Attachment D, Hydraulic Conductivity Values

Longevity Modeling Memo, Former Gordon Oil Refinery, Greybull, Wyoming

11/9/2020

This attachment provides a summary of the hydraulic conductivity values used in the longevity model and the sources/rationale for using these inputs. The longevity model is senstive to the input hydraulic conductivity, so a range of reasonable values was used, though not necessarily a range that encompasses all possible values of hydraulic conductivity at the site.

Sandstone is the geologic material most commonly associated with the LNAPL smear zone at the site. Hyrdaulic conductivity of sandstone can be widely variable depending on the grain size, sorting, and degree of consolidation (Driscoll 1986). The SCR, page 2-4, provided a summary of hydraulic conductivity parameters previously used in modeling efforts at the site. The migration to groundwater evaluation used hydraulic conductivity of cm/sec based on the geometric mean of hydraulic conductivity ranges in published literature. This value was used for the baseline scenario.

The contaminant transport modeling evaluation used cm/sec based on the range of values for sandstones reported in Driscoll (1986). Additionally, site-specific permeability data reported by SECOR (2007) were converted to hydraulic conductvity as described below. The median of these data was cm/sec, which is very close to the value provided above from the contaminant transport modeling evaluation. This value was used in the higher longevity scenario.

The default value for hydraulic conductivity from the API model database for clayey sand is 0.0223 meters per day, or cm/sec, which is consistent with values near the upper end of the range of the SECOR (2007) dataset (i.e., 25500 millidarcy), but probably more representative of conditions in unconsolidated sediment rather than bedrock. This value was used in the lower longevity scenario.

These three values of hydraulic spanning this range of hydraulic conductivities considered reasonable on a large scale at the site. The remainder of this attachement discusses the SECOR (2007) data, and the conversion of permeability to hydraulic conductivity.

## Permeability data from site soil samples

Klinkenberg (1941) developed a method to correct gas permeability to equivalent liquid permeability. The Klinkenberg-corrected permeability approximates the liquid permeability. Klinkenberg permeabilities were reported in SECOR (2007) Appendix E for 11 soil samples. The following are summary statistics on the 11 reported Klickenberg permeability values:

summary(import$`Klinkenberg Permeability (mD)`)

## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## 16.2 590.0 2150.0 4621.1 2930.0 25500.0

The locations of these samples were reviewed versus the site 3D model and the smear zone body. Sample AOC5-BH6 (11.25-11.75) 3-2A is the sample most associated with the smear zone in bedrock. The permeability reported for this sample (2150 mD) is, coincidentally, equal to the median of the dataset. Bedrock at the site is generally associated with low permeability, therefore samples AOC1-BH5 (17.00-17.50), AOC5-BH9 (16.50-17.00), AOC2-BH5 (16.00-16.50), and AOC6-BH2 (15.00-15.50) may also be representative of the upper bedrock zone. The mean of these samples is:

## [1] 315.475

## Conversion of Permeability to Hydraulic Conducitvity

Hydraulic conductivity is related to the intrinsic permeability of an aquifer, but it is also affected by the physical properties of the fluid flowing through the medium. The equation relating hydraulic conductivity and intrinsic permeability is:

where  
\* = hydraulic conductivty (cm/s)  
\* = intrinsic permeability of the matrix ()  
\* = fluid density (g/cc)  
\* = gravitational acceleration (constant, which has a value of 981 centimeters per second per second)  
\* = viscosity ()

Using this equation and the following:  
\* = 315.475 (mean of bedrock samples from above)  
\* = 1 (assumed, for water)  
\* = 89 (), equal to 0.89 centipoise, a representative value for water

Hydraulic conductivity (K) would be equal to:

## [1] 3.43157e-08

in centimeters per second or

## [1] 2.964876e-05

in meters per day. This is a reasonable “low” estimate for hydraulic conducitvity at the site.

If the following parameters are used, a slightly higher K is derived:  
\* = 2150 (value from AOC5-BH6 (11.25-11.75), median of entire dataset, representative of smear zone in bedrock)  
\* = 1 (assumed, for water)  
\* = 89 (), equal to 0.89 centipoise, a representative value for water

Hydraulic conductivity (K) would be equal to:

## [1] 2.338841e-07

## 

in centimeters per second or

## [1] 0.0002020759

in meters per day.

## References

Driscoll, F.G. 1986. Groundwater and wells. Johnson Division, St. Paul, Minn., 1,089p.

Klinkenberg, L. J.: 1941, The permeability of porous media to liquids and gases, Drilling and Production Practice, American Petroleum Inst., pp. 200–213.