Electro-Magnetics Survey

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Introduction

The objective of the survey was to measure ground conductivity using electro-magnetic (EM) techniques across a 120-metre transect. Ground conductivity can be measured using a variety of methods, including the Slingram method, also known as a moving transmitter-plus receiver system (Burger et al., 2006). The Slingram method uses a transmitter coil to generate an EM wave, called the primary wave, which is propagated both above and below the ground. The primary wave is altered if it encounters conductive material below the ground, which produces eddy, or alternating currents. These eddy currents produce their own EM wave, called the secondary wave. A combination of the primary and secondary EM waves is detected by the receiver coil, generating a conductivity measurement in milliSiemens per metre (mS/m). The Slingram method is useful for surveying regions with thick scrub as the transmitter and receiver are attached by a cable and can be moved independently of one another through the scrub.

The survey site was located in an area known as the potato patch in the woods behind Ogilvie's camp in Deep River, Ontario. We took data along a transect used the previous day by a team performing a resistivity survey. The starting point of the transect is marked by a peg with UTM coordinates 18 T 0297677 5115350 and the end is marked by a peg at 18 T 0297780 5115415. There is also an intermediate peg at 18 T 0297751 5115398. The intermediate peg is located 1-2 metres into the forest and is surrounded by thick scrub. Between the start and end pegs are several piezometers; From the start peg, these piezometers are labelled 30, 39, 54, 3, 38, 31, 33. These piezometers are spaced at regular intervals along the patch and then stop two metres before the intermediate peg.

Methods

A 120-metre transect was setup by first running a 90-metre tape measure from the start peg at the south-western end of the potato patch. It ran along the southern edge of the patch to the fork in the path. On the corner of the fork it travelled through some foliage and trees to keep the line straight. At this point the tape measure ran out so an intermediate peg was placed at 90 metres. A 30-metre tape measure was run from the end peg towards the intermediate peg. The markings ran out about a metre from the peg, but the tape continued for approximately one meter, meeting up with the end of the 90-metre tape.

To measure conductivity, we used an EM34-3 transmitter and receiver (Geonics Ltd, Mississauga, Canada). The transmitter was set to normal mode at a ten-metre separation, and a sensitivity of 10 mS/m. The Slingram method can generate a depth penetration of twice the separation under ideal conditions (Milsom and Eriksen, 2011); thus, our separation generates approximately a 20-metre depth penetration, under ideal conditions. Once the transect was set up, we placed the transmitter coil at 0 metres, and the receiver coil at 10 metres. We measured the horizontal dipole first by placing the coils parallel to the ground, with the measuring tape running through the middle of coils, and red labels facing up. We measured the vertical dipole second, at the same location, by placing the coils on their side, perpendicular to the ground, with red labels facing north, into the patch. We continued taking these measurements by moving both the transmitter and receiver in one metre increments until the receiver loop met the end peg. Conductivity was measured in milliSiemens per metre.

Data

The raw data for horizontal and vertical dipoles measured along the transect can be found in Table 1 in Appendix A. These data are plotted in Figures 1 and 2. The mean conductivity for the horizontal and vertical dipole, respectively was 0.3476 mS/m (+/- 0.1226 mS/m) and 0.1486 mS/m (+/- 0.2475 mS/m).

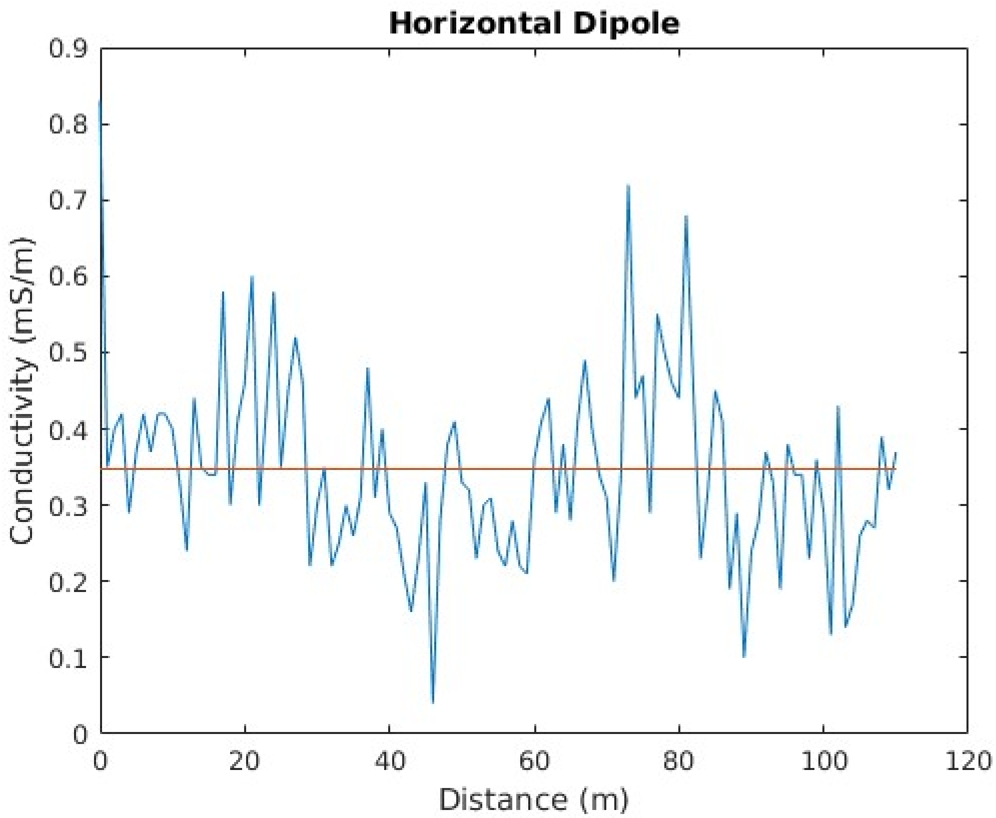

Figure 1: Plot of horizontal dipole measurements. X-axis displays the distance in metres from the start peg, y-axis displays the conductivity in milliSiemens per metre. The red line indicates the mean of these values (0.3476 mS/m, +/-0.1226 mS/m).

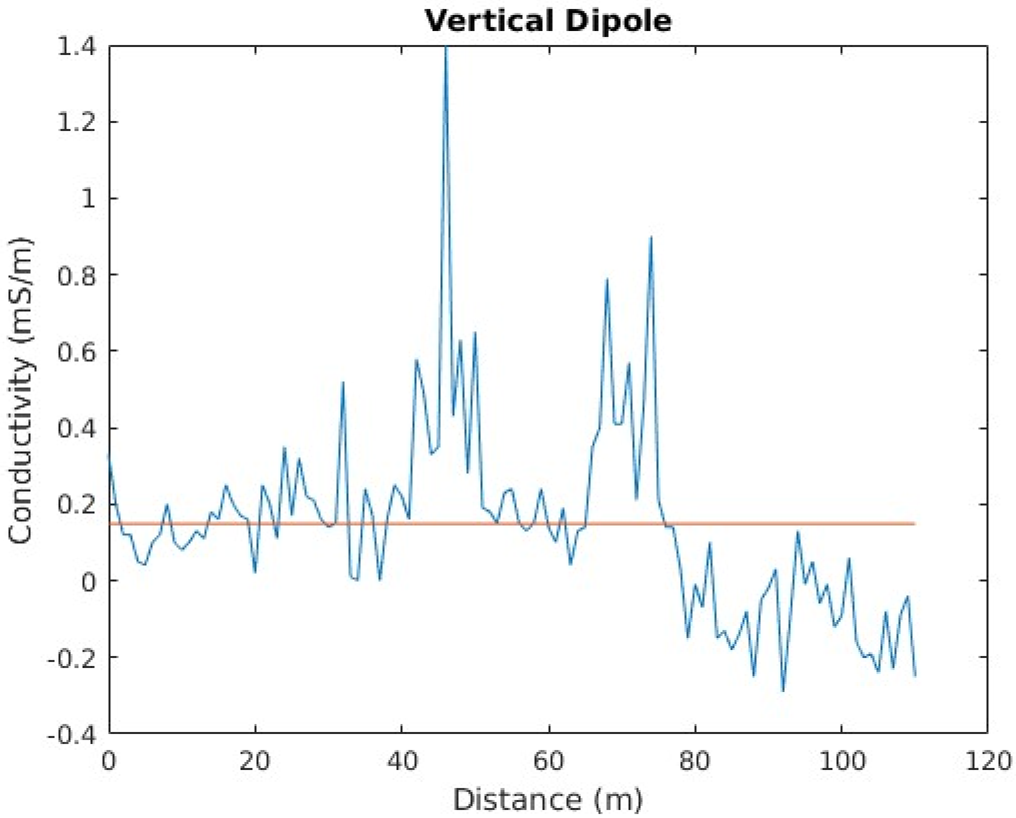

Figure 2: Plot of vertical dipole measurements. X-axis displays the distance in metres from the start peg, y-axis displays the conductivity in milliSiemens per metre. The red line indicates the mean of these values (0.1486 mS/m, +/- 0.2475 mS/m).

Discussion

There was less variation in the horizontal dipole (HD) measurements compared to the vertical dipole (VD) measurements as the standard deviation for these measurements, were 0.1226 and 0.2475 mS/m, respectively.

The VD data show a sharp spike around 45 to 47 metres (Figure 2). We hypothesise that this is due to a metal water bottle that was left next to a piezometer to the side of the line, near the 46-metre mark. This was noticed when the owner retrieved the bottle after the measurement at 48 metres was taken. Once noticed, another reading was taken at 47 metres; the initial reading for HD and VD, respectively, were 0.28 and 0.90 mS/m, while the second reading, after the bottle was removed, for HD and VD, respectively, were 0.32 and 0.43 mS/m. While there was not a large change in the HD measurement, the VD measurement dropped significantly. This supports our hypothesis that the metal water bottle affected the initial VD measurement.

Some VD measurements were negative (Figure 2). This could be due to the method in which the EM34-3 receiver calculates conductivity; the receiver rounds during calculation leading to a small negative error (Burger et al., 2009). A group that conducted an EM-survey on 18 August 2017 recorded a large negative value over a metal sheet buried in Becky's clearing, indicating that negative conductivity values can be due to the presence of large conductive materials, as opposed to rounding errors. Looking at both our and the 18 August data sets, we hypothesize that our negative values could be due to the direction of induced current instead of calculation error. Large anomalies, such as the one seen in the 18 August data set can change the direction of the induced current in the receiver coil, resulting in a negative anomaly. It is possible that the conductivity of the north-eastern end of the area that we surveyed caused a small opposite induced current that showed up as small negative values.

Conclusion

Considering all our data points were within the transmitter sensitivity range (10 mS/m), this indicates that the data is likely a good estimate of the ground conductivity of our survey location. Aside from the spike in vertical dipole between 45 and 47 metres from the presence of a metal water bottle, and the decrease in vertical dipole values near the end of the transect, there were no significant anomalies in our data.

The accuracy of the Slingram survey is highly dependent on the spacing between the transmitter and receiver, but it is difficult to keep this spacing consistent. We relied heavily on the instrument to identify the correct difference, but there was always some variation.

There appears to be more variation in the vertical dipole measurements than the horizontal, and this was seen even while collecting the data as the vertical values were much less stable than the horizontal. This was possibly due to difficulty in maintaining a consistent orientation when taking vertical readings. The distance between loops and their orientation in relation to each other and the ground can cause large variation. We always kept the same general orientation with the red tags facing north, however as they had to be held in position by hand it is impossible to keep them completely stable. Hence the sensitive instruments register readings with errors.

References

Burger, H.R. et al., 2006. Introduction to Applied Geophysics. Pearson Education.

Milson, J., and Eriksen, A. 2011. Field Geophysics, 4th Ed. John Wiley and Sons Ltd.

Appendix A

Transmitter distance from start peg (metres)	HD (mS/m)	VD (mS/m)
0	0.83	0.33
1	0.35	0.2
2	0.4	0.12
3	0.42	0.12
4	0.29	0.05
5	0.37	0.04
6	0.42	0.1

7	0.37	0.12
8	0.42	0.2
9	0.42	0.1
10	0.4	0.08
11	0.33	0.1
12	0.24	0.13
13	0.44	0.11
14	0.35	0.18
15	0.34	0.16
16	0.34	0.25
17	0.58	0.2
18	0.3	0.17
19	0.41	0.16
20	0.46	0.02
21	0.6	0.25
22	0.3	0.2
23	0.43	0.11
24	0.58	0.35
25	0.35	0.17
26	0.45	0.32
27	0.52	0.22
28	0.46	0.21
29	0.22	0.16
30	0.3	0.14
31	0.35	0.15
32	0.22	0.52
33	0.25	0.01
34	0.3	0
35	0.26	0.24
36	0.31	0.17
37	0.48	0
38	0.31	0.16
39	0.4	0.25
40	0.29	0.22
41	0.27	0.16
42	0.21	0.58
43	0.16	0.49
44	0.23	0.33
45	0.33	0.35
46	0.04	1.4
47	0.28	0.43
48	0.38	0.63
49	0.41	0.28

50	0.33	0.65
51	0.32	0.19
52	0.23	0.18
53	0.3	0.15
54	0.31	0.23
55	0.24	0.24
56	0.22	0.15
57	0.28	0.13
58	0.22	0.15
59	0.21	0.24
60	0.36	0.14
61	0.41	0.1
62	0.44	0.19
63	0.29	0.04
64	0.38	0.13
65	0.28	0.14
66	0.41	0.35
67	0.49	0.4
68	0.4	0.79
69	0.34	0.41
70	0.31	0.41
71	0.2	0.57
72	0.34	0.21
73	0.72	0.46
74	0.44	0.9
75	0.47	0.21
76	0.29	0.14
77	0.55	0.14
78	0.5	0.03
79	0.46	-0.15
80	0.44	-0.01
81	0.68	-0.07
82	0.45	0.1
83	0.23	-0.15
84	0.32	-0.13
85	0.45	-0.18
86	0.41	-0.14
87	0.19	-0.08
88	0.29	-0.25
89	0.1	-0.05
90	0.24	-0.02
91	0.28	0.03
92	0.37	-0.29

93	0.33	-0.09
94	0.19	0.13
95	0.38	-0.01
96	0.34	0.05
97	0.34	-0.06
98	0.23	-0.01
99	0.36	-0.12
100	0.29	-0.09
101	0.13	0.06
102	0.43	-0.16
103	0.14	-0.2
104	0.17	-0.19
105	0.26	-0.24
106	0.28	-0.08
107	0.27	-0.23
108	0.39	-0.09
109	0.32	-0.04
110	0.37	-0.25

Table 1: Horizontal and vertical dipole measurements for transect. HD = horizontal dipole; VD = vertical dipole; mS/m = milliSiemens per metre.