Resilience of Water Use Sectors to Climate Change in New Mexico

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New Mexico Interstate Stream Commission

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acre-feet	amount of water that covers 1 acre of land with 1 foot of water
AWRM	Active Water Resource Management
AG locale	area assessed for agricultural water use by the NMOSE in the Water Use and Conservation Reports from 1965 to 2015
anthropogenic	of, relating to, or resulting from the influence of human beings on nature
bank-full	the condition of the stream when the channel is full, and any additional discharge will result in the stream overflowing its banks
bank stability	of or relating to the ability of a streambank, including its soils and vegetation, to resist erosion from water flows and gravity
cfs	cubic feet per second
closed basin	a basin that retains water such that no outflow to other surface water bodies occurs
compact	an agreement between two or more states or between states and any foreign government; New Mexico has compacts on 8 river basins.
conjunctive use	A coordinated use of surface water and groundwater resources to maximize the availability of renewable supplies and reserve groundwater for drought periods
demand	the amount of water diverted to meet the conveyance and consumptive needs of a water use category (including return flow and depletions)
depletion	amount of water consumed from the water withdrawn or diverted
designated use	a component of Water Quality Standards of state or tribal laws approved by the U.S. EPA that describes the desired condition of a water body for a particular use (e.g., swimming and boating, drinking, irrigation)
diversion	the amount of water withdrawn or diverted from the source of supply
DWB	Drinking Water Bureau of New Mexico Environment Department
FEMA	Federal Emergency Management Agency
GIS	geographic information system
gpcd	gallons per capita per day
GW	groundwater

HUC	Hydrologic Unit Code is a numerical sequence that identifies a hydrological drainage basin (also called watershed or catchment) into successively smaller units from the largest geographic area to smaller areas. The first level (HUC 1) divides the US into 21 major geographic areas or regions, the second level (HUC 2) divides the 21 regions into 221 regions.
ICMP	industrial, commercial, mining and power
M	million
MHI	median household income
mined basin	aquifer in closed (no through-flowing streams) basin where recharge is much less than the discharges (through pumping and spring flow)
NEPA	National Environmental Policy Act
NMDA	New Mexico Department of Agriculture
NMED	New Mexico Environment Department
NMEMNRD	New Mexico Energy, Minerals and Natural Resources Department
NMFA	New Mexico Finance Authority
NMFAP	New Mexico Forest Action Plan
NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NMSA	New Mexico Statutes Annotated
perennial stream	a stream that normally has water in its channel at all times, except during infrequent periods of severe drought
PWS	public/private water supply system: A non-transient community water system that has 15 service connections or serves 25 people at least 60 days out of the year (does not include commercial, educational, and other transient water systems)
RQ	recreation and quality of life
resilience	the ability to anticipate, prepare for, and adapt to changing conditions and to withstand, respond to, and recover rapidly from disruptions
resilience element	an aspect, component or measure of water supply, use, or quality that affects the resilience of a water system or water use category to climate change
sinuosity	an expression of the tendency of a river to meander back and forth across its floodplain; can be expressed as the ratio of stream length to valley length

SNOTEL	SNOwpack TELemetry: snowpack data that is transmitted wirelessly from weather stations
SW	surface water
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geologic Survey
WH	watersheds and habitat

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Executive Summary

New Mexico is facing a future with higher temperatures, less water, increasing water demand, reduced snowpack and earlier snowmelt, and myriad adverse changes in watershed health due to climate change. If greenhouse gas emissions are not reduced to avert the predicted climate change shocks, our best hope is to build more resilience into our water use sectors. Even without climate change, New Mexico has a history of enduring cycles of drought, and thus building resilience against drought into the region's water supply and resource management is the best course of action. This report discusses the various elements that reflect the degree of vulnerability or resilience to climate change.

To understand the aspects that create resilience to climate change shocks, the New Mexico Interstate Stream Commission met with other state agencies, hosted a series of public meetings, and gathered input through a series of surveys. The conversations focused on five sectors of water use: (1) irrigated agriculture, (2) public/private water systems, (3) industrial, mining, commercial and power, (4) watersheds and habitat, and (5) recreation and quality of life. Input from the NMISC outreach on the aspects that define resilience was used to create a list of the aspects that meeting participants identified as important and explore how to quantify or assess the relative resilience associated with those aspects.

The two largest sectors of human water use in the state are agriculture (76%) and public water systems (9%). To understand the resilience of these two sectors in the state, various elements that create vulnerability and build resilience were examined. Where data are available to assess a resilience element, the degree of resilience is presented for irrigated agriculture and public water supply systems.

The most resilient irrigated agricultural locales are those that have a diverse supply in a stream-connected aquifer with sharing agreements. The agricultural systems along the Rio Grande from below the Otowi stream gage to the state line appear to be the most resilient in the Rio Grande surface water basin. Those systems along the Pecos River below the Acme stream gage are most resilient in the Pecos River surface water basin. Areas along the San Juan River are more resilient than systems that are groundwater dependent, but less resilient than those along the Rio Grande or Pecos because of the region's limited groundwater.

The resilience of a public/private supply system is strongly controlled by geography and the proximity to mined aquifers. Systems in eastern New Mexico that are relying on the declining High Plains aquifer are very vulnerable. Systems with access to multiple sources of water (i.e., access to both surface water and groundwater) are more resilient. Geography is not the only factor dictating the resilience of a public/private water supply, however. Some systems are less resilient than those in the same area due to their infrastructure strength and demand management capabilities.

Climate change is already happening, and experts predict that it will intensify. Significant ongoing commitment is needed to address vulnerabilities and build resilience into our water infrastructure, where indicated, to adapt to changing conditions. This report identifies many of the aspects that impact resilience and can be used as a guide for water systems and individuals to assess their relative vulnerability to climate change.

1. Introduction

This report describes the vulnerabilities due to climate change and the elements that increase resilience for five water use sectors: (1) irrigated agriculture (AG) and livestock watering, (2) public/private water systems (PWSs[1]) and self-supplied domestic wells, (3) industry, commercial, mining and power (ICMP), (4) watersheds and habitat (WH), and (5) recreation and quality of life (RQ). A report entitled *2021 Climate Change in New Mexico over the Next 50 Years: Impacts on Water Resources* (Dunbar et al., 2021) explored the various climate shocks that New Mexicans can expect over the next 50-years. Water users in the state need to understand their vulnerability to these shocks and identify the aspects of a system that reduce vulnerability and increase resilience.

Section 2 presents the aspects (or criteria) of water use sectors that increase resilience. Section 3 presents an analysis of some of the quantifiable criteria for AG and PWS. Section 4 presents the analysis of the water demand elements that were quantifiable for the AG and PWS water use sectors. Section 5 summarizes the findings and Section 6 provides recommendations based on the significant vulnerabilities to climate change and actions that can improve resilience.

2. Assessing Resilience to Climate Change

This assessment focuses on identifying the vulnerabilities of water use sectors to the projected climate change shocks that must be identified. Then, the elements which build resilience to adapt to these climate shocks can be evaluated.

2.1 Summary of Climate Shock Impacts to Water Supply and Demand

Table 1 summarizes the predicted climate shocks described by Dunbar et al. (2021) and NMISC and Lewis (2023) and the predicted impacts, where quantified. The expected reductions in stream flow, aquifer recharge, and snowpack, along with increases in droughts, fires, floods, and erosion,

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[1] Public and private water systems are non-transient community water systems that have 15 service connections or serve 25 people at least 60 days out of the year. Commercial, educational, and other transient water systems are not included in this category of use.

are shocks that will stress the supply of all sectors of water use and pose safety risks and hazards to water infrastructure. Warming temperatures and the longer growing season predicted by 2070 will increase water demand, as described in NMISC and Lewis, 2023. Firefighting efforts increase water demand whether from a community system or supplied by a reservoir.

Table 1. Summary of Climate Change Shocks to Water Supply, Water Demand and Safety

Climate Change Shock	Supply	Demand	Safety
Warmer temperature		5°F increase will result in 20 to 30% increase in annual water demand of irrigated crops, turf, and orchards by 2070[2]	
Longer growing season		19 to 42 days by 2070[2]	
Reduced runoff	25% less stream flow per year by 2070[3]		
Reduced recharge to aquifers	25% less recharge on average by 2070[3]		
Earlier snow melt	X		
Prolonged drought	X	X	
Increased frequency of fires	X	X	X
Increased frequency of floods	X		X
Increased erosion	X		

2.2 Resilience Elements

Water managers and stakeholders identified five groups of elements that can impact the resilience of water system:

- Water diversity
- Water availability
- Infrastructure capacity
- Watershed health
- Demand management

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[2] NMISC and Lewis, 2023

[3] Dunbar et al., 2021

For each of these groups, one or more climate shocks were identified (Table 2). Elements and criteria for assessing the level of resilience were created for each of the water use sectors: (1) irrigated agriculture and livestock watering (AG), (2) public/private systems (PWS)[4] and self-supplied domestic wells (3) industry, commercial, mining, and power (ICMP), (4) watershed health and habitat (WH), and (5) recreation and quality of life (RQ). (Because reservoirs are part of the infrastructure for water systems and recreation, reservoir evaporation is not treated as a separate water use category for this assessment; instead, it is considered as part of the supply and supports all water use sectors.)

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[4] Public and private water systems are non-transient community water systems that have 15 service connections or serve at least 25 people at least 60 days out of the year. Commercial, educational, and other transient water systems are not included in this category of use.

Table 2. Resilience Elements Identified by Stakeholders for All Sectors of Water Use

Resilience Element	Climate Shock	Impacted Component	Measure of Resilience	Water Users Impact
Supply				
Water diversity	Reduced runoff and recharge, prolonged drought	Surface water, groundwater supply	Percent surface water and groundwater	AG, PWS, ICMP, RQ
Water availability	Reduced runoff, prolonged drought	Surface water supply	Ratio of minimum stream flow to surface water diversion	AG, PWS, WH, RQ
	Reduced recharge to aquifers	Groundwater supply	Wells in stream-connected aquifers	AG, PWS, ICMP
			Saturated thickness of aquifer	AG, PWS, ICMP
			Declining aquifer	AG, PWS, ICMP
	Reduced runoff and recharge, prolonged drought	Surface water, groundwater supply	Projected supply-demand gap in 2060	All
			Water right ability to meet additional demand for landscape watering or future growth	AG, PWS, ICMP
			ESA[5]/Compact[6] issues: restrictions on water diversions to meet compact obligations	AG, PWS, ICMP
	Warmer temperatures	Surface water supply	Reservoir evaporation: percent of surface water supply impacted by evaporative losses	AG, PWS, WH, RQ
Infrastructure capacity	Prolonged drought, floods	Wells	Number of wells serving each PWS	PWS, ICMP
		Storage tanks	Days of treated water storage capacity	
	Reduced recharge to aquifers, increased demand	Monitoring	Resource monitoring, frequency of water level monitoring	PWS
	Early runoff, floods	Raw water storage	Volume of reservoirs to capture and store raw surface water	AG, PWS
	Increased stress on water systems	Equity	Ability of system to improve infrastructure	PWS

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[5] ESA = Endangered Species Act

[6] Compact = Interstate compact between New Mexico and a neighboring state

Resilience Element	Climate Shock	Impacted Component	Measure of Resilience	Water Users Impact
Supply (cont.)				
Infrastructure capacity (cont.)	Increased demand, drought	Managerial level	Volunteer or full-time employees	AG, PWS, ICMP
	Drought	Condition	Condition of acequias, ditches, pipes	AG, PWS, ICMP
	Warmer temperatures	Ability to meet peak daily demand (which will increase due to higher landscape watering requirements)	Peak summer daily demand compared to capacity to deliver	PWS
	Droughts, debris flows, damaging floods	Emergency supply	Drought Emergency Plan with backup supply	PWS
	Vulnerability to power outages	Increased demand for power	Systems with backup generators	AG, PWS, ICMP
Watershed health	Aridity, stressed vegetation	Soil condition	Erosivity Risk	All
	Fires/Floods	Forest condition	Post-fire erosion risk	All
	Floods	Soil health	Infiltration rate	AG, WH
		Infrastructure vulnerability	Proximity of facilities to flood plain	All
	Less return flow, less recharge, post-fire debris flows	Water quality	Salinity, turbidity, other contaminants	All
Demand				
Demand management	Drought	Sharing agreements	Managed/adjudicated shortage sharing agreements	AG, PWS
	Drought, warmer temperature longer growing season	Cropping pattern	Percent permanent crops	AG
	Drought, diminished supplies	Conservation plans	Enforceable Conservation Plan	PWS
	Drought, warmer temperature, longer growing season	Landscape watering	Per capita use and landscape watering as reflected in the per capita demand	PWS
	Drought	Water hardening	Capacity of supply relative to demand and level of per capita demand	PWS

2.3 Resilience of Water Use Sectors

Based on the information gathered through the public meetings, along with public surveys and conversations with stakeholders and water managers, matrices were developed for each water use sector (Appendix A). Individuals and communities can use the matrices to assess their degree of resilience to climate change.

The water diversity element is considered to be one of the most significant elements determining resilience to climate change according to surveys conducted in 2021. All sources of supply have a degree of vulnerability. Having a mix of primarily surface water and back-up groundwater supplies can help reduce a water system's vulnerability to drought. This conjunctive-use strategy enhances the resilience of a water supply by resting the aquifers so that the groundwater levels can "recover" (or at least not decline further) and be available during drought periods.

The overall availability of the supply is an important aspect of a resilient water supply that is dependent on local climate, geography, and geology. The historical availability of the supply is important for estimating the relative resilience of a water supply. Systems relying on surface water from streams where the lowest recorded annual flow was more than sufficient to meet their needs are more resilient than systems with a surface supply inadequate to meet existing water demands. Reservoir storage can increase resiliency, but surface water systems that store water in reservoirs are more vulnerable to loss of supply from increased evaporation as temperatures rise. Systems with a senior priority date are less vulnerable to priority enforcement.

Likewise, groundwater supplied systems are more resilient if their supply recharges rapidly or is relatively abundant, or if the historical trend in water level elevations shows no decline. Projected supply as a percentage of demand is also an important metric for quantifying resilience to climate change.

Infrastructure capacity plays a key role in creating resilience. The ability of a water system to maintain its infrastructure in good condition, meet applicable regulations, and respond to emergencies is critical to its resilience.

Some systems are run by volunteers, and some have a large organization devoted entirely to system operation. PWSs with volunteer or part-time staff are often strained by inadequate resources to manage their water systems. For instance, if a water well goes dry or has some other failure, a PWS with resources will likely be able to respond faster than a system that has a volunteer operator.

Adequate available funding and staffing for repairs and maintenance improves a system's capacity to adapt to climate change. Some systems lack the financial resources to manage and deliver clean water.

Other aspects include the capacity of the PWS to meet peak summer demands, which will likely increase as warmer temperatures result in greater water demand for landscaping. For systems that rely on surface water, storage helps mitigate the impacts of earlier runoff. Treating and delivering water also requires power, and climate change may result in temporary power supply shortages. Systems with redundant or emergency supplies of water are more resilient than systems that have not planned for a temporary disruption to their water supply.

Watershed health is important to all water use sectors and appears in each of the matrices (Appendix A). Watershed health is essential to delivering water, particularly for those systems diverting surface water and recharging aquifers. Upland watersheds risks from climate change as increased aridity stresses vegetation include the risk of more erosion, catastrophic fires, and subsequent debris flows. Reservoirs can fill with burned fuels and sediments, and the infrastructure associated with a PWS may be vulnerable if it is in the floodplain. The risk of erosion, even without fire effects, will increase for all areas of the state.

Demand management strategies, including conservation, can help create greater resilience because the administrative or physical infrastructure is in place to adapt. These include sharing agreements, efficient irrigation methods, adaptable cropping patterns, and conservation plans. Research has shown that communities, states, and countries that have rules in place for managing shortages are better able to maintain peace than those with no structure in place (Wolf, 2007). Implementation of water use restrictions with pre-determined thresholds can improve their effectiveness.

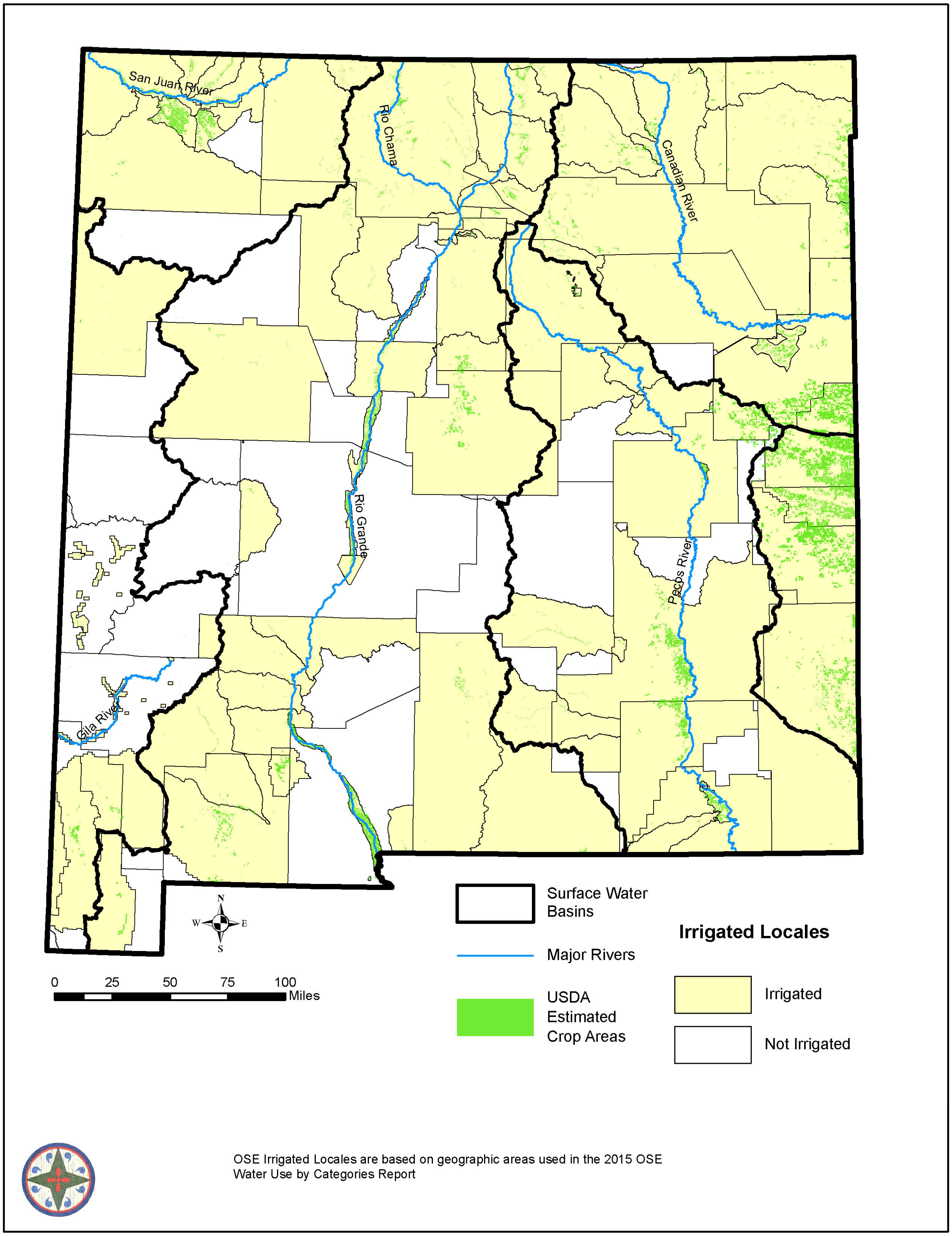
2.3.1 Resilience of Irrigated Agriculture and Livestock Watering

Irrigated agriculture consumes the lion's share of water utilized for human uses in New Mexico. Irrigated agriculture and its water use have been tracked by the New Mexico Office of the State Engineer (NMOSE) since 1965 based on the "irrigated locales" for which water use is estimated every five years (Figure 1). The NMOSE tracks the water use of 98 irrigated locales, including water applied to crops for Tribes, Nations, and Pueblos. The irrigated locales may correspond to irrigation districts or encompass much larger areas where irrigated crops are scattered throughout a county. Based on data collected by NMOSE for the 98 areas—including surface and groundwater diversions, acreage irrigated, irrigation method, and crops irrigated—water use from this sector totals 2.4 million acre-feet, which is 76% of the total water use in the state (Table 3).

Table 3. Summary of Water Diverted in 2015 for Irrigated Agriculture and Livestock Watering

Category	Total Withdrawal (acre-feet)			Percentage from Surface Water
	Surface Water	Groundwater	Total	
Irrigated agriculture	1,255,440	1,120,625	2,376,065	53%
Livestock watering	2,904	33,142	36,046	8%
Total	1,258,344	1,153,767	2,412,111	52%

Source: Magnuson et al., 2019



OSE Irrigated Locales are based on geographic areas used in the 2015 OSE Water Use by Categories Report

Figure 1. Irrigated Locales Used for the Water Use by Categories Reports

The resilience elements identified for irrigated agricultural systems are shown in Appendix A, Table A-1 (Pages A-1 through A-3). Some elements are currently quantifiable for the 98 irrigated locales, and some are not readily quantifiable. The information presented here is an overview of the relative resilience of irrigation districts and may not reflect the actual resilience of a particular farm. Each individual farmer, irrigation district, or acequia association knows their systems in greater detail and is in a better position to consider these elements and evaluate their own vulnerabilities and ways to build system resilience. Irrigation districts and farmers were given an opportunity to review and comment on the matrix as part of the webinars and surveys, and their input was helpful in identifying the vulnerabilities to climate change.

Infrastructure capacity plays a key role in creating resilient irrigated agriculture. The ability to store surface water can help mitigate the earlier spring runoff that is projected with climate change. Having dams, canals and ditches, and headgates that are in good condition can help improve the management of water and the overall resilience of the system.

Upland watershed health is vital to the resilience of farmland. The overall condition of the watershed contributes to erosion, which can deposit soils in reservoirs, reducing their storage capacity, and deposit sediment onto irrigated fields and obstruct or damage infrastructure. The health of vegetation will be stressed by warmer temperatures and the risk of erosion will be greater as plants are no longer able to hold the soil in place. Catastrophic fires, followed by intense storm events, can and have resulted in damaging debris flows capable of wiping out entire fields and attendant infrastructure.

The potential for more frequent storm events also results in greater flooding risk, and farmers might want to consider the proximity of their fields and infrastructure to the 500-year floodplain. On-farm soil health also plays a critical role in creating resilience. Water quality always plays a role in the health of an irrigated area and can be affected by warming temperatures, erosion, debris flows, and algal blooms.

Sharing agreements have been adopted by some irrigation districts and acequia communities and are vital to responding to drought by reducing the level of conflict during water shortages. The type of crops also impacts the flexibility of an AG system to adapt to shortages.

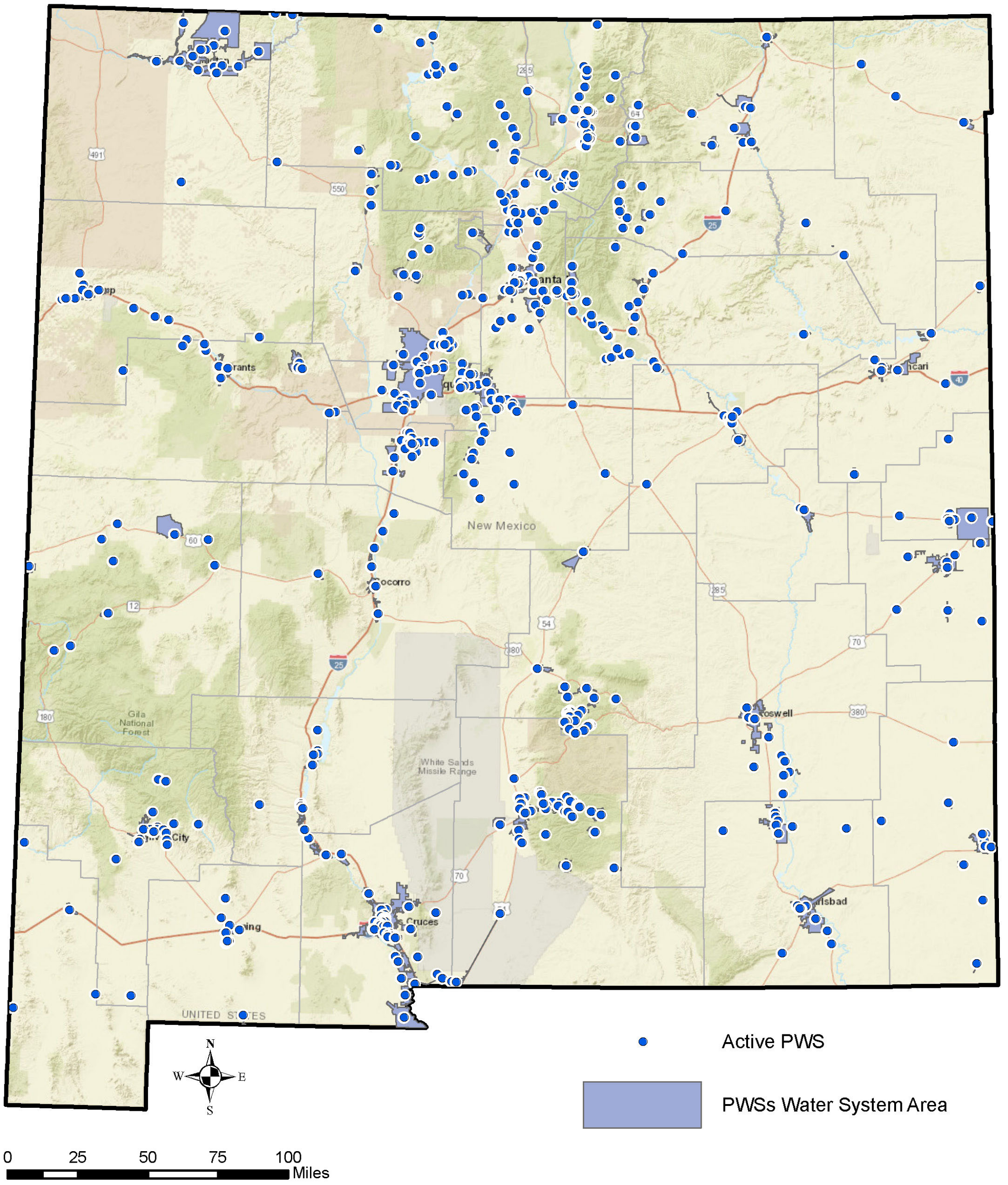
2.3.2 Resilience of Public Water Systems and Domestic Wells

New Mexico's 2.1 million residents use water for drinking, cooking, cleaning, and watering. The water is provided by public/private water systems (PWSs) to 86% of the population and by self-supplied domestic systems to 14% of the population (which includes all water use by Tribes, Pueblos, and Nations) (Magnuson et al., 2019). Most of the self-supplied homes obtain water from wells, some truck in water from an outside source, and others use cisterns to capture rainwater. Table 4 shows that over 300,000 acre-feet are diverted for this water use sector, representing about 10% of the total water diverted in 2015. The state does not have jurisdiction over the 21 Tribes, Pueblos, and Nations, some of which have public water systems while others haul water, particularly on the Navajo Nation. PWSs also provide water to non-residential customers, such as schools, commercial, industrial, and government customers. Figure 2 shows the 604 PWSs that are tracked by the Office of the State Engineer for the *Water Use by Categories* reports (Magnuson et al., 2019). The resilience elements that impact PWSs and domestic wells as identified in the public meetings are shown in Appendix A, Table A-2 (Pages A-4 through A-7).

Table 4. Summary of Water Diverted in 2015 for Public Water Supply Systems and Self-Supplied Domestic Wells

Category	Total Withdrawal (acre-feet)			Percentage from Surface Water
	Surface Water	Groundwater	Total	
Public water supply systems	87,399	196,758	284,157	31%
Domestic wells	0	27,949	27,949	0
Total	87,399	224,707	312,106	28%

Source: Magnuson et al., 2019



Active public and private water systems (PWSs) locations and service areas obtained from the 2020 NMOSE geodatabase of PWS (NMOSE, 2020d).

Figure 2. Public Water System Locations and Service Areas

The PWSs range from small, serving about 25 people and diverting less than one acre-foot per year, to large systems that provide water to our largest cities (serving up to over 600,000 people). The predicted decreases in streamflow and recharge, increases in water demand, and the increased risks of flooding and debris flows following catastrophic high-intensity wildfires are all climate change shocks that will stress PWSs and self-supplied communities. Some elements are currently quantifiable, and some criteria are not readily quantifiable. Individual water system or domestic well owners know the details of their systems and are in a better position to consider these aspects, if applicable, as they work to evaluate their own vulnerabilities and build system resilience.

Many PWSs participated in the September 2021 NMISC webinars and the surveys (NMISC, 2021) where they had the opportunity to review and comment on these elements. Their feedback helped to modify the analysis and correct data. The quantifiable elements are discussed in detail in Sections 3 and 4.

2.3.3 Resilience of Industrial, Commercial, Mining and Power

The NMOSE compiles water use for self-supplied industrial, commercial, mining and power (ICMP) water use sectors, including water used for these purposes by Tribes, Nations, and Pueblos (Magnuson et al., 2019). For entities that do not report meter data, water use is estimated. As described in more detail in the NMOSE *Water Use by Categories* report for 2015 (Magnuson et al., 2019):

- The industrial category includes self-supplied enterprises that process raw materials or manufacture durable or nondurable goods. This category also includes water used for the construction of highways, subdivisions, and other construction projects.
- The commercial category includes self-supplied businesses (e.g., motels, restaurants, recreational resorts, and campgrounds), public and private institutions (e.g., public and private schools and hospitals), self-supplied golf courses, greenhouses and nurseries that both produce and sell products to the general public on the same premises, and off-stream fish hatcheries that produce fish for release.
- The mining category includes the self-supplied enterprises that extract minerals occurring naturally in the earth's crust such as potash, coal, smelting ores, crude petroleum, and natural gas. This category also includes water used for oil and gas production (well drilling

and secondary recovery of oil), quarrying, milling (crushing, screening, washing, flotation, etc.), and other processing done at the mine site or as part of a mining activity, as well as water removed from underground excavations (mine dewatering) and stored in tailings ponds. The mining category also includes water used to irrigate new vegetative covers at former mine sites that have been reclaimed. It does not include the processing of raw materials, such as smelting ores, unless this activity occurs as an integral part of a mining operation and is included in an NMOSE permit.

- The power category includes all self-supplied power generating facilities and water used in conjunction with coal-mining operations that are directly associated with a power generating facility that owns and/or operates the coal mines.

The water derived from surface water, groundwater, and total withdrawals by ICMP water use sectors represents a total of 5% of the water diverted for all water use sectors in 2015. As shown in Table 5, the industrial and mining sectors are almost entirely dependent on groundwater and the commercial and power sectors have a more diverse supply portfolio as a group, but individual commercial entities or power plants may have only one source of supply.

Table 5. Summary of Water Diverted in 2015 by the Industrial, Commercial, Mining and Power Water Use Sectors

Category	Total Withdrawal (acre-feet)			Percentage from Surface Water
	Surface Water	Groundwater	Total	
Industrial (self-supplied)	0	8,718	8,718	0%
Commercial (self-supplied)	12,326	45,199	57,525	21.4%
Mining (self-supplied)	1,141	41,153	42,294	2.7%
Power (self-supplied)	39,677	10,742	50,419	78.7%

Source: Magnuson et al., 2019

Aspects of ICMP water systems that impact resilience are listed in Appendix A, Table A-3 (Pages A-8 through A-10). The water users in the ICMP sector are diverse and unique in how they use water, but the criteria for assessing resilience are nearly identical to the criteria that impact PWSs.

As with the PWS sector, infrastructure capacity plays a key role in creating resilient ICMP water systems:

- The ability to store raw surface water will help mitigate the earlier runoff that is projected with climate change for those systems that rely on surface water. Systems without a reservoir that use surface water will be dependent on the timing of snowmelt-driven streamflow.

- ICMP systems that have properly designed infrastructure with the ability to manage the possible increase in extreme precipitation events are more resilient.
- Each ICMP system with a greater distance from the facility to the water source, with long pipelines crossing arroyos or other drainages will be more vulnerable.
- Any facilities that are in the floodplain or up to 2 feet above the 100-year flood zone are vulnerable to the erosive forces during a storm and to sedimentation and damage from debris flows following a catastrophic fire.
- Another aspect of resilient ICMP water users is the frequency of operation and maintenance inspections, particularly after extreme precipitation events, or wildfire and extended drought. ICMP operations that have planned for the clearing of debris and addressing water quality conditions such as a dam release of acid-mine drainage are more resilient than those that have made no such plans.
- Facilities that also have an emergency plan to address damage to the electric grid or damage to other public utilities are more resilient. Those that have a plan that includes working with local, state, federal and local emergency managers are more resilient, particularly if the emergency response plan includes concerns for downstream stakeholders/environment/species.
- Facilities that work with hazardous materials and are equipped to contain potential contaminants during production and post-production are more resilient. Well-engineered plans for clean-up during production and post-production are more resilient.
- ICMP facilities that have developed cooperative agreements to manage water supply shortages through sharing agreements and have developed efficient methods to manage water are more resilient in facing supply shortages.

2.3.4 Resilience of Watersheds and Habitat

Watersheds and habitat are dependent on water as much as people are. For each of the three sectors previously discussed, upland watershed health is a key element in creating resilience for the human uses of water, because the majority of our water is supplied by the upland watersheds. For this section, this broad category of water use is intended to capture the aspects of the land surface that support native vegetation, wildlife, and flowing streams as well as water diversions for human use. The warmer temperatures and increased aridity predicted in 2070 will create more stress to the vegetation in our watersheds, in addition to the predicted declines in streamflow and recharge.

Numerous federal and state agencies are dedicated to managing forests and riparian areas. For a more in-depth understanding of how forests, riparian areas and habitat will be impacted by climate change, the reader is directed to the tools, analysis, and extensive research conducted by:

- U.S. Forest Service (USFS) Rocky Mountain Research Station (RMRS Publications - RMRS General Technical Reports (RMRS-GTR) (fs.fed.us)).
- U.S. Environmental Protection Agency (EPA) (Climate Resilience Evaluation and Awareness Tool (CREAT) Risk Assessment Application for Water Utilities | US EPA).
- U.S. EPA Recovery Potential Screening Tool contains watershed indicator datasets for assessing the vulnerability of HUC 12 Watersheds (nm-rps-scoring-tool-08122021.xlsm (live.com)).
- New Mexico Energy Minerals and Natural Resources Climate Change Task Force and the New Mexico Climate Risk Map (NM Climate Risk).

- New Mexico Energy Minerals and Natural Resources Forestry Division and the 2020 Forest Action Plan centered on climate adaptation and mitigation approaches (Forest Action Plan - Forestry (nm.gov)).
- New Mexico Environment Department (NMED) Watershed Protection Bureau (New Mexico Environment Department).
- New Mexico Department of Agriculture through its Healthy Soils Program increases awareness of soil health principles for climate-focused grassland management. (Healthy Soil Program - New Mexico Department of Agriculture (nmsu.edu)).

This discussion of the resilience of watersheds is an overview of some aspects of the vulnerabilities and resilience to climate change. The above-mentioned federal and state agencies are focused on the risks to watershed health posed by climate and non-climate stressors.

Climate shocks will stress the forests by increasing the risk of fire, lengthening the fire season, increasing the drought frequency and duration, increasing temperature and aridity, and reducing snowpack. Climate shocks will stress riparian areas through factors including reduced streamflow, warmer temperatures, increased erosion, and sedimentation.

The resilience elements that impact the health of watersheds and their ability to respond to climate change shocks are shown Appendix A, Table A-4 (Pages A-11 through 13). Almost all of New Mexico's water originates in the highest areas of an upland watershed, where precipitation is greater than evapotranspiration and forests hold the soil in place. Two key elements impact the resilience of these forests: the fire regime and the forest structure. Some forests, such as high-elevation spruce-fir forests, have stand replacement fires every few hundred years, while other forest types, such as ponderosa, historically experienced frequent ground fires every 5 to 7 years that reduced the fuel load and kept the forests at a relatively low density of trees. Forest structure changed significantly in the late 1800s and early 1900s, when land management practices changed. In the 1880s, access by railroad opened the opportunity for widespread livestock grazing (Hunt, 1951; USDA, 2001). The sudden high-intensity grazing combined with the practice of fire suppression reduced the natural processes that kept the forests healthy (NMEMNRD, 2020). If the forest has changed from its natural structure (density, connectivity, and species diversity) such that the natural processes (fire and pests) can no longer occur without catastrophic consequences, then the forest is less resilient. If the forest has a diversity of species, open meadows, appropriate density, then the forest is more resilient to widespread landscape changes from fire and pests.

At elevations below 7,000 feet, fewer trees are on rangelands to hold soil and shade the ground, primarily because precipitation decreases, and temperature increases at lower elevation. The condition of rangelands is important, particularly for wildlife that feed on the grasses and forbs that have historically thrived in New Mexico. Natural soil stability on rangelands and forests, expressed in terms of the ability to hold water and minimize erosion, is an element that impacts resilience. The ability to hold water can be assessed by considering the steepness of the landscape, the aspect, and the soil type. North-facing slopes have less sun exposure and thus less water lost to evaporation and more water available for vegetation. The erosivity of a watershed is often based on soil type, extent of impermeable surfaces, and presence of vegetation. Some of these elements cannot be changed but understanding the vulnerability of steep south facing slopes to erosion can guide land managers to plan accordingly.

Many of New Mexico’s streams begin in the forests and merge with tributaries as they flow downstream. Streams support wildlife and aquatic habitat and supply surface water. Critical to riparian health is the availability of water, from short-term snowmelt to spring flows that sustain baseflow year-round. With less runoff and less recharge, the availability of water to sustain the flow regime is threatened. Sustained flow in historically perennial streams is important to maintaining the riparian habitat, water quality, and temperature. River structure (i.e., bank stability, sinuosity, bank-full channel depth and width) that can respond to storm events without severe erosion, sedimentation, and flooding provides resilience. Resilient river structure requires a consistent baseflow to support the vegetation that creates a functioning riparian system.

Rivers need to be connected to floodplains to reduce the risk of severe downcutting and flooding. Land use practices impact the behavior of rivers. Impermeable pavement and other urban features channel water to arroyos and streams and reduce infiltration to groundwater, creating unnaturally high peak flows (e.g., flash floods) that may damage riverbanks and destroy riparian habitat. Rangeland management impacts soil health and the ability of the land to withstand higher temperatures and intense rainfall events.

Land managers, watershed associations, and other collaborative groups that are working on the management activities and the proper functioning of their watershed are improving resilience to climate change.

2.3.5 Resilience of Recreation and Quality of Life

Recreational activities and aspects of our environment that enhance quality of life are vulnerable to predicted climate change-related shocks that threaten to reduce the quality and availability of many outdoor activities, including skiing, whitewater rafting, fishing, wildlife viewing, birding, boating, gardening, hiking, biking, and just being in nature. The resilience elements for recreation and quality of life that were identified by stakeholders are detailed in Appendix A, Table A-5 (Pages A-14 through A-16).

With predicted changes in winter precipitation toward more rain and less snow, the ski industry and those who enjoy winter sports will be among the most impacted. Ski areas that have a diverse supply of water, such as available groundwater for making snow, will be more resilient, though still vulnerable. Cross-country skiers and snowmobile riders will have to seek higher elevations for the necessary snowpack to support their activities.

Boaters and anglers will have less surface water to enjoy. Wildlife viewing and bird watching at our nine National Wildlife Refuges depend, in part, on ponded water. Birds that can only take flight from water, and migratory birds that rest overnight on water for protection from predators are dependent on ponded water. Wildlife refuges that have a supplemental supply of water, such as a well with water rights, can divert water to ponds for wildlife habitat and increase the resilience to climate change. Boaters who depend on water in reservoirs will be negatively impacted by lower lake levels. Infrastructure, such as boat launches and docks, can be designed to be flexible to adapt to changing water levels.

Gardeners who derive their supply from a PWS or domestic well that is unable to meet demand will likely have to restrict outdoor water use. Forest and riparian health and rangeland conditions impact all aspects of recreation and quality of life. Smoke from forest fires can force all recreators indoors, and erosion can damage trails and infrastructure.

Debris flows, which are essentially fast-moving landslides, prevalent for years following high-intensity wildfires, are likely to increase. Debris flows have devastating impacts on riparian habitat (fish kills) and reservoirs, making conditions for fishing and recreational boating unsafe.

3. Assessment of Water Supply Resilience Elements for Agriculture and Public/Private Water Systems

This analysis of the resilience of irrigated agricultural (AG) and public/private systems (PWSs) to climate change is intended to help water managers understand the relative strength of our water systems to withstand the coming climate shocks and identify strategies to improve their resilience. The focus is on AG and PWSs because AG is the largest and PWS impacts the most people[7]. Robust datasets exist for these sectors of water use, including geographic information system (GIS) coverage of water service areas, irrigated acreage, and attendant infrastructure. Although such robust datasets are not readily available for other water-use sectors, the concepts utilized here apply. Figure 1 and Figure 2 show the irrigated locales and the PWSs evaluated for this analysis.

This section examines elements that affect how vulnerable water systems are to climate shocks, as well as how resilient a given system is. For this resilience assessment, reservoir evaporation is treated as a supply issue, rather than a demand. Increased evaporation will reduce the supply available in reservoirs.

In applying this analysis to specific areas, consider the following:

- The sources of data used for this analysis may contain errors.
- Resilience is nuanced, and the criteria presented are limited. Other criteria may be just as important.
- The assessment is not intended to rank one system against another, but to obtain a high-level view of the status of the state's water systems and identify priorities for funding necessary projects.

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[7] Reservoir evaporation is water lost to evaporation while held in storage for irrigation and public water systems and is 7% of the water used in 2015, which brings the total to 92%.

The following analysis is presented as a concept and is expected to evolve as more information is made available. The selected criteria and the datasets are all ripe for more engagement and revision.

3.1 Water Supply Diversity Resilience Element

By far the most serious impacts of projected warming temperatures are expected runoff reduction, reduced recharge, and the likely longer drought periods. New Mexicans are familiar with extended droughts and as a result, many AG and PWS systems have diversified their water sources to utilize renewable supplies when available and reserve groundwater for drought periods, a strategy called conjunctive use. All sources of supply have vulnerabilities. A mix of surface water and groundwater supplies can help reduce a water system's vulnerability to changing conditions. The conjunctive-use strategy enhances the resilience of a water supply by resting aquifers so that groundwater levels can recover, or at least not decline further, and be available during drought periods.

The data used to identify diversity of supply for AG and PWS systems was obtained from the NMOSE 2015 and 2010 *New Mexico Water Use by Categories* reports (Magnuson et al., 2019; Longworth et al., 2013). Figure 3 shows the percentage of diversions in irrigated locales that come from surface water, and Figure 4 shows the relative level of resilience. Figure 5 shows the percentage of surface water in a PWS's annual diversions in 2010 or 2015, while Figure 6 depicts the service areas of PWSs for their level of resilience for this element. Those AG locales and PWSs with 90% derived from either surface water or groundwater are the least resilient and those with a mix of surface water and groundwater (40 to 60% from each) are the most resilient.[8]

95 % of PWS systems rely on only one source of water supply.

Only 13 irrigated locales, accounting for about 20% of the water diverted for AG, have a diverse portfolio of water supply, with groundwater and surface water supply each between 40% and 60% of the system's supply. Another 8 locales use a mix of surface water and groundwater but rely on one type of source for more than 60% of their supply. Of the remaining 77 irrigated locales, 47 rely on surface water for more than 90% of their supply, and

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[8] A system that diverts primarily surface water, but has sufficient groundwater as a backup, is very resilient. Many systems that rely on surface water do not have ample groundwater available.

30 use only groundwater for more than 90% of their supply, representing 60% and 14% of the water diversions, respectively. Thus, 74% of irrigated agriculture diversions are from one source, either surface water or groundwater.

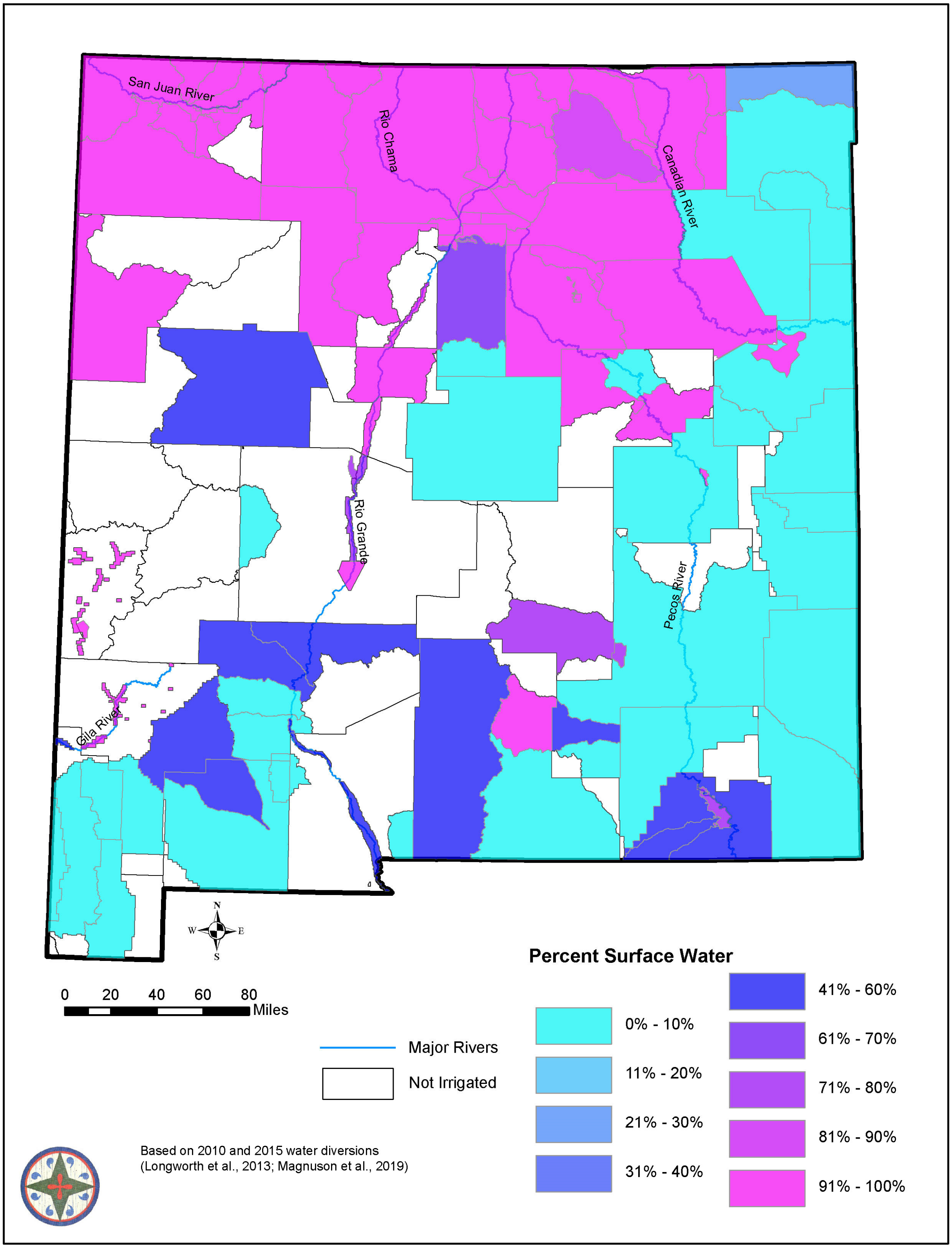
Only 22 PWSs have a diverse portfolio of water supply, but these very resilient PWS systems divert 38% of the water used by PWSs statewide. On the other hand, 546 PWSs use no surface water and are thus less resilient because they are wholly dependent on groundwater; these systems represent 58% of the water diverted by PWSs. Another 7 PWSs use surface water for 1 to 36% of their supply, which makes them more resilient than if they were entirely dependent on groundwater. The remaining 29 PWSs are dependent primarily on surface water, which creates vulnerability to droughts or other impairments to surface water. A system that has a groundwater supply that was not used in 2010 or 2015 may be more resilient than presented here.

The 22 PWSs with the greatest diversity in water supply divert 38% of the water diverted by PWSs and provide water to 42% of the population served by PWSs in New Mexico

Calculation: The levels of resilience in water diversity shown in Figures 4 and 6 were calculated using the following steps:

- Divide the amount of surface water used in 2015 by the total water use in 2015 (Magnuson et al., 2019)
- Divide the amount of surface water used in 2010 by the total water use in 2010 to examine any differences (Longworth et al., 2013)
- Utilize the percent surface water value for 2010 or 2015 that represents the most diverse water supply. If a system used no surface water in 2015 and a majority of surface water in 2010, calculate the percentage of surface water for the combined two years. If a system used all surface water one year and all groundwater another year, set the percentage at 50%.

The blue shaded areas in Figures 4 and 6 indicate those with the most diversity in water supply and thus the most resilience in terms of water diversity.



Based on 2010 and 2015 water diversions (Longworth et al., 2013; Magnuson et al., 2019)

Figure 3. Surface Water Percentage of Total Diversions Supplying AG Locales, 2010 and 2015

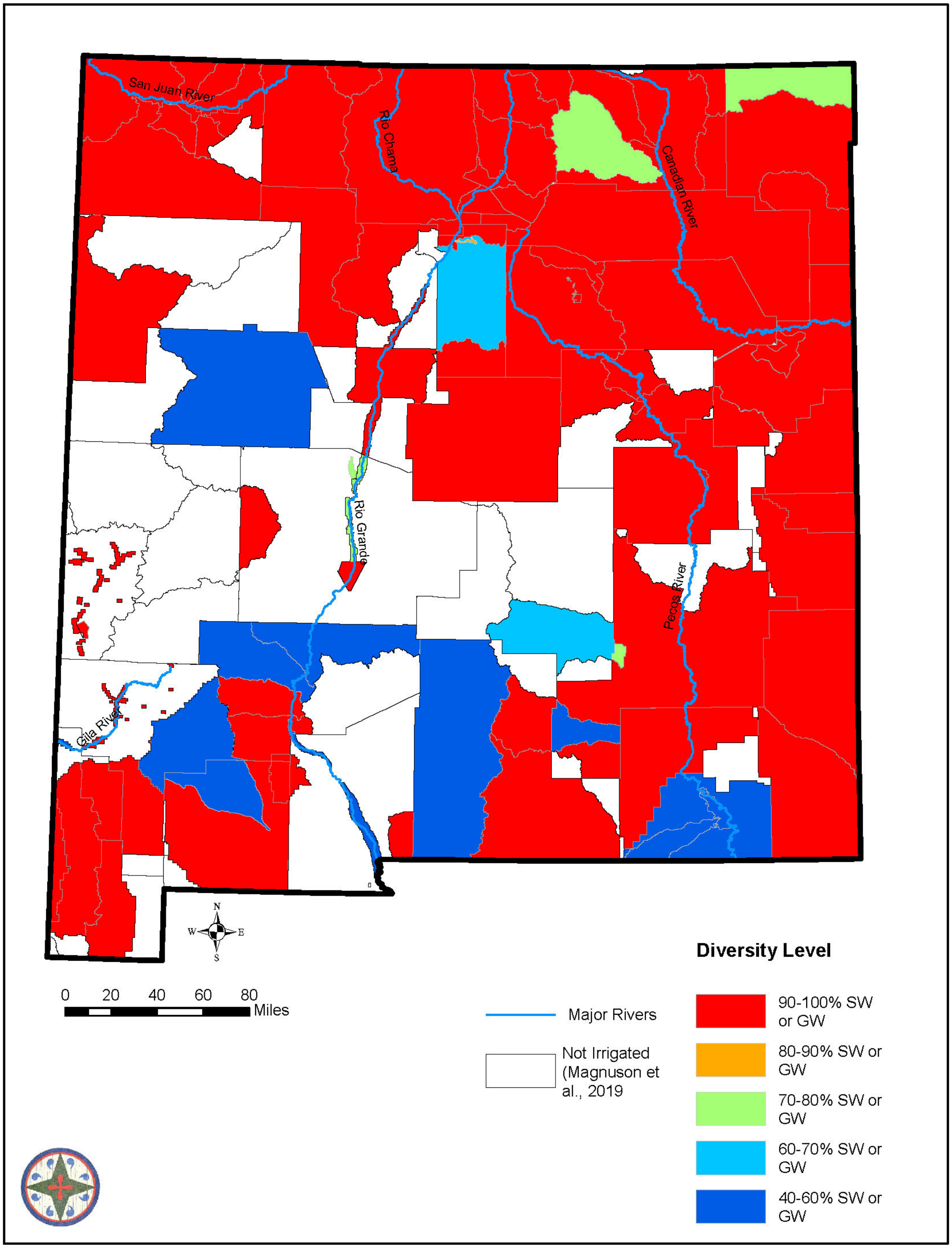
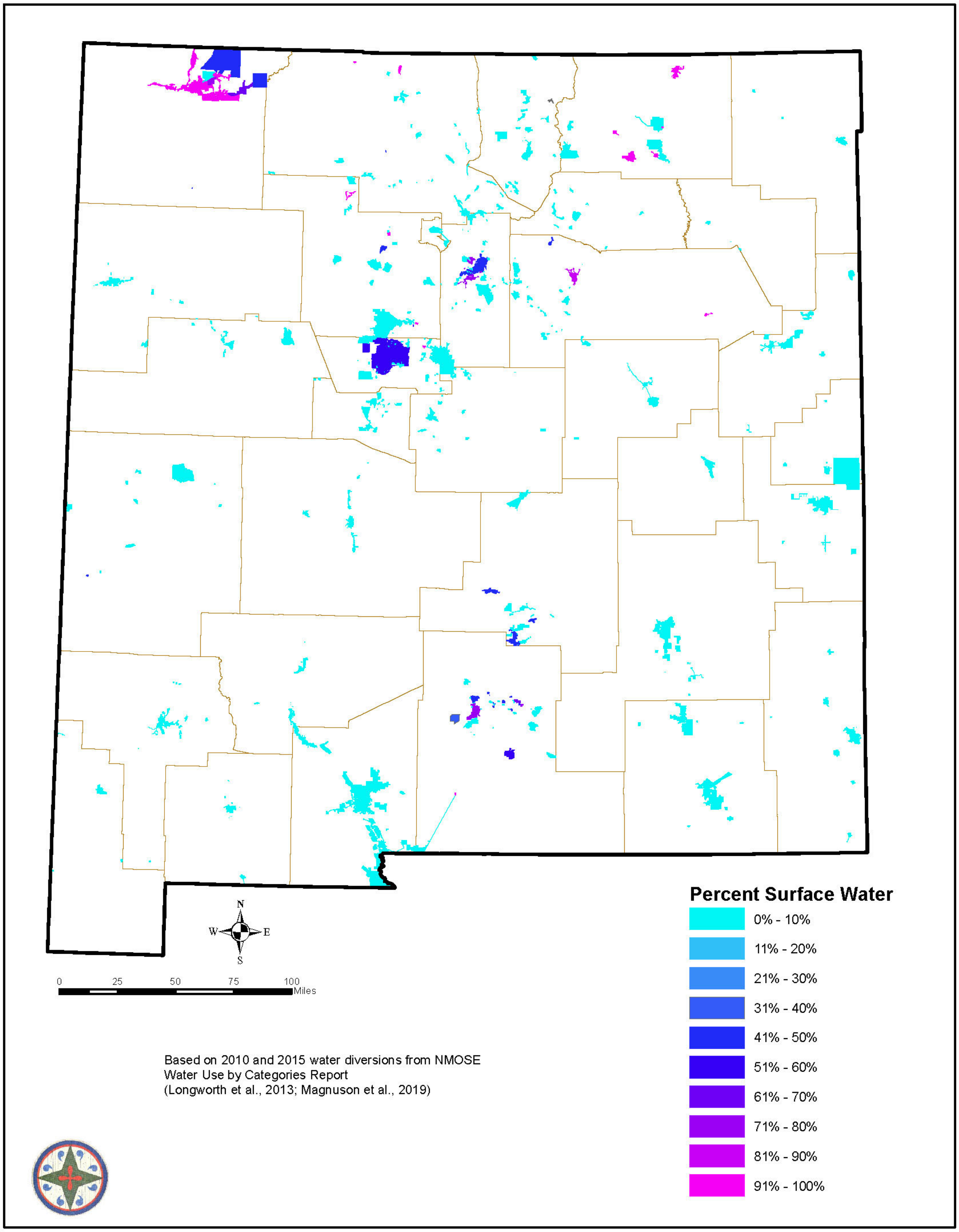


Figure 4. Water Supply Diversity for Irrigated Agriculture Locales



Based on 2010 and 2015 water diversions from NMOSE Water Use by Categories Report (Longworth et al., 2013; Magnuson et al., 2019)

Figure 5. Surface Water Percentage of Total Diversions Supplying Public/Private Water Systems, 2010 and 2015

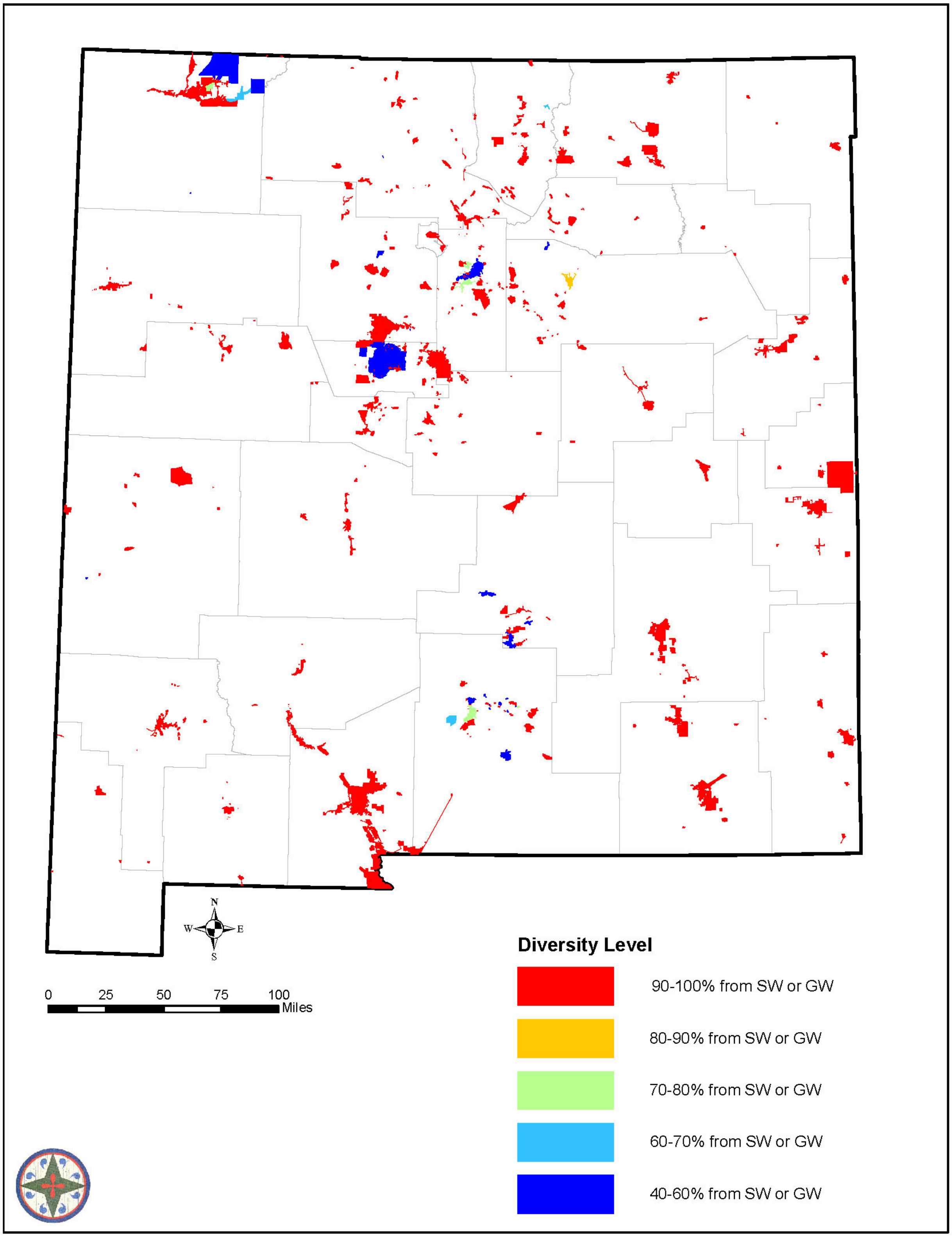


Figure 6. Water Supply Diversity for Public/Private Water Systems

3.2 Water Supply Availability Resilience Elements

Abundance of surface water or groundwater that is available to a water system, particularly in a dry year, impacts resilience. Diversions of neighboring users will have a cumulative impact on future availability. Three elements are used here to assess water availability: (1) ratio of surface water in the driest year to the water demand, (2) aquifer type, and (3) projected supply-demand gap.

3.2.1 Surface Water Availability

In the upper reaches of a stream, demands for surface diversions may be relatively insignificant to stream flow, even in the lowest flow years. To assess surface water availability for resilience, a ratio of surface water supply to demand was calculated by dividing the lowest recorded minimum annual flow by the water demand. If the ratio is one or less, the system is more vulnerable.

To assess surface water supply resilience, stream gage records from the U.S. Geologic Survey (USGS) were compiled. Using the National Hydrologic geodatabase of streams, the NMOSE *New Mexico Water Use by Categories 2015* report (Magnuson et al., 2019), facilities data obtained from the NMED Drinking Water Bureau (DWB), and the NMOSE Geodatabase of Public & Private Water Systems (NMOSE, 2020d), the point of diversion was compared to the nearest stream gage. Figure 7 shows the location of the active stream gages and the relative weight of the minimum streamflow recorded at the nearest gage. Figure 8 and Figure 9 show the surface water availability elements for AG locales and PWSs, respectively, where surface water is a significant component of the water supply. Three of the AG locales have a surface water supply where the flow in the lowest year is more than 50 times the demand, indicating a very resilient system with respect to this element. The other 47 AG locales have a ratio that is less than 1, indicating that they are very vulnerable to drought. Thirty-two of the 58 PWSs that divert surface water show that the minimum recorded streamflow was more than demand. More than half of the PWSs that utilize surface water are in the least resilient level, where the streamflow during the driest year was less than their surface water diversions in 2015.

55% of PWS that rely on surface water are very vulnerable during drought

Calculation: The levels of resilience in surface water availability shown in Figures 8 and 9 were calculated using the following steps:

- Download data for USGS stream gages in New Mexico (USGS, 2020).
- Identify the minimum annual streamflow recorded at USGS stream gages for the period of record.
- Connect the stream reach with the nearest gage that has a minimum of 10 years of record. If no gage is available in vicinity of surface water diversion, set minimum flow to 50% of surface water diversions in 2010 and 2015. If the gage is located below a confluence with a tributary that enters below the reach from which the PWS or AG locale diverts water, set the minimum flow to 50% of the gaged minimum flow.
- Convert the volume (acre-feet) of surface water used in 2015 into a rate of cubic feet per second (cfs) (assuming a growing season of 6 months for AG locales and year-round diversions for PWSs).
- Check surface water diversions in 2010; use 2010 diversions if no diversions in 2015.
- Locate the intake structure for each water system.
- Divide the minimum streamflow at the location of the intake structure by the rate used in 2015 (or 2010)[9].

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[9] The City of Santa Fe derives surface water from the Rio Grande, through diversion of San Juan-Chama project water, and from the Santa Fe River. The minimum flow rate was set equal to the combined minimum flow at the Rio Grande at Otowi and the Santa Fe River above McClure gages. The lowest annual flow recorded at the San Juan River near Archuleta Gage was in 1963 when Navajo Dam was filling, thus not representative of current conditions. The next lowest annual flow was in 2014 at the Archuleta Gage which was used as the minimum flow on the San Juan River. For Navajo Indian Irrigation Project, the minimum flow was set equal to the annual flow recorded at San Juan near Archuleta Gage in 2014 plus the NIIP diversion that occurs upstream of the Archuleta Gage in 2014.

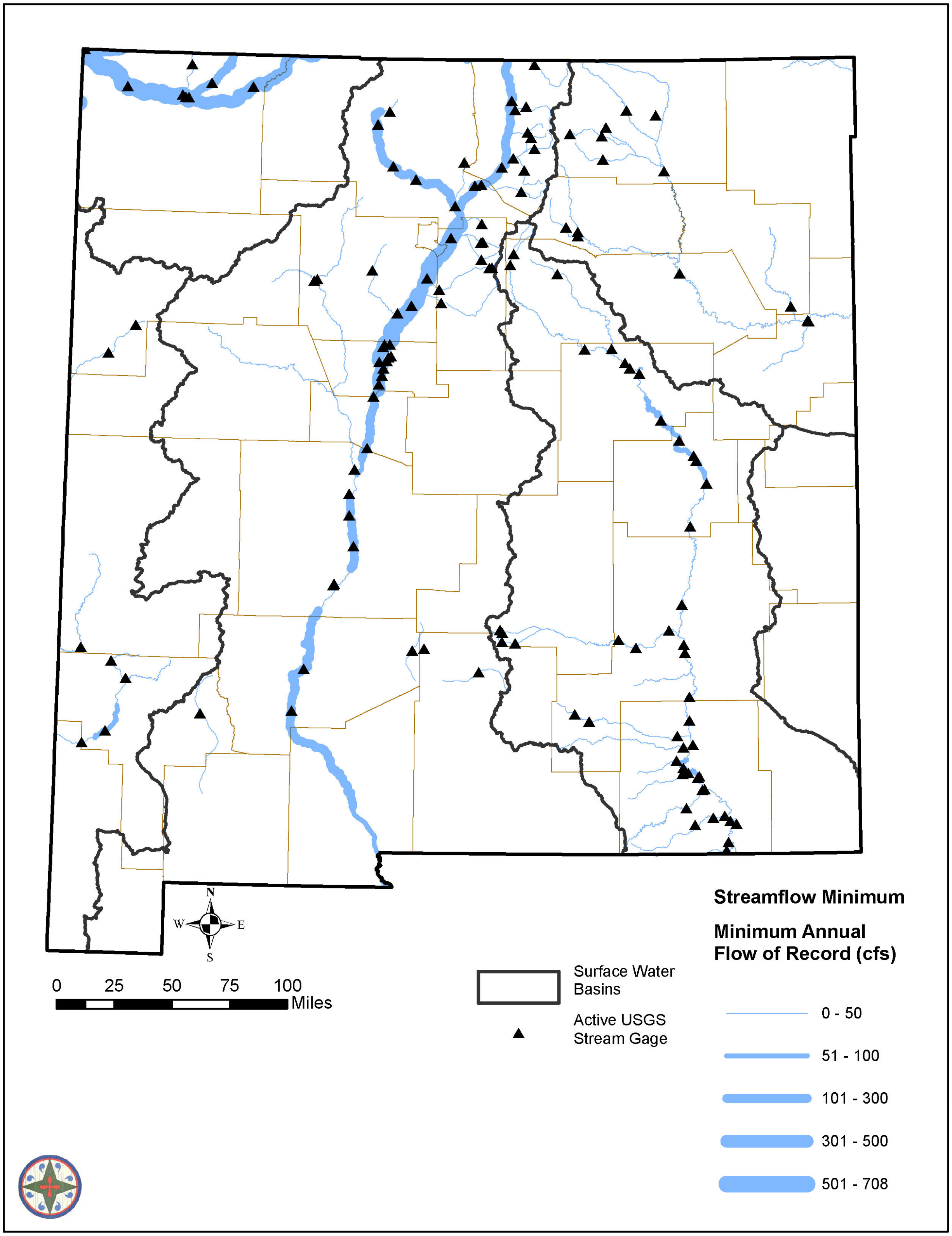
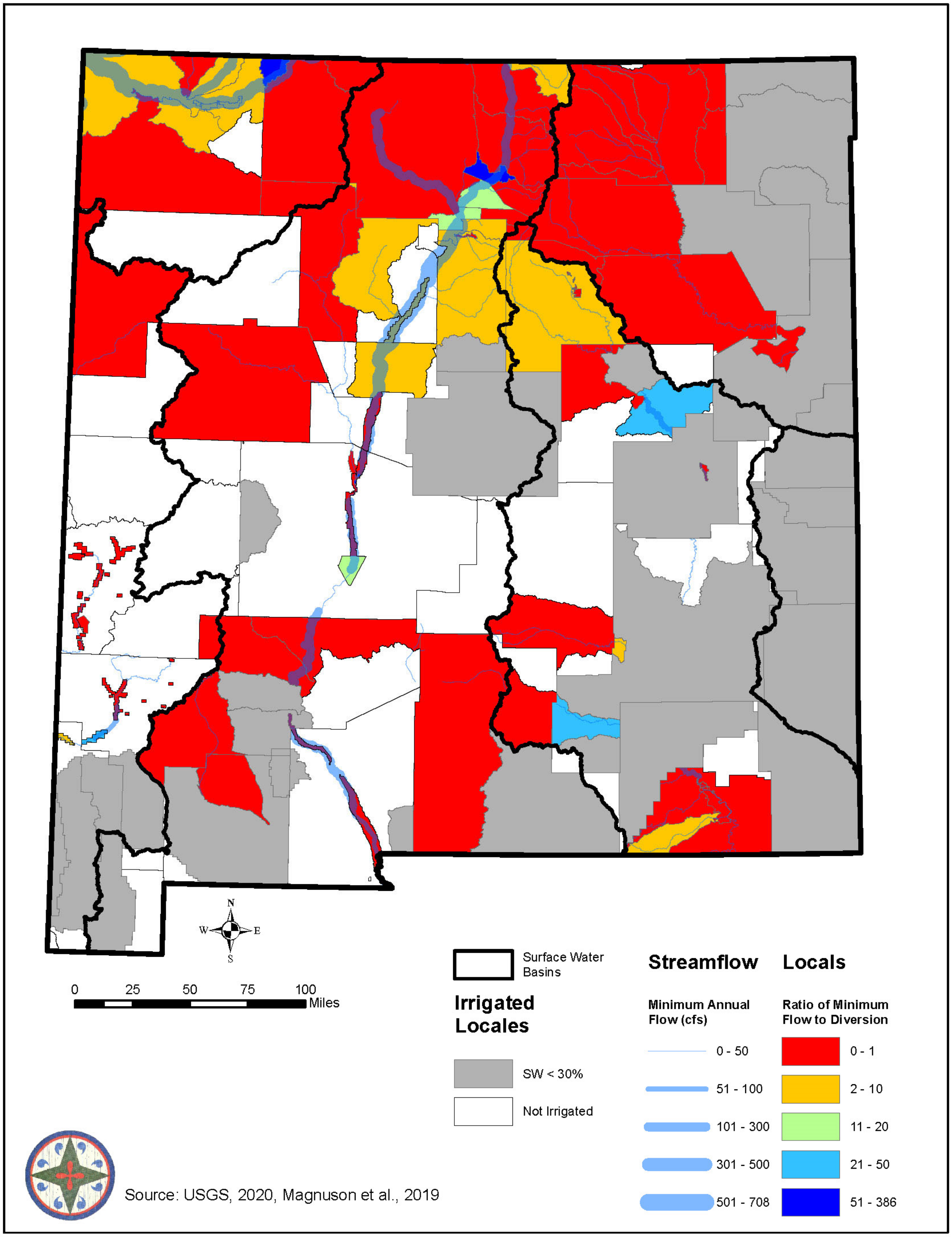
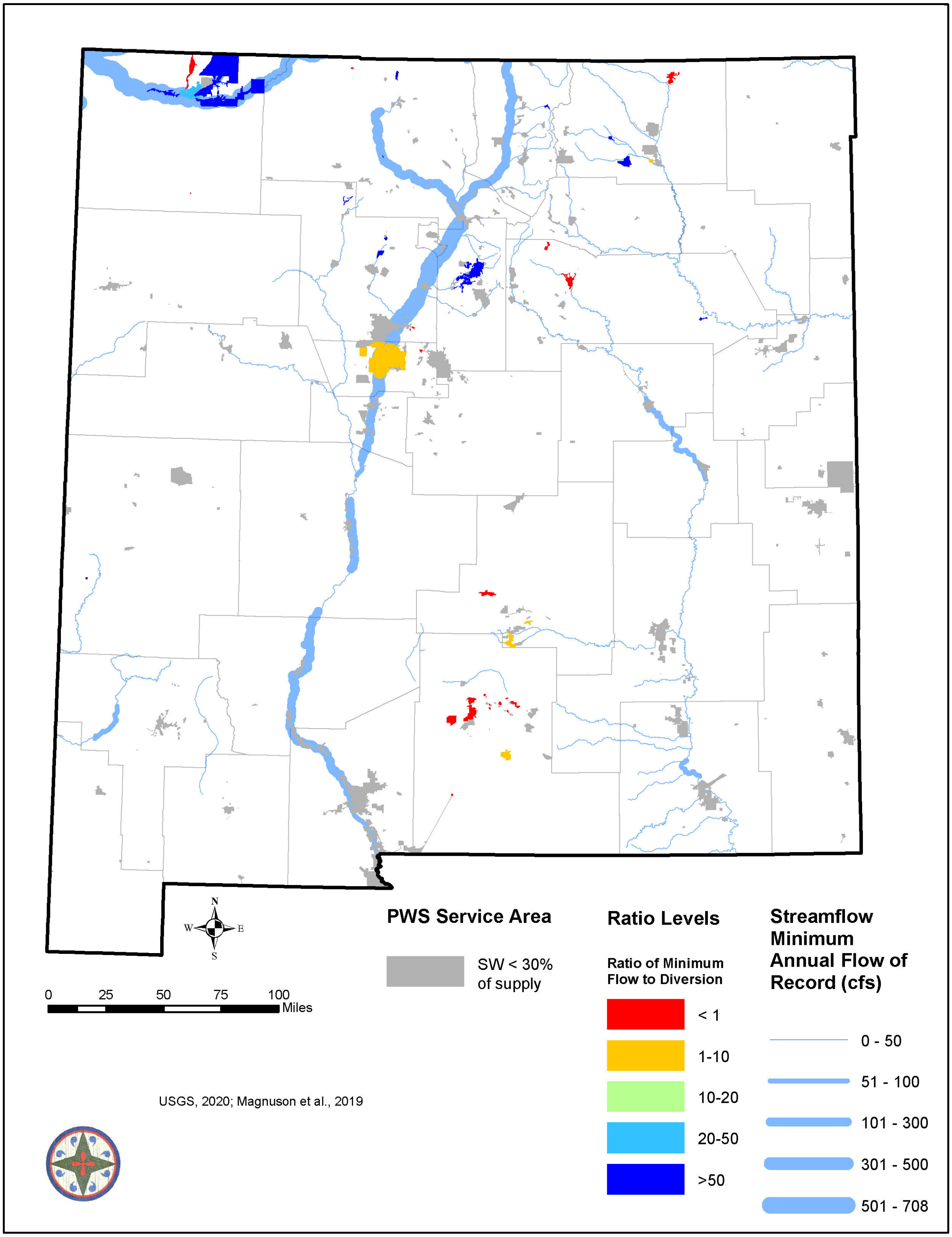


Figure 7. Minimum Recorded Streamflow and Active USGS Stream Gages



Source: USGS, 2020, Magnuson et al., 2019

Figure 8. Surface Water Supply Availability for Irrigated Agriculture Locales: Ratio of Minimum Annual Surface Water Flow to Total Diversion of Irrigated Locales



USGS, 2020; Magnuson et al., 2019

Figure 9. **Surface Water Availability Element: Ratio of Minimum Annual Surface Water Flow to Diversions by Public/Private Water Systems**

3.2.2 Groundwater Availability

Groundwater is extracted from aquifers in a diverse range of geologic and geographic settings, resulting in differing degrees of drought vulnerability. Wells in aquifers that are relatively shallow can be rapidly recharged from perennial or ephemeral streams. Wells near mountains receive recharge from snowmelt and seepage. Wells in isolated basins that do not have flowing streams are often in a state of groundwater mining, where the water levels have a history of long-term decline.

The *2018 New Mexico State Water Plan* identified 22 declared groundwater basins that are "closed" or not stream-connected where the water levels are declining[10]. Basins are designated closed for this report because the streams, whether perennial or ephemeral, do not leave the basin.

Aquifers in river basins that are managed to keep the river whole for interstate stream compact purposes, are more resilient to climate change than those without a perennial stream. New Mexico began managing the amount of pumping allowed in stream-connected aquifers through administration of water rights in 1956. With the connection between pumping a well and streamflow established by Theis in 1940 (Theis, C.V, 1940), the NMOSE began administering groundwater pumping to ensure that senior water rights were protected, and that New Mexico was able to meet water-delivery obligations of interstate compacts.

Predictions indicate that the rate of aquifer recharge will diminish and water levels in mined aquifers will likely decline at an accelerated rate. Figure 10 shows the basins that are part of an interstate compact and the groundwater basins with water-level declines. Figure 11 highlights the relative resilience of groundwater availability for AG locales that rely primarily on groundwater. Figure 12 shows the service areas of PWSs and their relative resilience for groundwater availability. Of the 57 AG locales that derive a portion of their supply from groundwater, 36 are in mined basins and 20 are in stream-connected aquifers. One AG locale has supply in both types of aquifers. A total of 447 PWSs have water supplies located in stream-connected aquifers.

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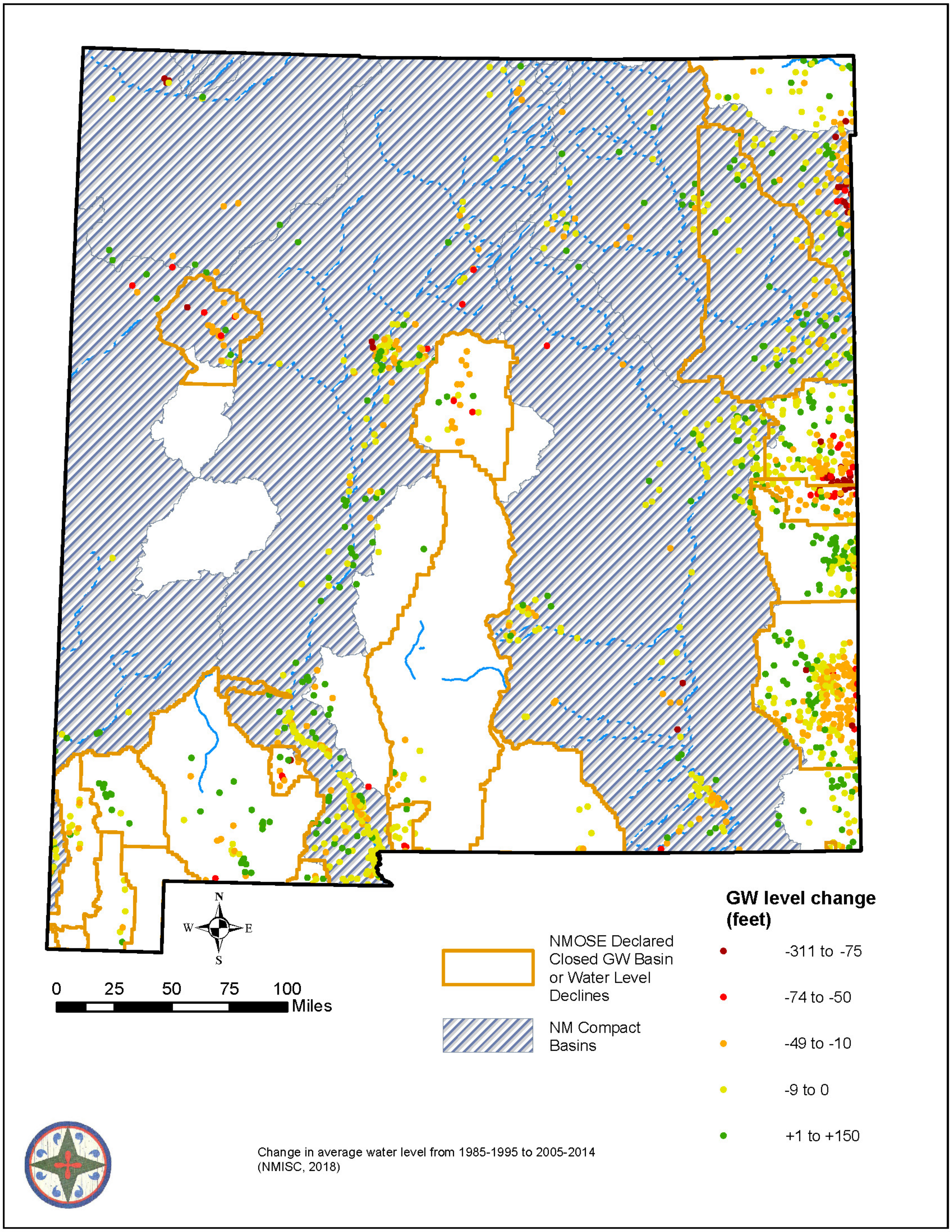
[10] The designation of "closed" has no relation to water right basins that are declared "closed" to new appropriations by the NMOSE.

Calculation: The levels of resilience in groundwater supply availability shown in Figures 11 and 12 were calculated using the following steps:

- Plot the extent of closed basins and compact basins from Figure 3.9 of the *2018 New Mexico State Water Plan*.
- Plot the location of each PWS service area (NMOSE, 2020d).
- Plot the location of AG locales (Magnuson et al., 2019).
- Plot the location of PWS infrastructure (NMED DWB, 2019).
- Determine the proximity of the above locations to Compact Basins, mined basins, and areas of water level decline (NMISC, 2018).

Data Gap: To improve on the assessment of groundwater availability, a map of the extent, depth, and water quality of aquifers with information about the aquifer properties — such as saturated thickness, hydraulic conductivity, storage coefficient—could be used to develop a more robust assessment of groundwater availability. The recharge rates and volume pumped by wells, along with the groundwater and surface water budgets, could be simulated in numerical models to accurately assess the short-term and long-term sustainability of groundwater supplies.

22% of PWS rely on mined aquifers



Change in average water level from 1985-1995 to 2005-2014 (NMISC, 2018)

Figure 10. New Mexico Compact Basins, Change in Average Water Level and Declared Groundwater Basins with Mined Aquifers

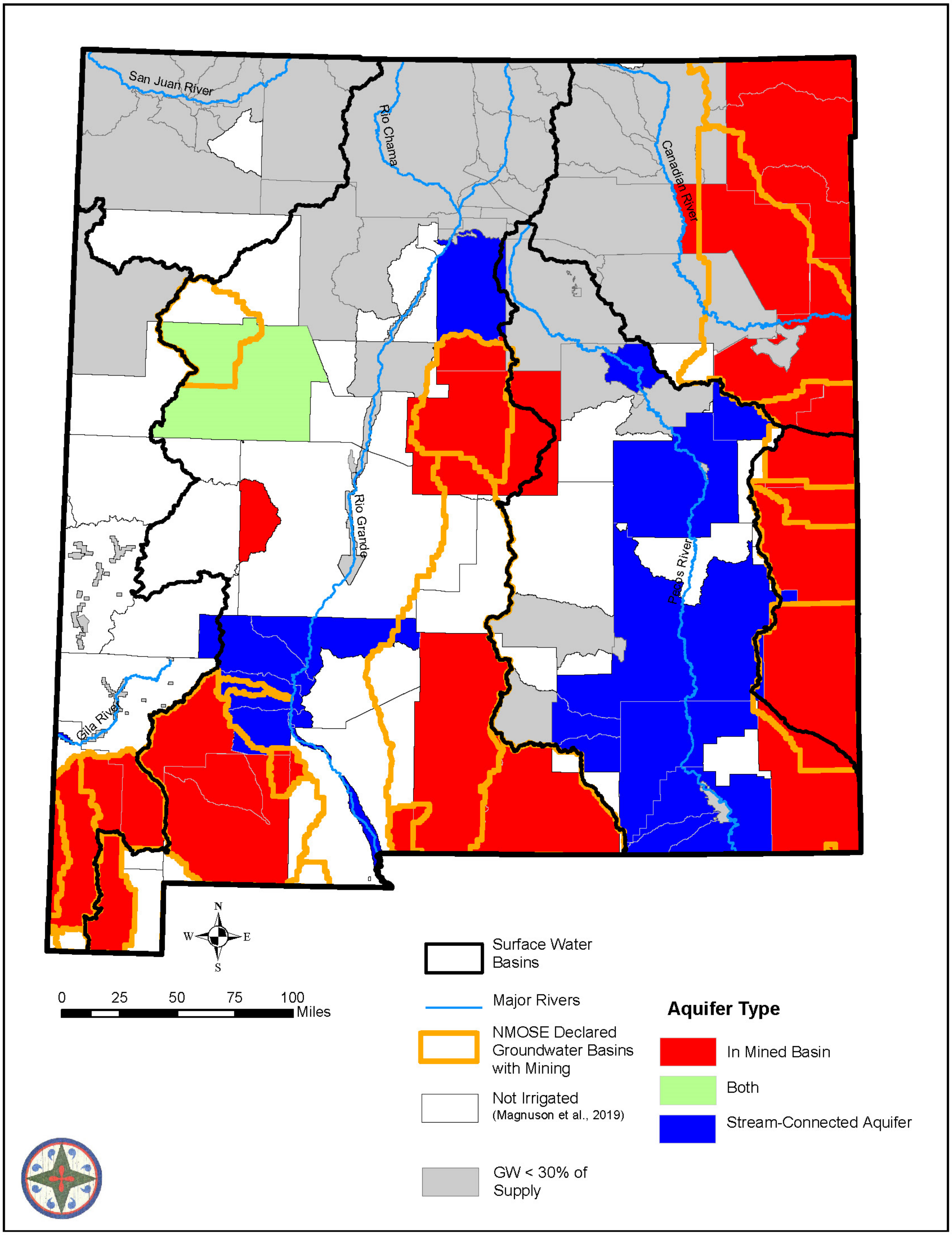


Figure 11. Groundwater Supply Availability Element: Aquifer Type for Groundwater-Dependent Irrigated Agriculture Locales

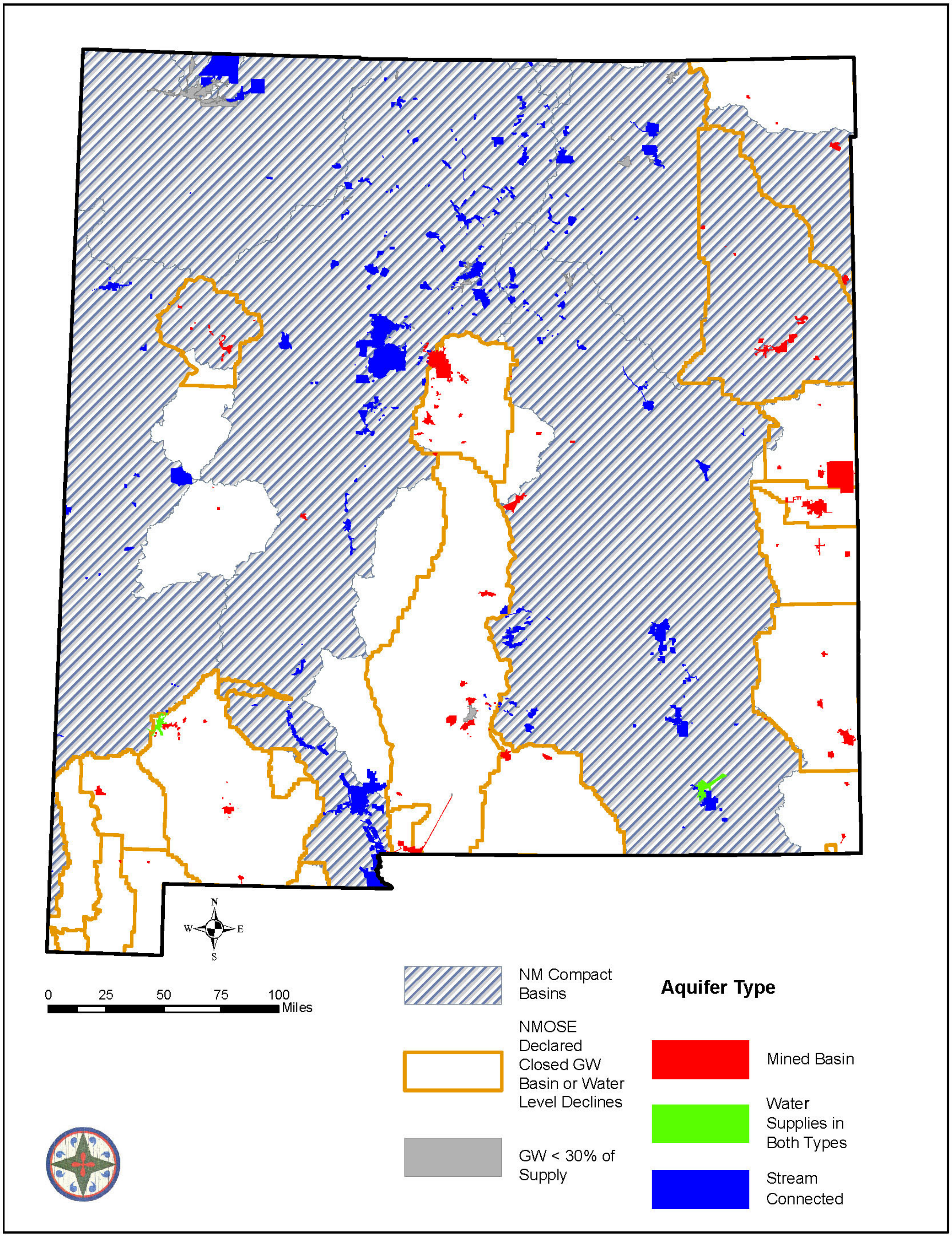


Figure 12. Groundwater Supply Availability Element: Aquifer Type for Groundwater-Dependent Public/Private Water Systems

3.2.3 Supply-Demand Gap

Future water demand and supply are projected to change even without climate change, and those changes add another dimension of vulnerability of systems to climate change. Each AG locale or PWS must understand the depletions created by other water users. The greater the number of straws in the same cup of water, the faster the supply will be depleted. While the predicted gap between supply and demand is poorly understood and a complex problem to solve, one method was developed for the 2016-17 regional water plans (NMOSE, 2021) that were compiled for the 2018 State Water Plan. This method simply assumed that the volume of water diverted in 2010 represented the average supply available to all sectors of water use, with the exception that the future supply in mined or closed basins was estimated using local models or by projecting water level declines. A drought scenario was also developed to estimate the surface and groundwater supply available during a prolonged drought. The future supply (both average and drought scenarios) was then compared to the projected future demand (both high and low projections) to estimate the projected supply-demand gap in 2060.

The resulting calculated gap under the worst-case scenario between a drought water supply and high demand projections for each of the 16 water planning regions in the state in the year 2060 is shown in Figure 13 (NMISC, 2018). The AG locales and PWSs that are in water planning regions whose projected supplies will meet only a fraction of the demand in 2060 are much less resilient than those with a greater percentage. Figure 14 shows the predicted supply as a percentage of the projected demand in 2060.

The projected water supply for each of the 16 water planning regions did not consider the water rights held in reserve by PWSs for future growth. Each PWS would need to consider their ability to meet future demands with regard to water rights and the sustainability of the water supply. Figure 15 and Figure 16 show the relative resilience of AG locales and PWSs, respectively, to the water supply-demand gap.

The projected future supply-demand gap in 2060 presented in the 2018 State Water Plan was also used to assess the water availability. A total of 47 (48%) of the irrigated locales are projected to have less than 40% of the supply needed to meet their demands under a high growth projection and drought scenario, resulting in the lowest resilience for this element.

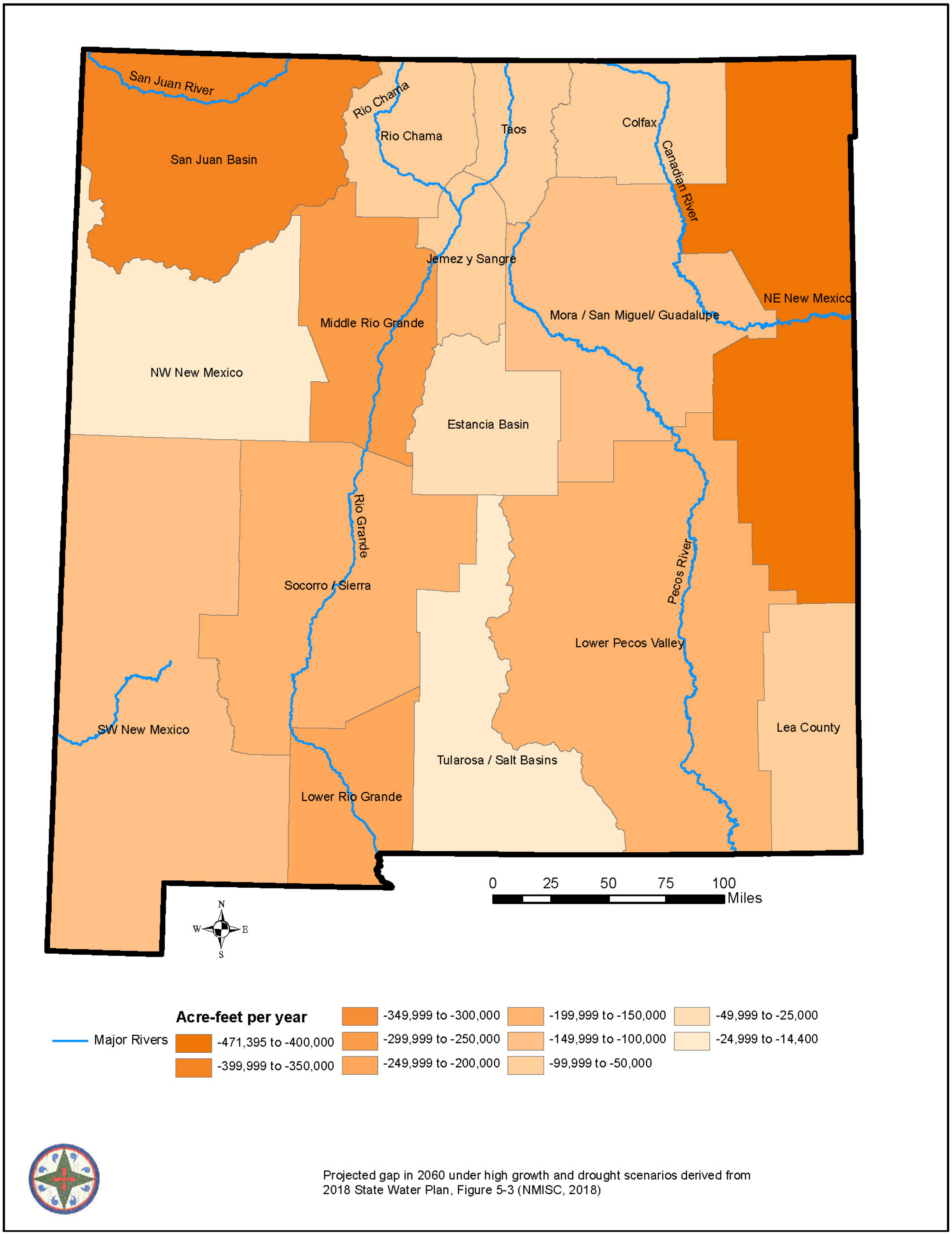
71% of PWS are in regions where the projected supply is less than 50 % of the projected demand in 2060.

The projected future supply-demand gap in 2060 presented in the 2018 State Water Plan was also used to assess water availability. A total of 208 (34%) of PWSs are projected to have less than 40% of the supply needed to meet their demands in 2060 under a high growth projection and drought scenario, representing 10% of the water diverted by PWSs and 9% of the population. These most vulnerable PWSs are located in the northeast and southwestern portions of the state.

Calculation: The levels of resilience in supply-demand gap shown in Figures 15 and 16 were calculated using the following steps:

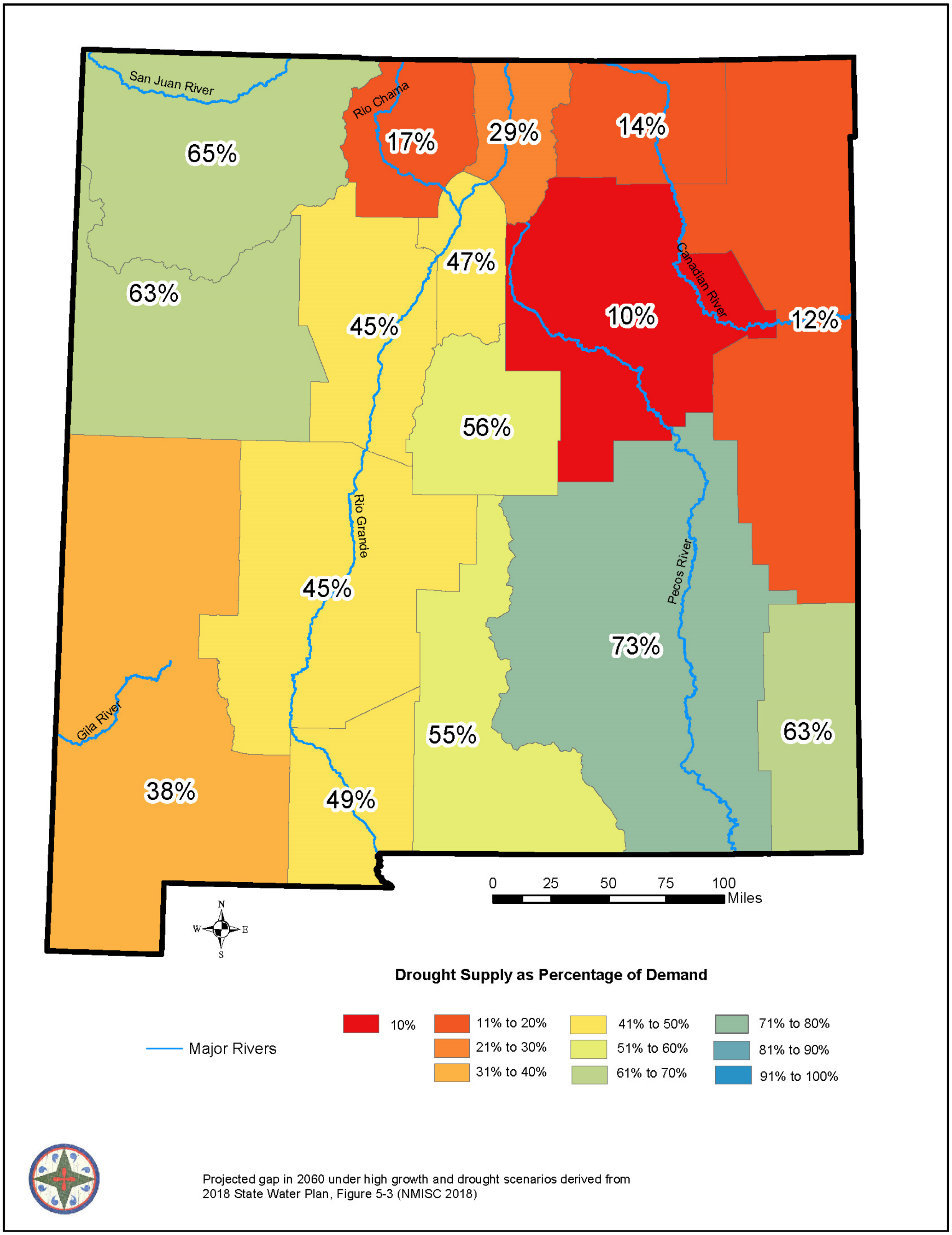
- Plot the water planning regions and the projected supply-demand gap (NMISC shapefile of water planning regions and values for Figure 5-3b of the 2018 State Water Plan)
- Plot the location of each PWS (NMOSE, 2020d)
- Plot the location of each irrigation locale (Magnuson et al., 2019)
- Calculate the drought supply as a percentage of demand in 2060 for each region by dividing the predicted supply in a drought scenario by the projected demand in 2060.
- Identify the water planning region for each AG locale and PWS.

Data Gap: To improve on the assessment of the supply-demand gap, each irrigated locale and PWS would need to understand their specific water rights, water supply portfolio and projected future demand to understand their particular vulnerability to this element. Regional groundwater-surface water models capable of simulating current and future diversions would assist water planners in understanding the physical limitations of the supplies.



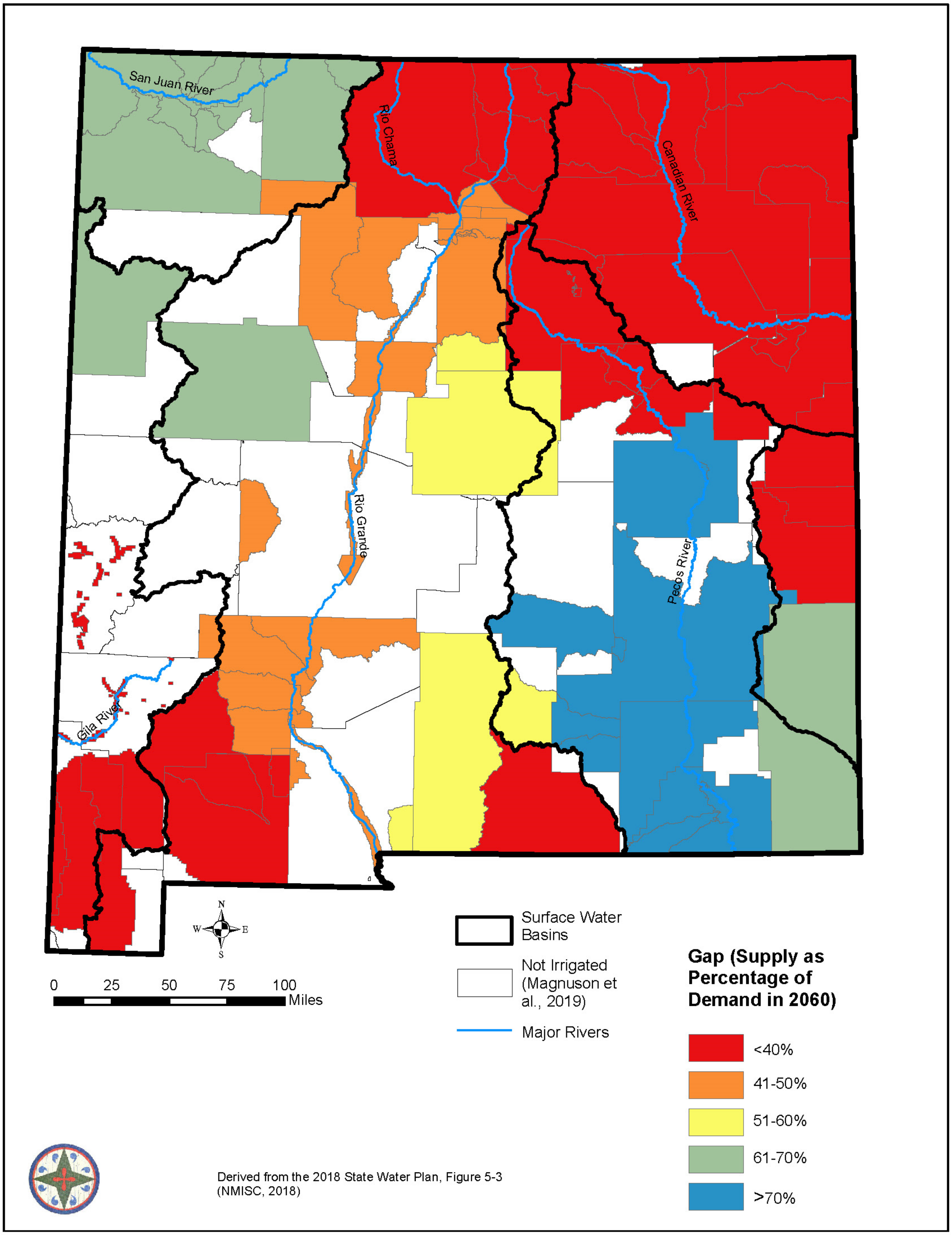
Projected gap in 2060 under high growth and drought scenarios derived from 2018 State Water Plan, Figure 5-3 (NMISC, 2018)

Figure 13. Estimated Water Supply Deficit for Water Planning Regions in 2060 under a High-Growth Population Projection and Drought Scenario



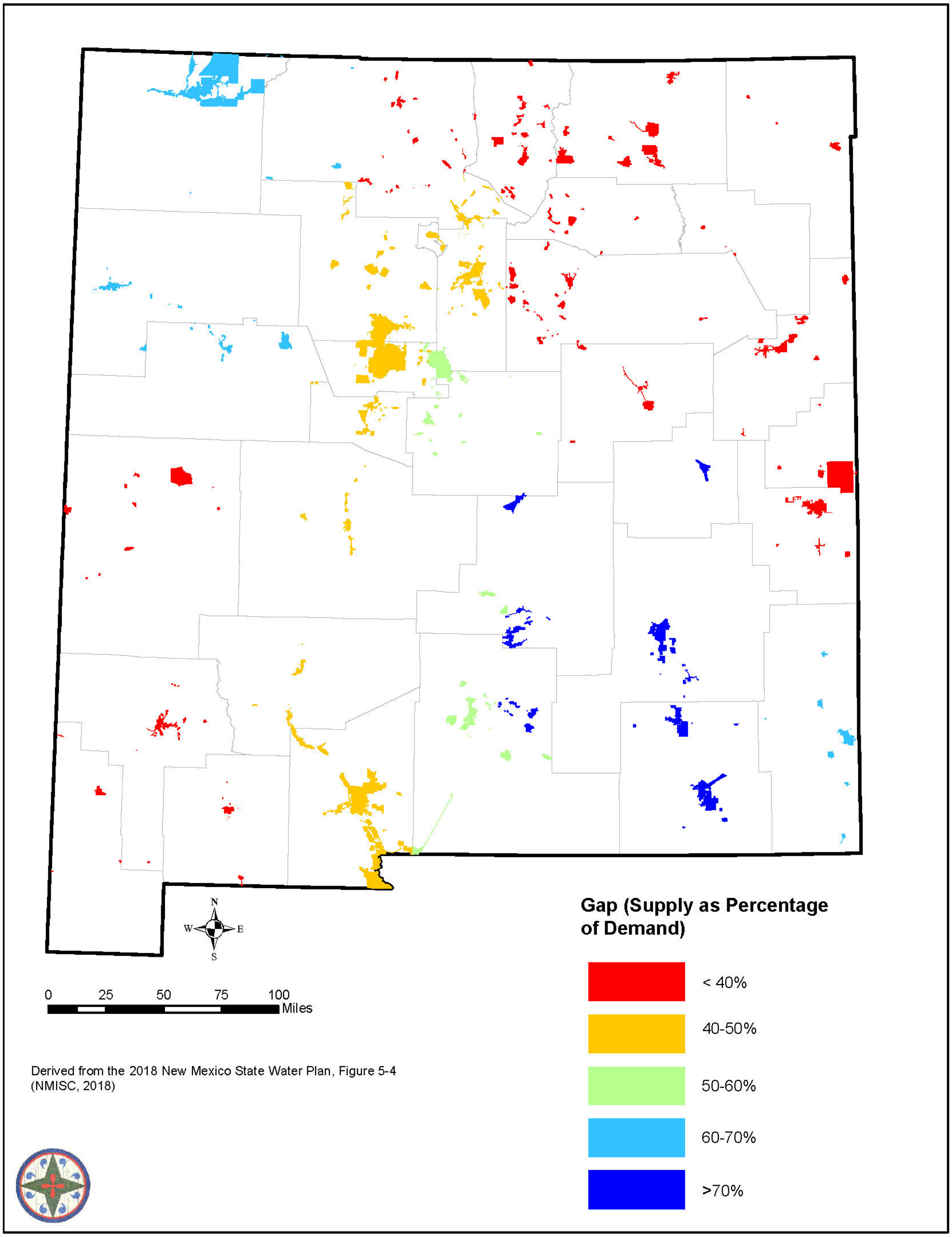
Projected gap in 2060 under high growth and drought scenarios derived from 2018 State Water Plan, Figure 5-3 (NMISC 2018)

Figure 14. Projected Supply as Percentage of Demand for Water Planning Regions in 2060 under a High-Growth Projection and Drought Scenario



Derived from the 2018 State Water Plan, Figure 5-3 (NMISC, 2018)

Figure 15. Water Supply Availability Element:
Supply-Demand Gap in 2060 for Irrigated Agriculture Locales



Derived from the 2018 New Mexico State Water Plan, Figure 5-4
(NMISC, 2018)

Figure 16. Water Supply Availability Element: Supply-Demand Gap in 2060 for Public/Private Water Systems

3.3 Infrastructure Capacity Resilience Elements

The infrastructure that supports the delivery and distribution of water plays a key role in developing resilience for all sectors that divert water. Data on infrastructure is readily available only for PWSs. Thus, this section focuses primarily on PWSs, with the exception of one element where data is available for the AG sector of water use.

Evaluating the ability of a water system to respond to crises involves many aspects. To capture resilience and capacity to respond to stresses, seven infrastructure elements were used: (1) the number of supply wells, (2) the capacity to store treated water, (3) the availability of an emergency supply of water, (4) resource monitoring, (5) ability to store raw water, (6) regulatory compliance, and (7) equity. Data for only one of these elements (ability to store raw water) is available for AG systems. GIS data for the regulatory compliance aspect is not available for PWSs, but a general summary of that element is provided here (Section 3.3.6).

Other factors not evaluated here include the age of the wells, the quality of the water, and the proximity to contaminants which can also impact the resilience of a water system. Aging infrastructure, leaking pipes, and collapsing wells put a strain on the resources of the water systems.

AG locales and PWSs come in all shapes and sizes, and thus, some elements may need to be considered together. For instance, small PWSs can be resilient with only a few wells, and it is feasible to build a storage tank to store several days' worth of water, but a system with just one well and no storage capacity is very vulnerable. A total of 197 PWSs out of the 577 that rely on groundwater (34%) have only one well. Most of the PWS (389 out of 604) have less than 3 days capacity to store treated water. For large systems it is not feasible to build the storage capacity to hold multiple days of water demand, but large systems can be resilient with multiple sources of water.

3.3.1 Number of Wells

The number of wells serving each PWS can be used to reflect the degree of infrastructure and resources available. If a system has only one well, which is the case for 197 out of 577 PWSs that rely on groundwater, that system is vulnerable compared to a system with multiple back-up

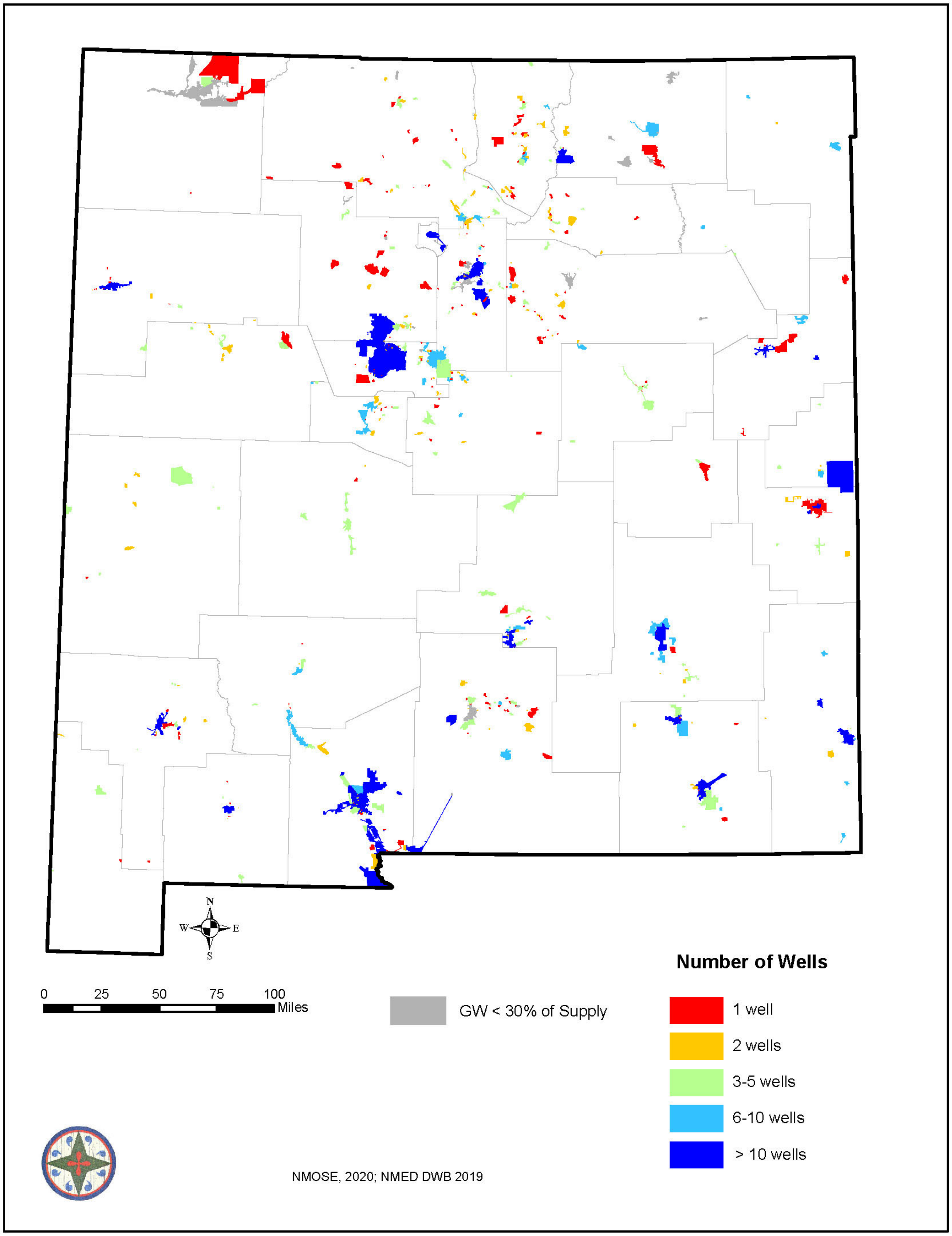
34% of PWS have only one well

wells. NMED recommends a minimum of two sources of groundwater extraction (NMED, 2006). Figure 17 shows the relative resilience of PWSs to this resilience element.

Calculation: The levels of resilience in the number of wells shown in Figure 17 were calculated using the following steps:

- Using an Access database of infrastructure facilities based on NMED DWB data (2019), count the facilities identified as wells to obtain the number of wells available to each PWS.
- Select the PWS where less than 30% of their supply is derived from surface water.
- Plot the number of wells for each PWS service area (NMOSE, 2020d).

Data Gap: The availability of sufficient infrastructure could be better assessed with summary information on wells serving irrigation districts and regions and details on the production capacity of each well.



NMOSE, 2020; NMED DWB 2019

Figure 17. Infrastructure Capacity Element: Number of Wells Serving Public/Private Water Systems

3.3.2 Treated Water Storage Capacity

The volume of treated water that a PWS can hold in storage tanks is important for increasing resilience for multiple reasons, including:

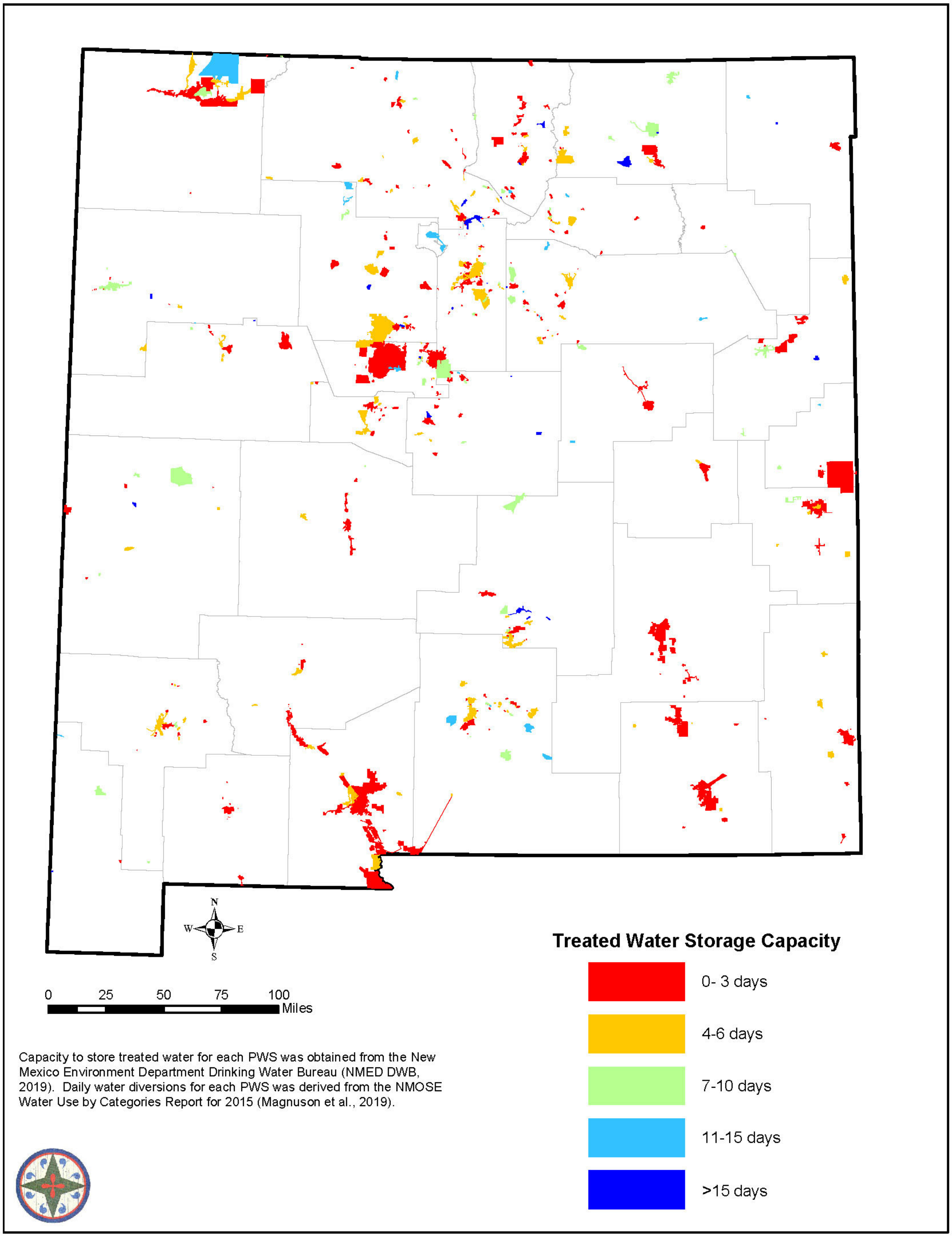
- The predicted increase in flood events, as well as the increase in demand during peak summer months increases the need for storage capacity, particularly for small systems with few wells. Flood events can temporarily impact surface water intake structures due to the threat of contaminants.
- A sudden loss of water supply due to power failure, water level decline, flooding, debris flows, etc. can be less disruptive if more water is held in storage.

81% of PWS have fewer than 3 days storage capacity

Storage tanks are generally sized for holding at least a day's flow at average demand or for fire flow requirements (as defined by local regulations), whichever is more (Health Research Inc., 2012). A PWS needs to balance between having enough capacity for improved resilience yet not overcapacity, which can degrade water quality if stored too long. Figure 18 shows the relative resilience of PWS based on the treated water storage capacity. Large PWS systems will likely have much less treated water storage capacity; however, the larger systems generally have multiple sources of supply.

Calculation: The levels of resilience in treated water storage shown in Figure 18 were calculated using the following steps:

- Obtain the population and per capita demand data for 2015 (Magnuson et al., 2019).
- Calculate the daily demand of a water system in 2015 by multiplying the population by the per capita demand.
- Obtain the capacity for storing treated water for the PWS from NMED DWB information (NMED DWB, 2019), which is publicly available at Drinking Water Watch (nm.gov)
- Divide the storage capacity of the PWS by the daily demand to obtain the number of days that storage capacity can potentially meet demand. This is the average annual daily demand and does not reflect the peak summer demand rate.



Capacity to store treated water for each PWS was obtained from the New Mexico Environment Department Drinking Water Bureau (NMED DWB, 2019). Daily water diversions for each PWS was derived from the NMOSE Water Use by Categories Report for 2015 (Magnuson et al., 2019).

**Figure 18. Infrastructure Capacity Element:
Treated Water Storage for Public/Private Water Systems**

3.3.3 Emergency Supply

PWSs are facing increased risks to water supplies and damage to infrastructure. Systems that are prepared with an agreement and necessary piping to receive an alternative supply of water during an emergency are more resilient. A 2021 survey of PWSs[11] asked a series of questions about each system's preparedness for emergencies (NMED DWB, 2021). Of the 410 PWSs that responded to the survey question enquiring about an emergency supply, 310 said they have an emergency supply of water, and 100 systems had no supply or said they would buy bottled water; 194 did not answer the survey. Figure 19 shows the relative resilience of PWSs based on the availability of an emergency supply of water.

50% of PWS have an emergency water supply

Calculation: The levels of resilience in emergency supply shown in Figure 19 were calculated using the following steps:

- Convert survey results (NMED DWB, 2021) to GIS and relate to the PWS Geodatabase (NMOSE, 2020d).
- Identify the status of emergency plans from the August 2021 DWB survey (NMED DWB, 2021).
- For large systems with multiple sources of supply and multiple well fields, show the system as having an emergency supply even if the survey was not completed or answer was negative.

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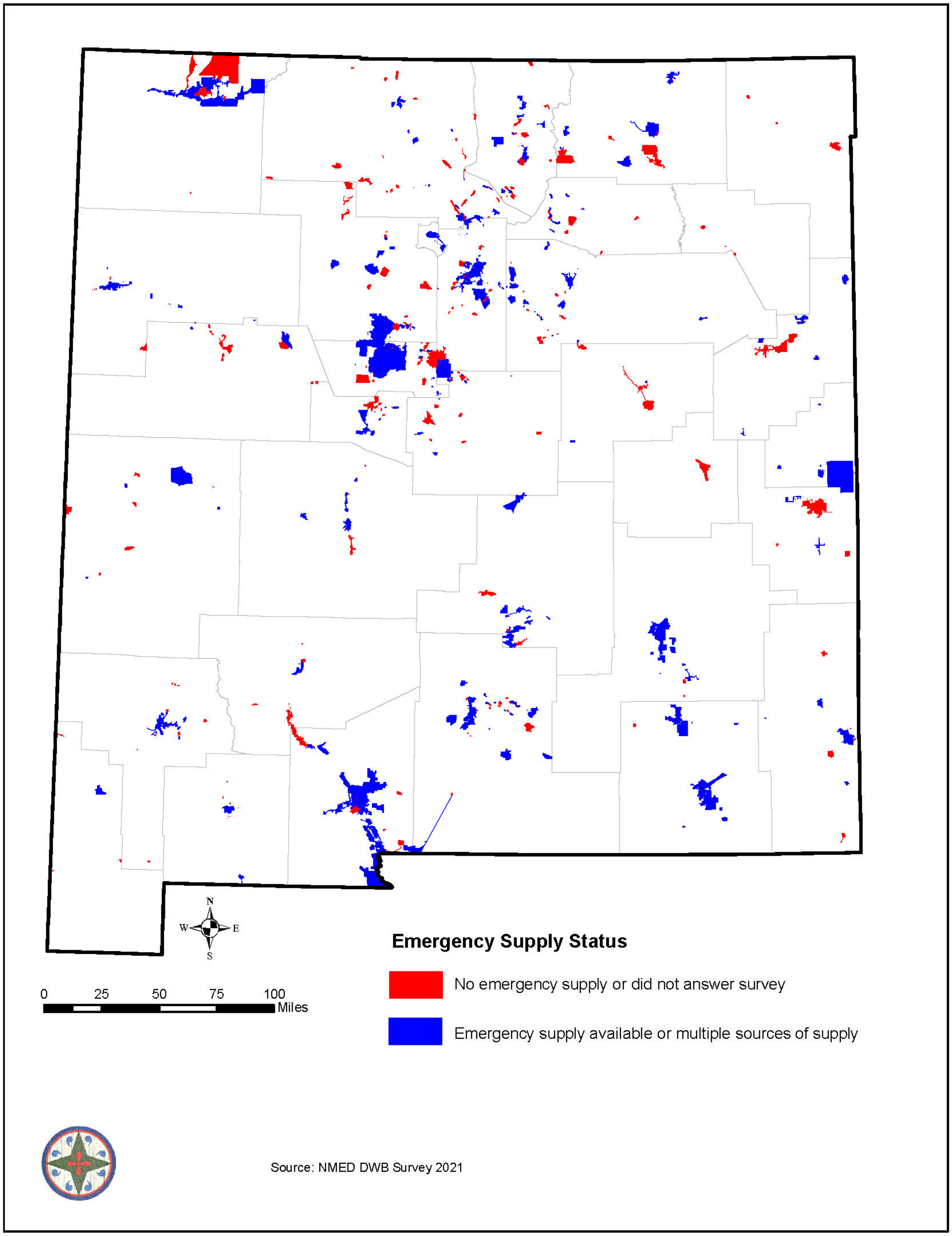
[11] The NMED DWB conducted a survey in July and August 2021, for which they contacted (or attempted to contact) each PWS and asked a series of questions.



Source: NMED DWB Survey 2021

Figure 19. Infrastructure Capacity Element: Emergency Supply Status for Public/Private Water Systems

3.3.4 Resource Monitoring

Another indication of infrastructure capacity and managerial strength of a PWS is the degree of awareness of the water resources. Understanding the rate of water-level decline in well fields and understanding the response of streamflow to precipitation events and snowpack melt are important to managing the water resources. The 2021 NMED DWB survey asked PWSs if water levels were monitored in their water supply wells. Of the 604 PWSs, 67% responded (NMED DWB, 2021), and 196 said they did not monitor water levels, or only infrequently measured the level and 24 of the systems do not have wells because they only divert surface water. For the 220 that do monitor water levels, some conduct such monitoring once every few years and others have pressure transducers installed that record more than one measurement a day.

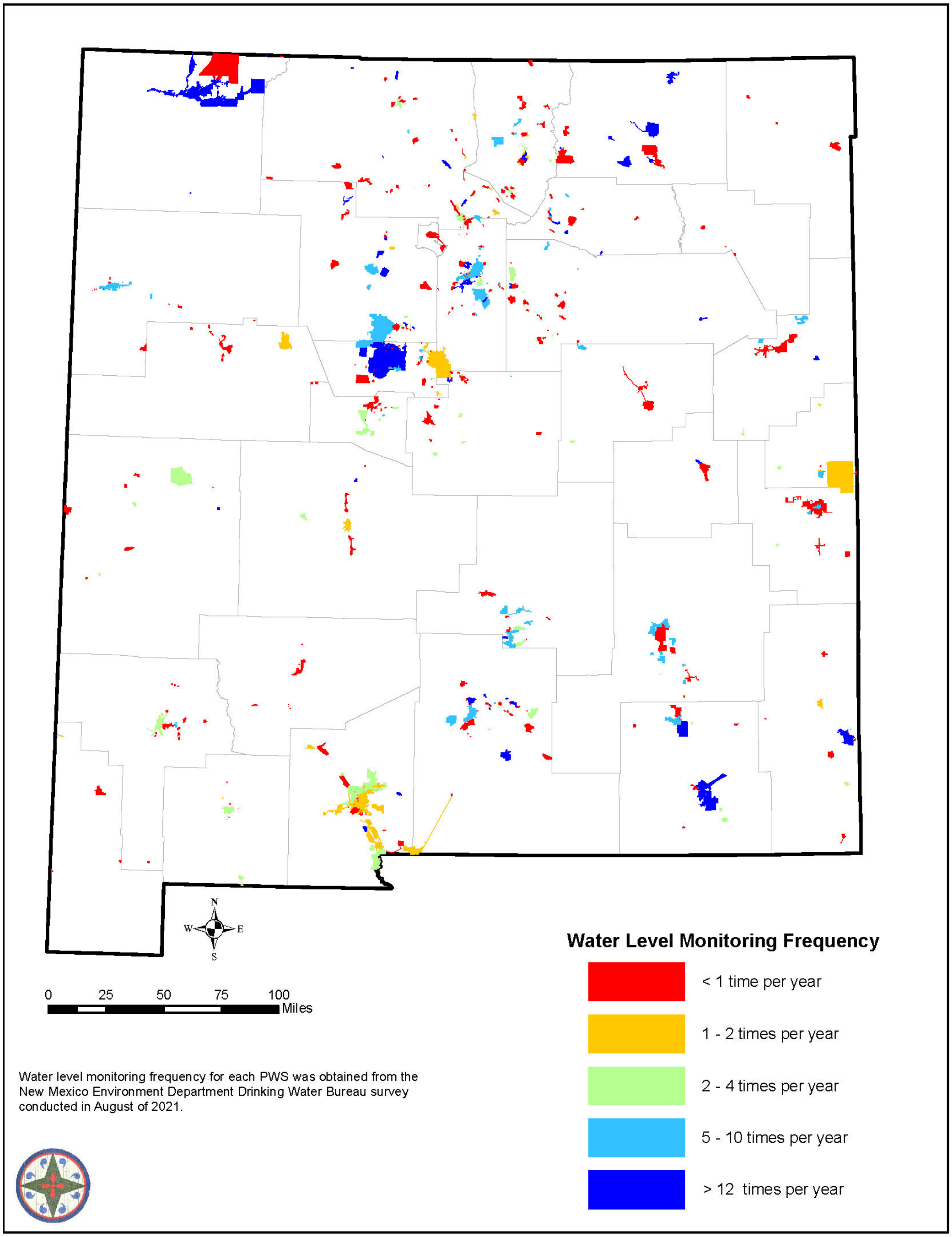
Figure 20 shows the frequency that PWSs monitor water levels. Monitoring water levels indicates the level of understanding that the PWS has for the resource and its sustainability. Those systems that did not answer the NMED DWB survey and those that responded “no” to the question were assumed to not measure water levels.

30% of PWS monitor water levels or stream flow more than once a year

Calculation: The levels of resilience in resource monitoring shown in Figure 20 were calculated using the following steps:

- Convert survey results (NMED DWB, 2021) to GIS and relate to the PWS Geodatabase (NMOSE, 2020d).
- Identify the frequency of water level measurements from the survey responses (NMED DWB, 2021).

Data Gap: Information on the PWSs that monitor streamflow and snowpack (by funding USGS stream gage stations or Natural Resources Conservation Service [NRCS] SNOTEL sites) could help balance this assessment to reflect the resource monitoring by PWSs that divert only surface water.



Water level monitoring frequency for each PWS was obtained from the New Mexico Environment Department Drinking Water Bureau survey conducted in August of 2021.

Figure 20. Infrastructure Capacity Element: Water-Level Monitoring Frequency by Public/Private Water Systems

3.3.5 Raw Water Storage

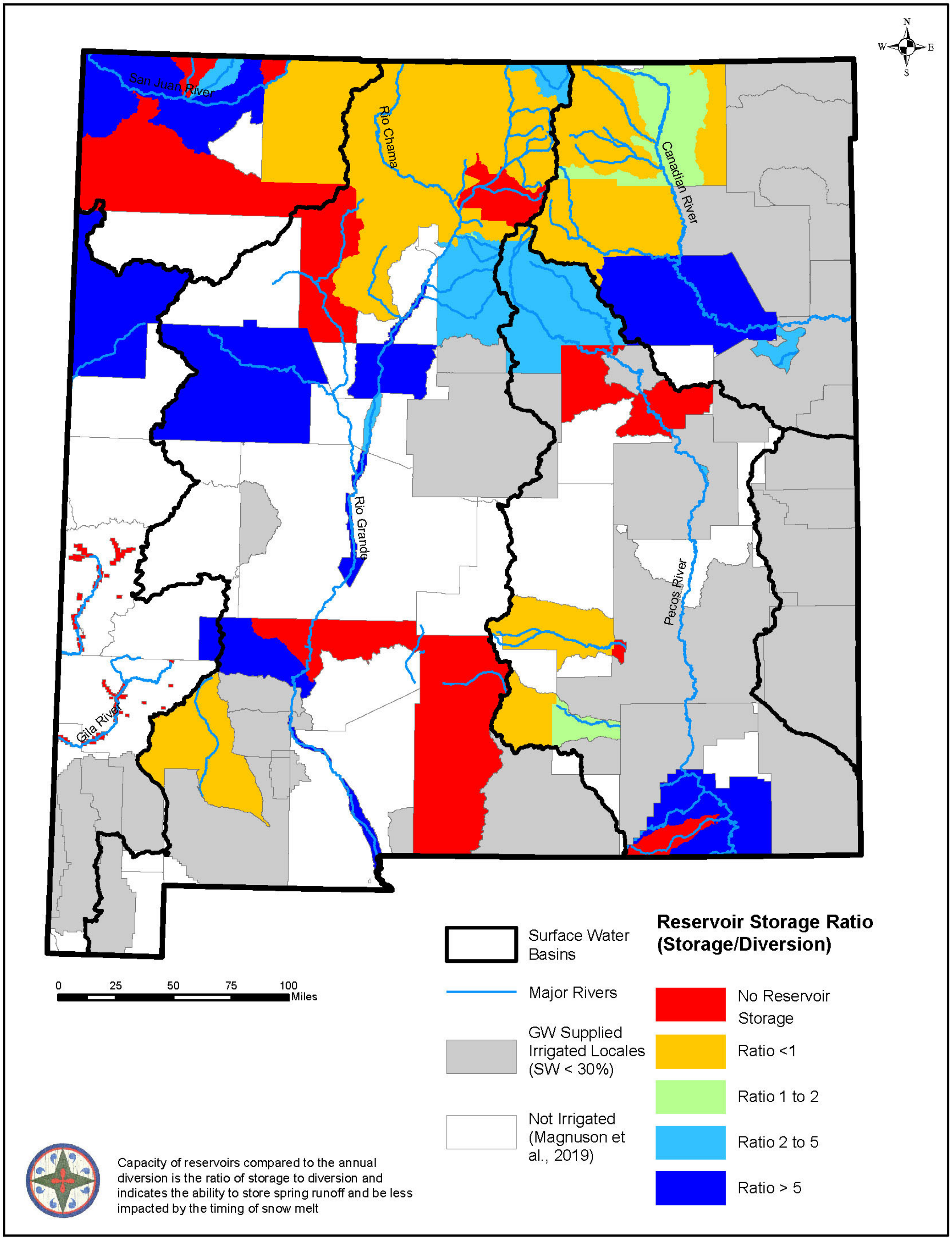
Spring runoff is predicted to occur earlier, which means less water will be stored in the high mountains. Systems with the ability to capture and store water for use some months later are more resilient than those without storage capacity. Figure 21 shows the AG locales that are dependent on surface water and the availability of reservoir storage as the ratio of storage capacity to water demand for the irrigation season. Figure 22 shows the PWSs that are dependent on surface water and the presence or absence of a storage reservoir. .

Of the 69 irrigated locales that divert surface water, 22 do not have a reservoir and are dependent on the timing of snowmelt-driven stream flow. The other 47 locales have some storage capacity. More than half of the 58 PWSs that rely on surface water have a reservoir to capture spring runoff and thus will be more resilient during years with earlier spring runoff.

> 45% of PWS that divert surface water do not have access to reservoir storage

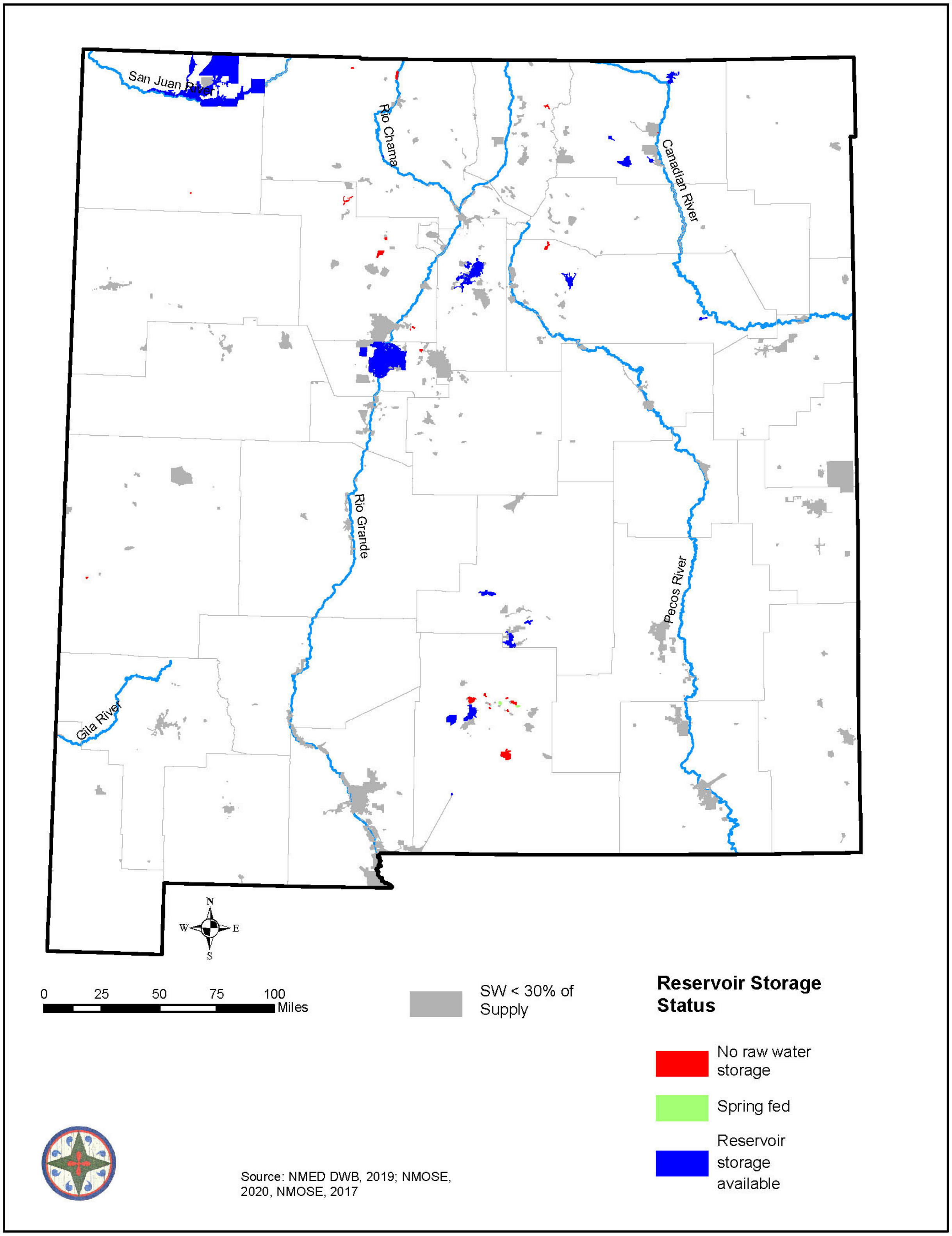
Calculation: The levels of resilience in raw water storage shown in Figures 21 and 22 were calculated using the following steps:

- Plot dam locations (NMOSE Dam Safety Bureau database [NMOSE, 2017] for state-regulated dams and U.S. Army Corps of Engineers database for other large dams [USACE, 2018]).
- For irrigated agriculture, calculate the reservoir storage ratio to annual diversion by dividing “normal storage capacity” designated in the dam databases (NMOSE, 2017; USACE, 2018) by the demand of a water system reported by the NMOSE *Water Use by Categories 2015* report (Magnuson et al., 2019).



Capacity of reservoirs compared to the annual diversion is the ratio of storage to diversion and indicates the ability to store spring runoff and be less impacted by the timing of snow melt

**Figure 21. Infrastructure Capacity Element:
Ratio of Reservoir Storage to Demand for Irrigated Agriculture Locales**



Source: NMED DWB, 2019; NMOSE, 2020, NMOSE, 2017

Figure 22. Infrastructure Capacity Element: Ability to Store Raw Water for Public/Private Water Systems

3.3.6 Regulatory Compliance

The U.S. EPA has established protective drinking water standards (1996 Safe Drinking Water Act) to protect public health[12] that all water systems must adhere to. The NMED DWB works with PWSs to conduct routine testing of water supply sources, and PWSs must report results of water testing to ensure that water quality standards are met. A system that repeatedly violates the reporting requirements or exceeds water quality standards indicates a system with poor management and weak infrastructure due to poor water quality. As of June 30, 2021, 231 (38%) of PWSs, serving water to 375,300 people or 18% of the population, currently have reported at least one violation of drinking water standards. The violations range from health-based violations to seemingly minor violations with regard to reporting requirements[13] (Himmelberger, 2021). PWSs can improve their resilience by improving their compliance with water quality regulations.

3.3.7 Equity (Financial Capacity to Improve Infrastructure)

The anticipated climate shocks of less supply and water quality impairments in the face of increased demand will challenge PWSs. Some PWSs have the ability to adapt to the anticipated changes by investigating options for drilling new wells or adding more storage capacity. The capacity of a PWS to improve infrastructure is reflected in part by its financial strength. The New Mexico Finance Authority (NMFA) Drinking Water State Revolving Loan Fund Policy (NMFA, 2019) defines the financial strength of water utilities based on the median household income (MHI) as a percentage of the average for the state of New Mexico:

- *Disadvantaged Entities*: An applicant whose MHI is greater than 80% but less than 100% of the State's MHI

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[12] The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources—rivers, lakes, reservoirs, springs, and ground water wells. (SDWA does not regulate private wells that serve fewer than 25 individuals.)

[13] PWSs are required to report water quality test results, and lack of reporting may be disguising a water quality violation

- *Severely Disadvantaged Entities*: An applicant whose MHI is less than 80% of the State's MHI

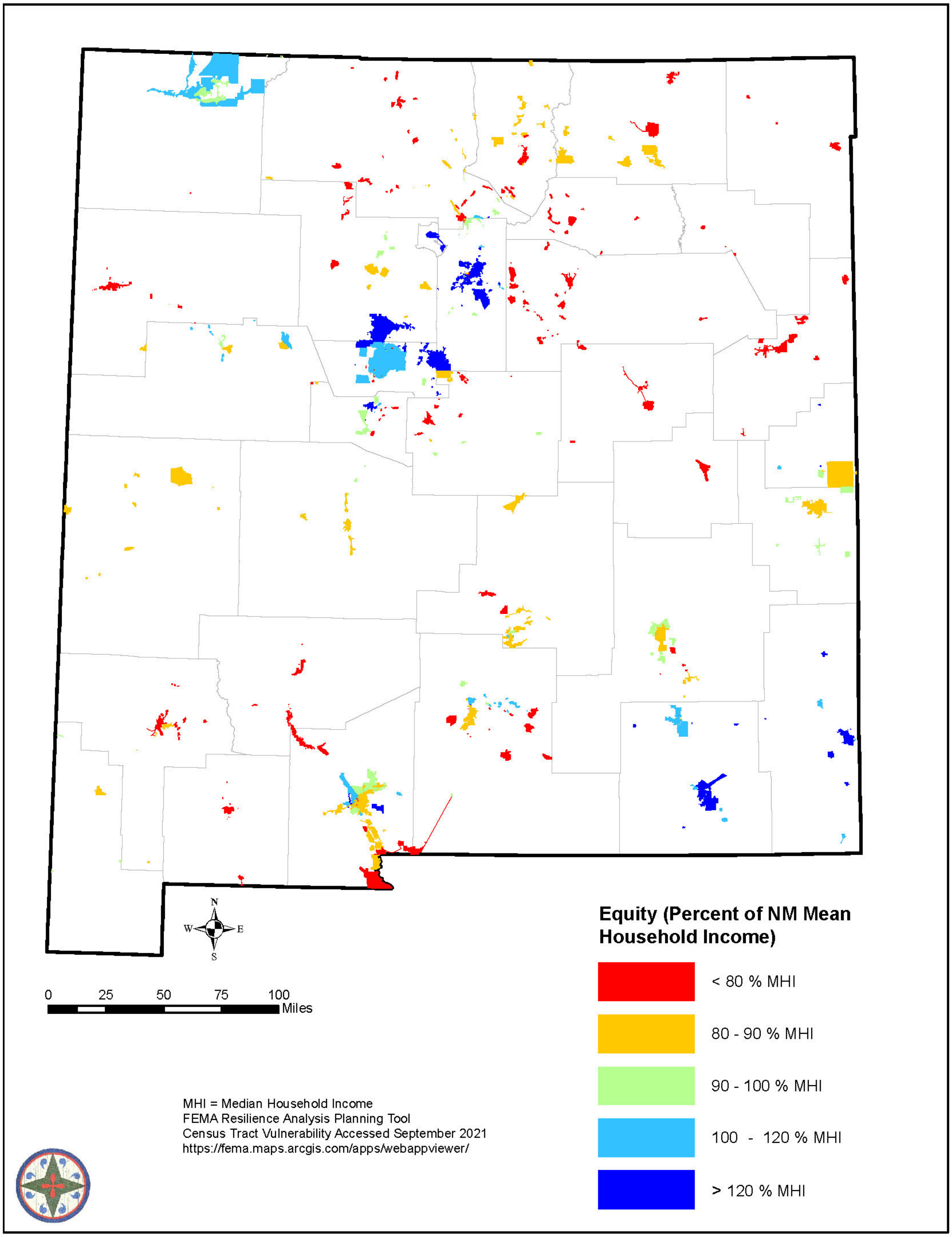
To assess this criterion, the Federal Emergency Management Agency (FEMA) Resilience Analysis Planning Tool (FEMA, 2021) was utilized to obtain the MHI by census tracts. The NMOSE geodatabase of PWS service areas (NMOSE, 2020d) was used to characterize the average MHI for each PWS.

Figure 23 shows the relative resilience to climate change based on the equity element. Unfortunately, about 40% of PWSs (and 8% of the water diverted) are considered Disadvantaged Entities by the New Mexico Finance Authority, with mean household incomes less than 80% of the state average.

60% of PWS have a
mean household income
<90% of the median

Calculation: The levels of resilience in equity shown in Figure 23 were calculated using the following steps:

- Plot census tracts in New Mexico.
- Plot PWS areas.
- Using ArcGIS, obtain the mean MHI of census tracts.
- Divide the mean MHI of the PWS by the State average.



MHI = Median Household Income
FEMA Resilience Analysis Planning Tool
Census Tract Vulnerability Accessed September 2021
https://fema.maps.arcgis.com/apps/webappviewer/

Figure 23. Infrastructure Capacity Element: Capacity to Improve Equity for Public/Private Water Systems

3.4 Upland Watershed Health Resilience Elements

Upland watershed health, particularly for those systems diverting surface water from tributaries to the Rio Grande or Pecos River, is essential to delivering water. Many of our upland watersheds are in an unhealthy condition due to a complex series of management and land use factors. Upland watersheds are at a greater risk to climate change as increased aridity stresses vegetation and increases the risk of more erosion and wildfires. Two elements that reflect upland watershed health are assessed here: (1) soil erosion potential and (2) post-fire debris flow risk. A third factor not evaluated here but is important for water systems to consider is the vulnerability to wildfire that can directly affect the wells, pipes, and storage infrastructure.

With warmer temperatures and increased aridity, the risks of catastrophic fires and subsequent debris flows are significant. Reservoirs fill with burned fuels and sediments, creating multi-year reclamation projects, and the infrastructure associated with a PWS may be vulnerable if it is in the floodplain. The risk of erosion, even without fire effects, will increase for all areas of the state.

3.4.1 Soil Erosion Potential

PWSs and AG are potentially at risk for increased erosion from degraded landscapes because of higher temperatures, increased aridity, and stress on vegetation. To evaluate this criterion, the risk of erosion was obtained from the 2020 New Mexico Forest Action Plan (NMFAP) (NMEMNRD, 2020). Farmlands and water infrastructure are at risk due to the volume of sediment that could be deposited on farms, clog surface water intake structures, damage well housing, and reduce the storage capacity of reservoirs.

The NMFAP used the K-factor, which determines the relative susceptibility to erosion, combined with slope, to create a classification of erosion hazard (NMEMNRD, 2020, Map 7A). Using this raster with the location and source of supply information in the NMOSE Geodatabase of Public & Private Water Systems (NMOSE, 2020d), the DWB database with surface water intake locations, and the NMOSE Geodatabase of Dams (2017) in New Mexico, the vulnerability of each system to climate shock (Figure 24) was estimated. Each PWS that diverts both surface water and groundwater was assigned the mean area weighted erosion risk value of each HUC12[14] watershed supplying surface water to the PWS. While surface water diversions are perhaps more impacted by floods and erosion, many wells are vulnerable because they are in the floodplain. All AG locales, regardless of the source of water, were evaluated using the mean area weighted erosion risk of the HUC 12 watersheds within the irrigated area.

About a 23% of PWS are in areas with a severe or very severe risk of erosion, none are without any risk

Figure 25 and Figure 26 show the relative resilience of AG locales and PWSs, respectively, for their vulnerability to soil erosion. Although none of the 98 AG locales are without risk of erosion, 28 have a severe and 12 have a very severe risk of erosion. All PWSs have some risk from erosion, and 137 have a severe to very severe risk.

Calculation: The levels of resilience to soil erosion shown in Figures 25 and 26 were calculated using the following steps:

- Obtain Erosivity Risk Raster (NMFAP2020_Threat_Postfire_ErosionHazard)-Values from 0 to 4 for Slight to Very Severe Risk.
- Calculate the statistics for the value for HUC12 watersheds in New Mexico from this Raster.
- Calculate the area weighted mean value for HUC12 watersheds both above the 57 surface water intake structures that serve PWSs and the 98 irrigation districts and below large reservoirs (Navajo and Cochiti) that are capable of absorbing debris flows.
- Apply the mean value of the HUC12 water service area to PWSs supplied by groundwater.

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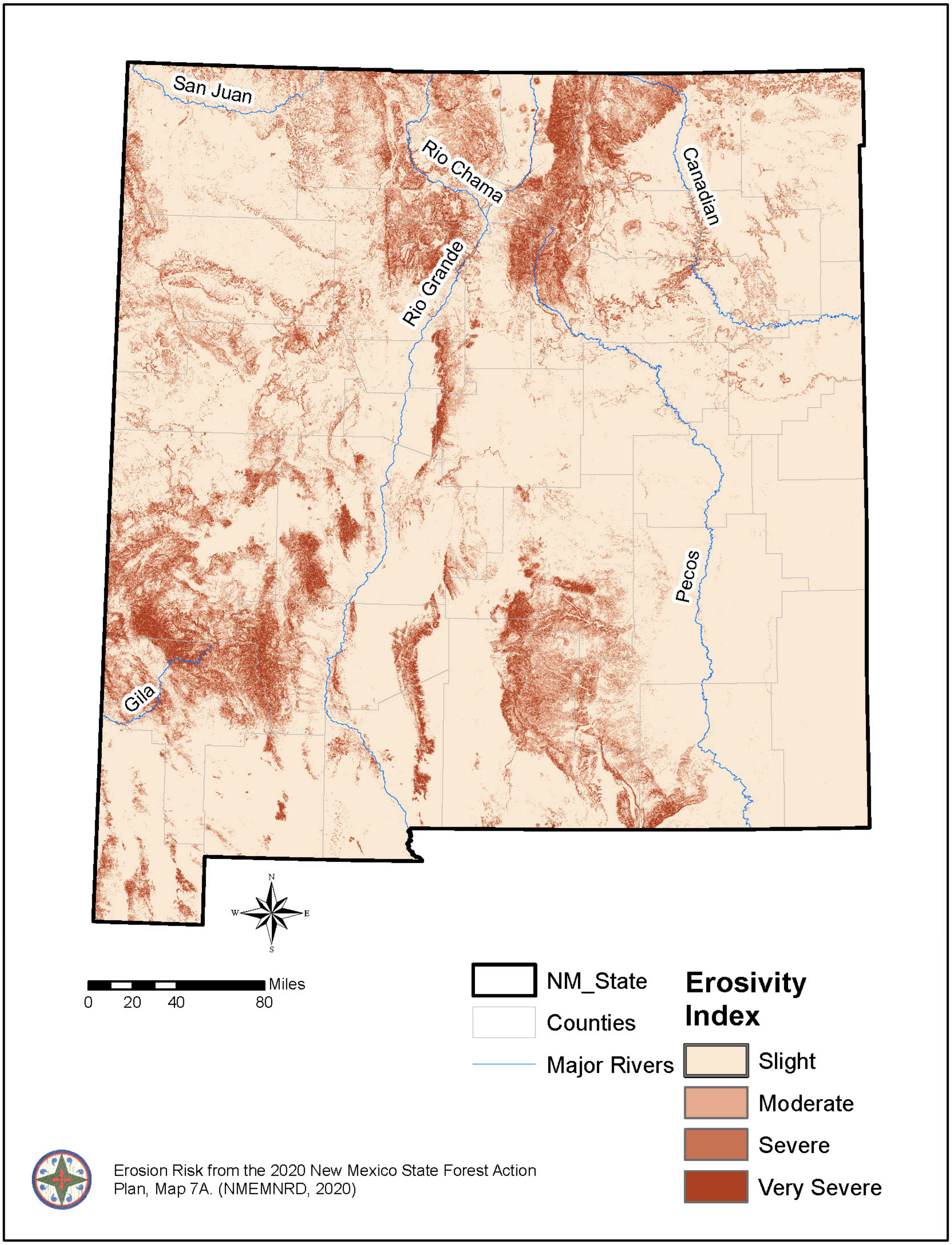
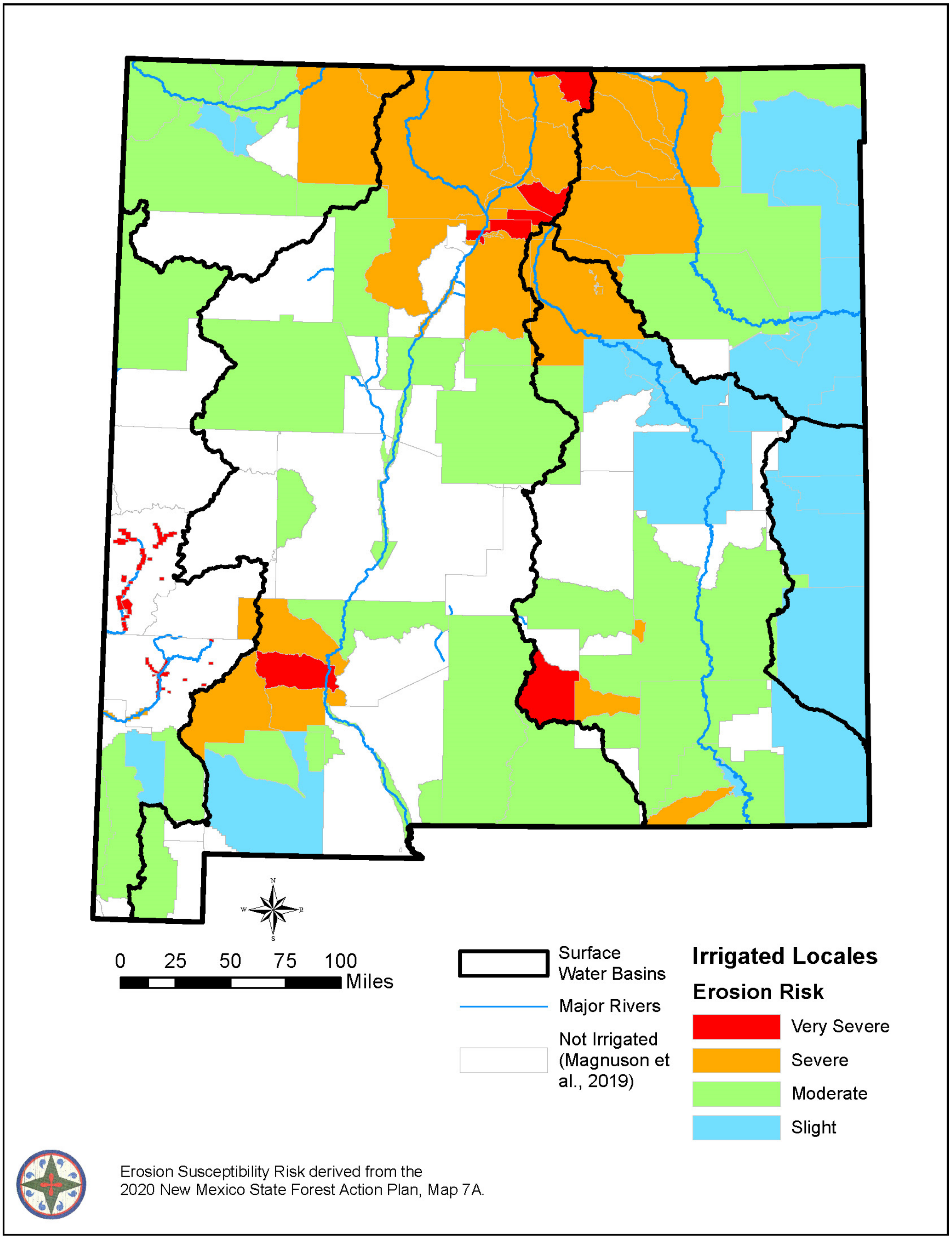
[14] HUC12 watershed refers to the USGS 12-Digit Hydrologic Unit Code.

Data Gaps: The location of the croplands could be evaluated rather than the large, irrigated areas designated by NMOSE. The location of infrastructure and croplands and the proximity to the 100-year floodplain could be incorporated into the assessment.



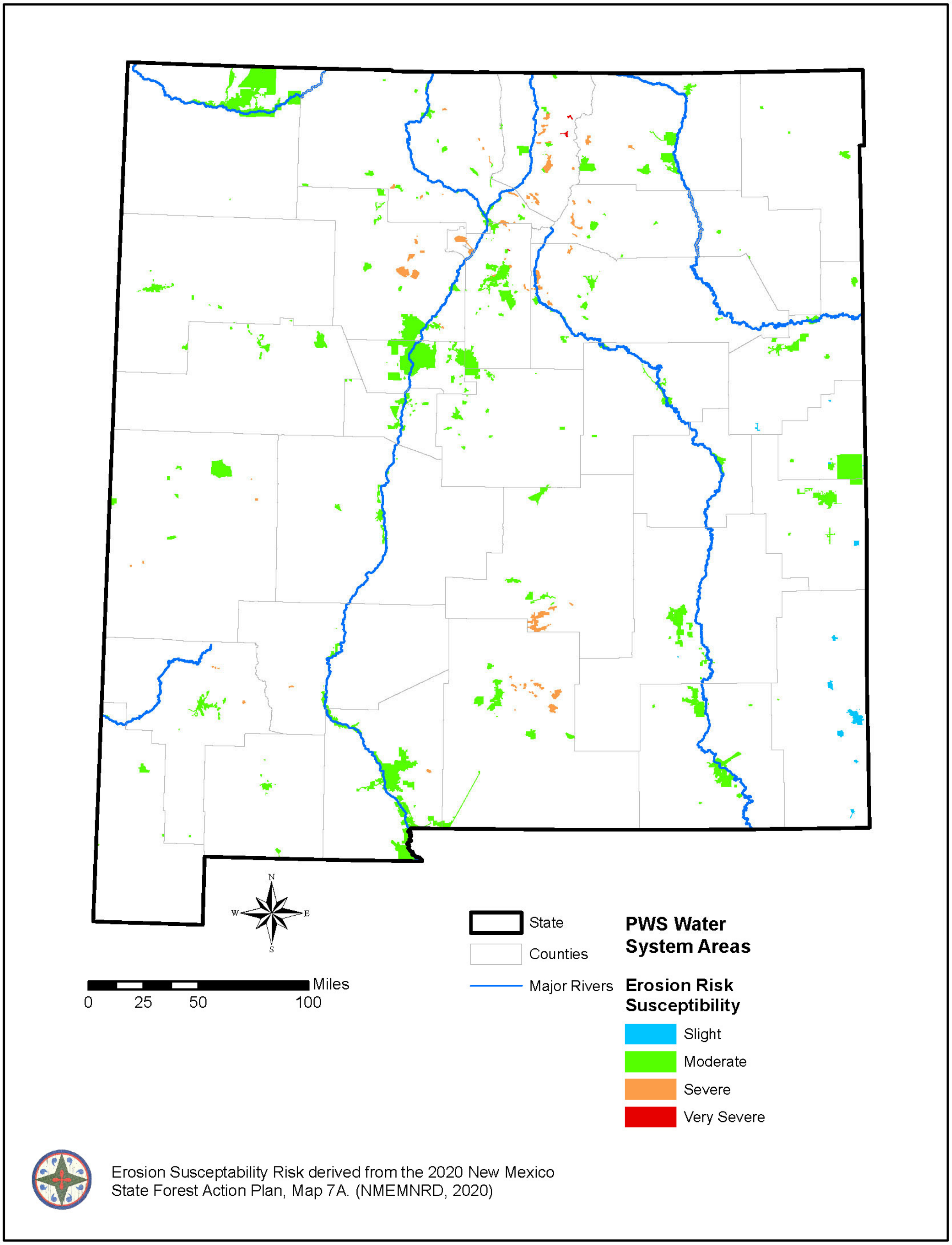
Erosion Risk from the 2020 New Mexico State Forest Action Plan, Map 7A. (NMEMNRD, 2020)

Figure 24. Erosion Susceptibility Classification Developed for the State Forest Action Plan



Erosion Susceptibility Risk derived from the 2020 New Mexico State Forest Action Plan, Map 7A.

Figure 25. Watershed Health Element: Erosivity Risk to Irrigated Agriculture Locales



Erosion Susceptability Risk derived from the 2020 New Mexico State Forest Action Plan, Map 7A. (NMEMNRD, 2020)

Figure 26. Watershed Health Element: Erosion Risk to Public/Private Water Systems

3.4.2 Post-Fire Debris Flow Risk

New Mexico’s forests are generally in an undesirable high-density condition brought on by decades of fire suppression and over-grazing that reduced the grass cover and favored small diameter, densely packed trees. Riparian areas have also suffered from land management and land use policies, including increased impermeable pavement that increases erosion during storm events.

The climate change forecast of higher temperatures and increased aridness sets the stage for a greater risk of catastrophic fires. Floods and debris flows can occur when rain falls on high-severity burn scars. Debris flows are sediment-laden flows that carry high volumes of debris (often burned vegetation) that can clog surface water intake infrastructure and irrigation works and fill water supply reservoirs with a mass of sediment, ash, and organic matter that may take many months or years to repair. Debris flows are most likely to occur downstream of vegetated areas that have erodible soils.

Many communities have been working for decades to restore forests and riparian areas, and they are improving their resilience to climate change, but most of the areas are relatively small in comparison with the state’s tens of millions of forested acres. A significant portion (on average 63%) of New Mexico’s surface water supply is derived from precipitation falling on the mountains in Colorado and is therefore not within our local capacity to manage the land (Lewis, 2023). Much of the water obligated to and utilized by downstream states originates as precipitation in Colorado and New Mexico’s mountains. Communities, including Las Vegas and Santa Fe, have worked extensively to treat the forests that supply their surface water. While the risk of a catastrophic fire is reduced by these forest restoration efforts, a risk remains.

This evaluation assessed the risk of potential debris flows following a high intensity fire using the NMFAP Post-Fire Erosion Hazard (NMEMNRD, 2020) (Figure 27). The overall risk factor was developed by applying the fire risk (forest conditions), debris flow likelihood (soil type and slope), and debris flow volume. This raster—along with the location and source of supply information in the NMOSE Geodatabase of Public & Private Water Systems (NMOSE, 2020d), the DWB database with surface water intake locations, and the NMOSE Geodatabase of Dams in New Mexico (NMOSE, 2017)—was used to estimate the vulnerability of each system to this climate shock (Figure 27).

Farmland is vulnerable to debris flows regardless of the water source, so all AG areas, regardless of the source of water, were evaluated using the mean area weighted post-fire erosion risk of the HUC12 watersheds within the irrigated area (Figure 28). Each PWS that diverts surface water was assigned the mean area weighted post-fire erosion hazard value of each HUC12[15] watershed supplying surface water to the PWS, as shown in Figure 29. PWSs supplied by groundwater were assigned the mean risk value for the HUC12 watershed(s) within their service area.

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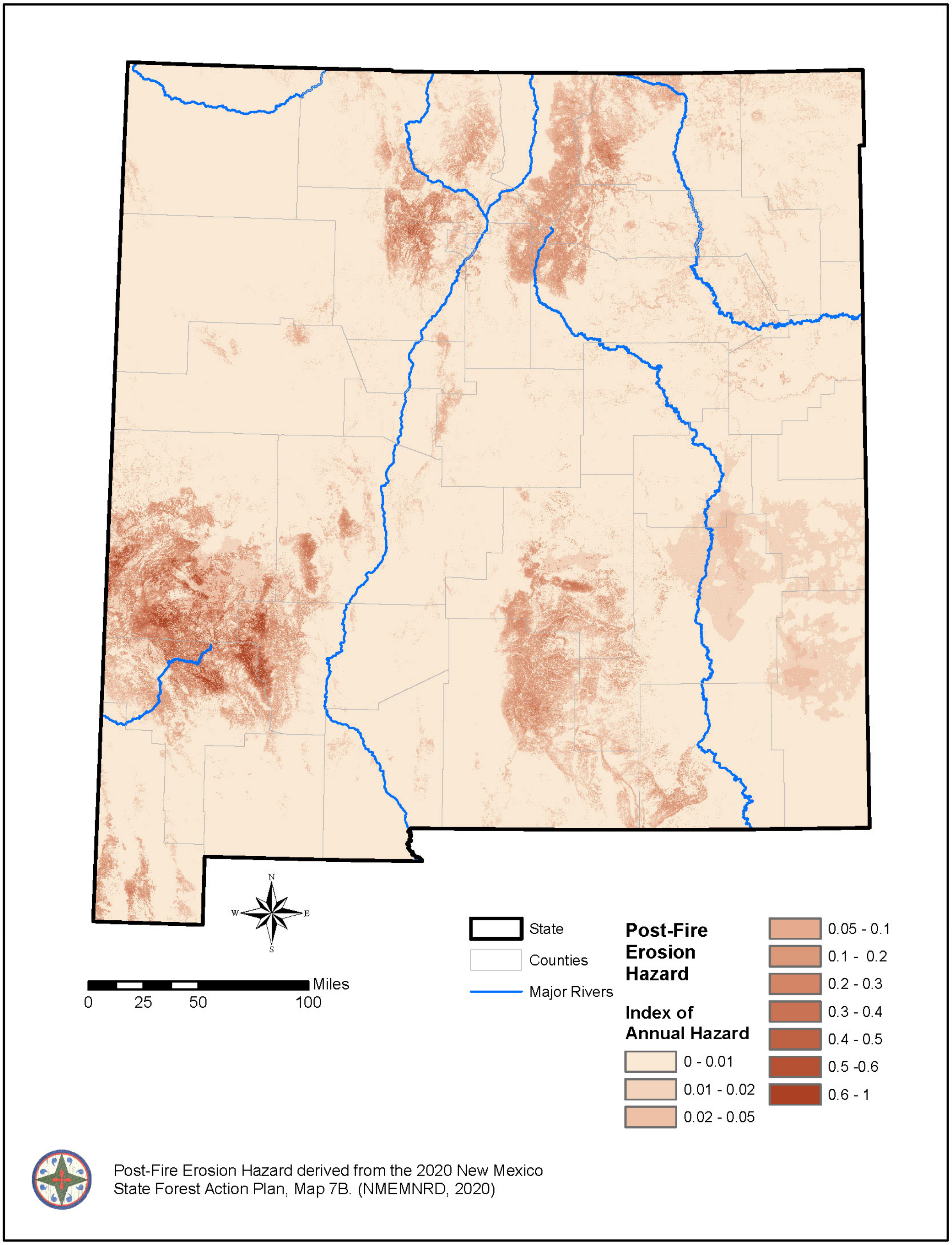
[15] HUC12 watershed means and refers to the USGS 12-Digit Hydrologic Unit Code

A significant number of AG locales are at risk from debris flows; 38 AG locales are downstream of watersheds with a very severe risk of debris flow and 18 have a severe risk. Most PWSs (369) have a very low risk of damage from debris flow, but 47 have a very severe risk, and 102 have a severe risk to a post-fire debris flow.

25% of PWS are in areas with a severe or very severe risk of a debris flow following a catastrophic fire

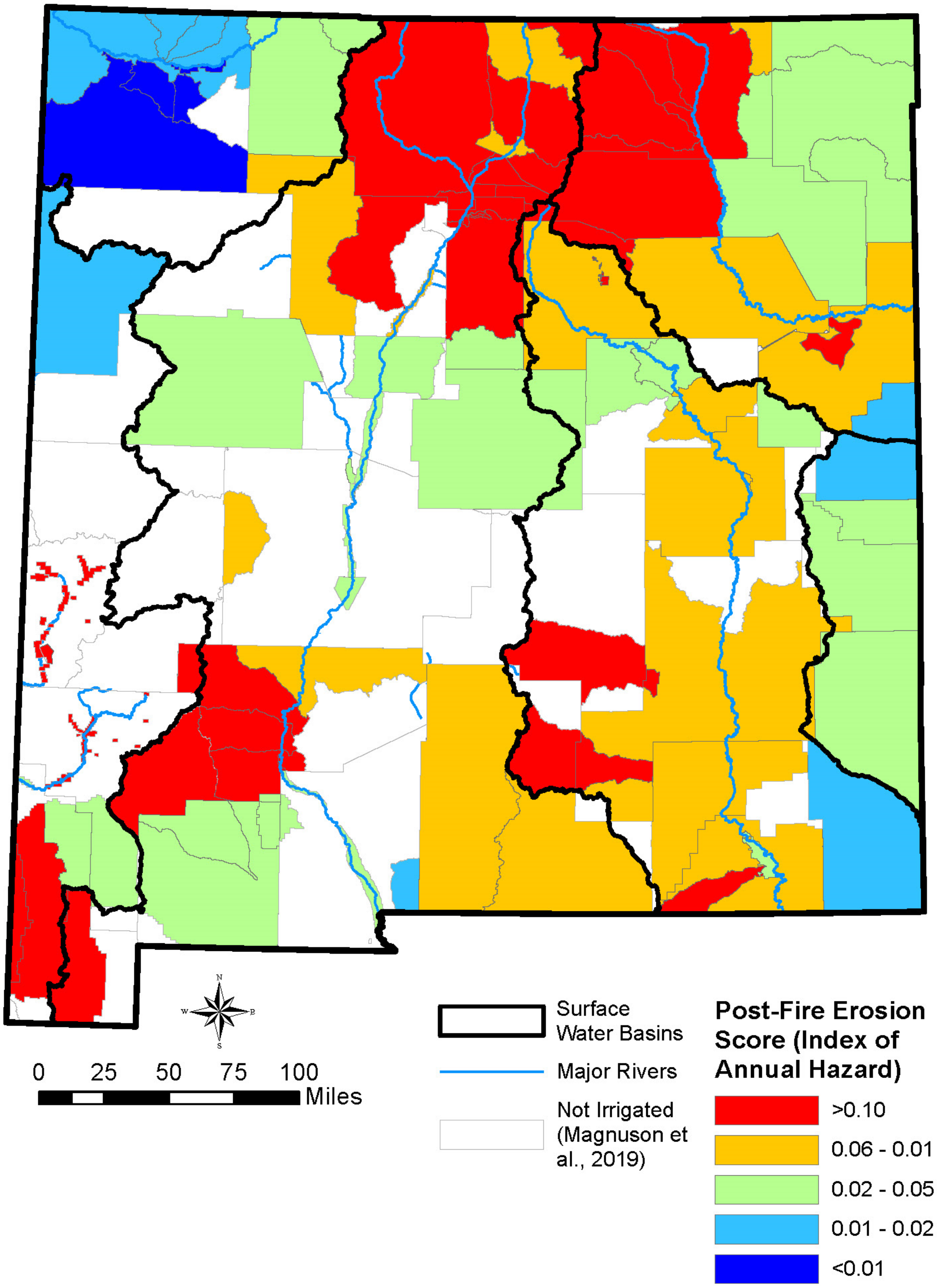
Calculation: The levels of resilience to post-fire debris flows shown in Figures 28 and 29 were calculated using the following steps:

- Obtain the Post-Fire Erosion Risk Raster (NMFAP2020_Threat_Postfire_ErosionHazard)- Values from 0 to 1 for the annual post-fire erosion risk.
- Use this Raster to calculate the statistics for the value for HUC12 watersheds in New Mexico.
- Calculate the mean value for HUC12 watersheds both above the 57 surface water intake structures that serve PWSs and the 98 irrigation districts and below large reservoirs (Navajo and Cochiti) that are capable of absorbing debris flows.
- Assign the mean value for post-fire debris flow for the HUC12 watersheds in groundwater-supplied PWSs.



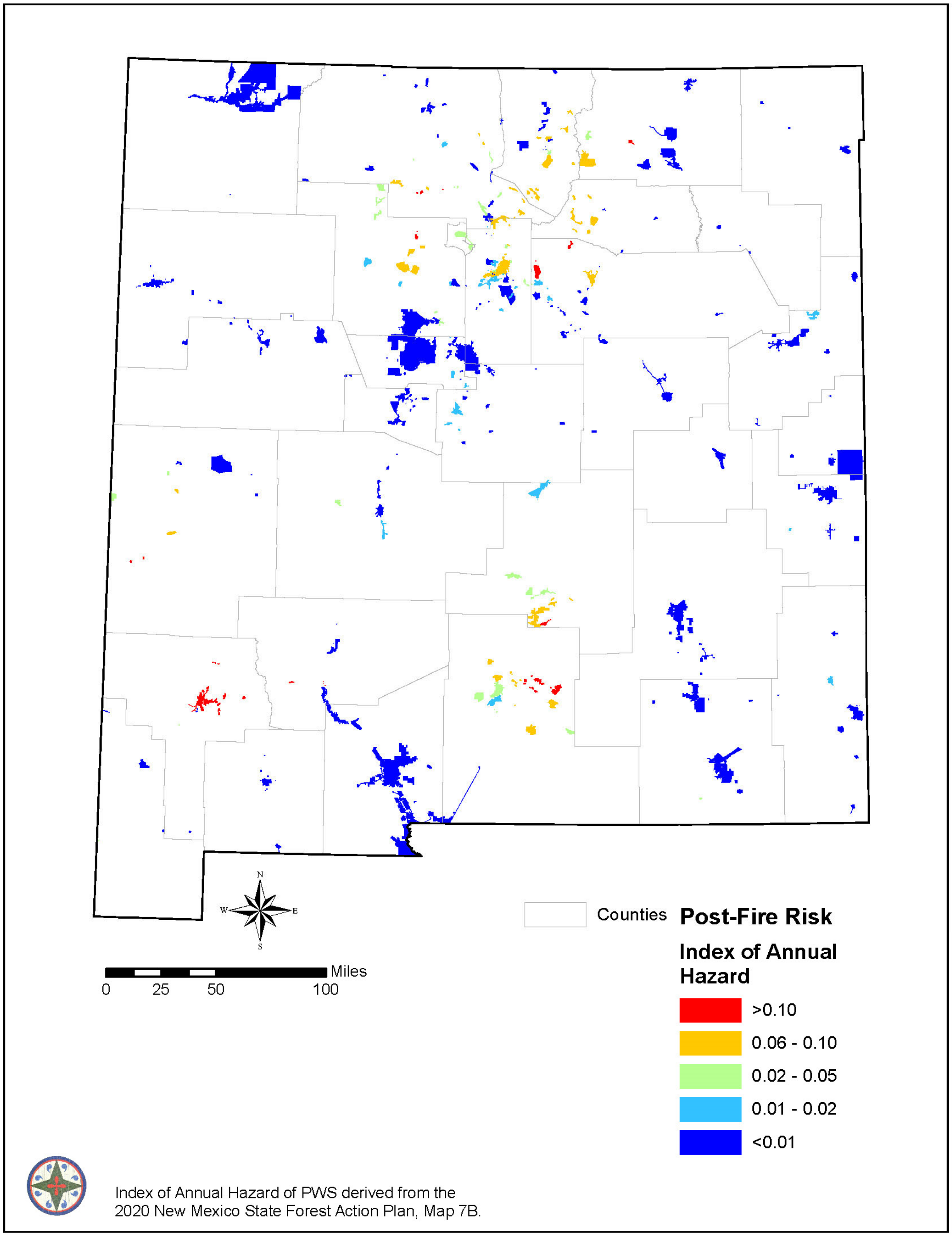
Post-Fire Erosion Hazard derived from the 2020 New Mexico State Forest Action Plan, Map 7B. (NMEMNRD, 2020)

Figure 27. Post-Fire Erosion Hazard Classification from the State Forest Action Plan



Derived from the Index of Annual Hazard
2020 New Mexico State Forest Action Plan, Map 7B.

Figure 28. Watershed Health Element: Post-Fire Erosion Risk to Irrigated Agriculture Locales



Index of Annual Hazard of PWS derived from the 2020 New Mexico State Forest Action Plan, Map 7B.

Figure 29. Watershed Health Element: Post-Fire Debris-Flow Risk to Public/Private Water Systems

4. Assessment of Water Demand Resilience Elements for Irrigated Agriculture and Public/Private Water Systems

The ability of an irrigation district or a PWS to manage the projected increases in demand based on increasing temperatures and longer growing seasons is a measure of that system's resilience. Demand management elements include: (1) sharing agreements, (2) cropping pattern, (3) irrigation methodology, (4) conservation plans, and (5) per capita water demand. The first three elements are largely specific to AG locales and the latter two are more applicable to PWSs.

The types of crops, whether annual or permanent, create a condition of resilience or adaptability that is within the control of the farmer. Permanent crops, such as pecan orchards, fruit orchards, and vineyards, require irrigation water each year or risk permanently losing the crops. Farms that grow annual crops are more flexible and, while it would be a hardship to reduce the acreage planted, doing so would not risk the loss of investment associated with establishing permanent crops. Fortunately, 72 of the 98 AG locales predominantly grow annual crops and thus have the flexibility to adjust irrigated acreage during shortages.

The irrigation methodology also impacts the resilience of each farm. Those with water-efficient irrigation methods, such as the drip irrigation used by 5 of the locales, are able to grow more with less water delivered to the farm. Thus, when supplies are limited, these farms are able to deliver more water to crops. The 72 locales that use flood irrigation to water crops are less efficient but may also provide recharge to other water users. While some of the "inefficiency" associated with canal leakage results in recharge to the aquifer, and the "lost" water often returns to the stream, this is not always the case. While irrigation return flows to surface water can be important in some areas of the state, the water leaking from canals is often lost to poor-quality aquifers. Sprinkler irrigation systems used in 21 of the AG locales have less ambiguous impacts; these systems lose water to evaporation with minimal return flows to the system. Farmers and irrigation districts that have a detailed understanding of their water budget can consider ways to achieve their goals with less water.

4.1 Sharing Agreements

Climate change projections include longer and more frequent drought periods. Research has shown that communities, states, and countries that have rules in place for managing shortages are better able to maintain peace among water users than those with no structure in place (Wolf, 2007). Priority administration[16] can be used to manage the distribution of water in adjudicated river basins, and shortage sharing agreements can also prepare a community to withstand the stress of a drought.

In the few watersheds that are adjudicated (Cimarron River and Costilla River), the water master will distribute water based on priority administration. Irrigation districts have a rigorous structure governing allocation of water to farmers (Figure 30).

The areas with shortage sharing agreements (such as the San Juan River basin, Rio Gallinas, and Rio Hondo Acequia Association) have an arrangement for sharing water that is much like the irrigation districts, where water is shared proportional to the acreage irrigated. Active Water Resource Management (AWRM) designated areas are in a position to develop sharing agreements, but the details of the status of such agreements are not known. Acequia associations are also positioned to develop sharing agreements, but the status of such agreements is not known, and the geographic areas of each acequia association are not available. Each farmer would benefit from understanding the terms of their sharing agreements and pursue the development of shortage sharing agreements where none exist.

Figure 31 shows the relative resilience of AG locales based on the current knowledge of adopted sharing agreements. Of the 98 irrigated locales, 46 do not have a sharing agreement, 13 are located within an AWRM, and 39 are more resilient because they have a procedure for sharing water during shortages.

Calculation: The levels of resilience due to sharing agreements shown in Figure 31 were calculated using the following steps:

- Identify the PWS and Irrigation districts in an adjudicated basin or otherwise managed.
- Collect information on existing sharing agreements from NMOSE and NMISC staff; request information for the New Mexico Acequia Association (none was provided).

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[16] Priority administration refers to the temporary curtailment of junior water rights in times of shortage so that more senior water rights can be served by the available supply

- Plot NMOSE irrigation districts (NMOSE, 2020a), adjudicated areas (NMOSE, 2020b), and AWRM areas (NMOSE 2020c) on a map.

PWSs are generally not included in basin-wide sharing agreements; thus, they were generally not included in this evaluation. Exceptions include the users of San Juan-Chama Project water, where shortages are shared equally among users of this water supply. Also, the City of Santa Fe delivers potable water to acequias with senior water rights during severe droughts, and the City of Las Vegas has a river sharing agreement with Gallinas River acequias (NMOSE, 2009).

Data Gap: Compile information on existing sharing agreements within AWRM areas and acequia associations.

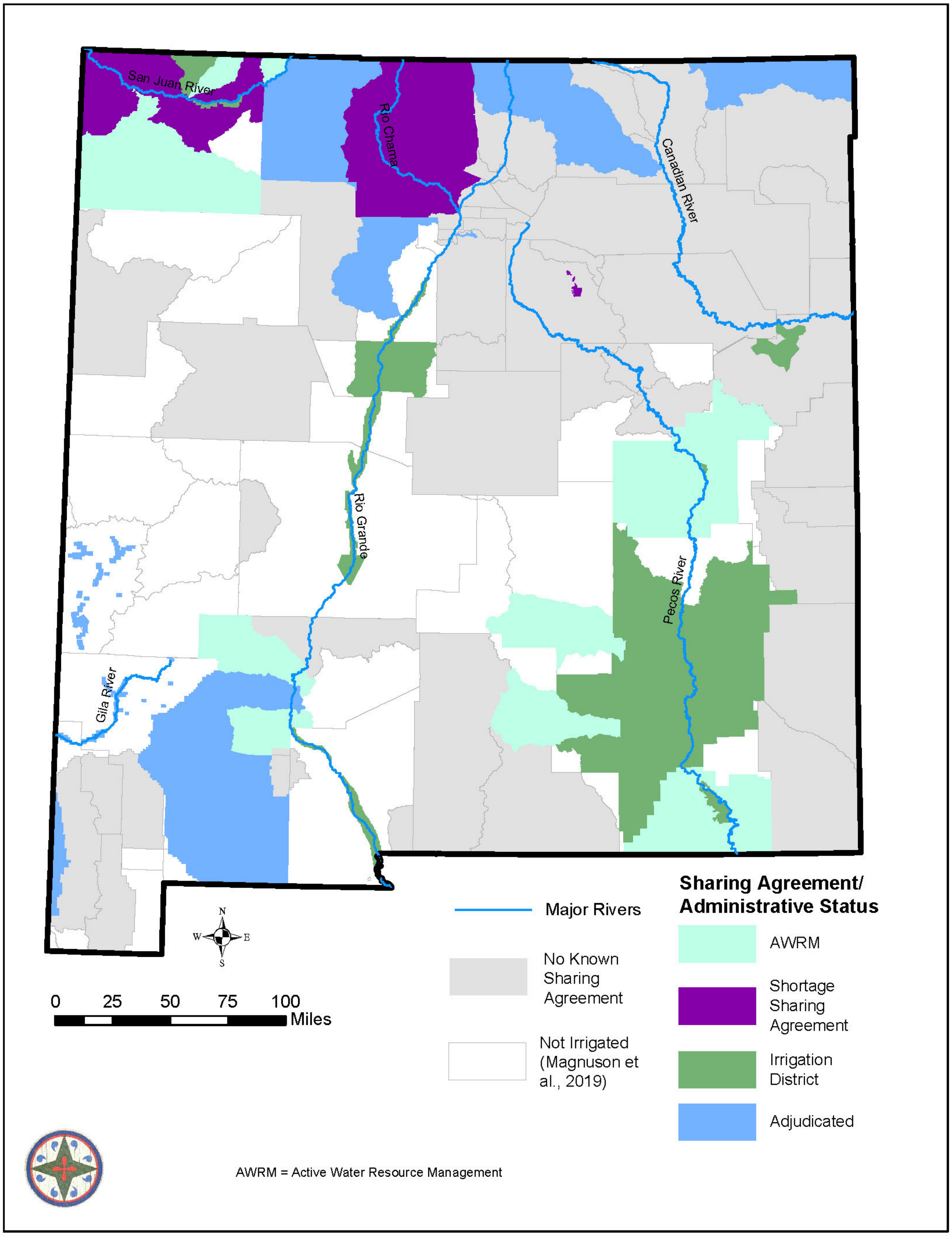


Figure 30. Irrigated Agriculture Locales with Sharing Agreements for Managing Water Distribution

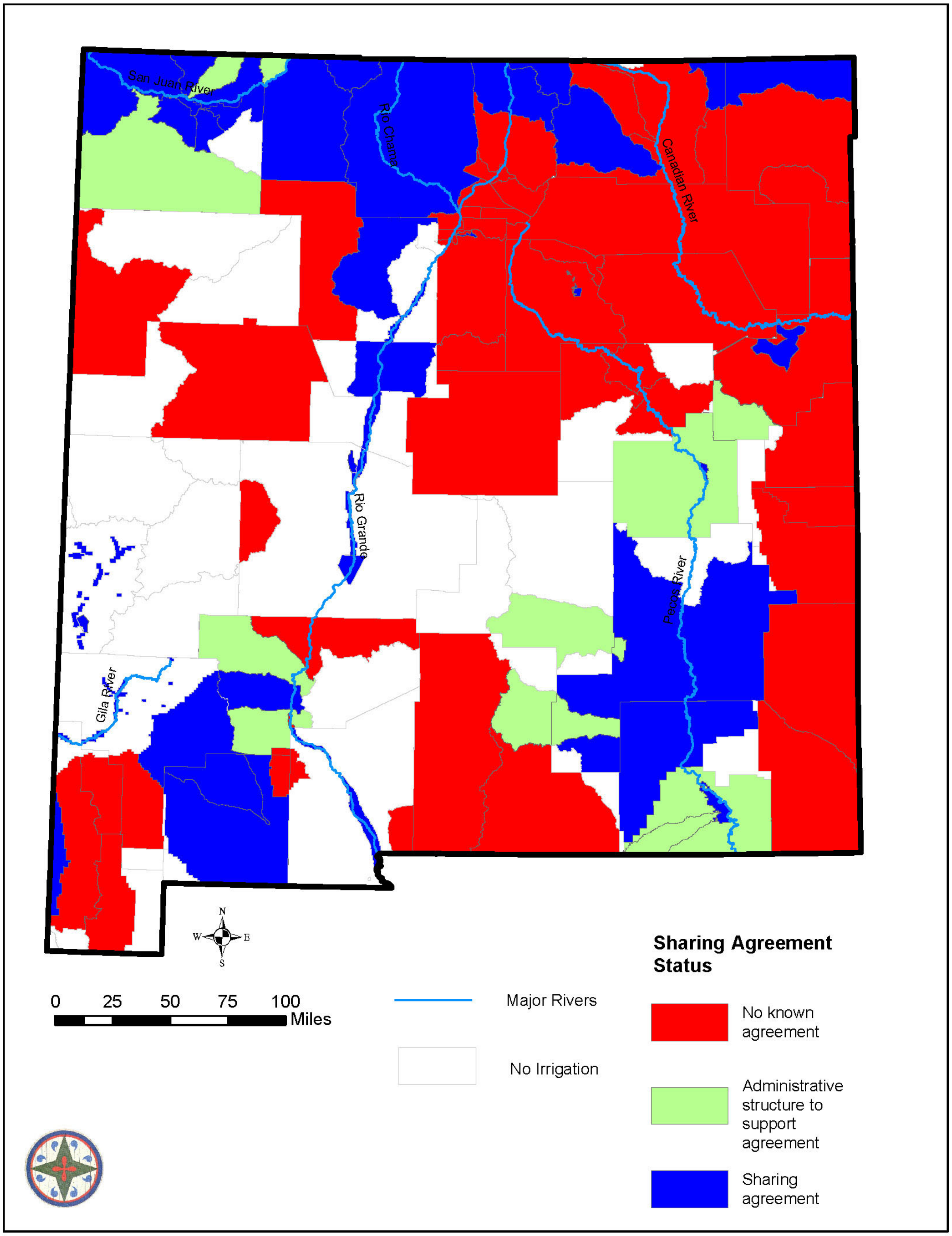


Figure 31. Demand Management Element: Sharing Agreements for Irrigated Agriculture Locales

4.2 Cropping Patterns

Higher temperatures and longer growing seasons will increase the demand for water, particularly for irrigated crops. Farmers that are accustomed to fluctuating surface water supplies have historically adapted by modifying their acreage irrigated. Of the total irrigated acreage, 6% is planted with permanent crops, including orchards (e.g., pecan trees, pistachio trees, fruit trees) and vineyards (Figure 32). Permanent crops require years of watering to reach maturation and cannot be fallowed during drought years without significant economic losses. Thus, the planting of permanent crops results in demand hardening (Johnson and Cody 2015). In contrast, vegetables, grain, pasture crops are annual, and the acreage planted can vary from year to year based on water supply forecasts. The farmers who have planted permanent crops not only have less flexibility in adapting to shortages but must be prepared for an increase in demand for water due to the longer growing season and warmer temperatures. This element was evaluated by compiling information collected for the NMOSE *New Mexico Water Use by Categories 2015* report (Magnuson et al., 2019), including the crop acreage for each of the 98 NMOSE irrigation areas (Valdez, 2021). Figure 33 shows the relative resilience based on the percentage of permanent crops in each AG locale.

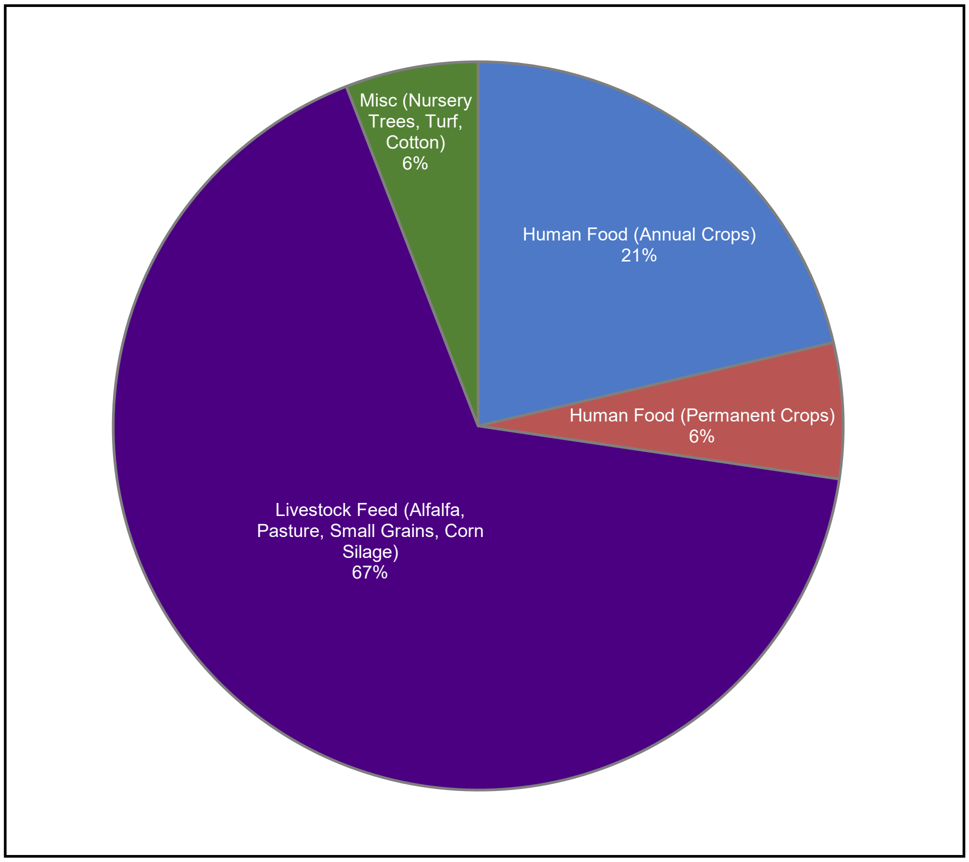
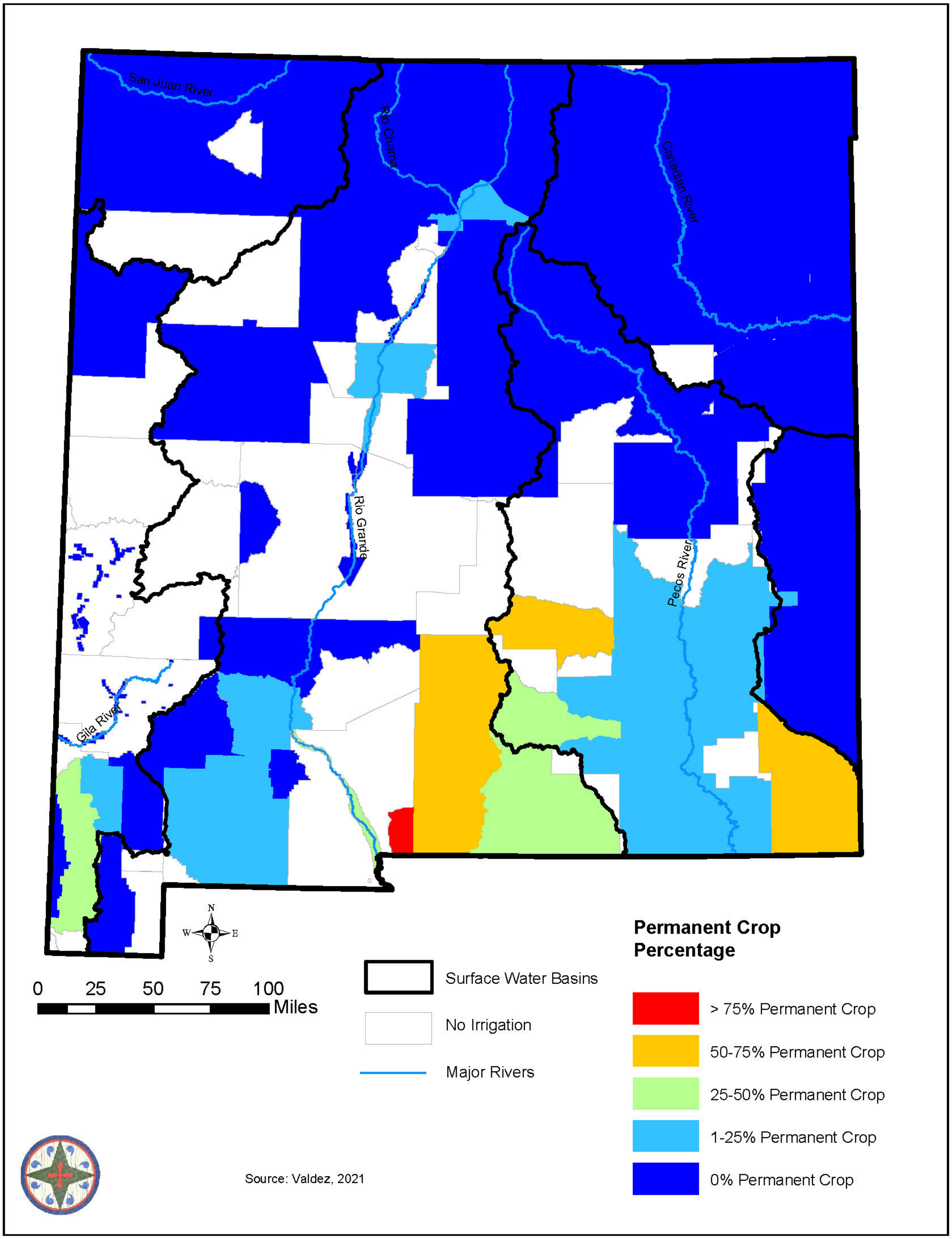


Figure 32. Crop Distribution for Irrigated Farmlands in New Mexico in 2015

Calculation: The levels of resilience due to cropping patterns shown in Figure 33 were calculated using the following steps:

- Enter the acreage of permanent crops (pecans trees, pistachio trees, fruit trees, grapes, and berries) for each of the 98 NMOSE AG locales used for estimating the 2015 water diversions (Valdez, 2021).
- Calculate the total area of permanent crops for each AG locale by summing the area of permanent crops.
- Divide the area of permanent crops by the total area irrigated in 2015 to obtain the percentage of permanent crops.
- Reconcile the AG locale names with the file names and plot the percentage of permanent crops.



Source: Valdez, 2021

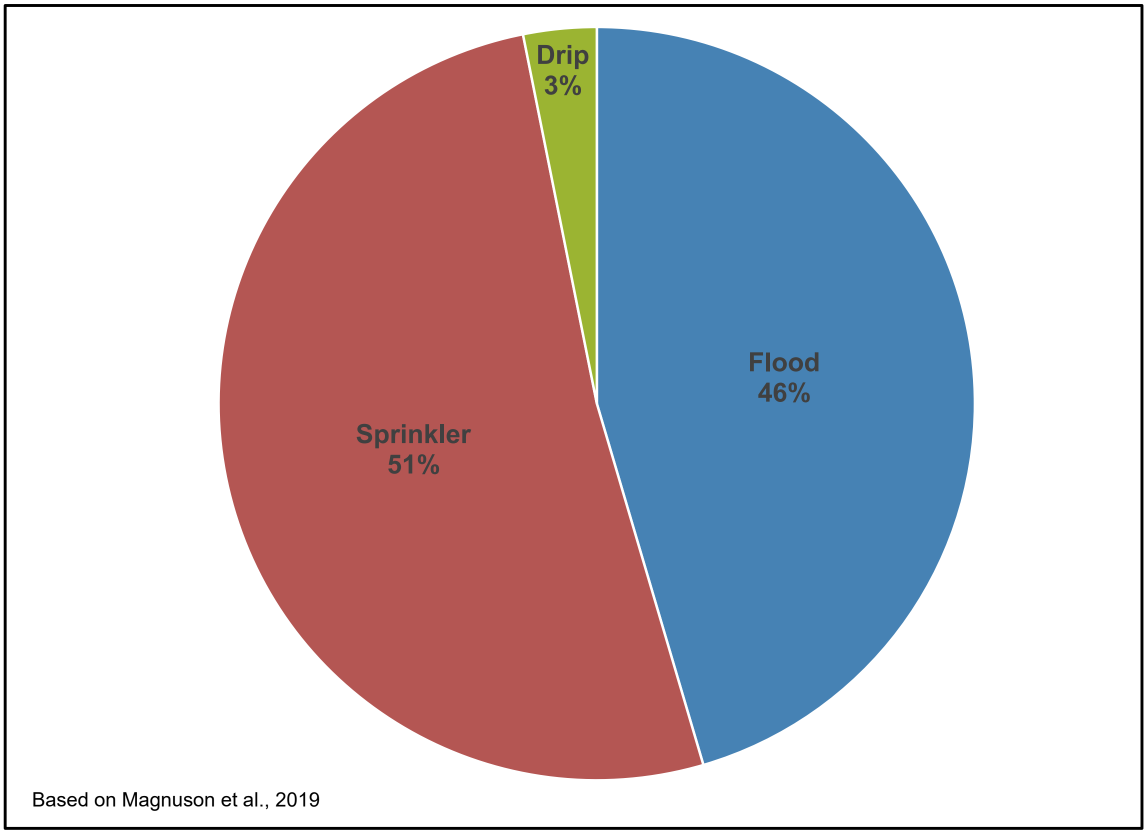
Figure 33. Demand Management Element: Cropping Patterns of Irrigated Agriculture Locales

4.3 Irrigation Methodology

Some methods of irrigation will be more impacted by the increased aridity caused by climate change than others. The method of irrigating crops impacts the demand through their total consumptive use of water (Figure 34). Consumptive use refers to the total water lost or consumed through direct evaporation or transpired by crops. Water that seeps into the ground or flows back to a ditch or stream is not part of the consumptive use. Systems that use drip irrigation (3% of total irrigated farmlands in the state) are more efficient, needing less water to grow the same equivalent acreage of crops, and are less susceptible to evaporation. Systems that use high-energy sprinklers to irrigate (51% of New Mexico farmlands) lose a greater portion of water to consumptive use due to evaporation, especially on windy days. Systems that flood irrigate (46%) lose more water to direct evaporation than drip systems, but less than high energy sprinkler systems. With warmer temperatures and greater aridity, the direct evaporation rate will increase, and less water will be available for the crops. Figure 35 shows the relative resilience of AG locales based on the predominant irrigation method. The irrigation method is more nuanced than presented in this exercise. Some sprinkler irrigation methods that use low energy precision application are much more efficient than a flood irrigation system without furrows or laser leveling (Vickers, 2001). Once again, each farmer understands their system and is in a better position to evaluate their vulnerability.

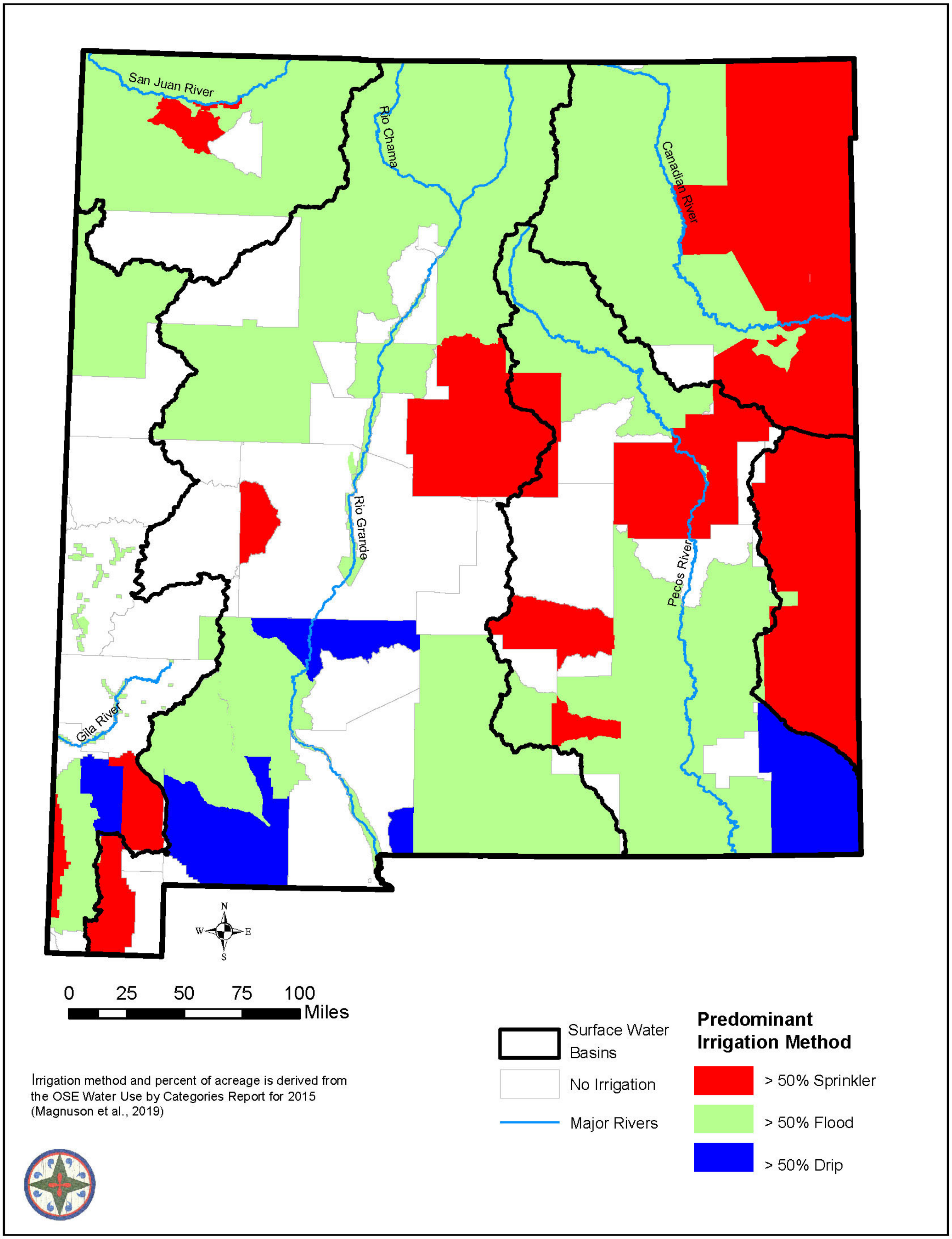
Calculation: The levels of resilience due to irrigation method shown in Figure 35 were calculated using the following steps:

- Calculate acreage for each irrigation type for each AG locale: flood, sprinkler, and drip (Magnuson et al., 2019).
- Calculate the percentage of the total crops irrigated using each method for each AG locale.



Based on Magnuson et al., 2019

Figure 34. Irrigation Method of Croplands in New Mexico in 2015



Irrigation method and percent of acreage is derived from the OSE Water Use by Categories Report for 2015 (Magnuson et al., 2019)

Figure 35. Demand Management Element: Predominant Irrigation Method of Irrigated Agriculture Locales

4.4 Conservation Plans

With the predicted reduced water supplies, PWSs may not be able to meet existing demands with existing supplies. PWSs can respond by reducing demand through the adoption of conservation and drought management plans. Demand reduction using conservation strategies ranging from incentives (e.g., rebates and tiered rate structures) to outdoor water restrictions and fines have been highly effective in reducing per capita demand.

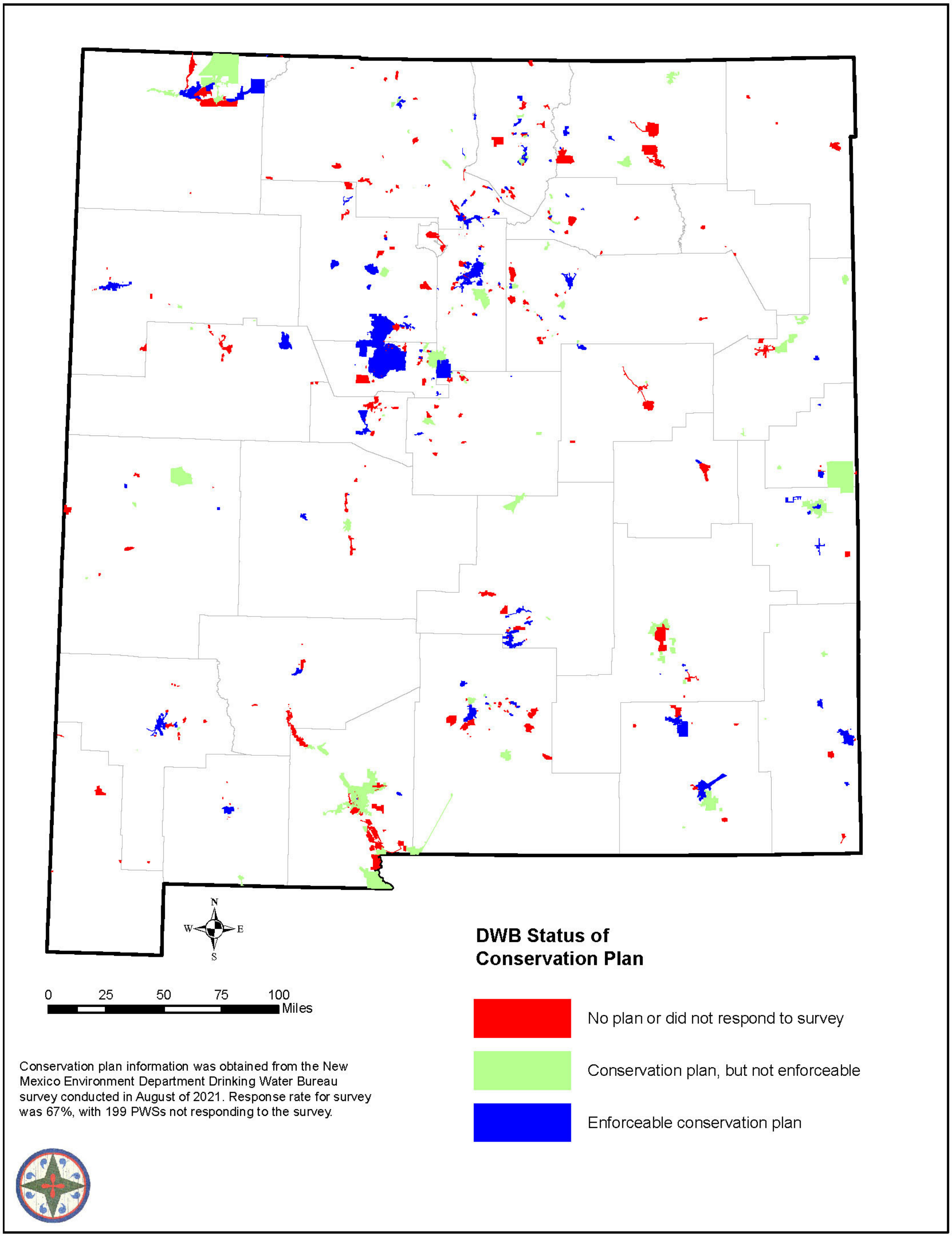
Communities that have conservation plans are better prepared for drought. Customers that understand the value of water have a greater ability to respond to future crises. Communities that have already reduced their per capita demand have less water demand "softness" for immediate reductions and, have "hardened" to some degree their water demand such that further reductions are more difficult.

The NMED DWB recently surveyed all PWSs and received responses from 407 systems, or 67 percent of the total number. Of the 267 with a conservation plan, 154 said that the plan is enforceable, as shown in Figure 36.

45% of PWS have a conservation plan

Calculation: The levels of resilience due to conservation plans shown in Figure 36 were calculated by:

- Aligning the NMED DWB survey results (NMED DWB, 2021) with the NMOSE geodatabase of PWSs (NMOSE, 2020d).



Conservation plan information was obtained from the New Mexico Environment Department Drinking Water Bureau survey conducted in August of 2021. Response rate for survey was 67%, with 199 PWSs not responding to the survey.

Figure 36. Demand Management Element: Water Conservation Plans of Public/Private Water Systems

4.5 Per Capita Water Use

With increasing temperatures and longer growing seasons, PWSs face increasing demand, particularly for landscape watering and evaporative cooler use. PWSs that already have a low per capita demand have to some degree "hardened" their water demand such that they are less able to reduce demand further during droughts. Customers that have a high per capita demand, however, are most likely using a significant amount of water for outdoor watering and will be less resilient to reductions in supply because their demand for water will also increase more significantly with higher temperatures and a longer growing seasons. As with AG, annual plants provide more opportunity when conservation measures are in place. Trees require water regardless of water restrictions, and while they have many valuable attributes, including reducing temperatures, they cannot go without water for a season. Figure 37 shows the relative resilience of PWSs based on their per capita demand.

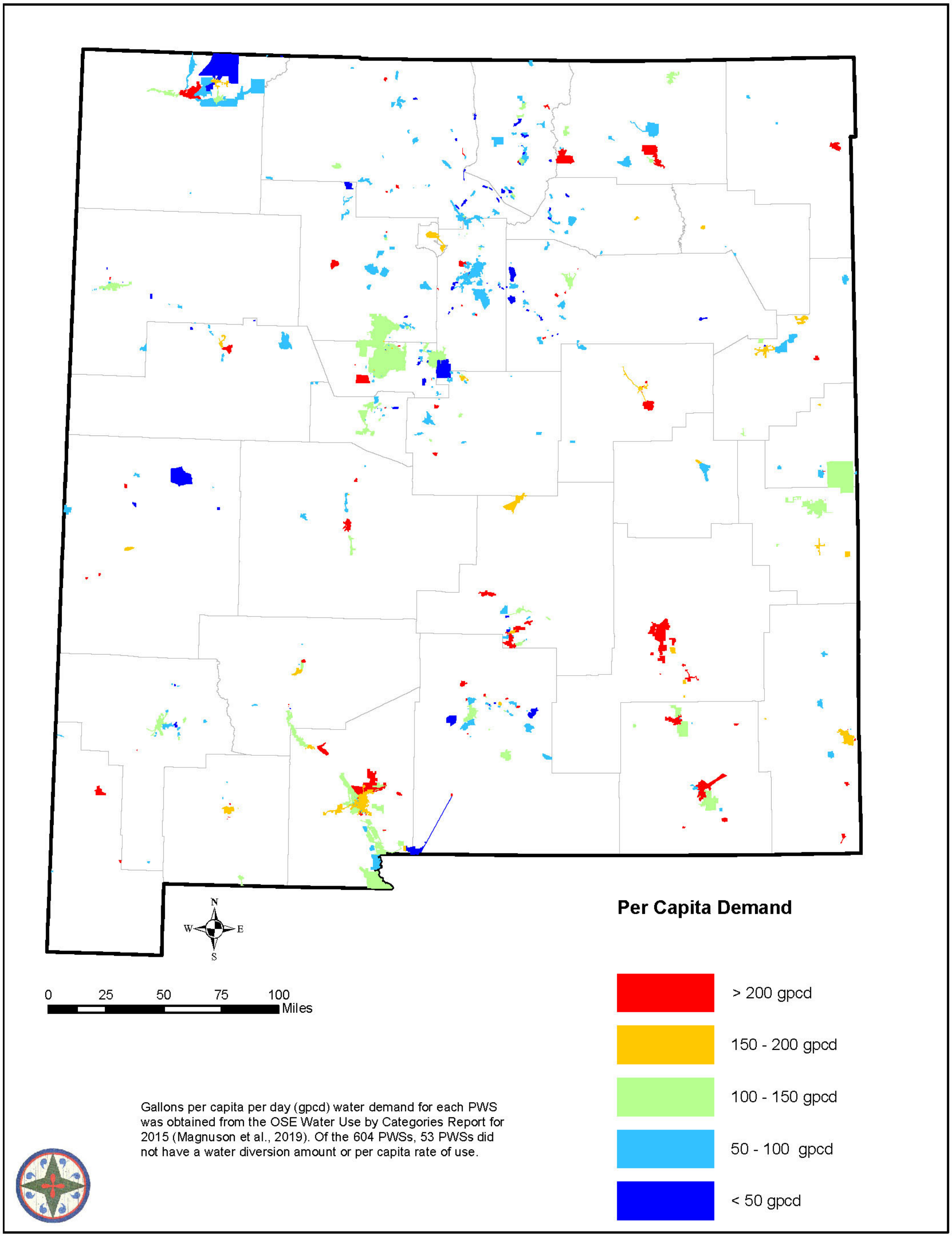
PWSs that work with customers to communicate the need to reduce water waste, plant appropriate landscaping, and install water-conserving fixtures will be less stressed during times of drought than those systems with unresponsive rate structures, incentives, or enforcement capabilities to raise awareness of the need to reduce water use. If the per capita demand is already less than 50 gallons per capita per day (gpcd) and the current capacity (either water rights or infrastructure) is strained to meet the current demand, the system is not very resilient, as further reduction in use through conservation measures is much more difficult.

Of the 604 PWSs, 330 PWSs (~55%) do not have a conservation plan, 115 have unenforceable plans, and the remaining 159 have enforceable conservation plans. The per capita demand for 98 PWSs is more than 200 gpcd, which indicates a high degree of vulnerability to increasing demands as temperatures rise. On the other hand, these 98 PWSs can adopt conservation plans and reduce their water demand significantly, increasing their resilience.

55% of PWS have a per capita demand greater than 100 gallons

Calculation: The levels of resilience due to per capita demand shown in Figure 37 were calculated by:

- Using the per capita demand rate provided by NMOSE's *2015 Water Use by Categories* report (Magnuson et al., 2019).



Gallons per capita per day (gpcd) water demand for each PWS was obtained from the OSE Water Use by Categories Report for 2015 (Magnuson et al., 2019). Of the 604 PWSs, 53 PWSs did not have a water diversion amount or per capita rate of use.

Figure 37. Demand Management Element: Per Capita Demand of Public/Private Water Systems

5. Summary

Assessing the resilience of a water system is nuanced and it is up to each water manager to understand the vulnerabilities of their system. Based on this analysis, the most resilient systems are AG locales that have a diverse water supply, are in a stream-connected aquifer and have a sharing agreement in place to address water shortages. The systems along the Rio Grande from below the Otowi Gage to the state line appear to be the most resilient in the Rio Grande surface water basin. Those systems along the Pecos River below Acme, NM, are most resilient in the Pecos River surface water basin. AG locales along the San Juan River are more resilient than systems that are groundwater dependent, but less resilient than those along the Rio Grande or Pecos because they have minimal groundwater supply as a backup supply when surface water is insufficient. About 60 out of the 98 locales, representing 55% of the water diverted for agriculture, are very vulnerable to climate change because either their surface water supply is currently insufficient, or their groundwater supply is in a mined aquifer.

An overview of the relative resilience of irrigated locales for the quantifiable elements is shown in Table 6. The size of each irrigated locale varies and thus the number of locales does not necessarily reflect the volume of water diverted or acreage irrigated.

The relative resilience of a PWS is strongly controlled by geography and the PWS's dependence on mined aquifers. Systems in eastern New Mexico that rely on the declining High Plains aquifer are very vulnerable[17]. Systems with access to multiple sources of water (i.e., both surface water and groundwater) are more resilient. Some PWSs are less resilient than those in the same area due to their infrastructure strength and demand management capabilities.

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[17] The communities of Clovis, Portales, Melrose, Texico, Grady and Elida, as well as Cannon Air Force Base and Curry and Roosevelt counties, are working on constructing a pipeline (known as the Eastern New Mexico Rural Water System) from Ute Reservoir, which will increase their resilience to climate change.

Table 6. Distribution of Irrigated Locales by Levels of Resilience

Resilience Elements		Number of irrigated Locales by Level of Resilience		
		Least Resilient	Moderately Resilient	Most Resilient
Water Diversity	Dependence on surface water or groundwater	79	6	13
Water Availability	Surface water: Ratio of minimum streamflow to surface water diversion	61	5	3
	Groundwater: Stream-connected aquifer or mined aquifer	36	1	20
	Projected supply-demand gap: Supply as percentage of total demand	70	18	10
Infrastructure Capacity	Reservoir storage: Ratio of storage to annual surface water diversion	41	11	17
Watershed Health	Soil erosion risk	40	58	0
	Post-fire debris flow risk	56	39	3
Demand Management	Sharing agreements	46	13	39
	Cropping patterns	4	22	72
	Irrigation methodology	21	72	5

Table 7 summarizes the number of PWSs for each resilience element based on the level of resilience. The majority of PWSs do not have a diverse water supply, but most are either in a stream-connected aquifer or have sufficient surface water supply. However, 146 of the 604 PWSs are either in a mined groundwater basin or do not have sufficient surface water supply. These 146 PWSs are the most vulnerable to climate change.

Where water supply can be secured, resilience can be enhanced by improving infrastructure, but this option is challenging for more than half of the PWSs that have a mean household income of less than 90% of the state's average. A surprising number of PWSs do not monitor water levels in their wells, indicating that they are not aware of the declining water supply. Most do not have an enforceable conservation plan and their per capita demand is much too high for the increasingly arid conditions.

Table 7. Distribution of Public/Private Water Systems for Each Resilience Element

Resilience Elements		Number of Public/Private Water Systems by Level of Resilience		
		Least Resilient	Moderately Resilient	Most Resilient
Water Diversity	Dependence on surface water or groundwater vs. conjunctive use	575	7	22
Water Availability	Surface water: Ratio of minimum annual flow ever recorded on stream to annual diversion	34	2	26
	Groundwater: Stream-connected or mined basin	133	2	448
	Projected supply-demand gap	427	113	64
Infrastructure Capacity	Number of wells	197	300	80
	Treated water storage capacity	491	85	28
	Emergency supply	294	0	310
	Resource monitoring	424	119	61
	Raw water storage	28	3	31
	Regulatory compliance	39	238	327
	Equity	365	146	93
Watershed Health	Soil erosion potential	137	467	0
	Post-fire debris flow risk	149	86	369
Demand Management	Conservation plan	330	115	159
	Per capita demand	131	389	84

6. Recommendations

Review of the resilience elements highlights some important issues and helped form the following recommendations:

1. Improve the mapping of saturated thickness and extent of aquifers. Collect more data on the rates of water level declines and the total volume of water pumped from each aquifer. With this knowledge extensive statewide numerical models could be built to simulate future conditions and improve the ability to assess the vulnerabilities to predicted climate change.

2. Many PWSs, such as the 197 PWSs that have only one well and rely entirely on groundwater, need more support to improve their infrastructure. Technical support for exploring options of developing a conjunctive use strategy for each PWS could assist communities in developing a diverse water supply and increasing their resilience to climate change.

3. Improve the rate of compliance with NMED DWB standards to ensure that the public is receiving safe drinking water. Increased staffing at the NMED DWB is recommended. Local technical capacity development and support is also essential.

4. Develop a tool to assist AG locales, PWSs, and any other water user to evaluate the relative resilience of their water system and help guide improvements.

5. Improve mapping and identification of infrastructure for AG and PWSs by collecting GPS coordinates of intake structures from streams and groundwater supply wells. The NMED DWB could improve the accuracy of their data if more resources were provided to this agency. NMOSE has a geodatabase of the water service areas for PWSs, but these areas will continue to change as populations change and water systems merge. An online tool that allows water managers to enter their data is recommended. With accurate data on infrastructure, systems that are vulnerable to floods and erosion can be identified.

6. Address equity issues with respect to the ability of a PWS to deliver clean drinking water to their customers. Consider the 40% of PWSs that serve customers with incomes less than 80% of the state's mean household income (MHI), the 45% of PWSs that are non-compliant with NMED Drinking Water regulations, the 25 to 50% of PWSs without an emergency supply, and the 30 to 50% that do not monitor water levels in their wells.

7. Increase the support of efforts by New Mexico State Forestry, USFS, Bureau of Land Management, NMED, and non-governmental organizations (NGOs) and other agencies to improve the health of soils and reduce erosion and damage to riparian areas.

8. Increase the support of efforts by New Mexico State Forestry, the USFS, NMED, and NGOs to reduce the risk of catastrophic wildfires through vegetation mapping, development of forest treatment prescriptions, and funding for treatment and monitoring.

9. Provide support for developing water sharing agreements in regions that want to adopt a mechanism to share during drought.

10. Provide technical and financial support for the of lands that use high-energy sprinklers or unimproved flood irrigation to improve irrigation efficiency. Conversion of irrigation methods,

such as laser leveling and furrows, low energy precision application, could extend the limited supply of water to grow food and eliminate water wasted to direct evaporation.

11. Technical support is needed to investigate areas where canal or ditch seepage results in water lost to poor-quality aquifers or otherwise results in loss of water to the local hydrologic system.

12. Encourage development of enforceable water conservation plans for the 55% of PWSs that have not adopted measures to reduce per capita water use.

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Appendix A

Matrices for Assessing Resilience to Climate Change

Table A-1. Matrix for Assessing Resilience of Irrigated Agriculture and Livestock Watering to Climate Change

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Supply				
Water Diversity	Dependence on surface water (SW) or groundwater (GW)	90-100% SW or 90-100% GW	40-60% SW or 40-60% GW	Consider the diversity of your water supply to adapt to wet and dry periods. Do you have SW to use during wet years to allow GW to recover? (See Figure 3 and Figure 4)
Water Availability	Priority date of water right	Junior water rights	Pre-compact water rights	Consider the vulnerability of your water system's water rights to priority calls or other legal issues that may make your water supply unavailable during drought.
	Surface water: Ratio of minimum SW flow to SW diversion	<1	>50	Is the ratio of surface water in a very dry year significantly more than your demand? (See Figure 8)
	Surface water: evaporation from reservoirs	Significant loss	Low loss	Consider the potential loss of your surface water supply due to increased evaporation from reservoirs as temperatures increase.
	Groundwater supply that is from a stream-connected aquifer or a mined aquifer	In a mined basin	In a stream-connected basin	Are your wells in a stream-connected aquifer or mined basin where average aquifer withdrawals exceed average recharge? (See Figure 11)
	Groundwater: Saturated thickness of aquifer	<100 feet thick aquifer	>400 ft	Consider the saturated thickness of the aquifer, the thickness of the water column in the well when pumping and the potential to deepen the well.
	Groundwater: Declining aquifer	>10-foot per year decline	No decline	What is the historical trend in water levels in your well field? Are the water levels relatively stable or is the level declining consistently?

Table A-1. Matrix for Assessing Resilience of Irrigated Agriculture and Livestock Watering to Climate Change (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
	Projected supply-demand gap (supply as % of the total demand)	<40%	>70%	Consider the future stress of the cumulative water diversions in your water planning region. (See Figure 15)
Supply (cont.)				
Infrastructure Capacity	Reservoir storage ratio to annual SW diversion	No storage	Greater than 5 times annual diversions	Consider the ability of your system to capture surface water runoff if snowmelt occurs much earlier? (Figure 21)
	Infrastructure condition	Minimal or no infrastructure or delivery system	Well maintained infrastructure, pipes, lined canals, latest technology	Consider the condition of your infrastructure and its efficiency, as well as ability to cope with floods and drought.
Watershed Health	Sedimentation of reservoirs	High risk	Low risk	Consider the potential loss of reservoir storage space due to an increased rate of sedimentation in the reservoir.
	Erosivity risk	High risk of sedimentation of infrastructure	Low risk of impacts to infrastructure	Consider the vulnerability of your infrastructure to sediment/erosion/flooding. Poor rangeland conditions can result in damaging sedimentation of infrastructure (see Figure 25).
	Post-fire debris flow risk	Very severe	No risk	Consider the vulnerability of your infrastructure to be impacted by a post-fire debris flow. (See Figure 28).
	Floodplain	Farm in the floodplain	Farm 2 feet above floodplain	Consider the proximity of your infrastructure or fields to the 100-year floodplain.
	Soil health	Poor	Good	Consider the condition of the soil on your farm, including both infiltration rate and ability to retain soil moisture.

Table A-1. Matrix for Assessing Resilience of Irrigated Agriculture and Livestock Watering to Climate Change (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
	Water quality	High risk to potential degradation	Low risk for drinking water quality violation, aesthetic impairment	Consider the proximity of your water system's infrastructure to potential sources of contamination that can increase the vulnerability during drought periods.
Demand				
Demand Management	Sharing agreement	No agreements	Adjudicated, irrigation district, shortage sharing, acequia associations with agreements	Consider the arrangements of your irrigation district or acequia association for managing water supply shortages. Those systems with a previously agreed upon plan are more resilient. (See Figures 30 and 31)
	Diversity of cropping pattern	90-100% orchards or other crops that are "permanent" and will be lost if not irrigated	90-100% annual crops - acreage planted can vary each year	Consider the flexibility to manage acreage planted if a high percentage of crops are permanent (e.g., orchards or vineyards). (See Figure 33)
	Irrigation methodology	> 50% High-energy sprinklers	> 50% drip or high efficiency application	Consider how much of the water diverted is lost to incidental depletions (evaporation from sprinklers, ponded water). Flood irrigation is considered moderately resilient for this exercise. With laser leveling, flood irrigation can be nearly as efficient as drip irrigation methods. (See Figure 35)

Table A-2. Matrix for Assessing the Resilience of Public/Private Water Supply Systems and Domestic Wells

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Supply				
Water Diversity	Mix of surface water (SW) and groundwater (GW)	90-100% SW or 90-100% GW	40-60% SW or 40-60% GW	Consider the diversity of your water supply to adapt to wet and dry periods. Do you have SW to use during wet years to allow GW to recover? (See Figure 6)
Water Availability	Priority date of water right	Junior water right	Pre-compact water right	Consider the vulnerability of your water system's water rights to priority calls or other legal issues that may make your water supply unavailable during drought.
	Surface water: Ratio of minimum annual flow ever recorded on stream to annual SW diversion	<1	>50	Is the ratio of surface water in a very dry year significantly more than your demand? (See Figure 9)
	Potential loss of supply due to increased evaporation from reservoirs	Significant loss	Low loss	Consider the risk for potential loss of supply from increased reservoir evaporation due to higher temperatures.
	Groundwater: Stream-connected or mined basin	In a mined basin	In a stream-connected basin	Are your wells in a stream-connected aquifer or in a mined basin where average aquifer withdrawals exceed average recharge? (See Figure 12)
	Groundwater: Saturated thickness of aquifer	<100 feet thick aquifer	>400 ft	Is the saturated thickness of the aquifer hundreds of feet thick?
	Groundwater: declining aquifer	>10-foot per year decline	No decline in water level in 20 years	What is the historical water level decline in your well? Are the water levels relatively stable or is the level declining consistently?
	Projected supply-demand gap (supply as % of the total demand)	<50%	>70%	Consider the future stress of the SW and GW diversions in your water planning region. (See Figure 16)

Table A-2. Matrix for Assessing the Resilience of Public/Private Water Supply Systems and Domestic Wells (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Infrastructure Capacity	Number of wells	1 well	> 10 wells	Larger systems require more wells than smaller systems to be resilient. Each PWS must consider what is appropriate, but one well generally does not create a resilient PWS. (See Figure 17)
	Treated Water Storage	0-3 days	>15 days	Storage tanks should be sized to meet at least a day's average demand or be able to meet fire flow requirements. (See Figure 18)
	Emergency Supply	No emergency supply	Emergency supply accessible	Consider the ability to provide a backup supply of water due to a catastrophic loss of infrastructure or water supply (debris flow, water level decline, dry stream). (See Figure 19)
	Resource monitoring	No water level monitoring	Monthly water level monitoring	Monitoring indicates awareness of resources and a degree of preparedness of declining resources. How often do you monitor the water levels in your wells? (See Figure 20)
	Meet summer peak demand	100% (of peak)	200% of peak	Consider the ability of your system to meet demand in peak summer months and ability to meet increasing demands during the summer for outdoor watering and use of evaporative coolers.
	Capture and store spring runoff	No storage, stream supplied	Reservoir storage	Consider the ability of your system to capture surface water runoff if snowmelt occurs much earlier. (See Figure 22)
	Managerial level	Volunteer staff	Multiple staff, technical support	Consider how well your water system operates and its ability to respond to future stresses brought on by climate change. Do you have multiple staff who are maintaining the infrastructure?

Table A-2. Matrix for Assessing the Resilience of Public/Private Water Supply Systems and Domestic Wells (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
	Regulatory Compliance	Repeat violations of Drinking Water Bureau (DWB) requirements	No DWB violations	Does your PWS meet requirements for providing safe water to your customers? Do you have multiple DWB or OSHA violations?
Infrastructure Capacity	Infrastructure condition	Poorly maintained	Well maintained infrastructure	Does your PWS have frequent system failures that result in suspended service to customers?
	Capacity to improve infrastructure (equity)	High percent water rate/income	Low percent water rate/income	Consider the financial resources available to your water system. Financially stressed communities are less able to prepare for and develop adaptation strategies. (See Figure 23)
Watershed Health	Watershed health: Erosivity index risk	Very severe risk	Low risk	Consider the vulnerability of your infrastructure to sediment/erosion/flooding. Poor rangeland conditions can result in damaging sedimentation of infrastructure. (See Figure 26)
	Watershed health: Debris flow risk	Very severe risk	Low risk	Consider the vulnerability of your Infrastructure to be impacted by a post-fire debris flow (See Figure 29)
	Proximity of infrastructure to floodplain	Infrastructure in 100-year flood plain	Infrastructure above 500-year flood plain	Consider the potential loss of wells, treatment facilities, distribution system from increased flood risk.
	Loss of supply due to loss of storage from increased erosion	Significant loss	No loss	Consider the risk for potential loss of supply from reduced reservoir storage due to sedimentation.
	Water quality	High risk to potential degradation	Low risk for drinking water quality violation, aesthetic impairment	Consider the proximity of your water system's infrastructure to potential sources of contamination that can increase the vulnerability during drought periods.

Table A-2. Matrix for Assessing the Resilience of Public/Private Water Supply Systems and Domestic Wells (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Demand				
Demand Management	Sharing agreements	No agreements	Sharing agreements, water banking, agreements for temporary leases	Consider the agreements developed between other water users in your community or watershed that help you prepare for future stresses brought on by climate change.
	Conservation plan	None	Enforceable	Does your water system have a conservation plan that can effectively reduce water demand? (See Figure 36)
	Pattern of landscape watering	>200 gpcd	< 50 gpcd	Consider the gallons per capita per day (gpcd) demand of the customers served by the water system. A low per capita demand can reflect the effectiveness of water conservation initiatives. A high per capita demand may reflect a significant amount of water used for outdoor watering that is likely to require more water as temperatures increase and growing seasons become longer. (See Figure 37)
	Demand hardening: Capacity of infrastructure (distribution and storage) to meet increased demand	Can only meet peak demand under 2021 conditions	Capacity to meet doubled peak demand	Consider the ability of your system to meet increased demand or reduce demand if supply is low. If your system is strained in its ability to meet current demands and the per capita water use is already very low (demand hardening), then the system is not very resilient.

Table A-3. Matrix for Assessing Resilience of Industry, Mining, Commercial and Power Water Use Sectors

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Supply				
Water Diversity	Dependence on surface water (SW) or groundwater (GW)	90-100% SW or 90-100% GW	40-60% SW or 40-60% GW	Consider the diversity of your water supply to adapt to wet and dry periods. If you use surface water (SW) what is the percent of the total supply? Do you have surface water to use during wet years to allow groundwater (GW) to recover?
Water Availability	Priority date of water right	Junior water right	Pre-compact water right	Consider the vulnerability of your water system's water rights to priority calls or other legal issues that may make your water supply unavailable during drought periods.
	Surface water: Ratio of minimum flow to surface water diversion	<1	>50	Consider the availability of your surface water supply, if applicable. Is the ratio of surface water in a very dry year significantly more than your demand?
	Surface water: Reservoir storage ratio to SW diversion	0-1	5-10	Consider the ability of your system to capture surface water runoff if snowmelt occurs much earlier?
	Groundwater: Stream-connected or mined basin	In a mined basin	In a stream-connected basin	Consider the availability of your groundwater supply. Are your wells in a stream-connected aquifer? Or are your wells in a mined basin where average aquifer withdrawals exceed average recharge?
	Groundwater: Saturated thickness of aquifer	<100 feet	>400 feet	Consider the saturated thickness of the aquifer, the thickness of the water column in the well when pumping and the potential to deepen the well.
	Groundwater: Water level changes in aquifer	>10-foot per year decline	No decline	Consider the historical rate of water level decline. Are the water levels relatively stable or is the level declining consistently?

Table A-3. Matrix for Assessing Resilience of Industry, Mining, Commercial and Power Water Use Sectors (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Safety				
Infrastructure Capacity	Infrastructure design to withstand flood events: culverts, stormwater ponds, waste piles, etc.	Facilities are located in the flood plain or up to 2 feet above the 100-year flood zone)	Properly designed, withstand 500-year 1-hour event	Consider the design of the infrastructure and the ability to handle the increased extreme precipitation events (100-year event, flooding, large storm events). What is the distance from the facility to the water source? Are there pipelines crossing arroyos or other drainages? Vulnerable facilities are those located in the floodplain or up to 2 feet above the 100-year flood zone.
	Infrastructure operation and maintenance (O&M) plan: Manages water, sediment and erosion (water treatment facility)	Infrequent inspections and maintenance after precipitation events, no O&M plan	Frequent inspections and maintenance after precipitation events, detailed O&M plan	Consider the operation and maintenance occurring after precipitation events, or other extreme events. Are there proper maintenance procedures at the facility? Are inspections up to date? Do operations have the possibility of cleaning and addressing water quality conditions such as dam release of acid- mine drainage?
	Emergency response plan	No options to divert effluent/ discharges	Backup plan for extreme events	Consider emergency plan for extreme events (storms, flooding, wildfire, drought) and if the facility has backup plans for emergencies. Does the emergency plan address damage to the electric grid or damage to other public utilities? Does it address working with local, state, federal and local emergency managers? Does the response plan include concerns for downstream stakeholders/environment/species?
	Remediation plan: Water quality cleanup /use of water treatment facilities	Large plume without or with passive cleanup approach	Small plume with engineered cleanup approach	Consider the vulnerability of contamination during production and post-production. Is there a well-engineered plan for clean up during production? Is there and well-engineered clean-up plan for post-production? Can you help with water quality issues by having a water treatment facility? Does the remediation plan include concerns for downstream stakeholders, environment, and species?

Table A-3. Matrix for Assessing Resilience of Industry, Mining, Commercial and Power Water Use Sectors (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Safety				
Watershed Health	Erosivity risk	High risk of sedimentation of infrastructure	Low risk of impacts to infrastructure	Consider the vulnerability of your infrastructure to sediment, erosion, and flooding from forests and rangelands. Poor rangeland or upstream streambank conditions can result in damaging sedimentation of infrastructure. (See Figure 24)
	Post-fire erosion risk	Infrastructure down stream of potential catastrophic wildfire	Low risk of impacts to infrastructure	Consider the vulnerability of infrastructure to post-fire debris flows. (See Figure 27)
Demand				
Demand Management	Sharing agreements	No agreement	Agreement(s) in place	Consider the agreements developed between other water users in your area, community, or watershed that help users prepare for future stresses.
	Ability to reduce demand	No conservation plan	Water conservation plan in place	Does your water use have a conservation plan that can effectively reduce demand? Can you recycle process water or utilize captured storm water?

Table A-4. Matrix for Assessing Resilience of Watersheds and Habitat

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Forest Health	Fire regime	Vulnerable to widespread/ uncharacteristic crown fire	Resistant to high-intensity fires or watershed-scale stand replacement fires	Consider the fire regime for the forest type. Is it at high risk for wildfire? Have any fuel treatments been implemented? (See Map 2A of the NMFAP [2020])
	Forest structure and composition	Fuel structure connected, uniform/ homogenous (vulnerable to threshold-type disturbance); largely shade tolerant/mesic species	Diversity of vegetation types and fuel structures, and disturbance; diverse species and drought tolerant populations	Is there effort to maintain or pursue optimal forest density and woody debris for a particular forest type to reduce the risk of catastrophic fire? Maintaining forest health reduces the risk of high-intensity wildfires and the related destruction of aquatic species and wildlife, structures, and soil erosion. (See Map 1 of the NMFAP [2020])
Soil Stability	Plant water availability	Surface aspects, steep slopes, low precipitation	Northeast aspects, flat/gentle slopes, high precipitation	How steep is your area of concern? Is it facing the north with less sun exposure or to the south where conditions are drier? Are the slopes steep such that the runoff rate will be too rapid for plants to absorb?
	Soil erosivity/ health	Highly erosive, no vegetation to protect and prevent erosion, low soil health	Well-developed, stable soils with ability to infiltrate moisture; plant structures are available to sustain and minimize erosion; high soil health	Whether flows are instream or upland, soil erosivity is important for the health of a stream and the water quality that is available downstream. What is the health of the soil? How erosive is it? (See Figure 24).

Table A-4. Matrix for Assessing Resilience of Watersheds and Habitat (cont.)

Element Group	**Resilience Element**	**Lowest Resilience**	**Highest Resilience**	**Considerations**
Riparian Health	Flow regime/ river processes	Insufficient baseflows, low water-holding capacity, sedimentation high due to erosion, high temperatures, poor water quality	Sustained baseflows, high water holding/ infiltration capacity, enough water to support in-stream flows, low sedimentation, temperatures and water quality support designated uses of the water body	Consider the flows of the watershed (springs, ponds, wetlands, streams). Are they properly connected and supporting each other to maintain proper temperatures, baseflows, and helping the overall quality of the flows? Indicators of a healthy flow regime, such as wetlands, are important.
	River structure	Severely down cut streams, disconnected from floodplain, straight/low-complexity streams; unprotected banks erosion and excess sedimentation	Stream system functioning properly, streams connected to floodplains, complex structures (e.g., pools, braided streams, wet meadows); well-maintained banks	Consider the structure of the watershed. Is the structure complex? Are the banks at risk for high erosion and cutting? Is the system resilient to impacts of drought and/or flooding?
	Riparian status	Little to no riparian vegetation, homogeneous coverage of non-native species, no wetlands, no riparian connectivity, increased non-native encroachment, removal and decreased regeneration of native vegetation	Diversity of riparian vegetation, high abundance of native species, woody vegetation shading stream in sections, species richness and high diversity, riparian connectivity, floodplain connectivity, possibility of wetland environment, decrease in non-native encroachment, increase in native vegetation	Consider the riparian areas along stream systems. They are needed to maintain bank stability and shade surface water. Consider wetlands, moist soil units and riparian connectivity. Without a healthy riparian area, there is decreased soil moisture especially in the growing season. Is there increased non-native encroachment in stressed areas? Are there changes in floodplain connectivity and morphology? What about increased removal and decreased regeneration of critical vegetation by foraging animals, both wild and domestic?

Table A-4. Matrix for Assessing Resilience of Watersheds and Habitat (cont.)

Element Group	Resilience Element	Lowest Resilience	Highest Resilience	Considerations
Management	Land use	Watershed/habitat heavily (negatively) impacted by land use practices	Watersheds/habitats with little land use impact, in a more "natural" state; green infrastructure in place to capture storm and floodwaters; well-developed water/watershed management plans in place	Consider the different kinds of local land use around watersheds and whether they are beneficial for the health of terrestrial and aquatic aspects of the watershed/habitat health. Does this watershed/habitat have green infrastructure? Is it impactful to the overall health of the system?
	Landscape management	Little opportunity for intervention (e.g., management dictated by statute)	Social/collaborative support (e.g., watershed association)	Are property owners and stakeholders actively working to develop and implement management plans? Do these efforts support the community to not deplete water/soil resources to the point where they cannot be resilient?

Table A-5. Matrix for Assessing Resilience of Recreation and Quality of Life

Element Group	Resilience Element	Low Resilience	High Resilience	Considerations
Water Diversity	Water supply diversity	Dependent on surface water or precipitation only	Groundwater for backup supply (snow making, water for bosque)	Consider the diversity of the water supply to adapt to wet and dry periods. Is there surface water during wet years which allows groundwater to recover? Are there other supplies when there is insufficient snowpack or precipitation?
Water Availability	Surface water (SW) and snowpack	Streamflow or snowpack is often too low or doesn't meet water quality standards to sustain designated uses (fisheries, wildlife viewing, rafting, kayaking, skiing), viewshed unpredictable (impacted by low reservoirs, low flows in streams)	Sufficient flow or snowpack and meets water quality standards to maintain designated uses, streamflows predictable, viewshed predictable	Consider the availability of supply. Is the ratio of surface water in a very dry year significantly more than demand? Is normal snowpack available for activity demand even in low years? Is the quality or temperature of available water meeting standards for designated uses?
	Public water supply resilience	Severe limitations on outdoor watering and landscaping (gardening, golf courses)	No restrictions on outdoor watering (gardening, golf courses)	Consider the resilience of your public water system or other source of supply for providing water for activities that enhance your quality of life.

Table A-5. Matrix for Assessing Resilience of Recreation and Quality of Life (cont.)

Element Group	Resilience Element	Low Resilience	High Resilience	Considerations
Infrastructure	Adaptable infrastructure	Outdoor recreation infrastructure in floodplain or unusable during low streamflow, or low lake levels, or without snowpack	Outdoor recreation infrastructure above floodplain and usable during varying stream or lake levels, or with/without snowpack (ability to diversify recreational activities)	Consider the condition of your infrastructure and its ability to cope with floods, higher temperatures, and drought. Is it adaptable to varying stream or lake levels or with/without snow? Is there a diversification of recreation activities when other activities cannot occur?
Watershed Health	Forest health	High risk of catastrophic wildfire	Low risk of catastrophic wildfire	Consider the vulnerability of your activities and infrastructure to be impacted by a wildfire, as well as post-fire debris flow (past fire history is an indicator of possibility of future wildfires). (See Figure 27)
	Riparian health	Poor health of riparian area	Healthy riparian area	Consider the indicators of a healthy riparian area, especially vegetation. Is there a diversity of riparian vegetation, mostly or all native species, woody vegetation shading stream in sections? Are wetlands healthy?
	Rangeland condition	Erosion risk high	Erosion risk low	Consider the vulnerability of your activities and infrastructure to sediment/erosion/flooding. Poor rangeland conditions can result in damaging sedimentation of infrastructure. (See Figure 24)

Table A-5. Matrix for Assessing Resilience of Recreation and Quality of Life (cont.)

Element Group	Resilience Element	Low Resilience	High Resilience	Considerations
Demand Management	Management ability	No ability to time releases or perform adaptable management (ex. to adjust to low snowpack)	Reservoir storage allows for timing of releases for recreation / fishing. Adaptable management (ex. for alternative adjustments based on snowpack)	Consider the ability to meet increased demand or reduce demand if supply is low (SW, GW, and snowpack). If the system/area is strained in its ability to meet current demands and the per capita water use is already very low, then the system is not very resilient to climate change. Do you have adaptable management plans? Do you have alternative management plans to adjust to lower reservoir levels, river flows, lower snowpack?