MICHIGAN GEOLOGICAL SURVEY

Ottawa County Annual Water Quality Forum

What do we know about anthropogenic impact(s) to Lake Michigan shorelines?

Review of today, 12 year shoreline study (Dr. Ronald Chase), current research methods, how to quantify potential impacts.

John A. Yellich, CPG, Director, MGS

November 19, 2018

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Lake Michigan Shoreline
Sleeping Bear to St. Joseph/Benton Harbor, Michigan

- Within 2- 3 miles of Lake Michigan shoreline.
- Estimate, 50% dune sands.
- 50% glacial moraine, bedded sand, clay & gravels
- Where is the growth on Lake Michigan shoreline, which areas are experiencing growth?
- Bluff or dune areas, to live near or on, which are the most popular?
- These areas represent some of the highest value properties on Lake Michigan.
- What are the geological issues with each?

What are the two major shoreline differences?

Dunes vs Bluffs!

- Dunes migrate, summer and winter.
- Many houses on dunes need fortification.
  - Can you live with it?
  - There are areas of concern for drinking water supplies.
- Bluffs have higher elevation from beach.
- Bluffs have potential for failure and recession.
  - Can you afford to loose your house?
  - Can you engineer a fix to bluffs?
- What are some of the causes for failure?

THE MITIGATION OF COASTAL BLUFF EROSION BY REMOVAL OF GROUND WATER (1996 – 2008)

Ronald B. Chase
Alan E. Kehew

WESTERN MICHIGAN UNIVERSITY
(Michigan Geological Survey – 2018)
John A. Yellich, Director

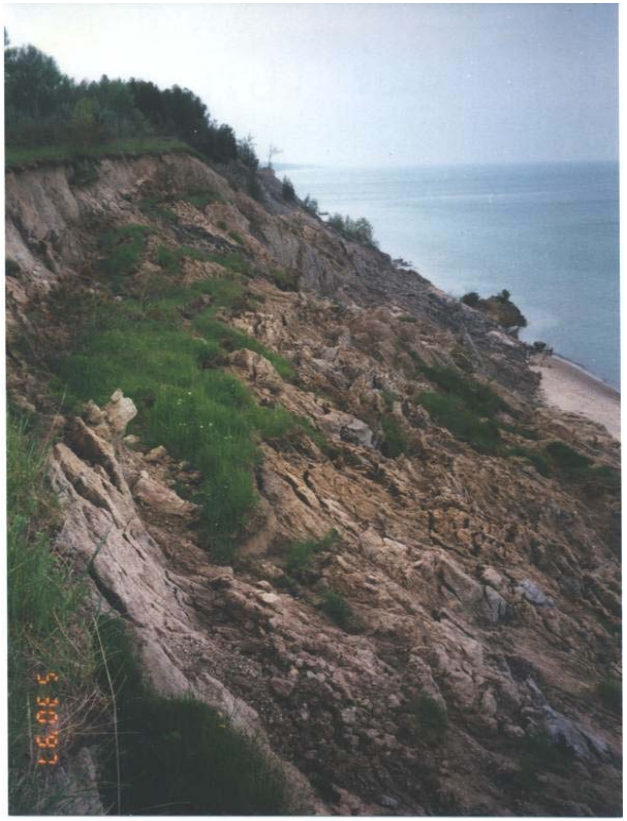
FUNDING SOURCES

U.S. Army Research Office – for investigations into the causes and mechanisms of bluff failure (Phase 1, 1996 - 1999).

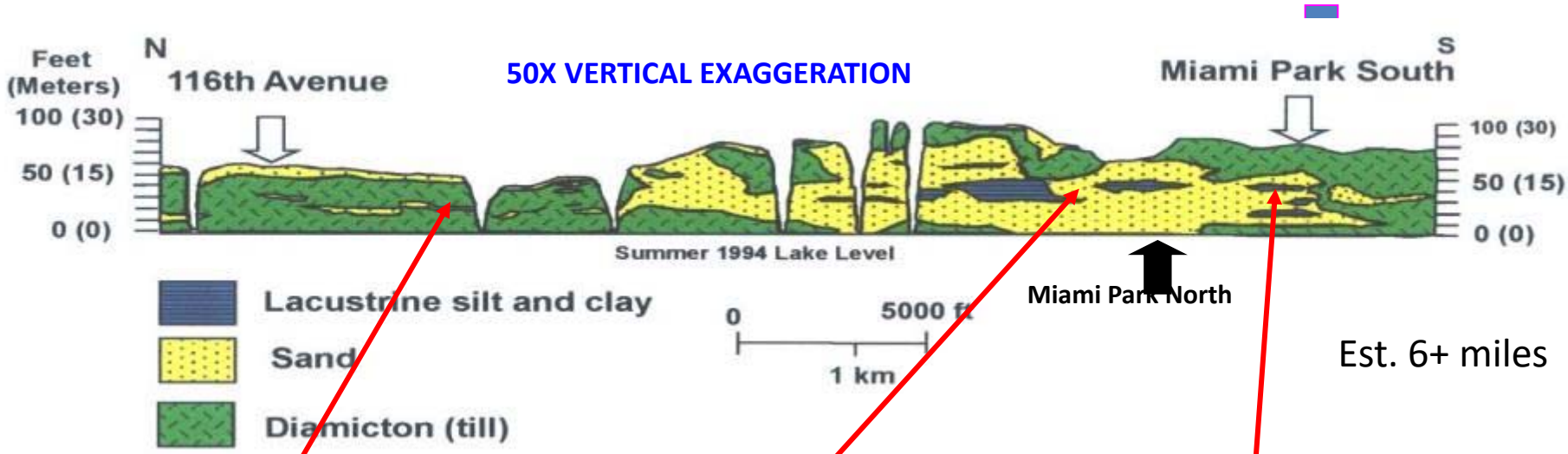
U.S. Army Corps of Engineers – for geotechnical field support to test the removal of ground water as a failure mitigation strategy (Phase 2, 2000 – 2008).

Presented November 2018

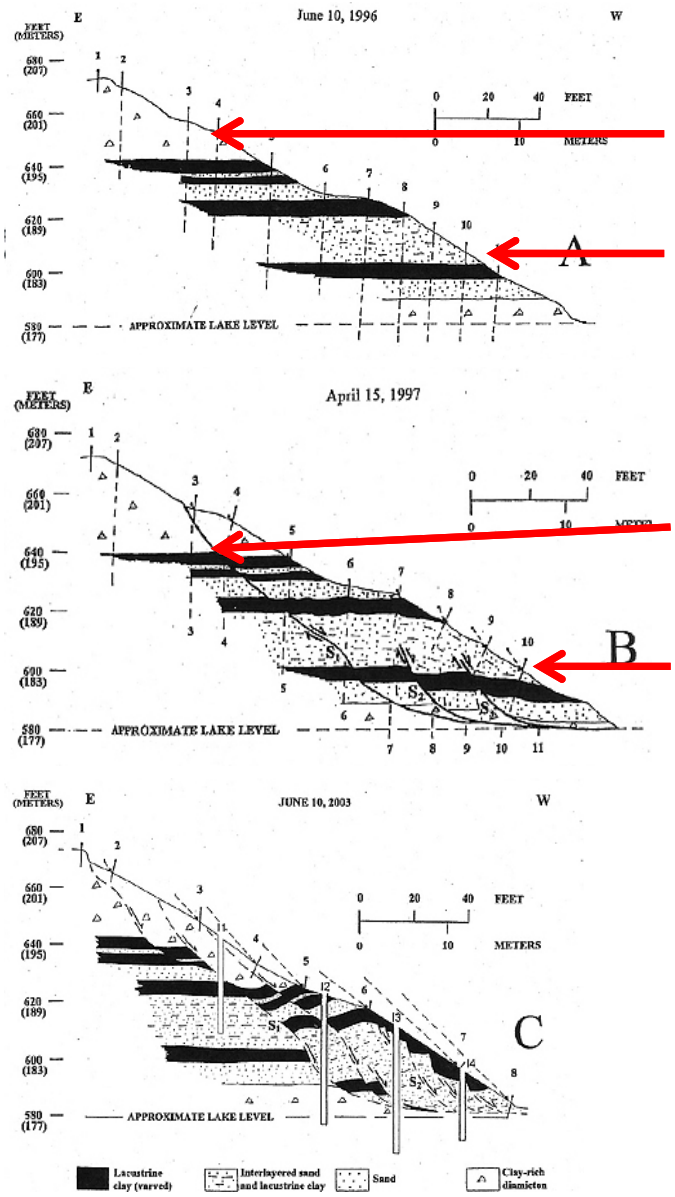
EXAMPLES OF POST – 1997 LANDSLIDES IN ALLEGAN COUNTY, MICHIGAN



BLUFF STRATIGRAPHY
First stage of study



MECHAMISMS OF COASTAL BLUFF EROSION IN LAYERED SOILS (those most susceptible to large landslide activity)



The areas most susceptible to damaging landslides are those where the soil is interlayered sand and clay. Ground water collects in sand above impermeable clay layers.

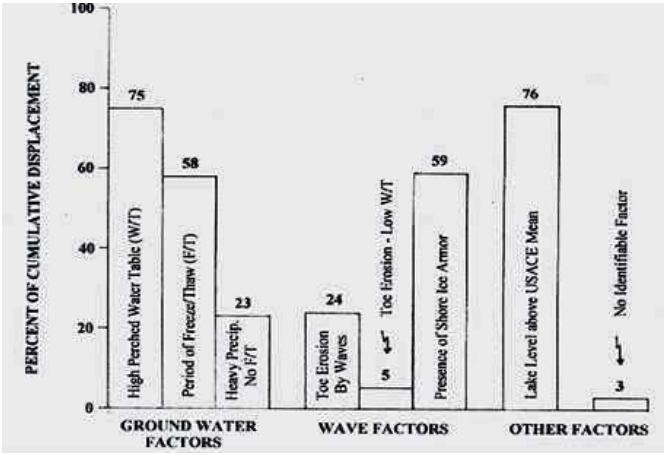
When sand layers above clay become perched saturation zones, soil is weakened to the point when it can no longer support the overlying bluff.

Displacements propagate through the soil, usually upward from lower layers.

Eventually, enough integrated fractures develop to produce general failure, either through many displacement events over time or one or two massive failures that are sudden.

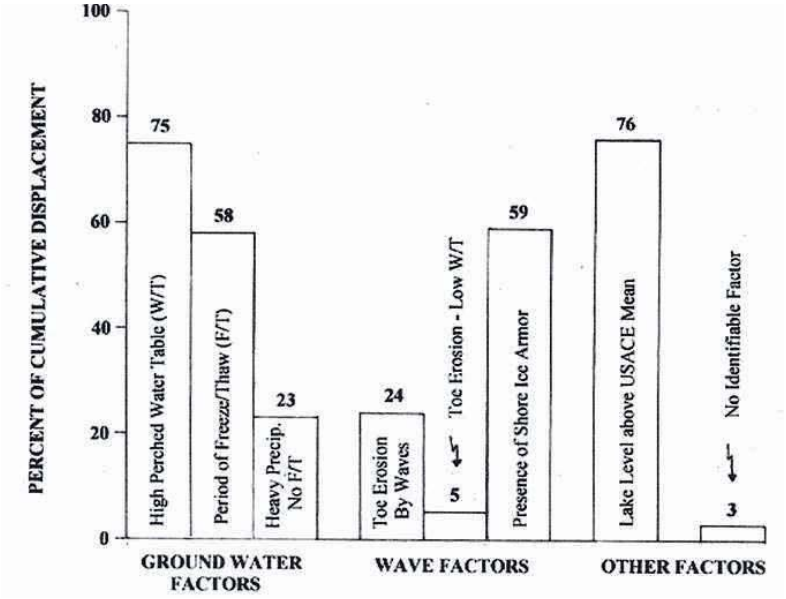
ELEVEN-YEAR HISTORY OF MONITORING DISPLACEMENT VERSUS GROUND WATER, WAVE, AND CLIMATE FACTORS

RELATIONSHIPS AMONG BLUFF MATERIAL DISPLACEMENTS AND CAUSES



1. High perched water table—75% of the displacement occurred while the perched water table elevation was in the upper 40% of its range of fluctuation. Freeze-thaw conditions existed through 77% of this time interval (see following point).
2. Period of freeze-thaw—58% of the displacement occurred during seasonal freeze-thaw cycles, defined as the time interval between the first and last two-day period when air temperatures dropped below 32 °F (0 °C).
3. Heavy precipitation, no freeze-thaw—23% of the displacement occurred when a total two-day precipitation outside of the freeze-thaw time interval exceeded 1 in. (2.54 cm). (Runoff and infiltration)
4. Toe erosion by waves—24% of the displacement occurred when wave height measurements received from NOAA buoy 45007 were at or greater than those heights that were recorded when wave on-lap barely reached the toe of the bluff. Today?

RELATIONSHIPS AMONG BLUFF MATERIAL DISPLACEMENTS AND CAUSES (continued)



5. Toe erosion, low water table—5% of the displacement occurred during periods of toe erosion (see previous point) when the perched water table was not defined as being high (see previous). (NOTE: This does not depict our situation in 2017)
6. Presence of shore ice armor—59% of the displacement occurred while shore ice armored the bluff from wave attack, as measured from the first seasonal buildup of ice to the date of ice breakup.
7. No identifiable factor—3 % of the displacement occurred at times other than those listed above. Such displacements probably represent the delayed release of residual strain from previous displacements.
8. Lake level above USACE mean—76% of the displacement occurred while the Lake Michigan surface elevation was at or above its mean of 577.5 ft. (176 m).

GROUND WATER MONITORING FIVE MILES NORTH OF SOUTH HAVEN, MI (2003 – 2008)

~520 Feet

WELLS WERE DRILLED TO INSTALL:

- **DISPLACEMENT MONITORING INSTRUMENTS AND PIEZOMETERS – GREEN TRIANGLES**
- **GROUND WATER PUMPING WELLS – YELLOW CIRCLES**

ALL ELEMENTS OF DISPLACEMENT AND CAUSES WERE MONITORED HOURLY AND RECORDED ON R.CHASES' LAB COMPUTER IN KALAMAZOO

SUPERIMPOSED DATA SUMMARIES INDICATE THAT

1) THE GROUND WATER TABLE RISES DURING FREEZING (water discharge is blocked by ice development) AND DROPS DURING THAW (when the dammed water is released).
2) DOWNHILL DISPLACEMENT EVENTS TEND TO OCCUR DURING TIMES OF FREEZING (increased pore pressure) AND THAWING (increased flow pressure during water release and discharge as the dam "bursts").
3) These are the partially defined geological engineering results!
4) What are the potential causes for these impacts?

What causes groundwater increases near bluffs?

Land development changes an area from trees to habitable property along the beach front, starts with:

- **Removing major and minor natural vegetation,**
- **Ground surface is leveled,**
- **Generally, there is no municipal sewage or water,**
  - **Houses are built,**
  - **Septic systems are installed,**
- **Fertilizer is applied to lawns, then watering lawns,**
- **Driveway or streets are installed, may be paved,**
- **Surface water runoff is minimally controlled,**
- **Where are your water wells, are they protected, and**
- **Was the geology mapped in sufficient detail to development solutions or identify buried perched zones?**

What causes groundwater increases near bluffs?

Septic systems

- **Do we need septic systems so close to the beach or should we use closed or aerobic systems?**
- **Septic systems inject discharges to shallow zones, nitrates and water/liquids saturate the shallow glacial system.**
- **Where is your water well?**
- **What is the potential for a saturated bluff face?**

What causes groundwater increases near bluffs? Continued!

Surface water runoff

- Increasing impermeable areas, roofs, driveways and roads,
  - Then, where is runoff directed.
- Was there an assessment of where the surface water will be discharged and how it reaches the lake (local drain commissioner-stormwater review)?
- Segregate the impacted vs clean runoff.
- What is the potential for improper infiltration and a saturated bluff face of NaCl, fertilizer, and septic liquids?
  - Concern for both NaCl and nitrates in system - now an impact to drinking water/groundwater and Lake Michigan.

What should we do to minimize impact from anthropogenic/human actions? – Some Solutions!

- This is one set of choices or options:
- First, was the geology mapped in sufficient detail to project potential impact for buried perched zones?
- Do we need septic systems so close to the beach?
  - Should septic systems be open, closed or aerobic?
    - Septic systems need to be closed, holding tanks.
  - Septic systems inject discharges to shallow zones, nitrates and liquids to the shallow glacial system, impacts bluff face.
- Surface runoff needs to be controlled and infiltration to subsurface, at or below the bluff face or at the lake level.
  - Control NaCl impacts.
- Water wells for each house, should you have a subdivision well?
- Can we put many of these mitigation factors together to reduce the potential for bluff and slope recession and groundwater impacts?

USGS Great Lakes shoreline collaborative research proposal for 2018-2022!

USGS, Michigan, Indiana, Illinois, Wisconsin and Minnesota geological surveys are developing a collaborative research project.

- **USGS - FEDMAP proposal for a five year study!**
  - **This represents some of the highest value properties on Lake Michigan.**
- **Map geology and then project slope/beach dynamics.**
- **Look at incremental changes, over the last 20 years and project to future.**
- **All State surveys will contribute a research component to the beach/slope stability studies.**
- **Integrate the Corp of Engineers into this program.**
- **What are the conditions that will impact stability: septic, surface drainage,**
- **Prepare a model for what shoreline/geologic areas are prone to failure?**

Michigan Geological Survey Research

Demonstration

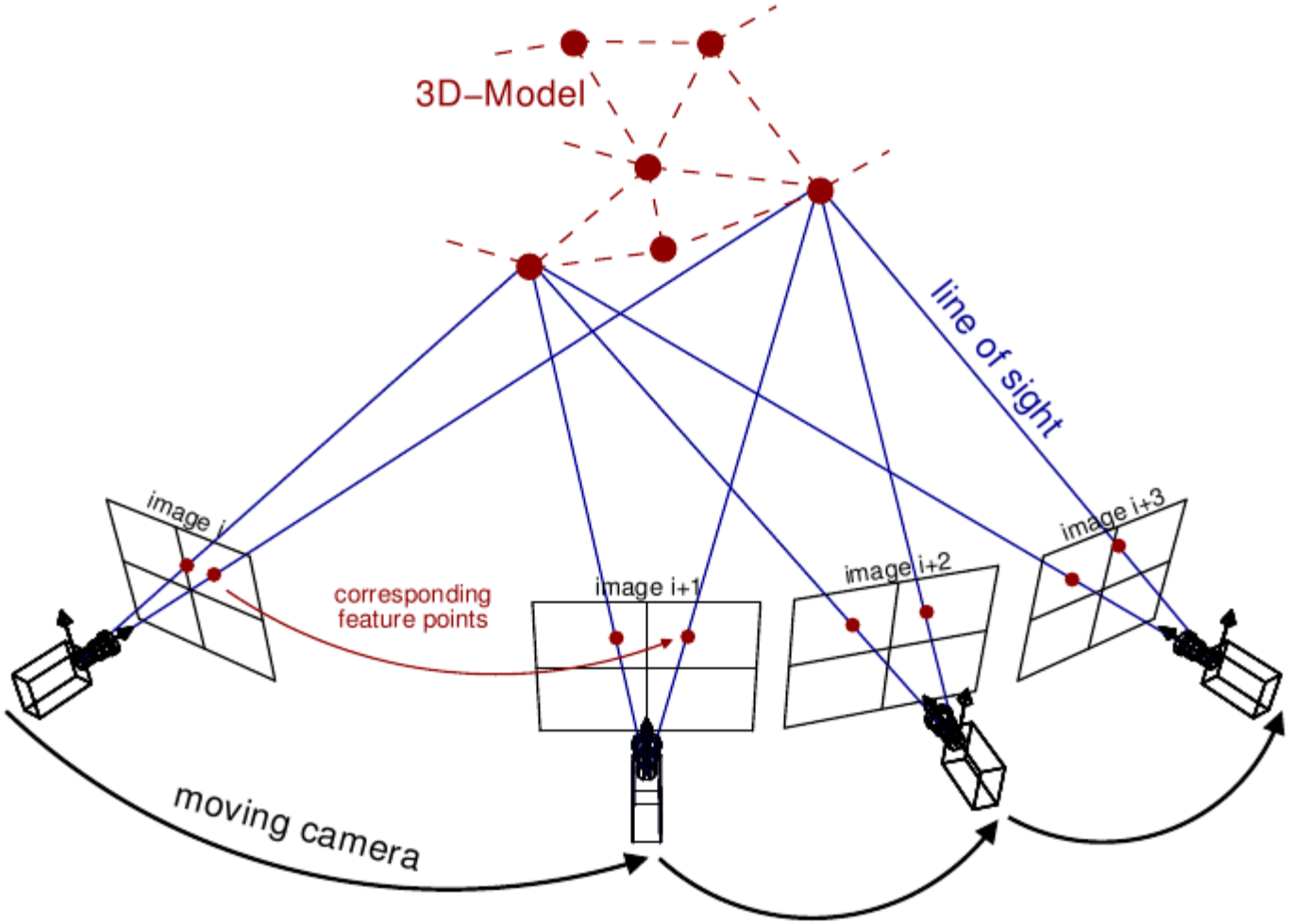
A component to the USGS collaborative research.

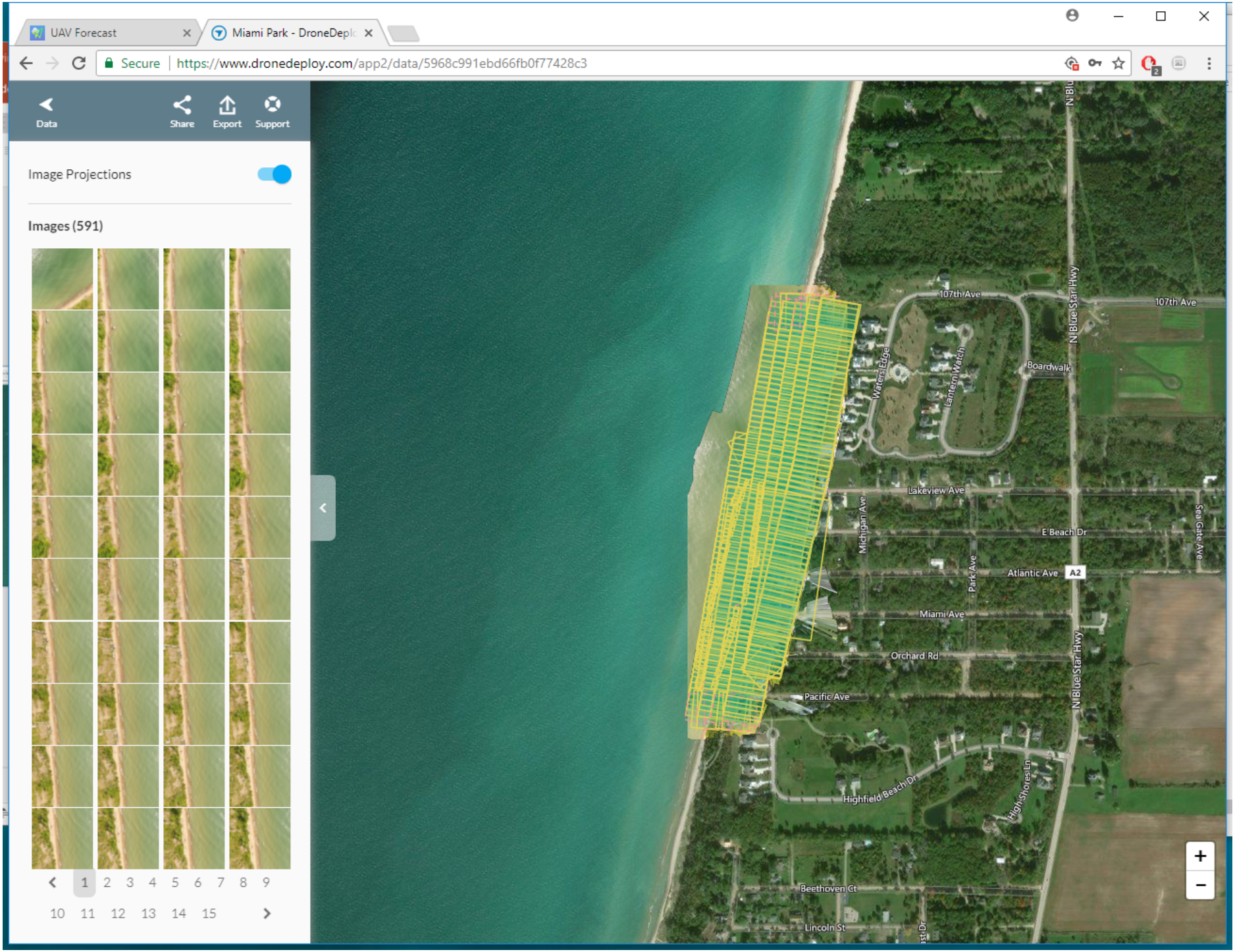
- **Drone flight of Miami Beach – July 2017**
- 2D, 3D, Elevation, Vegetation

- http://bit.ly/2iKvk5o

Today’s equipment

SfM (Structure from Motion)




UAV Forecast
Miami Park - DroneDeplc
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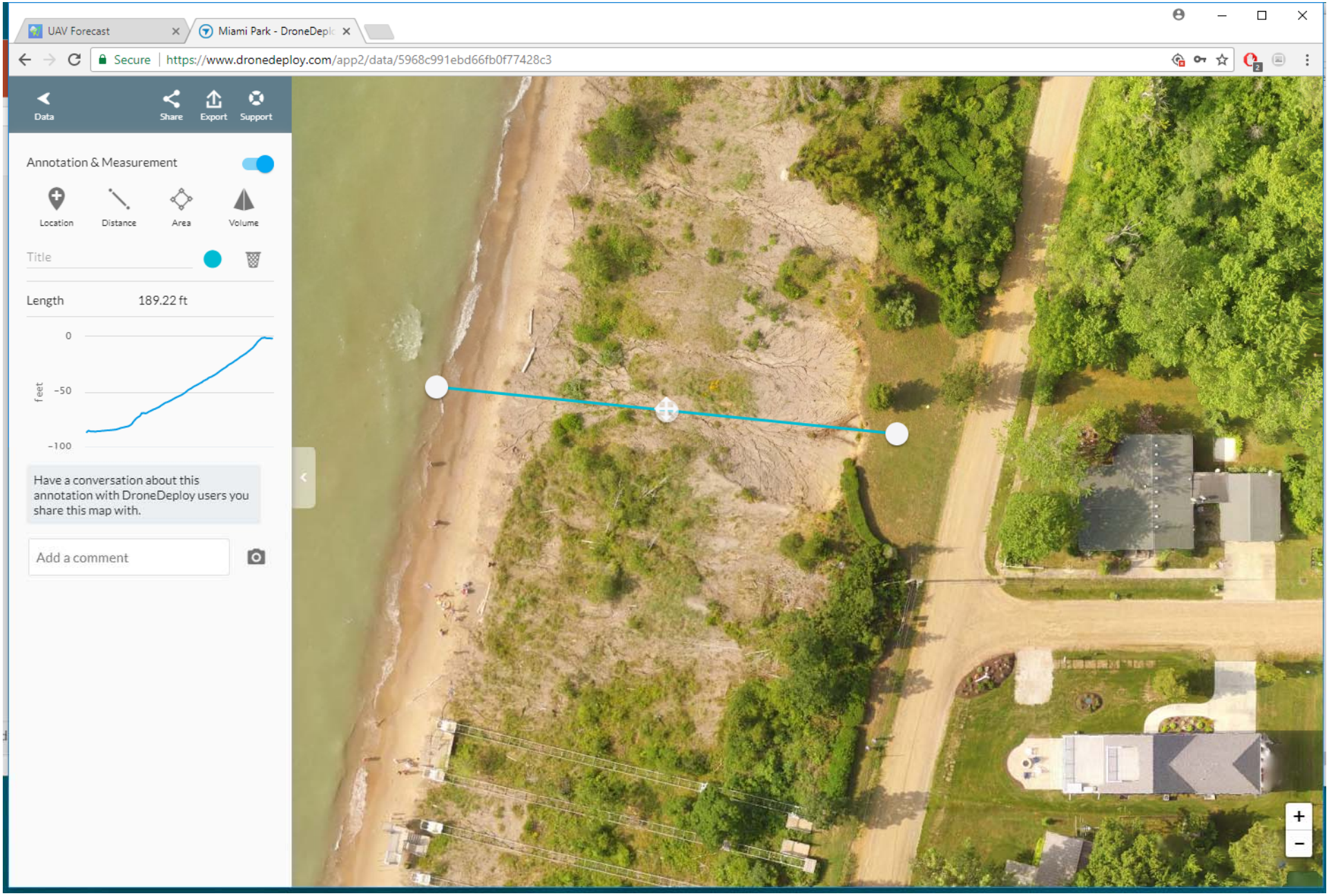
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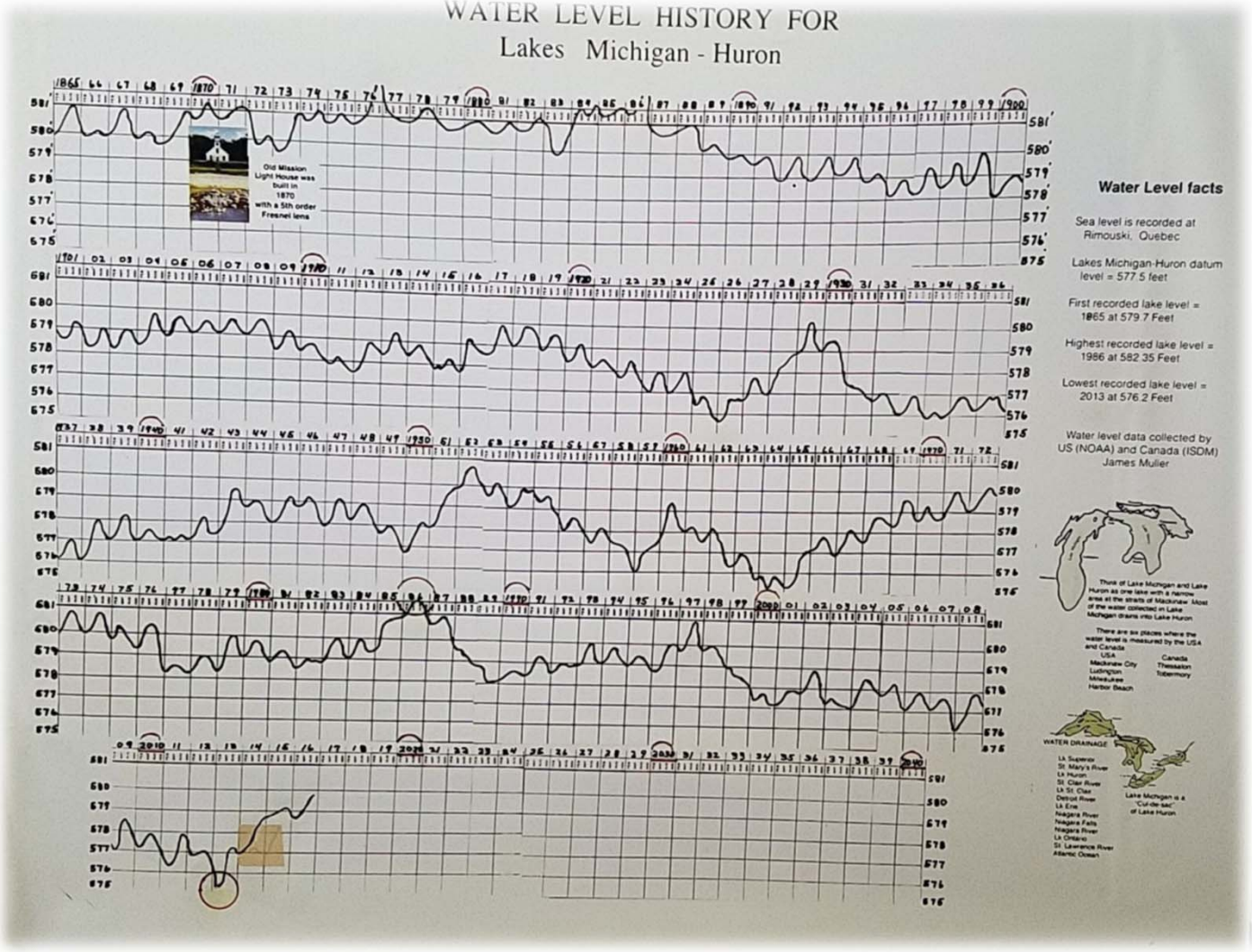
Review, Shorelines, Lake levels 1865 to 2016

- 3288 miles of great lakes shorelines



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What do we know about anthropogenic impact(s) to Lake Michigan shorelines?

Some answers or more questions?

DISCUSSION

Thank you!

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