SECTION 227

# Stabilization of a Coastal Bluff by Bluff Dewatering

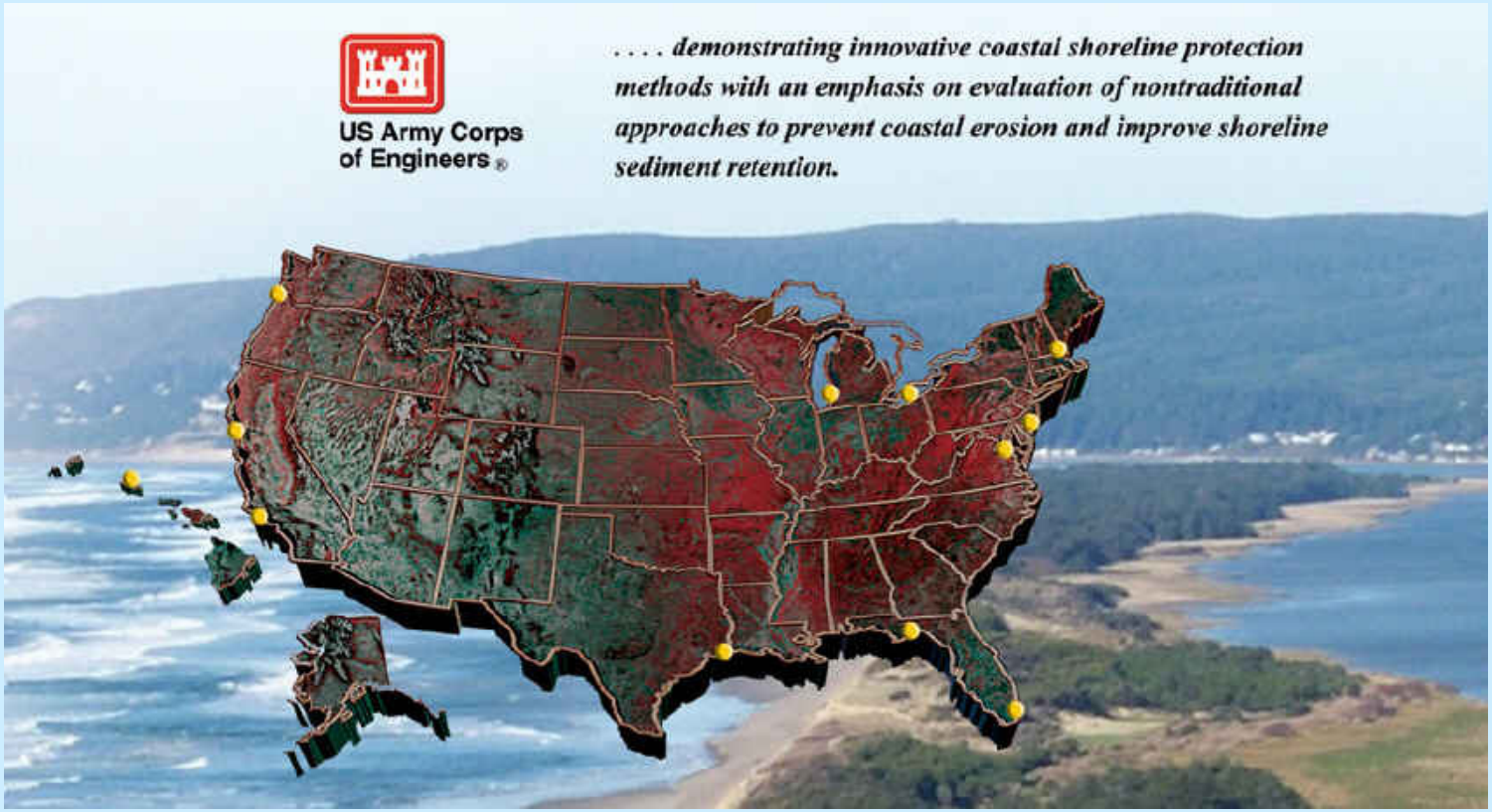
## Allegan County, MI

## Section 227

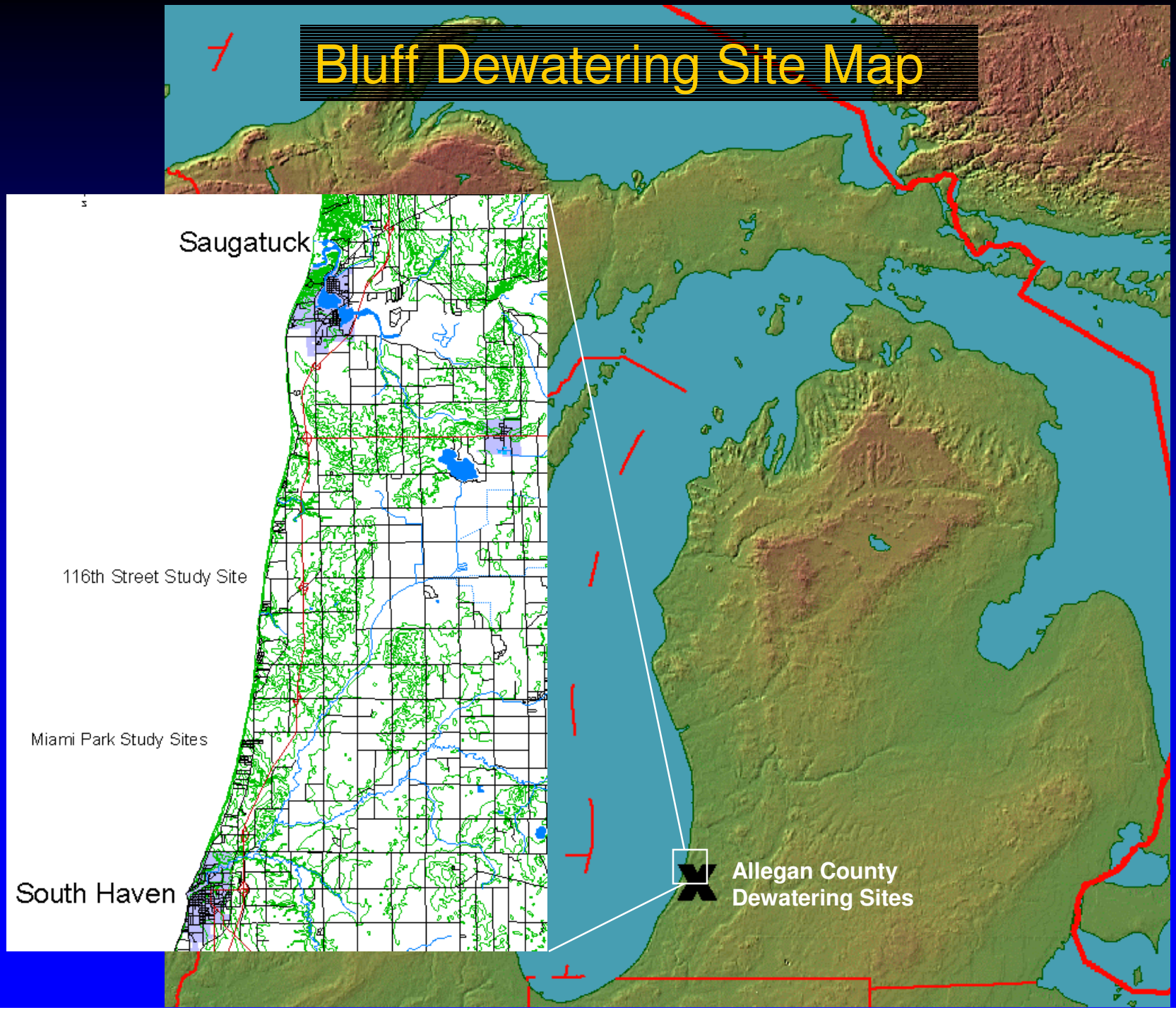
**Great Lakes Hydraulics and Hydrology Office**
*If it flows, we can model it!*

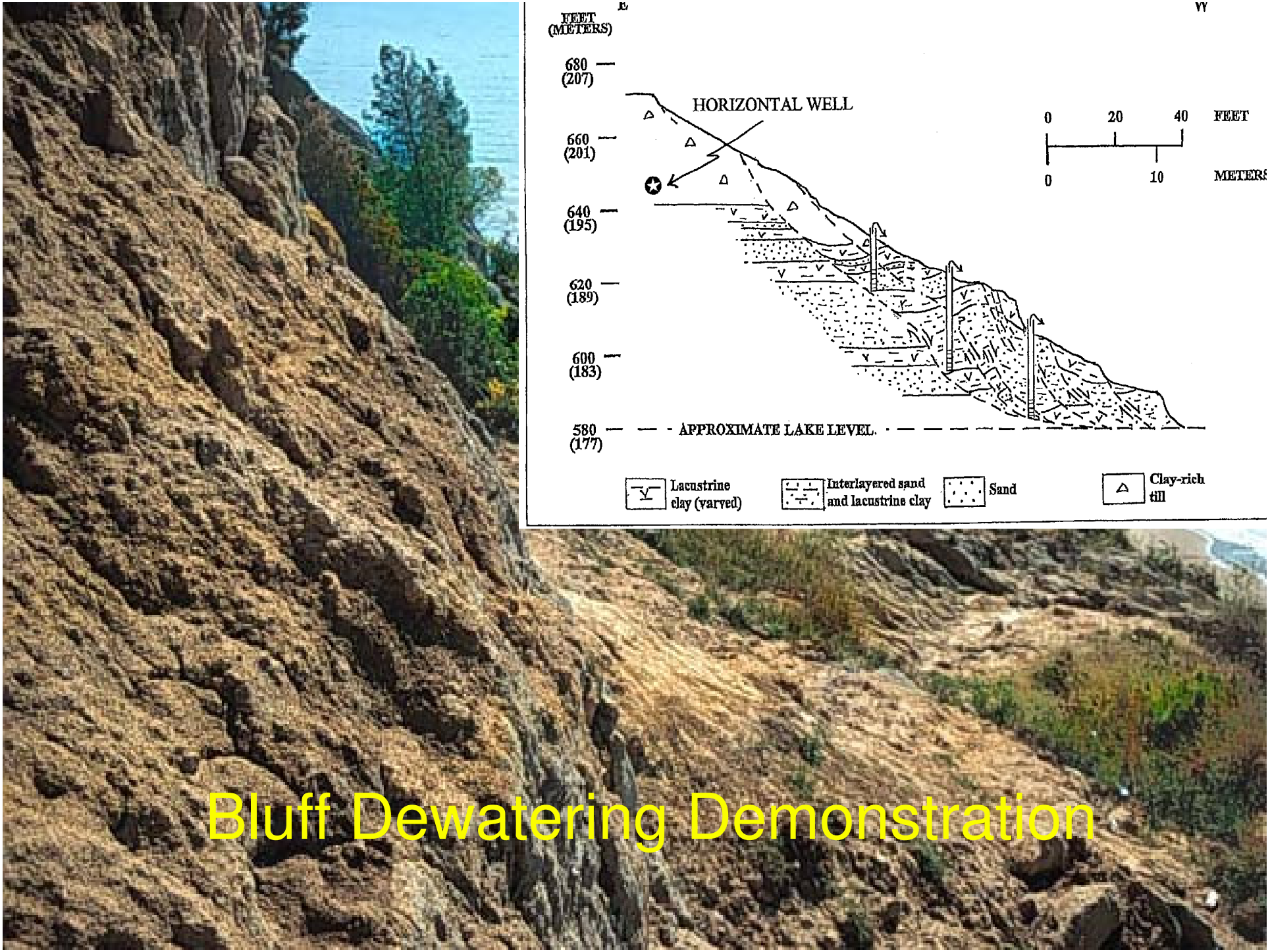
SECTION 227

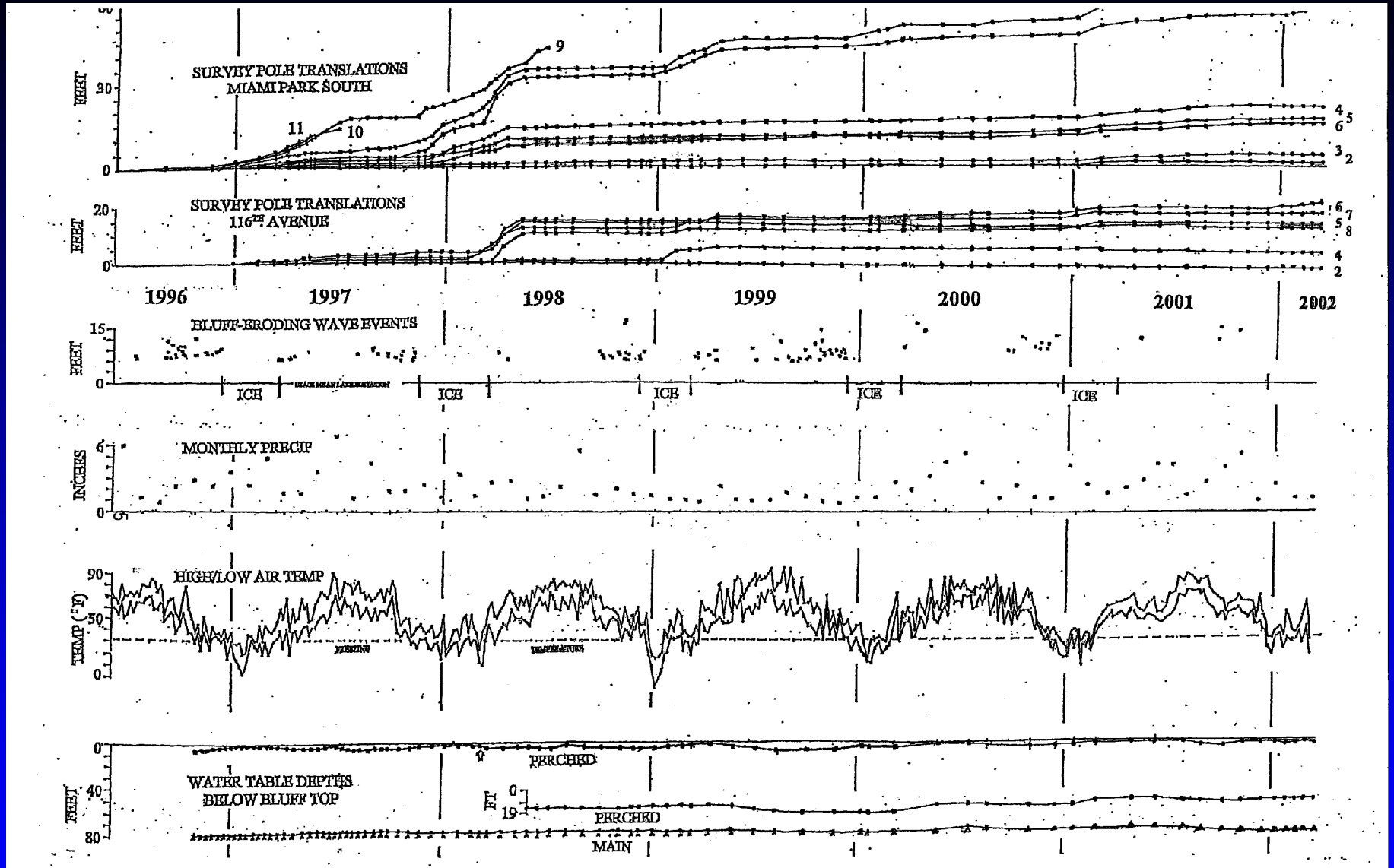
# National Shoreline Erosion Control Demonstration and Development Program

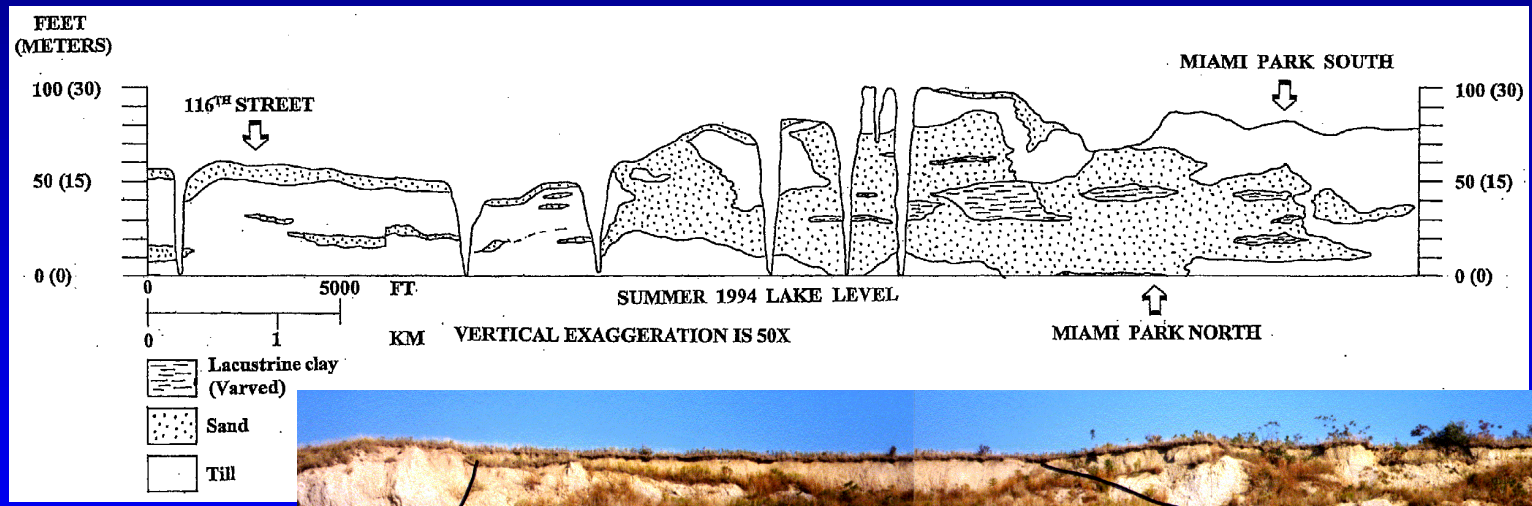


# Bluff Dewatering Site Map




FEET
(METERS)
680
(207)
660
(201)
640
(195)
620
(189)
600
(183)
580
(177)
HORIZONTAL WELL
0
20
40
FEET
0
10
METERS
APPROXIMATE LAKE LEVEL
Lacustrine clay (varved)
Interlayered sand and lacustrine clay
Sand
Clay-rich till
Bluff Dewatering Demonstration


SURVEY POLE TRANSLATIONS
MIAMI PARK SOUTH
FEET
30
0
9
11
10
4
5
6
3
2
SURVEY POLE TRANSLATIONS
116TH AVENUE
20
0
6
7
5
8
4
2
1996
1997
1998
1999
2000
2001
2002
BLUFF-ERODING WAVE EVENTS
15
0
ICE
ICE
ICE
ICE
ICE
MONTHLY PRECIP
INCHES
6
0
HIGH/LOW AIR TEMP
TEMP (°F)
90
50
0
0
PERCHED
WATER TABLE DEPTHS
BELOW BLUFF TOP
40
80
0
19
PERCHED
MAIN




Stratigraphic profile along the shoreline bluff showing locations and views of the three dewatering sites.

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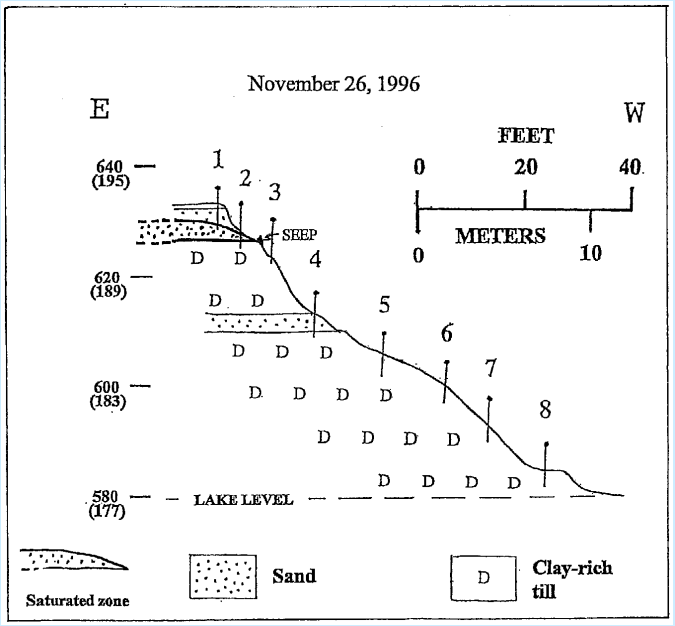
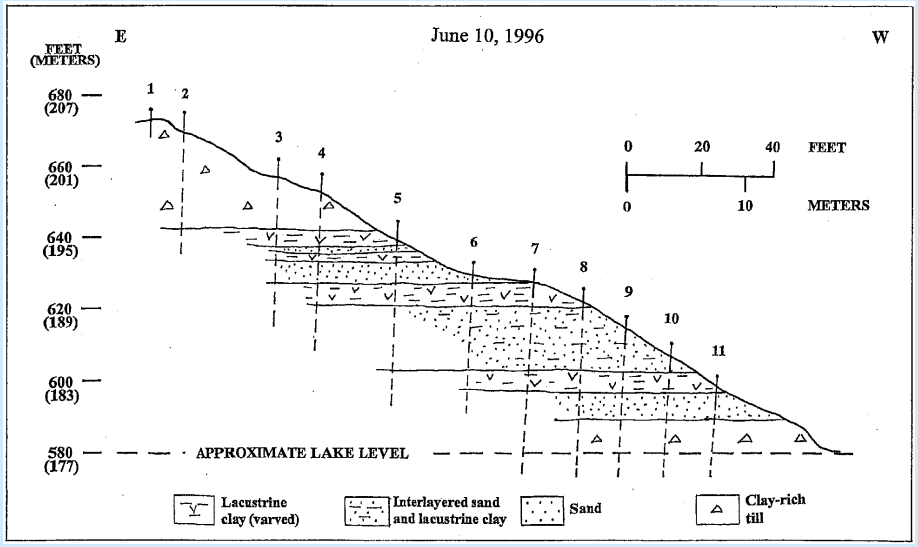
# Stratigraphy



# Miami Park South

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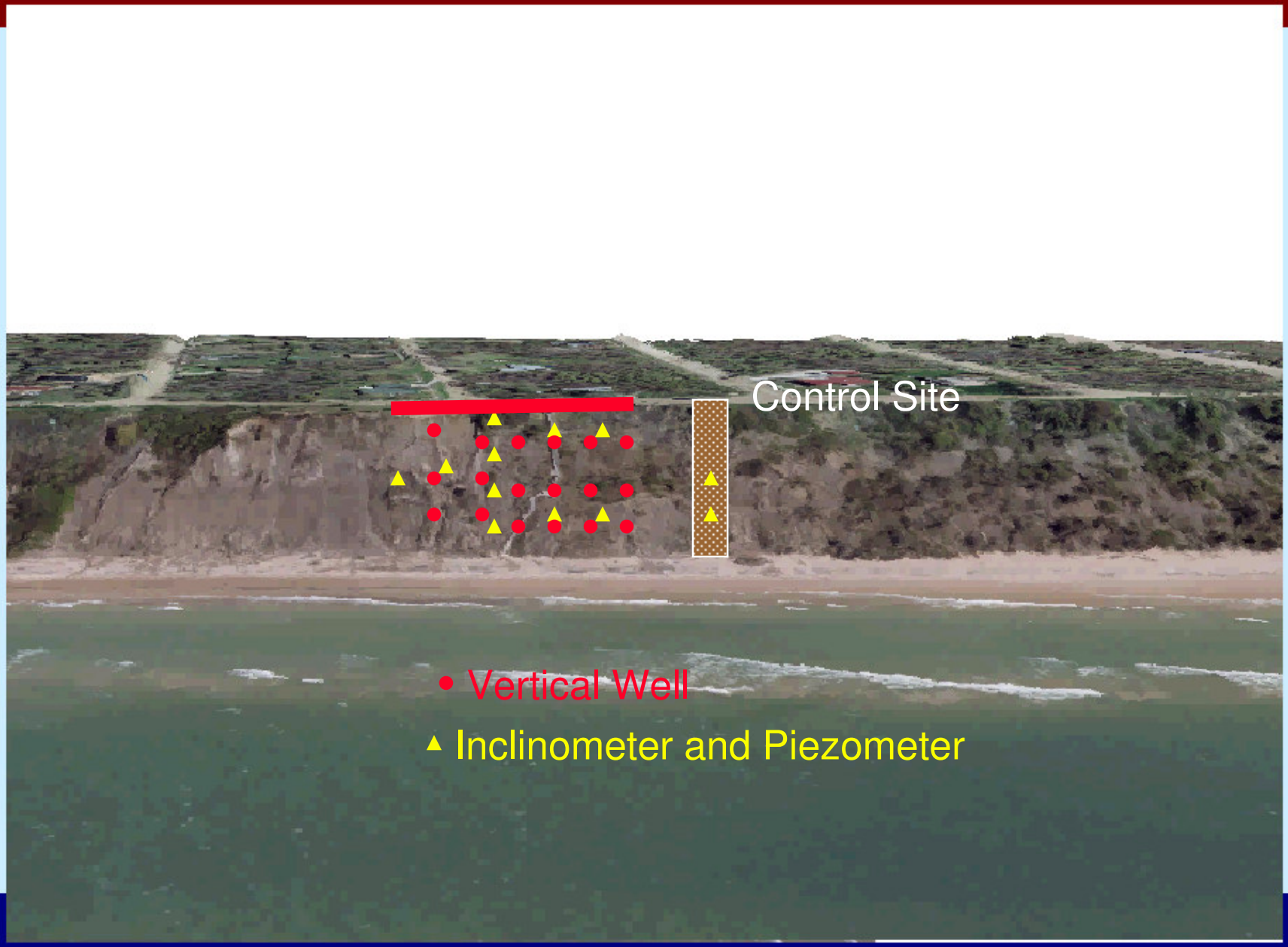
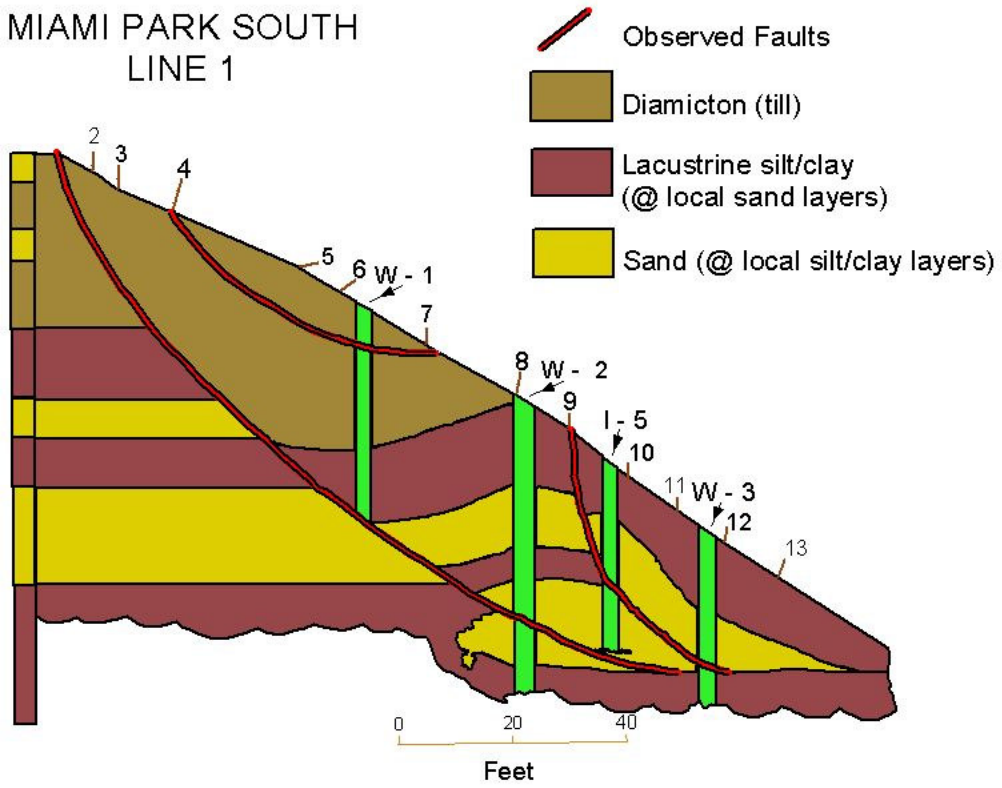
# Miami Park South

SECTION 227



SECTION 227


MIAMI PARK SOUTH
LINE 1
Observed Faults
Diamicton (till)
Lacustrine silt/clay
(@ local sand layers)
Sand (@ local silt/clay layers)
2
3
4
5
6
W - 1
7
8
W - 2
9
I - 5
10
11
W - 3
12
13
0
20
40
Feet

# Miami Park North

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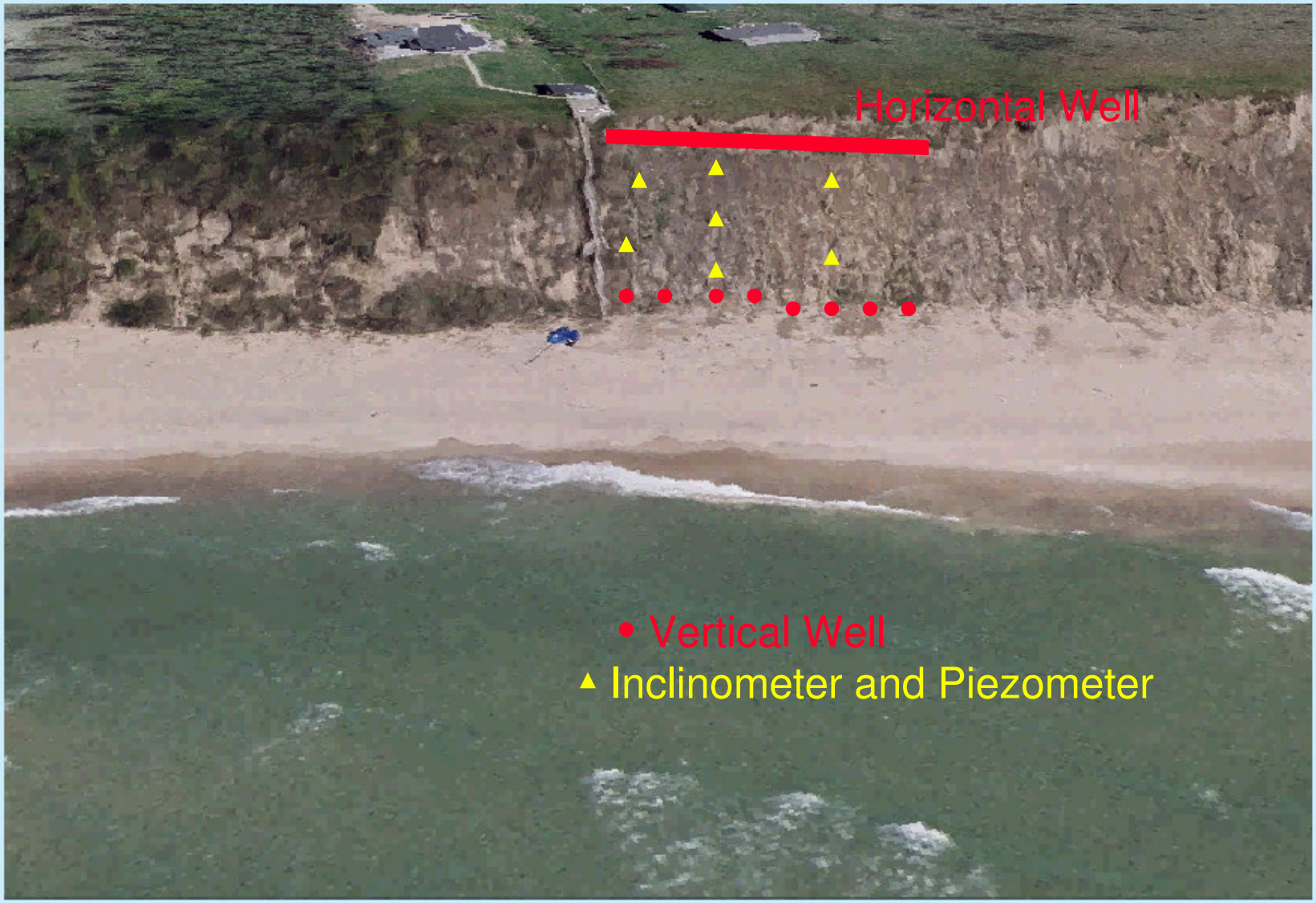
# Miami Park North

SECTION 227



# 116th Ave. Site

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# 116th Ave. Site

SECTION 227

# Construction

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# Construction

SECTION 227

# Piezometers

SECTION 227

# Inclinometers

SECTION 227

# Inclinometers

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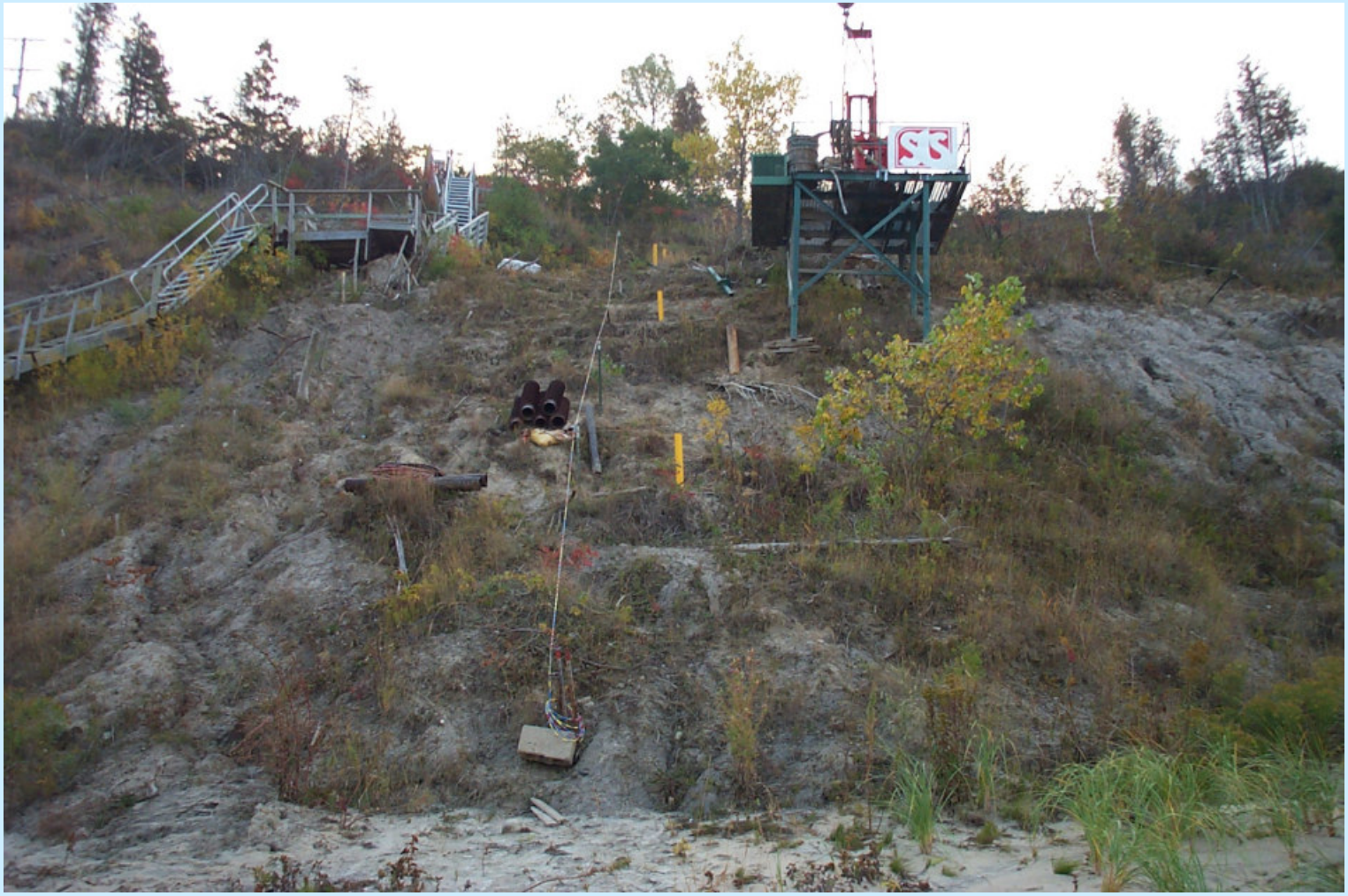

# Flow Meters

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# Data House

SECTION 227

# Data House

SECTION 227

# Sampling

SECTION 227

# Monitoring Program

SECTION 227

## Aerial Photography

# Monitoring Program

SECTION 227

## Topographic LIDAR

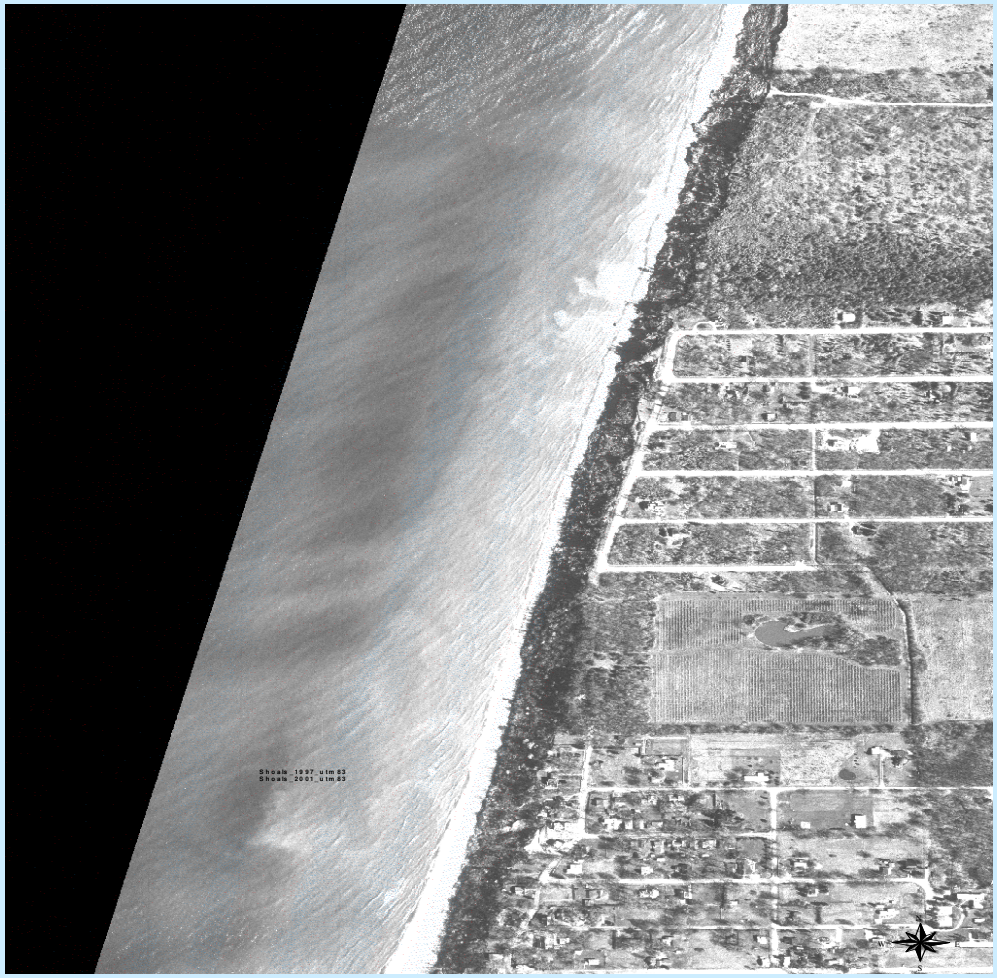
# Monitoring Program

SECTION 227

## Bathymetry

**SHOALS**

Blue 1997
Red 2001



# Monitoring Program

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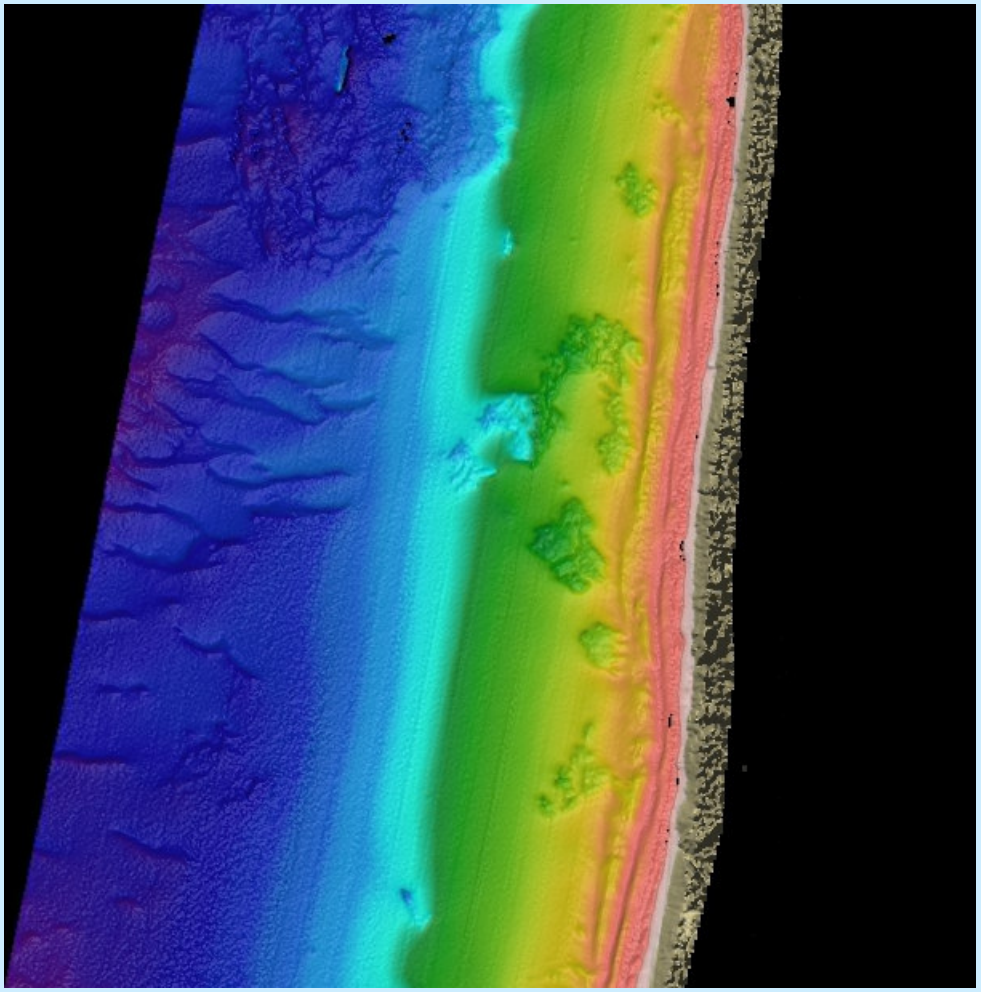
## SHOALS



# Monitoring Program

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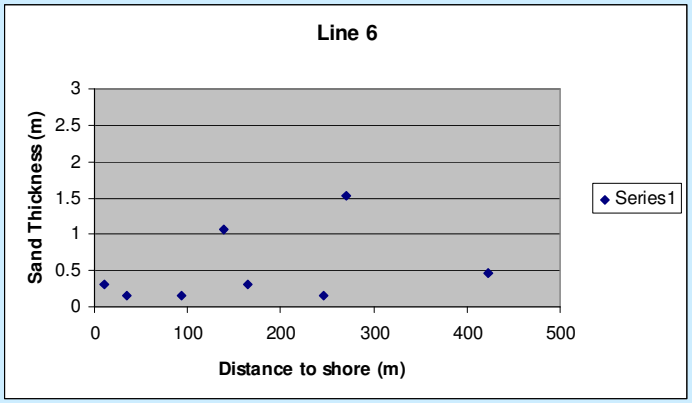
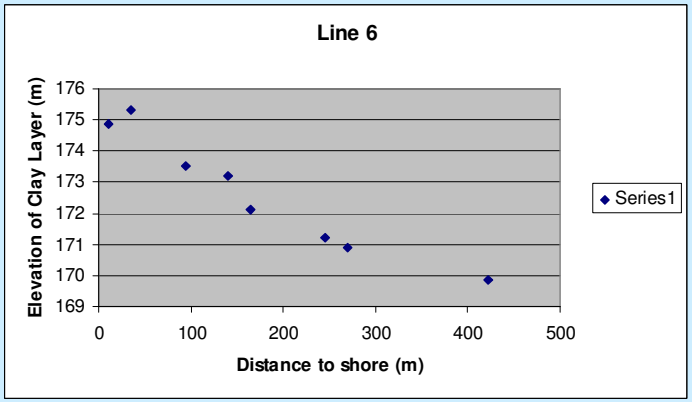
## Sand Probing




Sand Bar Thickness




Elevation of Till Surface

# Monitoring Program

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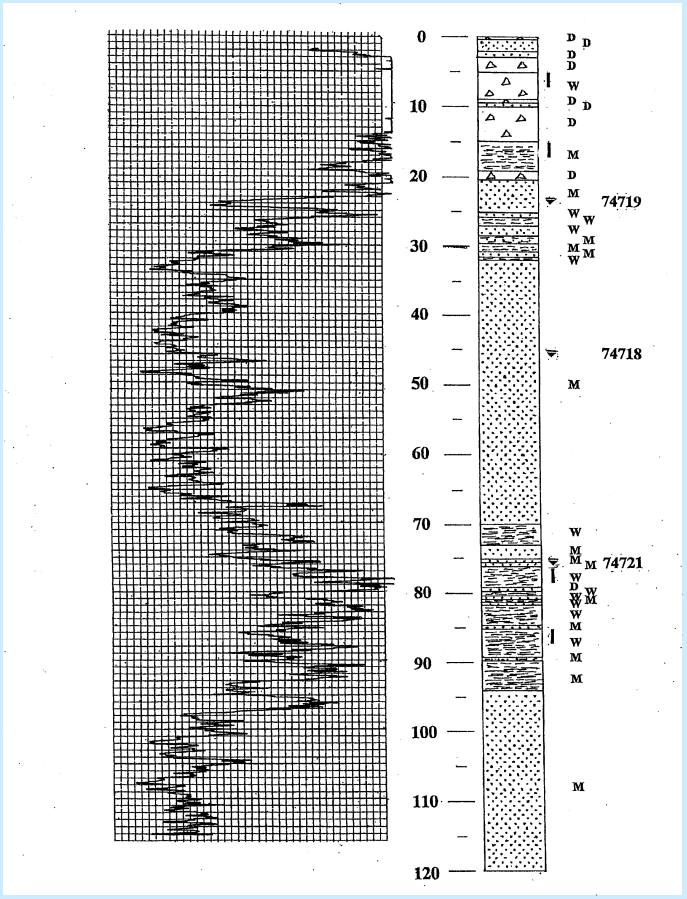
## Soil Borings/GW Monitoring



# Monitoring Program

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## Meteorological Data

- Precipitation
- Wind Speed
- Wind Direction
- Air Temp
- Humidity

# Monitoring Program

## Web Cameras

USACE Engineer Research and Development Center
Cold Regions Research and Engineering Laboratory

**Web Camera Images at ERDC/CRREL Allegan MI**

Latest Information and Recent images from active cameras

**Camera 1 at Allagen MI**

Table of images from above camera or

**Camera 2 at Allegan MI**

Table of images from above camera or

https://webcam.crrel.usace.army.mil/allegan/

# Piezometric Surface vs Displacement

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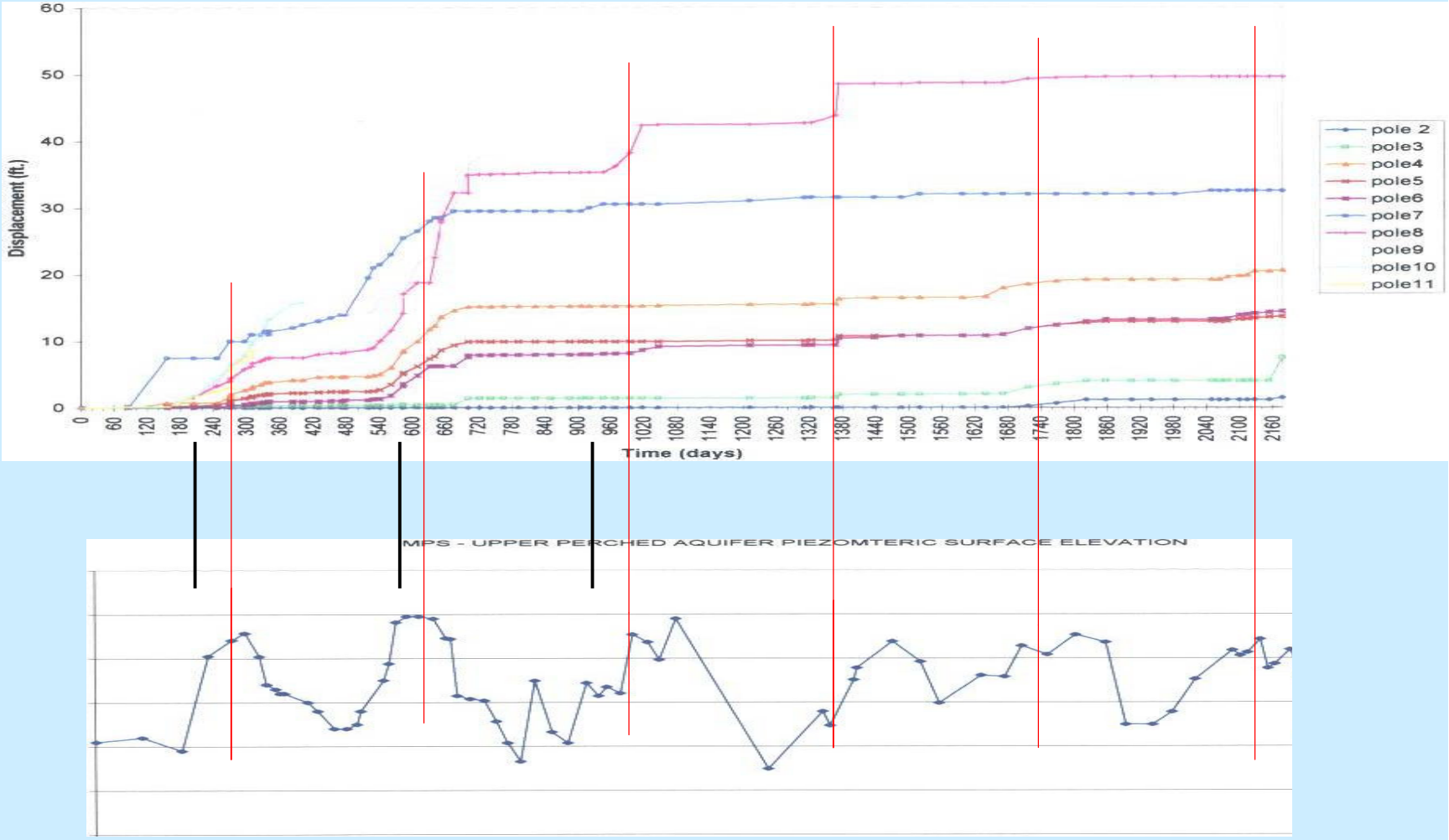


**Red Lines Mark Periods of Maximum Displacement Rates**

# Piezometric Surface vs. Air Temperature

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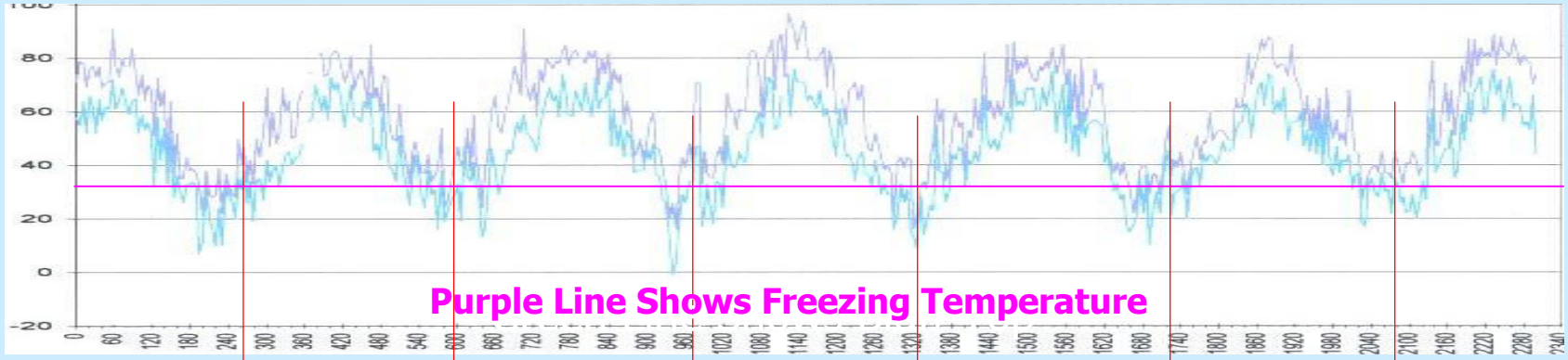


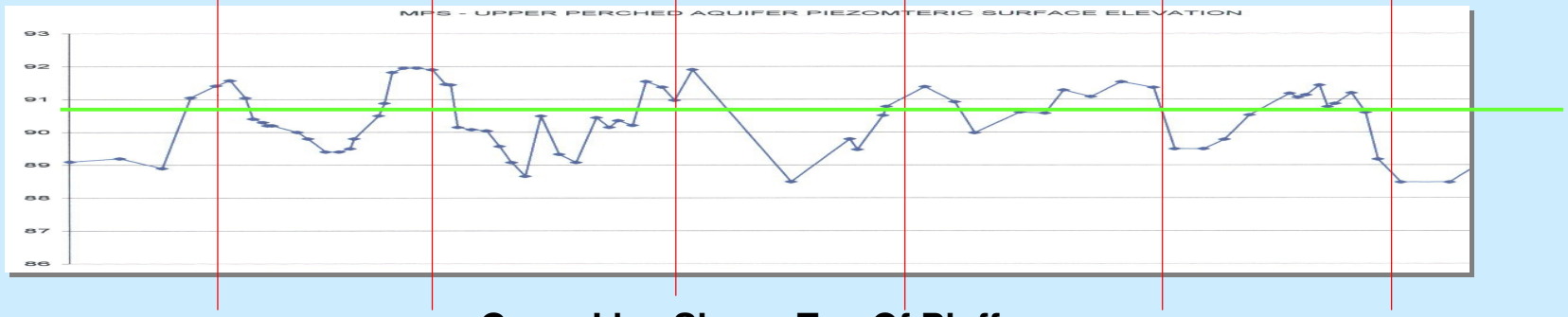


**Green Line Shows Top Of Bluff**

**Red Lines Mark Periods of Maximum Displacement Rates**

# MIAMI PARK SOUTH POLE DISPLACEMENT VERSUS LAKE LEVEL RELATIVE TO DATUM

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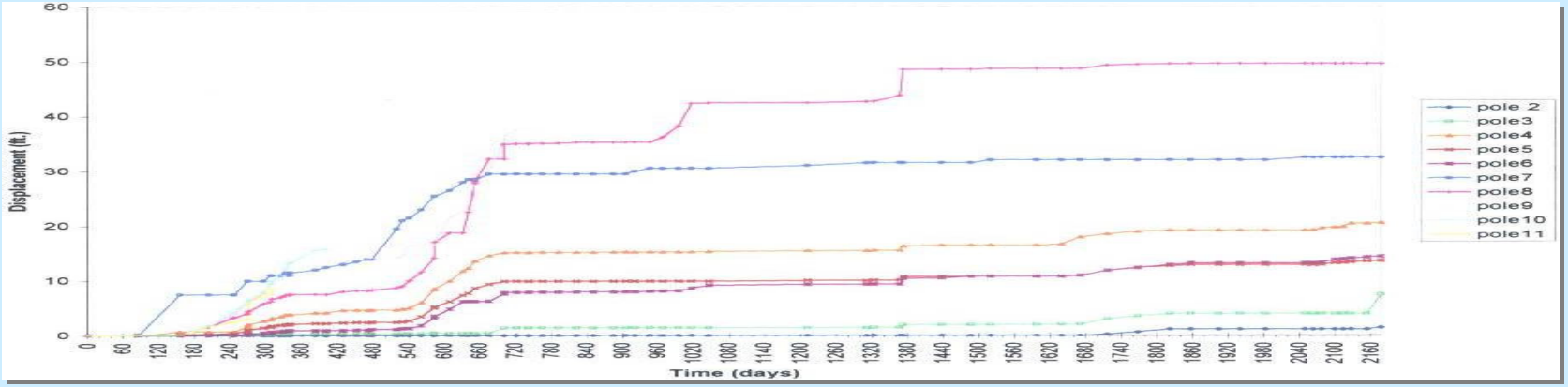
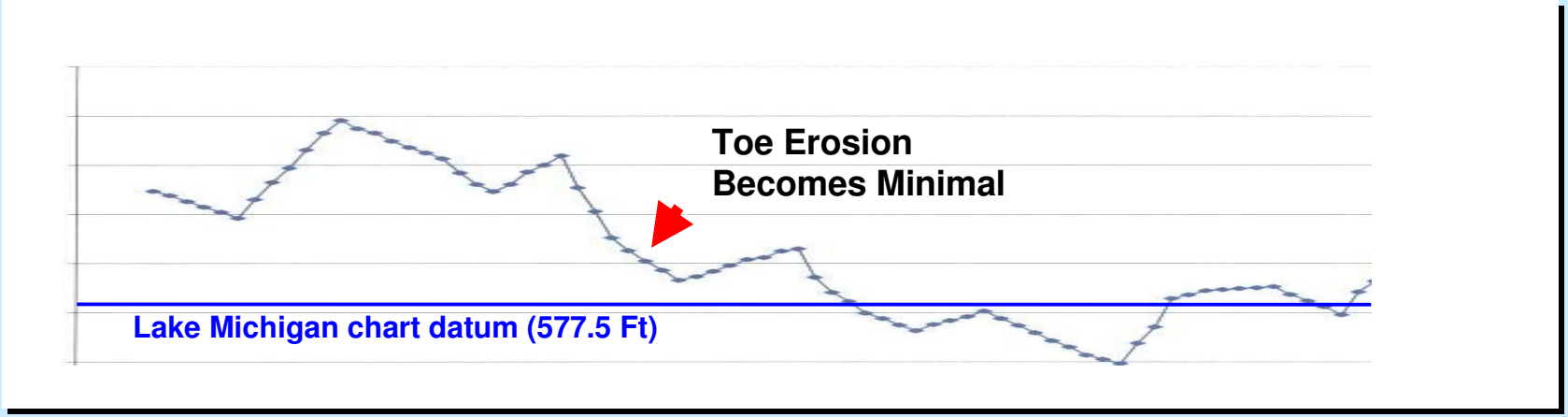
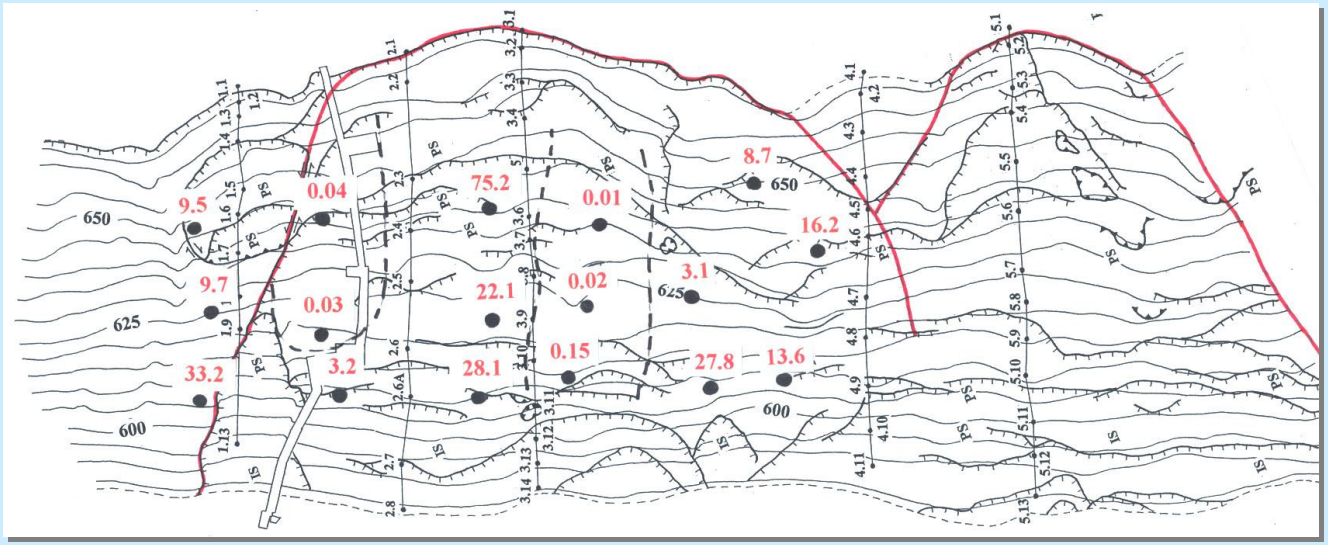
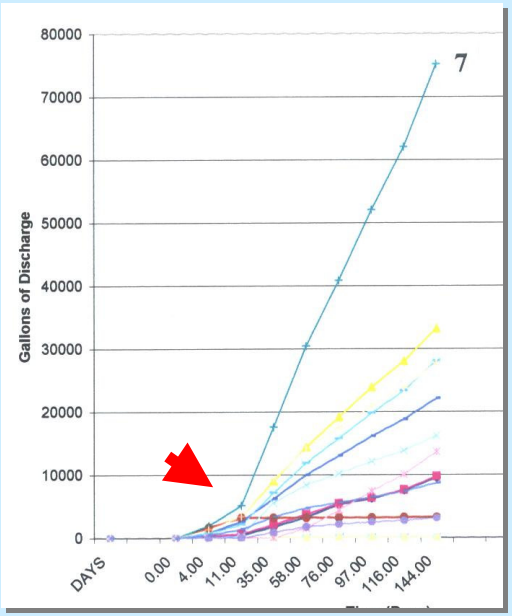


# PUMPED REMOVAL OF GROUND WATER BETWEEN 12/17/04 AND 5/10/05




**Numbers are an thousands of gallons pumped**




- A 14 day lag occurred from first freeze to winter pumping levels
- Over 250,000 gallons removed (1750 gal/day or 1.22 gal/min)
- Shortly after dewatering began, the flow pattern changed. Much water appeared to be piped to well #7, which accounts for 30% of water removed. Well 6 dried up.
- Water distribution is very uneven due to block slumping and smearing of impermeable lacustrine clay into shear zones.

# GROUND WATER REMOVAL
# EFFECTS ON LOCAL BLUFF DISPLACEMENTS

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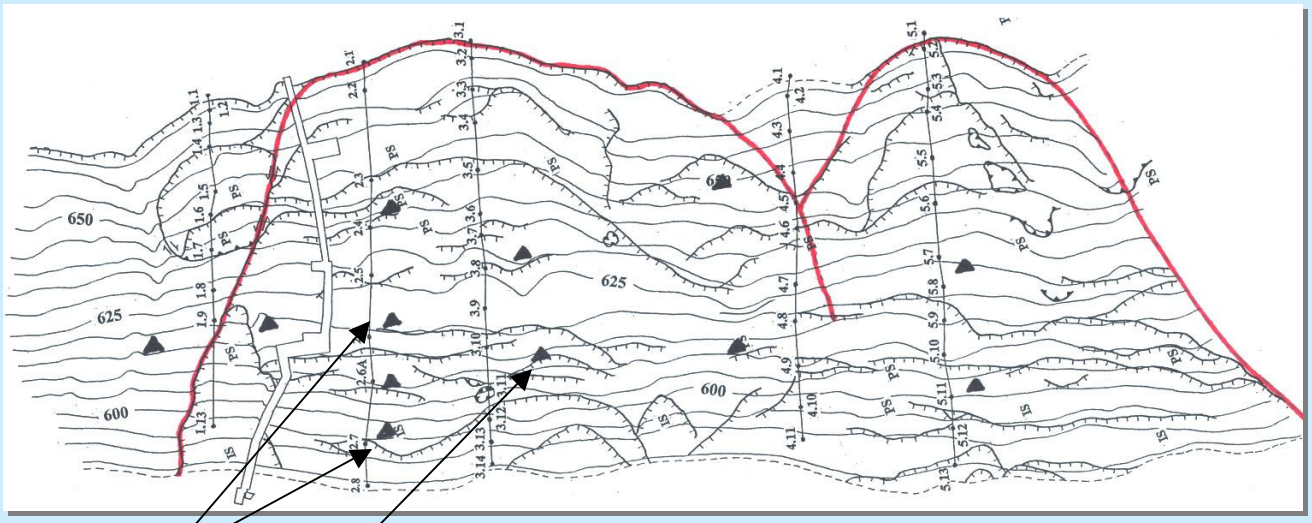


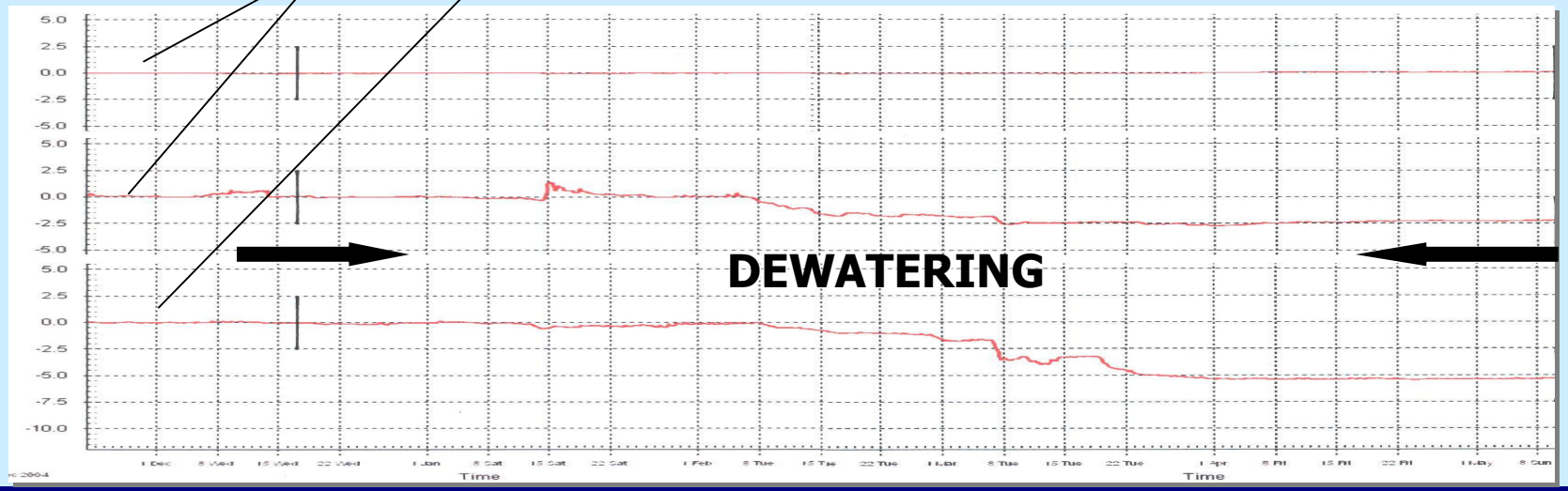

# NO GROUND WATER REMOVAL (CONTROL SITE): EFFECTS ON LOCAL BLUFF DISPLACEMENT

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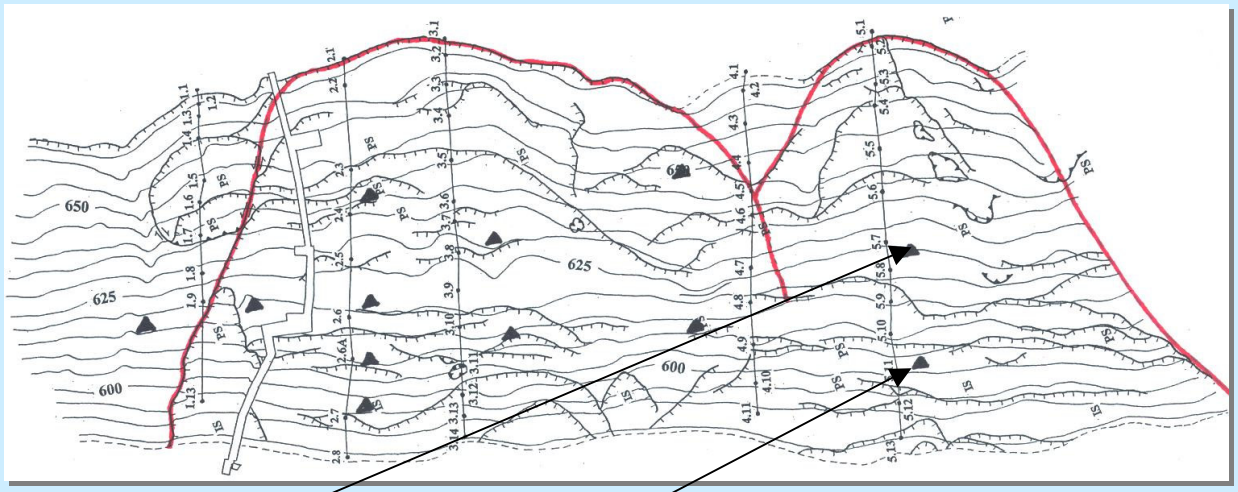


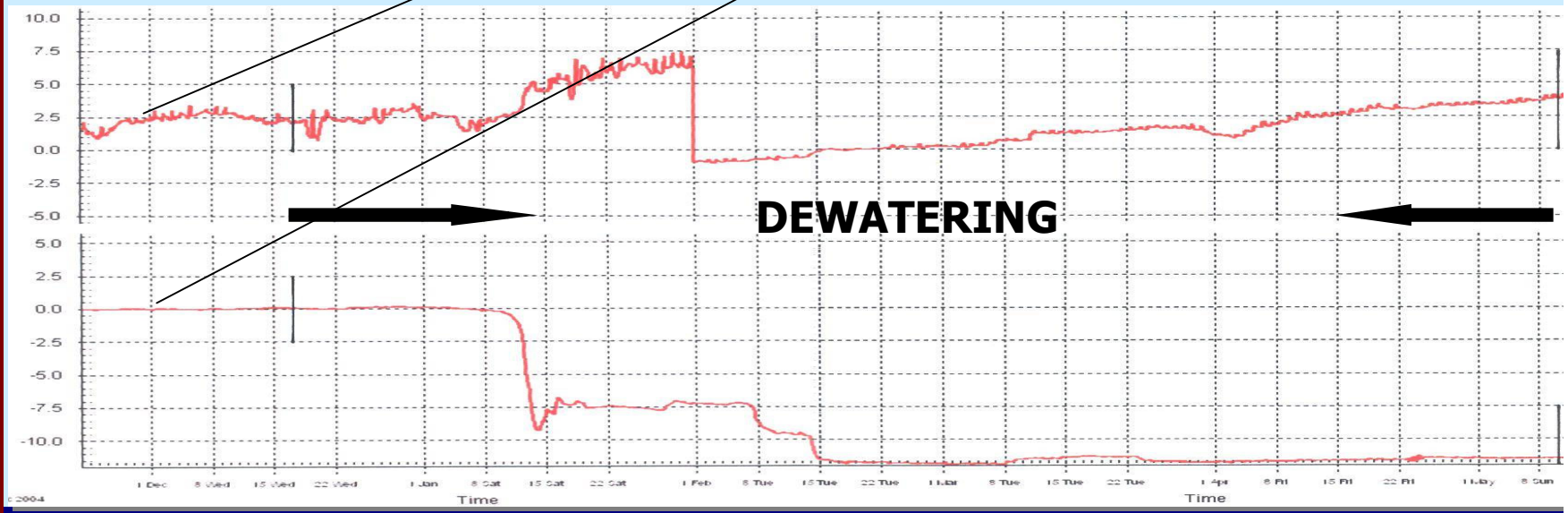

# Conclusions

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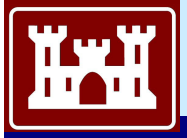
- Most bluff displacements occur during winter-spring months and result when frozen bluff faces block ground water discharge to create elevated pore pressures in soils.

- Once the bluff face is frozen and pore pressures begin to rise, changes in ground water flow directions develop gradually.

- Removal of perched ground water during the winter-spring (conducted during 2004-05) created a three times more stable bluff than did the non-removal of ground water over the same time interval.

- Repeated experiments between now and 2008 will demonstrate whether the bluff stabilization shown in 2004-05 is an equilibrium event or an anomaly.



# For Further Information:

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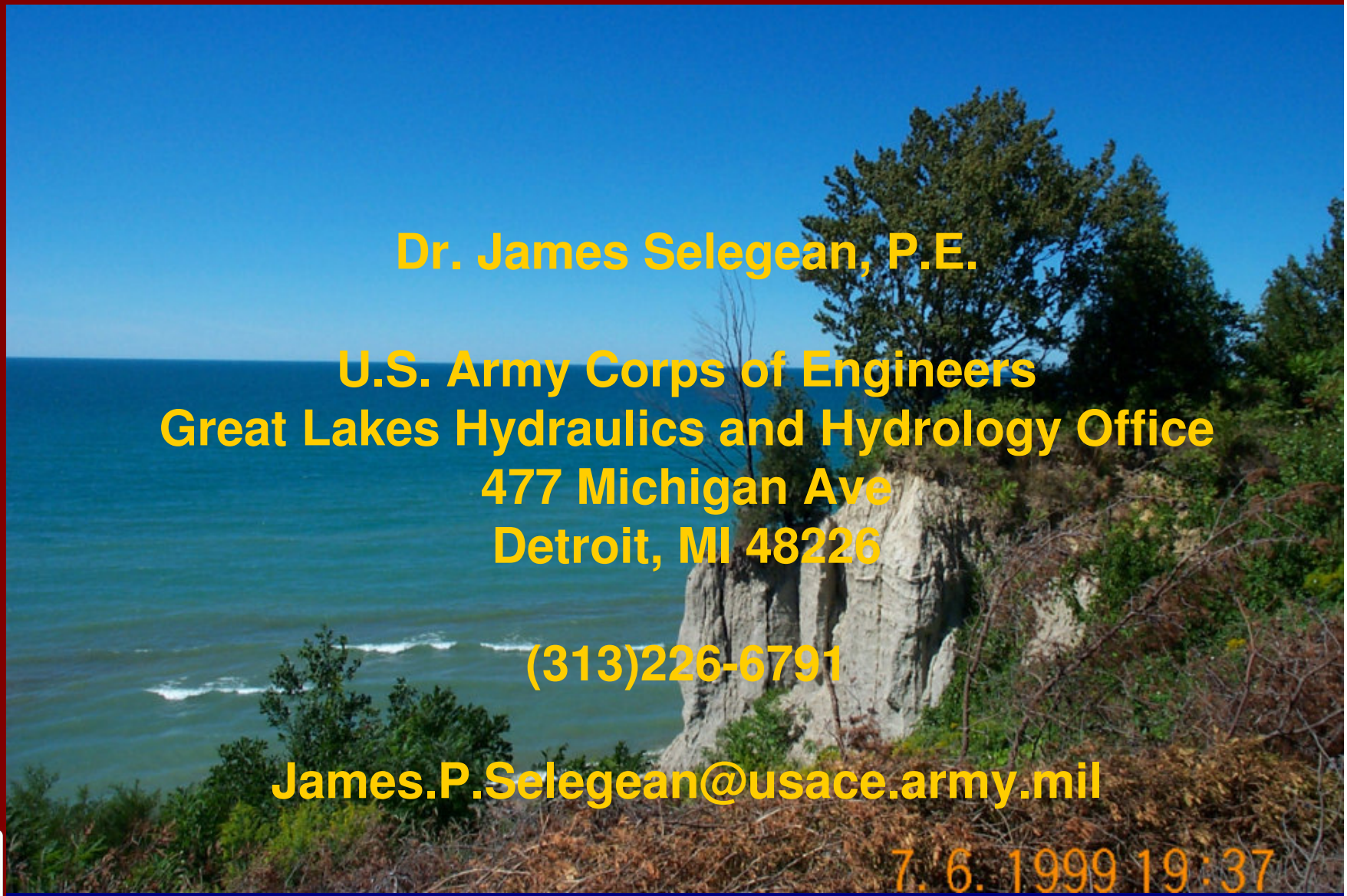


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