Hyper-alkaline Waters in Calumet Wetlands (South Chicago, IL)

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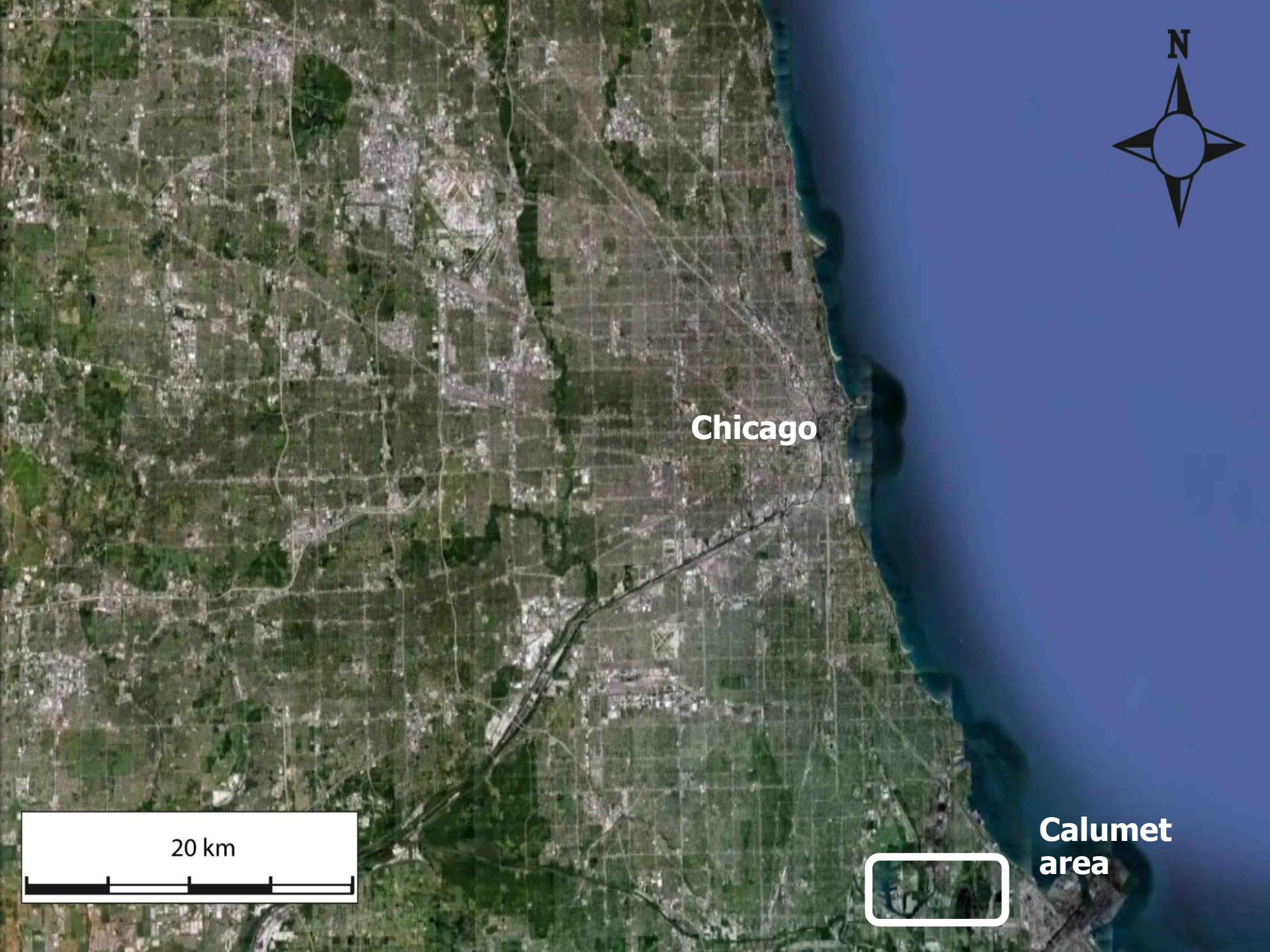
Geology and Environmental Geosciences

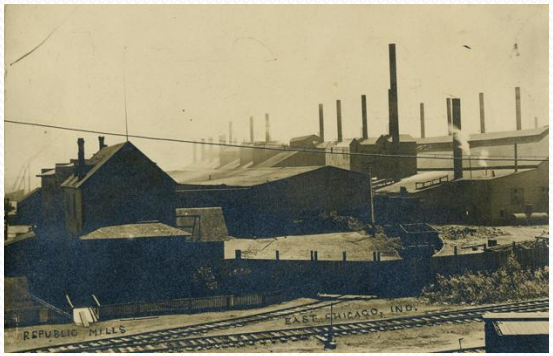
Introduction

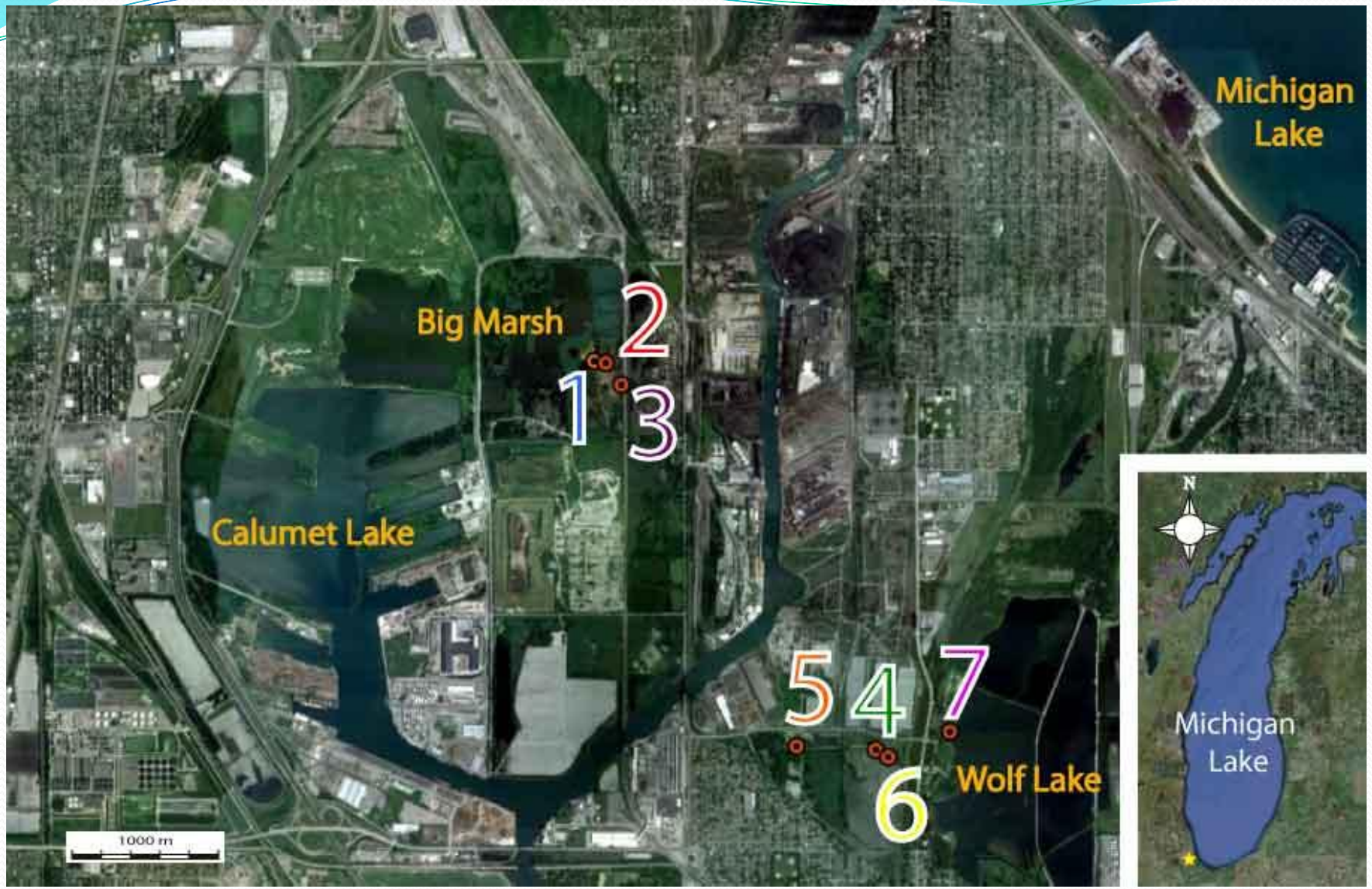
- Hyper-alkaline (pH up to 13) surface and groundwater habitats
- Seasonal and site-specific differences in pH (9-13) and heavy metal concentration
- Unique site for study of alkaliphilic and alkalitolerant organisms


N
Chicago
20 km
Calumet
area

Industrial History of Calumet

- 1870s: building of Calumet Harbor – large scale industrial development
- Steel production- ore from Michigan
- Dumping of waste products to infill wetlands
  - Creating new land – very heterogeneous
  - Eliminating breeding grounds for insects




Michigan Lake
Big Marsh
2
1
3
Calumet Lake
5
4
7
6
Wolf Lake
1000 m
N
Michigan Lake

Big Marsh Site Grouping

Calumet Wetland & Wolf Lake

Geochemistry of Sites

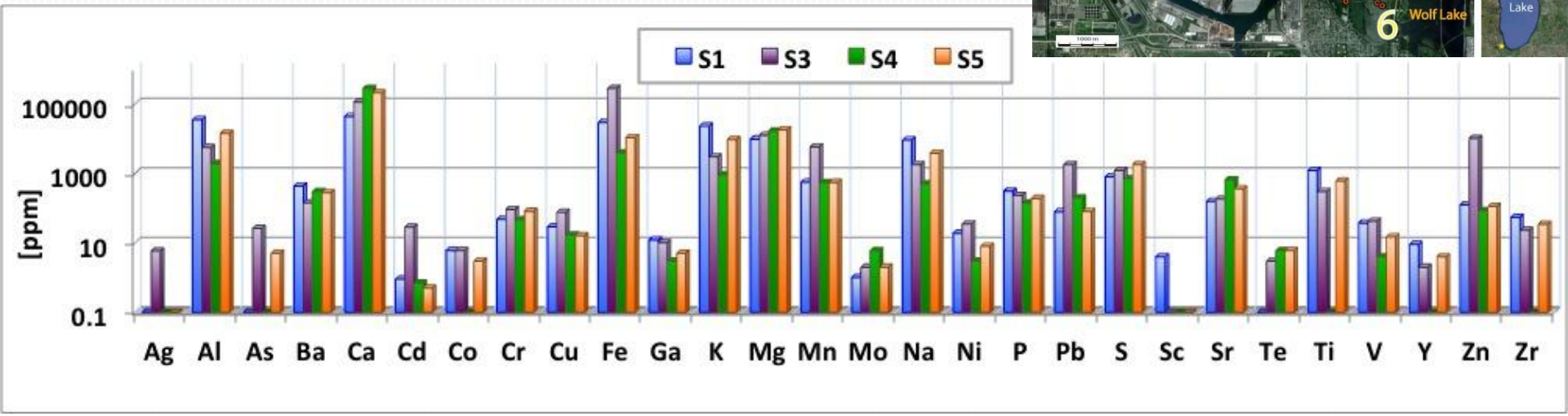
- High temperature slags with Ca-Si minerals
  - Includes metallic Fe and Mn and other steel additives
- Long term weathering:
  - Rankinite: $Ca_3Si_2O_7 + 7H_2O = 3Ca^{2+} + 2H_4SiO_4 + 6OH^-$
  - Larnite: $Ca_2SiO_4 + 4H_2O = 2Ca^{2+} + H_4SiO_4 + 4OH^-$
  - Akermanite:
    - $Ca_2MgSi_2O_7 + 7H_2O = 2Ca^{2+} + Mg^{2+} + 2H_4SiO_4 + 6OH^-$
- Origin of Ca-OH water with strongly temperature-dependent high pH
- On contact with atmosphere: $CO_2 + H_2O = 2H^+ + CO_3^{2-}$

  $Ca^{2+} + CO_3^{2-} = CaCO_3$

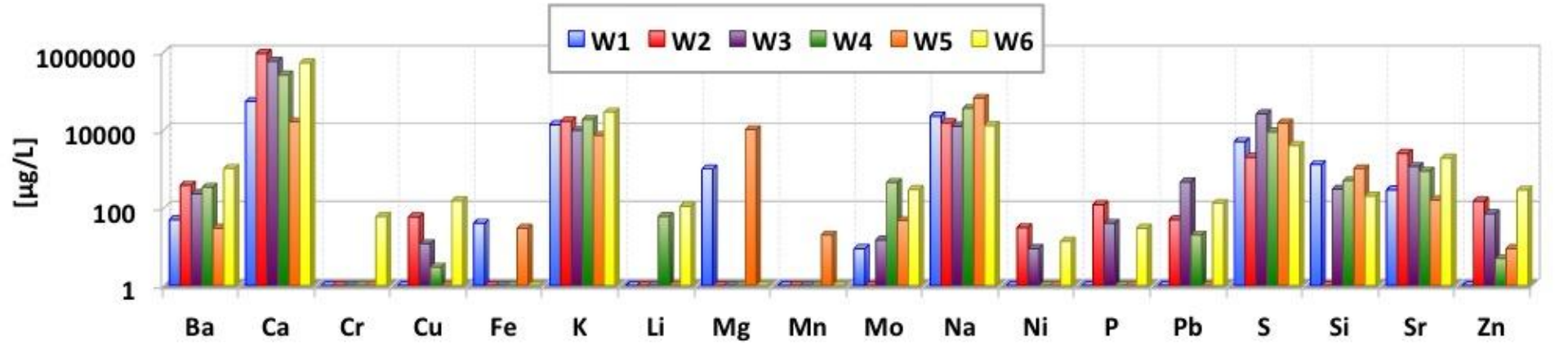
Roadcap *et al.,* 2005, Groundwater 43(6):806-816.

Geochemistry

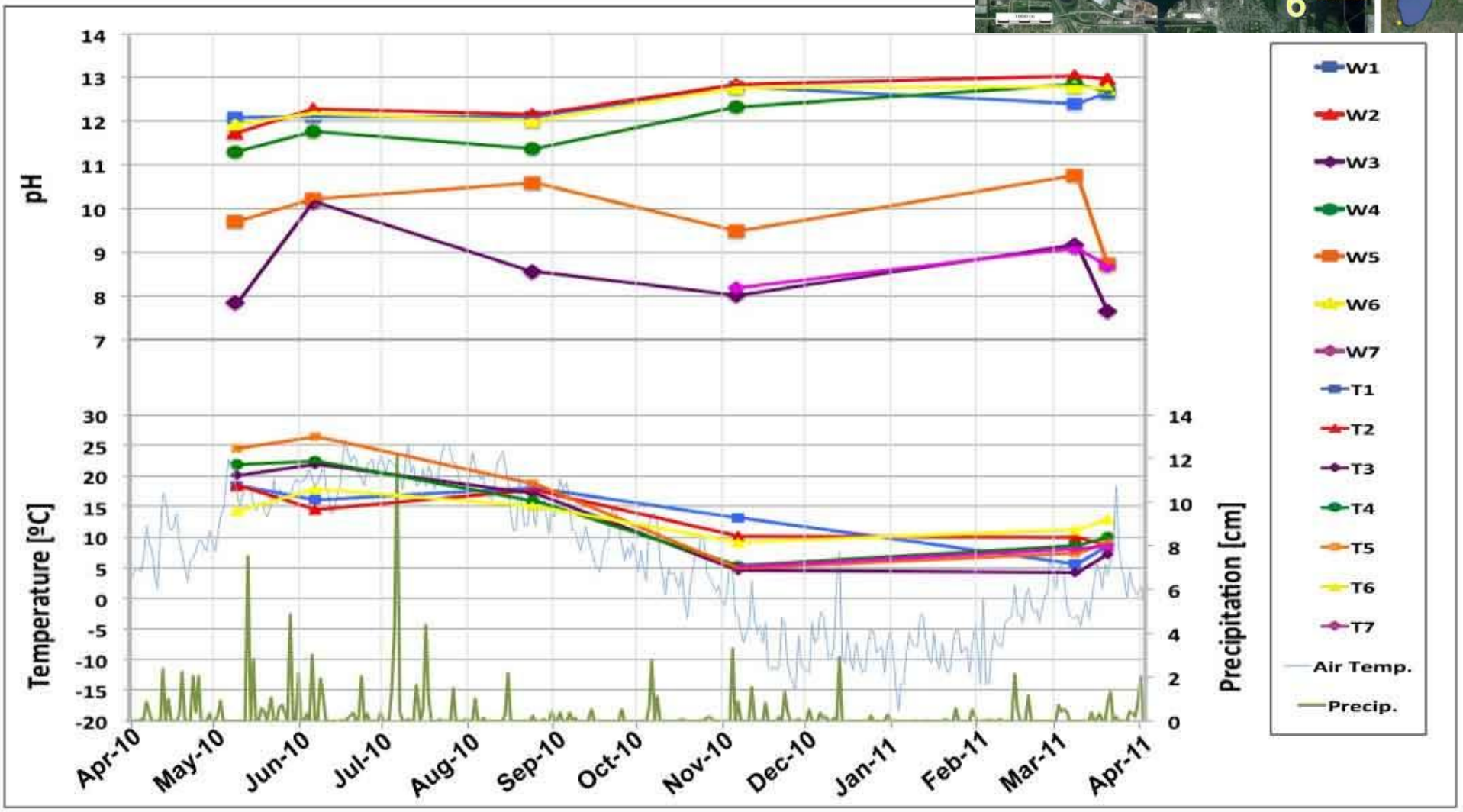
Soil



Water

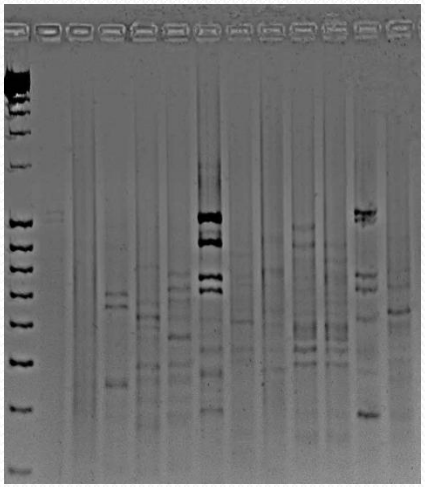


Water pH and Temperature



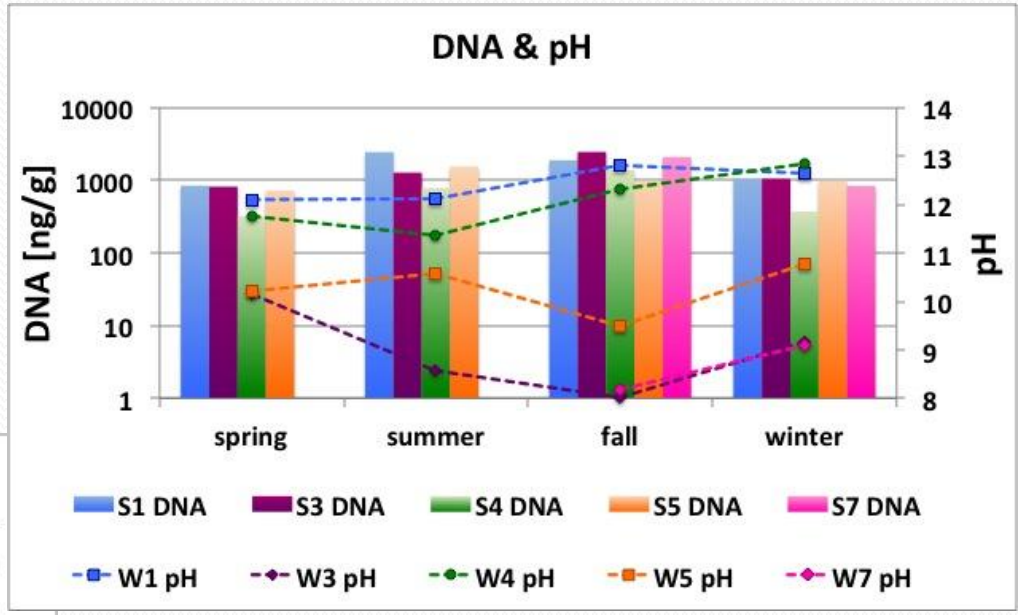
Microbial Community

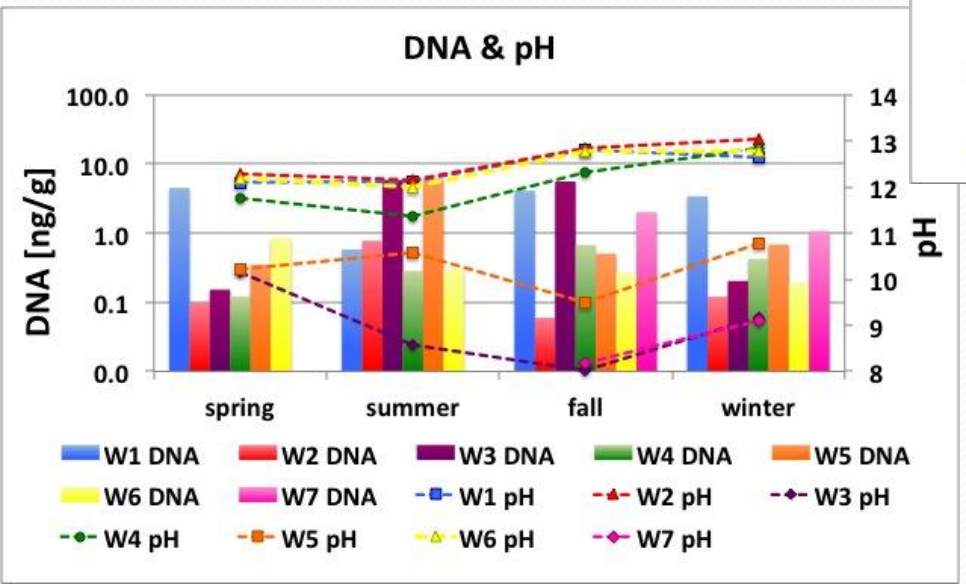
- From sediment and water, different seasons
  - Issues with methods in this environment
- DNA extracted using MoBio PowerSoil Isolation kit
- DNA was assessed using the Ribosomal Intergenic Spacer (RIS) primer set: Fail Safe buffer
  - 16S 1406F: TGY ACA CAC CGC CCG T
  - 23S 115R: GGG TTB CCC CAT TCR G
    - (Cardinale et al., 2004)
- Visualized on 2% SFR agarose TAE gel
  - Analyzed using GelQuest software (SequentiX)
  - DNA similarity index was calculated using a modified Jaccard index (Nei and Li, 1979)

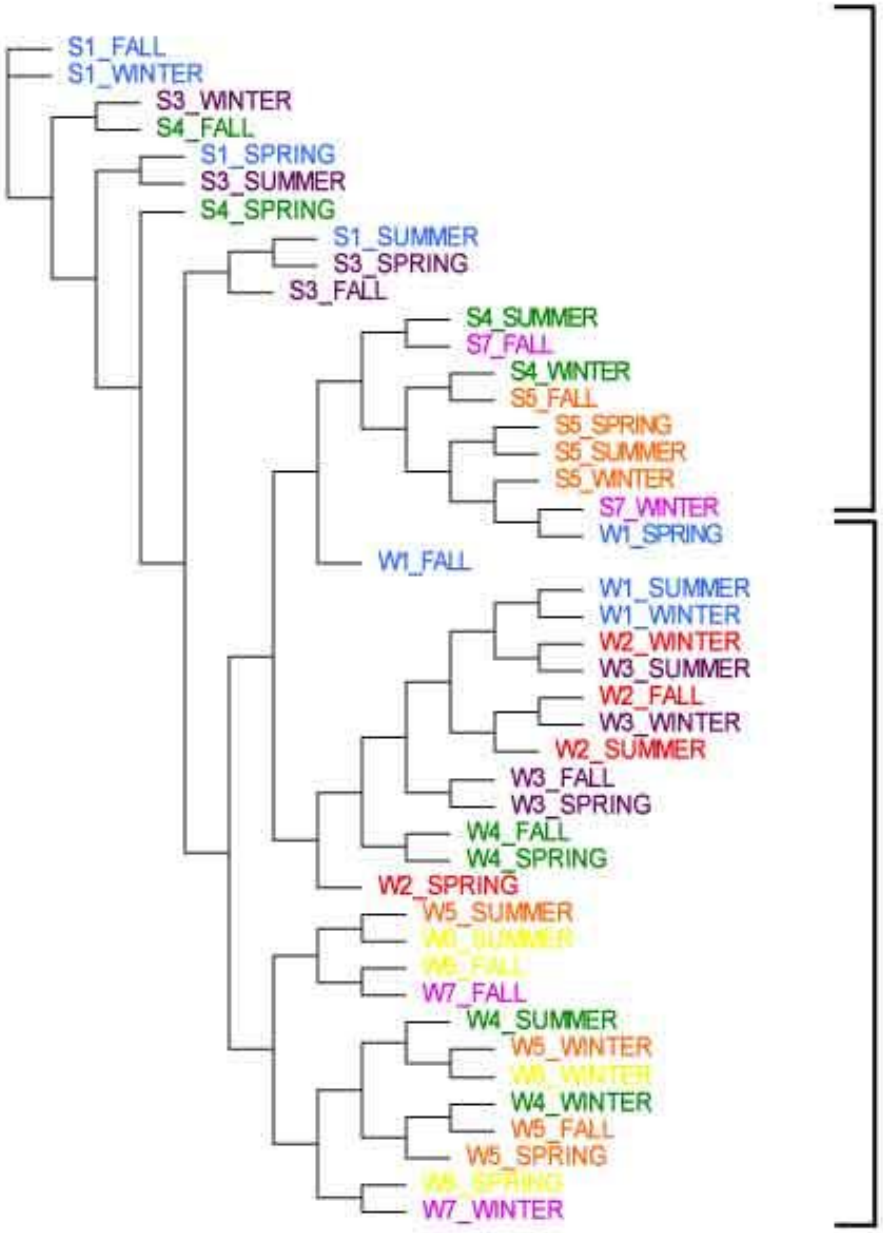


pH & DNA Conc.

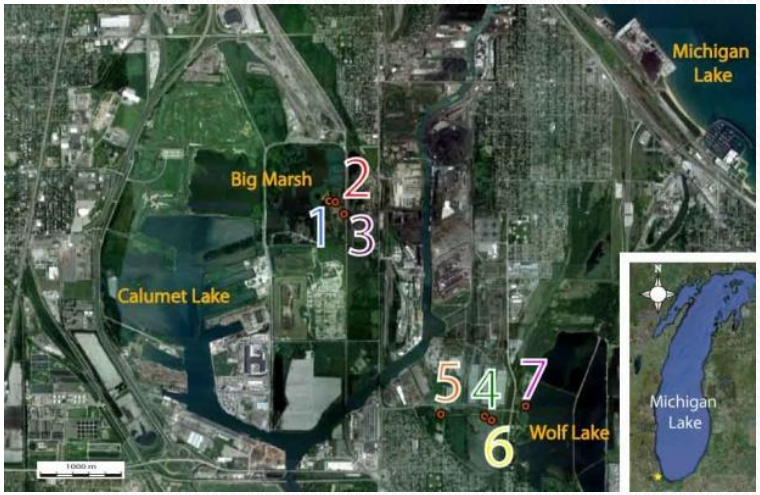

Michigan Lake
Big Marsh
2
1
3
Calumet Lake
5
4
7
6
Wolf Lake
Michigan Lake


DNA & pH
DNA [ng/g]
10000
1000
100
10
1
14
13
12
11
10
9
8
pH
spring
summer
fall
winter
S1 DNA
S3 DNA
S4 DNA
S5 DNA
S7 DNA
W1 pH
W3 pH
W4 pH
W5 pH
W7 pH


DNA & pH
DNA [ng/g]
100.0
10.0
1.0
0.1
0.0
14
13
12
11
10
9
8
pH
spring
summer
fall
winter
W1 DNA
W2 DNA
W3 DNA
W4 DNA
W5 DNA
W6 DNA
W7 DNA
W1 pH
W2 pH
W3 pH
W4 pH
W5 pH
W6 pH
W7 pH

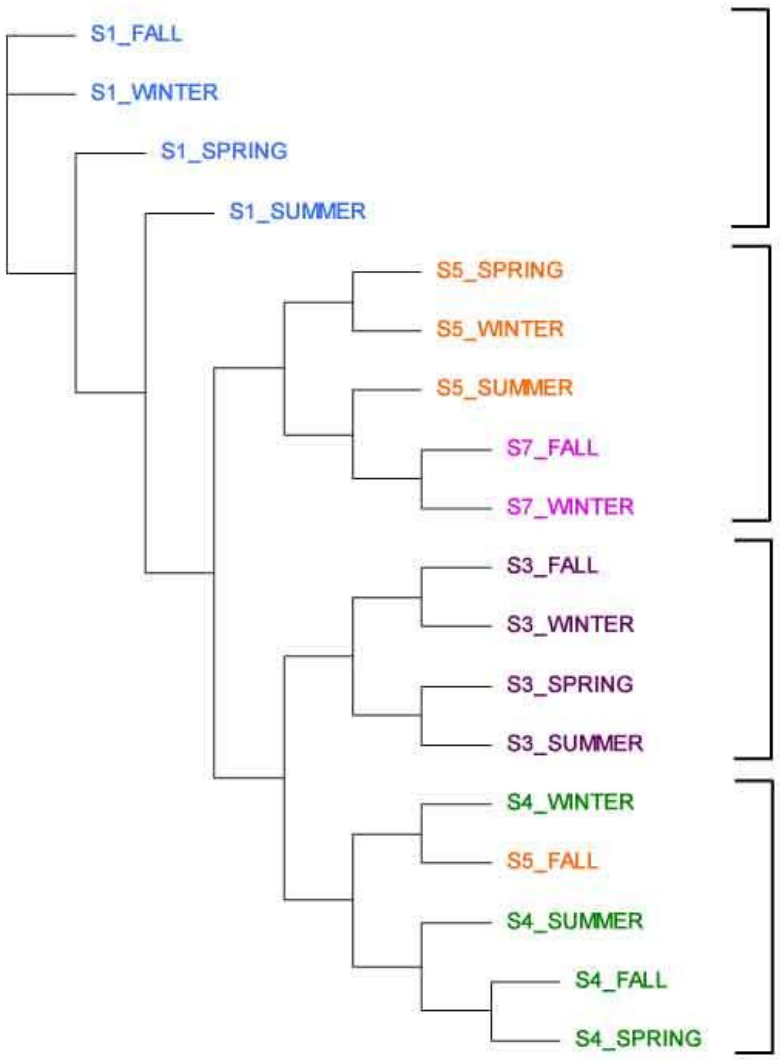

S1_FALL
S1_WINTER
S3_WINTER
S4_FALL
S1_SPRING
S3_SUMMER
S4_SPRING
S1_SUMMER
S3_SPRING
S3_FALL
S4_SUMMER
S7_FALL
S4_WINTER
S5_FALL
S5_SPRING
S5_SUMMER
S5_WINTER
S7_WINTER
W1_SPRING
W1_FALL
W1_SUMMER
W1_WINTER
W2_WINTER
W3_SUMMER
W2_FALL
W3_WINTER
W2_SUMMER
W3_FALL
W3_SPRING
W4_FALL
W4_SPRING
W2_SPRING
W5_SUMMER
W7_FALL
W4_SUMMER
W5_WINTER
W4_WINTER
W5_FALL
W5_SPRING
W7_WINTER

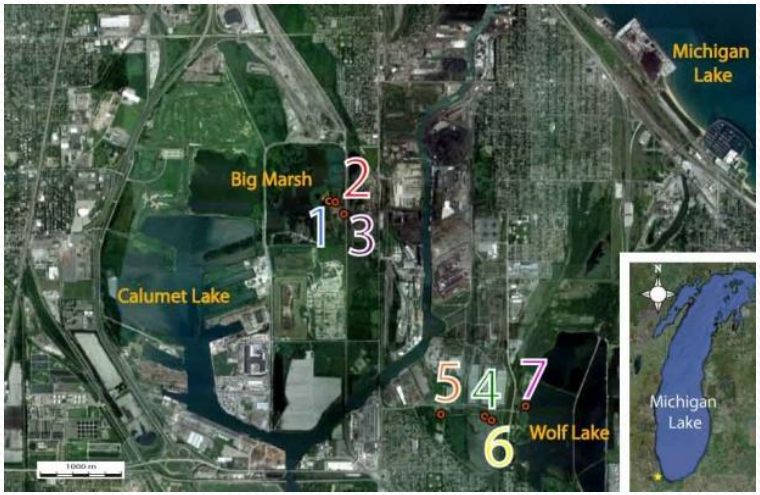
Soil


Michigan Lake
Big Marsh
2
1
3
Calumet Lake
5
4
7
6
Wolf Lake
Michigan Lake

Water

Soil


S1_FALL
S1_WINTER
S1_SPRING
S1_SUMMER
S5_SPRING
S5_WINTER
S5_SUMMER
S7_FALL
S7_WINTER
S3_FALL
S3_WINTER
S3_SPRING
S3_SUMMER
S4_WINTER
S5_FALL
S4_SUMMER
S4_FALL
S4_SPRING


Michigan Lake
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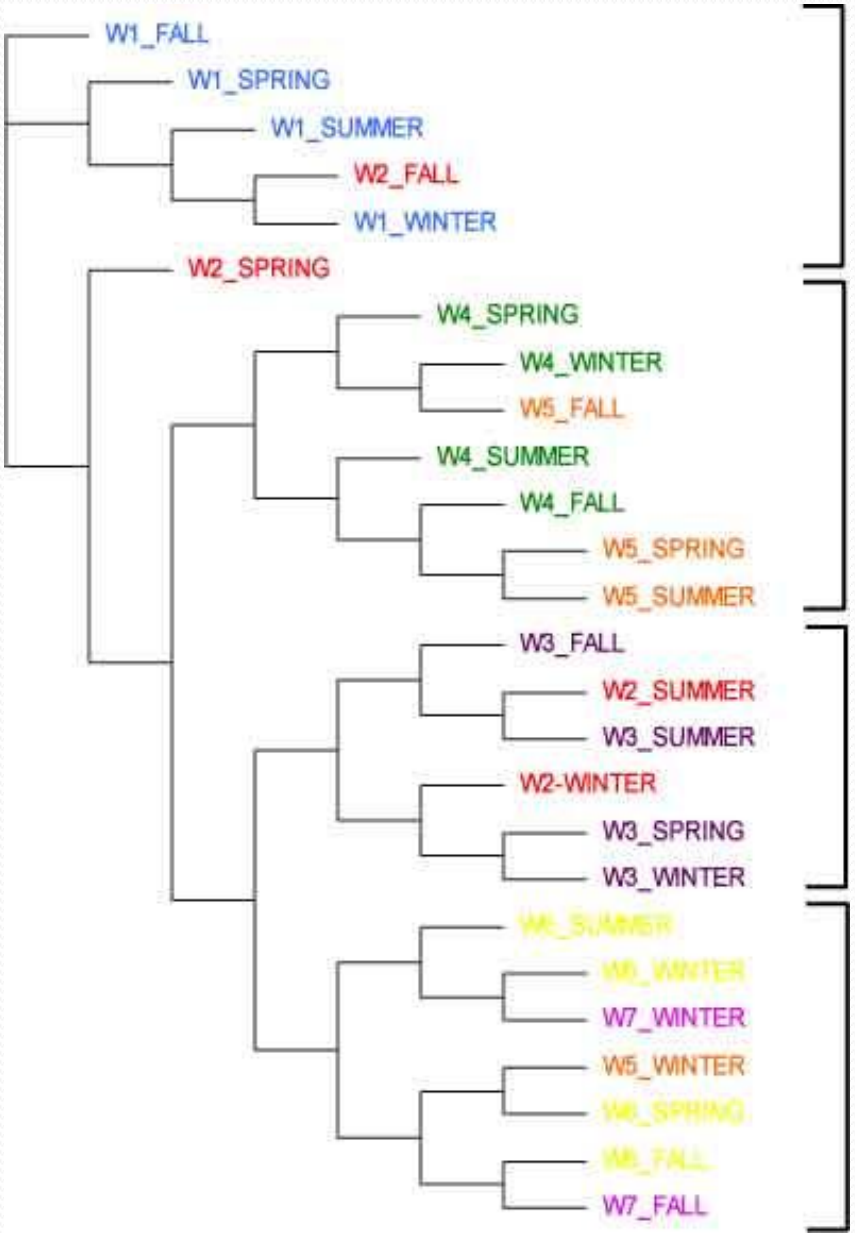
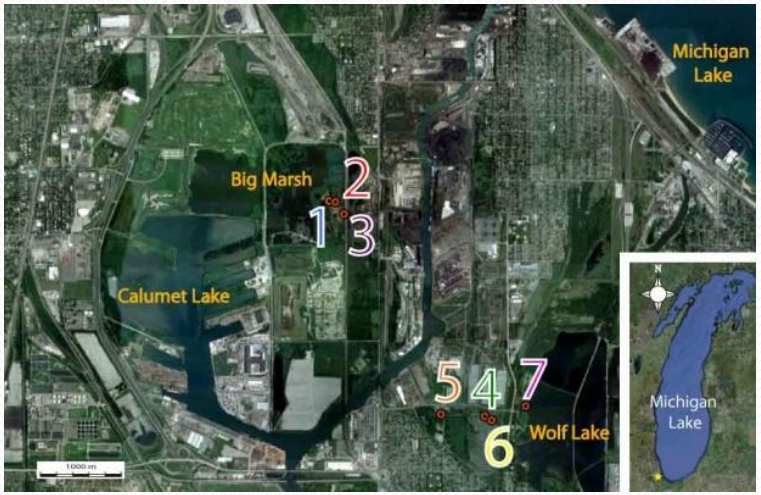
Wolf Lake
Michigan Lake

Water


W1_FALL
W1_SPRING
W1_SUMMER
W2_FALL
W1_WINTER
W2_SPRING
W4_SPRING
W4_WINTER
W5_FALL
W4_SUMMER
W4_FALL
W5_SPRING
W5_SUMMER
W3_FALL
W2_SUMMER
W3_SUMMER
W2-WINTER
W3_SPRING
W3_WINTER
W6_SUMMER
W6_WINTER
W7_WINTER
W5_WINTER
W6_SPRING
W6_FALL
W7_FALL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6
Wolf Lake
Michigan Lake

Remediation

- Laboratory columns are being constructed to test reactive barriers and determine how these influence the microbial communities.
- Sand, dolomite, and apatite II™ (Chen et al., 1997)
- Water and sediment from different sites
- Beginning this summer

Conclusions

- Chemical analysis of major ions varied that sites 1-6
- Seasonal monitoring and sampling revealed strong influence of temperature on pH at sites 1, 2, 4, and 6
  - Influence of pH on DNA concentrations was not significant
- DNA concentrations in soil samples were up to three orders magnitude higher than those in water samples
  - Soils providing microorganisms with microniche-protection throughout the year.
  - More research
- DNA fingerprint analysis showed:
  - Microbial communities differ between water and soil
  - Geographically related communities clustered closer together
  - More research

Acknowledgements

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