Using geophysics to better understand wetland hydrogeology

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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
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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)
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
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
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.
Marl Resistivity (Conductivity) = 20 ohm m (50 mS/m)
Bedrock Resistivity (Conductivity) = 250 ohm m (4 mS/m)
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 $\Rightarrow$ Better conductor
  • Changing Coil orientation $\Rightarrow$ changes depths sensed

Vertical

Horizontal
EM-31 Operation

Integrate depth response to get cumulative response

Contribution from all material below depth on x-axis

Taken from McNeill, 1980.

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

\[ \sigma_{\text{air}} = 0 \text{ mS/m} \]

<table>
<thead>
<tr>
<th>Layer</th>
<th>( \sigma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>0 mS/m</td>
</tr>
<tr>
<td>Marl/Organic Sediment</td>
<td>( \sigma_1 = 57 \text{ mS/m} ) (adjusted from 50 mS/m to fit depths)</td>
</tr>
<tr>
<td>Dolomite Bedrock</td>
<td>( \sigma_2 = 4 \text{ mS/m} )</td>
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</tbody>
</table>

\[ d = d_{\text{marl}} + d_{\text{air}} \]

\( d_{\text{air}} = 0.85 \text{ m} \)

Photo – Ken Bradbury
Three Layer System

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

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

- Measured by EM-31
- Estimated and assumed from resistivity lines
- Estimated instrument height for \( z_{\text{air}} = d_{\text{air}} / \text{coil spacing} \);
  \( R_V(z_{\text{air}}) \) from graph of \( R_V(z) \)

Only unknown left. Do algebra to solve for \( R_V(z_{\text{marl}} + z_{\text{air}}) \). Once known, then can find \( z_{\text{marl}} \) and finally \( z_{\text{marl}} \times \text{coil spacing of 3.7 m} = d_{\text{marl}} \).
Poor Estimate
Wells show sand over dolomite

Poor Estimate
More peat, less marl along creek
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?