PUBLIC COMMENT DRAFT

TOTAL MAXIMUM DAILY LOADS

FOR THE

CANADIAN AND UPPER RIO GRANDE BASIN LAKES

APRIL 15, 2024

Prepared by

New Mexico Environment Department, Surface Water Quality Bureau

Monitoring, Assessments, and Standards Section

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Executive Summary

Section 303(d) of the Federal Clean Water Act, 33 U.S.C. § 1313(CWA), requires states to develop Total Maximum Daily Load (TMDL) management plans for water bodies determined to be water quality limited. A TMDL is defined as "a written plan and analysis established to ensure that a water body will attain and maintain water quality standards including consideration of existing pollutant loads and reasonably foreseeable increases in pollutant loads" (USEPA 1999). A TMDL defines the amount of a pollutant a water body can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. It further identifies potential methods, actions, or limitations that could be implemented to achieve water quality standards. TMDLs are defined in 40 Code of Federal Regulations Part 130 (40 C.F.R. § 130.2(i)) as the sum of individual Waste Load Allocations (WLAs) for point sources, and Load Allocations (LAs) for nonpoint source and background conditions, and a Margin of Safety (MOS) in acknowledgement of various sources of uncertainty in the analysis.

The New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) conducted water quality surveys on the Dry Cimarron River and Canadian River watersheds in 2015-2016, and on the Upper Rio Grande watershed in 2017-2018, including the lakes addressed in this TMDL. Eagle Nest Lake was previously sampled in 1999 and 2005, Santa Cruz Lake in 2000 and 2009, and Shuree Pond North and Lake Maloya in 2006. Each lake discussed in this TMDL has water quality monitoring stations located upstream, downstream and in the lake to evaluate the impact of tributary streams and ambient water quality conditions. Assessment of data generated during the Dry Cimarron River and Canadian River watersheds 2015-2016 monitoring efforts was conducted according to the 2017 Comprehensive Assessment and Listing Methodology (CALM) (NMED/SWQB 2017), while assessment of data generated during the Upper Rio Grande watershed 2017-2018 monitoring efforts was conducted according to the 2019 CALM (NMED/SWQB 2019). This TMDL document addresses the documented impairments as summarized in Table ES-1 below. Additional information regarding these impairments can be reviewed in the 2024-2026 Assessment Rationale, previously known as the Reason of Decision (ROD) (NMED/SWQB 2024).

During the next scheduled Canadian and Dry Cimarron, and Upper Rio Grande water quality surveys, TMDL targets will be re-examined and potentially revised, as this document is an evolving management plan. If new data indicates that the targets used in this analysis are not appropriate and/or if new standards are adopted, the load capacity will be adjusted accordingly. When water quality standards have been achieved, the waterbody will be moved to the appropriate category in the IR.

Table ES-1: TMDL Assessment Units by USGS 8-digit Hydrologic Unit Code

Assessment Unit Name	AU_ID	TMDL(s)
HUC 13020101 - Upper Rio Grande		
Santa Cruz Lake	NM-2118.B_00	Aluminum, Nutrients, Temperature
HUC 11080002 - Cimarron		
Eagle Nest Lake	NM-2306.B_00	Nutrients
Lake Maloya	NM-2305.B_20	Nutrients
Shuree Pond North	NM-2306.B_30	Nutrients

Table ES-2: TMDL for Eagle Nest Lake

New Mexico Standards Segment	20.6.4.315 NMAC and 20.6.4.13(E) NMAC
Assessment Unit Identifier	NM-2306.B_00
NPDES Permit(s)	None
Segment Area	1817.29 acres
Parameters of Concern	Plant Nutrients (Total Nitrogen and Total Phosphorous)
Designated Uses Affected	High Quality Coldwater Aquatic Life
USGS Hydrologic Unit Codes (8)	11080002: Cimarron
Size of Watershed	184.45 square miles
Land Type	Ecoregion 21a: Alpine Zone (0.1%) Ecoregion 21b: Crystalline Subalpine Forests (13.9%) Ecoregion 21c: Crystalline Mid-Elevation Forests (20.0%) Ecoregion 21e: Sedimentary Subalpine Forests (6.3%) Ecoregion 21f: Sedimentary Mid-Elevation Forests (20.0%) Ecoregion 21g: Volcanic Subalpine Forests (7.6%) Ecoregion 21h: Volcanic Mid-Elevation Forests (1.2%) Ecoregion 21j: Grassland Parks (30.9%)
Land Use/Cover	60.2% forest, 29.3% shrubland, 3.2% developed, 2.9% herbaceous, 2.3% wetlands, 1.6% water, less than 1.0% each – planted/cultivated and barren
Geology	32.8% purely sedimentary, 25.7% purely unconsolidated, 15.9% purely igneous, 15.5% igneous and metamorphic, 8.3% purely metamorphic, 1.4% water, 0.4% sedimentary and unconsolidated
Land Ownership/Management	90.8 % Private, 6.9% State Game and Fish, 1.6% Forest Service, less than 1.0% of each – Tribal and State
Probable Sources	Abandoned Mines (Inactive/Tailings); Active Mines (Gravel); Angling Pressure; Bridges/Culverts/RR Crossings; Campgrounds (Defined); Channelization; Crop Production (Cropland or Dry Land); Dams/Diversions; Dirt or Gravel Roads; Flow Alteration (from Water Diversions); Highway/Road/Bridge Runoff; Hiking Trails; Logging Ops – Legacy; Low Water Crossing; Municipal Point Source Discharge; On-Site Treatment Systems (Septic, etc.); Residences/Buildings; Rangeland Grazing (Dispersed); Site Clearance (Land Development); Storm Water Runoff due to Construction; Urban Runoff/Sewers; Waterfowl; Wildlife other than Waterfowl
IR Category	5/5A
Priority Ranking	High
WLA + LA + MOS = TMDL	
Total Nitrogen	0 mg/L + 0.81 mg/L + 0.09 mg/L = 0.9 mg/L
Total Phosphorous	0 mg/L + 0.027 mg/L + 0.003 mg/L = 0.03 mg/L

Table ES-3: TMDL for Lake Maloya

New Mexico Standards Segment	20.6.4.312 NMAC and 20.6.4.13(E) NMAC
Assessment Unit Identifier	NM-2305.B_20
NPDES Permit(s)	None
Segment Area	115.54 acres
Parameters of Concern	Plant Nutrients (Total Nitrogen and Total Phosphorous)
Designated Uses Affected	Coldwater Aquatic Life
USGS Hydrologic Unit Codes (8)	11080001: Canadian Headwaters
Size of Watershed	20.80 square miles
Land Type	Ecoregion 21f: Sedimentary Mid-elevation Forests (25.2%) Ecoregion 21j: Grassland Parks (64.8%)
Land Use/Cover	41.4% herbaceous, 41.0% shrubland, 13.6% forest, 2.9% wetlands, 1.1% water, less than 1.0% each – developed and planted/cultivated
Geology	36.9% purely igneous, 55.1% purely sedimentary, 8.0% unconsolidated
Land Ownership/Management	51.1% BLM, 48.9% Private
Probable Sources	Grazing in Riparian or Shoreline Zones; Highway/Road/Bridge Runoff (Non-Construction Related); Impervious Surface/Parking Lot Runoff; Off-Road Vehicles; Other Recreational Pollution Sources; Rangeland Grazing; Drought-Related Impacts; Unspecified unpaved road or trail; Waterfowl; Watershed Runoff Following Forest Fire; Wildlife other than Waterfowl
IR Category	5/5A
Priority Ranking	High
WLA + LA + MOS = TMDL	
Total Nitrogen	0 mg/L + 0.81 mg/L + 0.09 mg/L = 0.9 mg/L
Total Phosphorous	0 mg/L + 0.027 mg/L + 0.003 mg/L = 0.03 mg/L

Table ES-4: TMDL for Santa Cruz Lake

New Mexico Standards Segment	20.6.4.121 NMAC and 20.6.4.13(E) NMAC
Assessment Unit Identifier	NM-2118.B_00
NPDES Permit(s)	None
Segment Area	92.95 acres
Parameters of Concern	Plant Nutrients (Total Nitrogen and Total Phosphorous), Temperature, Aluminum (Total)
Designated Uses Affected	High Quality Coldwater Aquatic Life
USGS Hydrologic Unit Codes (8)	13020101: Upper Rio Grande
Size of Watershed	98.40 square miles
Land Type	Ecoregion 21a: Alpine Zone (4.8%) Ecoregion 21b: Crystalline Subalpine Forests (33.2%) Ecoregion 21c: Crystalline Mid-Elevation Forests (40.2%) Ecoregion 21d: Foothill Shrublands (13.0%) Ecoregion 22h: North Central New Mexico Valleys and Mesas (8.8%)
Land Use/Cover	75.0% forest, 19.6% shrubland, 4.5% herbaceous, less than 1.0% each – water, planted/cultivated, developed, and wetlands
Geology	47.2% purely metamorphic, 29.1% mixed igneous and metamorphic, 16.1 % purely igneous, 7.4% sedimentary
Land Ownership/Management	83.3% Forest Service, 8.3% Bureau of Land Management, 8.2% Private, less than 1.0% each – Tribal and State
Probable Sources	Angling Pressure; Bridges/Culverts/RR Crossings; Dumping/Garbage/Trash/Litter; Fire Suppression (Thinning/Chemicals); Highway/Road/Bridge Runoff; Hiking Trails; Logging Ops – Legacy; On-Site Treatment Systems (Septic, etc.); Paved/Gravel/Dirt Roads; Pavement/Impervious Surfaces; Inappropriate Waste Disposal; Rangeland Grazing (dispersed); Residences/Buildings; Site Clearance (Land Development); Waste from Pets (high concentration); Wildlife other than Waterfowl
IR Category	5/5A
Priority Ranking	High
WLA + LA + MOS = TMDL	
Total Nitrogen	0 mg/L + 0.81 mg/L + 0.09 mg/L = 0.9 mg/L
Total Phosphorous	0 mg/L + 0.027 mg/L + 0.003 mg/L = 0.03 mg/L
Aluminum (total)	0 mg/L + 0.315 mg/L + 0.035 mg/L = 0.35 mg/L
Temperature	0 kJ/day + 2.64 x 10^{10} kJ/day + 4.65 x 10^{9} kJ/day = 3.10 x 10^{10} kJ/day

Table ES-5: TMDL for Shuree Pond North

New Mexico Standards Segment	20.6.4.314 NMAC and 20.6.4.13(E) NMAC
Assessment Unit Identifier	NM-2306.B_30
NPDES Permit(s)	None
Segment Area	6.19 acres
Parameters of Concern	Plant Nutrients (Total Nitrogen and Total Phosphorous),
Designated Uses Affected	High Quality Coldwater Aquatic Life
USGS Hydrologic Unit Codes (8)	11080002: Cimarron
Size of Watershed	1.97 square miles
Land Type	Ecoregion 21e: Sedimentary Subalpine Forests (13.9%) Ecoregion 21f: Sedimentary Mid-Elevation Forests (86.1%)
Land Use/Cover	54.9% forest, 22.8% shrubland, 21.4% herbaceous, less than 1.0% each – wetlands and water
Geology	51.5% sedimentary, 44.3% unconsolidated, 4.2% igneous
Land Ownership/Management	100% Forest Service
Probable Sources	Drought-Related Impacts; Forest Roads (Road Construction and Use); Grazing in Riparian or Shoreline Zones; Highway/Road/Bridge Runoff; Off-Road Vehicles; Other Recreational Pollution Sources; Rangeland Grazing; Unspecified Unpaved Road or Trail; Waterfowl; Wildlife other than Waterfowl
IR Category	5/5A
Priority Ranking	High
WLA + LA + MOS = TMDL	
Total Nitrogen	0 mg/L + 0.81 mg/L + 0.09 mg/L = 0.9 mg/L
Total Phosphorous	0 mg/L + 0.027 mg/L + 0.003 mg/L = 0.03 mg/L

1.0 Background

The New Mexico Environmental Department (NMED) Surface Water Quality Bureau (SWQB) establishes TMDLs in this document for Santa Cruz Lake in the Upper Rio Grande watershed, and for Eagle Nest Lake, Lake Maloya and Shuree Pond North in the Canadian River watershed. The SWQB based impairment determinations on data collected during previous lake water quality surveys and during the Canadian River and Dry Cimarron 2015-2016 water quality survey and the Upper Rio Grande 2017-2018 water quality survey.

1.1 Lake and Watershed Description

1.1.1 Eagle Nest Lake

Eagle Nest Lake is a large alpine reservoir located in the Moreno Valley of the Sangre de Cristo Mountains. The lake has a surface area of 1817.28 acres and a maximum storage capacity of 81,360 acre-feet (NMED/SWQB 2005). The United States Geologic Survey (USGS) maintains a monitoring gage (USGS 07205500) in Eagle Nest Lake that records lake storage and lake surface elevation. Since 2020 lake storage has varied from 48,000 acre-feet to 35,000 acre-feet (USGS 2022). The reservoir was created in 1918 with the construction of a 140-foot-tall concrete dam that impounded the Cieneguilla, Six Mile and Moreno Creeks. Eagle Nest Lake provides water for recreation and irrigation and the dam outflow forms the Cimarron River. This reservoir is the main feature of Eagle Nest Lake State Park, which has been maintained by the New Mexico State Parks since 2004, while the lake itself is owned by the New Mexico Department of Game and Fish (NMDGF). The area is a popular fishing and camping area, with the NMDGF stocking and maintaining populations of rainbow and cutthroat trout, yellow perch, white sucker, and kokanee salmon (NMDGF 2020). Designated uses for Eagle Nest Lake include domestic water supply, public water supply, high quality coldwater aquatic life, irrigation, livestock watering, primary contact and wildlife habitat, with all uses being met except for high quality coldwater aquatic life (NMED/SWQB 2024).

1.1.2 Eagle Nest Lake Watershed

The Eagle Nest Lake watershed is made up of five HUC 12 watersheds (110800020101-110800020105) and covers 184.46 square miles of the high elevation Moreno Valley and surrounding Sangre de Cristo Mountains within the Canadian River basin. The watershed is located entirely in Colfax County. The elevation ranges from 8,083 feet at the lake outlet to 12,424 feet at the peak of Baldy Mountain, with an average elevation of 9,206 feet. The slope ranges from 0 degrees to 85 degrees, with an average slope of 13 degrees. The watershed receives approximately 22 inches of precipitation a year, with an average annual air temperature of approximately 41 degrees Fahrenheit. Runoff from stormwater and snowmelt is more consistent than most New Mexico watersheds given the watersheds high elevation and wetter climate, resulting in regular surface inputs to the lake from three main streams; Moreno Creek on the north shore, Sixmile Creek on the west shore, and Cieneguilla Creek on the south shore.

Cieneguilla Creek (AU ID: NM-2306.A_065), Moreno Creek (AU ID: NM-2306.A_060) and Sixmile Creek (AU ID: NM-2306.A_064) from Eagle Nest Lake to their headwaters and Eagle Nest Lake (AU ID: NM-2306.B_00) itself have been extensively monitored by the NMED SWQB.

- Cieneguilla Creek was first listed as impaired for sedimentation/siltation and turbidity in 1998 and in 2008 was first listed as impaired for nutrients, temperature, and *E. coli*. TMDL's were prepared by the NMED SWQB for the sedimentation/siltation and turbidity impairments in 2004, and for nutrients, temperature, and *E. coli* in 2010. The current 303(d) Integrated Reporting (IR) category for these impairments is 4A, meaning a TMDL has been developed by NMED SWQB and approved by the EPA.

- TMDLs for fecal coliform and turbidity were developed for Moreno Creek in 2000. Fecal coliform was removed as a cause of impairment in 2008 because the criterion was changed to *E. coli* during the 2005 triennial review of water quality standards and data from the 2006 Canadian watershed survey indicated a full support conclusion for *E. coli*. Turbidity was removed as a cause of impairment in 2010 after low exceedance values were observed. The turbidity TMDL remains as a protective TMDL. Moreno Creek was listed as impaired for temperature and nutrients following the 2006 Canadian watershed survey. TMDLs for temperature and nutrients were developed for Moreno Creek in 2010. During the 2015-2016 Canadian/Dry Cimarron watershed survey, new data showed that Moreno Creek was no longer impaired for nutrients but still impaired for temperature. During the 2018 assessment period the nutrient impairment was removed for Moreno Creek, with the current 303(d) IR category for temperature listed as 4A. The nutrient TMDL remains as a protective TMDL.
- TMDLs were developed for Sixmile Creek in 2000 to address fecal coliform and turbidity impairments. Nutrients and temperature were added as impairments for Sixmile Creek in 2008 after the 2006 Canadian watershed survey. In 2018, nutrients were removed as an impairment for Sixmile Creek, while temperature, *E. coli* and turbidity remained as causes of impairment. Temperature and *E. coli* TMDLs were developed in 2010, and a turbidity TMDL was developed in 2004. The current 303(d) IR category for temperature, *E. coli* and turbidity in Sixmile Creek is 4A.
- Eagle Nest Lake was listed as impaired for mercury in fish tissue in 1996 because of fish consumption advisories issued for the lake. After sampling in 2005, arsenic and dissolved oxygen were added to the list of impairments. Changes to the mercury in fish tissue criterion were adopted after the 2005 triennial review and the mercury in fish tissue impairment for Eagle Nest Lake was removed, however a fish consumption advisory remained in place. Following the 2015-2016 Canadian and Dry Cimarron water quality survey, sample data revealed a new impairment for nutrients (replacing dissolved oxygen as the cause of non-support) and no exceedances in arsenic samples warranted the delisting of that impairment for Eagle Nest Lake. The lake is currently impaired for nutrients.

The Moreno Valley is a fault-edged valley situated between the Taos Range and the Cimarron Range of the Sangre de Cristo Mountains. Rocks range in age from Precambrian to Quaternary, and significant folding and faulting have disrupted all geologic units located in the Moreno Valley. (Colpitts 1990). The eastern portion of the valley is lower in elevation compared to the western portion. Alluvial fans cover much of the valley floor, predominantly from stream deposits of the ample gravel and sand in the surrounding mountains (Chronic 1987). Sedimentary rocks underlie approximately 32.8% of the watershed, unconsolidated rocks approximately 25.7%, igneous rocks approximately 15.9%, igneous and metamorphic rocks approximately 15.5%, metamorphic rocks approximately 8.3%, sedimentary and unconsolidated rocks approximately 0.4%, and 1.4% of the watershed is water (**Figure 1.3**). Soils in the watershed are typically well-drained within the Moreno Valley, while surface outcroppings along the surrounding mountain ranges inhibit infiltration rates. Hydrologic Group A soils (high infiltration rate) make up approximately 7.1% of the watershed, Group B soils (moderate infiltration rate) 49.5% of the watershed, Group C soils (slow infiltration rate) 8.2% of the watershed, Group D soils (very slow infiltration rate) 34.4% of the watershed, while the remaining hydrologic soil groups are unknown (0.8% of watershed) (**Figure 1.6**).

As of 2019, land cover for the watershed is approximately 60.2% forest (an increase of 0.9% since 2001), 29.3% shrubland (a decrease of 1.4% since 2001), 3.2% developed, 2.9% herbaceous, 2.3% wetlands, 1.5% water, and <1.0% each planted/cultivated and barren (**Figure 1.4**). Approximately 29.0% of the watershed is situated in Level IV Ecoregion 21c (Crystalline Mid-Elevation Forests), 28.9% is situated in Ecoregion 21f (Sedimentary Mid-Elevation Forests), 20.2% is situated in Ecoregion 21b (Crystalline Subalpine Forests), 10.9% is situated in Ecoregion 21g (Volcanic Subalpine Forests), 9.2% is situated in Ecoregion 21e (Sedimentary Subalpine Forests), 1.7% is situated in Ecoregion 21h (Volcanic Mid-Elevation Forests) and 0.1% is situated in Ecoregion 21a (Alpine) (**Figure 1.2**). A small portion of the south-west watershed is located within the Camino Real Ranger District of the Carson National Forest. Major land uses in the area include private land ownership and recreation, such as camping, hunting, hiking, boating and fishing. Within Colfax County (includes entire Eagle Nest Lake watershed) the Bald Eagle (*Haliaeetus leucocephalus*), Mexican Spotted Owl (*Strix occidentalis lucida*), New Mexican Meadow Jumping Mouse (*Zapus hudsonius luteus*), Organ Mountains Colorado Chipmunk (*Neotamias quadrivittatus australis*), Pacific Marten (*Martes caurina*), Piping Plover (*Charadrius melodus*), Southern Redbelly Dace (*Chrosomus erythrogaster*), Star Gyro (*Gyraulus crista*), Suckermouth Minnow (*Phenacobius mirabilis*), White-Tailed Ptarmigan (*Lagopus leucura*), and the Yellow-Billed Cuckoo (*Coccyzus americanus*) are listed as either Threatened or Endangered by state and/or federal agencies (NHNM Species Information, https://nhnm.unm.edu/, accessed 03/17/2022).

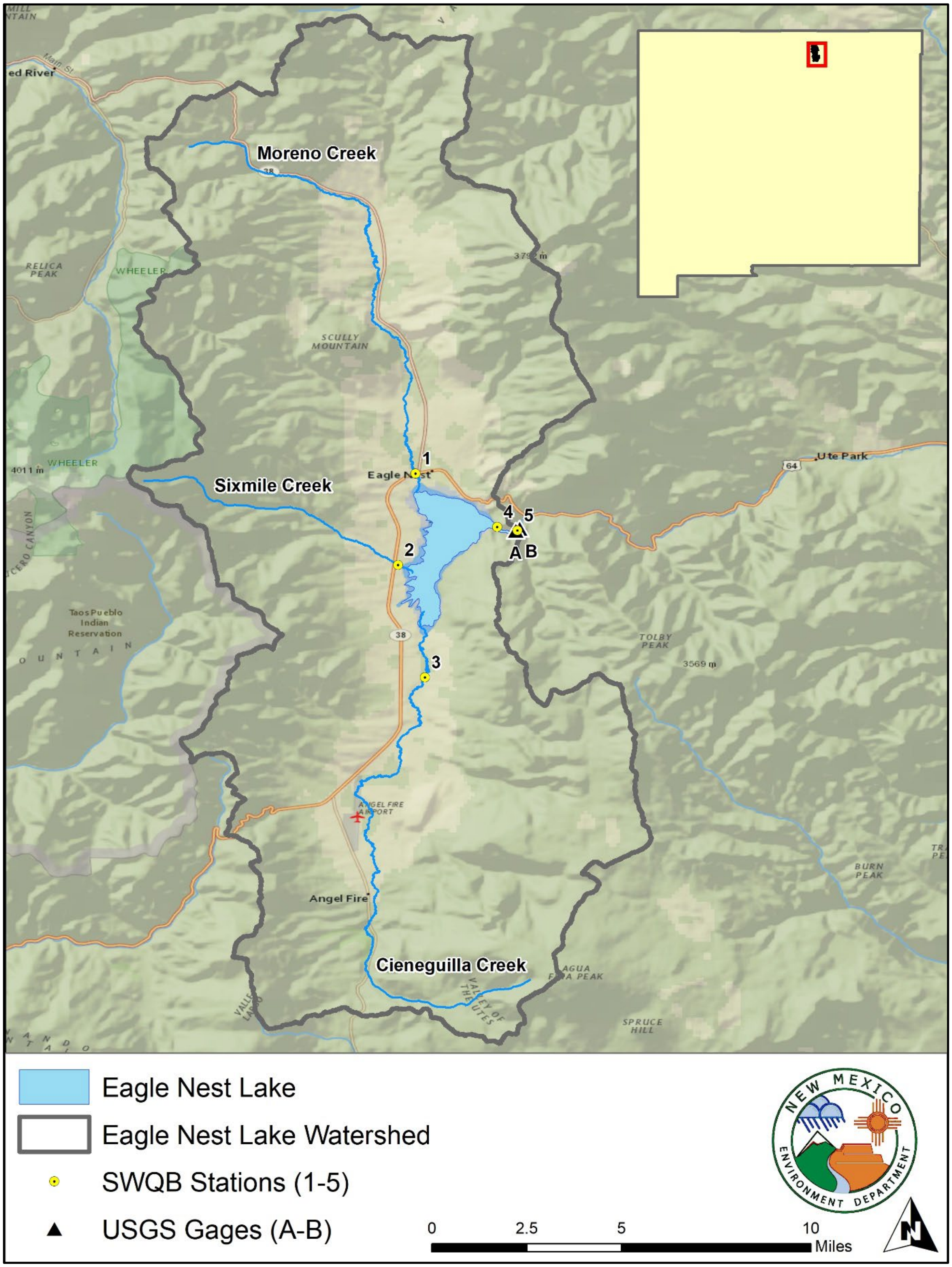

Figure 1.1 Overview map of the Eagle Nest Lake watershed. SWQB Stations (1-5) and USGS Gages (A-B) are identified in Table 1.1.

Table 1.1 Relevant SWQB Stations and USGS Gages shown in Figure 1.1.

Map Label	AU ID/Name	Station ID/Name
1	NM-2306.A_060, Moreno Creek (Eagle Nest Lake to headwaters)	05Moreno003.7, Moreno Creek at US 64
2	NM-2306.A_064, Sixmile Creek (Eagle Nest Lake to headwaters)	05Sixmil001.4, Sixmile Creek at US 64
3	NM-2306.A_065, Cieneguilla Creek (Eagle Nest Lake to headwaters)	05Cieneg006.3, Cieneguilla Creek above Eagle Nest Lake
4	NM-2306.B_00, Eagle Nest Lake	05EagleNestDP, Eagle Nest Lake (Deep)
5	NM-2306.A_130, Cimarron River (Turkey Creek to Eagle Nest Lake)	05Cimarr078.1, Cimarron River at Eagle Nest Outlet
A	NM-2306.B_00, Eagle Nest Lake	USGS Gage 07205500, Eagle Nest Lake near Eagle Nest, NM
B	NM-2306.A_130, Cimarron River (Turkey Creek to Eagle Nest Lake)	USGS Gage 07206000, Cimarron River Below Eagle Nest Dam, NM

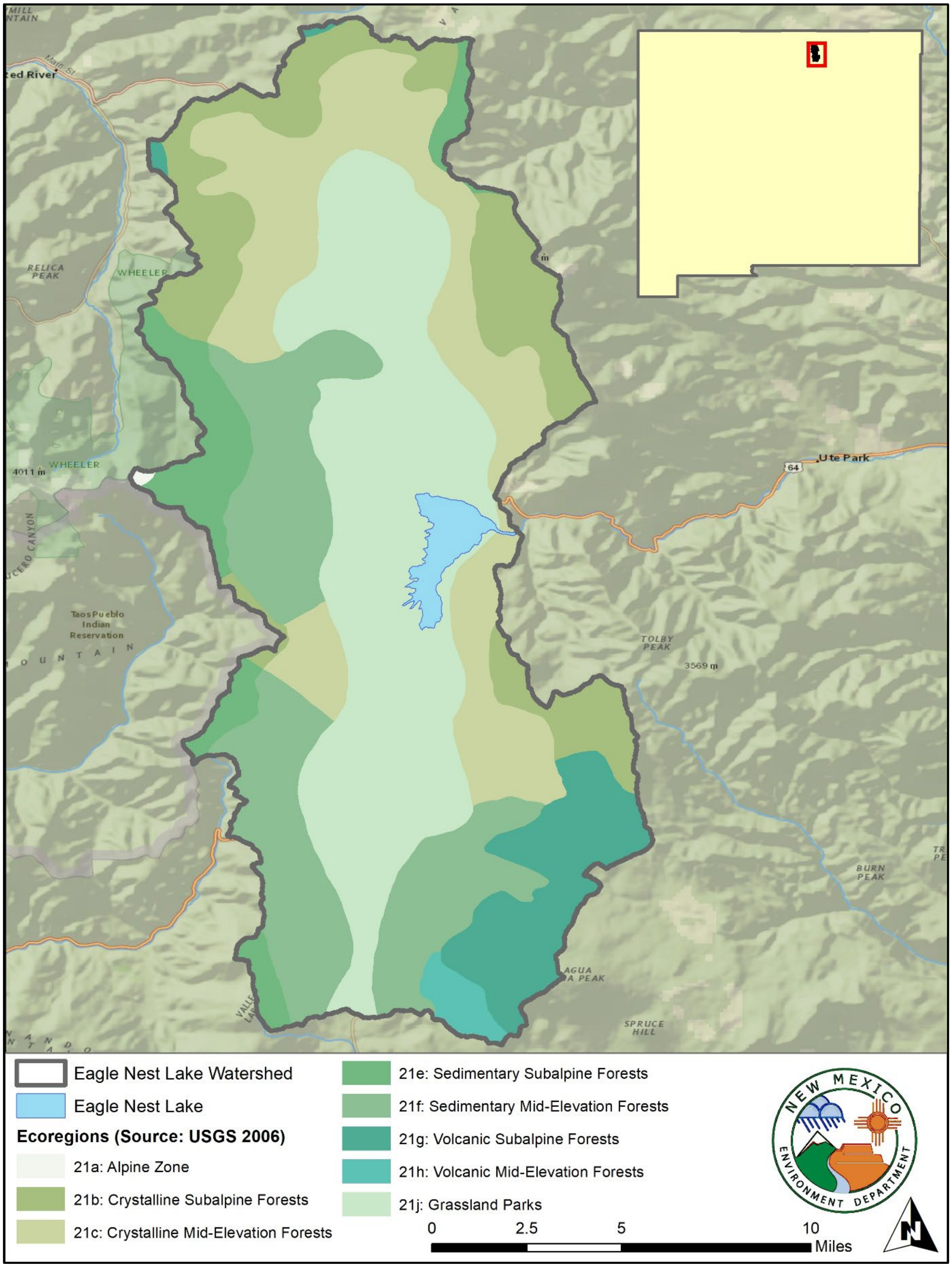

Figure 1.2 Ecoregions of the Eagle Nest watershed.

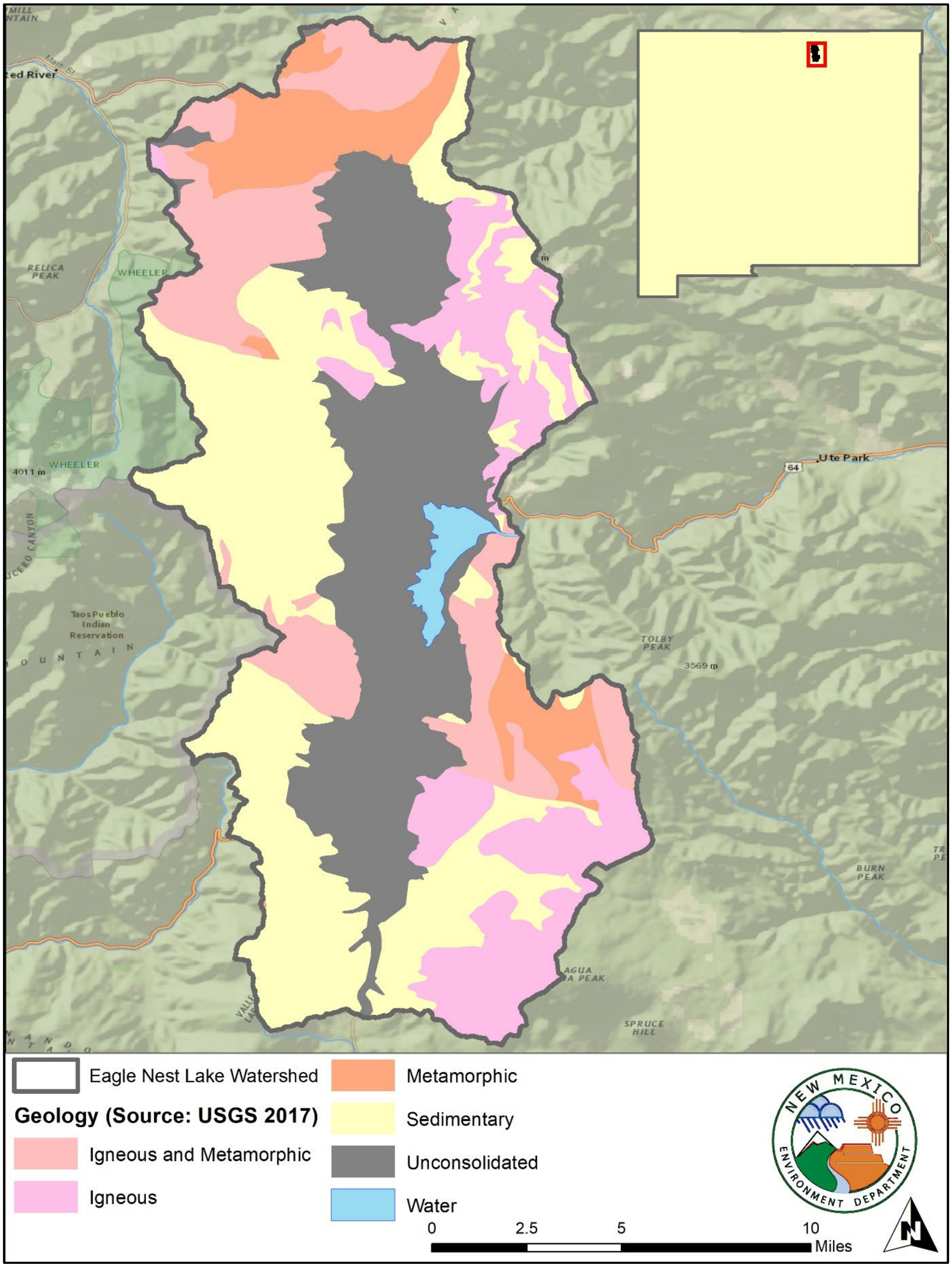

Figure 1.3: Surface geology of the Eagle Nest Lake watershed.

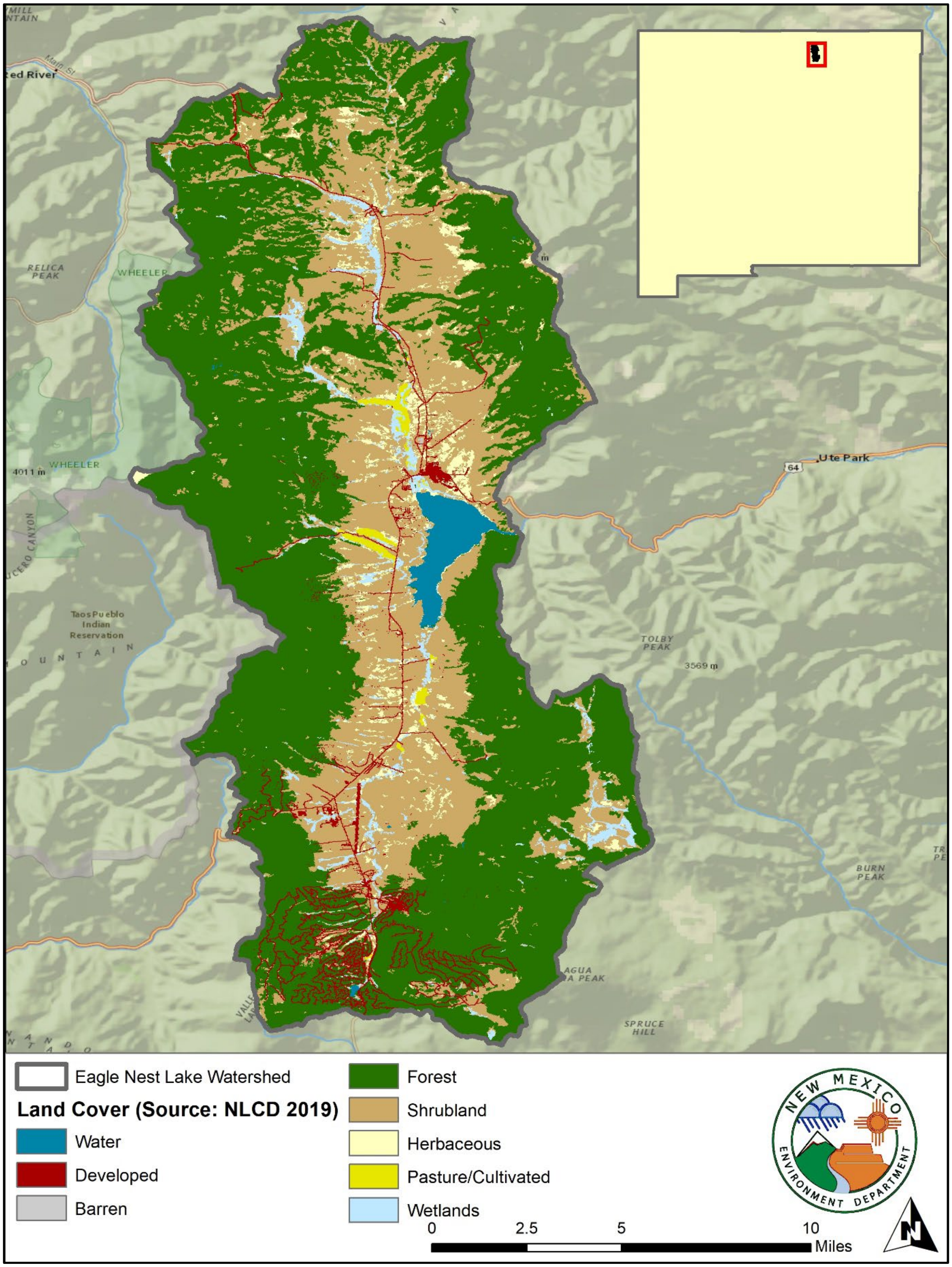

Figure 1.4: Land Cover of the Eagle Nest Lake watershed.

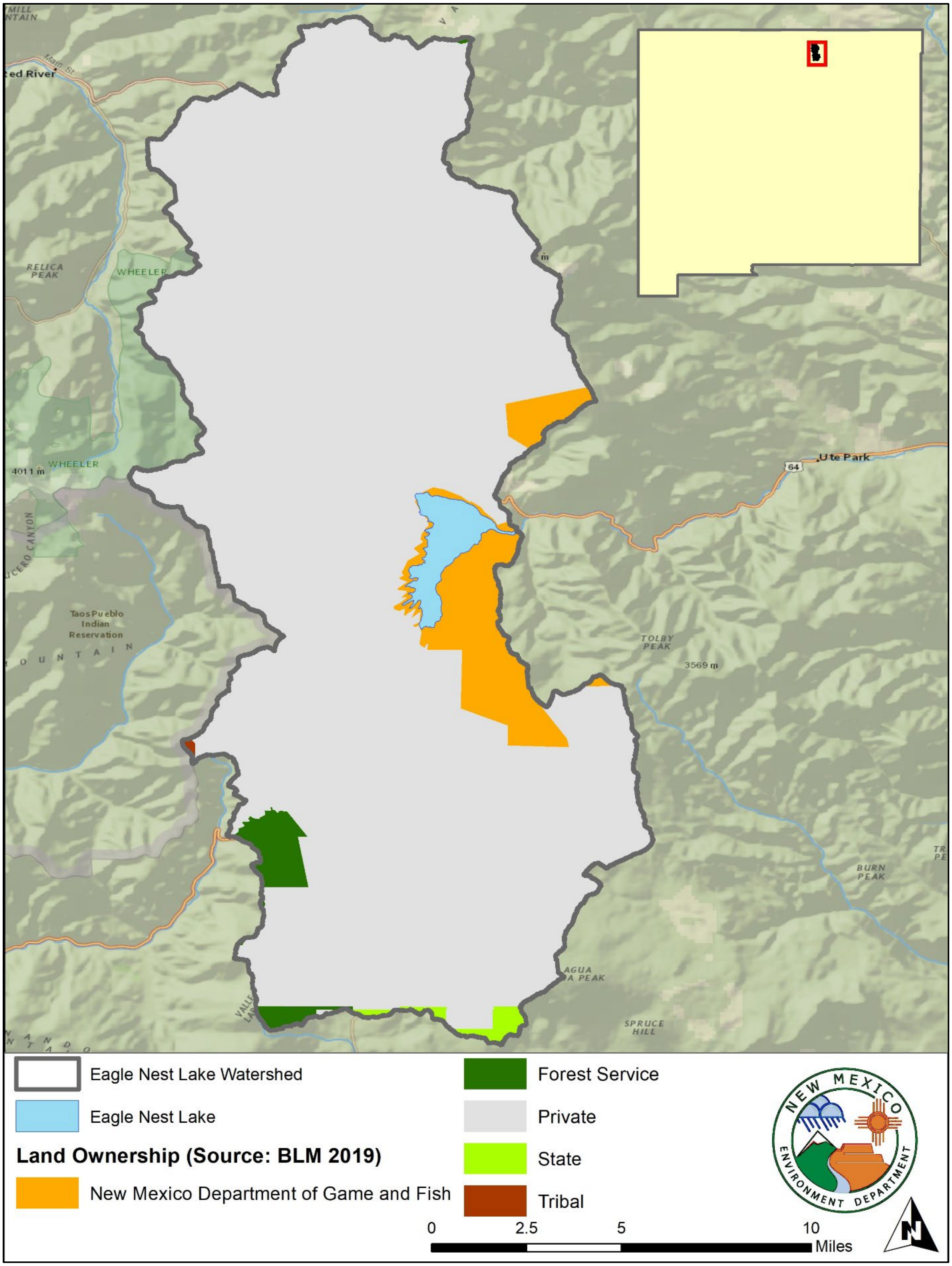

Figure 1.5: Land Ownership of the Eagle Nest Lake watershed.

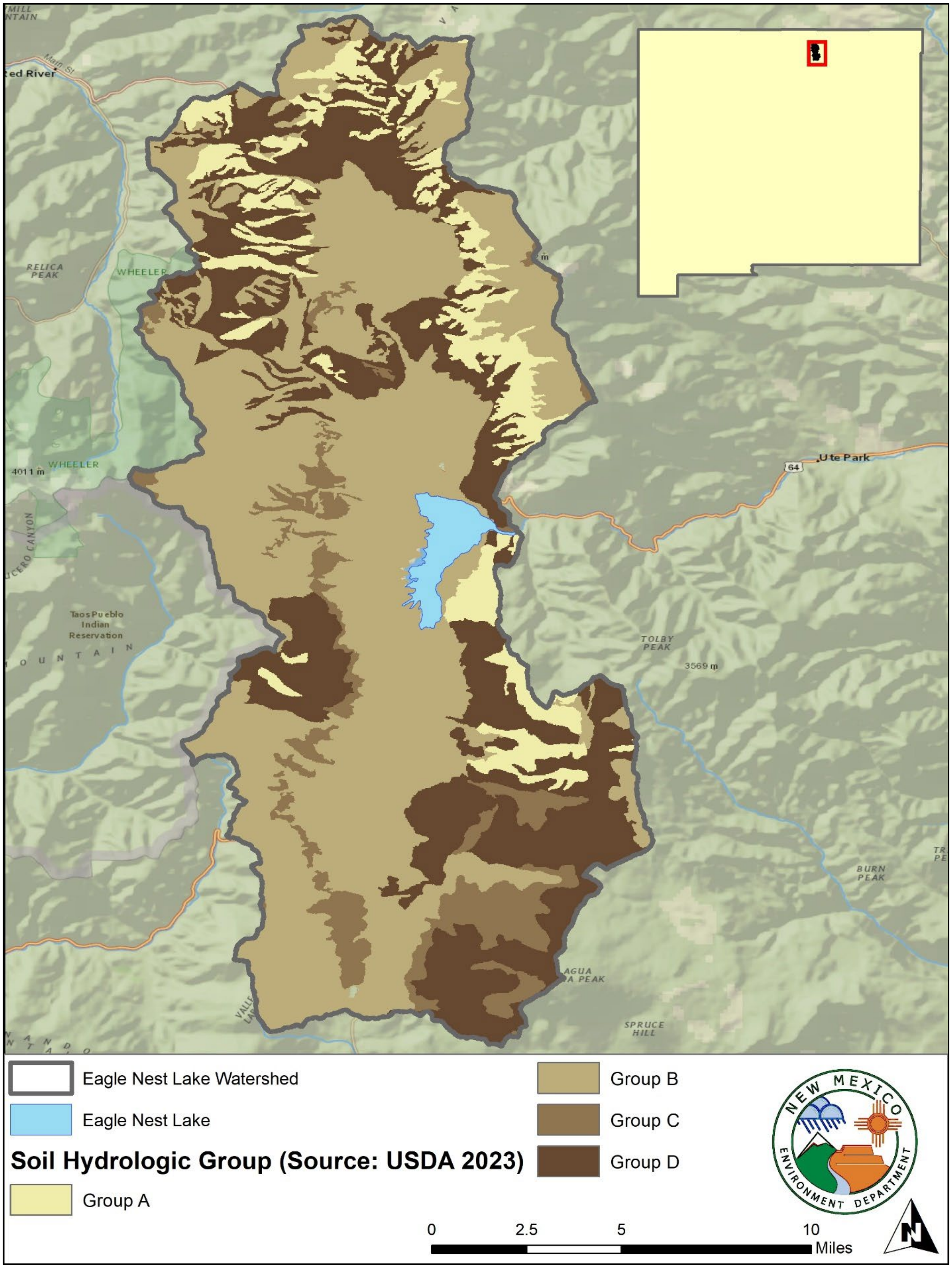

Figure 1.6: Soil Hydrologic Group classification of the Eagle Nest Lake watershed.

1.1.3 Lake Maloya

Lake Maloya is a reservoir located in north-eastern New Mexico on the border with Colorado. The lake has a surface area of 115.54 acres and a capacity of 3690 acre-ft (NMED/SWQ, 2006). The United States Geologic Survey maintains a monitoring station (USGS 07199450) on Lake Maloya to measure lake elevation and capacity. Since 2020 lake storage has varied from 3756 acre-ft to 3044 acre-ft (USGS, 2022). The City of Raton owns the 110-foot-tall earthen dam that creates Lake Maloya and uses the reservoir as a municipal water source. The original Lake Maloya dam was constructed in 1907 and was enlarged in 1949 to increase water storage of the reservoir (City of Raton 2020). Lake Maloya is also the main feature of the Sugarite Canyon State Park, a popular fishing and camping area. The New Mexico Department of Game and Fish (NMDGF) lists rainbow trout and white sucker as present in the reservoir (NMDGF 2020). Designated uses for Lake Maloya include coldwater aquatic life, irrigation, livestock watering, primary contact, public water supply, and wildlife habitat, with all uses being met except for coldwater aquatic life (NMED/SWQB 2024).

1.1.4 Lake Maloya Watershed

The Lake Maloya watershed is located within one HUC 12 watershed (110800010101) and covers 20.80 square miles of the Raton Mesas region in the upper reaches of the Canadian River basin. Approximately 85% of the watershed lies in Las Animas County, Colorado, while 15% of the watershed lies in Colfax County, New Mexico. The elevation ranges from 7,454 feet at the lake outlet to 9,537 feet along Raton Mesa, with an average elevation of 8,425 feet. Slopes range from 0 degrees to 84 degrees, with an average slope of 13 degrees. The watershed receives approximately 23 inches of precipitation a year, with an average annual air temperature of approximately 45 degrees Fahrenheit. The Lake Maloya watershed is in the higher elevation region of the Raton Mesas with a cooler and wetter climate than the surrounding lower elevation plains, meaning runoff from stormwater and snowmelt is more consistent than lower elevation watersheds in New Mexico. Lake Maloya is fed by three streams, Schwachheim Creek and Chicorica Creek on the lake’s northern shore and Segerstorm Creek on the lake’s western shore.

Chicorica and Schwachheim Creek are both located entirely in Colorado, so there is very limited assessment data on these streams for New Mexico. Each stream does have one NMED SWQB monitoring station located at the lake inlet, but sampling has been limited at those locations. Segerstrom Creek is located mostly in Colorado and does not have a NMED SWQB monitoring station located along it. Until further sampling and assessment are completed, the impairment status of these three streams is unknown. Lake Maloya (AU ID: NM-2305.B_20) was first listed as impaired for temperature following a 2006 lake survey which found lake temperature exceedances in two of the six samples collected. Data collected during the 2015-2016 Canadian and Dry Cimarron water quality survey showed new impairments for nutrients and mercury, while temperature was removed as an impairment. Mercury was also removed as an impairment in 2020 because of mercury criterion changes that occurred in 2010, and the lake is currently listed as impaired for nutrients.

The Raton mesas area is located just east of the Sangre de Cristo mountains along the Colorado/New Mexico border. This area consists of many table-top mesas, the product of continuous erosion and geologic makeup. The mesas are capped by a layer of hard basalt from ancient volcanic activity, while soft shale from the Cretaceous period and sandstone mainly from the Tertiary period lie underneath (Lee 1921). Igneous rocks underlie approximately 36.9% of the watershed, sedimentary rocks approximately

55.1% and unconsolidated approximately 8.0% (**Figure 1.9**). Soils in the watershed typically have low infiltration, with the lowest infiltration rates found atop the many mesas throughout the watershed. Hydrologic Group B soils (moderate infiltration rate) make up approximately 1.8% of the watershed, Group C soils (slow infiltration rate) 28.4% of the watershed, Group D soils (very slow infiltration rate) 67.6% of the watershed, and 2.2% of the watershed does not have hydrologic soil group data (**Figure 1.12**).

As of 2019, land cover for the watershed is approximately 41.4% herbaceous (an increase of 37.5% since 2001), 41.0% shrubland (a decrease of 3.7% since 2001), 13.6% forests (a decrease of 33.6% since 2001), 2.9% wetlands, 1.0% water and <1.0% each developed and planted/cultivated (**Figure 1.10**). Approximately 64.8% of the watershed is situated in Level IV Ecoregion 21j (Grassland Parks) and 25.2% is situated in Ecoregion 21f (Sedimentary Mid-elevation Forests) (**Figure 1.8**). Land ownership is approximately 51.1% Bureau of Land Management and 48.9% Private (**Figure 1.11**). Much of the watershed is in the Rocky Mountain District of the Bureau of Land Management. Major land uses in the area include livestock grazing and recreation, such as camping, hunting, hiking, boating, and fishing. Within Colfax County, NM and Las Animas County, CO the Bald Eagle (*Haliaeetus leucocephalus*), Canada Lynx (*Lynx canadensis*), Mexican Spotted Owl (*Strix occidentalis lucida*), New Mexican Meadow Jumping Mouse (*Zapus hudsonius luteus*), Organ Mountains Colorado Chipmunk (*Neotamias quadrivittatus australis*), Pacific Marten (*Martes caurina*), Piping Plover (*Charadrius melodus*), Southern Redbelly Dace (*Chrosomus erythrogaster*), Star Gyro (*Gyraulus crista*), Suckermouth Minnow (*Phenacobius mirabilis*), White-Tailed Ptarmigan (*Lagopus leucura*), and the Yellow-Billed Cuckoo (*Coccyzus americanus*) are listed as either Threatened or Endangered by state and/or federal agencies (NHNM Species Information, *https://nhnm.unm.edu/*, accessed 07/26/2022).

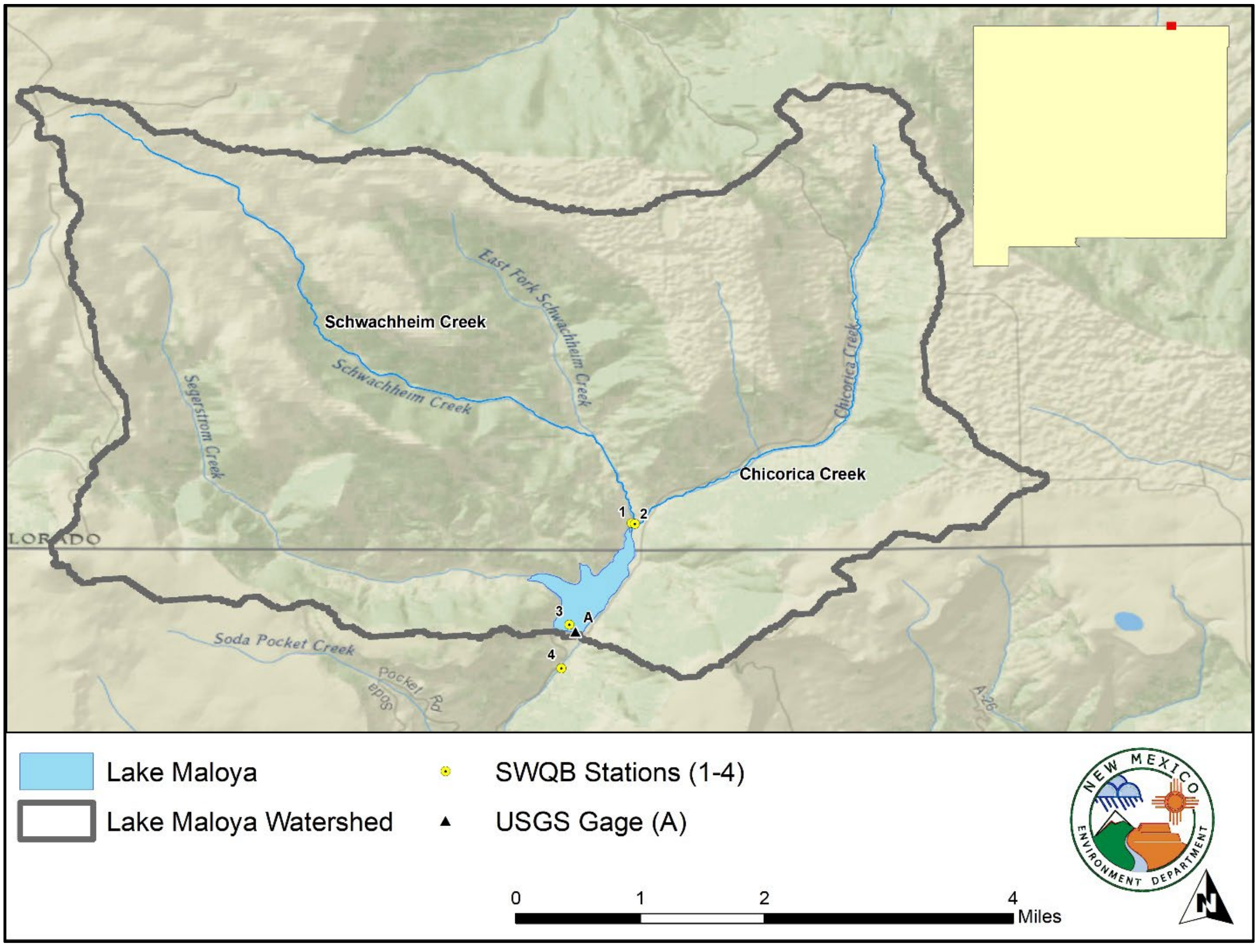

Figure 1.7: Overview map of the Lake Maloya watershed. SWQB Stations (1-4) and USGS Gage (A) are identified in Table 1.2.

Table 1.2: Relevant SWQB Stations and USGS Gage shown in Figure 1.6.

Map Label	AU ID/Name	Station ID/Name
1	NM-9000.A_02x, Canadian r basin inlet/outlets, drains, canals, conveyances	04LMaloSchwIn, Lake Maloya Inlet at Schwachheim Creek
2	NM-9000.A_02x, Canadian r basin inlet/outlets, drains, canals, conveyances	04LMaloChicIn, Lake Maloya Inlet at Chicorica Creek
3	NM-2305.B_20, Lake Maloya	04LMaloyaDeep, Lake Maloya (Deep)
4	NM-2305.A_251, Chicorica Creek (East Fork Chicorica to Lake Maloya)	04Chicor037.3, Chicorica Creek below Maloya
A	NM-2305.B_20, Lake Maloya	USGS Gage 07199450, Lake Maloya near Raton, NM

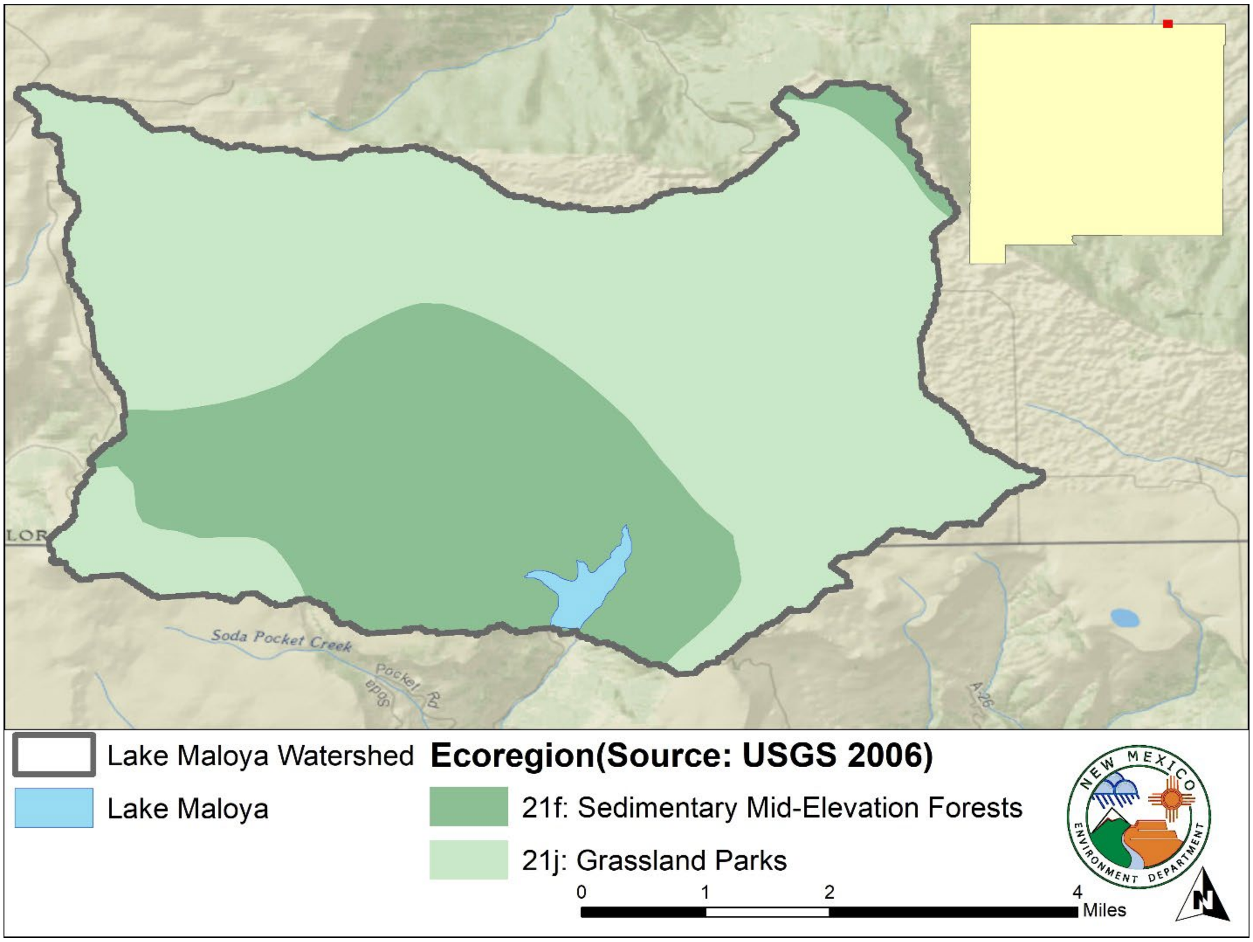

Figure 1.8: Ecoregions of the Lake Maloya watershed.

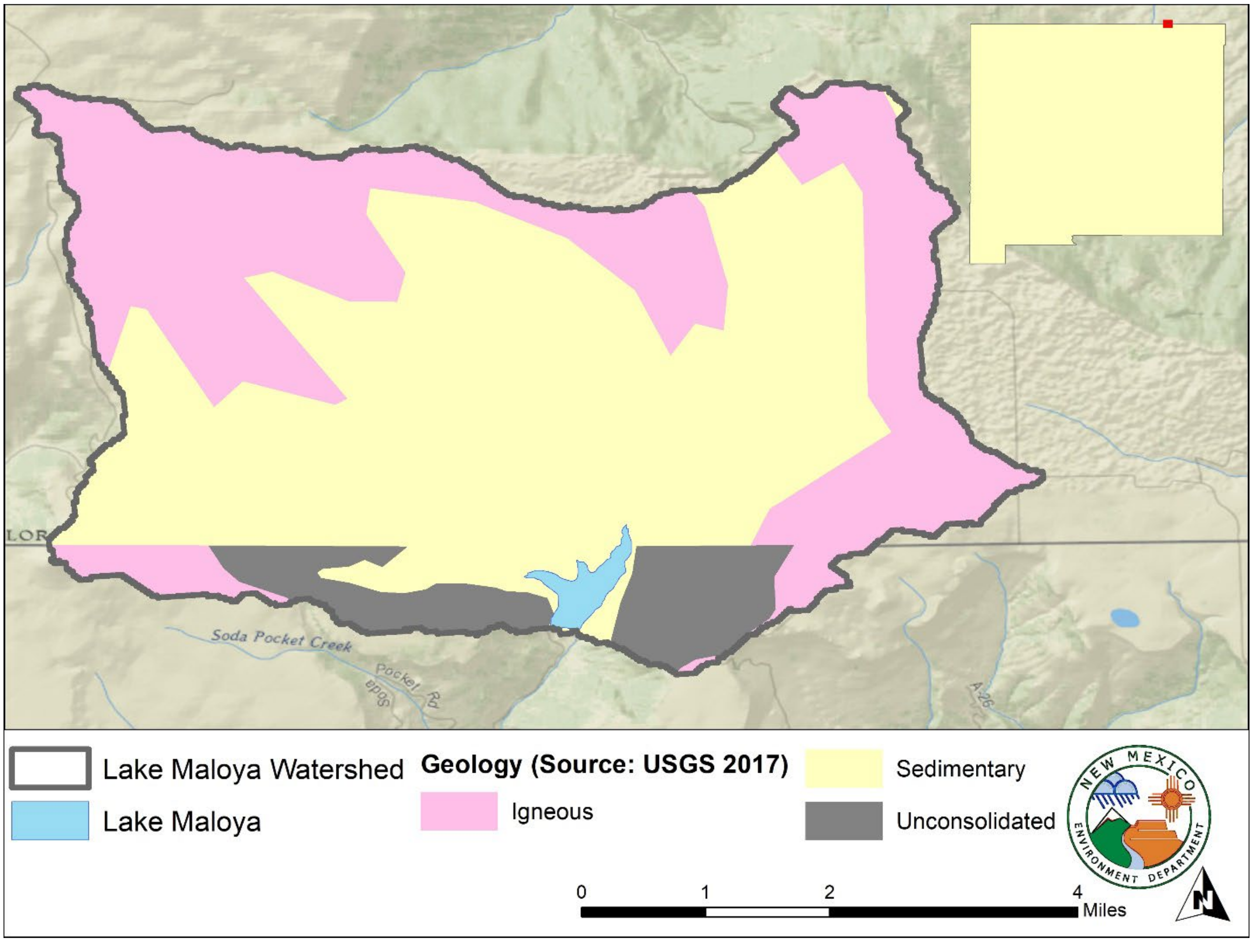

Figure 1.9: Surface geology of the Lake Maloya watershed.

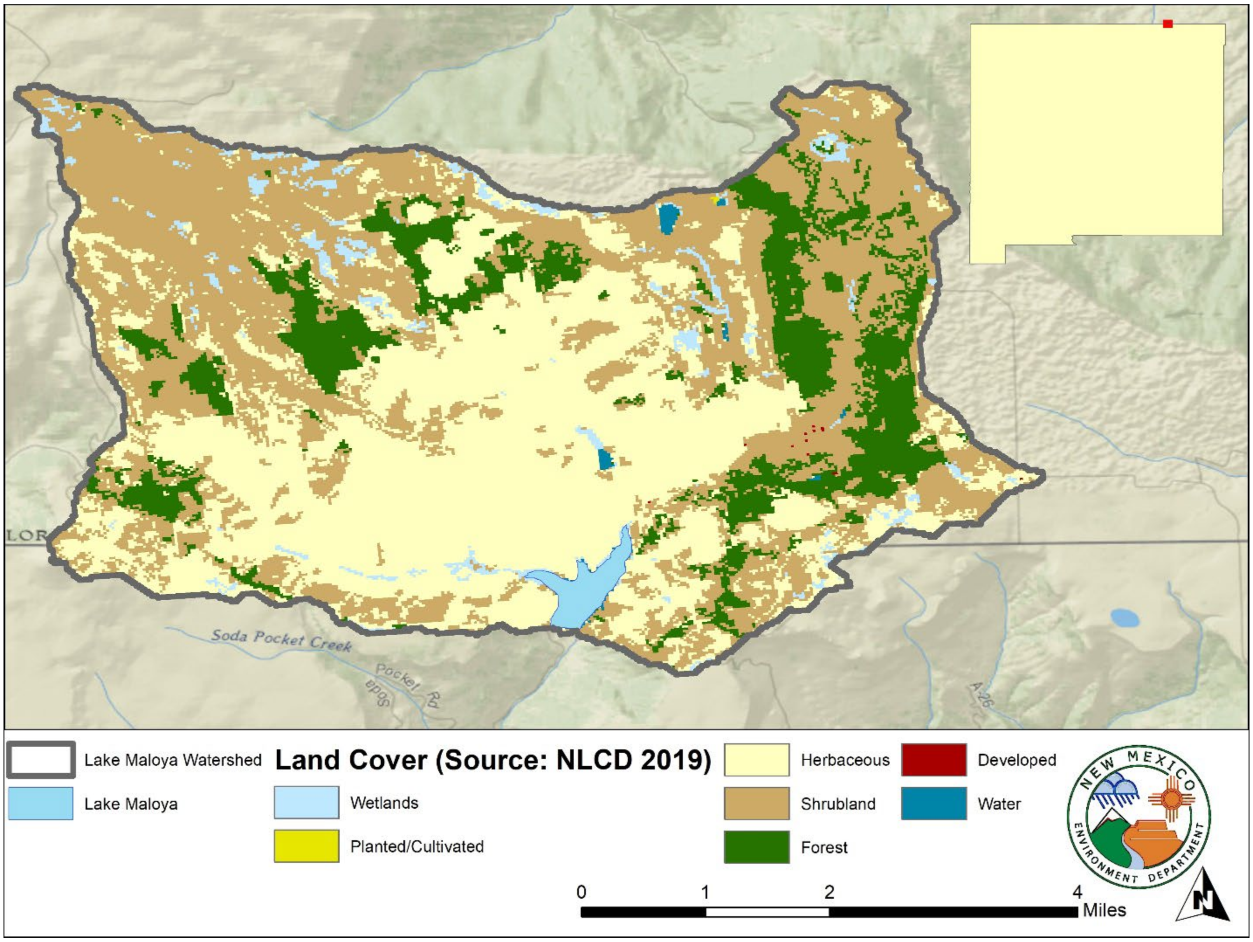

Figure 1.10: Land Cover of the Lake Maloya watershed.

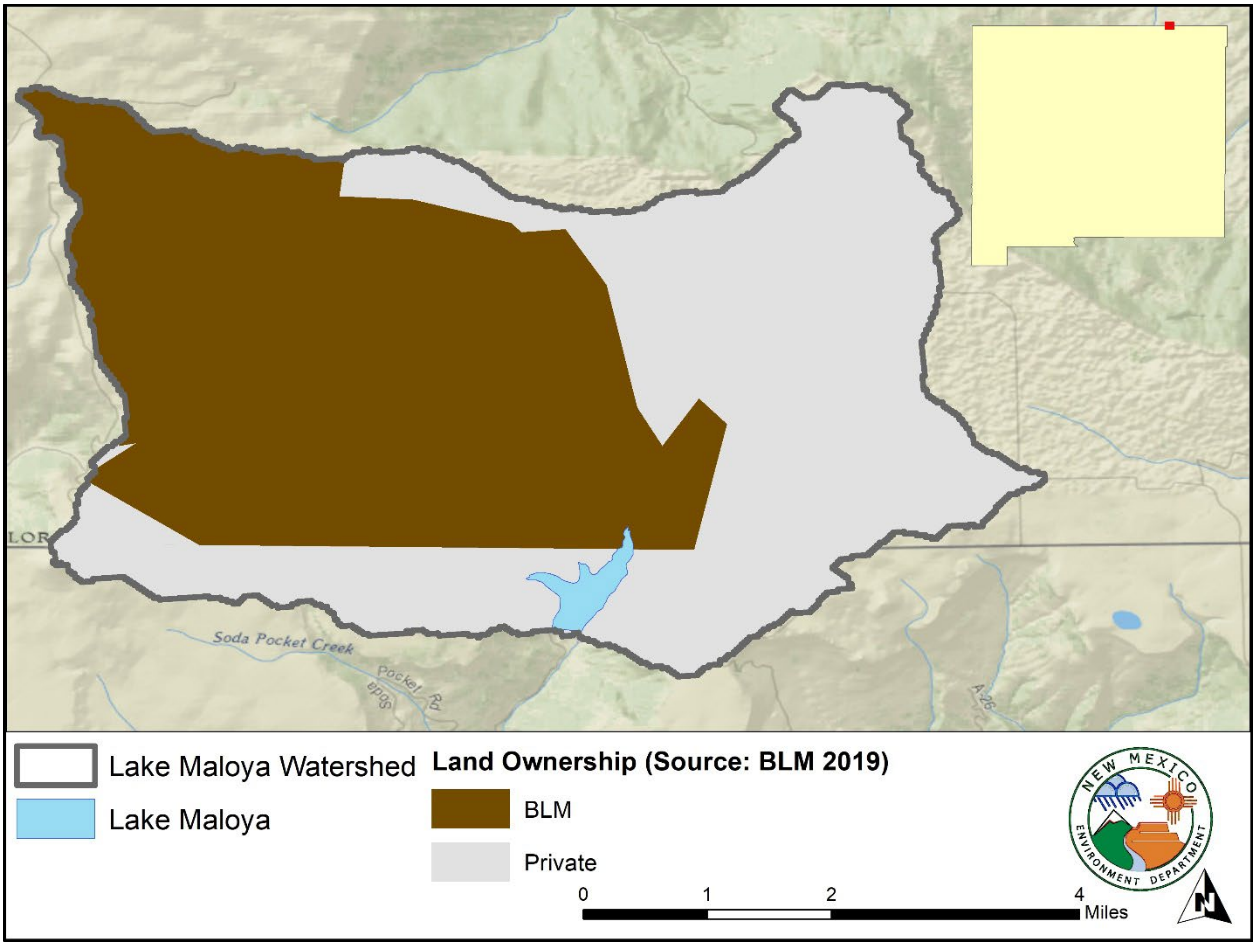

Figure 1.11: Land Ownership of the Lake Maloya watershed.

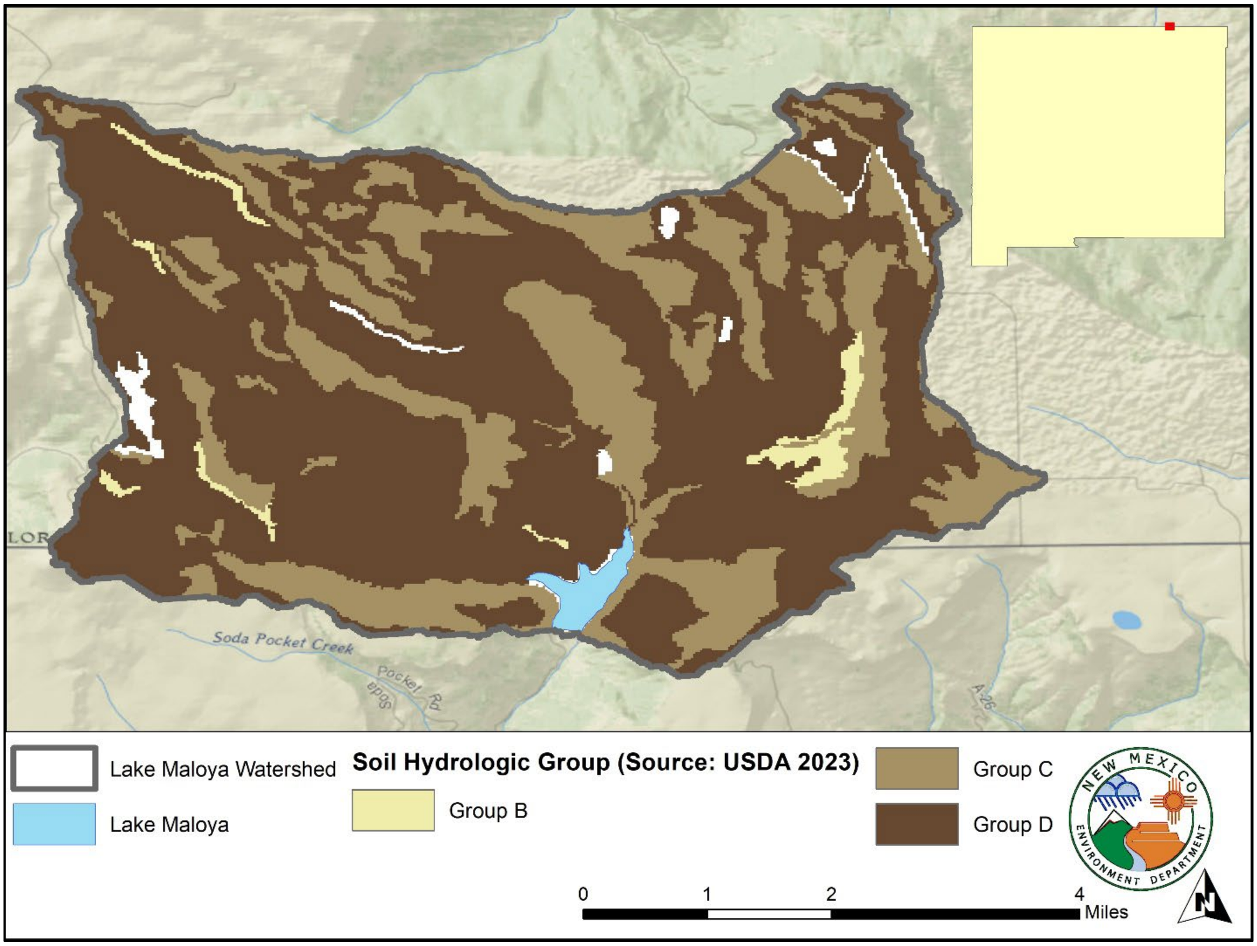

Figure 1.12: Soil Hydrologic Group classification of the Lake Maloya watershed.

1.1.5 Santa Cruz Lake

Santa Cruz Lake is a reservoir located in north-central New Mexico in the Sangre de Cristo foothills near the town of Chimayo. The reservoir is the main feature of the Santa Cruz Recreational Area, managed and maintained by the Bureau of Land Management (BLM), providing hiking, fishing, camping and boating opportunities for the public. The New Mexico Department of Game and Fish (NMDGF) lists rainbow trout, brown trout and bluegills as present in the lake (NMDGF 2006). The largest recorded rainbow trout caught in New Mexico was fished from Santa Cruz Lake on March 13, 1999, weighing 31lb., 12.5 oz. (NMDGF 2020). The Santa Cruz Irrigation District constructed a 125ft tall concrete dam in 1929 to create Santa Cruz Lake for the purposes of flood control, irrigation and recreation (NMED/SWQB 2009). The Santa Cruz Irrigation District manages releases from Santa Cruz Lake for irrigation, and lake levels can drop significantly during times of high irrigation needs (NMED/SWQB 2009). Santa Cruz Lake is fed by the Rio Medio and the Rio Frijoles, which converge just upstream of the lake to form the Santa Cruz River. The reservoir has a surface area of 100 acres, with an estimated capacity of about 3,000 acre-feet (NMED/SWQB 2009), while the National Inventory of Dams (NID) lists the reservoir maximum capacity at 5,948 acre-feet (NID 2021). Designated uses for Santa Cruz Lake include domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, primary contact and wildlife habitat, with all uses being met except for high quality coldwater aquatic life (NMED/SWQB 2024).

1.1.6 Santa Cruz Lake Watershed

The Santa Cruz Lake watershed is made up of three HUC 12 watersheds (130201011001, 130201011002, 130201011104) and covers 98.40 square miles of the western Sangre de Cristo Mountains in the Upper Rio Grande basin. Approximately 83% of the watershed lies in Santa Fe County, while 17% of the watershed lies in Mora County. The elevation ranges from 6,190 feet at the lake outlet to 13,067 feet at Truchas Peak, with an average elevation of 9,041 feet. Slopes range from 0 degrees to 86 degrees, with an average slope of 22 degrees. The watershed receives approximately 25 inches of precipitation a year, with an average annual air temperature of approximately 43 degrees Fahrenheit. Runoff from stormwater and snowmelt is more consistent than many New Mexico watersheds given the eastern portion of the watershed's higher elevation and wetter climate, resulting in regular surface input from the Santa Cruz River.

The Santa Cruz River (AU ID: NM-2118.A_51) was included in the 2017-2018 Upper Rio Grande survey. Exceedances were observed for aluminum and thermograph data showed impairment for temperature. During the 2020 assessment period, the Santa Cruz River was listed as impaired for aluminum and temperature, and lead was noted as a parameter of concern. TMDLs were written for total recoverable aluminum and temperature for this AU and included in the Upper Rio Grande TMDL document. They are pending WQCC approval and the outcome of the Court of Appeals Case Number A-1-CA-40799, NM Environment Department v. Water Quality Control Commission. Santa Cruz Lake (AU ID: NM-218.B_00) was sampled during 2009 and again during the 2017-2018 Upper Rio Grande survey. Temperature impairment was noted during the 2009 survey. Aluminum, nutrients, and temperature were all noted as impairments during the 2017-2018 survey and are the current impairments for Santa Cruz Lake.

The western portion of the Santa Cruz Lake watershed is in the Espanola Badlands, which consists of coalesced alluvial fans formed in the Tertiary time. These alluvial fans have been eroded into the present-day ridges, valleys and badlands that make up the lower elevation western portion of the Santa Cruz Lake watershed (Chronic 1987). The Santa Fe Mountains, a subrange of the Sangre de Cristo Mountains, occupy the eastern portion of the Santa Cruz Lake watershed. These mountains are fault-block mountains and fault lines run along the west and east sides of the mountains. The Santa Fe mountains are comprised of mainly Precambrian rock (Clark 1966). Metamorphic rocks underlie approximately 47.2% of the watershed, mixed igneous and metamorphic rocks approximately 29.1%, 16.1% purely igneous rocks, and 7.4% purely sedimentary rocks. (**Figure 1.15**) (USGS 2017). Soils in the watershed are typically well draining, however sporadic surface outcroppings inhibit infiltration rates in the high elevation mountain peaks on the eastern side of the watershed and in the badlands closer to the lake on the western side of the watershed. Hydrologic Group A (high infiltration rate) make up approximately 19.1% of the watershed, Group B soils (moderate infiltration rate) 31.3% of the watershed, Group C soils (low infiltration rate) 34.5% of the watershed, Group C/D soils (low/very low infiltration rate) 0.7% of the watershed, Group D soils (very low infiltration rate) 8.4% of the watershed, and 6% of the watershed does not have hydrologic group soil data (**Figure 1.18**).

As of 2019, land cover for the watershed is approximately 75.0% forest (a decrease of 9.5% since 2001), 19.6% shrubland (an increase of 7.3% since 2001), 4.5% herbaceous (an increase of 2.1% since 2001), and <1.0% each water, planted/cultivated, wetlands, and water (**Figure 1.16**). Approximately 40.2% of the watershed is situated in Level IV Ecoregion 21c (Crystalline Mid-Elevation Forests), 33.2% is situated in Ecoregion 21b (Crystalline Subalpine Forests), 13.0% is situated in Ecoregion 21d (Foothill Shrublands), 8.8% is situated in Ecoregion 22h (North Central New Mexico Valleys and Mesas), and 4.8% is situated in Ecoregion 21a (Alpine) (**Figure 1.14**). Land ownership is approximately 83.3% Forest Service, 8.3% Bureau of Land Management, 8.2% Private and <1.0% each Tribal and State (**Figure 1.17**). Much of the watershed is within the Espanola Ranger District of the Santa Fe National Forest. Major land uses in the area include livestock grazing and recreation, such as camping, hunting, hiking, boating, and fishing. Within Mora and Santa Fe counties, including the Santa Cruz Lake watershed, the Bairds Sparrow (*Ammodramus bairdii*), Bald Eagle (*Haliaeetus leucocephalus*), Boreal Owl (*Aegolius funereus*), Broad-Billed Hummingbird (*Cynanthus latirostris*), Gray Vireo (*Vireo vicinior*), Great Plains Lady's Tresses (*Spiranthes magnicamporum*), Lilljeborg's Pea-Clam (*Pisidium lilljeborgi*), Mexican Spotted Owl (*Strix occidentalis lucida*), Mountain Lily (*Lilium philadelphicum var. adninum*), New Mexican Meadow Jumping Mouse (*Zapus hudsonius luteus*), Northern Beardless-Tyrannulet (*Camptostoma imberbe*), Pacific Marten (*Martes caurina*), Rio Grande Silvery Minnow (*Hydognathus amarus*), Santa Fe Cholla (*Cylindroputia viridiflora*), Southern Pocket Gopher (*Thomomys umbrinus*), Southwestern Willow Flycatcher (*Empidonax traillii extimus*), Spotted Bat (*Euderma maculatum*), Suckermouth Minnow (*Phenacobius mirabilis*), White-Tailed Ptarmigan (*Lagopus leucura*), Yellow Lady's-Slipper (*Cypripedium parviflorum var. pubescens*), and Yellow-Billed Cuckoo (*Coccyzus americanus*) are listed as either Threatened or Endangered by state and/or federal agencies (NHNM Species Information, *https://nhnm.unm.edu/*, accessed 03/17/2022).

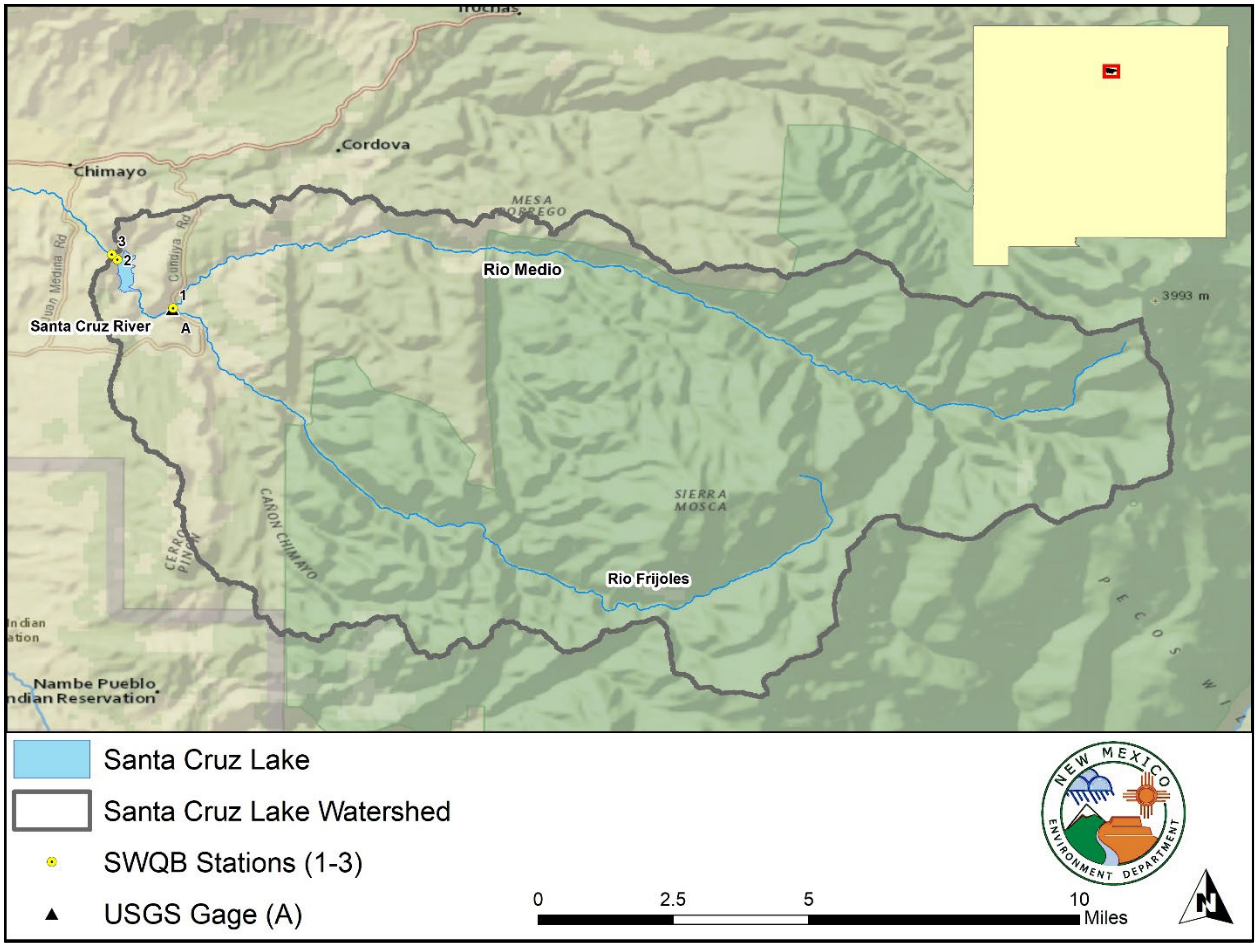

Figure 1.13: Overview map of the Santa Cruz Lake watershed. SWQB Stations (1-3) and USGS Gage (A) are identified in Table 4.1.

Table 1.3: Relevant SWQB Stations and USGS Gage show in Figure 1.11.

Map Label	AU ID/Name	Station ID/Name
1	NM-2118.A_51, Santa Cruz River (Santa Cruz Reservoir to Rio Medio)	28SanCruz019.1, Santa Cruz River at USGS Gage 08291000
2	NM-2118.B_00, Santa Cruz Lake	28SantaCruzDp, Santa Cruz Lake (deep)
3	NM-2111_50, Santa Cruz River (Santa Clara Pueblo bnd to Santa Cruz Dam)	28SanCru016.0, Santa Cruz River below Santa Cruz Lake
A	NM-2118.A_51, Santa Cruz River (Santa Cruz Reservoir to Rio Medio)	USGS Gage 08291000, Santa Cruz River near Cundiyo, NM

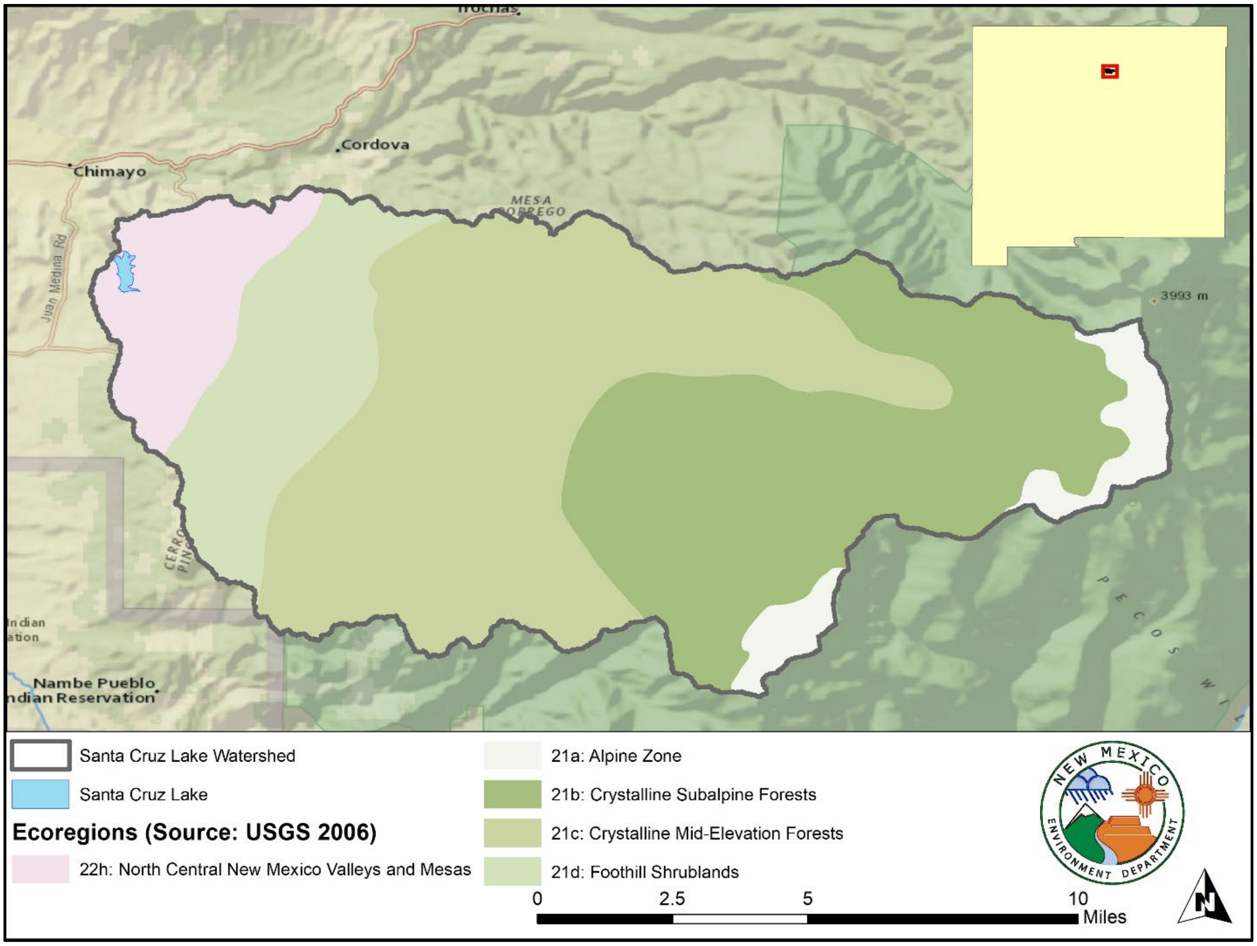

Figure 1.14: Ecoregions of the Santa Cruz Lake watershed.

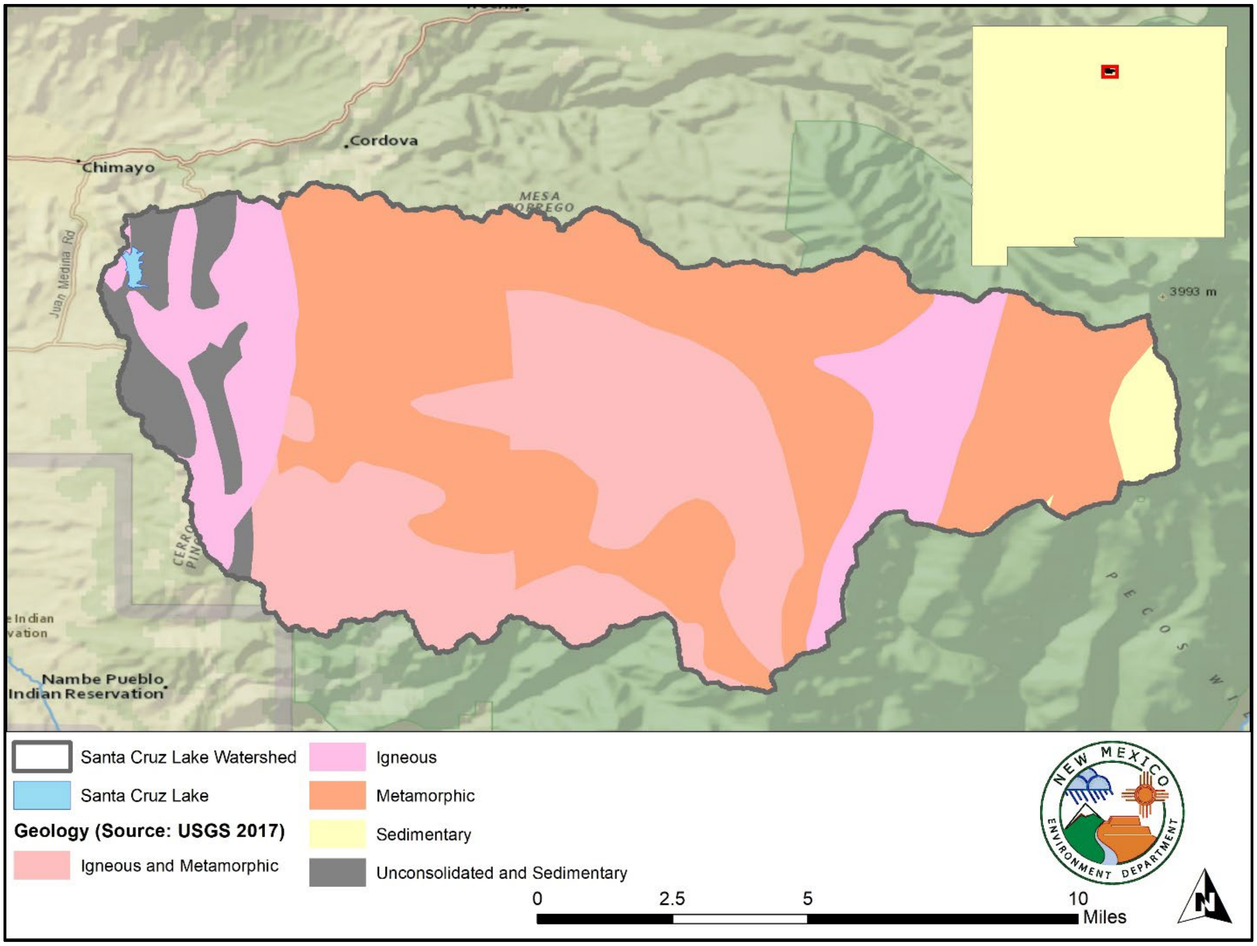

Figure 1.15: Surface geology of the Santa Cruz Lake watershed.

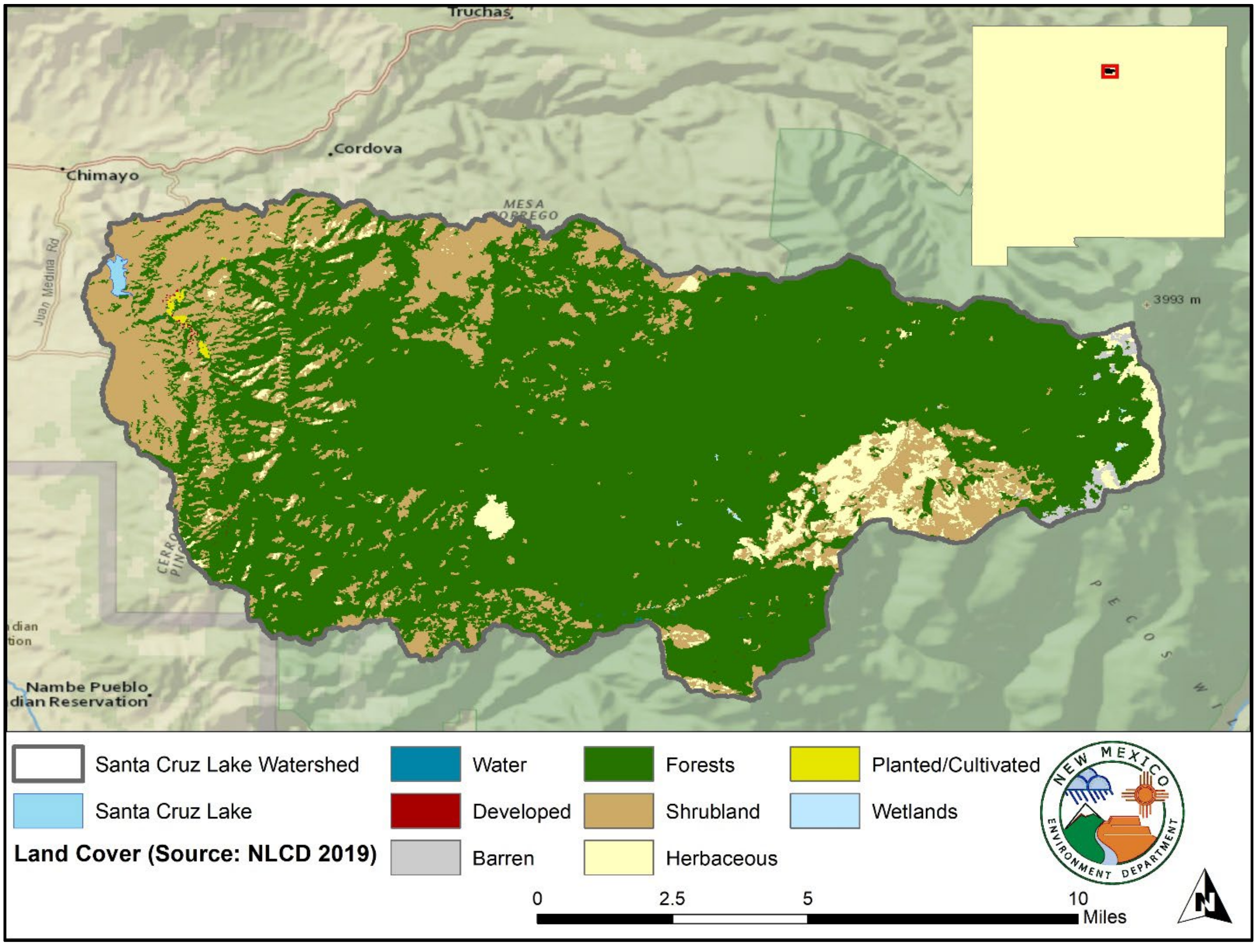

Figure 1.16: Land Cover of the Santa Cruz Lake watershed.

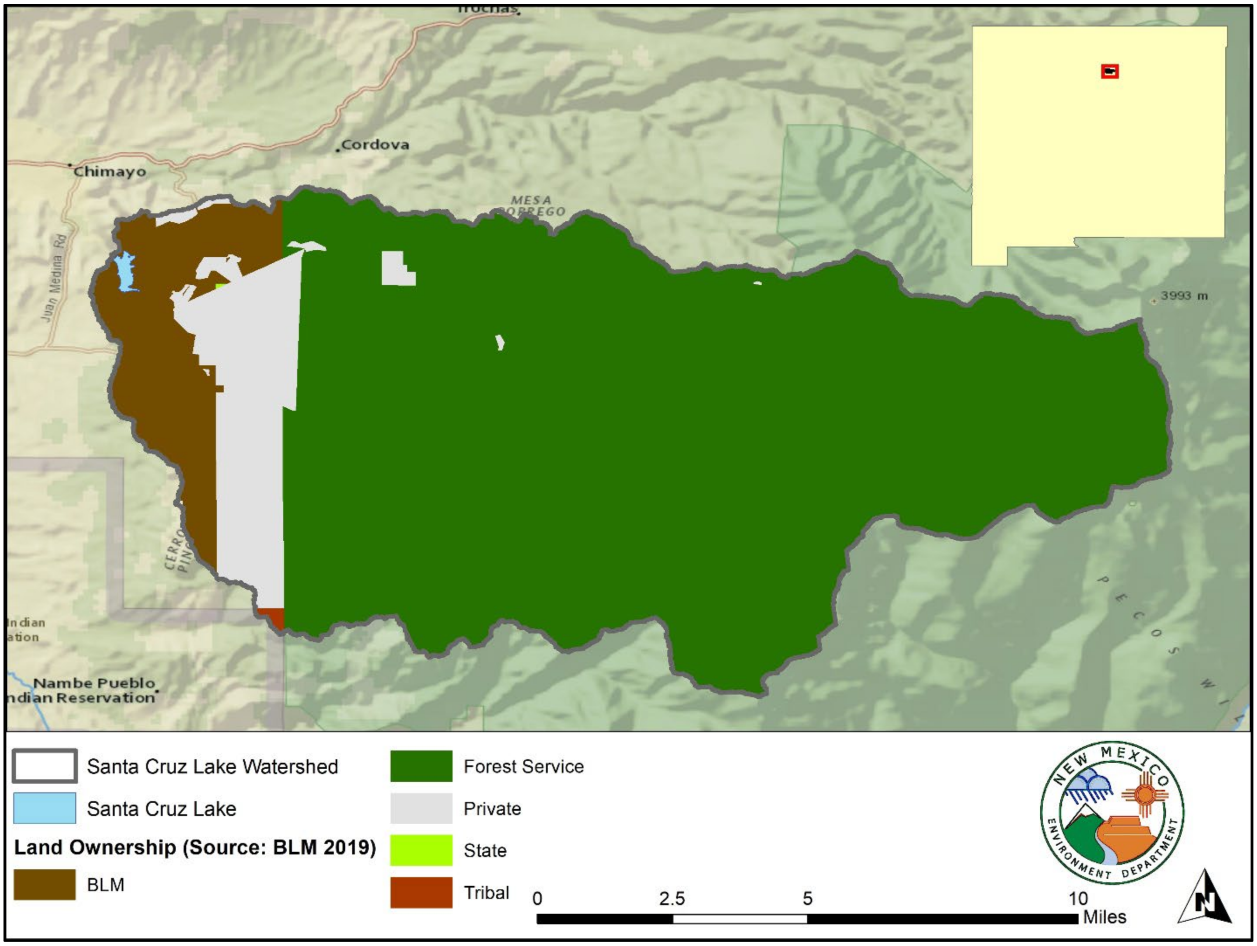

Figure 1.17: Land Ownership of the Santa Cruz Lake watershed.

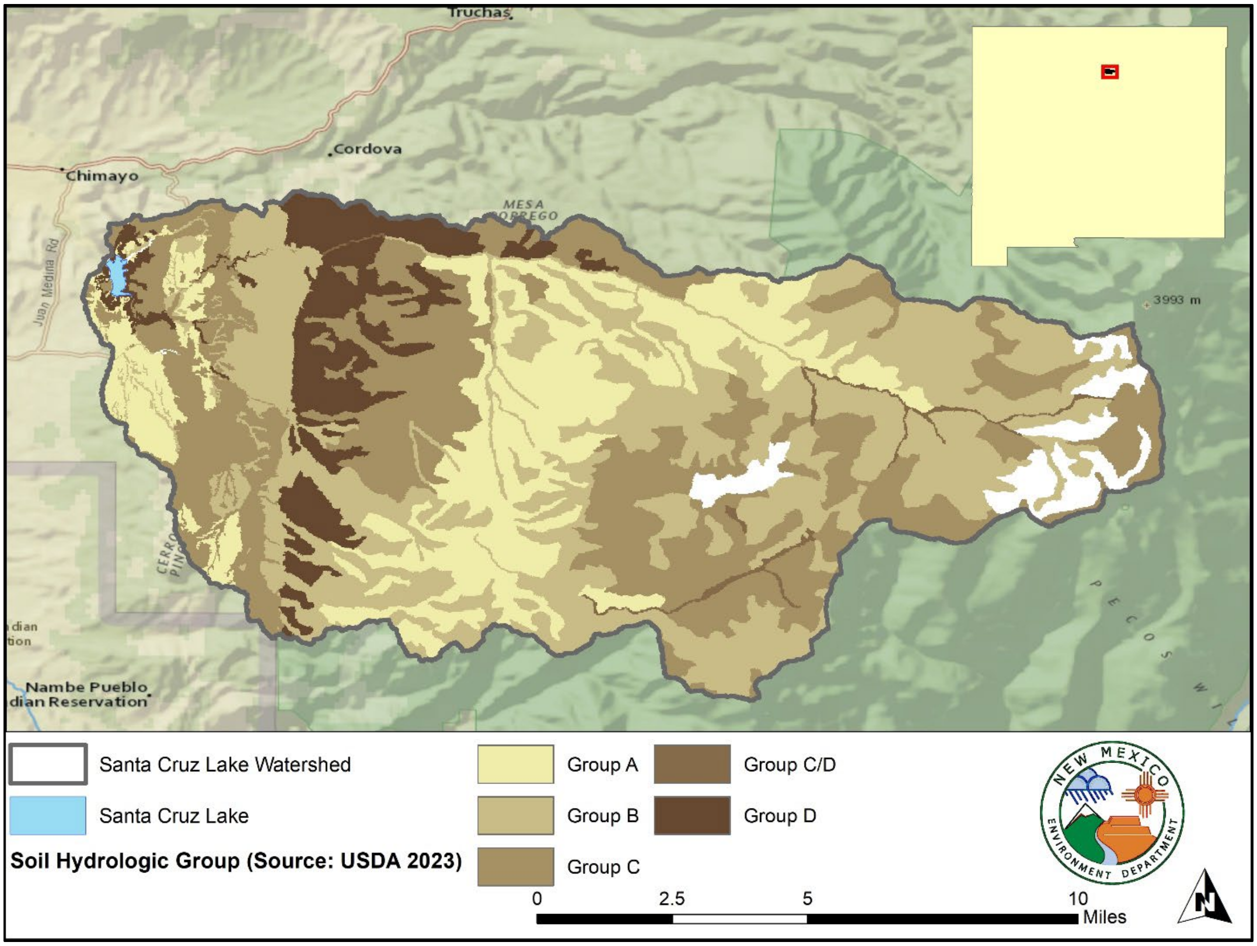

Figure 1.18: Soil Hydrologic Group classification of the Santa Cruz Lake watershed.

1.1.7 Shuree Pond North

Shuree Pond North is a small impoundment along Shuree Creek located near other small ponds. Shuree Pond North is the most significant impoundment in the cluster. The reservoir has a surface area of 6.19 acres (NMED/SWQB 2024) and a storage capacity of 54 acre-ft. Shuree Pond North is impounded by a 42-foot-tall earthen dam, completed in 1971, that is owned by the United States Forest Service (USFS). The reservoir is in the Valle Vidal Unit of the Carson National Forest. The USFS manages the Shuree Lakes Fishing area, which includes Shuree Pond North. A small population of rainbow trout is stocked and maintained by the NMDGF (NMED/SWQB 2006). Designated uses for Shuree Pond North include domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, primary contact and wildlife habitat, with all uses being met except for high quality coldwater aquatic life (NMED/SWQB 2024).

1.1.8 Shuree Pond North Watershed

The Shuree Pond North watershed is located within one HUC 12 watershed (110800020202) and covers 1.98 square miles of the Sangre de Cristo Mountains in the upper reaches of the Canadian River basin. The watershed is located entirely in Colfax County. The elevation ranges from 9,284 feet at the lake outlet to 11,122 feet at an unnamed mountain peak, with an average elevation of 9,839 feet. Slopes range from 0 degrees to 70 degrees, with an average slope of 11 degrees. The watershed receives approximately 22 inches of precipitation a year, with an average annual air temperature of approximately 43 degrees Fahrenheit. Surface input to Shuree Pond North is limited and occurs mainly during the annual snowmelt, otherwise flow from Shuree Creek is intermittent and often dry.

Sampling was attempted at Shuree Creek just above Shuree Pond North during the 2015-2016 Canadian and Dry Cimarron, however during each sampling event the stream was dry. Therefore, no data has been collected at Shuree Creek, the creek remains unassessed, and it is unknown if the stream is impaired. Shuree Pond North (AU ID: NM-2306.B_30) was sampled during the 2015-2016 Canadian and Dry Cimarron water quality survey and during the 2018 assessment was found to be impaired for nutrients.

Sedimentary rocks underlie approximately 51.5% of the watershed, unconsolidated approximately 44.3%, and 4.2% purely igneous rock (**Figure 1.21**) (USGS 2017). Soils in the watershed are typically not well-drained, except for the ridges along the north and east edges of the watershed. Hydrologic Group A soils (high infiltration rate) make up approximately 15.3% of the watershed, Group B soils (moderate infiltration rate) 21.3% of the watershed, Group C soils (low infiltration rate) 50% of the watershed, Group D soils (very low infiltration rate) 12.9% of the watershed, and there is no hydrologic soil group data for 0.5% of the watershed (**Figure 1.24**).

As of 2019, land cover for the watershed is approximately 54.9% forest, 22.8% shrubland, 21.4% herbaceous, and <1.0% each wetland and water (**Figure 1.22**). There were no changes in land cover from 2001 to 2019. Approximately 86.1% of the watershed is situated in Level IV Ecoregion 21f (Sedimentary Mid-Elevation Forests) and 13.9% is situated in Ecoregion 21e (Sedimentary Subalpine Forests) (**Figure 1.20).** Land ownership is 100% Forest Service (**Figure 1.23**). The entire watershed is within the Questa Ranger District of the Carson National Forest. Major land uses in the area include recreation, such as camping, hunting, hiking, boating and fishing. Within Colfax County, including the Shuree Pond North watershed, the Bald Eagle (*Haliaeetus leucocephalus*), Mexican Spotted Owl (*Strix occidentalis lucida*), New Mexican Meadow Jumping Mouse (*Zapus hudsonius luteus*), Organ Mountains Colorado Chipmunk (*Neotamias quadrivittatus australis*), Pacific Marten (*Martes caurina*), Piping Plover (*Charadrius melodus*), Southern Redbelly Dace (*Chrosomus erythrogaster*), Star Gyro (*Gyraulus crista*), Suckermouth Minnow (*Phenacobius mirabilis*), White-Tailed Ptarmigan (*Lagopus leucura*), and the Yellow-Billed Cuckoo (*Coccyzus americanus*) are listed as either Threatened or Endangered by state and/or federal agencies (NHNM Species Information, *https://nhnm.unm.edu/*, accessed 03/17/2022).

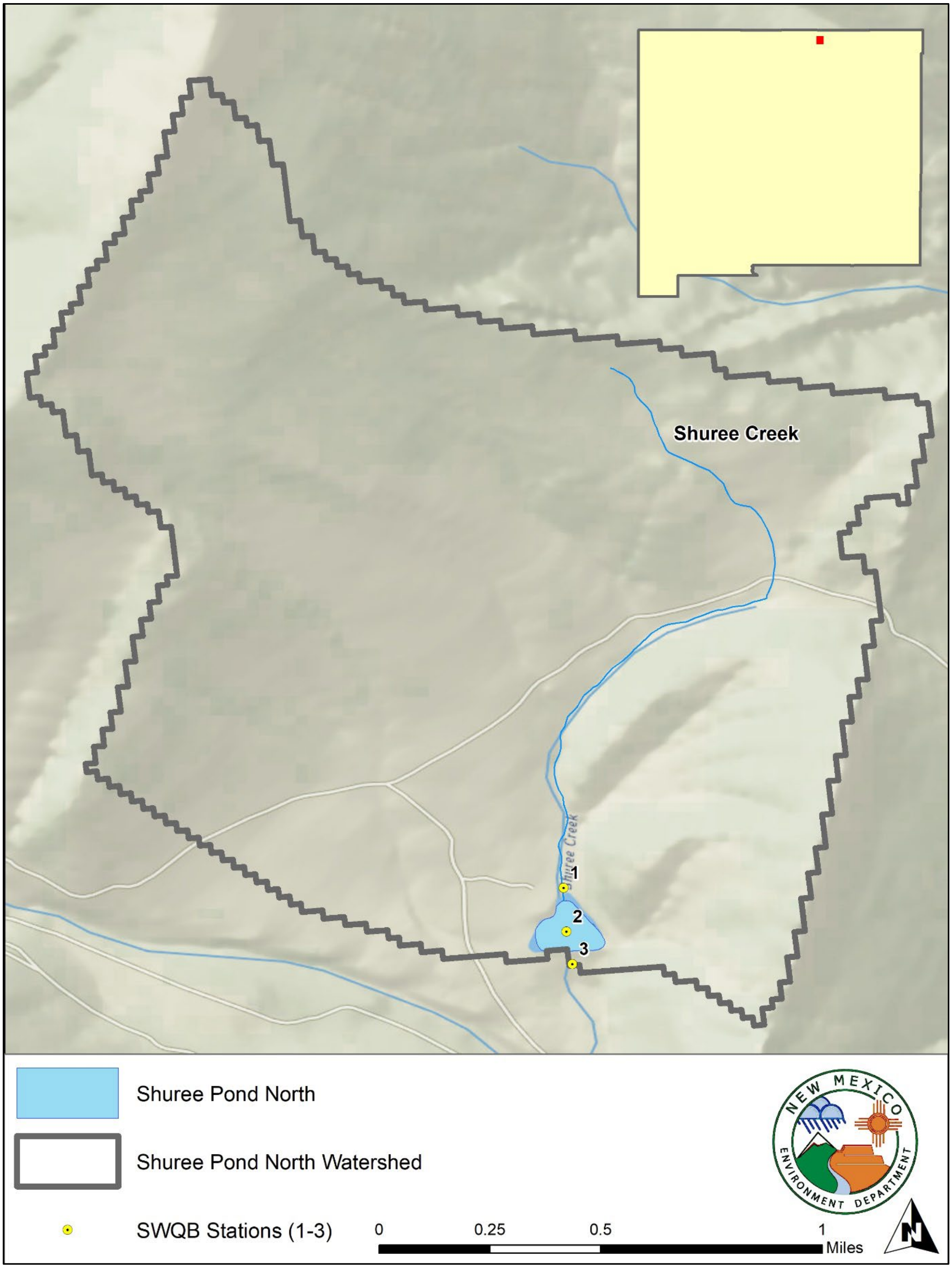

Figure 1.19: Overview map of the Shuree Pond North watershed. SWQB Stations (1-3) are identified in Table 5.1.

Table 1.4: Relevant SWQB Stations shown in Figure 1.16.

Map Label	AU ID/Name	Station ID/Name
1	NM-2306.B_30, Shuree Pond (North)	05ShurCr000.8, Shuree Creek above Shuree Pond
2	NM-2306.B_30, Shuree Pond (North)	05NShureeDeep, North Shuree Pond (Deep)
3	NM-2306.B_30, Shuree Pond (North)	05ShurCr000.6, Shuree Creek blw Shuree Pond

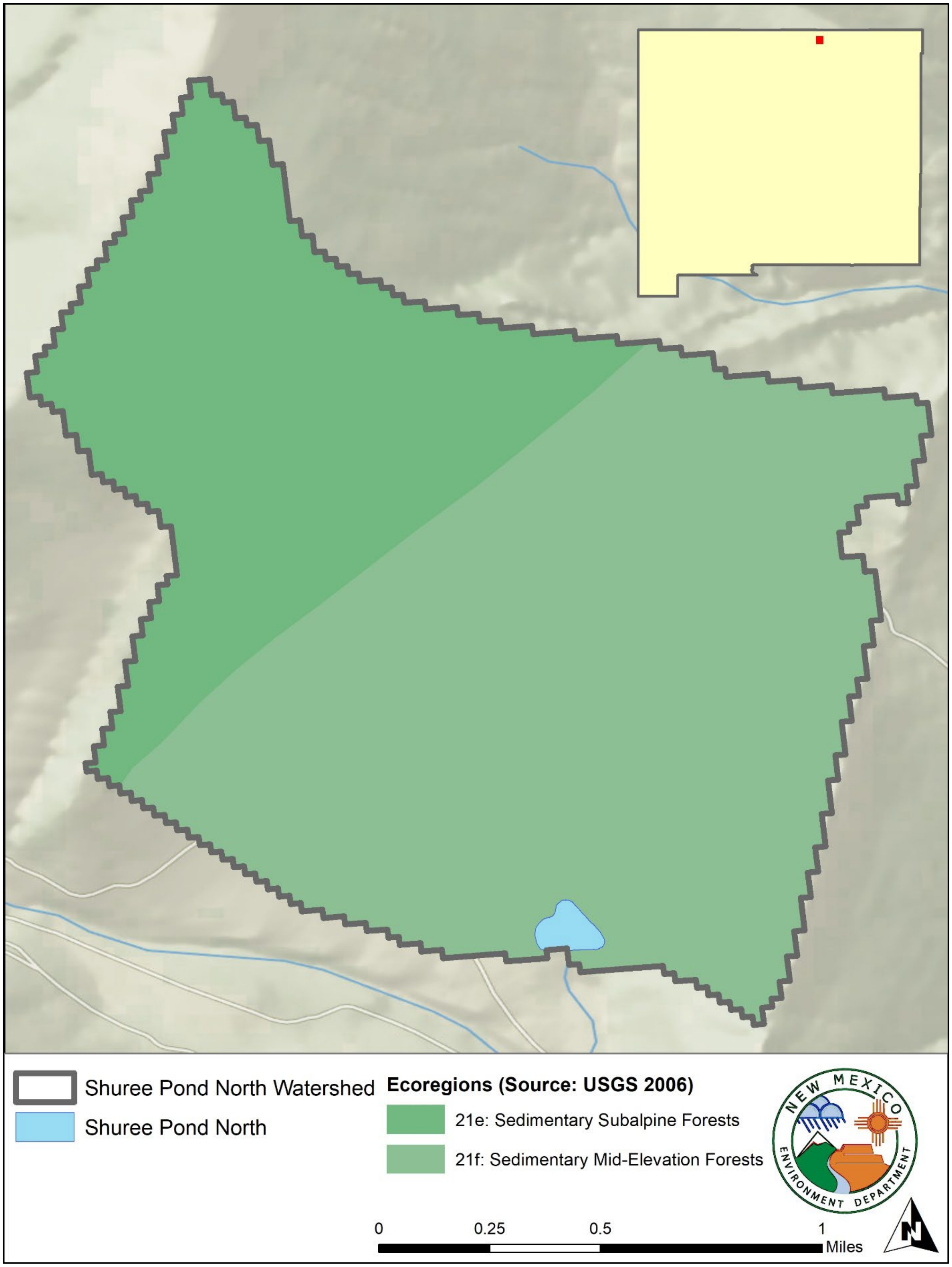

Figure 1.20: Ecoregions of the Shuree Pond North watershed.

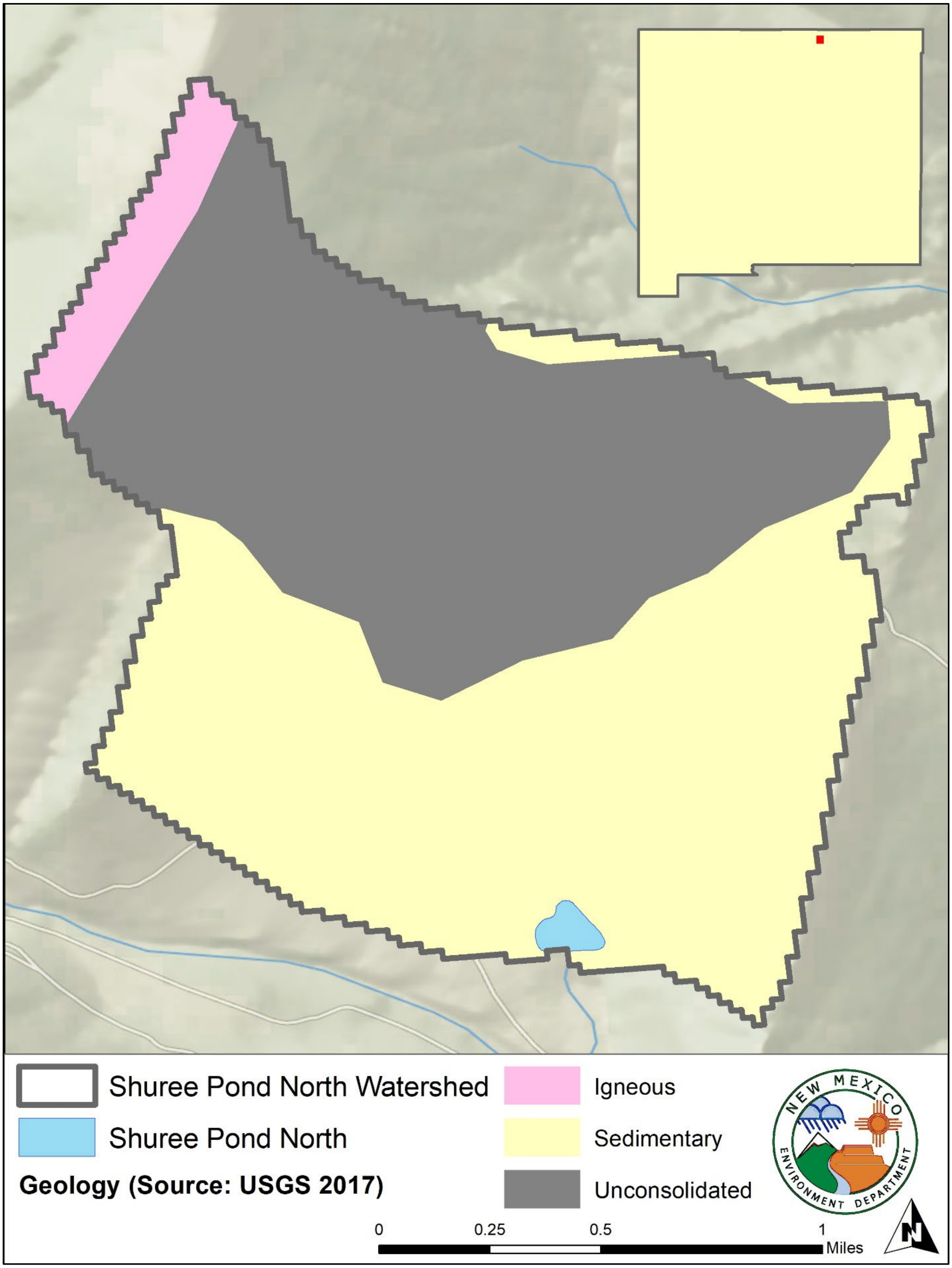

Figure 1.21: Surface geology of the Shuree Pond North watershed.

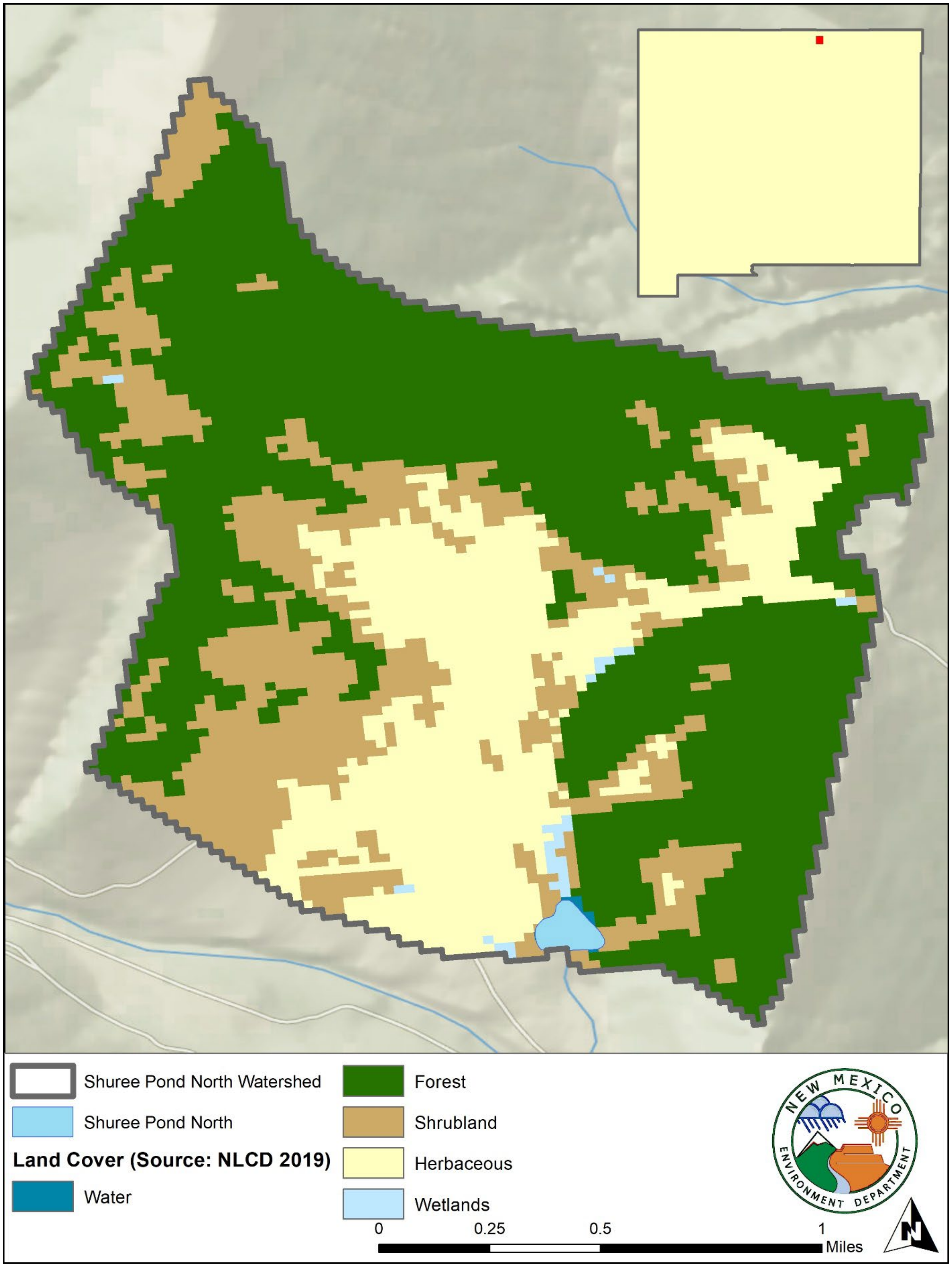

Figure 1.22: Land Cover of the Shuree Pond North watershed.

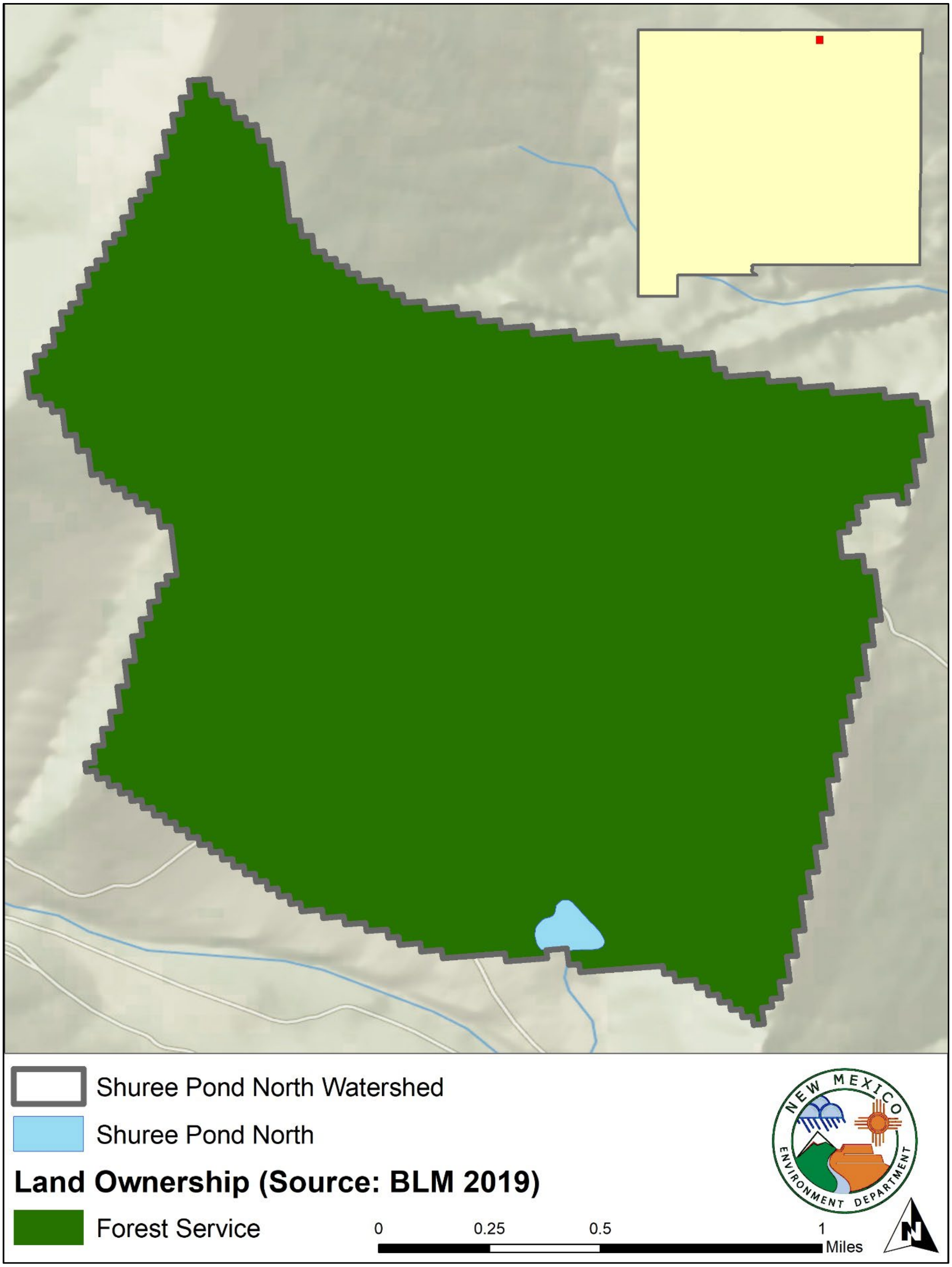

Figure 1.23: Land Ownership of the Shuree Pond North watershed.

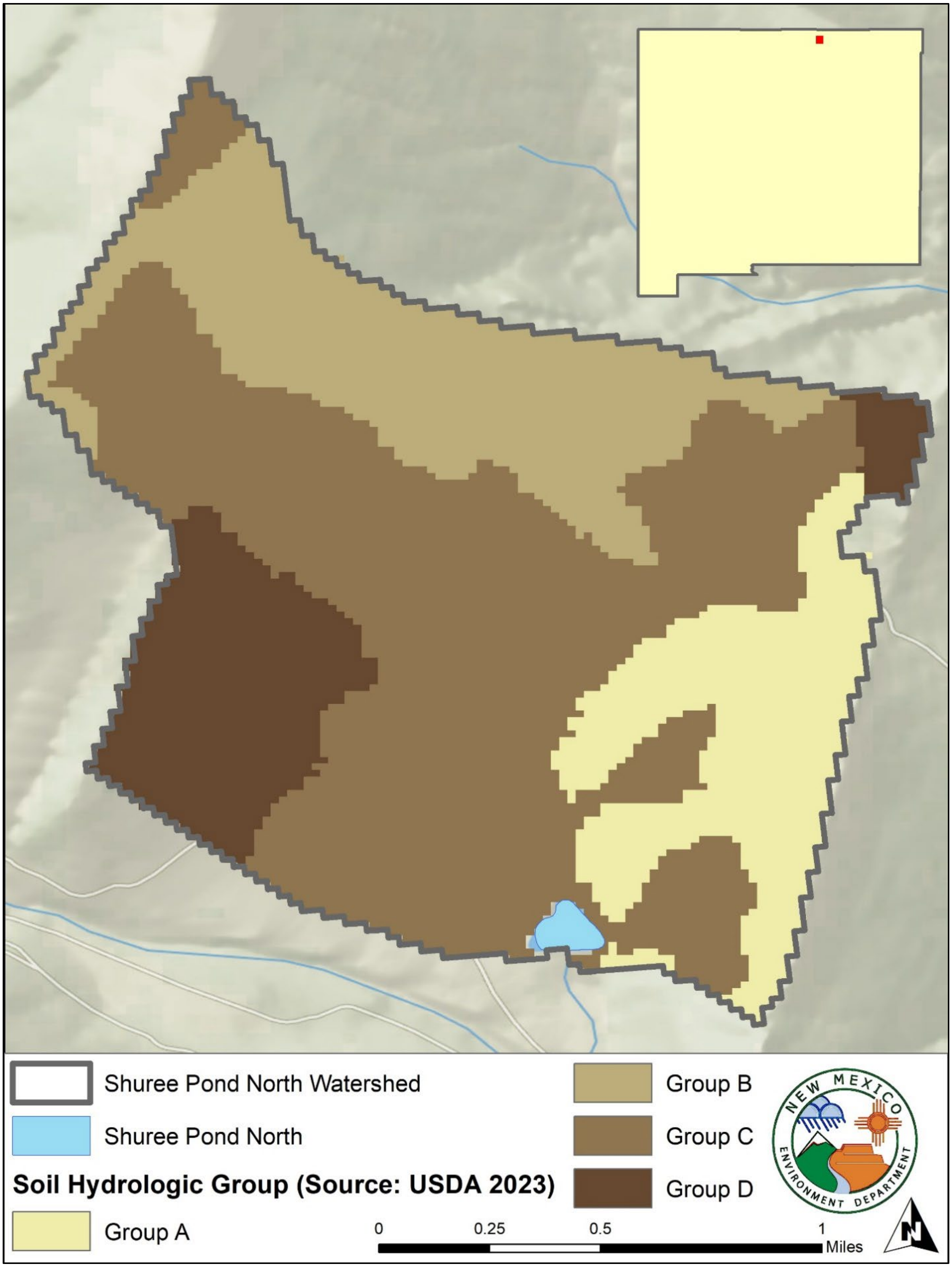

Figure 1.24: Soil Hydrologic Group classification of the Shuree Pond North watershed.

1.2 Water Quality Standards

Water quality standards for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North are set forth in the following sections of 20.6.4 NMAC:

20.6.4.315 CANADIAN RIVER BASIN: Eagle Nest lake.

A. Designated uses: high quality coldwater aquatic life, irrigation, domestic water supply, primary contact, livestock watering, wildlife habitat and public water supply.

B. Criteria: The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses except that the following segment-specific criteria apply: specific conductance 500 µS/cm or less; the monthly geometric mean of *E. coli* bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less. [20.6.4.315 NMAC – N, 7/10/2012]

20.6.4.312 Lake Maloya.

A. Designated uses: coldwater aquatic life, irrigation, livestock watering, wildlife habitat, primary contact and public water supply.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses.

[20.6.4.313 NMAC – N, 12/1/2010; A, 4/23/2022]

20.6.4.121 RIO GRANDE BASIN - Perennial tributaries to the Rio Grande in Bandelier national monument and their headwaters in Sandoval county and all perennial reaches of tributaries to the Rio Grande in Santa Fe county unless included in other segments and excluding waters on tribal lands.

A. Designated uses: domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and primary contact; and public water supply on Little Tesuque creek, the Rio en Medio, and the Santa Fe river.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: specific conductance 300 µS/cm or less; the monthly geometric mean of *E. coli* bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less. [20.6.4.121 NMAC - Rp 20 NMAC 6.1.2118, 10/12/2000; A. 5/23/2005; A, 12/1/2010; A, 2/14/2013] [NOTE: The segment covered by this section was divided effective 5/23/2005. The standards for the additional segments are under 20.6.4.126, 20.6.4.127 and 20.6.4.128 NMAC.]

20.6.4.314 CANADIAN RIVER BASIN - Shuree ponds (north and south).

A. Designated uses: high quality coldwater aquatic life, irrigation, domestic water supply, primary contact, livestock watering and wildlife habitat.

B. Criteria: The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses except that the following segment-specific criteria apply: specific conductance 500 µS/cm or less; the monthly geometric mean of *E. coli* bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less. [20.6.4.314 NMAC - N, 7/10/2012]

Additionally, general criteria applicable to all surface waters of New Mexico are outlined in 20.6.4.13 NMAC. With respect to nutrients, the following narrative criterion guidance is set forth in 20.6.4.13(E) NMAC:

20.6.4.13 GENERAL CRITERIA

E. Plant Nutrients: Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in the dominance of nuisance species in surface waters of the state.

This narrative criterion can be challenging to assess because the relationships between nutrient levels and impairment of designated uses are not defined, and distinguishing nutrients from “other than natural causes" is difficult. Numeric thresholds are necessary to establish targets for TMDLs, to develop water quality-based permit limits and source control plans, and to support designated uses within the watershed. Therefore, SWQB, with the assistance from USEPA and the University of Arkansas (Scott and Haggard 2011), developed nutrient-related thresholds, or *narrative translators*, to address both cause (TN and TP) and response variables (dissolved oxygen [DO], pH, chlorophyll-*a*, and percent cyanobacteria). Water quality assessments for nutrients are based on quantitative measurements of these causal and response indicators. If these measurements exceed the numeric nutrient threshold values, indicate excessive primary production, and/or demonstrate an unhealthy biological community, the waterbody is considered impaired. Narrative translators applicable to lakes for the narrative criteria outlined in 20.6.4.13 NMAC are outlined in Appendix D of the 2023 CALM (NMED/SWQB 2023[1]). Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North are all designated coldwater lakes, meaning total nitrogen is considered a nutrient impairment at levels above 0.9 mg/L and total phosphorous is considered a nutrient impairment at levels above 0.03 mg/L.

1.3 Antidegradation and TMDLs

New Mexico's antidegradation policy, which is based on the requirements of 40 C.F.R. § 131.12, describes how waters are to be protected from degradation (20.6.4.8(A) NMAC). At a minimum, the policy mandates that "the level of water quality necessary to protect the existing uses shall be maintained and protected in all surface waters of the state." Furthermore, the policy's requirements must be met whether or not a segment is impaired. TMDLs are consistent with this policy because implementation of a TMDL restores water quality so that existing uses (defined at 20.6.4.7(E)(3) NMAC at the highest quality of water that has been attained since 1975) are protected and water quality criteria are achieved.

The Antidegradation Policy Implementation Procedure establishes the process for implementing the antidegradation policy (Appendix A of NMED/SWQB 2020b[2]). However, certain specific requirements in the Antidegradation Policy Implementation Procedure do not apply to the Water Quality Control Commission's (WQCC) establishment of TMDLs because these types of water quality-related actions already are subject to extensive requirements for review and public participation, as well as various limitations on degradation imposed by state and federal law (NMED/SWQB 2020b).

1.4 Water Quality Monitoring Surveys

Monitoring of surface waters across the State typically occurs using a rotational watershed approach, meaning a given waterbody is generally surveyed intensively, on average, every eight to ten years. Monitoring occurs during the non-winter months (March through November), focuses on physical, chemical, and biological conditions in perennial waters, and includes sampling for most pollutants that have numeric and/or narrative criteria in the WQS. Each assessment unit (i.e., stream reach or lake/reservoir) is typically represented by one monitoring station, each of which receives 4–8 site visits during the survey. Larger lakes/reservoirs typically have both a deep and a shallow station.

The SWQB introduced a new strategy during the 2015-2016 seasons where a larger area is monitored over a two-year period, with 2-6 water chemistry samples collected at each AU per year (4-12 total samples over the entire survey). This two-year monitoring approach is intended to allow more data to be collected

[1] https://www.env.nm.gov/surface-water-quality/calm/
[2] https://www.env.nm.gov/surface-waterquality/wqmp-cpp/

from the highest priority waters to better capture inter-annual variability primarily due to hydrologic conditions during the sampling events.

Through public outreach, inter-agency coordination, and a scoring system considering a variety of factors, a three-tier monitoring system − primary, secondary, and tertiary – was developed to prioritize AUs. High ranking priority waters (primary AUs) receive the greatest amount of monitoring, whereas low ranking waters (i.e., tertiary AUs) receive the least.

1.5 Hydrologic Conditions

1.5.1 Eagle Nest Lake

The only active USGS gage in the Eagle Nest Lake watershed is at the dam (USGS 07205500: Eagle Nest Lake near Eagle Nest, NM), which records reservoir storage and elevation. An active USGS gage is located just downstream of the Eagle Nest Lake watershed at the outlet of the lake's dam (USGS 07206000: Cimarron River below Eagle Nest Dam, NM). The period of record for reservoir storage (USGS Gage 07205500) is from 1986 to present. Despite the New Mexico Dam Inventory listing the normal storage of Eagle Nest Lake at 81,000 acre-feet, that value is rarely met. Since the year 1986, the reservoir storage has only been above 81,000 acre-feet ten times, less than 1% of observations since the gage became active. The average reservoir storage from November 1986 to June 2022 is 49,244 acre-feet, with a high of 81,360 acre-feet in May 1994 and a low of 16,860 acre-feet in November 2014 (**Figure 1.25**). Data for this TMDL was collected during 2015-2016, when the reservoir had an average storage of 28,933 acre-feet, with a high of 35,510 acre-feet in June 2016 and a low of 17,210 acre-feet in May 2015 (**Figure 1.26**).

Based on the Koppen-Geiger climate classification system, the Eagle Nest Lake watershed exhibits a warm-summer humid continental climate in the lower elevations of the watershed and a subarctic climate in the higher elevations of the watershed (Beck 2018). Precipitation patterns are heavily influenced by the North American Monsoon season, which typically lasts from early July through September. An automated weather observing system (AWOS) weather station is located within the Eagle Nest Lake watershed at the Angle Fire Airport (KAXX, Elevation: 8330ft, (36.422, -105.2899)), however this single weather station is not representative of the entire watershed. Better estimates of area-weighted average climatic parameters, like precipitation, temperature, etc., can be extracted from the PRISM Climate Group recent years modeled data (PRISM 2022), which integrate and interpolate weather station data from the AWOS weather station as well as many others. Considering the 40-year period from 1981 to 2020 (the most recent complete year available from PRISM at the time of this writing), annual precipitation ranged from a low of 14.54 inches in 1981 and 2020 to a high of 30.34 inches in 1994 (**Figure 1.28**). Considering monthly precipitation, July and August are the wettest months, accounting for nearly 30% of annual precipitation on average (**Figure 1.27**). Average annual air temperatures have ranged from a low of 38.66 °F in 1992 to a high of 43.32 °F in 2017 (**Figure 1.29**). Monthly average air temperatures ranged between 23.6 °F in January to 58.6 °F in July (**Figure 1.27**). Annual dew point temperature values are fairly stable and monthly dew point temperatures tend to follow air temperature. Average annual dew point temperatures have ranged from a low of 18.77 °F in 2011 to a high of 25.14 °F in 1986 (**Figure 1.30**). Monthly average dew point temperatures are between 8.81 °F in January and 40.91 °F in August (**Figure 1.27**).

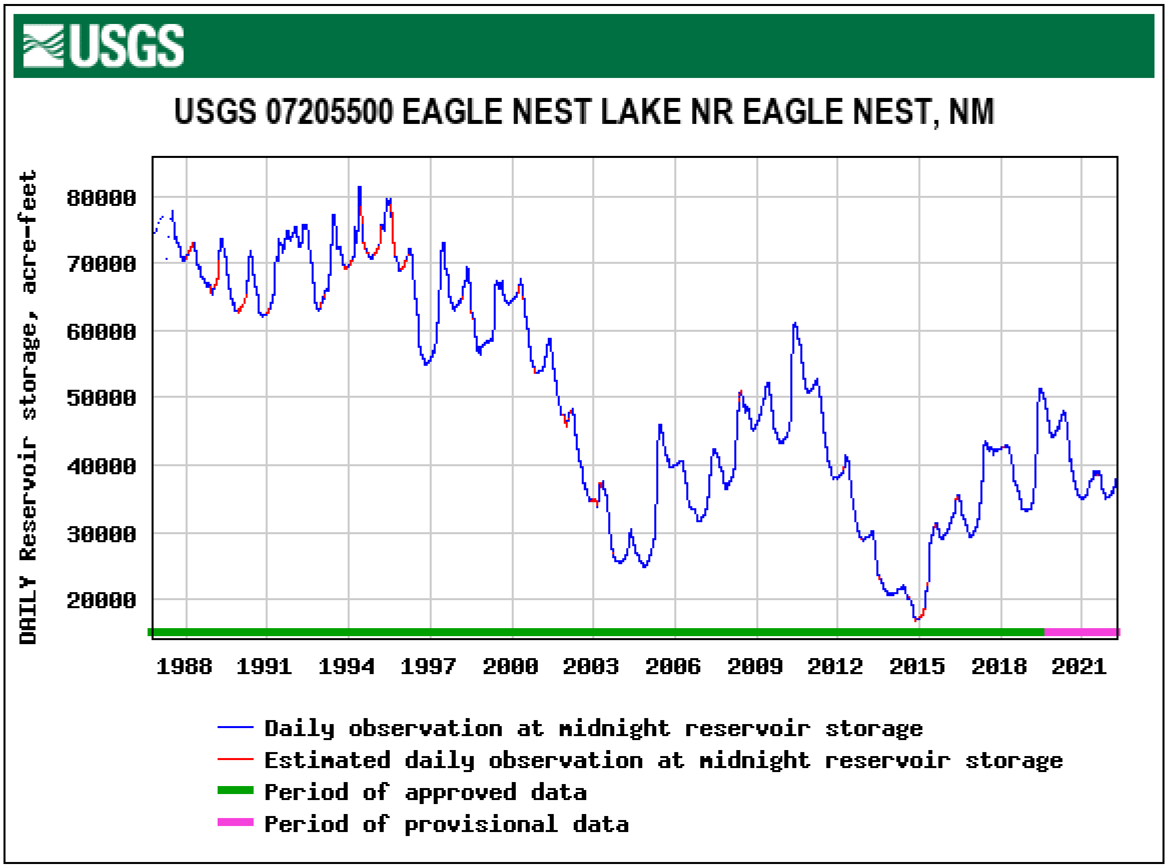

Figure 1.25: Lake Storage (acre-feet) for Eagle Nest Lake from 1986 to present.

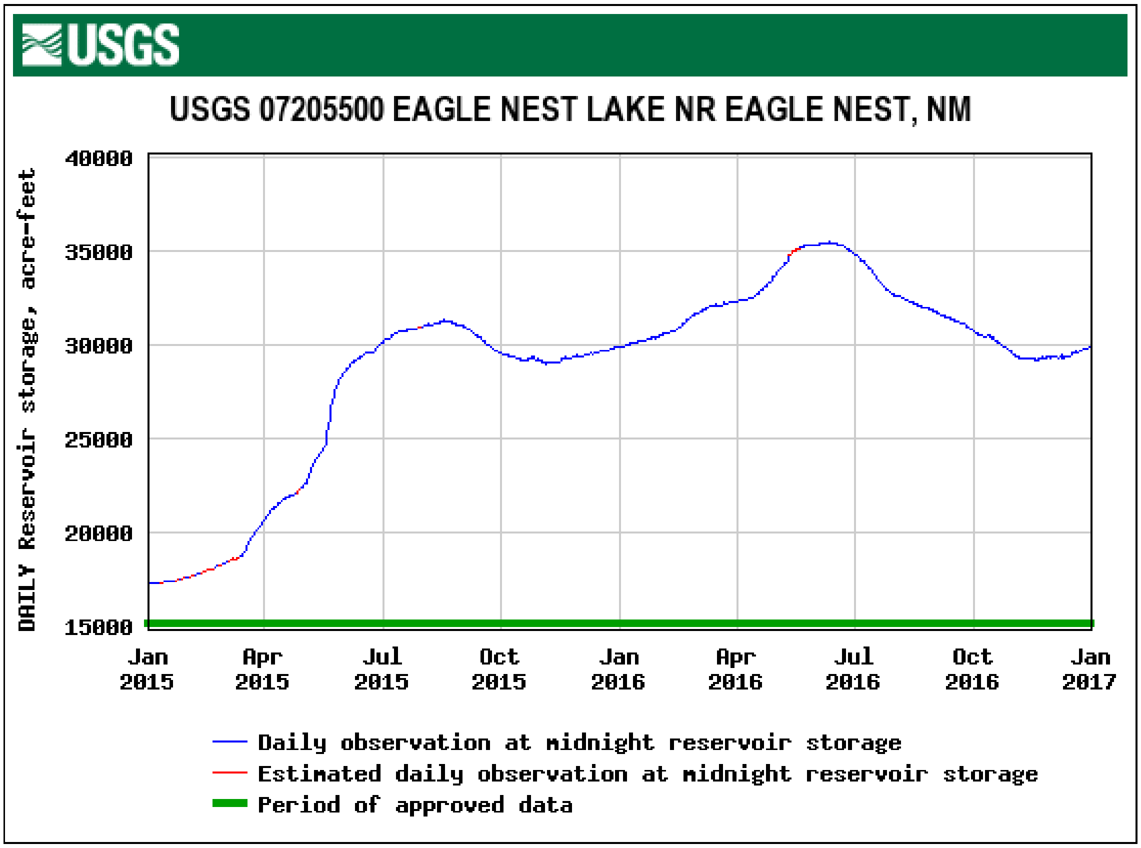

Figure 1.26: Lake storage (acre-feet) for Eagle Nest Lake during the 2015-2016 water quality survey.

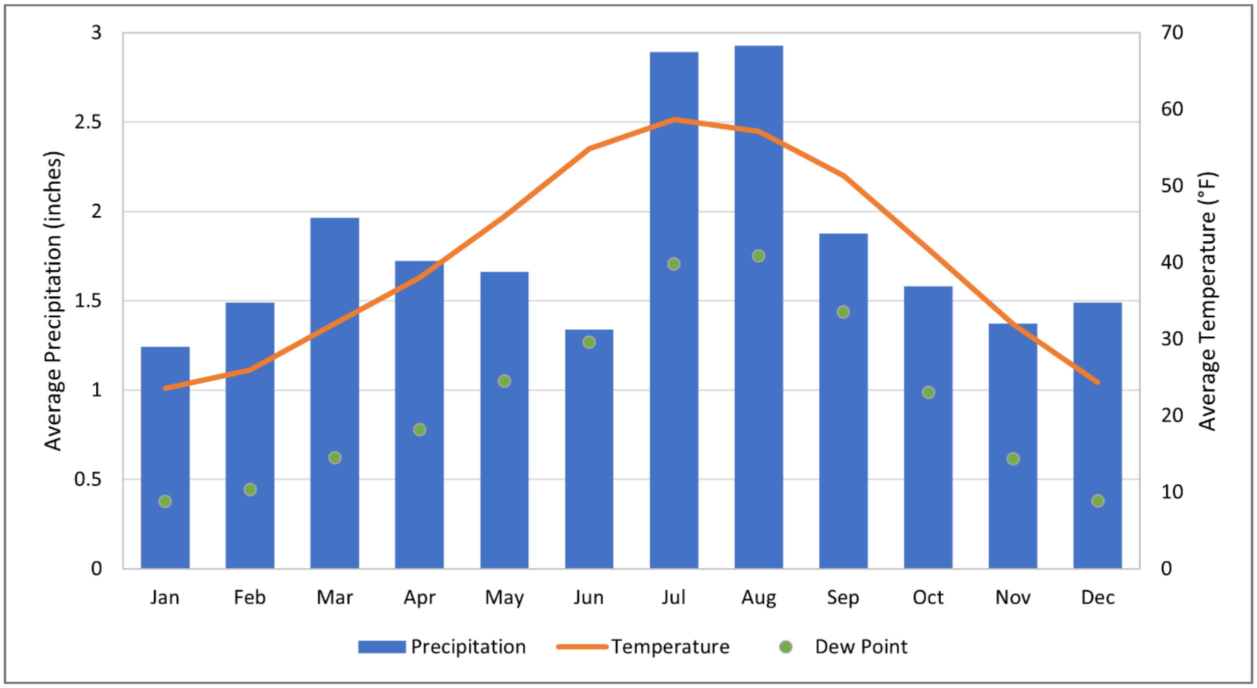

Figure 1.27: Climate overview for Eagle Nest Lake watershed.

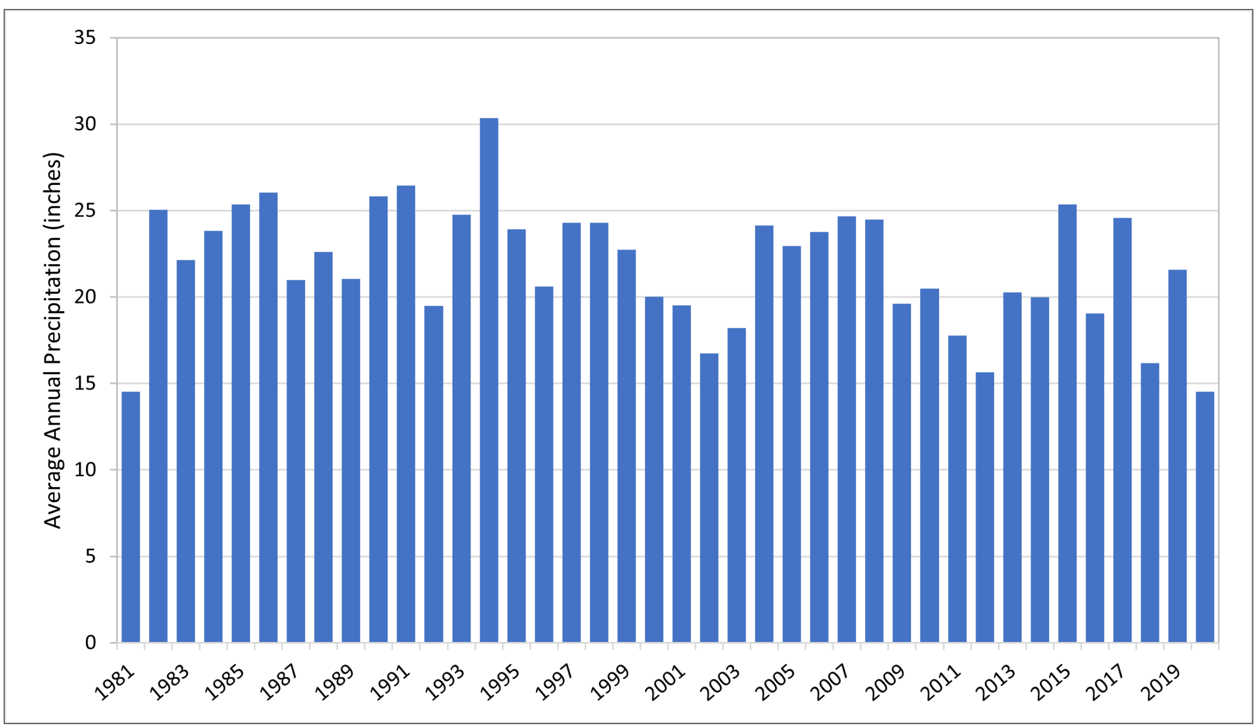

Figure 1.28: Average annual precipitation for Eagle Nest Lake watershed from 1981 to 2020.

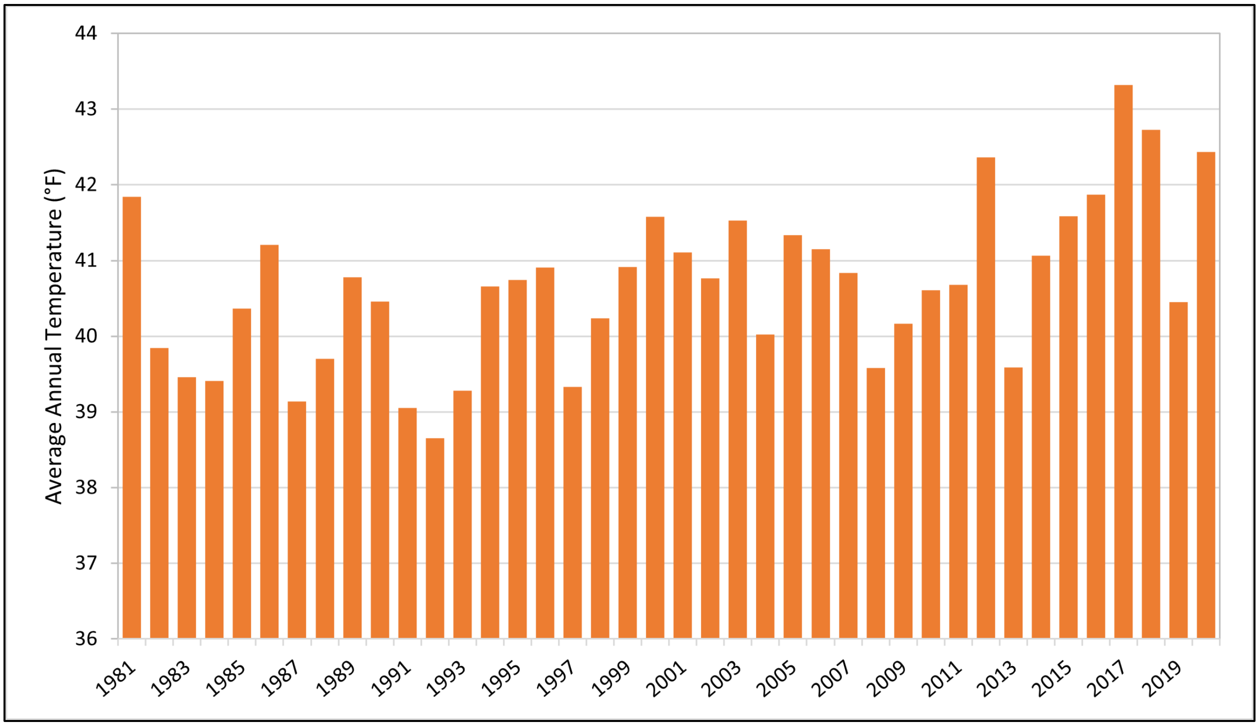

Figure 1.29: Average annual air temperature for Eagle Nest Lake watershed from 1981 to 2020.

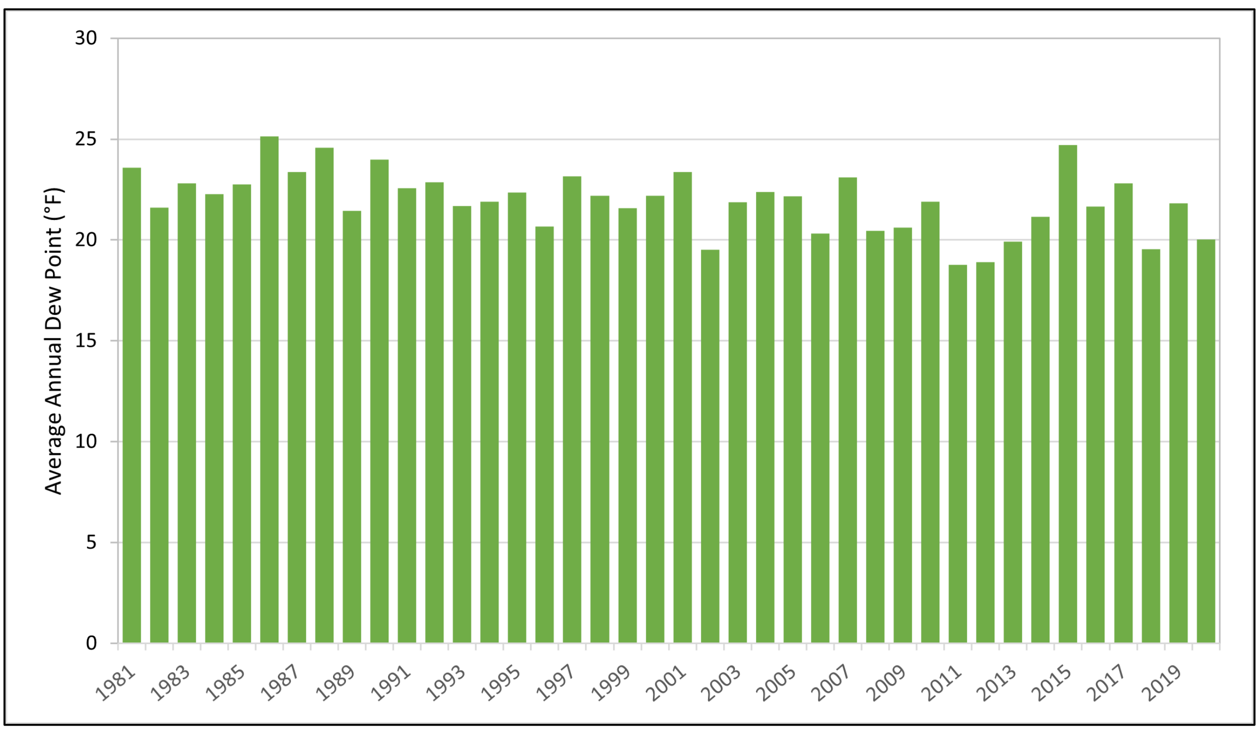

Figure 1.30: Average annual dew point temperature for Eagle Nest Lake watershed from 1981 to 2020.

1.5.2 Lake Maloya

The only active USGS gage in the Lake Maloya watershed is at the Lake Maloya dam (USGS 07199450: Lake Maloya near Raton, NM), which records reservoir storage and elevation. The period of record for reservoir storage is from October 1987 to present. Despite the New Mexico Dam Inventory listing the normal storage of Lake Maloya at 3690 acre-feet, the reservoir was only at or above that level around 24% during the period of record (**Figure 1.31**). Lake storage for the period of record has ranged from a low of 2220 acre-feet during January and February of 1991 to a high of 3949 acre-feet in April 2010. The NHD High Resolution Lake Maloya polygon is 115.54 acres, corresponding with an estimated storage of approximately 3237 acre-feet (Tetra Tech 2011). During the 2015-2016 water quality survey the average storage was 3620 acre-feet with a low of 3280 acre-feet in January 2015 to a high of 3856 acre-feet in May 2015 (**Figure 1.32**).

Based on the Koppen-Geiger climate classification system, the Lake Maloya watershed exhibits a warm-summer humid continental climate (Beck 2018). Precipitation patterns are heavily influenced by the North American Monsoon season, which typically lasts from early July through September. No weather stations exist within the Lake Maloya watershed, but there is a weather station at the nearby Raton Municipal Crews Field Airport (KRTN, Elevation: 6353 ft, (36.741, -104.508)). This single weather station is not representative of the entire watershed. Better estimates of area-weighted average climatic parameters, like precipitation, temperature, etc., can be extracted from the PRISM Climate Group's recent years modeled data (PRISM 2022), which integrates and interpolates weather station data from the AWOS weather station has well as many others. Considering the 40-year period from 1981 to 2020 (the most recent complete year available from PRISM at the time of this writing), annual precipitation ranged from a low of 12.09 inches in 2012 to a high of 32.54 inches in 2017 (**Figure 1.34**). Considering monthly precipitation, July and August are the wettest months, accounting for just over 30% of annual precipitation on average (**Figure 1.33**). Average annual air temperatures have ranged from a low of 43.14 °F in 1993 to a high of 47.78 °F in 2017 (**Figure 1.35**). Average monthly air temperatures range between 29.3 °F in December to 62.51 °F in July (**Figure 1.33**). Annual dew point temperatures have smaller variations when compared to precipitation and temperature, and average monthly dew point temperature values tend to follow air temperatures. Average annual dew point temperatures have ranged from a low of 21.13 °F to a high of 27.61 °F in 2017 (**Figure 1.36**). Monthly average dew point temperatures range from 8.98 °F in January to 44.80 °F in August (**Figure 1.33**).

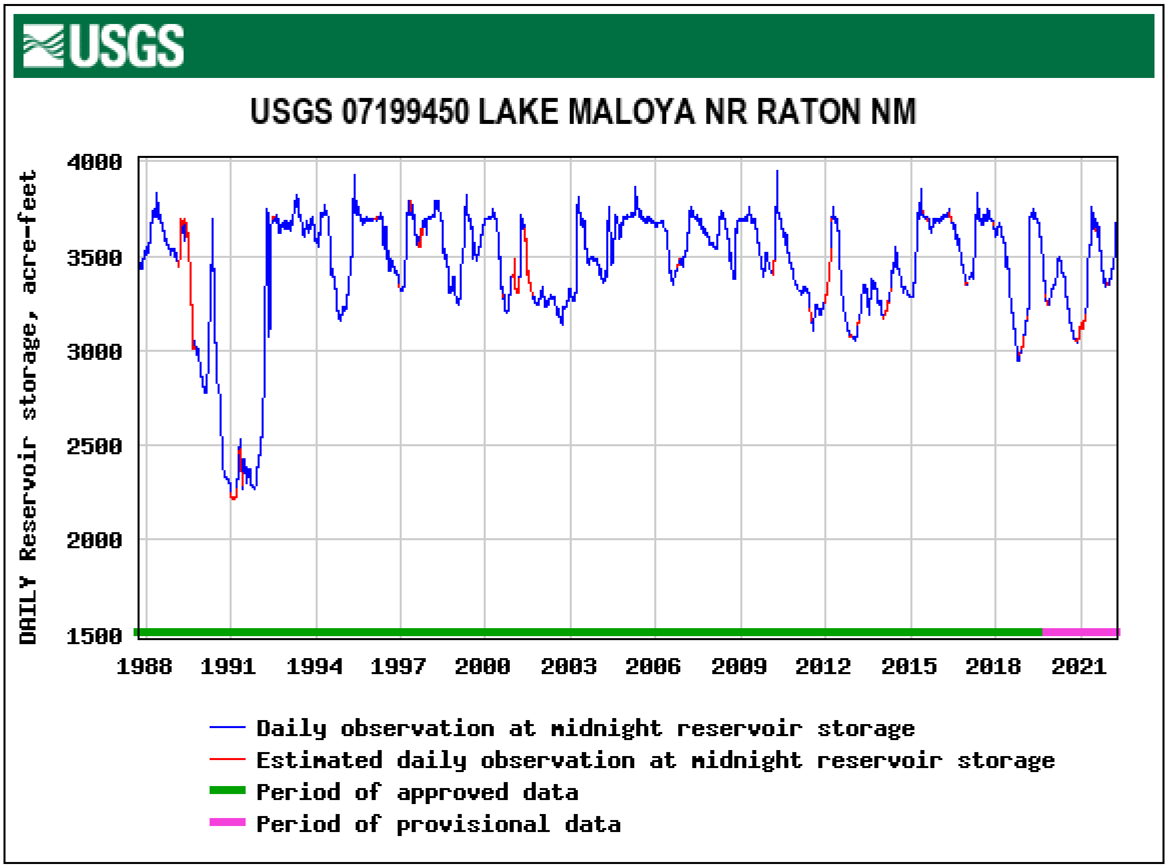

Figure 1.31: Lake Maloya storage (acre-feet) from 1987 to present.

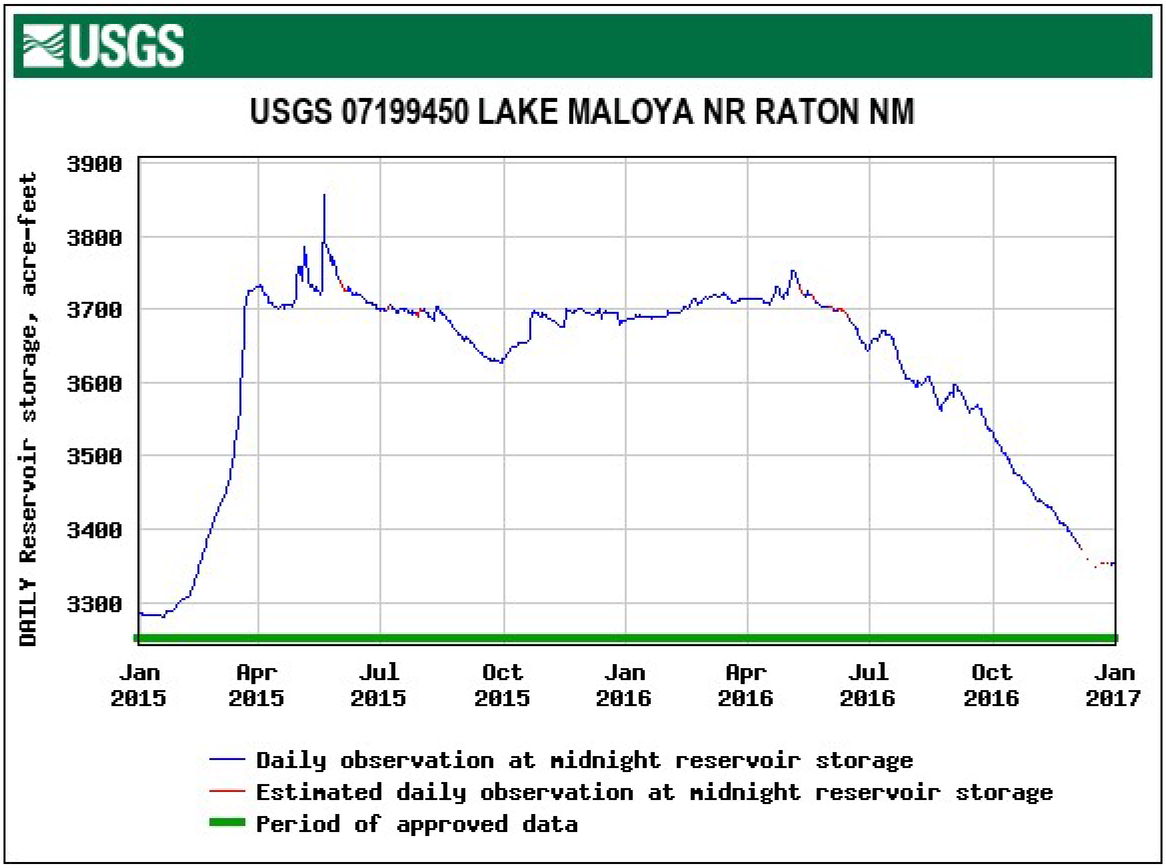

Figure 1.32: Lake storage (acre-feet) for Lake Maloya during the 2015-2016 water quality survey.

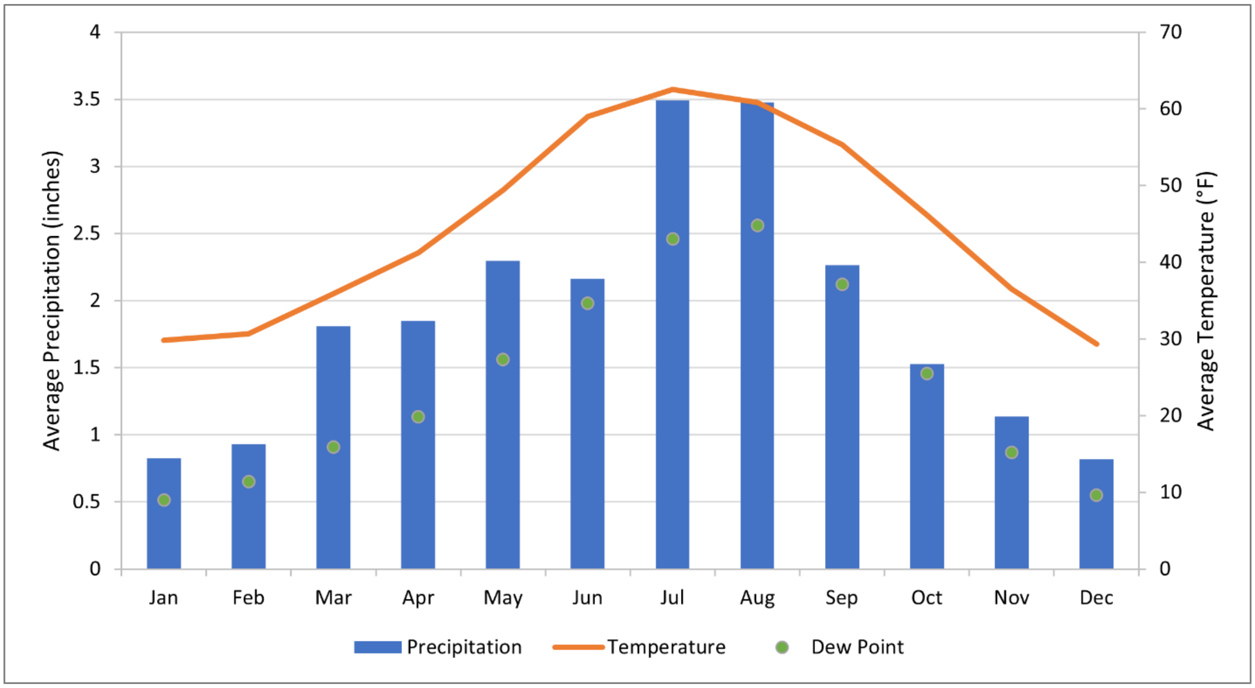

Figure 1.33: Climate overview for Lake Maloya watershed.

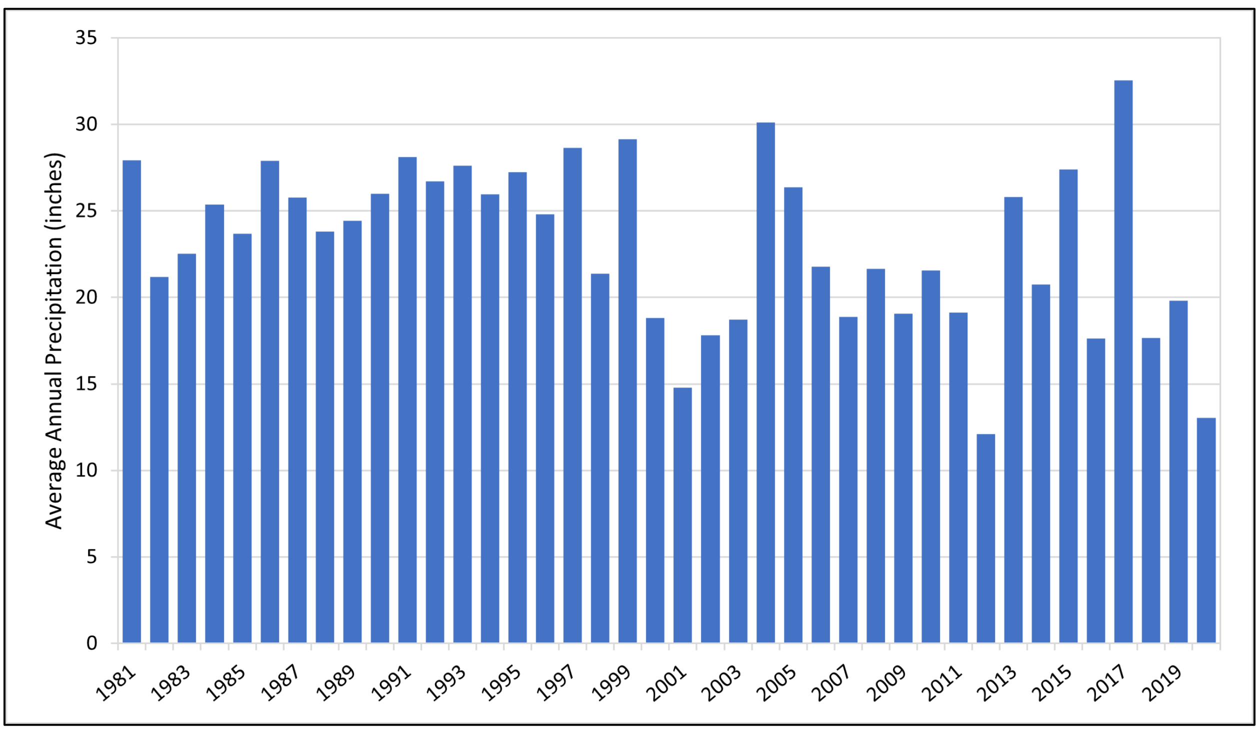

Figure 1.34: Average annual precipitation for the Lake Maloya watershed from 1981 to 2020.

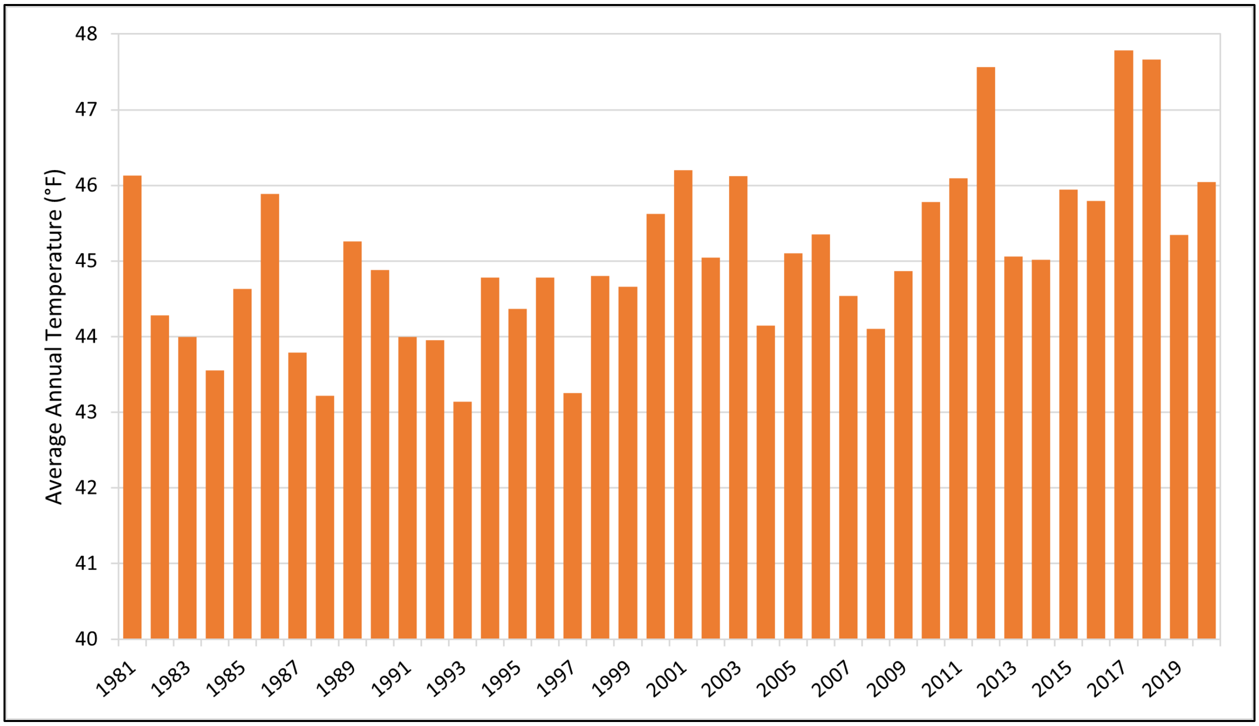

Figure 1.35: Average annual temperature for the Lake Maloya watershed from 1981 to 2020.

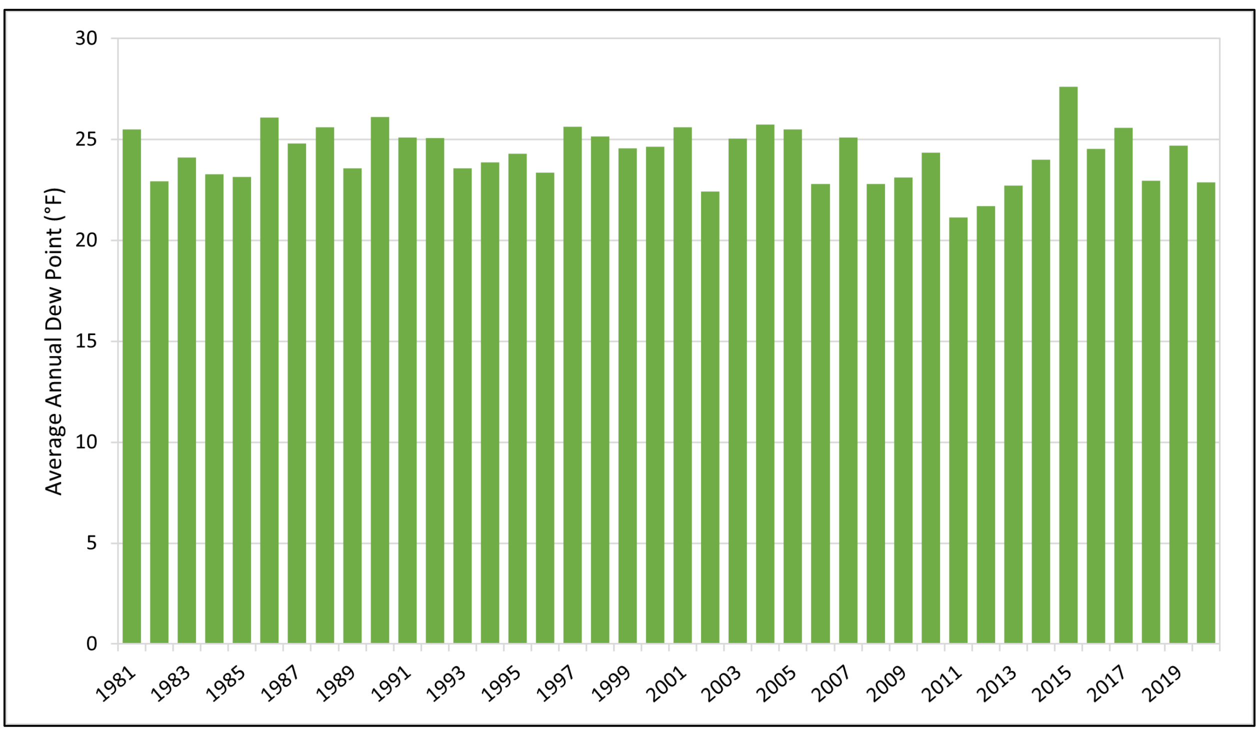

Figure 1.36: Average annual dew point temperature for the Lake Maloya watershed from 1981 to 2020.

1.5.3 Santa Cruz Lake

The only active USGS gage in the Santa Cruz Lake watershed is located about one mile upstream from the lake inlet on the Santa Cruz River (USGS 08291000: Santa Cruz River near Cundiyo, NM), situated just below the confluence of the Rio Medio and the Rio Frijoles. This gage measures mean daily discharge and has a period of record from October 1932 to present (**Figure 1.37**). The New Mexico Dam Inventory list the normal storage (also the spillway storage) at 3546.4 acre-feet, which corresponds to a surface area of 99.8 acres. The NHD High Resolution Santa Cruz Lake polygon is 92.95 acres, corresponding to an approximate storage capacity of 3005 acre-feet (URS 2010).

Based on the Koppen-Geiger climate classification system, the Santa Cruz Lake watershed exhibits a semi-arid cold climate in the lower elevations, a warm-summer humid continental climate in the middle elevations, and a subarctic climate in the highest elevations of the watershed (Beck 2018). Precipitation patterns are heavily influenced by the North American Monsoon season, which typically lasts from early July Through September. No weather stations exist within the Santa Cruz Lake watershed, but there is a RAWS weather station maintained by the US Forest Service in the nearby town of Truchas (Elevation: 8340 ft, (36.059, -105.769)). This single weather station is not representative of the entire watershed. Better estimates of area-weighted average climatic parameters, like precipitation, temperature, etc., can be extracted from the PRISM Climate Group's recent years modeled data (PRISM 2022), which integrates and interpolates weather station data from the RAWS weather stations as well as many others. Considering the 40-year period from 1981 to 2020 (the most recent complete year available from PRISM at the time of this writing), annual precipitation ranged from a low of 13.03 inches in 2020 to a high of 34.87 inches in 1994 (**Figure 1.39**). Considering monthly precipitation, July and August are the wettest months, accounting for nearly 30% of the annual precipitation on average (**Figure 1.38**). Average annual air temperatures have ranged from a low of 40.87 °F in 1992 to a high of 46.44 °F in 2017 (**Figure 1.40**). Average monthly air temperatures range between 26.08 °F in January to 61.54 °F in July (**Figure 1.38**). Annual dew point temperatures have smaller variations when compared to precipitation and temperature, and average monthly dew point temperature values tend to follow air temperatures. Average annual dew point temperatures have ranged from a low of 20.01 °F in 2011 to a high of 26.47 °F in 2015 (**Figure 1.41**). Monthly average dew point temperatures range from 10.62 °F in December to 42.84 °F in August (**Figure 1.38**).

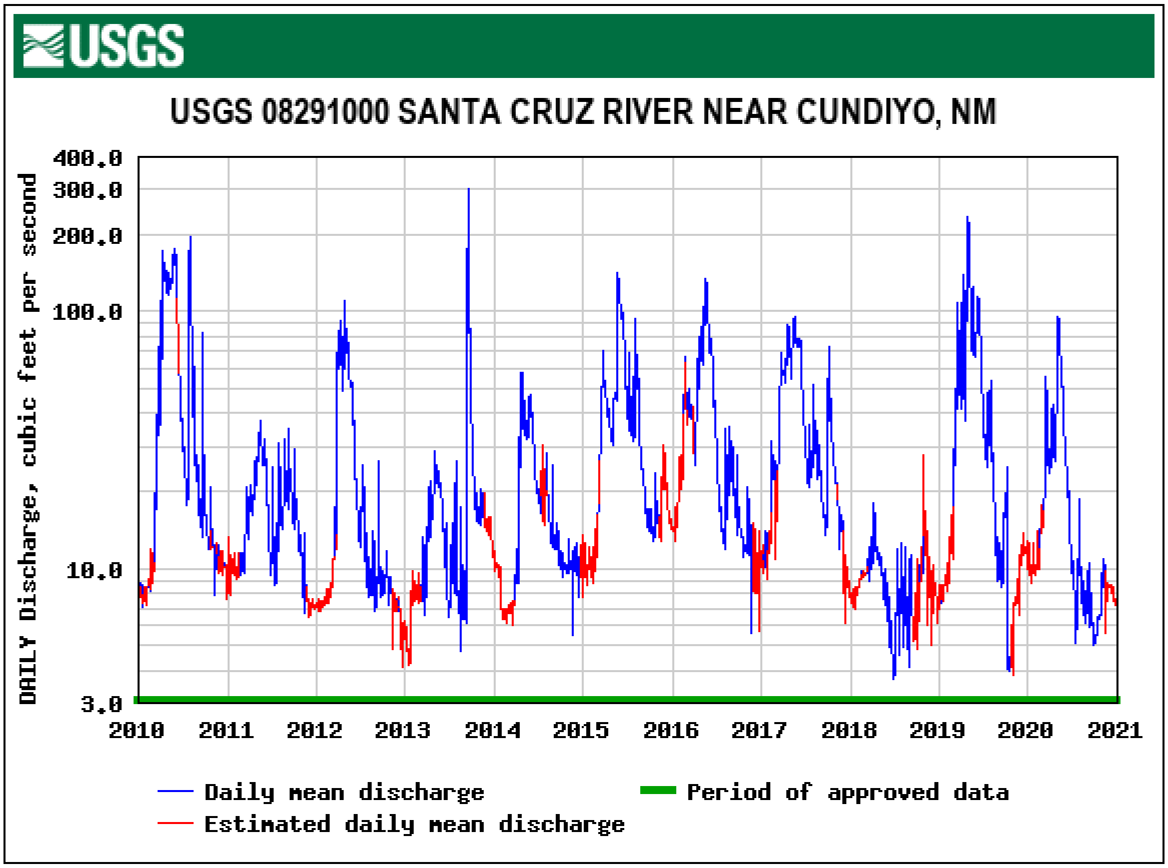

Figure 1.37: Average daily flow at USGS gage 08291000: Santa Cruz River near Cundiyo, NM from 2010 to 2021.

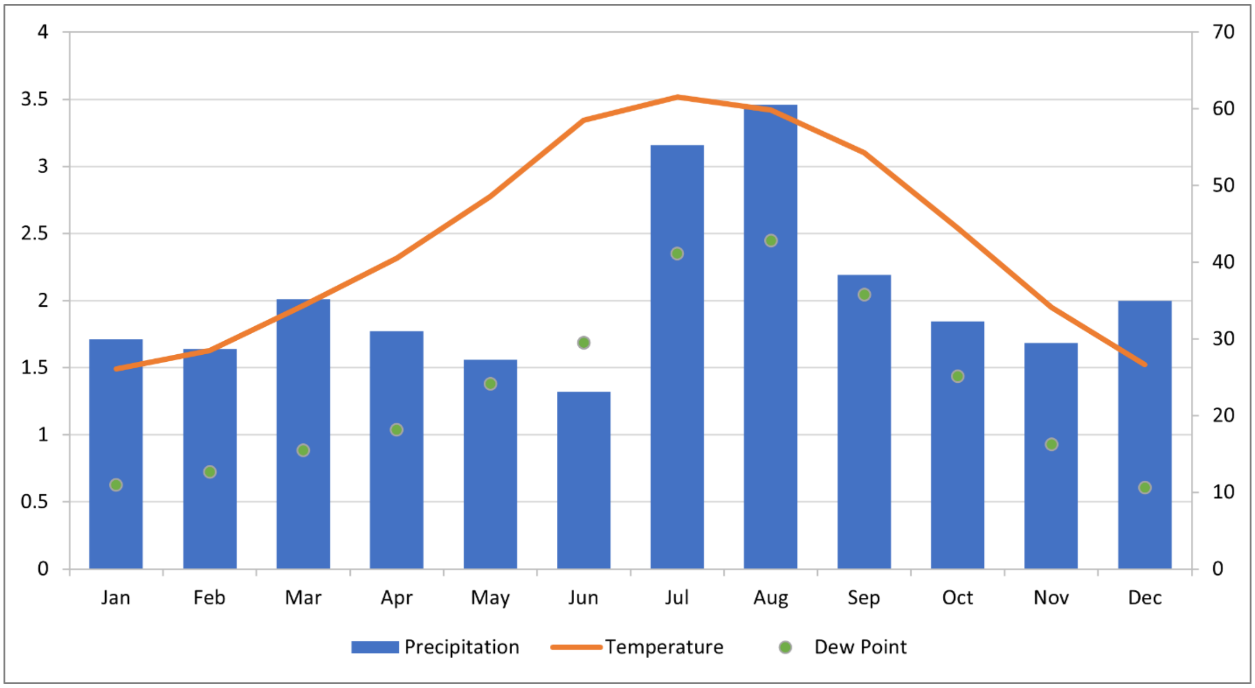

Figure 1.38: Climate overview of the Santa Cruz Lake watershed.

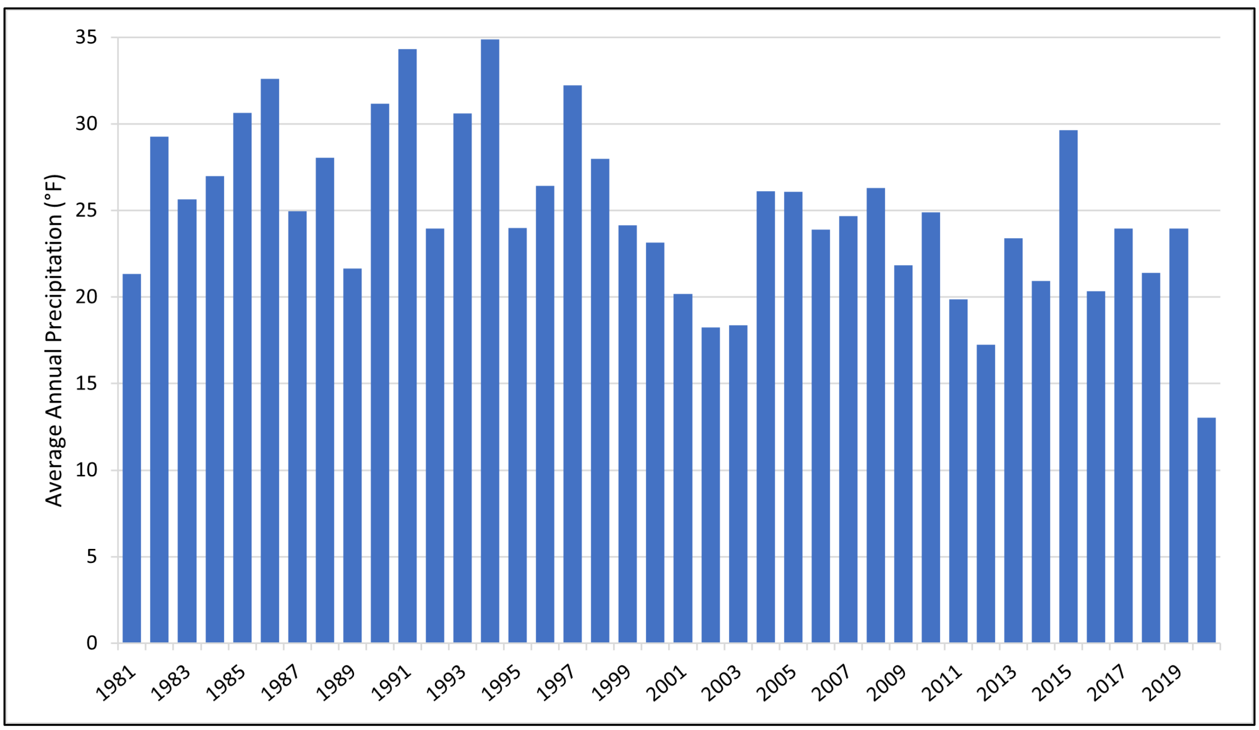

Figure 1.39: Average annual precipitation for the Santa Cruz Lake watershed from 1981 to 2020.

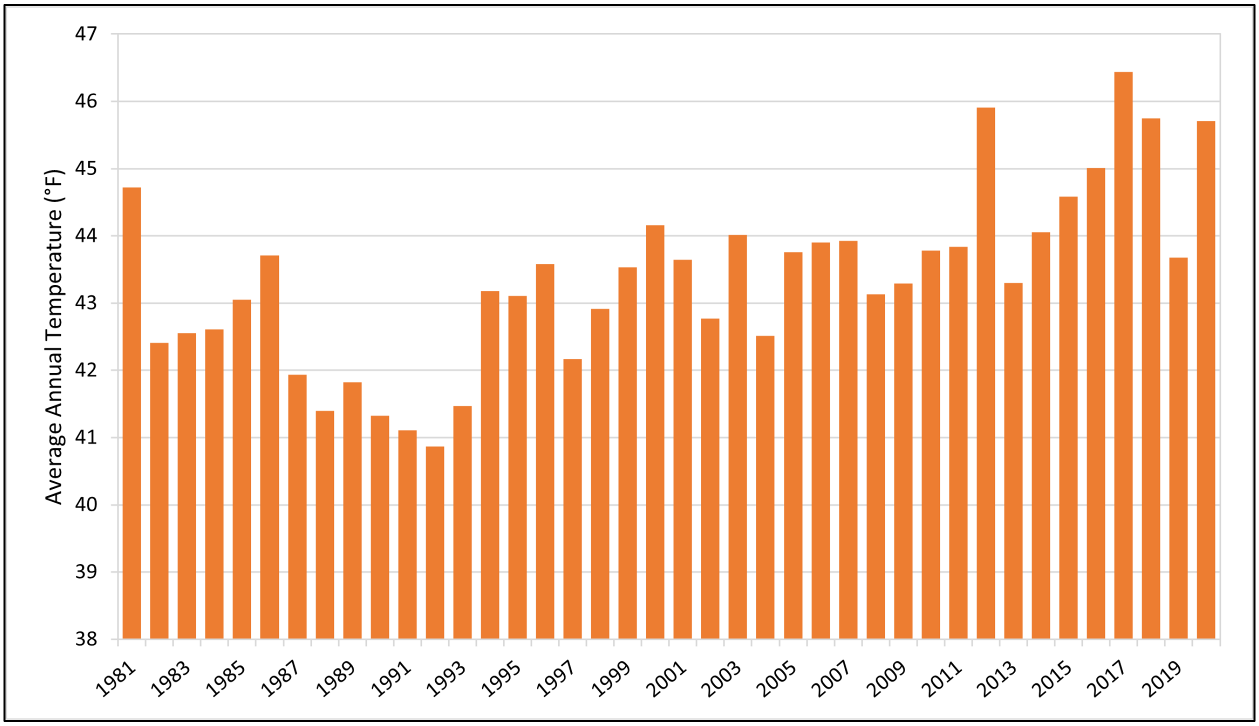

Figure 1.40: Average annual temperature for the Santa Cruz Lake watershed from 1981 to 2020.

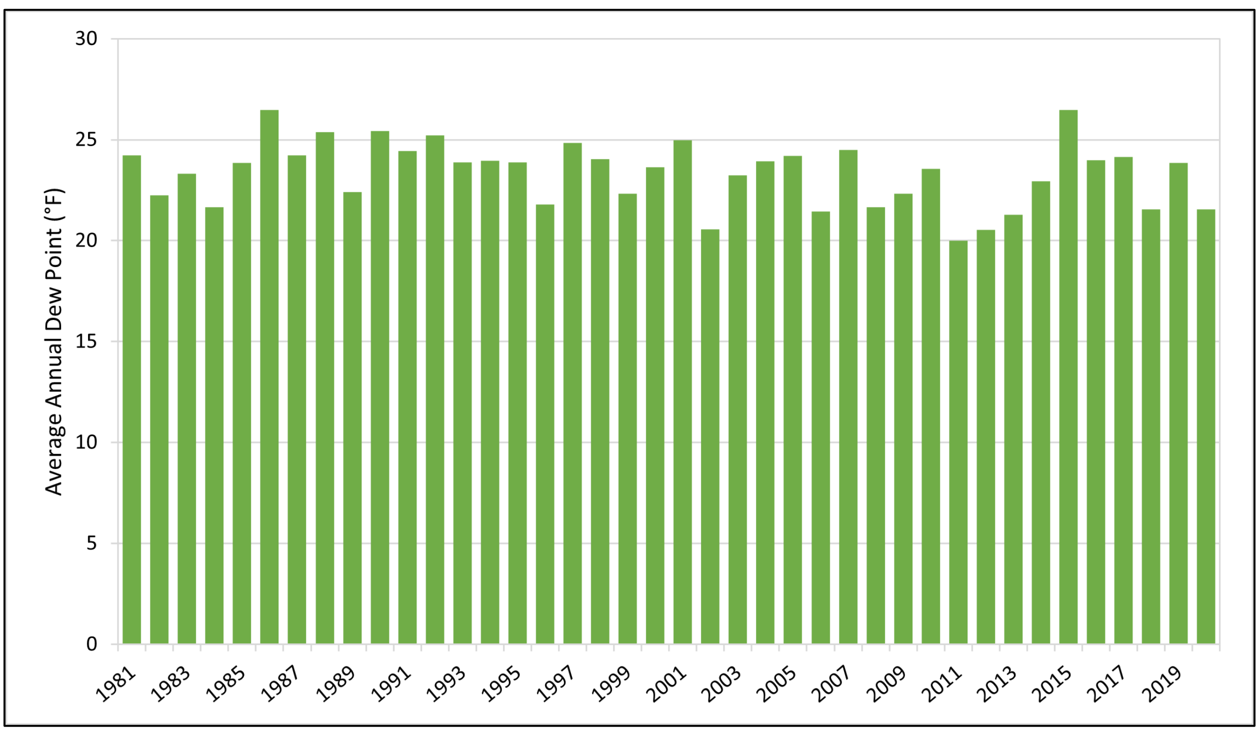

Figure 1.41: Average annual dew point temperature for the Santa Cruz Lake watershed from 1981 to 2020.

1.5.4 Shuree Pond North

There are no active USGS monitoring gages within the Shuree Pond North watershed, however reservoir storage data is available at the National Inventory of Dams (NID) website. Shuree Pond North is owned and operated by the US Forest Service, which list the normal reservoir storage at 40 acre-feet and the maximum reservoir storage at 54 acre-feet (NID 2021). These values are not actual observations, rather values based off the construction of the reservoir.

Based on the Koppen-Geiger climate classification system, the Shuree Pond North watershed exhibits a subarctic climate (Beck 2018). Precipitation patterns are heavily influenced by the North American Monsoon season, which typically lasts from early July through September. Due to its remote location, there are no weather stations in the Shuree Pond North watershed. Better estimates of area-weighted average climatic parameters, like precipitation, temperature, etc., can be extracted from the PRISM Climate Group's recent years modeled data (PRISM 2022), which integrates and interpolates weather station data from nearby weather stations. Considering the 40-year period from 1981 to 2020 (the most recent complete year available from PRISM at the time of this writing), annual precipitation ranged from a low of 14.24 inches in 2020 to a high of 27.98 inches in 1994 (**Figure 1.43**). Considering monthly precipitation, July and August are the wettest months, accounting for just over 30% of the annual precipitation on average (**Figure 1.42**). Average annual air temperatures have ranged from a low of 40.94 °F to a high of 45.10 °F in 2017 (**Figure 1.44**). Average annual dew point temperatures don't exhibit the same annual variations of precipitation and temperature, while average monthly dew point temperatures tend to follow air temperature values. Average annual dew point temperatures have ranged from a low of 18.69 °F in 2012 to a high of 25.16 °F in 1986 (**Figure 1.45**). Monthly average dew point temperatures range between 8.87 °F in January to 41.47 °F in August (**Figure 1.42**).

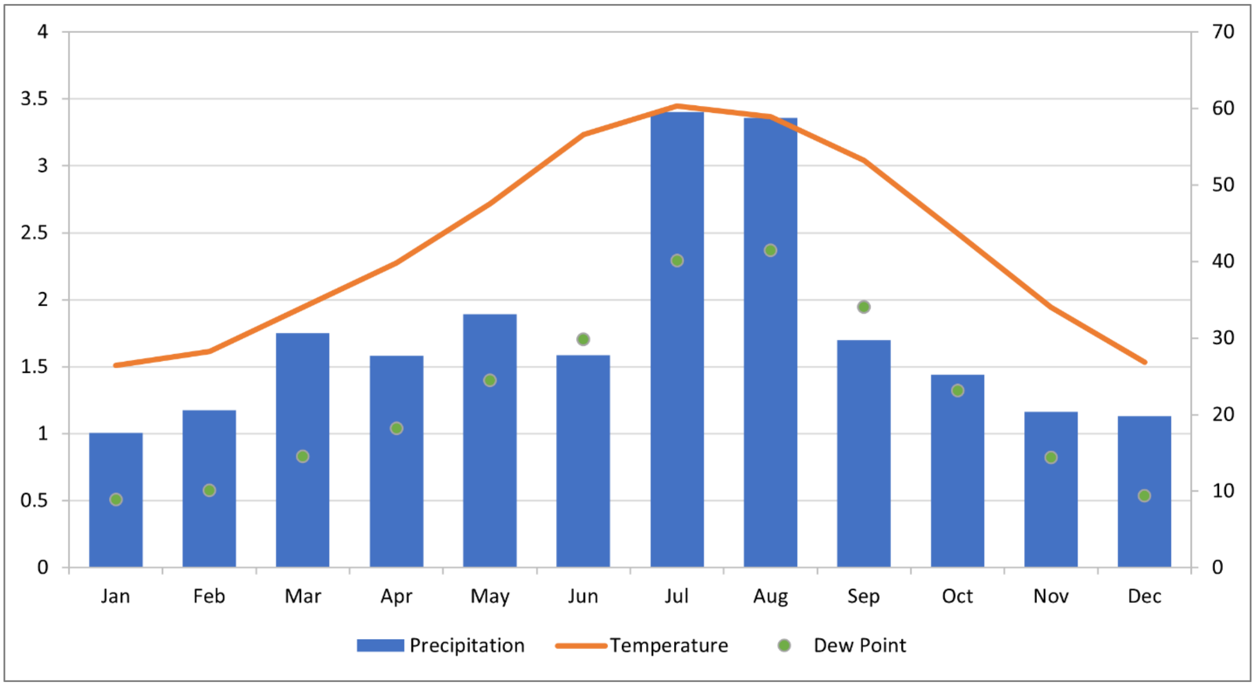

Figure 1.42: Climate overview of the Shuree Pond North watershed.

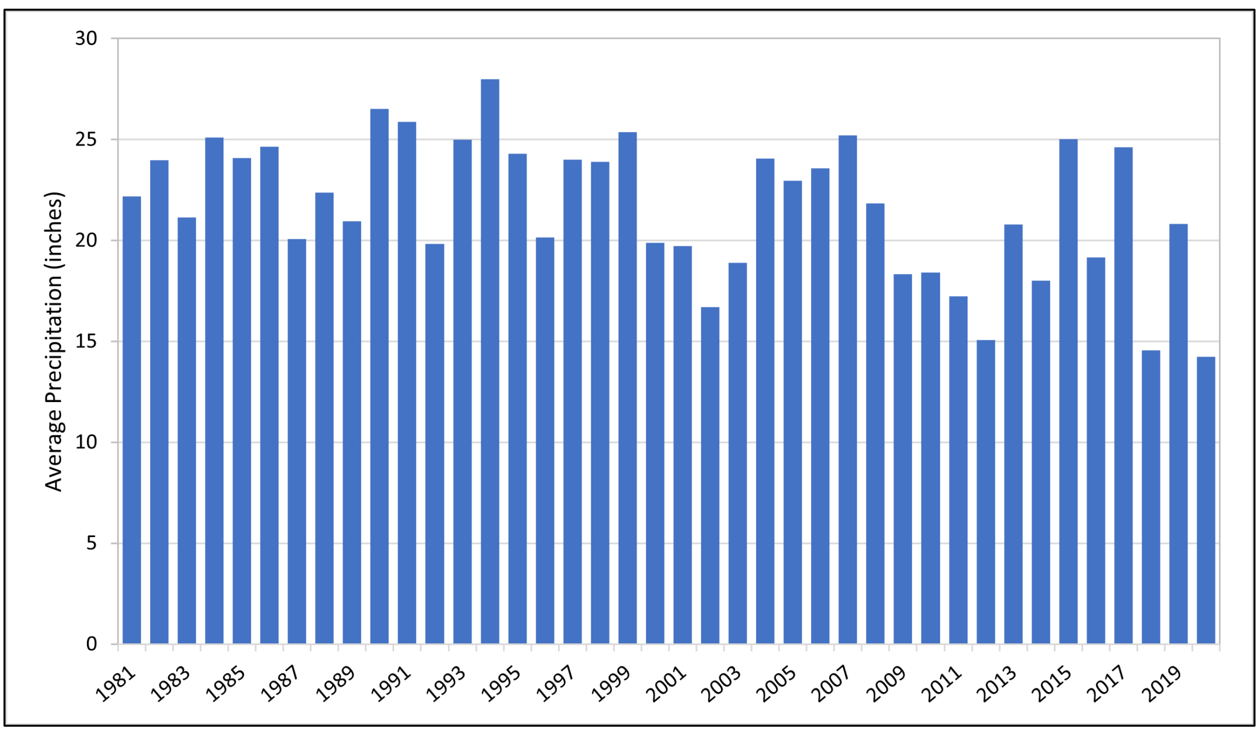

Figure 1.43: Average annual precipitation for the Shuree Pond North watershed from 1981 to 2020.

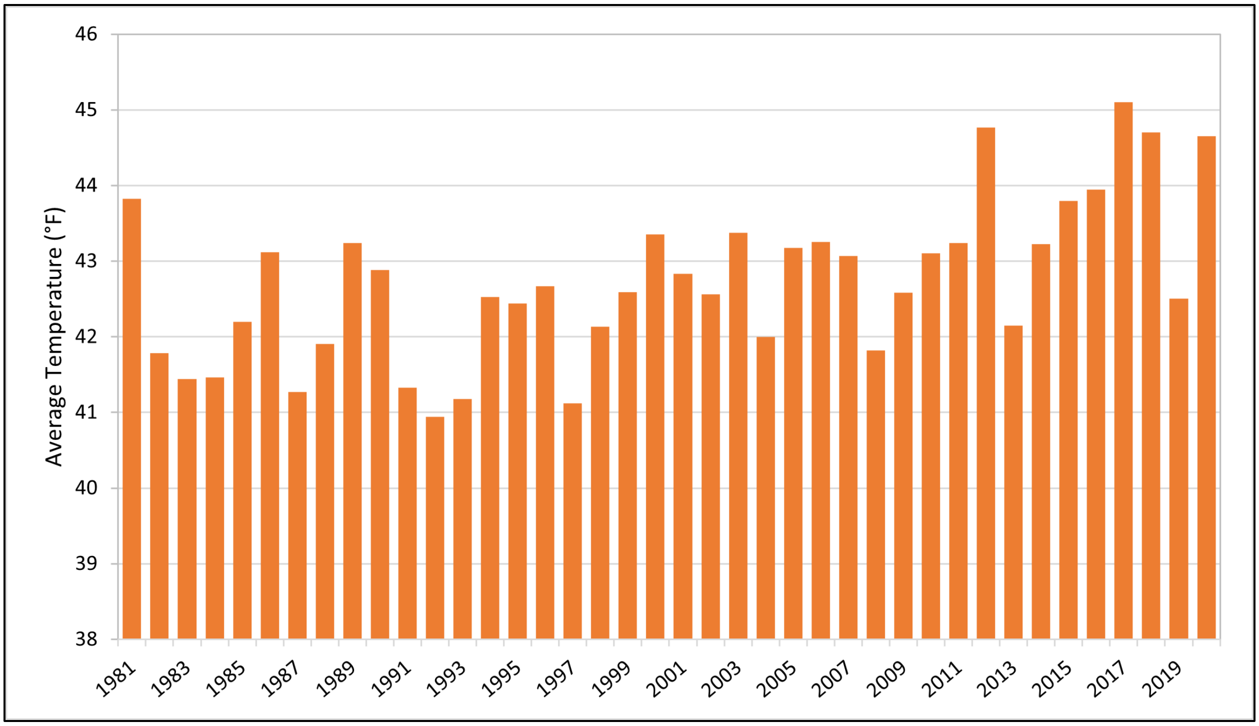

Figure 1.44: Average annual temperature for the Shuree Pond North watershed from 1981 to 2020.

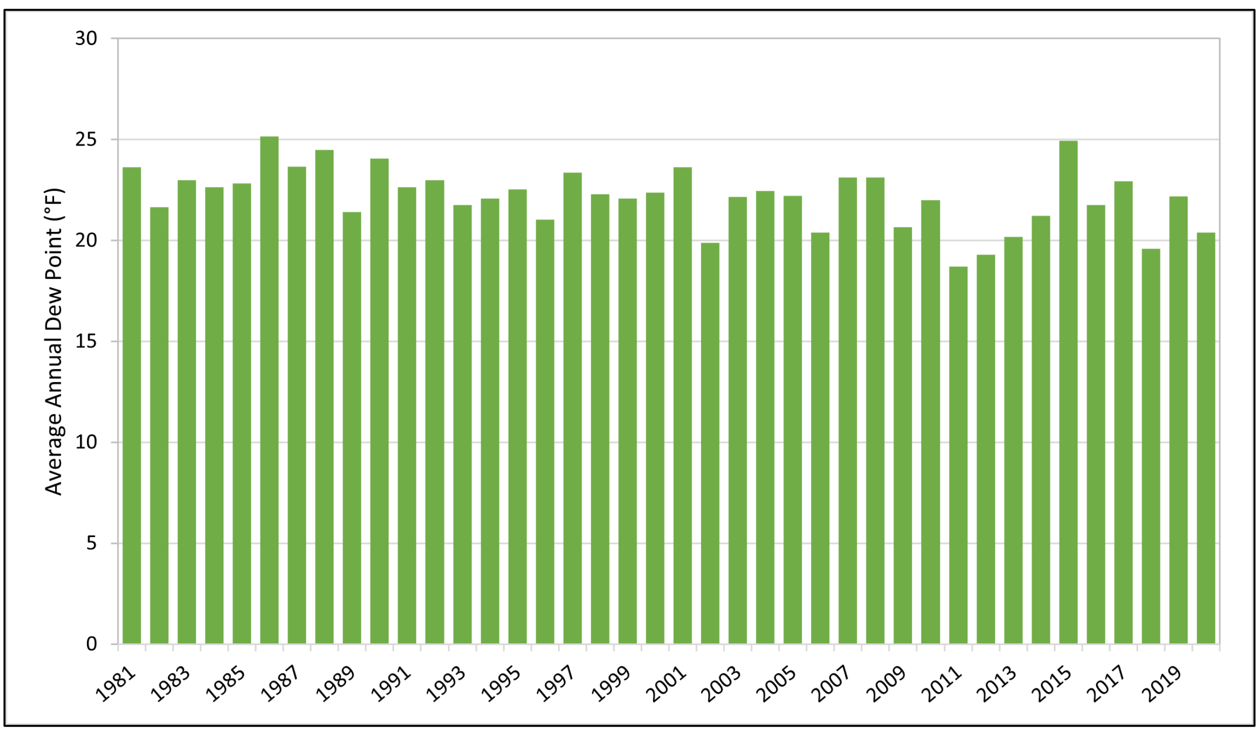

Figure 1.45: Average annual dew point temperature for the Shuree Pond North watershed from 1981 to 2020.

1.6 TMDL Uncertainties

Per EPA guidance (EPA 2002), TMDLs "should contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling." Uncertainties and assumptions in the TMDL process are detailed in the individual Margin of Safety subsections for each TMDL parameter. Uncertainties and assumptions related to the size of the available datasets and/or flow are detailed in the Target Loading Capacity and Flow subsections for each TMDL parameter. When modeling is used to develop a TMDL, water quality modeling results are summarized in the individual TMDL parameter sections and detailed in an appendix to the TMDL. In general, weaknesses in the TMDL analytical process include the limited availability of water quality data during the assessment process, limited flow and habitat measurements for TMDL development, and limited flow and water quality long-term gaging sites to be used during both the assessment and TMDL processes. Strengths in the TMDL analytical process include the robust assessment processes outlined in the Comprehensive Assessment and Listing Methodology (CALM) (NMED/SWQB 2021) especially related to assessments of narrative water quality standards, such as nutrients. Additional strengths include the use of regression equations to calculate TMDLs as well as the collection and subsequent discussion of NPDES permit effluent data as part of the TMDL development process.

2.0 Aluminum

Chronic high levels of aluminum (Al) can be toxic to fish, benthic invertebrates, and some single-celled plants. Aluminum concentrations from 0.1 to 0.3 mg/L (100 to 300 ug/L) increase mortality and retard growth, gonadal development, and egg production of fish. Information on the toxic forms of aluminum in natural waters suggest that soluble trivalent aluminum (Al^{3+}) exerts a toxic effect on fish by binding to the negative charge of gill tissues, thereby disrupting ionoregulatory and respiratory balance (Exley et al. 1991; Gensemer and Playle 1999). This charge interaction is complicated by subsequent polymerization of insoluble, positive-charged Al oxyhydroxides to fish gill tissues and thus both soluble and insoluble forms are implicated in the toxic response of fish to Al (Gensemer and Playle 1999).

In 2010, the WQCC updated the aquatic life use (ALU) criteria for aluminum from dissolved aluminum to hardness-dependent total recoverable aluminum (TR Al). In 2012, USEPA approved the change for use in waters where the pH is above 6.5. Aluminum-impaired waters of the Upper Rio Grande basin were within the applicable pH range during the 2017-2018 sampling events. The term "total recoverable" refers to the analytical method used in laboratory analysis and is essentially interchangeable with the term "total". "Total recoverable" is used here to reflect the language in 20.6.4.900.I NMAC, specifically, "For aluminum, the criteria are based on analysis of total recoverable aluminum in a sample that is filtered to minimize the mineral phase as specified by the department." Based on recommendations from an aluminum filtration study conducted by SWQB staff (NMED/SWQB 2012), if the turbidity exceeds 30 NTU, samples that will be analyzed for TR Al are filtered using a filter of 10 µm pore size that minimizes mineral-phase aluminum without restricting amorphous or colloidal phases. To be conservative, the TMDLs are calculated to protect against exceedance of the chronic criterion, which is more stringent than the acute criterion.

2.1 Target Loading Capacity

To meet aquatic life designated uses, the SWQB Comprehensive Assessment and Listing Methodology (NMED/SWQB 2023) says that for any one chemical/physical pollutant, there shall be no more than one exceedance of the acute criterion, and no more than one exceedance of the chronic criterion in three years. Exceedances of the WQS were identified by assessment of the data from the 2017-2018 SWQB Upper Rio Grande intensive water quality survey, as shown in **Table 2.1**. Consequently, Santa Cruz Lake was listed on the 2020-2022 Integrated CWA §303(d)/§305(b) List (NMED/SWQB, 2020) for aluminum. Results of laboratory analyses of the samples are shown in **Appendix A.**

Santa Cruz Lake was listed as impaired for TR Al in 2020, along with the Santa Cruz River AU upstream of the lake (NM-2118.A_51) and the Santa Cruz River AU downstream of the lake (NM-2111_50). A stream TMDL including the Santa Cruz River was written in 2022.

Table 2.1 Exceedances of the Hardness-based Total Recoverable Al WQS.

TMDL Watershed	Parameter	Exceedances (chronic)	Exceedances (acute)
Santa Cruz Lake	**Aluminum, Total Recoverable**	**2/4**	**1/4**

2.2 Flow

40 CFR 130.7(c)(1) requires states to calculate a TMDL using the critical conditions for stream flow, with TMDLs generally described in mass units per time (USEPA 2007). Given historic variability of reservoir levels, however, a single-value mass-based TMDL based on daily loading would only offer appropriate protections for a single reservoir level. A concentration-based TMDL would offer appropriate protections at all lake levels, therefore TMDLs for the impaired lakes included in this document are described first in concentrations per volume (**Table 2.3**) and second as mass-based values for average reservoir storage and the corresponding critical reservoir storage (**Table 2.4**).

Determining the critical flow conditions for a lake is more complex than simply considering low-flow conditions of a stream. Available data on reservoir storage varies greatly for the reservoirs and lakes across New Mexico. A review of USGS data from multiple reservoirs located across northern New Mexico and southern Colorado was used to determine critical conditions for reservoirs in this TMDL. The USGS average capacity was compared to the minimum observed capacity for the reservoirs included in the review. The average minimum observed capacity of the reservoirs was 9.86% of the USGS average capacity. For this TMDL, the critical conditions of the reservoirs will be listed as 10% of the average storage. **Table 2.2** describes the reservoir storage data available for Santa Cruz Lake. For ease of implementation, estimated surface water inputs of TR Al necessary to achieve concentration-based TMDL values are described in mass-based units for average reservoir storage values and critical conditions.

Table 2.2 Normal and critical reservoir storage for Santa Cruz Lake.

Reservoir/Lake	Data Source	Reservoir/Lake Volume (acre-feet)
Santa Cruz Lake (Average Storage)	Calculated based on ratio of surface area to storage volume (NHD and URS 2010)	3,005 acre-feet
Santa Cruz Lake (Critical Storage)	10% of calculated volume based on ratio of surface area to storage volume (NHD and URS 2010)	300.5 acre-feet

2.3 TMDL Calculations

The TMDL was calculated as a concentration based TMDL and a mass based TMDL. As described above, a concentration based TMDL will offer protection at all lake storage levels. For a concentration based TMDL, the water quality standard criteria as defined in 20.6.4 NMAC, will be the TMDL value. In **Equation 2.1,** the TMDL value would be the water quality standard criteria for TR Al and would be used to calculate the other remaining variables in the equation. Calculations of those variables are described below. Once concentration values have been determined for each part of **Equation 2.1**, conversions must be used to calculate the mass based TMDL. Detailed conversion tables are available in **Appendix B.**

This subsection describes the relationship between the numeric TR Al targets and the allowable pollutant-level by determining the total assimilative capacity of the waterbody, or loading capacity, for the pollutant. The loading capacity is the maximum amount of pollutant loading that a waterbody can receive while meeting its water quality objectives. The TMDLs for Santa Cruz Lake are as follows: first the Margin of Safety (MOS) is subtracted as described in Section 2.4, then the Waste Load Allocation (WLA) is subtracted as described in Section 2.5.1, and the remainder is the Load Allocation (LA) as described in Section 2.5.2 and **Equation 2.1**.

$$\mathbf{WLA + LA + MOS = TMDL} \qquad \textbf{(Eq. 2.1)}$$

TMDLs are presented below in **Table 2.3** as concentration-based values and in **Tables 2.4** as mass-based values for the average and critical reservoir storage. Chronic aluminum criteria were calculated at the average hardness value that was measured during the survey sampling events that resulted in exceedances of the WQS (data show in **Appendix A**). More information on this calculation is available in 20.6.4.900 NMAC, subsection I.

Table 2.3 Concentration-based TR Al TMDLs.

TMDL Watershed	MOS (mg/L)	LA (mg/L)	WLA (mg/L)	TMDL (mg/L)
Santa Cruz Lake	0.035	0.315	0	0.35

Table 2.4 Concentration-based TR Al TMDLs, expressed as masses for the average and critical reservoir storage values.

Reservoir Storage Volume	MOS (lbs/day)	LA (lbs/day)	WLA (lbs/day)	TMDL (lbs/day)
Santa Cruz Lake Average Storage (3005 acre-feet)	285.90	2573.07	0	2858.97
Santa Cruz Lake Critical Storage (300.5 acre-feet)	28.58	257.31	0	285.89

2.4 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For these TR Al TMDLs, the 10% MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- Conservative Assumptions
    - Treating TR Al as a pollutant that does not readily degrade in the environment.

- Explicit Recognition of Potential Errors
    - Uncertainty exists in sampling nonpoint sources of pollution. A conservative MOS for this element is therefore **5%**.
    - There is inherent variability in lake volumes, both measured and estimated. A conservative MOS for this element in lakes is **5%**.

2.5 Waste Load Allocations and Load Allocations

2.5.1 Waste Load Allocation

There are no active individual National Pollutant Discharge Elimination System (NPDES) permits that discharge to the aluminum impaired AUs, therefore the WLA for these TMDLs is zero.

Sediment and associated contaminants are considered components of industrial storm water discharges covered under NPDES General Permits. Stormwater discharges from construction activities are transient, occurring mainly during construction activity, and during storm events. Coverage under the NPDES Construction General Permit (CGP) for construction sites greater than one (1) acre, or less than one (1) acre if they are part of a common plan of development that will be equal to or greater than one (1) acre, requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The 2022 CGP also includes state-specific requirements for SWPPPs. The SWPPP must include site-specific interim and permanent stabilization, managerial, and structural solids, erosion and sediment control best management practices (BMPs) and/or other controls that are designed to prevent to the maximum extent practicable an increase in the sediment yield and flow velocity from pre-construction, pre-development conditions to assure that applicable standards in 20.6.4 NMAC, including the antidegradation policy, and TMDL WLAs are met. This requirement applies to discharges both during construction and after construction operations have been completed. Currently in the 2022 CGP, EPA defines "sediment-related parameter" as a pollutant parameter that is closely related to sediment such as turbidity, total suspended solids (TSS), total suspended sediment, transparency, sedimentation, and siltation. For discharge covered under the CGP to a water that is impaired for a parameter other than a sediment-related parameter or nutrients, EPA will inform the operator if any additional controls are necessary to meet water quality standards.

Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the 2021 NPDES Multi-Sector General Permit (MSGP). The MSGP also requires preparation of a SWPPP. Based on the industrial sector, some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values reflect State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. While these sources are not given individual allocations, they are addressed through other means, including BMPs, and other stormwater pollution prevention conditions. Implementation of a SWPPP that meets the requirements of a General Permit is generally assumed to be consistent with this TMDL. Loads that are in compliance with the General Permits are therefore currently included as part of the LA.

2.5.2 Load Allocations

The load allocation (LA) accounts for the non-point sources (NPS) of pollution in the respective watersheds. Nonpoint sources include all other categories not classified as point sources (i.e., WLAs). In order to calculate the LA, the WLAs and the MOS were subtracted from the TMDL using **Equation 2.2**.

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Eq. 2.2)}$$

therefore,

$$\mathbf{LA = TMDL - MOS - WLA}$$

2.5.3 Load Reductions

The load reductions necessary to meet target loads were calculated as the difference between the calculated daily target load and the mean measured load. Load reductions necessary are given as both concentrations (**Table 2.5**) and masses (**Table 2.6**).

Table 2.5: Calculation of load reduction for TR Al necessary to achieve target concentrations.

TMDL Watershed	Parameter	Target Concentration (mg/L)[a]	Mean Measured Concentration (mg/L)[b]	Concentration Reduction Necessary (mg/L)[c]	Percent Reduction Necessary[d]
Santa Cruz Lake	TR Al	0.315	0.87	0.555	64%

Notes: *(a)* Target Concentration = TMDL – MOS. The MOS is not included in the concentration reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured concentration.
(b) The measured concentration is the magnitude of point and nonpoint sources. It is calculated using mean measured exceedance values (Appendix A).
(c) Concentration reduction necessary is the concentration by which the existing measured concentration must be reduced to achieve the target concentration and is calculated as follows: Measured Concentration – Target Concentration.
(d) Percent reduction necessary is the percent the existing measured concentration must be reduced to achieve the target concentration and is calculated as follows: (Measured Concentration – Target Concentration) / Measured Concentration x 100.

Table 2.6: Calculation of surface runoff load reduction for TR Al necessary to achieve target concentrations, expressed as masses.

TMDL Watershed	Hardness (mg/L)	Target Load (lbs/day)[a]	Mean Measured Load (lbs/day)[b]	Load Reduction Necessary (lbs/day)[c]	Percent Reduction Necessary[d]
Santa Cruz Lake Average Storage (3005 acre-feet)	37	2573.07	7106.59	4533.52	64%
Santa Cruz Lake Critical Storage (300.5 acre-feet)	37	257.31	710.65	453.34	64%

Notes: *(a)* Target Concentration Mass = TMDL – MOS, expressed as mass based on lake storage volume. The MOS is not included in the load reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.
(b) The measured concentration mass is the magnitude of point and nonpoint sources, expressed as mass based on lake storage volume. It is calculated using mean measured exceedance values (Appendix A).
(c) Load reduction necessary as mass is the mass by which the existing measured concentration must be reduced to achieve the target concentration as mass and is calculated as follows: Measured Concentration as Mass – Target Concentration as Mass.
(d) Percent reduction necessary is the percent the existing measured load must be reduced to achieve the target load and is calculated as follows: (Measured Concentration Mass – Target Concentration Mass) / Measured Concentration Mass x 100.

2.6 Probable Pollutant Sources

SWQB conducted an assessment of the probable sources of impairment of the AUs draining into the nutrient impaired lakes according to Standard Operating Procedure 4.1, Revision 2, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; see also Appendix B). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 2.7 displays probable pollutant sources for all causes of impairment, including aluminum within each AU in the TMDL study areas, as determined by the field reconnaissance and knowledge of watershed activities. The draft probable source list will be reviewed and modified as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of impairment will be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 2.7 Probable Sources for Non-Point pollution in the Santa Cruz Lake watershed.

Lake Watershed	Probable Sources
Santa Cruz Lake	Angling Pressure; Dumping/Garbage/Trash/Litter; Fire Suppression (Thinning/Chemicals); Rangeland Grazing (dispersed); Bridges/Culverts/RR Crossings; Highway/Road/Bridge Runoff; Hiking Trails; Inappropriate Waste Disposal; Residences/Buildings; Logging Ops – Legacy; On-Site Treatment Systems (Septic, etc.); Paved/Gravel/Dirt Roads; Pavement/Impervious Surfaces; Site Clearance (Land Development); Waste from Pets (high concentration); Wildlife other than Waterfowl

2.7 Consideration of Seasonal Variation

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variation." Data used in the calculation of this TMDL were collected during the spring, summer, and fall to ensure coverage of any potential seasonal variation in the system. Exceedances were observed during spring and fall seasons, which captured lake storage level alterations related to the growing season and early monsoonal rains. The critical condition used for calculating the TMDL is considered to be conservative and protective of the water quality standard under all lake storage levels. Calculations made under average lake storage levels during the specific watershed monitoring survey, in addition to using other conservative assumptions as described in the previous section on MOS, should be protective of the water quality standards designed to preserve aquatic life in the lake. It was assumed that if critical conditions were met during this period, coverage of any potential seasonal variation would also be met.

2.8 Future Growth

Growth estimates for counties in New Mexico are available from the University of New Mexico (https://gps.unm.edu/pop/population-projections.html, accessed 02/14/2024). These estimates project growth to the year 2040. The county included in this TMDL are Santa Fe County and Mora County (including the Santa Cruz Lake watershed).

Table 2.8: Future growth estimates for Mora and Santa Fe counties.

County	Watershed	2020	2025	2030	2035	2040	% Increase (2020-2040)
Mora	Santa Cruz Lake	4,470	4,256	4,024	3,772	3,509	-21.50%
Santa Fe	Santa Cruz Lake	150,488	153,311	155,641	157,291	158,420	5.27%

Estimates of future growth are not anticipated to lead to a significant increase in nutrients that cannot be controlled with BMPs. However, it is imperative that BMPs continue to be utilized to improve road conditions and grazing allotments and adhere to SWPPP requirements related to construction and industrial activities covered under the general permit. Any future growth would be considered part of the existing load allocation, assuming persistence of the hydrologic conditions used to develop these TMDLs.

3.0 Plant Nutrients

Nutrient assessments for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North were included in the 2020-2022 CWA Integrated §303(d)/§305(b) List of Assessed Waters (NMED/SWQB 2020). Assessment of water quality data indicated impairments of total nitrogen (TN) of the CALM coldwater lake threshold of 0.9 mg/L in Eagle Nest Lake, Lake Maloya, and Shuree Pond North, impairments of total phosphorus (TP) of the CALM coldwater lake threshold of 0.03 mg/L in Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North (NMED/SWQB 2023).

Nitrogen and phosphorus are essential for proper functioning of aquatic ecosystems. However, nuisance levels of algae and other aquatic vegetation can develop rapidly in response to nutrient enrichment when other factors (e.g., light, temperature, substrate) are not limiting.

3.1 Target Loading Capacity

There are two potential causes of nutrient enrichment in any given water body: excessive phosphorus and/or nitrogen. Phosphorous is found in water primarily as orthophosphate. In contrast nitrogen may be found as several species, all of which must be considered in nutrient loading. Total nitrogen is defined as the sum of Nitrate + Nitrite (N+N) and Total Kjeldahl Nitrogen (TKN). Presently, there is no USEPA-approved method to test for total nitrogen, however adding the results of USEPA methods 351.2 (TKN) and 353.2 (N+N) is appropriate for estimating total nitrogen (APHA 1989). While not a USEPA-approved method, Method SM4500-N for Total Nitrogen using a persulfate digest, is an approved method in the SWQB QAPP (NMED/SWQB 2021) and is used in cases where a lower detection limit is needed.

The applicable threshold values for causal variables for lakes included in this nutrient TMDL are 0.9 mg/L for total nitrogen and 0.03 mg/L for total phosphorus based on the value identified for cold lakes in Appendix D of the 2023 CALM (NMED/SWQB 2023). Lakes included in the cold lake group are lakes with a designated use of High Quality Coldwater Aquatic Life and Coldwater Aquatic Life, which includes every lake in this TMDL (NMED/SWQB 2023). The nutrient threshold values were used for water quality assessments and as a starting point for TMDL development. For New Mexico lakes, potential numeric nutrient targets were collated from the water quality standards, SWQB analyses of existing data, other state agency examples or published literature. Colorado and Montana are two Mountain West states that have recently adopted numeric TN and TP standards. Colorado adopted interim nutrient limits which have a TN:TP ratio of 11.4 and 11.8 for warm and cold-water streams and rivers, respectively (Colorado Department of Public Health and Environment 2013). Montana's nutrient standards have TN:TP ratios that range from 2.4 to 13.3, with an average ratio of 7.6 (Montana Department of Environmental Quality 2014). Target values were selected for the CALM based on ecoregional considerations and best professional judgement. The target TN values is derived from change point and regression tree analyses of existing water quality data from New Mexico (Scott and Haggard 2011). The target TP value is derived from the boundary between mesotrophic and eutrophic lakes identified by Nurnberg (1996).

Table 3.1: Applicable nutrient-related thresholds for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North.

Ecoregion	21 – Southern Rockies (Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, Shuree Pond North) & 22 – Arizona/New Mexico Plateau (Santa Cruz Lake)
Aquatic Life Use	High Quality Coldwater (Eagle Nest Lake, Santa Cruz Lake, Shuree Pond North) & Coldwater (Lake Maloya)
Chlorophyll-*a*	≤ 7.5 µg/L[(a)]
Cyanobacteria	≤ 38%[(a)]
Dissolved Oxygen	6.0 mg/L[(a)]
Total Nitrogen	≤ 0.9 mg/L[(a)]
Total Phosphorus	≤ 0.03 mg/L[(a)]

Notes: (a) Threshold value identified for coldwater lakes in 2021 CALM.

During the 2015-2016 Canadian River watershed survey, including Eagle Nest Lake, Lake Maloya and Shuree Pond North, exceedances were observed in both the causal variables (total nitrogen and total phosphorus) and response variables (chlorophyll-*a*, cyanobacteria, dissolved oxygen, and pH). Eagle Nest Lake observed two exceedances (40%) of the total nitrogen threshold and six exceedances (100%) of the total phosphorus threshold (**Table 3.2**). In addition to the nutrient measurements, the response variables chlorophyll-*a*, cyanobacteria, and dissolved oxygen all also exceeded applicable thresholds (**Table 3.3**). pH measurements did not exceed the applicable threshold. Lake Maloya observed two exceedances (40%) of the total nitrogen threshold and two exceedances (40%) of the total phosphorus threshold (**Table 3.2**). In addition to the nutrient measurements, the response variables chlorophyll-a, cyanobacteria, dissolved oxygen, and pH all also exceeded applicable thresholds (**Table 3.3**). Shuree Pond North observed one exceedance (33%) of the total nitrogen threshold and two exceedances (66%) of the total phosphorus threshold (**Table 3.2**). In addition to the nutrient measurements, the response variables chlorophyll-a and pH both also exceeded applicable thresholds (**Table 3.3**). Cyanobacteria and dissolved oxygen concentration measurements did not exceed the applicable thresholds.

During the 2017-2018 Upper Rio Grande watershed survey, including Santa Cruz Lake, exceedances were observed for both the causal and response variables. Santa Cruz Lake observed no exceedances of the total nitrogen threshold and three exceedances (60%) of the total phosphorus threshold (**Table 3.2**). In addition to the nutrient measurements, the response variables chlorophyll-a, cyanobacteria, and dissolved oxygen all exceeded applicable thresholds (**Table 3.3**).

Table 3.2 Causal variable exceedance ratios[(a)] of applicable water quality criteria.

TMDL Watershed	Parameter	Associated Criterion/Threshold	Exceedance Ratio[(a)]
Eagle Nest Lake	Total Nitrogen	0.90 mg/L	2/5
	Total Phosphorus	0.03 mg/L	6/6
Lake Maloya	Total Nitrogen	0.90 mg/L	2/5
	Total Phosphorus	0.03 mg/L	2/5
Santa Cruz Lake	Total Nitrogen	0.90 mg/L	0/5
	Total Phosphorus	0.03 mg/L	3/5
Shuree Pond North	Total Nitrogen	0.90 mg/L	1/3
	Total Phosphorus	0.03 mg/L	2/3

Notes: (a) Exceedance ratio is the number of exceedances observed in the total number of samples.

Table 3.3 Response variable exceedance ratios[(a)] of applicable water quality criteria.

Parameter	Eagle Nest Lake	Lake Maloya	Santa Cruz Lake	Shuree Pond North
Chlorophyll-a	3/4	3/5	3/5	1/2
Cyanobacteria	4/6	1/4	3/5	0/2
Dissolved Oxygen (DO)	1/6	1/5	2/5	0/3
pH	0/5	1/5	0/4	2/3

Notes: (a) Exceedance ratio is the number of exceedances observed in the total number of samples.

3.2 Flow

40 CFR 130.7(c)(1) requires states to calculate a TMDL using the critical conditions for stream flow, with TMDLs generally described in mass units per time (USEPA 2007). Given historic variability of reservoir levels, however, a single-value mass-based TMDL based on daily loading would only offer appropriate protections for a single reservoir level. A concentration-based TMDL would offer appropriate protections at all lake levels, therefore TMDLs for the impaired lakes included in this document are described first in concentrations per volume (**Table 3.5a**) and second as mass-based values for average reservoir and the corresponding critical conditions (**Table 3.5b**).

Determining the critical flow conditions for a lake is more complex than simply considering low-flow conditions of a stream. Available data on reservoir storage varies greatly for the reservoirs and lakes across New Mexico. A review of USGS data for multiple reservoirs located across northern New Mexico and southern Colorado was used to determine critical conditions for reservoirs in this TMDL. The USGS average capacity was compared to the minimum observed capacity for the reservoirs included in the review. The average minimum observed capacity of the reservoirs was 9.86% of the USGS average capacity. For this TMDL, the critical conditions of the reservoirs will be listed as 10% of the average storage. **Table 3.4** describes the reservoir storage data available for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North. For ease of implementation, estimated surface water inputs of both TN and TP necessary to achieve concentration-based TMDL values are described in mass-based units for average reservoir storage values and critical conditions.

Table 3.4: Reservoir storage capacities.

Reservoir/Lake	Data Source	Reservoir/Lake Volume (acre-feet)
Eagle Nest Lake	2015-2016 Average Storage (USGS Gage: 07205500)	28,933 acre-feet
Eagle Nest Lake	10% of 2015-2016 Average Storage (USGS Gage: 07205500)	2,893.3 acre-feet
Lake Maloya	2015-2016 Average Storage (USGS Gage: 07199450)	3,620 acre-feet
Lake Maloya	10% of 2015-2016 Average Storage (USGS Gage: 07199450)	369 acre-feet
Santa Cruz Lake	Calculated based on ratio of surface area to storage volume (NHD and URS 2010)	3,005 acre-feet
Santa Cruz Lake	10% of calculated volume based on ratio of surface area to storage volume (NHD and URS 2010)	300.5 acre-feet
Shuree Pond North	Normal Storage (National Inventory of Dams)	40 acre-feet

Shuree Pond North	10% of Normal Storage (National Inventory of Dams)	4 acre-feet

3.3 TMDL Calculation

The TMDL was calculated as a concentration based TMDL and a mass based TMDL. As described above, a concentration based TMDL will offer protection at all lake storage levels. For a concentration-based lake nutrient TMDL, the water quality standard numeric criteria as defined in Appendix D of the NMED SWQB CALM or segment specific numeric criteria in 20.6.4 NMAC, will be the TMDL value (NMED/SWQB 2023). In **Equation 3.1,** the TMDL value would be the water quality standard criteria for TN or TP and would be used to calculate the other remaining variables in the equation. Calculations of those variables are described below. Once concentration values have been determined for each part of **Equation 3.1**, conversions must be used to calculate the mass based TMDL. Detailed conversion tables are available in **Appendix B.**

This subsection describes the relationship between the numeric nutrient targets and the allowable pollutant-level by determining the total assimilative capacity of the waterbody, or loading capacity, for the pollutant. The loading capacity is the maximum amount of pollutant loading that a waterbody can receive while meeting its water quality objectives. The TMDLs for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North are allocated as follows: first the Margin of Safety (MOS) is subtracted as described in Section 3.4, then the Waste Load Allocation (WLA) is subtracted as described in Section 3.5.1, and the remainder is the Load Allocation (LA) as described in Section 3.5.2 and **Equation 3.1**.

$$\mathbf{WLA + LA + MOS = TMDL} \qquad \textbf{(Eq. 3.1)}$$

Every lake has a specific carrying capacity for nutrients based on applicable WQS. This carrying capacity, or TMDL, is defined as the concentration of pollutant that can be carried without violating the target concentration for that constituent. These TMDLs were developed based on observed concentrations using lake storage values from **Table 3.4** and the numeric targets. The specific carrying capacity of a receiving water for a given pollutant was estimated using **Equation 3.1**. The calculated carrying concentrations (i.e., TMDLs) for TN and TP are summarized in **Table 3.7a**. The same calculated concentrations, expressed as masses for the lake storage values in **Table 3.4** are also summarized in **Table 3.7b.**

Table 3.5a: Concentration-based Plant Nutrient TMDLs.

TMDL Watershed	Parameter	MOS (mg/L)	LA (mg/L)	WLA (mg/L)	TMDL (mg/L)
Eagle Nest Lake	Total Nitrogen	0.090	0.810	0.000	0.900
	Total Phosphorus	0.003	0.027	0.000	0.030

Lake Maloya	Total Nitrogen	0.090	0.810	0.000	0.900
	Total Phosphorus	0.003	0.027	0.000	0.030
Santa Cruz Lake	Total Nitrogen	0.090	0.810	0.000	0.900
	Total Phosphorus	0.003	0.027	0.000	0.030
Shuree Pond North	Total Nitrogen	0.090	0.810	0.000	0.900
	Total Phosphorus	0.003	0.027	0.000	0.030

Table 3.5b: Concentration-based Plant Nutrient TMDLs, expressed as masses for average storage and critical storage.

Reservoir Storage Volume[(a)]	Parameter	MOS (lbs/day)	LA (lbs/day)	WLA (lbs/day)	TMDL (lbs/day)
Eagle Nest Lake 2015-2016 Average (28,933 acre-feet)	Total Nitrogen	7,078.37	63,705.34	0.00	70,783.71
	Total Phosphorus	235.95	2,123.51	0.00	2,359.46
Eagle Nest Lake 10% of 2015-2016 Average (2,893 acre-feet)	Total Nitrogen	707.83	6370.53	0.00	7078.36
	Total Phosphorus	23.59	212.35	0.00	235.94
Lake Maloya 2015-2016 Average (3620 acre-feet)	Total Nitrogen	885.62	7,970.60	0.00	8,856.22
	Total Phosphorus	29.52	265.69	0.00	295.21
Lake Maloya 10% of 2015-2016 Average (362 acre-feet)	Total Nitrogen	88.56	797.06	0.00	885.62
	Total Phosphorus	2.95	26.57	0.00	29.52
Santa Cruz Lake Normal Storage (3005 acre-feet)	Total Nitrogen	735.16	6,616.48	0.00	7,351.64
	Total Phosphorus	24.51	220.55	0.00	245.05
Santa Cruz Lake 10% of Normal Storage (300 acre-feet)	Total Nitrogen	73.51	661.65	0.00	735.16
	Total Phosphorus	2.45	22.05	0.00	24.50
Shuree Pond North Normal Storage	Total Nitrogen	9.79	88.07	0.00	97.86

(40 acre-feet)	Total Phosphorus	0.33	0.94	0.00	1.27
Shuree Pond North 10% of Normal Storage (4 acre-feet)	Total Nitrogen	0.979	8.807	0.00	9.786
	Total Phosphorus	0.033	0.094	0.00	0.127

Notes: *(a)* Reservoir Storage Volume is listed as the average reservoir storage (acre-feet) during the watershed surveys for Eagle Nest Lake, and Lake Maloya. Normal reservoir storage (acre-feet) for Santa Cruz Lake and Shuree Pond North were obtained from the National Inventory of Dams and represent the most accurate value for average reservoir storage. Critical conditions are 10% of either the average reservoir storage or the normal reservoir storage.

3.4 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For these nutrient TMDLs, the 10% MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- Conservative Assumptions
  - Treating phosphorus and nitrogen as pollutants that do not readily degrade in the environment.

- Explicit Recognition of Potential Errors
  - Uncertainty exists in sampling nonpoint sources of pollution. A conservative MOS for this element is therefore **5%.**
  - There is inherent variability in lake volumes, both measured and estimated. A conservative MOS for this element in lakes is **5%.**

3.5 Waste Load Allocations and Load Allocations

3.5.1 Waste Load Allocation

There are no National Pollutant Discharge Elimination System (NPDES) individual permits in the Lake Maloya, Santa Cruz Lake, and Shuree Pond North watersheds. There is one NPDES individual permit in the Eagle Nest Lake watershed (NPDES Permit: NM0060503) addressing total nitrogen and total phosphorus for the city of Angel Fire and its wastewater treatment plant effluent discharge. This permit and the associated WLA are included in the 2010 Cimarron River Watershed (Canadian River to Headwaters) TMDL for Cieneguilla Creek (NMED/SWQB 2010). Therefore, the WLA for this permit will not be included in the Eagle Nest Lake TMDL.

There are no Municipal Separate Storm Sewer System (MS4) permits in any of the lake watersheds included in this document. However, excess nutrient loading may be a component of some store water discharges covered under general NPDES permits. There may be storm water discharges from construction activities covered under the NPDES Construction General Permit (CGP). Permitted sites require preparation of a Stormwater Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs) and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions to assure that WLAs or applicable water quality standards, including the antidegradation policy, are met. Compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Stormwater discharges from active industrial facilities are generally covered under the current NPDES Multi-Sector General Permit (MSGP). This permit also requires preparation of an SWPPP, which includes specific requirements to limit (or eliminate) pollutant loading associated with the industrial activities in order to minimize impacts to water quality. Compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with these TMDLs.

It is not possible to calculate individual WLAs for facilities covered by these General Permits at this time using available tools. Loads that are in compliance with the General Permits are therefore currently included as part of the LA.

3.5.2 Load Allocation

The load allocation (LA) accounts for the non-point sources (NPS) of pollution in the respective watersheds. Nonpoint sources include all other categories not classified as point sources (i.e., WLAs). In order to calculate the LA, the WLAs and the MOS were subtracted from the TMDL using **Equation 3.2.**

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Eq. 3.2)}$$

therefore,

$$\mathbf{LA = TMDL - MOS - WLA}$$

3.5.3 Load Reductions

The load reductions necessary to meet target loads were calculated as the difference between the calculated daily target load and the measured load. Load reductions necessary are given as both concentrations (**Table 3.7a**) and masses (**Table 3.7b**).

Table 3.7a: Calculation of load reductions for TN and TP necessary to achieve target concentrations.

TMDL Watershed	Parameter	Target Concentration (mg/L)[a]	Mean Measured Concentration (mg/L)[b]	Concentration Reduction Necessary (mg/L)[c]	Percent Reduction Necessary[d]
Eagle Nest Lake	Total Nitrogen	0.810	0.900	0.090	10.0%
	Total Phosphorus	0.027	0.090	0.063	70.0%
Lake Maloya	Total Nitrogen	0.810	1.480	0.670	45.3%
	Total Phosphorus	0.027	0.051	0.024	47.1%
Santa Cruz Lake	Total Nitrogen	0.810	0.400	0.000	0.0%
	Total Phosphorus	0.027	0.031	0.004	12.9%
Shuree Pond North	Total Nitrogen	0.810	0.880	0.070	8.0%
	Total Phosphorus	0.027	0.049	0.022	44.9%

Notes: *(a)* Target Concentration = TMDL – MOS. The MOS is not included in the concentration reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured concentration.

(b) The measured concentration is the magnitude of point and nonpoint sources. It is calculated using mean measured exceedance values (Appendix A).

(c) Concentration reduction necessary is the concentration by which the existing measured concentration must be reduced to achieve the target concentration and is calculated as follows: Measured Concentration – Target Concentration.

(d) Percent reduction necessary is the percent the existing measured concentration must be reduced to achieve the target concentration and is calculated as follows: (Measured Concentration – Target Concentration) / Measured Concentration x 100.

Table 3.7b: Calculation of surface runoff load reductions for TN and TP necessary to achieve target concentrations, expressed as masses.

TMDL Watershed	Parameter	Target Load (lbs/day)[(a)]	Mean Measured Load (lbs/day)[(b)]	Load Reduction Necessary (lbs/day)[(c)]	Percent Reduction Necessary[(d)]
Eagle Nest Lake (2015-2016 Average Storage: 28,933 acre-feet)	Total Nitrogen	63,705	70,783	7,078	10.0%
	Total Phosphorus	2,123	7,078	4,954	70.0%
Lake Maloya (2015-2016 Average Storage: 3,620 acre-feet)	Total Nitrogen	7,970	14,563	6,592	45.3%
	Total Phosphorus	265	501	236	47.1%
Santa Cruz Lake (Calculated from NHD polygon and corresponding storage: 3005 acre-feet)	Total Nitrogen	6,616	3,267	0	0.0%
	Total Phosphorus	221	253	32	12.9%
Shuree Pond North (NID normal storage: 40 acre-feet)	Total Nitrogen	88.07	95.68	7.61	8.0%
	Total Phosphorus	2.93	5.33	2.39	44.9%

Notes: *(a)* Target Concentration Mass = TMDL – MOS, expressed as mass based on lake storage volume. The MOS is not included in the load reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.

(b) The measured concentration mass is the magnitude of point and nonpoint sources, expressed as mass based on lake storage volume. It is calculated using mean measured exceedance values (Appendix A).

(c) Load reduction necessary as mass is the mass by which the existing measured concentration must be reduced to achieve the target concentration as mass and is calculated as follows: Measured Concentration as Mass – Target Concentration as Mass.

(d) Percent reduction necessary is the percent the existing measured load must be reduced to achieve the target load and is calculated as follows: (Measured Concentration Mass – Target Concentration Mass) / Measured Concentration Mass x 100.

3.6 Probable Pollutant Sources

SWQB conducted an assessment of the probable sources of impairment of the AUs draining into the nutrient impaired lakes according to Standard Operating Procedure 4.1, Revision 2, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; see also **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 3.6 displays probable pollutant sources for all causes of impairment, including plant nutrients within each AU in the TMDL study areas, as determined by the field reconnaissance and knowledge of watershed activities. The draft probable source list will be reviewed and modified as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of impairment will be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 3.6: Probable Sources for the Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North watersheds.

Lake Watershed	Probable Sources
Eagle Nest Lake	Abandoned Mines (Inactive/Tailings); Active Mines (Gravel); Angling Pressure; Bridges/Culverts/RR Crossings; Campgrounds (Defined); Channelization; Crop Production (Cropland or Dry Land); Dams/Diversions; Dirt or Gravel Roads; Flow Alteration (from Water Diversions); Highway/Road/Bridge Runoff; Hiking Trails; Logging Ops – Legacy; Low Water Crossing; Municipal Point Source Discharge; On-Site Treatment Systems (Septic, etc.); Residences/Buildings; Rangeland Grazing (Dispersed); Site Clearance (Land Development); Storm Water Runoff due to Construction; Urban Runoff/Sewers; Waterfowl; Wildlife other than Waterfowl
Lake Maloya	Grazing in Riparian or Shoreline Zones; Highway/Road/Bridge Runoff (Non-Construction Related); Impervious Surface/Parking Lot Runoff; Off-Road Vehicles; Other Recreational Pollution Sources; Rangeland Grazing; Drought-Related Impacts; Unspecified unpaved road or trail; Waterfowl; Watershed Runoff Following Forest Fire; Wildlife other than Waterfowl

Santa Cruz Lake	Angling Pressure; Bridges/Culverts/RR Crossings; Dumping/Garbage/Trash/Litter; Hiking Trails; Fire Suppression (Thinning/Chemicals); Highway/Road/Bridge Runoff; Inappropriate Waste Disposal; Logging Ops – Legacy; On-Site Treatment Systems (Septic, etc.); Paved/Gravel/Dirt Roads; Pavement/Impervious Surfaces; Rangeland Grazing (dispersed); Residences/Buildings; Site Clearance (Land Development); Waste from Pets (high concentration); Wildlife other than Waterfowl
Shuree Pond North	Drought-Related Impacts; Forest Roads (Road Construction and Use); Grazing in Riparian or Shoreline Zones; Highway/Road/Bridge Runoff; Off-Road Vehicles; Other Recreational Pollution Sources; Rangeland Grazing; Unspecified Unpaved Road or Trail; Waterfowl; Wildlife other than Waterfowl

3.7 Linkage between Water Quality and Pollutant Sources

The source assessment phase of TMDL development identifies sources of nutrients that may contribute to both elevated nutrient concentrations and the stimulation of algal growth in a waterbody (**Figure 2.1**). Where data gaps exist or the level of uncertainty in the characterization of sources is large, the recommended approach to TMDL assignments requires the development of allocations based on estimates utilizing the best available information.

Phosphorus and nitrogen generally drive the productivity of algae and macrophytes in aquatic ecosystems, therefore they are regarded as the primary limiting nutrients in freshwaters. The main reservoirs of natural phosphorus are rocks and natural phosphate deposits. Weathering, leaching, and erosion are all processes that breakdown rock and mineral deposits allowing phosphorus to be transported to aquatic systems via water or wind. The breakdown of mineral phosphorus produces inorganic phosphate ions ($H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}) that can be absorbed by plants from soil or water (USEPA 1999). Phosphorus primarily moves through the food web as organic phosphorus (after it has been incorporated into plant or algal tissue) where it may be released as phosphate in urine or other waste by heterotrophic consumers and reabsorbed by plants or algae to start another cycle (Nebel and Wright 2000).

The largest reservoir of nitrogen is the atmosphere. About 80% of the atmosphere by volume consists of nitrogen gas (N_2). Although nitrogen is plentiful in the environment, it is not readily available for biological uptake. Nitrogen gas must be converted to other forms, such as ammonia (NH_3 and NH_4^+), nitrate (NO_3^-), or nitrite (NO_2^-) before plants and animals can use it. Conversion of gaseous nitrogen into usable mineral forms occurs through three biologically mediated processes of the nitrogen cycle: nitrogen fixation, nitrification, and ammonification (USEPA 1999). Mineral forms of nitrogen can be taken up by plants and algae and incorporated into their tissue. Nitrogen follows the same pattern of food web incorporation as phosphorus and is released in waste primarily as ammonium compounds. The ammonium compounds are usually converted to nitrates by nitrifying bacteria, making it available again for uptake, starting the cycle anew (Nebel and Wright 2000).

Rain, overland runoff, groundwater, drainage networks, and industrial and residential waste effluents transport nutrients to receiving waterbodies. Once nutrients have been transported into a waterbody they can be taken up by algae, macrophytes, and microorganisms either in the water column or in the benthos; they can sorb to organic or inorganic particles in the water column and/or sediment; they can accumulate or be recycled in the sediment; or they can be transformed and released as a gas from the waterbody (**Figure 2.1**).

As noted above, phosphorus and nitrogen are essential for proper functioning of ecosystems. However, excess nutrients cause conditions unfavorable for the proper functioning of aquatic ecosystems. Nuisance levels of algae and other aquatic vegetation (macrophytes) can develop rapidly in response to nutrient enrichment when other factors (e.g., light, temperature, substrate) are not limiting (**Figure 2.1**). The relationship between nuisance algal growth and nutrient enrichment in aquatic systems has been well documented in the literature (Welch 1992; Van Nieuwenhuyse and Jones 1996; Dodds et al. 1997; Chetelat et al. 1999). Unfortunately, the magnitude of nutrient concentration that constitutes an “excess” is difficult to determine and varies by ecoregion. The recommended level of total phosphorus to avoid algal blooms in nitrogen-limited ecosystems is 0.01 to 0.1 mg/L and 0.1 mg/L to 1 mg/L of total nitrogen. The upper end of these ranges also supports less biological diversity.

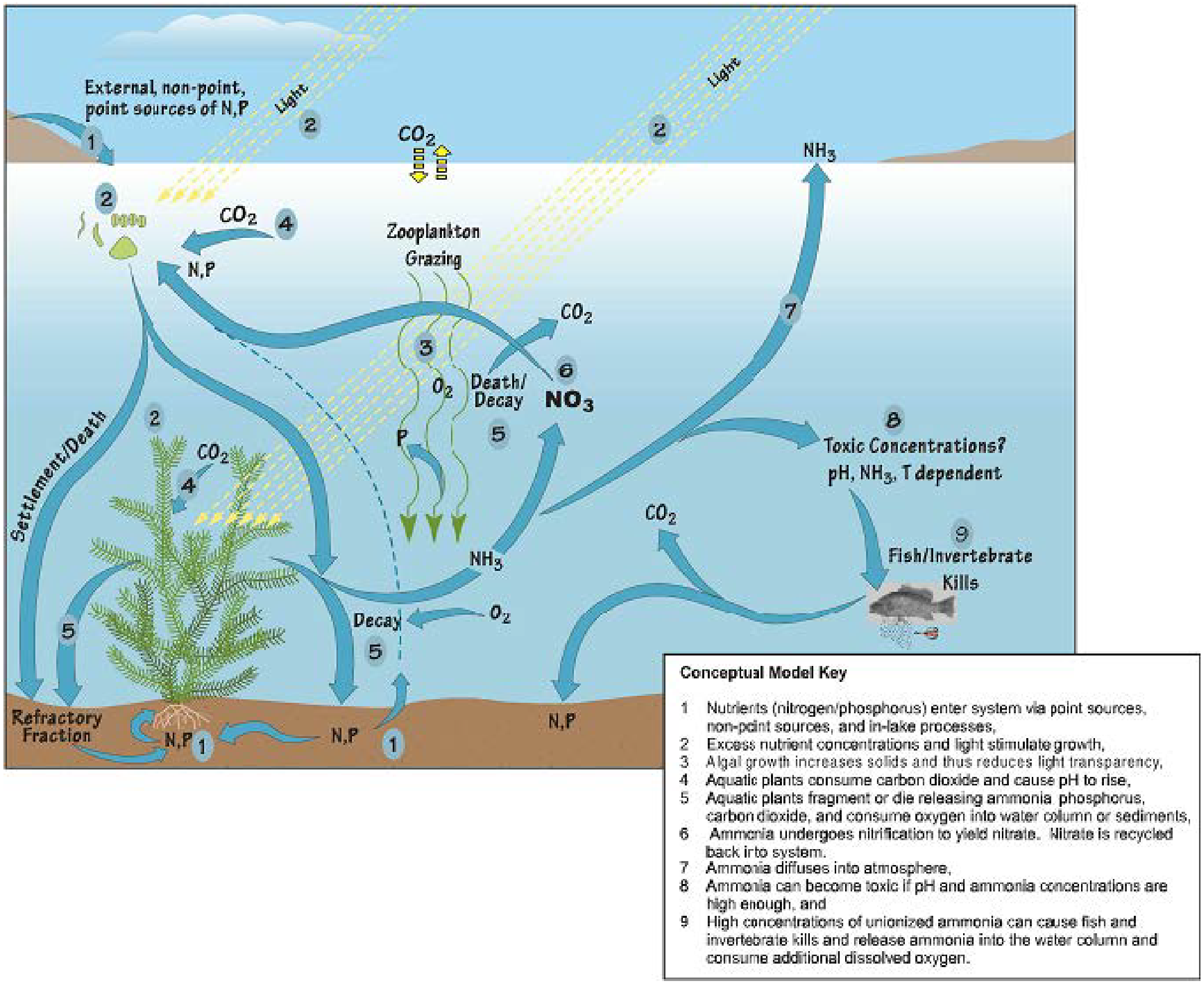

Figure 2.1: Nutrient conceptual model (USEPA 1999)

The presence of plant nutrients in a lake often varies primarily as a function of surface runoff nutrient concentrations, surface runoff volume, and the hydrologic residence time of the lake. As surface runoff nutrient concentrations increase and surface runoff volume decreases through water diversions and/or drought-related stressors, the lake cannot effectively dilute its constituents, causing the concentration of plant nutrients to increase. These in-lake nutrient increases can be further exacerbated if the hydrologic residence time of the lake increases due to impoundments and/or the lake volume drops due to drought-related stressors. Nutrients more readily reach a lake from land uses in close proximity to the lake because the hydrological pathways are shorter and have fewer obstacles than land uses located farther away from the lake. During periods of intense precipitation, such as that common to the monsoonal precipitation dynamics that define New Mexico's climate, distant land uses can become directly hydrologically connected to the lake, thus transporting nutrients to the lake from distant parts of the lake watershed. Additionally, any land cover transitions that reduce vegetation, especially near riparian corridors (e.g., ongoing and legacy grazing effects), and increase runoff ratios effectively serve to increase the nutrient transport capacity of surface runoff in both magnitude and distance.

3.8 Consideration of Seasonal Variability

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variation." Data used in the calculation of this TMDL were collected during the spring, summer, and fall to ensure coverage of any potential seasonal variation in the system. Exceedances were observed during summer and fall seasons, which captured lake storage level alterations related to the growing season and summer monsoonal rains. The critical condition used for calculating the TMDL is considered to be conservative and protective of the water quality standard under all lake storage levels. Calculations made under average lake storage levels during the specific watershed monitoring survey, in addition to using other conservative assumptions as described in the previous section on MOS, should be protective of the water quality standards designed to preserve aquatic life in the lake. It was assumed that if critical conditions were met during this time period, coverage of any potential seasonal variation would also be met.

3.9 Future Growth

Growth estimates for counties in New Mexico are available from the University of New Mexico (https://gps.unm.edu/pop/population-projections.html, accessed 02/14/2024). Growth estimates for counties in Colorado area available from the State Demography Office (https://data.colorado.gov/Demographics/Total-Population-by-County-by-Year/9dd2-kw29, accessed 02/14/2024). These estimates project growth to the year 2040. Counties included in this TMDL are Colfax County (including Eagle Nest Lake, Shuree Pond North, and Lake Maloya watersheds), Santa Fe County and Mora County (including Santa Cruz Lake watershed), and Las Animas County (including the Colorado potion of the Lake Maloya watershed).

Table 3.7: Future growth estimates for Colfax, Mora, Santa Fe and Las Animas (CO) counties.

County	Watershed	2020	2025	2030	2035	2040	% Increase (2020-2040)
Colfax	Eagle Nest Lake, Lake Maloya, Shuree Pond North	11,752	10,712	9,621	8,480	7,313	-20.75%
Mora	Santa Cruz Lake	4,470	4,256	4,024	3,772	3,509	-21.50%
Santa Fe	Santa Cruz Lake	150,488	153,311	155,641	157,291	158,420	5.27%
Las Animas (CO)	Lake Maloya	14,479	14,256	13,962	13,403	12,653	-12.61%

Estimates of future growth are not anticipated to lead to a significant increase in nutrients that cannot be controlled with BMPs. However, it is imperative that BMPs continue to be utilized to improve road conditions and grazing allotments and adhere to SWPPP requirements related to construction and industrial activities covered under the general permit. Any future growth would be considered part of the existing load allocation, assuming persistence of the hydrologic conditions used to develop these TMDLs.

4.0 Temperature

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Natural temperatures of a water body fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations but may affect existing community structure and geographical distribution of species. Anthropogenic impacts such as thermal pollution, deforestation, flow modification and climate change can modify these natural temperature cycles, often leading to deleterious impacts on aquatic life communities. Such modifications may contribute to changes in geographic distribution of species and their ability to persist in the presence of additional stressors such as introduced species. One mechanism by which temperature affects fish is that warmer water has a lower capacity for dissolved oxygen. In addition to direct effects, the toxicity of many chemical contaminants increases with temperature (Caissie 2006).

4.1 Target Loading Capacity

Fish and other aquatic organisms have specific ranges of temperature tolerance and preference. Cold water fish such as salmonids (salmon and trout) are especially vulnerable to increased water temperature. For that reason, coldwater criteria are typically designed primarily to support reproducing populations of salmonids. A coolwater Aquatic Life Use (ALU) was approved by the WQCC in October 2010, to support aquatic life whose physiologic tolerances are intermediate between those of warmwater and coldwater aquatic life (NMED/SWQB 2009). Acute temperature criteria (such as New Mexico's T_{MAX}) are intended to protect aquatic life from lethal exposures, whereas chronic criteria (the 4T3 or 6T3) protect from sub-lethal exposures sufficient to cause long-term detrimental effects (Todd *et al*. 2008). The acute and chronic criteria are established to protect the most sensitive members of fish communities, based on laboratory studies of the upper thermal limits of individual species.

ALU temperature water criteria differ for rivers or streams and lakes or reservoirs. When collecting river or stream temperature data, a thermograph is typically deployed to continuously measure temperature. When collecting lake or reservoir temperature data, a temperature reading is captured at every meter of the water column from the surface of the waterbody to the lakebed. The temperature profile is then examined for the presence of a thermocline (greater than 1°C change per meter). If a thermocline is present, then temperature measurements within the epilimnion (above the thermocline) are averaged. If no thermocline is detected (i.e., the lake is well mixed), measurements taken from the upper one-third of the water column are averaged (NMED/SWQB CALM 2023). The averaged temperature values are considered a "grab" sample, and this sample is used as an equivalent to the typical 4T3/6T3 criterion and is used to determine lake temperature impairments.

When assessing continuous temperature data, the 4T3 criterion means the threshold temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days, and the 6T3 criterion means the threshold temperature not to be exceeded for six or more consecutive hours in a 24-hour period on more than three consecutive days.

Table 4.1 Aquatic Life Use Temperature (°C) Water Quality Criteria for Lakes or Reservoirs

Criterion	High Quality Coldwater (HQCWL)	Coldwater (CWAL)	Marginal Coldwater (MCWAL)	Coolwater (CoolWAL)	Warmwater (WWAL)	Marginal Warmwater (MWWAL)
4T3 Equivalent[(a)]	20	---	---	---	---	---
6T3 Equivalent[(a)]	---	20	25	29	32.2	32.2

Notes: *(a)* The average temperature of the epilimnion or the upper 1/3 of the water column is used as a 4T3/6T3 equivalent when sampling lakes and reservoirs.

Assessment of the 2017-2018 Upper Rio Grande watershed lake temperature data determined that Santa Cruz Lake (HQCWL) was impaired for temperature. Temperature data are presented in **Appendix A.**

Table 4.2 Temperature criterion and exceedances for Santa Cruz Lake.

Lake	Designated ALU	Temperature Criterion (°C)	Exceedances
Santa Cruz Lake	High Quality Coldwater	20	2/5

4.2 Flow

40 CFR 130.7(c)(1) requires states to calculate a TMDL using the critical conditions for stream flow, with TMDLs generally described in mass units per time (USEPA 2007). Given historic variability of reservoir levels, however, a single-value mass-based TMDL based on daily loading would only offer appropriate protections for a single reservoir level. A concentration-based TMDL would offer appropriate protections at all lake levels, therefore TMDLs for the impaired lakes included in this document are described first in concentrations per volume (**Table 3.6a**) and second as mass-based values for average reservoir and the corresponding critical conditions (**Table 3.6b**).

Determining the critical flow conditions for a lake is more complex than simply considering low-flow conditions of a stream. Available data on reservoir storage varies greatly for the reservoirs and lakes across New Mexico. A review of USGS data for multiple reservoirs located across northern New Mexico and southern Colorado was used to determine critical conditions for reservoirs in this TMDL. The USGS average capacity was compared to the minimum observed capacity for the reservoirs included in the review. The average minimum observed capacity of the reservoirs was 9.86% of the USGS average capacity. For this TMDL, the critical conditions of the reservoirs will be listed as 10% of the average storage. **Table 4.3** describes the reservoir storage data available for Santa Cruz Lake. For ease of implementation, estimated surface water inputs of both TN and TP necessary to achieve concentration-based TMDL values are described in mass-based units for average reservoir storage values and critical conditions.

Table 4.3 Normal and critical reservoir storage for Santa Cruz Lake.

Reservoir/Lake	Data Source	Reservoir/Lake Volume (acre-feet)
Santa Cruz Lake (Average Storage)	Calculated based on ratio of surface area to storage volume (NHD and URS 2010)	3,005 acre-feet
Santa Cruz Lake (Critical Storage)	10% of calculated volume based on ratio of surface area to storage volume (NHD and URS 2010)	300.5 acre-feet

4.3 TMDL Calculations

The calculation for a temperature TMDL is expressed in **Equation 4.1**:

$$WQS(°C) \times Flow\ (cfs) \times (1.023 \times 10^{7}) = TMDL\ (kJ/day) \qquad \textbf{Eq. (4.1)}$$

For temperature TMDLs, the WQS criterion is the temperature specified either by the designated ALU or segment-specific criteria. For this lake TMDL, the critical flow is represented as 10% of the normal reservoir storage during the time temperature samples were taken. Reservoir storage is measured in acre-feet/day and must be converted to cubic feet/second (cfs) to be used in the temperature TMDL equation. **Appendix B** shows the conversion from acre-feet/day to cfs for Santa Cruz Lake. The conversion factor is the variable needed to correct the TMDL units to kJ/day. Details of the derivation of the temperature TMDL equation are presented in **Appendix E. Table 4.4** shows the TMDL calculation value for Santa Cruz Lake.

Table 4.4 Temperature TMDL calculation

Lake	Temperature Criterion (°C)	Critical Storage (cfs)	Conversion Factor	TMDL (kJ/day)
Santa Cruz Lake	20	151.61	1.023×10^{7}	3.10×10^{10}

The TMDL is further allocated to a Margin of Safety (MOS), Waste Load Allocation (WLA; permitted point sources), and Load Allocation (LA; nonpoint sources), according to **Equation 4.2**:

$$\textbf{WLA + LA + MOS = TMDL} \qquad \textbf{(Eq. 4.2)}$$

4.3.1 Margin of Safety

The CWA requires that each TMDL be calculated with a MOS, intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs, and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation.

Because of the uncertainty in determining the critical storage value of Santa Cruz Lake, an **explicit MOS of 5%** is being assigned. In recognition of the likelihood of future increases in air temperature and evaporative demand, an **additional explicit 10% MOS** is also being assigned to Santa Cruz Lake.

Table 4.5: MOS value for Santa Cruz Lake temperature TMDL

Lake	**MOS (15%)** (kJ/day)
Santa Cruz Lake	4.65×10^9

4.3.2 Waste Load Allocation

There are no active individual National Pollutant Discharge Elimination System (NPDES) individual permits that discharge to or upstream of Santa Cruz Lake. There are also no Municipal Separate Storm Sewer System (MS4) permits in this watershed. Therefore, no WLA is assigned.

There may be storm water discharges from industrial, including construction, activities covered under the National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP) or Multi-Sector General Permit (MSGP). Excess temperature loading may be a component of some storm water discharges covered under general NPDES permits. Stormwater discharges from industrial, including construction, activities are generally considered transient because they occur mainly during the construction itself and/or only during storm events.

Coverage under the USEPA NPDES CGP for construction sites one (1) acre or greater or smaller if part of a common plan of development require preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions. Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES MSGP. The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values reflect State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements. State certification of federal permits ensure that applicable water quality standards, including the antidegradation policy, are met. Compliance with a CGP or MSGP SWPPP that meets the requirements of the general permits is generally assumed to be consistent with this TMDL. Loads that are in compliance with the General Permits are therefore currently included as part of the LA.

4.3.3 Load Allocation

Load Allocation is pollution from any nonpoint source(s) or natural background and is addressed through Best Management Practices (BMPs). Since there are no WLAs in the Santa Cruz Lake watershed, the LA is equal to the TMDL value minus the MOS.

Table 4.5 Temperature TMDL load allocations.

Lake	MOS (kJ/day)	WLA (kJ/day)	LA (kJ/day)	TMDL (kJ/day)
Santa Cruz Lake	4.65×10^{9}	0	2.64×10^{10}	3.10×10^{10}

4.4 Probable Pollutant Sources

SWQB conducted an assessment of the probable sources of impairment of the AUs draining into the nutrient impaired lakes according to Standard Operating Procedure 4.1, Revision 2, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; see also **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 4.6 displays probable pollutant sources for all causes of impairment, including temperature within each AU in the TMDL study areas, as determined by the field reconnaissance and knowledge of watershed activities. The draft probable source list will be reviewed and modified as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of impairment will be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 4.6: Probable Sources for the Santa Cruz Lake watershed.

Lake Watershed	Probable Sources
Santa Cruz Lake	Angling Pressure; Bridges/Culverts/RR Crossings; Dumping/Garbage/Trash/Litter; Fire Suppression (Thinning/Chemicals); Highway/Road/Bridge Runoff; Hiking Trails; Inappropriate Waste Disposal; Logging Ops – Legacy; On-Site Treatment Systems (Septic, etc.); Paved/Gravel/Dirt Roads; Pavement/Impervious Surfaces; Rangeland Grazing (dispersed); Residences/Buildings; Site Clearance (Land Development); Waste from Pets (high concentration); Wildlife other than Waterfowl

4.5 Consideration of Seasonal Variation

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variation." Data used in the calculation of this TMDL were collected during the spring, summer, and fall to ensure coverage of any potential seasonal variation in the system. Exceedances were observed during the summer season, which captured lake storage level alterations related to the growing season and summer monsoonal rains. The critical condition used for calculating the TMDL is considered to be conservative and protective of the water quality standard under all lake storage levels. Calculations made under average lake storage levels during the specific watershed monitoring survey, in addition to using other conservative assumptions as described in the previous section on MOS, should be protective of the water quality standards designed to preserve aquatic life in the lake. It was assumed that if critical conditions were met during this time period, coverage of any potential seasonal variation would also be met.

4.6 Future Growth

Growth estimates for counties in New Mexico are available from the University of New Mexico (https://gps.unm.edu/pop/population-projections.html, accessed 02/14/2024). These estimates project growth to the year 2040. The county included in this TMDL are Santa Fe County and Mora County (including the Santa Cruz Lake watershed).

Table 4.7: Future growth estimates for Mora and Santa Fe counties.

County	Watershed	2020	2025	2030	2035	2040	% Increase (2020-2040)
Mora	Santa Cruz Lake	4,470	4,256	4,024	3,772	3,509	-21.50%
Santa Fe	Santa Cruz Lake	150,488	153,311	155,641	157,291	158,420	5.27%

Estimates of future growth are not anticipated to lead to a significant increase in nutrients that cannot be controlled with BMPs. However, it is imperative that BMPs continue to be utilized to improve road conditions and grazing allotments and adhere to SWPPP requirements related to construction and industrial activities covered under the general permit. Any future growth would be considered part of the existing load allocation, assuming persistence of the hydrologic conditions used to develop these TMDLs.

5.0 Monitoring

Pursuant to CWA Section 106(e)(1), 33 U.S.C. Section 1251, the SWQB has established appropriate monitoring methods, systems and procedures in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the New Mexico Water Quality Act, NMSA 1978, Sections 74-6-1 to -17, the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State.

The monitoring strategy establishes the methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of such controls, and to conduct water quality assessments. SWQB revised its 10-year monitoring and assessment strategy (NMED/SWQB 2016) and submitted it to USEPA Region 6 for review in June 2016. The strategy details both the extent of monitoring that can be accomplished with existing resources plus expanded monitoring strategies that could be implemented given additional resources. The SWQB utilizes a rotating basin approach to water quality monitoring. In this approach, a select number of watersheds are intensively monitored each year with an established return frequency of approximately every eight to ten years.

The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. This document, called the Quality Assurance Project Plan, is updated regularly, and approved by USEPA Region 6. In addition, the SWQB identifies the data quality objectives required to provide information of sufficient quality to meet the established goals of the program. Current priorities for monitoring in the SWQB are driven by the CWA Section 303(d) list of streams requiring TMDLs or TMDL alternatives; water bodies identified as needing ALU verification; the need to monitor unassessed perennial waters; and water bodies receiving point source discharge(s). Once assessment monitoring is completed, those reaches showing impacts and requiring a TMDL will be targeted for more intensive monitoring. The methods of data acquisition include fixed-station monitoring, intensive surveys of priority assessment units (including biological assessments), and monitoring of industrial, federal, and municipal dischargers, as specified in the SWQB Standard Operating Procedures.

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the water body and which can be revisited in accordance with the current monitoring strategy. This information will provide time relevant information for use in CWA Section 303(d) listing and 305(b) report assessments and to support the need for developing TMDLs. The approach provides:

- systematic, detailed review of water quality data which allows for a more efficient use of valuable monitoring resources;
- information at a scale where implementation of corrective activities is feasible;
- an established order of rotation and predictable sampling in each basin which allows for enhanced coordinated efforts with other programs; and
- program efficiency and improvements in the basis for management decisions.

It should be noted that a watershed would not be ignored during the years in between water quality surveys. The rotating basin program will be supplemented with other data collection efforts such as on-going studies being performed by the USGS and USEPA. Data will be analyzed, and field studies will be conducted to further characterize acknowledged problems and TMDLs will be developed and implemented accordingly. Both long-term and intensive field studies can contribute to the State's Integrated 303(d)/§305(b) listing process for waters requiring TMDLs.

6.0 Implementation of TMDLs

When approving TMDL documents, USEPA takes action on the TMDL, LA, WLA, and other components of the TMDL as needed (e.g., MOS and future growth). USEPA does not take action on the implementation section of the TMDL, and USEPA is not bound to implement any recommendations found in this section, in particular if they are found to be inconsistent with CWA and NPDES regulations, guidance or policy.

6.1 Point Sources – NPDES Permitting

There are no NPDES individual permits in the Lake Maloya, Santa Cruz Lake, or Shuree Pond North watersheds. There is one NPDES individual permit in the Eagle Nest Lake watershed: NPDES permit NM0030503 for the Village of Angel Fire wastewater treatment plant, permit effective date July 1, 2023 through June 30, 2028. NPDES permit NM0060503 includes phased effluent limits for total nitrogen and total phosphorus and a Total Phosphorous/Total Nitrogen Reduction Plan for the Village of Angel Fire Wastewater Treatment Plant effluent discharge. This permit and the associated WLA are included in the 2010 Cimarron River Watershed (Canadian River to Headwaters) TMDL for Cieneguilla Creek (NMED/SWQB 2010). Therefore, the WLA for this permit will not be included in this TMDL.

6.2 Nonpoint Sources

6.2.1 WBP and BMP Coordination

Public awareness and involvement will be crucial to the successful implementation of these plans and improved water quality. A WBP is a written plan intended to provide a long-range vision for various activities and management of resources in a watershed. It includes opportunities for private landowners and public agencies to reduce and prevent nonpoint source impacts to water quality. This long-range strategy will become instrumental in coordinating efforts to achieve water quality standards in the watershed. The WBP is essentially the Implementation Plan, or Phase Two, of the TMDL process. The completion of the TMDLs and WBPs leads directly to the development of on-the-ground projects to address surface water impairments in the watershed. BMPs to be considered as part of on-the ground-projects to address nutrients and other impairments include establishment of additional riparian vegetation and/or stream channel restoration work, grazing exclusions, and rangeland restoration aimed at slowing/reducing surface runoff to stream channels. Additional information about the reduction of nonpoint source pollution can be found online at: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution.

6.2.2 Clean Water Act 319(h) Funding

The Watershed Protection Section of the SWQB can provide USEPA Section 319(h) funding to assist in implementation of BMPs to address water quality problems on reaches listed as category 4 or 5 waters on the Integrated 303(d)/§305(b) list where WBPs have been developed or to complete BMP demonstration projects in areas without WBPs to encourage further planning and implementations in the watershed. These monies are available to all private, for-profit, and nonprofit organizations that are authenticated legal entities, or governmental jurisdictions including: cities, counties, tribal entities, federal agencies, or agencies of the state. Proposals are submitted through a Request for Proposal (RFP) process. Selected projects typically require a non-federal match, ranging between 10-40% of the total project cost consisting of funds and/or in-kind services. Funding is available, generally annually, for both watershed-based planning and on-the-ground projects to improve surface water quality and associated habitat. Further information on funding from the CWA Section 319(h) and announcements of funding opportunities can be found at the SWQB website: https://www.env.nm.gov/surface-water-quality/watershed-protection-section/.

6.2.3 Other Funding Opportunities and Restoration Efforts

Several other sources of funding exist to address impairments discussed in this TMDL document. NMED's Construction Programs Bureau assists communities in need of funding for WWTP upgrades and improvements to septic tank configurations. They can also provide matching funds for appropriate CWA Section 319(h) projects using state revolving fund monies. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP) program can provide assistance to private landowners in the basin for water quality and other natural resource improvement projects. The USDA Forest Service aligns their mission to protect lands they manage with the TMDL process and are another source of assistance. The US Bureau of Land Management (BLM) has several programs in place to provide assistance to improve unpaved roads and grazing allotments.

The SWQB annually makes available CWA Section 604(b) funds through a Request for Quotes (RFQ) process. The SWQB requests quotes from regional public comprehensive planning organizations to conduct water quality management planning as defined under Sections 205(j) and 303(e) and the CWA. The SWQB seeks proposals to conduct water quality management planning with a focus on projects that clearly address the State's water quality goals to preserve, protect and improve the water quality in New Mexico. The SWQB encourages proposals focused on TMDLs and UAAs or other water quality management planning activities that will directly address identified water quality impairments. The SWQB 604(b) RFQ is released annually in September.

In addition to CWA Section 319(h) grant funding, the Watershed Protection Section of the SWQB administers the state-funded River Stewardship Program as another source of funding for improving surface water quality and river habitat in New Mexico. The New Mexico Legislature appropriated $1,250,000 in state funds for the River Stewardship Program during the 2020 Legislative Session. The River Stewardship Program has the overall goal of addressing the root causes of poor water quality and stream habitat. Objectives of the River Stewardship Program include: "restoring or maintaining hydrology of streams and rivers to better handle overbank flows and thus reduce flooding downstream; enhancing economic benefits of healthy river systems such as improved opportunities to hunt, fish, float or view wildlife; and providing state matching funds required for federal CWA grants." Funding for the River Stewardship Program varies and ranges from $1,250,000 annually to over $10,000,000 appropriations to the program from various State sources, including capital outlay funds ($1,250,000 - $2,300,000 annually), Land of Enchantment Conservation Legacy funds ($1,250,000+ annually), and one-time special appropriations such as American Rescue Plan Act Coronavirus State and Local Fiscal Recovery Funds ($10,000,000 appropriation in 2022). A competitive Request for Proposals process is conducted annually or biannually to select projects for funding. Additional funding sources for watershed protection and improvement projects are listed in Appendix C of the New Mexico Nonpoint Source Management Plan, available at https://www.env.nm.gov/surface-water-quality/nps-plan.

Information on additional watershed restoration funding resources is available on the SWQB website at https://www.env.nm.gov/surface-water-quality/watershed-protection-section/.

6.3 QWET Modeling Concept Overview

These TMDLs were developed with the support of the Watershed Ecosystems Tool (WET), a graphical user interface (GUI) for the coupled one-dimensional hydrodynamic-ecosystems model GOTM-FABM-PCLake, which was developed by Aarhus University in Denmark to model a multitude of ecosystem parameters in lakes and reservoirs (Anders, 2017). WET can be accessed through the QGIS plugin QWET, which allows model creators to build the WET model within QGIS. Data needs to create a WET model range from simple estimates to continuous time series datasets. The Soil and Water Assessment Tool (SWAT) can also be used as input data for the WET model. The lakes included in this TMDL have a range of data availability ranging from detailed USGS gage stations to just a few hand measurements collected by NMED SWQB staff. Detailed information on specific input data for each lake model is available in **Appendix D**.

QWET models were created for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North to address impairment for nutrients and a QWET model was developed for Santa Cruz Lake to address impairment for temperature.

6.3.1.1 QWET Nutrient Modeling

The QWET nutrient models for Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North were created using various physical, chemical, and meteorological input data that is described in depth in **Appendix D**. The models were manually calibrated using grab sample measurements collected during two water quality surveys, the 2015-2016 Dry Cimarron and Canadian River survey and the 2017-2018 Upper Rio Grande survey. Details on calibrated data can be found in **Appendix D**. The models were run from 1995 to 2020 to predict average daily total phosphorus and total nitrogen levels for the lakes named above. Numerous inputs are used to calculate the lake nutrient concentration in the WET model, including nutrient loading values, model coefficients, lake volume and area, and meteorological conditions. QWET allows the model user to create different nutrient loading scenarios to evaluate the impacts non-point source nutrient increases or decreases will have to the overall total nitrogen (TN) and total phosphorus (TP) concentration values. Five nutrient parameters can be manipulated, organic phosphorus, phosphate, organic nitrogen, nitrate, and ammonia.

Nutrient reduction scenarios were created for each lake and for each TMDL and target concentration value specified in Chapter 3 of this document. To reach desired TN concentrations, organic nitrogen, nitrate, and ammonia values were reduced and to reach desired TP concentrations, organic phosphorus, and phosphate were reduced. A reduction scenario for Santa Cruz Lake’s TN concentration was not created because sampled data did not exceed the nutrient threshold.

6.3.1.1.1 Nutrient Results

Eagle Nest Lake

Multiple nutrient reduction scenarios were explored until modeled lake nutrient concentrations met both the TMDL and target concentration values. At the lakes current state, a 65% reduction in TN nutrient loading will result in Eagle Nest Lake achieving the TMDL of 0.90 mg/L and a 73% reduction in TN nutrient loading will result in Eagle Nest Lake achieving the target concentration of 0.81 mg/L. At the lakes current state, a 60% reduction in TP nutrient loading will result in Eagle Nest Lake achieving the TMDL of 0.03 mg/L and a 63% reduction in TP nutrient loading will result in Eagle Nest Lake achieving the target concentration of 0.027 mg/L.

Lake Maloya

Multiple nutrient reduction scenarios were explored until modeled lake nutrient concentrations met both the TMDL and target concentration values. At the lakes current state, a 72% reduction in TN nutrient loading will result in Lake Maloya achieving the TMDL of 0.90 mg/L and a 78% reduction in TN nutrient loading will result in Lake Maloya achieving the target concentration of 0.81 mg/L. At the lakes current state, a 32% reduction in TP nutrient loading will result in Lake Maloya achieving the TMDL of 0.03 mg/L and a 34% reduction in TP nutrient loading will result in Lake Maloya achieving the target concentration of 0.027 mg/L.

Santa Cruz Lake

Multiple nutrient reduction scenarios were explored until modeled lake nutrient concentrations met both the TMDL and target concentration values. At the lakes current state, a 55% reduction in TP nutrient loading will result in Santa Cruz Lake achieving the TMDL of 0.03 mg/L and a 60% reduction in TP nutrient loading will result in Santa Cruz Lake achieving the target concentration of 0.027 mg/L. Currently, Santa Cruz Lake does not exceed the 0.90 mg/L concentration threshold for TN. No modeling was needed to find nutrient reduction values for TN in Santa Cruz Lake.

Shuree Pond North

Multiple nutrient reduction scenarios were explored until modeled lake nutrient concentrations met both the TMDL and target concentration values. At the lakes current state, a 23% reduction in TN nutrient loading will result in Shuree Pond North achieving the TMDL of 0.90 mg/L and a 31% reduction in TN nutrient loading will result in Shuree Pond North achieving the target concentration of 0.81 mg/L. At the lakes current state, a 62% reduction in TP nutrient loading will result in Shuree Pond North achieving the TMDL of 0.03 mg/L and a 66% reduction in TP nutrient loading will result in Shuree Pond North achieving the target concentration of 0.027 mg/L.

6.3.1.2 QWET Temperature Modeling

Lake temperature is heavily influenced by solar radiation, air temperature, lake volume, and lake surface area, with limited influence from shoreline shading (Sharma et al., 2015). Lake temperature mitigation techniques are not as straight forward as stream temperature mitigation techniques. Forced mixing and dredging are examples of more immediate lake temperature mitigation strategies, however these mitigation strategies and their associated costs may be unrealistic for communities in New Mexico. Reducing lake temperatures needs to be approached at a watershed level or even larger. Multiple lake temperature studies have found that freshwater lakes are warming as global temperatures warm, especially alpine lakes because most alpine areas are experiencing higher rates of air temperature increases (Indicators of Climate Change in California, 2022). Actions that can be taken at the watershed level include reducing the temperature of inflowing water, improving riparian habitats, and controlling bank erosion (EPA, 2014).

The Santa Cruz Lake QWET temperature model was created using various physical, chemical, and meteorological input data that is described in depth in **Appendix D.** The model was manually calibrated using sonde measurements of lake temperature during the Upper Rio Grande 2017-2018 water quality survey. Detailed calibration data can be found in **Appendix D.** The model was run from 1995 to 2020 to predict average daily lake temperatures for Santa Cruz Lake. Cloud cover, air temperature, wind speed, and lake volume all contribute to lake temperature calculation in QWET, with air temperature being the most influential. QWET allows the model user to create different climate scenarios to the evaluate the impact of decreasing or increasing air temperatures on lake temperatures. There is no option to alter shoreline shading of the lakes because it would have minimal impact on the lake temperature.

6.3.1.2.1 Temperature Results

With a calibrated temperature model, different climate scenarios can be run within QWET to change the predicted lake temperature. Changes to temperature are determined monthly, so different temperature increases or decreases can be applied per month or season. The temperature model shows Santa Cruz Lake summer water temperatures typically peak around 25 degrees C. This is five degrees higher than the 20 degree C threshold for high quality coldwater aquatic life lakes (HQCWAL) in New Mexico (NMED SWQB 2023). The goal of creating the QWET temperature model for Santa Cruz Lake is to find out what decrease in air temperature needs to be achieved for Santa Cruz Lake to meet the 20 degree C water temperature threshold.

A decrease in summer air temperature was emphasized because that is when the lake exceeds the designated water temperature threshold. Many different climate scenarios were created, but the scenario that produced the best results was air temperature decreases of 2 degrees C from October through April and 8 degrees C from May through September. These are large air temperature decreases needed to obtain the HQCWAL temperature threshold and highlights the magnitude of the temperature impairment of Santa Cruz Lake. There is also initial work being done to study the attainability of Santa Cruz Lake as a HQCWAL designated lake, as it is the lowest elevation and furthest south HQCWAL lake in New Mexico.

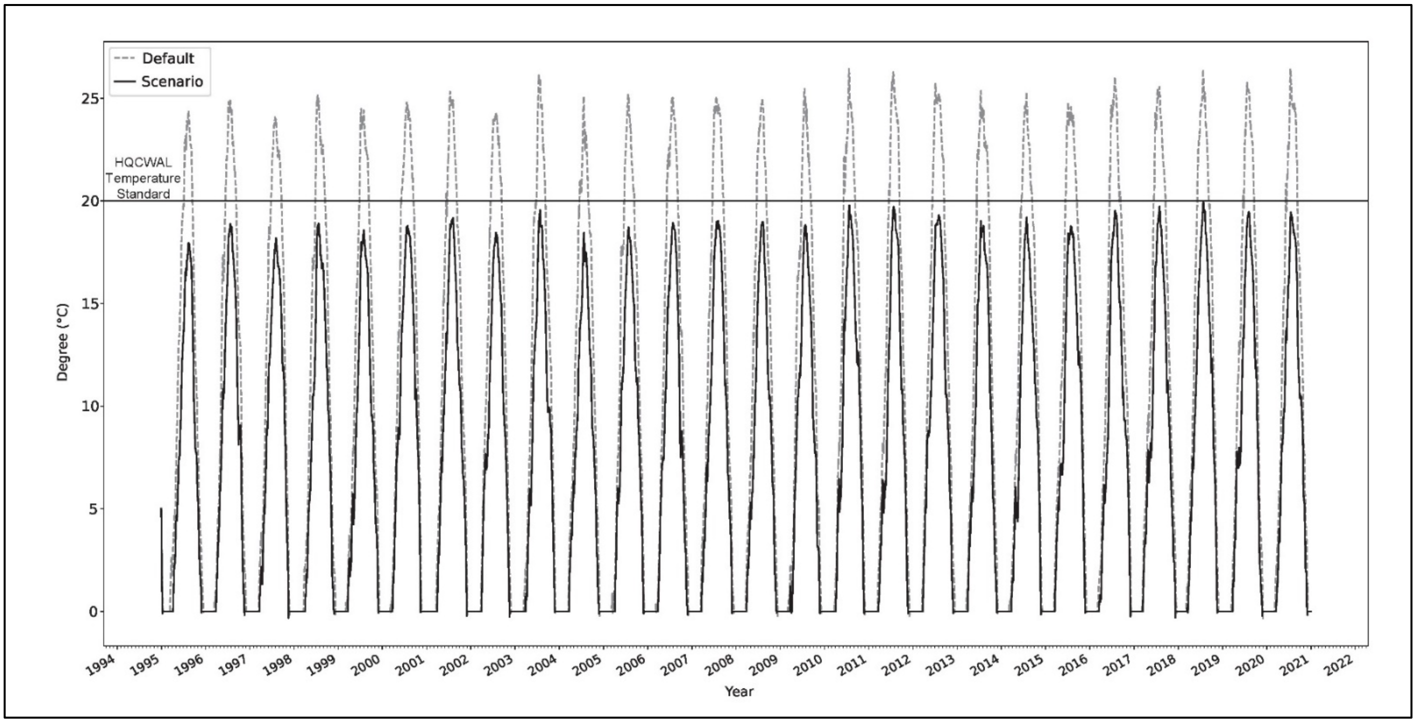

Figure 6.1: Comparison between the default (current) water temperature output and the water temperature output for the climate scenario of a decrease in air temperature of 2 degrees C from October through April and a decrease in air temperature of 8 degrees C from May to September. The black line at 20 degrees C shows the HQCWAL water temperature threshold.

7.0 Applicable Regulations and Reasonable Assurances

New Mexico's Water Quality Act, New Mexico Statutes Annotates (NMSA) 1978 Sections 74-6-1 to -17 (Act), authorizes the WQCC to "promulgate and publish regulation to prevent or abate water pollution in the state" and to require permits. The Act authorizes a constituent agency to take enforcement action against any person who violates a water quality standard. Several statutory provisions on nuisance law could also be applied to NPS water pollution. The Act also states in Section 74-6-12(A):

> *The Water Quality Act (this article) does not grant to the commission or to any other entity the power to take away or modify the property rights in water, nor is it the intention of the Water Quality Act to take away or modify such rights.*

In addition, the State of New Mexico Surface Water Quality Standards (20.6.4.6(C) NMAC) states:

> *Pursuant to Subsection A of Section 74-6-12 NMSA 1978, this part does not grant to the water quality control commission or to any other entity the power to take away or modify property rights in water.*

New Mexico policies are in accordance with the federal CWA Section 101(g):

It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by this Act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources.

New Mexico's CWA Section 319 Program has been developed in a coordinated manner with the State's CWA Section 303(d) process. All watersheds that are targeted in the annual §319 request for proposal process coincide with the State's biennial impaired waters list as approved by USEPA. The State has given a high priority for funding, assessment, and restoration activities to these watersheds.

As a constituent agency, NMED has the authority under NMSA 1978, Section 74-6-10 to issue a compliance order or commence civil action in district court for appropriate relief if NMED determines that actions of a "person" (as defined in the Act) have resulted in a violation of a water quality standard including a violation caused by a NPS. The NMED NPS water quality management program has historically strived for and will continue to promote voluntary compliance to NPS water pollution concerns by utilizing a voluntary, cooperative approach. The State provides technical support and grant monies for implementation of BMPs and other NPS prevention mechanisms through Section 319 of the CWA. Since portions of this TMDL will be implemented through NPS control mechanisms, the New Mexico Watershed Protection Program will target efforts to this and other watersheds with TMDLs.

In order to obtain reasonable assurances for implementation in watersheds with multiple land owners, including federal, state, and private land, NMED has established Memoranda of Understanding (MOUs) with various federal agencies, in particular the U.S. Forest Service and the BLM. MOUs have also been developed with other state agencies, such as the New Mexico Department of Transportation. These MOUs provide for coordination and consistency in dealing with NPS issues.

The time required to attain standards for all reaches is estimated to be approximately 10-20 years. This estimate is based on a five-year time frame implementing several watershed projects that may not be starting immediately or may be in response to earlier projects. Stakeholders in this process will include the SWQB, and other parties identified in the WBP. The cooperation of watershed stakeholders will be pivotal in the implementation of these TMDLs as well.

8.0 Public Participation

Public participation was solicited in development of this TMDL, pursuant to CWA §303(d) and Section XIV of the New Mexico Statewide Water Quality Management Plan and Continuing Planning Process. The draft TMDL was made available for a 30-day comment period beginning April 15th and ending May 15th at 5:00 pm. The draft document Notice of Availability was advertised via email distribution lists and webpage postings. Two virtual public meetings were attended by ## stakeholders on May 1st.

A response to public comments will be added to the TMDL document as **Appendix F**.

Once the TMDL is approved by the EPA, the next step for public participation will be development of WBPs and water quality restoration projects, including those that may be funded by CWA Section 319(h) grants managed by SWQB.

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Appendix A: Water Quality Data

Total recoverable aluminum data:

Exceedances of the applicable criteria are shown in bold red font.

Santa Cruz Lake (AU: NM-2118.B_00)

Date	Hardness (mg/L)	Acute criterion (mg/L)	Chronic criterion (mg/L)	TR Al (mg/L)
3/30/17	32	0.718	0.288	**0.98**
10/16/17	43	1.08	0.431	**0.76**
4/11/18	42	1.04	0.418	0.04
7/24/18	82	2.61	1.04	0.38

Mean hardness of samples with WQS exceedance = 37 mg/L

Plant nutrients data:

Exceedances of the applicable criteria are shown in bold red font.

Eagle Nest Lake (AU: NM-2306.B_00)

Applicable Thresholds: TN (0.9 mg/L) , TP (0.03 mg/L)

Date	TN (mg/L)	TP (mg/L)
4/9/15	**1.07**	**0.066**
10/29/15	**1.17**	**0.137**
5/16/16	0.61	**0.049**
7/20/16	0.79	**0.055**
9/27/16	0.68	**0.116**
11/1/16	MDP	**0.142**

Lake Maloya (AU: NM-2305.B_20)

Applicable Thresholds: TN (0.9 mg/L), TP (0.03 mg/L)

Date	TN (mg/L)	TP (mg/L)
4/8/15	0.71	0.029
10/28/15	**4.08**	0.03
5/5/16	**0.95**	0.03
8/12/16	0.79	**0.048**
10/19/16	0.89	**0.12**

Santa Cruz Lake (AU: NM-2118.B_00)

Applicable Thresholds: TN (0.9 mg/L), TP (0.03 mg/L)

Date	TN (mg/L)	TP (mg/L)
3/30/17	0.49	**0.039**
8/3/17	0.37	0.018
10/16/17	0.424	**0.04**
4/11/18	0.25	0.011
7/24/18	0.45	**0.047**

Shuree Pond North (AU: NM-2306.B_30)
Applicable Thresholds: TN (0.9 mg/L), TP (0.03 mg/L)

Date	TN (mg/L)	TP (mg/L)
10/14/15	**1.18**	0.018
8/22/16	0.75	**0.05**
10/25/16	0.71	**0.078**

Temperature data:

Exceedances of the applicable criteria are shown in bold red font.

Santa Cruz Lake (AU: NM-2118.B_00)

Designated ALU: High Quality Coldwater

Temperature Criterion[(a)] (°C): 20

Date	Measured Temperature (°C)
3/30/17	7.58
8/3/17	**21.34**
10/16/17	13.72
4/11/18	12.09
7/24/18	**23.77**

Appendix B : Conversion Tables

Conversion calculations for converting nutrient TMDL values from concentration based to mass based.

Watershed	Parameter	TMDL (mg/L)	mg/L to lbs/L	lbs/L	lbs/L to lbs/acre-feet	lbs/acre-feet	lbs/acre-feet to lbs	TMDL (lbs/day)
Eagle Nest Lake (28,933 acre-feet)	TN	0.9	0.9 / 453592.33[(a)]	1.98416E-06	1.98416E-08 * 1233000[(b)]	2.446469939	2.446469939 * 28933[(c)]	70783.71
	TP	0.03	0.03 / 453592.33[(a)]	6.61387E-08	6.61387E-08 * 1233000[(b)]	0.081548998	0.081548998 * 28933[(c)]	2359.46
Lake Maloya (3,620 acre-feet)	TN	0.9	0.9 / 453592.33[(a)]	1.98416E-06	1.98416E-08 * 1233000[(b)]	2.446469939	2.446469939 * 3620[(c)]	8856.22
	TP	0.03	0.03 / 453592.33[(a)]	6.61387E-08	6.61387E-08 * 1233000[(b)]	0.081548998	0.081548998 * 3620[(c)]	295.21
Santa Cruz Lake (3,005 acre-feet)	TN	0.9	0.9 / 453592.33[(a)]	1.98416E-06	1.98416E-08 * 1233000[(b)]	2.446469939	2.446469939 * 3005 [(c)]	7351.64
	TP	0.03	0.03 / 453592.33[(a)]	6.61387E-08	6.61387E-08 * 1233000[(b)]	0.081548998	0.081548998 * 3005[(c)]	245.05
Shuree Pond North (40 acre-feet)	TN	0.9	0.9 / 453592.33[(a)]	1.98416E-06	1.98416E-08 * 1233000[(b)]	2.446469939	2.446469939 * 40 [(c)]	97.86
	TP	0.03	0.03 / 453592.33[(a)]	6.61387E-08	6.61387E-08 * 1233000[(b)]	0.081548998	0.081548998 * 40[(c)]	3.26

Notes: *(a)* 453592.33 is the conversion factor used to convert mg/L to lbs/L. The concentration based TMDL values (mg/L) are divided by the conversion factor (453592.33). The new value is the concentration based TMDL but expressed as lbs/L.

(b) 1233000 is the conversion factor used to convert lbs/L to lbs/acre-feet. The concentration based TMDL values (lbs/L) are multiplied by the conversion factor (1233000). The new value is the concentration based TMDL but expressed as lbs/acre-feet.

(c) To convert the TMDL values from concentration based to a mass, the lbs/acre-feet value must be multiplied by the volume of the lake (acre-feet). This equation gives the TMDL value as a mass, expressed in pounds per day in relation to the volume of the lake.

Conversion of lake volume from acre-feet/day to cubic feet/sec for lake temperature TMDL.

Santa Cruz Lake Critical Storage (acre-feet/day)	Conversion Factor (acre-feet/day to cubic-feet/second)	Santa Cruz Lake Critical Storage (cubic-feet/second)
300.5	0.50451	151.61

Notes: (a) To convert a lake volume from acre-feet/day to cubic-feet/second, multiply the lake volume (acft/day) by the conversion factor (0.50451). This equals the lake volume in cubic-feet/second.

Appendix C: Source Documentation

The approach for identifying probable sources of impairment is documented in SWQB Standard Operating Procedure (SOP) 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-waterquality/sop/). "Sources" are defined as activities that may contribute pollutants or stressors to a water body (USEPA, 1997). The list of "Probable Sources of Impairment" in the Integrated 303(d)/305(b) List, Total Maximum Daily Load documents (TMDLs), and Watershed-Based Plans (WBPs) is intended to include any and all activities that could be contributing to the identified cause of impairment, which are supported by evidence strong enough to establish presumption but not proof. Probable Source categories are selected from Appendix A of SOP 4.1, which was adapted from the EPA ATTAINS database.

USEPA, through guidance documents, strongly encourages states to include a list of Probable Sources for each listed impairment. According to the 1998 Section 305(b) report guidance, "…, states must always provide aggregate source category totals…" in the biennial submittal that fulfills CWA section 305(b)(1)(C) through (E) (USEPA, 1997). The list of "Probable Sources" is not intended to single out any particular landowner or single land management activity and has therefore been labeled "Probable" and generally includes several sources for each known impairment.

Any new impairment listing will be assigned a Probable Source of "Source Unknown." During sampling events, Monitoring Team staff select applicable Probable Sources from a drop-down menu on the Stream/River Field Data Form. Information gathered by the Monitoring Team is used to generate a draft Probable Source list in consequent TMDL planning documents. The TMDL writer then revises the list using aerial imagery, Geographic Information System data, and other available records. The list is also reviewed by Watershed Protection Section staff with knowledge of the AU and watershed. These draft Probable Source lists will be finalized with watershed group/stakeholder input during the pre-survey public meeting, TMDL public meeting, WBP development, and various public comment periods. The Probable Source list in the approved TMDL will be used to update the subsequent Integrated List.

Data on Probable Sources gathered by Monitoring and Assessment Section staff and Watershed Protection Section staff during water quality surveys and watershed restoration projects is housed in the NMED Surface Water Quality Information Database (SQUID). More specific information on Probable Sources of Impairment is provided in individual watershed planning documents (e.g., TMDLs, WBPs, etc.) as they are prepared to address individual impairments by AU.

Literature Cited:

USEPA. 1997. Guidelines for preparation of the comprehensive state water quality assessments (305(b) reports) and electronic uptakes. EPA-841-B-97-002A. Washington, D.C

Appendix D: Modeling Input Data and Calibration

D 1.0 Introduction

This appendix provides lake specific physical, flow and nutrient loading, and meteorological data for input into the QWET model. Physical input data includes lake surface area, coordinates of the lake center, bathymetric data if available, and maximum lake depth. QWET requires either continuous flow and nutrient loading data or estimated constant loading values. Nutrient loading parameters needed are organic phosphorus, phosphate, organic nitrogen, nitrate, and ammonia. Meteorological inputs for the QWET model are formatted at a daily timestep and include air pressure, cloud cover fraction, dew point, temperature, and wind speed. Observation data can also be used for calibration purposes. In the following sections, data sources for these parameters are discussed for each lake to be modeled using QWET.

D 2.0 Physical Input Data

D 2.1 Surface Area

The surface area of the lakes was obtained from the USGS NHD+ GIS geodatabase. Within the geodatabase, the polygons of the lakes have their surface area stated in the attribute table. The surface area is in acres in the geodatabase and must be converted to meters squared for the QWET model.

D 2.2 Bathymetric Data

If there is bathymetric data available, then that is the preferred method for the QWET physical configuration. However, it is very unlikely that lakes and reservoirs in New Mexico will have bathymetric data. There was no bathymetric data available for the lakes included in this TMDL, so a different method using only the lake's max depth was used.

D 2.3 Coordinates

The longitude and latitude of the center of the lake are required. To obtain these values, polygons of the lakes from the USGS NHD+ GIS geodatabase were projected to the WQS84 geographic projection. Then, the coordinates at the polygon's centroid were calculated within the layer's attribute table. QWET requires the polygons to be projected into WQS84 before determining the coordinates.

D 2.4 Maximum Depth

The maximum depth of lakes in this document were calculated from lake depth profiles collected during water quality surveys conducted by the NMED SWQB monitoring team. All recorded maximum depths taken during relevant monitoring surveys were averaged for one lake depth value per lake. This depth value is used as the maximum depth in QWET. The value must be converted from feet to meters.

D 3.0 Flow and Nutrient Loading Data

D 3.1 Flow Data

Continuous flow data is preferred for the QWET model, however if that method is chosen there must also be continuous nutrient loading data. Most lakes in New Mexico do not have continuous nutrient loading data, so a constant flow rate method was established. A variety of methods were used to calculate a constant flow rate for each lake in the TMDL. The constant flow rate for a lake is the average daily water inflow in cubic feet per second.

The New Mexico Office of the State Engineer (OSE) operates and maintains a stream gage network throughout the state. Three OSE stream gages (Cieneguilla Creek, Moreno Creek, and Sixmile Creek) monitor the inflow to Eagle Nest Lake. The average daily flow from March 13th, 2013, to December 21st, 2020, for each gage was used to calculate an average daily flow for Eagle Nest Lake. QWET only needs one constant flow value, so each stream gages average flow was added together for one constant flow value.

The USGS also operates and maintains a stream gage network, with USGS Gage 08291000 Santa Cruz River near Cundiyo, NM located just upstream from Santa Cruz Lake. Average annual daily flow was downloaded from 1995 to 2020 and a constant flow value for Santa Cruz Lake was calculated. The Santa Cruz River is the only inlet to Santa Cruz Lake.

Lake Maloya and Shuree Pond North do not have OSE or USGS stream gages located at their lake inlets. The NMED SWQB monitoring team has collected flow data at the lake inlets during water quality surveys, but there isn't enough data to create a constant flow value. To circumvent this, the Thomas Equation (**Equation D 3.1**) was used to calculate a constant flow value for Lake Maloya and Shuree Pond North. The Thomas Equation requires the user to find a nearby gaged watershed within 50% to 150% of the original ungagged watershed. The equation then calculates an estimated daily average flow based on the gaged watershed's size and stream gage readings (Thomas et al, 1997).

$$Q_u = Q_g \left(A_u / A_g\right)^{0.5}$$ **Equation D 3.1**

Q_u = Flow (cubic feet per second) at ungagged station/watershed
Q_g = Flow (cubic feet per second) at gaged station/watershed
A_u = Area (square miles) of ungagged watershed
A_g = Area (square miles) of gaged watershed

The ungagged watershed size for Lake Maloya is 20.7 square miles. The gaged watershed must be between 50% (10.35 square miles) and 150% (31.05 square miles) of the ungagged watershed. USGS gage 08252500 Costilla Creek above Costilla Dam, NM and its watershed were used for the Thomas Equation because of the similar geography and environment to the Lake Maloya watershed and the appropriate size (25.01 square miles).

The ungagged watershed size for Shuree Pond North is 1.97 square miles. The gaged watershed must be between 50% (0.96 square miles) and 150% (2.96 square miles) of the ungagged watershed. USGS gage 08253500 Santistevan Creek near Costilla, NM and its watershed were used for the Thomas Equation because of the similar geography and environment to the Shuree Pond North watershed and the appropriate size (2.15 square miles).

D 3.2 Nutrient Loading Data

There is limited nutrient loading data for most lakes in New Mexico, and for the lakes included in this TMDL there are only a handful of samples collected by the NMED SWQB monitoring team. For this reason, a constant value approach was taken. The Water Quality Portal (WQP) was used to create average loading values for organic phosphorus, phosphate, organic nitrogen, nitrate, and ammonia to Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North. The WQP collates publicly available water-quality data from the USGS, EPA and over 400 state, federal, tribal, and local agencies.

Water quality data can be downloaded from the WQP based on a radius from a given point. For this project, a radius of 20 miles around Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North was used. This radius was used because it coincides with the Level III EPA Ecoregion(s) that are encompassed by the lake watersheds. The 20-mile radius for Eagle Nest Lake, Lake Maloya and Shuree Pond North include water quality data from other nearby lakes within the Southern Rockies Ecoregion, while the 20-mile radius for Santa Cruz Lake includes water quality data from other nearby lakes within the Southern Rockies Ecoregion and the AZ/NM Plateau Ecoregion. The water quality data within the 20-mile radius was used to create the average nutrient loading values for the lakes. The water quality data ranges from the 1980's to the present day.

D 4.0 Meteorological Data

QWET requires meteorological data at a daily time step. The model creator can use pre-defined meteorological time series data from the European Center for Medium-Range Weather Forecasts (ECMWF) as a minimum requirement or meteorological time series data can be created from more detailed sources for more accurate modeling. The later method was chosen for the models used in this TMDL. Data sources include the PRISM climate dataset, ASOS (automated surface observing systems) and AWOS weather stations, and long-term average monthly data from the Nation Center for Environmental Information and the Western Regional Climate Center.

D 4.1 Air Pressure

Air pressure (hPa) is required for the QWET model. For Eagle Nest Lake, Lake Maloya, Santa Cruz Lake and Shuree Pond North an average monthly value was used. The average monthly value was calculated from the Santa Fe Airport ASOS weather station. An average monthly value was used because of significant data gaps from the weather station. No other nearby weather stations have reliable air pressure data for the time period needed.

D 4.2 Cloud Cover Fraction

Cloud cover fraction (0-1) is required for the QWET model. For Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North an average monthly value was used. For Lake Maloya, the average monthly precent of possible sunshine from the Pueblo, CO weather station was used as cloud cover fraction data. The period of record for this weather station is 1965 to 1983. This data is available from the National Center for Environmental Information (NCEI). For Santa Cruz Lake, the average monthly percent of possible sunshine from the Albuquerque, NM weather station was used as cloud cover fraction data. The period of record for this weather station is 1965 to 1983. This data is also available from NCEI. For Eagle Nest Lake and Shuree Pond North, the average monthly percent of possible sunshine from the Albuquerque, NM weather was used as cloud cover fraction data. However, the average monthly values were lowered by 10% to account for higher cloud cover in the mountainous areas of the Eagle Nest Lake and Shuree Pond North watersheds.

D 4.3 Dew Point

Dew point (°C) data is required for the QWET model. Daily dew point data was created using the PRISM Climate Group GIS raster data layers. Daily dew point rasters were downloaded from January 1st, 1995, to December 31st, 2020, covering the Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North watersheds. These GIS rasters were then reprojected and clipped to the watershed boundaries. Then a python script is used to run zonal statistics on the rasters to create an average daily dew point value for each watershed.

D 4.4 Temperature

Temperature (°C) is required for the QWET model. Daily temperature data was created using the PRISM Climate Group GIS raster data layers. Daily temperature rasters were downloaded from January 1st, 1995, to December 31st, 2020, covering the Eagle Nest Lake, Lake Maloya, Santa Cruz Lake, and Shuree Pond North watersheds. These GIS rasters were then reprojected and clipped to the watershed boundaries. Then a python script was used to run zonal statistics on the rasters to create an average daily temperature value for each watershed.

D 4.5 Wind Speed

Wind speed (meter/second) is required for the QWET model. Daily wind speed data was created using nearby AWOS and ASOS weather stations with average monthly wind speed data. Average monthly wind speed data was used because there are no weather stations recording wind speed located within the lake watersheds included in this TMDL. Eagle Nest Lake and Shuree Pond North wind speed data was obtained from the Taos Airport AWOS, Lake Maloya wind speed data was obtained from the Raton Airport ASOS, and Santa Cruz Lake wind speed data was obtained from the Santa Fe Airport ASOS.

D 5.0 Observation Data

Model calibration was conducted for each QWET model using water quality data collected by the NMED SWQB monitoring team. Lake sampling procedures are described in depth in SOP 12.1 (Lake Sampling). NMED SWQB SOPs can be found here. Measured data used to calibrate the QWET models are temperature, total nitrogen, and total phosphorus. The observation data was collected during the most recent water quality surveys in the lake watersheds; 2015-2016 for Eagle Nest Lake, Lake Maloya and Shuree Pond North and 2017-2018 for Santa Cruz Lake. The tables below contain detailed information on the observation data used to calibrate the QWET models.

D 6.0 Calibration

Manual calibrations were conducted on the temperature and nutrient models used in this TMDL. QWET does not specify the amount of data points needed for a successful calibration, however there is strong evidence that 3 or more years of continuous or regular data samples are needed to conducted a thorough calibration of a hydrologic model (Shen et al., 2022; Moriasi et al., 2015). The calibration data used for the QWET temperature and nutrient models was collected by the NMED SWQB monitoring team during the lake watershed's respective water quality survey. The number of available calibration data points is significantly below the standard recommendation of 3 or more years. There are three to six nutrient calibration data points per lake and 112 temperature calibration data points for Santa Cruz Lake. This lack of data complicated the calibration process and adds significant levels of uncertainty to the model output. However, only general trends of the model output are being analyzed, not specific model output values. Therefore, the models are still being used to discuss reductions needed in air temperature and nutrient inputs for the lakes to meet their designated uses. Additionally, the averaged constant nutrient loading values used for the QWET nutrient models were used as calibration parameters. These values were adjusted in some models to match the calibration data available.

The performance measure used to evaluate these calibrations was Pearson's coefficient of determination (R^2). R^2 values can range from 0 to 1, with values closer to 1 generally indicating a better preforming model and R^2 values above 0.60 considered satisfactory for most hydrologic models (Moriasi *et al*. 2015).

Performance measures can be skewed by lack of data, so in addition to R^2 these models are also evaluated by visually comparing the model output and the calibration data points. For example, the Shuree Pond North nutrient model has three calibration data points and the R^2 value could be skewed lower or higher than expected because of this lack of data. By visually evaluating plots of the calibration data and model output, the model user could infer that the model is accurate enough to be used to analyze general trends. This process was used to evaluate the calibration of the nutrient QWET models. The Santa Cruz Lake temperature model had enough data to calculate a reasonable R^2 value.

D6.1 Temperature Calibration

Five temperature sampling events were conducted by the NMED SWQB monitoring team at Santa Cruz Lake during the 2017 – 2018 water quality survey. Each temperature sampling event collects multiple temperature readings at different lake depths. Overall, a total of 112 temperature data points were used to calibrate the Santa Cruz Lake QWET temperature model. An R^2 value of 0.89 was achieved during the manual calibration, however a lack of calibration data could be skewing this value.

D6.2 Nutrient Calibration

Total nitrogen (TN) and total phosphorus (TP) samples were collected by the NMED SWQB monitoring team during the 2015-2016 and 2017-2018 water quality surveys. Three samples of TN and TP were used for the Shuree Pond North manual calibration, five samples of TN and TP were used for the Lake Maloya, and Santa Cruz Lake manual calibrations, and six samples of TN and TP were used for the Eagle Nest Lake manual calibration. Because of the extremely limited number of nutrient calibration data points, a performance measure and visually comparing the calibration data points and model output were both employed to evaluate the effectiveness of the nutrient models. The nutrient models were calibrated to produce the best fitting output data according to the few calibration points available.

Model input data used for QWET nutrient and temperature modeling.

Variable	Eagle Nest Lake	Lake Maloya	Santa Cruz Lake	Shuree Pond North
Physical Variables				
Surface Area (m^2)	7354098.3	467575.7	376156.8	25050.0
Latitude (deg)	36.529	36.988	35.975	36.755
Longitude (deg)	-105.254	-104.373	-105.917	-105.194
Maximum Depth (m)	5.59	6.25	6.51	1.52
Flow and Nutrient Loading Variables				
Flow (m^3/s)	0.38	0.25	0.73	0.07
Organic Phosphorus (mg/L)	0.12	0.12	0.12	0.12
Phosphate (mg/L)	0.12	0.11	0.17	0.12
Organic Nitrogen (mg/L)	0.44	0.52	0.52	0.40
Nitrate (mg/L)	0.97	2.35	0.25	0.57
Ammonia (mg/L)	0.17	0.11	0.14	0.14

Calibration Data used for QWET nutrient models.

Eagle Nest Lake Nutrient Observation Data		
Date	Total Nitrogen (mg/L)	Total Phosphorus (TP)
04/09/2015	1.07	0.066
10/29/2015	1.17	0.137
05/16/2016	0.61	0.049
07/20/2016	0.79	0.055
09/27/2016	0.68	0.116
11/01/2016	1.05	0.142
Lake Maloya Nutrient Observation Data		
Date	Total Nitrogen (mg/L)	Total Phosphorus (TP)
04/08/2015	0.71	0.029
10/28/2015	4.08	0.03
05/05/2016	0.95	0.03
08/12/2016	0.79	0.048
10/19/2016	0.89	0.12
Santa Cruz Lake Observation Data		
Date	Total Nitrogen (mg/L)	Total Phosphorus (TP)
03/30/2017	0.49	0.039
08/03/2017	0.37	0.018
10/16/2017	0.35	0.04
04/11/2018	0.26	0.011
07/24/2018	0.36	0.047
Shuree Pond North Observation Data		
Date	Total Nitrogen (mg/L)	Total Phosphorus (TP)
10/14/2015	1.18	0.018
08/22/2016	0.75	0.05
10/25/2016	0.71	0.078

Appendix E: Calculation of Temperature TMDL

Calculation of Temperature TMDL

Problem Statement: Convert Temperature Criteria into a Daily Load

Background

The temperature of water is essential for proper metabolic regulation in the aquatic community. Water at a given temperature has a thermal mass that can be represented in units of energy (thermal energy). There are a variety of sources of temperature loading to a waterbody, including air temperature, solar radiation and point source discharge (if present). In addition, how the temperature loading to a stream is translated to the thermal mass of the stream is dependent on its hydrologic characteristics and condition of riparian area (i.e., shading).

The calculation of a TMDL target is governed by the basic equation,

Eq1. *WQS criterion * flow * conversion factor = TMDL target capacity*

For Temperature TMDLs, the WQS criterion is a temperature specified either by the designated Aquatic Life Use (ALU) or site-specific criteria and can be either a maximum temperature or time-duration temperature such as the 4T3 or 6T3.

Flow will generally use the 4Q3 low-flow for the critical flow unless another flow statistic or multiple flow conditions are more appropriate for the situation.

The conversion factor is a variable needed to 1) convert units used by SWQB for flow (in cfs) to cubic meters (m^3) and 2) convert change in water temperature (C) to a volumetric heat capacity (kJ/(m^3*C).

Calculation of Thermal Energy

The thermal loading capacity of a volume is governed by the following equation,

Eq2. *thermal energy = specific heat capacity * mass * change in temperature*

Specific heat capacity is the amount of energy needed to raise the temperature of one kilogram of a substance by 1 degree Celsius.

Mass can be replaced by volume via density.

Accepted Scientific Units for the variables above are:

thermal energy = kilojoule (kJ) (calories are less common and considered archaic)

specific heat capacity = kJ/(kg*C)

mass = kilograms (kg)

change in temperature = Celsius (C)

The specific heat capacity of water at 25^{o}C = 4.182 kJ/(kg*C). This is the isobaric (under constant pressure) value for heat capacity at an absolute atmospheric pressure of 585 mmHg. Note: varying water temperature and absolute pressure to minimum and maximum ambient values has a negligible effect on the resulting heat capacity.

Calculation of Conversion Factor

Flow (cfs) to (m3/day)

Eq3. 1 cf/s * 86,400 s/day * 0.0283 m3/cf = 2445.12 m3/day

Heat Capacity to Volumetric Heat Capacity

Eq4. 4.182 kJ/(kg*C) * 1000 kg/m3 = 4,182 kJ/(m3*C)

Note: water density varies with temperature but only at a fraction of a percent.

Conversion Factor = 2445.12 m3/day * 4,182 kJ/(m3*C) = 1.023E+07 kJ/(day*C)

Form of TMDL Equation

Eq5. Δ [**^{o}C**] x [**cfs]** x 1.023E+07 = TMDL (kJ/day)

Input variables in **bold**, Δ**^{o}C** = (WQC - 0**^{o}C)** and **cfs** = critical flow

The resulting value is the increase in kJ/day above 0^o Celsius.

Appendix F: Response to Comments