USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Investigation of Three-Point Scheme for Identifying Local and Regional Groundwater Flow Characteristics as Applied to Wellhead Protection and Site Remediation

Project Duration**:** 09/01/96 - 08/31/98

Federal Funds Requested: $45,000

Non-Federal Funds Pledged: $92,272

Principal Investigator**:** Dr. Stephen E. Silliman, The University of Notre Dame

Congressional District: Third

Statement of Critical Regional or State Water Problems

The Midwestern states rely heavily on groundwater resources as primary sources for drinking water, water for industry, and water for agriculture. Protection of high quality groundwater resources and remediation of contaminated groundwater resources are two management activities which are becoming increasingly crucial to long term management of groundwater resources. Both protection and remediation require knowledge of the flow characteristics of a particular groundwater aquifer system. Unfortunately, physical heterogeneity (that is, spatial variation in the sediments comprising at groundwater aquifer) can make prediction of flow direction, chemical transport, and response to pumping an extremely difficult task for the hydrologist.

Our inability to characterize the physical heterogeneity within an aquifer leads to significant uncertainty m our predictions of groundwater flow and transport behavior. Recent research (e.g. Cole and Silliman, 1996) demonstrates that uncertainty in characterizing the regional gradient can be as high as 90(in terms of direction). Further, uncertainty in characterizing the flow field has been shown to lead to large uncertainty. in the proper placement of piezometers used to monitor the movement of a chemical plume. At present, these uncertainties are generally recognized by the hydrologist, but, due to lack of tools to aid in characterization, not formally included in most hydrologic analyses (e.g., delineation of wellhead protection areas). As a result, management of groundwater is generally based on our best estimate of mean behavior, rather than on consideration of the range of behavior likely to occur at a field site (similar to a situation in which might attempt to design flood control strategies based purely on consideration of mean fiver flow rather than on the analysis of flood events such as the 10-year, 50-year, and 100-year floods). A significant need therefore exists to develop cost-effective tools whereby uncertainties in the flow and transport characteristics of a groundwater system may be quantified.

Statement of Results / Benefits

Recent mathematical theory has provided hope that, given appropriate data sets from a field site, the problem of predicting groundwater movement may become increasingly tractable, at least in a statistical sense. Primary among the required data sets are measures of: (1) the regional gradient in the hydraulic head, (2) local variations in this regional gradient, and (3) the length scales over which the hydraulic conductivity is correlated. Unfortunately, each of these measures are difficult to quantify at a field site except through exhaustive, expensive field sampling combined with numerical modelling. As a result, many of the mathematical results existing in the literature are not being utilized. This is particularly unfortunate as much of this literature provides the tools whereby the uncertainty in both flow and transport *characteristics* of a particular aquifer can be statistically quantified.

The proposed research effort will build both on the recent stochastic literature and on work recently completed at Notre Dame which was specifically targeted at utilizing simple field experiments to respond to the three data needs outlined in the previous paragraph. Based solely on depth-to-water measurements (already collected in essentially all field efforts involving groundwater flow), tiffs new method has been shown to provide high quality estimates of both the mean regional gradient and local variations in this gradient. Further, this technique provides an indirect measure of the correlation length scale of the hydraulic conductivity. This length scale is critical to the application of the stochastic results available in the literature. As such, this method has the potential to revolutionize our approach to well head protection by providing reliable measures of both the regional gradient and the uncertainty in the gradient. These measures will be invaluable in assigning probabilities for such events as contamination from potential sources within and around a delineated wellhead protection area. Further, these measures will represent significant advances in our ability to design and monitor remediation efforts at sites where site specific information is limited. The goal of the present study is to extend and assess the utility of this technique through application to a variety of geologic and hydrologic settings through direct analysis of published data sets and numerical simulation of various hydrologic and geologic conditions (e.g. outwash sediments, alluvial sediments, karst formations, fractured rock, etc.). The primary benefits of this effort will be in establishing the proper application of this technique under a variety of settings and transferring this technology into active use. Secondary benefits will include significant educational experience for a number of graduate and undergraduate students, and technology transfer direction to industry.