Cross-hole electrical resistivity imaging to study water and nitrate infiltration processes at Harrington Research Farm, Prince Edward Island, Canada

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Nitrate is a necessary nutrient for plants, originating from both natural and anthropogenic sources, such as mineralization of organic matter and agricultural fertilizers. However, high concentrations of nitrate in water can negatively affect aquatic ecosystems and human health. 3D Electrical Resistivity Imaging (ERI) is one of the techniques being used at AAFC's Harrington Research Farm near Charlottetown, Prince Edward Island, to investigate the subsurface transport of nitrate including (i) the time taken to percolate to the water table, (ii) the partitioning between (slow) matrix and (fast) fracture flow, and (iii) the generation of perched water table overlying low permeability layers that may give rise to lateral flow and discharge to surface water at certain times of year. The infiltration of water and electrical conductive tracer can cause changes in subsurface resistivity distribution. Thus, 3D imaging and monitoring of resistivity may be used to infer water/tracer pathways and the downward velocity of water. Since nitrate is highly soluble, its movement may be similarly monitored, although its progress may be delayed by chemical reactions along the way.

To monitor groundwater movement with 3D ERI through the ~17 m thick vadose zone, without sacrificing resolution at depth, a cross-hole measurement geometry is used. There are 24 electrodes, spaced 0.68 m apart in each of three boreholes located at the vertices of an equilateral triangle with 9 m sides. An additional 8 "trench electrodes" are buried at 0.5m depth along each side of the triangle. Soil moisture, temperature and electrical conductivity are being monitored using 11 Decagon 5TE sensors in each borehole. Borehole casings have been removed and all electrodes and sensors buried below surface so they can remain in place during farming operations. Each ERI survey involves the acquisition of a sequence of apparent resistivity measurements with different kinds of dipole-dipole configurations. Initial surveys, acquired between early September and late December, 2014 reveal a model consisting of five sub-horizontal layers, in general agreement with the expected geology of overburden overlying interbedded fluvial sandstone and shale layers. Two of these layers are more electrically conductive and are thought to represent shale-rich units which are expected to impede water infiltration and could give rise to perched water table conditions. Future work will involve the production of time-lapse images to monitor natural water infiltration and the application of a conductive tracer to enhance our ability to image ground water pathways and variations in the speed of infiltration.

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