Monitoring a Failed Septic System with Electromagnetic (EM) Conductivity

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In 2001, the Ft. Wayne – Allen County Health Department identified several failing septic systems in the suburbs of Ft. Wayne, IN, through field observation and water-quality monitoring of nearby streams. One such system had been installed in a fine-textured (35 to 50 percent clay) soil, and serviced a 3-bedroom home on a 0.8 ha (2 acre) lot.

The system was mapped in December 2001 and again in July 2002 with the DUALEM-2 as well as several other EM induction (EMI) instruments. (The use of trademarks is for descriptive purposes only, and does not imply endorsement by the authors.) The DUALEM-2 is designed to measure ground conductivity at low-induction-number (LIN). The instrument contains coils that operate in both the horizontal co-planar (HCP) and perpendicular (PRP) geometries. Transmitter-receiver separation is about 2 m. At LIN, the PRP geometry is sensitive to conductivity fluctuations to a depth of about 1.2 m beneath the instrument, and the HCP geometry is sensitive to a depth of about 3 m.

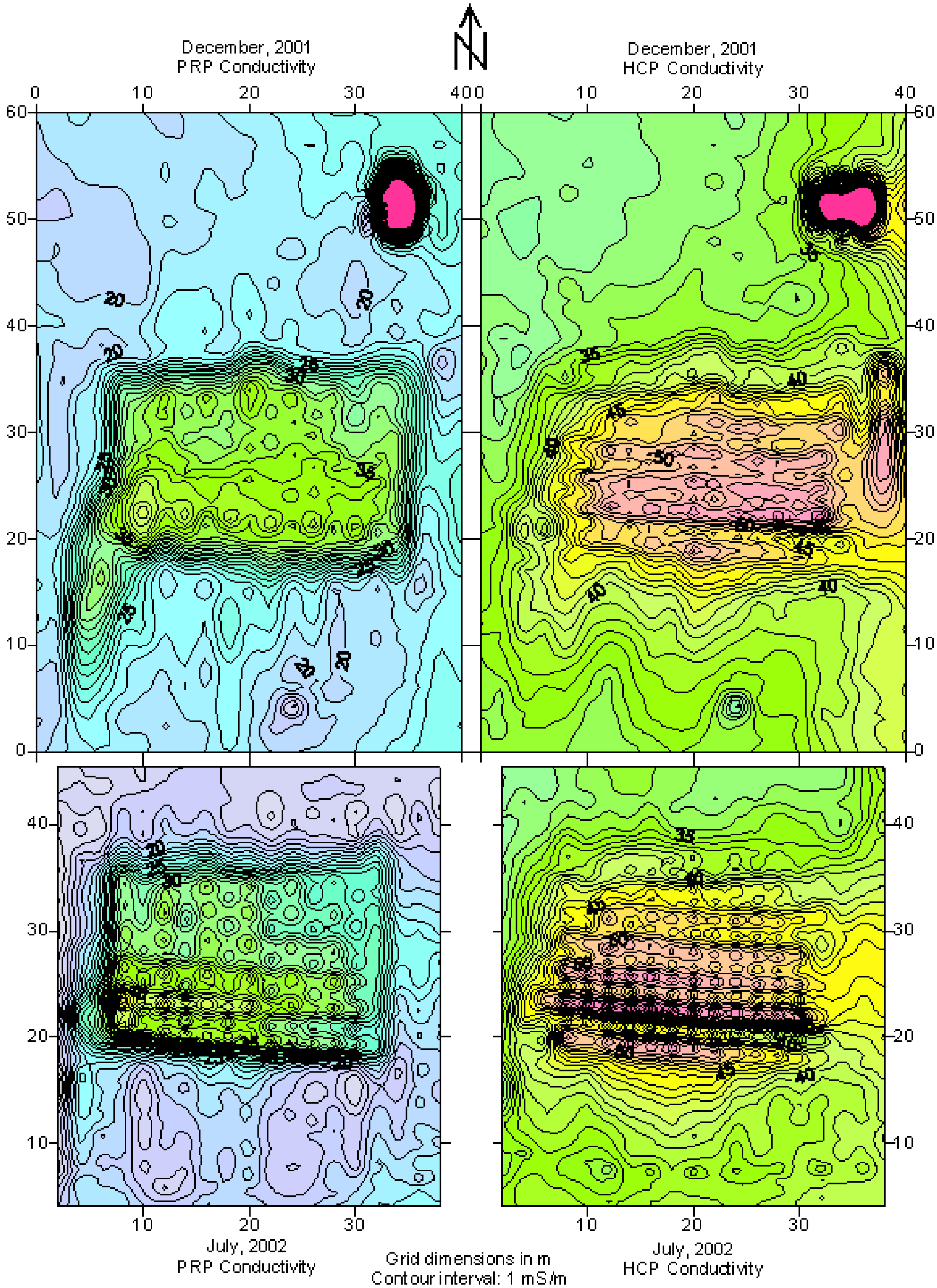
To evaluate the location of the septic system absorption field and contaminant distribution, the DUALEM-2 was carried at low ground-clearance aligned with north-south traverses spaced at 2-m intervals. Although the surveys progressed along serpentine paths, the transmitter-receiver orientation of the instrument was kept consistent. Continuous measurements were recorded at walking speed (about 1.2 m/s). A 1-Hz sample rate was used in December; in July a 2-Hz rate was used. Figure 1 shows the DUALEM-2 in use during the July survey.

Figure 1: DUALEM-2 progressing northward on line 36 E.

(Photo: Dr. Byron Jenkinson, Purdue University)

Figure 2 shows the apparent conductivities measured for both surveys. The smaller area surveyed during July lies within the area surveyed in December. Line positions and the north-south extent of the July survey have been adjusted to minimize lag. The strongly conductive feature in the northeastern corner of the December area is the response of the steel septic tank.

Figure 2: DUALEM-2 apparent conductivities.



The ground was saturated at the time of the December survey. Prior to the survey, the septic system had failed due to hydraulic overloading, caused by excessive water use in the home and heavy precipitation, which resulted in ponded wastewater on the lawn.

The area slopes very gently to the south, so conductivities in the northern portion of the December survey, away from the septic tank, may be most indicative of pre-construction background values in wet conditions. PRP values in this area, at about 21 mS/m, are somewhat lower than HCP values, at about 36 mS/m. This contrast arises from the greater sensitivity of the PRP geometry to the less conductive materials, i.e. air, turf and lighter-textured topsoil, immediately beneath the instrument. Furthermore, the conductivity of the carbonate-rich subsoil is thought to increase with depth, as the degree of carbonate leaching decreases.

By July the ground had become dry, browning the cover of short grass (see figure 1). In the months before the survey, the combination of dry weather and a large reduction in water use in the home had removed the hydraulic overload from the septic system.

HCP conductivities at the northern fringe of the July survey are essentially the same as those measured in the same area in December. Comparable PRP conductivities were about 4 mS/m lower in July. Temporal variation in soil moisture and soil temperature should be expected to cause some fluctuation in measured conductivity. Instrument variability is also a possible factor, as different DUALEM-2s were used for the two surveys. Nevertheless, to the depth of PRP sensitivity, it would appear that the decrease in conductivity due to the drying of the soil is slightly greater than the increase in conductivity due to the warming of the soil and its remaining moisture. Soil temperature and moisture should be more stable through the greater depth of HCP sensitivity, as indicated by the little-changed HCP conductivities.

The rectangular area of elevated PRP conductivity common to both surveys shows the absorption field of the septic system. In the December survey, elevated PRP conductivities extend downslope (i.e. southward) from the southwestern, south-central and eastern edges of the absorption field, indicating likely pathways of contaminant seepage at or near the surface.

The December downslope extensions of HCP conductivity from the southwestern and south-central edges of the absorption field are relatively weak. The extension from the eastern edge appears to have the greatest breadth and continuity at both HCP and PRP depths, suggesting that a seep at this location would be the most substantial.

In the July survey, the downslope extensions are diminished significantly in both amplitude and continuity. However, the amplitude of the absorption-field conductivity shows little overall change from December to July. Given the variables of moisture and temperature, there is no clear decrease in the quantity of dissolved solids in the field.

The contours in the absorption field show east-west linear trends, which are more pronounced in the July survey, and are strongest in the HCP map. The nature of the trends is consistent with the expected layout of drain tiles and trenches in the absorption field.

Figure 3 is a view to the east across the survey area from about 24 N. Taken in July 2002, the view shows east-west strips of grass that become progressively green and vigorous downslope (i.e. to the right). The strips coincide with the east-west conductivity trends, and confirm the elevated levels of moisture and dissolved nutrients in the trenches around the drain tiles.

Figure 3: July 2002 - View to the east along line 24 N.

(Photo: B. Jenkinson)

The white disk in the right-side foreground of the view is the cover of the observation port of the septic system. Allowing for about 1 m of positional uncertainty in the maps, the small and local decrease in HCP conductivity at about 6 E and 21 N might be the geophysical expression of the port. More significantly, this location is the origin of the strongest downslope extension of PRP conductivity mapped in December 2001. Thus, the observation port was the likely source of the most serious at-surface seepage of contaminants from the septic system.

The surveys at this site demonstrate the use of EMI to identify the locations and depths of septic-system failure, and to confirm the cessation of failure. To be useful, the EMI data must be stable, accurate, precisely positioned, and collected both during failure and after the implementation of corrective measures. Acquisition of EMI data prior to construction would improve the diagnosis of any subsequent failure and, thus, the effectiveness of remediation.

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