School of Geography and Development
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GROUNDWATER POLLUTION POTENTIAL IN PINAL COUNTY, ARIZONA USING DRASTIC METHODOLOGY

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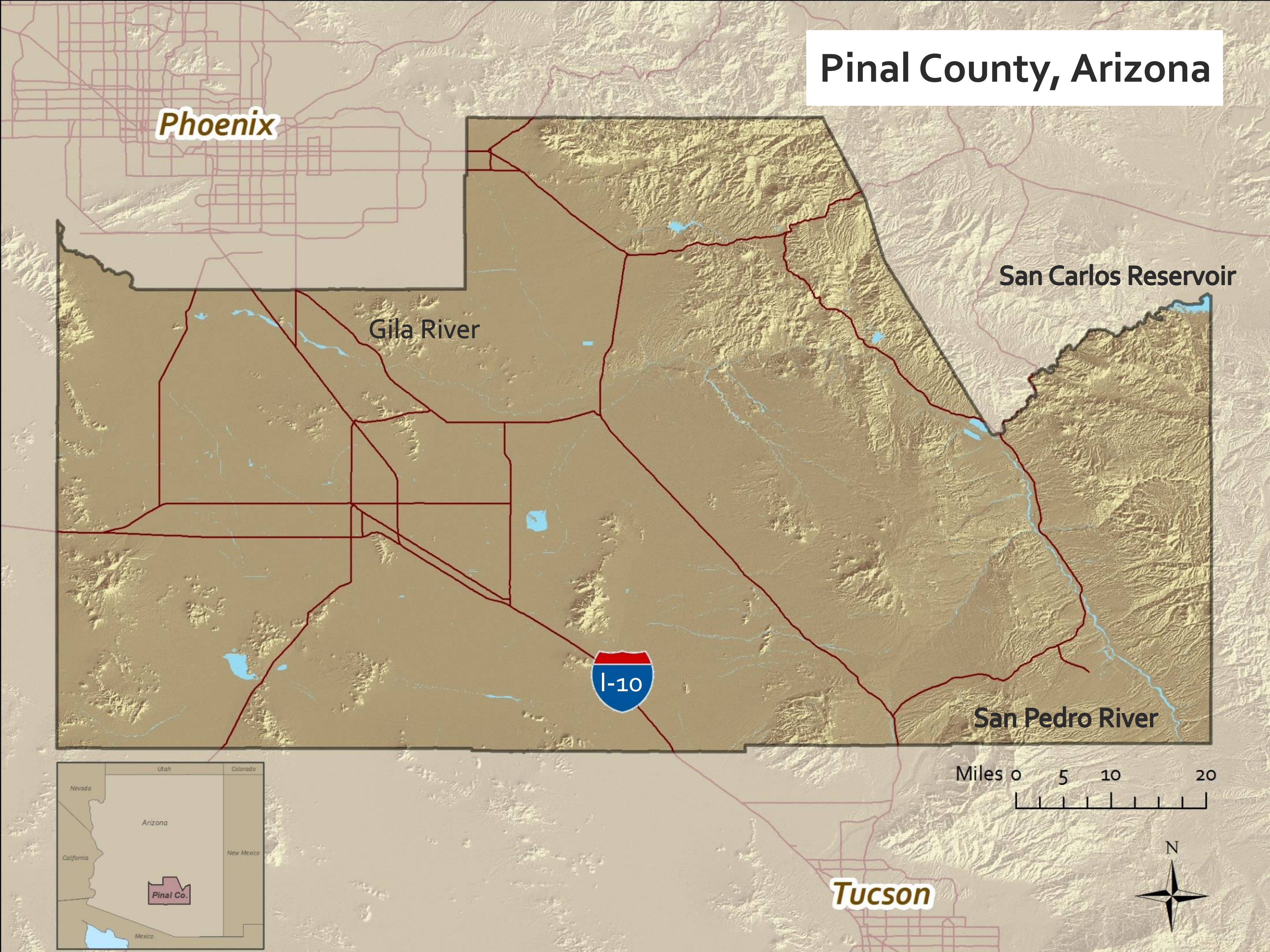
PINAL COUNTY, ARIZONA

- **Pinal County is located in southern Arizona between Phoenix and Tucson, home to approximately four hundred thousand residents.**

- **Primary land uses include irrigated farmland with mostly uninhabited desert in the northeastern mountains.**




Pinal County, Arizona
Phoenix
San Carlos Reservoir
Gila River
I-10
San Pedro River
Miles 0 5 10 20
N
Tucson
Utah
Colorado
Nevada
Arizona
California
New Mexico
Pinal Co.
Mexico

GROUNDWATER POLLUTION

- Pinal County relies heavily on irrigation to water crops in the middle of the desert.
- Pesticides and nutrient runoff can easily find their way into the drinking water of Pinal's residents.
- Land must be classified by its contamination potential before commercial or agricultural development can begin.

OBJECTIVES

Which areas of Pinal County, Arizona are most susceptible to groundwater pollution?

- Collect seven layers of hydro-geologic data
- Prepare data for DRASTIC Index System
- Assess the potential for groundwater pollution in Pinal County, Arizona

OVERVIEW

- Background
  - DRASTIC Methodology
- Data
  - Collection and Preparation
- Application of DRASTIC Index
  - Standard vs Agricultural Weight System
- Analysis and Results
- Questions

DRASTIC METHODOLOGY

- **The DRASTIC Method was developed by the EPA in 1987 as a standardized evaluation system to assess land for contamination vulnerability.**
- **Each letter of the acronym DRASTIC stands for a different hydro-geologic parameter needed for the assessment.**

D: Depth to Water

R: Net Recharge

A: Aquifer Media

S: Soil Media

T: Topography

I: Impact of the Vadose Zone

C: Hydraulic Conductivity

DRASTIC EQUATION

Each of the seven components are assigned a numerical rating based on a given ranking system for the parameter. Then they entered into the equation below to achieve a final index score.

$$(D_r * D_w) + (R_r * R_w) + (A_r * A_w) + (S_r * S_w) + (T_r * T_w) + (I_r * I_w) + (C_r * C_w)$$

r = rating of the parameter (variable)
w = weight of the parameter (constant)

EXAMPLES

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} + \begin{bmatrix} 5 & 6 \\ 7 & 8 \end{bmatrix} = \begin{bmatrix} 6 & 8 \\ 10 & 12 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \times \begin{bmatrix} 4 & 4 \\ 4 & 4 \end{bmatrix} = \begin{bmatrix} 4 & 8 \\ 12 & 16 \end{bmatrix}$$

DEPTH TO WATER

Source:

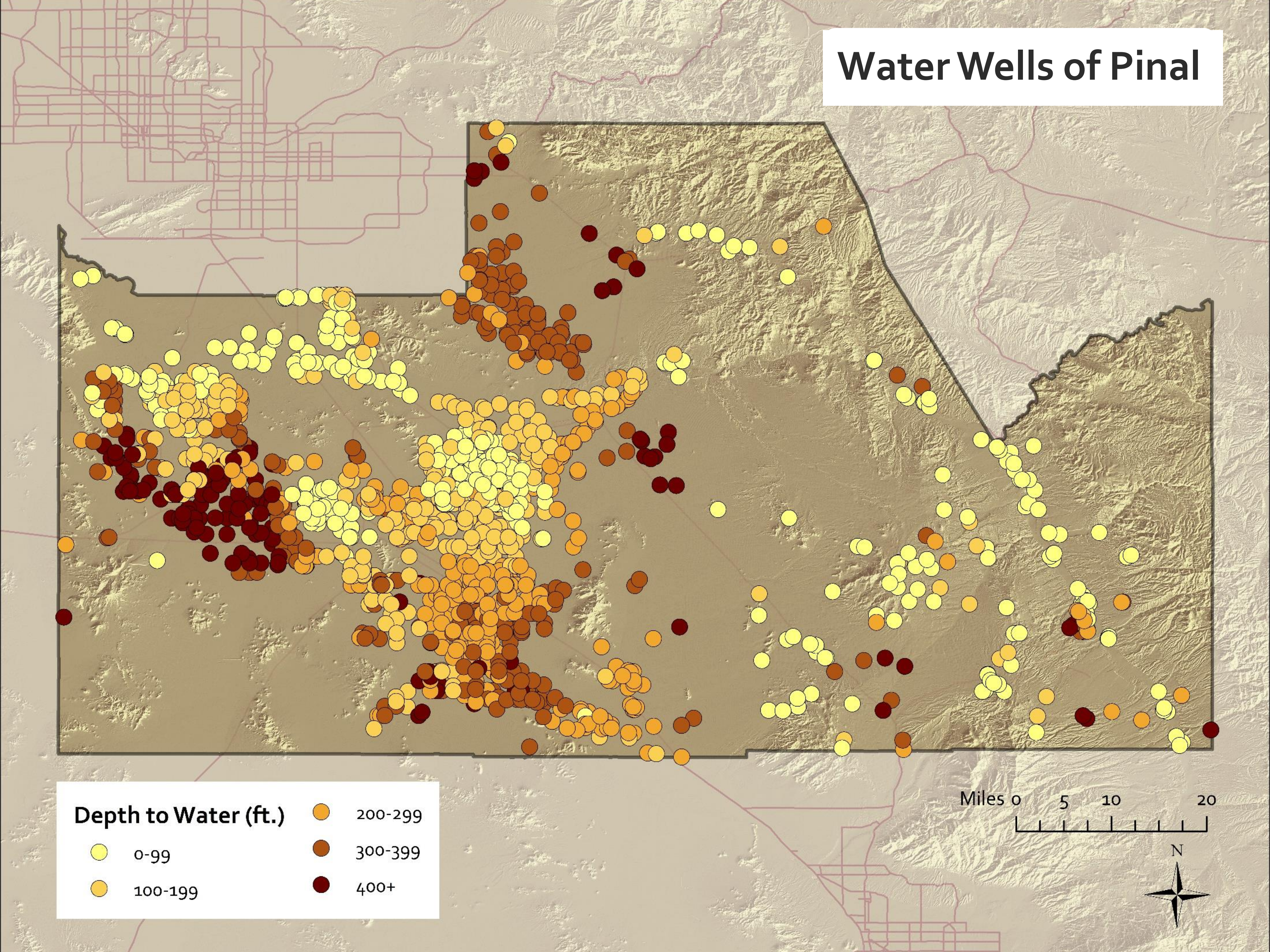
USGS Ground Water Site Inventory

Tools:

Project – WGS84
Clip – Pinal County
Kriging – Water Depth Interpolation
Reclassify – DRASTIC Rating

Preparation:

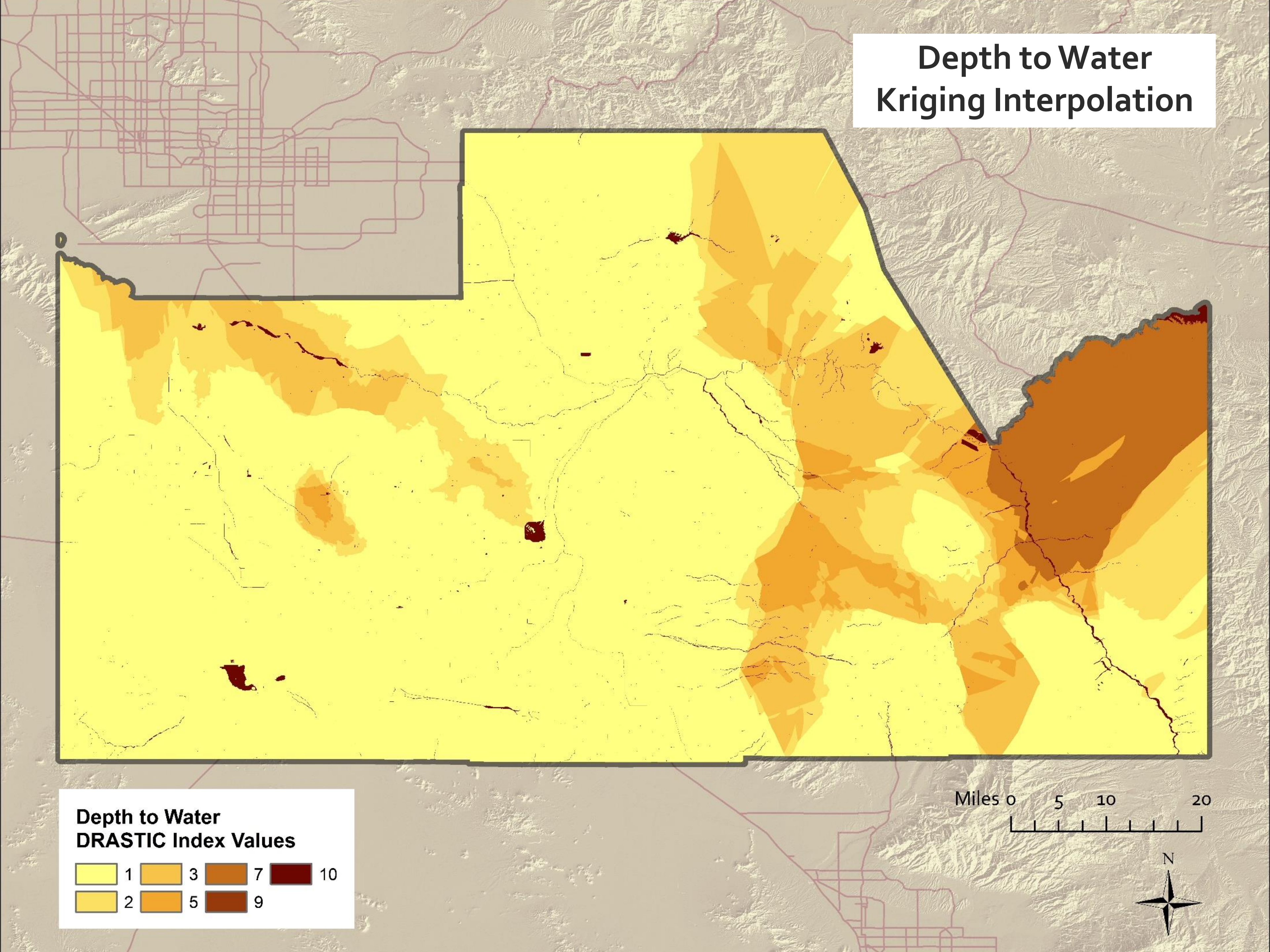
Selected wells tested for water table depth between the years of 2000 and 2013 and between the months of October and February. 1500+ wells remained.


Water Wells of Pinal
Depth to Water (ft.)
0-99
100-199
200-299
300-399
400+
Miles 0 5 10 20
N

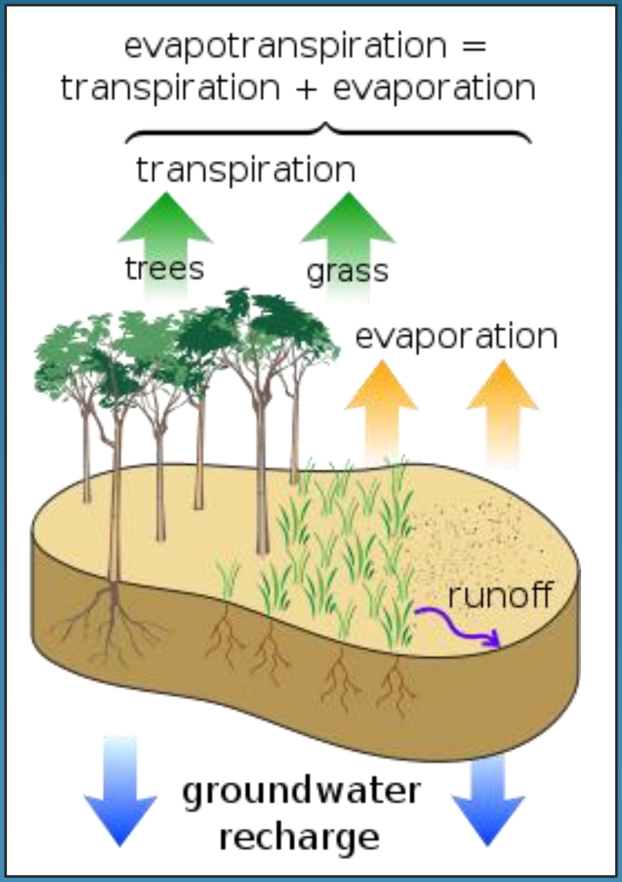
KRIGING

- Kriging is a flexible interpolator that can create a predictive surface model.
- Investigative tool that explores auto- and cross-correlation between points dependent on distance.

Range (feet)	Rating
0-5	10
5-10	9
15-30	7
30-50	5
50-75	3
75-100	1
100+	1


Depth to Water
Kriging Interpolation
Depth to Water
DRASTIC Index Values
1
2
3
5
7
9
10
Miles 0
5
10
20
N

NET RECHARGE



- Groundwater recharge is the hydrologic process where water percolates downwards from surface water to groundwater.
- In Pinal County, higher recharge levels are observed in mountainous catchment areas and irrigated cropland.

NET RECHARGE

Range (inches)	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9

Source:

US Geological Survey

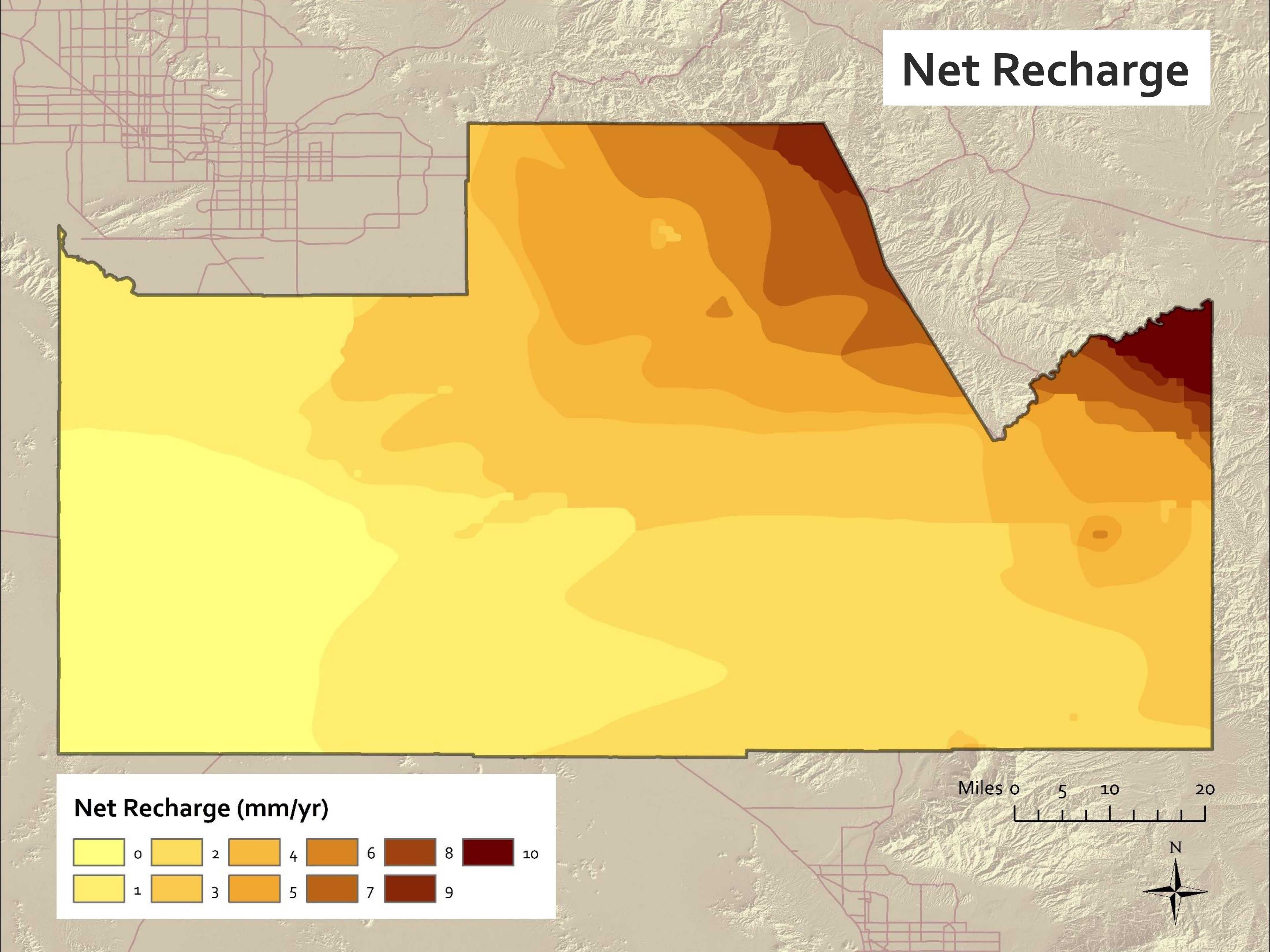
Tools:

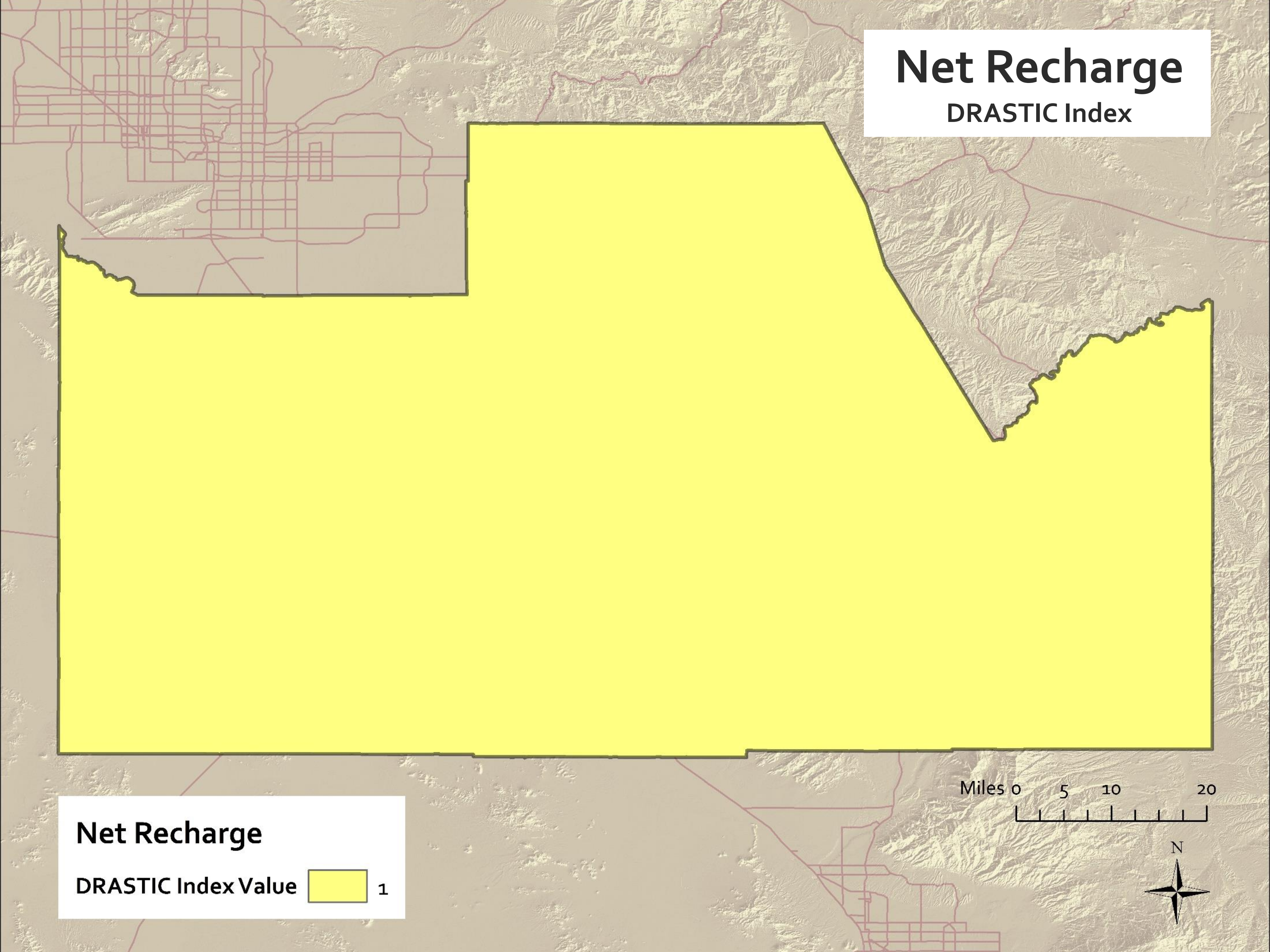
Project – WGS84
Clip – Pinal County
Smooth Polygon – PAEK Algorithm
Reclassify – DRASTIC Rating

Preparation:

Smoothed pixelated areas using the polynomial approximation with exponential kernel algorithm, converted units from millimeters to inches, reclassified the values according to its DRASTIC rating.

Net Recharge




Net Recharge
DRASTIC Index
Net Recharge
DRASTIC Index Value
1
Miles 0 5 10 20
N

AQUIFER MEDIA

Source:

DRASTIC Analysis…Pinal County Report, Moulton 1992

Tools:

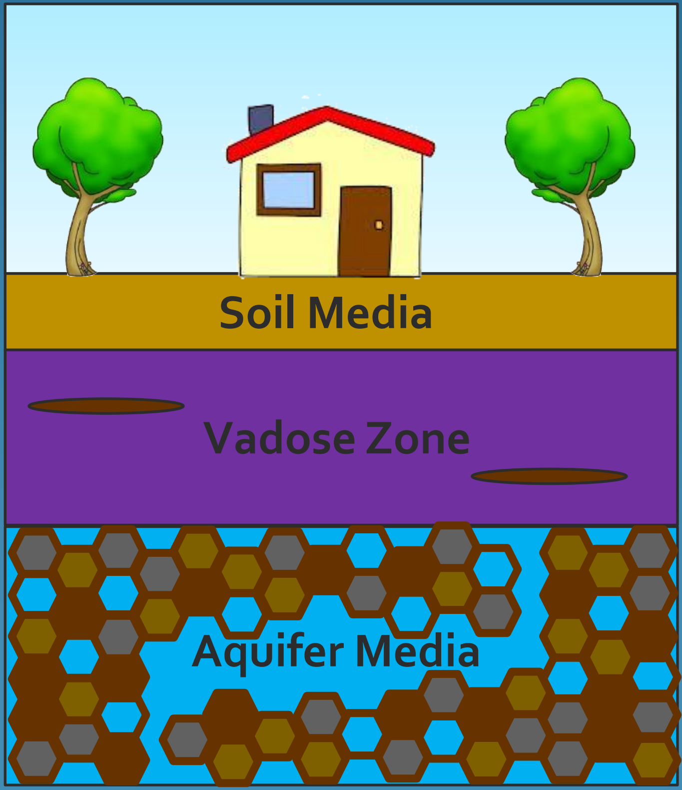
Georeferencing

- Transform using second order polynomial
- RMSE of 0.00133
- Rectify

Define projection – WGS84

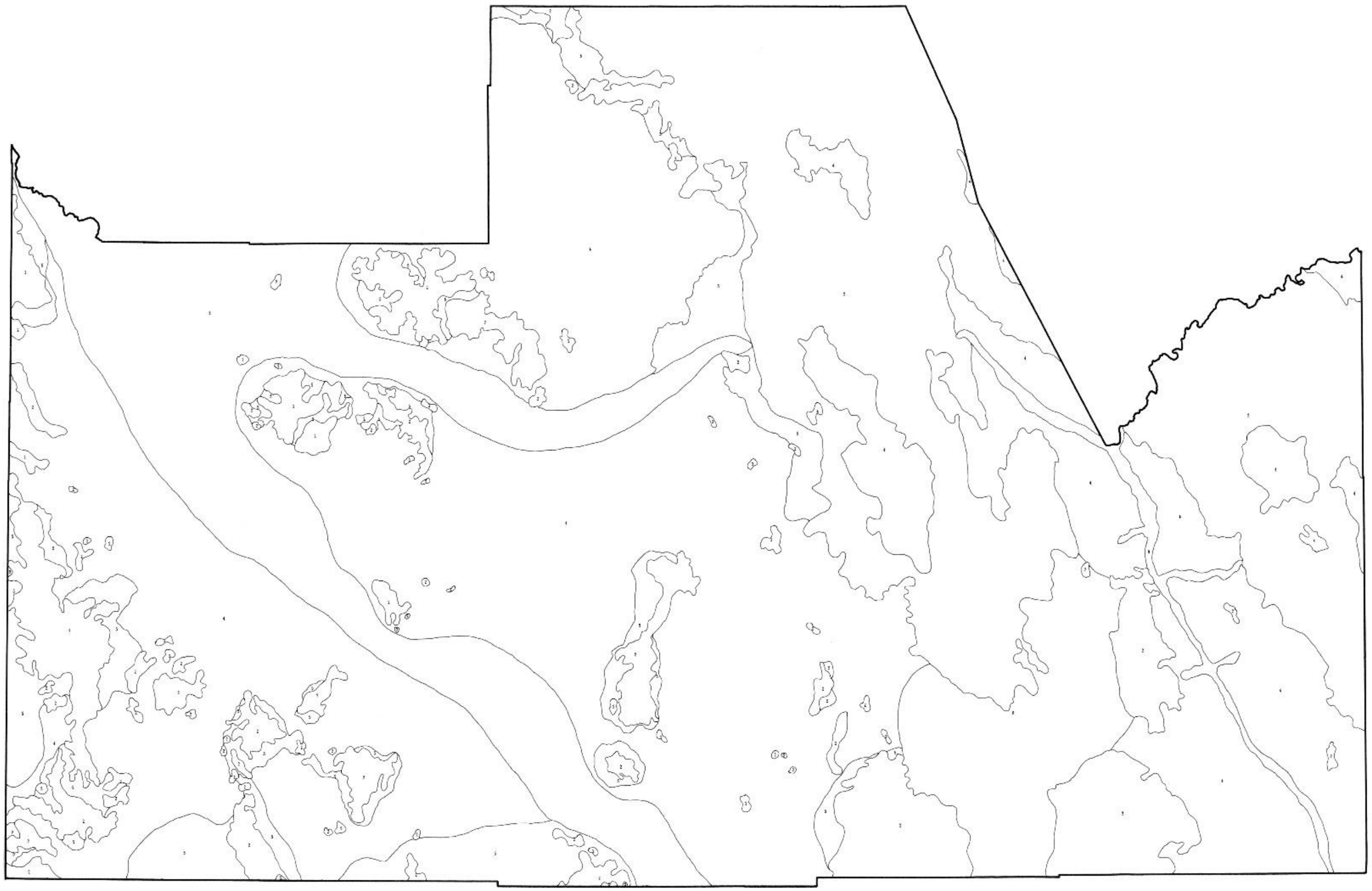
Cut Polygon

Integrate



AQUIFER MEDIA RATING

Range	**Rating**	**Typical Rating**
Massive Shale	1-3	2
Metamorphic/Igneous	2-5	3
Weathered Metamorphic/Igneous	3-5	4
Thin Bedded Sandstone, Limestone, Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	9-10	10



AQUIFER MEDIA		
Range	Rating	Typical Rating
Massive Shale	1 - 3	2
Metamorphic/Igneous	2 - 5	3
Clay	3	3
Weathered Metamorphic/Igneous	3 - 5	4
Clay and Sand	4	4
Glacial Till	4 - 6	5
Bedded Sandstone, Limestone and Shale Sequences	5 - 9	6
Clay and Gravel	5 - 6	6
Massive Sandstone	4 - 9	6
Massive Limestone	4 - 9	6
Sand and Gravel	4 - 9	8
Basalt	2 - 10	9
Karst Limestone	9 - 10	10
General Weight = 3	Pesticide Weight = 3	

DRASTIC Analysis of Pinal County

by

Donna L. Moulton
Arizona Geological Survey

for

Arizona Department of Environmental Quality

with Digital Mapping by
Advanced Resource Technology Lab

September 1992

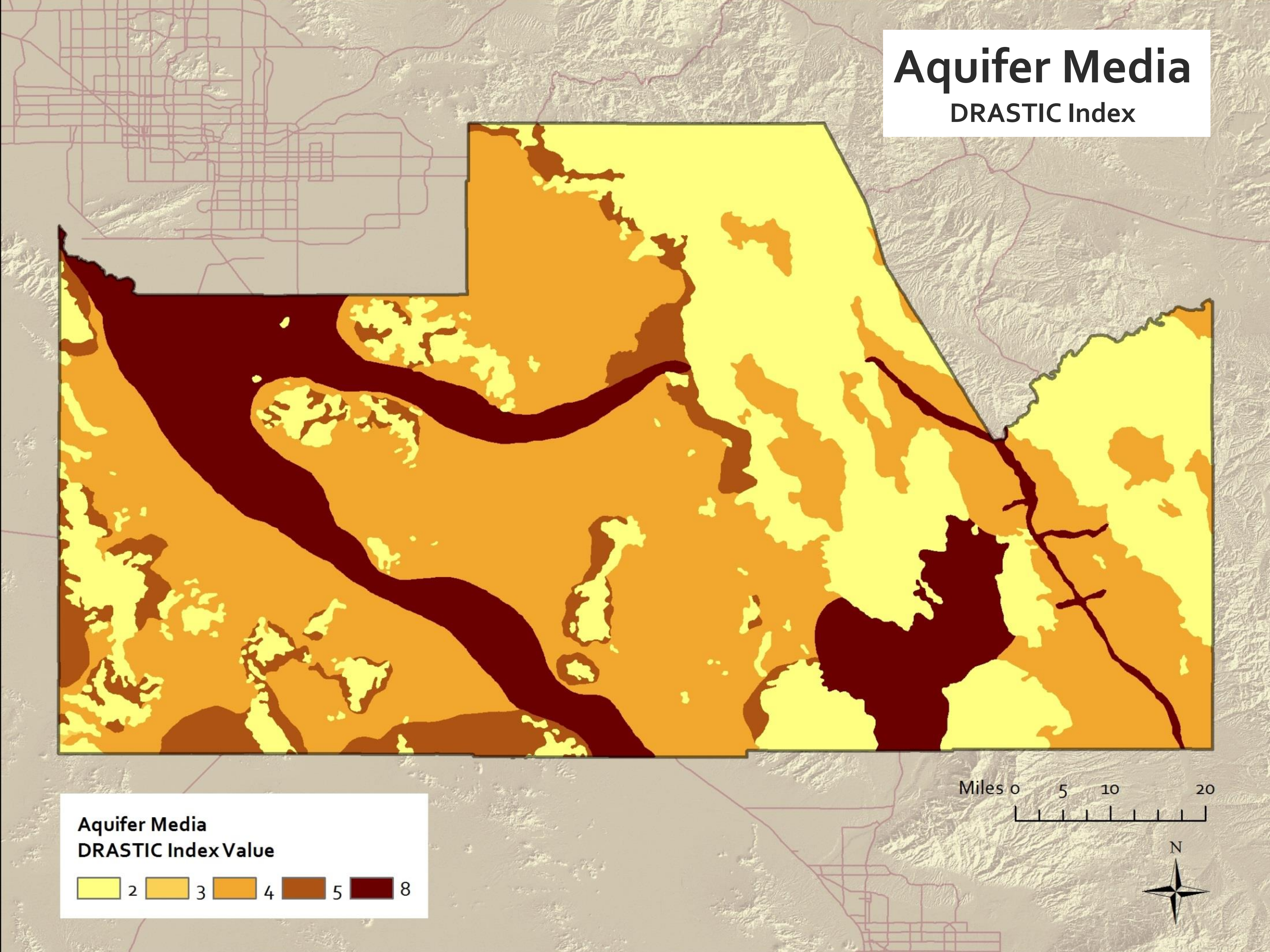
Scale 1:250,000

5 0 5 10 15 20 miles

5 0 5 10 15 20 25 30 Kilometers

NORTH

Plate 4 of 9: Aquifer Media


Aquifer Media
DRASTIC Index
Miles 0 5 10 20
N
Aquifer Media
DRASTIC Index Value
2
3
4
5
8

SOIL MEDIA

Source:

US General Soil Map

Tools:

Clip – Pinal County

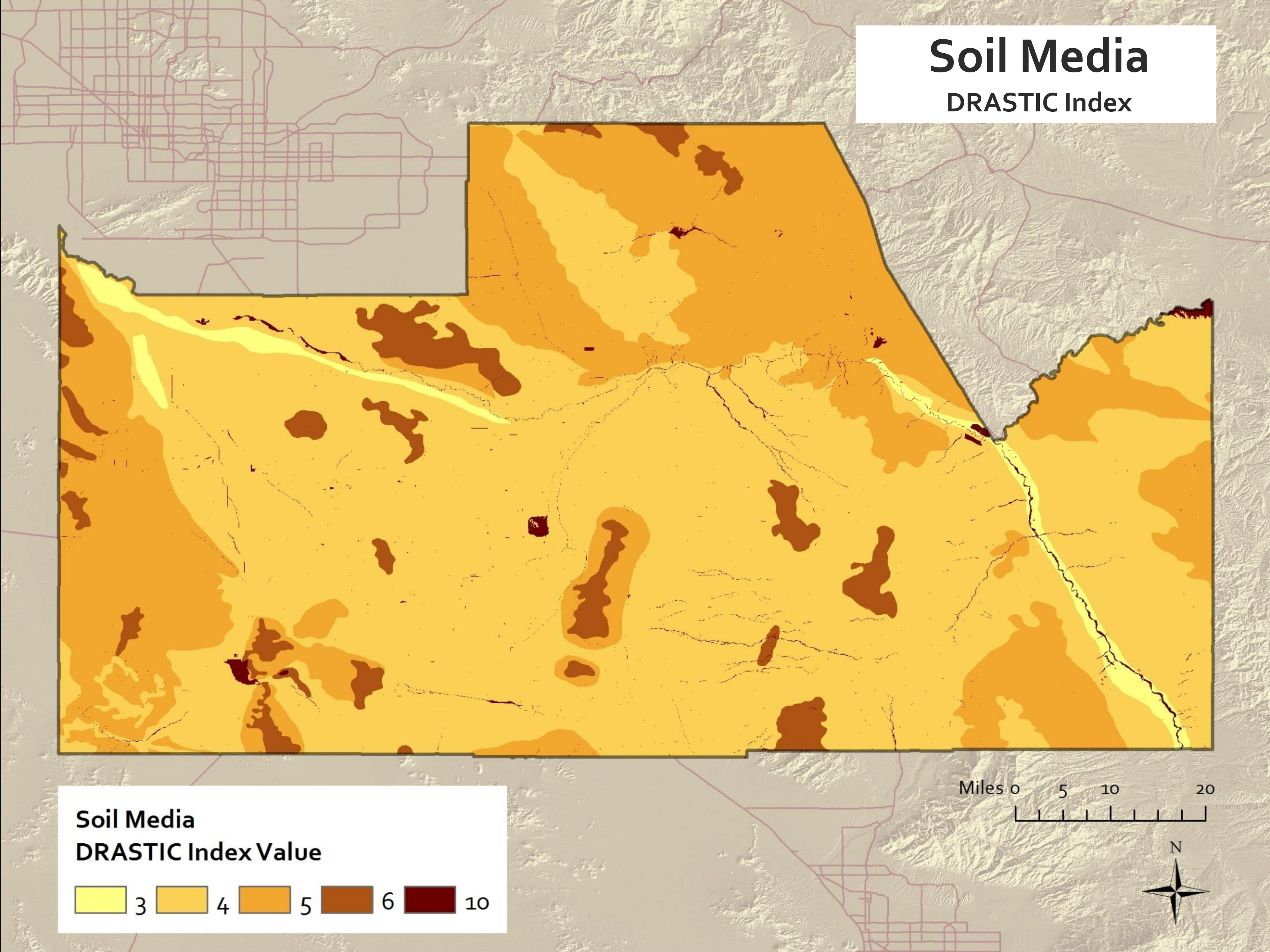
Join – Field key

Combine – Water

Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Nonshrinking and Nonaggregated Clay	1

Preparation:

Created database of the field key table to join to the shapefile, which resulted in a soil series legend for the vector layer. Researched the soil series and gave each polygon a value according to its DRASTIC rating.


Soil Media
DRASTIC Index
Soil Media
DRASTIC Index Value
3
4
5
6
10
Miles 0 5 10 20
N

TOPOGRAPHY

Source:

USGS National Map Viewer

Tools:

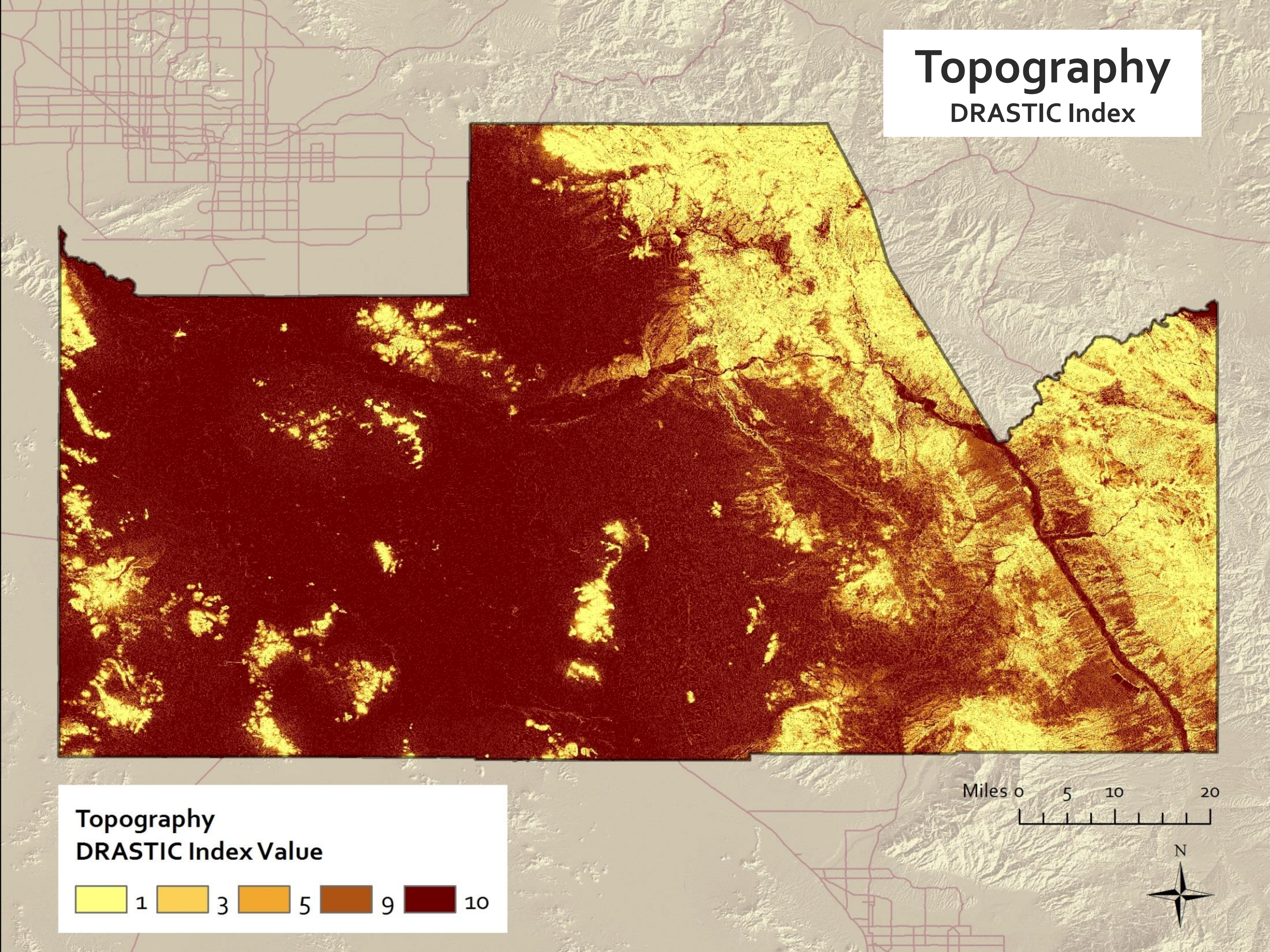
Mosaic – NED tiles
Clip – Pinal County
Slope – Percent Incline
Hillshade – Contrast
Reclassify – DRASTIC Rating

Range (% Slope)	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1

Preparation:

Used the slope tool to calculate topological percent slope throughout Pinal County. Reclassified slope values according to their DRASTIC rating.

Topography
DRASTIC Index



IMPACT OF THE VADOSE ZONE

Source:

DRASTIC Analysis…Pinal County Report, Moulton 1992

Tools:

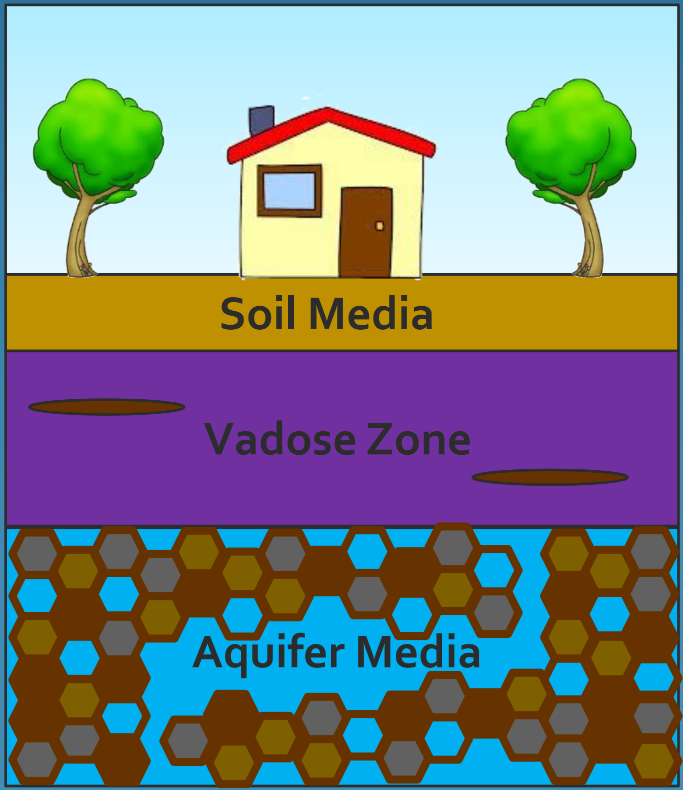
Georeferencing

- Transform using second order polynomial
- RMSE of 0.00107
- Rectify

Define projection – WGS84

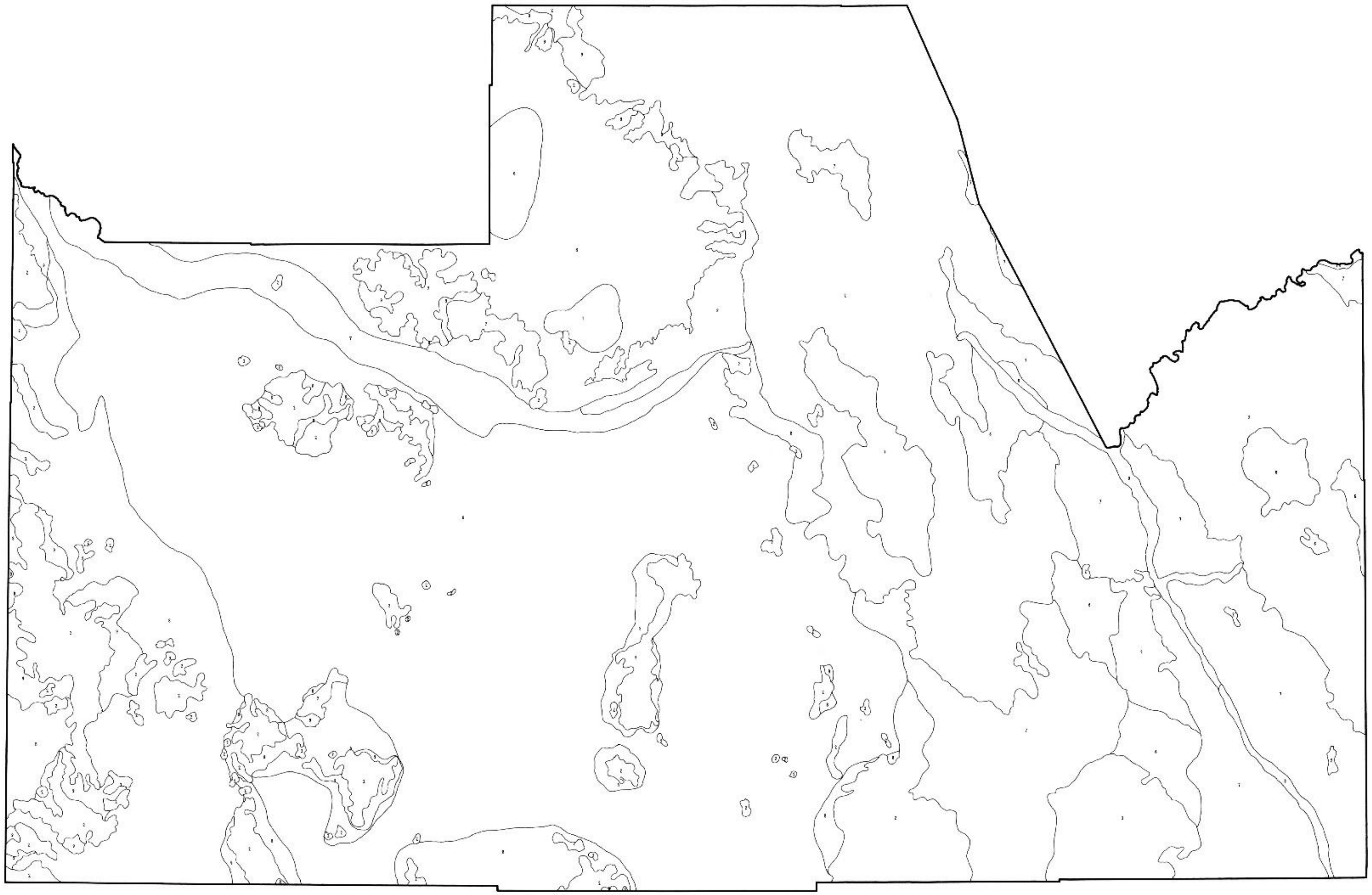
Cut Polygon

Integrate



VADOSE ZONE RATING

Range	**Rating**	**Typical Rating**
Silt/Clay	1-2	1
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10
Caliche greater than 5 meters thick (Moulton, 1992)	*1*	*1*
Conglomerate (Moulton, 1992)	*7*	*7*



IMPACT OF THE VADOSE ZONE MEDIA		
Range	Rating	Typical Rating
Confining Layer	1	1
Caliche Greater Than 5' Thick	1	1
Silt/Clay	2 - 6	3
Shale	2 - 5	3
Limestone	2 - 7	6
Sandstone	4 - 8	6
Bedded Limestone, Sandstone, Shale	4 - 8	6
Sand & Gravel w/ signif. Silt & Clay	4 - 8	6
Metamorphic/Igneous	2 - 8	4
Sand and Gravel	6 - 9	8
Basalt	2 - 10	9
Karst Limestone	8 - 10	10
General Weight = 5	Pesticide Weight = 4	

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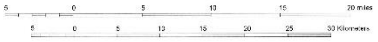
September 1992

Scale 1:250,000

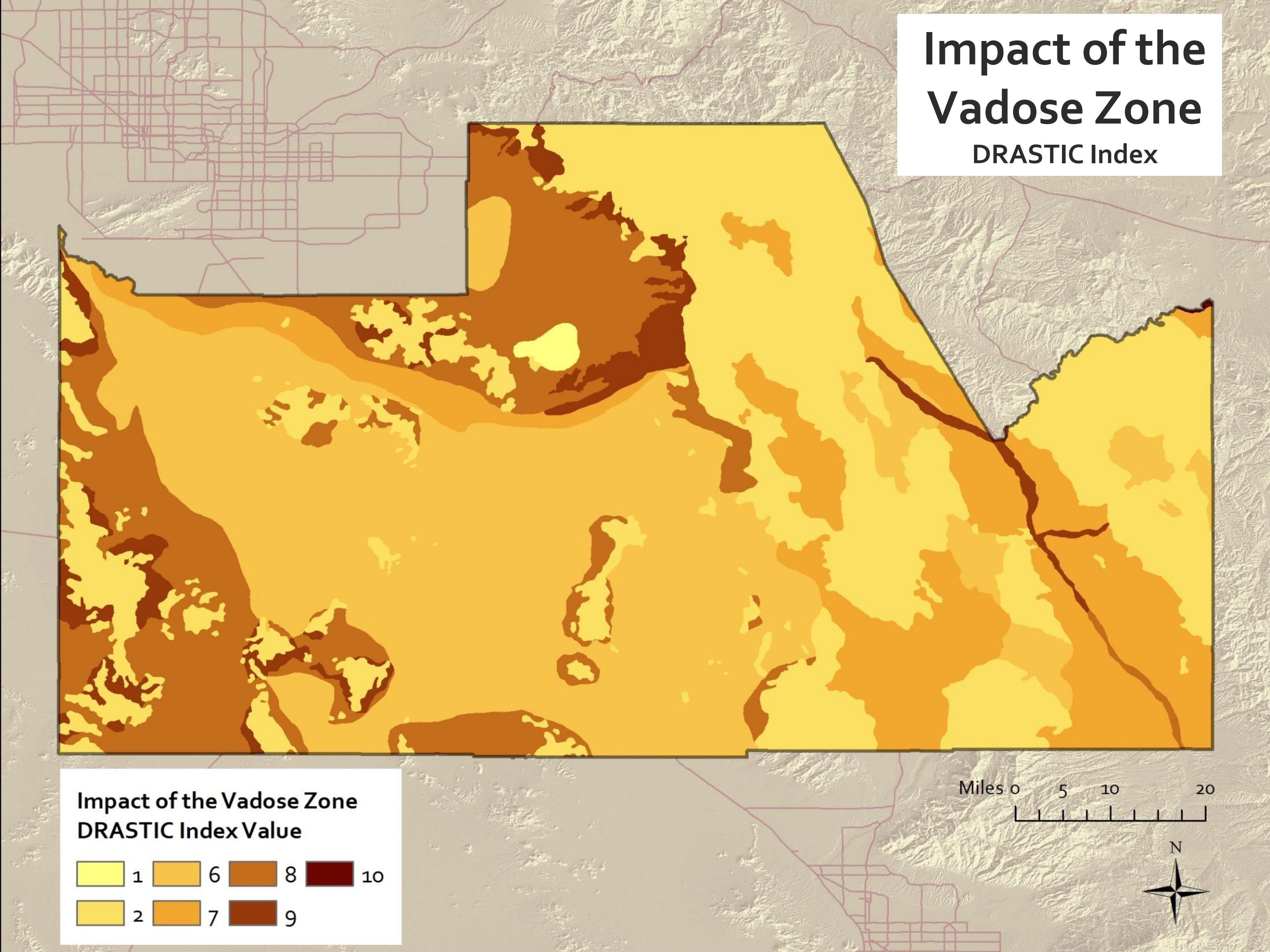


NORTH

Plate 8 of 9: Impact of Vadose

Impact of the Vadose Zone

DRASTIC Index



HYDRAULIC CONDUCTIVITY

Source:

DRASTIC Analysis…Pinal County Report, Moulton 1992

Tools:

Georeferencing

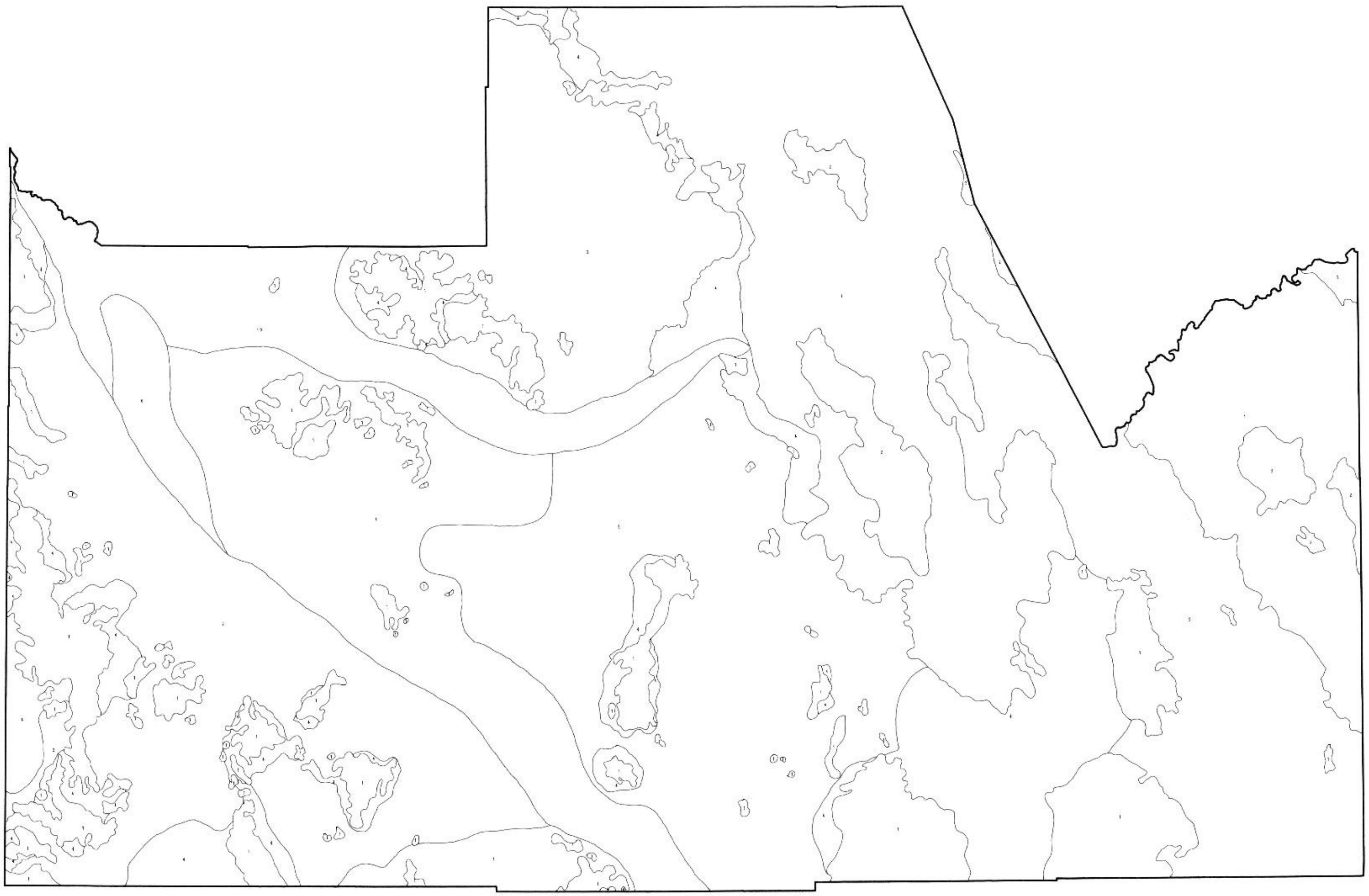
- Transform using second order polynomial
- RMSE of 0.00111
- Rectify

Define projection – WGS84

Cut Polygon

Integrate

Range (gpd/ft$^{2)}$	Rating
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10



HYDRAULIC CONDUCTIVITY (GPD/FT^2)	
Range	Rating
1 - 100	1
100 - 300	2
300 - 700	4
700 - 1000	6
1000 - 2000	8
2000+	10
General Weight = 3	Pesticide Weight = 2

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September 1992

Scale 1:250,000

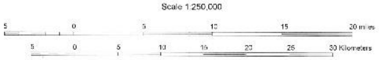
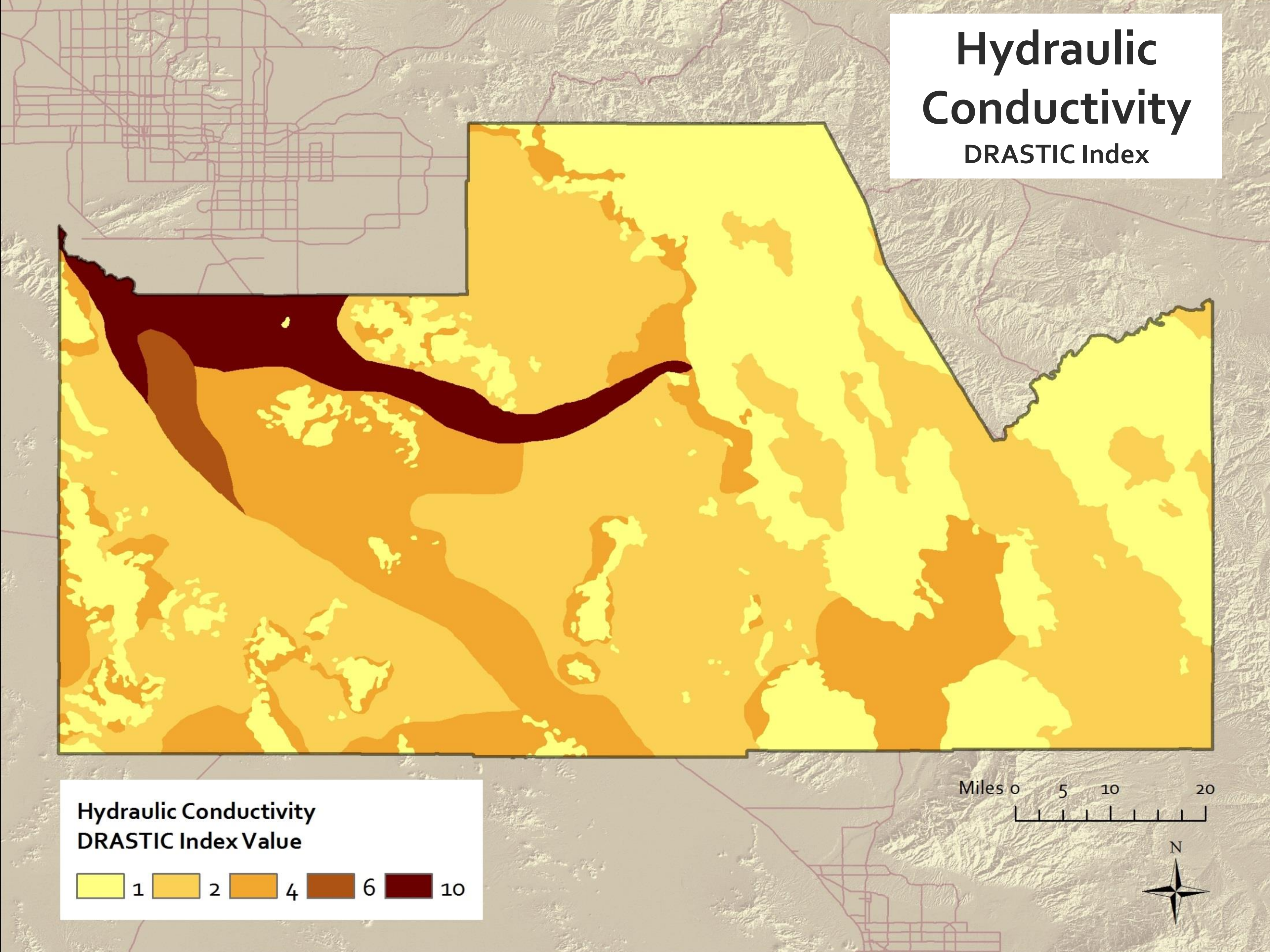


Plate 9 of 9: Hydraulic Conductivity

Hydraulic Conductivity

DRASTIC Index



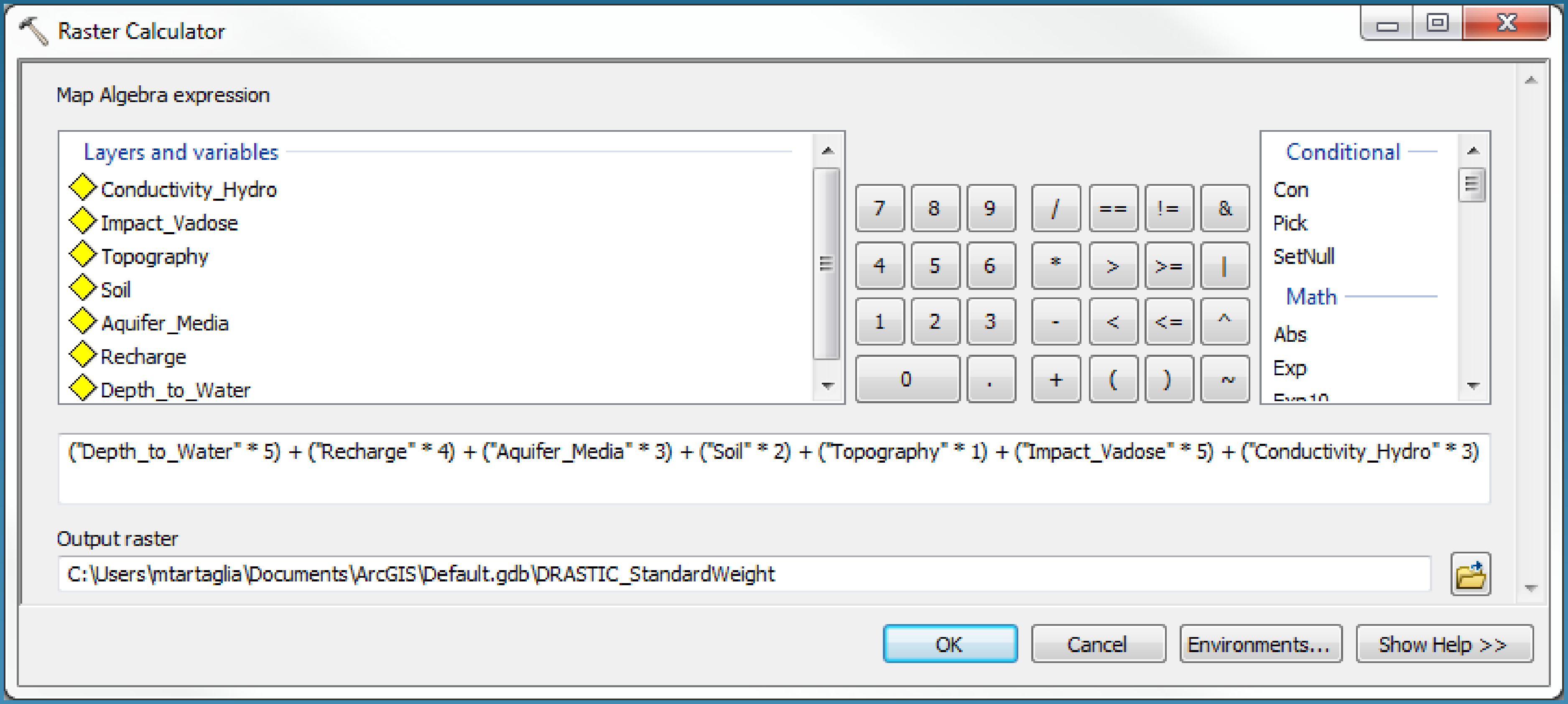
APPLICATION OF THE DRASTIC INDEX

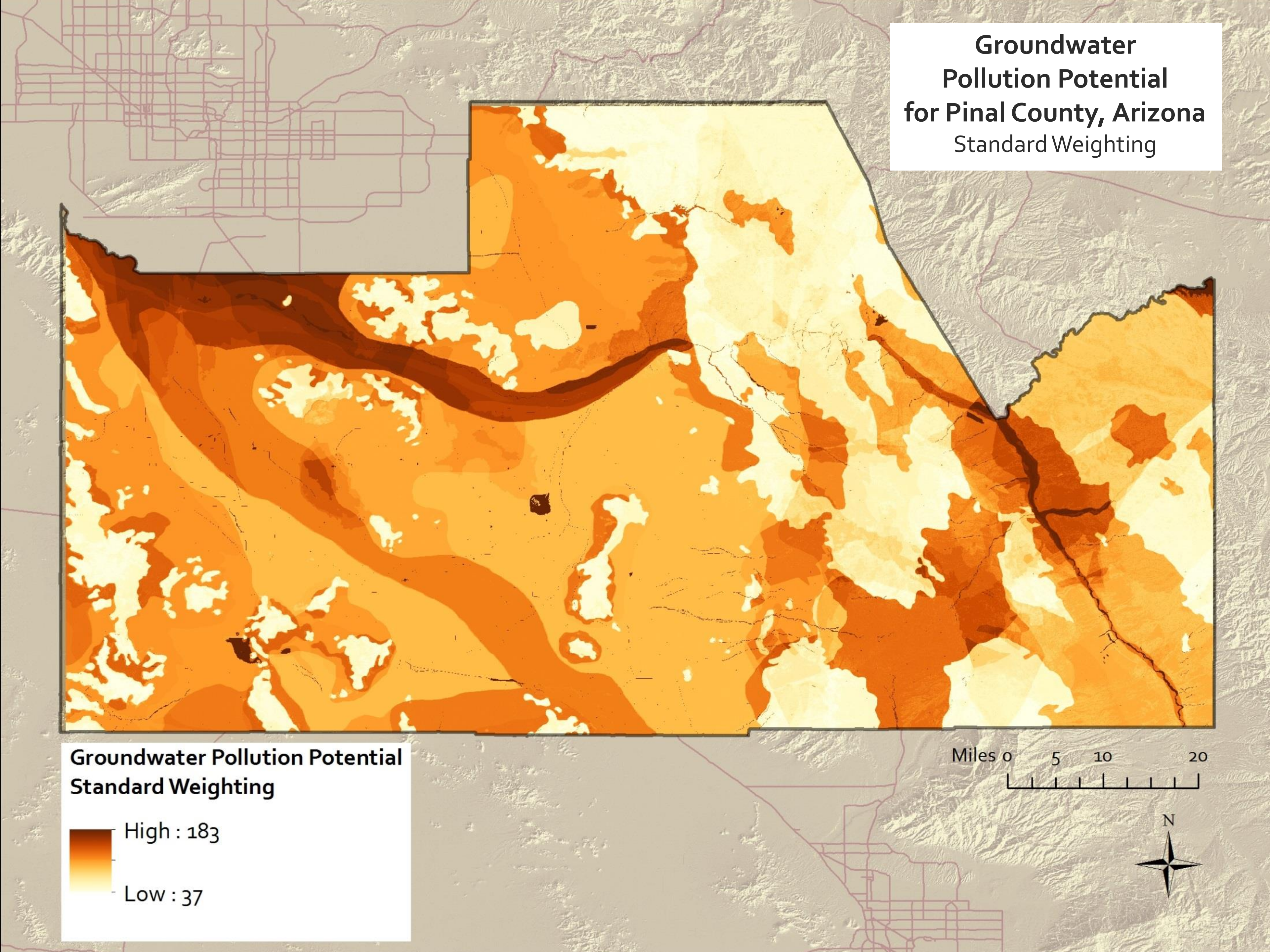
$$(D_r * D_w) + (R_r * R_w) + (A_r * A_w) + (S_r * S_w) + (T_r * T_w) + (I_r * I_w) + (C_r * C_w)$$

r = rating of the parameter (variable)
w = weight of the parameter (constant)

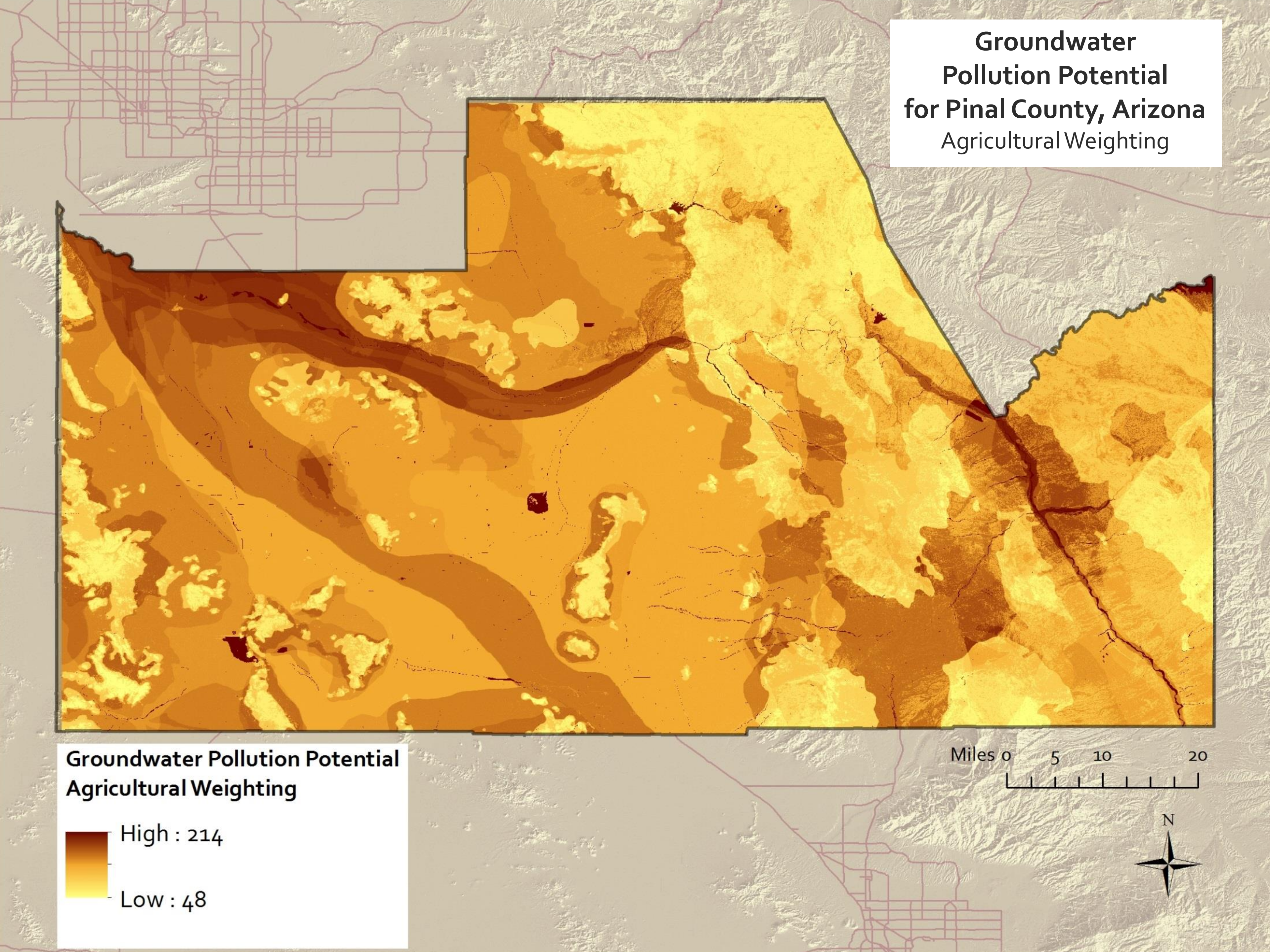
Feature	Standard Weight	Agricultural Weight
Depth to Water Table	5	5
Net Recharge	4	4
Aquifer Media	3	3
Soil Media	2	5
Topography	1	3
Impact of the Vadose Zone	5	4
Hydraulic Conductivity of the Aquifer	3	2

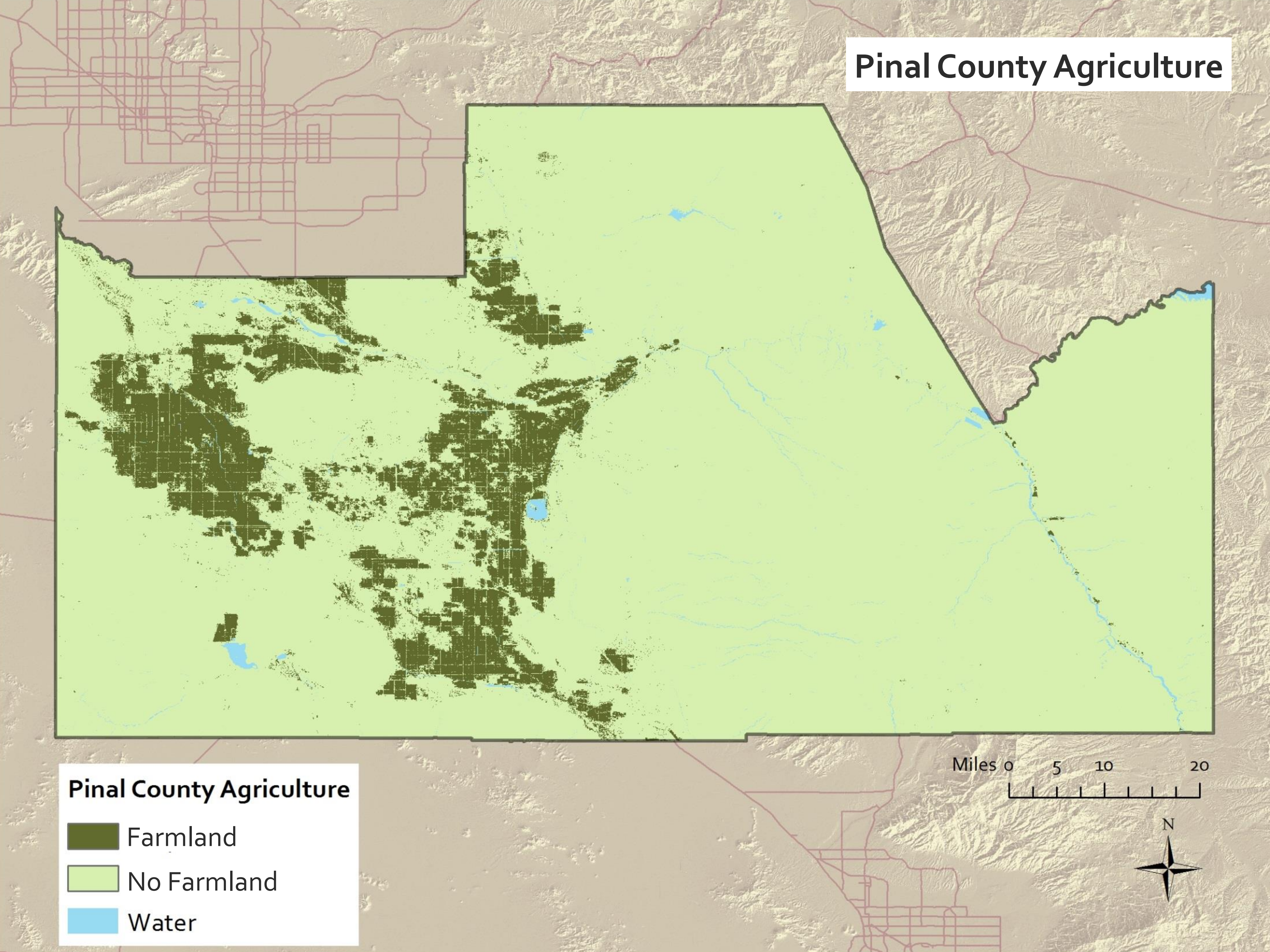
RASTER CALCULATION

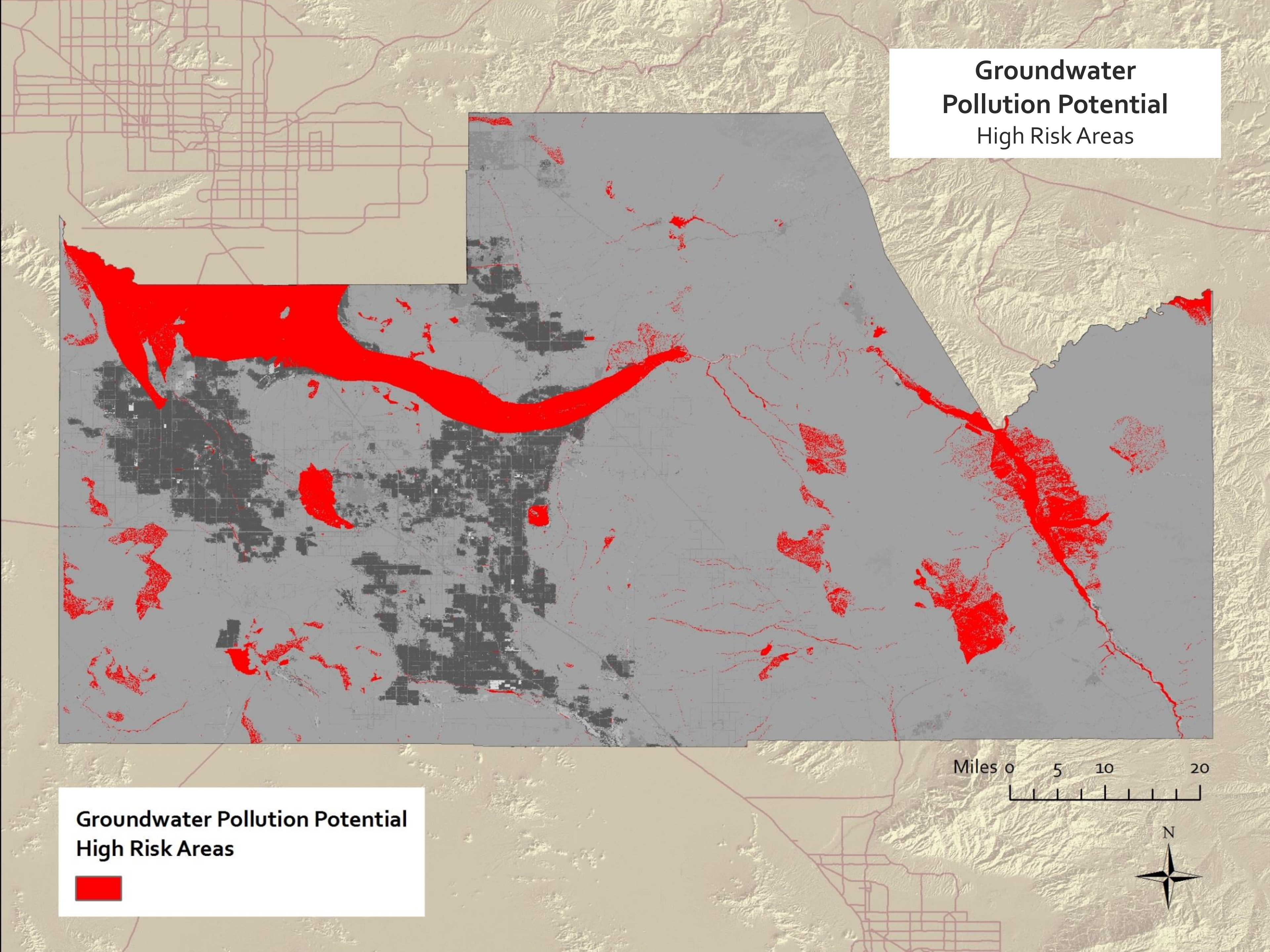




Groundwater Pollution Potential for Pinal County, Arizona
Standard Weighting
Groundwater Pollution Potential
Standard Weighting
High : 183
Low : 37
Miles 0 5 10 20
N


Groundwater
Pollution Potential
for Pinal County, Arizona
Agricultural Weighting
Groundwater Pollution Potential
Agricultural Weighting
High : 214
Low : 48
Miles 0 5 10 20
N


Pinal County Agriculture
Miles 0 5 10 20
N
Pinal County Agriculture
Farmland
No Farmland
Water


Groundwater
Pollution Potential
High Risk Areas
Miles 0 5 10 20
N
Groundwater Pollution Potential
High Risk Areas

CONCLUSIONS

Which areas of Pinal County, Arizona are most susceptible to groundwater pollution?

Pinal County, Arizona is most susceptible to groundwater pollution around water sources such as the Gila River and the San Pedro River. There is less pollution potential in the center of the county and around the mountainous northern region.

Commercial and agricultural developers should be aware of these areas and can use the DRASTIC maps as a screening or planning resource.

Further work will include publishing these results to ArcGIS online and making them readily available to the residents of Pinal County, Arizona.

QUESTIONS?

Sources:

Aller, Linda. *DRASTIC: a standardized system for evaluating ground water pollution potential using hydrogeologic settings*. Ada, Okla.: Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 1985.
Moulton, Donna L., and Steven Slaff. *DRASTIC analysis of the potential for groundwater pollution in Pinal County, Arizona*. Tucson, Ariz.: Arizona Geological Survey, 1992.
Sinkevich, Michael G., M. Todd Walter, Arthur J. Lembo, Brian K. Richards, Natalia Peranginangin, Sunnie A. Aburime, and Tammo S. Steenhuis. "A GIS-Based Ground Water Contamination Risk Assessment Tool For Pesticides." *Ground Water Monitoring and Remediation* 25, no. 4 (2005): 82-91.
Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: "http://soils.usda.gov/technical/classification/osd/index.html" [Accessed 10 February 2008]. USDA-NRCS, Lincoln, NE.