North Lake Wave Propagation & Water Quality

A Phased Study of the Water Quality and Wave Propagation Dynamics Currently Impacting a Small Southeast Wisconsin Freshwater Lake: Waukesha

Presentation
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Primary Research Study Team

Carroll University

- Mike Mortensen, Director of Aviation Science
- Joseph Piatt, Ph.D., M.S.C.E - Professor of Chemistry and Environmental Science
- Alex Navin, Student of Chemistry
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Southeastern Regional Planning Commission

- Tom Slawski, Ph.D. - Chief Biologist
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Terra Vigilis

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- Camryn Phillips, Brookfield East student researcher, Internship

Introduction

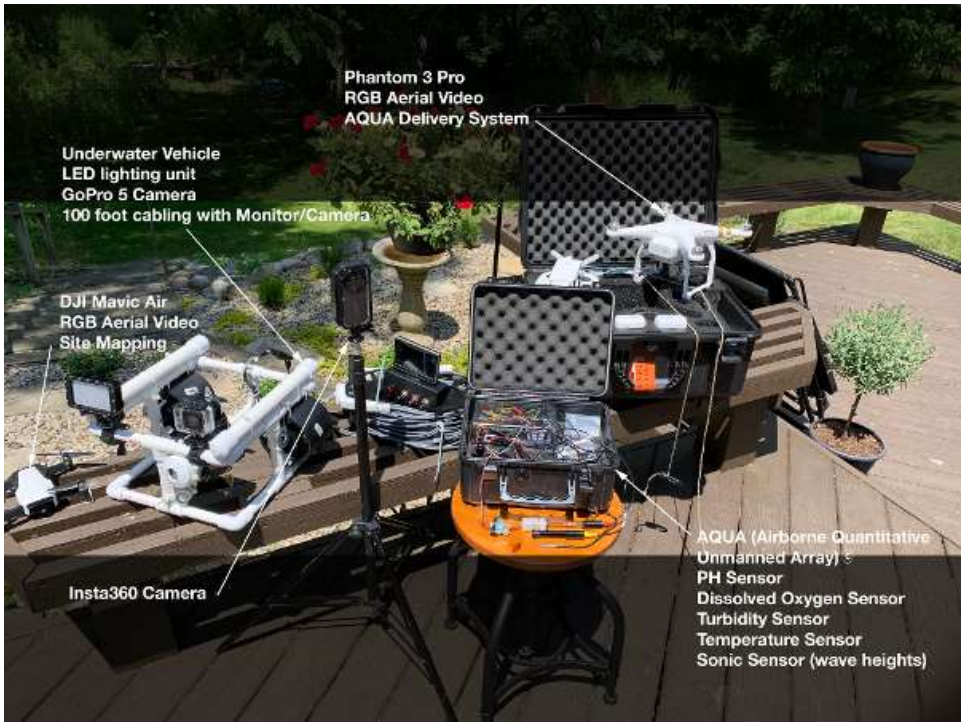
The North Lake Management District (NLMD) requested a formal study to address water quality and wave propagation effects on shoreline, surface and subsurface areas on North Lake. North Lake is a freshwater glacial lake consisting of 440 acres. The lake is located in southeast Wisconsin in Waukesha County. North Lake has 237 property owners. The Lake has four inlets and a single outlet. The deepest portion of the Lake is 78 feet. The lake has a marl bottom and is used for recreational boating, fishing and related water sports (“North Lake", n.d.)

Recent use of wave enhancing water craft on North Lake has become a stated concern by a large number of Lake residents due to large wave effects. The NLMD appointed a study committee (consisting of lake resident representatives) in 2017-8 to investigate these concerns. This committee was charged with producing recommendations to address the problem which resulted in a series of “Safe Boater” guidelines. The impact of the guidelines were studied and a lake resident survey was issued in 2019. Plans are in place to repeat the resident survey again in the fall of 2020. Survey results in 2019 also highlighted strong resident concern for a comprehensive water quality study.

A multi-agency effort was undertaken in the spring of 2020 to combine the resources of Carroll University and the Southeastern Regional Planning Commission to conduct this study. A private commercial drone firm was also retained to allow for measurements of water quality and wave propagation effects (surface and subsurface) as a portion of this work.

Preliminary Sites and Equipment

North Lake Preliminary Analysis Sites



North Lake Study - Equipment

North Lake Study - Equipment

Jenna Bales with the remote underwater vehicle and Alex Navin with the DJI Mavic Air Drone at Site 1

The research team has prepared a summary of preliminary results gathered in Phase 1 of this research. The purpose of the preliminary review is to allow the full research team an

opportunity to discuss the data gathered in 4 primary study domains with North Lake residents.

These domains include the following:

Domain 1

Measurements of wave heights, frequency, duration and depth (subsurface) of all the primary engine powered vessels that are in use on North Lake were taken. These vessels include pontoon boats, personal watercraft, water ski boats and wave enhancing “wakeboard” boats.

Aerial mapping helps create an accurate 3D aerial map of the selected shoreline. This will be used to measure shoreline erosion over time. The aerial mapping also allows our team to develop displacement maps which are used to create 3D models of waves. We determine wave heights from the 3D displacement models.

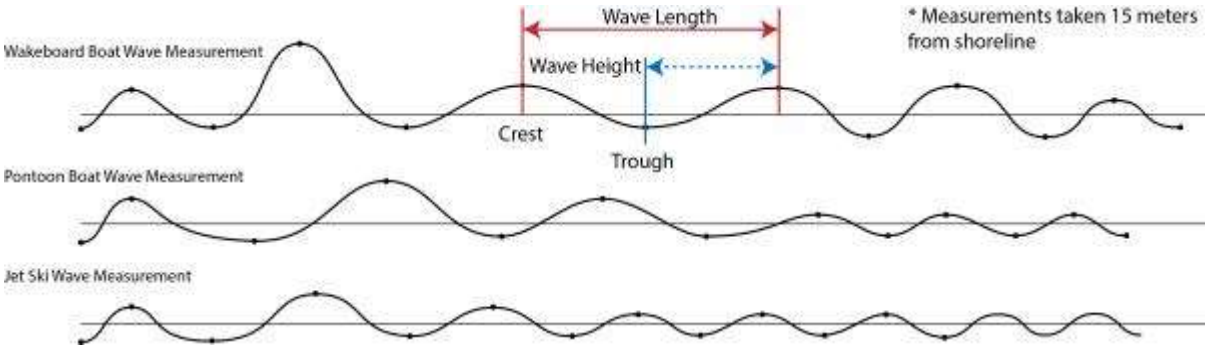
Wave Measurements at 15 meters from shoreline

Wakeboard Boat Wave		
Wavelength	Height	Time
	-2 @	0;00;03;17
	+2" @	0;00;04;11
15' - 4"	-2" @	0;00;05;21
	+8" @	0;00;06;10
17' - 11"	-2" @	0;00;07;21
	+4" @	0;00;08;13
20'-5"	-2" @	0;00;10;05
	+3.5" @	0;00;10;28
15'-4"	-2" @	0;00;12;18
	+4" @	0;00;13;10
12'-10"	-3" @	0;00;14;15
	+2" @	0;00;15;06
	-3" @	0;00;16;20
	+4" @	0;00;17;10

Pontoon Boat Wave		
Wavelength	Height	Time
	-1 @	0:00;31;19
	+3" @	0;00;32;12
20'-5"	-3" @	0;00;34;10
	+5" @	0;00;35;12
17' - 11"	-2" @	0;00;36;23
	+3" @	0;00;37;23
17' - 11"	-1" @	0;00;39;01
	+1.5" @	0;00;39;22
10' - 3"	-2" @	0;00;40;29
	+1" @	0;00;41;25
10' - 3"	-1" @	0;00;42;19
	+1" @	0;00;43;10
	-2" @	0;00;44;11
	+1" @	0;00;45;03

Jet Ski Wave		
Wavelength	Height	Time
	-1 @	0:00;11;19
	+2" @	0;00;12;12
12'-5"	-2" @	0;00;14;16
	+3" @	0;00;15;12
15' - 4"	-2" @	0;00;16;21
	+3" @	0;00;17;21
17' - 2"	-1" @	0;00;19;01
	+1.5" @	0;00;19;18
11' - 6"	-1" @	0;00;20;27
	+1" @	0;00;21;22
11' - 3"	-1" @	0;00;22;12
	+1" @	0;00;23;02
	-1" @	0;00;24;11
	+1" @	0;00;25;00

Wave Measurements Using Visualization and Timecode



Wave Measurement-Created by Michael Mortensen in Adobe Premier

Aerial Visualization of Different Types of Waves

Pontoon Boat and Jet Ski Wave Visualization

Wakeboard Boat Wave Visualization

Alex Navin preparing to launch the drone for aerial mapping at the North end of Wildwood Point (Site 3).

Jenna Bales preparing to launch the drone for aerial mapping at the South end of Wildwood Point (Site 3)

Mapping

GNSS + RTK + CPs

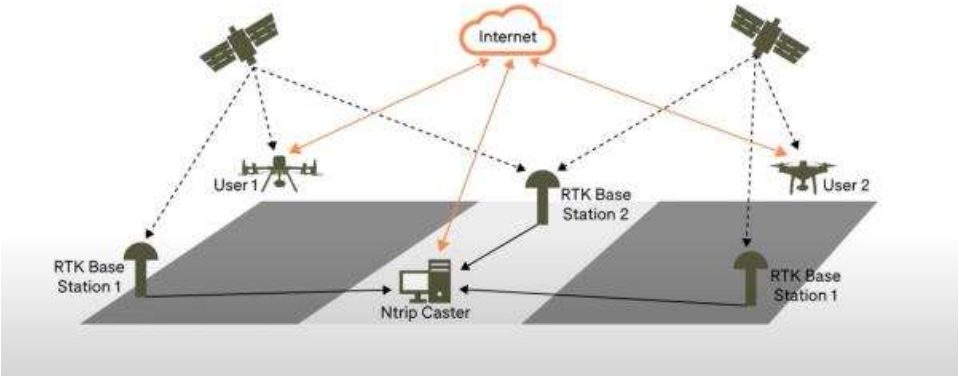
Pix4D Capture/Sitescan

Pix4Dmatic/Drone2Map/DroneDeploy

2D/Multispectral/Thermal

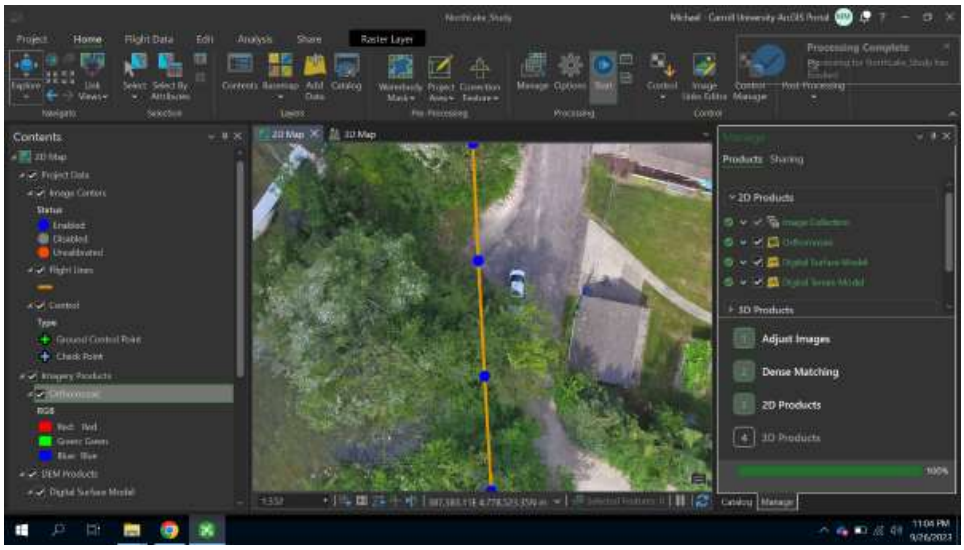
Phantom 4K + RTK

Mavic Pro 3T



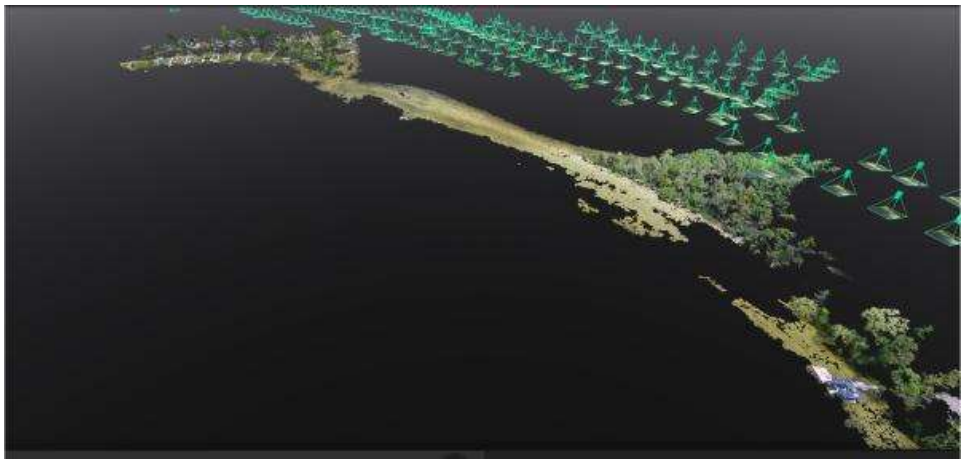
Global Positioning

GNSS and RTK control points

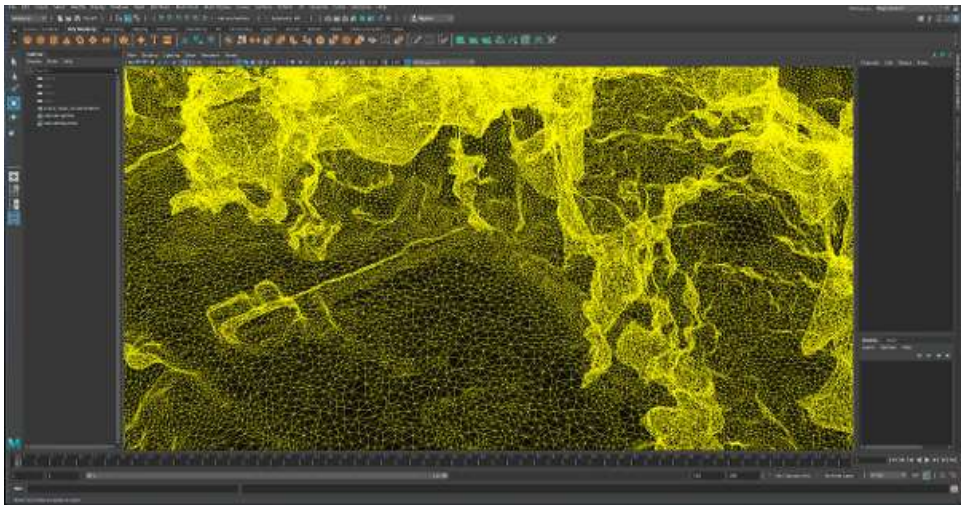


Drone2Map

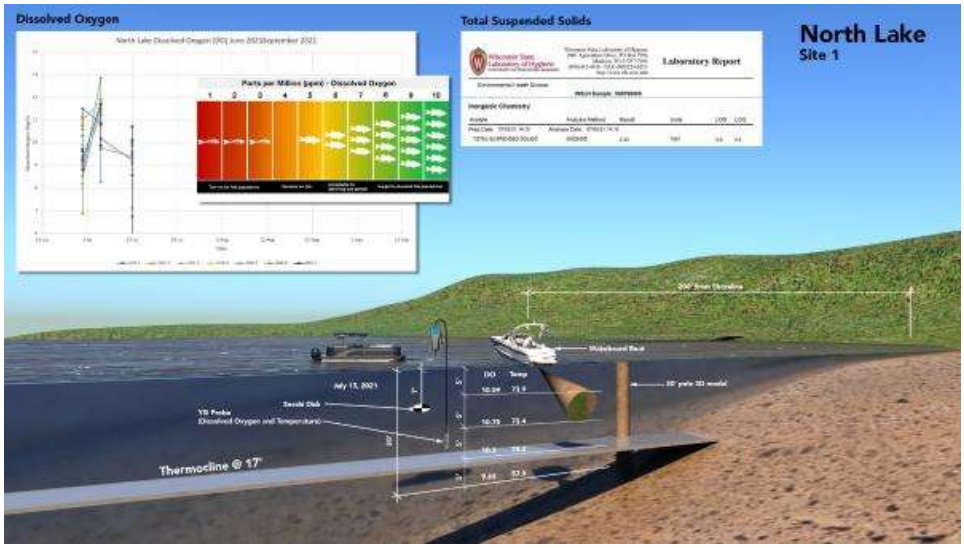
Site Mapping Location 1



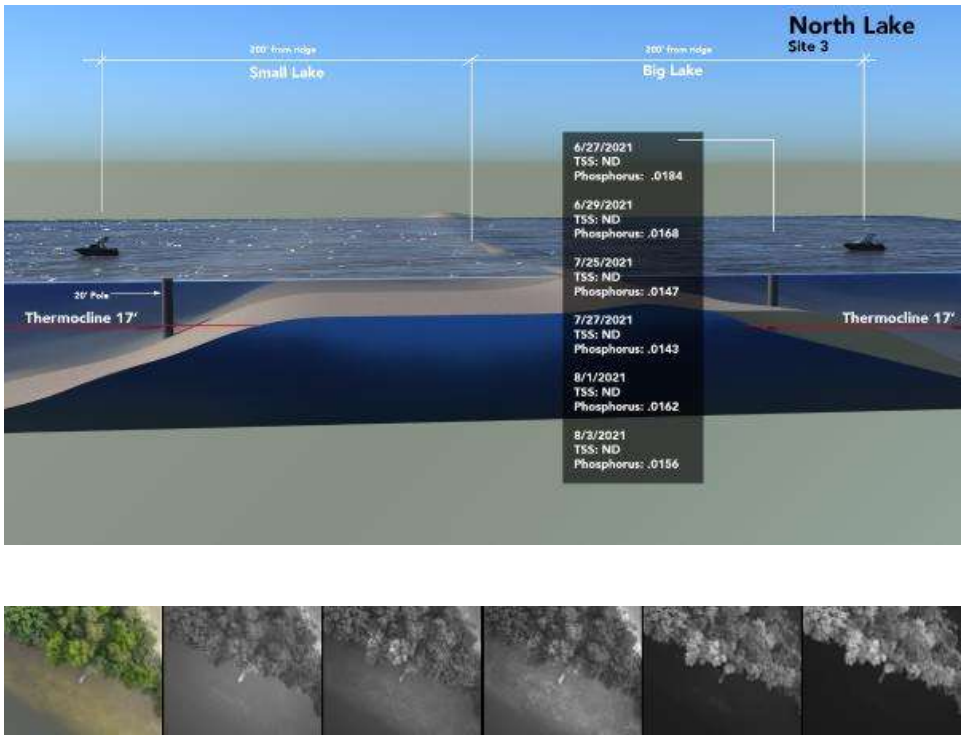
3D Mapping Model



3D Wireframe of Site 1



Prop Wash



Multispectral Mapping at Wildwood Point

Multispectral Camera Filters: Healthier vegetation reflects different types of light then unhealthy vegetation. According to the Normal Difference Vegetation Index (NDVI) algorithm, near infrared light is reflected by vegetation and red-light is absorbed by vegetation (“What is NDVI (Normalized Difference Vegetation Index)? - GIS ...”, n.d.).

Domain 2

Water quality measurements of Dissolved oxygen (DO), pH, secchi depths, and water temperature were collected. Lab analysis at Carroll University using Ion chromatography revealed concentrations of chloride, nitrate, and sulfate concentrations. Other common anions were not abundant in North Lake. Organic carbon content of sedimentation samples taken in the lake were determined as well.

In Situ Measurements:

Secchi Depth Chart and Map - Interactive

Dissolved Oxygen Chart - Interactive

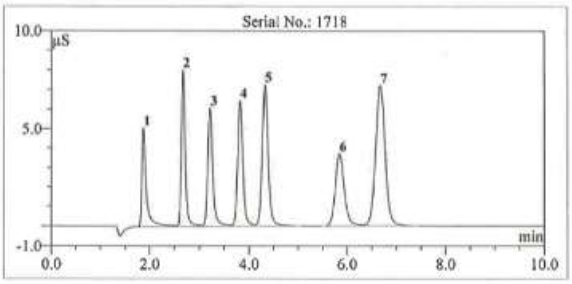
pH Chart - Interactive

Water sampling around the lake was done once a month starting in June and ending in August. Trial 1 sampling was done in June. Trial 2 sampling was done in July. Trial 3 sampling was done in August. Water samples were taken in situ at each site (1-7). The water samples were brought back to Carroll University and labeled/stored for Ion chromatography.

Standards of 2x, 5x, 10x, 20x, and full strength were prepared from the Seven Anions Standard Dionex Solution. The actual concentration of the standard solution and dilution series was calculated using stock concentration values provided on the bottle of the Dionex solution. This process was done each time before running the water samples.

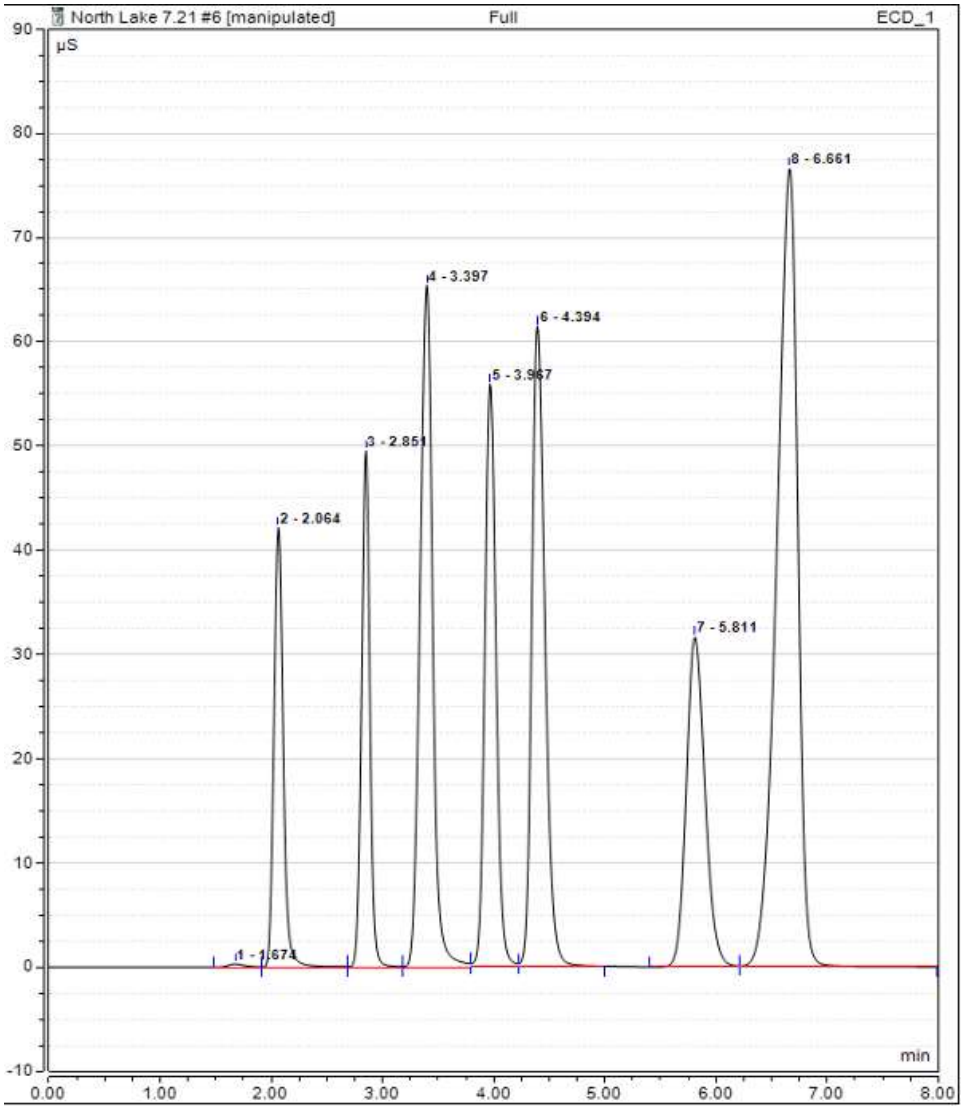
Ion Chromatography Results:

Chromatograms are useful in displaying order of elution, retention times, and peak areas. The retention times of each water samples were compared to that of the following image to discern what anion was in the mixture.

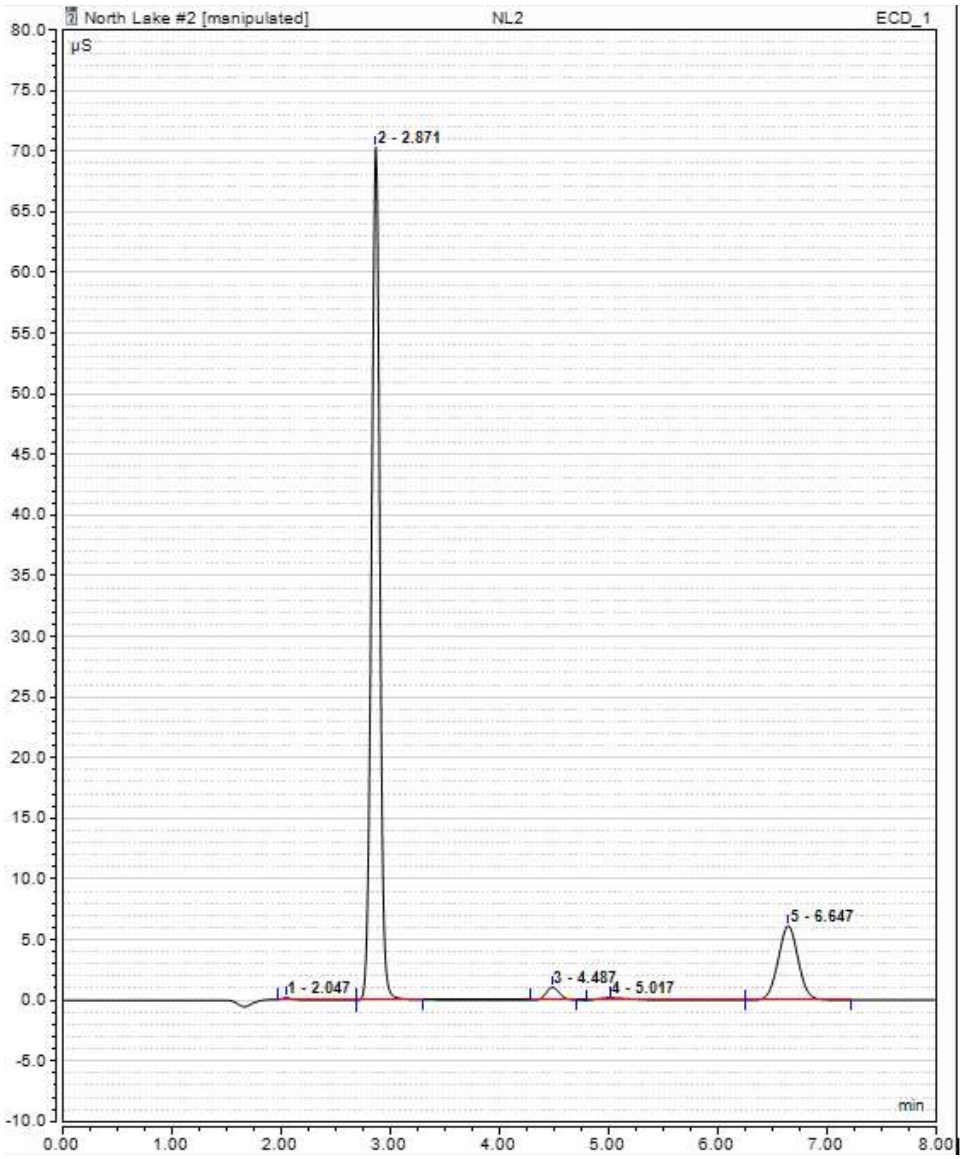


No.	Peak Name
1	Fluoride
2	Chloride
3	Nitrite
4	Bromide
5	Nitrate
6	Phosphate
7	Sulfate

A reference figure for order of elution and retention times. Picture courtesy of Dionex Corporation ("Ion Chromatography (IC) | Thermo Fisher Scientific - US", n.d.)

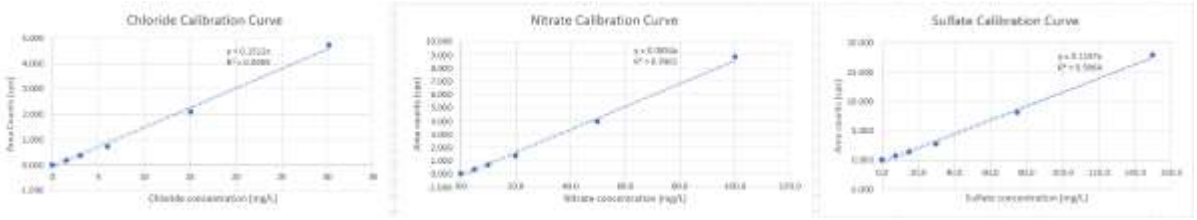


Trial 2 Full Standard Chromatogram Example



Trial 1, Site 1 Water Sample Chromatogram

Trial 1: June, 2020



Trial 1 Calibration Curves for Chloride, Nitrate, and Sulfate

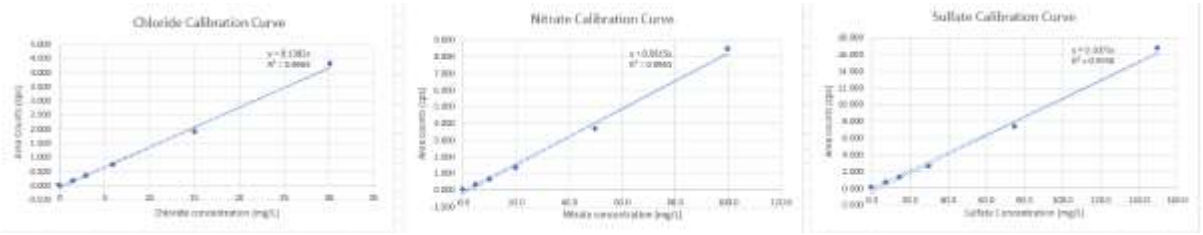
Location	Chloride concentration (mg/L)
Site 1	40.92
Site 2	40.75
Site 3	41.36
Site 4	41.78
Site 5	42.482
Site 6	43.13
Site 7	43.58

Location	Nitrate concentration (mg/L)
Site 1	1.78
Site 2	1.83
Site 3	1.83
Site 4	1.85
Site 5	1.90
Site 6	1.92
Site 7	1.48

Location	Sulfate concentration (mg/L)
Site 1	11.21
Site 2	11.29
Site 3	11.33
Site 4	11.33
Site 5	11.01
Site 6	10.75
Site 7	11.20

Trial 1 Anion Concentrations

Trial 2: July, 2020



Trial 2 Calibration Curves for Chloride, Nitrate, and Sulfate

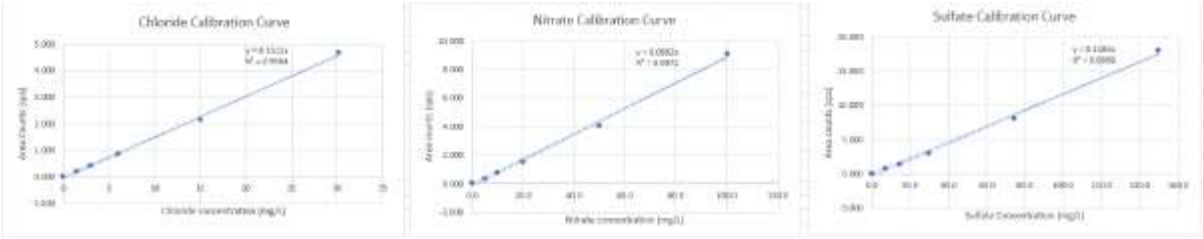
Location	Chloride Concentration (mg/L)
Site 1	48.79
Site 2	48.53
Site 3	49.11
Site 4	48.45
Site 5	48.87
Site 6	49.03
Site 7	50.87

Location	Nitrate Concentration (mg/L)
Site 1	0.91
Site 2	0.73
Site 3	0.65
Site 4	0.52
Site 5	0.29
Site 6	0.25
Site 7	0.46

Location	Sulfate Concentration (mg/L)
Site 1	11.04
Site 2	10.84
Site 3	11.25
Site 4	11.36
Site 5	11.03
Site 6	10.66
Site 7	11.24

Trial 2 Anion Concentrations

Trial 3: August, 2020



Trial 3 Calibration Curves for Chloride, Nitrate, and Sulfate

Location	Chloride concentration (mg/L)
Site 1	47.45
Site 2	47.60
Site 3	48.70
Site 4	48.80
Site 5	49.61
Site 6	49.49
Site 7	48.96

Location	Nitrate concentration (mg/L)
Site 1	0.49
Site 2	0.58
Site 3	0.54
Site 4	0.47
Site 5	0.48
Site 6	0.56
Site 7	0.64

Location	Sulfate Concentration (mg/L)
Site 1	11.03
Site 2	11.13
Site 3	11.24
Site 4	11.23
Site 5	11.353
Site 6	11.429
Site 7	11.287

Trial 3 Anion Concentrations

- Normal Chloride Range: 1-100mg/L (“Chlorides in Fresh Water”, n.d.)
- Normal Nitrate Range: Less than 1mg/L to 10mg/L (“5.7 Nitrates | Monitoring & Assessment | US EPA”, n.d.)
- Normal Sulfate Range: ~20mg/L typically but range from 2-250mg/L in lakes (“Sulfate in Drinking-water”, n.d.)

Organic Carbon Content Sediment Analysis:

Sediment samples were collected in in August 2020. Samples were stored in glass containers and brought back to Carroll University for storage and analysis. From each sediment sample taken from the lake, there were two smaller samples of the original taken and analyzed. Sample 2-1 and 2-2 are sediment samples taken from shallow water in the shoreline (Site 1). Sample 3-1 and 3-2 are sediment samples taken from the deep water in the shoreline (Site 1). Sample 4-1 and 4-2 are sediment samples taken from Wildwood Point (Site 3).

Samples were placed into dishes. Each dish was placed in an oven to dry at 105℃ for 24 hours. After 24 hours, all samples were placed in a dessicator for approximately 15 minutes. Samples were then placed in a furnace set to 450℃ for combustion. The oven was turned off and samples were removed 24 hours after. Reweighing of samples followed the cooling process.

3% - 5% Organic carbon content (Foc) is within normal ranges for lake sediments (Representative Values for Foc", n.d.).

Samples	Organic Carbon Content (Foc)	Percent Organic Carbon Content (%Foc)
Sample 2-1	0.035	3.502
Sample 2-2	0.029	2.927
Sample 3-1	0.239	23.877
Sample 3-2	0.047	4.742
Sample 4-1	0.038	3.848
Sample 4-2	0.037	3.717

North Lake Sediment Sample Organic Carbon Content (%Foc)

Alex Navin preparing samples for Ion Chromatography

Alex Navin and Jenna Bales preparing sediments for Organic carbon content analysis

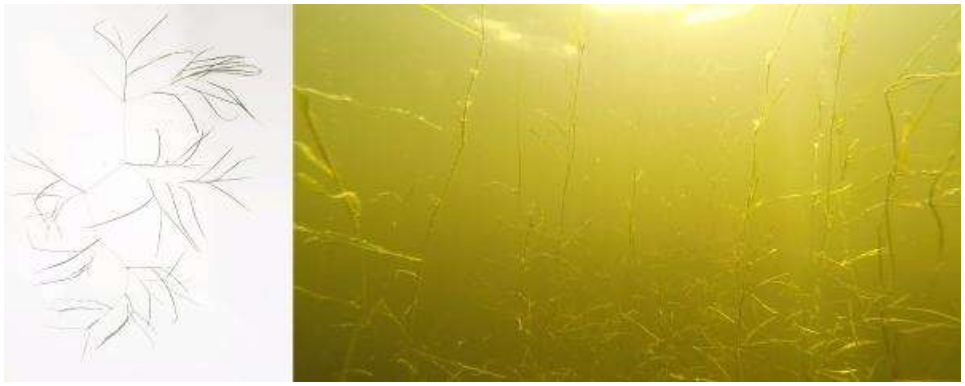
Domain 3

Measures and sampling of surface and subsurface plant life have been gathered by the research team. This sampling will

allow species identification and analyses for invasive weed risk.

Underwater ROV Footage

Sago Pondweed



Sago Pondweed

Both Flat-stem pondweed and Fries Pondweed were observed visually but it was difficult to tell the difference on camera. This plant was noticeable throughout many points in the lake especially Sites 5, 6, and 7. According to the USDA, this plant

can become "weedy" if it is managed properly (“Plant Fact Sheet for Sago Pondweed”, n.d.).

Vallisneria

Vallisneria americana

Otherwise known as Eel Grass, this plant provides habitats for fish and is rooted in the lakebed. This plant is native to the state of Wisconsin (“Vallisneria americana - Online Virtual Flora of Wisconsin”, n.d.).

Eurasian Milfoil

Eurasian Watermilfoil

Eurasian Watermilfoil is an invasive species that can cause habitat loss for native plants and creates habitats that are not

suitable for native aquatic life (“Plant Fact Sheet for Eurasian Watermilfoil”, n.d.)

Other plant-life found in North Lake:

- Clasping Leaf Pondweed
- Elodea
- Coontail
- Variable Leaf Pondweed
- Chara

Domain 4

Measures of plume development based upon wave propagation effects have been gathered. Imaging of plume content and spread characteristics are being analyzed relative to weed sprout areas.

Aerial Video of Plume Activity Below Water Surface in Early August

Control Variables Being Measured

The confounding effects of surface wind, ambient temperature, barometric pressure and rain fall (river inlet run-off) are also being tracked. The sample sites on the lake include multiple locations and various depths.

Phase 1 Highlights

- The preliminary data show clear differences between the wave heights, frequencies, and duration as well as both surface and subsurface depths of wave energy produced by different types of powered vessels on North Lake.

- The preliminary data show development of sedimentation “plumes” from wave enhancing vessels which impact

shoreline on North Lake.

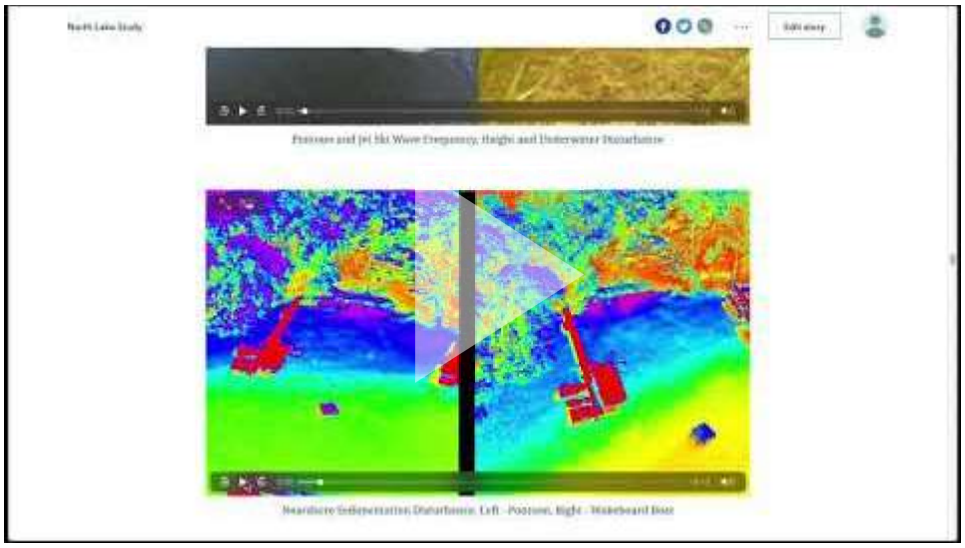
- The preliminary data show sedimentation elements which have potential for impacting plant growth for selected species of plants on North Lake.

- The preliminary data show variability in water clarity and dissolved oxygen levels in selected portions of North Lake.

- The preliminary data has allowed identification of selected chemical compounds in the water of North Lake which merit additional study and monitoring.

- The preliminary data has allowed identification of a range of plant species which have both positive and negative impacts on the lake and merits additional study.

Links for more information on this project



A 10 minute YouTube video explaining the content of this research project

Listen to The Box Office Insider Podcast on Spotify as Sara Meyer interviews Mike Mortensen, Jenna Bales, and Alex Navin

Acknowledgments

- Thank you to Dr. Piatt and Professor Mortensen for guidance during this project
- Thank-you to Dr. Tim Tyre for providing resources for us through TerraVigilis
- Thank-you to the Mr. Chris Kadrich and the Carroll Chemistry Department for providing solutions/supplies/equipment
- Thank-you to the Carroll University Honors Center for providing funding for this project through the Pioneer Scholar Program

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