Using geophysics to better understand wetland hydrogeology

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uw oshkosh Geology
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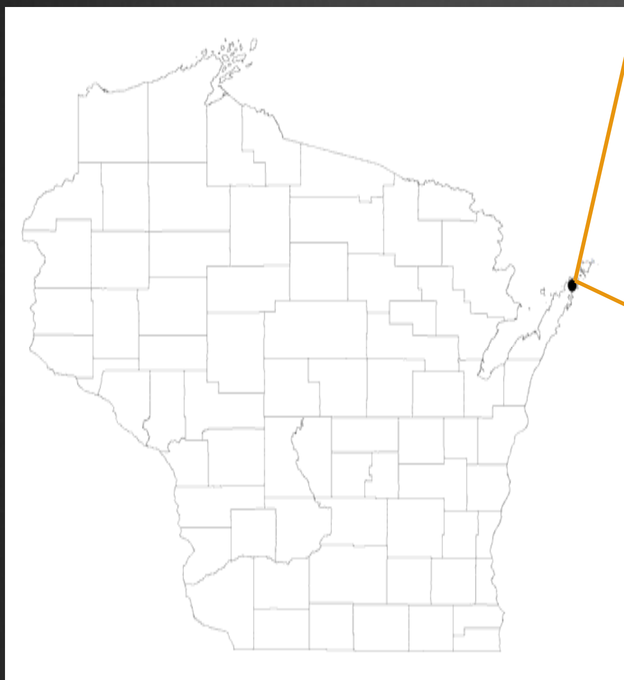
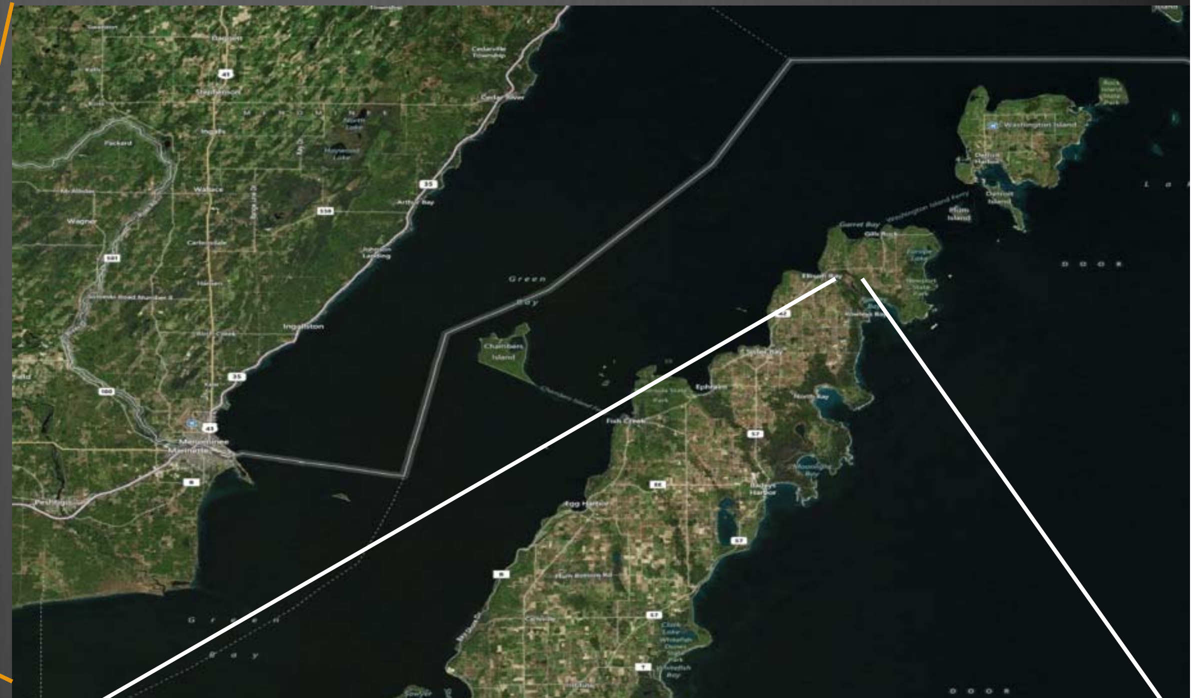
DEPARTMENT of GEOSCIENCE
University of Wisconsin-Madison

WISCONSIN COASTAL MANAGEMENT PROGRAM

Site Location





Geophysics is often a good choice for wetland studies

- Flat
- Often no trees or other obstructions
- No “cultural” interference
- Equipment is relatively portable and unlikely to become stuck

Photo - Ken Bradbury

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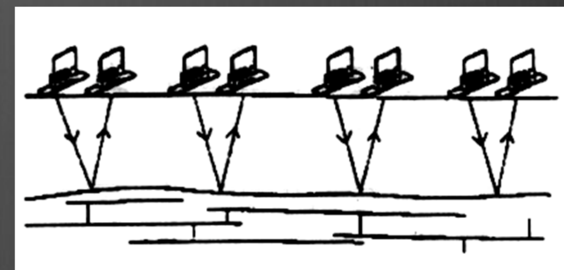
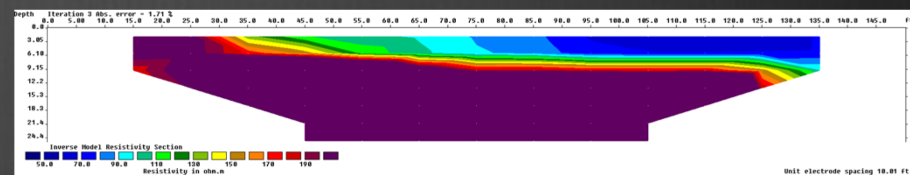
Geophysics Used

- Ground Penetrating Radar



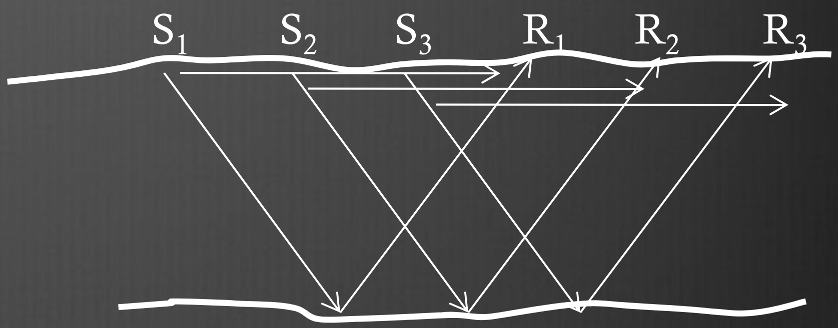
- Electrical Resistivity Imaging

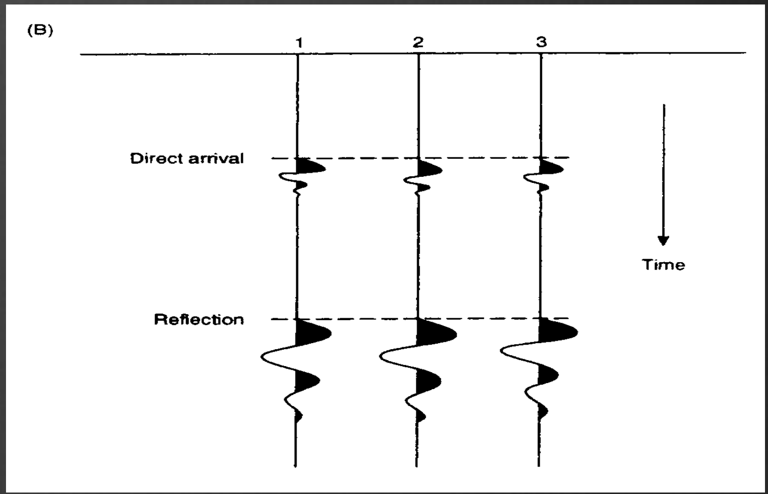


- EM-31 Ground Conductivity Meter

RADAR

- Radio Detection and Ranging
- Developed in 1940s
- Basic Principle
  - Send out a radio wave pulse
  - Then look for reflections
  - The first part of the record is a direct wave (usually includes an air wave too)

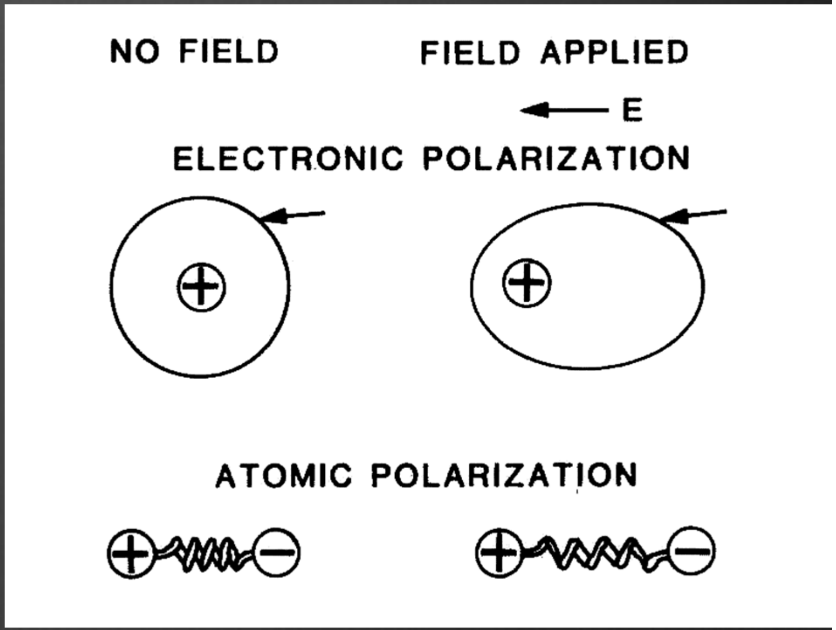




Reynolds

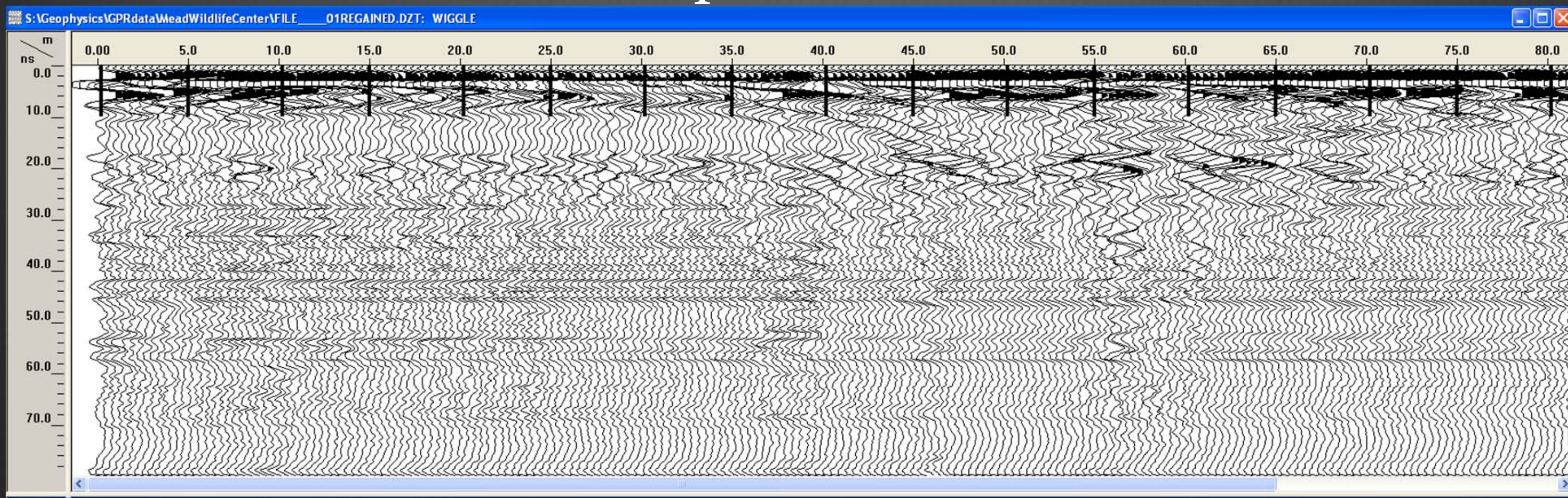
Radio (EM) waves travel through earth.

- The waves stretch the electron clouds around atoms and create dipoles.
- Easily stretched dipoles (high dielectric constants) have low velocities (water).
- Good conductors allow the electrons to move from atom to atom. That current takes all the wave energy. Can't see deep into conductors like metals or clays.
- Couldn't use GPR in the Bog proper

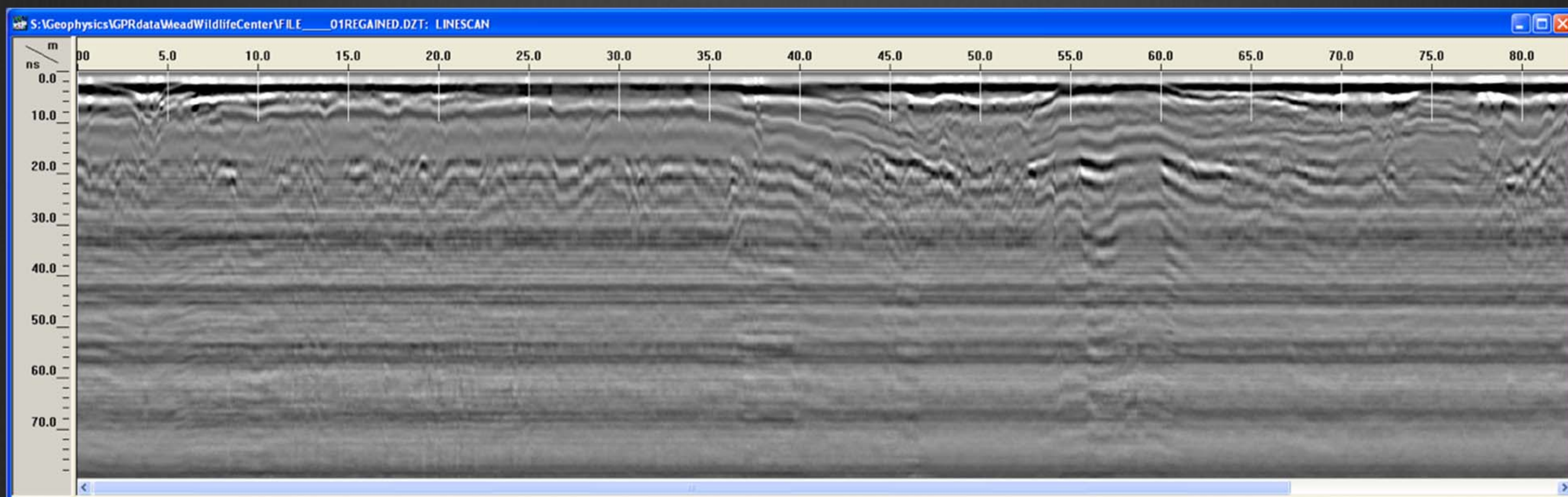


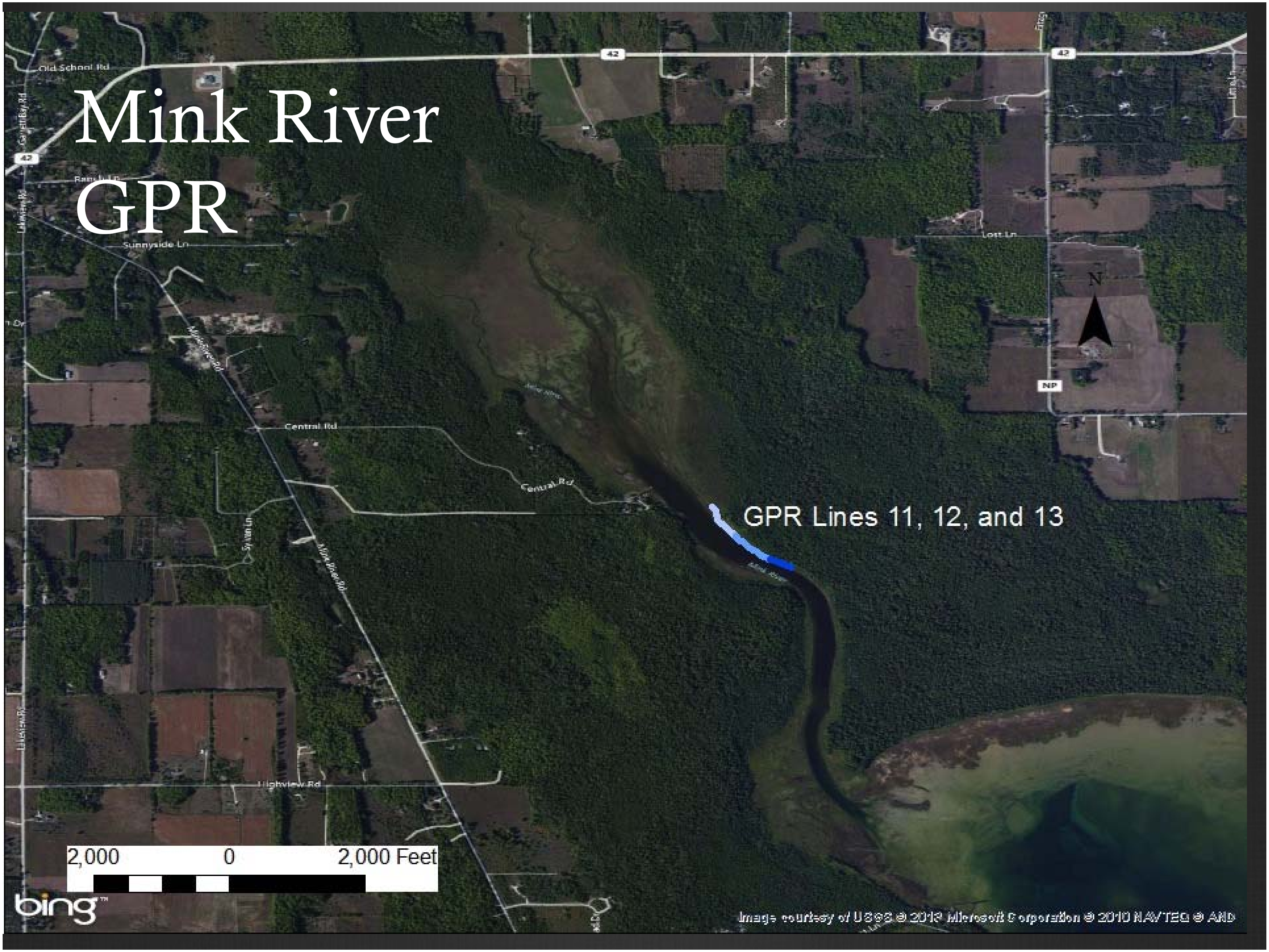
Reynolds

View data as a series of amplitude traces over distance …



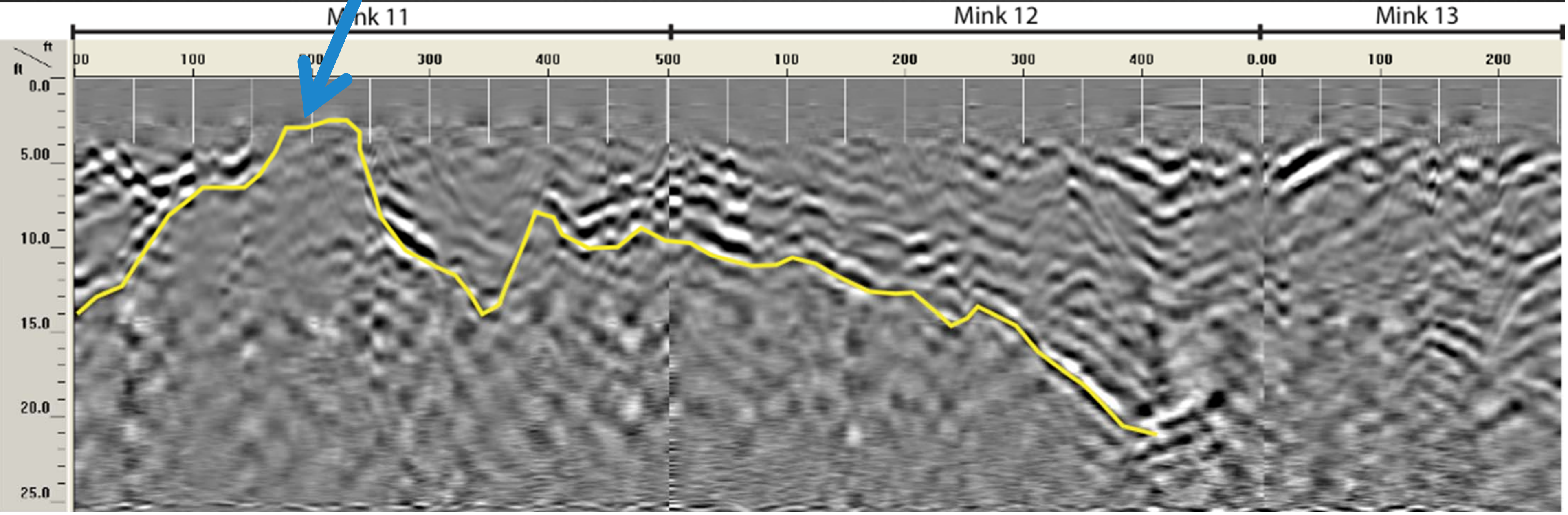
or as an intensity plot with distance.




Mink River
GPR
GPR Lines 11, 12, and 13
N
2,000
0
2,000 Feet
Old School Rd
Sunnyside Ln
Central Rd
Central Rd
Highview Rd
Lost Ln
Mink River Rd
bing
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND

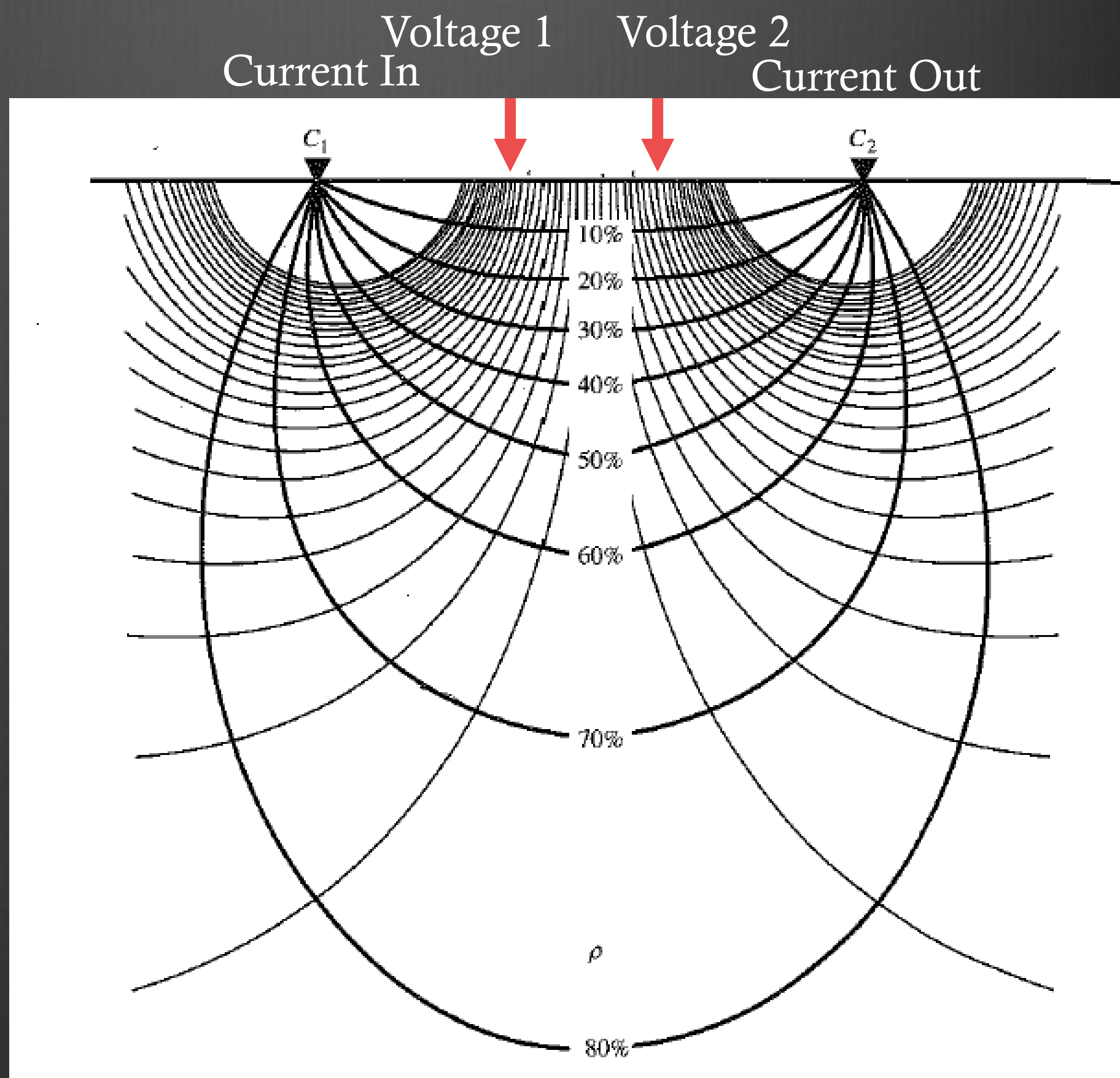
GPR Results

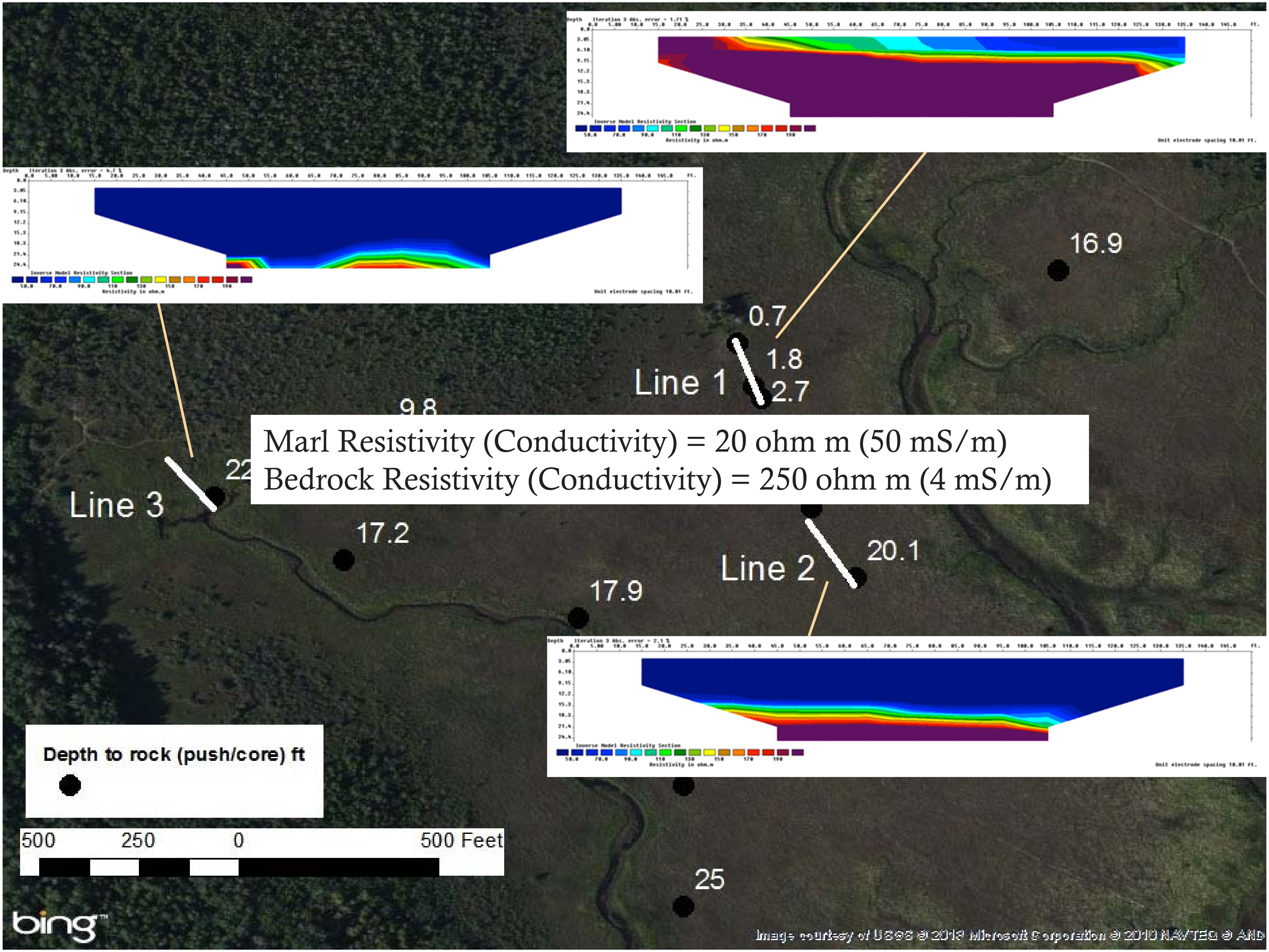
Reflector comes to the surface



Electrical Resistivity Imaging

- Analogous to groundwater flow
- Current electrodes like injection and pumping wells
- Voltage electrodes like piezometers
- Get electrical conductivity rather than hydraulic conductivity
- Variations in materials cause flow lines to warp that can be seen in the voltages.
- Multiple sets of electrodes allow tomography of subsurface.



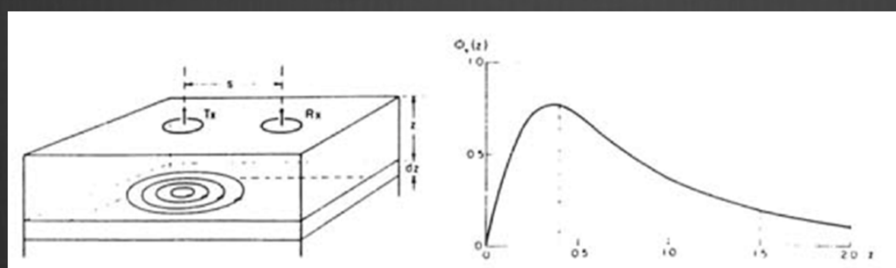


16.9
0.7
1.8
Line 1
2.7
9.8
Marl Resistivity (Conductivity) = 20 ohm m (50 mS/m)
Bedrock Resistivity (Conductivity) = 250 ohm m (4 mS/m)
Line 3
17.2
20.1
Line 2
17.9
Depth to rock (push/core) ft
500 250 0 500 Feet
25
bing
Image courtesy of USGS © 2010 Microsoft Corporation © 2010 NAVTEQ © AND

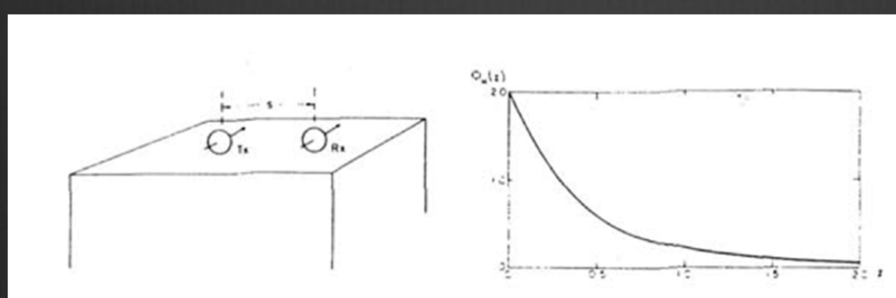
EM-31 Operation

- Operating Principle
  - Instrument induces electrical current in earth with alternating current in coil in one end of instrument. (No direct contact with ground)
  - Coil in other end senses the current in the earth.
  - More induced current ➔ Better conductor
  - Changing Coil orientation ➔ changes depths sensed

Vertical

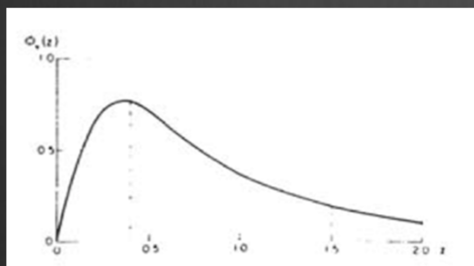


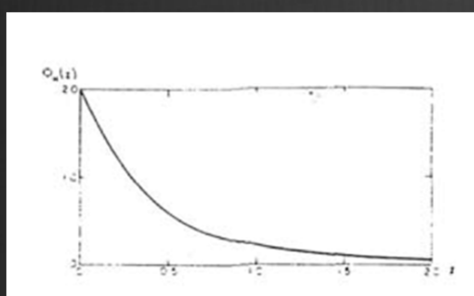
Horizontal



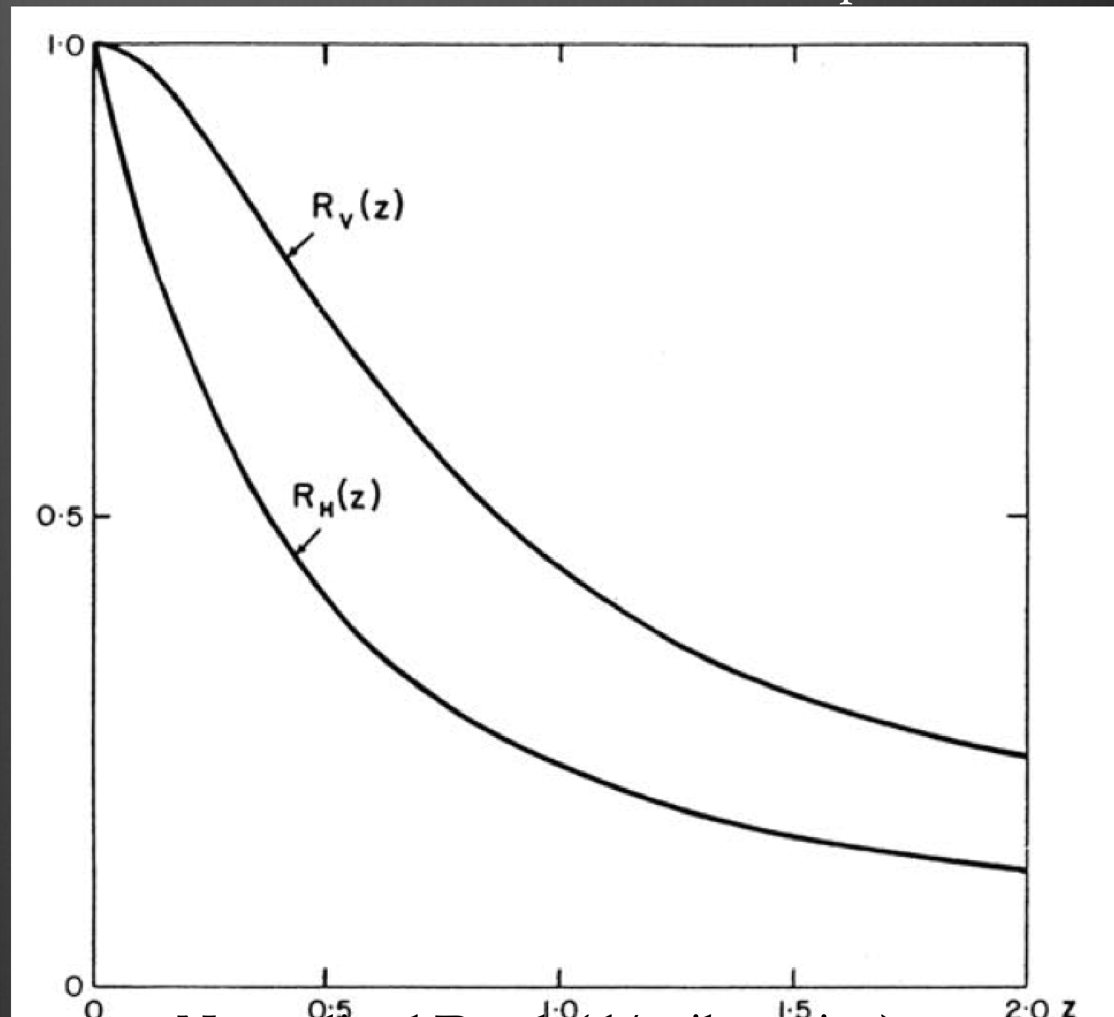
EM-31 Operation

Integrate depth response to get cumulative response





Contribution from all material below depth on x-axis



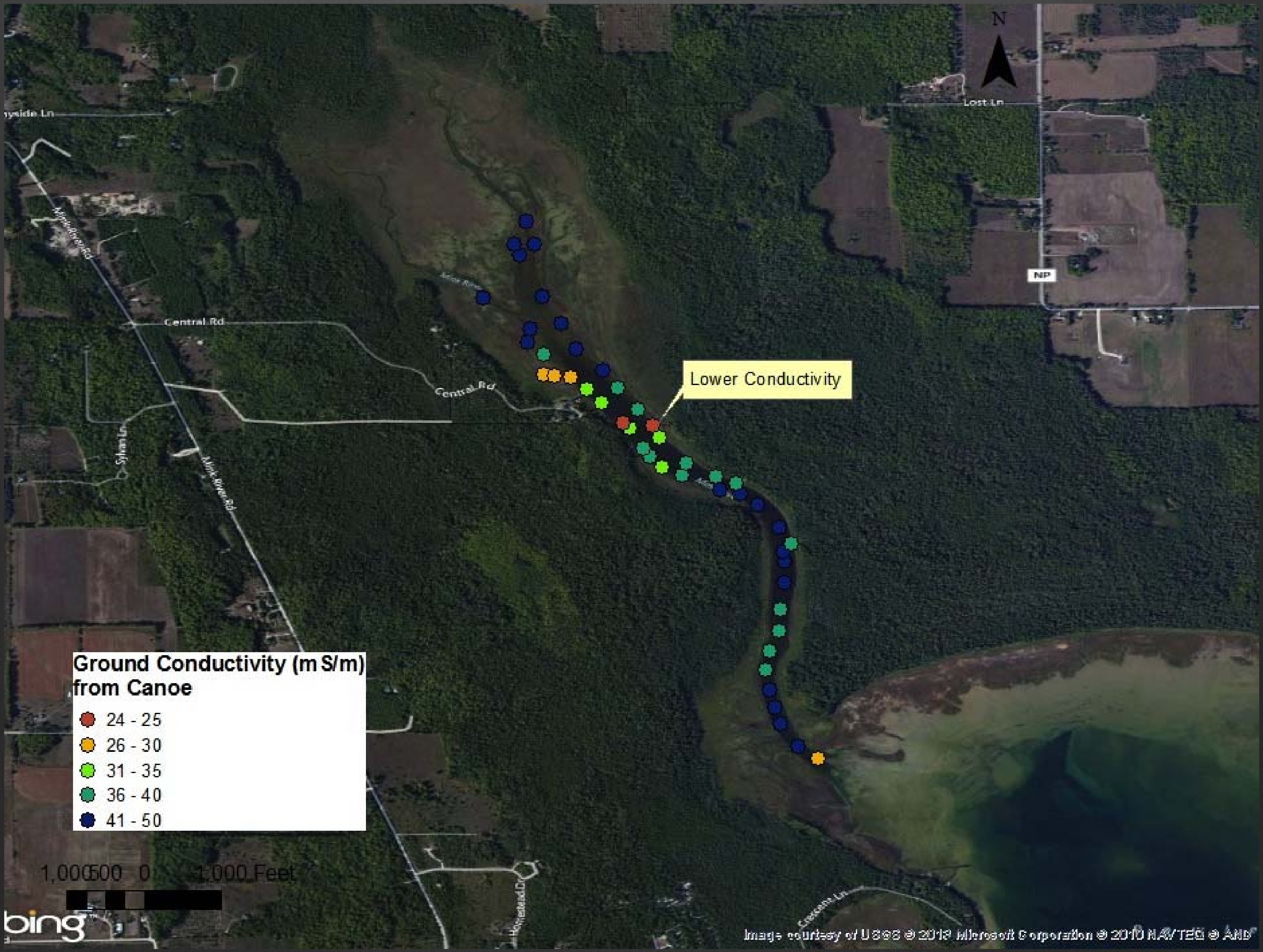
Normalized Depth (d/coil spacing)

1.8 3.7 5.5 7.4 m

Taken from McNeill, 1980.

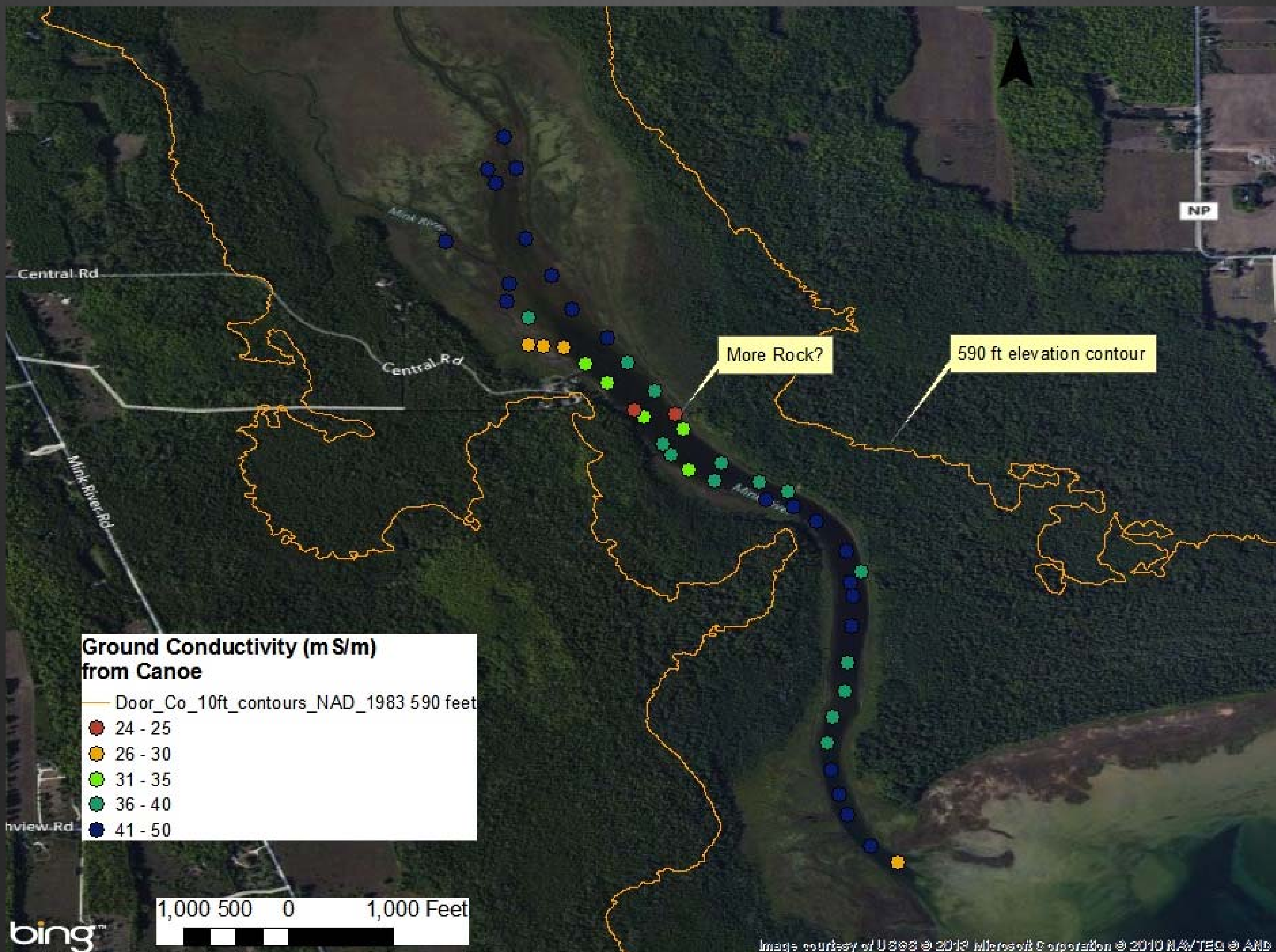
Results

EM31 data collected in canoe



Results

EM31 data collected in canoe



Three Layer System
including air

Photo – Ken Bradbury

d_{air}=0.85 m

$d=d_{marl}+d_{air}$

Air

σ_{air}= 0 mS/m

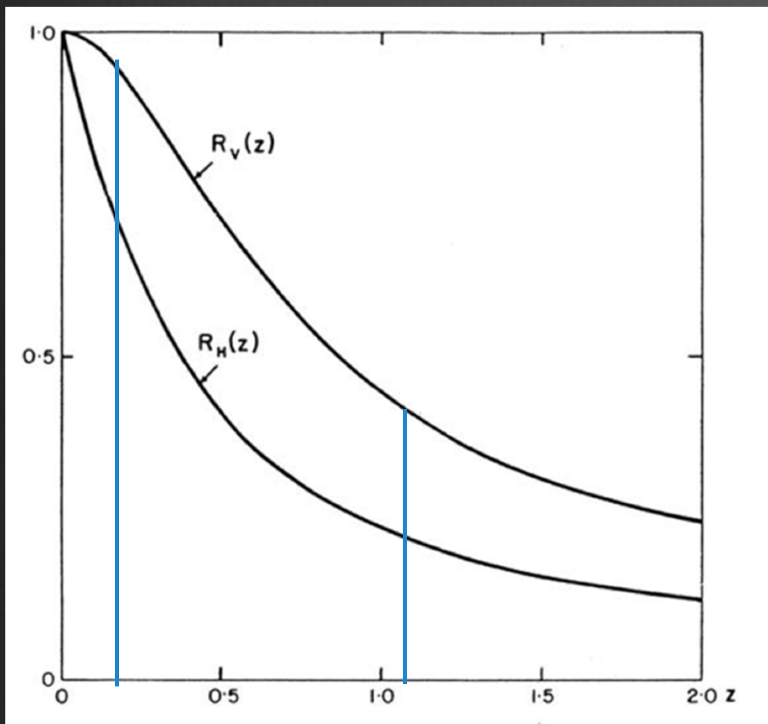
Marl/Organic Sediment

σ_1= 57 mS/m (adjusted from 50 mS/m to fit depths)

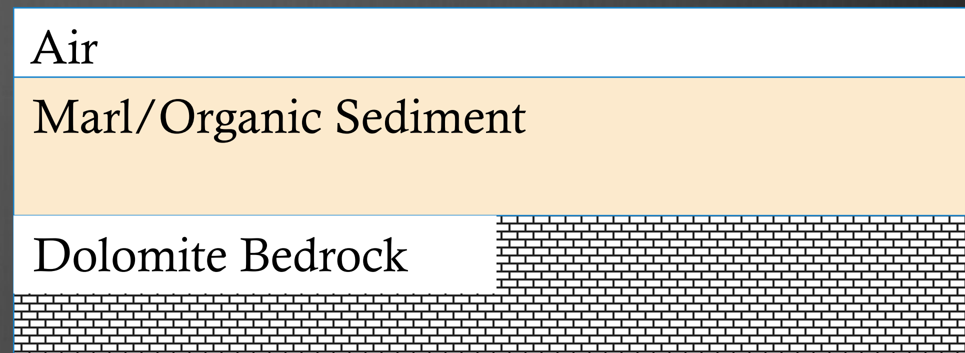
Dolomite Bedrock

σ_2= 4 mS/m

Three Layer System



z_{air} $z_{air\_} + z_{marl}$



$$\sigma_a = \sigma_{air}\left[1 - R_V\left(z_{air}\right)\right] + \sigma_1\left[R_V\left(z_{air}\right) - R_V\left(z_{marl} + z_{air}\right)\right] + \sigma_2 R_V\left(z_{marl} + z_{air}\right)$$

Three Layer System

$$\sigma_a = \cancel{\sigma_{air}}^{\,0}\left[1 - R_V\left(z_{air}\right)\right] + \sigma_1\left[R_V\left(z_{air}\right) - R_V\left(z_{marl} + z_{air}\right)\right] + \sigma_2 R_V\left(z_{marl} + z_{air}\right)$$

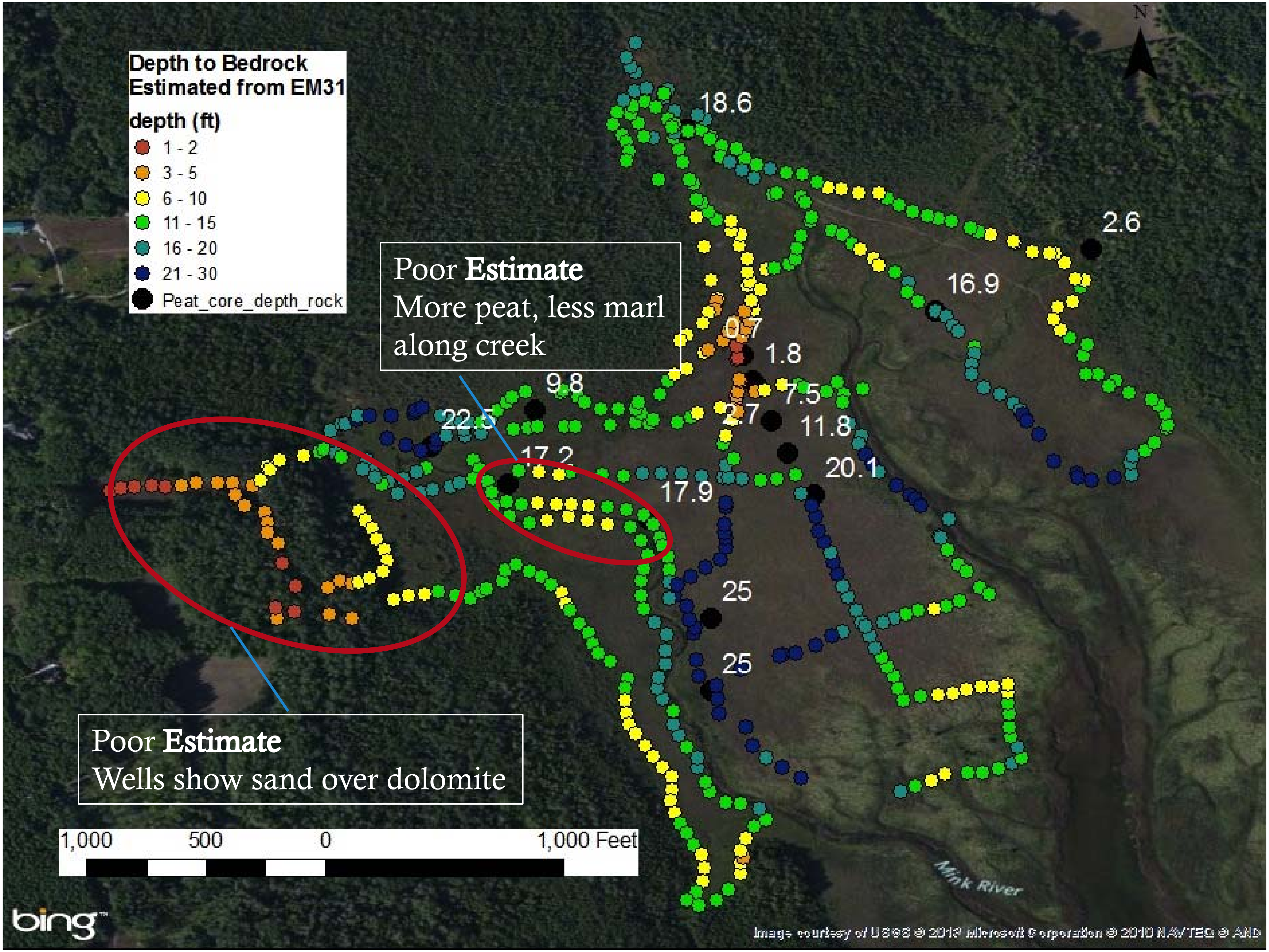
Measured by EM-31

Estimated and assumed from resistivity lines

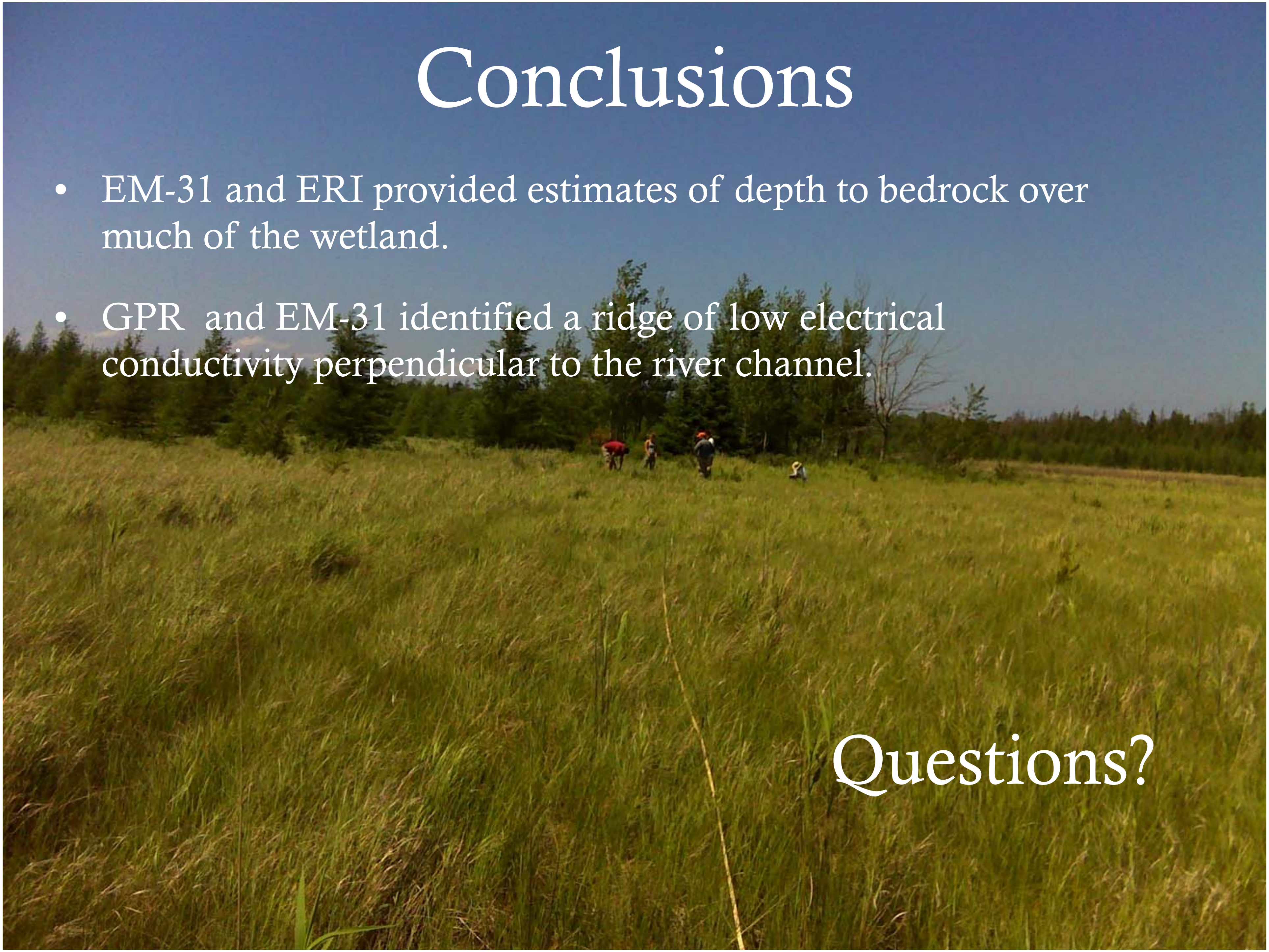
Estimated instrument height for $z_{air}=d_{air}$/coil spacing;
Rv (z_{air}) from graph of Rv(z)

$$R_V\left(z_{marl} + z_{air}\right)$$

Only unknown left.
Do algebra to solve for $R_V(z_{marl}+z_{air})$.
Once known, then can find z_{marl}
and finally z_{marl} x coil spacing of 3.7 m = d_{marl}



Depth to Bedrock
Estimated from EM31
depth (ft)
1 - 2
3 - 5
6 - 10
11 - 15
16 - 20
21 - 30
Peat_core_depth_rock
Poor Estimate
More peat, less marl along creek
Poor Estimate
Wells show sand over dolomite
18.6
2.6
16.9
0.7
1.8
9.8
7.5
22.5
2.7
11.8
17.2
20.1
17.9
25
25
1,000
500
0
1,000 Feet
N
Mink River
bing
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND


Conclusions
• EM-31 and ERI provided estimates of depth to bedrock over much of the wetland.
• GPR and EM-31 identified a ridge of low electrical conductivity perpendicular to the river channel.
Questions?