

# STUDY PROCEDURES

## GROUND-WATER AQUIFER SENSITIVITY ASSESSMENT

### Review of Assessment Techniques

The goal in selecting an assessment technique was to select the most sophisticated technique (thereby allowing the incorporation of all relevant information), which could be utilized with existing and readily available data. Future maintenance and updating had to be considered as well as the level of expertise required to use the technique. Specifically, the model should: 1) accommodate regional areas as small as those represented by USGS 7.5 minute topological maps, 2) use readily available data, and 3) allow subsequent updates to be undertaken without high level expertise. In September 1993, the U.S. Environmental Protection Agency (EPA) released *A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination* (USEPA 1993). It provides a comprehensive evaluation of numerous techniques and methods, each method reviewed in terms of information required, expertise level necessary, intended uses, and experiences of applications that had been performed. Based on this evaluation and local and state considerations of available information, technical expertise required, and need for future updating, the DRASTIC method was selected. The method was designed as a true aquifer sensitivity method and allowed for modification.

### DRASTIC Model Modification

The DRASTIC model rates relative sensitivity of land units by integrating information on vadose zone geology, soils, recharge, hydraulic conductivity, slope, aquifer media, and depth to ground water in determining a ranking of ground-water sensitivity. It was designed to allow flexibility so that the local hydrogeological setting and its parameters could be weighted appropriately. The hydrogeological setting is defined by the spatial representation of designated mappable units. The mappable units incorporate the major hydrogeological factors which affect and often control ground-water movement. Thus, the modifications to DRASTIC were incorporated in both the selection of and weighting of these factors.

### Hydrologic Parameters and Data Acquisition

The hydrogeological factors are depth to the water table (D), net recharge to the aquifer (R), aquifer media (A), soil media (S), topography (T), impact of the vadose zone (I) and hydraulic conductivity of the aquifer (C). These factors, or parameters, comprise the acronym DRASTIC. Each parameter is described as follows.

#### Depth-to-Water Table (D)

Depth to water refers to the depth from the land surface to the surface of the saturated zone in an unconfined aquifer or to the top of the confined aquifer. The data for the depth to water parameter were derived from the USGS Ground-Water Site Inventory Database (GWSI). The database is maintained by the USGS and contains information for nearly all areas of the state. These ground-water sites (wells) are selected for monitoring that provided an ability to acquire ongoing information, where the well's construction information was known, and that provided a good spatial dispersion. Well monitoring is performed by USGS staff and cooperators assuring quality information. The GWSI database includes local well identification numbers; latitude and longitude locations for each well; well construction information such as depth of well, diameter, casing, date of construction, aquifer code, and others; depth to the water table; and date of each measurement. Most sites are measured annually with selected sites measured more frequently. EBID provides monthly water-level data to GWSI for 41 wells in the Mesilla Valley.

The information was extracted from the state USGS computer site with the assistance of USGS personnel by defining the area desired and the GWSI parameters to be included in the selection. The resulting file was

transferred from the USGS computer to the WRRI computer. The file was imported into database file (dbf) format and was further manipulated in this form.

For the depth-to-water table parameter, the latitude and longitude coordinates, and the depths to water for water wells in the Mesilla Valley and surrounding area including northwest El Paso County, Texas were used to create a water depth contour map. This database contained 797 observation sites with 10,204 depth to water table measurements. The measurements' dates spanned the period from the mid-1950s through 1994 with most sites being measured annually and selected sites measured more frequently. To develop a GIS coverage that represented the parameter, a single measurement for each site was selected. A selection was made from the database of sites having measurements within the last five-year period (January 1, 1990-December 31, 1994). This resulted in 242 sites. The most recent measurement was selected from this set. The water depth ranged from less than 5 feet to greater than 300 feet (Wilkins and Garcia 1995).

The site locations (latitude and longitude) were converted to decimal degrees. The database was then imported into ARC/INFO format and reprojected from the Geographic Coordinate System to the Universal Transverse Mercator coordinate system. To ensure sufficient data points throughout the study area, additional information from the Texas well database provided by the Texas Water Development Board was incorporated into the database.

To develop the depth-to-water contour coverage, the geostatistical technique of kriging was used. Kriging is a commonly used statistical technique to estimate the regional distribution of model values based upon scattered data points or measurements (Davis 1986). The gaussian semivariogram kriging model was utilized since it best represented the data. The next step was to create a polygon coverage (latticepoly) that represented areas of water-level depths based on attribute values. The depth-to-water table interval range, and the DRASTIC rating, weight, and resulting index are listed in Table 1.

Table 1. Depth-to-water table parameter rating (Dr), weight (Dw), and index (D)

Range <sup>1</sup> (feet)	Rating <sup>1</sup> (Dr)	Weight <sup>2</sup> (Dw)	Index (D)
0-5	10	5	50
5-10	9	5	45
10-20	8	5	40
20-30	7	5	35
30-50	5	5	25
50-70	3	5	15
70-100	2	5	10
100+	1	5	5

<sup>1</sup> Modified for local conditions from Aller et al, 1985, table 4.

<sup>2</sup> From Aller et al, 1985, table 3.

### Net Recharge (R)

The primary source of ground water is precipitation and seepage from losing streams that infiltrate through the unsaturated zone to the water table. Net recharge indicates the amount of water per unit area of land which penetrates the ground surface and reaches the water table. The Mesilla Valley lies within an arid region where evapotranspiration exceeds regional precipitation. Therefore, the only significant potential recharge to the aquifer is through deep percolation resulting from agricultural irrigation, and infiltration from losing-water bodies such as the Rio Grande, irrigation canals and drains.

To depict this recharge parameter, it was necessary to separate agricultural areas from nonagricultural areas. This was accomplished by using two digital land use maps (El Paso and Las Cruces quads of the scale 1:250,000) for the geographic area. These digital land use maps were acquired from the USEPA over the internet. Level 1 land use codes (Anderson et al. 1976) were utilized to classify the maps (Table 2). Potential net recharge for non-irrigated land is considered to be between zero and 2 inches per unit area (Frenzel and

Kaehler 1990). Potential net recharge of irrigated land and water bodies is considered to be in excess of 10 inches per unit area (Frenzel and Kaehler 1990). All agricultural land in the area receives irrigation water for successful crop production. Urban and built-up areas, rangeland, and barren land were assigned a rating of 1. Agricultural areas, water bodies, and wetlands were assigned a rating of 9. This digital map was clipped to match the project study area and to provide the coverage for the net recharge parameter.

Table 2. Net recharge parameter rating (Rr), weight (Rw), and index (R)

Land Use Code <sup>1</sup>	Land Use <sup>1</sup>	Rating (Rr) <sup>2</sup>	Weight (Rw) <sup>3</sup>	Index (R)
1	Urban or Built-Up Land	1	4	4
2	Agricultural Land	9	4	36
3	Rangeland	1	4	4
4	Forest Land	1	4	4
5	Water	9	4	36
6	Wetland	9	4	36
7	Barren Land	1	4	4

<sup>1</sup> USGS land use and land cover classification system for use with remote sensor data (modified from Anderson et al. 1976).

<sup>2</sup> Modified for local conditions from Aller et al, 1985, table 5.

<sup>3</sup> From Aller et al, 1985, table 3.

### Aquifer Media (A)

The shallow aquifer system in the Mesilla Valley is made up of the saturated part of the inner-valley fill, and channel sands and gravels in underlying beds of the Camp Rice Formation (Strain 1966) of the Upper Santa Fe Group (Hawley et al. 1969; Seager et al. 1971, 1976, 1982, 1987; Hawley 1975, 1978; Gile et al. 1981; Gustavson 1991) that were deposited by an ancestral Rio Grande during the mid to late Pliocene interval of basin filling.

The Santa Fe Group and the Rio Grande floodplain alluvium constitute the major aquifer for the valley and together are referred to as the “basin-fill deposits” in the USGS Open File Report 88-305 (Frenzel and Kaehler 1990). The stratigraphy, lithology, and geologic history of the Santa Fe Group and younger units were described by Hawley and others (1969), Seager and others (1971), Hawley (1975), Lovejoy and Hawley (1978), and Seager and others (1984). The basin-fill primarily consists of sands and gravels, with intermittent over-bank clay deposits.

To depict the aquifer media parameter, the 1:500,000 scale 1993 surface geology digital map (Dane and Bachman 1965) was clipped to match the project study area and reclassified to differentiate between the unconsolidated alluvium (Qal), basin-fill deposits (Qab), basalt flows (Qb) and cones, the Santa Fe Group (QTs), and the generally consolidated bedrock of the pre-Santa Fe Group. The alluvium is composed primarily of floodplain deposits consisting of channelized sands and gravels, with intermittent over-bank clay deposits. The basin-fill deposits consist of thin discontinuous cover of alluvial sands, gravels, and clays; eolian sands; and lacustrine deposits that overlie the Santa Fe Group. The basalt flows and cones generally postdate the Santa Fe Group and are limited in areal extent. The Santa Fe Group consists of unconsolidated to moderately consolidated sedimentary deposits, minor ash-fall volcanoclastics, and some volcanic rocks. The sedimentary deposits comprise lacustrine deposits of alternating layers of sand and clay; alluvial-fan deposits composed of sand, gravel, silt, and clay; and fluvial-facies composed of sand with lenses of gravel, silt, clay and sandy clay. The fluvial-facies are the most extensive deposits and contain most of the fresh water in the basin. These classes were assigned the DRASTIC ratings and weight listed in Table 3.

Table 3. Aquifer media parameter rating (Ar), weight (Aw) and index (A)

Ptype <sup>1</sup>	Aquifer media <sup>1</sup>	Rating (Ar) <sup>1</sup>	Weight (Aw) <sup>2</sup>	Index (A)
Qab	Sand and gravel w/silt and clay	6	3	18
Qal	Sand and gravel w/silt and clay	6	3	18
Qb	Basalt	9	3	27
QTs	Sand and gravel w/silt and clay	6	3	18
pQTs	pre-Santa Fe Group rocks	4	3	12

<sup>1</sup> Modified for local conditions from Aller et al, 1985, table 6.

<sup>2</sup> From Aller et al, 1985, table 3.

### Soil Media (S)

In general, a soil's pollution potential is affected largely by the type and amount of clay present, the shrink/swell potential (controlling the development of macropores and other secondary permeability features), and the soil's grain size. The DRASTIC index includes soils ratings appropriate for the pollution potential associated with development of secondary permeability.

The data were acquired from the NRCS state office in Digital Line Graph (DLG) format (USGS 1990). The data received included database files that contained information concerning soil characteristics and an individual DLG file for each 1:24,000 (7.5 minute) Quadrangle map for Doña Ana County.

The soil coverage was developed by NRCS using the GRASS mapping system. These files were then imported into ARC/INFO and modified so that the attribute database would contain the Map Unit Symbol and Map Unit Name for each soil series. Based on the soil characteristics of the Map Unit Symbol (soil classification contained in the Soil Survey of Doña Ana County Area, New Mexico 1980), values were assigned as specified by the DRASTIC model (Aller et al. 1985, p. 8-9). The selection of a value for the parameter was based on the most restrictive soil zone that occurred in the profile. The DRASTIC values for the parameter were then attached to the database. Table 4 contains the soil media and DRASTIC rating, weight and resulting index.

Table 4. Soil media parameter rating (Sr), weight (Sw) and index (S)

Soil Media <sup>1</sup>	Rating (Sr) <sup>1</sup>	Weight (Sw) <sup>2</sup>	Index (S)
Basalt	1	5	5
Caliche	1	5	5
Carbonate Hardpan	1	5	5
Carbonate-cemented	1	5	5
Clay	1	5	5
Clay Loam	3	5	15
Dumps	1	5	5
Gravel	10	5	50
Gravel Pit	1	5	5
Lime-coated Basalt	1	5	5
Limestone Bedrock	1	5	5
Loam	5	5	25
Loamy Sand	8	5	40
Rock Outcrop	1	5	5
Sand	9	5	45
Sandy Clay	2	5	10
Sandy Clay Loam	4	5	20
Sandy Loam	7	5	35
Silt	4	5	20
Silty Clay	2	5	10
Silty Loam	5	5	25
Thin or Absent	1	5	5
Water	10	5	50
Outside of Soil Survey	1	5	5

<sup>1</sup> Modified for local conditions from Aller et al, 1985, table 7.

<sup>2</sup> From Aller et al, 1985, table 3.

## Topography (T)

The topography coverage was derived from USGS Digital Elevation Model (DEM) files obtained over the Internet. A DEM consists of an array of elevations for ground positions that are usually at regularly spaced intervals. The 1-degree DEM provides coverage in 1- by 1-degree blocks and is available for all of the contiguous United States, Hawaii, and most of Alaska. The basic elevation model is produced by the Defense Mapping Agency (DMA) using cartographic and photographic sources.

The 1-degree DEM consists of a regular array of elevations referenced horizontally on the geographic coordinate (latitude/longitude) system of the World Geodetic System 1984 Datum. Elevation data located on the degree lines (all four sides) correspond to the same profiles on adjoining DEM blocks. Elevations are in meters relative to mean sea level. Spacing of the elevations along and between each profile is at 3 arc-seconds with 1,201 elevations per profile.

The DEMs for the 1:250,000 scale Las Cruces and El Paso quads were acquired and imported into ARC/INFO using the function 'demlattice.' The two lattices were then merged into one large lattice that was then clipped by a coverage of the study area. The lattice coverage was then used to derive a polygon coverage that represented the slope (or topography) for the study area. The latticepoly command used a lookup table to assign codes to the range in slope. This code was then used to attach a DRASTIC parameters database to the coverage. The topography rating, weight, and index are listed in Table 5.

Table 5. Topography parameter rating (Tr), weight (Tw), and index (T)

Range (Percent Slope)	Rating (Tr)	Weight (Tw) <sup>1</sup>	Index (T)
0-2	10	3	30
2-6	9	3	27
6-12	5	3	15
12-18	3	3	9
18+	1	3	3

<sup>1</sup> From Aller et al, 1985, table 3.

## Impact of the Vadose Zone Media (I)

The lithology of the vadose zone is made up of the unsaturated part of the inner-valley fill, and channel sands and gravels in underlying beds of the Camp Rice Formation (Strain 1966) of the Upper Santa Fe Group (Hawley et al. 1969; Seager et al. 1971, 1976, 1982, 1987; Hawley 1975, 1978; Gile et al. 1981; Gustavson 1991) that were deposited by an ancestral Rio Grande during the mid to late Pliocene interval of basin filling. The vadose zone media ratings, weights and index are listed in Table 6.

Table 6. Vadose zone media parameter rating (Ir), weight (Iw) and index (I)

Ptype <sup>1</sup>	Vadose Zone Media <sup>1</sup>	Rating (Ir) <sup>1</sup>	Weight (Iw) <sup>2</sup>	Index (I)
Qab	Sand and gravel w/silt and clay	6	4	24
Qal	Sand and gravel w/silt and clay	6	4	24
Qb	Basalt	9	4	36
QTs	Sand and gravel w/silt and clay	6	4	24
pQTs	Pre-Santa Fe group	4	4	16

<sup>1</sup> Modified for local conditions from Aller et al, 1985, table 9.

<sup>2</sup> From Aller et al, 1985, table 3.

## Hydraulic Conductivity of the Aquifer (C)

The hydraulic conductivity coverage was derived from work that had been conducted for the City of Las Cruces Wellhead Protection Program (Hanson et al. 1994) and from the ground-water modeling work for the Mesilla Basin (Frenzel and Kaehler 1990). A digital file that contained spatial representation of areas with similar hydraulic conductivity was imported into ARC/INFO and modified.

The first modification of the file included assigning geographic control points so that the coverage could be

rotated and projected into the UTM coordinate system. The second involved modifying the “K” values originally assigned to the polygons representing hydraulic conductivity. These values were multiplied by a conversion factor that would match the requirements for the hydraulic conductivity parameter for the DRASTIC model (Aller et al. 1985, p. 8-9). The DRASTIC values for the parameter were then attached to the attribute database for analysis. The original file contained the hydraulic conductivity values in K units. Table 7 below contains the transformed values and the DRASTIC rating, weight, and index.

Table 7. Hydraulic conductivity of the aquifer parameter rating (Cr), weight (Cw), and index (C) ( $\text{gpd}/\text{ft}^2 = 7.48 * K (\text{ft}/\text{day})$ )

Zone	Hydraulic Conductivity <sup>1</sup> (ft/day)	Hydraulic Conductivity (gpd/ft <sup>2</sup> )	Rating (Cr)	Weight <sup>2</sup> (Cw)	Index (C)
K1	140.0	1047.20	5	2	10
K2	70.0	523.60	4	2	8
K3	22.0	164.56	2	2	4
K4	18.0	136.64	2	2	4
K5	11.0	82.28	1	2	2
K6	4.5	33.66	1	2	2
K7	0.0	0.00	1	2	2

<sup>1</sup> From Frenzel and Kaehler 1990, Fig. 20, p. 49

<sup>2</sup> From Aller et al, 1985, table 3.

### Combining DRASTIC Parameter Coverages

Data tables containing the index values and parameter ranges are joined to the feature attribute table for each parameter coverage based upon the range value classification. To aid in interpreting and evaluating the natural sensitivity assessment, a GIS layer was developed for each parameter.

The seven parameter coverages were combined together by geometric intersection of the polygon coverages. All polygons from the seven coverages were split at their intersections and preserved in the output coverage. The output coverage contained the combined polygons and feature attribute tables of all seven coverages. For each polygon the feature attribute table generated contained a field for each DRASTIC parameter index value and the area of each polygon. To obtain the final (combined) DRASTIC index values, a new field was created in the feature attribute table of the natural sensitivity (NATSEN) coverage. This NATSEN index was calculated by summing the DRASTIC parameters and placing the result in the field. The weights assigned for the purpose of combining the parameters are those recommended for an agricultural application of the model (Aller et al. 1985). Table 8 lists the weights for each of the DRASTIC parameters.

Additional analysis was performed to create a table that contained the combined DRASTIC values, frequency of occurrence, and the summation of the area for each value. Bar graphs of the combined DRASTIC value-frequency and DRASTIC value-area were created in order to assist in grouping the index values into ranges of sensitivities.

Table 8. Assigned weights for combining DRASTIC parameters (from Aller et al. 1985, Table 3)

DRASTIC parameter	Weight
Depth-to-water table	5
Net recharge	4
Aquifer media	3
Soil media	5
Topography	3
Impact of the vadose zone	4
Hydraulic conductivity	2