

Groundwater Vulnerability - Methodology

Notes

- ◆ Except where noted all geoprocessing was performed in ESRI ArcGIS Desktop 9.1.

Methods

1. Input Data

1.1. Population Density

1.1.1. Data Source: 2000 Census Block Centroids (U.S. Census Bureau)

1.1.2. Calculated using “Kernel Density” tool where search radius = 1800 meters and density units = square kilometers. Raw data reclassified to five classes using natural breaks algorithm.

1.2. Stream Density

1.2.1. Data Source: High-resolution National Hydrography Dataset (USGS)

1.2.2. Stream density calculated by dividing watershed area by total length of streams in watershed and converting to raster where value_field = stream density. Raw data reclassified to five classes using natural breaks algorithm.

1.3. Sensitive Karst Feature Density

1.3.1. Data Sources: Caves (WVDNR); Sinkholes (USGS)

1.3.2. Cave and sinkhole coverages merged into one shapefile. Density calculated using “Kernel Density” tool where search radius = 998.95 meters and density units = square miles. Raw data reclassified to five classes using natural breaks algorithm.

1.4. Groundwater Recharge Potential

1.4.1. Topographic Index

1.4.1.1. Slope

1.4.1.1.1. Data Source: 1/3 arc-second National Elevation Dataset (USGS)

1.4.1.1.2. Calculated using “Slope” in TauDEM 3.1 tool where units = degrees and flow direction input raster derived using D-infinity method. Slope in degrees converted to radians (required for calculation of topographic index) by multiplying slope raster by $180 \div 3.14159$. Raw data reclassified to five classes using natural breaks algorithm.

1.4.1.2. Upstream Drainage Area

1.4.1.2.1. Data Source: 1/3 arc-second National Elevation Dataset (USGS)

1.4.1.2.2. Upstream drainage area (aka “flow accumulation” or “specific catchment area”) calculated using TauDEM 3.1 with D-infinity flow direction raster as input. Raw data reclassified to five classes using natural breaks algorithm.

1.4.1.3. Soil Permeability

1.4.1.3.1. Data Source: Saturated hydraulic conductivity – Jefferson County Digital Soil Survey (NRCS-SSURGO)

1.4.1.3.2. SSURGO map unit polygons converted to raster using where value_field = ksat_rep (representative value of saturated hydraulic conductivity). Raw data reclassified to five classes using natural breaks algorithm.

1.4.1.4. Topographic index calculated in Raster Calculator using formula: $\text{Ln}([\text{upstream drainage area}] / (\text{Tan}([\text{slope}] * [\text{soil permeability}])))$. Raw data reclassified to five classes using natural breaks algorithm.

1.4.2. Distance from Stream

1.4.2.1. Data Source: High-resolution National Hydrography Dataset (USGS)

1.4.2.2. Calculated in TauDEM 3.1 using rasterized streams and D-8 flow direction raster (derived from 1/3 arc-second National Elevation Dataset) as inputs. This method provides the hydrologic distance to a stream as opposed to euclidean distance. Raw data reclassified to five classes using natural breaks algorithm.

- 1.4.3. “Groundwater Recharge Potential” calculated in Raster Calculator using formula: Distance from Stream + Topographic Index. Raw data reclassified to five classes using natural breaks algorithm.
- 1.5. Hydraulic Conductivity
 - 1.5.1. Data Source: Well data in USGS Open File Report 2005-1407 “Fracture Trace Map and Single-Well Aquifer Test Results in a Carbonate Aquifer in Jefferson County, West Virginia”.
 - 1.5.2. Hydraulic conductivity calculated by dividing transmissivity by saturated thickness (= well depth-water level) and then calculating mean value throughout a given geologic formation (ave_K). Converted to raster where value_field = ave_K. Raw data reclassified to five classes using natural breaks algorithm.
- 1.6. Transmissivity
 - 1.6.1. Data Source: Well data in USGS Open File Report 2005-1407 “Fracture Trace Map and Single-Well Aquifer Test Results in a Carbonate Aquifer in Jefferson County, West Virginia”.
 - 1.6.2. Transmissivity calculated by determining mean transmissivity throughout a given geologic formation (ave_transm). Converted to raster where value_field = ave_transm. Raw data reclassified to five classes using natural breaks algorithm.
- 1.7. Source Water Protection Area
 - 1.7.1. Data Source: Source Water Assessment Program, West Virginia Bureau for Public Health, Environmental Engineering Division (2004)
 - 1.7.2. Source water protection areas converted to separate shapefiles according to class (i.e. C, NC, or NTNC). Each class then converted to separate raster where value_field = “5” for C; “3” for NTNC; and “2” for NC. Added all three rasters together using Raster Calculator and reclassified to 5 classes using the natural breaks algorithm.
 - 1.7.3. Scores for Source Water Protection Areas were assigned subjectively based on relative risk to water consumers within their respective area.
- 1.8. Septic System Density
 - 1.8.1. Data Source: 2005 Buildings (Jefferson County Addressing Office)
 - 1.8.2. Extracted addressable buildings from buildings shapefile using “Select by Attribute” with “layer”=A3010. Addressable building polylines converted to polygons by converting polylines to DXF format and then converting DXF file to polygons. Derived polygon centroids from polygons using Visual Basic script “Polygon to Centroid 1.1”. Extracted centroids not located within a wastewater service area and saved as shapefile. Calculated density of addressable building centroids using “Kernel Density” where search radius = 1609 meters and density units = square miles. Raw data reclassified to five classes using natural breaks algorithm.
2. Calculation of Groundwater Vulnerability Index
 - 2.1. Raw data for all variables were reclassified to a scale of 1-5 in relation to impact on groundwater vulnerability using the Jenks natural breaks classification method in ESRI ArcGIS Desktop. The natural breaks method is most suitable for data that does not possess a statistically normal distribution. The reclassification process allows for data to be indexed to common scale where data layers can then be added together to form a cumulative index.
 - 2.2. Groundwater Vulnerability (output grid: [grdwtr_vul08u]) = [Population Density] + [Stream Density] + [Karst Feature Density] + [Groundwater Recharge Potential] + [Hydraulic Conductivity] + [Transmissivity] + [Source Water Protection Areas] + [Septic Density]
 - 2.3. Groundwater Vulnerability output [grdwtr_vul08u] indexed to a scale of 1-10 by dividing the maximum value by the product of the maximum value times 0.1 (output grid: [grdwtr_vul08i]).
 - 2.4. Indexed output [grdwtr_vul08n] then reclassified to a value of “1” for moderately vulnerable areas and to a value of “2” for highly vulnerable areas (output grid: [grdwtr_vul08r]) using a 10 class natural breaks classification where classes 8-9 were classified as “moderately vulnerable” and class 10 as “highly vulnerable” per Planning Department staff recommendation.