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Research Interests

In the northern United States and southern Canada, glacial sediments form complex, near-surface aquifers that are frequently contaminated by chlorinated solvents and other industrial compounds. These sediments are characterized by abrupt lateral and vertical changes in texture associated with highly variable depositional environments. Characterization of the spatial variability of such deposits poses significant geological and geostatistical challenges, particularly when exhaustive field sampling at such sites is either physically or fiscally prohibitive. Deterministic approaches, which seek to impose a single, most likely model of the distribution of aquifer units or properties between control points, provide a means for delineating field scale distribution of aquifer units. These aquifer models often form the conceptual basis for groundwater flow and contaminant transport simulations, imparting a primary control on contaminant migration predictions. In contrast to deterministic specification, smaller scale spatial variability is often modeled stochastically using geostatistics. A wide variety of geostatistical simulation approaches have been developed to provide spatially varying parameter estimates, each with the ability to generate multiple, equiprobable realizations while honoring measurements made at known points. However, recent advances in geostatistical techniques for modeling heterogeneous parameter distributions, such as sequential indicator simulation and Markov chain-based transition probability methods, have not yet been applied to the description of glacial deposits or incorporated into contaminant transport models for highly variable sediments of this type. Furthermore, the effect of varying multiple aquifer parameters, with and without dependence on a random permeability field, has yet to be adequately explored in the context of contaminant migration and persistence.

My research seeks to assess uncertainty in subsurface transport simulation predictions resulting from the adoption of spatial variability models associated with:

a) alternative conceptual geologic models;

b) alternative geostatistical algorithm choices; and

c) simultaneous variation of multiple independent and dependent aquifer properties.

I am interested in quantifying the affects of such modeling decisions on transport of both dissolved (aqueous phase) and immiscible (nonaqueous phase) contaminants.

In my dissertation research, I conducted a series of numerical experiments using alternative stochastic algorithms to model porosity, permeability, and associated capillary parameter distributions within a single glacial depositional unit for which a three-dimensional array of sediment particle size distributions and porosity measurements were available. Subsequent transfer of multiple stochastic realizations to numerical flow and transport simulators permitted Monte Carlo evaluation of uncertainty in flow and transport model behavior (i.e., definition of a range of predicted values for specific model metrics) related to a specified stratigraphic correlation model or geostatistical simulation algorithm. My first set of experiments involved the infiltration and entrapment of a dense nonaqueous phase liquid (DNAPL) contaminant. Subsequent investigations assessed DNAPL dissolution, recovery and contaminant mass flux. Finally, models developed for the preceding investigations were used to evaluate three-dimensional advective and dispersive solute contaminant transport. Comparisons of predictions from sets of stochastic realizations with those based upon deterministic end-member geologic models representing idealized cases of parameter spatial distribution (e.g., homogeneous or
perfectly stratified models) began to define the circumstances under which such idealized representations can successfully bound non-linear flow and transport model behavior. These studies sought to advance the geological sciences through the integration of stratigraphic and geostatistical modeling methods while contributing to environmental engineering efforts aimed at remediating contaminated aquifers (e.g., the design of traditional pump-and-treat aquifer remediation systems as well as a diverse range of emerging technologies such as surfactant enhanced aquifer remediation, co-solvent flushing, and partitioning interwell tracer tests).

In my current research, I am investigating the field-scale variability of aquifer systems. I believe significant improvements can be made to aquifer characterization, particularly of complex glacial aquifers, through the application of allostratigraphy (or sequence stratigraphy as it is commonly applied in the petroleum industry) to interpret field-scale hydrostratigraphic architectures. This approach can be combined with indicator geostatistics to model the distribution of lithofacies and aquifer properties within such deterministic frameworks. Because of its reliance on the identification of chronostratigraphically-significant bounding surfaces, the application of an allostratigraphic approach should facilitate the identification of stratigraphic elements deposited and preserved in response to major episodes of Pleistocene continental glaciation in North America. Such a line of investigation, when coupled with the modeling of fluid flow and contaminant transport, can provide important insights into the architecture of glacial aquifer systems and the opportunity to develop new conceptual models about the fate and transport of ground water contaminants within such systems.

One such site of interest to me is the Pall Life Sciences, Inc. site west of Ann Arbor, Michigan, where 1,4-dioxane, a miscible, conservative solvent, has migrated more than 1.5 km in different directions in multiple aquifer horizons. Petrophysical and lithologic description logs from more than 100 wells at the site are available to facilitate deterministic stratigraphic correlation and to provide conditioning points for geostatistical simulation. Time series concentration and hydraulic head data from approximately 90 monitoring and 60 private wells, beginning in the mid-1980s, are also available to constrain deterministic stratigraphic interpretations and evaluate the accuracy of numerical flow and transport predictions. My objective in investigating this site is to find ways to quantify the uncertainty in field-scale contaminant transport pathways and to demonstrate the efficacy of hybrid models as a planning tool for environmental decision-makers seeking to protect or remediate groundwater resources in complex aquifer systems.

Finally, I have a general interest in bridging the gaps between academic, industrial, and governmental approaches to solving issues of natural resource management and environmental concern. Public policy needs to be informed by individuals who can speak the language of science, engineering, economics, and regulatory affairs. I believe those who most fully appreciate the viewpoints that differing constituencies contribute to policy formation can best facilitate the identification of common ground necessary to enact workable policy. Consequently, I look for opportunities to collaborate with researchers and governmental agency representatives to provide expertise for the quantification of risk and uncertainty in environmental decision-making.