KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

TECHNICAL MEMORANDUM

| | | | |
|---|---|---|---|
| **To:** | Rex Vaughn, Cedar Lake Improvement Board | **Date:** | August 22, 2019 |
| **From:** | Josh Kieser, Field Manager<br>Mark Kieser, Senior Scientist<br>Susan Benston, GIS Specialist | **cc:** | Doug Pullman |
| **RE:** | **Bathymetric Mapping and Sediment Assessment Survey** | | |

## 1. Introduction

Kieser & Associates, LLC (K&A) was retained by the Cedar Lake Improvement Board (CLIB) to perform bathymetric mapping and sediment thickness assessments of Cedar Lake. Objectives included the creation of a bathymetric map of the lake bottom in fine detail, as well as an assessment of sediment thickness measurements from sediment surface to a confining sand or clay till layer below accumulated muck. These tasks align with the stated objectives of the Cedar Lake WMP for understanding and potentially addressing organic muck sediment build-up in Cedar Lake.[1] The outcomes of these efforts are summarized herein and illustrated by the maps and graphs in Attachments A-E. Additionally, recommended next steps are included toward a pathway to best assess options for addressing muck accumulation.

## 2. Cedar Lake Bathymetry

K&A field staff conducted bathymetric mapping efforts from May 20-22, 2019. This involved piloting a vessel equipped with GPS and sonar technologies throughout the entirety of Cedar Lake while maintaining approximately 100ft wide passes to ensure thorough coverage of the lake bottom. GPS and sonar data were digitally recorded at less-than-one-second intervals throughout the data collection process. K&A processed these data to create a bathymetric map in fine detail. The data were also uploaded to the Biobase™ online platform to retain the sonar log and to assist with analyses of the sonar track comparisons of lake bathymetry and lake bottom composition.[2]

The detailed bathymetric map is included herein as Attachment A. Separate files, suitable for printing at a larger scale, are being provided to the CLIB under separate cover. The aforementioned Biobase-generated lake bottom composition map is included for reference as Attachment B.

## 3. Cedar Lake Sediment Assessment

During the bathymetric mapping process, K&A field staff collected supplemental data on sediment thickness and sediment compression using a specialized suite of manual assessment tools. Sediment assessment stations were chosen to provide a representative sampling of the

[1] http://www.cedarlakewmp.net/
[2] https://www.biobasemaps.com/

potential sediment thicknesses at various depths and locations throughout Cedar Lake. A GPS waypoint was recorded at each station. The sediment assessment method was performed twice at each station with results averaged during data analysis. Field data collection included: 1) water depth (via sonar), 2) manual water depth measurement, 3) sediment compression testing, and 4) sediment thickness measurements. Descriptions of these assessment methods are outlined in Section 3.1 of this memorandum.

Sediment compression and sediment thickness were calculated by subtracting the water depth as recorded in field data collection steps 1 and 2 from the total depths recorded in methods 3 and 4, respectively. Field data and calculations for the northern wetlands portions of Cedar Lake, the northern main body of the lake, and areas south of the causeway are found in Tables 1-3, respectively. Additional analyses of these results are discussed in Section 4 of this memorandum.

Attachment C provides a map of K&A sediment thickness data plotted at the sediment assessment stations throughout Cedar Lake. Attachment D includes graphs of the data for each assessment station, alongside images of the sonar log and the Biobase composition maps for comparison. Attachment E defines areas of the lake subsequently used to estimate volumes of muck sediments.

### 3.1. Description and Purpose of Sediment Assessment Methods

The methods used in this assessment are summarized as follows.

**1. Water depth (Sonar):** Measured using a Lowrance Elite-7ti sonar depth finder unit with an HDI 83/200kzH transducer.

**2. Manual water depth:** Measured by gently lowering a Secchi disk to the lake bottom and recording the depth from the water surface. The purpose of this assessment is to confirm the sonar depth reading at the specific location used to assess the amount of loose, flocculent sediment on the lake bottom under the following methods.

*Figure 1. K&A sediment compression tool.*

**3. Sediment compression:** Measured by lowering a 5lb conical steel weight (Figure 1) to 1ft above the lake bottom, then allowing the tool to free-fall, thereby compressing the organic sediment, and recording the depth of from the water surface to compute penetration in relation to the sediment surface. The purpose of this assessment is to understand how the top layer of organic muck sediment responds to the force of compression, a valuable metric for assessing the feasibility of certain management options. This is also done to gather data that might corroborate "sediment hardness" maps produced through BioBase™ data processing of water depths. Anecdotally, this method provides some insight as to the question: "If someone stepped onto the lake bottom here, how far down might they sink into the muck?"

**4. Sediment thickness:** Measured by penetrating the lake bottom with a thin, metered aluminum rod of 12ft length until it reached the "hard pan" below the organic sediment layer and recording the depth from the water surface. The purpose of this assessment is to understand the total thickness of organic sediment accumulation above a more impenetrable sand or clay till layer reflective of a glacial hard pan. This method is important for any future calculations of sediment volumes in Cedar Lake and for determining the feasibility and potential need for future sediment management strategies.

## 4.0. Results & Analysis

This section provides the results and analyses of the May 2019 Cedar Lake sediment assessments. Tables 1-3 contain relevant field data and results of the sediment assessments for northern wetlands, northern and southern portions of the lake, respectively. (Refer to Attachment C for sediment station locations.) Where sediment thickness is reported as greater than (">") a depth in feet, this indicates that these areas exceeded the capacity of the measurement rod length. Results reported as "NC" indicate no sediment thickness data were computed due to a water depth at or near 12 feet. Weather conditions during each portion of the survey are included with each table.

*Table 1. Sediment Assessment Data Table, Cedar Lake – Northern Wetlands Area.*

***Date:*** *5/21/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds NE 5-10mph then E/ESE 3-7mph, Temps 50-56F.*
***Date:*** *5/22/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds ESE 6-13mph, Temps 42-51, Light rain*

| GPS Waypoint | Water Depth | Sediment Compression | Sediment Thickness |
|---|---|---|---|
| | *ft* | *ft* | *ft* |
| **196** | 2.0 | 2.0 | 6.2 |
| **197** | 2.1 | 0.9 | 7.9 |
| **198** | 1.8 | 0.6 | 2.8 |
| **199** | 1.2 | 1.9 | 3.3 |
| **200** | 1.8 | 1.9 | 4.2 |

*Table 2. Sediment Assessment Data Table, Cedar Lake – Northern Portion of Lake (NC means not calculated).*

***Date:*** *5/21/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds NE 5-10mph then E/ESE 3-7mph, Temps 50-56F*
***Date:*** *5/22/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds ESE 6-13mph, Temps 42-51, Light rain*

| GPS Waypoint | Water Depth | Sediment Compression | Sediment Thickness |
|---|---|---|---|
| | *ft* | *ft* | *ft* |
| **196** | 2.0 | 2.0 | 6.2 |
| **197** | 2.1 | 0.9 | 7.9 |
| **198** | 1.8 | 0.6 | 2.8 |
| **199** | 1.2 | 1.9 | 3.3 |
| **200** | 1.8 | 1.9 | 4.2 |
| **202** | 2.0 | 2.0 | 4.7 |
| **207** | 4.2 | 1.7 | 2.1 |
| **209** | 4.8 | 2.5 | 3.2 |
| **211** | 4.5 | 1.8 | 5.5 |

| | | | |
|---|---|---|---|
| **212** | 3.8 | 1.6 | 3.7 |
| **213** | 3.9 | 2.1 | >8.1 |
| **214** | 4.0 | 2.0 | 5.8 |
| **215** | 9.3 | 3.2 | NC |
| **216** | 4.7 | 2.6 | 7.1 |
| **217** | 7.8 | 1.4 | 3.9 |
| **218** | 5.0 | 3.0 | 4.4 |
| **219** | 4.6 | 2.7 | 6.2 |
| **221** | 4.5 | 1.9 | >7.5 |

*Table 3. Sediment Assessment Data Table, Cedar Lake – Southern Portion of Lake (NC means not calculated).*

***Date:*** *5/20/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds NNW 10-12mph, Temps 48-51F*
***Date:*** *5/21/2019* ***Assessor:*** *J. Kieser* ***Weather:*** *Winds NE 5-10mph then E/ESE 3-7mph, Temps 50-56F*

| GPS Waypoint | Water Depth | Sediment Compression | Sediment Thickness |
|---|---|---|---|
| | *ft* | *ft* | *ft* |
| **179** | 5.0 | 1.0 | 2.3 |
| **180** | 4.5 | 0.5 | 3.2 |
| **181** | 3.6 | 1.9 | 3.2 |
| **182** | 11.5 | 1.5 | NC |
| **184** | 5.1 | 4.7 | 6.1 |
| **187** | 4.0 | 2.8 | >8.0 |
| **188** | 2.3 | 1.6 | 9.0 |
| **189** | 3.0 | 2.5 | 8.2 |
| **190** | 3.3 | 3.5 | >8.7 |
| **191** | 5.0 | 1.0 | 3.7 |

Further assessments of the direct sediment measurements were conducted by estimating the sediment compression layer and total sediment thickness as seen in sonar log images found in Attachment D. Figures 2 and 3 illustrate the results of these comparisons.

The comparison illustrated in Figure 2 shows a relatively strong correlation between sonar readings of the uppermost soft muck layer and compression test data. This correlation could eventually be used to map areas where the softest surficial sediments are noted. (No correlations were identified between BioBase™ "hardness" data maps that provided with interpolated bathymetric mapping data, and sediment compression testing field results.)[3]

[3] BioBase™ hardness data are often used by other lake consultants in Michigan to suggest soft, muck bottom treatment areas for laminar flow aeration. Hardness "maps" are also used as the metric for inferring how such aeration has "hardened" the surficial muck sediment layer. Of particular note is how the BioBase™ software guidance specifically denotes the need to correlate their reported "hardness" data with actual field measurements. K&A is not aware of any such correlations ever attempted or reported in LFA projects that purport to have "hardened" muck sediments. As K&A found no such correlations here, we are not reporting on hardness mapping that was provided by BioBase™ with Cedar Lake bathymetric data and mapping. Examples of such maps for Cedar Lake are, however, included in Attachment D herein.)

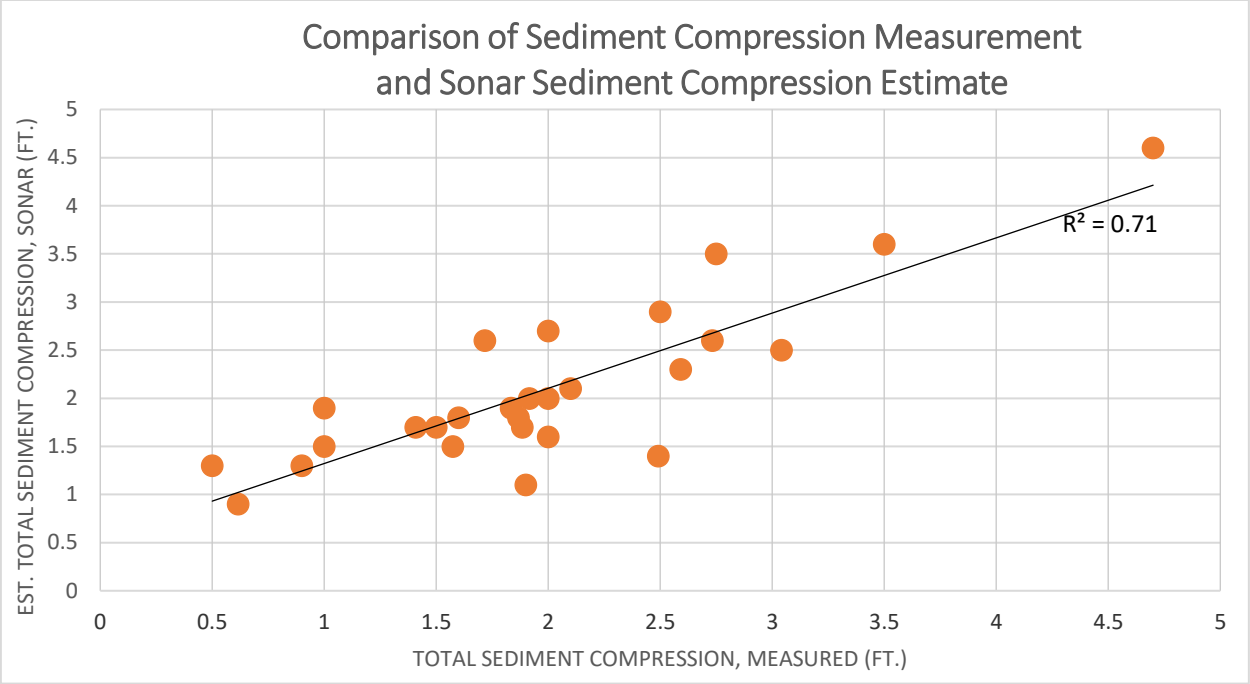



*Figure 2. Sediment compression measurements compared to estimated sonar sediment compression layer.*

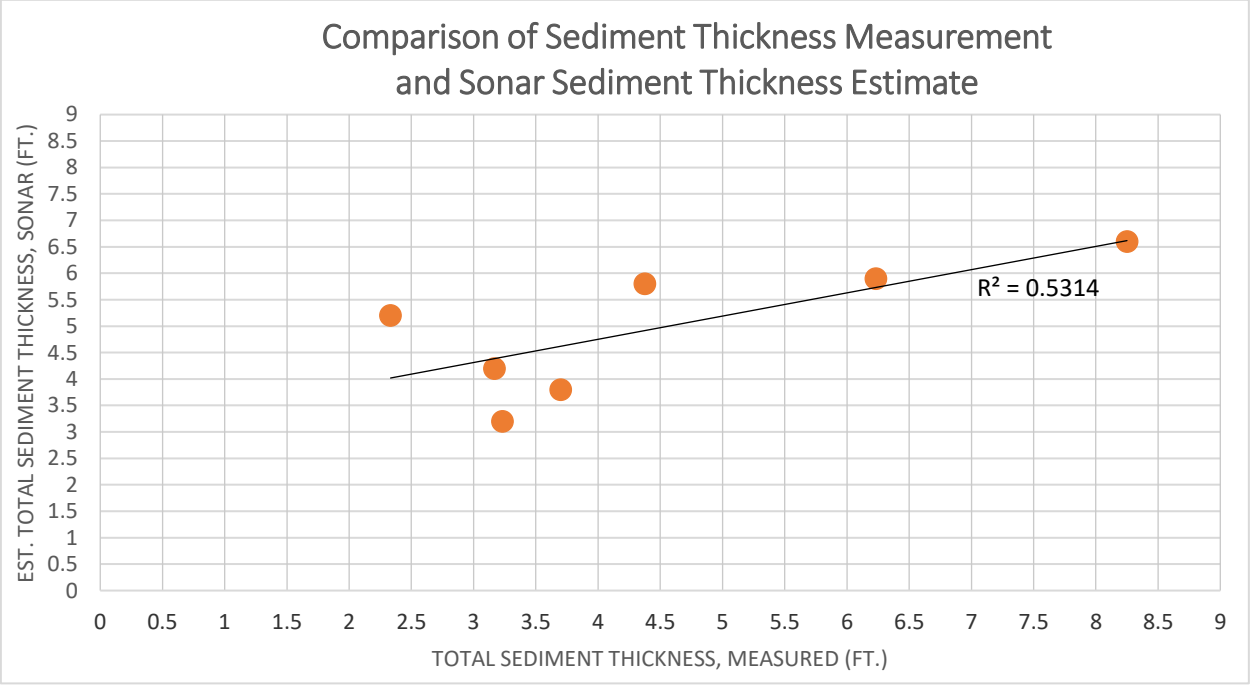



*Figure 3. Sediment thickness measurements compared to estimated sonar sediment thickness layer.*

With a relatively weak correlation in Figure 3, K&A would not suggest at this time, that sonar readings of sediment thickness could be derived for the entire sonar reading database. This

partially relates to certain sonar images being omitted from this analysis due to limited visibility of the total sediment thickness reading from the sonar database when the unit's auto-range capability for depth precluded visual imagery. In addition, the limited length of the sediment thickness rod did not allow for physical thickness measurements of the muck stratum at select water depth locations.

Finally, sediment thickness measurements were used to preliminarily estimate the volume of organic muck sediment throughout the lake. For this analysis, the lake was divided into three portions: 1) open water in the northern-most wetland area and Cedar Lake outlet; 2) main body of Cedar Lake north of the causeway (excluding the northern wetlands area), and; 3) Cedar Lake south of the causeway. For each portion of Cedar Lake, the average sediment thickness (in yards) calculated with available measurements from Tables 1-3, was multiplied by the lake's surface area (yards$^2$) for areas with depths generally greater than 4 feet (which is equivalent to about a 100-foot distance from the water's edge along shorelines). Other areas excluded from muck volume calculations included deeper trenches as determined by 2019 bathymetry. Attachment E shows the areas delineated for volume calculations in each of the three areas of the lake; Table 4 presents the corresponding surface areas. The resulting calculations for initial estimates of muck sediment volume reported as million yards$^3$ as shown in Table 5.

*Table 4. Surface areas for mapped lake sediments and corresponding waypoints included in each area.*

| Cedar Lake Mapped Sections | Waypoints | Surface Area (yards$^2$) |
|---|---|---|
| Northern Wetland | 196, 197, 198, 199, 200 | 40,345 |
| Main Body North of Causeway | 202, 212, 213, 214, 215, 216, 217, 218, 221, 209, 207, 211, 219 | 3,261,402 |
| South of Causeway | 179, 180, 181, 182, 184, 187, 188, 189, 190, 191 | 468,937 |

*Table 5. Average sediment thickness and estimated volumes of organic muck sediment volume throughout Cedar Lake.*

| **Average Sediment Thickness – Northern Wetland** | **Estimated Sediment Volume** |
|---|---|
| ***yards*** | ***Million cubic yards*** |
| 1.6 | 0.06 |
| **Average Sediment Thickness – Main Body North of Causeway** | **Estimated Sediment Volume** |
| ***yards*** | ***Million cubic yards*** |
| 1.7 | 5.54 |
| **Average Sediment Thickness – South of Causeway** | **Estimated Sediment Volume** |
| ***yards*** | ***Million cubic yards*** |
| 1.9 | 0.89 |

## 5. Discussion

Accumulated muck sediments appear to be relatively evenly distributed across Cedar Lake given observed depths to an underlying hard pan layer. This constrains physical muck sediment removal options in any areas of the lake. A dredging operation would need to continuously move mechanical equipment to remove only accumulated muck from dredging depths of less than approximately 12 feet below the water surface to avoid disturbance of the glacial till layers beneath observed muck build-up. This would dictate a fairly active removal effort to continuously cover more area versus an option to dredge at greater depths in more static locations whereby deepened areas would allow over time, muck from non-dredged areas to more evenly re-distribute over time. Such active mechanical removal constraints add costs to dredging operations.

Considering the three lake segments, it is likely that any form of physical sediment removal at scale with dredging would necessarily focus on areas away from shorelines where there was uniformity in water depth and sediment thickness. (Hence, the rationale for not including shoreline and trench areas.) It would also be less likely that sediment removal in the northern-most wetland areas would occur because of habitat disturbance and likely lower frequency of recreational uses that would benefit from increased depths (for example, recreational boating, water skiing, jet skiing). Physical sediment removal in the southern-most portions of the lake would require finesse with mechanical operations due to more variable bathymetry and shoreline non-linearity. Muck removal in the main body of the lake would be more accommodating to larger scale mechanical operations.

Notable here in these preliminary discussions is that muck sediments in previously un-dredged portions of Cedar Lake have a history of about 10,000-12,000 years of accumulation since the last glacial retreat. Though this very preliminary, initial study did not attempt to address the age or accretion rate of sediments, it would be prudent to weigh the costs of muck sediment management with the accrual rates under current aquatic vegetative growth conditions. As denoted in the Cedar Lake Watershed Management Plan, the lake does not receive any significant sediment inputs from tributaries or the shoreline. Thus, accumulated muck is largely attributable to the natural aging of lakes through seasonal growth and die-off of plants growing in the lake.

Seasonal/annual aquatic plant die-off is of course somewhat accelerated by treatment and subsequent re-growth of troublesome aquatic plants such as hybridized Eurasian Watermilfoil. Forecasting future lake water quality and aquatic plant responses to muck removal must also be considered. This could be partially achieved by more specifically examining plant growth conditions in “trench” areas at selective locations along the Cedar Lake shoreline. These previously dredged trenches seem to accumulate more extensive plant growths (D. Pullman, personal communication, 2019) than other open water, undisturbed sediment areas. As sediment

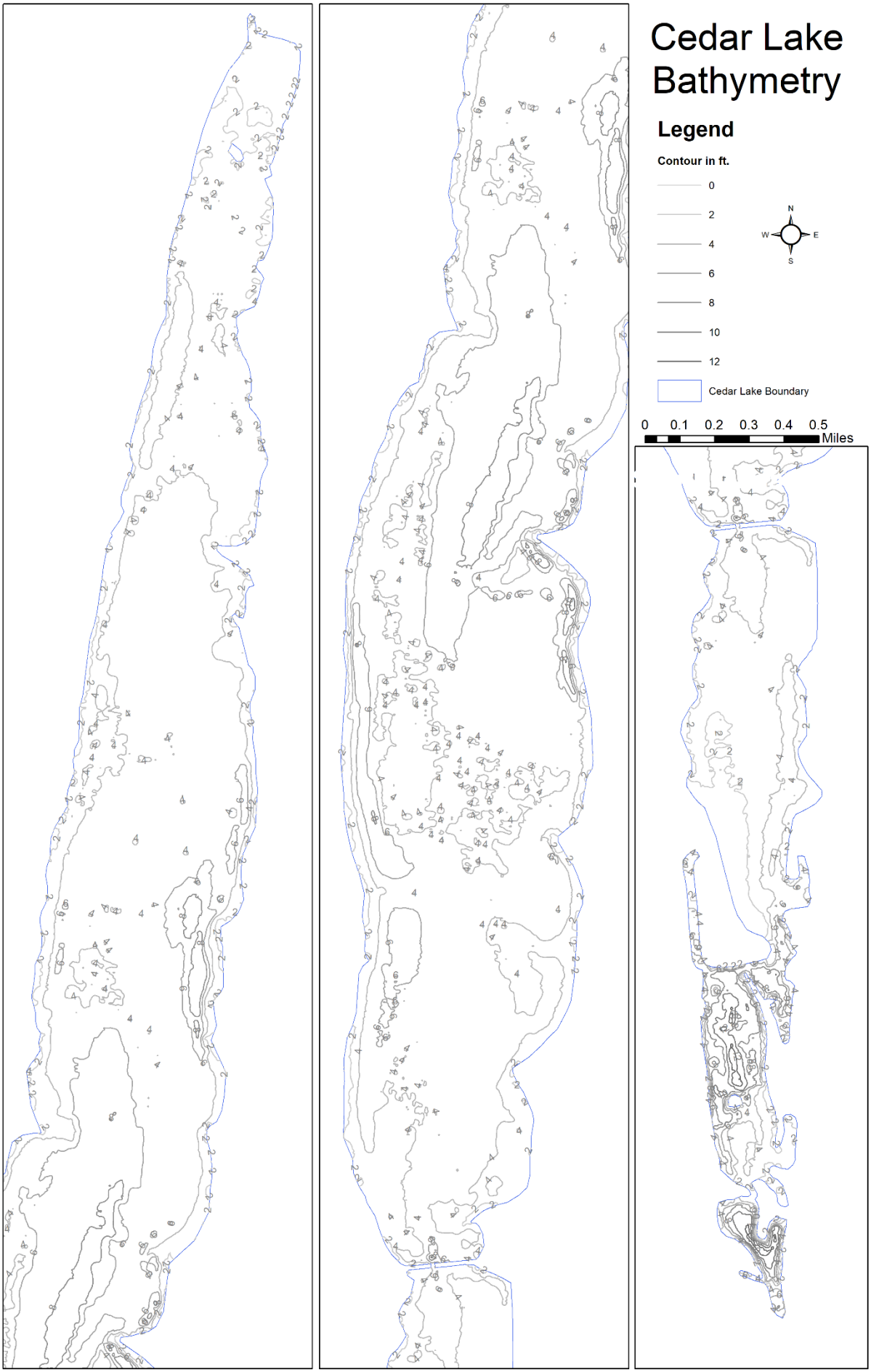
removal is a major disturbance to the natural balance of any lake, a whole host of considerations must be taken into account beyond just contracting and permitting conditions necessary for physical removal and disposal of dredge spoils. Certainly costs will weigh into any decision-making process. Considering that perhaps the theoretically most efficient cost/cubic yard of material removed/disposed might be $0.50, ~6.5 million cubic yards dredge materials from the main body and southern lake presents a price tag of over $3,000,000. Commonly, the average low-cost dredging operation is closer to $1/cubic yard. Selective dredging and/or other alternatives could be examined in future discussions.

## 6. Recommended Next Steps

Based on the results of the bathymetric mapping and sediment assessment survey, K&A recommends the following as next steps toward further development of potential future management strategies related to muck sediment management:

- Discuss the potential scope and costs of a major sediment management effort with AICLA/CLIB, likelihood of success and pros and cons.
- If there are specific dredging interests, conduct strategic conversations with state regulatory agencies to determine their willingness to potentially permit dredging activities on Cedar Lake.
- If permittable, develop preliminary cost estimates for implementing various sediment removal strategies including soil disposal and/or alternative approaches. Such options might include:
    - Large scale dredging
    - Selective area dredging
    - Innovative re-use for dredge spoils (to reduce over disposal costs)
    - Alternative deployment of shoreline mat installations on a home-by-home basis
    - Other non-traditional options[4]
- Develop and implement a scope of work for contaminant analysis of sediment chemistry and organic matter content in strategically targeted areas to assess dredge disposal/permitting constraints.
- Determine management strategies, timeline and costs in relation to the Cedar Lake WMP and permitting needs for pursuing desired strategies.

[4] Laminar Flow Aeration with Bioaugmentation (LFA) is a popularized 'sediment' treatment technique being deployed in several Michigan Lakes and other selective locations in the U.S. Consultant reporting has suggested a host of benefits could be/have been achieved over 1 to several years of application. Some of these reported results are anecdotally supported by lake users. Purported benefits have included muck reduction, sediment 'hardening', nuisance aquatic plant control, and nuisance algal bloom control. The state of Michigan in 2017 instituted new permitting and monitoring requirements around these applications out of concern for known and/or suspected ecological disruptions with some lake applications. K&A has directly studied a number of these applications stemming back to the mid-1990s and has yet to find conclusive and irrefutable examples of reproducible and directly measured benefits. This is not to cast aspersions, rather to set the backdrop for Cedar Lake such that if any LFA approach is ever considered, pilot demonstrations under controlled conditions should be a mandatory prerequisite to demonstrate benefits before any funds are committed for full-scale application. K&A has found no peer-reviewed scientific literature published to date that specifically supports the contention of the broad-scale LFA benefits touted in applications based on our exhaustive reviews conducted to date. Of the few directly applicable publications, none could find demonstrable scientific evidence to support claims.




**Attachment A**

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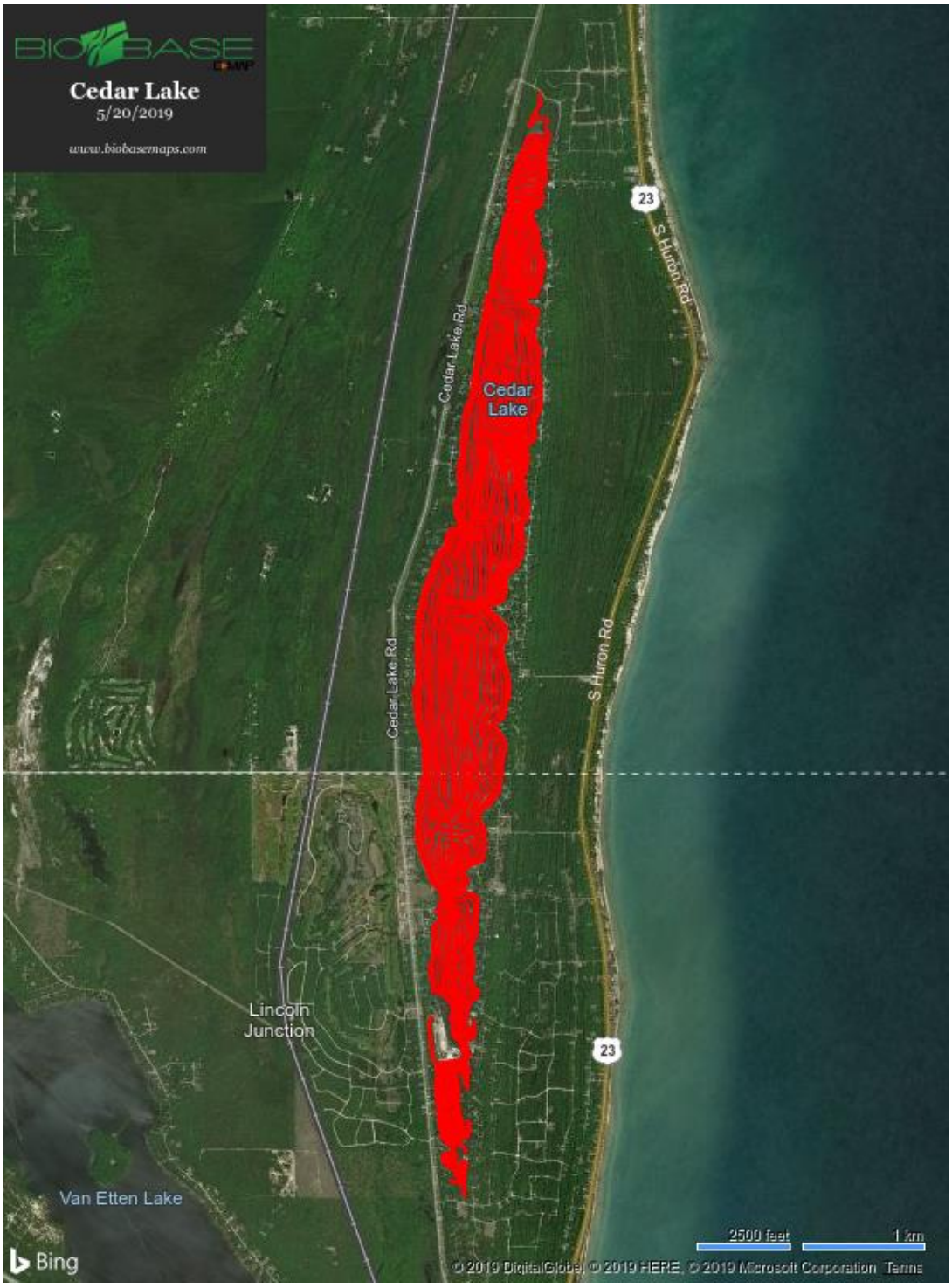


GPS track of K&A bathymetric mapping and sediment assessment survey efforts on Cedar Lake, 5/20/19 – 5/22/19.

**Attachment B**

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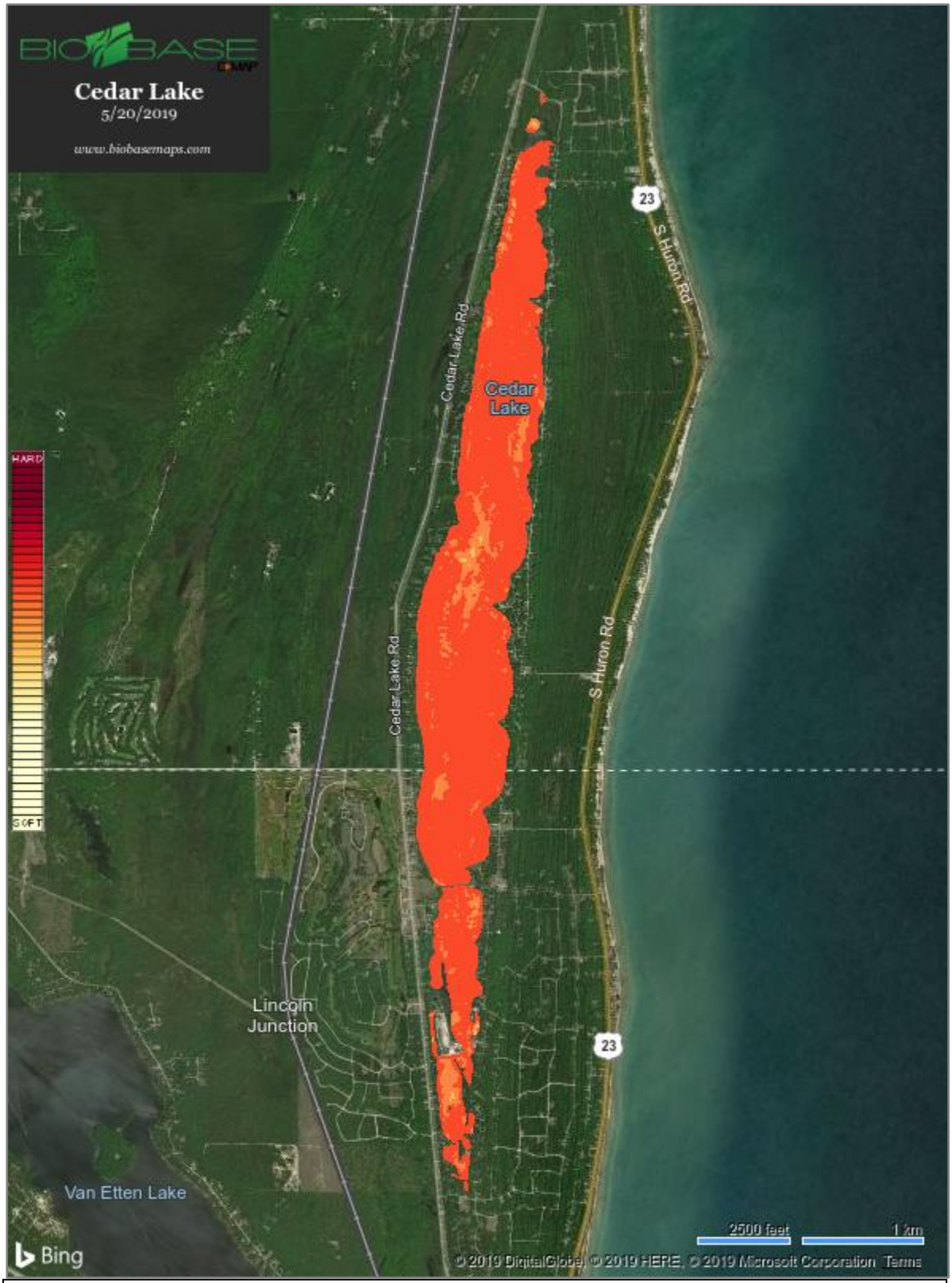
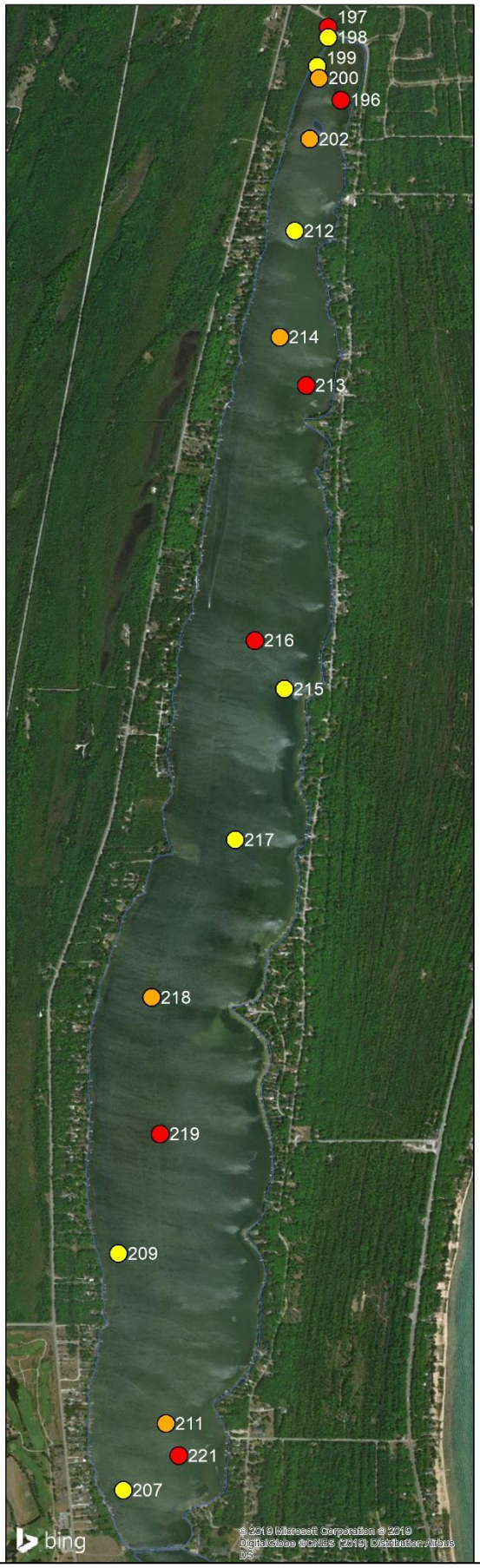



Biobase lake bottom composition (hardness) layer for Cedar Lake, 5/20/19 – 5/22/19. This map is meant to be used for comparative purposes only.

The Biobase composition algorithms estimate the acoustic reflectivity of the lake bottom by processing the sonar signal. Signals "bounce" more on hard lake bottoms and are "absorbed" more on soft lake bottoms. Note that composition is not available at depths <1.5ft. More information about the Biobase composition layer can be found at: <https://blog.biobasemaps.com/2019/04/11/composition-algorithm-improved/>

**Attachment B**




# Cedar Lake Sedimentation Measurements

N
W
E
S

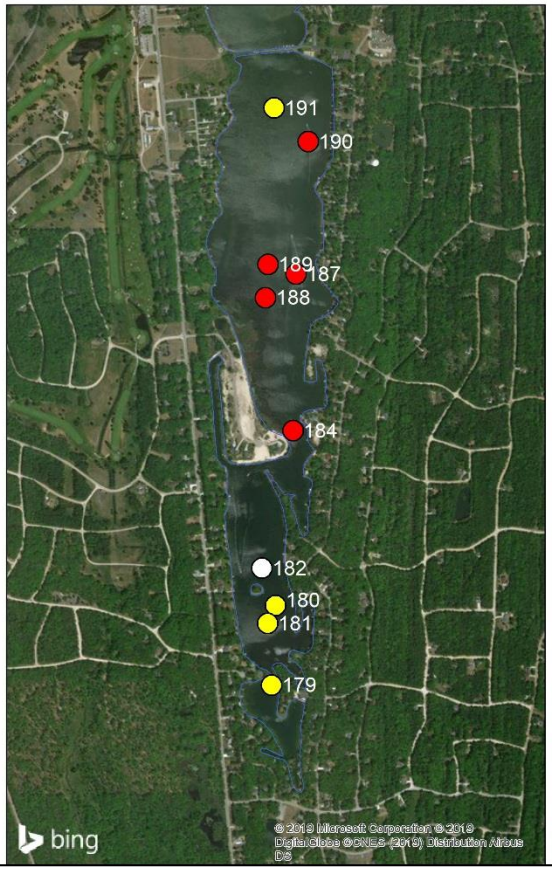
## Legend

Sediment Thickness Total

- 0 - 2 ft.
- 2.1 - 4 ft.
- 4.1 - 6 ft.
- > 6 ft.
- Cedar Lake Boundary

0 0.25 0.5 0.75 1 Mile






K&A sediment thickness assessment results for each assessment station waypoint for Cedar Lake, 5/20/19 – 5/22/19.

**Attachment C**

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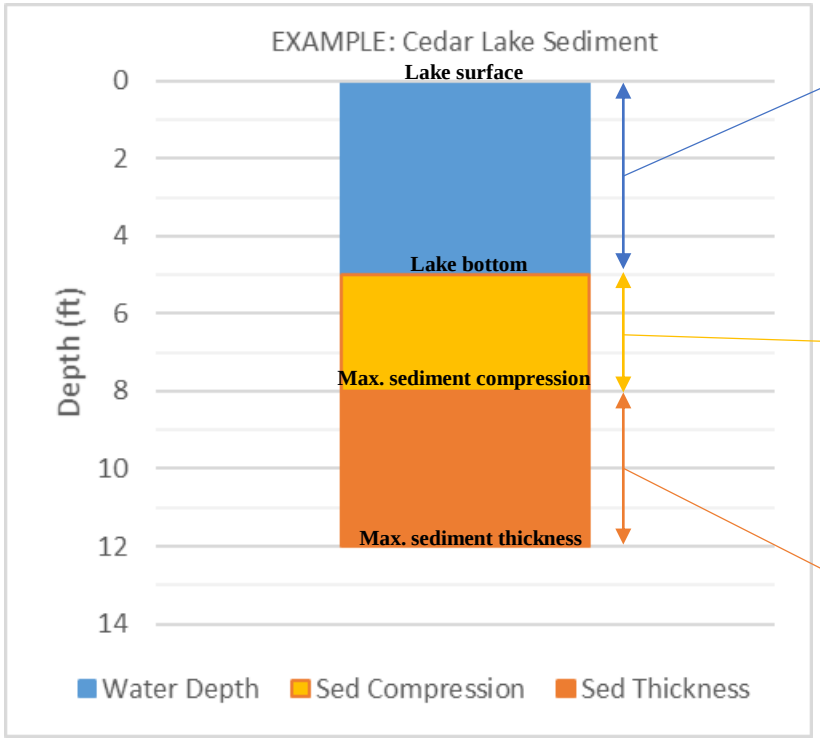
# Description of Cedar Lake Sediment Assessment Graphs

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| *Assessment Location* | *Lake surface to lake bottom* | *Lake surface to max. sediment compression* | *Lake surface to max. sediment thickness (hard-pan)* |
| EXAMPLE | 5 | 8 | 12 |




**Manual water depth:** Distance from the lake surface to the top of the organic sediment (lake bottom).

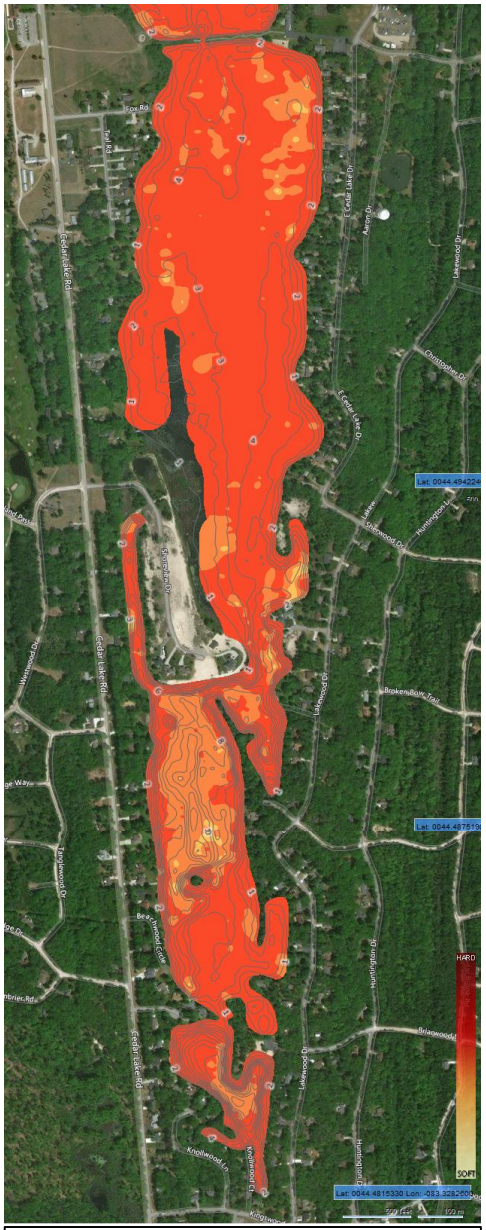
**Sediment compression:** Measured by lowering a 5lb conical steel weight to 1ft above the lake bottom, then allowing the tool to free-fall, thereby compressing the organic sediment, and recording the depth from the water surface.

***The purpose of this assessment*** is to understand how the top layer of organic muck sediment responds to the force of compression. This method is meant to help answer the question: If someone stepped onto the lake bottom here, how far down might they sink into the muck?

**Sediment thickness:** Measured by penetrating the lake bottom with a thin, metered aluminum rod of 12ft length until it reached the "hard pan" below the organic sediment layer and recording the depth from the water surface.

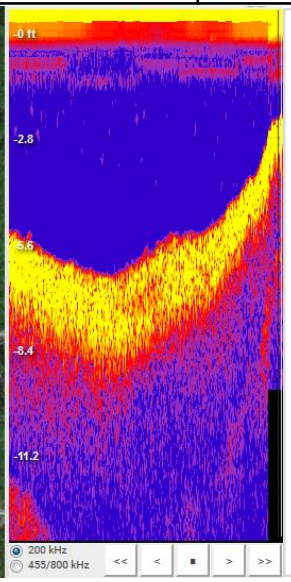
***The purpose of this assessment*** is to understand the total depth of organic sediment accumulation above the impenetrable sand or clay till layer. This method is important for any future calculations of sediment volumes in Cedar Lake and for determining the feasibility and potential need for future management strategies.

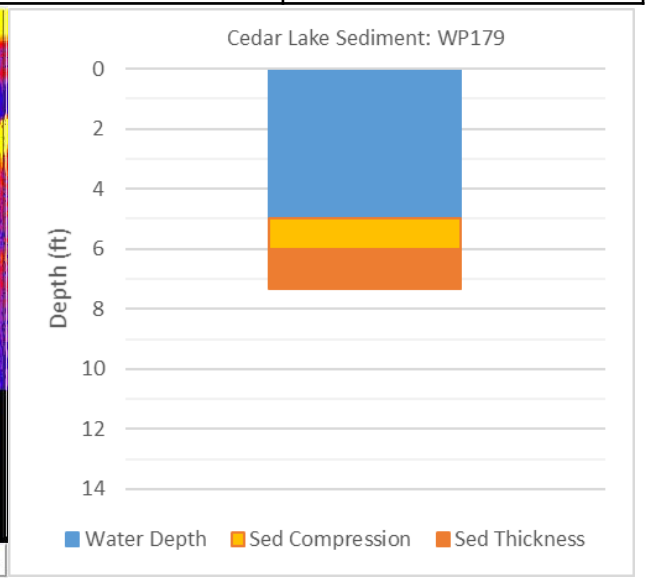

Cedar Lake South sediment assessment station waypoints



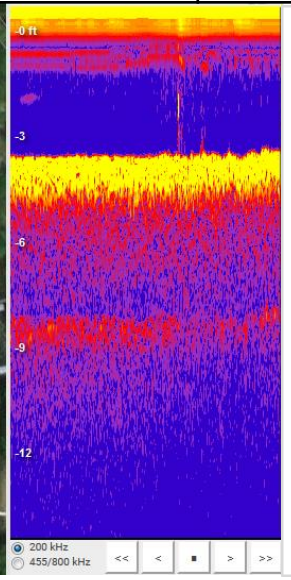
Cedar Lake South Biobase composition layer, for comparative use.

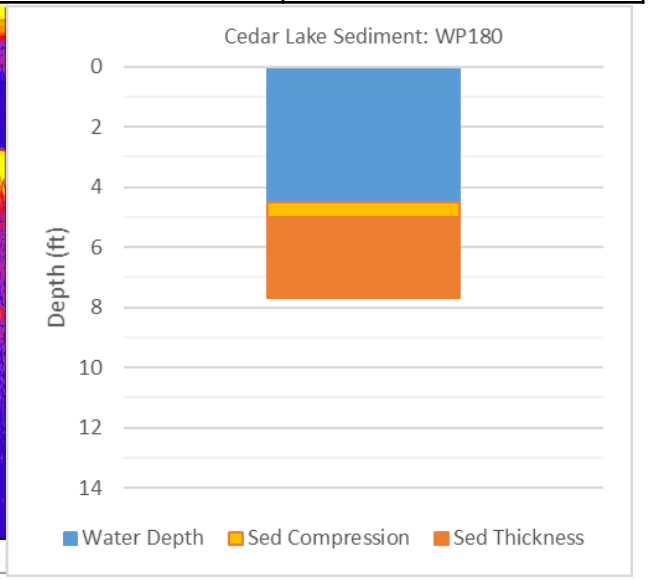
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 179 | 5 | 6 | 7.33 |

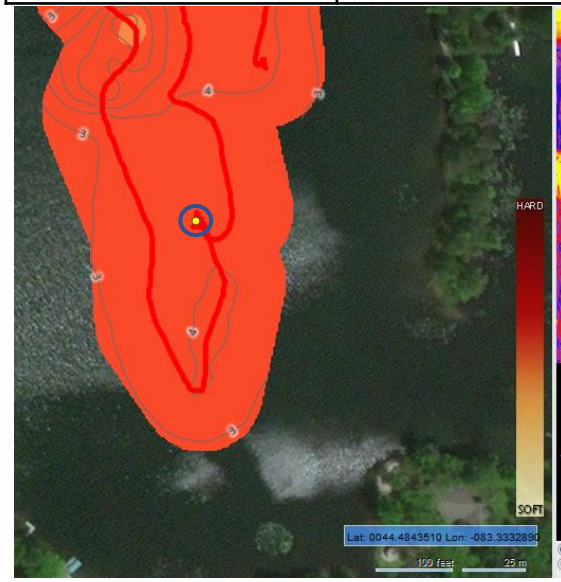



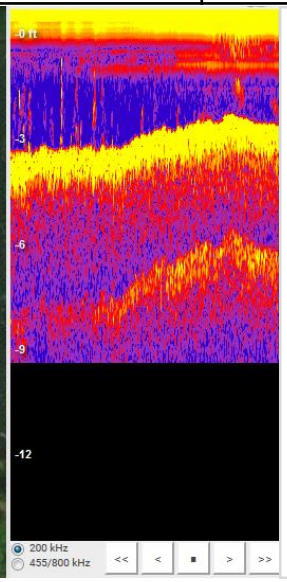

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 180 | 4.5 | 5 | 7.67 |

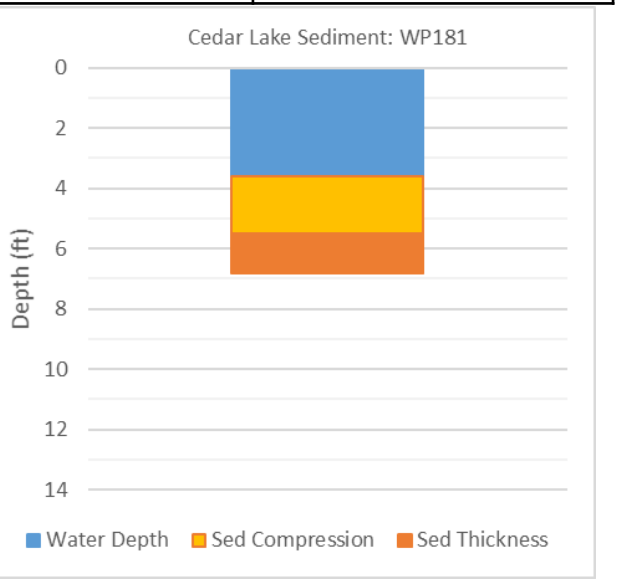



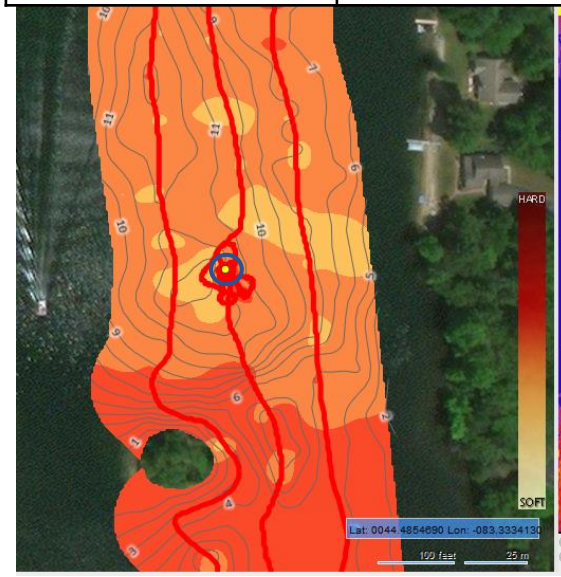
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 181 | 3.6 | 5.5 | 6.83 |

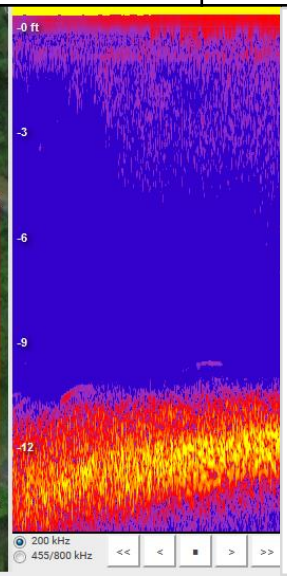


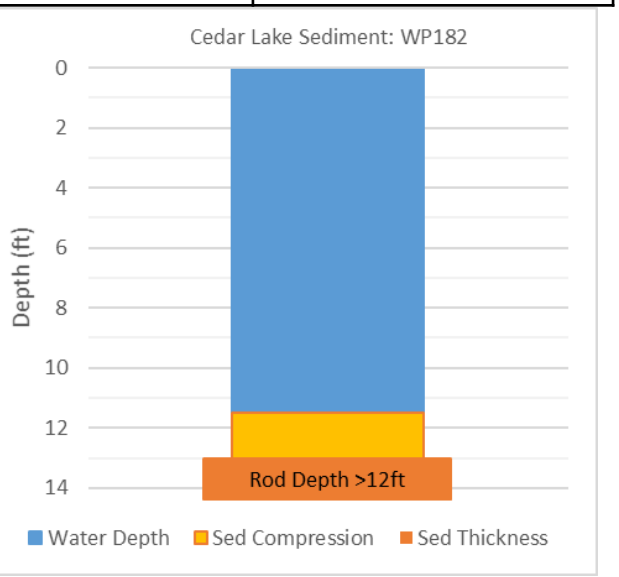



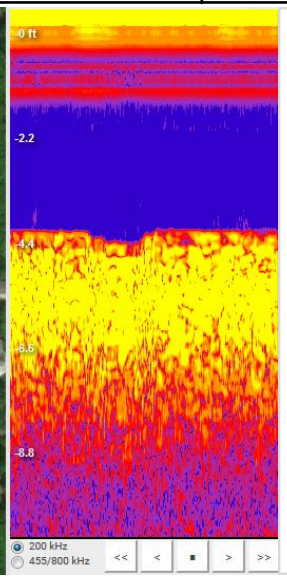

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 182 | 11.5 | 13 | >14 |

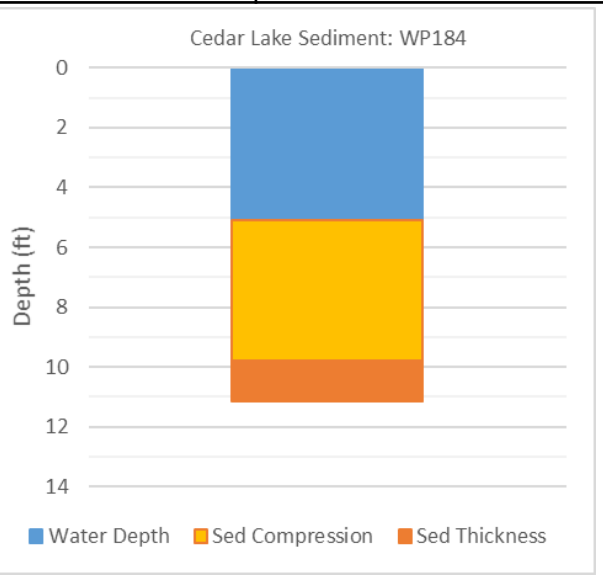


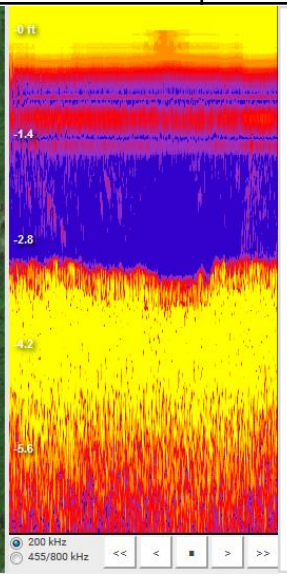



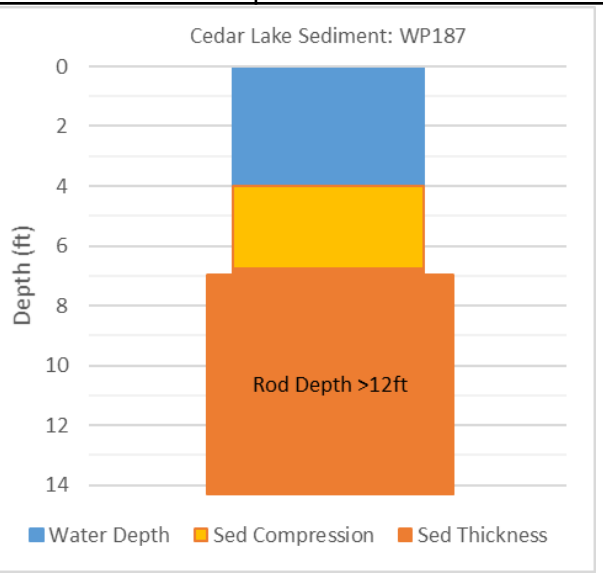
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 184 | 5.1 | 9.8 | 11.16 |

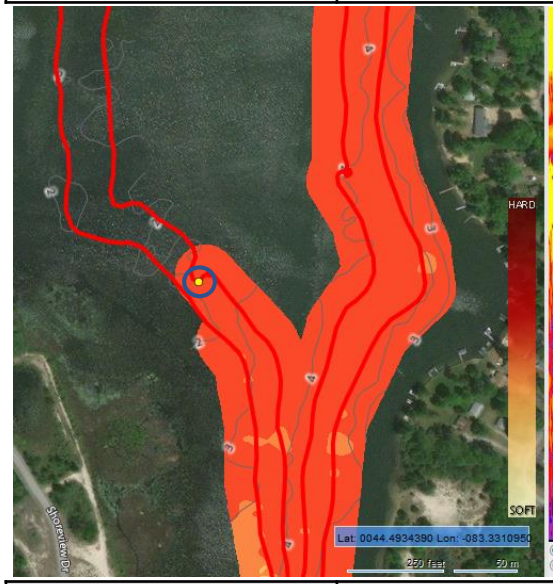



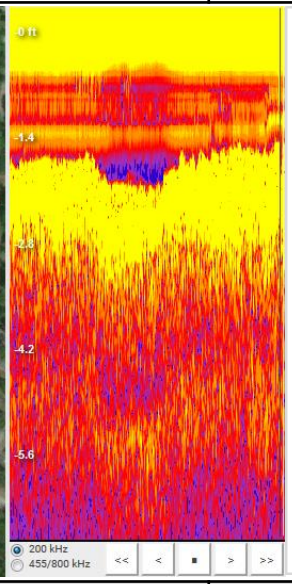

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 187 | 4 | 6.75 | >14 |

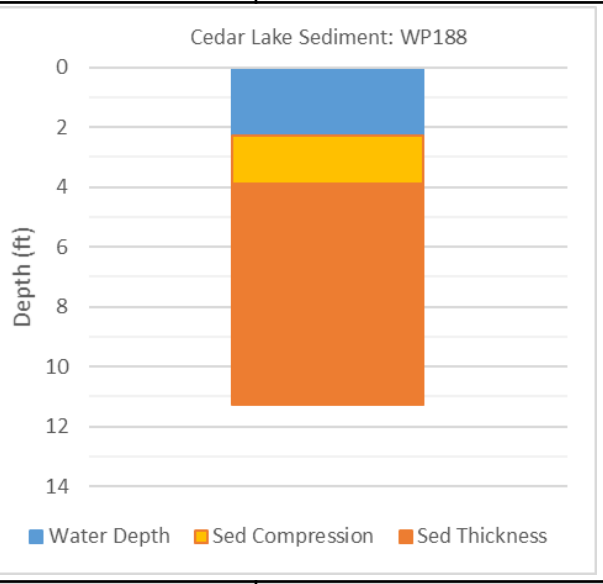



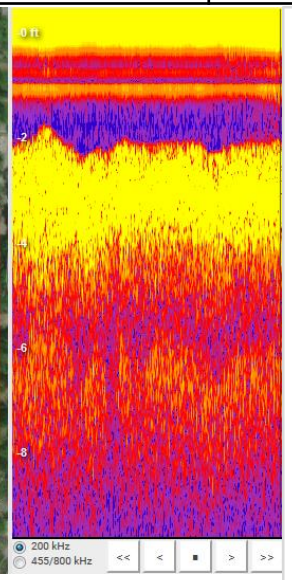
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 188 | 2.3 | 3.9 | 11.29 |

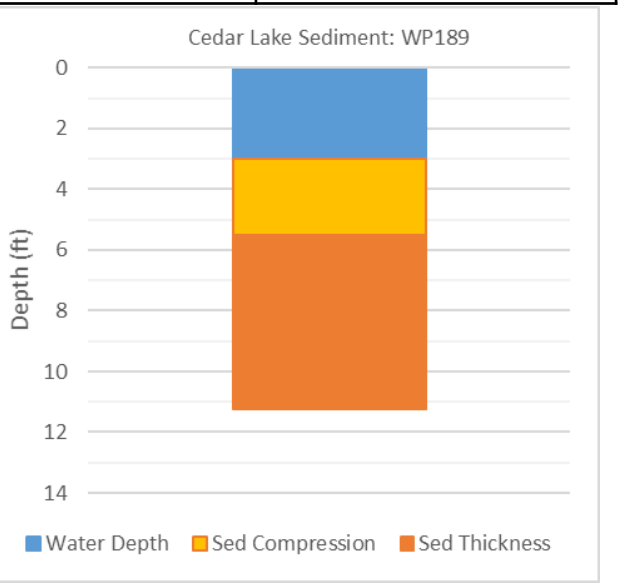


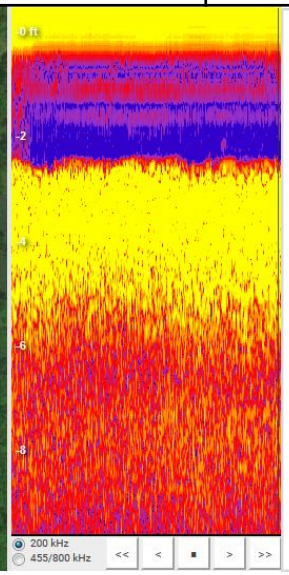



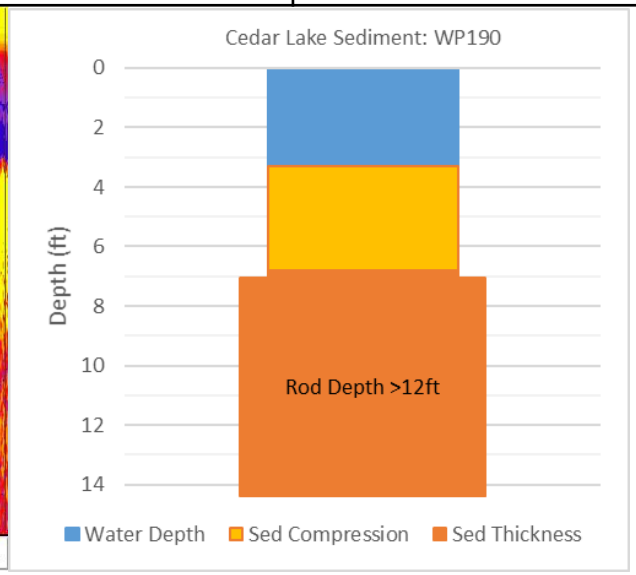

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 189 | 3 | 5.5 | 11.25 |

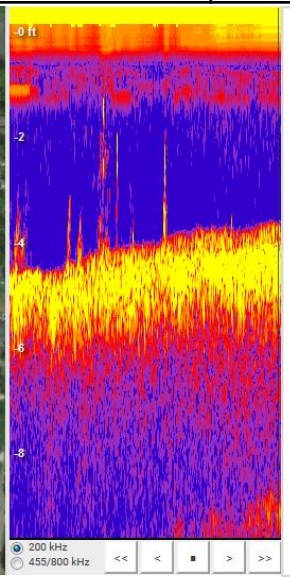



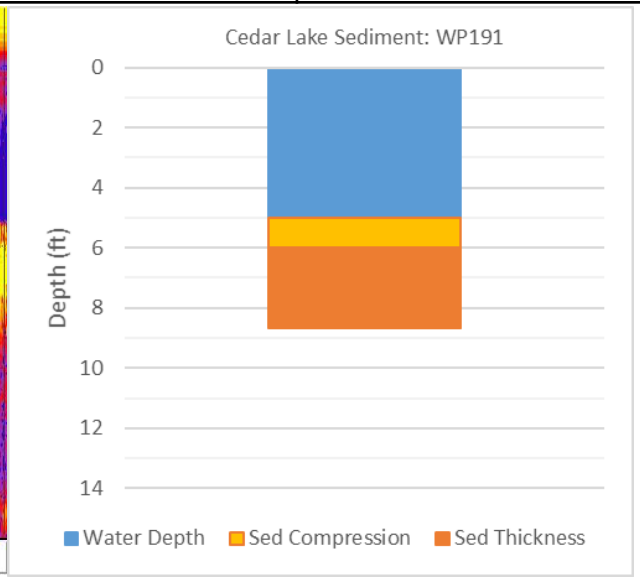
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 190 | 3.3 | 6.8 | >14 |

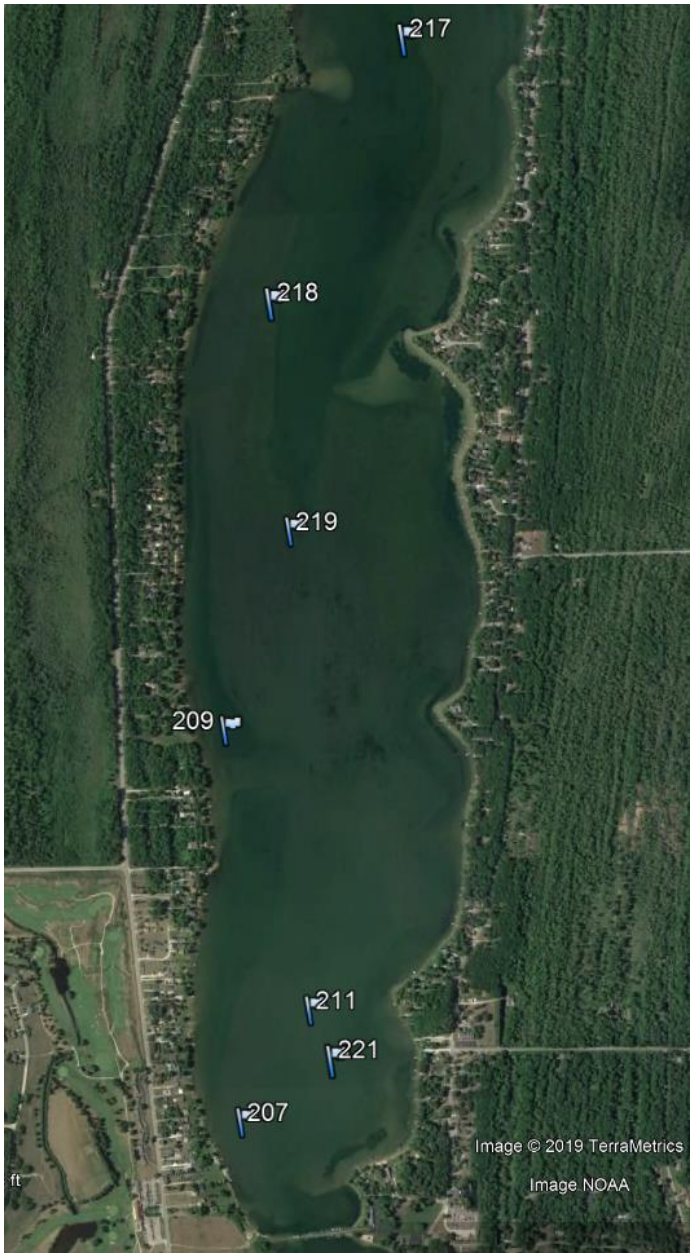



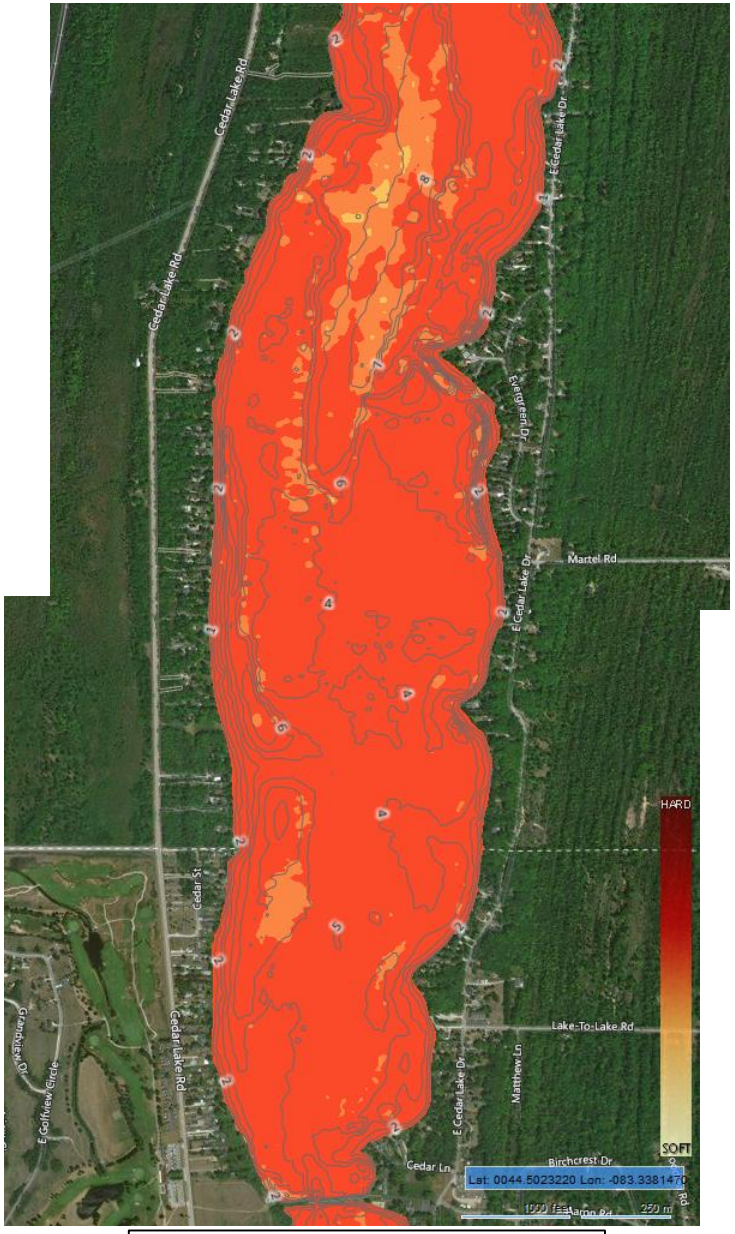

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 191 | 5 | 6 | 8.67 |

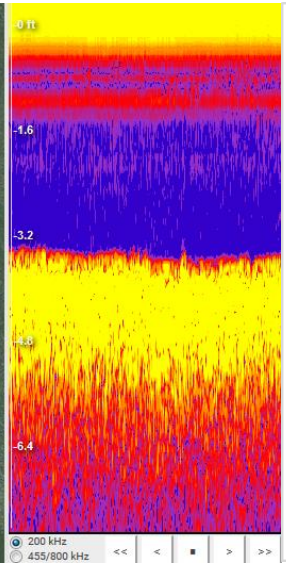


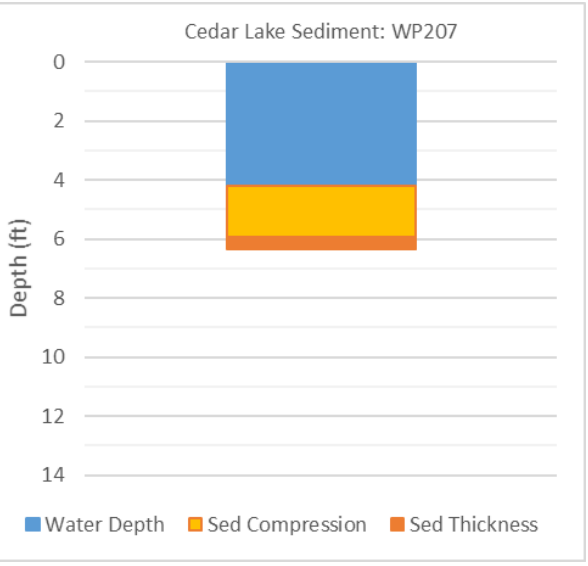

Cedar Lake North (part 1) sediment assessment station waypoints



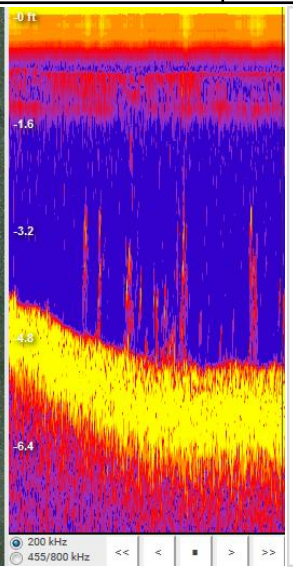

Cedar Lake North (part 1) Biobase composition layer, for comparative use.

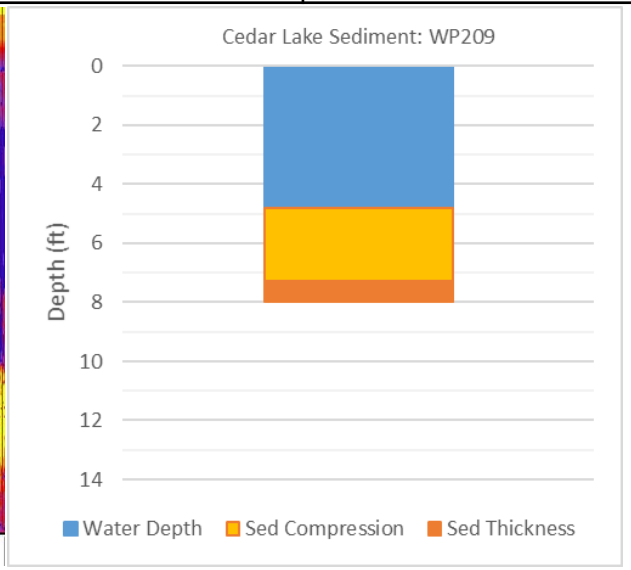
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 207 | 4.2 | 5.92 | 6.33 |

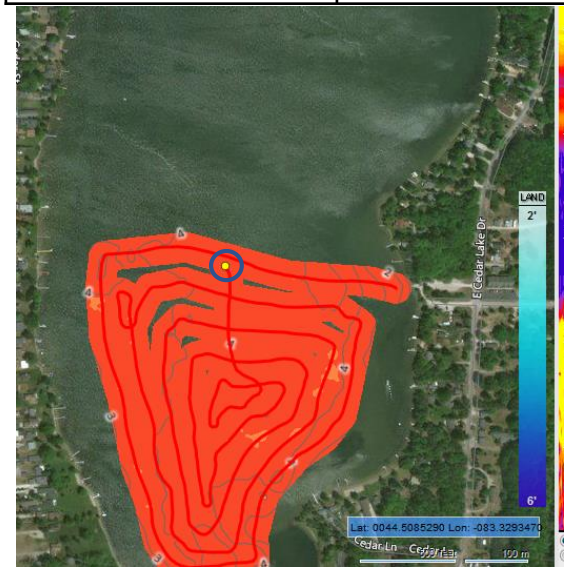



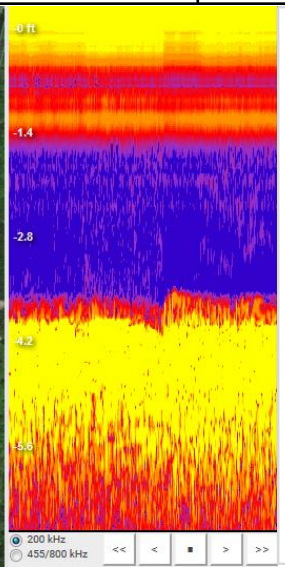

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 209 | 4.8 | 7.29 | 8 |

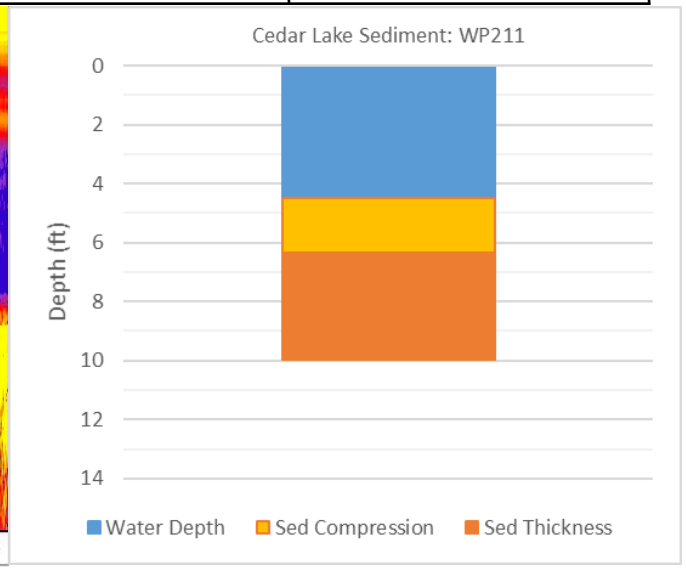



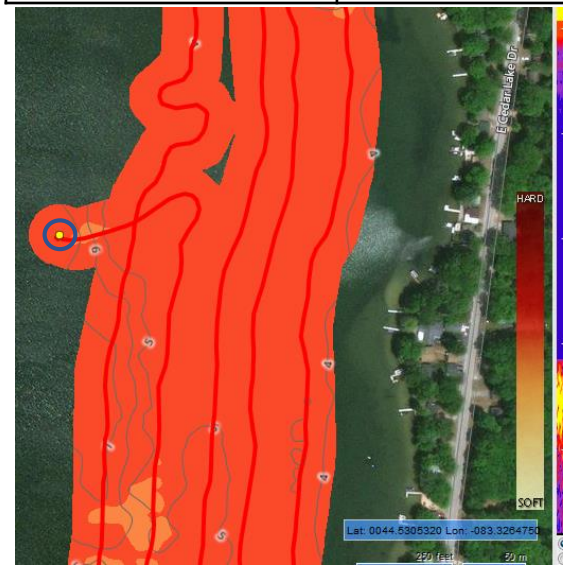
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 211 | 4.5 | 6.33 | 9.96 |

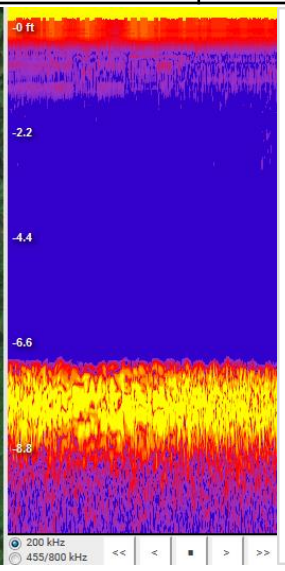


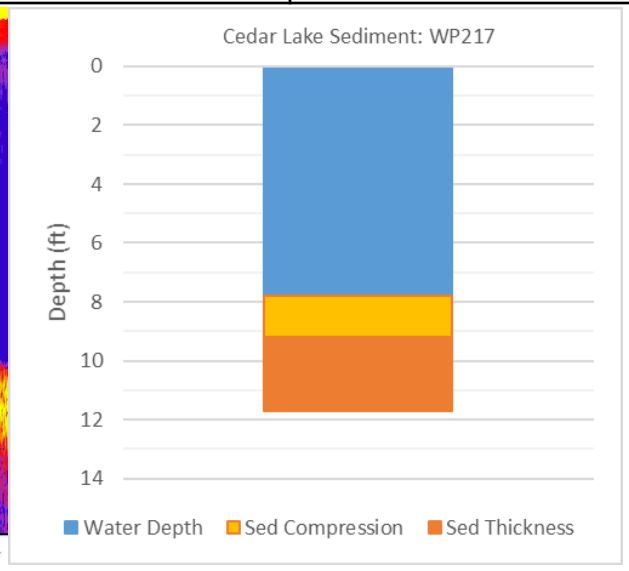



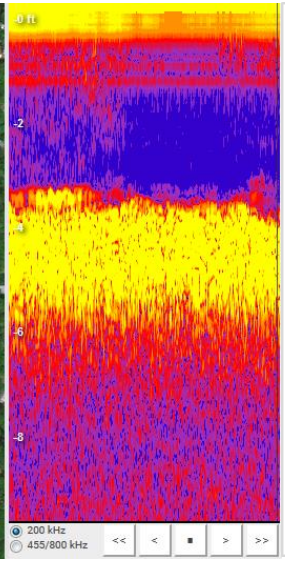

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 217 | 7.8 | 9.21 | 11.71 |

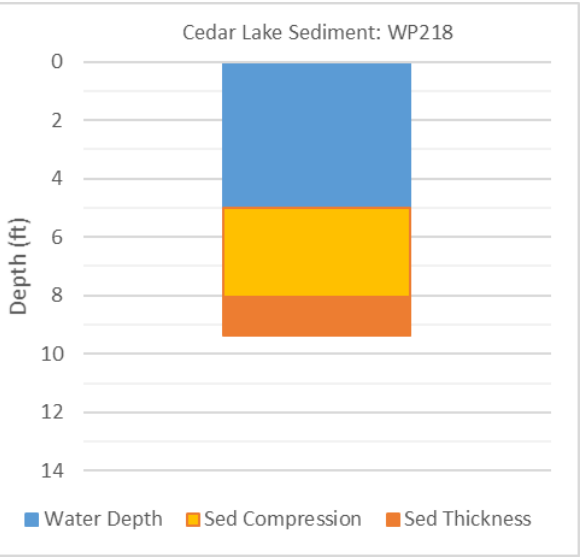


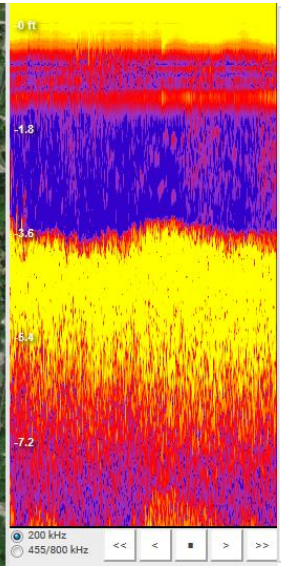



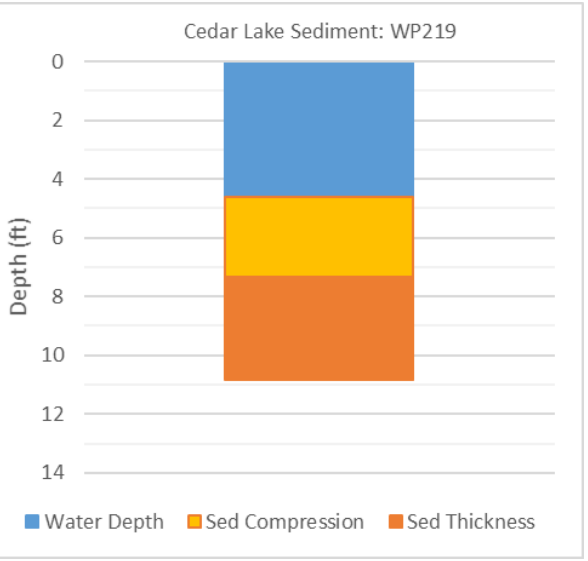
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 218 | 5 | 8.04 | 9.37 |

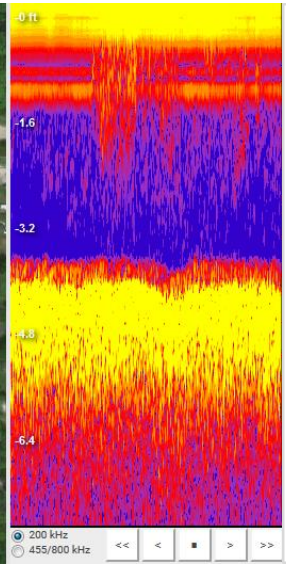



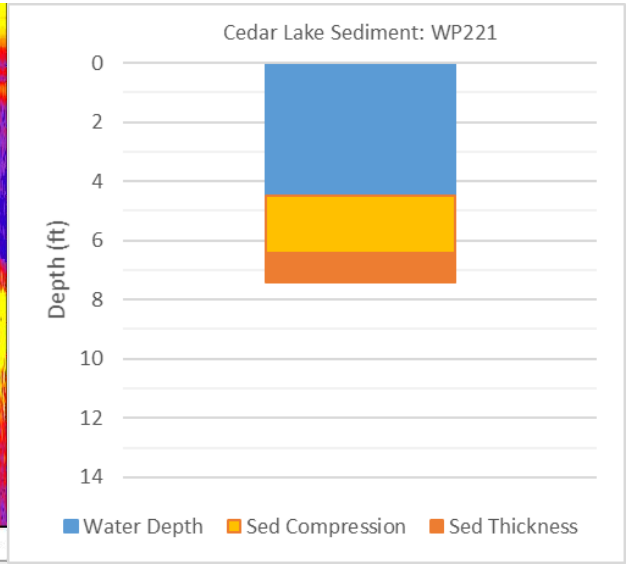

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 219 | 4.6 | 7.33 | 10.83 |

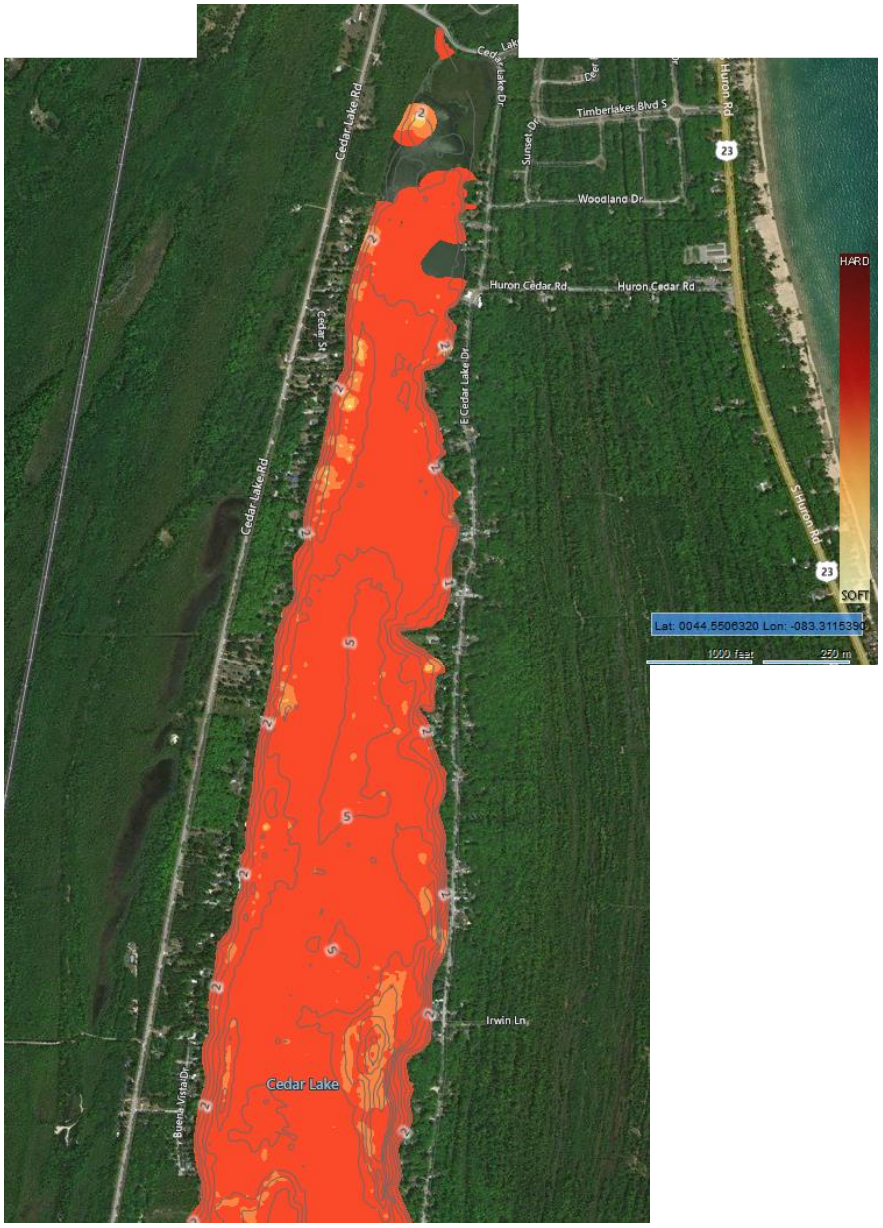



| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 221 | 4.5 | 6.42 | >14 |

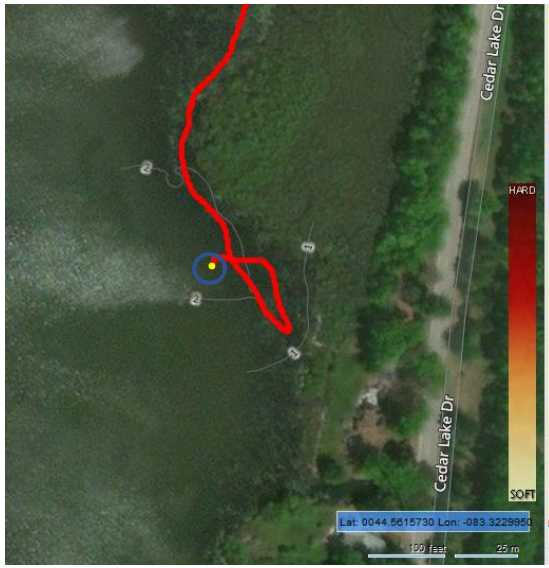



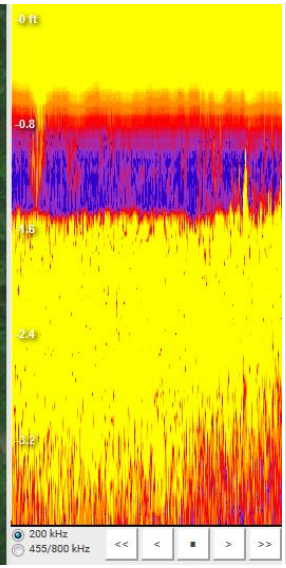

Cedar Lake North (part 2) sediment assessment station waypoints

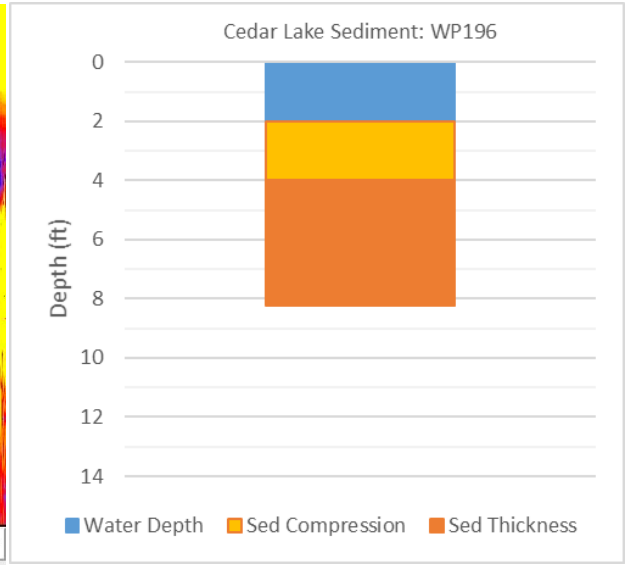



Cedar Lake North (part 2) Biobase composition layer, for comparative use.

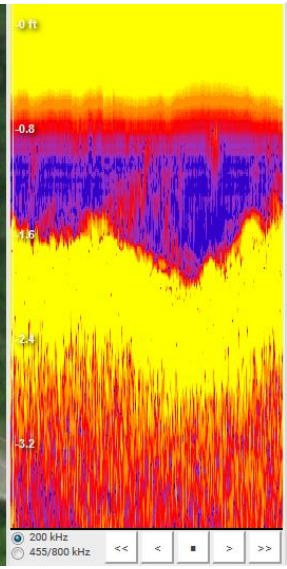
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 196 | 2 | 4 | 8.25 |

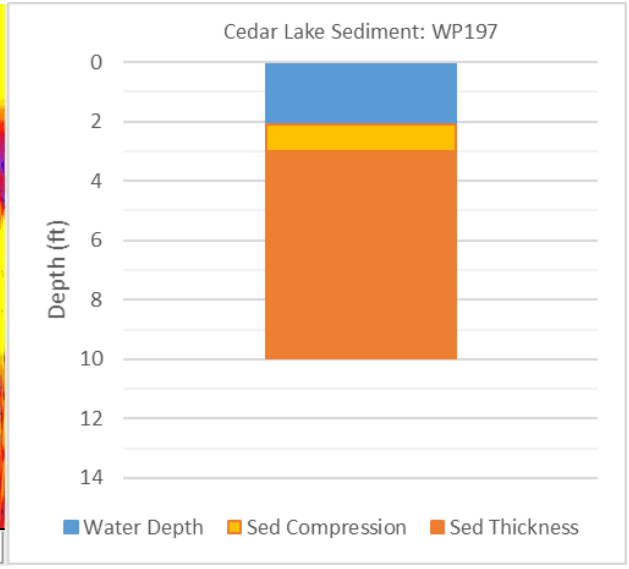


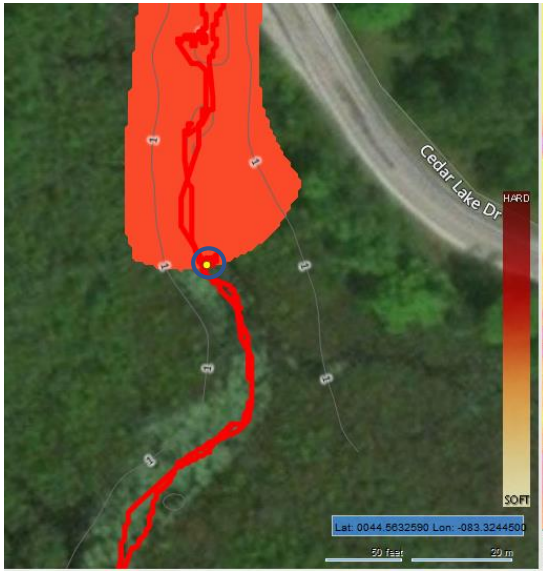



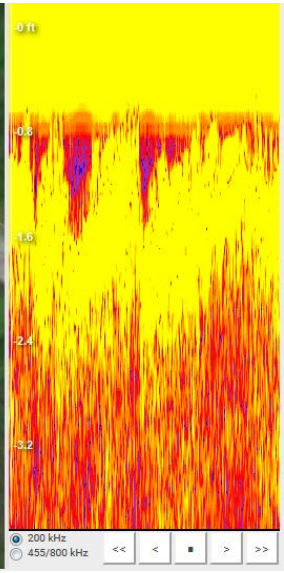

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 197 | 2.1 | 3 | 9.96 |

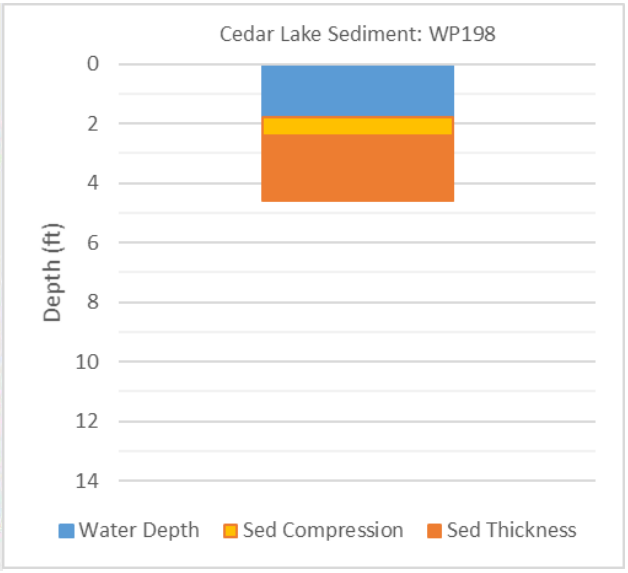



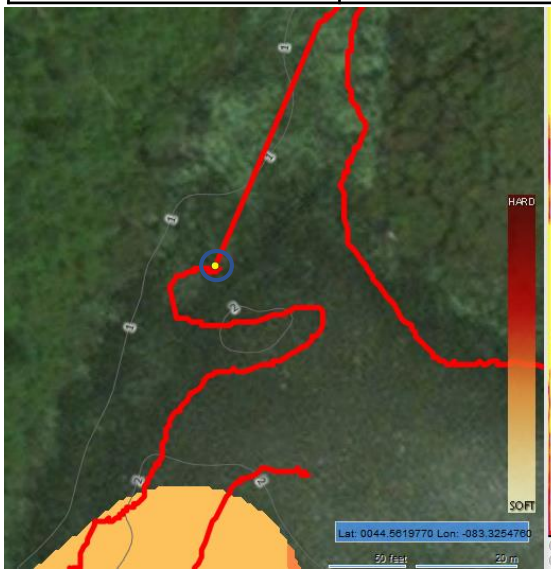
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 198 | 1.8 | 2.42 | 4.58 |

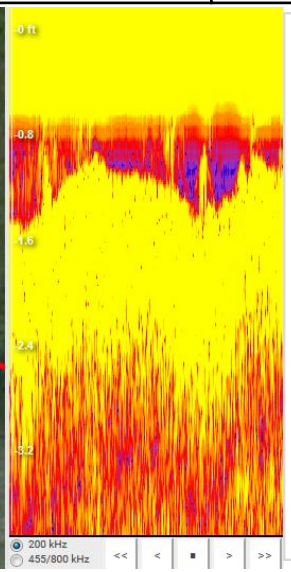


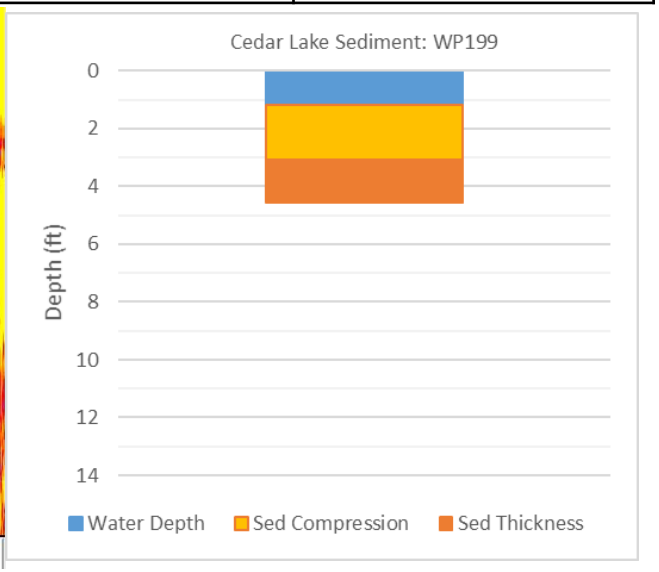



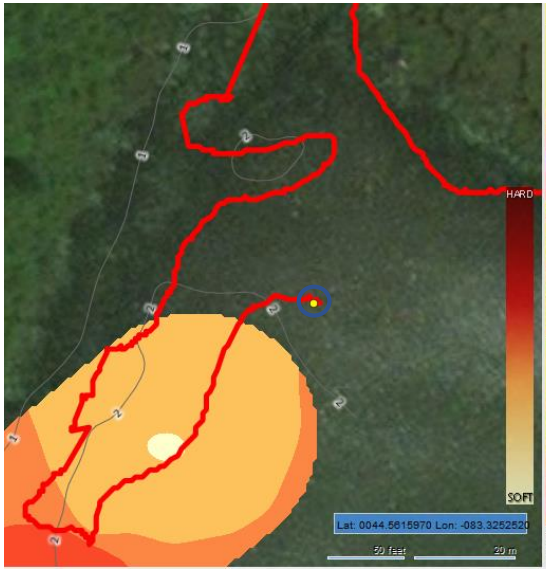

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 199 | 1.2 | 3.08 | 4.54 |

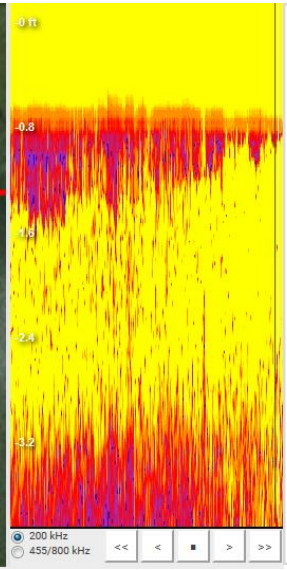


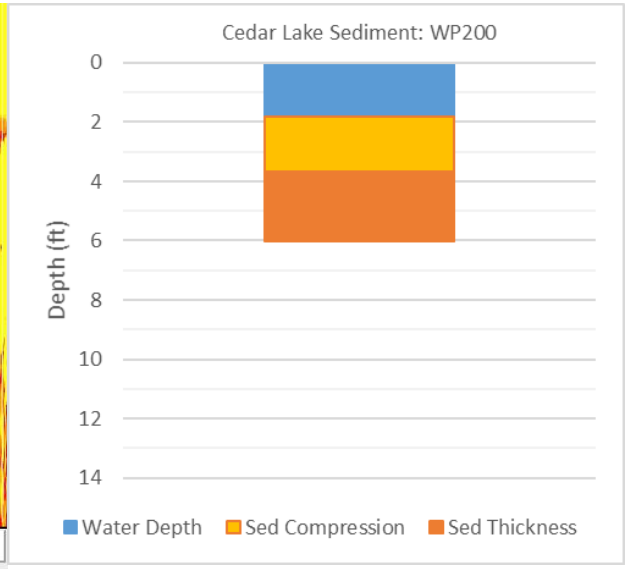



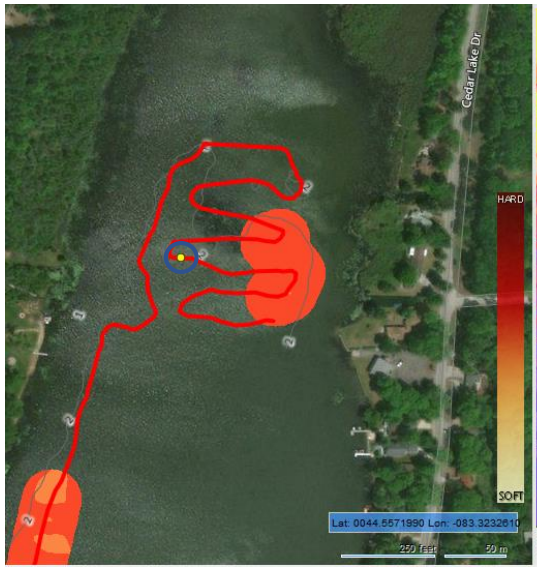
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 200 | 1.8 | 3.67 | 6.04 |

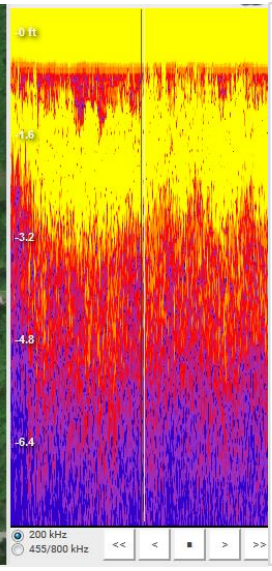


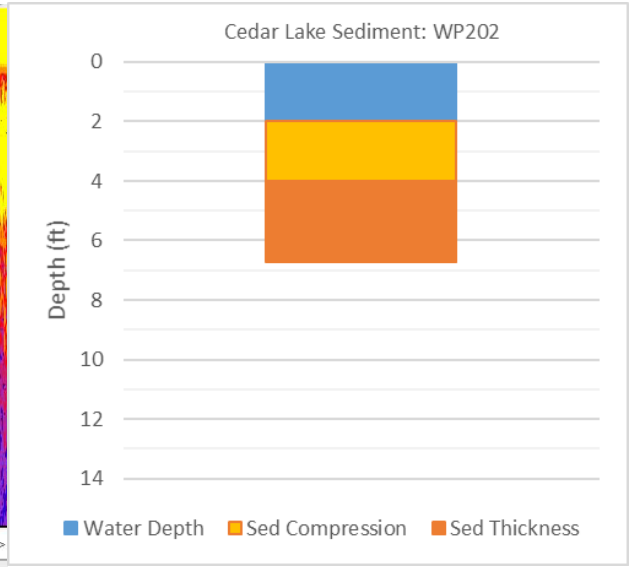



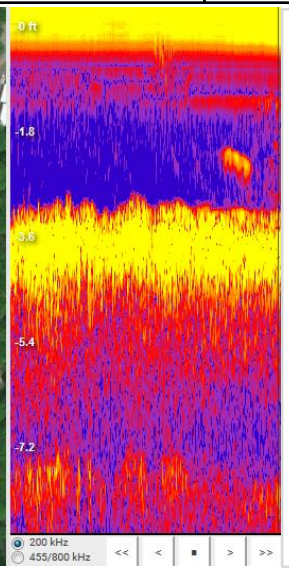

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 202 | 2 | 4 | 6.71 |

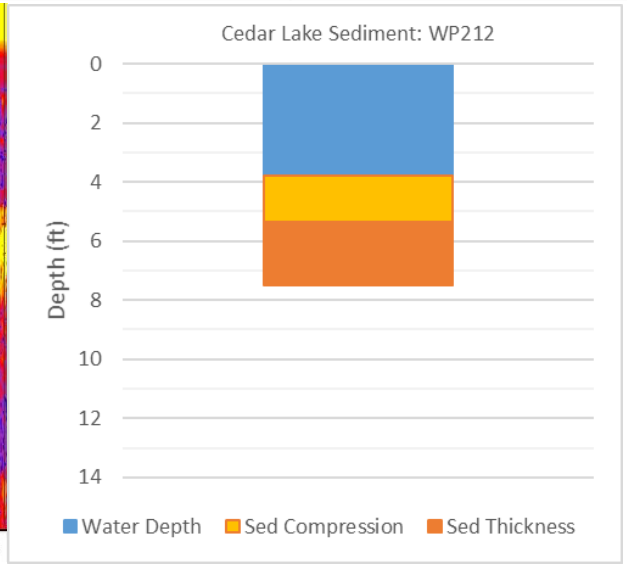


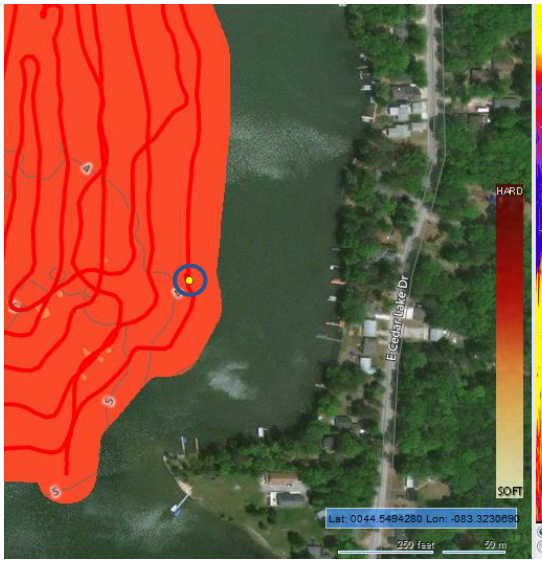



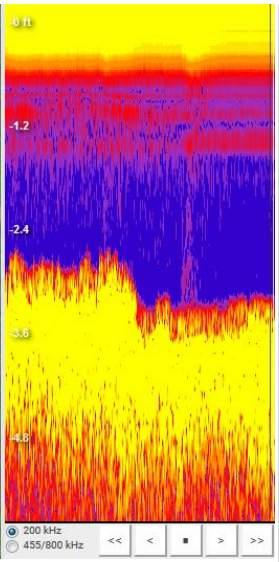
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 212 | 3.8 | 5.37 | 7.5 |

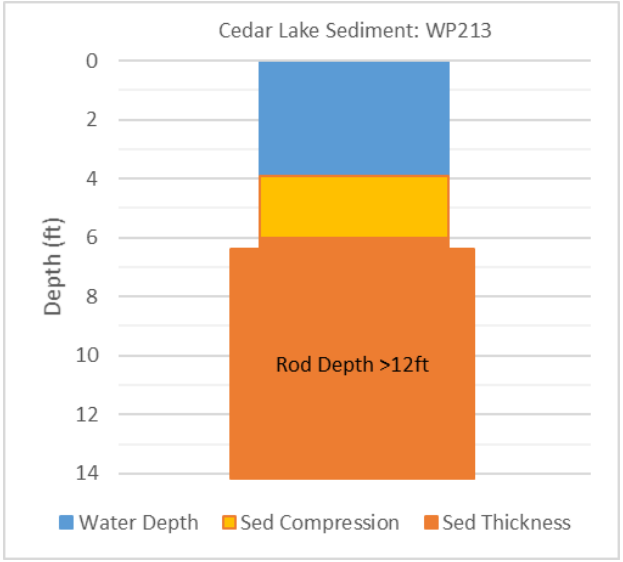



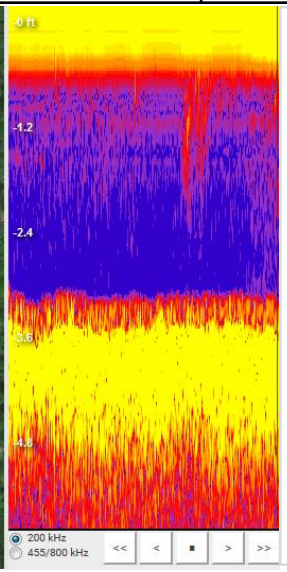

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 213 | 3.9 | 6 | >14 |

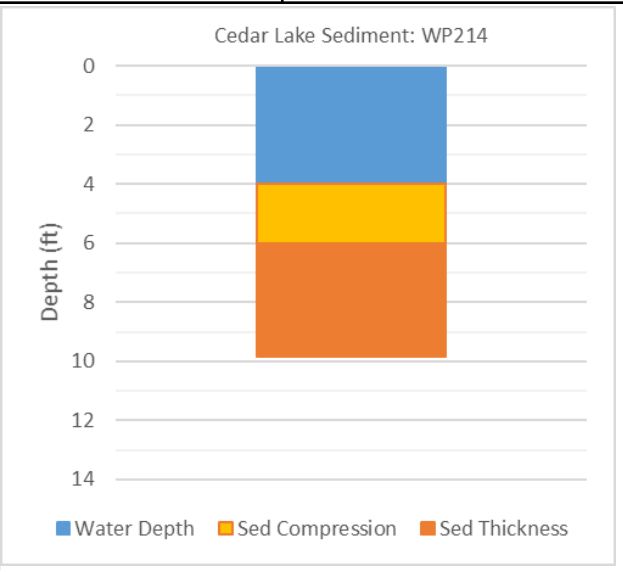


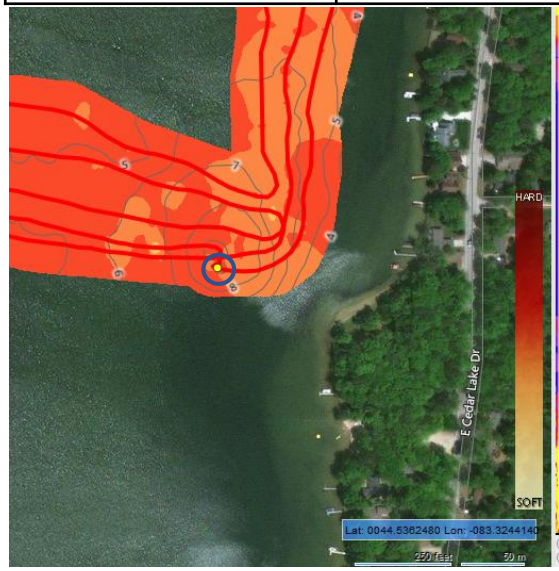



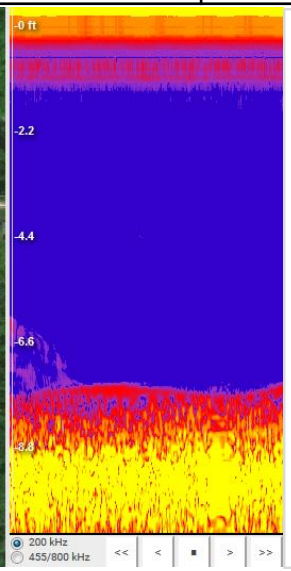
| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 214 | 4 | 6 | 9.83 |

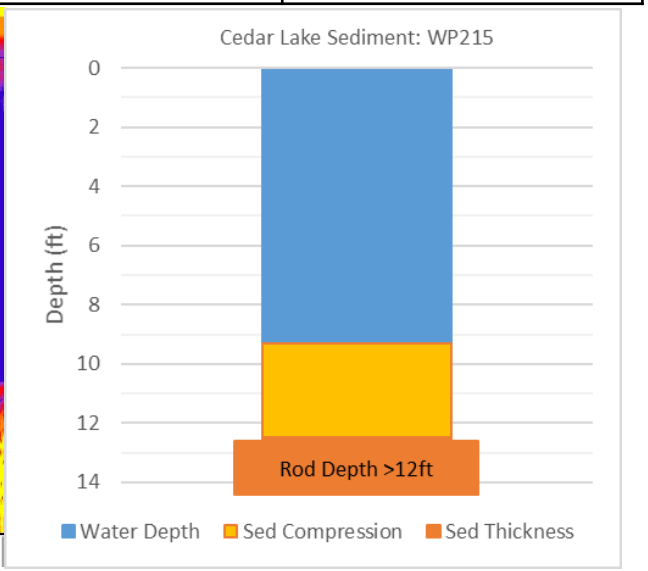



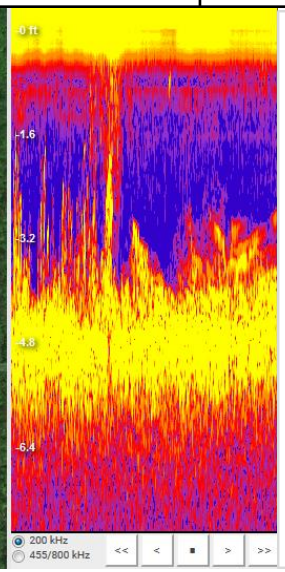

| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 215 | 9.3 | 12.5 | >14 |

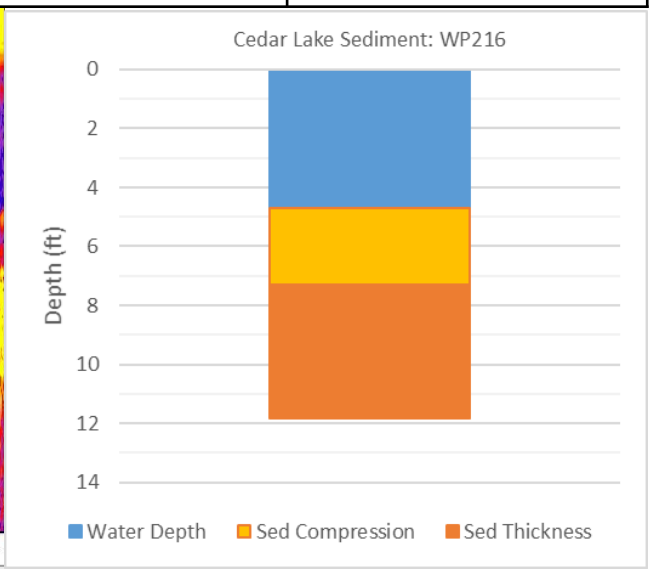


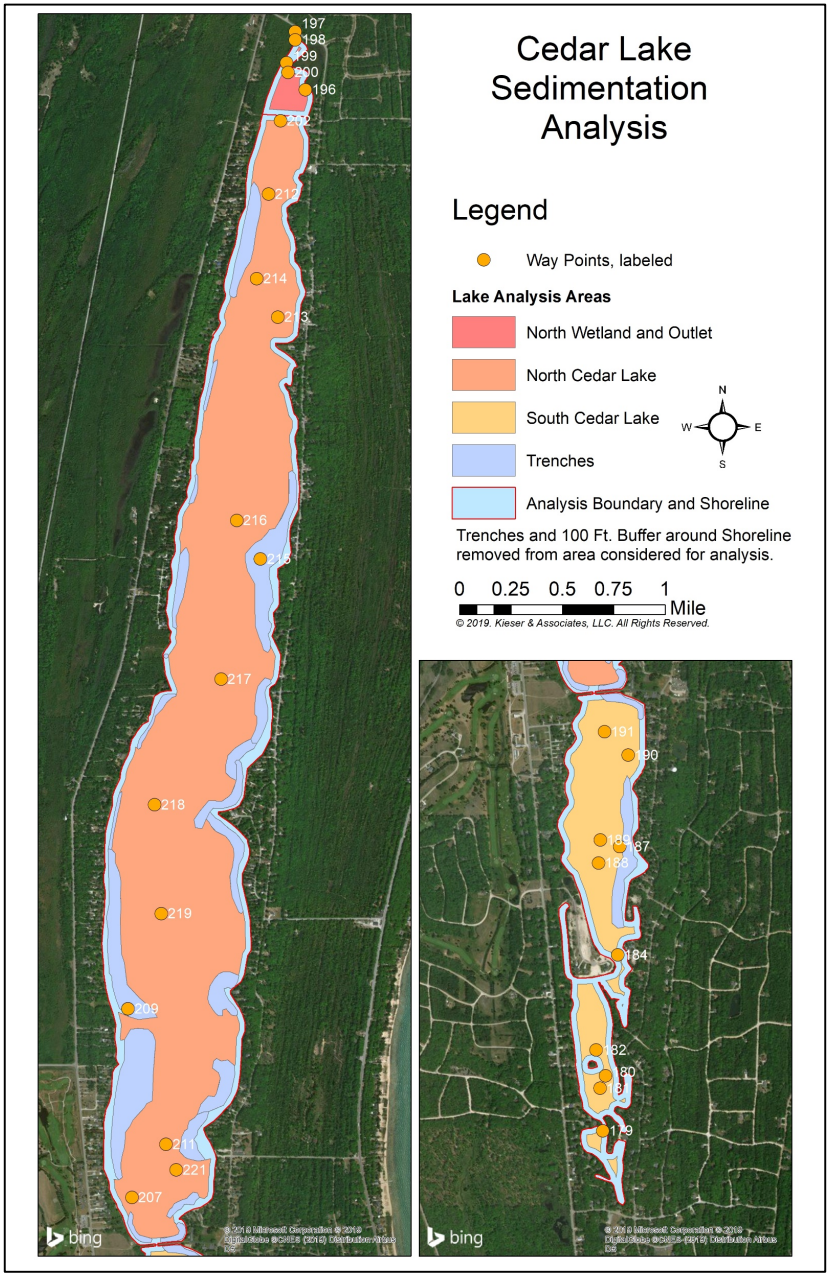



| GPS Waypoint | Water Depth (ft) | Compression Total Depth (ft) | Thickness Total Depth (ft) |
|---|---|---|---|
| 216 | 4.7 | 7.29 | 11.83 |




Cedar Lake sediment assessment station waypoints; bathymetrically identified trenches; and North Wetland and Outlet, North Cedar Lake and South Cedar Lake Potential Dredging Areas