Impacts of Acid Precipitation and Buffering on Two Lotic Ecosystems

A Report to the Pierce Cedar Creek University Consortium Research Board

Submitted by Taryn Dunham, Central Michigan University and Professor Thomas K. Rohrer, Director of Environmental Studies, Central Michigan University, Mount Pleasant MI 48859.

Introduction

Our project evaluated the impact that a large, upstream body of water might have on buffering acidic rainfall reaching a small Michigan stream as compared to an adjacent stream without such an upstream body of water. The stream selected for study was Cedar Creek, a small lowland stream having a moderately sized lake as part of its drainage basin. Brewster Lake is a small, inland lake of glacial origin located in Baltimore Township of Barry County, Michigan. It has been isolated from any industrial use or public access since at least 1952. The lake has been classified as a meso-oligotrophic lake and has been the subject of limited research (Pierce, pers. comm.; Cimo and Wolfson, 2001). The outfall of the lake drains into Cedar Creek.

The lake is located entirely within the Pierce Cedar Creek Institute property and is part of a dedicated nature preserve. Pierce Cedar Creek Institute is located on 661 acres of land. The makeup of the property is 40% forest cover, 45% wetlands, 13% upland forest and fields, and 2% lake surface. The previous owner of the majority of the property, naturalist Dr. H. Lewis Batts, protected the land from development or degradation, and most of it has remained untouched for the past 50 years. The Batts family had a small cottage near the shore of the lake but used it infrequently so that even recreational pressures were minimal. Pierce Cedar Creek Institute maintains the property as a preserve under an easement granted by Southwest Michigan Land Conservancy (PCCI, 2005). This makes this lake ideal for limnological study and could serve as a basis for a long-term ecological research (LTER) site.

The soils surrounding Brewster Lake and Cedar Creek are classified as Houghton muck. This soil has a typical surface layer of black muck and has a moderately slow to moderately rapid permeability. Also the available water capacity is very high and the surface runoff is very slow. Most areas of this soil support wetland shrubs or marsh grasses.

The ridges on Pierce Cedar Creek Institute property are made of a Marlette-Oshtemo complex that is 40-50 percent Marlette soil and 40-45 percent Oshtemo soil. The Marlette soils typically have a dark grayish brown loam surface layer, and moderately slow permeability. They also have a high available water capacity and very rapid surface runoff. The Oshtemo soils typically have a surface layer of dark brown sandy loam, and moderately rapid permeability. Their available water capacity is moderate and they have a medium surface runoff. This complex of soil is common around lakes and swamps and along rivers. As part of this study we also evaluated the buffering capacity of native soils on pH.

Limnological Profiles from Previous Studies

Studies conducted by Honsowitz and Rohrer of Central Michigan University in 2005 provided a good baseline of pH data for the Brewster Lake ecosystem. The pH of Brewster Lake water from samples collected in the 2005 study varied from 6.7 to 10.1. pH generally was highest in surface water samples and decreased with depth. Organic acids in lake sediments may have been responsible for this observation. There also appeared to be a relationship between lake water pH and the relative contribution of surface and groundwater sources to the lake water. Early in the study, during an extremely dry period when groundwater sources would have been expected to dominate, the pH was higher, running from 7.5 to 9.5 at surface to mid-depths. During one sampling period, approximately 24 hours after a major rain event, the pH dropped to 7.5 to 7.8 throughout the water column. It was expected that this was the result of the inflow of acidic precipitation to the lake basin after the rain event that was caught before buffering by carbonates and bicarbonates was complete.

Materials and Methods

The pH measurements of the water column were conducted using a YSI multiparameter probe with a 10-meter cable for the sensor unit. Measurements were made for dissolved oxygen, pH, and temperature, a minimum of three days per week over the 12-week study period. Fixed rain collection gauges were also established and rainfall measured throughout the study period. Rain water pH was measured after precipitation events. Actual sampling events and duration were determined in the field based on precipitation events and weather patterns. Measurements were taken at the locations shown on the attached map. The data collected was evaluated to determine how the two branches of Cedar Creek respond to inputs of acid precipitation.

Limnological profiles were made periodically to show how the temperature, pH, and dissolved oxygen of Brewster Lake varied compared to depth. These profiles were made by taking measurements with the YSI multiparameter probe at one foot intervals, starting with the waters surface and ending approximately one foot above the lake bottom. Each profile was recorded and based on a northern sink hole of Brewster Lake.

A total of twenty-five soil samples were also collected from the sub-drainage basins of each stream watershed using a stainless steel soil borer. The samples were homogenized, using ten grams from each sample to make the mixture, and then divided up into five samples of fifty grams each. These five samples were added to given solutions with different pH values and evaluated to see how the general soil makeup of the sub-drainage basins responds to precipitation with different levels of pH. Also, samples from the upland soils as well as the wetland soils were prepared separately but in the same manner in order to evaluate how they individually respond to the solutions with different levels of pH.

Results and Discussion

The goal of the project was to determine if acid precipitation has a measurable impact on in-stream pH levels for various time periods after precipitation events and if upstream waters exert any buffering effect on in-stream pH. The hypothesis was that the stream having a large upstream body of water (Brewster Lake) contributing to its flow would be able to more quickly buffer out the impacts of the acid precipitation and exhibit a higher pH after rain events than the adjacent stream which did not have this upstream body of water to provide buffering capacity. The null hypothesis was that there would be no significant difference in the results from the two streams.

The data showed that there was no significant difference in the results from the two stream reaches. By comparing the tables from all sites it could be seen that the variation in pH was not significant enough to state that the stream with the large upstream body of water contributing to its flow could more quickly buffer out the impacts of the acid precipitation and exhibit a higher pH after rain events than the adjacent stream. It could also be concluded from the data that acid precipitation did not have a measurable impact on in-stream pH levels.

A possible source of error in the results was the lack of substantial rainfall for the research period. Also, when looking at the data it can be seen that there is a natural variation in the pH, temperature, and dissolved oxygen percentage of the waters. This natural variation could have covered up a change caused by any acid precipitation.

From the soil data collected it could be concluded that the homogenized mixture of soil had the ability to raise the pH of the solutions added to a neutral level. It could also be concluded that the upland soils reacted in the same way while the wetland soils lacked the ability to significantly make a change to the solutions pH. This indicated that overall the soils in the drainage basin as well as the upland soils were capable of neutralizing acid precipitation however the wetland soils were not.

Recommendations for Further Study

It is recommend that further study be performed to determine the specific ionic components of upland and wetland soils to determine which ions may be present and act to raise the pH of ambient precipitation from the basin.

References:

American Public Health Association. 2001. Standard Methods for the Examination of Water and Wastewater. AMPH. Washington, D. C. 974pp.

Berresheim, H.; Wine, P.H. and Davies D.D., (1995). Sulfur in the Atmosphere. In Composition, Chemistry and Climate of the Atmophere, ed. H.B. Singh. Van Nostran Rheingold.

Brimblecombe, P (1996). Air Composition and Chemistry. Cambridge University Press. ISBN 0-521-45366-6

Cimo, L. F. and L. G. Wolfson. 2001. Brewster Lake Qualitative Assessment. Report to the Pierce Cedar Creek Institute (unpublished). 11 pp. + appendices.

Eisenberg, D. and W. Kauzmann. 1969. The Structure and Properties of Water. Oxford University Press. New York. 296pp.

Guthrie, Michael. 2005. Natural Resource Conservation Service. United States Department of Agriculture. East Lansing MI. Personal communication.

Hutchinson, G. Evelyn. 1938. Chemical stratification and lake morphology. Proc. Nat. Acad. Sciences. 24:63-69.

Hutchinson, G. E. 1957. A Treatise on Limnology. John Wiley and Sons. New York. 1015 pp.

Hynes, H. B. N. 1970. The Ecology of Running Waters. University of Toronto Press. Toronto, Ontario, Canada. 202pp.

Pierce Cedar Creek Institute. 2005. Web site at www.cedarcreekinstitute.org
USGS. 2000. The term "acid rain" is commonly used to mean the deposition of acidic components in rain, snow, fog, dew, or dry particles. The more accurate term is "acid precipitation." (USGS)

Seinfeld, John H.; Pandis, Spyros N (1998). Atmospheric Chemistry and Physics - From Air Pollution to Climate Change. John Wiley and Sons, Inc. ISBN 0-471-17816-0

Rodhe, H., et. Al.(2005) “The Global Distribution of Acidifying Wet Deposition.” Environmental Science & Technology. v. 36 no. 20 (October 15 2005) p. 4382-8.

US Department of Agriculture. 1990. Soil Survey of Barry County, Michigan. National Cooperative Soil Survey. 187 pp + soil survey maps.

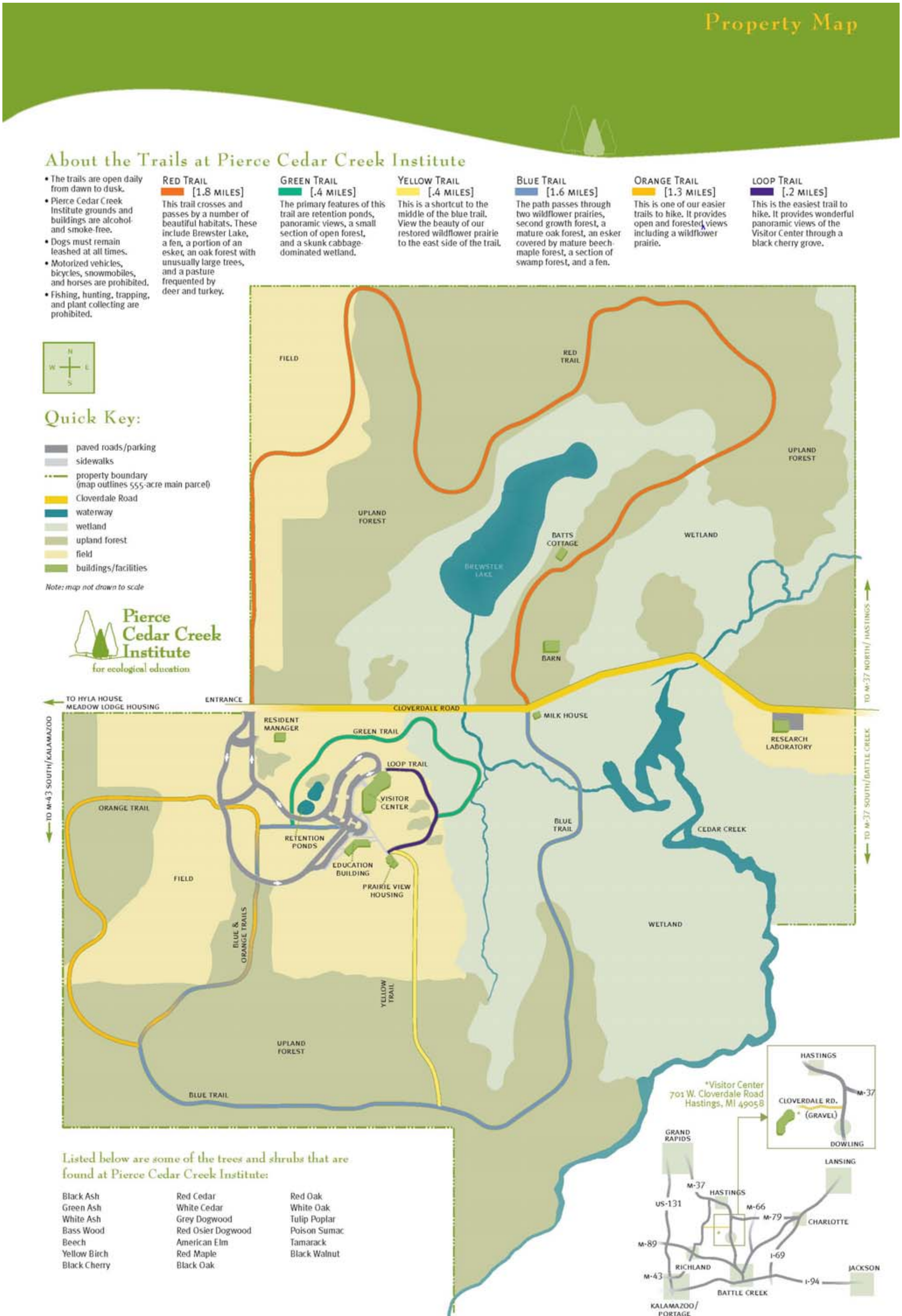
USGS. 2000. The term "acid rain" is commonly used to mean the deposition of acidic components in rain, snow, fog, dew, or dry particles. The more accurate term is "acid precipitation." (USGS)

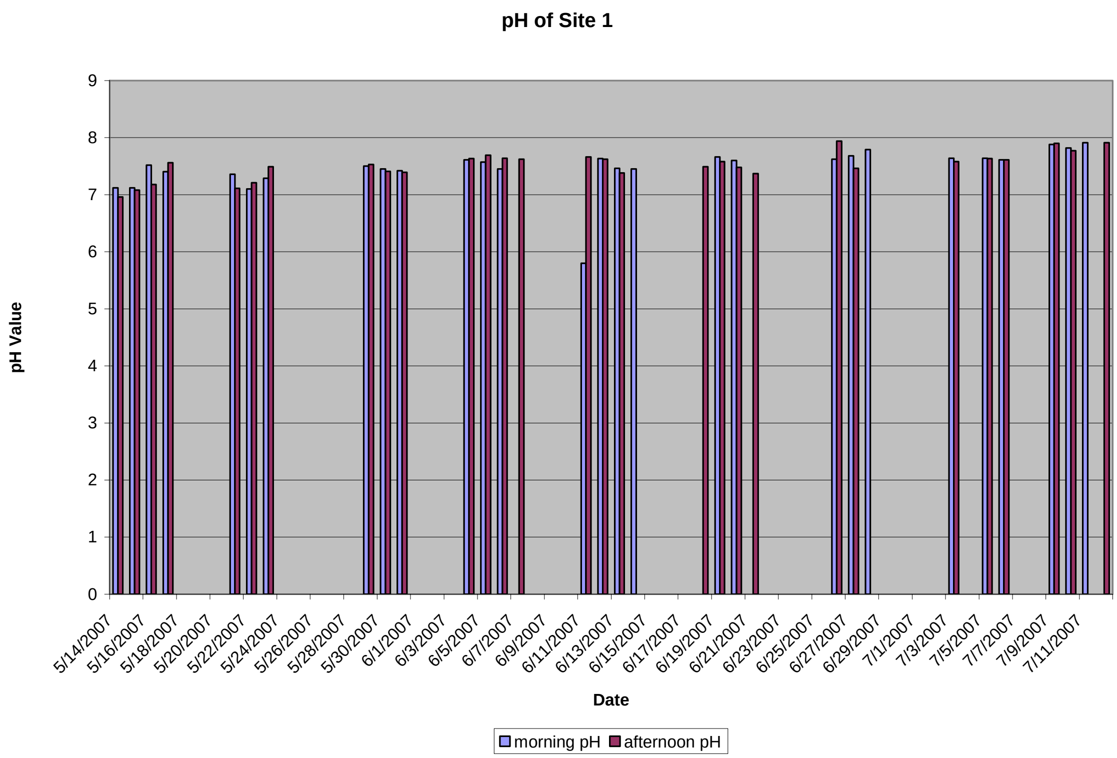
Wetzel, Robert G. 1975. Limnology. W.B. Saunders, Company, Philadelphia. 743pp.

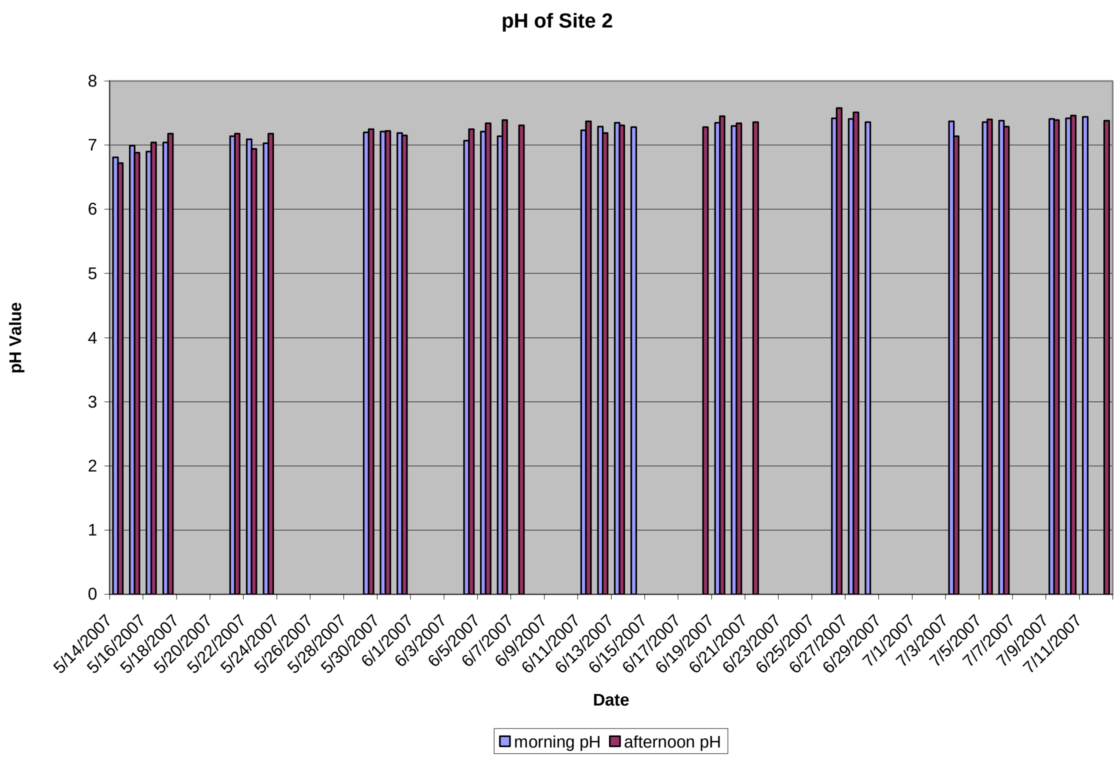
Attachments:

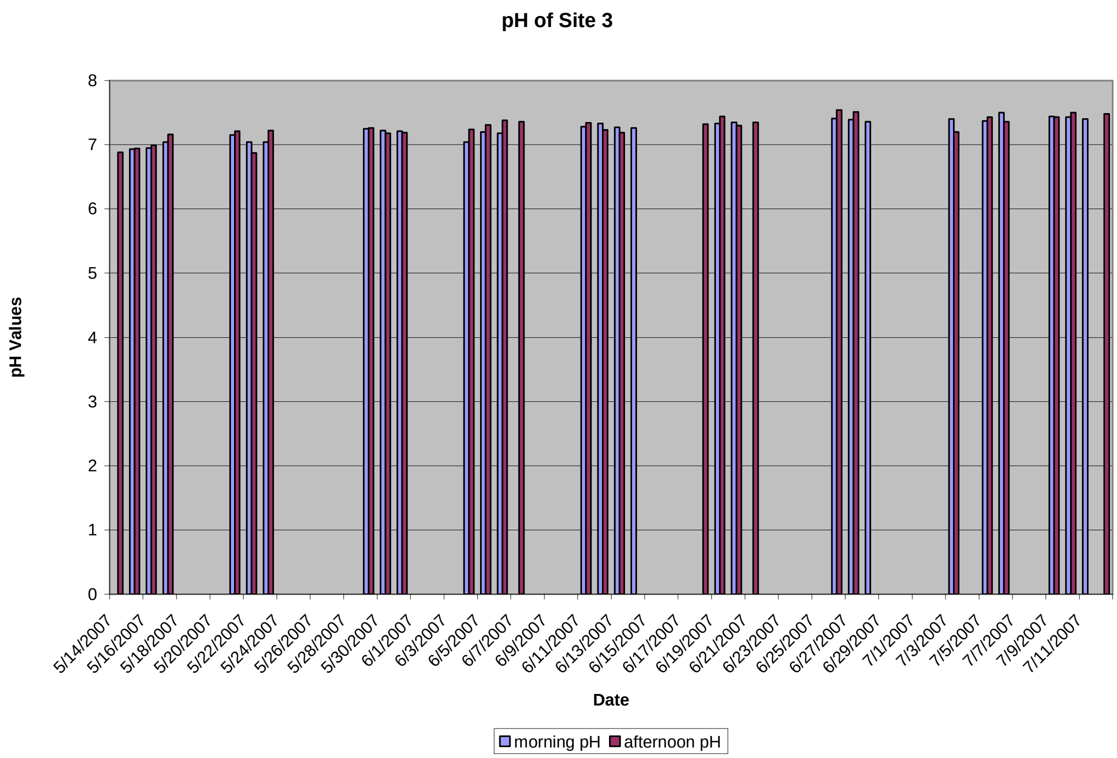
Study location map

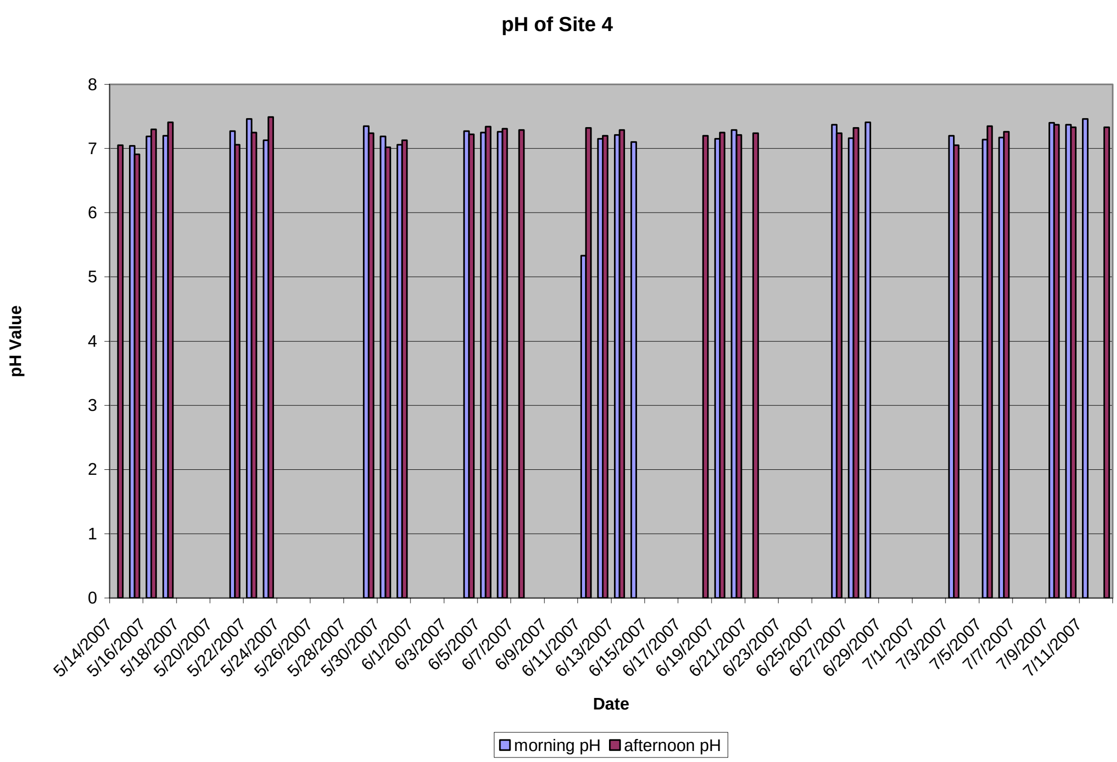
Data tables

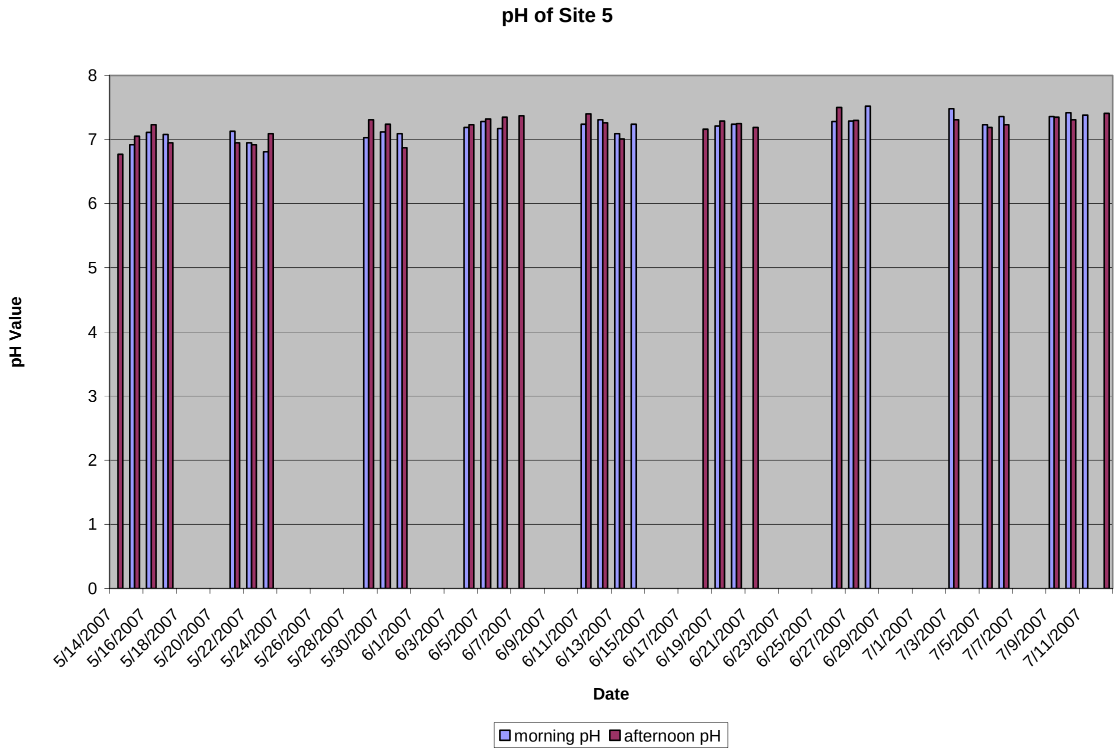

Property Map
About the Trails at Pierce Cedar Creek Institute
• The trails are open daily from dawn to dusk.
• Pierce Cedar Creek Institute grounds and buildings are alcohol- and smoke-free.
• Dogs must remain leashed at all times.
• Motorized vehicles, bicycles, snowmobiles, and horses are prohibited.
• Fishing, hunting, trapping, and plant collecting are prohibited.
Red Trail [1.8 miles]
This trail crosses and passes by a number of beautiful habitats. These include Brewster Lake, a fen, a portion of an esker, an oak forest with unusually large trees, and a pasture frequented by deer and turkey.
Green Trail [.4 miles]
The primary features of this trail are retention ponds, panoramic views, a small section of open forest, and a skunk cabbage-dominated wetland.
Yellow Trail [.4 miles]
This is a shortcut to the middle of the blue trail. View the beauty of our restored wildflower prairie to the east side of the trail.
Blue Trail [1.6 miles]
The path passes through two wildflower prairies, second growth forest, a mature oak forest, an esker covered by mature beech-maple forest, a section of swamp forest, and a fen.
Orange Trail [1.3 miles]
This is one of our easier trails to hike. It provides open and forested views including a wildflower prairie.
Loop Trail [.2 miles]
This is the easiest trail to hike. It provides wonderful panoramic views of the Visitor Center through a black cherry grove.
Quick Key:
paved roads/parking
sidewalks
property boundary (map outlines 555-acre main parcel)
Cloverdale Road
waterway
wetland
upland forest
field
buildings/facilities
Note: map not drawn to scale
Pierce Cedar Creek Institute
for ecological education
FIELD
RED TRAIL
UPLAND FOREST
BATTS COTTAGE
WETLAND
BREWSTER LAKE
BARN
TO HYLA HOUSE MEADOW LODGE HOUSING
ENTRANCE
CLOVERDALE ROAD
MILK HOUSE
RESIDENT MANAGER
GREEN TRAIL
LOOP TRAIL
VISITOR CENTER
ORANGE TRAIL
RETENTION PONDS
EDUCATION BUILDING
PRAIRIE VIEW HOUSING
BLUE TRAIL
CEDAR CREEK
RESEARCH LABORATORY
FIELD
BLUE & ORANGE TRAILS
YELLOW TRAIL
WETLAND
UPLAND FOREST
BLUE TRAIL
TO M-43 SOUTH/KALAMAZOO
TO M-37 NORTH/HASTINGS
TO M-37 SOUTH/BATTLE CREEK
*Visitor Center
701 W. Cloverdale Road
Hastings, MI 49058
HASTINGS
M-37
CLOVERDALE RD.
(GRAVEL)
DOWLING
GRAND RAPIDS
LANSING
M-37
HASTINGS
US-131
M-66
M-79
CHARLOTTE
M-89
I-69
RICHLAND
JACKSON
M-43
I-94
BATTLE CREEK
KALAMAZOO/PORTAGE
Listed below are some of the trees and shrubs that are found at Pierce Cedar Creek Institute:
Black Ash
Green Ash
White Ash
Bass Wood
Beech
Yellow Birch
Black Cherry
Red Cedar
White Cedar
Grey Dogwood
Red Osier Dogwood
American Elm
Red Maple
Black Oak
Red Oak
White Oak
Tulip Poplar
Poison Sumac
Tamarack
Black Walnut

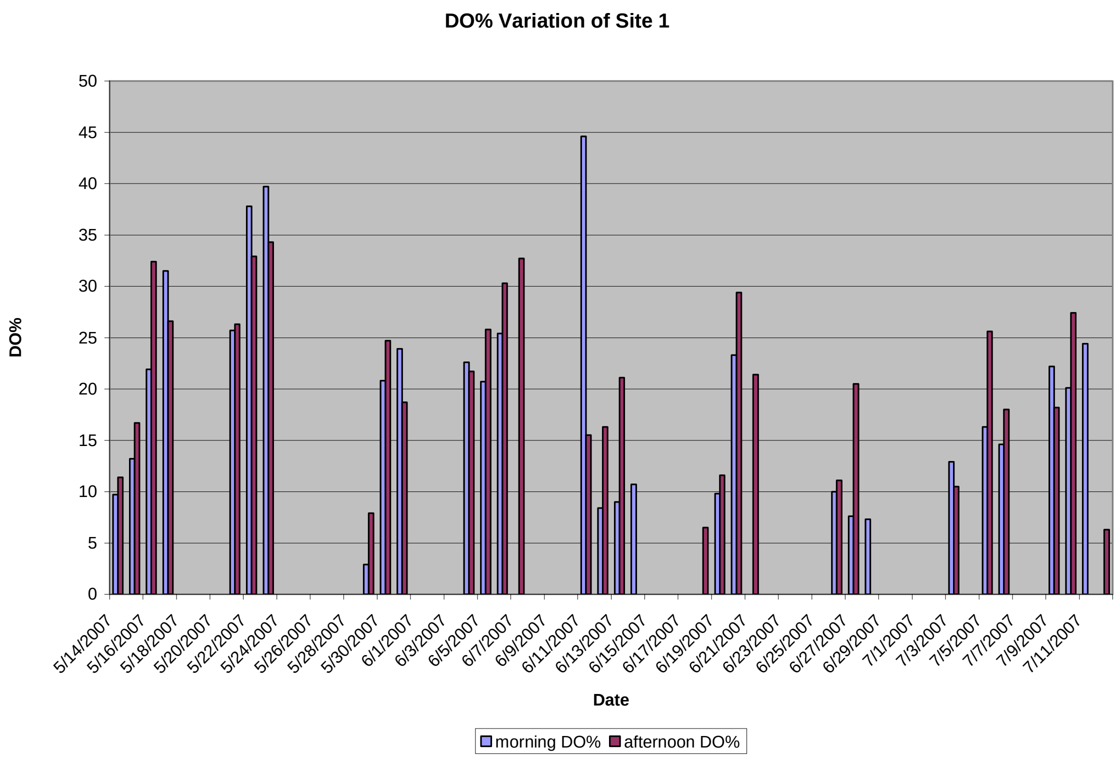

pH of Site 1
pH Value
Date
morning pH
afternoon pH

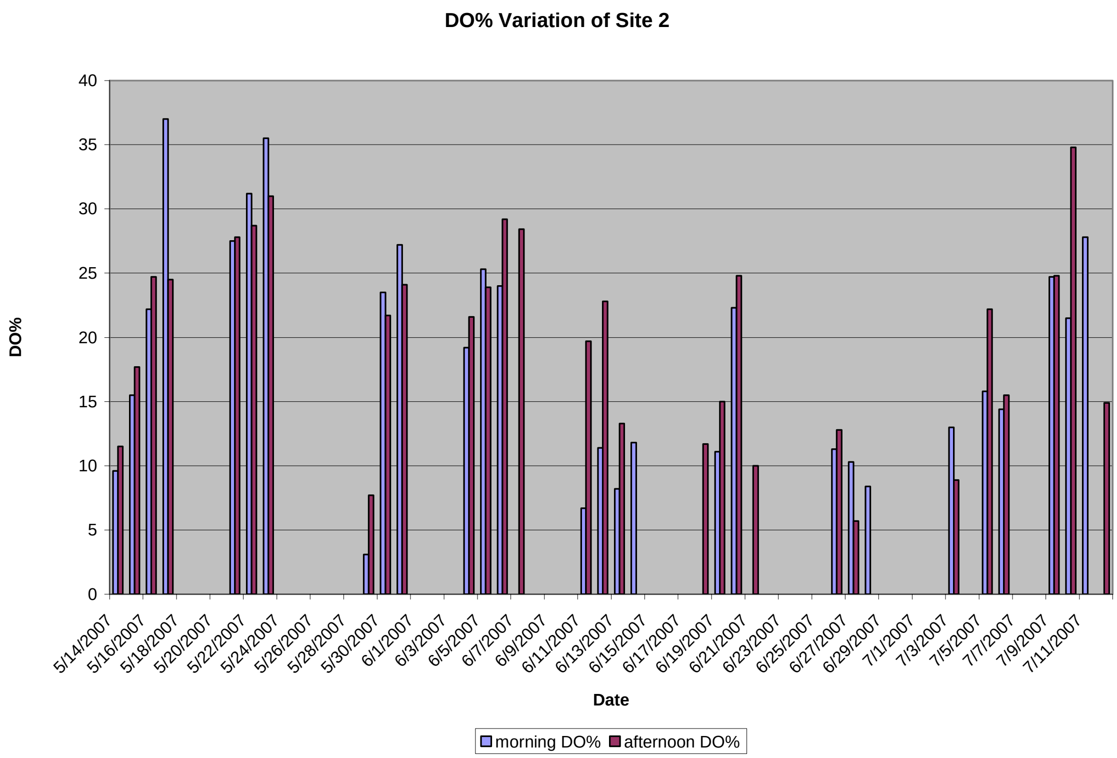

pH of Site 2
pH Value
Date
morning pH
afternoon pH

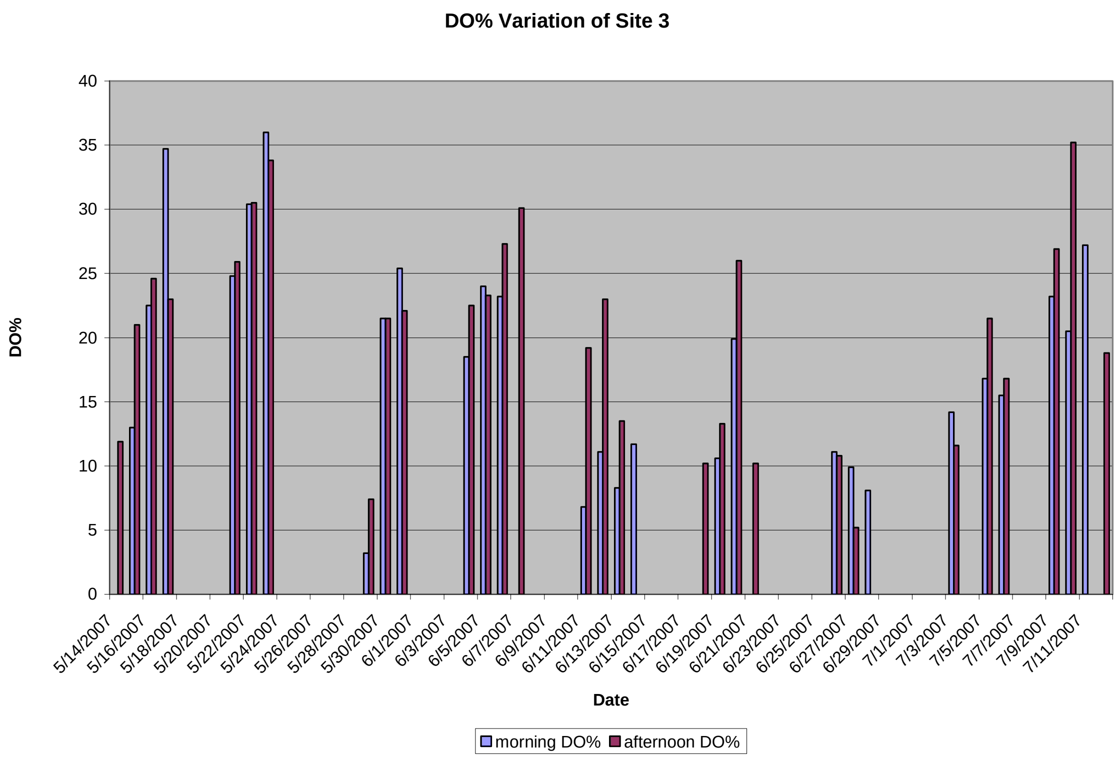

pH of Site 3
pH Values
Date
morning pH
afternoon pH

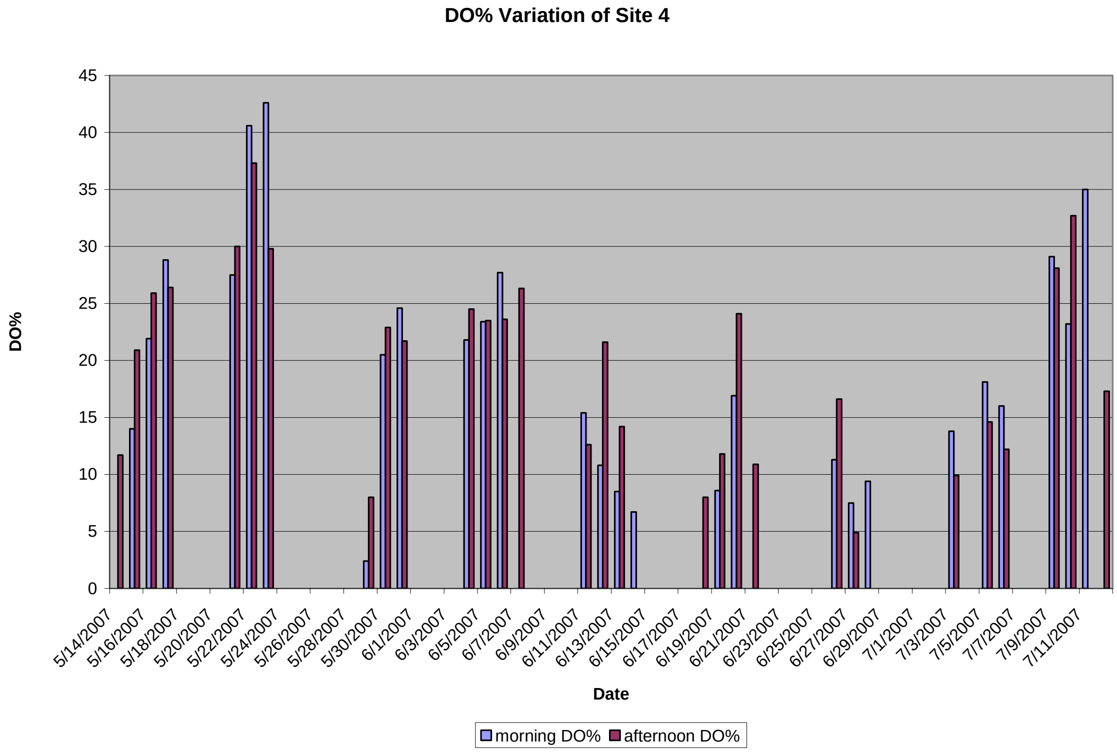

pH of Site 4
pH Value
Date
morning pH
afternoon pH

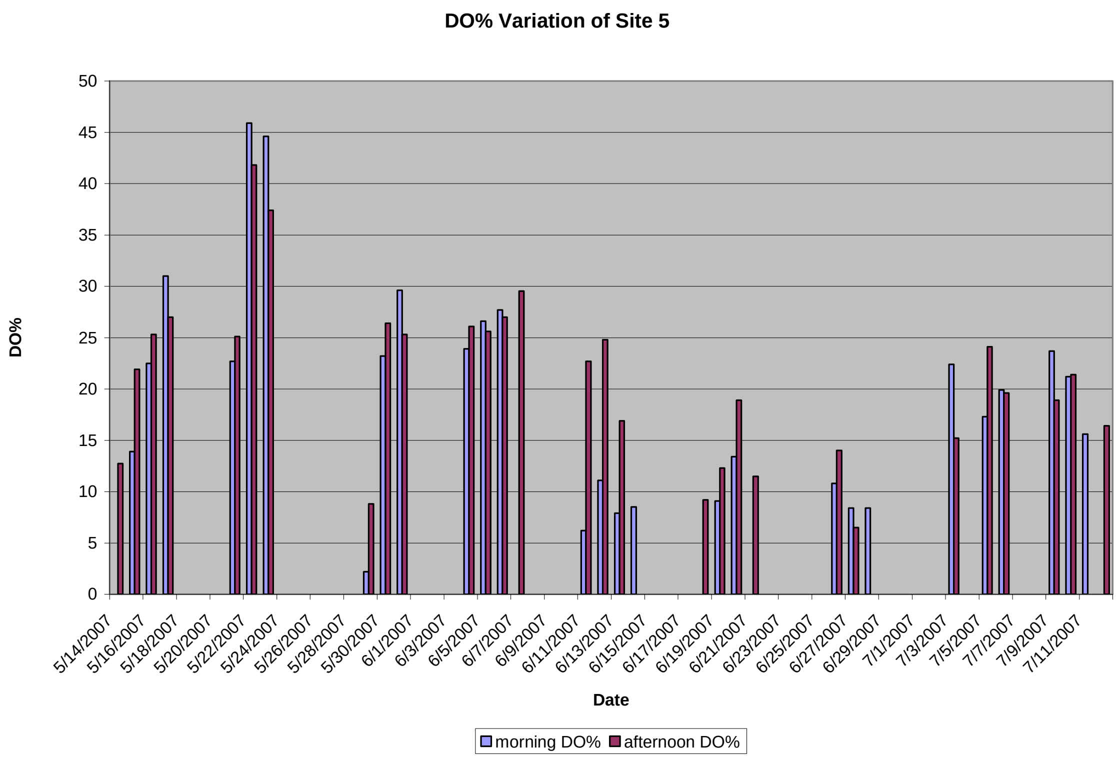

pH of Site 5
pH Value
8
7
6
5
4
3
2
1
0
5/14/2007
5/16/2007
5/18/2007
5/20/2007
5/22/2007
5/24/2007
5/26/2007
5/28/2007
5/30/2007
6/1/2007
6/3/2007
6/5/2007
6/7/2007
6/9/2007
6/11/2007
6/13/2007
6/15/2007
6/17/2007
6/19/2007
6/21/2007
6/23/2007
6/25/2007
6/27/2007
6/29/2007
7/1/2007
7/3/2007
7/5/2007
7/7/2007
7/9/2007
7/11/2007
Date
morning pH
afternoon pH


DO% Variation of Site 1
DO%
50
45
40
35
30
25
20
15
10
5
0
5/14/2007
5/16/2007
5/18/2007
5/20/2007
5/22/2007
5/24/2007
5/26/2007
5/28/2007
5/30/2007
6/1/2007
6/3/2007
6/5/2007
6/7/2007
6/9/2007
6/11/2007
6/13/2007
6/15/2007
6/17/2007
6/19/2007
6/21/2007
6/23/2007
6/25/2007
6/27/2007
6/29/2007
7/1/2007
7/3/2007
7/5/2007
7/7/2007
7/9/2007
7/11/2007
Date
morning DO%
afternoon DO%

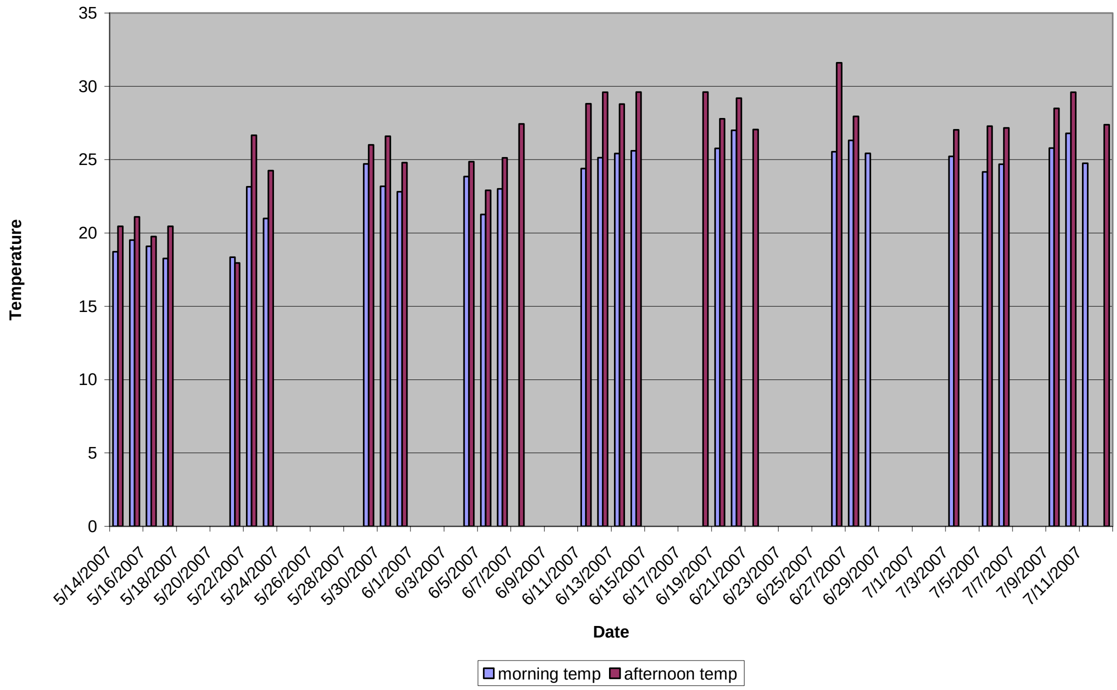

DO% Variation of Site 2
DO%
40
35
30
25
20
15
10
5
0
5/14/2007
5/16/2007
5/18/2007
5/20/2007
5/22/2007
5/24/2007
5/26/2007
5/28/2007
5/30/2007
6/1/2007
6/3/2007
6/5/2007
6/7/2007
6/9/2007
6/11/2007
6/13/2007
6/15/2007
6/17/2007
6/19/2007
6/21/2007
6/23/2007
6/25/2007
6/27/2007
6/29/2007
7/1/2007
7/3/2007
7/5/2007
7/7/2007
7/9/2007
7/11/2007
Date
morning DO%
afternoon DO%


DO% Variation of Site 3
DO%
40
35
30
25
20
15
10
5
0
5/14/2007
5/16/2007
5/18/2007
5/20/2007
5/22/2007
5/24/2007
5/26/2007
5/28/2007
5/30/2007
6/1/2007
6/3/2007
6/5/2007
6/7/2007
6/9/2007
6/11/2007
6/13/2007
6/15/2007
6/17/2007
6/19/2007
6/21/2007
6/23/2007
6/25/2007
6/27/2007
6/29/2007
7/1/2007
7/3/2007
7/5/2007
7/7/2007
7/9/2007
7/11/2007
Date
morning DO%
afternoon DO%

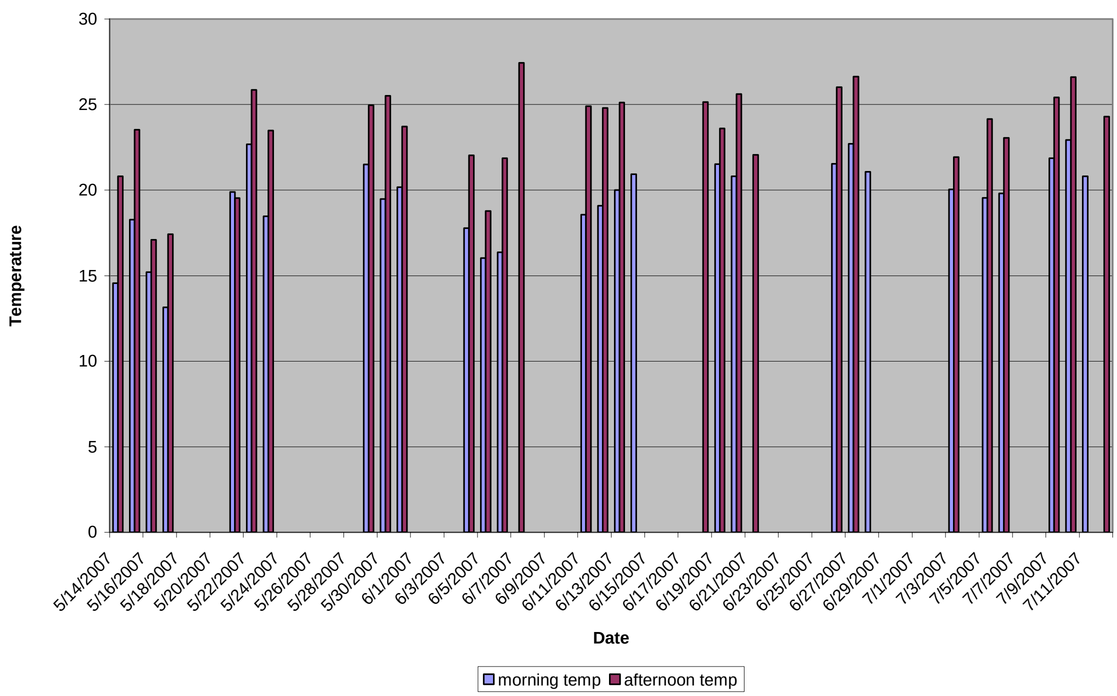

DO% Variation of Site 4
DO%
Date
morning DO%
afternoon DO%

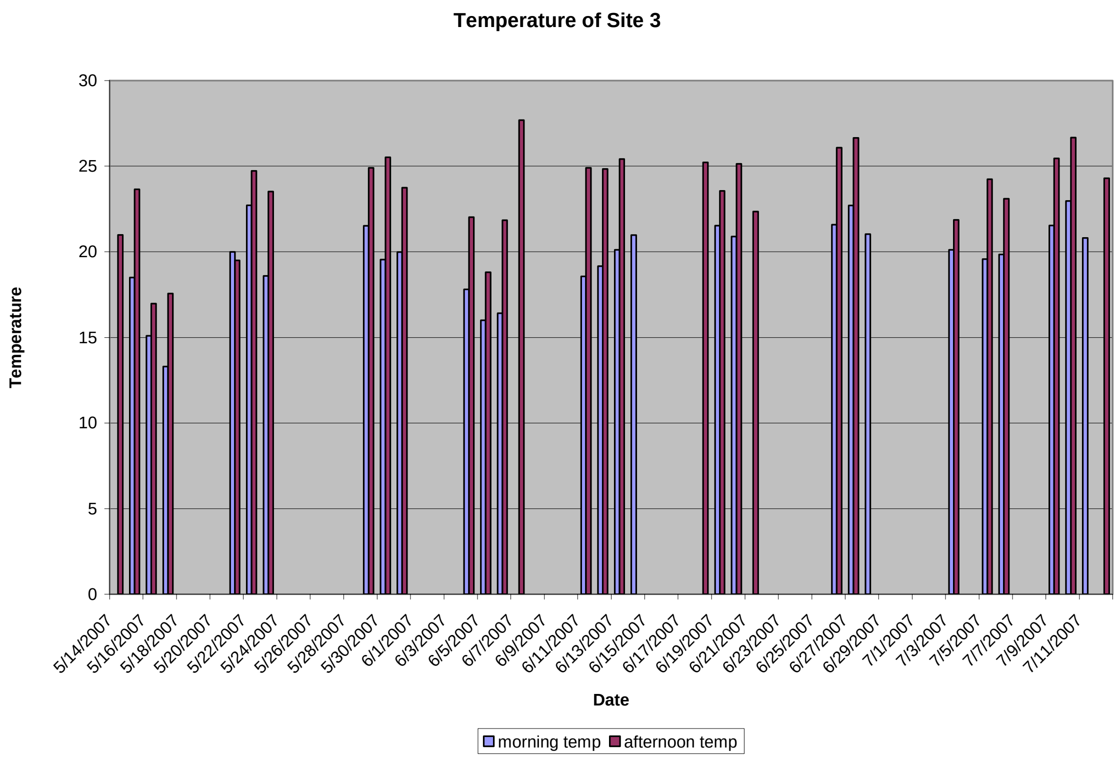

DO% Variation of Site 5
DO%
Date
morning DO%
afternoon DO%

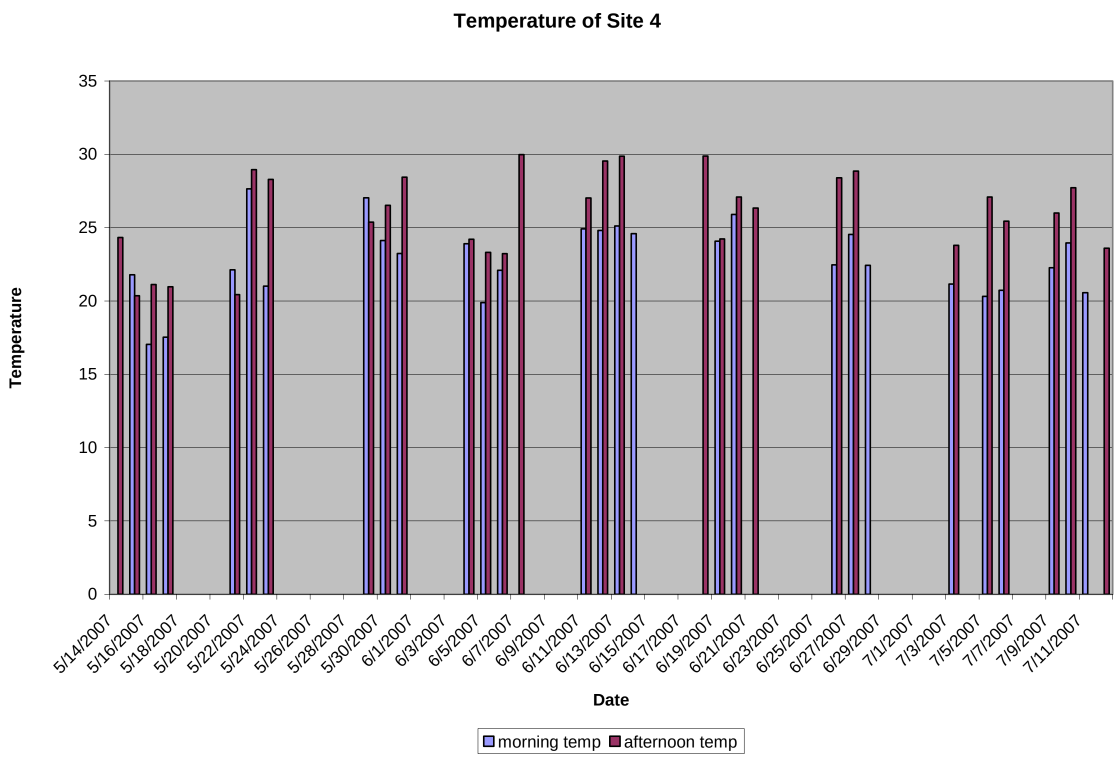
Temperature of Site 1



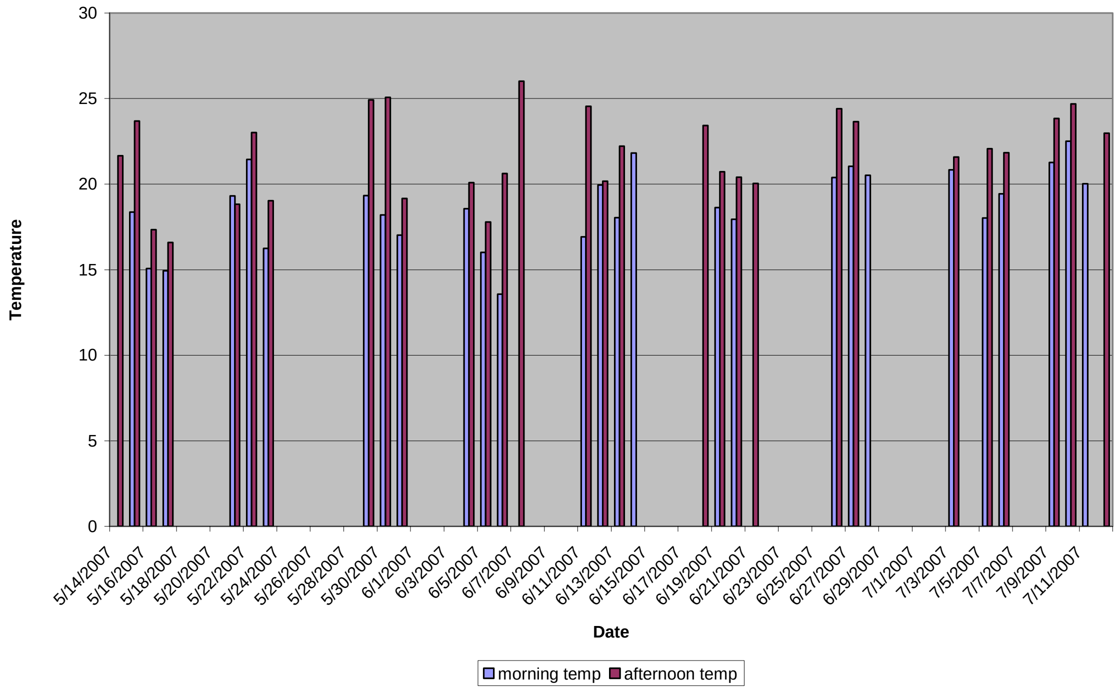
Temperature of Site 2



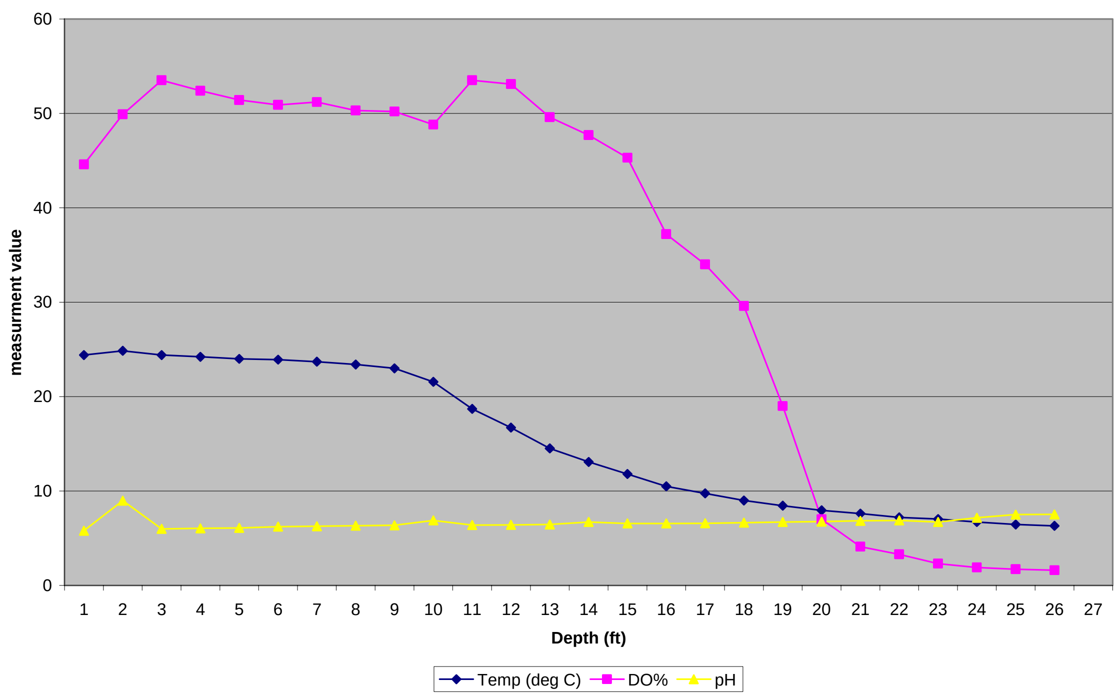

Temperature of Site 3
Temperature
Date
morning temp
afternoon temp


Temperature of Site 4
Temperature
Date
morning temp
afternoon temp

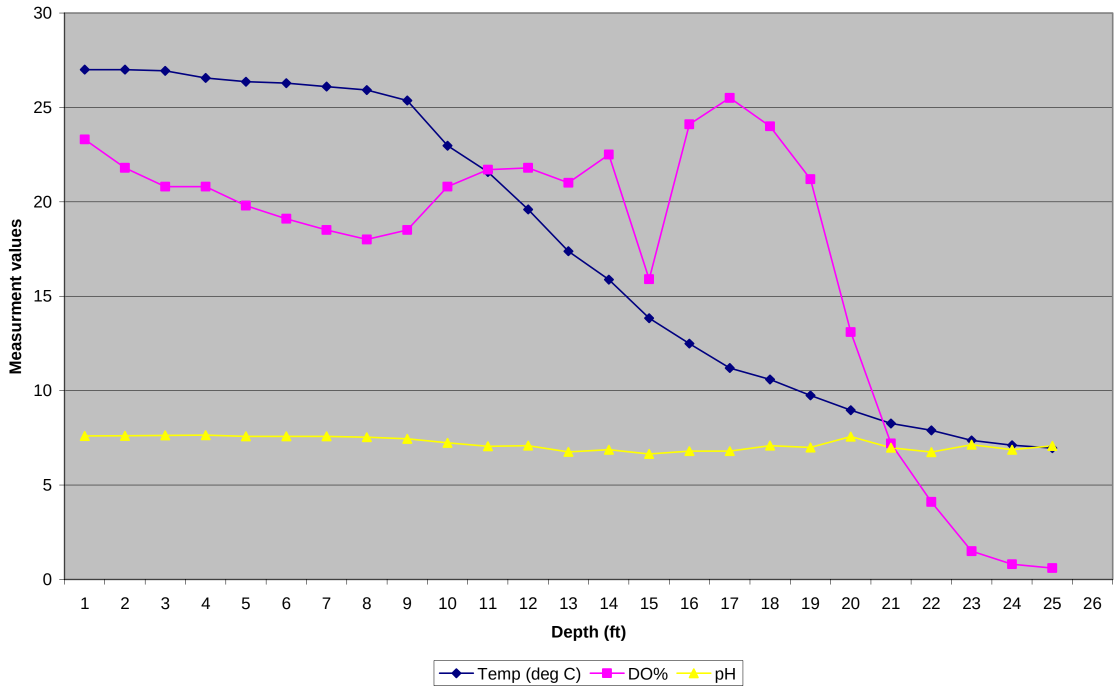
Temperature of Site 5



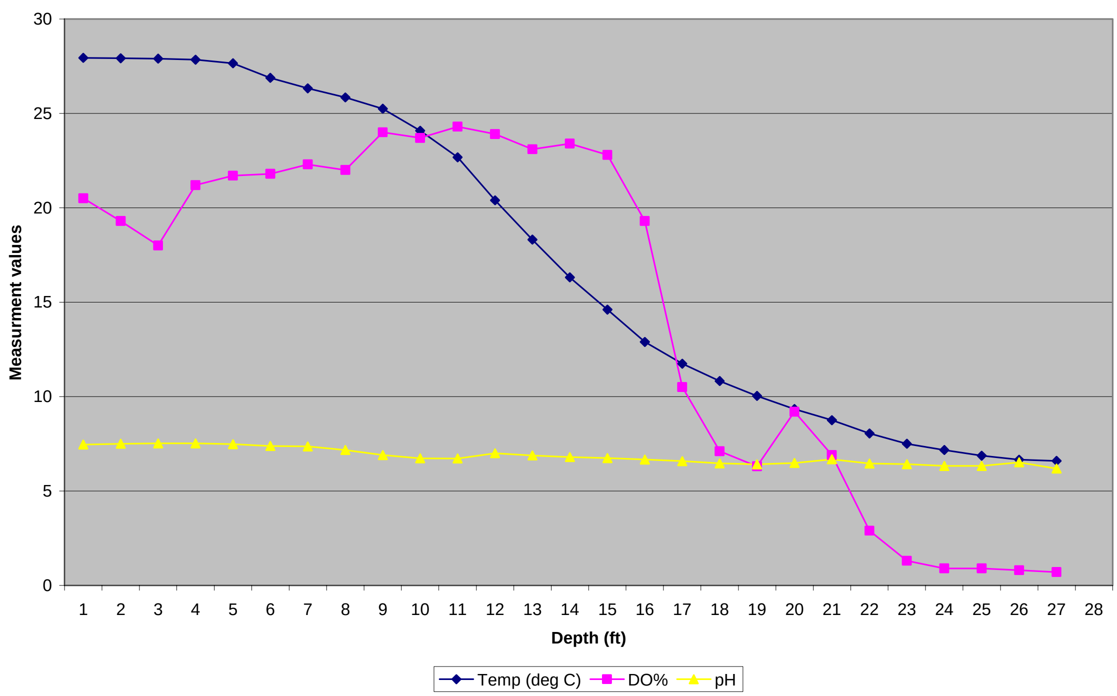
Limnological Profile of Brewster Lake (6-11-07)

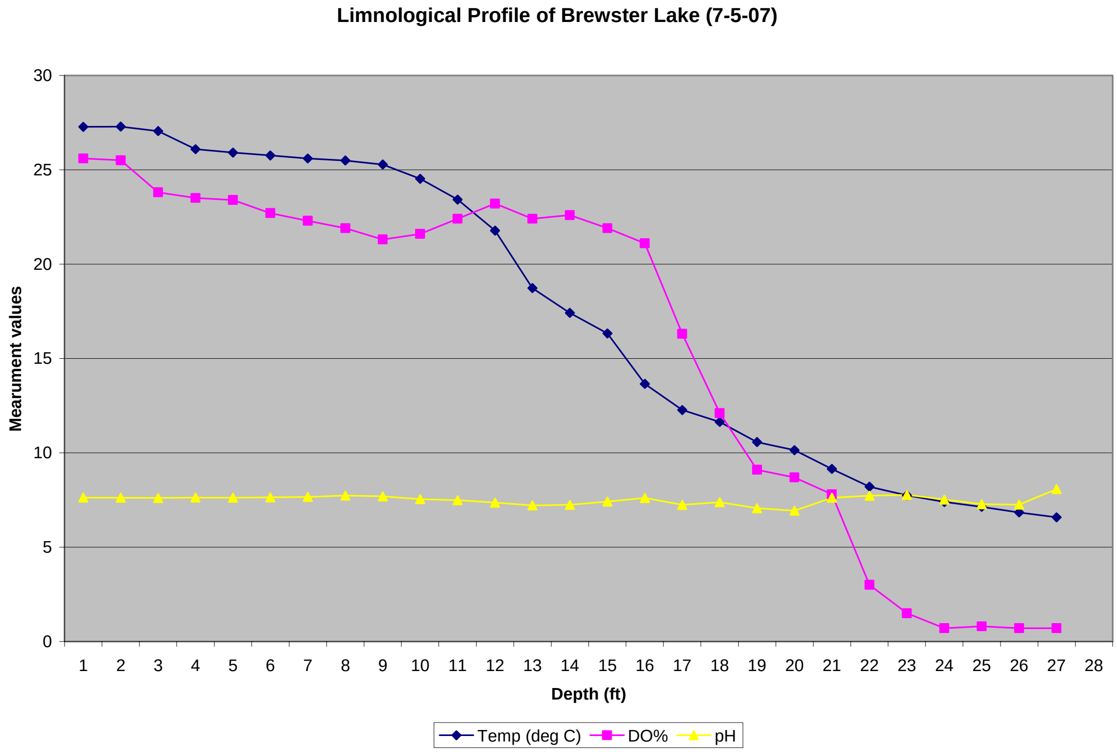


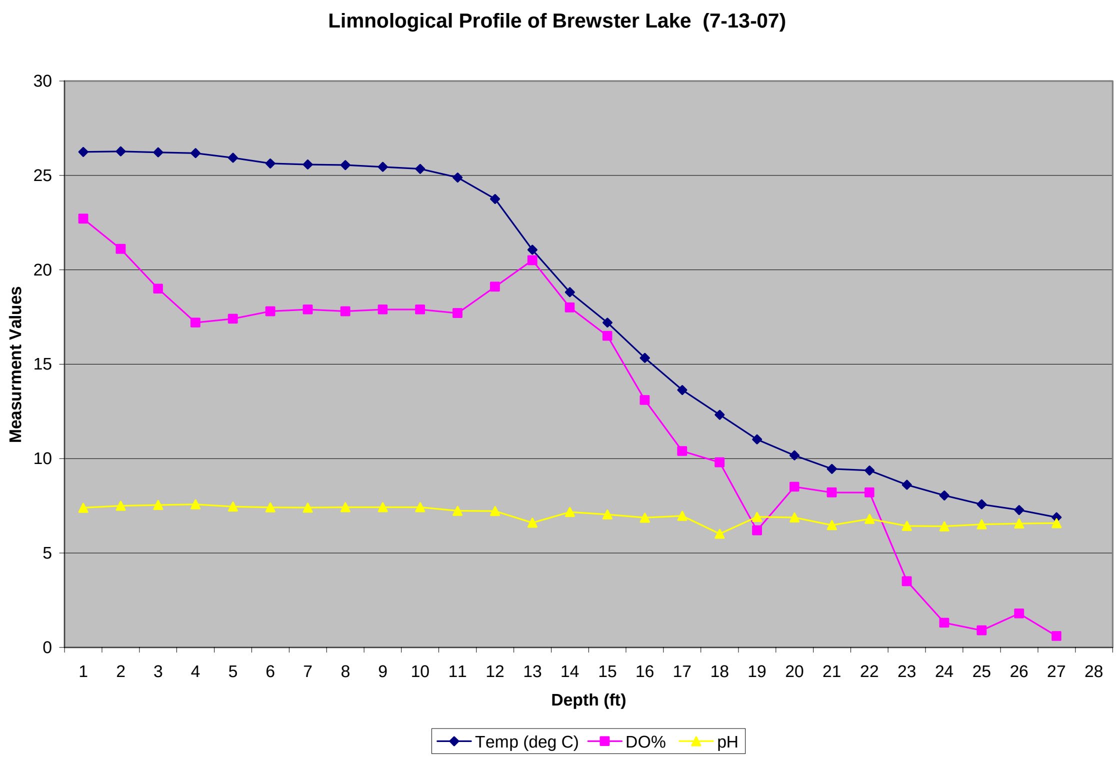
Limnological Profile of Brewster Lake (6-20-07)

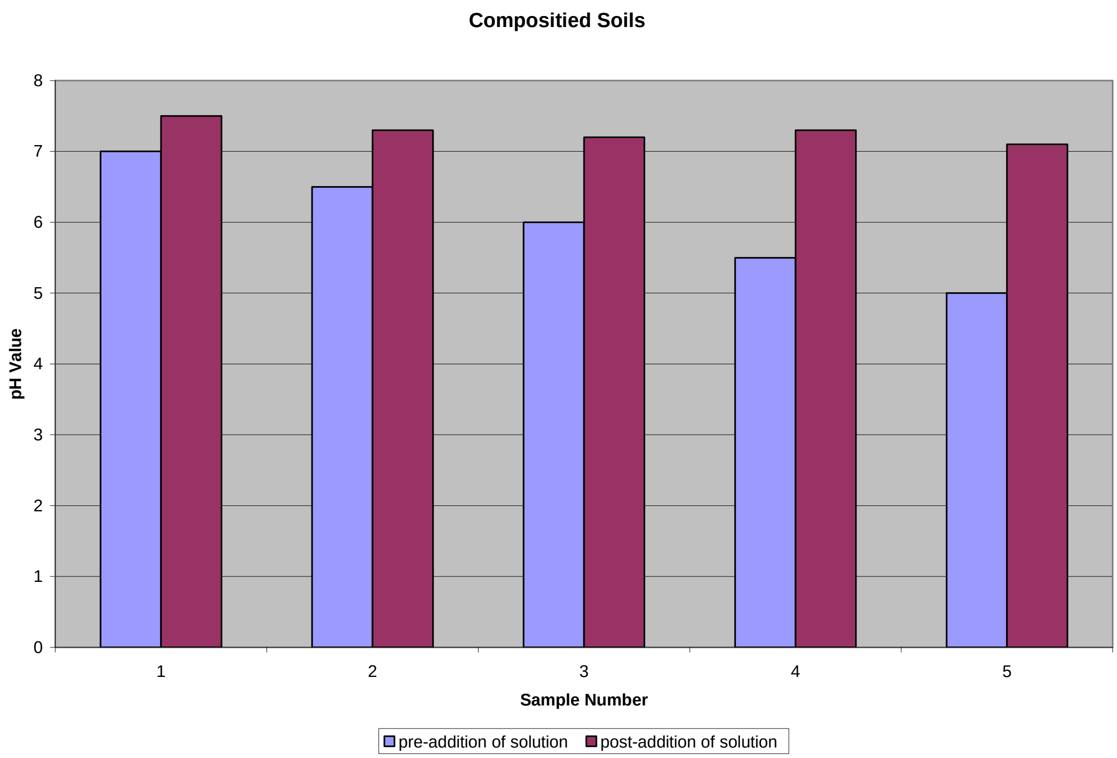


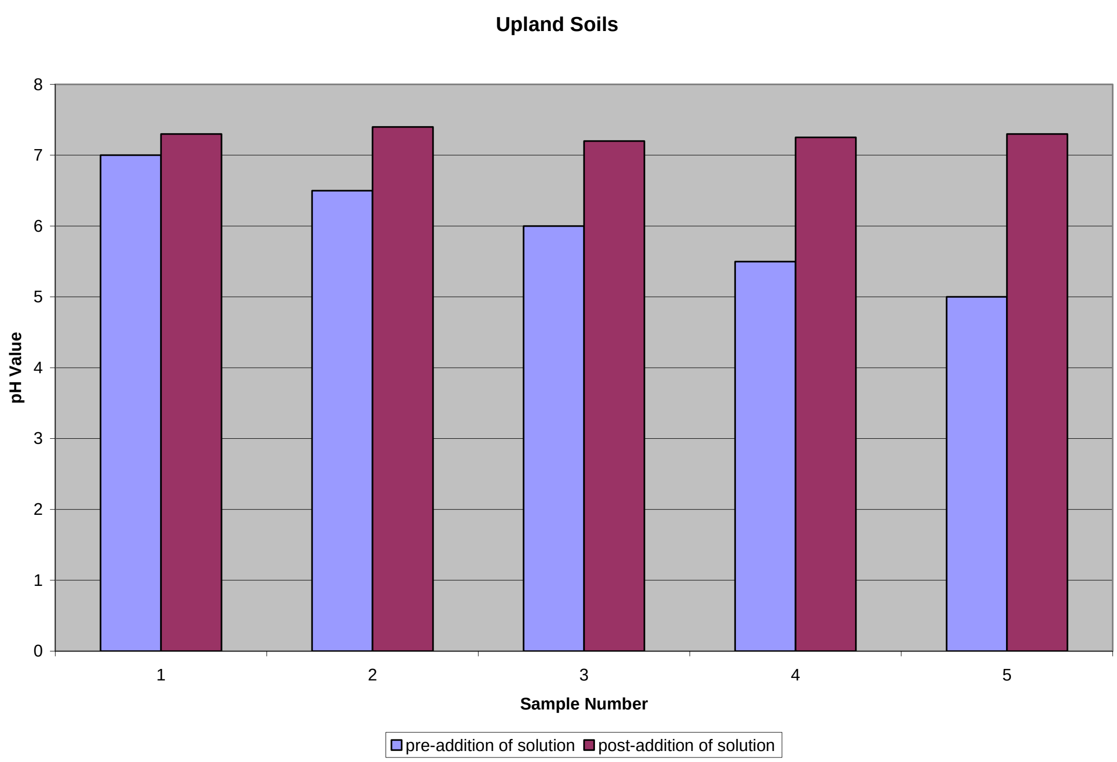
Limnological Profile of Brewster Lake (6-27-07)

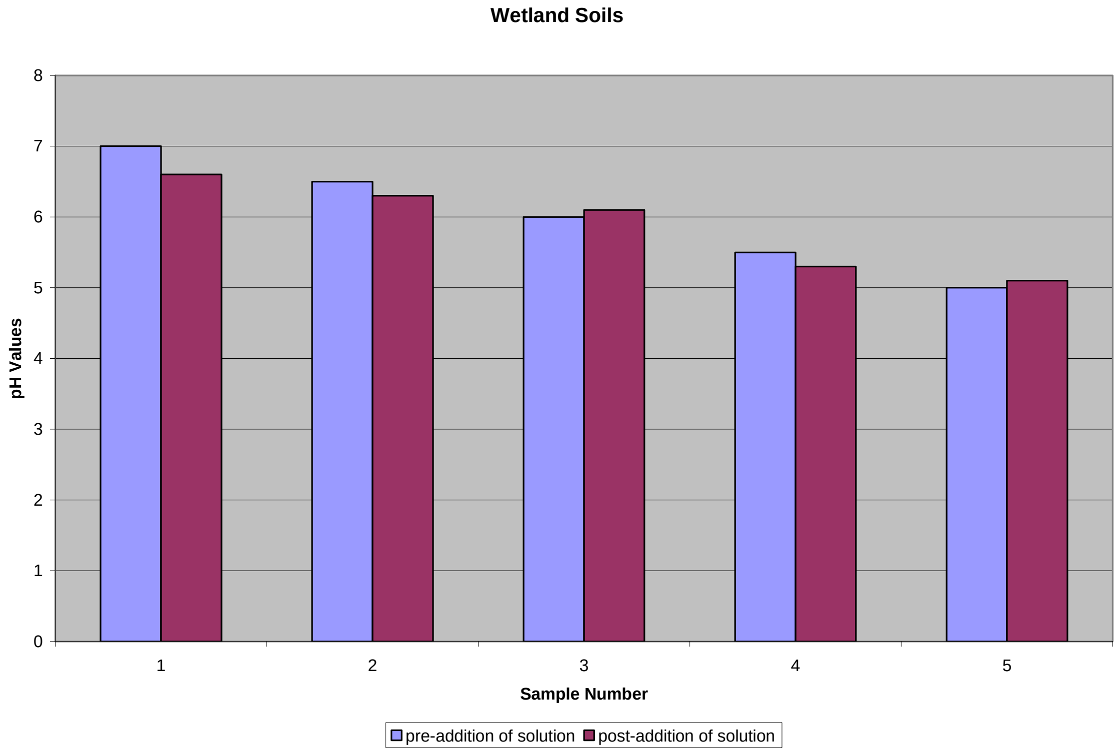



Limnological Profile of Brewster Lake (7-5-07)
Mearument values
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Depth (ft)
Temp (deg C)
DO%
pH


Limnological Profile of Brewster Lake (7-13-07)
Measurment Values
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Depth (ft)
Temp (deg C)
DO%
pH


Compositied Soils
pH Value
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Sample Number
pre-addition of solution
post-addition of solution


Upland Soils
pH Value
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Sample Number
pre-addition of solution
post-addition of solution


Wetland Soils
pH Values
0
1
2
3
4
5
6
7
8
1
2
3
4
5
Sample Number
pre-addition of solution
post-addition of solution