USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Project ID: 2003MA19G

Title: A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management

Project Type: Research

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Keywords: fracture characterization, domain analysis, well yield, fractured rock aquifers, groundwater availability, groundwater mapping, borehole geophysics

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Abstract: The use of bedrock wells to meet residential and commercial water supply needs continues to increase in the northeastern United States. Yet the ability to identify new sources of water in the bedrock with better than average yield, establish accurate zones of contribution to bedrock wells and understand the complex hydraulic interconnections among the bedrock fracture system, overburden aquifers and surface water bodies remains elusive. Clearly, it is cost prohibitive to collect detailed and discrete fracture data at every well site. Perhaps a better approach is to utilize existing information augmented by the collection of low-cost field data to develop regional conceptual models of the groundwater flow system. Water managers can then use these conceptual models as a framework for beginning to understand bedrock flow behavior, recharge characteristics and sustainability. For example, recent fieldwork in Massachusetts has shown that metamorphic rocks with steeply dipping foliation that exhibit well-developed, foliation-parallel partings exert a strong directional anisotropy on flow. These partings also provide excellent vertical communication with the overlying sand and gravel aquifers. Under pumping conditions, bedrock wells located in this geologic setting showed an elongated cone of depression parallel to the foliation. Wetlands, streams and overburden wells also showed immediate

water level reductions in response to pumping. The groundwater flow behavior observed in this system was reacting to the geologic setting.By comparison, a massive granite overlain by impermeable lacustrine sediments that exhibits one moderately well developed set of near-vertical tectonic joints but is dominated by subhorizontal sheeting (unloading) joints will have a much different groundwater response under pumping conditions. In this case, the vertical joints provide an avenue of vertical recharge and the sheeting joints provide a radial connection to the pumping well. The lacustrine sediments will reduce recharge from vertical leakage and local streams and wetlands will be less affected by pumping. The actual source of recharge may be some distance away from the well where the bedrock fractures are exposed or lacustrine sediments are absent. Each of these cases produces a different groundwater flow behavior that can be conceptualized from a basic understanding of the geologic setting. Each case also requires groundwater managers to think differently about the source of recharge, potential contaminant pathways and how to invoke appropriate protection strategies. Accordingly, reasonably well-posed conceptual models of ground water flow behavior can be gleaned from a basic understanding of the geologic setting. The geologic setting, in turn, can be described reasonably well using available data supplemented with relatively low cost field measurements. Although the approach described here will not predict the yield of a well at a specific location, it will provide water managers with a conceptual framework from which to define more detailed site-specific investigations and guide more intelligent and cost-effective planning decisions. The objectives of this project are to gather regional bedrock aquifer characterization data and use this information to construct regional conceptual models of the fractured-rock aquifers in the Nashoba Terrane in Massachusetts. The project will involve: 1) collection and synthesis of fracture characterization data over the region, 2) mapping of the spatial distribution (domain analysis) of fracture sets and their characteristics, 3) compilation and statistical analysis, including variography, of available well data to link spatial continuity of well yields to characteristics of the fractured rock system, 4) collection of optical and acoustic televiewer data from selected boreholes to verify sheeting joints, 5) development of a mapping classification system that uses the notion of “litho groups” to characterize bedrock units in terms of their fracture characteristics, physical properties and geologic setting (eg., overburden type and thickness) and 6) preparation of a qualitative conceptual model of groundwater flow behavior in each litho group category. The proposed work makes use of existing USGS data and resources. It is part of a much larger integrated study being conducted by the Northborough office of the USGS on the Geohydrology of the Nashoba Terrain, Massachusetts. This larger scale project will collect data at three scales, regional, quadrangle and well-field scale and will provide the data necessary to verify the conceptual models developed as part of the work proposed here. This larger scale project also involves the participation of USGS scientists from the Water Resources Discipline, USGS mappers from the BRASS (Bedrock Regional Aquifer Systematics Study) program, and the Office of the Massachusetts State Geologist. The funds requested are primarily for student support.
