MODELING OF GROUND-WATER FLOW ALONG A CROSS SECTION THROUGH A RECLAIMED SURFACE COAL MINE IN WESTERN PENNSYLVANIA[1]

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Abstract. A cross-sectional (two-dimensional) ground-water flow model was developed to demonstrate the direction and rate of ground-water flow in mined and unmined sections through a reclaimed surface coal mine in the bituminous field of western Pennsylvania. Modeling was performed using a steady-state option of MODFLOW, a finite-difference computer program. The water-table configuration and vertical hydraulic gradients were determined from static water levels measured in 10 wells screened at 1 of 3 horizons along the cross section. The water table was simulated as either a constant-head or constant-recharge boundary, and the lower and lateral extent of the local flow system as no-flow boundaries. Hydraulic conductivities (K), boundaries, and recharge rate were varied in a series of simulations to evaluate simple to complex hydrogeologic conditions and flow-system geometries. Ranges of values of K (in feet per day) for spoil, coal and sandstone, and shale and underclay lithologies were modeled (K_{MODEL}) considering estimates from textbook tabulations (K_{TB}), published aquifer-test results (K_{AQ}), specific-capacity data using a form of the Theis equation (K_{SC}), and site-specific slug tests (K_{SL}) as follows:

LITHOLOGY	K_{TB}	K_{AQ}	K_{SC}	K_{SL}	K_{MODEL}
Mine spoil	--	10^0 -10^2	--	--	10^1 -10^2
Coal and sandstone	10^{-5}-10^1	10^{-3}-10^2	10^{-2}- 10^3	10^{-1}- 10^1	10^0 -10^1
Shale and underclay	10^{-8}-10^{-4}	10^{-6}-10^{-2}	10^{-2}- 10^2	10^{-2}- 10^{-1}	10^{-2}-10^{-1}

Values for K_{TB} are relatively low, because they reflect the low primary porosity of the sedimentary bedrock, whereas values of K_{SC} are greater, because they reflect results of pumping tests at water-supply wells that typically are completed in zones where secondary fractures and joints and bedding planes predominate. Values of K_{MODEL} are generally within the range of values for K_{AQ} and K_{SL}, which were obtained from aquifer tests of strata underlying the study area and vicinity. Models were calibrated by adjusting values of K_{MODEL} to match the measured water levels.

When the water table was simulated as a constant-head boundary, resultant recharge distributions were unrealistic, thus subsequent models were constructed whereby recharge was specified as a constant or a variable flux distributed across the water table boundary. The varied recharge simulation accounts for effects of two leaky aquitards (underclays) that cause seepage at the toe of spoil--thus reduced vertical percolation and increased downslope recharge. The model results indicate that flow paths are predominantly horizontal through transmissive units (spoil, coal, and sandstone) and vertical through confining units (shale and underclay). The average linear velocities generally are greater in transmissive units (10 - 650 feet per year) than in confining units (0.1 - 10 feet per year), assuming porosities of 25, 15, and 10 percent, respectively for spoil, coal and sandstone, and shale and underclay. These results add to the understanding of the hydrogeology and geochemical evolution of ground water at the mine. Such information on flow paths and velocities also is useful in the planning of ground-water monitoring schemes, specifically sample spacing and timing intervals.

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