Groundwater Flux Modeling of Chlorinated Compounds through Metamorphic Fractured Bedrock in Rhode Island

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Background/Objectives. EHS Support LLC and ESS Group, Inc. (herein called the project team) have been actively working on preparation of a comprehensive conceptual site model for a USEPA Region 1 CERCLA-regulated site in Rhode Island. Impacts at the Site originated from the direct disposal of various chemicals and manufacturing residuals into open pits. These mass discharges of anthropogenic constituents have resulted in both extensive subsurface NAPLs and large dissolved phase plumes. A component of this work was to ascertain if the mass flux of dissolved chlorinated aliphatic hydrocarbons, petroleum hydrocarbons, and 1,4-dioxane out of the shallow fractured metamorphic bedrock could be the principal source of the plume observed in the overlying Pleistocene glacial overburden.

Approach/Activities. The project team providedmultiple lines of evidence indicating that flux is occurring between the bedrock and overburden, and that this flux is the primary mechanism controlling constituent concentrations within the overburden. These lines of evidence include: Statistical evaluation of the stability of groundwater concentrations in the unconsolidated deposits; Distribution of COCs and key components within the bedrock and overburden where upflow to the overburden is anticipated to be occurring; Secondary indicators of groundwater flux including groundwater temperature differentials between the bedrock and unconsolidated deposits and spatial variability observed in the unconsolidated deposits; Statistical evaluation of vertical head differentials; Results of analytical modeling of contaminant transport using BIOCHLOR and BIOSCREEN which validate the historical empirical calculations and are able to match actual groundwater concentrations; and, Calculation of the mass flux along two transects at the uppermost predominate bedrock fracture and at the bedrock/overburden interface.

Results/Lessons Learned. After a constant upward head gradient was determined by statistical evaluation, the vertical fate and transport analysis through the upper bedrock into the overburden using the Domenico Equation between well pairs screened in each unit supported that the system acted like a porous media. BIOCHLOR and BIOSCREEN modeling was able to calibrate all three chemical groups using the same flow field but different first order decay coefficients. Using the first order decay coefficients from the analytical modeling, an attenuation factor was determined for each analyte. Bedrock concentrations were then contoured for each analyte over the 4-acre source area and the attenuation factor was applied for the fate and transport up into the overburden. Thus, a flux for each analyte was developed for both the bedrock and the bedrock/overburden interface. It was estimated that 23.5 pounds per year of total VOCs is leaving the bedrock fracture system over the 4-acre site while only 0.9 pounds per year is entering the overburden. This upward migration of constituents was determined to be the predominate source of the low-level plume observed in the overburden. The surprising lesson learned was that the groundwater movement could be analytically modeled as porous media without supporting evidence from Site drilling. This application will have ramifications for future remedial activities in this area.