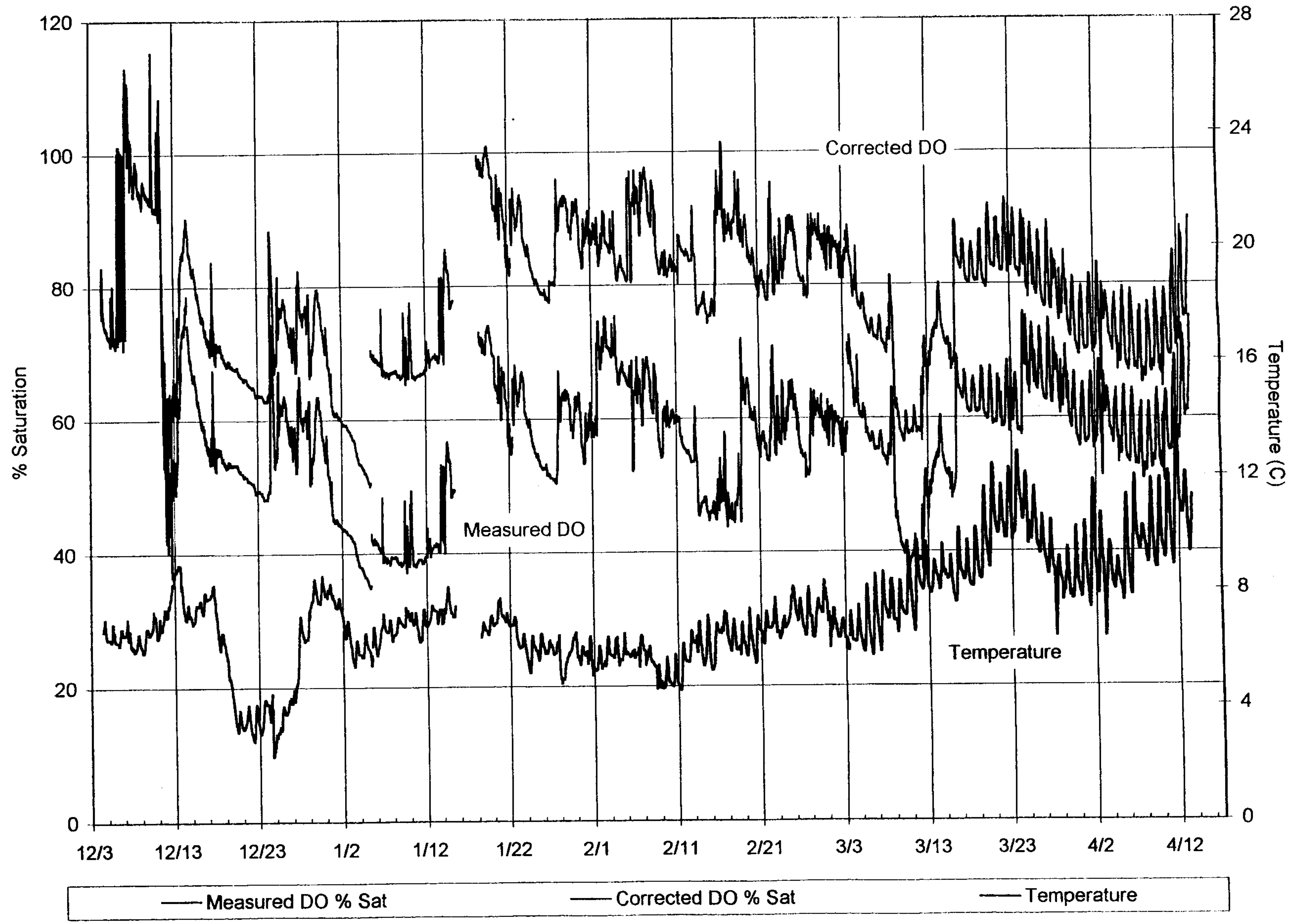


Figure D-6
Comparison of Uncorrected and Corrected DO Percent Saturation
Des Moines Creek Golf Course Weir



AR 042830

Figure D-7
Comparison of Uncorrected and Corrected DO
Des Moines WWTP

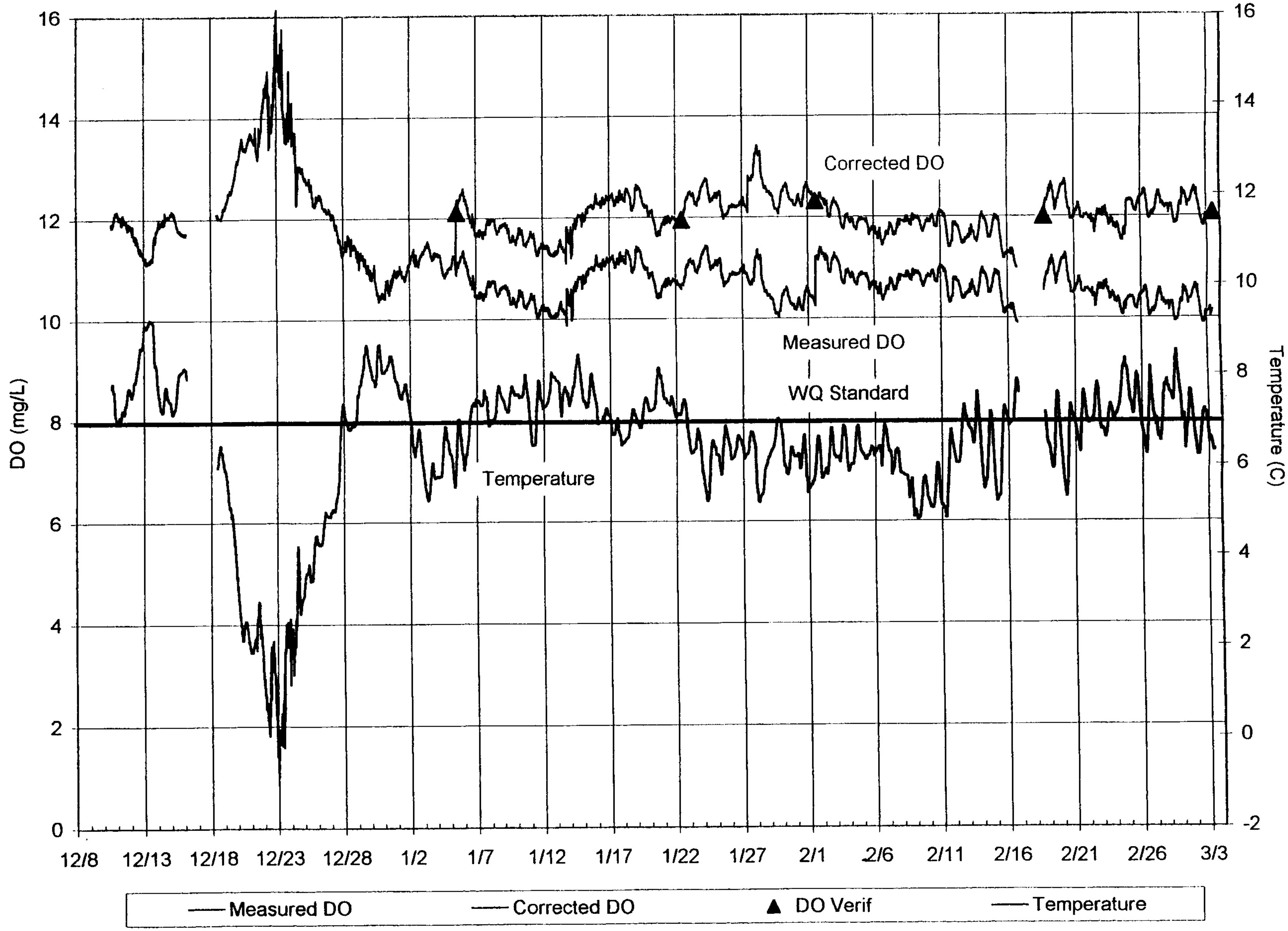
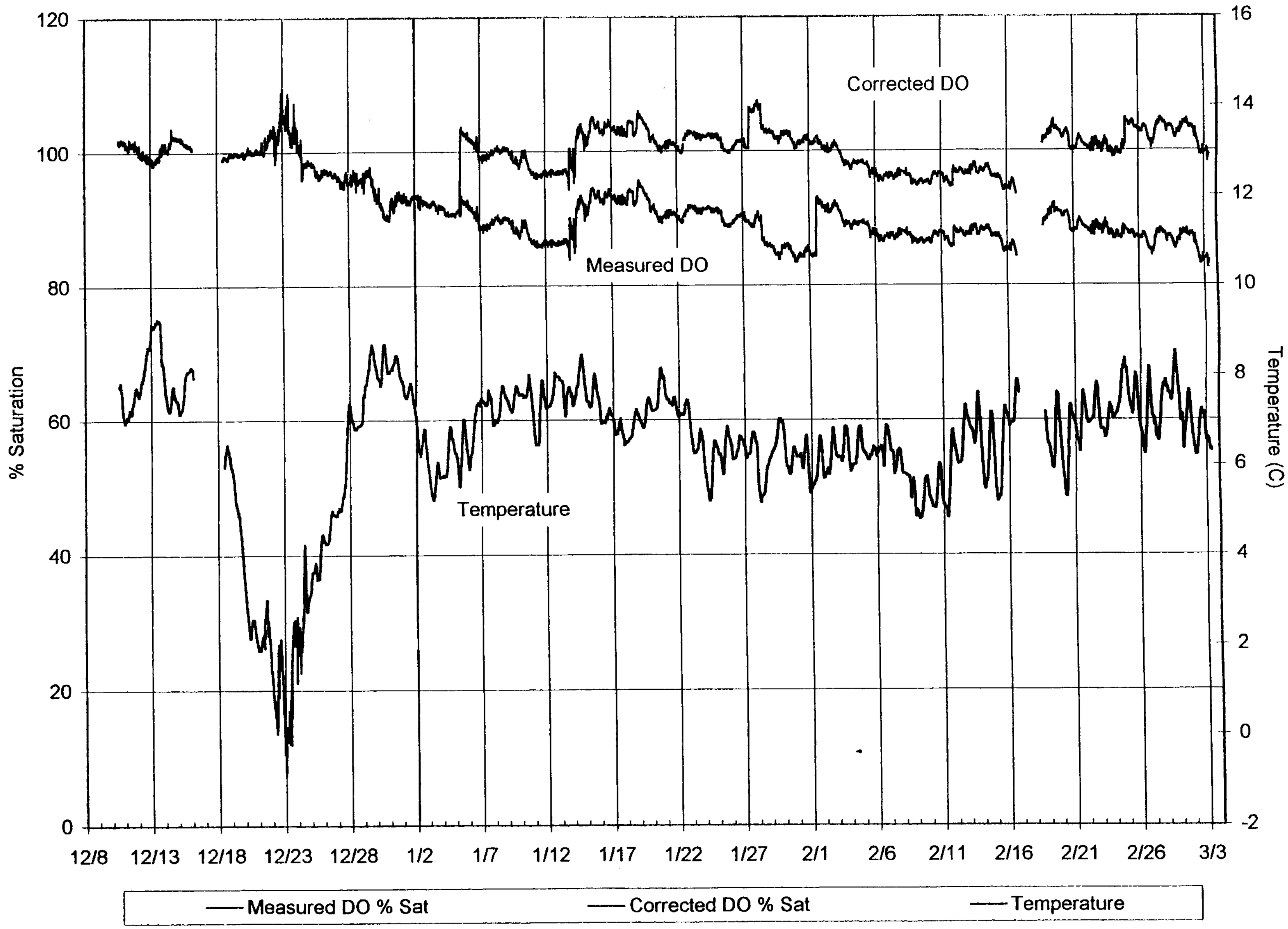


Figure D-8
Comparison of Uncorrected and Corrected DO Percent Saturation
Des Moines WWTP



AR 042832

Figure D-9
Comparison of Uncorrected and Corrected DO
Des Moines Creek Mouth Monitoring Data

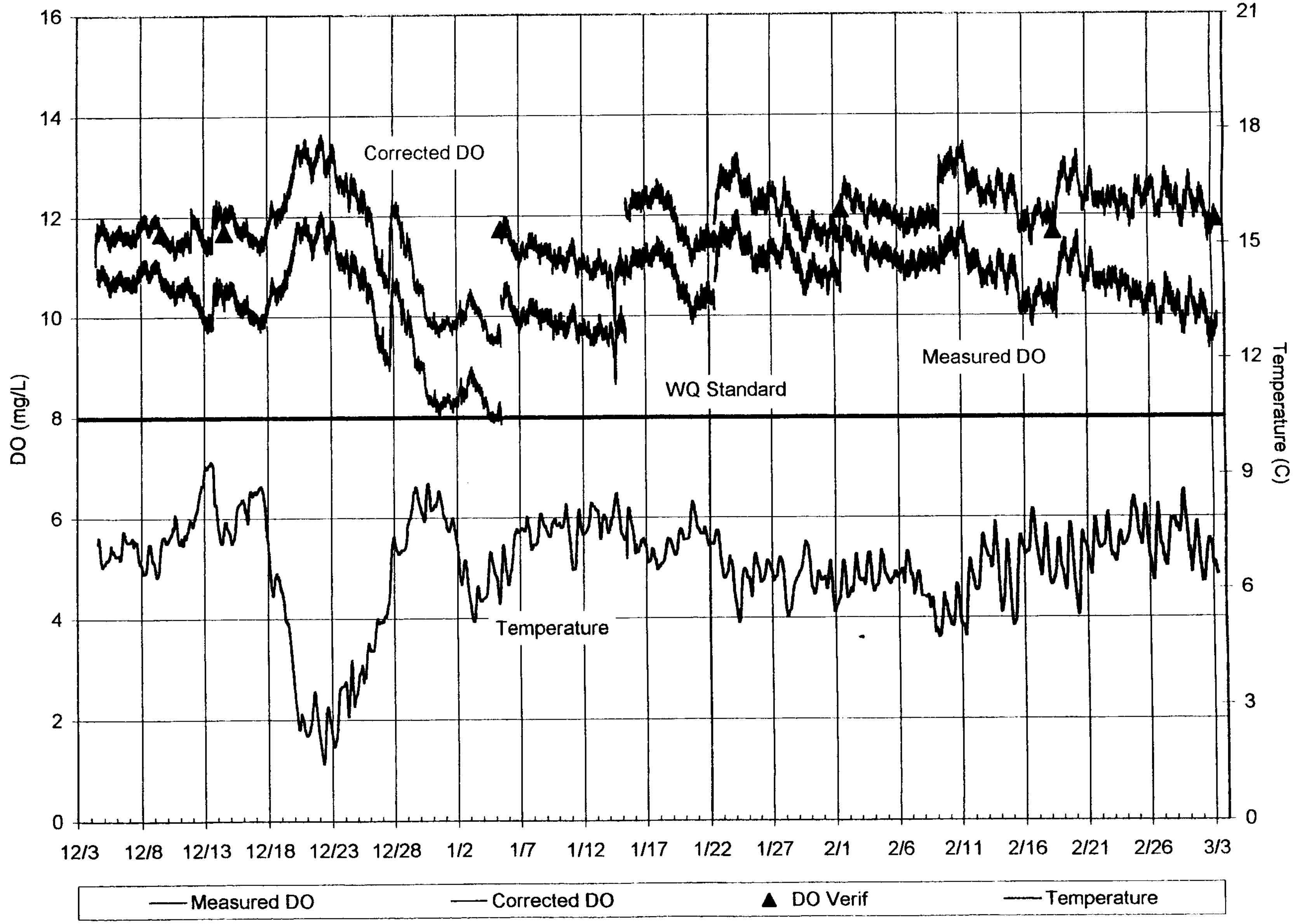


Figure D-10
Comparison of Uncorrected and Corrected DO Percent Saturation
Des Moines Creek Mouth Monitoring Data

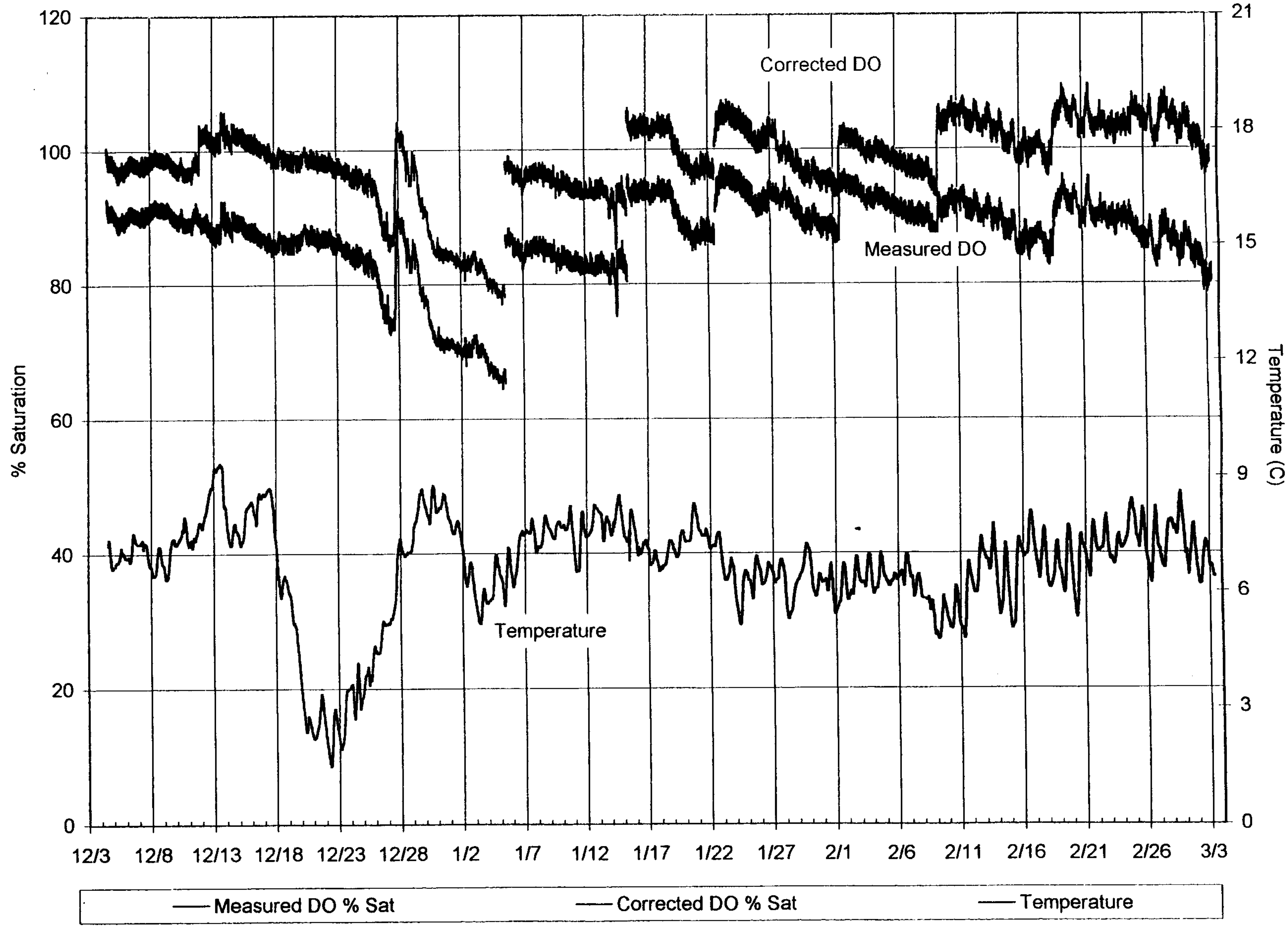


Figure D-11
Comparison of Uncorrected and Corrected DO
Miller Creek Lake Reba

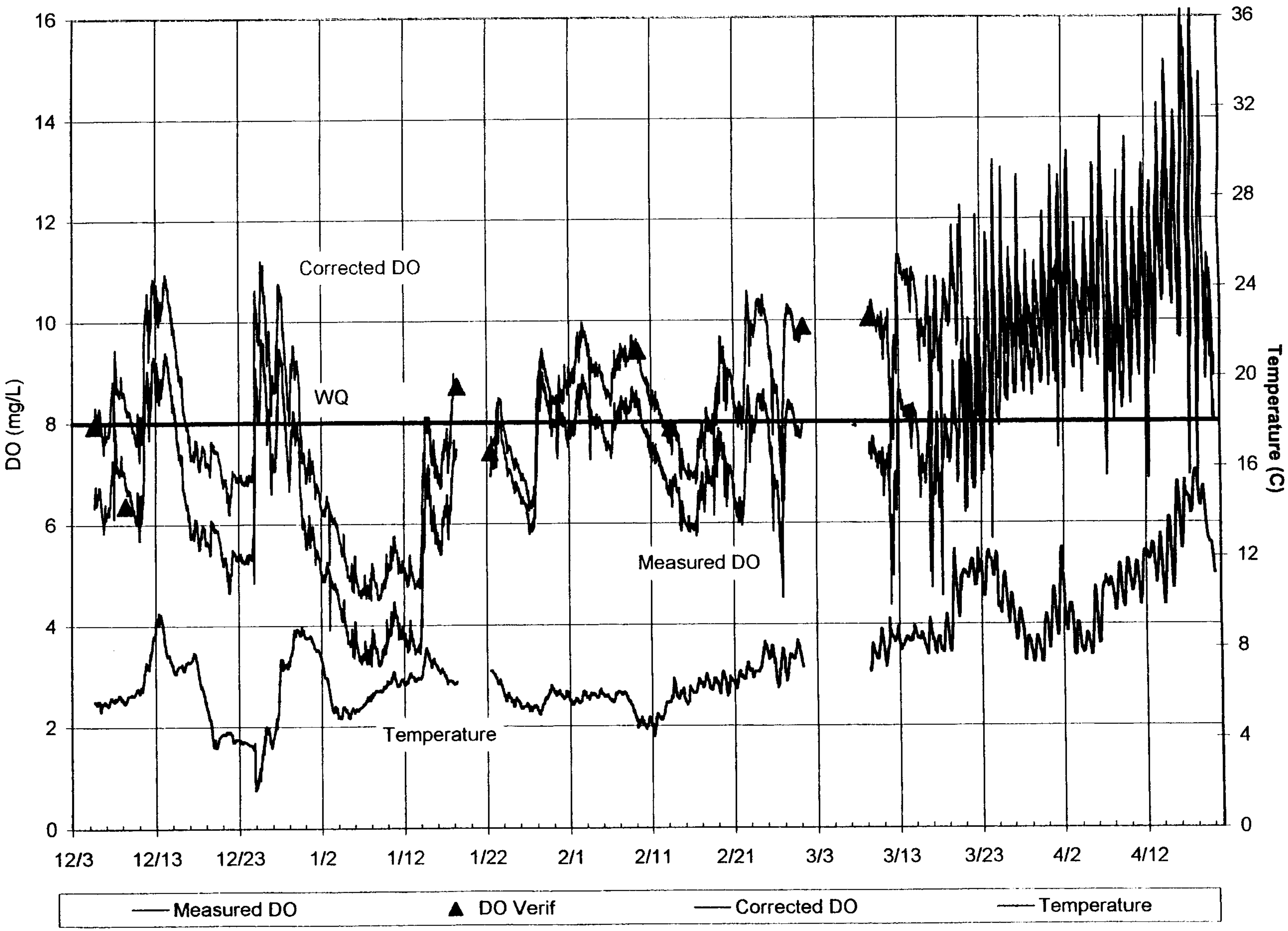
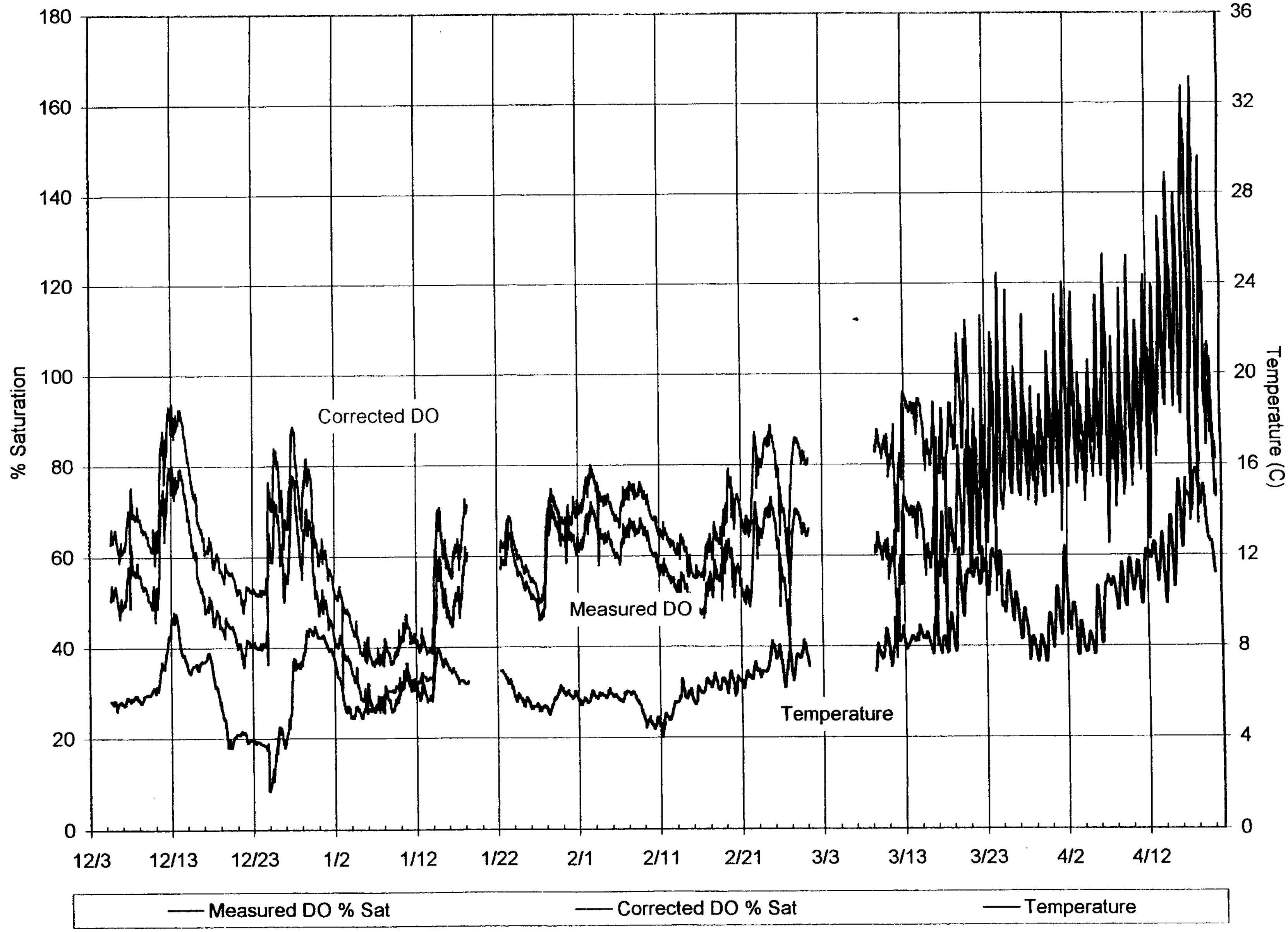


Figure D-12
Comparison of Uncorrected and Corrected DO Percent Saturation
Miller Creek Lake Reba



AR 042836

Figure D-13
Comparison of Uncorrected and Corrected DO
Miller Creek Detention Facility

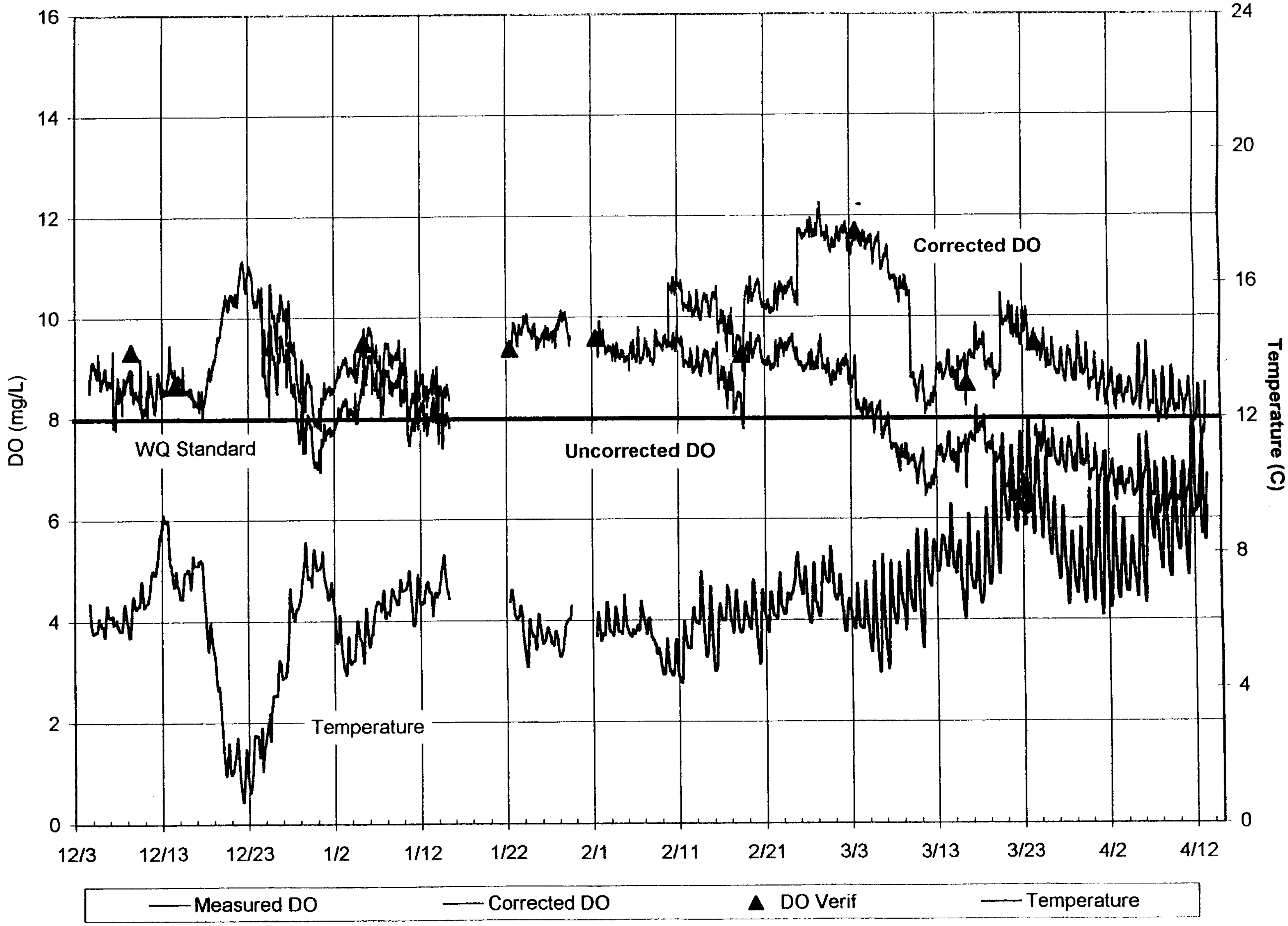


Figure D-14
Comparison of Uncorrected and Corrected DO Percent Saturation
Miller Creek Detention Facility

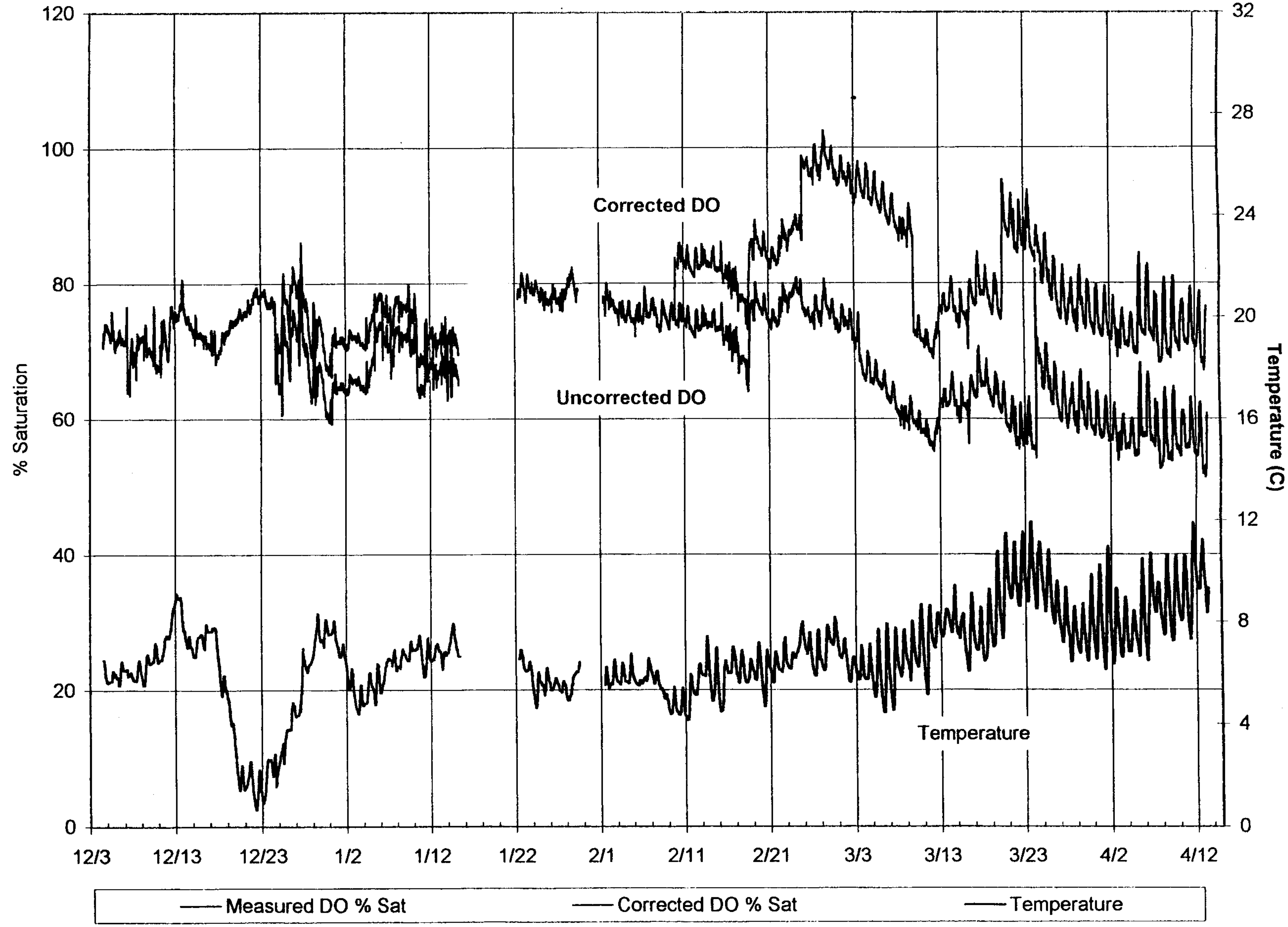


Figure D-15
Comparison of Uncorrected and Corrected DO
Miller Creek SW Surburban Sewer District WWTP

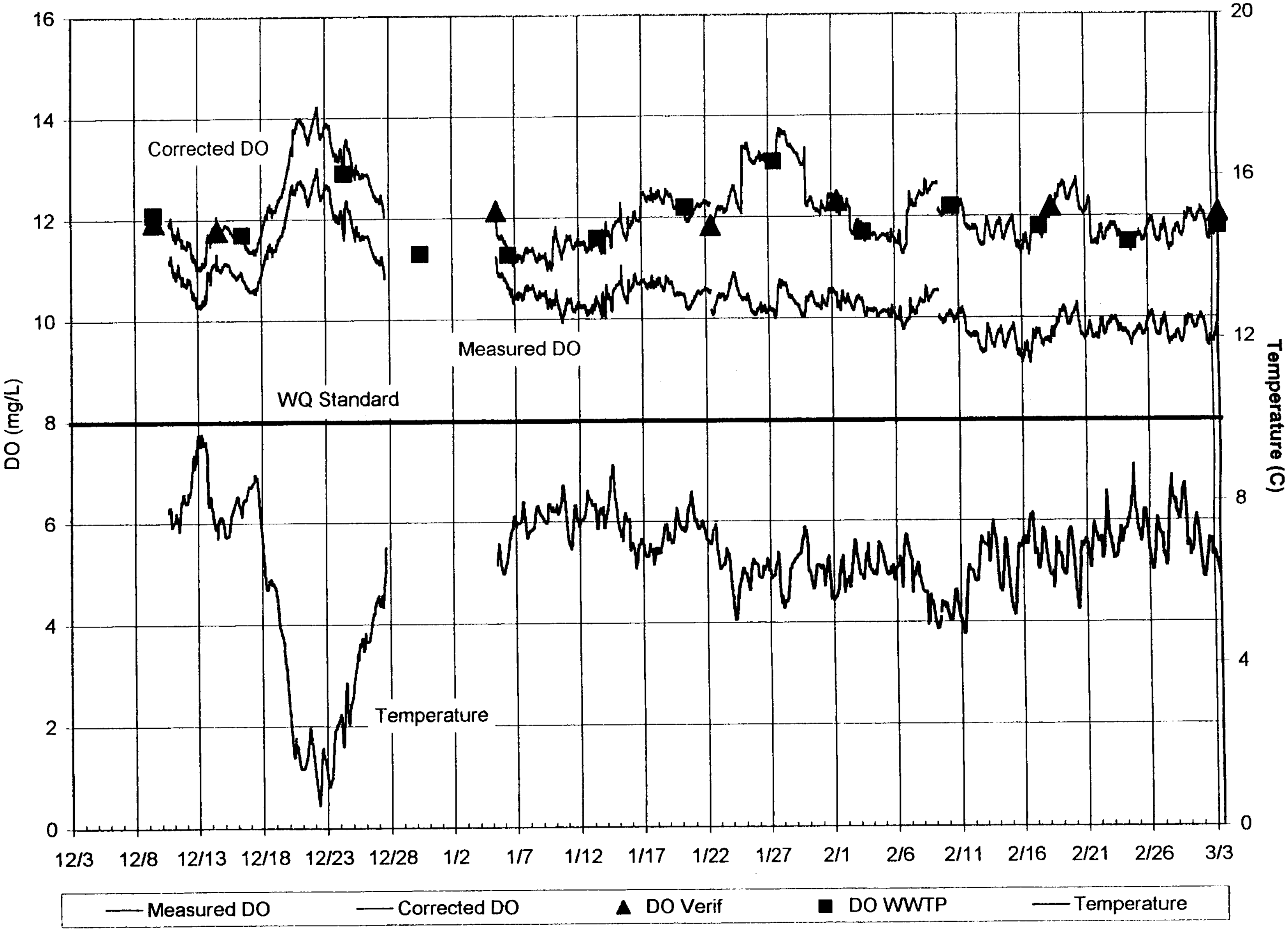
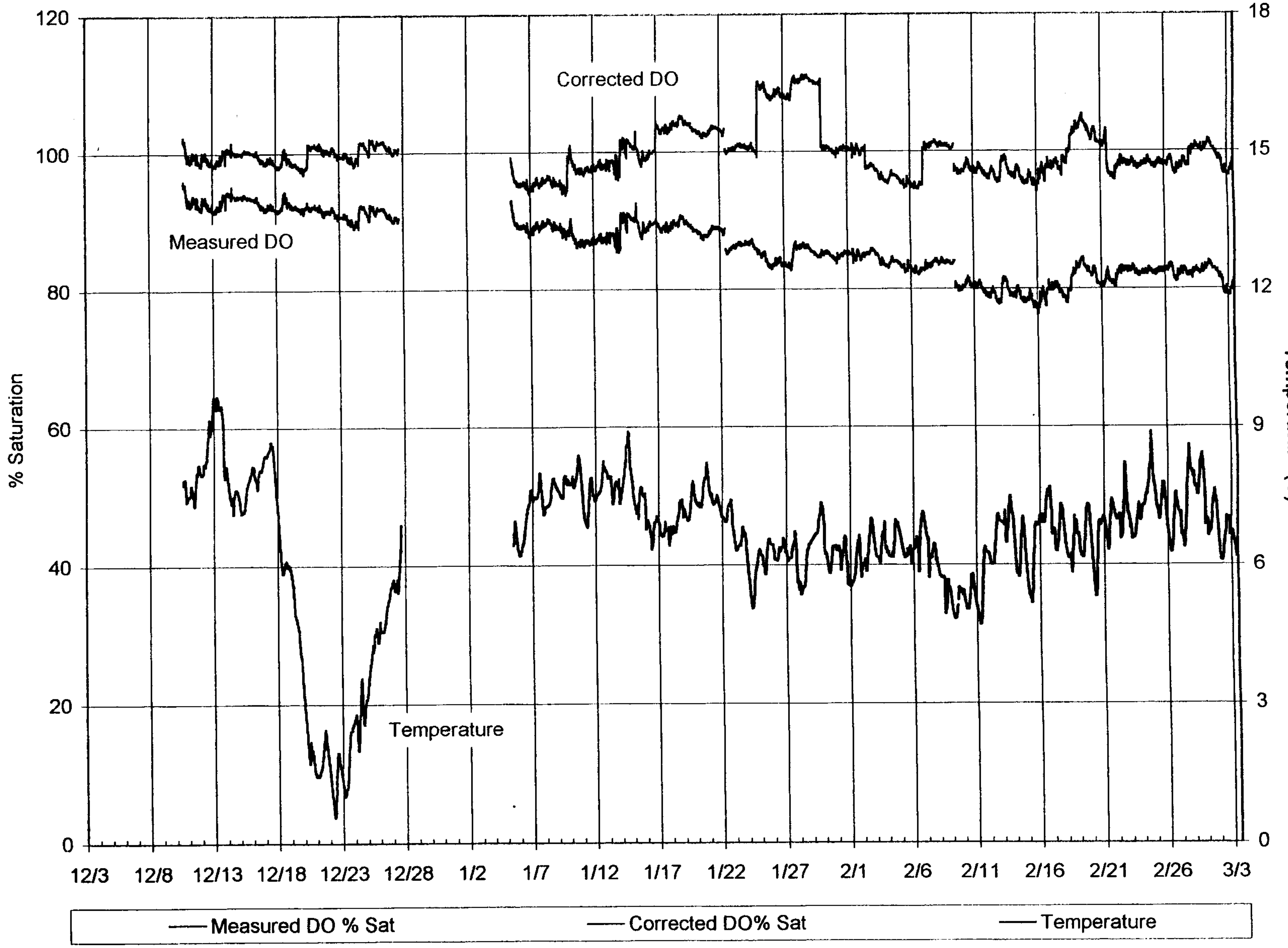


Figure D-16
Comparison of Uncorrected and Corrected DO Percent Saturation
Miller Creek WWTP



AR 042840

Figure D-17
Comparison of Uncorrected and Corrected DO
Miller Creek Mouth

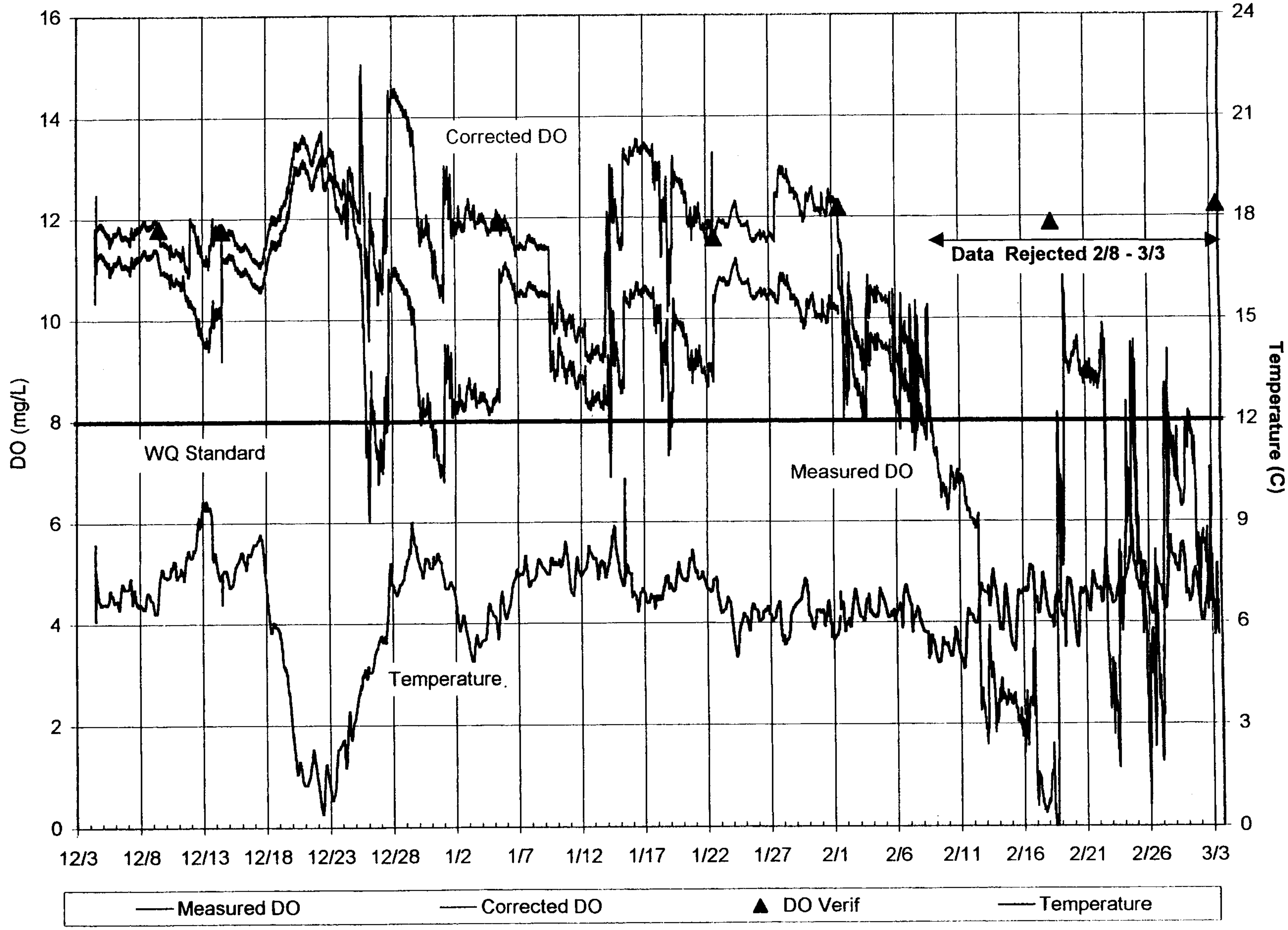
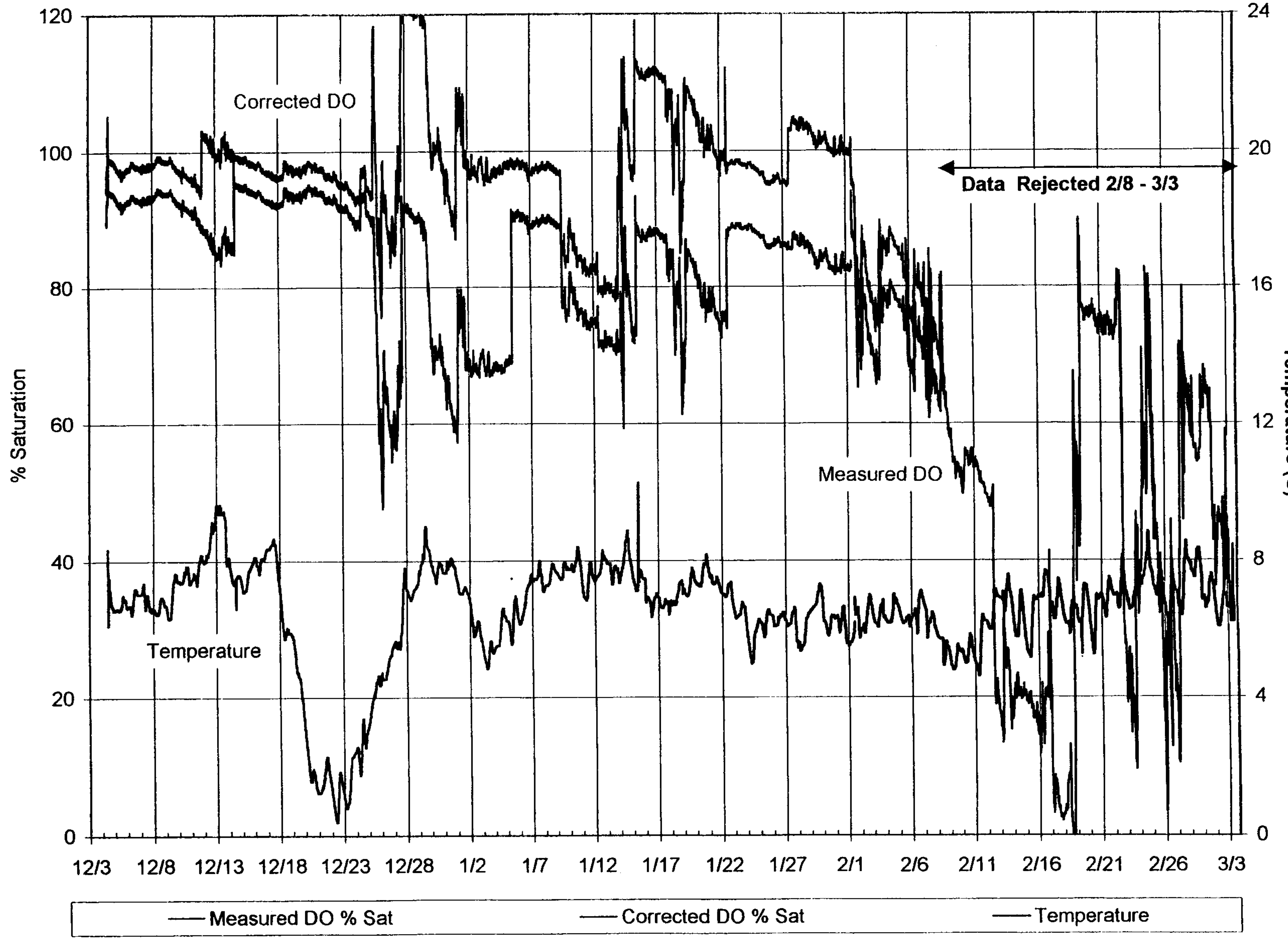


Figure D-18
Comparison of Uncorrected and Corrected DO Percent Saturation
Miller Creek Mouth

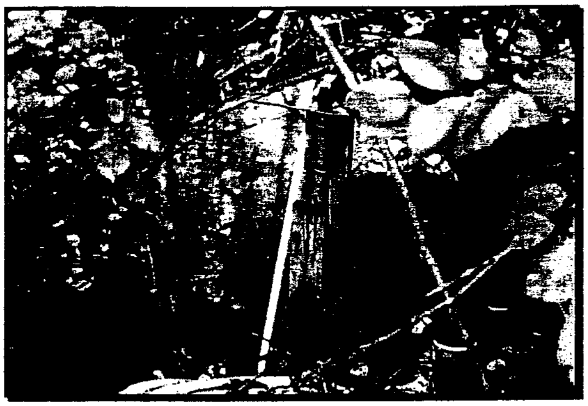


COSMOPOLITAN ENGINEERING GROUP

Appendix E

Photos

Civil, Environmental, and Recreational Consulting



SDN1 outlet freeflow through marsh then into Lake Reba – abandoned KC Crestgage[1]

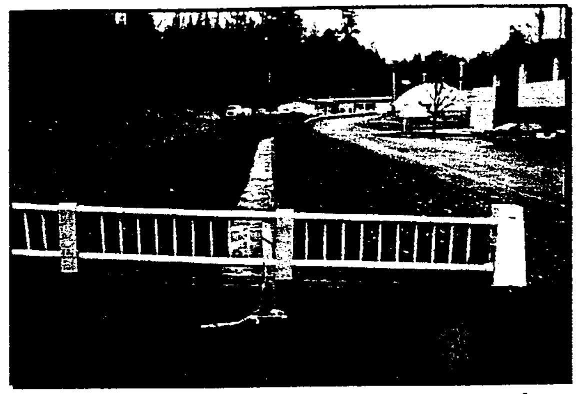
NEPL on SR 518 (landmark is fir tree, 24" CMP) [1]

SDN1/518 – outlet on SR 518[1]

SDN1 – SR 518 off-ramp, runoff before combining in SDN1 (not sampled)[1]

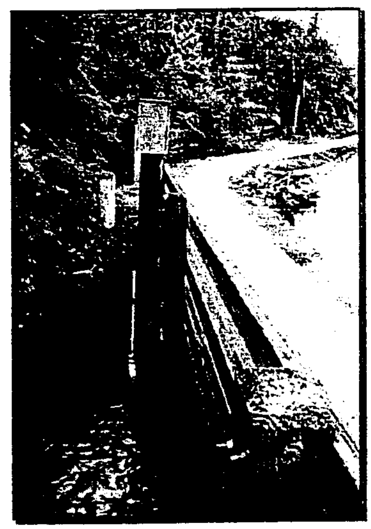
Lake Reba outlet and POS gauge (there is a float in background for PMX Treatment System)[1]

Miller Creek Detention Facility[2]



Miller Creek SW Suburban Treatment Plant[2]
Installation – Looking Upstream

Miller Creek Detention Facility[2] *–*
Looking Upstream



Miller Creek at Mouth Installation[2]

Miller Creek SW Suburban
Treatment Plant[2] *Installation*

Miller Creek at Mouth Installation[2] *–*
Looking Upstream

NW Pond Inlet – Des Moines Creek[1]

Outlet of NW Pond Cell 3[2]

NW Pond Cell 2 as seen from west[2] *(empty field adjacent to parking area for industrial)*

East Basin Tyee Pond Outlet[1] *looking South at Des Moines Creek*

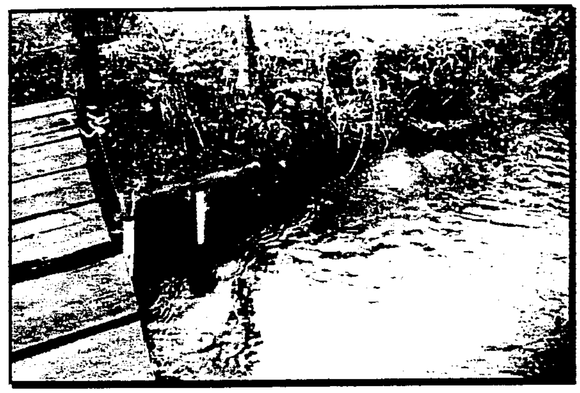
Golf Course keyed gate, NW Pond Cell 3 (Cell 2 is beyond cattails and trees)

Golf Course Weir[2] *(KC gauge)*

AR 042846

Midway WWTP on Des Moines Creek[2] Installation

Midway WWTP on Des Moines Creek[2] Installation – Looking Downstream



Des Moines Creek at Mouth Installation[2]

Des Moines Creek at Mouth Installation[2] – Looking Downstream

---

[1] Tributary Grab Sample Station
[2] Continuous DO and Temp Monitoring

AR 042847

COSMOPOLITAN ENGINEERING GROUP

Appendix F

NW Pond 3 and Lake Reba Conductivity and DO, 3/9/99 to 4/20/99

NW Pond 3 and Lake Reba Conductivity, DO, and Temperature Profiles, 1/22/99

Civil, Environmental, and Recreational Consulting

Figure F-1
Lake Reba and NW Pond 3 Conductivity Profiles

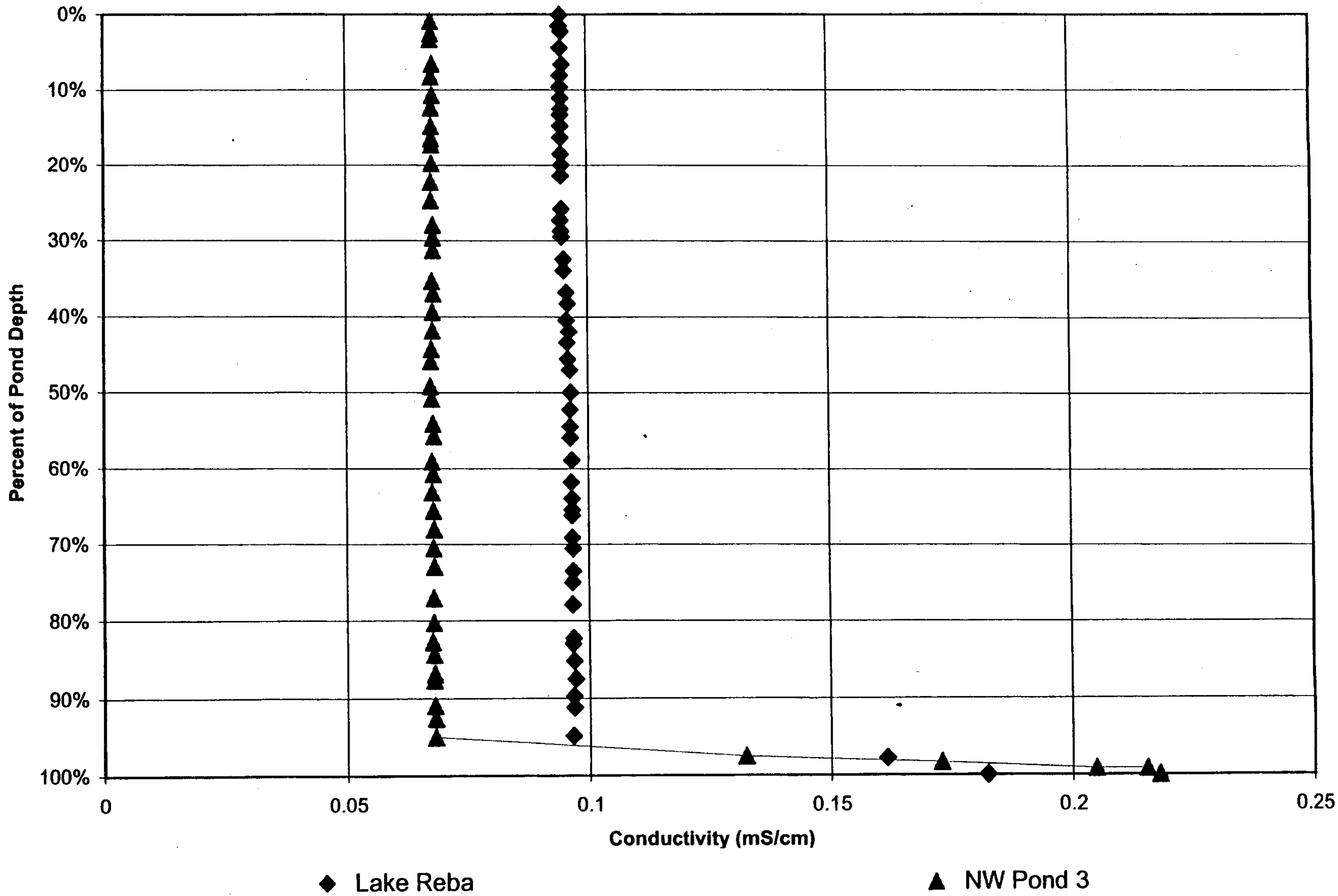
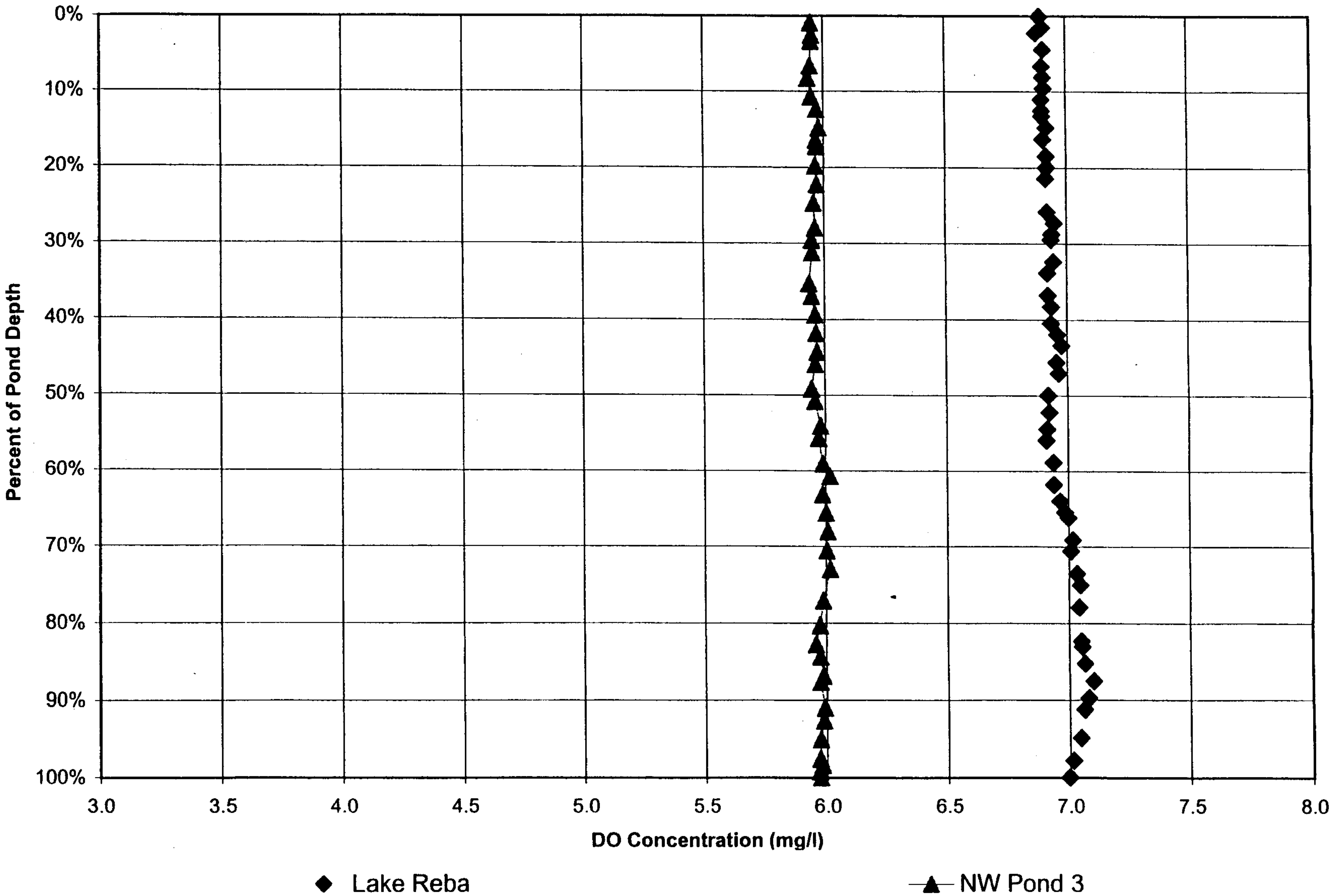


Figure F-2
Lake Reba and NW Pond 3 DO Concentration Profiles



AR 042850

Figure F-3
Lake Reba and NW Pond 3 Temperature Profiles

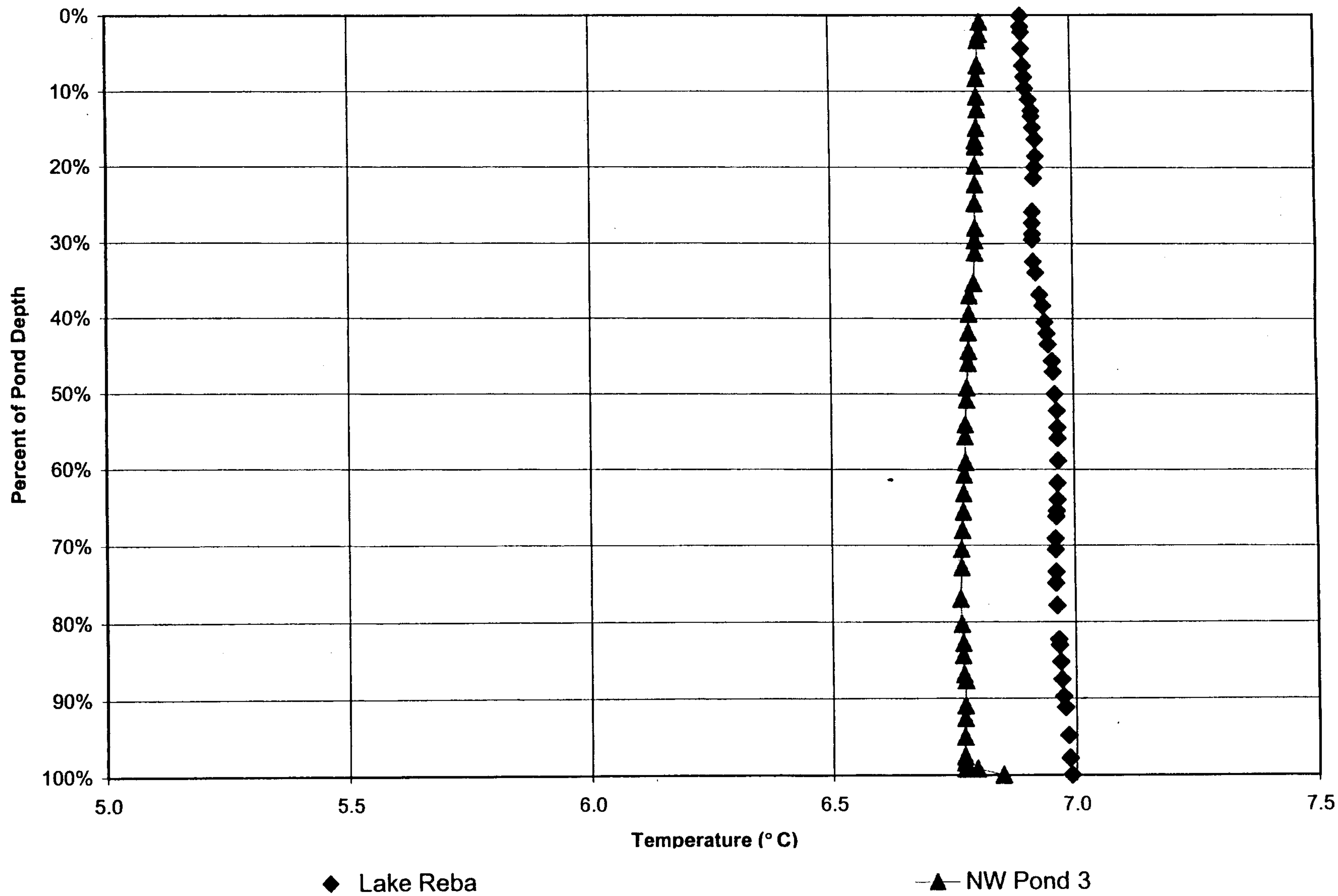
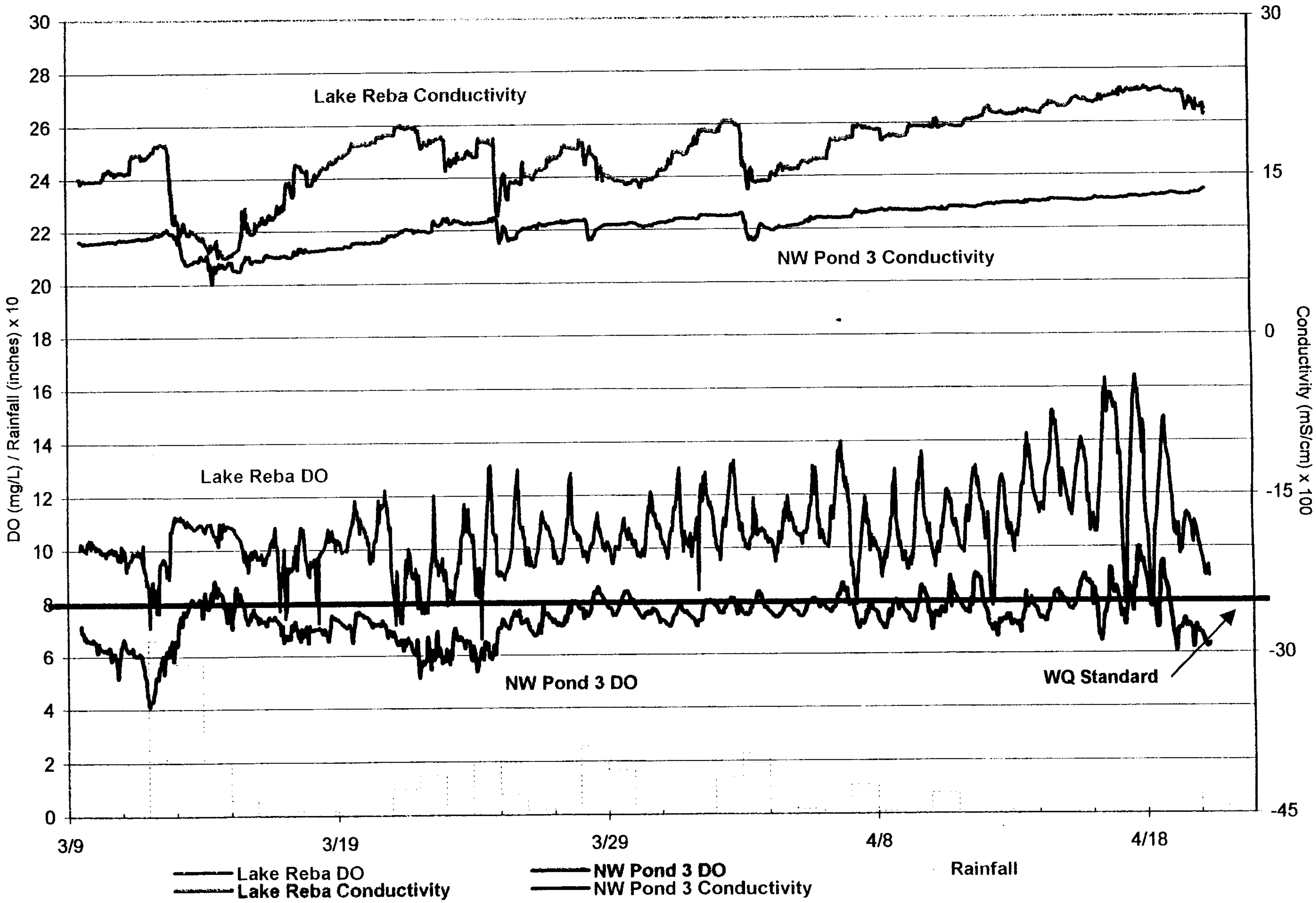


Figure F-4
Lake Reba and NW Pond 3 - DO and Conductivity
March - April



AR 042852

Appendix G

General DO Concentration Observations

COSMOPOLITAN ENGINEERING GROUP

Civil, Environmental, and Recreational Consulting

Printed on Recycled Paper

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

APPENDIX G: GENERAL DO CONCENTRATION OBSERVATIONS

G.1 DISSOLVED OXYGEN IN CREEKS FOLLOWING DEICING EVENTS

Note: References to characteristics of the figures followed by a number, i.e. (①), are identified on the corresponding figure.

G.1.1 December Deicing Event – Miller Creek

The DO data for each of the sampling stations for this event are presented in Figure 7. A sharp increase in DO was recorded in Lake Reba beginning at 22:10 on 12/24 (①). Because the hydrographs for outfalls SDN3 and SDN4 indicate runoff started at approximately 10:00 on 12/24, it is likely that this aerated runoff caused the sharp DO increase in Lake Reba.

Figure 7 shows that at approximately 15:00, prior to the discharge of runoff from outfalls SDN3 and SDN4 through Lake Reba, a noticeable depression in DO occurred at the three stations downstream from Lake Reba (②). This depression occurred before deicing chemicals were discharged from Lake Reba, as discussed in Section 5.2. It is apparent that the airfield deicing and subsequent runoff were not responsible for the DO depression.

The DO readings at the Miller Creek mouth station became very erratic at about midday on 12/25 (③). This is attributed to sediment fouling the Hydrolab DO meter (Appendix D). If the wide fluctuations and downward trends in DO had been accurate, similar fluctuations should have also been recorded at the Miller Creek WWTP station, which is just 0.3 miles upstream. From the start of the study through 12/25, the concentrations at the mouth and the WWTP were very similar in terms of magnitude and trend (Figures 5 and 7).

High flows at the WWTP station pushed the Hydrolab mounting hardware out of the flow on 12/27. Data from the WWTP station after this time are not shown on the graph. The sharp increase in DO concentration at the Miller Creek mouth at 17:30 on 12/27 (④) is **not** due to a change in the correction factor. The relatively smooth trend in concentration at the mouth after this point suggests that the fouling of the meter cleared at about the same time that the instrument was forced out of the creek at the WWTP. Therefore, data recorded at the Miller Creek mouth from 12/25 to 12/27 are considered to be unreliable.

The slow decrease in DO concentration recorded near the Miller Creek WWTP station from 12/25 through 12/27 (⑤) was due to an increase in water temperature. The DO concentration remained slightly greater than 100% saturation during this entire period (Appendix D, Figure D-16) and remained more than 4 mg/L above the water quality standard of 8.0 mg/L.

There was no depression in DO at any of the Miller Creek sampling stations that could be attributed to deicing chemicals after runoff from the December deicing event. Conversely stormwater with high DO concentrations resulted in increased DO concentrations in Lake Reba shortly after runoff began. During the period that deicing chemicals were present in the system, DO concentration at all stations exceeded the water quality standard of 8.0 mg/L.

G.1.2 December Deicing Event – Des Moines Creek

The DO data previously presented in Figure 8 are presented again in Figure G-1, except this time the flow recorded at the NW Pond 3 outlet is superimposed rather than the daily rainfall. The figure shows that the increase in DO concentration in NW Pond 3 and at the Golf Course weir are related to the increasing discharge from the NW Ponds. Rising discharge rates at the onset of precipitation always increased previously depressed DO concentrations in the NW Ponds.

The slow decline in DO concentration at the Des Moines WWTP and Des Moines Creek mouth stations in the days following the peak concentrations (①) is primarily due to the increase in water temperature in the creek (i.e., 100% saturated DO concentration decreased from 13.7 mg/L to 12.1 mg/L, while the water temperature increased from 2.3°C to 7°C). The sampler at the Des Moines Creek Mouth station experienced an apparent downward drift in the instrument readings beginning on 12/23 before runoff related to the deicing event (Appendix D, Figure D-10).

The DO concentration at the Golf Course weir increased sharply beginning at 12:15 on 12/24 (②). This spike corresponds to the first increase in flow out of the pond. The rapid increase in DO in NW Pond 3 at 0:00 on 12/25 (③) is due to the aerated runoff making its way through the ponds and reaching the Seabird sampler, which was located near the pond outlet. Prior to that time, the DO in NW Pond 3 was approximately 2.0 mg/L. The low DO in the NW Ponds prior to the event runoff was due, in part, to the ice cover that formed during the prior cold weather and also to the extended period of dry weather that occurred prior to the deicing event (0.13 inches in 10 days from 12/14 to 12/23).

The fluctuations in DO concentration in NW Pond 2 and NW Pond 3 closely correspond in time with fluctuations in flow rate through the pond (and therefore rainfall). Increases in flow on December 25, 27, and 29 were followed by increases in DO concentrations in the ponds (④,⑤,⑥).

As with Miller Creek, there was no depression in DO in Des Moines Creek during the December deicing event that could be attributed to the impacts of runway deicing chemicals. DO concentrations in the NW Ponds were below the water quality standard of 8.0 mg/L prior to the deicing runoff event, but increased sharply when the runoff began. DO concentrations exceeded the water quality standard at the three downstream stations before, during, and after the deicing event.

G.1.3 February Deicing Event - Miller Creek

DO concentrations measured at the Miller Creek sampling stations during the second deicing event are presented in Figure 10. Runway deicing occurred on February 9 and was followed by four days of dry weather before the first measurable rain, and the first runoff, on February 13.

The downward trend in DO concentration in Lake Reba beginning on February 9 (①) is similar to what was observed on other occasions when there was little or no precipitation (and consequently no stormwater runoff) for a period of several days (see Figure 4 for a plot of DO data for Lake Reba for the entire study period). A slight depression of approximately 0.8 mg/L in DO concentration was measured in Lake Reba for 8 hours on February 14 (②), following the runoff, but changes in DO concentration at the Miller Creek Detention Facility and Miller Creek WWTP stations during this period were less than 0.5 mg/L. The DO concentration at the Miller Creek WWTP station exceeded the water quality standard by 3-4 mg/L throughout this period.

The sharp increase in DO shown for the Miller Creek Detention Facility at 0:00 on February 10 (③) was due to an increase in the correction factor applied to the recorded data. The 0.5 mg/L drop in DO recorded on 2/9 at the Miller Creek WWTP during the deicing period (④) is an artifact caused by the Hydrolab being removed and redeployed to charge the batteries.

As described in Appendix D, Section D.9, the Hydrolab at the Miller Creek mouth sampling station was subject to persistent and continual fouling of the DO meter housing with grit and sediment after about February 8. Consequently, DO data are not reliable for this station for the February deicing event and are not plotted on Figure 10.

There was no change in DO concentration in Miller Creek following the February deicing event that can be attributed to the effect of deicing chemicals. In Lake Reba, DO decreased from 9 mg/L to 7.7 mg/L between the time of the deicing chemical application and the first storm four days later. As discussed in Section 5.1.2, this trend was similar to that observed during other dry weather periods.

G.1.4 February Deicing Event – Des Moines Creek

DO concentrations measured at the Des Moines Creek sampling stations during the February deicing event are presented in Figure 11. This figure shows that the DO concentrations in NW Pond 3 followed a slow downward trend similar to Lake Reba during the 7-day period from 2/9 to 2/16. However, the DO concentrations measured at the Des Moines WWTP and mouth stations both exceeded water quality standards by 3 to 4 mg/L.

DO at the Golf Course weir also exceeded the water quality standard at all times. The graph of DO concentration for the Golf Course weir station shows a 1.0 mg/L increase in DO over a period of 2.5 hours beginning at 4:30 on 2/13, followed by a drop in DO from 11.2 mg/L at 7:00 to 9.2 mg/L at 17:00 (still 1.2 mg/L above the water quality standard)(①). This period

AR 042858

corresponds closely to the time when flows over the weir began to increase, according to King County flow rate data recorded at the weir[1].

The following observations suggest that factors other than BOD_5 exertion by the deicing chemicals were responsible for the drop in the DO concentration at the weir:

1. The DO concentration dropped relatively quickly but there was no corresponding drop over the same period in either the ponds upstream of the weir or at the downstream stations. If this drop in DO was due to BOD_5 being exerted, a similar drop at the other sites would be expected to occur as well.

2. Once the DO concentration reached a minimum (17:00 2/13) it remained nearly constant for more than two days. The DO membrane was completely covered with silt when the meter was serviced five days after the drop in DO concentration was recorded, suggesting the drop in measured DO was likely due to fouling of the meter. Once the meter was serviced, an immediate increase of 3.5 mg/L was recorded.

DO concentrations in the NW Ponds fell gradually after the deicing chemicals were applied, and were below the water quality standard of 8.0 mg/L. However, this trend is similar to that observed during other dry weather periods when DO decreased and conductivity increased (see Section 5.1.7).

Sharp increases in DO concentration shown for NW Pond 2 on February 9 (②), the Golf Course weir on February 11 (③) and February 16(④), and the Des Moines Creek mouth on 2/9 (⑤) are due to changes in the correction factors applied to the recorded data.

Compared to the December 1998 deicing event, the February deicing event was much smaller in terms of the amount of deicing chemical applied. No appreciable change in DO in Des Moines Creek could be attributed to the discharge of BOD_5 from the stormwater outfalls following the February deicing event.

[1] At 5:00 on February 13, the flow rate measured at the weir was 3.2 cfs, and by 7:15, the flow had increased to 13 cfs. This was the peak flow measured for the period from February 9 to February 16.

G.2 INSTREAM DISSOLVED OXYGEN PROFILES

The effect of a wastewater discharge on a creek can be assessed using a plot of DO concentration versus distance from the point of discharge. Figures G-2 through G-6 show how DO concentrations varied spatially in the creek systems. If a BOD-related DO sag was being exerted, DO concentrations during periods of runoff following a deicing event would be lower than those measured at background conditions. The data plotted in these figures are tabulated in Tables G-1 and G-2, along with the corresponding DO saturation data.

G.2.1 December Deicing Event – Des Moines Creek

Figure G-2 presents the DO profile for the Des Moines Creek stations monitored during the December deicing event. Spatial profiles for four different points in time are presented: (1) background conditions on December 9; (2) pre-runoff conditions on December 21; (3) initial runoff conditions on December 24; and (4) post-initial runoff conditions on December 25.

Figure G-2 shows that the three stations downstream from the NW Ponds had concentrations greater than the water quality standard of 8.0 mg/L during each of the four plotted conditions. The low DO from NW Pond 3 was reaerated quickly in Des Moines Creek, as shown by the rapid recovery at the Golf Course weir. No downstream DO sag occurred during the deicing event. Conversely, low DO from NW Pond 3 was replenished rapidly, to above water quality standards. The lowest DO concentrations measured at the Des Moines WWTP and Des Moines Creek Mouth stations were measured during the background condition.

At the NW Ponds and the Golf Course weir DO concentration and saturation level were lower during the pre-runoff and initial runoff periods than during background conditions. However, these conditions occurred before deicing chemicals passed through the Ponds and were discharged to the creek (as indicated by conductivity data discussed in Section 5.2.1).

Because DO concentrations and saturation levels decreased and were less than the water quality standard during the pre-runoff conditions, it is clear that factors other than BOD_5 exerted by the deicing chemicals caused the deficit in the NW Ponds. Low DO concentrations occurred in the NW Ponds during several other periods of little or no rainfall (see Figure 4, January 2-12, for example).

Table G-1 DO Profiles; December Deicing Event and January 6-14

DES MOINES CREEK												
	Concentration[3] (mg/L)						% Saturation					
Condition	Northwest Pond Inlet	NW Pond 2	NW Pond 3	Golf Course Weir	Des Moines WWTP	Des Moines Mouth	Northwest Pond Inlet	NW Pond 2	NW Pond 3	Golf Course Weir	Des Moines WWTP	Des Moines Mouth
Background, 12/9 14:00[1]	10.9(G)	5.4	5.2	9.6(G)	12.0(G)	11.7(G)	90	44	42	80	N/A[4]	99
Pre-Initial Runoff, 12/21 12:00	11.7(G)	4.4	3.7	8.6	13.4	12.9	91	34	33	66	100	97
Initial Runoff, 12/24 13:30	11.7(G)	3.5	2.0	9.6	13.7	12.5	89	27	15	74	102	97
Post-Initial Runoff, 12/25 10:30	12.2(G)	3.6	7.1	10.3	12.7	12.5	81	28	52	79	98	97
1/6 12:00 (similar to pre-initial runoff)[1,5]	N/A[2]	3.6	0.3	8.3	12.1	11.3	N/A	29	2.2	69	101	95
1/14 0:00 (similar to initial runoff)[1,6]	N/A[2]	3.2	1.7	8.5	11.6	10.8	N/A	26	14	71	98	91

MILLER CREEK								
	Concentration[3] (mg/L)				% Saturation			
Condition	Lake Reba	Miller Creek Detention Facility	Miller Creek WWTP	Miller Creek Mouth	Lake Reba	Miller Creek Detention Facility	Miller Creek WWTP	Miller Creek Mouth
Background, 12/9 9:30 – 12:30[1]	8.2	9.3(G)	11.9(G)	11.8(G)	66	77	N/A[4]	99
Pre-Initial Runoff, 12/21 10:00	6.9	10.3	13.8	13.4	53	76	101	97
Initial Runoff, 12/24 13:30	6.9	10.3	12.9	12.2	52	77	99	93
Post-Initial Runoff, 12/25 9:30	9.8	9.4	12.9	12.0	72	71	101	93

(1) No deicing chemicals applied prior to sampling. Sampled 9 days prior to runway deicing chemical application.
(2) Grab samples not collected
(3) Concentrations shown are adjusted data from in-stream DO meters, unless noted as grab samples (G), which were analyzed using Winkler titrations
(4) Temperature not recorded
(5) Sampled 13 days and 4.12 inches of rainfall after December deicing event
(6) Sampled 21 days and 4.82 inches of rainfall after December deicing event

AR 042861

Table G-2 DO Profiles; February Deicing Event

DES MOINES CREEK												
	Concentration[3] (mg/L)						% Saturation					
Condition	Northwest Pond Inlet	NW Pond 2	NW Pond 3	Golf Course Weir	Des Moines WWTP	Des Moines Mouth	Northwest Pond Inlet	NW Pond 2	NW Pond 3	Golf Course Weir	Des Moines WWTP	Des Moines Mouth
Background, 3/1 10:00[1]	N/A[2]	7.5	7.5	10.4	12.5	12.0	N/A	63	61	86	104	100
Pre-Runoff, 2/9 9:30	11.3(G)	8.1	8.3	10.4	12.0	11.9	88	64	64	83	95	95
Initial Runoff, 2/13 10:30	11.3(G)	6.5	6.8	10.2	11.7	12.4	91	52	54	84	97	103
Post Initial Runoff, 2/14 10:30	N/A[2]	6.1	5.8	9.5	11.8	12.8	N/A	49	46	78	97	105

MILLER CREEK								
	Concentration[3] (mg/L)				% Saturation			
Condition	Lake Reba	Miller Creek Detention Facility	Miller Creek WWTP	Miller Creek Mouth[4]	Lake Reba	Miller Creek Detention Facility	Miller Creek WWTP	Miller Creek Mouth
Background, 3/1 10:00[1]	9.9	11.5	12.1	N/A	82	96	101	N/A
Pre-Initial Runoff, 2/9 9:30	9.4	9.4	12.6	N/A	73	74	101	N/A
Initial Runoff, 2/13 10:30	7.8	10.3	11.8	N/A	62	84	99	N/A
Post-Initial Runoff, 2/14 10:30	7.6	10.4	11.9	N/A	61	84	98	N/A

(1) No deicing chemicals applied prior to sampling. (Last deicing chemicals were applied on 2/9, 20 days and 3.37 inches of rainfall prior.)
(2) Grab samples not collected
(3) Concentrations shown are corrected data from in-stream DO meters, unless noted as grab samples (G)
(4) Data unreliable after 2/8/99. See Appendix D.

G.2.2 Non-Deicing Event Profiles – Des Moines Creek

Dissolved oxygen for periods unrelated to runway deicing show that a DO deficit similar to that measured after the December deicing event occurred when deicing chemicals were not present. Figure G-3 presents five DO profiles: (1) – (3) the background, pre-initial runoff, and initial runoff conditions for the December deicing event; (4) a profile for January 6 at 12:00 when DO concentrations in the NW Ponds were at their lowest levels (after more than five days of dry weather); and (5) a profile for January 14 at 0:00 after 0.26 inches of rainfall in the previous 24 hours and the DO concentrations in NW Pond 3 had begun to increase. This condition is similar to that identified as the initial runoff period following a deicing event when 0.25 inches of rain has fallen after the application of deicing chemicals.

The data presented in Figure G-3 are also presented in Table G-1 along with the corresponding saturation data. This figure and table show that, except for NW Pond 3, the concentrations and saturation levels that existed during the pre-runoff and initial runoff periods following the December deicing event were very similar to those measured in January when deicing chemicals were absent. In NW Pond 3, the DO concentrations and saturation levels were lower in January than they were immediately following the deicing event.

These observations again show that deicing chemicals did not contribute to the DO deficit that was observed in the NW Ponds immediately following the December deicing event. The profiles shown in Figures G-2 and G-3 show that the DO deficits in the NW Ponds immediately following the deicing event and 13 and 20 days later were similar. These facts establish that some factor other than runoff that contained BOD_5 following the deicing event was responsible for the deficits in the NW Ponds. Deficits in the NW Ponds were rapidly reaerated a short distance downstream from the NW Pond 3 outlet

G.2.3 December Deicing Event – Miller Creek

The DO profile for the Miller Creek drainage for the December deicing event (Figure G-4) was similar to that for Des Moines Creek in that the DO concentration and percent saturation were lower at the upstream end (Lake Reba) during the pre-runoff and initial runoff periods than at background conditions. However, the concentrations measured at Lake Reba were the same during the pre-runoff and initial runoff conditions.

Dissolved oxygen concentrations at the Miller Creek Detention Facility, approximately 0.4 miles downstream from the Lake Reba outlet, were above background levels. All concentrations measured at the downstream stations were greater than the water quality standard. As shown in Table G-1, the DO saturation level at the Miller Creek Detention Facility was essentially unchanged during the period following the deicing event. Dissolved oxygen concentrations at the stations downstream from Lake Reba following the deicing event were all greater than those measured at background.

There was no evidence of BOD_5 being exerted in the Miller Creek Drainage following the December deicing event.

G.2.4 February Deicing Event – Des Moines and Miller Creeks

Figures G-5 and G-6 and Table G-2 present DO profiles for Des Moines and Miller Creeks for the February deicing event. For the February deicing event, the 0.6-1.0 inches of rainfall required to represent Sampling Condition 3, Post-Initial Runoff, did not occur until nine days after the last deicing chemicals were applied. Consequently profiles representative of a condition more similar to that for the "Post-Initial Runoff" condition for the first deicing event were developed. These profiles in Figures G-5 and G-6 are based on concentrations measured 24 hours after the Initial Runoff condition. Selection of this time period as representative of the Post-Initial Runoff condition is conservative because less rainfall, and consequently less runoff, from the runways had occurred than if there had been the required 0.6-1.0 inches of rainfall.

The background condition selected for comparison to this event was March 1, two weeks after the Post-Initial Runoff condition, 20 days and 3.37 inches of rainfall after the application of deicing chemicals.

Dissolved oxygen profiles for the February deicing event showed that concentrations and saturation levels downstream of the NW Ponds were similar at all conditions. Decreases in percent saturation were observed in the NW Ponds at the pre-runoff and initial runoff conditions, but not to the extent that was measured during the December deicing event.

In Lake Reba and at the Miller Creek Detention Facility, DO concentrations and saturation levels were lower (by at least 0.5 mg/L and 19%) at the pre-runoff condition, prior to rainfall and runoff following the deicing event, than at the background condition. A slight (11%) decline in percent saturation was observed at Lake Reba on Miller Creek from the pre-runoff condition to the initial runoff condition, but DO concentrations and saturation levels at the downstream points on Miller Creek were essentially unchanged. Dissolved oxygen data were not available for the Miller Creek Mouth station because the data collected from the Hydrolab were unreliable after February 8 (see Appendix D).

Because of the low rainfall, and therefore low flushing of the systems, during and after the February deicing event, BOD_5 from the deicing chemicals could have been exerted. Yet no discernable decrease in DO was observed after the event. Therefore it is clear that the February deicing event had no adverse affects.

Figure G-1
Des Moines Creek DO Monitoring Data
December 1998 Deicing Event (DO and Flow Rate)

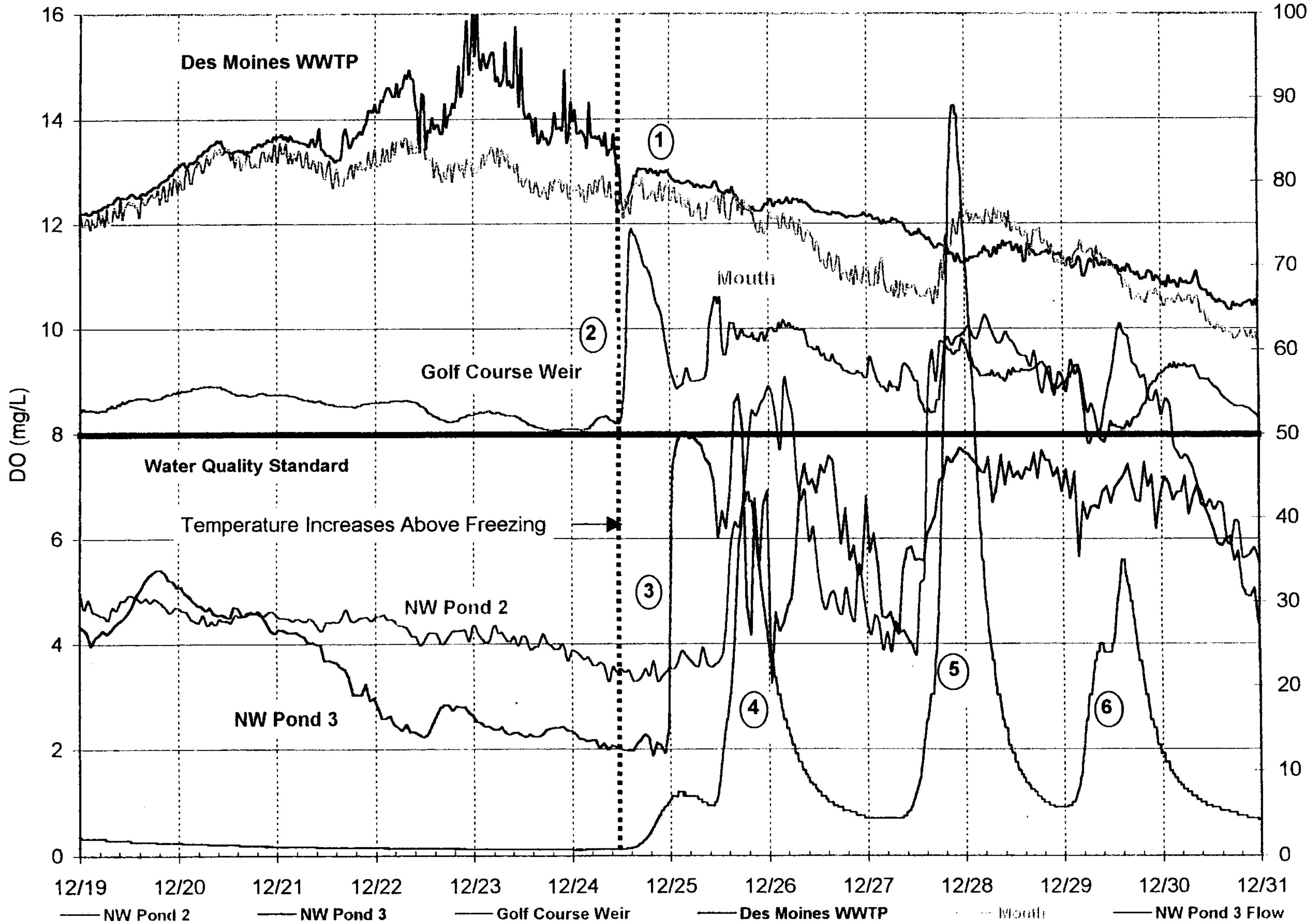


Figure G-2
Des Moines Creek DO Profiles
Background and December Deicing Event

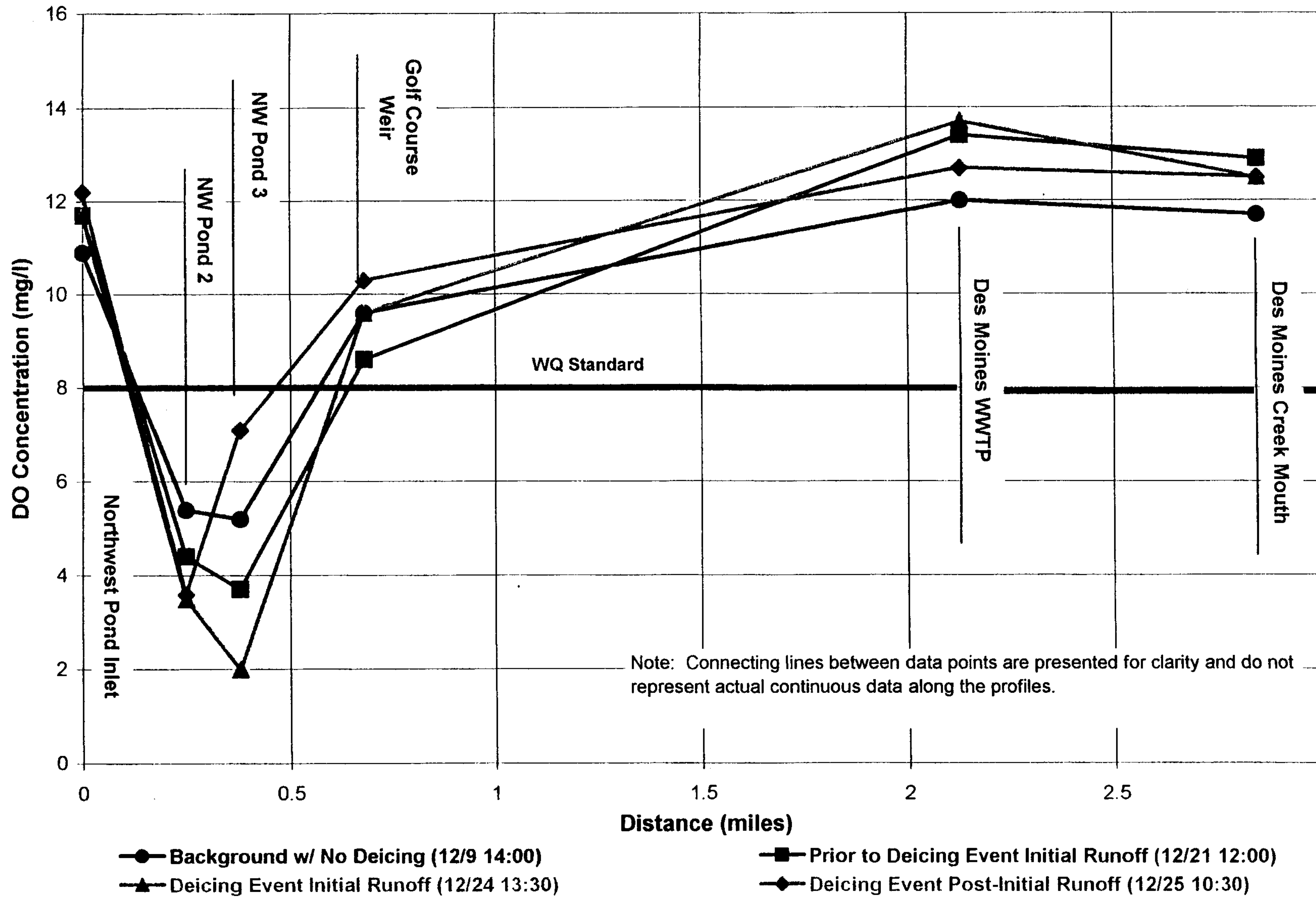


Figure G-3
Des Moines Creek DO Profiles
Background, December Deicing Event, January 6 - 14

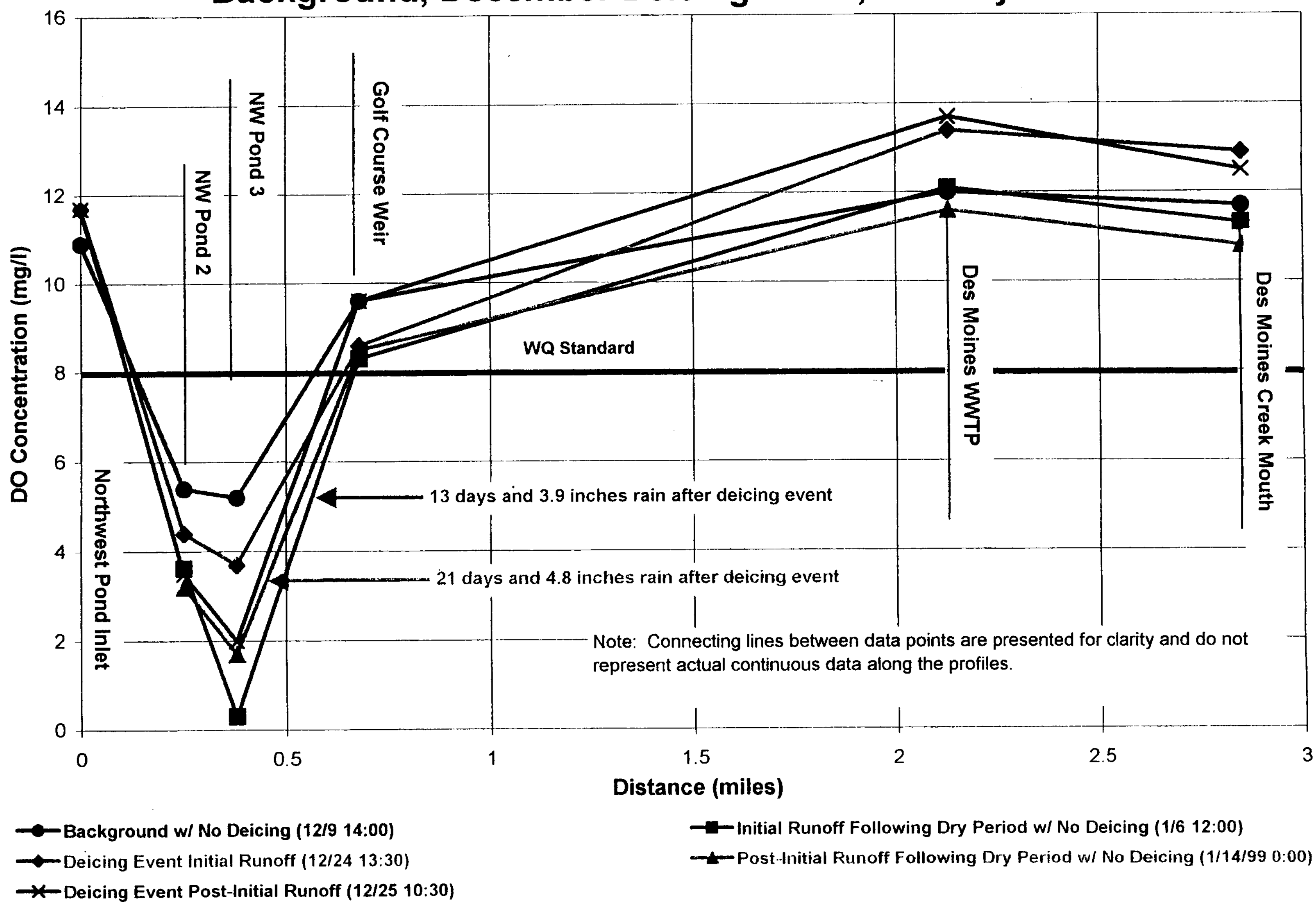


Figure G-4
Miller Creek DO Profiles
Background and December Deicing Event

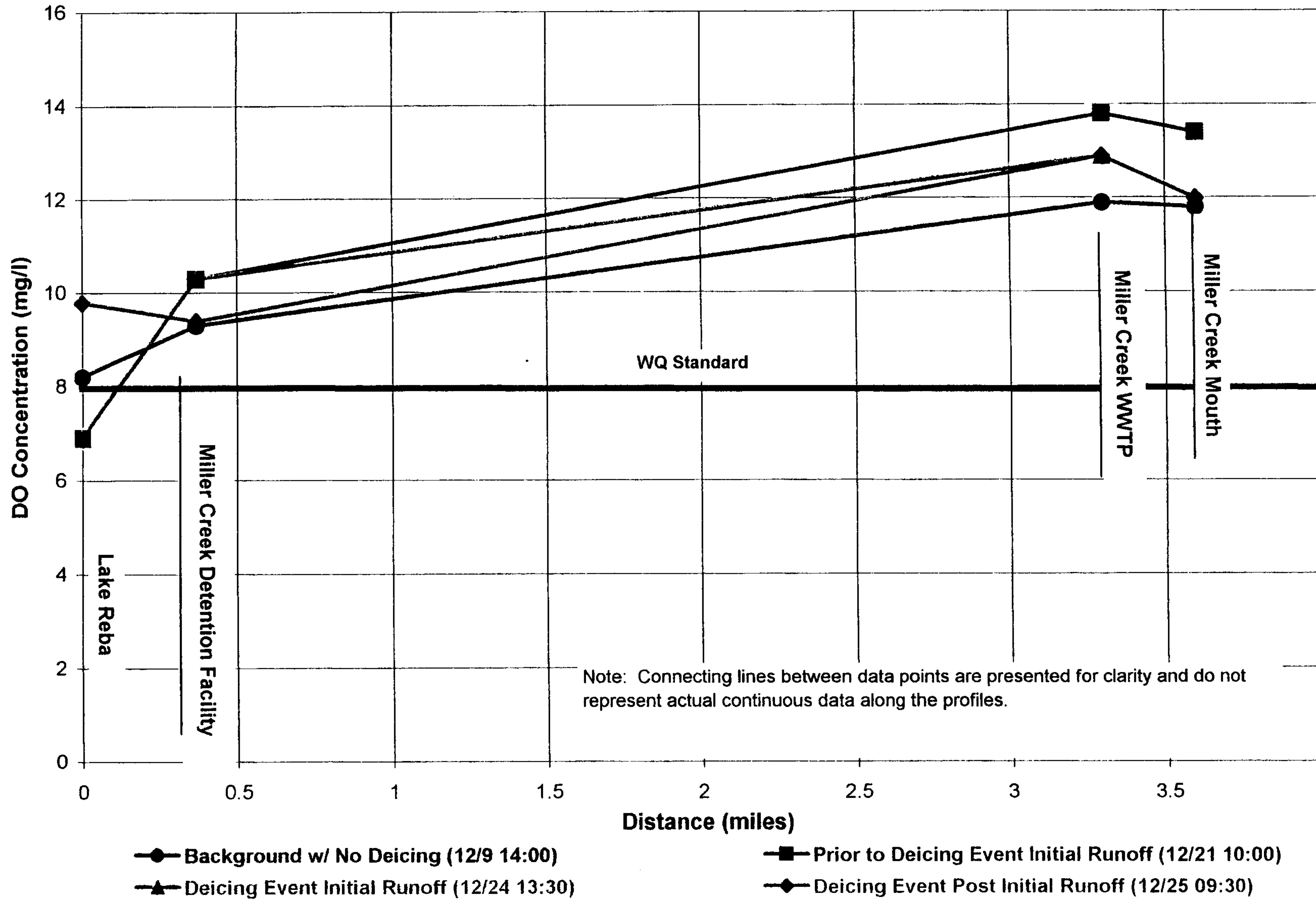


Figure G-5
Des Moines Creek DO Profiles
Background and February Deicing Event

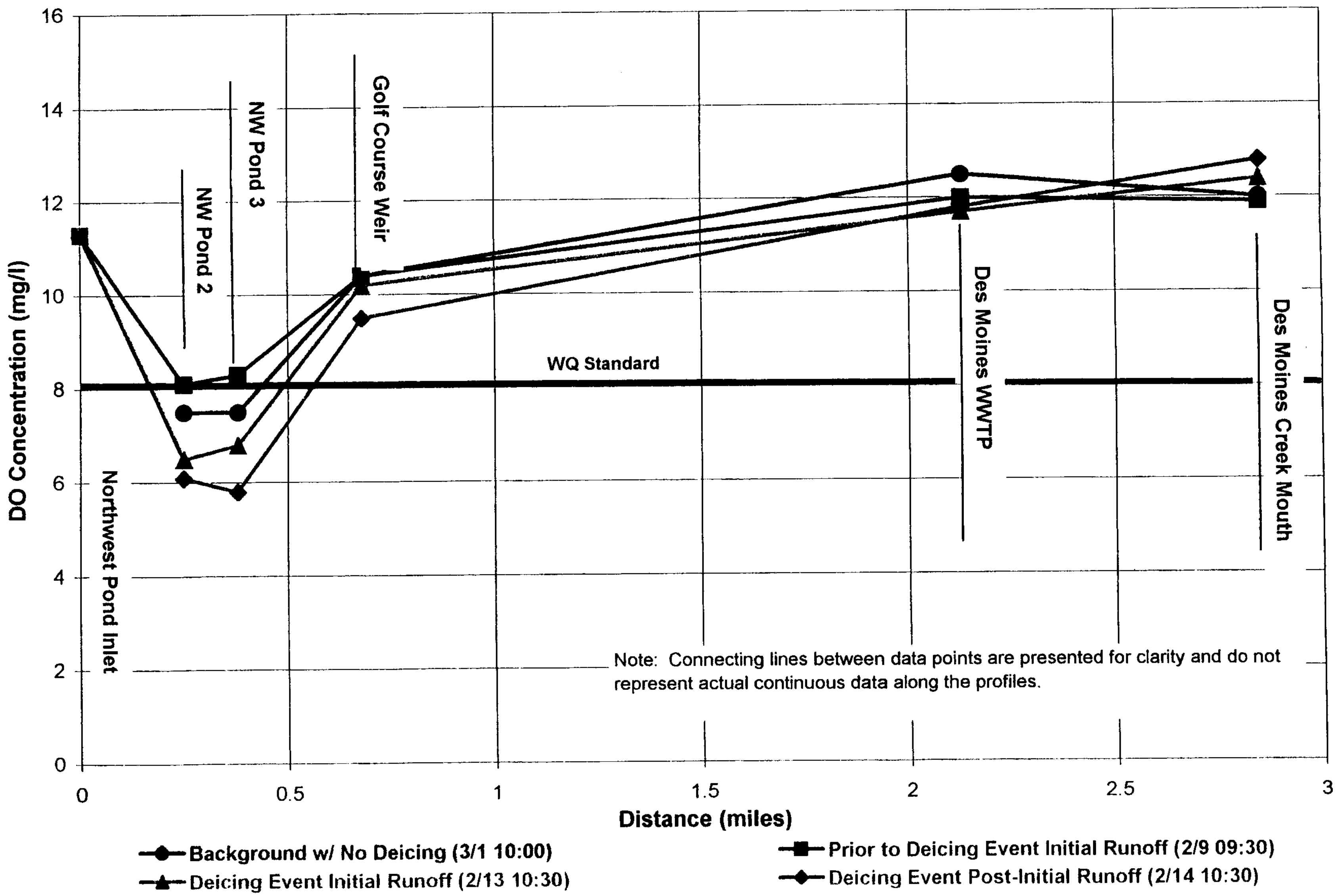
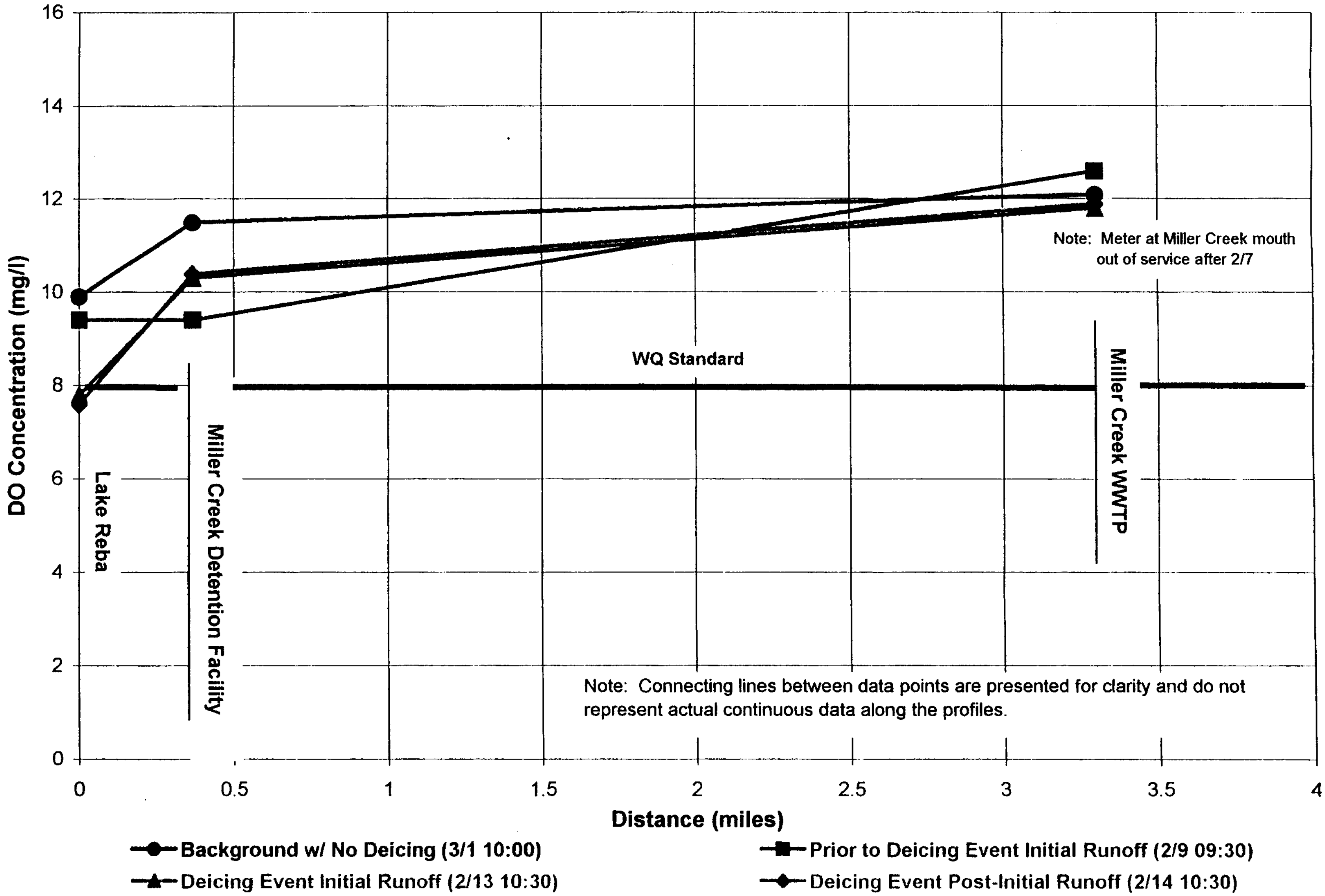


Figure G-6
Miller Creek DO Profiles
Background and February Deicing Event



AR 042871