

Investigation of Fluid Flow Behavior through Discontinuous Rock Masses

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Fluid flow through a discontinuous rock mass is controlled by factors that include: (a) different rock types that exist in the rock mass, (b) the discontinuity geometry network in each rock type, (c) hydraulic properties of the rock discontinuities, (d) in situ stress distribution in the rock mass, (e) hydraulic properties of each rock matrix, (f) fluid flow interaction between each rock matrix and the existing discontinuities, (g) degree of saturation of the rock matrix blocks and the discontinuities, (h) Groundwater table, and (i) hydraulic boundary conditions such as the sources, sinks, and no flow boundaries. Because of the large extent and great depth of the DUSEL proposed at Homestake mine, the above factors are expected to vary considerably spatially. Because many activities such as (a) dewatering, (b) excavation through blasting, (c) excavation through tunnel boring machines, (d) drilling, (e) construction of laboratories, (f) in situ stress determination through hydraulic fracturing or over-coring, and (g) performance of various types of geoscience, geo-engineering, physics and biological tests are expected to take place at the DUSEL during a long time period, the rock mass conditions are expected to vary considerably with respect to time too. That means a golden opportunity exist to study the fluid flow behavior at DUSEL under many different scenarios over a large range of spatial and time scales.

It is proposed to perform the following tasks with time to investigate fluid flow behavior at the DUSEL: (1) Use of the available core data and mine records to develop a rock mass geology model in three-dimensions; (2) Use of the available discontinuity geometry data along with new discontinuity geometry mapping at locations where data are lacking to develop three-dimensional discontinuity geometry networks in each of the main rock types that exist at the DUSEL; (3) Tracer tests to determine connectivity between discontinuities; (4) Sampling of discontinuities to perform closure tests on single discontinuities and to determine relation between normal stress and normal displacement; (5) Sampling of discontinuities to perform aperture measurements on single discontinuities and to determine relation between normal stress and aperture; (6) Sampling of discontinuities to perform fluid flow tests on single discontinuities under different normal stresses and to determine the effect of normal stress on hydraulic properties; (7) Sampling of rock matrix for each of the main rock types that exist at DUSEL to perform fluid flow tests to determine the hydraulic properties; (8) Sampling of rock blocks that contain single discontinuities to study fluid flow interaction between each rock matrix and a single discontinuity; (9) Monitoring of the groundwater table; (10) Monitoring of hydraulic conditions of the sources, sinks and no flow boundaries in the region around the Homestake mine; (11) In situ stress measurements; (12) Fluid flow monitoring in the rock mass; (13) Three-dimensional discrete fracture flow and continuum flow numerical modeling to simulate steady state flow in the rock mass; (14) Packer tests in boreholes with monitoring of ground water levels in surrounding holes; (15) Three-dimensional discrete fracture flow numerical modeling to simulate packer tests conducted in the field; (16) Determination of influenced regions for packer tests through three-dimensional discrete fracture flow modeling; (17) Determination of Representative Elementary Volumes (REVs) through three-dimensional discrete fracture flow modeling; (18) Determination of three-dimensional hydraulic conductivity tensor for selected REVs through three-dimensional discrete fracture flow modeling; (19) Three-dimensional equivalent continuum flow modeling to simulate packer tests conducted in the field; (20) Comparison between results obtained through discrete fracture flow modeling and equivalent continuum modeling.

Completion of the aforementioned tasks will shed light to the following aspects: (1) Effect of excavation, drilling, hydraulic fracturing and over-coring activities on discontinuity geometry network in the rock mass; (2) Effect of excavation, drilling, hydraulic fracturing and over-coring activities on in situ stress of the rock mass; (3) Effect of excavation, drilling, hydraulic fracturing and over-coring activities on fluid flow behavior of the rock mass; (4) Effect of depth on discontinuity geometry network; (5) Effect of depth on the in situ stress of the rock mass; (6) Effect of depth on aperture distribution of single rock fractures; (7) Effect of depth on the fluid flow behavior of the rock mass; (8) Relation between fracture closure and aperture distribution of single rock fractures; (9) Effect of thermal loading on discontinuity geometry network; (10) Effect of thermal loading on in situ stress; (11) Effect of thermal loading on fluid flow behavior; (12) Relation between fracture anisotropy and fluid flow anisotropy; (13) Applicability of equivalent continuum flow modeling for fractured rock masses.