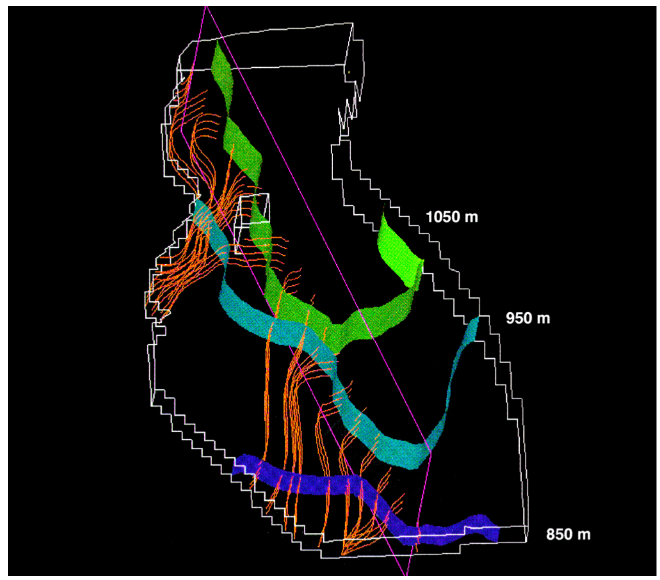
Sandia National Laboratories

Analysis of Long Term, Regional-Scale Ground-Water Flow

Need

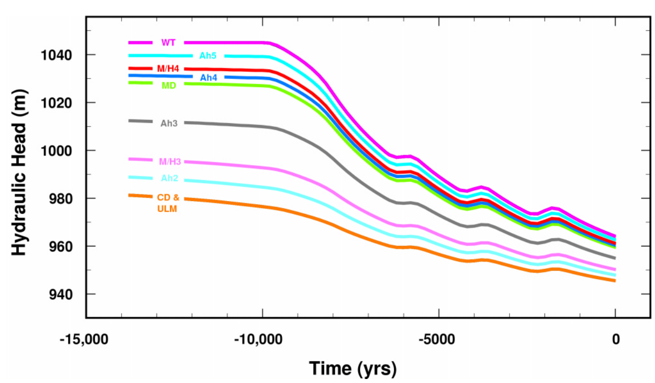
Solution of some geotechnical problems, such as radioactive / hazardous waste disposal or ground-water resource management, requires information on the impact of long-term, regional-scale flow on local-scale flow and transport. Regional scale flow controls the boundary conditions on local-scale numerical simulations for specific geotechnical problems. This regional-scale class of problems differs from other geohydrologic applications in that much larger areas, thicker stratigraphic sections, and longer time periods must be simulated, and that natural boundaries of the hydrologic system must be represented. These simulations typically require computer codes that are capable of simulating 3-dimensional, transient ground-water flow with a moving water table in highly heterogeneous model domains.



Numerical simulation of 3-dimensional flow [note orange streamlines] in the Delaware Basin, which surrounds the Waste Isolation Pilot Plant [WIPP] site (Wallace, 1994).

Description

Analysis of regional-scale flow systems at Sandia National Laboratories utilizes a multi-disciplinary approach that includes geologic, hydrologic, and chemical characterization; analysis of paleo climates; development of advanced numerical codes; and visualization of simulation results. An important tool in this approach is a computer code that simulates 3-dimensional, regional ground-water flow over tens of thousands of years and for a wide range of climatic conditions. Fundamental to this approach is the concept that regional ground-water flow in humid climates is driven by a shallow water table that is a subdued replica of the local land surface, whereas flow in arid climates is driven by a water table at depth that is sloped along regional gradients of the land

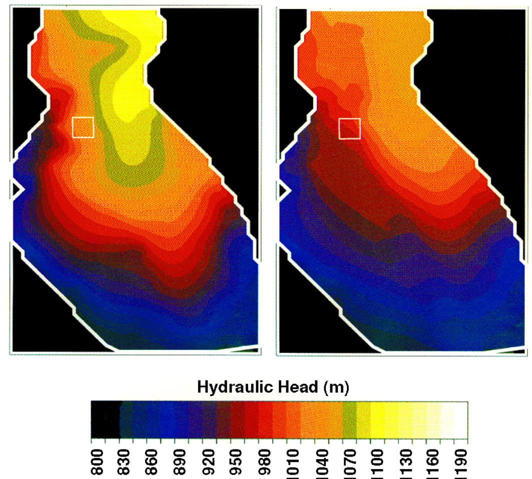


Plot showing the impact of climatic change over the past 14,000 years on the water table and hydraulic heads for selected stratigraphic units at the center of the WIPP site.

surface. Assessing the impact of long-term climatic change on a local portion of the flow system requires numerical simulations that capture water table movement in response to transitions between humid and arid climates. The transient, 3-dimensional code developed by the Sandia WIPP Project is unique in that it applies free-surface and seepage-face boundary conditions at a regional scale, is robust even if extremely large contrasts in hydraulic conductivity are present, and uses a numeric mesh that adaptively deforms so that its upper surface conforms to the moving water table.

Example Application

The Waste Isolation Pilot Plant [WIPP] is a proposed repository for defense-generated transuranic waste. Performance assessment for this repository required an assessment of the impact of long-term climatic change on ground-water flow and radionuclide transport. Ground-water flow was simulated over a time period ranging from the end of a wet climate associated with the last ice age 14,000 years ago to 10,000 years in the future. Flow was simulated in 10 hydrostratigraphic units over an area of approximately 6000 square kilometers. Superimposed on the long-term changes in the flow system are short-term changes caused by alternating wet and dry periods over the past 8,000 years. This problem is complex in that ground-water flow directions and velocities change in response to the drying climate in this area. Simulations of a wide range of possible future climates indicates that flow rates in the Culebra dolomite could increase by a factor of about two for the wettest possible future climates.



Simulated distribution of hydraulic head at 14,000 years in the past (left) and present time (right) for the stratigraphic unit (Culebra Dolomite) containing the most likely off-site transport pathway in the event of a borehole breach of the WIPP repository.

References

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