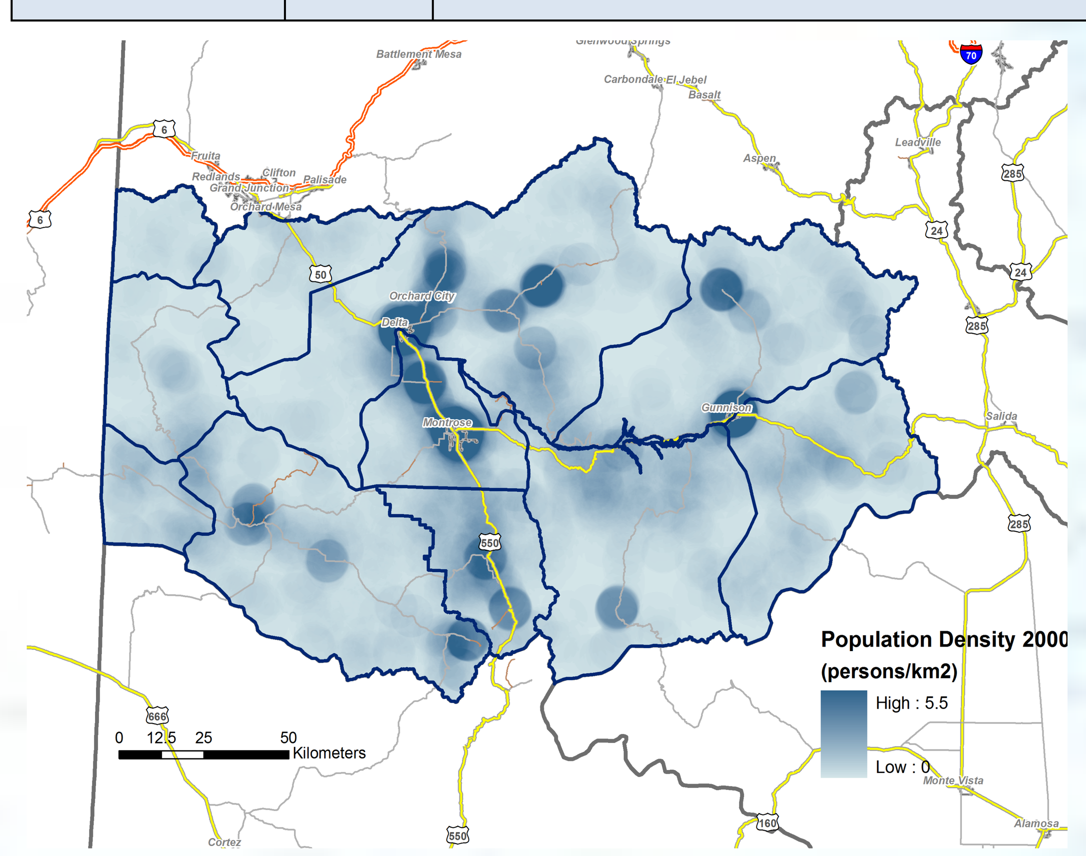
Water Resource Vulnerability: Gunnison River Basin, Colorado

An Integrated Approach to Analyzing Vulnerability at the Water District Level

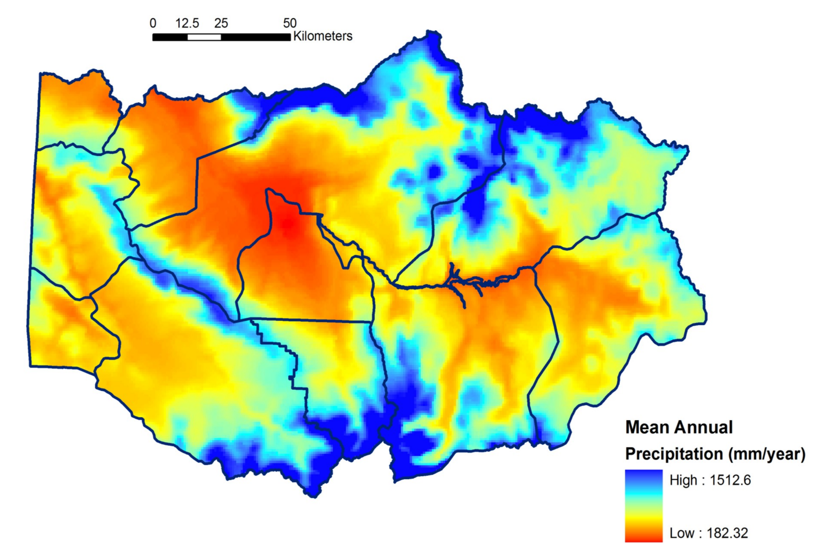
Project Purpose

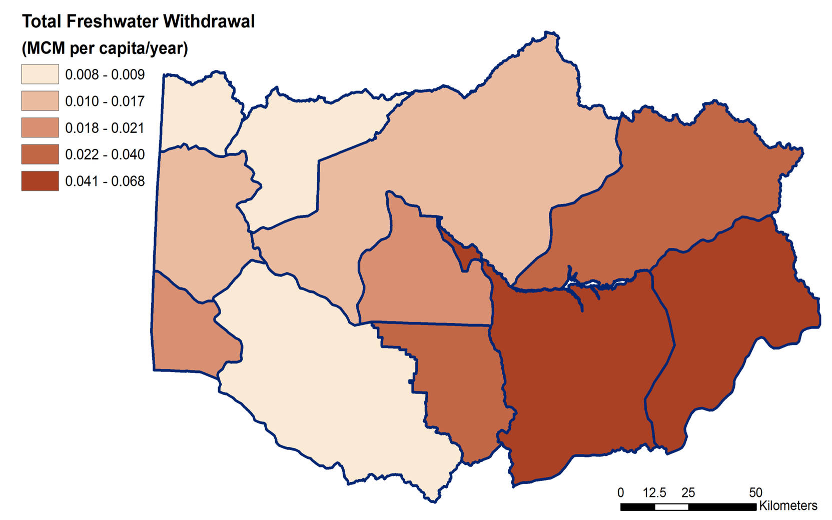
The purpose of this analysis is to demonstrate an integrated spatial approach to determining water resource vulnerability at the water district level. The experimental area is the Gunnison River Basin (USGS HUC Codes 140200-01 through 06), a sub-watershed of the Colorado River Basin. Water districts are defined by micro drainage systems, and vulnerability can be understood as "a measure of a system's susceptibility to adverse changes in ambient conditions" (Hurd *et al.*, 2006). Changes in ambient conditions may be environmentally driven or anthropogenically driven. This project explores GIS techniques for considering a range of anthropogenic and environmental stresses on the *quantity* of freshwater resources in order to define by water district the hierarchy of water resource vulnerability within the watershed. The analysis integrates a series of 6 vulnerability indicators (a.k.a. water resource stressors) to predict which districts face the highest water resource vulnerability (See table below). These indicators are only a sampling of potential vulnerability criteria.

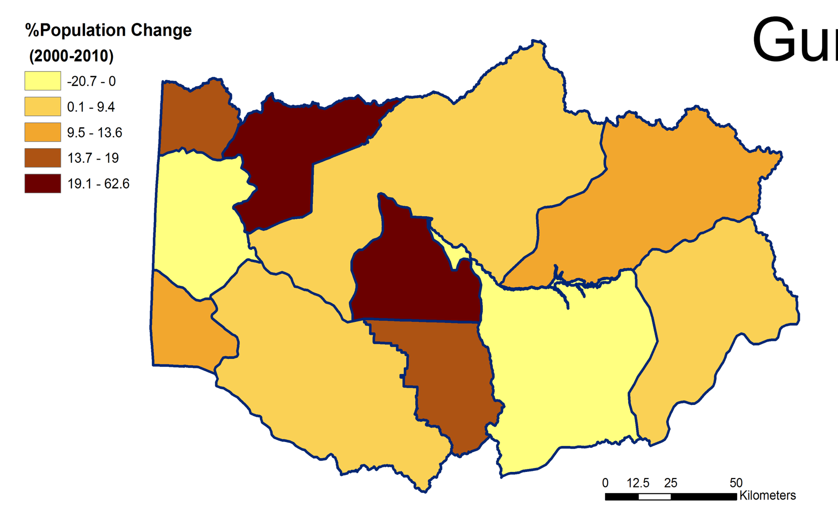
Vulnerability Criteria	Weight	Importance
Mean Annual Precipitation[1] (1971-2000)	25%	Localized precipitation is important to overall water systems of a region; precipitation serves to recharge groundwater, encourage range productivity, and stabilize water resources.
Mean Annual Potential Evapotranspiration[2] (1950-2000)	25%	Potential evapotranspiration (PET) represents the potential for water loss from surface waters and waters stored in surface soils; PET takes into account spatial variability in humidity, heat, and wind.
Water Demand: withdrawal per capita[3] (2000)	20%	Total freshwater withdrawals take into account water used in agriculture, industry, hydropower, domestic usage etc. The withdrawals were normalized by calculating per capita demand. Withdrawal does not translate into water consumed; however, any water withdrawal can be a stressor to existing resources even when returned to the water cycle.
% Population Change[4] (2000-2010)	15%	The faster a population grows, the greater the stress on localized available water resources (i.e. demand increases while supply stays the same).
% Canopy Cover[5] (2001)	10%	The 'green water cycle' (water found in trees, soils, roots) stabilizes water supply and is especially important to arid regions like CO.
Reservoir Storage[6] (Normalized by district area) (2000)	5%	The water quantity stored in reservoirs is representative of water supply and can determine availability of water in times of water need.



Cartography: Briana Seapy
Date: 6 May, 2011
Data Sources: PRISM 2000[1], CGIAR 2000[2], USGS 2000[3,6], TIGER 2000/2010[4], NLCD 2001[5], Colorado Division of Water Resources 2011[6]
Map Projection: NAD 1983, UTM Zone 13N, Meters







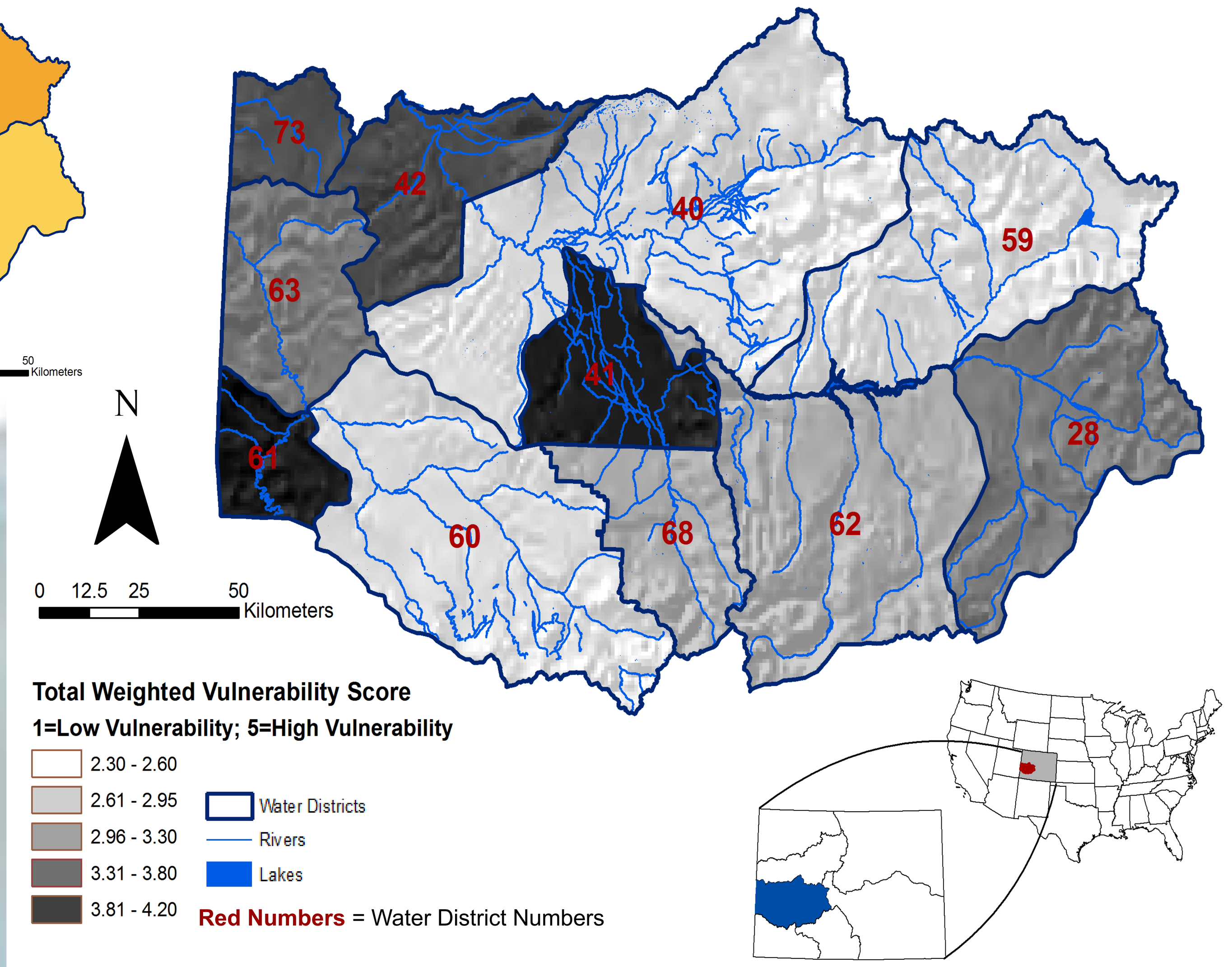
Methodology

The two central challenges to determining water resource vulnerability at the district level were selecting appropriate vulnerability indicators (relevant, important, and with available data), and aggregating tabular and spatial data to the district level. The table to the left details the selected indicators and their relative weight and importance. The maps to the right spatially display the stressors. These indicators were selected based on a previous study's vulnerability criteria (Hurd 2006), data availability, and personal judgment; they serve to demonstrate the integrated technique for assessing vulnerability and do not represent and exhaustive list of relevant vulnerability indicators.

In terms of aggregating data to the district level, the raster layers simply required the use of zonal statistics and the subsequent reclassification of the zonal statistics' 'output' into quantiles. Each quantile was designated an appropriate vulnerability score (1=lowest vulnerability, 5=highest vulnerability) and each district was scored based on the quantile into which it fell. For example, a district with high potential evapotranspiration (PET) and high precipitation received a '5' for the PET indicator (high vulnerability), and a '1' for the precipitation indicator (low vulnerability).

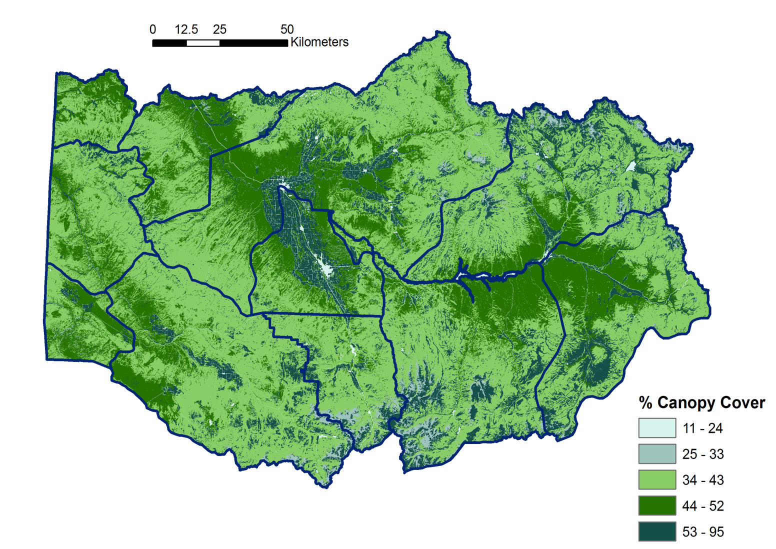
The rest of the tabular data, including population and water withdrawal data, was available at the county level and had to be aggregated to the district level. To do this, a population proportion was created using block population centroids and the polygon intersects between Colorado Counties and Colorado Water Districts. The population centroid points for each intersection were selected in order to sum the total population and find the population proportion of each county that fell into each water district. The sums were then used to calculate % population change from 2000-2010 and the proportions were used to determine water withdrawals at the district level. Reservoir storage was calculated by summing the tabular storage information for dams by district. To standardize results, water

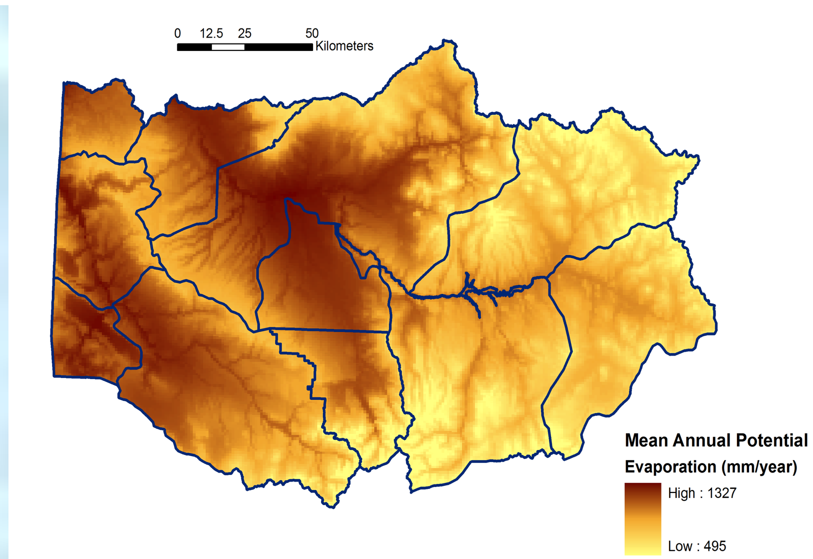
Gunnison River Basin: Water District Vulnerability

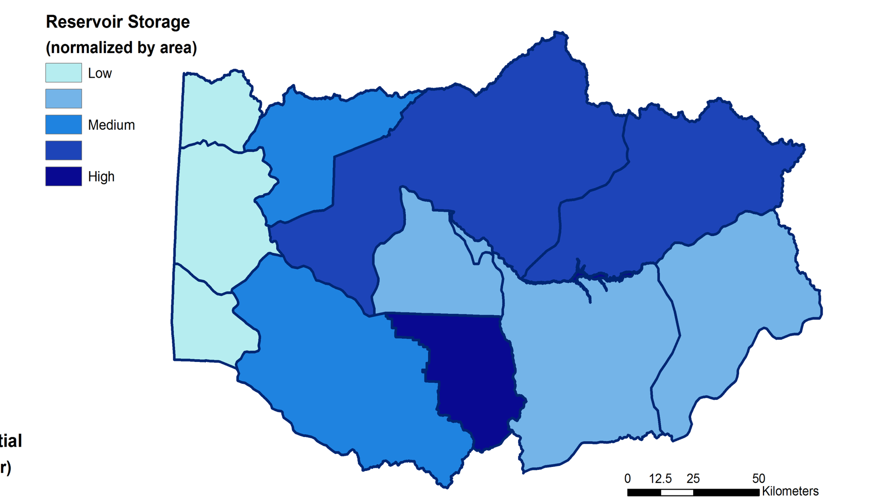


Methodology (Con't)

withdrawal was normalized by district population and reservoir storage was normalized by district area. Each district then received a vulnerability score for all indicators based on tabular data, again from 1-5, and again based on quantiles. The final weighted scores can be found in the table to the right.







Analysis of Approach

The approach used to determine water resource vulnerability in this analysis serves a distinct analytical purpose in that it aggregates relevant scientific information to an environmentally and politically relevant level—the water district— and it integrates climatic, geophysical, and population vulnerability factors. The method, however, also ignores numerous potential stressors (e.g. water quality stressors) and does not answer several questions that would be key to a thorough vulnerability analysis. What if water resources used in one district are in fact coming from a different water district? How much weight does each stressor

Analysis of Approach (Con't)

actually deserve (i.e. how sensitive are water resources to the various anthropogenically and environmentally driven changes in supply and demand)? Future research should build upon the complexity of this methodology by answering these questions and integrating the answers into a more thorough spatial analysis of water resources.

Water District Name	District Number	Monitoring Capacity: Stream Gage Count	Overall Weighted Vulnerability Score
East Basin River	59	8	2.3
San Miguel River Basin	60	5	2.4
North Fork	40	20	2.6
Upper Gunnison River	62	5	2.8
Upper Uncompahgre River	68	7	2.95
Tomichi Creek	28	6	3.1
Dolores River Basin	63	0	3.3
Lower Gunnison River	42	6	3.65
Little Dolores River	73	0	3.8
Lower Uncompahgre River	41	6	4.15
Paradox Creek	61	3	4.2

Conclusions

The final vulnerability results, visually displayed in the central map, demonstrate a spatial trend in which western districts tend to be more vulnerable with the Lower Uncompahgre River serving as a distinct outlier. The high population change, high PET, low precipitation, and low reservoir storage combine to heavily stress water resources of the Lower Uncompahgre River District and distinguish the district from its low-to-moderately stressed neighbors.

Generally speaking, an accurate integrated vulnerability analysis that spatially determines water resource vulnerability can effectively direct future water-management by allowing existing populations to efficiently focus their water-management strategies and infrastructure plans in order to avoid water shortages in the case of natural disasters, low precipitation years, or booming populations.

Hurd, B., C.Brown, J.Greenlee, A. Granados, M. Hendrie. 2006. Assessing Water Resource Vulnerability for Arid Watersheds: GIS-based Research in the Paso del Norte Region. *New Mexico Journal of Science.* 44:1-23.

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