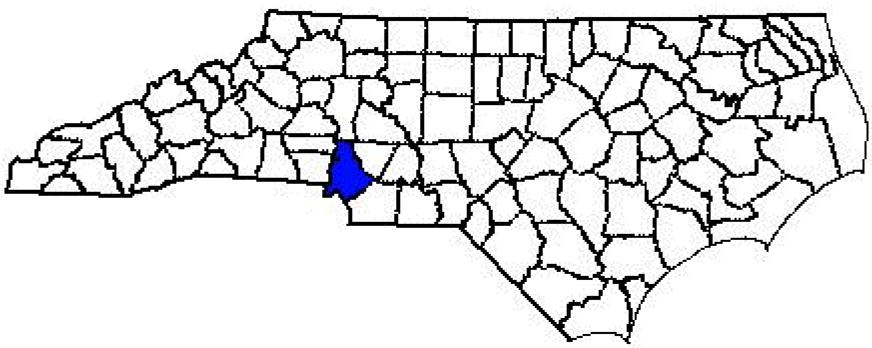
ANNUAL REPORT FOR 2003



Mallard Creek Mitigation Site
Mecklenburg County
Project No. 8.U670123
TIP No. R-211 WM

Office of Natural Environment & Roadside Environmental Unit
North Carolina Department of Transportation
December 2003

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SUMMARY

The following report summarizes the monitoring activities that have occurred in the past year at the Mallard Creek Mitigation Site. This site was originally constructed in 1994 and underwent remediation in 1997. Monitoring activities in 2003 represent the sixth year of monitoring following the remediation. The site must demonstrate both hydrologic and vegetation success for a minimum of three years or until the site is deemed successful.

The Mallard Creek Site is divided into two sites. Site 1 is the smaller of the two, containing three groundwater gauges, one surface gauge, and two vegetation plots. Site 2 contains seven groundwater gauges, one surface gauge, one rain gauge, and four vegetation plots. Site 2, which is located across Mallard Creek Church Road from Site 1, is at a slightly higher elevation than its counterpart.

The daily rainfall data depicted on the gauge data graphs is recorded from an onsite rain gauge that was installed on May 4, 2000. Additional Charlotte rainfall data used for the 30-70 graph was provided by the NC State Climate Office. The onsite rain gauge experienced periodic malfunctions; therefore, rainfall data from the Charlotte weather station was used for the gauge graphs. In 2003, Charlotte experienced a wet growing season, resulting in an average to above average rainfall year.

In October 2003, The Catena Group, Inc. conducted a site visit to evaluate the Mallard Creek Mitigation Site. The investigation examined soil features to determine any correlation between the past and current conditions on the site. The report can be found in Appendix C (Mitigation Site Soil Analysis).

For Site 1, two of the three groundwater-gauges revealed saturation greater than 12.5% of the growing season. The one groundwater-gauge that did not meet success experienced malfunctions throughout the entire growing season. The surface gauge located on Site 1, revealed periodic inundation throughout the growing season.

Hydrologic data indicated that Site 2 also met the hydrologic success criteria for the sixth year of monitoring. All seven groundwater gauges exceeded the success criteria of 12.5% saturation during the growing season. The surface gauge located on Site 2, revealed periodic inundation throughout the growing season.

There were six vegetation-monitoring plots established throughout the planting areas; two plots in Site 1 and four plots in Site 2. The 2003 vegetation monitoring revealed an average density of 508 trees per acre. This average is well above the minimum success criteria of 320 trees per acre. NCDOT proposes to discontinue vegetation monitoring at the Mallard Creek Mitigation Site.

The Mallard Creek Church Road widening project, U-2508C, was let for construction on November 20, 2001. This highway project will add additional hydrology to the site during the construction. NCDOT will continue hydrology monitoring until completion of the highway project.

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The Mallard Creek Mitigation Site, located in Mecklenburg County, consists of two separate wetland sites. Both are situated along SR 2833 (Mallard Creek Church Road), just east of US 29 (Figure 1). The two sites serve as mitigation for wetland impacts associated with the Charlotte Outer Loop (R-211 DA, USACE Action I.D. 199200013).

Both sites, totaling 10 acres in size, consist of bottomland hardwood forest restoration and creation. The sites were initially constructed and planted in 1994; however, hydrologic and vegetation problems forced remediation in 1997. Remediation activities involved grading both sites to more accurately reflect groundwater profiles.

The site was developed in cooperation with Mecklenburg County. As a result of this partnership, the county will incorporate the mitigation sites into a greenway plan for the area. A boardwalk has been constructed on Site 2 as part of the Mecklenburg County Parks and Recreation system. An additional section of boardwalk will be constructed adjacent to Site 1 when Mallard Creek Church Road is widened.

1.2 PURPOSE

In order to demonstrate successful mitigation, hydrologic and vegetative criteria must be met for a minimum of three consecutive years or until the site is deemed successful. Success criteria are based on federal guidelines for wetland mitigation. These guidelines stipulate criteria for both hydrologic conditions and vegetation survival. The following report details the results of hydrologic and vegetative monitoring during the 2003-year at the Mallard Creek Mitigation Site.

Activities in 2003 reflect the sixth year of monitoring following the remediation efforts in 1997. Included in this report are analyses of both hydrologic and vegetative monitoring results.

Figure 1. Site Location Map

1.3 PROJECT HISTORY

October 1994	Site 1 & 2: Grading Construction
February 1995	Site 2: Planted; Site 1: No Planting
September 1995	Vegetation Monitoring (1yr.)
March - November 1996	Hydrologic Monitoring
September 1996	Vegetation Monitoring (2 yr.)
October 1997	Site 1 & 2: Remediation, Grading Construction
February 1998	Site 2: Boardwalk Construction
January-February 1998	Tree Planting: Site 1 & 2
May 1998	Monitoring Gauges Installed
May - November 1998	Hydrologic Monitoring (1 yr.)
September 1998	Vegetation Monitoring (1 yr.)
May - November 1999	Hydrologic Monitoring (2 yr.)
September 1999	Vegetation Monitoring (2 yr.)
March - November 2000	Hydrologic Monitoring (3 yr.)
September 2000	Vegetation Monitoring (3 yr.)
December 2000	Water Main Fixed Adjacent to Site 1
March - November 2001	Hydrologic Monitoring (4 yr.)
June 2001	Vegetation Monitoring (4 yr.)
March - November 2002	Hydrologic Monitoring (5 yr.)
August 2002	Vegetation Monitoring (5 yr.)
March - November 2003	Hydrologic Monitoring (6 yr.)
October 2003	Vegetation Monitoring (6 yr.)
October 2003	Soils Investigation

1.4 DEBIT LEDGER

Table 1. Mallard Creek Mitigation Site Debit Ledger

Mallard Creek	Mit. Plan			Ratios	TIP DEBIT
Mecklenburg Co.					
Habitat	Acres At Start:	Acres Remaining	% Remaining		R-211DA, DD, DB
BLH Restoration/Creation	9.1	0	0.0		9.1
TOTAL		0			

BLH: Bottomland Hardwood

2.0 HYDROLOGY

2.1 SUCCESS CRITERIA

In accordance with federal guidelines for wetland mitigation, the success criteria for hydrology state that the area must be inundated or saturated (within 12" of the surface) by surface or groundwater for at least a consecutive 12.5% of the growing season. Areas inundated or saturated for less than 5% of the growing season are always classified as non-wetlands. Areas inundated or saturated between 5% - 12.5% of the growing season can be classified as wetlands depending upon factors such as the presence of wetland vegetation and hydric soils.

The growing season in Mecklenburg County begins March 22 and ends November 11 (235 days). These dates correspond to a 50% probability that temperatures will drop to 28°F or lower after March 22 and before November 11.[1] Based on the current guidelines, the optimum hydrology requires 12.5% of this season, or at least 29 consecutive days. Local climate must also represent average conditions for the area.

[1] Natural Resources Conservation Service, Soil Survey of Mecklenburg County, North Carolina, p.61.

2.2 HYDROLOGIC DESCRIPTION

In May of 1998, ten groundwater gauges, one rain gauge, and one surface water gauge were installed at the Mallard Creek Mitigation Sites. The original rain gauge was replaced on May 4, 2000. In April 2003, one surface gauge was installed on Site 2 (Figure 2). The automatic groundwater gauges record daily readings of groundwater depth.

The Mallard Creek Site was designed to receive hydrologic input from both rainfall and runoff from Mallard Creek Church Road. The hydrologic monitoring should show the reaction of the groundwater level to specific rainfall events. The 2003 data represents the sixth growing season for hydrologic monitoring following the remediation efforts in 1997.

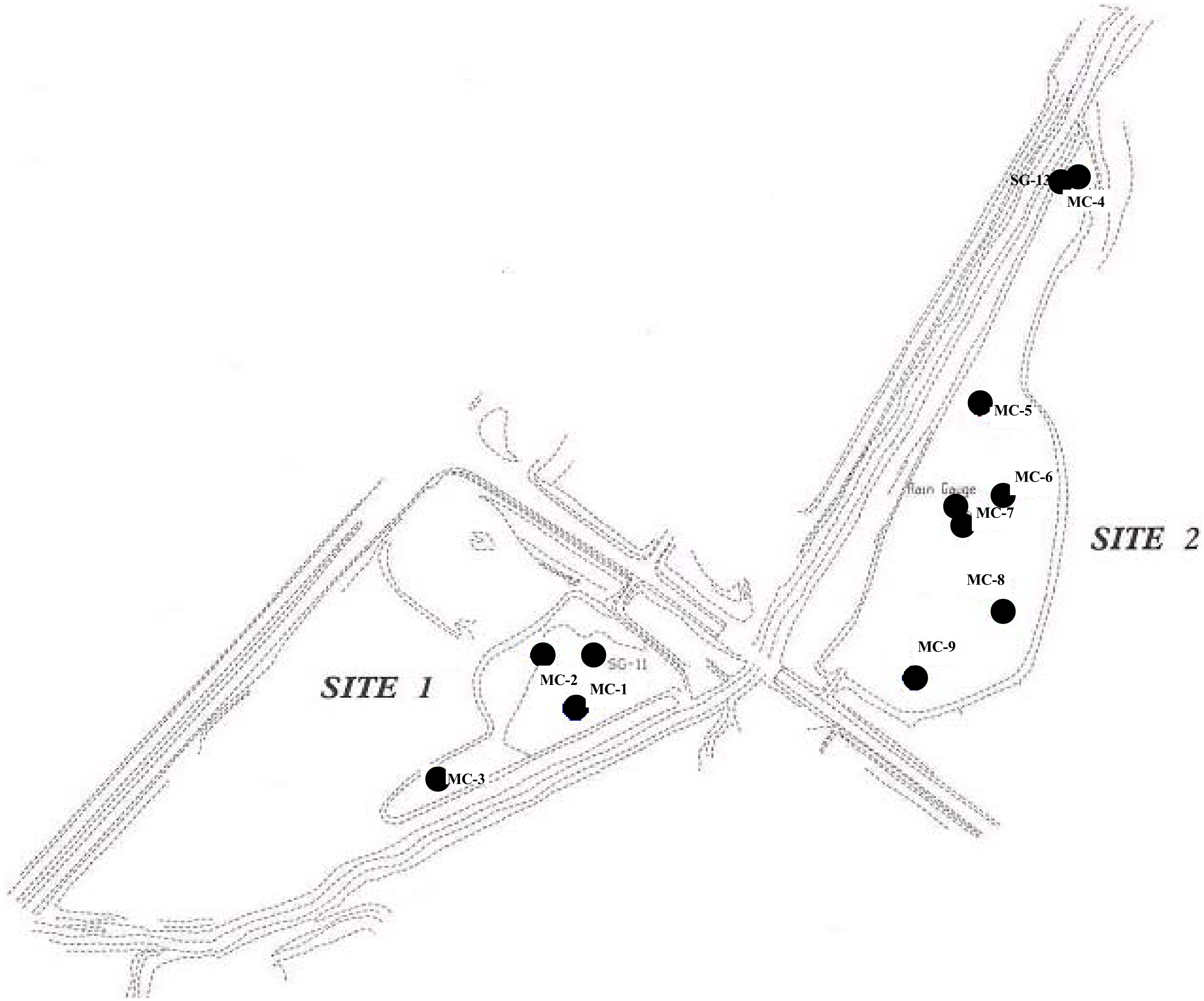


Figure 2. Gauge Location Map

N

Not to Scale

2.3 RESULTS OF HYDROLOGIC MONITORING

2.3.1 Site Data

To determine if the site met the federal guidelines (saturation within 12 inches of the surface for at least 12.5% of the growing season), the maximum number of consecutive days that the groundwater was within twelve inches of the surface was determined for each gauge. This number was converted into a percentage of the 235-day growing season (March 22 – November 11). The results are presented in Table 2.

Table 2. 2003 Hydrologic Monitoring Results

Monitoring Gauge	<5%	5-8%	8-12.5%	>12.5%	Actual %	Success Dates
Site 1						
MC-1	×				4.7	
MC -2				×	42.6	March 22-June 29
MC -3				×	44.7	April 2-July 15
Site 2						
MC -4				×	39.6	March 22-June 22
MC -5				×	68.5	March 22-Aug 29
MC -6				×	44.3	March 22-Sept. 2
MC -7				×	37.4	March 22-June 17
MC -8				×	17.4	April 3-May 1 May 22-June 23
MC -9				×	17.9	April 2-May 13 July 13-August 22
MC -12				×	70.2	March 22-Sept 2

Specific Gauge Problems:

- Gauge (MC-1) experienced malfunctions such as battery failure and gauge replacement during the growing season (April 2 - October 1).
- Gauges (MC-2, MC-3, MC-7, MC-8, and MC-9) all experienced battery failure and gauge malfunctions during the growing season.

Appendix A contains hydrologic graphs. The maximum number of consecutive days is noted on each graph. The individual precipitation events, shown on the monitoring gauge graphs as bars, represent data obtained from the Charlotte weather station.

The placement of the groundwater gauges and a graphical representation of the hydrologic monitoring results are provided in Figure 3.

2.3.2 Climatic Data

Figure 4 is a comparison of 2002 and 2003 monthly rainfall to historical precipitation for the area. This comparison indicates whether 2003 was “average” in terms of climate conditions by comparing the rainfall to that of historical rainfall (data collected between 1972 and 2003). The NC State Climate Office provided all of the historical data.

For the 2003-year, November (02’), December (02’), March, April, May, June, July, and August experienced above average rainfall. The months of January, October, and November recorded below average rainfall for the site. February and September experienced average rainfall. Overall, 2003 experienced an average to above average rainfall year.

2.4 CONCLUSIONS

For Site 1, two of the three groundwater-gauges revealed saturation greater than 12.5% of the growing season. The one groundwater-gauge that did not meet success experienced malfunctions throughout the growing season. The surface gauge located on Site 1, revealed periodic inundation throughout the growing season.

Hydrologic data indicated that Site 2 also met the hydrologic success criteria for the sixth year of monitoring. All seven groundwater gauges exceeded the success criteria of 12.5% saturation during the growing season. The surface gauge located on Site 2, revealed periodic inundation throughout the growing season.

NCDOT proposes to continue monitoring the Mallard Creek Mitigation Site for hydrology until completion of the highway project (U-2508C).

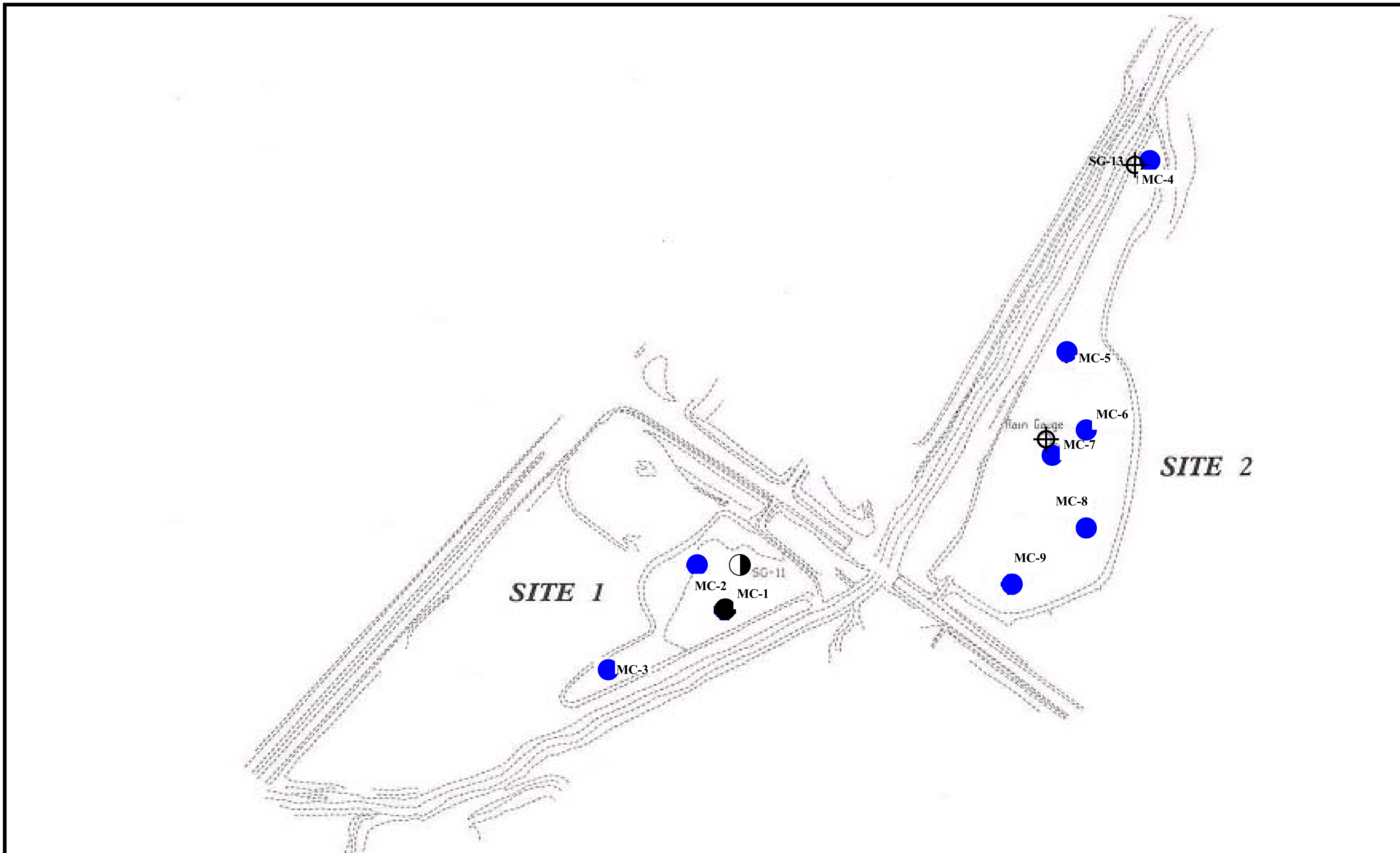


Figure 3. 2003 Hydrologic Monitoring Gauge Results

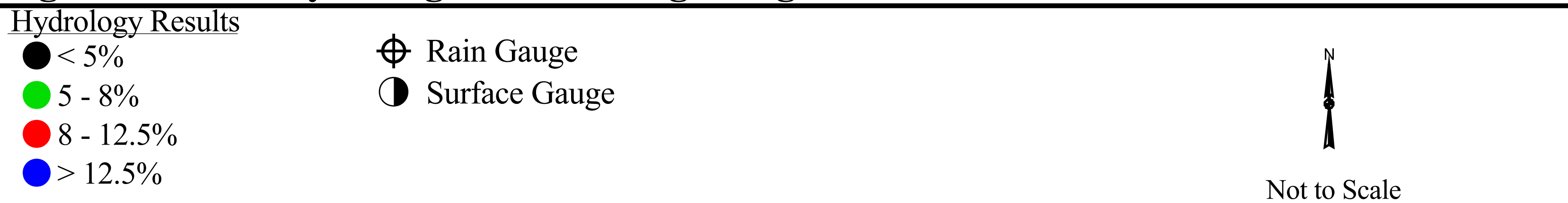
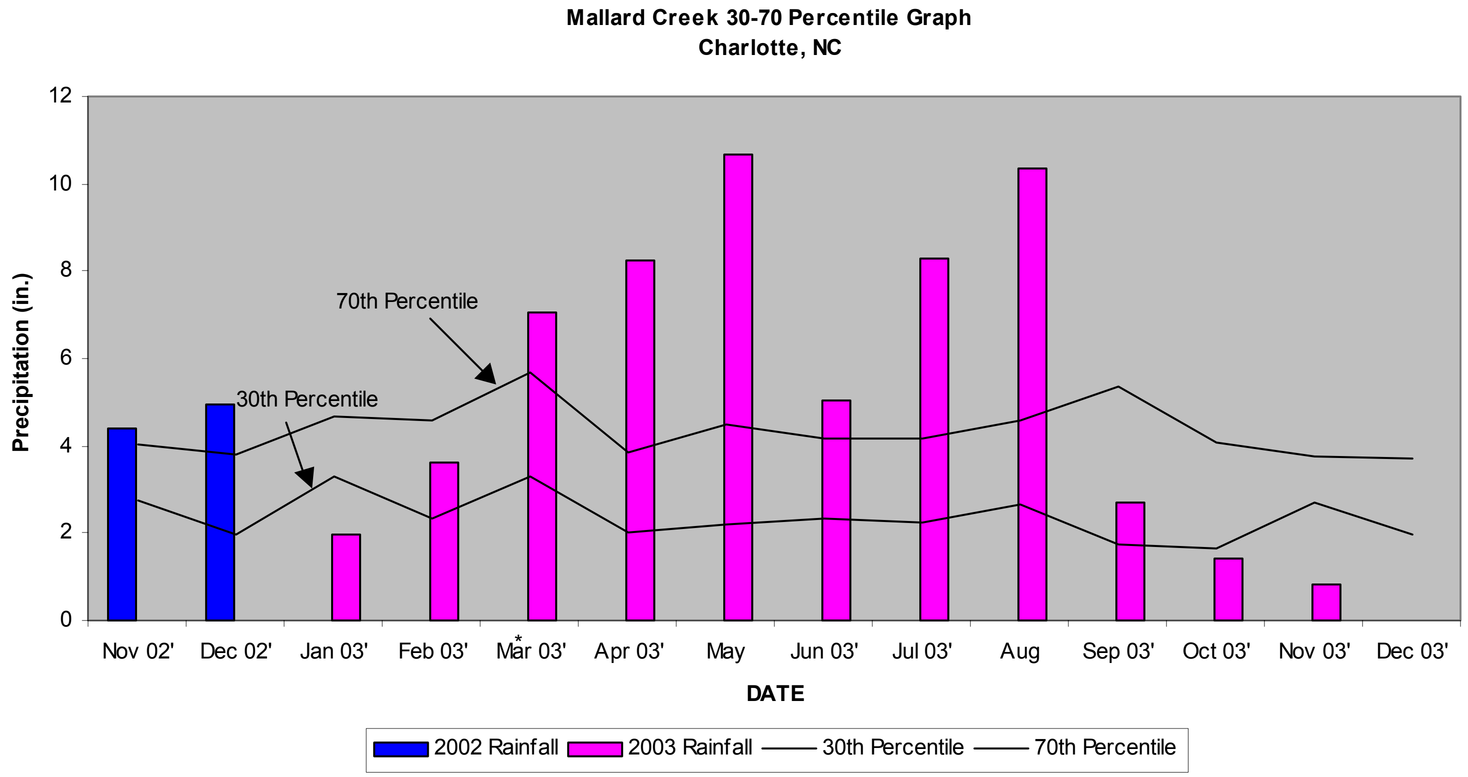


Figure 4. 30-70 Percentile Graph



3.0 VEGETATION: MALLARD CREEK MITIGATION SITE (YEAR 6 MONITORING)

3.1 SUCCESS CRITERIA

Success criteria state that there must be a minimum of 320 trees per acre surviving for three consecutive years.

3.2 DESCRIPTION OF SPECIES

The following tree species were planted in the Wetland Creation Area:

Fraxinus pennsylvanica, Green Ash

Nyssa sylvatica var. *sylvatica*, Blackgum

Quercus lyrata, Overcup Oak

Quercus nigra, Water Oak

3.3 RESULTS OF VEGETATION MONITORING

Table 3. Vegetation Monitoring Statistics

Plot # (Type)	Green Ash	Blackgum	Overcup Oak	Water Oak	Total (6 year)	Total (at planting)	Density (Trees/Acre)
1(BLH)	16		4		20	31	439
2(BLH)	9		16	1	26	27	655
3(BLH)	14		14		28	35	544
4(BLH)	11	2	9	3	25	31	548
5(BLH)	18		6	2	26	38	465
6(BLH)	19		2		21	36	397
	Average Density						**508**

Site Notes: Other species noted: cottonwood, various grasses, black willow, lespedeza, *Juncus* sp., boxelder, horse-nettle, smartweed, foxtail, swamp chestnut oak, *Panicum* sp., woolgrass, volunteer green ash, and sycamore. A few cattails were noted in and around Plots 5 and 6.

3.4 CONCLUSIONS

Approximately 10 acres of this site were re-graded in the Fall of 1997. The Mallard Creek Mitigation Site consists of two wetland mitigation sites. Site 1 is a 2.8 acre site located in the southwest quadrant of the intersection of SR 2833 and Mallard Creek, while the remaining 7.2 acres are located directly across SR 2833 in the northwest quadrant. There were six vegetation-monitoring plots established throughout the planting areas; two plots in Site 1 and four plots in Site 2. The 2003 vegetation monitoring revealed an average density of 508 trees per acre. This density is well above the minimum success criteria of 320 trees per acre.

NCDOT proposes to discontinue vegetation monitoring at the Mallard Creek Mitigation Site.

4.0 OVERALL CONCLUSIONS/RECOMMENDATIONS

In October 2003, The Catena Group, Inc. conducted a site visit to evaluate the Mallard Creek Mitigation Site. The investigation examined soil features to determine any correlation between the past and current conditions on the site. The report can be found in Appendix C (Mitigation Site Soil Analysis).

For Site 1, two of the three groundwater-gauges revealed saturation greater than 12.5% of the growing season. The one groundwater-gauge that did not meet success experienced malfunctions throughout the growing season. Hydrologic data indicated that Site 2 also met the hydrologic success criteria for the sixth year of monitoring. All seven groundwater gauges exceeded the success criteria of 12.5% saturation during the growing season. The surface gauges on both sites revealed periodic inundation throughout the growing season.

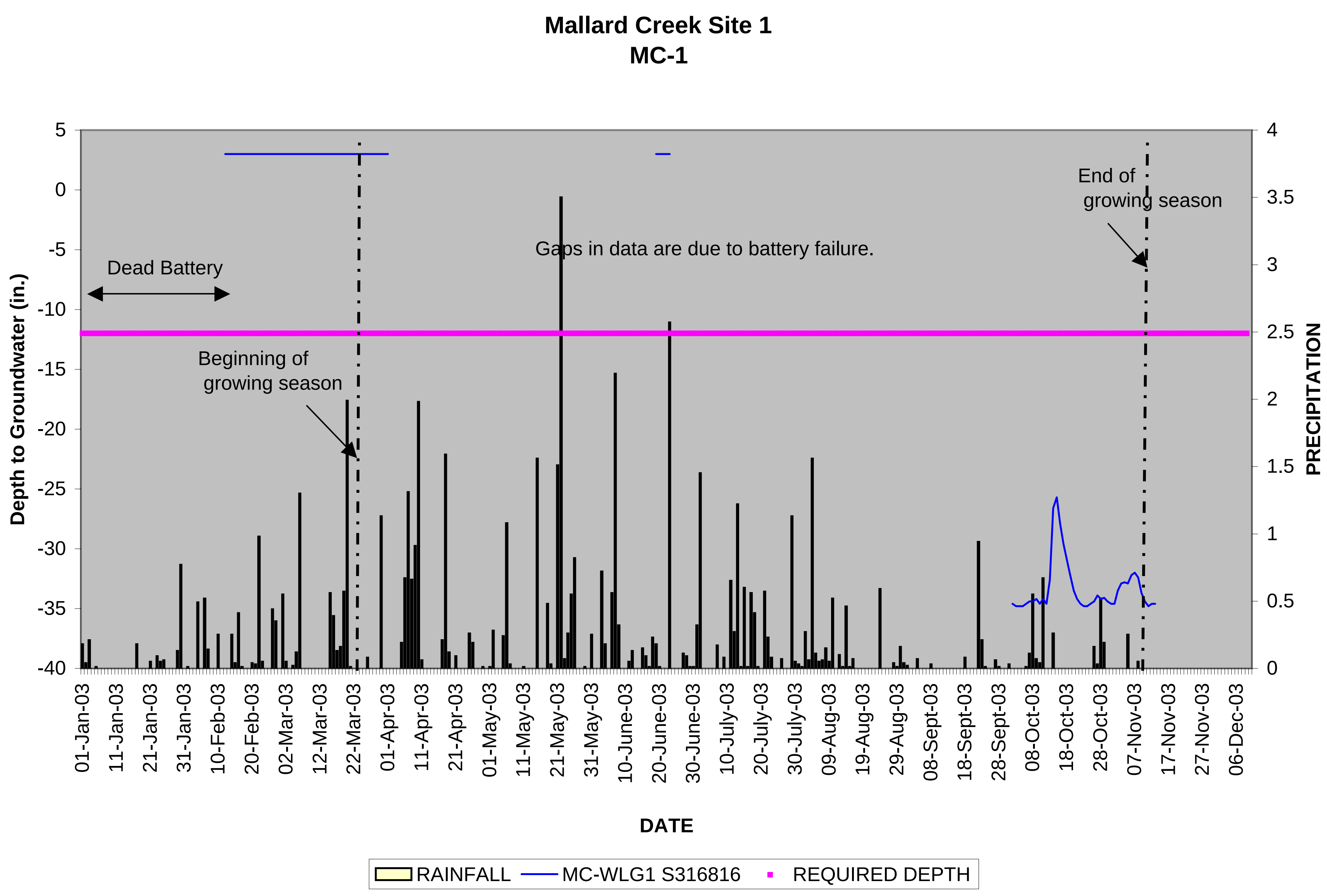
The 2003 vegetation monitoring revealed an average density of 508 trees per acre. This average is well above the minimum success criteria of 320 trees per acre. NCDOT proposes to discontinue vegetation monitoring at the Mallard Creek Mitigation Site.

The Mallard Creek Church Road widening project, U-2508C, was let for construction on November 20, 2001. This highway project will add additional hydrology to the site during the construction. NCDOT will continue hydrology monitoring until completion of this highway project.

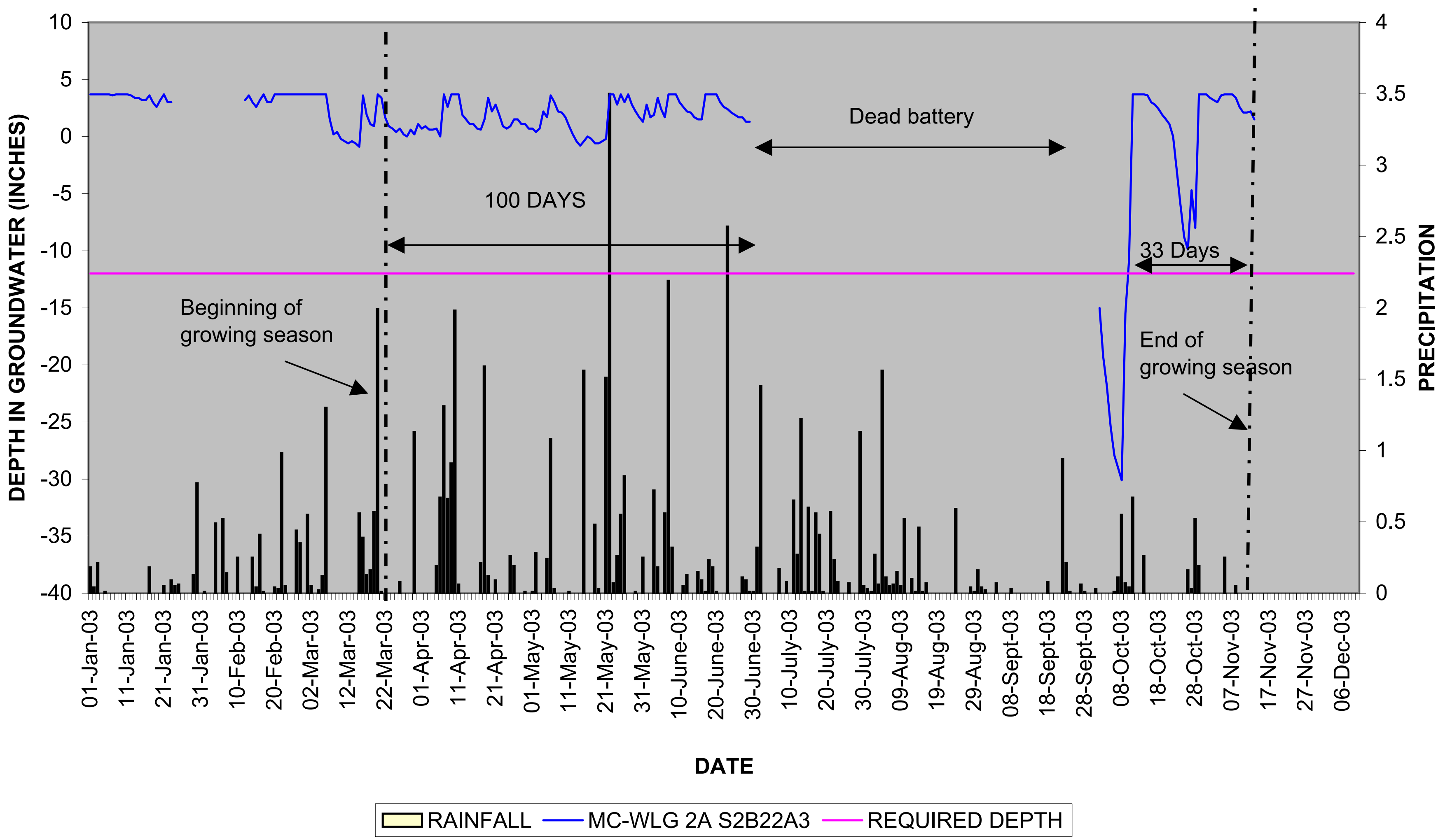
APPENDIX A

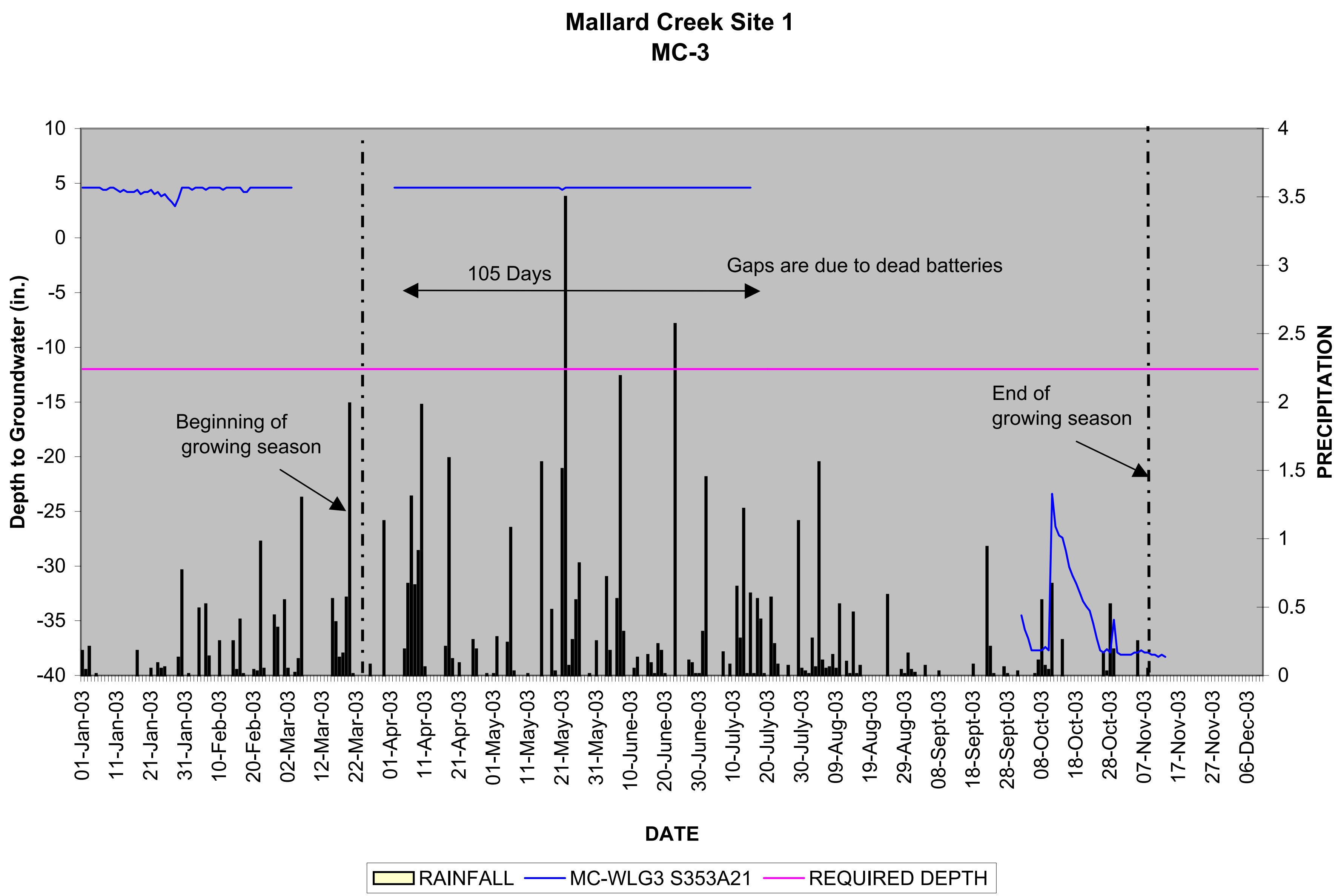
GAUGE DATA GRAPHS

GROUNDWATER GAUGE GRAPHS


Mallard Creek Site 1
MC-1
Depth to Groundwater (in.)
PRECIPITATION
DATE
Dead Battery
Beginning of growing season
Gaps in data are due to battery failure.
End of growing season
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
28-Oct-03
07-Nov-03
17-Nov-03
27-Nov-03
06-Dec-03
RAINFALL
MC-WLG1 S316816
REQUIRED DEPTH

Mallard Creek Site 1
MC-2





Mallard Creek Site 1
MC-3
Depth to Groundwater (in.)
PRECIPITATION
DATE
105 Days
Gaps are due to dead batteries
Beginning of growing season
End of growing season
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
28-Oct-03
07-Nov-03
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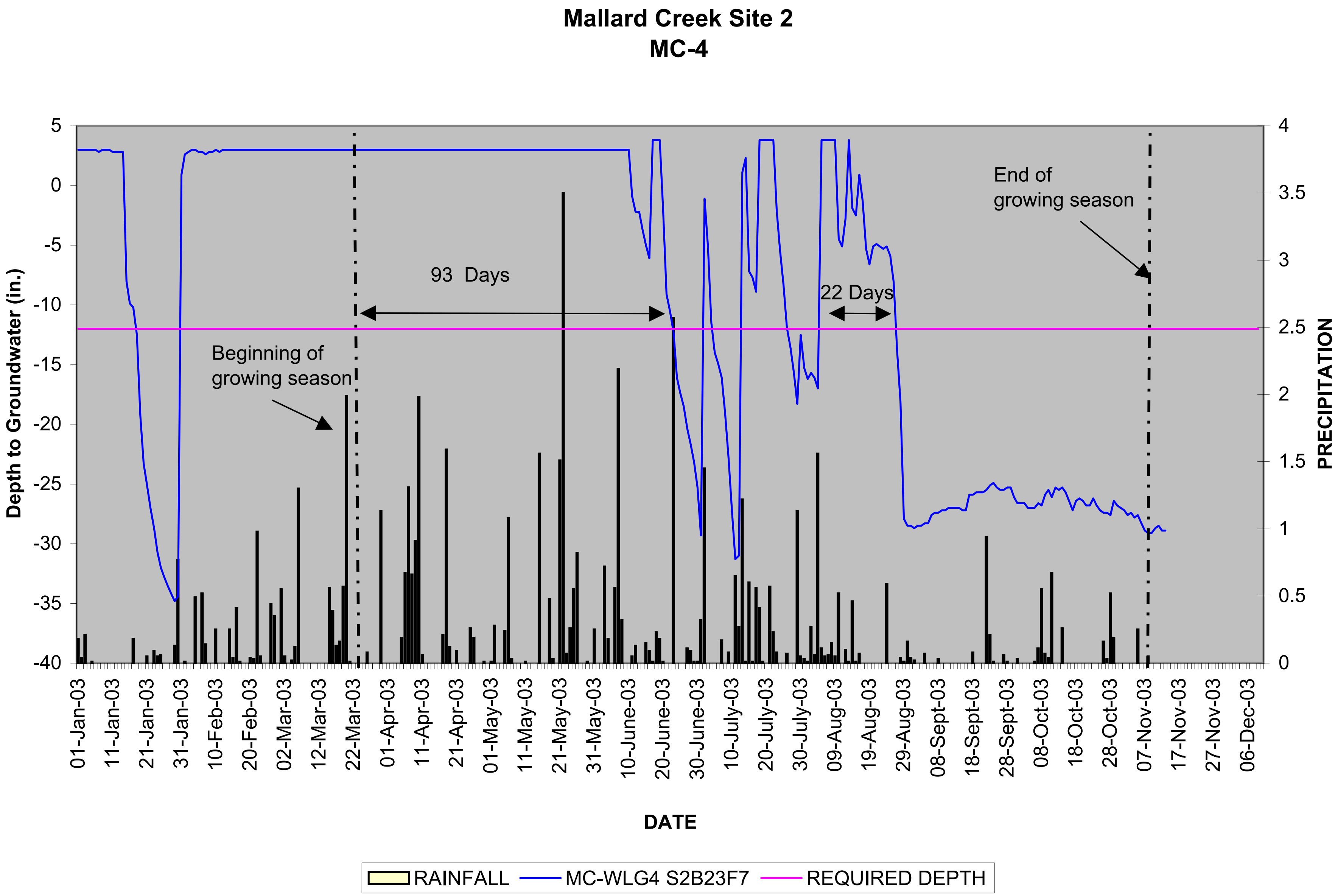
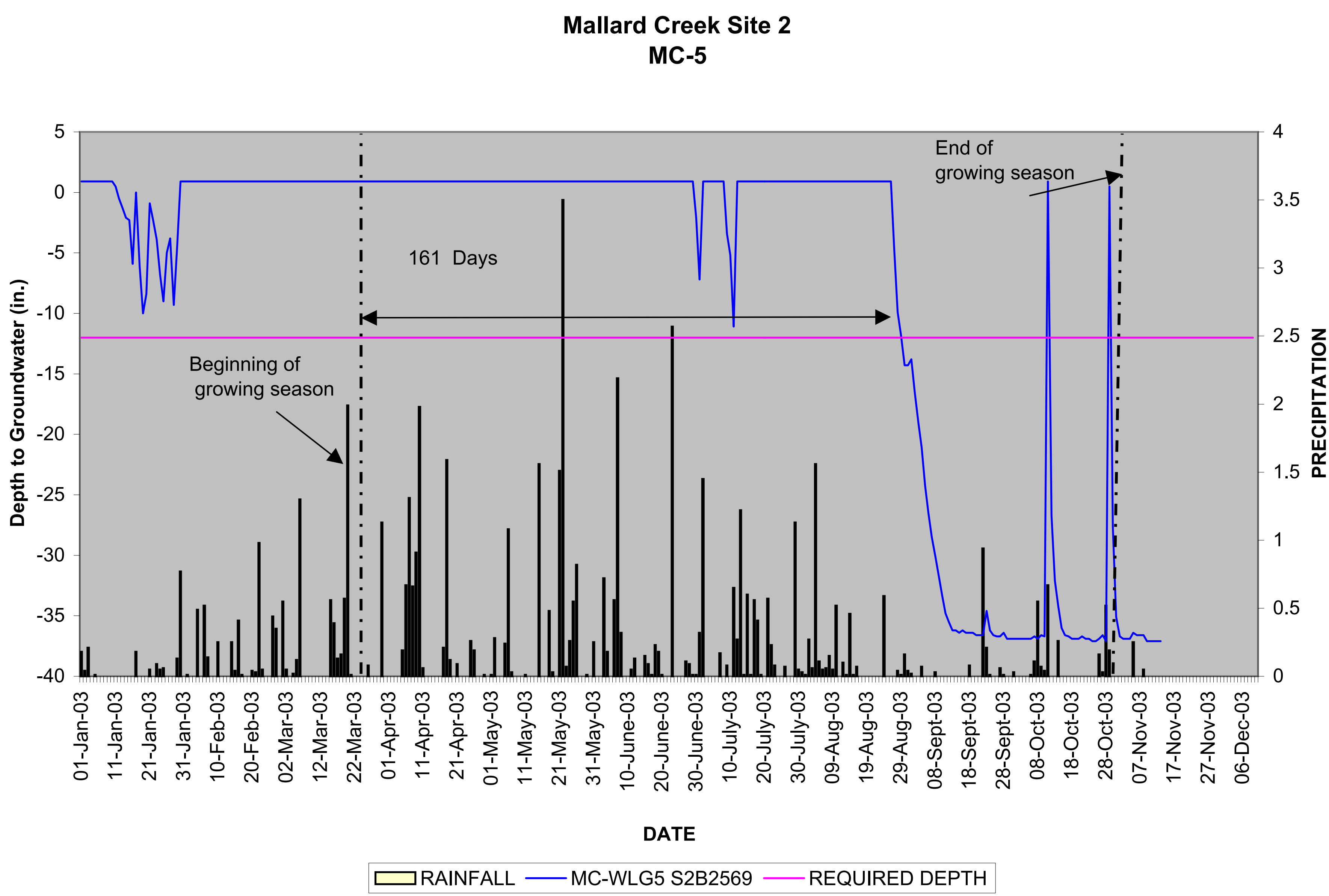
27-Nov-03
06-Dec-03
RAINFALL
MC-WLG3 S353A21
REQUIRED DEPTH



Mallard Creek Site 2
MC-4
Depth to Groundwater (in.)
PRECIPITATION
DATE
93 Days
22 Days
Beginning of growing season
End of growing season
RAINFALL
MC-WLG4 S2B23F7
REQUIRED DEPTH



Mallard Creek Site 2
MC-5
Depth to Groundwater (in.)
PRECIPITATION
DATE
161 Days
Beginning of growing season
End of growing season
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
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18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
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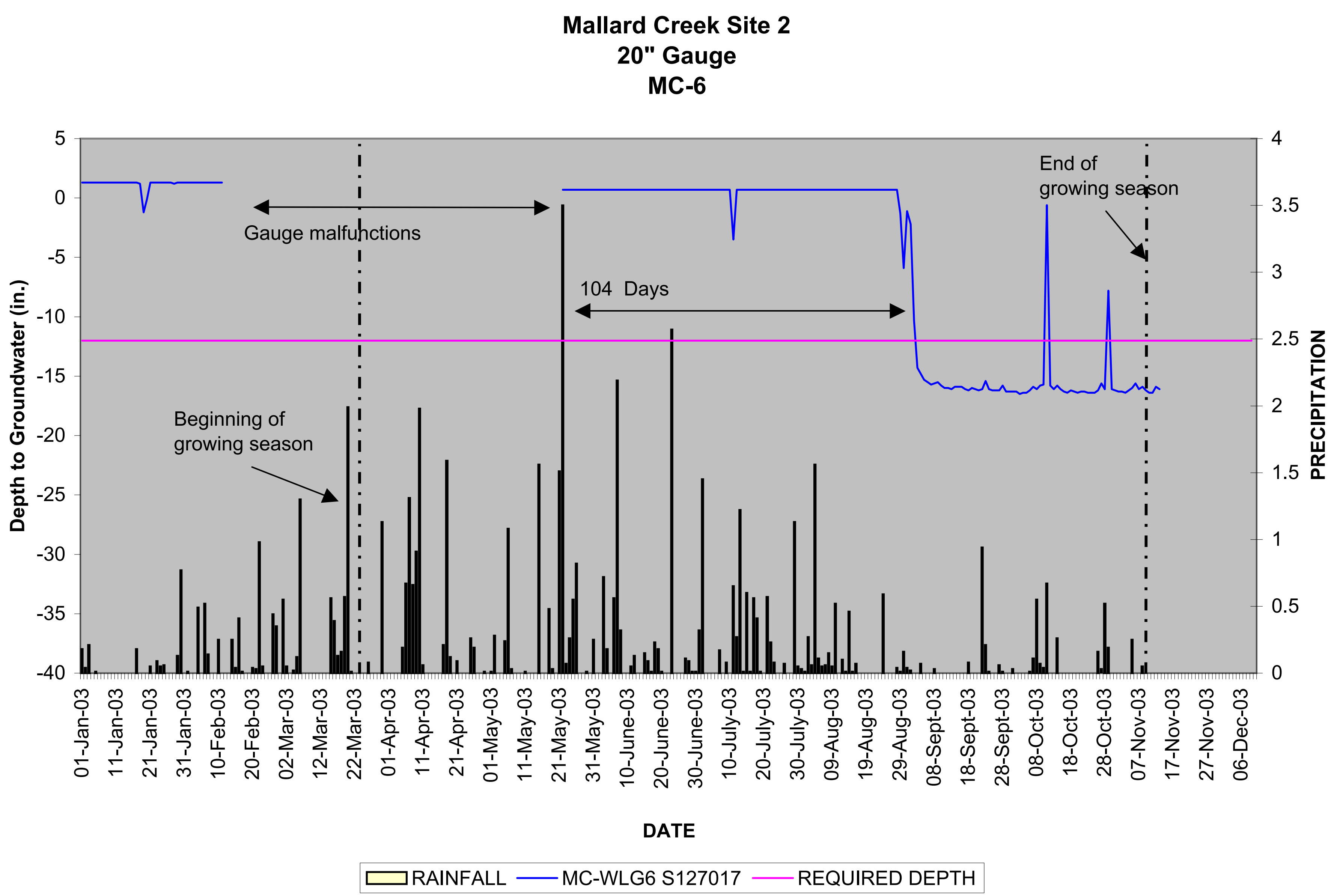
RAINFALL
MC-WLG5 S2B2569
REQUIRED DEPTH



Mallard Creek Site 2
20" Gauge
MC-6
Depth to Groundwater (in.)
PRECIPITATION
DATE
Gauge malfunctions
104 Days
Beginning of growing season
End of growing season
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
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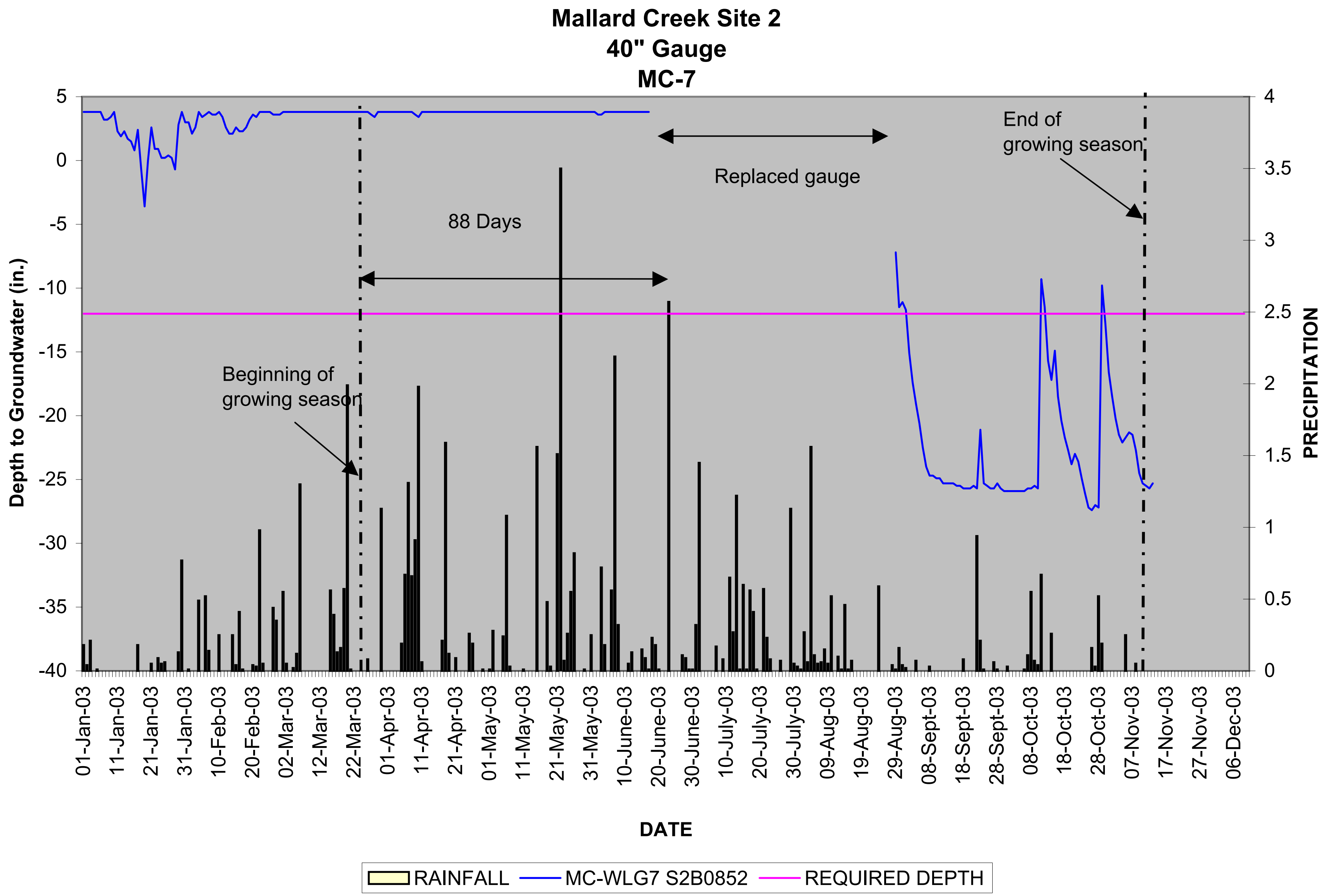
06-Dec-03
RAINFALL
MC-WLG6 S127017
REQUIRED DEPTH


Mallard Creek Site 2
40" Gauge
MC-7
Depth to Groundwater (in.)
PRECIPITATION
DATE
Beginning of growing season
88 Days
Replaced gauge
End of growing season
RAINFALL
MC-WLG7 S2B0852
REQUIRED DEPTH
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
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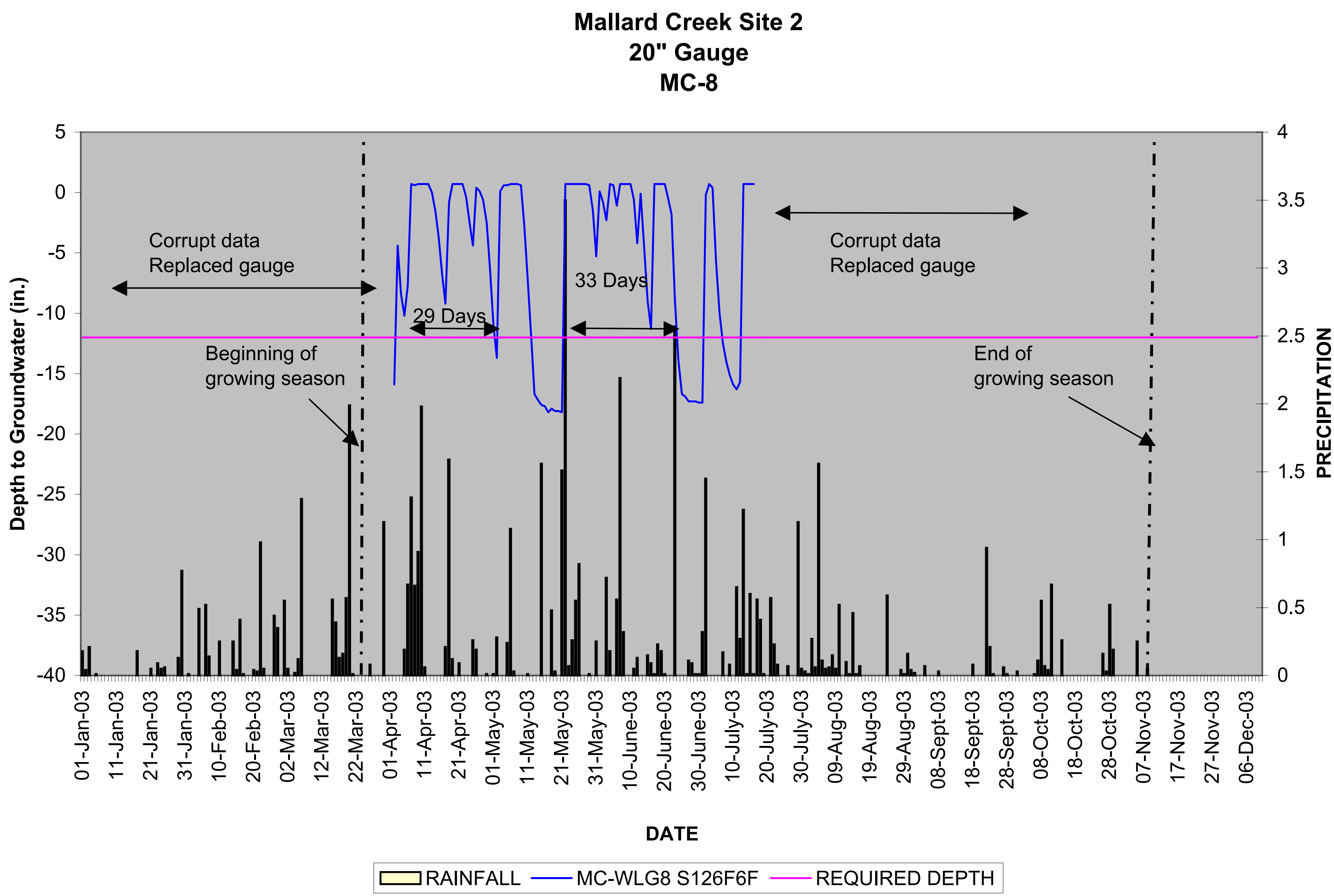
17-Nov-03
27-Nov-03
06-Dec-03



Mallard Creek Site 2
20" Gauge
MC-8
Depth to Groundwater (in.)
PRECIPITATION
DATE
Corrupt data
Replaced gauge
Beginning of
growing season
29 Days
33 Days
Corrupt data
Replaced gauge
End of
growing season
RAINFALL
MC-WLG8 S126F6F
REQUIRED DEPTH
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
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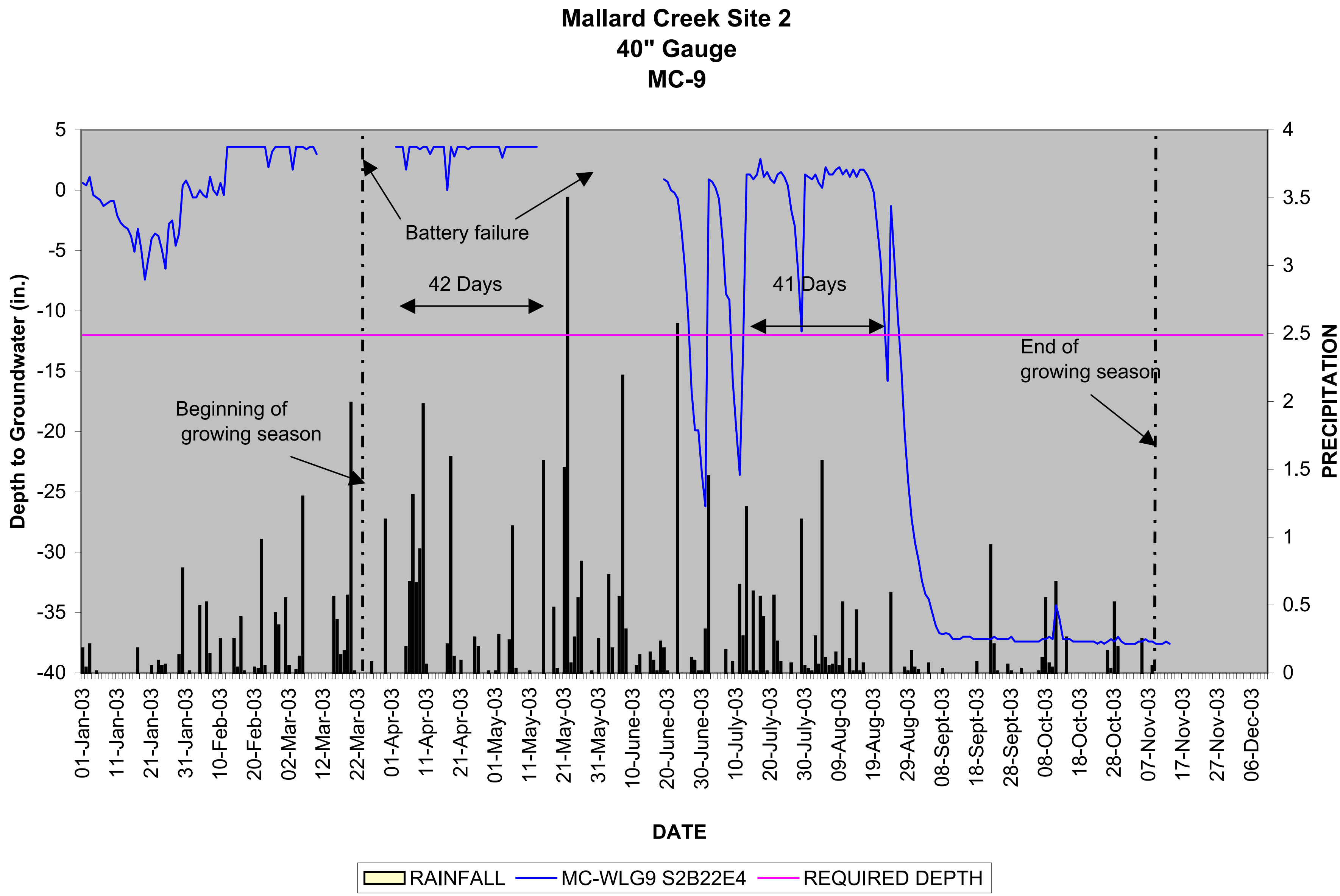
27-Nov-03
06-Dec-03



Mallard Creek Site 2
40" Gauge
MC-9
Depth to Groundwater (in.)
PRECIPITATION
5
0
-5
-10
-15
-20
-25
-30
-35
-40
4
3.5
3
2.5
2
1.5
1
0.5
0
Battery failure
42 Days
41 Days
Beginning of growing season
End of growing season
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
28-Oct-03
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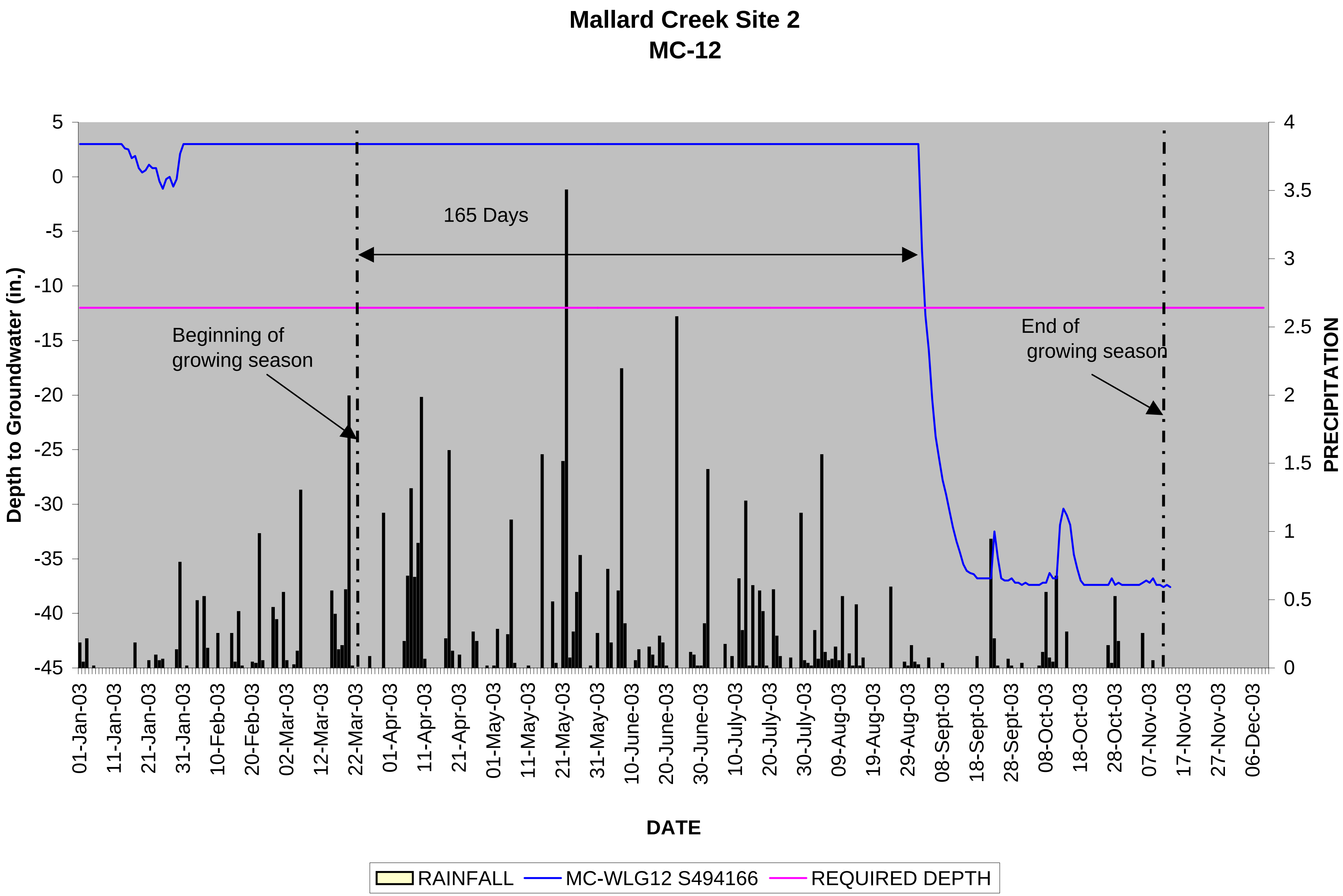
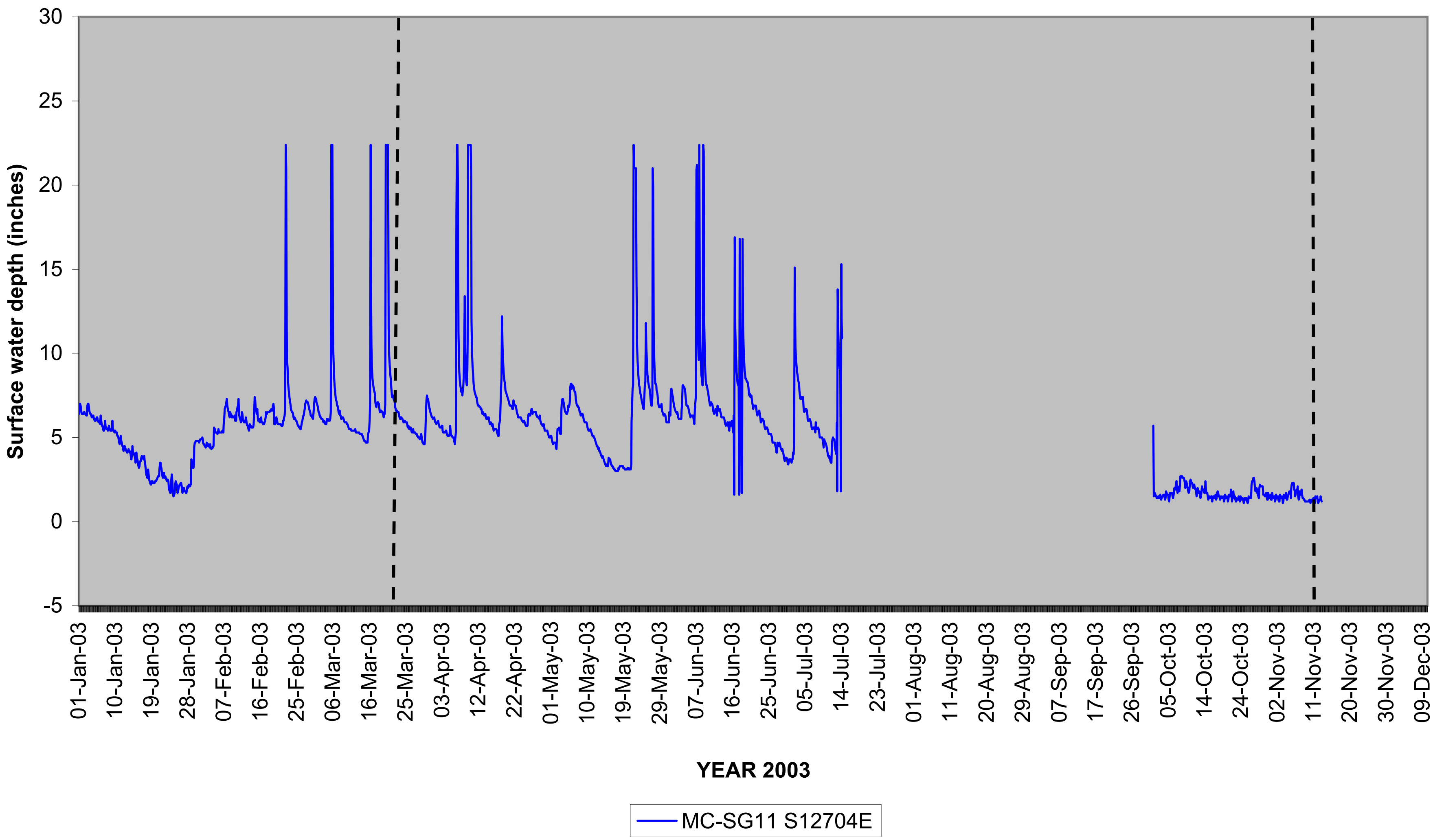
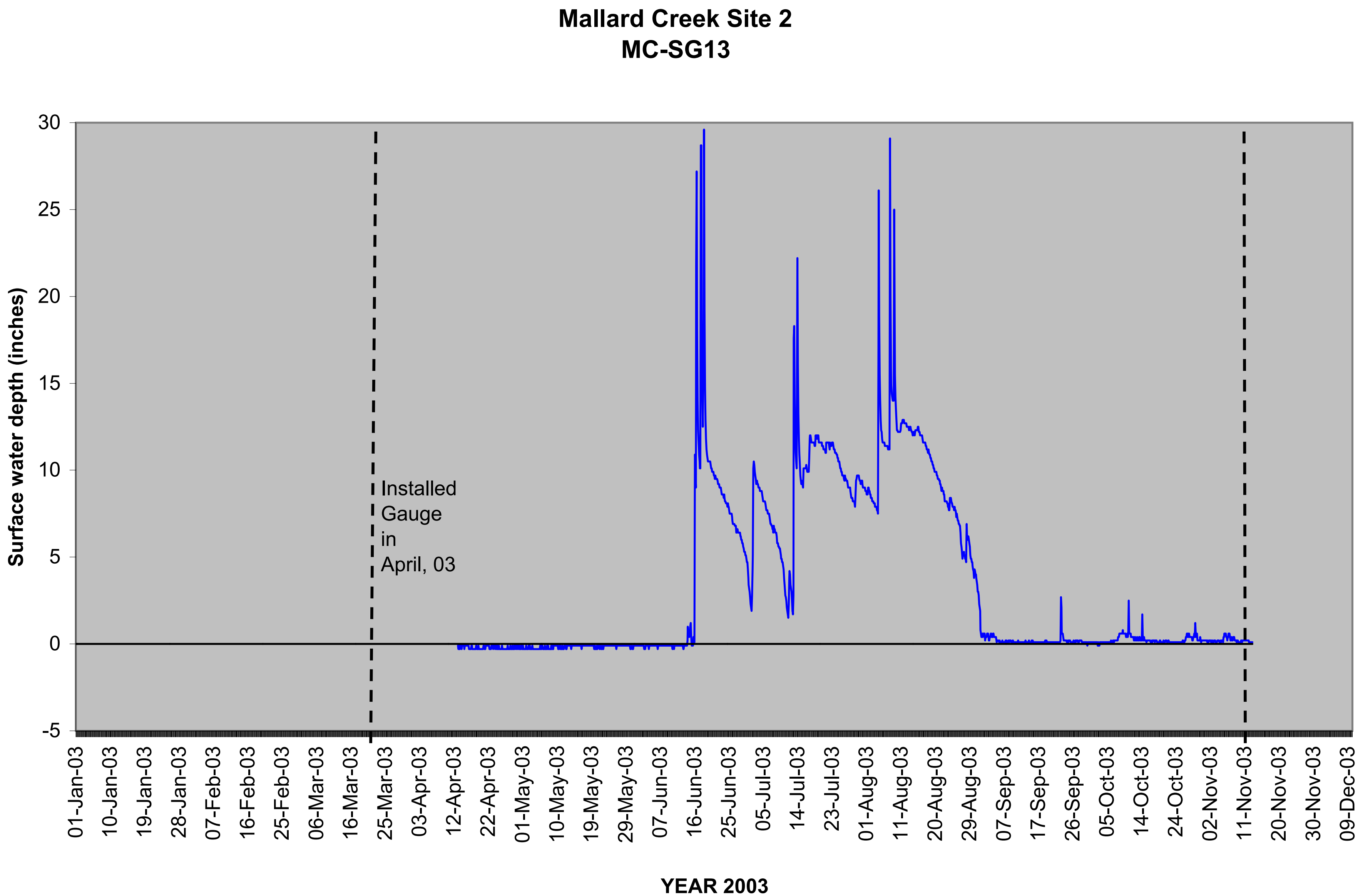
27-Nov-03
06-Dec-03
DATE
RAINFALL
MC-WLG9 S2B22E4
REQUIRED DEPTH


Mallard Creek Site 2
MC-12
165 Days
Beginning of growing season
End of growing season
Depth to Groundwater (in.)
PRECIPITATION
DATE
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
4
3.5
3
2.5
2
1.5
1
0.5
0
01-Jan-03
11-Jan-03
21-Jan-03
31-Jan-03
10-Feb-03
20-Feb-03
02-Mar-03
12-Mar-03
22-Mar-03
01-Apr-03
11-Apr-03
21-Apr-03
01-May-03
11-May-03
21-May-03
31-May-03
10-June-03
20-June-03
30-June-03
10-July-03
20-July-03
30-July-03
09-Aug-03
19-Aug-03
29-Aug-03
08-Sept-03
18-Sept-03
28-Sept-03
08-Oct-03
18-Oct-03
28-Oct-03
07-Nov-03
17-Nov-03
27-Nov-03
06-Dec-03
RAINFALL
MC-WLG12 S494166
REQUIRED DEPTH

SURFACE WATER GAUGE GRAPHS

Mallard Creek Site 1
MC-SG11





Mallard Creek Site 2
MC-SG13
Surface water depth (inches)
30
25
20
15
10
5
0
-5
Installed
Gauge
in
April, 03
01-Jan-03
10-Jan-03
19-Jan-03
28-Jan-03
07-Feb-03
16-Feb-03
25-Feb-03
06-Mar-03
16-Mar-03
25-Mar-03
03-Apr-03
12-Apr-03
22-Apr-03
01-May-03
10-May-03
19-May-03
29-May-03
07-Jun-03
16-Jun-03
25-Jun-03
05-Jul-03
14-Jul-03
23-Jul-03
01-Aug-03
11-Aug-03
20-Aug-03
29-Aug-03
07-Sep-03
17-Sep-03
26-Sep-03
05-Oct-03
14-Oct-03
24-Oct-03
02-Nov-03
11-Nov-03
20-Nov-03
30-Nov-03
09-Dec-03
YEAR 2003

APPENDIX B

SITE PHOTOS

PHOTO AND PLOT LOCATIONS

MALLARD CREEK


Photo 1


Photo 2

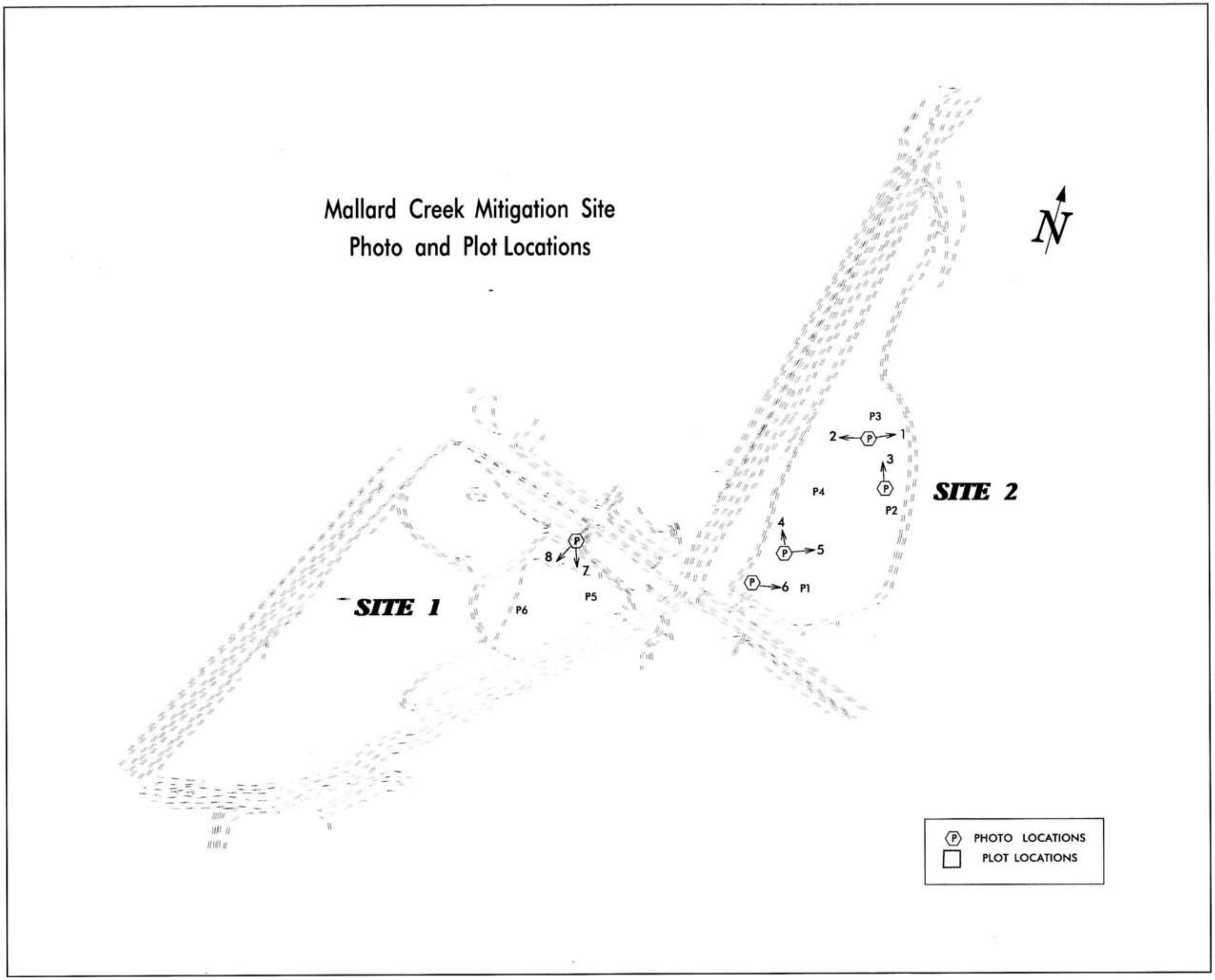

Photo 3


Photo 4


Photo 5


Photo 6

2003



Mallard Creek Mitigation Site
Photo and Plot Locations
N
SITE 1
SITE 2
P1
P2
P3
P4
P5
P6
1
2
3
4
5
6
7
8
PHOTO LOCATIONS
PLOT LOCATIONS

APPENDIX C

MITIGATION SITE SOIL ANALYSIS

INTRODUCTION

The Little Sugar Creek Mitigation Site and Mallard Creek Mitigation Site are the property of the North Carolina Department of Transportation (NCDOT). Both sites are located in Mecklenburg County, NC and have been constructed to provide wetland mitigation for NCDOT road projects in the county.

Little Sugar Creek was constructed in the winter of 1996-97. The site was modified in 2002 in an effort to increase its hydrologic regime. Mallard Creek was constructed in 1994 and underwent remediation in 1997. It is divided into two sites. Site 1 is located south of Mallard Creek Church Road. Site 2 is located on the opposite side of Mallard Creek Church Road.

The hydrologic success as stated in the both Mitigation Plans reads:

> "…that the area must be inundated or saturated (within 12" of the surface) by surface or groundwater for at least a consecutive day percentage of 12.5% of the growing season. Areas inundated or saturated for less than 5% of the growing season are always classified as non-wetlands. Areas inundated or saturated between 5% - 12.5% of the growing season can be classified as wetlands depending on upon factors such as the presence of the wetland vegetation and hydric soils."

Aside from Mallard Creek Site 1, which has met the hydrologic success criteria for five consecutive years, neither Little Sugar Creek nor Mallard Creek Site 2 have yet to fully meet the hydrologic success criteria, despite efforts to modify both sites. As a result, the US Army Corps of Engineers has requested that NCDOT determine the area of each site that has failed to meet the hydrologic success criteria. Furthermore, they have requested that NCDOT immediately provide alternative mitigation for the failed section of the Little Sugar Creek Site through in-lieu payments to the North Carolina Wetlands Restoration Program (WRP).

However prior to abandoning the failed sections and relinquishing the associated mitigation credits, NCDOT has chosen to do additional research on the sites. It is anticipated that this research will determine if the sites exhibit any characteristics that suggest those failed sections could potentially meet the success hydrologic success criteria. To this end, NCDOT has requested The Catena Group, Inc. to investigate both sites, concentrating on the soils perspective.

Purpose

The purpose of this report is to evaluate the Little Sugar Creek Mitigation Site and the Mallard Creek Mitigation Site. The investigation will examine the physical and morphological features of the soils, as well as physical features of each site, in order to determine any correlation between the past and current conditions. Based on these findings, an assessment of the future viability of each site will be performed.

Wetland Creation

Wetland creation has been defined as the conversion of a persistent upland or shallow-water area into a wetland by human activity (Mitsch and Gosselink, 2000). Both of the subject sites can be considered creation sites in that they involved removal and grading of earth to create areas of sustained hydrology at or near the soil surface.

The hydrologic success criteria for both sites require saturation within 12-inches of the soil surface for at least 12.5% of the growing season for five consecutive years. In Mecklenburg County, the growing season begins March 22 and extends through November 11 (235 days), which equates to 29 consecutive days. If alterations are made to the site, then the five-year monitoring periods must begin anew. While both sites have been altered, they have been continually monitored since their creation.

Ecological Development of Created Wetlands

Understanding the complex nature of wetlands well enough to successfully create or restore their function requires substantial training in plants, soils, wildlife, hydrology, water quality, and engineering. According to Mitsch and Wilson (1996), a major flaw in the measurement of wetland mitigation success is the limited amount of time that regulators and the land development process allow for newly created wetlands to develop before passing judgment. After five years of monitoring a mitigation wetland, only a general idea of the wetlands ecological trajectory can be known. The further the conditions are in the beginning from the targeted natural steady state, the longer it will take for that system to reach or approach steady state. For example, the replacement time frame for freshwater marshes is typically 15 or 20 years, far beyond the current requirement of a 5 year establishment. Other wetland types such as forested wetlands, coastal wetlands, or peatlands may take even longer (50 years to a lifetime) for wetland functions to be restored (Mitsch and Gosselink, 2000).

Wetland soils

Wetland soils are both the medium in which many of the wetland chemical transformations take place and are the primary storage of available nutrients for most wetland plants. They are often described as hydric soils, defined by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) as "soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part".

Wetland soils are of two types, mineral or organic. Nearly all soils have some organic material, but when a soil has less than 20 to 35 percent organic matter (on a dry weight basis), it is considered a mineral soil, as are the soils in both mitigation sites.

Wetland Soils Formation

When soils are inundated with water for an extended period, anaerobic conditions usually result. The rate at which oxygen can diffuse through the soil is drastically reduced, about 10,000 times slower than oxygen diffusion through a drained soil. This low diffusion rate leads relatively quickly to anaerobic, or reduced conditions, with the time required for oxygen depletion on the order of several hours to a few days after inundation begins (Mitsch and Gosselink, 2000).

When a mineral soil is exposed to anaerobic conditions, it develops certain characteristics that allow for its identification. These characteristics are collectively called redoximorphic features, defined as features formed by the reduction, translocation, and/or oxidation of iron (Fe) and manganese (Mn) oxides (Mitsch and Gosselink, 2000). Soil inundation results in the development of these features, such as a reduced matrix and redox concentrations (i.e., zones of apparent accumulation of Fe-Mn oxides).

The development of redoximorphic features in mineral soils is mediated by micro-biological processes. The rate at which they are formed depends on four conditions, all of which must be present:

1. Saturated conditions
2. Sustained anaerobic conditions
3. Sufficient soil temperature (5˚ C is often considered "biological zero," below which much biological activity ceases or slows considerably)
4. Presence of organic matter to serve as a substrate for microbial activity (Mitsch and Gosselink, 2000)

If microorganisms are not present, redoximorphic features will not form. If organic carbon levels are too low, there may be insufficient microbial respiration to deplete the diffused oxygen levels, even when the soil is saturated (Richardson and Vepraskas, 2001). Moving water tends to carry oxygen into the soil and retards the onset of Fe reduction (Richardson and Vepraskas, 2001). The time required for Fe reduction to occur after initiation of saturation or inundation depends on soil conditions. Studies indicate that Fe reduction can take as little as one day to as long as four or more weeks (Richardson and Vepraskas, 2001). There is a lag between the onset of saturation and the onset of Fe reduction, and the length of the lag period depends on both soil temperature and organic matter percentage (Richardson and Vepraskas, 2001).

The oxidation of Fe can occur quickly. Laboratory experiments have shown that after eight hours approximately 78% of the ferrous iron had oxidized at 20˚ C while approximately 60% of the iron had oxidized in three hours (Richardson and Vepraskas, 2001).

A reduced matrix requires that the ferric iron cations in oxides or hydroxides to be reduced. Iron depletions require the same conditions as a reduced matrix and that the solubilized ferrous iron has moved to another portion of the soil. The formation of redox concentrations requires the solubilized iron from one area of the soil to become oxidized in another areas of the soil, forming Fe masses, pore linings, or nodules. The time required to form a reduced matrix has not been determined (Richardson and Vepraskas, 2001).

Oxidized rhizospheres are another characteristic of mineral wetland soils. They result from the capacity of many hydrophytes to transport oxygen through above-ground stems and leaves to below-ground roots. Mineral soils that are seasonally flooded, particularly by alternate wetting and drying, develop spots of highly oxidized materials called redox (redoximorphic) concentrations. Redox concentrations are orange/reddish-brown due to iron, or dark reddish-brown/black spots due to manganese. Redox concentrations are relatively insoluble, enabling them to remain in soil long after it has been drained (Mitsch and Gosselink, 2000).

Another extremely important factor in the development of soils is the development of vegetation. Bare exposed soil has a much slower rate of infiltration and a higher rate of runoff than soil with established vegetation. As vegetation becomes established it performs the following functions:

- reduces the amount of soil erosion
- retains water on the site for longer periods, thus increasing the time for infiltration
- forms an insulating layer that retains moisture in the soil

- provides food and cover thereby promoting the growth of micro and macro organisms.

In addition to these functions, as the roots develop in the soil and development of soil structure ensues, the following benefits are realized:

- increased porosity and water infiltration
- subsurface accumulation of organic matter and improved water holding capacity
- creation of pathways for micro and macro organisms and nutrients to enter the soil.

While these functions are listed separately, they are interdependent and self promoting. The development of soils and plants will continually compliment one another even after the wetland has reached steady state.

Wetland Soils – Current Versus Relict Redoximorphic Features

Redox concentrations indicate where oxidation has occurred in the past. By themselves, these features give no indication of how long a soil has been saturated and reduced. A relict reduction feature is one that has formed in the past and persists in the soil where it can no longer form today, thus giving the impression a soil is wetter than it really is. Redoximorphic features that are either redox depletions or redox concentrations are the most likely morphological features to be relict. The reduced matrix must be kept reduced and can never be relict. Any time a morphological feature, which had to form along a macropore, is found in the matrix or away from a pore, it can be assumed that it did not form recently and should be considered relict. When redox concentrations form, they have diffuse boundaries, sometimes seen as a halo or ring, around the iron concentration. Diffuse boundaries are assumed to indicate that the feature is forming or has formed in the recent past and is reflecting current hydrologic conditions. When redox concentrations begin to dissolve, or are mixed into the matrix, they acquire sharp boundaries within the matrix, and are thus considered features that are no longer forming, or relict (Richardson and Vepraskas, 2001).

Occasionally morphological features do not form in soils that are seasonally saturated and reduced, especially floodplain soils. The reasons for this are not completely understood, but probably relate to the fact that little Fe reduction occurs, possible due to one or more of the following: low amounts of organic carbon at the time of saturation, a high pH, high levels of manganese oxides in the soil, or large amounts of dissolved oxygen in the water (Richardson and Vepraskas, 2001).

LITTLE SUGAR CREEK MITIGATION SITE

The Little Sugar Creek Mitigation Site occurs within the Charlotte Belt which is composed of igneous and metamorphic rocks covered by regolith consisting of weathered in place residuum and soil. Field activities revealed that bedrock on site is overlain by 10 to 15 feet of clayey soil at the surface with saprolite underneath. The landscape is characterized by a low floodplain with clay ridges, small depressions, and relict stream channels (ESI, 1995).

The soils were mapped by the NRCS as being dominated by the Monacan mapping unit. These are nearly level, somewhat poorly drained soils that have a predominantly loamy subsoil and were formed in fluvial sediment on floodplains (Soil Conservation Service, 1980). The construction plan called for the removal and stockpiling of the top six inches of the soil for replacement once the grading was completed.

Personnel from The Catena Group, Inc. visited the site on October 20, 2003. A hand auger was used to perform detailed soil boring analyses adjacent to four groundwater monitoring gauges, LSC 4, 6, 8, and 11. A detailed description of each is included in Attachment A. The first profile, Soil Profile 1, was performed at LSC 6, which met the hydrologic success criteria for greater than 12.5% of the growing season in 2002.

The soil at LSC 6 showed clear evidence of recent development of redoximorphic features near the soil surface. There were both concentrations and depletions in the top 13 inches, which also corresponded with the effective rooting depth. In the horizons below the root zone, only areas of concentrations were found, including manganese masses, until the C3 horizon, at a depth of 51+ inches, where depletions of chroma 2 began.

The soil profile at LSC 6 is fluvial in origin with little development. However, the fact that areas of depletions are present in the surface horizons (in correlation with the 13 inch effective rooting depth), yet not below this level, indicates that this soil is only just beginning to develop. It is anticipated that as the vegetation continues to establish itself, the soil will continue its development. This will result in the development of improved infiltration and wetter conditions for the reasons previously detailed in this report.

Soil Profile 2 was taken adjacent to LSC-4, which thus far has had a hydrologic regime of less than 5% of the growing season. This soil has developed from residuum, as opposed to fluvial sediments. In this soil, areas of depletions and concentrations are evident throughout the soil profile in contrast and abundance typical of more well developed soils.

The surface horizon of Soil Profile 2 is 10 inches thick and has areas of concentrations and depletions. The subsurface horizon immediately beneath the surface horizon exhibits the same colors and features except for the lack of depletions. This is the same trend noted in Soil Profile 1. However, in Soil Profile 2 the depletions were few and faint while those in Soil Profile 1 were common and distinct, which corresponds well with the slightly reduced hydrologic regime registered near LSC-4. Nevertheless, the important item of note is that this area also appears to be developing hydric soil, albeit at a slower pace than LSC-6, and assuming conditions remain constant, the area is expected to become wetter over time.

Soil Profile 3 was placed near LSC-8, which in 2002 met the wetland hydrology criteria for 12.3% of the growing season. This profile exhibits the same features and characteristics as those in Soil Profile 1, except that the development of the surface horizon(s) is even more pronounced than the subsurface horizons.

Soil Profile 4 was taken near LSC-11, which in 2002 met the wetland hydrology for 6.8% of the growing season. The spreading of topsoil after grading was completed is clearly evident at this site. The topsoil layer is 8 inches and is immediately underlain by parent material. However, once again, areas of concentration and depletions are evident in the topsoil. While this soil will also continue to develop, it is anticipated that it will take considerably longer since the underlying parent material is a medium that is more difficult to weather and develop than the soil found in other areas of the site.

MALLARD CREEK MITIGATION SITE

Less design information is available on the Mallard Creek Mitigation Site, but the information obtained suggests that the site was graded down to where the average ground water table exists, as much as 24-inches in some locations. The well data over two years in the late 1990's indicates that Site 1 met the wetland hydrology requirements while Site 2 was failing in some areas and successful in others.

Personnel from The Catena Group, Inc. visited the site on October 20, 2003. A hand auger was used to perform detailed soil boring analyses adjacent to three monitoring gauges, MW- 2, 5, and 8. The detailed description of each is included in Attachment B.

The first profile, Soil Profile 5, was taken at MW-2 in Site 1. This profile exhibited more hydric features than any of the other profiles. As might be expected, this area has proven to be the wettest area in either mitigation site, based on groundwater gauge data. This soil is developing from alluvial sediments and actually revealed a buried hydric soil horizon at 41 inches. Also interesting to note is the lushness and density of the vegetation throughout this site when compared with the vegetation from the others.

Soil Profiles 6 and 7 were performed in Site 2 at MW-8 and MW-5, respectively. The most obvious difference between profile 5 and profiles 6 and 7 is that these soils are developing from residuum. This soil was graded down to the target elevation without any topsoil placed back over the top. Newly formed redoximorphic features are much more difficult to discern in these profiles since they are developing in a soil medium that already contained both relict and recently developed redoximorphic features. Nevertheless, there appears to be some evidence that these soils are beginning to develop such as small manganese concretions and oxidized rhizospheres.

DISCUSSION

The soils at both the Little Sugar Creek and Mallard Creek Mitigation Sites exhibit signs of recent soil development that is occurring at least partially under hydric conditions. Sites that have been consistently wetter exhibit more hydric features that are easier to discern than those which have been drier. This does NOT necessarily indicate that these wetter areas are simply exposed to longer periods of inundation. There are likely a multitude of other factors, such as better soil structure or more organic matter in the soil, that are causing differences in hydroperiod.

Stolt et al. (2000) note other factors that often impact soils in created wetlands:

1. As the top soil was removed and reapplied once grading was completed, the soil profiles were altered in a way that may be hindering the steady pace of hydric soil development.
2. Soils of constructed wetlands are often higher in temperature due to the lack of vegetation and organic matter, and possibly drier conditions. This leads to faster microbial activity and less accumulation of organic matter.
3. The water table rises and falls more quickly in constructed wetlands than in natural wetlands. This may be due to the lack of organic matter and soil structure. Soils high in organic matter have higher water holding capacities, which, in turn, improve reducing conditions.
4. In areas that are graded down, the exposed soil layer has not had the same exposure to the level of organic acids and intensity of weathering as subsoil in a natural wetland.

The effect of vegetation cannot be understated. Plants add organic matter and increase structure (through root growth) so that more water can infiltrate and percolate down through the soil profile. As plants die and detritus is incorporated into the soil profile by microorganisms and other fauna, the organic matter content increases, increasing water holding capacity and structure. This process takes time. Initially, more surface water will run off then infiltrate into the soil. Once plants are established and the amount of organic matter starts to increase, more water will infiltrate into the soil, the water holding capacity will continue to increase, and the soils will start to display more hydric indicators.

The soil profiles show that recently developed redoximorphic features are present. While there is no guarantee that these soils will eventually become hydric, they need more time to develop before any conclusions can be reached. All wetlands take time to form, especially constructed wetlands. They should not be expected to form quickly. If the desired hydrology takes longer than expected to become established, so will hydric soils and hydrophytic plants. This does not necessarily mean, however, that these mitigation sites are not achieving some of the desired functions that they were intended to perform. They both capture storm water runoff from nearby roadways, and the Little Sugar Creek site also retains water from the nearby shopping mall/hospital complex. These functions should not be overlooked while these sites continue to develop.

ATTACHMENT A

Little Sugar Creek Soil Profiles

Soil Profile 1 (LSC-6)

A 0-7 inches; dark yellowish brown (10YR 3/4) silt loam with common distinct strong brown (7.5YR 5/8) concentrations and common distinct brown (10YR 4/3) concentrations; friable, medium, subangular blocky structure breaking to coarse granular structure.

Bw1 7-13 inches; strong brown (7.5YR 5/6) sandy loam with few prominent dark red (2.5YR 3/6) concentrations and common distinct light yellowish brown (10YR 6/4) depletions; friable, medium subangular blocky structure. Effective rooting depth 13 inches.

Bw2 13-24 inches; strong brown (7.5YR 5/6) sandy loam with few distinct yellowish red (5YR 5/8) concentrations; very friable, subangular blocky structure. Hard manganese concretions present.

C1 24-38 inches; yellowish brown (10YR 5/6) sandy loam; massive structure. 20% manganese concretions.

C2 38-51 inches; yellowish brown (10YR 5/6) sandy loam, massive structure. 25% hard manganese concretions and soft manganese masses.

C3 51-60+ inches; light yellowish brown (10YR 6/4) sandy loam with few distinct light brownish gray (10YR 6/2) depletions; massive structure.

Soil Profile 2 (LSC-4)

A1 0-10 inches; dark yellowish brown (10YR 4/6) fine sandy loam with common distinct strong brown (7.5YR 4/6) concentrations and few faint dark yellowish brown (10YR 4/4) depletions; friable, granular structure.

A2 10-16 inches; dark yellowish brown (10YR 4/6) fine sandy loam with common faint strong brown (7.5YYR 4/6) concentrations; very friable, granular structure. Effective rooting depth 15 inches.

EB 16-28 inches; strong brown (7.5YR 4/6) sandy loam with common distinct brown (10YR 4/3) depletions; very friable, coarse subangular blocky structure.

Btg1 28-45 inches; brown (7.5YR 4/4) clay loam with common faint strong brown (7.5YR 4/6) concentrations and common distinct dark grayish brown (10YR 4/2) depletions; firm, subangular blocky structure.

Btg2 45-60+ inches; brown (7.5YR 4/4) clay with common faint strong brown (7.5YR 4/6) concentrations and many distinct dark graying brown (10YR 4/2) depletions; firm, subangular blocky structure. Common soft manganese masses.

Soil Profile 3 (LSC-8)

A 0-3 inches; dark yellowish brown (10YR 4/4) sandy loam with common distinct strong brown (7.5YR 4/6) concentrations and few faint brown (10YR 4/3) depletions; friable, subangular blocky breaking to granular structure.

Bw 3-9 inches; dark yellowish brown (10YR 4/4) clay loam with few distinct strong brown (7.5YR 5/6) concentrations and common distinct dark grayish brown (10YR 4/2) depletions; friable, subangular blocky structure. Effective rooting depth 10 inches.

BC 9-22 inches; dark yellowish brown (10YR 4/4) sandy loam, very friable, weak subangular blocky structure.

C 22-60+ inches; dark yellowish brown (10YR 4/6) sandy loam; massive structure.

Soil Profile 4 (LSC-11)

A 0-8 inches; yellowish brown (10YR 5/4) clay loam with few distinct strong brown (7.5YR 5/8) concentrations and common faint brown (10YR 5/3) depletions; friable, subangular blocky structure. Effective rooting depth 8 inches.

2C 8+ inches; parent material.

ATTACHMENT B

Mallard Creek Soil Profiles

Soil Profile 5 (MW-2)

A 0-6 inches; dark yellowish brown (10YR 4/4) silt loam with common distinct grayish brown (10YR 5/2) depletions and few distinct strong brown (7.5YR 4/6) concentrations; friable, subangular blocky structure.

Bw 6-16 inches; dark yellowish brown (10YR 4/4) clay loam with common distinct grayish brown (10YR 5/2) depletions, few distinct strong brown (7.5YR 4/6) concentrations, and few prominent red (2.5YR 4/6) concentrations; friable, subangular blocky structure. Effective rooting depth 12 inches.

2C 16-22 inches; dark yellowish brown (10YR 4/4) sandy clay loam with many distinct grayish brown (2.5Y 5/2) depletions and common distinct yellowish red (5YR 4/6) concentrations; friable, subangular blocky structure.

3Cg 22-30 inches; grayish brown (2.5Y 5/2) silt loam with common prominent yellowish red (5YR 4/6) concentrations; friable, subangular blocky structure.

4C 30-41 inches; dark yellowish brown (10YR 4/4) sandy clay with common distinct grayish brown (10YR 5/2) depletions; firm, subangular blocky structure.

Ab 41-55 inches; gray (10YR 5/1) clay loam with common distinct strong brown (7.5YR 5/8) concentrations; firm, subangular blocky structure.

Bgb 55-60+ inches; gray (10YR 5/1) sandy loam with few distinct yellowish brown (10YR 5/8) concentrations.

Soil Profile 2 (MW-8)

AB 0-12 inches; strong brown (7.5YR 4/6) clay loam with many distinct brown (10YR 5/3) depletions; friable, coarse, subangular blocky structure. Common, small manganese concretions.

Bt 12-26 inches; brown (10YR 5/3) clay loam with many distinct yellowish red (5YR 4/6) concentrations; friable, subangular blocky structure.

Btg1 26-39 inches; gray (10YR 5/1) clay with many distinct dark yellowish brown (10YR 4/6) concentrations and common distinct yellowish brown (10YR 5/8) concentrations; friable, subangular blocky structure.

Btg2 39-48 inches; gray (10YR 6/1) clay with many distinct brownish yellow (10YR 6/8) concentrations; very firm, subangular blocky structure.

Btg3 48+ inches; bluish gray (5PB 6/1) clay with many prominent yellowish brown (10YR 5/8) concentrations; very firm, subangular blocky structure. Few manganese concretions present.

Soil Profile 3 (MW-5)

AC 0-6 inches; brown (7.5YR 4/4) clay loam with many distinct strong brown (7.5YR 5/6) concentrations and common distinct brown (10YR 4/3) depletions; friable, subangular blocky structure.

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