Vulnerability Assessment

VULNERABILITY

As used in this report, *vulnerability* refers to the sensitivity of groundwater to contamination, and is determined by intrinsic characteristics of the aquifer. It is distinct from *pollution risk*, which depends not only on vulnerability but also on the existence of pollutant loading. The seriousness of the impact on water use depends on the extent and magnitude of the pollution episode and the value of the groundwater resource.

DRASTIC

The EPA developed DRASTIC to be a standardized system for evaluating groundwater vulnerability to pollution. The primary purpose of DRASTIC is to provide assistance in resource allocation and prioritization of many types of groundwater-related activities and to provide a practical educational tool.

The method has four assumptions:

1. the contaminant is introduced at the ground surface;
2. the contaminant is flushed into the groundwater by precipitation;
3. the contaminant has the mobility of water;
4. the area being evaluated by DRASTIC is 100 acres or larger.

DRASTIC was not designed to deal with pollutants introduced in the shallow or deep subsurface by methods such as leaking underground storage tanks, animal waste lagoons, or injection wells. The methodology is not designed to replace on-site investigations or to locate any type of facility or practice. For example, DRASTIC does not reflect the suitability of a site for waste disposal. Although DRASTIC may be one of many criteria used in siting decisions, it should not be the sole criterion.

DRASTIC considers seven hydrogeologic factors, which are described below:

Depth to Water (D): The depth to water is the distance, in feet, from the ground surface to the water table. It determines the depth of material through which a contaminant must travel before reaching the aquifer. Thus, the shallower the water depth, the more vulnerable the aquifer is to pollution.

Net ***R***echarge (R): The primary source of recharge is precipitation, which infiltrates through the ground surface and percolates to the water table. Net recharge is the total quantity of water per unit area, in inches per year, which reaches the water table. Recharge is the principal vehicle for leaching and transporting contaminants to the water table. The more the recharge, the greater the chance for contaminants to reach the water table.

Aquifer Media (A): Aquifer media refers to the consolidated or unconsolidated rock that serves as an aquifer. The larger the grain size and the more fractures or openings within the aquifer, the higher the permeability, and thus vulnerability, of the aquifer. In unconsolidated aquifers, the rating is based on the sorting and amount of fine material within the aquifer. In consolidated aquifers, the rating is based on the amount of primary porosity and secondary porosity along fractures and bedding planes.

Soil Media (S): Soil media is the upper weathered zone of the earth, which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge that can infiltrate into the ground. In general, the less the clay shrinks and swells and the smaller the grain size of the soil, the less likely contaminants will reach the water table.

Topography (T): Topography refers to the slope of the land surface. Topography helps control the likelihood that a pollutant will run off or remain long enough to infiltrate through the ground surface. Where slopes are low, runoff is small, and the potential for pollution is greater. Conversely, where slopes are steep, runoff capacity is high and the potential for pollution to reach groundwater is lower.

Impact of the Vadose Zone Media (I): The vadose zone is the unsaturated zone above the water table. The texture of the vadose zone determines the time of travel of the contaminant through it. In surficial aquifers, the ratings for the vadose zone are generally the same as the aquifer media. Sometimes a lower rating is assigned if the aquifer media is overlain by a less permeable layer such as clay.

Hydraulic ***C***onductivity of the Aquifer (C): Hydraulic conductivity refers to the rate at which water flows horizontally through an aquifer. The higher the conductivity, the more vulnerable the aquifer.

Each of the seven DRASTIC hydrogeologic factors is assigned a rating from 1-10 based on a range of values. The ranges and ratings for each hydrogeologic factor are listed in Appendix B. The ratings are then multiplied by a relative weight ranging from 1-5. The most significant factors have a weight of 5; the least significant have a weight of 1.

The equation for determining the DRASTIC index is:

$$D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w = \text{DRASTIC Index}$$

where the letters *D*, *R*, *A*, *S*, *T*, *I*, *C* represent the seven hydrogeologic factors, *r* designates the rating, and *w* the weight. An example DRASTIC calculation is shown in Table 2. The smallest possible DRASTIC index rating is 23, and the largest is 226.

The resulting DRASTIC index represents a relative measure of groundwater vulnerability. The higher the DRASTIC index, the greater the vulnerability of the aquifer to contamination. A site with a low DRASTIC index is not free from groundwater contamination, but it is less susceptible to contamination compared with the sites with high DRASTIC indices.

Table 2. DRASTIC ranges, ratings, numbers, and index calculation for the Ogallala hydrogeologic basin

HYDROGEOLOGIC BASIN: Ogallala				
HYDROGEOLOGIC FACTOR	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water (ft)	>100	5	1	5
Net **R**echarge (in/yr)	0-2	4	1	4
Aquifer Media	sand and gravel	3	7	21
Soil Media	clay loam to fine sandy loam, and loamy fine sand	2	5	10
Topography (% slope)	0-2	1	10	10
Impact Vadose Zone	sand and gravel with silt, clay & caliche	5	6	30
Hydraulic **C**onductivity (gpd/ft^2)	100-300	3	2	6
		DRASTIC Index		86

For a complete discussion of the DRASTIC method, refer to the EPA publication *DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings* by Aller and others (1987).

METHODOLOGY

Each hydrogeologic basin was evaluated in terms of DRASTIC's seven hydrogeologic factors. One rating for each factor was assigned to each hydrogeologic basin, and one DRASTIC index was calculated for each basin. The ArcView (ESRI, 1997) Geographic Information System (GIS) was used to compile the geospatial data, to compute the DRASTIC indices, and to generate the final vulnerability map. The DRASTIC ranges, ratings, numbers, and indices for each hydrogeologic basin are listed in Appendix C.

Depth to water (D) was determined for each hydrogeologic basin from the average depth to the first water zone, obtained from the OWRB database of well drillers' logs. Figure 4 shows the DRASTIC ratings for depth to water, by basin. Average depth to water ranges from 15-30 feet in alluvium and terrace deposits to greater than 100 feet in the Ogallala basin.

Net recharge (R) rates for the basins were obtained from the literature; when not available in the literature, rates were estimated based on those of basins with similar lithology, topography, and

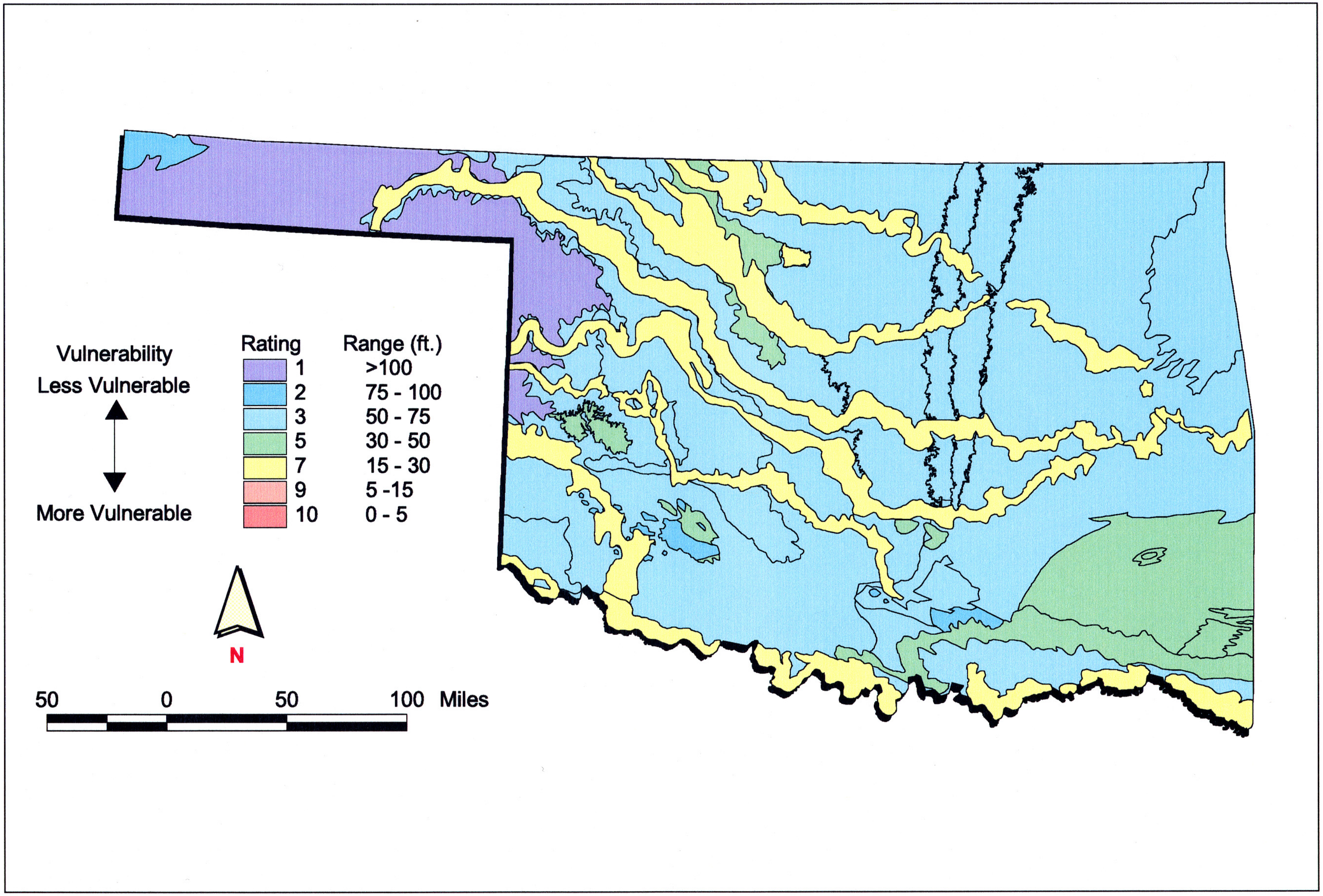

Figure 4. Map showing DRASTIC ratings for depth to water (D), by hydrogeologic basin.

climatic conditions. As can be seen in Figure 5, recharge rates for most of the basins are in the ranges of 0-2 and 2-4 inches per year. Estimated recharge rates for the Boone and Arbuckle-Simpson basins are 4-7 inches per year.

Information on aquifer media (A) and impact of the vadose zone media (I) was obtained from groundwater basin studies and the hydrologic atlases of Oklahoma. Because all of the hydrogeologic basins in this study are exposed at the surface, the ratings for these factors are the same unless data were available suggesting that the permeability in the shallow portion of the basin differs from deeper portions. The Ogallala basin, for example, has layers of caliche in the unsaturated zone that make the vadose zone less permeable than the deeper, saturated portion of the aquifer. DRASTIC ratings for aquifer media and the impact of the vadose zone are shown in Figures 6 and 7. Ratings assigned to the hydrogeologic basins range from 2 for the basins composed of igneous rocks, to 10 for the cavernous Blaine basin in southwestern Oklahoma.

The DRASTIC rating for soil media (S) was determined with soil information from the U.S. Department of Agriculture's State Soil Geographic Database (STATSGO), represented on a 1:250,000-scale map. Twenty-four surface texture classifications were identified in Oklahoma from the STATSGO data, and are displayed in Figure 8.

The soil textures were assigned a DRASTIC rating based on thickness, type of clay, texture, and permeability. Map units with soil textures of weathered and unweathered bedrock were generally less than 10 inches thick, as determined from the depth to bedrock. In accordance with the DRASTIC methodology, they were classified as thin or absent, and assigned a rating of 10. The clay and silty clay surface textures were evaluated in terms of their shrink/swell potential and were found to have a moderate to very high shrinkage rate. Following DRASTIC methodology, they were assigned a rating of 7. The surface texture classifications that did not directly correspond to a DRASTIC soil type were evaluated in terms of permeability. Most of the gravelly soils have moderate permeability rates of 0.6-2.0 inches per hour, and were assigned a DRASTIC rating of 5. The classifications for soil surface textures and the assigned DRASTIC ratings are listed in Table 3.

After a DRASTIC rating was assigned to each soil texture, a representative DRASTIC rating was assigned to each hydrogeologic basin. To do this, ArcView GIS software computed the area-weighted average of the DRASTIC soil media ratings by basin, and generated histograms for each basin so that the modal distribution of the soil media ratings could be evaluated. In most basins, the area-weighted average was used. However, the soil media ratings did not follow normal distribution in the North Fork of the Red River, Cretaceous, and Tishomingo Granite basins. In these basins, higher DRASTIC ratings reflecting the more vulnerable soils were assigned instead of the weighted average.

Figure 9 illustrates how the DRASTIC soil media rating for the Boone hydrogeologic basin was determined. As displayed graphically and in map view, DRASTIC ratings of 3, 4, and 5 were assigned based on soil texture. The area-weighted average of the soil ratings for the basin is 4.8. Although not normally distributed, a soil media rating of 5 was determined to represent the basin.

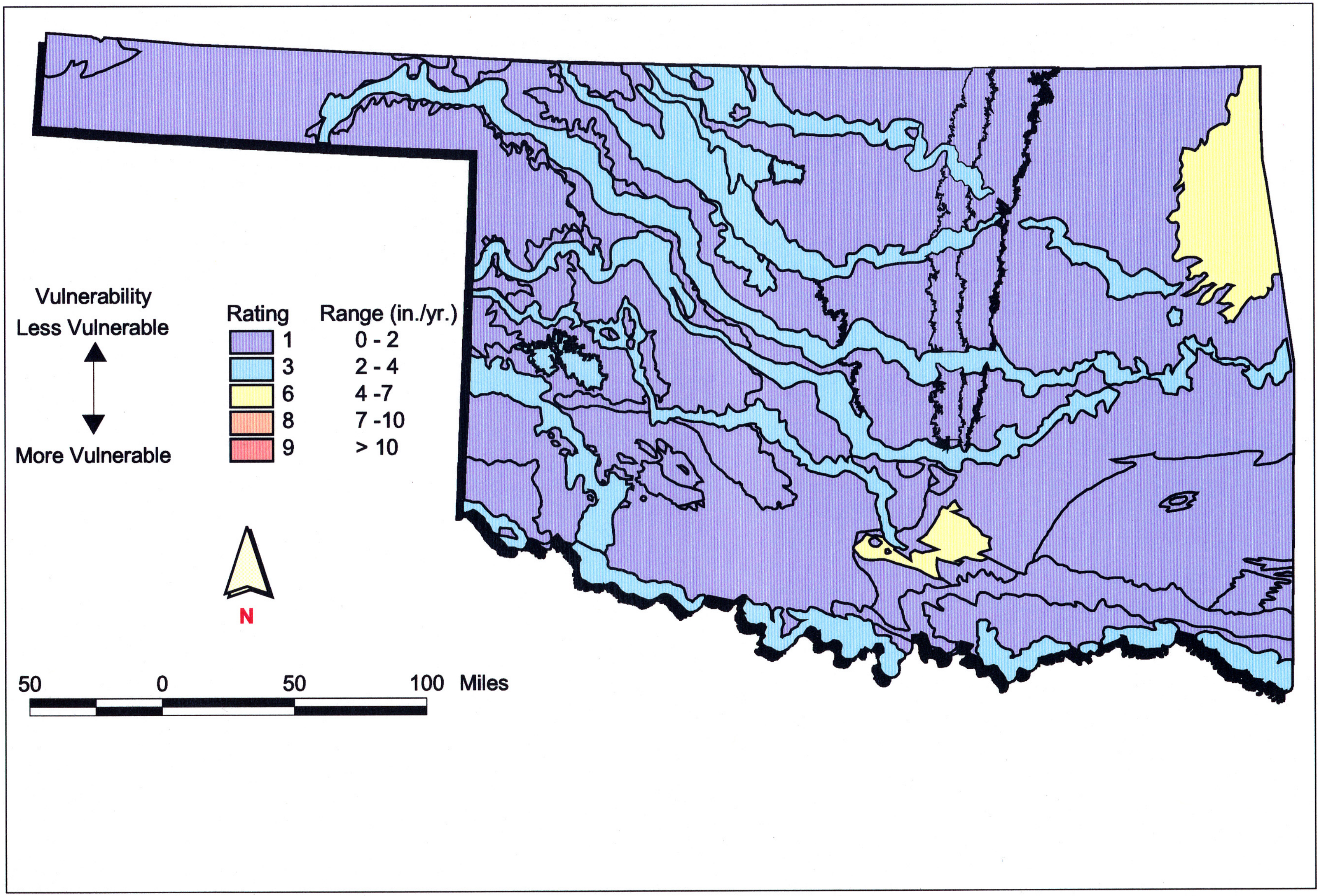

Figure 5. Map showing DRASTIC ratings for net recharge (R), by hydrogeologic basin.