United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard, Suite 200 Newtown Square, PA 19073**

Subject: Soil - Geophysical Assistance **Date:** 30 May 2007

To: Paul Benedict
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Purpose:
Electromagnetic induction (EMI) is being used to as a validation tool and to help select sampling sites for the salinity appraisal of Kittson County, Minnesota, and MLRA 56, the Red River Valley of the North. The purpose of this investigation was to conduct high intensity EMI surveys on portions of twenty fields that represent different classes, which were determined with MODIS. Detailed plots and the locations of six optimal sampling sites were developed using the ESAP (version 2.35) software developed by USDA-ARS, US Salinity Laboratory in Riverside, California. Soil sampling at the 120 selected locations was accomplished during the following week by USDA personnel.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
David Potts, Supervisory Soil Scientist, USDA-NRCS, Baudette, MN

Activities:
All field activities were completed during the period of 7 to 11 May 2007.

Summary:
This trip report provides a record of the MODIS generated class index values and site locations (Appendix 1) that were selected for intensive surveys with the EM38DD meter. A summary of the basic EC_a statistics for these EMI are listed in Appendix 2. Plots of EC_a data and the locations of sample sites are also enclosed in this summary report.

With kind regards,

James A. Doolittle
Research Soil Scientist
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cc:
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Equipment:
An EM38DD meter was used in this investigation. This meter is manufactured by Geonics Limited (Mississauga, Ontario).[1] The meter is portable and requires only one person to operate. No ground contact is required with this meter. Lateral resolution is approximately equal to the intercoil spacing. The EM38DD meter has a 1-m intercoil spacing and operates at a frequency of 14,600 Hz. When placed on the soil surface, the EM38DD meter provides theoretical penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively.

The Geonics DAS70 Data Acquisition System was used with the EM38DD meter to record and store both EC_a and GPS data.[1] The acquisition system consists of an EMI meter, an Allegro field computer, and a Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack).[1] With the acquisition system, the EM38DD meter is keypad operated and measurements are automatically triggered.

To help summarize the results, the SURFER for Windows (version 8.0) software, developed by Golden Software, Inc., was used to construct the two-dimensional simulations shown in this report.[1] Grids were created using kriging methods with an octant search.

Selection of Study Sites (Scott Lesch):
Drs. Dennis Corwin, Scott Lesch, and David Lobell provided a list of 93 sites in Kittson County based on MODIS (Moderate-resolution imaging spectroradiometer) data. The following is Scott Lesch's description of the procedures he used to select these sites:

> *"MEVI (mean enhanced vegetation index) values from MODIS imagery collected at multiple time frames above Kittson County were subjected to a principal components analysis. The first principal component (EVIPC1) was then extracted from this analysis and used as a stratification variable across the county. These spatial EVIPC1 readings were separated into 20 distinct classes, and 5 potential sampling locations were randomly chosen from within each class. The salinity sampling plan called for selecting a field corresponding to one of these five locations within each class, surveying these fields using EMI techniques, and acquiring a limited set of calibration soil samples based on the observed spatial EMI pattern.*
>
> *In summary, this project employed a two-stage sampling approach. Stage 1 was set up as a stratified random sampling plan (where the EVIPC1 data was used as the stratification variable). Stage 2 was set up as a model-based (sensor directed) sampling plan, where soil samples within each field were chosen to represent the observed range and spatial variation in the EMI pattern observed within each field.*
>
> *The fundamental goal of this project is to test if the mean estimated salinity levels across the 20 surveyed fields are correlated with the corresponding EVIPC1 values (associated with these fields). If a strong correlation can be established, then it should be possible to use the EVIPC1 data (derived from the MODIS imagery) to predict the spatial salinization potential across Kittson county (and hopefully the larger Red River Valley)."*

These procedures provided 2 to 5 potential site locations in each of the 20 distinct classes. From this list Dave Potts selected 1 site from each of the 20 classes for EMI surveying and soil sampling. Sites were selected based on access and proximity to one another (to expedite survey operations). The locations and EVIPC1 of each of the selected sites are listed in Appendix 1.

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

Survey Procedures:
A mobile (using an ATV) EMI survey was completed at each of the twenty selected field sites in Kittson County. A mobile EMI survey provides more comprehensive site coverage, in a shorter period of time, and with less effort than the pedestrian surveys. In this survey, an EM38DD meter was towed behind an ATV in a plastic toboggan at speeds of 1 to 4 m/sec. Using the NAV38DD program, both GPS and EC_a data were simultaneously recorded on an Allegro CX field computer.

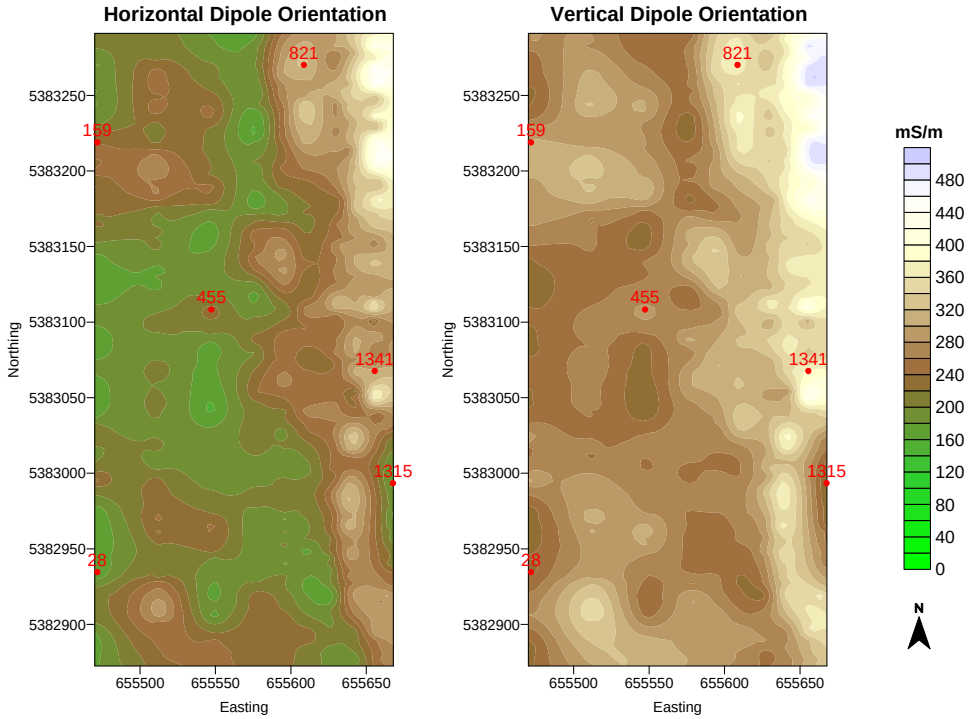
All data were entered into an Excel spreadsheet. The apparent conductivity (EC_a) data recorded on the Excel spreadsheet were processed thru the ESAP Software Suite. EC_a data were not temperature corrected. Although high levels of soil salinity (extensive areas greater than 400 mS/m) existed in some fields, a natural log transformation was not applied to the data. Plots of EC_a data collected with the EM38DD meter in both the horizontal and vertical dipole orientations at each site were firstly prepared using the ESAP Software Suite. One of the statistical programs available in ESAP is the Response Surface Sampling Design (RSSD). This program generates an optimal sampling design based on the EC_a data. The optimal sampling design provides the best possible information for generating predictive models of soil salinity. Based on the response surface sampling design, six optimal sampling locations were selected with the surveyed portions of each field. A buffering procedure was not used, and, as a consequence, many soil sample sites were located near field borders.

Plots and a listing of the locations of the six optimal sampling locations within each surveyed field were compiled and copies were left in the Kittson County Field Office for use by soil scientists who would be involved in soil sampling during the following week. The collected soil samples will be tested for EC from saturated paste extract, saturation percent, and field moisture content. In addition, chloride will be determined on the upper and lower layers.

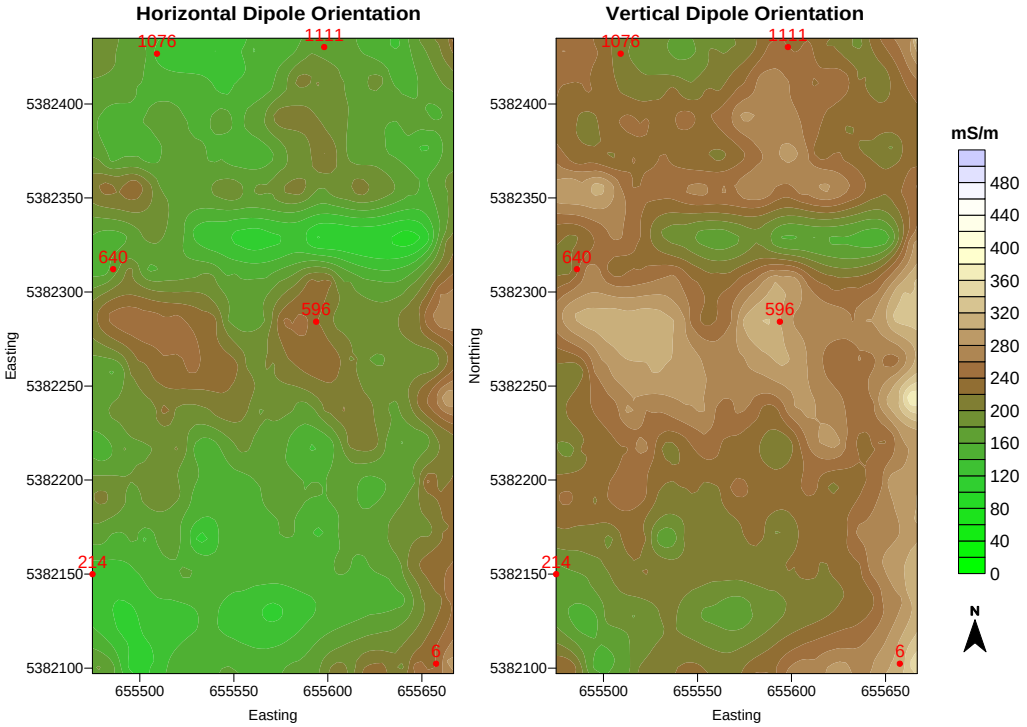
Results:
Appendix 2 summarizes the basic EC_a statistics for the 20 site that were surveyed. A very superficial examination of the data suggests that for measurements taken in either dipole orientation with the EM388 DD meter, modest, negative correlations between the class numbers and average EC_a ($r = -0.51$). In general, the spatial variability of EC_a within sites was generally higher for those fields with lower class numbers (presumably more saline).

Spatial Patterns of EC_a:
Spatial patterns of EC_a within each of the twenty sites are shown in the accompanying plots. Sites have been arranged according to ascending “class” numbers. Sites varied in EC_a. For display purposes, sites were organized into two groups: those with $EC_a > 250$ mS/m and those with $EC_a < 250$ mS/m. Different color scales and intervals were used for each group. In each of the accompanying figures, separate plots show the distribution of EC_a in both the shallower-sensing (0 to 75 cm) horizontal or deeper-sensing (0 to 150 cm) vertical dipole orientations. The locations of sample sites and their identifier are shown in these plots.

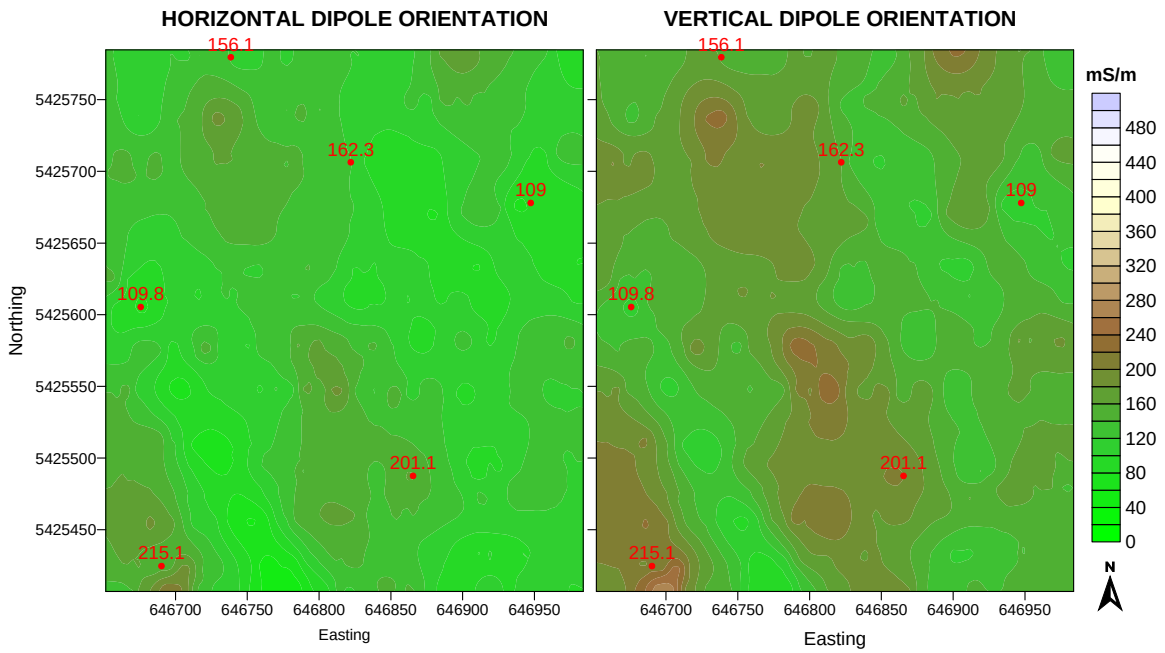
KITTSON COUNTY - SITE 1; CLASS 1
EM38DD METER



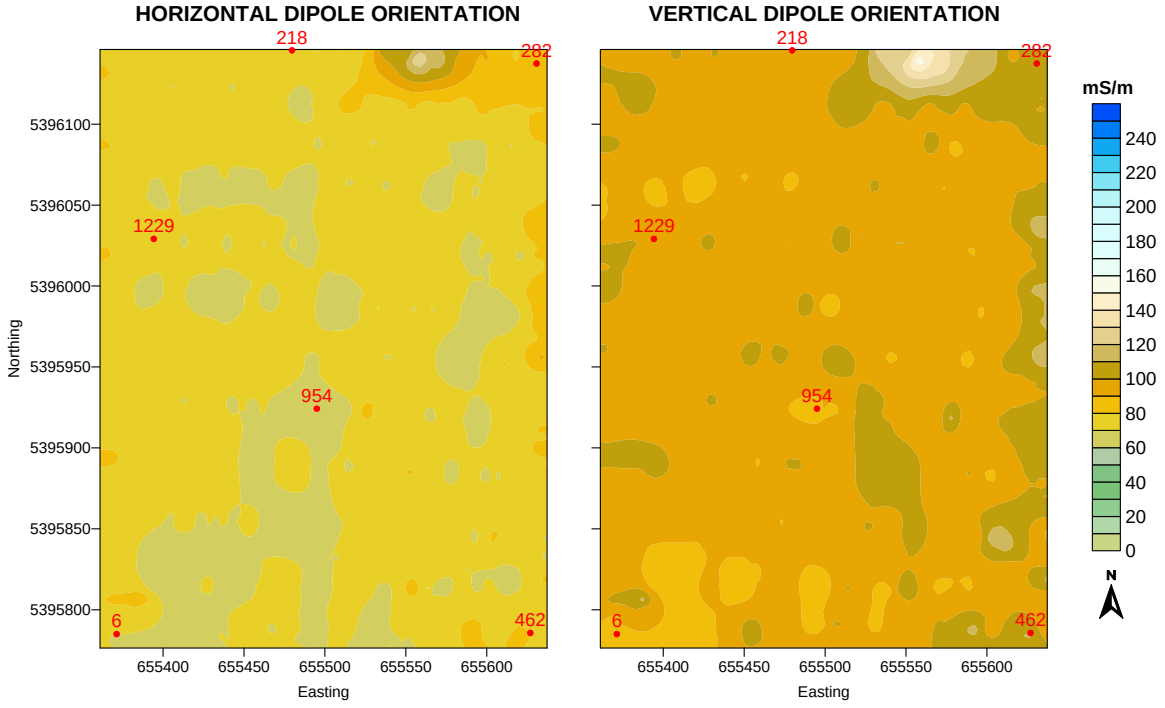
KITTSON COUNTY - SITE 2; CLASS 2
EM38DD METER



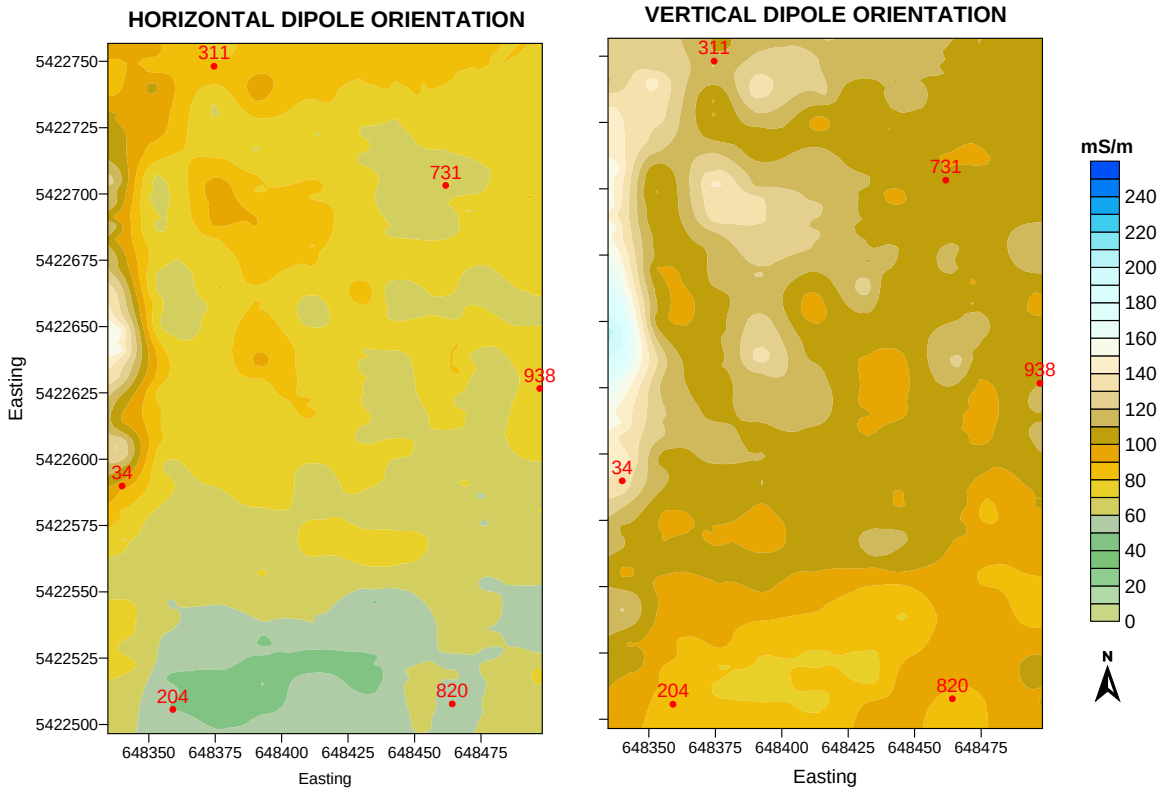
KITTSON COUNTY - SITE 7; CLASS 3
EM38DD METER



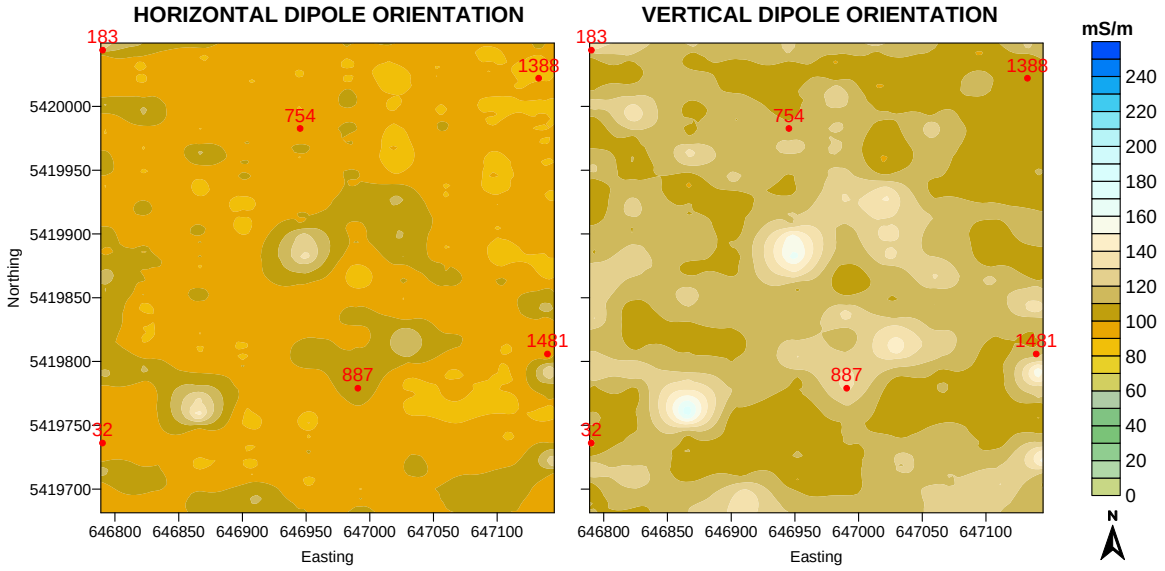
KITTSON COUNTY - SITE 13; CLASS 4
EM38DD METER



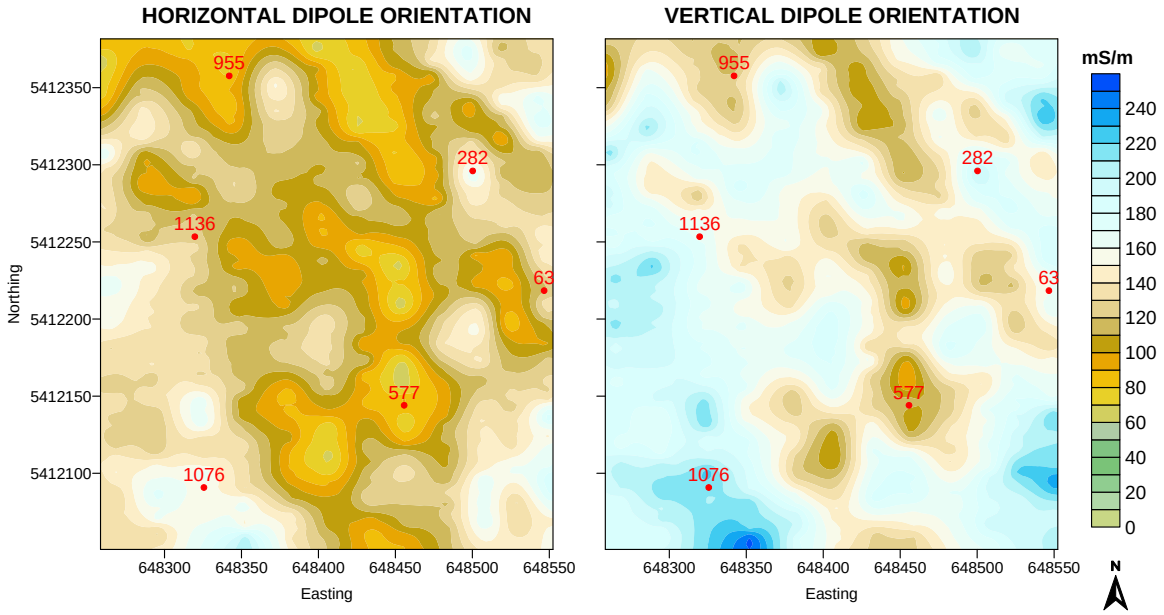
KITTSON COUNTY - SITE 6; CLASS 5
EM38DD METER



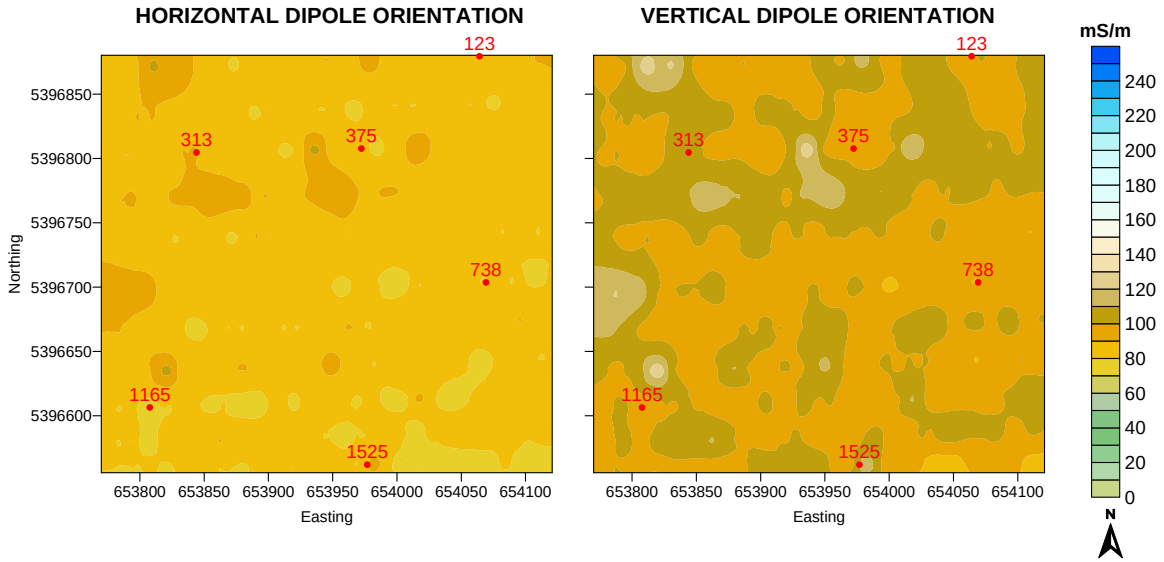
KITTSON COUNTY - SITE 19; CLASS 6
EM38DD METER



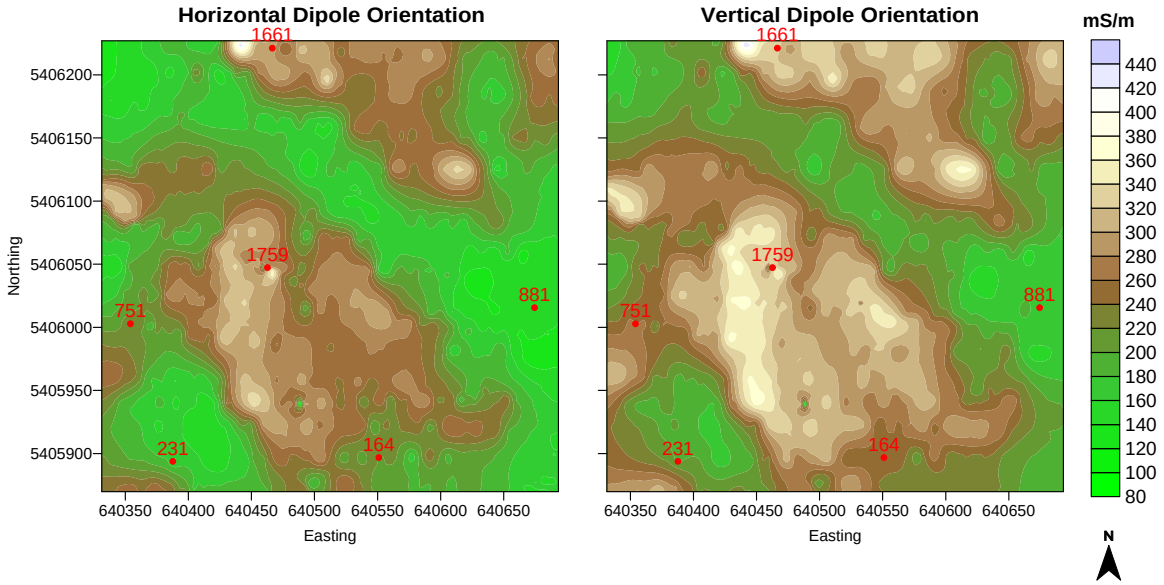
KITTSON COUNTY - SITE 9; CLASS 7
EM38DD METER



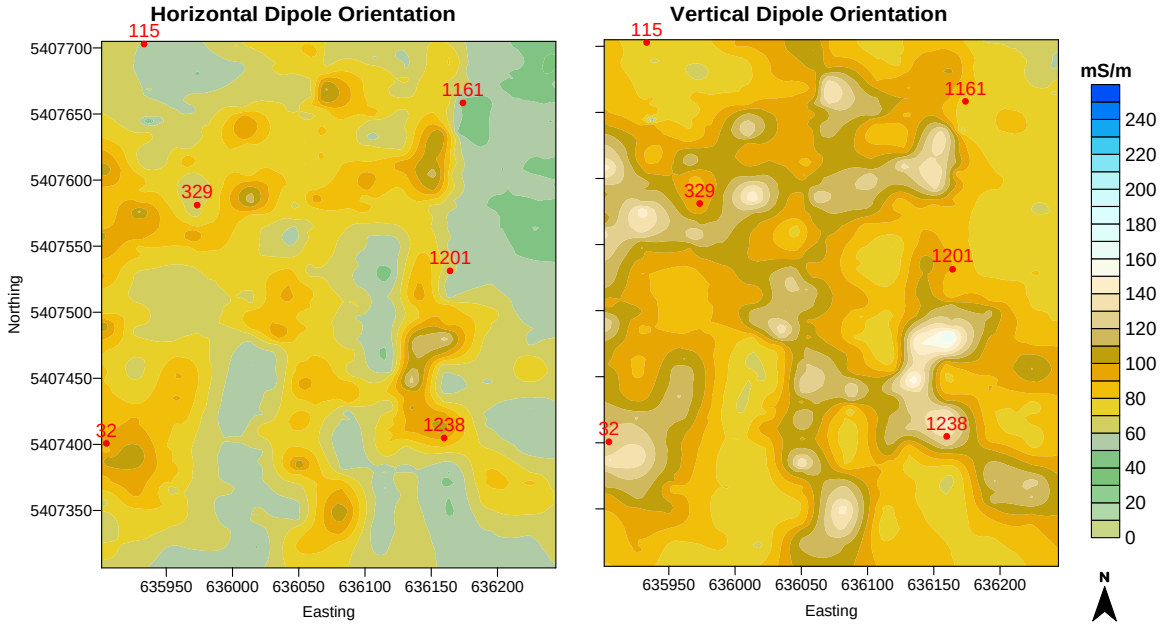
KITTSON COUNTY - SITE 14; CLASS 8
EM38DD METER



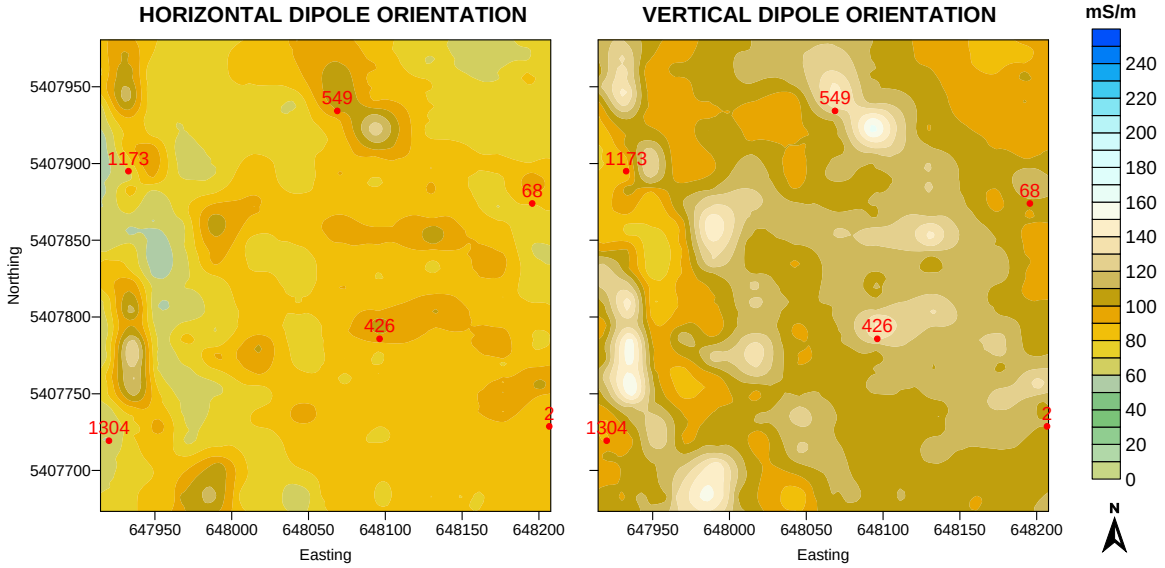
KITTSON COUNTY - SITE 3; CLASS 9
EM38DD METER



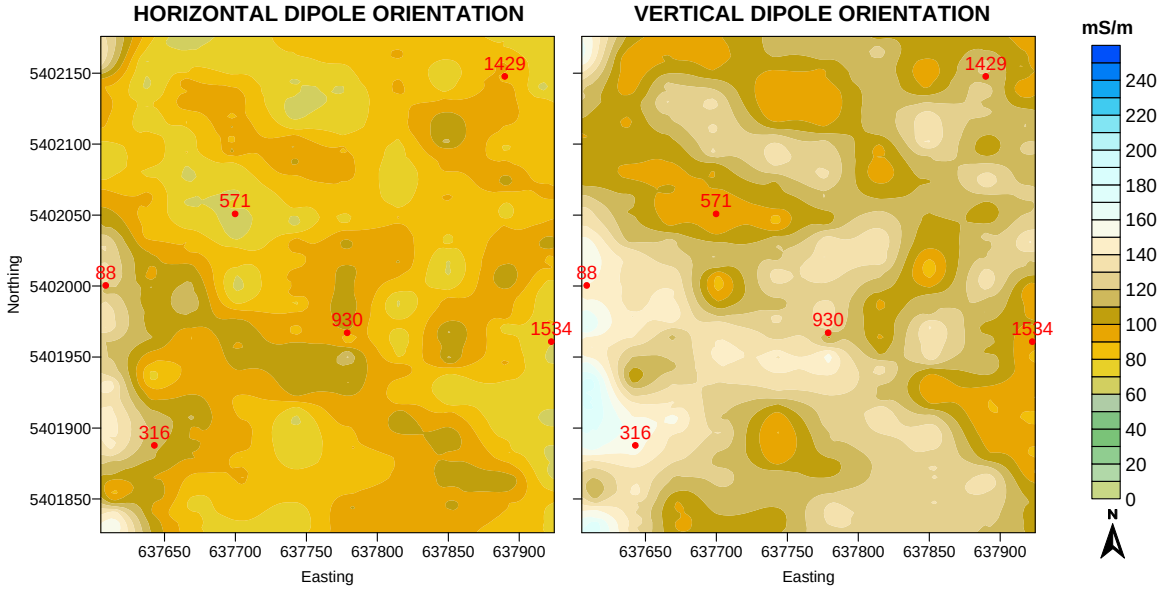
KITTSON COUNTY - SITE 4; CLASS 10
EM38DD METER



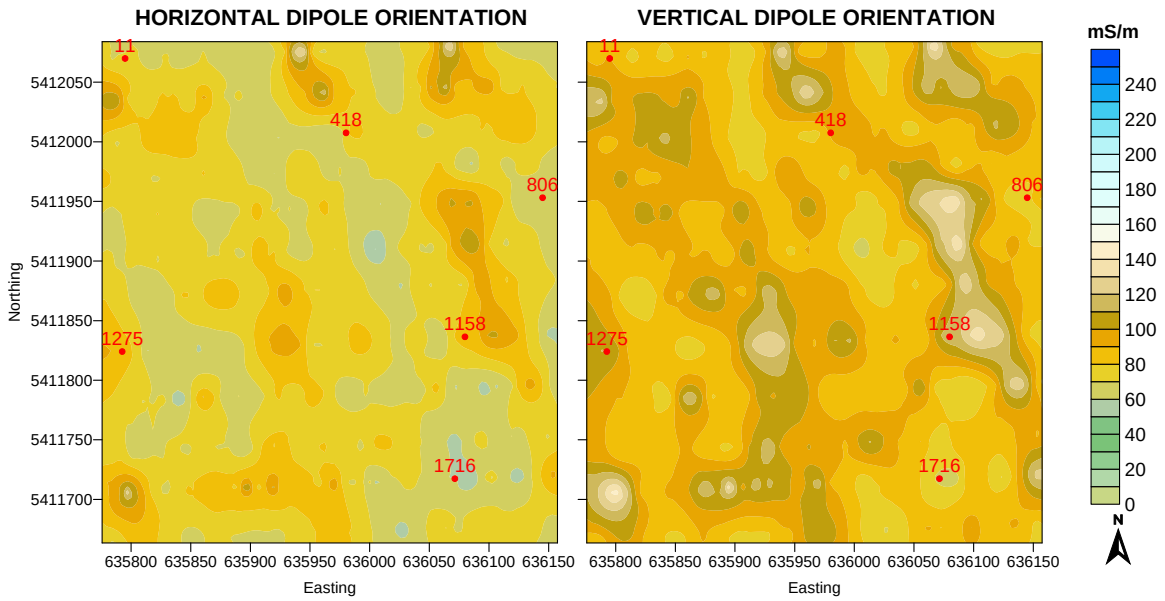
KITTSON COUNTY - SITE 11; CLASS 11
EM38DD METER



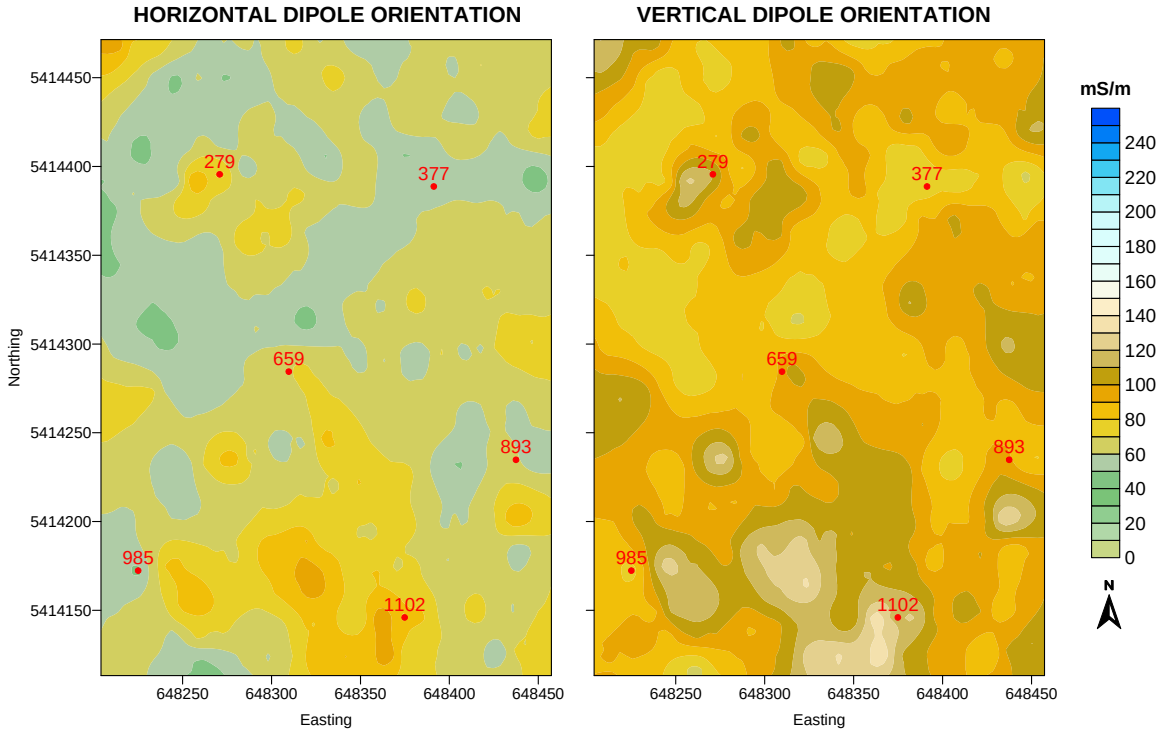
KITTSON COUNTY - SITE 17; CLASS 12
EM38DD METER



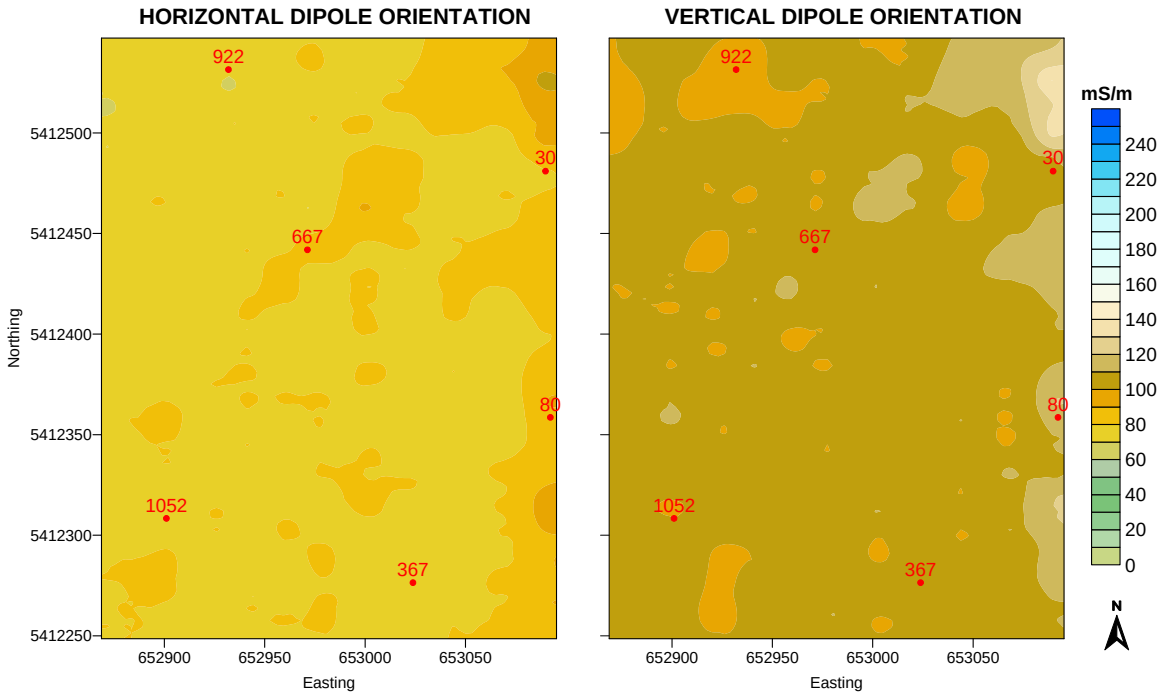
KITTSON COUNTY - SITE 18; CLASS 13
EM38DD METER



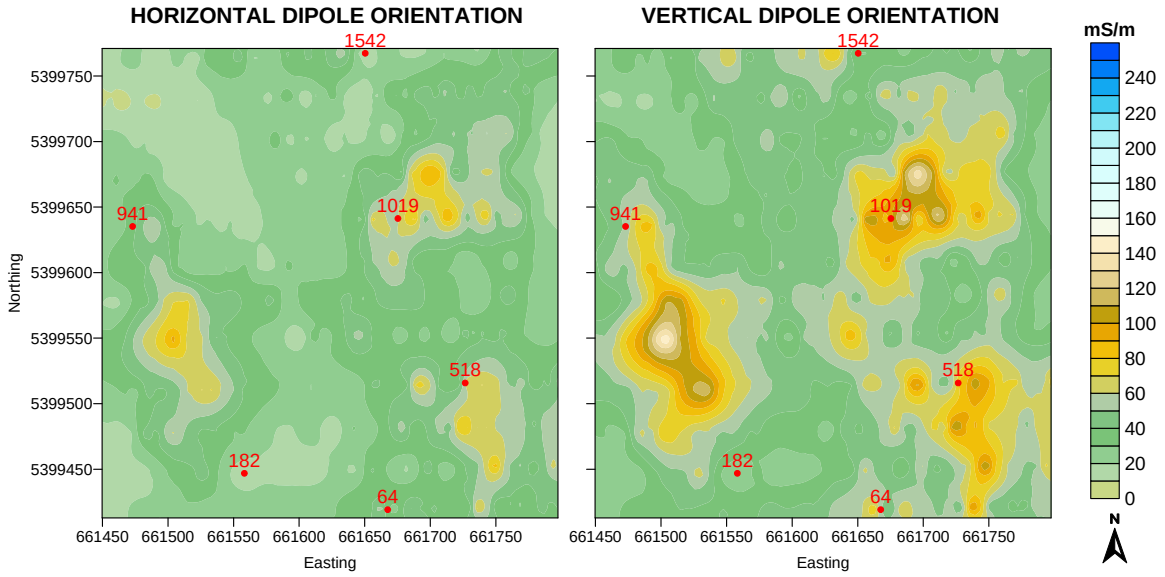
KITTSON COUNTY - SITE 10; CLASS 14
EM38DD METER



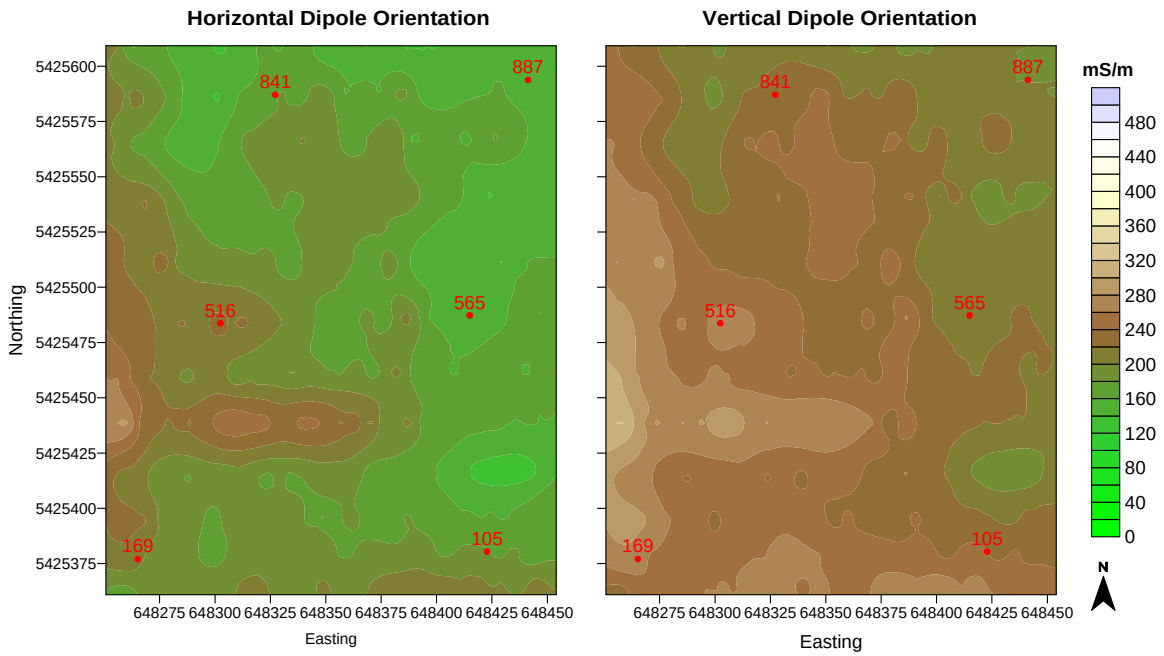
KITTSON COUNTY - SITE 8; CLASS 15
EM38DD METER



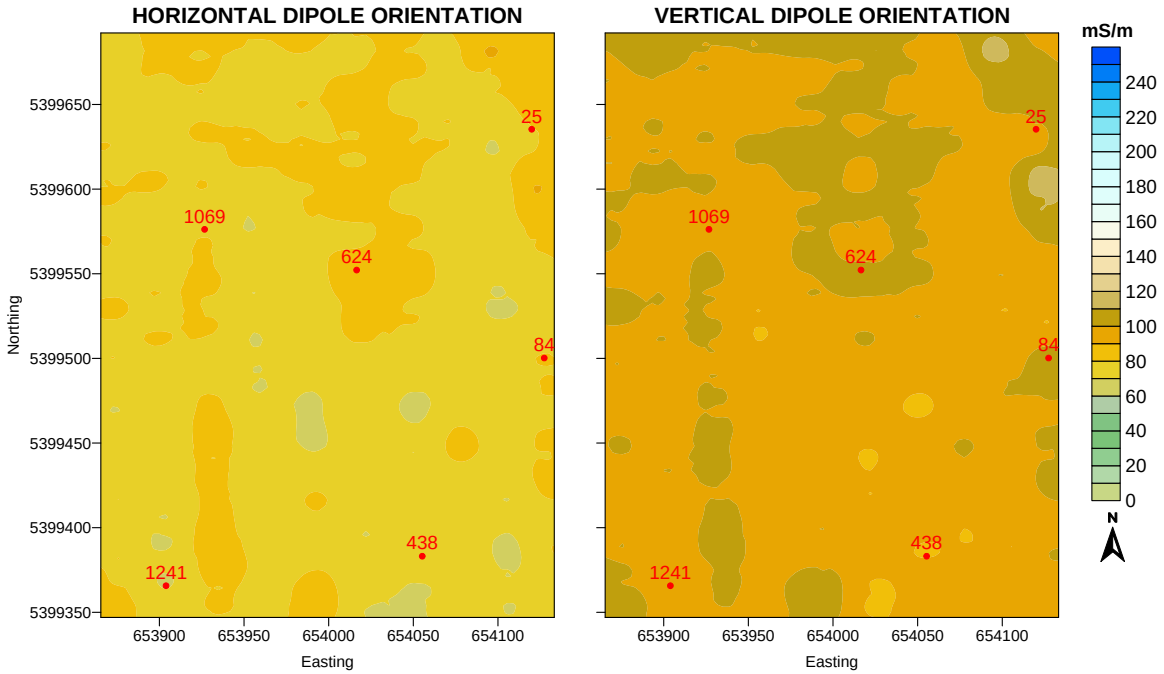
KITTSON COUNTY - SITE 20; CLASS 16
EM38DD METER



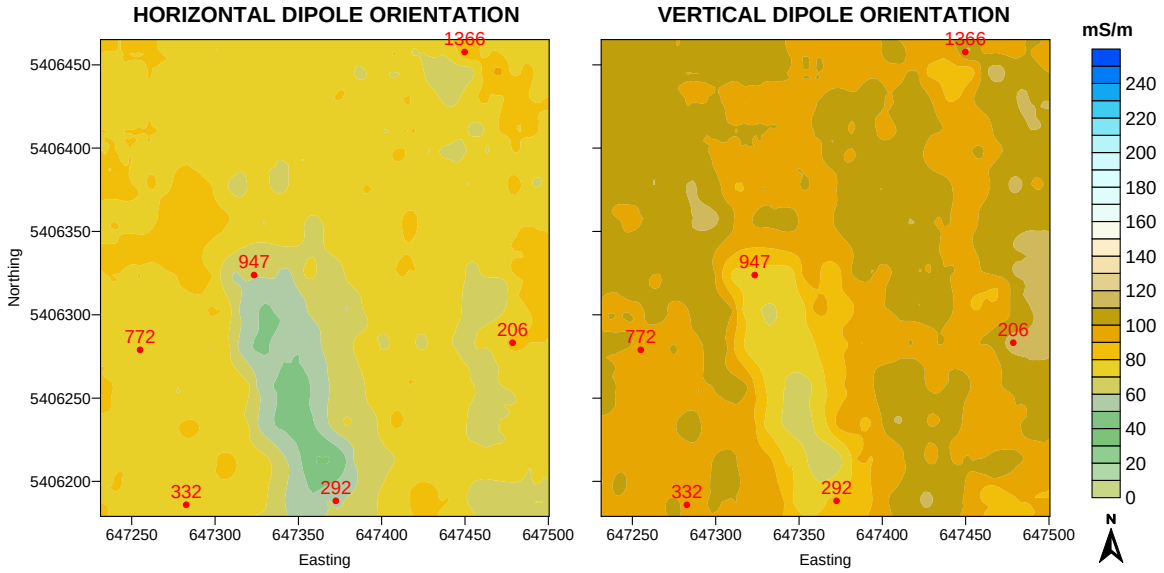
KITTSON COUNTY - SITE 5; CLASS 17
EM38DD METER



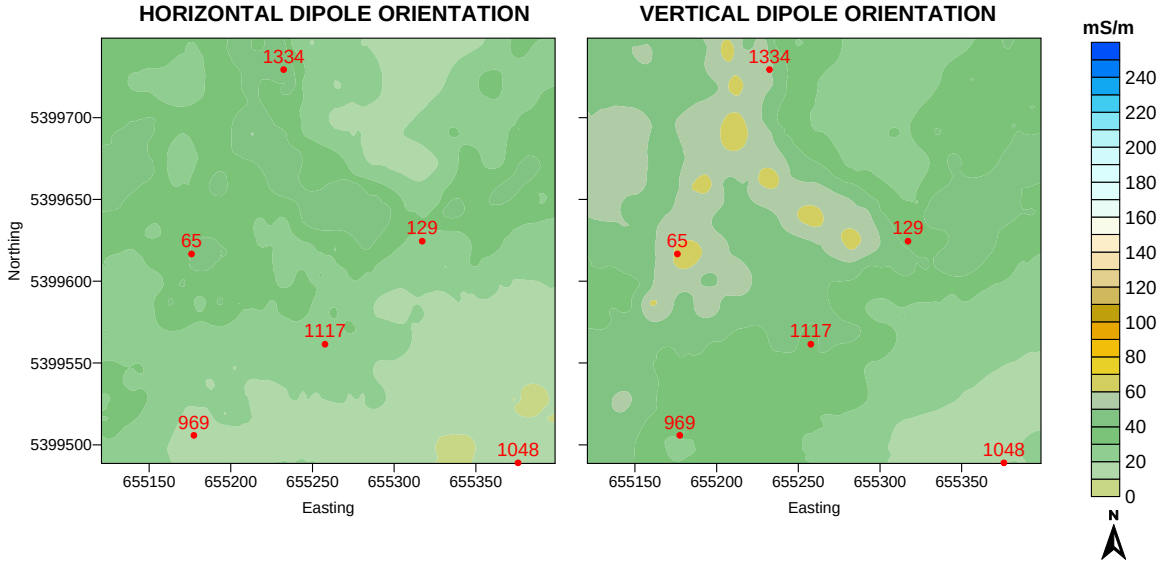
KITTSON COUNTY - SITE 15; CLASS 18
EM38DD METER



KITTSON COUNTY - SITE 12; CLASS 19
EM38DD METER



KITTSON COUNTY - SITE 16; CLASS 20
EM38DD METER



APPENDIX 1

MODIS generated, randomly selected site locations in Kittson County. Sites stratified by EVI-Class (20 Classes).

Obs	Modis Class	evipc1	mevi	Easting	Northing
1	1	-2.69282	2987.95	646018	5425483
2	1	-2.58408	3031.12	655236	5383463
3	1	-2.63841	3009.55	656680	5384615
4	1	-2.97421	2876.24	655144	5386797
5	1	-2.59564	3026.53	657386	5385747
6	2	-2.32718	3133.11	655266	5382351
7	2	-2.25897	3160.19	653731	5384534
8	2	-2.31040	3139.77	655881	5386818
9	2	-2.45249	3083.36	653640	5387868
10	2	-2.25025	3163.65	644640	5422110
11	3	-2.08315	3229.99	646749	5425502
12	3	-2.05814	3239.92	645373	5422129
13	3	-2.16995	3195.53	647920	5381041
14	3	-2.08023	3231.15	645198	5428798
15	3	-2.03426	3249.40	643908	5422091
16	4	-1.85330	3321.24	645988	5426594
17	4	-1.96214	3278.03	655634	5395710
18	4	-1.82270	3333.39	645663	5411014
19	4	-1.94363	3285.38	653114	5380068
20	4	-1.91935	3295.02	652933	5386737
21	5	-1.76856	3354.88	642813	5407603
22	5	-1.60668	3419.15	649034	5422226
23	5	-1.73680	3367.49	653054	5382291
24	5	-1.74766	3363.18	654559	5381220
25	5	-1.65844	3398.60	657137	5394639
26	6	-1.49635	3462.95	649362	5409999
27	6	-1.53413	3447.95	656556	5389061
28	6	-1.33610	3526.57	658923	5383566
29	6	-1.36647	3514.51	646896	5419944
30	6	-1.38199	3508.35	646163	5419925
31	7	-1.22008	3572.63	648569	5412203
32	7	-1.08252	3627.24	655328	5380128
33	7	-1.03063	3647.84	658123	5385768
34	7	-1.18151	3587.94	644195	5410976
35	7	-1.11937	3612.61	642557	5417607
36	8	-0.72179	3770.45	651594	5408947
37	8	-0.82239	3730.51	646213	5389895
38	8	-0.87897	3708.05	646867	5421056
39	8	-0.88398	3706.06	648276	5395510
40	8	-0.96116	3675.42	654132	5396780
41	9	-0.52191	3849.80	649153	5417780
42	9	-0.59814	3819.54	657998	5390214
43	9	-0.44275	3881.23	651955	5395609
44	9	-0.58811	3823.52	641176	5414235
45	9	-0.62065	3810.60	640638	5406436
46	10	-0.08866	4021.80	636205	5407438
47	10	-0.34622	3919.55	642273	5428723
48	10	-0.12431	4007.65	648894	5399976
49	10	-0.24365	3960.27	643747	5399841

APPENDIX 1 (Continued)
MODIS generated, randomly selected site locations in Kittson County. Sites stratified by EVI-Class (20 Classes).

Obs	Modis Class	evipc1	mevi	Easting	Northing
50	10	-0.15844	3994.10	647717	5416629
51	11	0.22605	4146.74	643776	5398730
52	11	0.25310	4157.48	649985	5386657
53	11	0.30501	4178.09	642530	5389800
54	11	0.05335	4078.18	647953	5407737
55	11	0.35937	4199.67	635498	5406309
56	12	0.48627	4250.05	637482	5415255
57	12	0.43987	4231.63	637810	5401917
58	12	0.45335	4236.98	640806	5399767
59	12	0.66627	4321.51	630726	5421766
60	12	0.53327	4268.71	656308	5397953
61	13	0.83962	4390.33	637509	5414144
62	13	0.85423	4396.13	636097	5411884
63	13	0.86821	4401.68	651994	5421194
64	13	0.99310	4451.26	648243	5424429
65	13	0.95882	4437.65	641626	5396451
66	14	1.25610	4555.67	650799	5411150
67	14	1.28864	4568.59	647043	5414387
68	14	1.11280	4498.78	639031	5411957
69	14	1.04602	4472.27	650890	5407815
70	14	1.24270	4550.35	643633	5404287
71	15	1.40877	4616.28	658672	5392458
72	15	1.51469	4658.33	652970	5412321
73	15	1.56305	4677.53	646484	5407698
74	15	1.30446	4574.87	629158	5426178
75	15	1.57275	4681.38	644626	5394303
76	16	1.68544	4726.12	645750	5407679
77	16	1.60456	4694.01	642220	5402027
78	16	1.65960	4715.86	629942	5423972
79	16	1.69940	4731.66	660689	5399189
80	16	1.76416	4757.37	648915	5426672
81	17	1.84257	4788.50	637262	5424148
82	17	1.94824	4830.45	659155	5401370
83	17	1.92720	4822.10	648213	5425541
84	17	1.95504	4833.15	648716	5406645
85	17	1.89317	4808.59	655387	5404602
86	18	2.19642	4928.98	656246	5400176
87	18	2.12335	4899.97	652540	5401186
88	18	2.01783	4858.08	654071	5399003
89	19	2.22385	4939.87	636116	5380744
90	19	2.20980	4934.29	647248	5406606
91	20	2.88126	5200.86	655511	5400156
92	20	2.62821	5100.40	654806	5399024
93	20	2.78861	5164.08	654040	5400115

Appendix 2.
Basic statistics for the twenty sampled fields.
With the exception of *Number*, all values are measures of EC_a expressed in mS/m

Class	Site	Dipole	Number	Mean	Std. Dev	Minimum	25%tile	75%tile	Maximum
1	Site 1	HDO	1411	234.4	51.6	150.8	195.6	265.3	457.0
1	Site 1	VDO	1411	298.1	49.3	215.0	261.1	327.9	502.4
2	Site 2	HDO	1139	173.7	34.4	88.9	152.6	194.5	301.4
2	Site 2	VDO	1139	239.1	38.3	141.8	216.1	264.3	383.3
3	Site 9	HDO	1416	119.7	25.9	47.3	103.0	136.0	217.1
3	Site 9	VDO	1416	160.8	29.5	83.0	141.4	179.5	272.9
4	Site 10	HDO	1625	73.9	6.8	57.3	69.6	76.9	130.8
4	Site 10	VDO	1625	97.1	7.7	77.4	92.5	100.4	158.8
5	Site 17	HDO	989	73.0	15.3	41.0	65.4	77.6	166.9
5	Site 17	VDO	989	107.8	17.6	75.6	98.0	113.9	200.8
6	Site 5	HDO	1538	96.8	8.3	78.4	91.1	100.4	153.0
6	Site 5	VDO	1538	114.5	11.2	95.0	106.8	119.9	179.0
7	Site 3	HDO	1402	119.8	25.2	62.3	101.9	135.6	213.0
7	Site 3	VDO	1402	162.8	29.9	88.4	140.9	183.6	252.6
8	Site 15	HDO	1587	84.4	5.0	70.5	81.3	87.1	105.3
8	Site 15	VDO	1587	100.1	6.3	83.6	95.9	102.6	130.1
9	Site 7	HDO	1843	186.7	55.1	0.0	143.1	235.9	425.3
9	Site 7	VDO	1843	256.7	53.8	31.8	211.1	300.9	438.8
10	Site 14	HDO	1520	70.2	15.4	0.0	58.4	79.0	128.8
10	Site 14	VDO	1520	95.1	19.0	8.4	80.0	107.4	172.8
11	Site 11	HDO	1448	81.3	12.1	51.3	73.6	87.0	131.8
11	Site 11	VDO	1448	107.9	15.0	71.4	98.3	114.5	166.3
12	Site 19	HDO	1587	91.0	16.4	61.8	78.8	99.8	159.9
12	Site 19	VDO	1587	119.2	19.2	84.1	103.8	132.1	190.9
13	Site 4	HDO	1908	75.0	11.0	48.5	67.6	80.0	137.8
13	Site 4	VDO	1908	92.3	14.0	61.9	82.4	99.9	143.5
14	Site 8	HDO	1231	64.6	9.8	41.4	57.1	70.1	104.1
14	Site 8	VDO	1231	93.7	13.2	65.6	84.0	102.0	140.1
15	Site 18	HDO	1161	78.9	5.2	65.6	75.4	81.8	103.3
15	Site 18	VDO	1161	105.2	6.1	88.5	101.3	108.0	140.6
16	Site 20	HDO	1592	34.3	15.8	6.0	22.9	42.3	96.6
16	Site 20	VDO	1592	51.8	21.0	16.0	37.6	60.9	150.4
17	Site 12	HDO	948	182.7	25.2	129.9	164.6	195.3	286.8
17	Site 12	VDO	948	239.0	23.4	183.0	222.3	254.5	322.3
18	Site 13	HDO	1399	77.1	4.7	63.3	73.9	80.3	93.9
18	Site 13	VDO	1399	97.7	4.4	84.1	94.8	100.4	119.1
19	Site 6	HDO	1421	72.7	8.5	38.1	69.5	78.1	92.4
19	Site 6	VDO	1421	97.2	9.7	59.9	93.4	103.3	116.8
20	Site 16	HDO	1335	28.2	8.6	6.1	21.5	33.9	53.4
20	Site 16	VDO	1335	39.7	10.8	12.1	31.8	46.8	69.5