United States Department of Agriculture	**Natural Resources Conservation Service**	**11 Campus Boulevard Suite 200 Newtown Square, PA 19073** Phone 610-557-4233; FAX 610-557-4136

Subject: SOI – Electromagnetic Induction (EMI) Comparative Field Studies **Date:** 19 August 2002

To: Jane E. Hardisty
State Conservationist
USDA-NRCS
6013 Lakeside Drive
Indianapolis, Indiana 46278

Purpose:
This study is a continuation of field investigations that were conducted on 3 to 5 December 2001(Doolittle, 2002). In that study, EMI successfully detected buried septic tanks and absorption fields. A recommendation of this earlier study was to revisit these sites during a drier time of the year. This would allow a more complete assessment of the capacity of EMI to detect buried absorption lines and field drains under different soil and temperature conditions.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Byron Jenkinson, Graduate Student, Agronomy Department, Purdue University, W. Lafayette, IN
Brad Lee, Assistant Professor, Agronomy Department, Purdue University, W. Lafayette, IN
Richard Taylor, President, Dualem Inc., Milton, Ontario, Canada
Wes Tuttle, Soil Scientist (Geophysical), USDA-NRCS, Wilkesboro, NC

Activities:
Field activities were completed on 25 July 2002.

Findings and Recommendations:

1. At each site, under drier soil conditions, results were similar for the Dualem-2 meter, EM38DD meter, and GEM300 sensor. Each instrument detected the absorption fields. Areas of higher apparent conductivity defined these features. At the Hursh Road site, each instrument detected areas of discharge emanating from the absorption fields. However, no instrument provides unambiguous images of the absorption fields' drain lines and trenches.

2. Field conditions were noticeably drier and warmer than experienced in December 2001. However, results were similar for both investigations. EMI provides an all season tool for the detection and delineation of absorption fields and septic tanks.

3. Plots of data collected parallel with the drain lines provided improved definition of the absorption fields. The observed differences in spatial patterns of apparent conductivity may be a manifestation of these instruments's variable susceptibility to subtle differences in apparent conductivity or signal interference with changes in the orientation of the meter's axis.

4. The participants are deeply indebted to Rick Taylor, President of Dualem Inc., for his participation and the use of his meters in this survey. The results of the surveys with the Dualem-2 and Dualem-4 meters have been forwarded to Dr Brad Lee under a separate cover letter and will not be reported in this report. In general, results obtained with the Dualem meters were similar to those obtained with the EM38DD meter and the GEM300 sensor.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
R. Ahrens, Director, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866
B. Lee, Assistant Professor, Agronomy Department, Purdue University, 1150 Lilly Hall of Life Sciences, West Lafayette, IN 47907-1150
B. Hudson, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
T. Neely, State Soil Scientist/MLRA Office Leader, USDA-NRCS, 6013 Lakeside Drive, Indianapolis, Indiana 46278
C. Olson, National Leader for Soil Investigations, USDA-USDA, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866
R. Taylor, President, Dualem Inc., 540 Churchill Avenue, Milton, Ontario, Canada L9T 3A2
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 974, Federal Building, Room 206, 207 West Main Street, Wilkesboro, NC 28697

Equipment:
The instruments used in this study included the Dualem-2 meter, EM38DD meter, and GEM300 sensor. No ground contact is required with these devices. Lateral resolution is approximately equal to the intercoil spacing. The Dualem-2 meter, EM38DD meter, and GEM300 sensor have 2, 1, and 1.3 m intercoil spacings, respectively. All of these devices are portable and require only one person to operate.

Dualem Inc. manufactures the Dualem-2 meter.[1] Taylor (2000) describes the principles of operation for this meter. The meter consists of one transmitter and two receiver coils. One receiver coil and the transmitter coil provide a perpendicular (P) geometry. The other receiver coil provides a horizontal co-planar (HC) geometry with the transmitter coil. This dual system permits two depths to be simultaneously measured without rotating the coils. The depth of penetration is "geometry limited" and is dependent upon the intercoil spacing, coil geometry, and frequency. The Dualem-2 meter operates at a frequency of about 9800 Hz. The Dualem-2 meter provides simultaneous penetration depths of 1.3 and 3.0 m in the P and HC geometries, respectively. The meter is keypad operated and measurements can either be automatically or manually triggered.

Geonics Limited manufactures EM38DD meter.[1] Geonics Limited (2000) describes the principles of operation for this meter. The depth of penetration is "geometry limited" and is dependent upon the intercoil spacing, coil geometry, and frequency. The EM38DD operates at a frequency of 14,600 Hz. It has effective penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively (Geonics Limited, 2000). The EM38DD meter consists of two EM38 meters bolted together and electronically coupled. One unit acts as a master unit (meter that is positioned in the vertical dipole orientation and having both transmitter and receiver activated) and one unit acts as a slave unit (meter that is positioned in the horizontal dipole orientation with only the receiver switched on). The Geonics EM38Dpro Data Logging System was used to record and store both EMI and GPS data (Geonics Limited, 2002). [1] The logging system consists of an EM38DD meter, Allegro field computer,

[1] Trade names are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

Trimble AG114 GPS receiver, backpack and frame for GPS, and associated cables. With the logging system, the EM38DD meter is keypad operated and measurements can either be automatically or manually triggered.

The GEM300 multifrequency sensor is manufactured by Geophysical Survey Systems, Inc. [1] Won and others (1996) describe the use and operation of this sensor. This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed coil separation. With the GEM300 sensor, the penetration depth is considered “skin depth limited” rather than “geometry limited.” The skin-depth represents the maximum depth of penetration and is frequency and soil dependent: low frequency signals travel farther through conductive mediums than high frequency signals. Theoretical penetration depths of the GEM300 sensor are dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequencies. Multifrequency sounding with the GEM300 theoretically allows multiple depths to be profiled with one pass of the sensor. The sensor is keypad operated and measurements can either be automatically or manually triggered. The simultaneous measurement of apparent conductivity in both dipole orientations is not possible with the GEM300 sensor; the sensor must be rotated to measure both dipole orientations.

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

Study Sites:

Two previously studied, failed septic systems (Doolittle, 2002) were returned to in Allen Counties, Indiana. One site is at 11030 Schwartz Road (SE1/4, Section 34, T. 32 N., R. 13 E). This site is located in areas that had been mapped as Pewamo silty clay loam and Blount silt loam, 0 to 2 percent slopes (Kirschner and Zachary, 1969). The very deep, very poorly drained Pewamo soil formed in tills on moraines and lake plains. Pewamo is a member of the fine, mixed, active, mesic Typic Argiaquolls family. The very deep, somewhat poorly drained Blount soil is moderately deep or deep to dense till. Blount is a member of the fine, illitic, mesic Aeric Epiaqualfs family.

The other site is at 6716 Hursh Road (SE1/4, Section 19, T. 32 N., R. 13 E). This site is located in an area that had been mapped as Morley silt loam, 2 to 6 percent slopes, moderately eroded (Kirschner and Zachary, 1969). The very deep, moderately well drained Morley soil formed in tills and is moderately deep to dense till. Morley is a member of the fine, illitic, mesic Oxyaquic Hapludalfs family.

Field Procedures:

Survey procedures were simplified to expedite fieldwork. At each site, two parallel sets of orthogonal lines were laid out. These four lines defined the perimeter of a rectangular grid area. Dimensions of the grids were 36 by 34 m (about 0.12 ha) at the Hursh Road site and 34 by 18 m (about 0.06 ha) at the Schwartz Road site. Along each of the four perimeter lines, survey flags were inserted in the ground at intervals of 2 m. These flags served as grid line end points and provided ground control. Walking at a fairly uniform pace between similarly numbered flags on opposing sets of parallel lines in a back and forth pattern across each grid area completed a survey. Each EMI device was operated in the continuous mode with measurements recorded at a 1-sec interval with the EM38DD meter and the GEM300 sensor, and at a 0.5 sec interval with the Dualem-2 meter. For each traverse line, the location of each measurement was later adjusted to provide a uniform interval between observation points.

For each instrument, surveys were completed along both north-south and east-west trending grid lines. Two surveys were conducted with the EM38DD and the Dualem-2 meters. One survey was conducted in north-south directions between similarly numbered flags on the two opposing east-west trending base lines. The other survey was conducted in east-west directions between similarly numbered flags on the two opposing north-south trending base lines. Surveys were conducted in the continuous mode with both the EM38DD and the Dualem-2 meters held about 1 to 2 inches above the ground surface with their long axis parallel to the direction of traverse.

When operated in the continuous mode, the GEM300 sensor cannot be rotated to record measurements in both dipole orientations. As a consequence, four separate surveys were required with the GEM300 sensor at each site. Two surveys (one in the horizontal and one in the vertical dipole orientation) were conducted in north-south directions between similarly numbered flags on the two opposing east-west trending base lines. The other two surveys (one in the horizontal and one in the vertical dipole orientation) were conducted in east-west directions between similarly numbered flags on the two opposing north-south trending base lines. Surveys were completed with the GEM300 sensor held at hip height with its long axis parallel to the direction of traverse.

Spatial Discrepancies

Because of the distance between the transmitting and receiving coils and the time delay in data logging, slight spatial discrepancies will exist in EMI data. These offsets and delays, as well as the gridding methods and contour intervals used in computer simulations, are responsible for the “herringbone” patterns that occur in the accompanying plots. As the relative location of the absorption fields within each survey area was desired, the herringbone patterns, while aesthetically displeasing, did not interfere with this analysis.

Frohlich and Lancaster (1986) observed differences in spatial patterns of apparent conductivity when comparing data collected in north-south directions with data collected in east-west directions over the same survey area. In this study, plots of data collected parallel with the drain lines generally provided improved definition of the absorption fields.

Drift or instrument error can also occurs and may be responsible for some of the elongated patterns of apparent conductivity seen in some of the accompanying plots. Drift is caused by the effect of heating and cooling on the length or straightness of the instrument and on the conductivity of electrical components in the instrument (Rick Taylor, personal communication). Drift is often more noticeable on simulated plots that use narrow contour intervals.

Noise:

Noise is unwanted signal interference that interferes with desired signals and spatial patterns. Data collected at the Hursh Road site were noisier than data collected at the same site in December or data collected at the Schwartz Road site. Possible sources of noise are summer atmospheric, engine ignition from nearby construction equipment, cell phones, etc. This type of noise is generally represented on the enclosed plots as random points of anomalously high or low EMI responses that are not associated with any known feature. Another source of noise is interference from known cultural sources. At the Schwartz Road site, a fairly large, above ground swimming pool with a deck, and a newly installed buried pumping system with a metallic plate cover produced significant and recognizable levels of signal interference in the southwest corner of the survey area. Susceptibility to subtle levels of signal interference is known to vary with meter placement and changes in the orientation of the meter’s axis on succeeding survey lines.

Results:

Schwartz Road, Allen County, Indiana.

The site is located in the backyard of a residential home. A 34- by 18-m grid was established across the site. The grid interval was 2 m. At the time of the survey the soil was relatively dry and the lawn was noticeably greener over the drain lines (which extended in an east-west direction across the survey area).

The grid area was bordered on the southwest corner by a fairly large, above ground swimming pool with a deck. The home was located to the immediate west of the grid area. The grid area contained a metallic tetherball pole and several small trees. Major repairs had been competed on a collapse tile line and a pumping system with a large metallic plate-cover had been installed in the time between the two surveys. These features produced high levels of noise that were easily distinguishable in the data sets.

Basic statistics for the EMI surveys completed with the EM38DD meter and the GEM300 sensor are shown in tables 1 and 2. Table 1 shows comparative data for surveys conducted in December and July for traverses orientated in an east to west direction. Table 2 shows comparative data for surveys conducted in December and July for traverses orientated in a north to south directions.

Table 1
Basic Statistics for the EMI Surveys of the Schwartz Road Site in Allen County, Indiana.
July 2002
(All measurements are in mS/m)
Surveys conducted in East-West Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	**HDO**	**6030Hz-V**	**9810Hz-V**	**14790Hz-V**	**6030Hz-H**	**9810Hz-H**	**14790Hz-H**
Number	239	239	244	244	244	243	243	243
Average	41.9	27.2	85.0	80.4	80.6	55.5	52.6	54.0
SD	10.9	10.4	81.7	52.7	35.1	48.5	32.1	23.0
Minimum	26.1	14.1	50.9	54.3	56.7	18.2	24.9	35.7
Maximum	102.2	85.4	772.7	618.2	424.9	508.5	328.1	242.8
First	35.7	21.7	63.2	65.4	69.5	42.3	43.3	46.8
Median	40.2	25.0	68.2	70.5	74.2	45.3	46.1	49.8
Third	45.5	28.7	75.0	76.9	81.2	49.2	50.2	53.2

December 2001
(All measurements are in mS/m)

Surveys conducted in East-West Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	**HDO**	**6030Hz-V**	**9810Hz-V**	**14790Hz-V**	**6030Hz-H**	**9810Hz-H**	**14790Hz-H**
Number	655	655	656	656	656	630	630	630.0
Average	43.5	24.6	60.9	57.1	56.2	33.8	30.9	31.3
SD	8.3	7.2	44.9	27.0	17.1	18.8	11.5	8.0
Minimum	-17.8	-27.3	-15.5	20.9	27.1	-65.3	-48.6	-33.2
Maximum	67.8	39.1	892.2	517.1	366.5	267.5	164.6	109.5
First	37.5	19.9	52.3	50.2	50.4	27.7	26.0	27.2
Median	44.4	26.0	56.8	55.0	55.0	31.4	30.0	31.1
Third	48.9	29.3	60.9	59.0	59.2	34.5	32.9	34.1

For surveys conducted with the EM38DD meter along east-west traverse lines, data collected on the two survey dates were surprisingly similar. Because of noticeably differences in soil moisture and temperatures, greater difference in EMI responses had been anticipated. In the July survey, apparent conductivity averaged 41.9 and 27.2 mS/m in the vertical and horizontal dipole orientations, respectively. In the December survey, apparent conductivity averaged 43.5 and 24.6 mS/m in the vertical and horizontal dipole orientations, respectively. The observed range in values and the variability (standard deviation (SD)) did vary between the two surveys. However, for residential surveys or surveys conducted over disturbed sites, these factors principally reflect the locations of the measurements relative to above- and below-ground, interfering, cultural anomalies.

For surveys conducted with the EM38DD meter along north-south traverse lines, data collected on the two survey dates were also similar (Table 2). In the July survey, apparent conductivity averaged 40.7 and 21.6 mS/m in the vertical and horizontal dipole orientations, respectively. In the December survey, apparent conductivity averaged 43.4 and 25.0 mS/m in the vertical and horizontal dipole orientations, respectively. Data collected with the

EM38DD on different dates and traverse orientations were basically similar for the two survey dates. Differences were principally attributed to the locations of the EMI measurements relative to cultural features and not to differences in soil temperature or soil moisture.

Table 2
Basic Statistics for the EMI Surveys of the Schwartz Road Site in Allen County, Indiana.
July 2002
(All measurements are in mS/m)
Surveys conducted in North-South Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	234	234	243	243	243	247	247	247
Average	40.7	21.6	74.8	74.4	77.6	53.3	49.9	52.0
SD	9.0	11.0	34.9	18.2	13.6	33.7	18.7	12.6
Minimum	18.8	7.4	18.0	46.9	10.4	20.2	26.6	13.6
Maximum	88.5	78.3	493.8	251.9	155.2	261.6	193.8	152.9
First	35.0	16.2	64.9	67.1	71.6	42.0	42.6	47.0
Median	38.9	18.9	68.6	71.0	75.6	44.8	46.0	49.9
Third	44.7	22.3	74.6	76.8	82.4	49.4	50.5	53.4

December 2001
(All measurements are in mS/m)
Surveys conducted in North-South Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	599	599	665	665	665	657	657	657
Average	43.4	25.0	59.1	55.9	55.9	34.8	31.1	30.7
SD	8.0	5.3	27.8	15.4	10.3	23.6	16.9	9.8
Minimum	-6.2	6.7	12.2	28.6	35.3	19.8	-4.7	-7.9
Maximum	71.7	40.0	547.9	275.7	190.4	374.4	306.6	163.9
First	38.0	21.0	51.2	49.7	50.3	28.1	26.0	26.6
Median	43.0	25.4	56.4	54.6	55.4	31.2	29.4	30.0
Third	49.2	29.1	60.8	59.7	60.3	34.0	31.8	32.5

For surveys conducted with the GEM300 sensor along east-west traverse lines, data collected on the two survey dates were dissimilar (see Table 1). In the July survey, in the vertical dipole orientation, apparent conductivity averaged 85.0, 80.4, and 80.6 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. However, in the December survey, in the vertical dipole orientation, apparent conductivity averaged only 60.9, 57.1, and 56.2 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In the July survey, in the horizontal dipole orientation, apparent conductivity averaged 55.5, 52.6, and 54.0 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. However, in the December survey, in the horizontal dipole orientation, apparent conductivity averaged only 33.8, 30.9, and 31.3 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively.

Data collected with the GEM300 sensor along north-south traverse lines were also dissimilar for the two survey dates (see Table 2). In the July survey, in the vertical dipole orientation, apparent conductivity averaged 74.8, 74.4, and 77.6 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. However, in the December survey, in the vertical dipole orientation, apparent conductivity averaged only 59.1, 55.9, and 55.9 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In the July survey, in the horizontal dipole orientation, apparent conductivity averaged 55.3, 49.9, and 52.0 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. However, in the December survey, in the horizontal dipole orientation, apparent conductivity averaged only 34.8, 31.1, and 30.7 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively.

Measurements collected with the GEM300 sensor in the July survey were anomalously high and attributed to signal interference. The higher July measurements were initially attributed to the fact that the GEM300 sensor is held at hip height, measures a greater column of air, and is more responsive to air temperatures than the EM38DD meter which is held very close (within 2 inches) to the soil surface. However, as similar differences were not obtained at the Hurst Road site, the higher measurements recorded in July at the Schwartz Road site are attributed to interference from above- and below-ground, cultural features. As repairs had been conducted on the septic system and a new below-ground pump installed with a large metallic cover, the higher and more variable July measurements are principally associated with the sensor's sensitivity to these features. The GEM300 sensor is held at hip height and appears to be more strong influenced by cultural features than the EM38DD meter, which is operated close to the ground surface. It should be noted that data collected with the GEM300 sensor on the same date and orientation, but in different traverse orientations were similar (see tables 1 and 2).

On both survey dates, apparent conductivity increased with increased soil depth (for both averaged and median values, measurements obtained in the vertical dipole orientation were higher than those obtained in the horizontal dipole orientation). This is attributed to increase water, clay, and/or contaminants at increasing soil depths. Negative and high positive values are attributed to interference from cultural features that occurred within or near the survey area.

Figure 1 contains plots of apparent conductivity measured with the EM38DD meter at the Schwartz Road site. The two left-hand plots are for the survey that was conducted along east-west trending grid lines. The two right-hand plots are for the survey that was conducted along north-south trending grid lines. The two upper plots in Figure 1 show the spatial distribution of apparent conductivity measured with the EM38DD meter in the horizontal dipole orientation. The two lower plots show the spatial distribution of apparent conductivity measured with the EM38DD meter in the vertical dipole orientation. In each plot, the isoline interval is 5 mS/m. The locations of observation points for the two surveys are shown in the upper plots.

Regardless of the directions in which the data were collected, broad spatial patterns are similar in each plot. The buried pump with metallic cover and the closely adjoining swimming pool with deck produced the anomalously high values of apparent conductivity in the southwest portion of the survey area. The area of higher apparent conductivity that extends across the central portion of the survey area is the absorption field. Because of the depth to the a absorption field, spatial patterns are perhaps more revealing in the plots prepared from data collected with the EM38DD meter in the deeper-sensing, vertical dipole orientation. In addition, EMI data collected along east-west survey lines, which parallel the direction of the drainage lines, provide a more continuous pattern that more closely corresponds to the actual location of the absorption field.

Figures 2 and 3 show the results of the EMI survey conducted with the GEM300 sensor along north-south and east-west trending grid lines, respectively. In each figure, data collected at 6030 Hz, 9810 Hz, and 14790 Hz are shown in the left-hand, middle, and right-hand plots, respectively. For each frequency, data collected in the horizontal and vertical dipole orientations are shown in the upper and lower sets of plots, respectively. In each plot, the color interval is 5 mS/m. The locations of observation points for the two surveys are shown in the left-hand plots.

Spatial patterns shown in these plots are closely similar to the spatial patterns of apparent conductivity that were simulated from data collected with the EM38DD meter (see Figure 1). Like the data acquired with the EM38DD meter, data collected with the GEM300 sensor are anomalously high over the buried pump with metallic cover and near the closely adjoining swimming pool with deck. However, because the GEM300 sensor was operated at hip height rather than near the soil surface, a larger and more pronounced zone of interference appears in both the north-south and east-west data sets.

In figures 2 and 3, a zone of relatively high apparent conductivity that extends across the central portion of the survey area identifies the location of the absorption field. As with the EM38DD meter, the absorption field is best defined in data collected in the deeper-sensing, vertical dipole orientation and along traverse lines that were conducted parallel with the drain lines (east-west traverses).

Spatial patterns are similar in the data collected with each EMI device. Although the sharp rectangular outline of the absorption field has not been captured in the EMI surveys, conductivity decreases from the distribution box along the drainage lines and away from the absorption field. This rather diffuse pattern is indicative of contaminant flow away from its source. Compared with data measured with the EM38DD meter, data measured with the GEM300 sensor are higher. However, absolute values of apparent conductivity are in themselves non-indicative. Relative values and spatial patterns of apparent conductivity are the most revealing and provide the most useful informative. In this respect, the data sets are similar.

For the GEM300 sensor, spatial patterns of apparent conductivity collected in the same dipole orientation are remarkably similar for data collected at different frequencies (see figures 2 and 3). For each of the surveys conducted with the GEM300 sensor, strong (r = 0.855 to 0.981) and significant (0.001 level) correlations existed between data collected at different frequencies (6030, 9810, 14790 Hz) but in similar dipole orientations. As the spatial patterns appearing in figures 2 and 3 are similar, it is doubtful that the use of multiple frequencies provides multiple depths of observation or any additional information about this site. Won and others (1996) specifically designed the GEM300 sensor to detect buried objects. They noted that each frequency and dipole orientation will provide a slightly different picture of a buried object. Buried objects may be more easily detected at a particular frequency. Each frequency and dipole orientation will provide a slightly different visual presentations of the site. However, more information appears to be provided in data that are collected with one frequency and two dipole orientations than in data that are collected at multiple frequencies and only one dipole orientation. In addition, the use of multiple frequencies requires additional time and expenses to process and display the data.

The EM38DD and the GEM300 sensor produced similar results at the Schwartz Road site. Both instruments detected the absorption field. However, neither instrument defined the presence and location of the absorption field’s individual drain lines and trenches.

Site 2 - Hursh Road, Allen County, Indiana.
The site was located in a yard of a residential home. A 36- by 34-m grid was established across the site. The grid interval was 2 m. The grid area was located on the lawn to the west and southwest of the home. At the time of the survey the soil was relatively dry and the grass was greener over the drain lines.

Basic statistics for the EMI surveys that were completed with the EM38DD meter and the GEM300 sensor are shown in tables 3 and 4. Table 3 shows comparative data for surveys conducted in December and July with traverses orientated in an east to west direction. Table 4 shows comparative data for surveys conducted in December and July with traverses orientated in a north to south directions.

Data collected with the EM38DD meter on different dates and traverse orientations were similar. Slight differences in the averaged and median measurements obtained with the EM38DD meter between the survey dates were attributed principally to differences in the location of the survey areas and the sample size. In July, for surveys conducted along east-west trending grid lines, apparent conductivity averaged 26.5 and 11.3 mS/m in the vertical and horizontal dipole orientations, respectively. In the December survey, apparent conductivity averaged 33.1 and 12.8 mS/m in the vertical and horizontal dipole orientations, respectively. In July, for surveys conducted along north-south traverse lines, apparent conductivity averaged 25.6 and 10.8 mS/m in the vertical and horizontal dipole orientations, respectively. In the December survey, apparent conductivity averaged 31.7 and 11.8 mS/m in the vertical and horizontal dipole orientations, respectively.

Table 3
Basic Statistics for the EMI Surveys of the Hursh Road Site in Allen County, Indiana.
July 2002
(All measurements are in mS/m)
Surveys conducted in East-West Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	477	477	428	428	428	436	436	436
Average	26.5	11.3	43.8	45.3	48.1	28.9	28.6	30.7
SD	5.9	3.9	6.5	6.5	6.6	4.6	4.4	4.2
Minimum	16.0	4.4	30.2	31.9	35.2	15.9	15.5	14.0
Maximum	45.2	28.3	59.8	60.5	64.4	58.0	41.9	44.4
First	22.1	8.5	38.6	40.6	43.1	25.4	25.4	27.8
Median	24.7	10.3	43.2	44.4	47.2	28.5	28.0	30.4
Third	30.8	13.5	48.4	49.9	52.5	31.8	31.6	33.6

December 2001
(All measurements are in mS/m)
Surveys conducted in East-West Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	1150	1151	1083	1083	1083	1018	1018	1018
Average	33.1	12.8	40.0	38.9	42.0	20.1	16.7	19.3
SD	7.2	5.0	12.8	8.9	7.7	7.4	5.8	5.2
Minimum	11.7	-0.2	7.2	25.8	29.6	-2.7	1.0	7.3
Maximum	68.5	44.2	367.7	193.4	108.5	67.6	44.3	38.4
First	28.2	9.8	33.3	32.4	35.7	17.1	13.2	15.8
Median	30.4	11.5	38.4	37.5	40.6	19.6	15.7	18.1
Third	36.7	15.1	45.5	44.4	47.7	24.8	21.0	23.3

At the Hursh Road site, data collected with the GEM300 sensor in the same orientation, but on different dates or in different traverse orientations were similar. Slight differences in the averaged and median measurements obtained with the GEM300 sensor between the survey dates were attributed principally to differences in the location of the survey areas and the sample size. For surveys conducted with the GEM300 sensor, data collected on the two survey dates were also similar. In July, for surveys along east-west traverse lines in the vertical dipole orientation, apparent conductivity averaged 43.8, 45.3, and 48.1 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In December, for surveys along east-west traverse lines in the vertical dipole orientation, apparent conductivity averaged 40.0, 38.9, and 42.0 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In July, for surveys along east-west traverse lines in the horizontal dipole orientation, apparent conductivity averaged 28.9, 28.6, and 30.7 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In December, for surveys along east-west traverse lines in the in the horizontal dipole orientation, apparent conductivity averaged 20.1, 16.7, and 19.3 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In July, for surveys conducted with the GEM300 sensor along north-south traverse lines in the vertical dipole orientation, apparent conductivity averaged 40.6, 41.3, and 43.1 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In December, for surveys conducted with the GEM300 sensor along north-south traverse lines in the vertical dipole orientation, apparent conductivity averaged 39.5, 36.3, and 39.0 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In July, for surveys conducted with the GEM300 sensor along north-south traverse lines in the horizontal dipole orientation, apparent conductivity averaged 25.4, 21.0, and 23.3 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively. In December for surveys conducted with the GEM300 sensor along north-south traverse lines in the horizontal dipole orientation, apparent conductivity averaged 25.7, 24.2, and 26.1 mS/m at frequencies of 6030, 9810, and 14790 Hz, respectively.

Table 4
Basic Statistics for the EMI Surveys of the Hursh Road Site in Allen County, Indiana.
July 2002
(All measurements are in mS/m)
Surveys conducted in North-South Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	466	466	448	448	448	458	458	458
Average	25.6	10.8	40.6	41.3	43.1	25.7	24.4	26.1
SD	5.6	3.4	6.0	6.1	6.1	4.7	3.9	3.6
Minimum	15.4	3.8	28.4	28.9	31.1	11.8	2.6	14.3
Maximum	43.2	20.8	55.2	56.4	60.0	88.2	36.1	39.5
First	21.4	8.3	35.9	36.9	38.5	22.9	21.9	23.6
Median	24.3	10.3	39.9	40.5	41.9	25.3	24.0	25.7
Third	29.5	13.1	45.0	45.8	47.2	28.1	26.8	28.5

December 2001
(All measurements are in mS/m)
Surveys conducted in North-South Directions

	EM38DD	EM38DD	GEM300	GEM300	GEM300	GEM300	GEM300	GEM300
	VDO	HDO	6030Hz-V	9810Hz-V	14790Hz-V	6030Hz-H	9810Hz-H	14790Hz-H
Number	1127	1127	1083	1083	1083	1165	1165	1165
Average	31.7	11.8	39.5	36.3	39.0	25.4	21.0	23.3
SD	6.8	4.6	17.0	11.1	8.5	6.7	5.4	4.9
Minimum	20.1	-2.5	27.9	24.9	28.0	16.1	12.5	15.1
Maximum	81.4	26.1	488.1	290.5	184.0	96.5	63.0	50.4
First	27.0	8.8	32.8	30.0	33.0	21.3	17.2	19.6
Median	29.0	10.8	37.4	34.6	37.4	24.0	19.8	22.2
Third	34.8	14.5	43.9	41.2	44.0	29.0	24.6	26.9

Figure 4 contains plots of apparent conductivity measured with the EM38DD meter at the Hursh Road site. The two upper plots show the spatial distribution of apparent conductivity measured with the EM38DD meter along east-west trending grid lines. The two lower plots show the spatial distribution of apparent conductivity measured with the EM38DD meter along north-south trending grid lines. The two left-hand plots show the spatial distribution of apparent conductivity measured with the EM38DD meter in the horizontal dipole orientation. The two right-hand plots show the spatial distribution of apparent conductivity measured with the EM38DD meter in the vertical dipole orientation. In each plot, the isoline interval is 4 mS/m. The locations of observation points for the two surveys are shown in the left-hand plots.

Regardless of the directions in which the data were collected, broad spatial patterns are similar in each plot. The area of higher apparent conductivity that extends across the central portion of the survey area is the absorption field. Because of the depth to the absorption field, spatial patterns are perhaps more revealing in the plots prepared from data collected with the EM38DD meter in the deeper-sensing, vertical dipole orientation. In addition, EMI data collected along east-west survey lines, which parallel the direction of the drainage lines, provide a more continuous pattern that more closely corresponds to the actual dimensions of the absorption field. In plots of the data collected in the vertical dipole orientation, fingers of slightly higher apparent conductivity can be seen extending southward from the center and southwest corner and eastward from the eastern margin of the absorption field. These fingers adjoin high conductivity areas and suggest possible discharge of waste products from the absorption field.

Figures 5 and 6 show the results of the EMI survey conducted with the GEM300 sensor along north-south and east-west trending grid lines, respectively. In each figure, data collected at 6030 Hz, 9810 Hz and 14790 Hz are shown in the left-hand, middle, and right-hand plots, respectively. For each frequency, data collected in the horizontal and vertical dipole orientations are shown in the upper and lower sets of plots, respectively. In each plot, the color interval is 4 mS/m. The locations of observation points for the two surveys are shown in the left-hand plots.

All plots in figures 5 and 6 contain some minor herringbone patterns caused by the reorientation of the transmitter and receiver coils along succeeding traverse lines. Data collected with the GEM300 sensor at the Hursh Road site contains several non-repeating point anomalies that are suspected to represent spurious system noise. In each of the plots in figures 5 and 6, patterns of apparent conductivity are elongated in the direction of traverse. These patterns are a form of noise and may represent equipment drift, the alignment of the transmitter and receiver coils, and/or the offsets or delays in signal recording.

The GEM300 sensor clearly defined the general location of the absorption field. In figures 5 and 6, a zone of relatively high apparent conductivity that extends across the central portion of the survey area identifies the location of the absorption field. As with the EM38DD meter, the absorption field is best defined in data collected in the deeper-sensing, vertical dipole orientation and along traverse lines that were conducted parallel with the drain lines (east-west traverses). A linear, east-west trending pattern of higher apparent conductivity is evident in the southern portion of the absorption field. This area is suspected of more evolved failure and consequently having higher levels of contaminants. Also, though more weakly expressed, areas of slightly higher apparent conductivity extend eastward from the eastern portion and southward from the south-central portion, and the southeast and southwest corners of the absorption field. These extended patterns of slightly higher apparent conductivity suggest possible discharge of waste products from the absorption field.

Spatial patterns of apparent conductivity collected in the same dipole orientation, but at different frequencies are similar (see figures 5 and 6). As reported for the Schwartz Road site, the use of multiple frequencies does not appear to provide any additional information about absorption field sites. For each of the four surveys completed with the GEM300 sensor, strong ($r = 0.982$ to 0.988) and significant (0.001 level) correlations existed between most data collected at different frequencies (6030, 9810, 14790 Hz) but in the same dipole orientation. However, for traverses conducted in north-south directions and in the horizontal dipole orientation, lower correlations ($r = 0.558$ and 0.602) were found to exits between data collected at 6030 Hz and at 9810 and 14790 Hz. This low correlation reflects the non-repeating point anomalies that are evident in the upper plots of Figure 5 and believed to represent spurious system noise.

The EM38DD meter and the GEM300 sensor clearly detected the absorption field at the Hursh Road site. Each instrument detected areas of discharge emanating from the east and south portions of the absorption field. Once again, compared with data measured with the EM38DD meter, EMI responses measured with the GEM300 sensor are higher. However, relative values and spatial patterns of apparent conductivity obtained with the two instruments are similar and provide evidence as to the location of the absorption field.

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EMI SURVEY AT SCHWARTZ ROAD SITE
ALLEN COUNTY, INDIANA
EM38DD METER

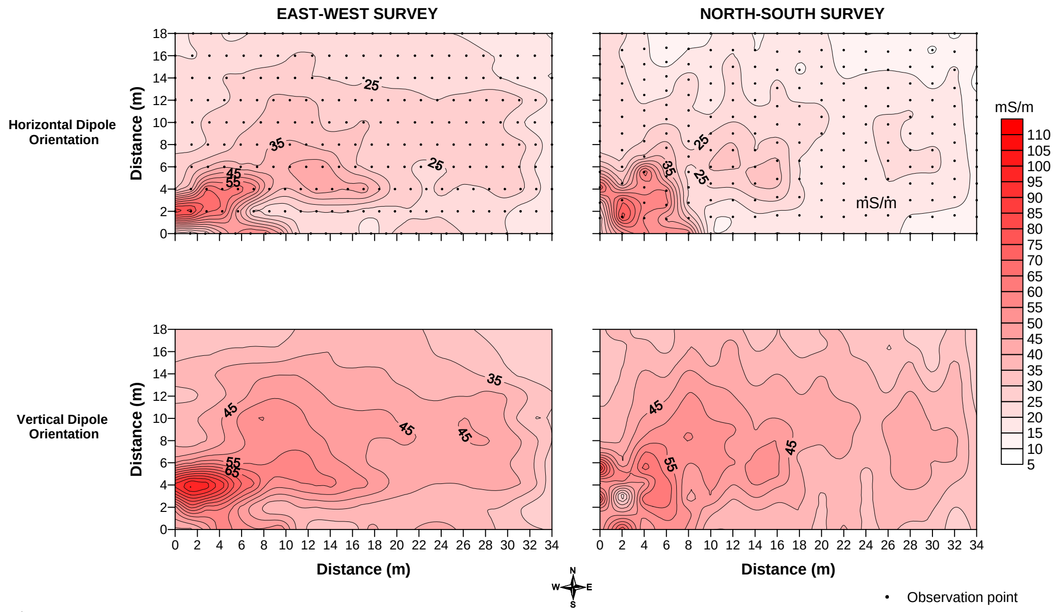

Figure 1

EMI SURVEY AT SCHWARTZ ROAD SITE
ALLEN COUNTY, INDIANA
GEM300 SENSOR
NORTH-SOUTH SURVEY

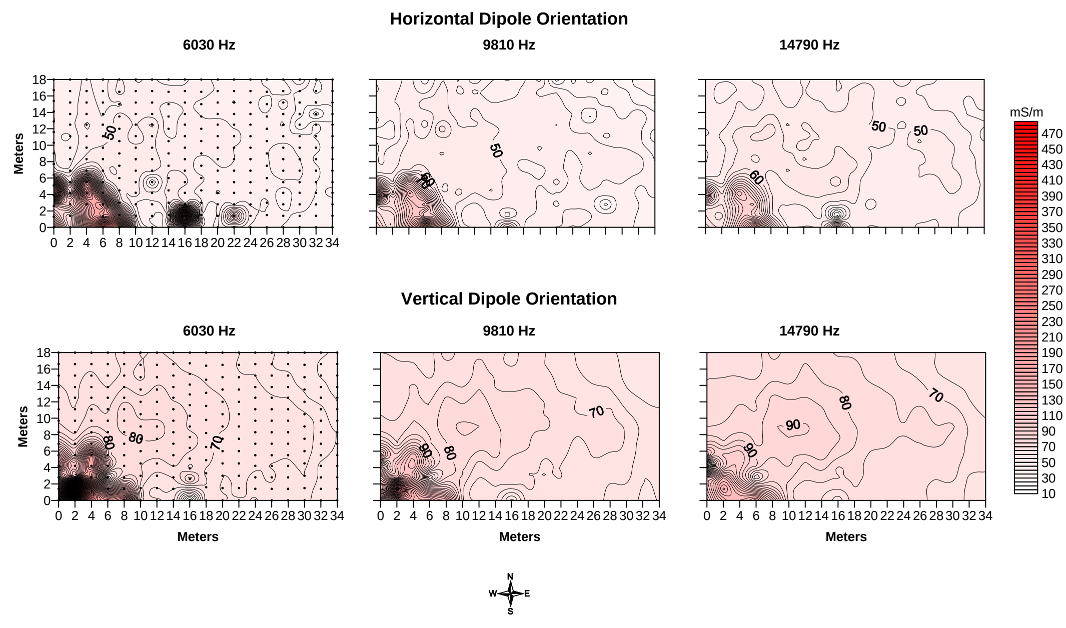

Figure 2

EMI SURVEY AT SCHWARTZ ROAD SITE
ALLEN COUNTY, INDIANA
GEM300 SENSOR
EAST-WEST SURVEY

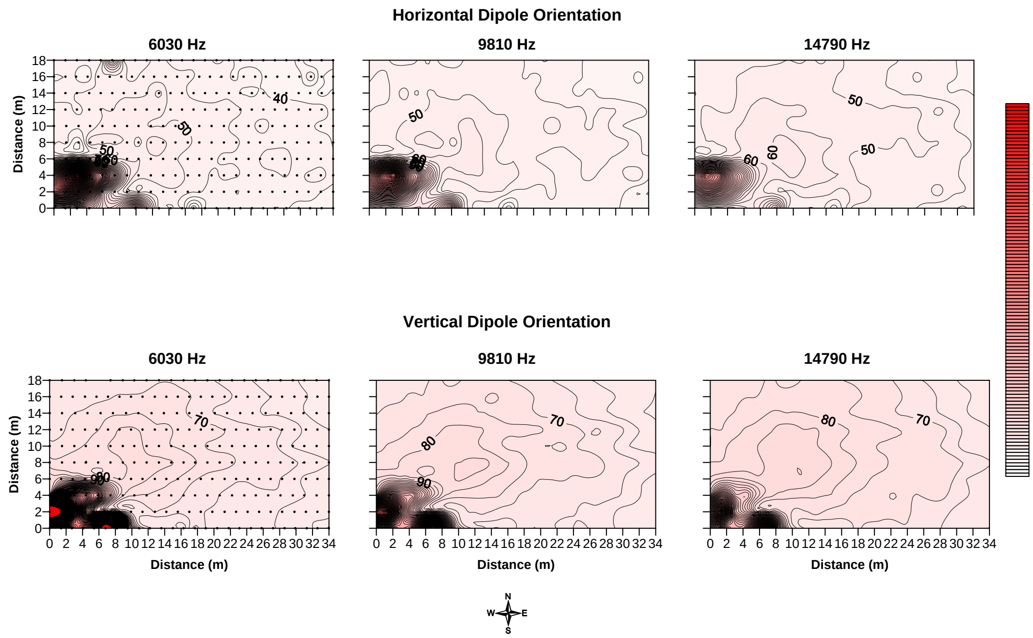

Figure 3

• Observation point

EMI SURVEY AT HURSH ROAD SITE
ALLEN COUNTY, INDIANA
EM38DD METER
EAST-WEST SURVEY

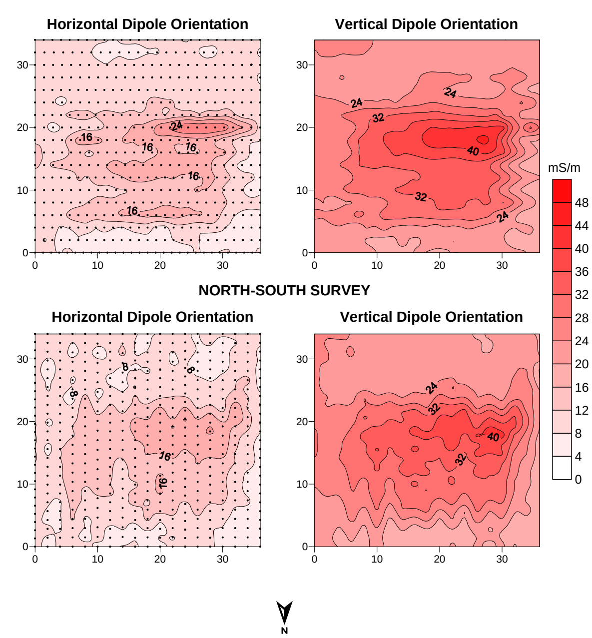

Figure 4

• Observation point

EMI SURVEY AT HURSH ROAD SITE
ALLEN COUNTY, INDIANA
GEM300 SENSOR
NORTH-SOUTH SURVEY

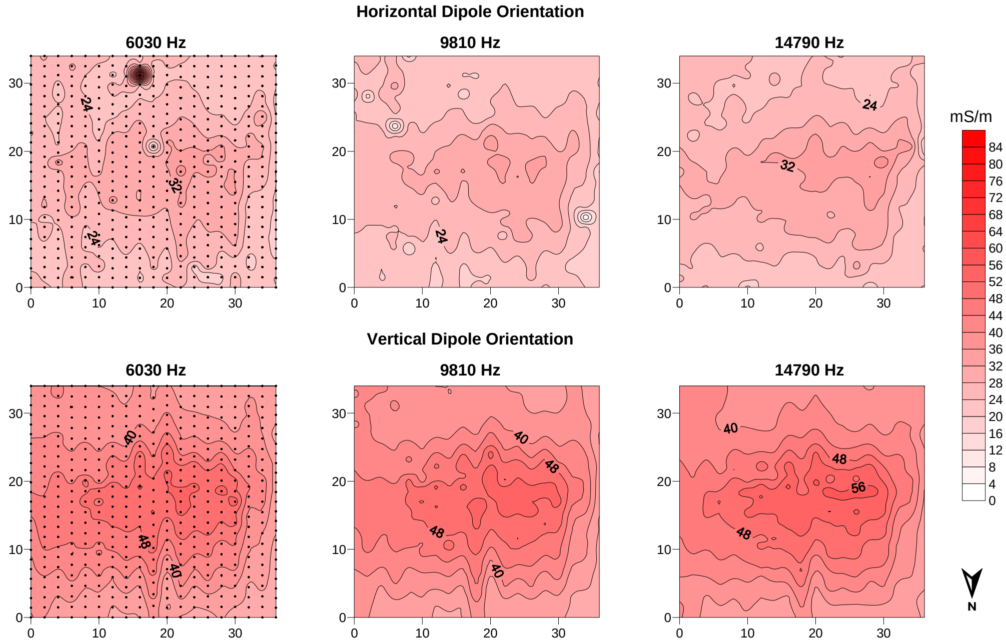

Figure 5

EMI SURVEY AT HURSH ROAD SITE
ALLEN COUNTY, INDIANA
GEM300 SENSOR
EAST-WEST SURVEY

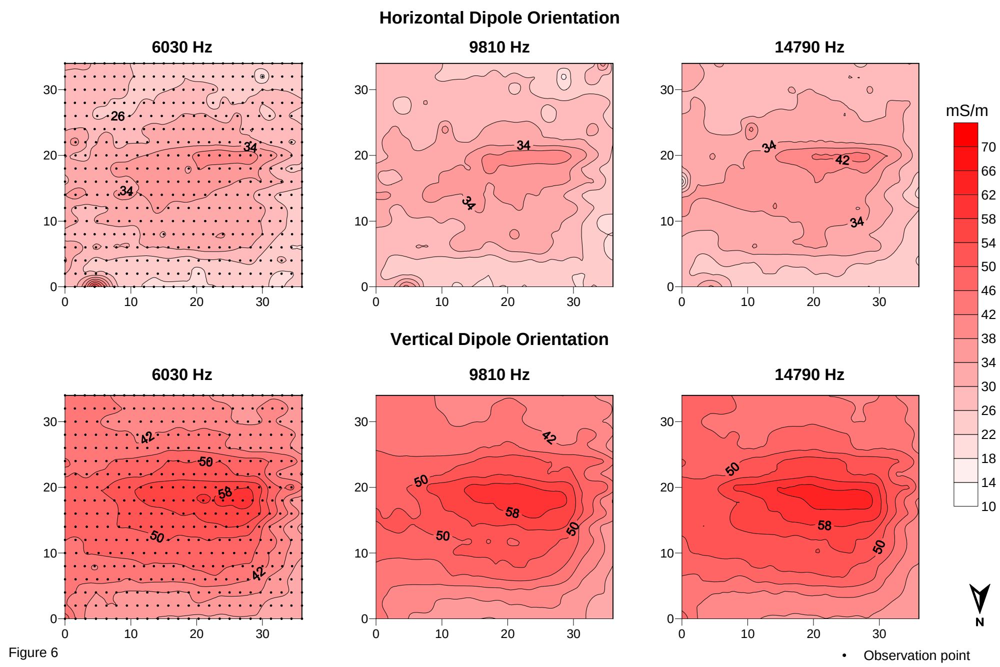

Figure 6