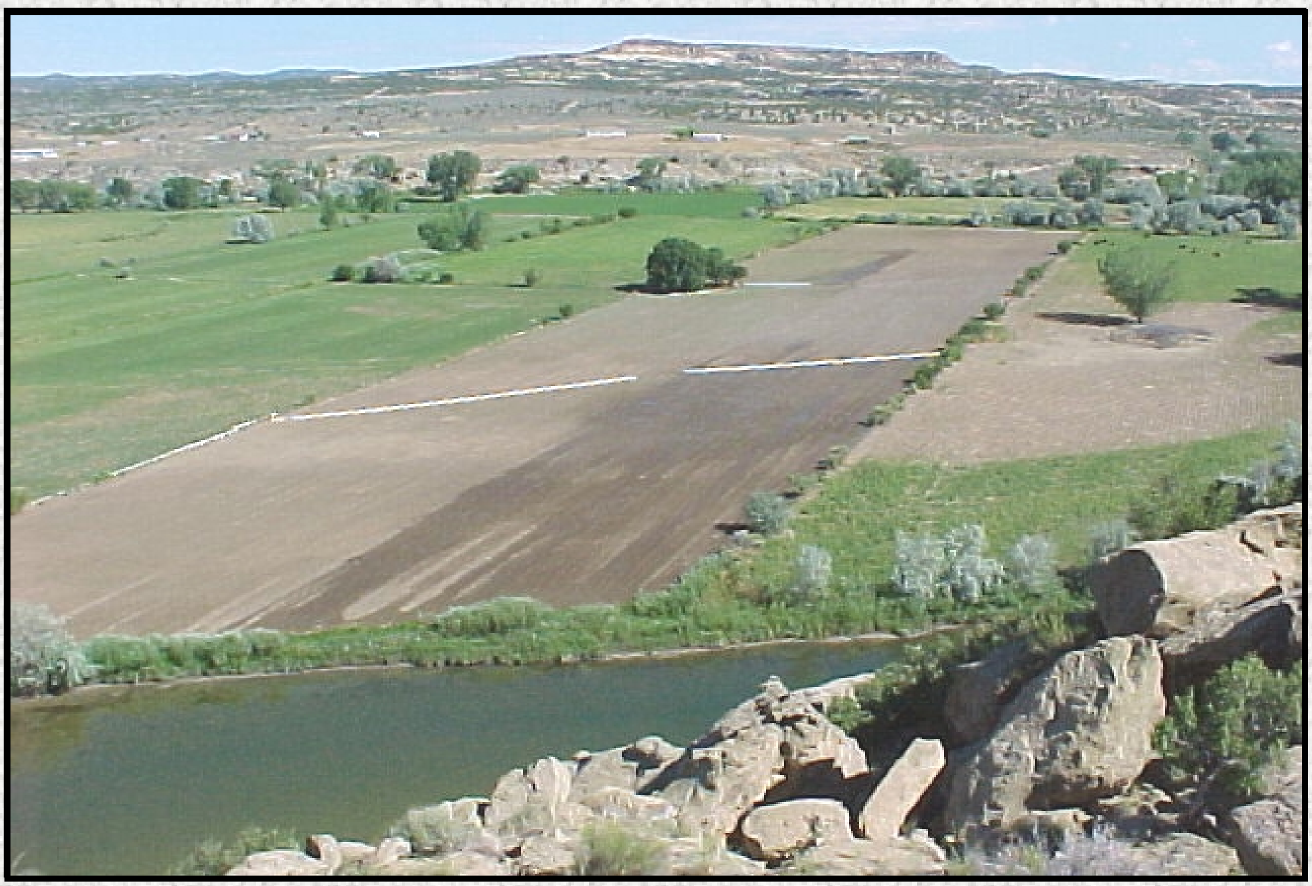
San Juan Hydrologic Unit Regional Water Plan

Prepared By

San Juan Water Commission



VOLUME III

September 2003

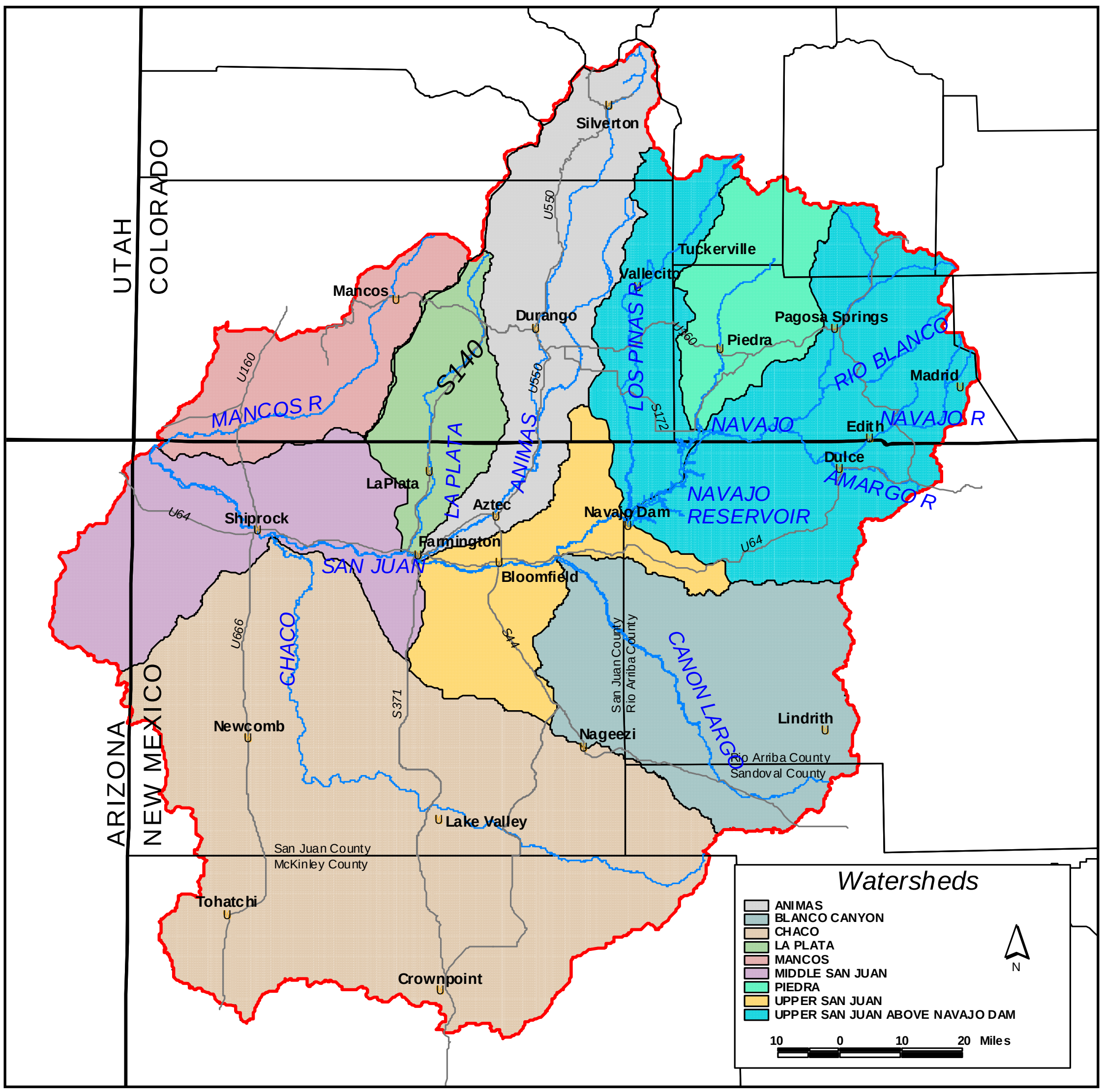
Water Supply Assessment

Table of Contents

1.0 Introduction

The San Juan Hydrologic Unit is located in the northwest corner of New Mexico and extends into Colorado, Utah, and Arizona. For the purposes of this study, the San Juan Hydrologic Unit was divided into nine watersheds (see Figure 1-1). This report evaluates the water supply available to New Mexico in seven of the nine watersheds. The two watersheds that are not included in this study are the Piedra Watershed and the Mancos Watershed. They are not included because the water supplies from these basins are either completely within another state or it is not economically feasible to consider them a viable water supply for New Mexico.

Figure 1-1: San Juan Hydrologic Unit



1.1. **General San Juan Hydrologic Unit Characteristics**

1.1.1. Historical weather data

1.1.1.1. Precipitation

The current locations of the NOAA cooperative stations within and around the San Juan Hydrologic Unit were obtained. The available monthly precipitation values through 1997 for 105 stations within the San Juan Hydrologic Unit were reviewed. The number of years of data available and the average monthly and average annual values for each stations period of record were calculated. To estimate long term precipitation values for each watershed, Thiessen Polygons were created using weather stations that had a period of record of 30 years or more. The precipitation values for each station were adjusted based on the area of the Thiessen Polygon within the given watershed. Table 1-1 summarizes the average annual precipitation for the entire San Juan Hydrologic Unit. Precipitation summaries for each watershed are presented in each watershed section.

Table 1-1: Calculated Average Precipitation for the San Juan Hydrologic Unit

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.12	0.98	1.20	0.92	0.87	0.65	1.53	1.93	1.42	1.37	1.02	1.13	14.26

1.1.1.2 Evaporation

There are six pan evaporation stations of record within the San Juan Hydrologic Unit, two in Colorado and four in New Mexico. Descriptions of the individual stations were not available, but most class A pans are installed above ground, allowing effects such as radiation on the side walls and heat exchanges with the pan material. These effects tend to increase the evaporation totals and are adjusted by multiplying the total pan evaporation by 0.70 or 0.80 to more closely estimate the naturally occurring evaporation. Many stations do not measure evaporation during winter month. A "0.00" total indicates no measurement is taken. Evaporation values for each station are shown below in **Table 1-2**.

Table 1-2: Pan Evaporation Data for the San Juan Hydrologic Unit

COLORADO		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Elevation
VALLECITO DAM	1948-2000	0.00	0.00	1.91	3.81	5.26	6.20	6.07	5.28	4.36	3.04	1.60	0.00	37.53	7650
WAGON WHEEL GAP 3 N	1948-1972	0.00	0.00	0.00	0.00	6.69	7.90	7.15	5.81	5.30	2.61	0.00	0.00	35.46	8510
NEW MEXICO		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
FARMINGTON 3 NE	1914-1978	0.00	0.00	3.83	6.88	8.49	10.00	9.97	8.71	6.49	3.96	2.01	0.00	60.34	5400
FARMINGTON AG SCIENCE C	1978-2000	0.00	0.00	0.00	7.95	10.42	12.35	12.51	10.71	8.15	5.73	0.00	0.00	67.82	5630
GALLUP RANGER STN	1966-1975	0.00	0.00	0.00	6.61	9.31	12.12	10.50	8.70	7.95	5.07	2.20	0.00	62.46	6640
NAVAJO DAM	1963-2000	0.00	0.00	0.00	6.58	9.10	11.07	11.24	9.66	7.22	4.83	0.00	0.00	59.70	5770

1.1.2. Surface Water Yields

Surface water yields are the reliable amount of water that is physically available within the watershed. The following assumptions are general assumptions that were used to estimate the surface water yields for all of the watersheds:

1. Reliable flow is the quantity of water that has been historically available at least 90% of the time (90% probability). The ISC defines the flow as dependable if it is available 90% of the time (*Regional Water Plans, Work Breakdown Structure Memorandum, March 6, 1998, Brian C. Wilson, NM State Engineer Office.*).
2. Monthly values for the 90% probability flow are presented to provide insight on the reliability of the flow. The monthly 90% probability flows do not equate to the annual 90% probability flows. Each month's historical data was evaluated and the 90% probability flow determined. These monthly values do not all occur in the same year. For example, zero monthly flows in the 90% probability flows indicate that the gage was dry at least 10% of the period of record.
3. Reliable flow was assumed to be the flow available to the entire watershed. As a result, the location selected to determine the reliable flow was the closest USGS gage station to the top of the watershed. This flow does not include accretions that occur within the watershed downstream of the gage station selected to represent the available flow. Accretion flows downstream of the selected gage station would be accounted for in the downstream watershed. For example, the surface water yield of the Middle San Juan Watershed would include accretions that occurred in the Animas Watershed below the selected Animas gage station.
4. Flows from some of the watersheds are not controlled or dependent upon releases from Navajo Reservoir. However, to evaluate the available water supply under the current operating criteria for Navajo Reservoir, flows within each watershed were summarized for the entire available period of record as well as for the period of record for the current operation of Navajo Reservoir. It was estimated that the current operating criteria for Navajo Reservoir began in 1985.
5. Surface water yields presented in this report represent the physical quantity of water available. They do not consider legal limitations to water use.

1.2. **Groundwater**

1.2.1. Description of San Juan Structural Basin

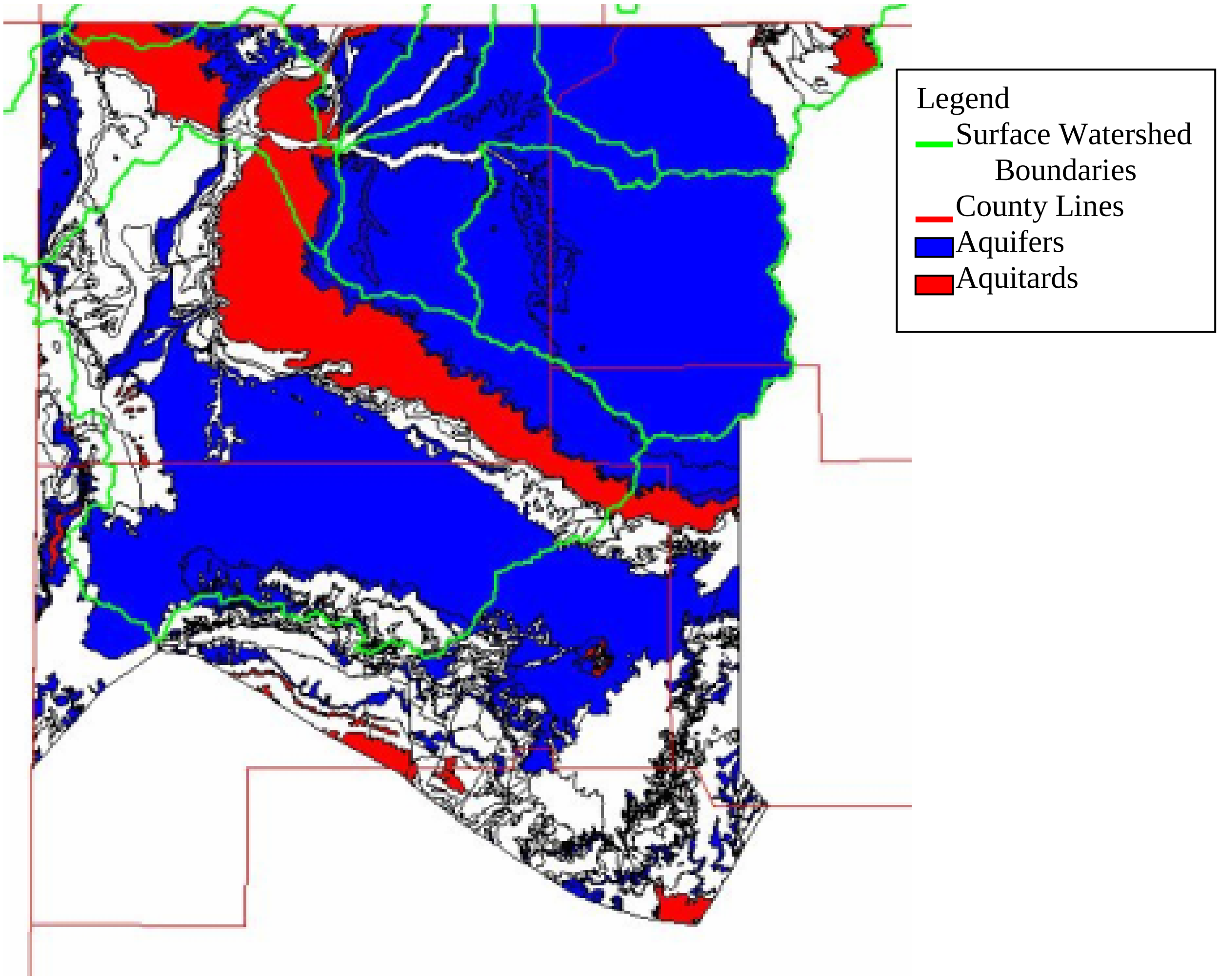
This section of the study was compiled from five reports, with several other reports referenced. No new information was generated during the study. These reports summarize the findings of:

- several U.S. Geological Survey reports,
- a New Mexico Bureau of Mines and Mineral Resources report, and
- a 40-year water planning study for the San Juan, Cibola, and McKinley Counties in northwestern New Mexico.

The complete individual well log and well tables used in those reports have not been included in this report. Selected figures and tables from the referenced report have been included to clarify information used in this study.

The groundwater within the study area is within the San Juan Structural Basin. This basin is a northwest-trending, asymmetric structural depression at the eastern edge of the Colorado Plateau. It is located in Arizona, Utah, Colorado, and New Mexico. The total area of the structural basin is approximately 21,600 mi^2. Figure 1-2 illustrates the boundary and features of the basin.

Figure 1-2: San Juan Structural Basin



The San Juan Structural Basin boundary is well defined with structural relief as much as 20,000 feet. Uplifted areas generally mark the extent of the basin. The San Juan Mountains create the northern boundary. The eastern boundary is marked by the Sierra Nacimiento. The Zuni and Chaska Mountains are the southern and western boundaries. The basin center is troughlike containing as much as 14,000 feet of sedimentary rocks. The sedimentary rocks dip basinward from the basin margins toward the deepest part of the basin. The most distinct type of structure in the Colorado Plateau is the monocline. The largest, The Hogback monocline, forms a sharp boundary between the marginal platforms and the central basin. Sedimentary rocks of Jurassic and Cretaceous age crop out around the basin rim and over a broad area in the southern and western parts of the basin, forming the marginal platforms. Faulting is prevalent in parts of the basin with displacement of several thousand feet along major faults.

The groundwater occurrence, movement, and quality in the San Juan Structural Basin are subject to geologic control. The occurrence of groundwater generally is found within the sandstone aquifers. The San Juan Structural Basin includes major aquifers in Quaternary valley-fill structures and Tertiary, Cretaceous, Jurassic, and Triassic aged sandstones. The basin is overlying a Precambrian basement complex. The Triassic and younger aged structures are less extensive than the total structural basin and cover an approximate area of about 19,400 mi^2. Only the Triassic through Tertiary sedimentary rocks are emphasized in this study because the major aquifers in the basin are in these rocks. Quaternary valley-fill structure aquifers are considered directly connected to the surface water and therefore not included as groundwater.

In a New Mexico Bureau of Mines and Natural Resources' hydrologic report, it describes the creation of the major geologic formations in the San Juan Structural Basin based on the age of the structure.

> The Jurassic strata were deposited in various desert environments (dune fields, playas, saline lakes, and wet alluvial aprons). Alluvial or fluvial deposition continued, at least locally, into Early Cretaceous time; however, the record is spotty and incomplete, suggesting that this was also a period of at least local non-deposition or erosion. Late Cretaceous time was markedly different. The shoreline of a vast but shallow inland sea that bisected the North American continent from the Arctic Ocean to the Gulf of Mexico during this time shifted back and forth across the area now occupied by the San Juan Basin. The sequence of alternating marine and nonmarine coastal deposits that constitutes the Upper Cretaceous of the region gives silent testimony to the restless nature of this shoreline. By Tertiary time, the sea had retreated from the area and the formation of the basin was accelerating. Structural activity, at least uplift of marginal regions, continued during Paleocene time, as shown by the angular unconformity between the Nacimiento Formation (Paleocene) and overlying San Jose Formation (Eocene) in the area opposite the Nacimiento uplift north of Cuba. (Stone, et. al., 1983, pg. 16)

The aquifers in the San Juan Structural Basin are considered confined and artesian because the regional geologic structure and confinement by overlying mudstones, clays, and other structures that have relatively lower hydraulic conductivity. There is interaquifer movement, or leakage, where the differences in the potentiometric surfaces of the aquifers could reach as much as 200 feet.

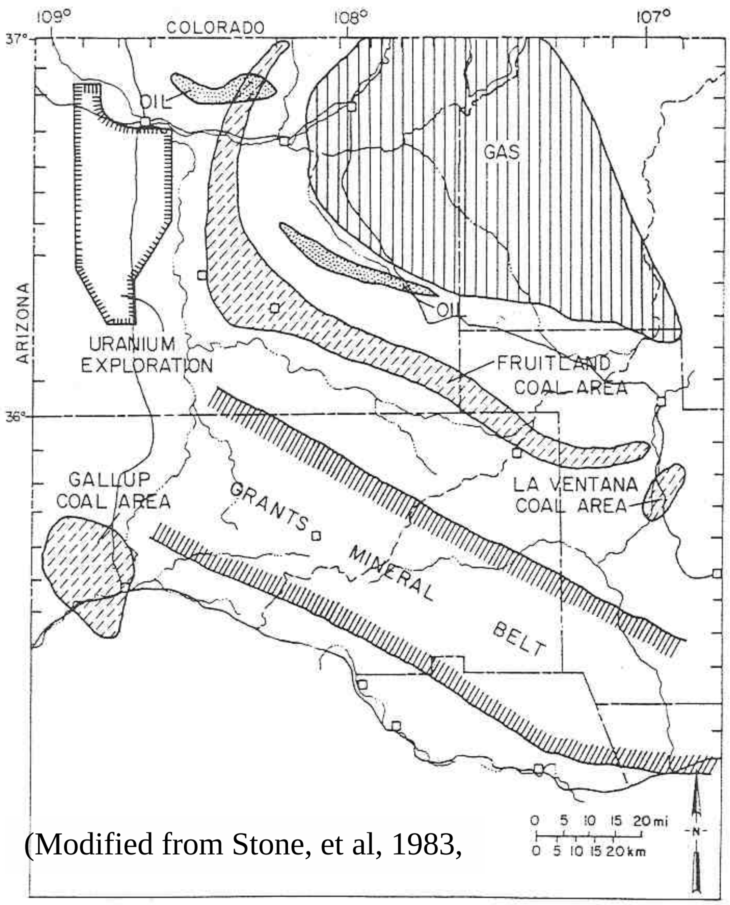
Recharge of the aquifers in the San Juan Structural Basin generally occurs in the topographically high outcroppings along the basin margin. Discharge is generally in the low elevations within the basin, specifically the San Juan River in the northwest portion of the study area.

A steady-state flow model was completed in 1996 by the USGS. Part of this model was to estimate the amount of recharge to the San Juan structural basin. The U.S. Geological Survey published its findings in the Water-Resource Investigations Report 95-4187. They indicate that the recharge rate for most of the San Juan structural basin ranges between 0.1-0.8 inches per year. The basin average is approximately 0.14 inches per year or about one percent of the yearly precipitation. For the entire San Juan Structural Basin, this amounts to approximately 195-cfs discharge in the steady-stead model.

The groundwater quality within the basin is impacted by several factors, such as residence time, over and underlying formations, presence of energy resources, and depth. Many of these factors are interrelated, and therefore not discussed separately.

The San Juan Structural Basin is recognized as mineral rich. Deposits of coal and uranium have been mined from within the basin. Gas, oil, and methane wells have been constructed. However, the energy resources also have negatively impacted the quality of the groundwater in much of the basin. Saline water, high total dissolved solid concentrations, is typical near energy resource deposits. Figure 1-3 illustrates the location of the principal mineral resources of the basin.

Figure 1-3: Principal Mineral Resources in the San Juan Basin



(Modified from Stone, et al, 1983,

1.2.2. Aquifer Characterizations

1.2.2.1. Definitions

In order to describe the characteristics of the aquifers, basic definitions of the terms used are provided below.

Specific Conductance is the electronic measure of salinity. It is the reciprocal of resistance. It is reported in micromhos unit. It is related to the water quality parameter total dissolved solids (TDS) by multiplying the specific conductance by 0.7 to get an approximate TDS value in mg/L.

Storage Coefficient is a unitless number used to indicate the volume of water released from storage per unit surface area of porous medium per unit change in hydraulic head. The maximum decrease in hydraulic head was 300 feet. The average decrease is approximately 275 feet.

Transmissivity is the rate at which water is transmitted through a cross section of media having the dimensions unit width and total thickness as height under a unit hydraulic gradient. It has the units of feet squared per day.

Hydraulic Conductivity is the volume of water that will move in a unit time under a unit hydraulic gradient through a unit area of saturated material. It has the units of feet per day.

Specific Capacity is the relationship between the discharge of a well and the drawdown of the water level in the well. It is reported in the units of gallons per minute per foot of drawdown.

1.2.2.2. Characteristics of Aquifers

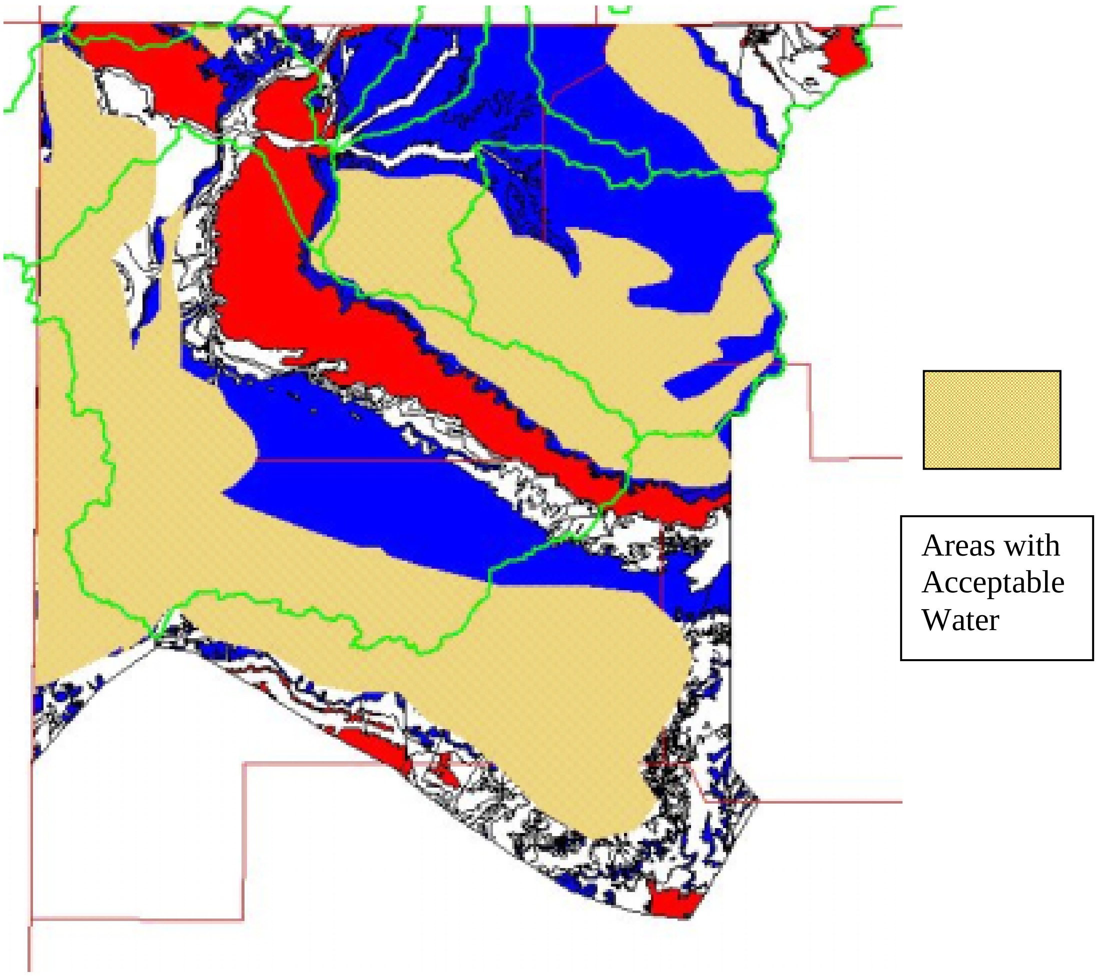
All of the following geologic and aquifer characteristics, specific conductance, were compiled from five reports on the San Juan Structural Basin. No new information was created for this report. The reports used were:

- Hydrogeology and Water Resources of San Juan Basin, New Mexico, Hydrology Report 6, by Stone, et al, 1983.
- U.S. Geological Survey, Hydrogeology and Steady-State Simulation of Ground-Water Flow in the San Juan Basin, New Mexico, Colorado, Arizona, and Utah, Water-Resources Investigations Report 95-4187, 1996.
- U.S. Geological Survey, Geochemistry of Ground Water in the Gallup, Dakota, and Morrison Aquifers, San Juan Basin, New Mexico, Water-Resources Investigations Report 94-4253, 1995.
- U.S. Geological Survey, Summary of the San Juan Structural Basin Regional Aquifer-System Analysis, New Mexico, Colorado, Arizona, and Utah, Water-Resources Investigations Report 95-4188, 1996.
- 40-Year Regional Water Plan, New Mexico State, Planning and Development District 1, San Juan, McKinley, Cibola Counties, by Leedshill-Herkenhoff, Inc., John W. Shomaker, Inc., and Charles T. DuMars, March 1994.

The range of characteristics were gathered from each report source and then combined to form a total range, which is reported below. The information is not specifically referenced due to the multiple sources used to gather the ranges. However, all the information may be found in the identified reports.

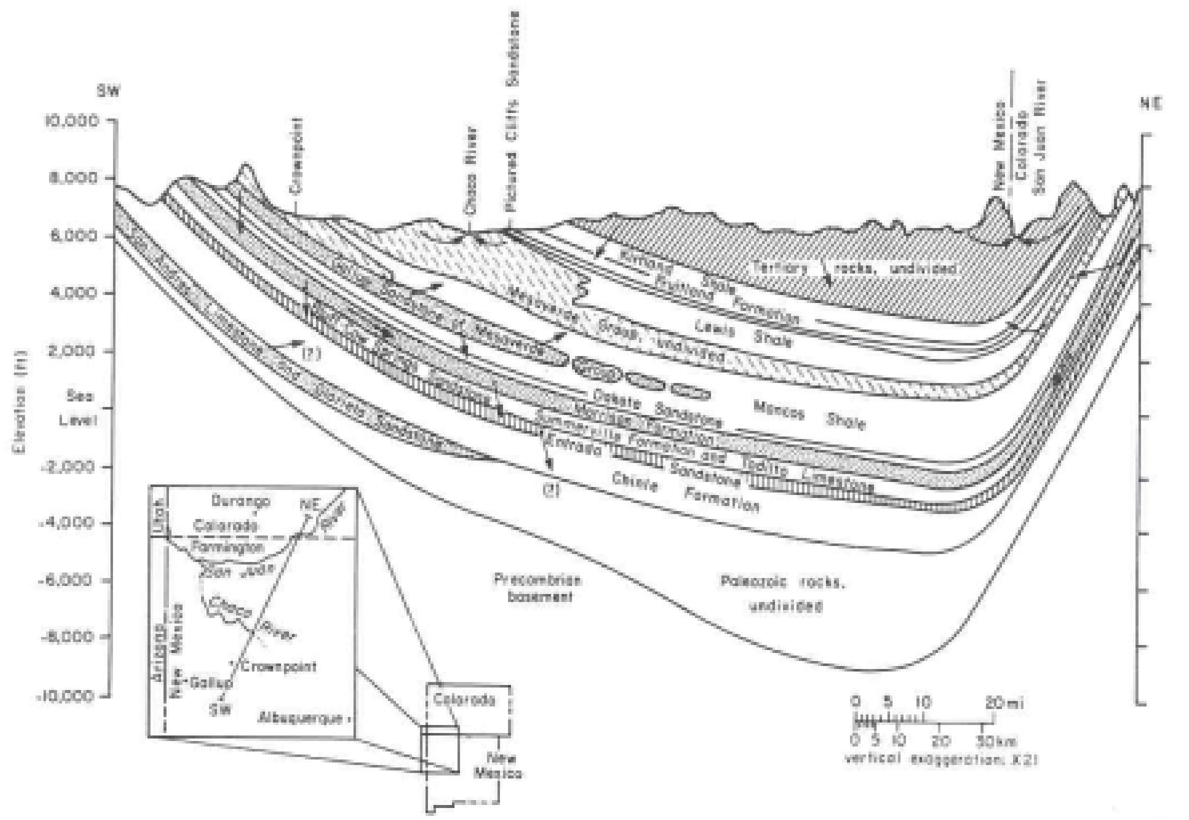
The areas considered during this study are exclusively within New Mexico. Much of the major aquifers are located along the southern and western basin boundary. Figure 1-4 shows the surface drainage basins over the areas of acceptable groundwater. This study is limited to the groundwater within the surface basins. However, some calculations were required outside of the study area in order to adequately determine quantities of available water.

Figure 1-4: Locations of Acceptable Groundwater



The following profile, Figure 1-5 illustrates the aquifers.

Figure 1-5: San Juan Structural Basin Profile



(Modified from Stone, et al, 1983, pg 22)

The eight major aquifers within the study boundary that contain acceptable and retrievable groundwater quality are identified as:

- the San Jose Formation,
- the Animas and Nacimiento Formations,
- the Ojo Alamo Sandstone,
- the Menefee Formation,
- the Point Lookout Sandstone,
- the Gallup Sandstone,
- the Dakota Sandstone and;
- the Morrison Formation.

Tertiary sandstone aquifers can be grouped together due to the fact they were deposited during similar environments and have similar characteristics. These deposits include the San Jose Formation, the Nacimiento Formation, and the Ojo Alamo Sandstone. The groundwater within these units is associated with the alluvial and fluvial sandstone aquifers.

The recharge, flow, and discharge of these units are also similar. Recharge occurs in the higher elevations of the exposed outcroppings. The flow direction follows the contours lower to the deep canyons that cut the Tertiary deposits where there may be discharge. This flow would occur through the valley-fill structures and into the San Juan River.

The water quality within the Tertiary deposits is probably derived at the interfaces with adjacent shale beds. The exposed area of the interface and intertonguing increases the amount of dissolved solids in the groundwater. There may also be mixing of the fresh water of these aquifers with saline water from the deeper aquifers in areas of intense fracturing or high head differentials across the confining units.

1.2.2.2.1. San Jose Formation

The San Jose Formation is of Eocene age. It is the youngest rock unit in the San Juan Structural Basin. It occurs over the surface of the majority of the central part of the basin. It is a series of interbedded sandstones and mudstones. The total thickness of the San Jose Formation ranges from less than 200 feet in the west and south to nearly 2,700 feet between Cuba and Gobernador. The hydrologic properties of the San Jose Formation are largely untested.

The wells in the formation have reported a specific conductance from a low of 320 to a high of 5,000 micromhos with the median value being 2,000 micromhos. From two wells, a transmissivity of 40 to 120 ft^2/day has been reported. The flow rate ranges between 0.15 gallons per minute (gpm) to 61 gpm. The median flow rate of the 46 wells reviewed was 5 gpm. One specific capacity test indicated 0.23 gpm per foot of drawdown.

1.2.2.2.2. Animas and Nacimiento Formations

The Animas and Nacimiento Formations are considered together because they occupy the same geologic strata within the San Juan Structural Basin. Since the majority of the Animas Formation is located outside of the study area, this formation will be referred to as the Nacimiento Formation.

The Nacimiento Formation is of Paleocene age. It is directly underlying the San Jose Formation and overlying the Ojo Alamo Sandstone. It is a series of undivided black, carbonaceous mudstones and white, coarse-grained sandstones. It is assumed that the formation is mainly a mudstone unit. The overall thickness ranges from 400 feet to more than 2,000 feet in structural center.

The specific conductance of the Nacimiento Formation has been reported from around 1,500 micromhos to more than 4,000 micromhos. The average value for the unit is approximately 2,000 micromhos. The transmissivity is 100 ft^2/day in some of the more continuous, coarse-grained sandstones. Tests from 6 wells produced a specific capacity of 0.24 to 2.3 gpm per foot of drawdown. The flow from 53 wells ranged from 2 to 90 gpm with a median flow rate of 7.5 gpm.

1.2.2.2.3. Ojo Alamo Sandstone

The Ojo Alamo Sandstone aquifer has the best potential of supplying adequate quality groundwater to the metropolitan areas along the San Juan River.

The Ojo Alamo Sandstone unit is of Paleocene age and is the lowest Tertiary rock unit in the structural basin. It ranges in thickness from 70 to 300 feet. It overlays the Kirtland Shale unit, which contains a significant amount of energy resources.

Near the outcroppings, the specific conductance is approximately 1,000 micromhos, while in deeper areas it has been reported to be 9,000 micromhos. The transmissivity from 10 tests, from depths less than 1,100 feet, range from 57 to 164 ft^2/day with the median value being 104 ft^2/day. In three tests greater than 1,100 feet, the transmissivity is significantly lower at values of 0.05, 0.35, and 0.39 ft^2/day. The flow rate from 19 wells within the Ojo Alamo Sandstone report flow rates from 1.2 to 112 gpm, with a median rate of 12 gpm. The specific capacity ranges from 0.1 to 2.04 gpm per foot of drawdown. The median specific capacity is 0.26 gpm per foot of drawdown.

1.2.2.2.4. Menefee Formations

The Cretaceous sandstones were deposited in fluvial, coastal, or marine environments. These units intertongue in a very complex series of transgressive/regressive pulses. These sandstone aquifers include the Menefee Formation, the Point Lookout Sandstone, the Dakota Sandstone, and the Gallup Sandstone. The groundwater is found in the sandstone units.

The outcroppings of these aquifers are narrow with very minimal high elevation exposure. Infiltration is the primary method of recharge. The structural makeup of the Cretaceous sandstones may influence the groundwater flow directions, but elevation mainly controls the direction.

The hydraulic conductivity of these sandstone units will be low due to the fine nature of the grains. Also, the quality of the groundwater is controlled by the aquifer's characteristics. Higher transmissivities indicate fresher groundwater while areas with lower transmissivities have groundwater that is more saline. Also, shales over and underlying and intertonguing with the sandstones are common throughout the basin. This will also provide a source for dissolved solids.

The Menefee Formation, late Cretaceous age, has been divided into two members, one bearing coal and the other barren of coal. It is also the center unit in The Hogback monocline west of Farmington.

It ranges between 400 to 1,000 feet in thickness. It consists of interbedded claystones, siltstones, shale, coal, and sandstone. It overlays the Point Lookout Sandstone. The Cliff House Sandstone unit overlays it, which is also considered an aquifer, but has poor quality groundwater.

Few wells penetrate the full thickness of the Menefee Formation, for this reason, it is difficult to calculate the transmissivity of the unit. Reported values include 2.7 to 112 ft^2/day with 10 ft^2/day the median of 9 tests. It has a hydraulic conductivity of 0.017 ft/day. A total of 83 wells showed a flow rate range from 2 to 308 gpm, with a median rate of 10 gpm. The specific capacity was report from 37 wells and ranged from 0.2 to 0.57 gpm per foot of drawdown with a median value of 0.11 gpm per foot of drawdown.

1.2.2.2.5. Point Lookout Sandstone

The Point Lookout Sandstone unit, of late Cretaceous age, is also well exposed in the Hogback monocline. The thickness ranges from 40 to 415 feet. The sandstone unit is intertongued in many locations with a shale unit.

The specific conductance of the sandstone unit reported values from 1,500 micromhos to extremely high values of 59,000 micromhos.

There are several contradicting reported transmissivity values. They range from as low as 0.4 to 240 ft^2/day. The median value is 70 ft^2/day. A storage coefficient for the unit is reported as 0.000041. The hydraulic conductivity ranges from 0.002 to 0.02 ft/day with the median value 0.0058 ft/day.

Flow from 22 wells show rates form 1 to 360 gpm with a median rate of 20 gpm. The specific capacity ranges from 0.02 to 1.67 gpm per foot of drawdown.

1.2.2.2.6. Gallup Sandstone

The Gallup Sandstone unit does not extend the full structural basin. It is found only in the southwestern quarter of the structural basin. It is a major source of good quality groundwater.

The thickness of the sandstone ranges from 93 to 700 feet. It lies over the Mancos Shale unit and under the Cravasse Canyon Formation. Pumping from this aquifer for municipal supplies have greatly lowered the water levels within the aquifer. The specific conductance ranges from a minimal value to a maximum of approximately 2,000 micromhos.

The transmissivity ranges from 15 to 390 ft^2/day, with the high value obtained near an area suspected to have significant fractures, with a median value of 123 ft^2/day from 17 wells. The storage coefficient has been reported as 0.000002 and 0.000033. Hydraulic conductivities average 0.1 ft/day. Data reported from 49 wells indicated flows from 1 to 645 gpm with the median flow of 42 gpm. The specific capacity of 0.12 to 2.1 gpm per foot of drawdown were recorded from 13 wells with a median value of 0.46 gpm per foot of drawdown.

1.2.2.2.7. Dakota Sandstone

The Dakota Sandstone unit is made up of sandstone, mudstone, and coal. It is of the late Cretaceous age. Its thickness ranges from 200 to 300 feet. It is overlain by the Mancos Shale unit and overlays the Morrison Formation. Few wells are drilled just into the Dakota Sandstone. Most wells may have a screened layer in the unit, but continue into the Morrison Formation.

The specific conductance of the Dakota Sandstone is less than 2,000 micromhos near the outcrops to more than 10,000 micromhos in the deeper parts of the basin. Transmissivities have been recorded from 44 to 85 ft^2/day with the median value being 50 ft^2/day. The hydraulic conductivity is 0.03 ft/day for part of the aquifer.

Reported from 30 wells, the flow rate ranges from 1 to 75 gpm with a median flow of 12 gpm. The specific capacity ranges from 0.03 to 3.67 gpm per foot of drawdown with a median value of 0.06 gpm per foot of drawdown from 13 wells.

1.2.2.2.8. Morrison Formation

The Jurassic sandstones, of which only the Morrison Formation is considered in this study, were deposited in either the alluvial-fan system or the eolian deposition system under arid conditions. The Morrison Formation is an alluvial deposition unit.

The method of recharge for the Morrison Formation is outcropping on uplifts, exposure along the surface to facilitate infiltration, and fracturing. The flow of groundwater within this aquifer is determined by the geometry and orientation of the permeability zones. The freshness of the Morrison aquifer is attributed to the higher hydraulic conductivities associated with coarser textures.

The Morrison Formation is a major aquifer in the San Juan Structural Basin. It is of the late Jurassic age. It is also a major source of uranium. It consists of non-marine sandstone, mudstone, shale, and minor limestone. The total thickness of the unit ranges from 330 to 915 feet.

Specific conductance of the unit ranges from less than 1,000 to more than 10,000 micromhos. Transmissivity ranges from 2 to 480 ft^2/day with a median value of 115 ft^2/day from 31 tests. Storage coefficient values range from 0.00002 to 0.0002. Hydraulic conductivities are from 0.025 to 0.39 ft/day.

A review of 83 wells showed flow rates from 1 to 2,250 gpm with the median well flow rate 30 gpm. The specific capacity ranged from 0.01 to 3.98 gpm per foot of drawdown. The median value was 0.42 gpm per foot of drawdown from 32 tests.

1.2.2.2.9. Other Formations

Other Jurassic and older formations contain regional aquifers. However, the outcropping locations, the quality of the groundwater, and to the depth to the groundwater restricted them from this study.

1.2.3. Quantification of Useable Groundwater

When an estimate is made of the volume of water in a confined aquifer of adequate water quality for use, it must be evaluated with a clear understanding of the assumptions made for the calculations. The total volume of water stored may be vast, but it may be totally impractical or nearly impossible to release it due to the aquifer characteristics. Draw down and well spacing may be limiting or the amount of time required to pump even a small portion may make it completely unreasonable. This study identified reported areas of good quality groundwater. It will be necessary to perform a localized study to determine the most appropriate areas to develop as future ground water recovery areas.

1.2.3.1. Assumptions

Several assumptions were required to calculate the amount of quality ground water available. These assumptions follow:

1. The ground water must have a specific conductance of less than 1,500 micromhos. The specific conductance is related to the water quality parameter total dissolved solids (TDS) by multiplying the specific conductance by 0.7 to get an approximate TDS value in mg/L. Drinking water standards indicate that the maximum TDS for primary water use is 1,000 mg/L TDS. When the TDS level is above the 1,000 mg/L limit, it becomes too saline to justify its use. Isopotential lines were from information gathered by Stone, et al, 1983. This information was compared to the input information for the USGS steady-state model.
2. The median aquifer characteristic was used unless documentation proved otherwise.
3. All aquifers were assumed to be confined for calculation purposes.
4. Valley-fill, unconfined, and shallow aquifers were assumed to be directly connected to surface water flow and not included in the calculations.
5. As the good quality groundwater is pumped, poorer quality water will flow to replace the removed volume. Pumping also may increase leakance between aquifers within the structural basin by increasing the head difference across confining units. It was assumed that a sufficient number of wells within several well fields would mine the ground water, eliminating the requirement to address the declining quality in the calculations. The effect of mining the groundwater would increase leakance and decrease water quality.
6. In areas without water quality information, the quality of the ground water was assumed to be in excess of the 1,000 mg/L TDS limit. Drinking water standards indicate that the maximum TDS for primary water use is 1,000 mg/L TDS.
7. Maximum depth to the aquifer assumed to be 2,000 ft. Some areas are approximately 2,400 ft deep to the bottom of the aquifer.
8. Springs and seeps were considered surface water and not included in the quantity calculations.

1.2.3.2. Calculations

The volume of water that flows in an aquifer is described by Darcy’s Law. Darcy’s Law is defined by the flow volume equal to the hydraulic conductivity times the hydraulic gradient times the flow area.

The steps used to calculate the volume of groundwater available to be released from storage was 1) determine the storage coefficient of each aquifer, 2) multiply the storage coefficient by both the acceptable hydraulic head loss and the surface area of the areas identified as having a specific conductance less than 1,500 micromhos.

This value, reported in units of acre-feet, represents the amount of mineable groundwater.

The hydraulic head available in each aquifer was found using tables from Stone, et al, in their 1983 Hydrologic Report 6 for the New Mexico Bureau of Mines and Mineral Resources.

Stone delineated the bottom and top elevations of each aquifer and mapped the potentiometric head. This information was compared to reported potentiometric heads from the USGS Water-Resource Investigations Report 95-4187, a steady-state simulation of the ground water in the San Juan Structural Basin.

The areas of acceptable groundwater quality were also obtained from figures presented in the Stone, et al, report. These areas were mapped in GIS and overlayed on the surface drainage basins. Using the aquifer characteristics presented earlier, the area of influence was estimated from these locations. The surface area was then translated to the aquifer to establish the area of storage that would be releasing the groundwater for use in the calculation.

Calculations of the groundwater quantities were made for each of the surface watersheds.

Complete calculations for the aquifers and watersheds are contained in Appendix A

1.2.3.3. Results

The following table is a summary of the quantification calculations.

Table 1-3: Available Groundwater per Basin

BASIN NAMES	**QUANTITY (acre-ft)**
Upper San Juan above Navajo Dam	5,745
Blanco Canyon	14,800
Upper San Juan	1,753
Chaco	36,884
Middle San Juan	9,276
Outside basin boundaries (within San Juan Structural Basin)	45,615
TOTAL	**114,073**

The limit of groundwater quality identified for this study represents fresh groundwater that potentially would not require treatment for salinity to use as a municipal source. Increasing the acceptable level of TDS, potentially requiring treatment, would result in a larger quantity of groundwater being available. Since the discharge of the entire San Juan Structural Basin is only 195 cfs (141,000 acre-feet), it is unlikely that all of the 114,073 is a sustainable water supply. There is insufficient information to determine how much is sustainable and sustainability would likely be area specific and not watershed or basin-wide sustainability. Furthermore, Stone, et al, reported that up to approximately two million acre-ft of slightly saline groundwater could be released from the San Juan Structural Basin with a water-level decrease of 500 feet (1983, pg. 60). However, the San Juan Structural Basin is larger than the San Juan Hydrologic Unit.

1.3. **Water Quality Issues**

This section describes the basin-wide surface water quality issues.

1.3.1. Total Maximum Daily Loads (TMDL) Information

EPA has mandated that each State identify all the water bodies that have unsupported uses as a result of specific pollutants. The TMDL study for the San Juan Hydrologic Unit is scheduled to start in 2004. This schedule puts the basin near the bottom of the list of impaired water basins.

According to the State of New Mexico 2000-2002 303(d) List for Assessed Stream and River Reaches, water bodies within the study area support all uses except fishery uses. The following table summarizes the contents of the 303(d) List.

Table 1-4: Summary of 303(d)

Water Body	Unsupported Use(s)	Specific Pollutant
San Juan River – Navajo Nation to Hogback	Warm water fishery, Marginal cold water fishery	Stream bottom deposits
San Juan River – Canon Largo to Navajo Dam	High quality cold water fishery,	Temperature, stream bottom deposits
San Juan River – Animas River to Canon Largo	Warm water fishery, Marginal cold water fishery	Stream bottom deposits and fecal coliform
San Juan River – Navajo Nation Boundary to Hogback	Warm water fishery, Marginal cold water fishery	Stream bottom deposits
Animas River – San Juan River to Estes Arroyo	Warm water fishery, Marginal cold water fishery	Stream bottom deposits
Animas River – Estes Arroyo to State line	Cold water fishery	Stream bottom deposits
La Plata River – San Juan River to State line	Limited warm water fishery, Marginal cold water fishery	Plan nutrients

The probable sources of the specific pollutants are listed as agriculture, resource extraction, removal of riparian vegetation and streambank modification, rangeland. Urban runoff is identified as a probable source for fecal coliform only.

Supporting the identification of unsupported fishery uses on the San Juan River are data collected since October 1991 for the San Juan River Basin Recovery Implementation Program (SJRBRIP)[1].

1.3.2. State of New Mexico Standards for Interstate and Intrastate Surface Waters

The State of New Mexico Water Quality Control Commission publishes its listing of water quality standards for the principal water bodies of the state. The following table summarizes the standards of the water bodies within the study area:

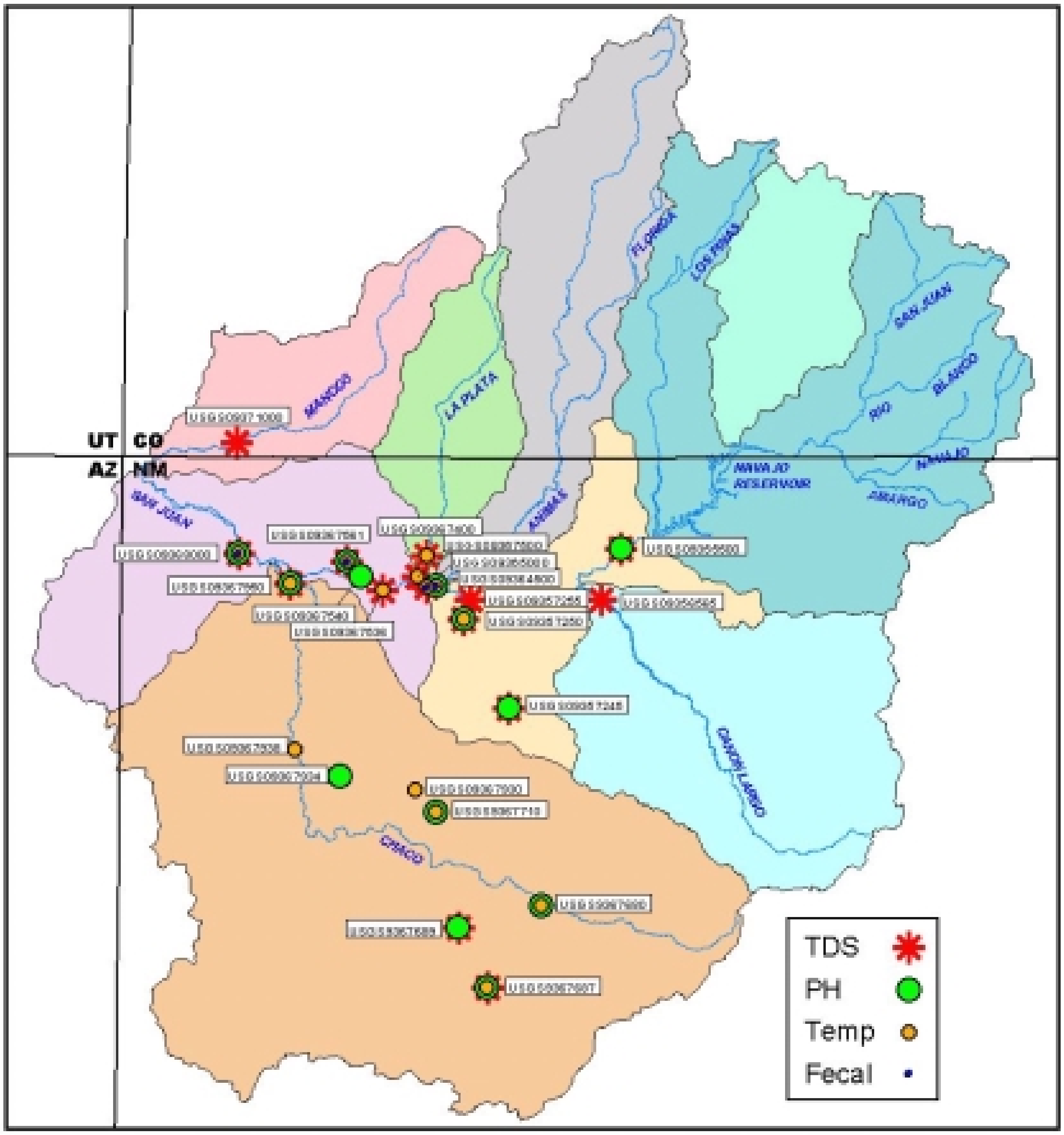
[1] USBR, "Navajo Reservoir Operations Preliminary Final Environmental Impact Statement, pg. III-94, 2003.

Table 1-5: State of New Mexico Surface Water Quality Standards

Water Body	pH	Temp (°F)	Fecal Coliform (colony forming units)	Other
San Juan River Blanco, downstream Chaco and Mancos	Between 6.6 and 9.0	< 90	400/100 mL single sample 200/100 mL monthly mean	none
San Juan River Blanco to Navajo Dam	Between 6.6 and 8.8	< 68	200/100 mL single sample 100/100 mL monthly mean	< 10 NTU turbidity < 400 μmhos/cm
La Plata River	Between 6.6 and 9.0	< 90	400/100 mL single sample 200/100 mL monthly mean	None
Animas River San Juan to Aztec	Between 6.6 and 9.0	< 80.6	400/100 mL single sample 200/100 mL monthly mean	
Animas River Upstream of Aztec	Between 6.6 and 9.0	< 68	400/100 mL single sample 200/100 mL monthly mean	<0.1 mg/L phosphorus
Navajo and Los Pinos	Between 6.6 and 8.8	< 68	200/100 mL single sample 100/100 mL monthly mean	<0.1 mg/L phosphorus

Water quality obtained from the USGS was imported to a MicroSoft Access database file and queried for the above parameters. Figure 1-6 illustrates those stations within the study boundary that experienced exceedances of the above water quality standards.

Figure 1-6 Water Quality Standards Exceedance Locations



The exceedances for pH, temperature, fecal coliform, and turbidity are included in Appendix B. Phosphorus standards were not exceeded.

1.3.3. Total Dissolved Solids

Total Dissolved Solids (TDS) is a frequently used parameter for evaluating water quality. Municipal uses are typically limited to waters with less than 1,000 mg/l TDS. Agricultural uses are frequently limited to 800 to 1,200 mg/l depending on the ability of the soils to drain and move salts away from root zones. Crop types determine the root zone depths.

The water quality issues section of the 1994 40-Year Regional Water Plan, Planning and Development District 1 identifies salinity as a "long-term water quality issue." Much of this long-term issue is related to the salt loading (1.2 million tons per year) at Bluff, Utah.

However, there is a difference between loading and concentration. Loading has significance to downstream uses but concentration has significance to the uses within the San Juan Hydrologic Unit. Although there are instances of extremely high concentrations associated with return flows from NIIP lands in the Gallegos and Ojo Amarillo Washes (3,000 mg/l) and the Hogback area (15,000 mg/l), the principal surface water supplies – San Juan, Animas, and La Plata Rivers, have exhibited few instances of moderate to high salinity concentrations. Implementation plans to mitigate pollutants from these return flow areas should be included in the TMDL study to be completed in 2004.

A review of the water quality data identified the stations that experience TDS readings greater than 1,200 mg. Figure 1.6 shows the location of those stations.

The frequency of the TDS exceedance represents 7.5% of the TDS measurements (249 of 3,334 records).

1.3.4. Polynuclear Aromatic Hydrocarbon (PAH)

Because of the significant oil and gas industry in the San Juan Hydrologic Unit, there have been questions about the impact of PAH from these industries on the water quality of the region. The Bureau of Land Management (BLM) issued a draft Resource Management Plan and Environmental Impact Statement on oil and gas leasing. This document resulted in an on-going PAH study being conducted by the BLM Farmington Field Office. The fiscal year 2002 project proposal for this study states:

> "The sediment and water sampling program has been relatively ineffective. The Reasons for this may be attributed to the short life of PAHs, which are quickly partitioned either to sediment or biota, sediment cycling and removal, the complete absence of PAHs from the San Juan or Animas Rivers, or a combination of all these factors."

It was concluded by the study participants that monitoring of the rivers will be discontinued and their efforts focused on storm water collection and air monitoring. Therefore, it can be concluded for this regional plan that the principal water supplies for the San Juan Hydrologic Unit are not impaired by PAH.

1.3.5. Surface Water Quality Summary

The following conclusions were developed from the data evaluated for this study:

- The surface water quality throughout the San Juan Hydrologic Unit supports all uses except for fisheries according to 303(d) List for assessed streams.
- The State of New Mexico Standards for Surface Waters are exceeded primarily in the San Juan River below the confluence with the Animas River.
- TDS exceeds 1,200 mg/l at several locations but their frequency of exceedance is only 7.5 percent of the samples.
- Generally, the water quality of surface water supplies do not impair the uses in the basin and do not reduce the available water supply.

1.4. **Snotel Monthly Averages**

The snow water content monthly averages were calculated using data downloaded from the Western Regional Climate Center (WRCC) website. The results of the monthly calculations are shown in the followings table:

Table 1-6 Calculated Monthly Snotel Averages

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Start Year	End Year
BEARTOWN	10.38	13.77	19.49	24.05	26.13	12.13	0.22	0.10	0.03	0.10	1.89	6.70	1982	2002
CASCADE #2	4.44	8.38	11.15	8.70	0.81	0.16	0.01	0.00	0.00	0.00	0.12	2.06	1990	200
CHAMITA	3.38	6.41	8.81	8.76	1.38	0.01	0.00	0.01	0.00	0.00	0.27	1.62	1941	2001
COLUMBUS BASIN	7.60	15.58	18.97	25.52	27.33	11.48	1.24	0.03	0.03	0.04	3.03	6.21	1994	2002
CASCADE	5.26	8.41	11.38	11.97	4.15	0.04	0.05	0.00	0.01	0.02	0.26	2.33	1936	2002
CUMBRES TRESTLE	10.29	16.21	21.20	27.42	23.65	5.30	0.01	0.01	0.01	0.15	1.23	5.93	1972	2002
EL DIENTE PEAK	4.15	8.27	11.80	13.92	9.92	1.27	0.01	0.01	0.00	0.00	0.38	2.52	1987	2002
IDARADO	5.57	8.30	11.23	14.26	11.01	1.01	0.02	0.01	0.00	0.01	0.31	2.91	1981	2001
LIZARD HEAD PASS	6.18	8.98	12.39	15.69	15.17	4.35	0.00	0.01	0.01	0.01	0.64	3.61	1981	2001
LONE CONE	6.93	11.14	15.18	17.13	9.98	0.73	0.00	0.01	0.00	0.01	0.57	3.96	1965	2001
LILY POND	6.36	8.85	12.70	15.73	15.27	2.42	0.01	0.02	0.03	0.11	0.85	3.42	1981	2001
MIDDLE CREEK	8.87	11.38	14.99	18.69	20.38	10.36	0.01	0.02	0.03	0.14	2.22	6.17	1981	2001
MINERAL CREEK	6.15	9.33	12.53	15.29	12.73	2.06	0.01	0.02	0.00	0.01	0.84	3.73	1951	2002
MOLAS LAKE	6.79	9.70	13.13	15.58	12.24	4.08	0.00	0.03	0.03	0.02	0.93	3.70	1951	2002
MANCOS	5.22	10.07	13.68	14.63	9.80	2.53	0.02	0.08	0.10	0.14	0.90	3.26	1994	2001
RED MOUNTAIN PASS	9.86	15.37	22.03	28.34	29.93	15.44	0.19	0.01	0.01	0.12	1.66	5.87	1951	2002
SENORITA DIVIDE #2	3.46	6.25	8.28	8.76	1.56	0.01	0.00	0.01	0.01	0.00	0.15	1.29	1972	2001
SCOTCH CREEK	3.78	7.12	10.35	10.52	2.89	0.01	0.05	0.02	0.03	0.02	0.25	1.84	1987	2001
SLUMGULLION	6.61	8.58	10.82	13.23	14.67	4.47	0.01	0.01	0.00	0.04	1.78	4.73	1981	2001
SPUD MOUNTAIN	9.35	14.81	21.03	25.02	23.57	11.74	0.13	0.01	0.01	0.01	1.19	6.19	1951	2002
STUMP LAKES	7.24	10.49	14.66	18.33	20.45	10.99	0.52	0.01	0.01	1.38	1.89	5.31	1986	2002
UPPER RIO GRANDE	3.30	5.08	6.60	7.17	2.81	0.16	0.10	0.03	0.17	0.13	0.42	2.48	1936	1999
UPPER SAN JUAN	11.54	17.83	22.73	29.68	25.99	9.69	0.01	0.02	0.00	0.00	1.12	3.80	1936	2001
VALLECITO	6.23	10.61	13.70	16.90	14.88	2.55	0.02	0.00	0.01	0.01	0.91	4.30	1981	2001
WOLF CREEK SUMMIT	13.47	18.84	23.66	30.40	32.98	26.53	3.14	0.00	0.02	0.01	3.06	8.87	1951	2001

SNOTEL stations used are stations located within 25 miles of the San Juan Basin. The monthly values were assigned based on snow water content readings form the first week of the month or the last week of the previous month.

Monthly snow water content averages may not include continuous monthly readings through the period of record. The period of record indicates the earliest reading for any given month. Prior to 1976 one snow water content value a month was recorded for months from January to May. Therefore, the snow water content readings for months June through December do not precede 1976. After 1976 daily readings were recorded for the snow pack for each SNOTEL station for all months.

1.5. **Evaporation**

The Western Regional Climate Control Center lists four stations in the San Juan Basin that have historical evaporation data. Three stations are located in New Mexico and the other is located in Colorado. The daily pan evaporation was measured using a four-foot diameter Class A evaporation pan. The pan water level readings were adjusted to account for precipitation. Readings taken from pans located above the ground were reduced by 20 to 30% to account for increased evaporation caused by radiation on the sides of the pan. The average monthly evaporation for each station is shown in Table 1-7.

Table 1-7: Average Monthly Evaporation

Station Name	Station Elevation	Basin	Years of Data	Average Evaporation (in) Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Total
Farmington 3 NE	5400	Animas	1914-1978	3.83	6.88	8.49	10.00	9.97	8.71	6.49	3.96	2.01	60.34
Farmington AG Science C	5630	Middle San Juan	1978-200	0.00	7.95	10.42	12.35	12.51	10.71	8.15	5.73	0.00	67.82
Navajo Dam	5770	Upper San Juan	1963-2000	0.00	6.58	9.10	11.07	11.24	9.66	7.22	4.83	0.00	59.70
Vallecito Dam	7650	Upper San Juan Above Navajo Dam	1948-2000	1.91	3.81	5.26	6.20	6.07	5.28	4.36	3.04	1.60	37.53

No measurements were recorded for December, January, or February.

2.0 Water resources assessment for the planning region

2.1. Animas Watershed

2.1.1. Historical weather data

2.1.1.1. Precipitation

Table 2-1 presents the monthly and annual averages for the weather stations that contribute to the precipitation within the Animas Watershed. Figure 2-1 shows the locations of the weather stations within and around the Animas Watershed and provides a graph of the information included in Table 2-1.

Table 2-1: Average Precipitation for weather stations within the Animas Watershed

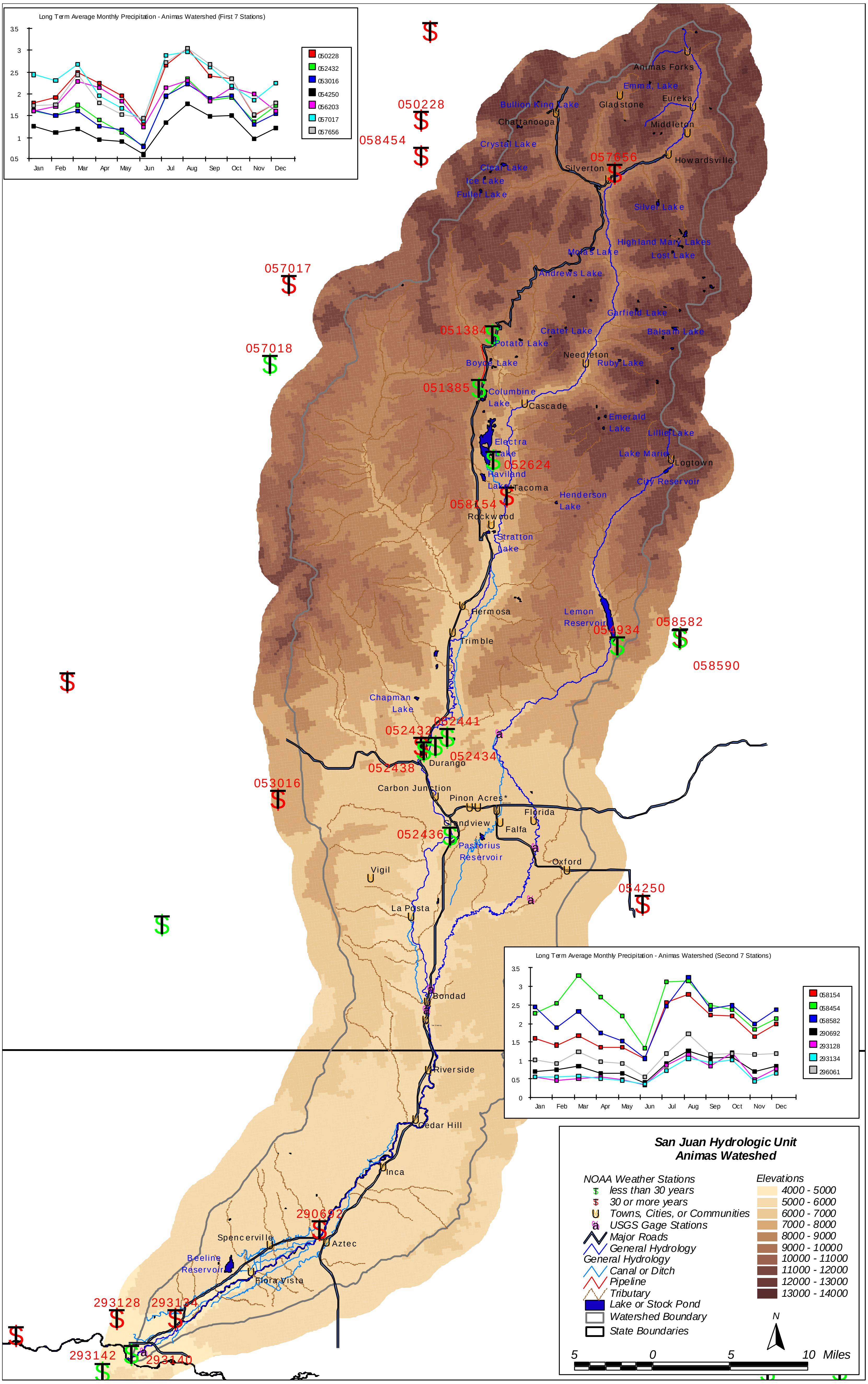
Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
050228	93	1.79	1.92	2.48	2.25	1.95	1.31	2.66	3.05	2.41	2.34	1.51	1.79	25.15
052432	92	1.61	1.50	1.74	1.40	1.12	0.80	1.94	2.34	1.85	1.91	1.36	1.73	19.45
053016	67	1.63	1.50	1.61	1.25	1.18	0.79	1.95	2.21	1.90	1.95	1.30	1.55	18.58
054250	63	1.25	1.11	1.20	0.94	0.90	0.61	1.34	1.77	1.47	1.51	0.97	1.21	14.79
056203	55	1.61	1.72	2.28	2.13	1.83	1.24	2.13	2.30	1.83	2.14	2.01	1.60	23.01
057017	89	2.44	2.32	2.68	1.96	1.67	1.39	2.87	2.97	2.62	2.17	1.86	2.24	27.54
057656	91	1.73	1.76	2.44	1.78	1.53	1.45	2.72	3.04	2.68	2.35	1.52	1.79	24.96
058154	39	1.60	1.42	1.68	1.37	1.37	1.05	2.57	2.78	2.23	2.20	1.66	1.98	21.33
058454	55	2.27	2.53	3.30	2.71	2.20	1.34	3.12	3.14	2.48	2.37	1.84	2.15	29.51
058582	58	2.46	1.90	2.33	1.75	1.54	1.07	2.47	3.25	2.39	2.49	1.99	2.37	25.81
290692	68	0.71	0.77	0.85	0.66	0.66	0.41	0.93	1.27	1.08	1.10	0.72	0.85	9.95
293128	31	0.57	0.48	0.53	0.58	0.49	0.34	0.88	1.18	0.86	1.21	0.49	0.79	8.10
293134	51	0.56	0.58	0.59	0.53	0.48	0.38	0.74	1.06	0.95	1.03	0.44	0.65	7.89
296061	35	1.03	0.94	1.25	0.98	0.93	0.58	1.19	1.72	1.16	1.19	1.18	1.19	13.32

To determine the average precipitation for the Animas Watershed, the precipitation values presented in Table 2-1 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-2.

Table 2-2: Calculated Average Precipitation within the Animas Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.53	1.43	1.73	1.37	1.23	0.89	1.90	2.26	1.82	1.81	1.38	1.57	18.95

Figure 2-1: NOAA Weather Stations within the Animas Watershed



2.1.2. Drainage basins and watersheds

The extent of the Animas Watershed is presented in Figure 2-2. It covers a total area of 1,370 square miles of which 230 square miles are in New Mexico. Approximately 210 square miles of the Animas Watershed in Colorado along the Colorado / New Mexico border is within the Southern Ute Indian Reservation. The primary source of water for this watershed is the Animas River. There are no significant storage reservoirs on the Animas River to control the flows in the river.

Agriculture is found along both sides of the Animas River. Approximately 4,500 acres are currently being irrigated within the Animas Watershed within New Mexico. The locations of the irrigated acreage are shown on Figure 2-2.

The topography of the Animas Watershed ranges from an elevation of approximately 5,240 feet to an elevation of approximately 13,600 feet. Figure 2-3 provide an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-4 shows an elevation distribution for the watershed.

There are six communities within the Animas Watershed in New Mexico. There are at least eight wastewater treatment plants within the watershed that discharge into the Animas River (See Figure 2-3). However, the only wastewater treatment plant that discharges into the Animas River in New Mexico is the Aztec wastewater treatment plant.

There are three surface water treatment plants that divert water from the Animas River within the New Mexico portion of the Animas Watershed (See Figure 2-3). The diversions supply the following surface water treatment plants:

1. Aztec water treatment plant – directly from the Animas River and from Aztec Ditch and Lower Animas Ditch.
2. Farmington water treatment plant – directly from the Animas River and from Farmington Lake and Willett Ditch.
3. Flora Vista water treatment plant

Figure 2-2: Animas Watershed

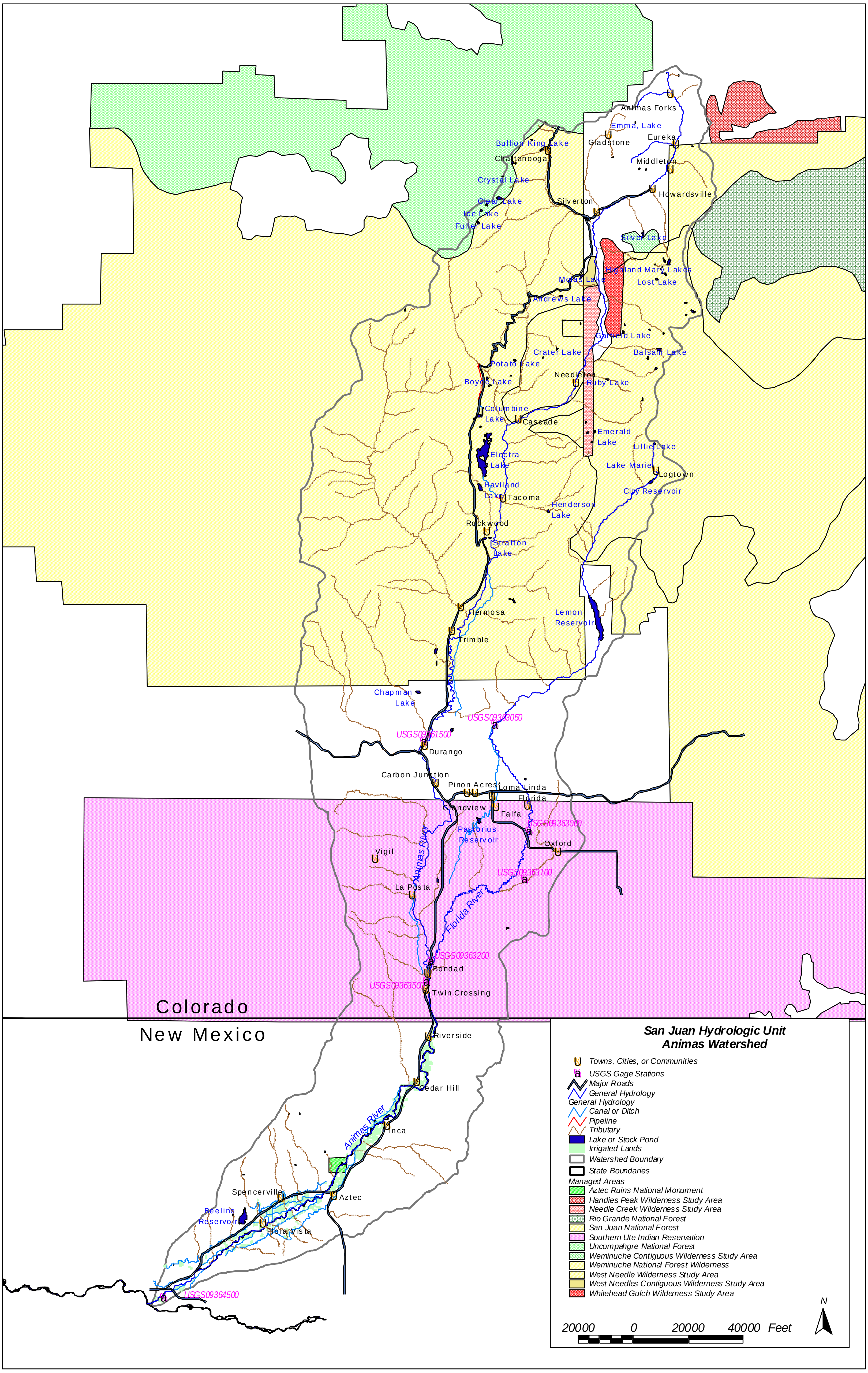


Figure 2-3: Topography Overview of the Animas Watershed

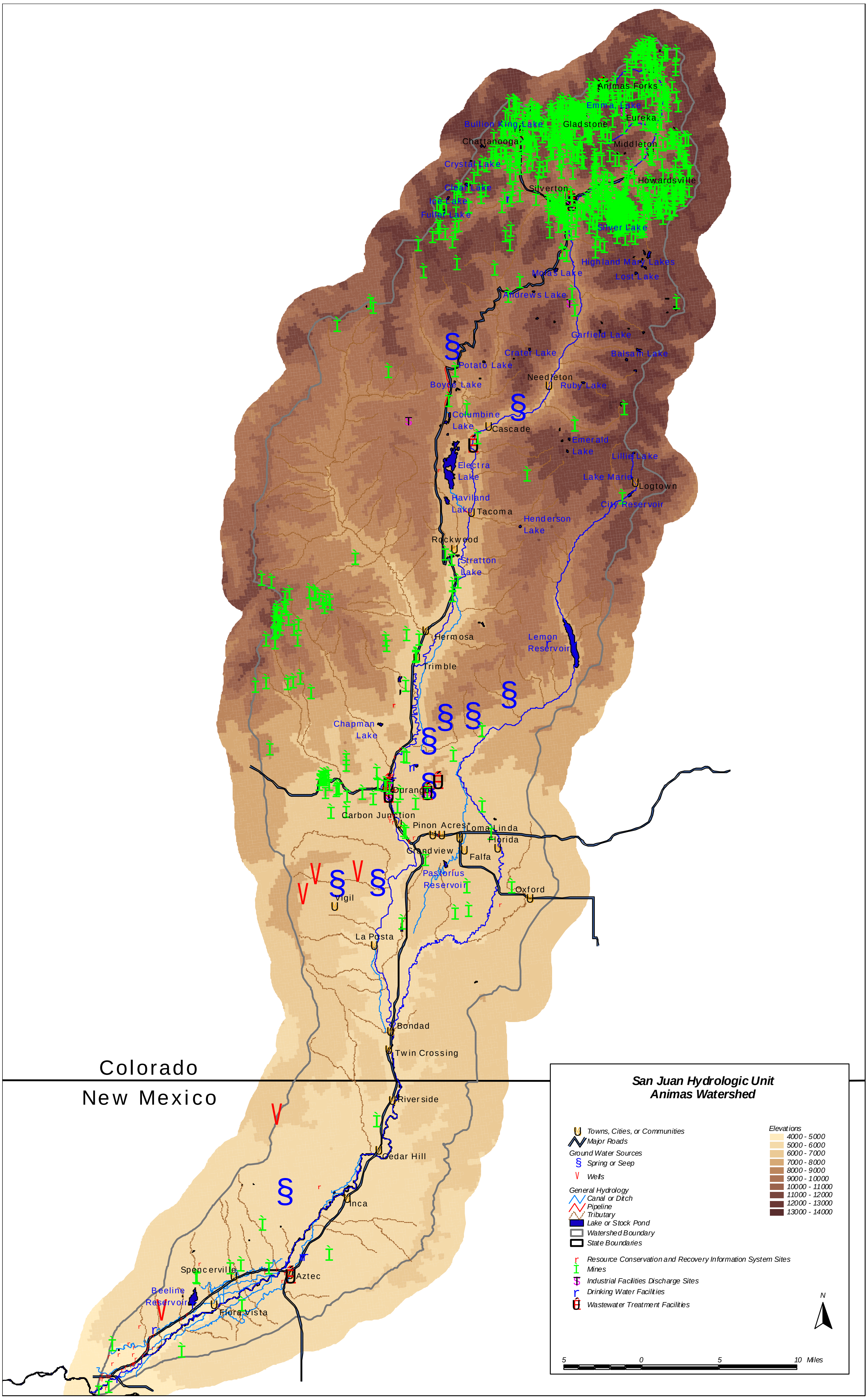
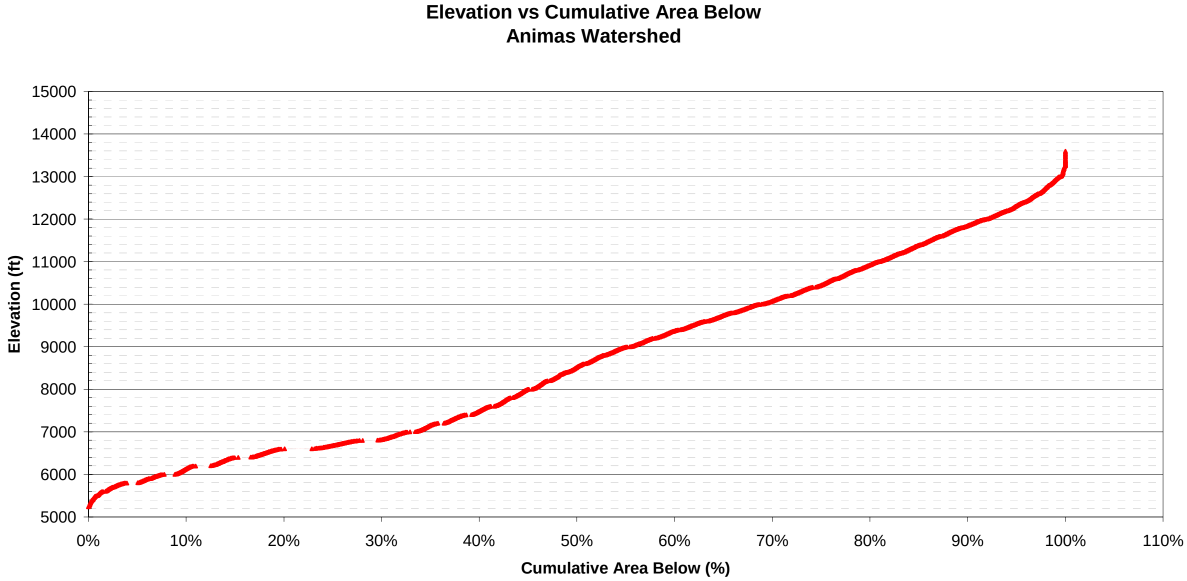


Figure 2-4: Elevation distribution in the Animas Watershed



2.1.3. Water supply

2.1.3.1. Surface water

2.1.3.1.1. Stream Flow data

The Animas River flows have historically been measured at several locations within the Animas Watershed. Most of the Animas Watershed is within Colorado, as a result, only the gaging stations within New Mexico and a few of the gaging stations within Colorado were evaluated. Table 2-3 provides the station identification number, the name, and the period of record for the USGS gage stations that were used to evaluate the flows on the Animas River.

Table 2-3: USGS Gage Stations on the Animas River within the Animas Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9361500	Animas River at Durango, CO	10/1897	9/2000
9363500	Animas River near Cedar Hill, NM	11/1933	9/2000
9364500	Animas River at Farmington, NM	9/1913	9/2000

In addition to the flow measurements taken on the Animas River, the USGS also obtained flow data on some of the tributaries to the Animas River. The station identification number, the name, and the period of record for the gage stations that were evaluated are provided in Table 2-4. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-1. The locations for the USGS gage stations listed in Table 2-3 and Table 2-4 are shown on Figure 2-2.

Table 2-4: USGS Gage Stations on tributaries of the Animas River within the Animas Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9363000	Florida River near Durango, CO	10/1910	9/1960
9363050	Florida River below Flor Farmers Ditch near Durango, CO	10/1967	9/1982
9363100	Salt Creek near Oxford, CO	10/1956	9/1983
9363200	Florida River at Bondad, CO	10/1956	9/1983

2.1.3.1.2. Surface water yields

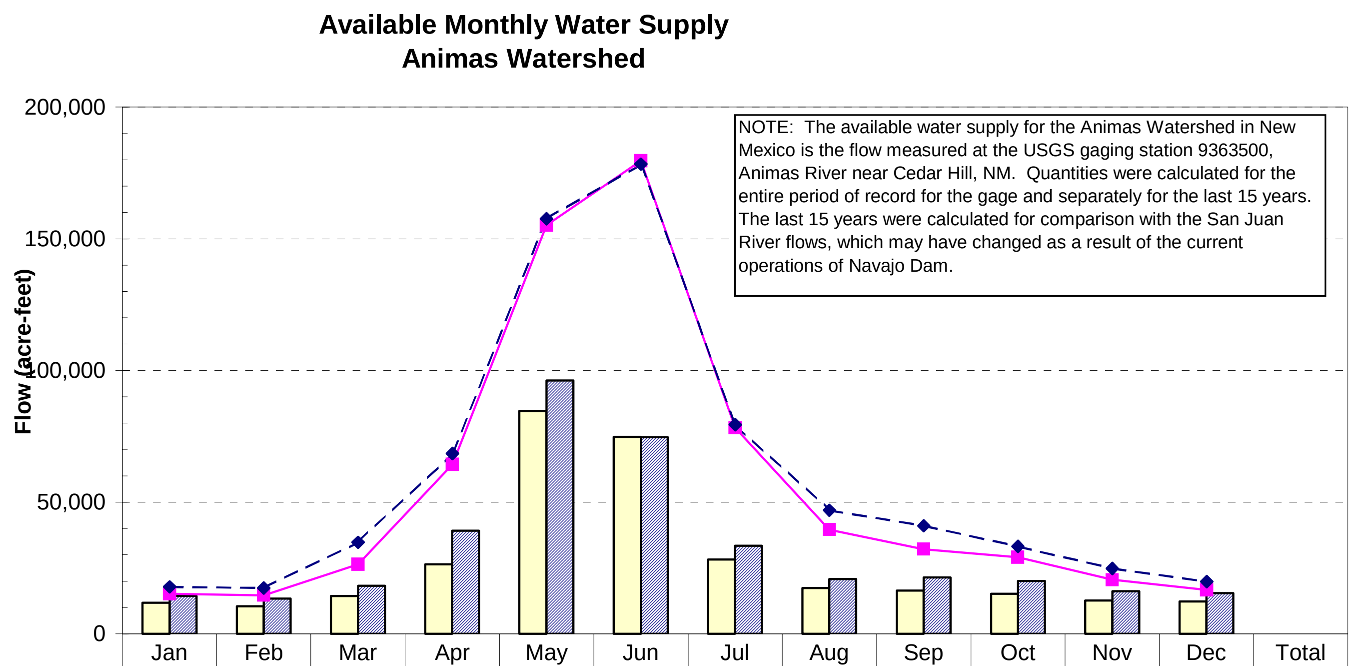
The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumption is specific for the Animas Watershed: measured flows at the USGS gaging station identified as 9363500, Animas River near Cedar Hill, NM was estimated as the available flow to the watershed.

The surface water yields that were calculated for the Animas Watershed are shown on Figure 2-5. The results presented include average flows and 90% probability flows for the period of record and for 1985 – 2000. The differences between the annual averages for these two periods are presented in Table 2-5.

Table 2-5: Comparison of flows for the Animas Watershed

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1933 – 2000	674,900	0%	406,500	0%
1985 – 2000	735,600	+ 9%	481,200	+ 18%

Figure 2-5: Surface Water Yields for the Animas Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	11,800	10,500	14,300	26,400	84,600	74,700	28,200	17,400	16,400	15,300	12,700	12,300	406,500
1985 - 2000 90% Probablility	14,300	13,400	18,200	39,200	96,200	74,600	33,400	20,800	21,400	20,100	16,200	15,500	481,200
Average	15,200	14,600	26,400	64,300	155,200	179,600	78,200	39,600	32,200	29,100	20,500	16,700	674,900
1985 - 2000 Average	17,800	17,400	34,700	68,500	157,600	178,300	79,400	46,900	41,000	33,200	24,800	19,800	735,600

2.1.3.1.3. Storage Reservoirs

There is only one major storage reservoir within the New Mexico portion of the Animas Watershed. It is the Farmington Lake Reservoir, which is located on a tributary to the Animas River (see Figure 2-3). Table 2-6 provides information relevant to the water supply.

Table 2-6: Animas Watershed Storage Reservoir Summary

Reservoir name:	Farmington Lake Reservoir
Date completed:	1964
Primary purpose:	Recreation
Owner / Operator:	City of Farmington
Maximum storage:	7,023 acre-feet
Surface area at maximum storage:	198 acres
Minimum pool:	
Normal storage:	6,703 acre-feet
Average surface area:	
Net evaporation rate:	
Average total evaporation:	
Normal earliest release date:	
Normal latest release date:	
Average release per year:	
Firm yield of reservoir (1 or 5 year intervals):	

2.2. **Blanco Canyon Watershed**

2.2.1. Historical weather data

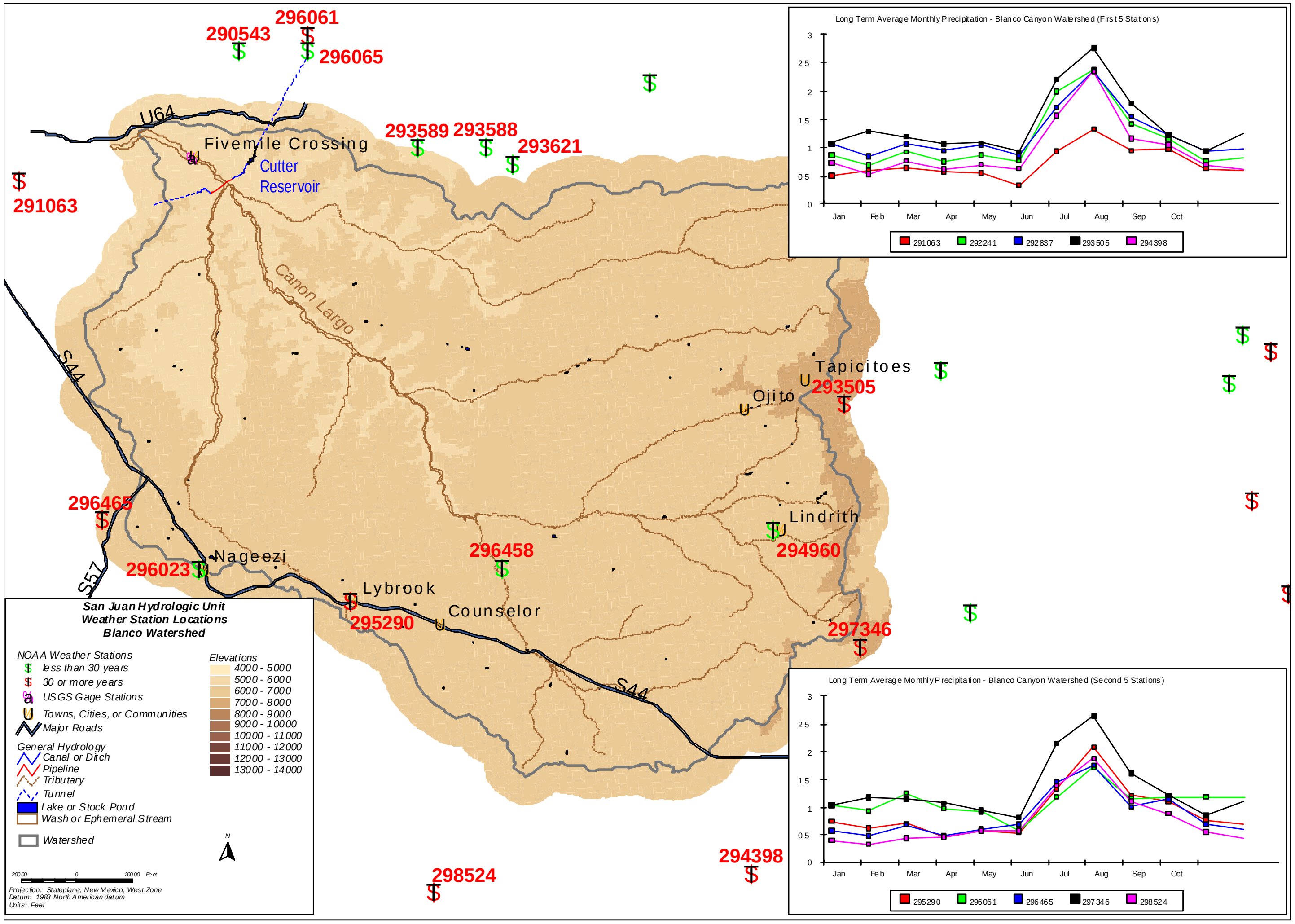
2.2.1.1. Precipitation

Table 2-7 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the Blanco Canyon Watershed. Figure 2-6 shows the locations of the weather stations within and around the Blanco Canyon Watershed and provides a graph of the information included in Table 2-7.

Table 2-7: Average Precipitation for weather stations within the Blanco Canyon Watershed

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
291063	67	0.51	0.6	0.64	0.57	0.55	0.34	0.94	1.32	0.95	0.98	0.63	0.60	8.51
292241	61	0.87	0.68	0.93	0.75	0.87	0.77	2.00	2.38	1.42	1.16	0.76	0.82	12.83
292837	63	1.07	0.84	1.07	0.95	1.04	0.86	1.71	2.36	1.55	1.23	0.92	0.99	14.71
293505	42	1.09	1.29	1.19	1.07	1.09	0.92	2.21	2.76	1.78	1.23	0.94	1.25	16.99
294398	55	0.73	0.53	0.76	0.61	0.69	0.63	1.57	2.34	1.17	1.05	0.70	0.62	11.06
295290	46	0.75	0.63	0.71	0.48	0.58	0.55	1.33	2.09	1.22	1.10	0.76	0.69	11.24
296061	35	1.03	0.94	1.25	0.98	0.93	0.58	1.19	1.72	1.16	1.19	1.18	1.19	13.32
296465	41	0.58	0.49	0.68	0.49	0.60	0.69	1.45	1.76	1.01	1.16	0.69	0.61	10.09
297346	40	1.03	1.17	1.16	1.08	0.95	0.82	2.16	2.64	1.61	1.21	0.86	1.11	15.92
298524	51	0.41	0.34	0.45	0.47	0.59	0.58	1.39	1.88	1.11	0.88	0.56	0.44	8.45

Figure 2-6: NOAA Weather Stations within the Blanco Canyon Watershed



To determine the average precipitation for the Blanco Canyon Watershed, the precipitation values presented in Table 2-7 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-8.

Table 2-8: Calculated Average Precipitation within the Blanco Canyon Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0.80	0.76	0.88	0.74	0.78	0.66	1.54	2.07	1.28	1.12	0.82	0.85	12.24

2.2.2. Drainage basins and watersheds

The extent of the Blanco Canyon Watershed is presented in Figure 2-7. It covers an area of approximately 1,700 square miles. Approximately 640 square miles of the watershed are within the Jicarilla Apache Nation. The primary source of surface water for this watershed is the Canon Largo, which is dependent on snowmelt, precipitation, and or shallow groundwater.

There is only very minor agricultural production within the Blanco Canyon Watershed.

The topography of the Blanco Canyon Watershed ranges from an elevation of approximately 5,540 feet to an elevation of approximately 8,000 feet. Figure 2-8 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-9 shows an elevation distribution for the watershed.

There are seven communities within the Blanco Canyon Watershed. There are no wastewater treatment plants or surface water treatment plants within the watershed.

Figure 2-7: Blanco Canyon Watershed

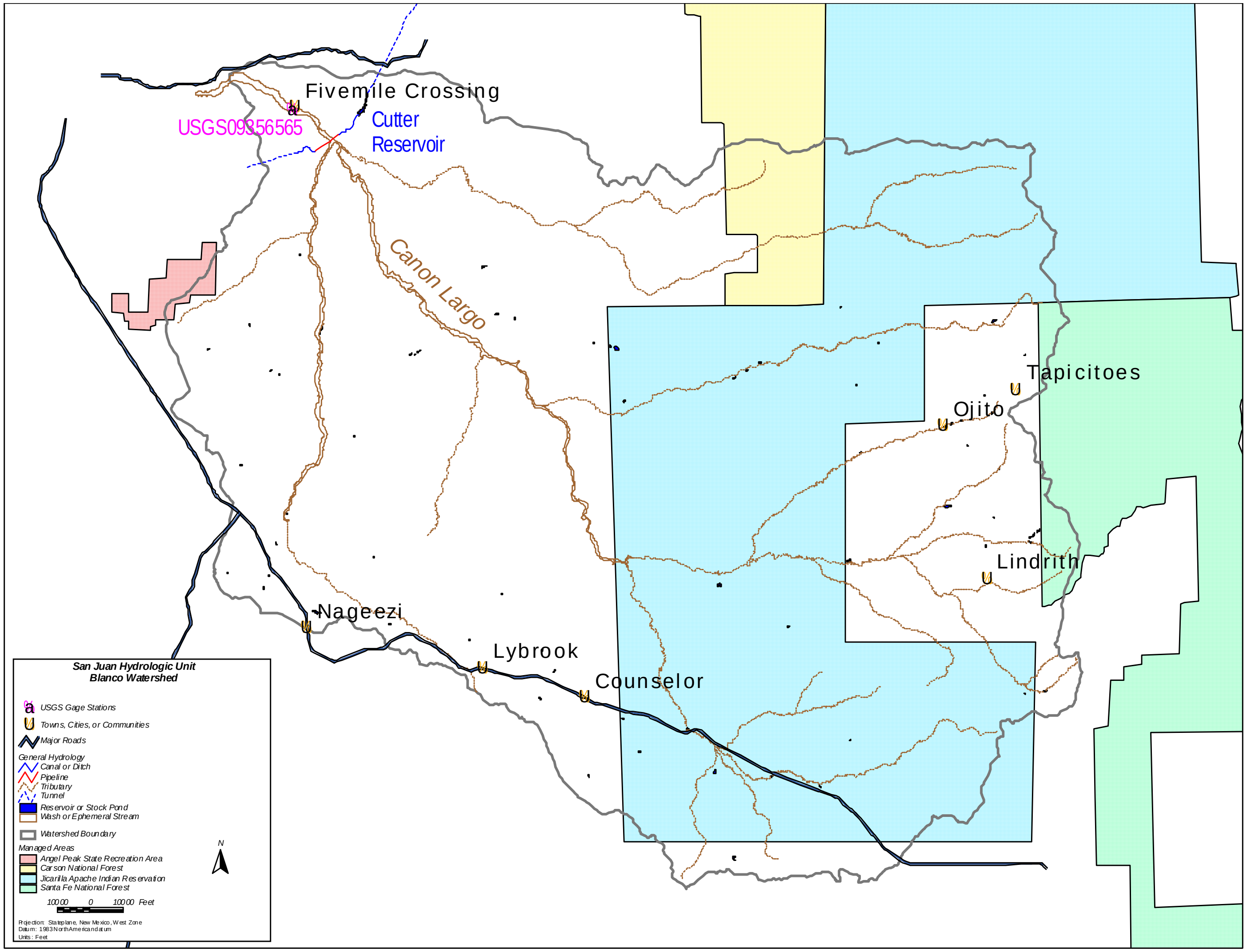


Figure 2-8: Topography Overview of the Blanco Canyon Watershed

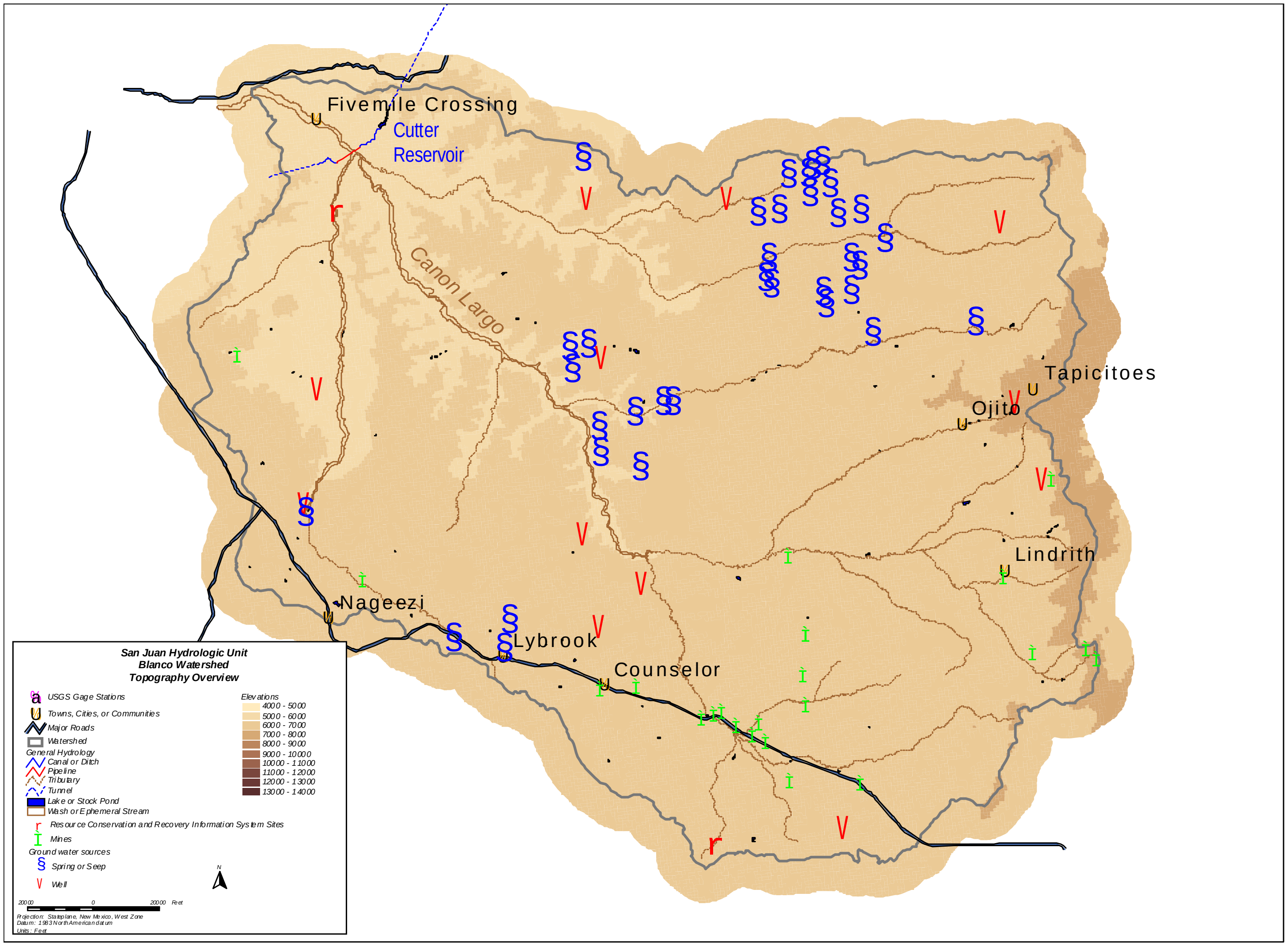
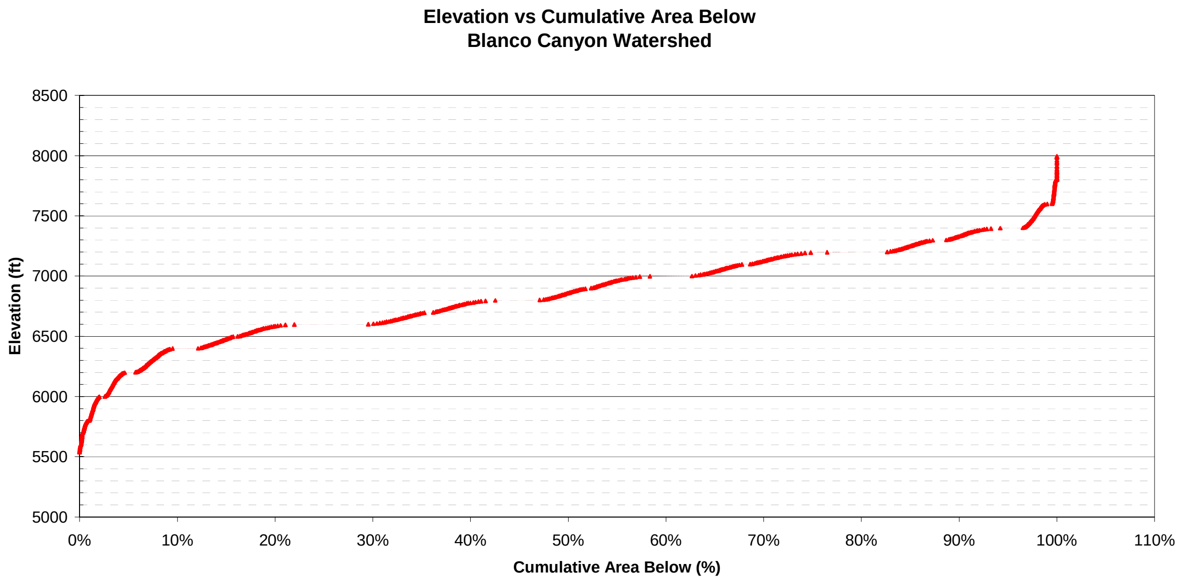


Figure 2-9: Elevation distribution in the Blanco Canyon Watershed



2.2.3. Water supply

2.2.3.1. Surface water

2.2.3.1.1. Stream Flow data

There is only one location within the Blanco Canyon Watershed where stream flow has historically been measured. Table 2-9 provides the station identification number, the name, and the period of record for that USGS gage station. The monthly data and graphs of the average monthly and 90% probability flows for this station are provided in Appendix C-2. The location for the USGS gage station listed in Table 2-9 is shown on Figure 2-7.

Table 2-9: USGS Gage Stations within the Blanco Canyon Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9356565	Canon Largo near Blanco, NM	10/1977	9/1981

2.2.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumptions are specific for the Blanco Canyon Watershed:

1. the only location where historical measured flows were available are at the USGS gaging station identified as 9356565, Canon Largo near Blanco, NM.
2. only three years of flow data were available at station 9356565. It was decided that three years of data was not sufficient to determine a reliable water supply. A

correlation was completed between gage 9356565 and the USGS stream gage 9367950, Chaco River near Waterflow, NM in the Chaco Watershed. Stream gage 9367950 was selected to correlate with because the Chaco Watershed was most similar in topography to the Blanco Canyon Watershed. Gage 9367950 had 17 years of flow data available. A correlation R^2 value of 0.61 was obtained.

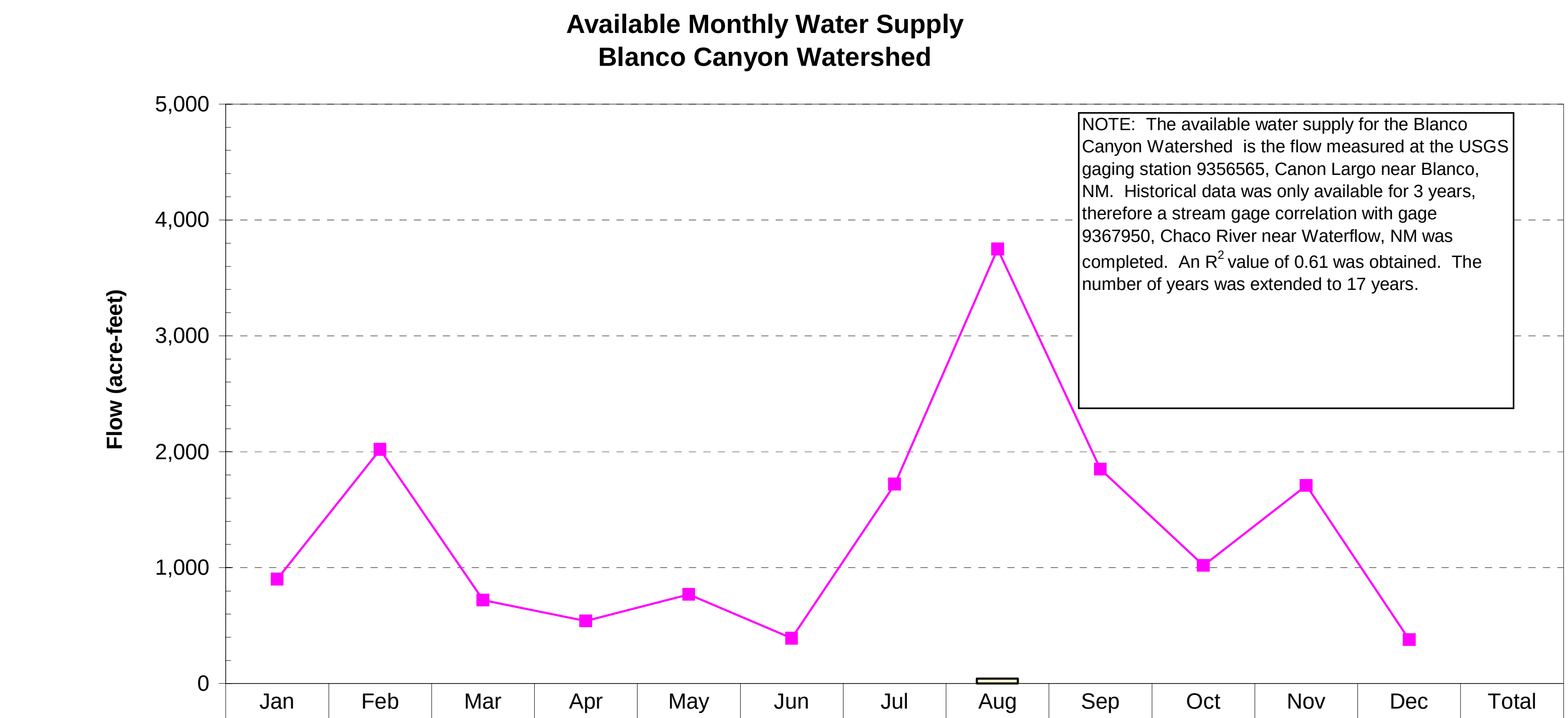
3. a correlation between stream flow and precipitation within the Blanco Canyon watershed was also completed but there was no apparent relationship between precipitation and stream flow.

The surface water yields that were calculated for the Blanco Canyon Watershed are shown on Figure 2-10. The results presented include average monthly and annual flows and monthly and annual 90% probability flows for the correlated period of record (1978 – 1994). The differences between the annual averages and 90% probabilities for the available historical flows and the correlated flows are presented in Table 2-10. The purpose of this table is to show the difference between the 3-year period of record and the extended correlated values.

Table 2-10: Comparison of flows for the Blanco Canyon Watershed

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1978 – 1981	15,000	0%	5,000	0%
1978 – 1994	15,900	6%	5,500	10%

Figure 2-10: Surface Water Yields for the Blanco Canyon Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	0	0	0	0	0	0	0	43	0	0	0	0	5,500
Average	900	2,020	720	540	770	390	1,720	3,750	1,850	1,020	1,710	380	15,900

2.2.3.1.3. Storage Reservoirs

There is only one major storage reservoir in the Blanco Canyon Watershed. However, it does not provide storage capacity for the Blanco Canyon Watershed. The storage reservoir is Cutter Reservoir, which is a regulating reservoir for NIIP and does not provide storage for the Blanco Canyon Watershed. Table 2-11 provides information relevant to the water supply.

Table 2-11: Blanco Canyon Watershed Storage Reservoir Summary

Reservoir name:	Cutter Reservoir
Date completed:	1972
Primary purpose:	Irrigation
Owner / Operator:	Department of Interior, Bureau of Indian Affairs
Maximum storage:	2,485 acre-feet
Surface area at maximum storage:	104 acre-feet
Normal storage:	1,793 acre-feet

2.3. **Chaco Watershed**

2.3.1. Historical weather data

2.3.1.1. Precipitation

Table 2-12 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the Chaco Watershed. Figure 2-11 shows the locations of the weather stations within and around the Chaco Watershed and provides a graph of the information included in Table 2-12.

Table 2-12: Average Precipitation for weather stations within the Chaco Watershed

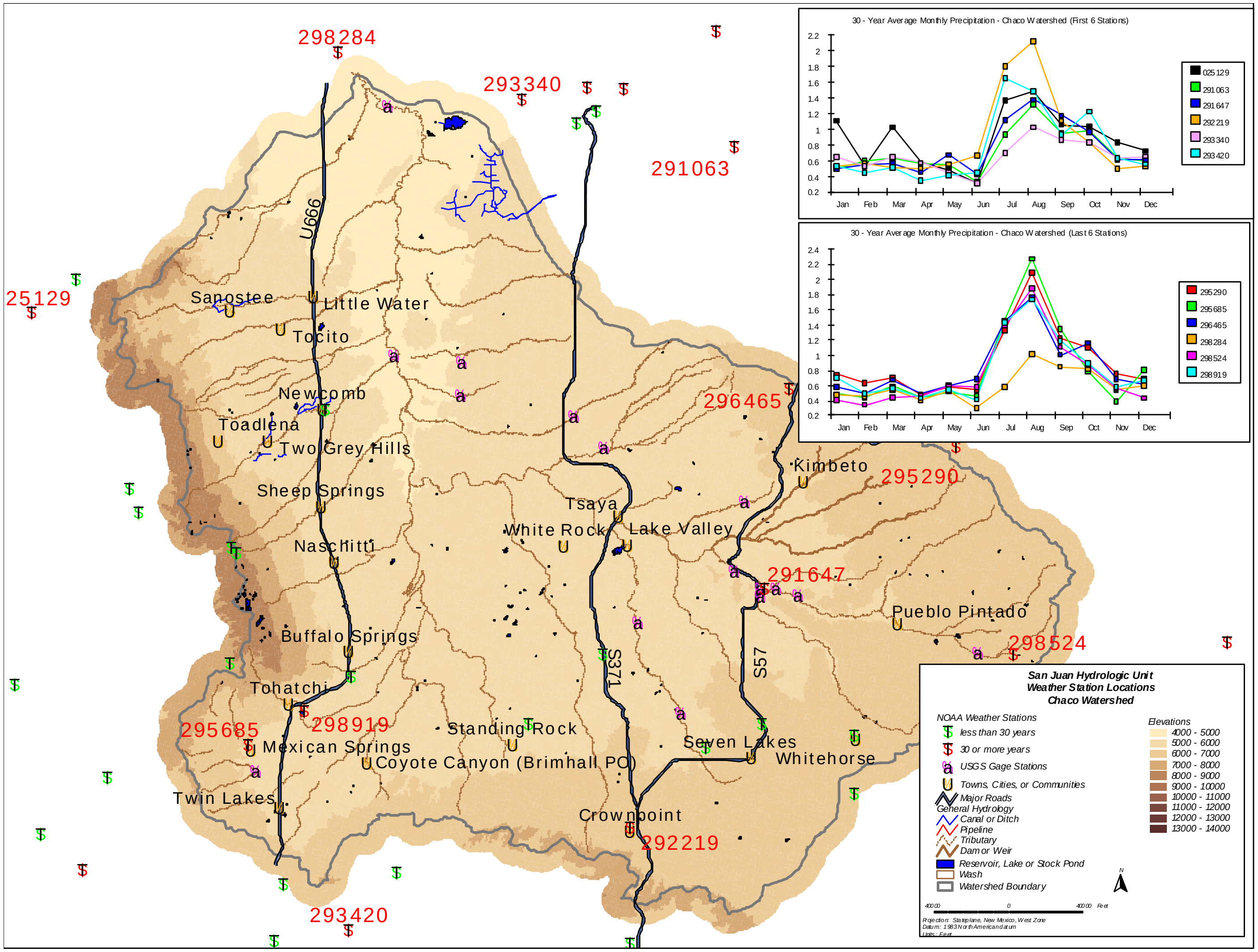
Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
025129	47	1.11	0.54	1.03	0.58	0.49	0.32	1.37	1.48	1.06	1.04	0.84	0.73	12.38
291063	67	0.51	0.60	0.64	0.57	0.55	0.34	0.94	1.32	0.95	0.98	0.63	0.60	8.51
291647	67	0.50	0.56	0.57	0.46	0.68	0.44	1.12	1.38	1.18	0.97	0.62	0.62	9.21
292219	40	0.53	0.57	0.52	0.51	0.56	0.67	1.81	2.12	1.11	0.84	0.50	0.54	10.24
293340	61	0.65	0.54	0.65	0.58	0.46	0.32	0.70	1.03	0.87	0.84	0.63	0.66	8.06
293420	32	0.54	0.45	0.52	0.35	0.42	0.45	1.65	1.49	0.94	1.23	0.64	0.56	9.29
295290	46	0.75	0.63	0.71	0.48	0.58	0.55	1.33	2.09	1.22	1.10	0.76	0.69	11.24
295685	39	0.49	0.45	0.59	0.45	0.52	0.46	1.46	2.28	1.35	0.79	0.40	0.81	9.98
296465	41	0.58	0.49	0.68	0.49	0.60	0.69	1.45	1.76	1.01	1.16	0.69	0.61	10.09
298284	67	0.48	0.46	0.54	0.41	0.53	0.30	0.58	1.02	0.85	0.82	0.55	0.60	6.82
298524	51	0.41	0.34	0.45	0.47	0.59	0.58	1.39	1.88	1.11	0.88	0.56	0.44	8.45
298919	50	0.71	0.50	0.56	0.44	0.55	0.42	1.43	1.74	1.19	0.89	0.58	0.66	10.15

To determine the average precipitation for the Chaco Watershed, the precipitation values presented in Table 2-12 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-13.

Table 2-13: Calculated Average Precipitation within the Chaco Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0.66	0.51	0.66	0.49	0.54	0.45	1.28	1.61	1.07	0.96	0.64	0.63	9.81

Figure 2-11: NOAA Weather Stations within the Chaco Watershed



2.3.2. Drainage basins and watersheds

The extent of the Chaco Watershed is presented in Figure 2-12. It covers a total area of 1,318 square miles, of which 270 square miles are in Arizona, 11 square miles are in Colorado, and the remaining 1,037 square miles are in New Mexico. Of the lands within New Mexico, approximately 770 square miles are within the Navajo Nation Reservation; approximately 115 square miles are within the Ute Mountain Ute Reservation.

Approximately 300 acres are currently being irrigated within the Navajo Nation outside of the Navajo Indian Irrigation Project within the Chaco Watershed. The locations of the irrigated acreage are identified on Figure 2-12.

The topography of the Chaco Watershed ranges from an elevation of approximately 5,230 feet to an elevation of approximately 13,600 feet. Figure 2-13 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-14 shows an elevation distribution for the watershed.

Figure 2-12: Chaco Watershed

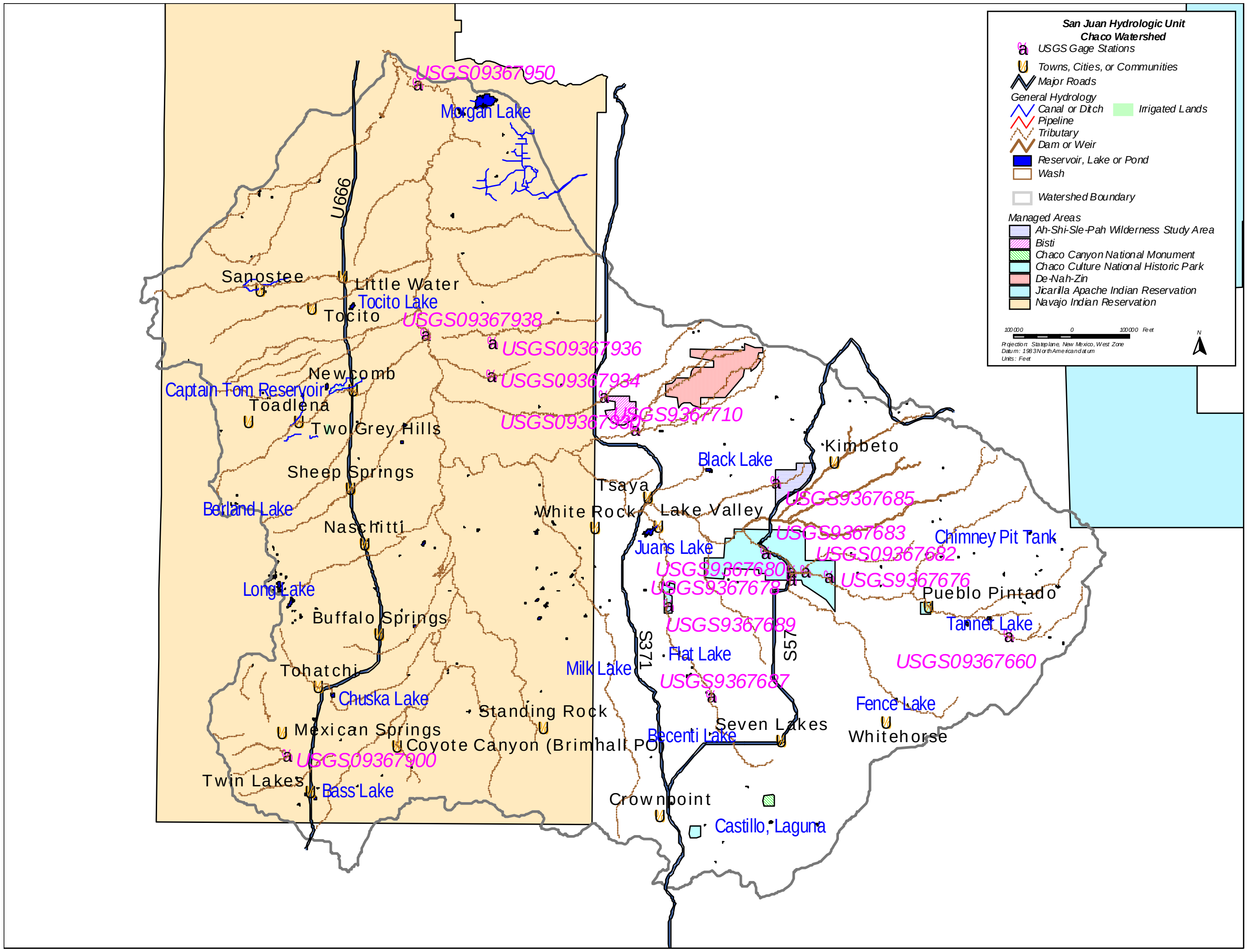


Figure 2-13: Topography Overview of the Chaco Watershed

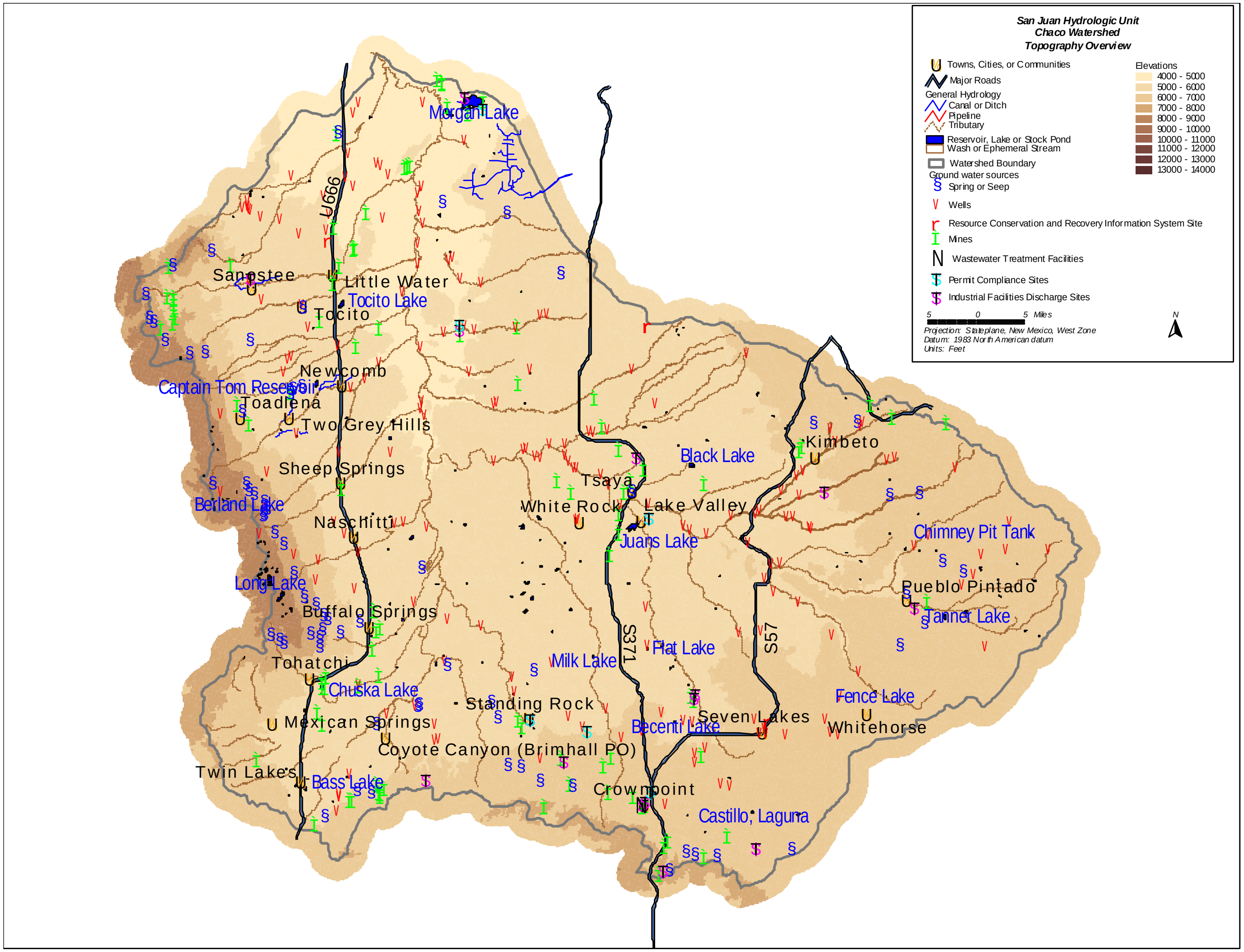
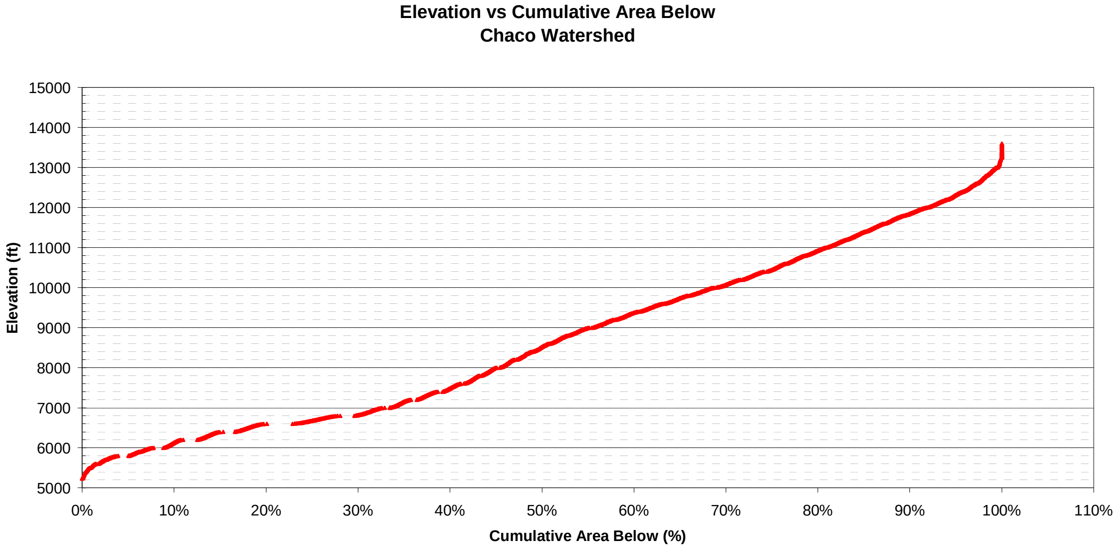


Figure 2-14: Elevation distribution in the Chaco Watershed



There is one wastewater treatment facility located within the watershed that discharge into the Chaco River. The wastewater treatment facility is located at Crownpoint.

There are no surface water treatment plant facilities within the Chaco Watershed.

2.3.3. Water supply

2.3.3.1. Surface water

2.3.3.1.1. Stream Flow data

The Chaco River flows have historically been measured at two locations within the Chaco Watershed. Table 2-14 provides the station identification number, the name, and the period of record for the USGS gage stations with available records that have been used to meter the Chaco River.

Table 2-14: USGS Gage Stations on the Chaco River within the Chaco Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9367938	Chaco River near Burnham, NM	10/1977	9/1982
9367950	Chaco River near Waterflow, NM	10/1977	9/1982

In addition to the flow measurements taken on the Chaco River, the USGS also obtained flow data on numerous tributaries to the Chaco River. The station identification number, the name, and the period of record for these gage stations are provided in Table 2-15. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-3. The locations of the USGS gage stations listed in Table 2-14 and Table 2-15 are shown on Figure 2-12.

Table 2-15: USGS Gage Stations on tributaries of the Chaco River within the Chaco Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9367660	Chaco Wash near Starlake Trading Post, NM	10/1977	9/1982
9367676	Chaco Wash at Eb at Chaco Canyon National Monument, NM	4/1980	10/1982
9367678	Fajada Wash at Chaco Canyon National Monument, NM	4/1980	9/1983
9367680	Chaco Wash at Chaco Canyon National Monument, NM	5/1976	4/1990
9367682	Gallo Wash at Chaco National Monument, NM	10/1977	9/1981
9367683	Chaco Wash near Pb at Bridge at Chaco National Monument, NM	4/1980	9/1983
9367685	Ah-Shi-Sle-Pah Wash near Kimbeto, NM	4/1977	9/1984
9367687	Kim-Me-Ni-Oli- Wash near Crownpoint, NM	10/1981	9/1983
9367689	Kim-Me-Ni-Oli- Wash near Lake Valley, NM	10/1981	9/1983
9367710	De-Na_Zin Wash near Bisti Trading Post, NM	1/1976	9/1982
9367900	Black Springs Wash near Mexican Springs, NM	5/1979	9/1982
9367930	Hunter Wash at Bisti Trading Post, NM	4/1975	9/1982
9367934	Teec-Ni-Di-Tso Wash near Burnham, NM	10/1977	9/1982
9367936	Burnham Wash near Burnham, NM	10/1977	9/1982

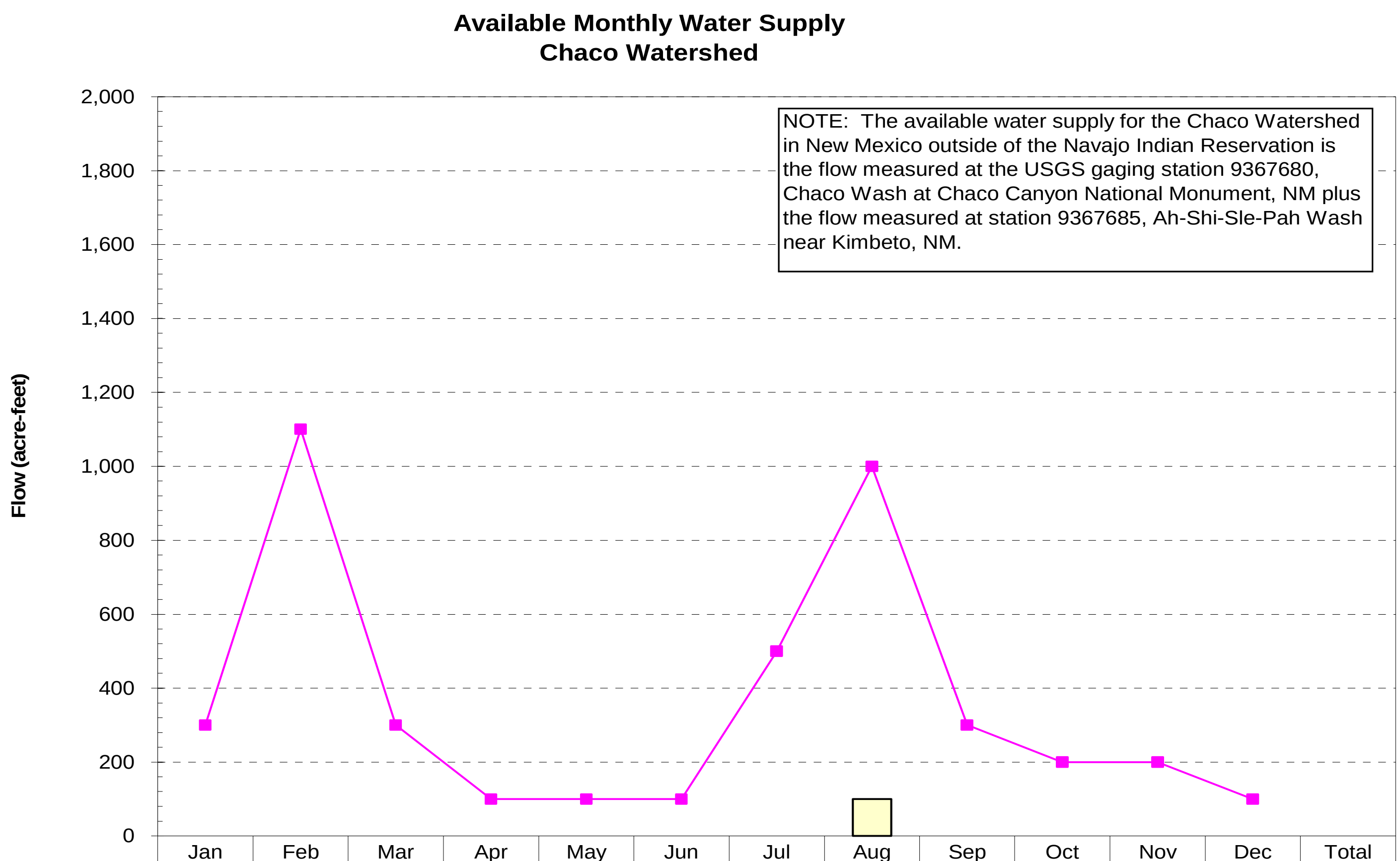
2.3.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumptions are specific for the Chaco Watershed:

1. reliable flow was assumed to be the flow available to the communities outside of the Navajo Nation. The water supply for the Navajo Nation will be calculated and provided by the Navajo Nation.
2. the available monthly water supply for the Chaco Watershed outside the Navajo Nation was calculated using the sum of the measured flows at the USGS gaging stations identified as 9367680, Chaco Wash at Chaco Canyon National Monument, NM and 9367685, Ah-Shi-Sle-Pah Wash near Kimbeto, NM.

The surface water yields that were calculated for the Chaco Watershed are shown on Figure 2-15. The results presented include average flows and 90% probability flows for the available period of record (1978 – 1983).

Figure 2-15: Surface Water Yields for the Chaco Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	0	0	0	0	0	0	0	100	0	0	0	0	2,000
Average	300	1,100	300	100	100	100	500	1,000	300	200	200	100	4,200

2.3.3.1.3. Storage Reservoirs

There is only one significant storage reservoir within the Chaco Watershed. It is in the Navajo Nation and does not affect the supply of the non-Navajo Nation study area. Table 2-16 provides information relevant to the water supply.

Table 2-16: Chaco Watershed Storage Reservoir Summary

Reservoir name:	Morgan Lake
Date completed:	1961
Primary purpose:	
Owner / Operator:	Arizona Public Service Company of New Mexico
Maximum storage:	42,800 acre-feet
Surface area at maximum storage:	1,260 acres
Minimum pool:	
Normal storage:	39,200 acre-feet
Average surface area:	
Net evaporation rate:	
Average total evaporation:	
Normal earliest release date:	
Normal latest release date:	
Average release per year:	
Firm yield of reservoir (1 or 5 year intervals):	

2.4. **La Plata Watershed**

The Middle San Juan Watershed, as defined by the USGS Hydrologic Unit Code, is the third largest watershed in the San Juan Hydrologic Unit. It includes a total area of approximately 1,950 square miles. For the purposes of this study, the USGS' defined Middle San Juan Watershed was divided into two sub-watersheds, the La Plata Watershed and the Middle San Juan Watershed. The watershed for the La Plata River is separated from the watershed for the San Juan River. The La Plata Watershed is the smallest watershed that was evaluated in this study. It has a total area of 620 square miles.

2.4.1. Historical weather data

2.4.1.1. Precipitation

Table 2-17 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the La Plata Watershed. Figure 2-16 shows the locations of the weather stations within and around the La Plata Watershed and provides a graph of the information included in Table 2-17.

Table 2-17: Average precipitation for weather stations within the La Plata Watershed

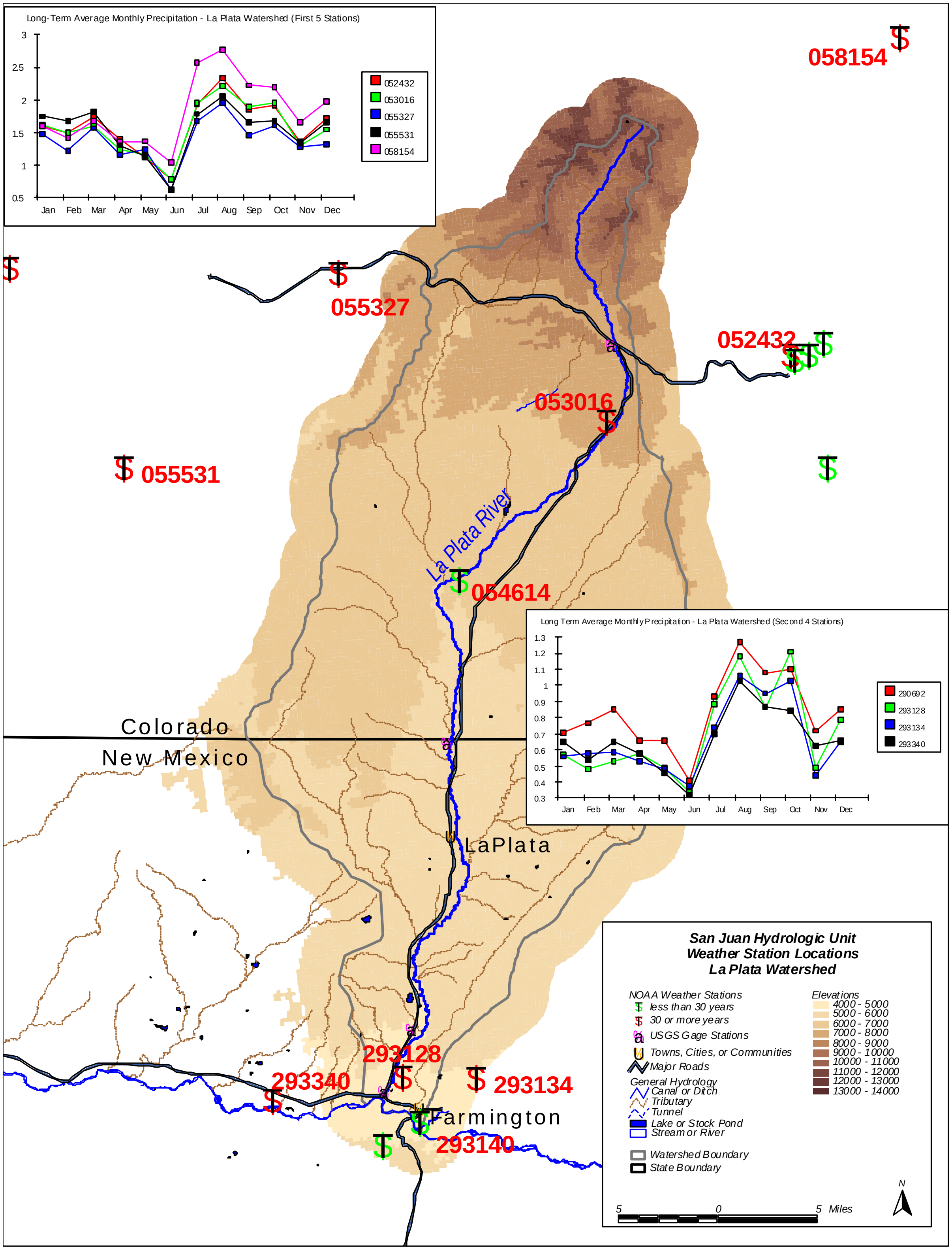
Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
052432	92	1.61	1.50	1.74	1.40	1.12	0.80	1.94	2.34	1.85	1.91	1.36	1.73	19.45
053016	67	1.63	1.50	1.61	1.25	1.18	0.79	1.95	2.21	1.90	1.95	1.30	1.55	18.58
055327	47	1.49	1.23	1.58	1.16	1.24	0.64	1.68	1.95	1.46	1.61	1.27	1.33	16.32
055531	76	1.75	1.68	1.82	1.31	1.15	0.62	1.79	2.06	1.66	1.67	1.35	1.66	18.23
058154	39	1.60	1.42	1.68	1.37	1.37	1.05	2.57	2.78	2.23	2.20	1.66	1.98	21.33
290692	68	0.71	0.77	0.85	0.66	0.66	0.41	0.93	1.27	1.08	1.10	0.72	0.85	9.95
293128	31	0.57	0.48	0.53	0.58	0.49	0.34	0.88	1.18	0.86	1.21	0.49	0.79	8.10
293134	51	0.56	0.58	0.59	0.53	0.48	0.38	0.74	1.06	0.95	1.03	0.44	0.65	7.89
293340	61	0.65	0.54	0.65	0.58	0.46	0.32	0.70	1.03	0.87	0.84	0.63	0.66	8.06

To determine the average precipitation for the La Plata Watershed, the precipitation values presented in Table 2-17 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-18.

Table 2-18: Calculated Average Precipitation within the La Plata Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.20	1.10	1.26	0.99	0.91	0.59	1.46	1.76	1.43	1.47	1.05	1.25	14.32

Figure 2-16: NOAA Weather Stations within the La Plata Watershed



2.4.2. Drainage basins and watersheds

The extent of the La Plata Watershed is presented in Figure 2-17. As mentioned earlier, it is the smallest watershed evaluated in this study. It covers a total area of 620 square miles, of which 200 square miles are in New Mexico. Approximately 32 square miles of the La Plata Watershed in New Mexico is within the Ute Mountain Indian Reservation. Approximately 25 square miles of the La Plata Watershed in Colorado along the Colorado – New Mexico border is in the Ute Mountain Indian Reservation. Approximately 265 square miles of the La Plata Watershed in Colorado along the Colorado – New Mexico border is in the Southern Ute Indian Reservation. The primary source of water for this watershed is the La Plata River. There are no significant storage reservoirs on the La Plata River to control the flows in the river.

Agriculture is found along both sides of the La Plata River. Approximately 2,750 acres in 2000 were irrigated within the La Plata Watershed within New Mexico. It has been as much as 3,300 acres as recently as 1994. The locations of the irrigated acreage are shown on Figure 2-17.

The topography of the La Plata Watershed ranges from an elevation of approximately 5,180 feet to an elevation of approximately 13,000 feet. Figure 2-18 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-19 shows an elevation distribution for the watershed.

There is only one community within the La Plata Watershed within New Mexico. It is the community of La Plata. There is also only one wastewater treatment plant located within the La Plata Watershed. It is the Farmington wastewater treatment plant, however, it discharges into the San Juan River upstream of the confluence with the La Plata River (See Figure 2-18).

There are no surface water treatment plants that divert water from the La Plata in New Mexico. Municipal water for this watershed is provided by the Farmington water treatment plant.

Figure 2-17: La Plata Watershed

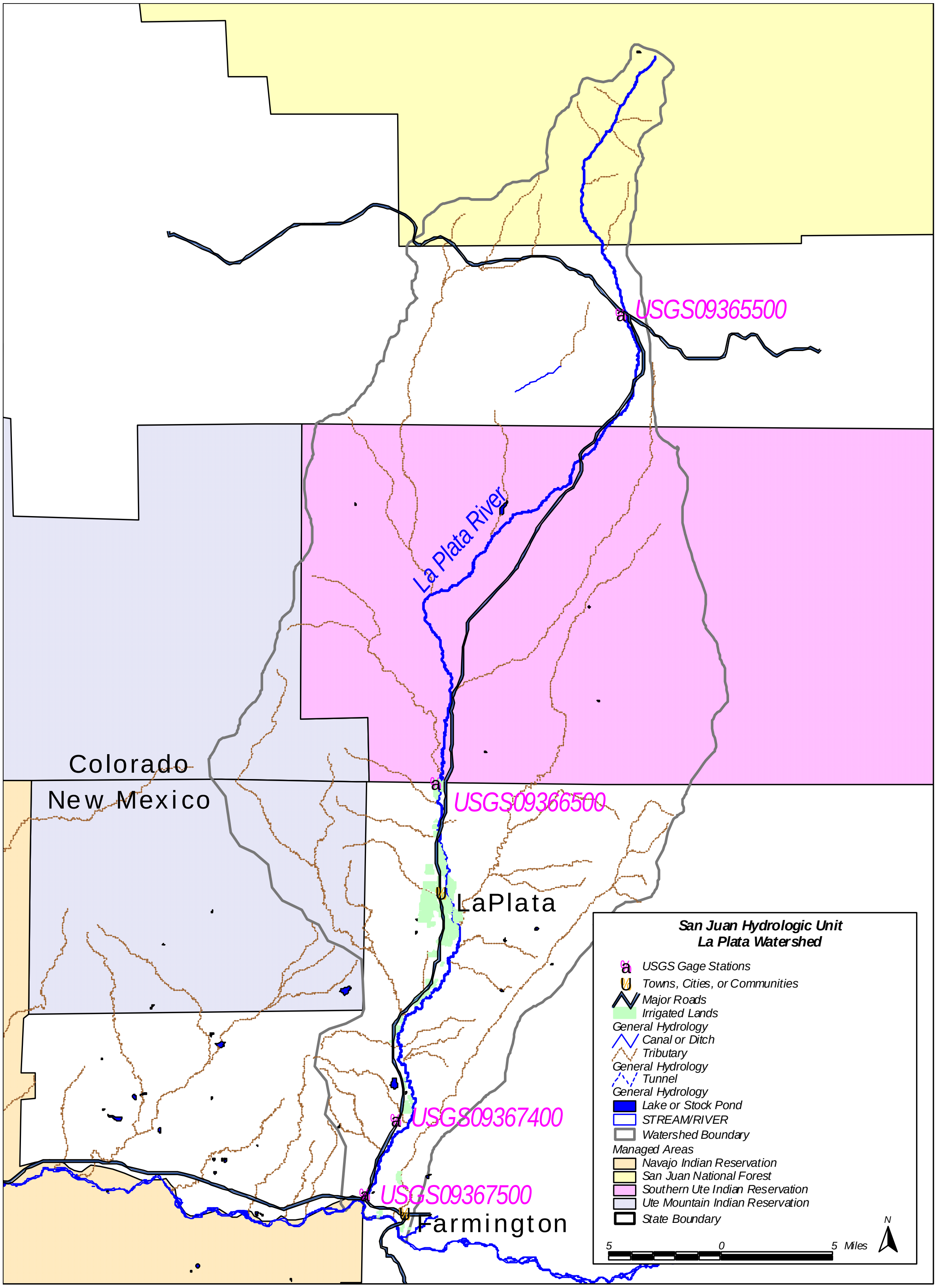


Figure 2-18: Topography Overview of the La Plata Watershed

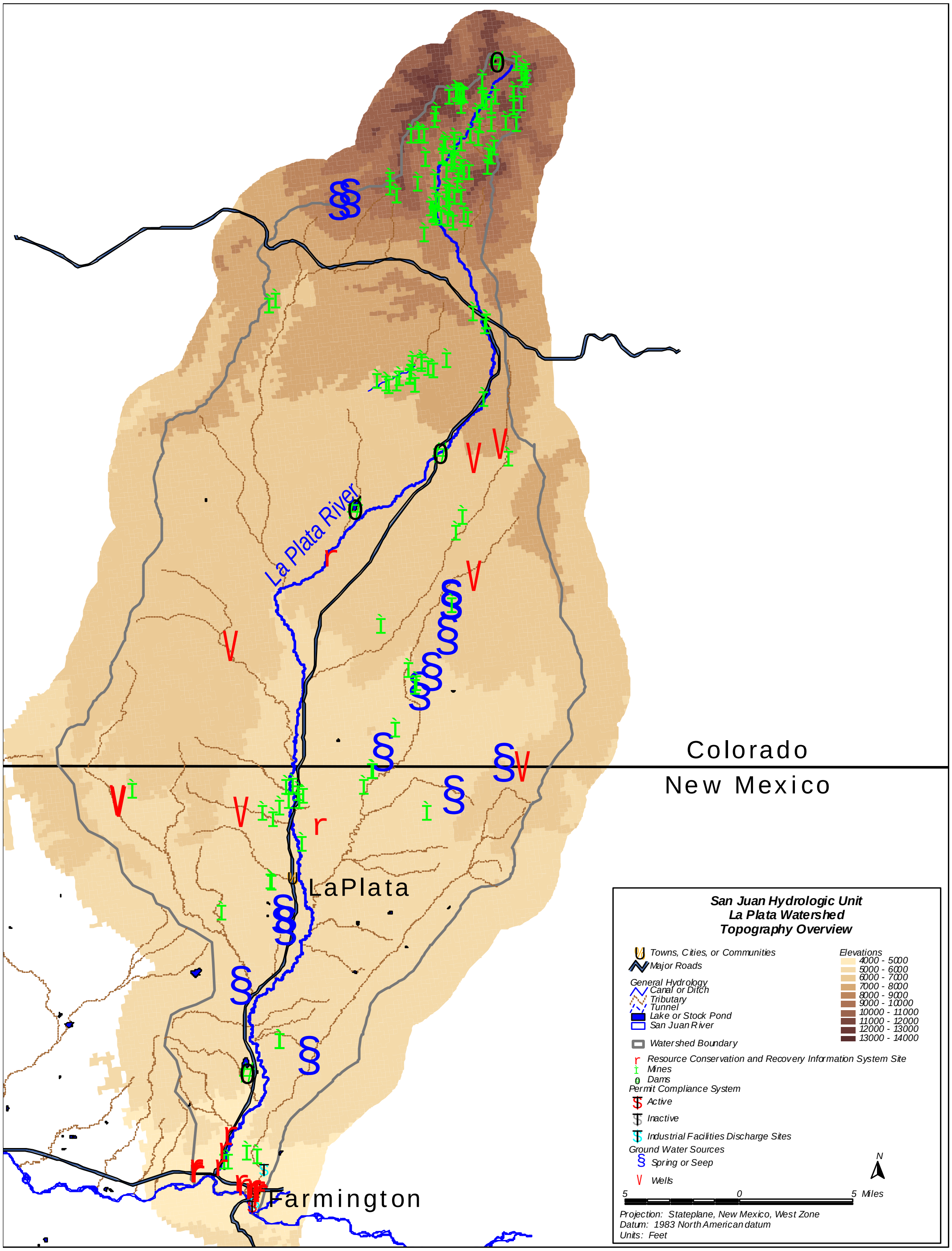
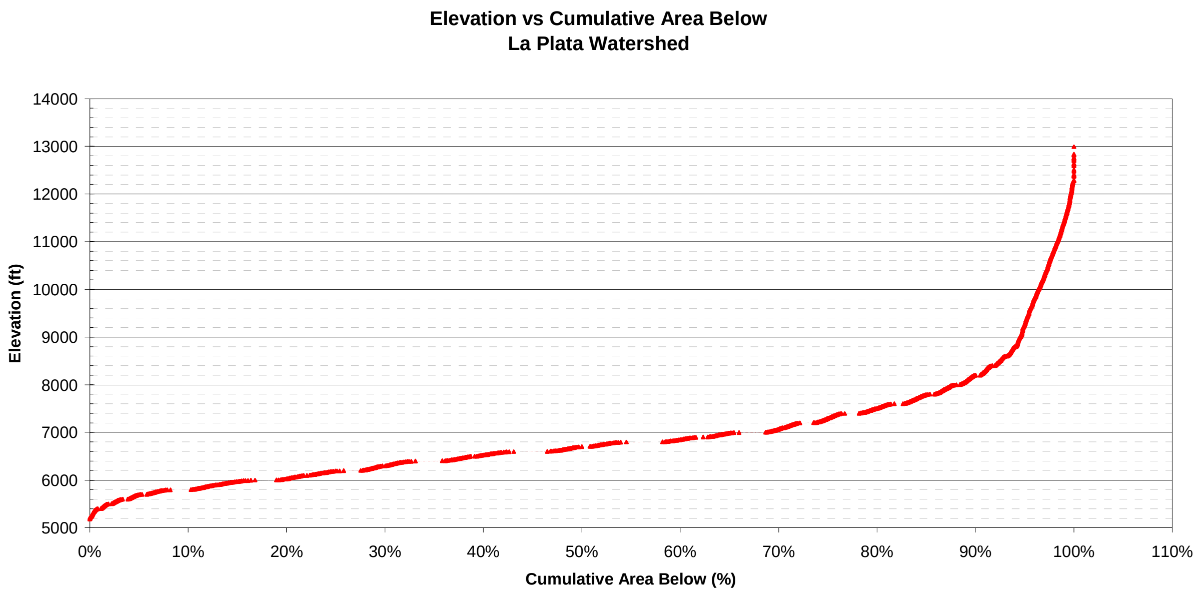


Figure 2-19: Elevation distribution in the La Plata Watershed



2.4.3. Water supply

2.4.3.1. Surface water

2.4.3.1.1. Stream Flow data

The La Plata River flows have historically been measured at several locations within the La Plata Watershed. Most of the La Plata Watershed is within Colorado, however, since the La Plata Watershed is so small and only one gaging station within Colorado was available, all of the gaging stations were evaluated. Table 2-19 provides the station identification number, the name, and the period of record for the USGS gage stations with available records that were used to evaluate the flows on the La Plata River.

Table 2-19: USGS Gage Stations on the La Plata River

Station ID	Station Name	Beginning Date	Ending Date
9365500	La Plata River at Hesperus, CO	10/1917	9/2000
9366500	La Plata River at Colorado – New Mexico State Line	10/1920	9/2000
9367500	La Plata River near Farmington, NM	3/1938	9/2000

In addition to the flow measurements taken on the La Plata River, the USGS also obtained flow data on some of the tributaries to the La Plata River. The station identification number, the name, and the period of record for the gage stations that were evaluated are provided in Table 2-20. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-4. The locations for the USGS gage stations listed in Table 2-19 and Table 2-20 are shown on Figure 2-17.

Table 2-20: USGS Gage Stations on tributaries of the La Plata River within the La Plata Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9367400	La Plata River tributary near Farmington, NM	10/1979	9/1983

2.4.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumptions are specific for the La Plata Watershed:

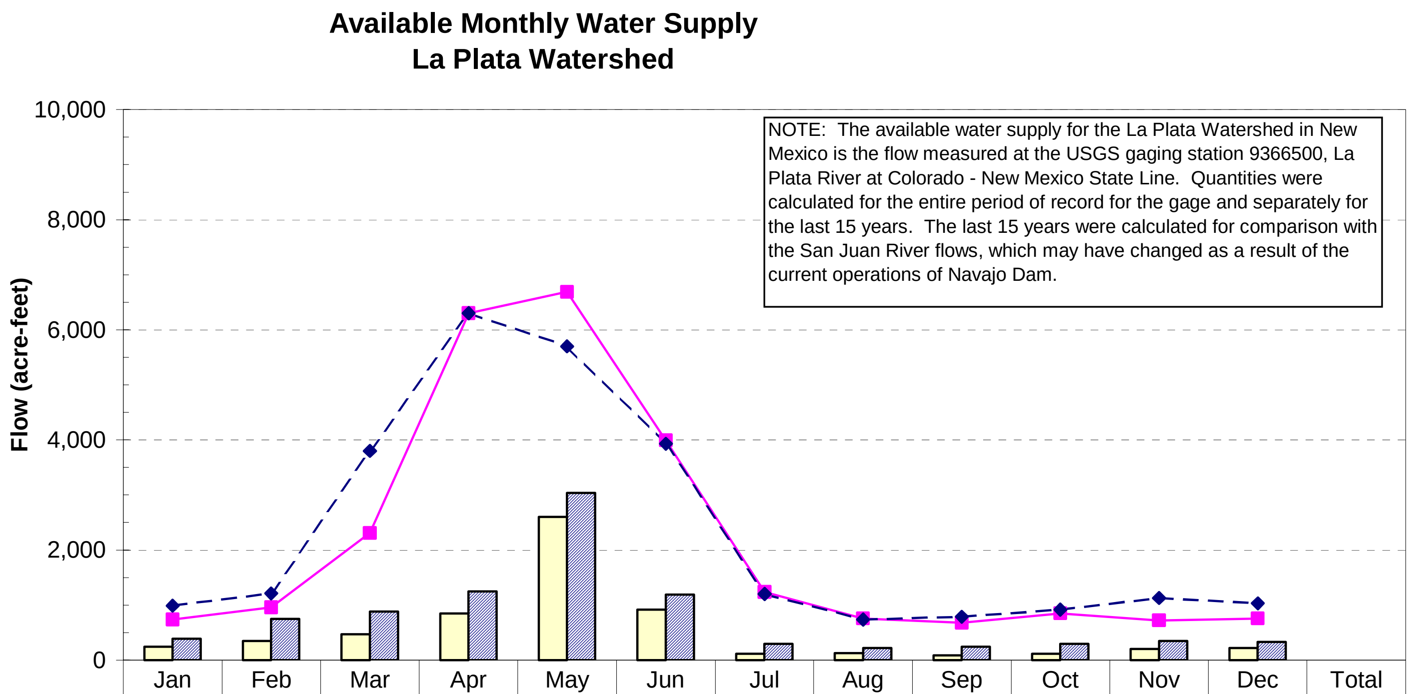
1. measured flows at the USGS gaging station identified as 9366500, La Plata River at Colorado – New Mexico State Line was estimated as the available flow to the watershed.

The surface water yields that were calculated for the La Plata Watershed are shown on Figure 2-20. The results presented include average flows and 90% probability flows for the period of record and for 1985 – 2000. The differences between the annual averages for these two periods are presented in Table 2-22.

Table 2-21: Comparison of flows for the La Plata Watershed

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1920 – 2000	26,000	0%	9,000	0%
1985 – 2000	29,000	+ 12%	11,500	+ 28%

Figure 2-20: Surface Water Yields for the La Plata Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	240	350	470	850	2,600	920	120	130	90	120	200	220	9,000
1985 - 2000 90% Probablility	390	750	880	1,250	3,040	1,190	300	220	240	300	350	330	11,500
Average	740	960	2,310	6,300	6,690	3,990	1,240	760	680	850	720	760	26,000
1985 - 2000 Average	990	1,210	3,800	6,300	5,700	3,930	1,200	740	790	920	1,130	1,030	29,000

2.4.3.1.3. Storage Reservoirs

There are not any major storage reservoirs within the La Plata Watershed in New Mexico. However, there was one minor reservoir identified. Table 2-22 provides information relevant to the water supply.

Table 2-22: La Plata Watershed Reservoir Summary

Reservoir name:	Jackson Lake
Date completed:	1919
Primary purpose:	Fish and Wildlife
Owner / Operator:	New Mexico Department of Game and Fish
Maximum storage:	1,020 acre-feet
Surface area at maximum storage:	69.30 acres
Normal storage:	911 acre-feet

2.5. **Middle San Juan Watershed**

The Middle San Juan Watershed, as defined by the USGS Hydrologic Unit Code, is the third largest watershed in the San Juan Hydrologic Unit. It includes a total area of approximately 1,950 square miles. For the purposes of this study, the USGS' defined Middle San Juan Watershed is divided into two sub-watersheds, the La Plata Watershed and the Middle San Juan Watershed. The La Plata Watershed is delineated as the watershed for the La Plata River. The Middle San Juan is delineated as the watershed for the San Juan River.

The Middle San Juan Watershed is the farthest downstream watershed on the San Juan River that is included in this study. Tributaries to the Middle San Juan Watershed include the Chaco Watershed, the La Plata Watershed, the Animas Watershed, and the Upper San Juan Watershed.

2.5.1. Historical weather data

2.5.1.1. Precipitation

Table 2-23 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the Middle San Juan Watershed. Figure 2-21 shows the locations of the weather stations within and around the Middle San Juan Watershed and provides a graph of the information included in Table 2-23.

Table 2-23: Average Precipitation for weather stations within the Middle San Juan Watershed

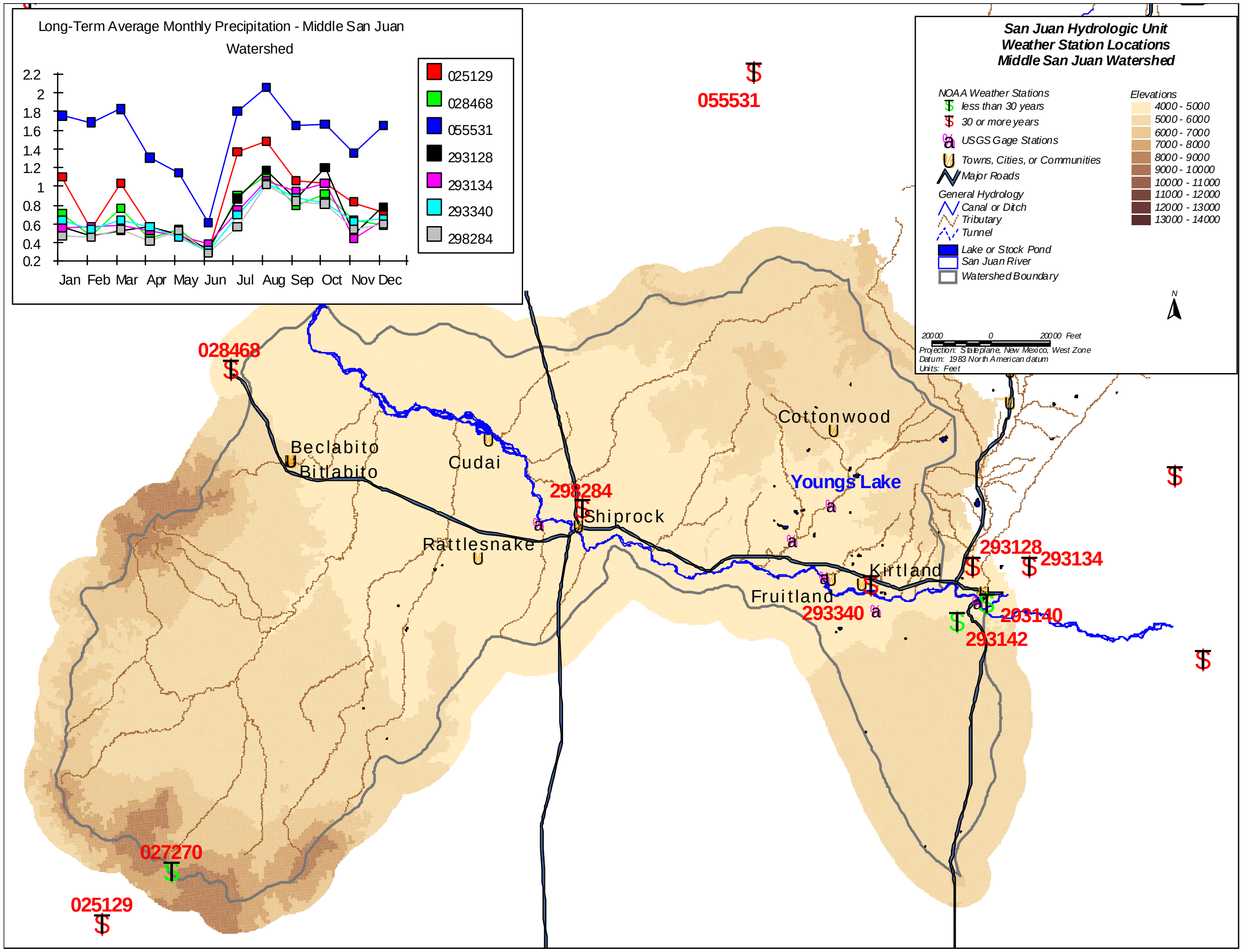
Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
025129	47	1.11	0.54	1.03	0.58	0.49	0.32	1.37	1.48	1.06	1.04	0.84	0.73	12.38
028468	36	0.72	0.48	0.77	0.44	0.55	0.32	0.91	1.12	0.8	0.92	0.64	0.59	8.39
055531	76	1.75	1.68	1.82	1.31	1.15	0.62	1.79	2.06	1.66	1.67	1.35	1.66	18.23
293128	31	0.57	0.48	0.53	0.58	0.49	0.34	0.88	1.18	0.86	1.21	0.49	0.79	8.1
293134	51	0.56	0.58	0.59	0.53	0.48	0.38	0.74	1.06	0.95	1.03	0.44	0.65	7.89
293340	61	0.65	0.54	0.65	0.58	0.46	0.32	0.7	1.03	0.87	0.84	0.63	0.66	8.06
298284	67	0.48	0.46	0.54	0.41	0.53	0.3	0.58	1.02	0.85	0.82	0.55	0.6	6.82

To determine the average precipitation for the Middle San Juan Watershed, the precipitation values presented in Table 2-23 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-24.

Table 2-24: Calculated Average Precipitation within the Middle San Juan Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0.67	0.62	0.73	0.60	0.56	0.36	0.81	1.14	0.87	0.90	0.66	0.73	8.73

Figure 2-21: NOAA Weather Stations within the Middle San Juan Watershed



2.5.2. Drainage basins and watersheds

The extent of the Middle San Juan Watershed is presented in Figure 2-22. It covers a total area of 1318 square miles, of which 270 square miles are in Arizona, 11 square miles are in Colorado, and the remaining 1,037 square miles are in New Mexico. Of the lands within New Mexico, approximately 770 square miles are within the Navajo Nation Indian Reservation; approximately 115 square miles are within the Ute Mountain Indian Reservation. The primary source of water for this watershed is the San Juan River, the Animas River, the La Plata River and the Chaco River.

Agriculture is found along both sides of the San Juan River. Approximately 8,200 acres are currently being irrigated within the Middle San Juan Watershed. The locations of the irrigated acreage are shown on Figure 2-22.

The topography of the Middle San Juan Watershed ranges from an elevation of approximately 4,750 feet to an elevation of approximately 9,700 feet. Figure 2-23 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-24 shows an elevation distribution for the watershed.

Figure 2-22: Middle San Juan Watershed

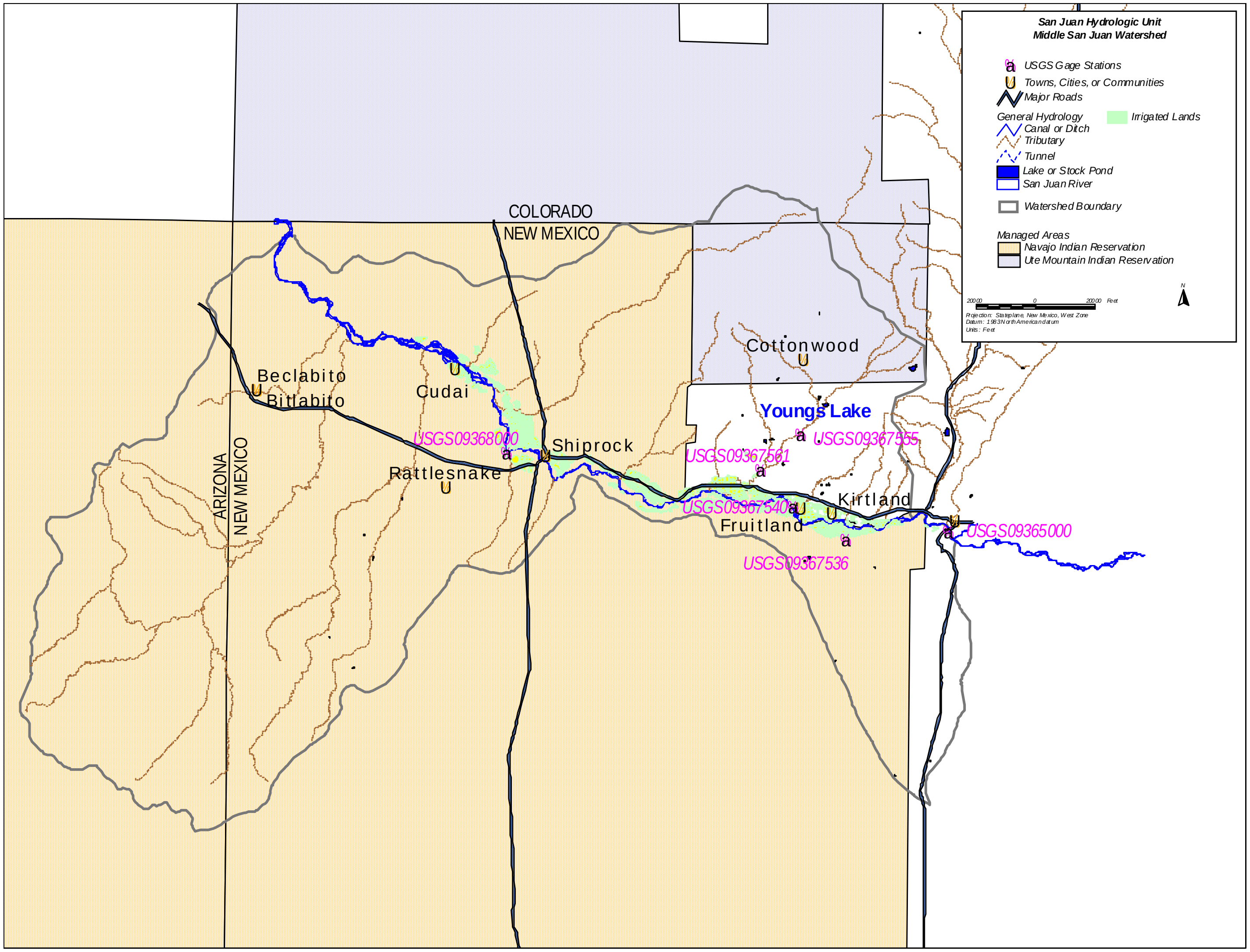


Figure 2-23: Topography Overview of the Middle San Juan Watershed

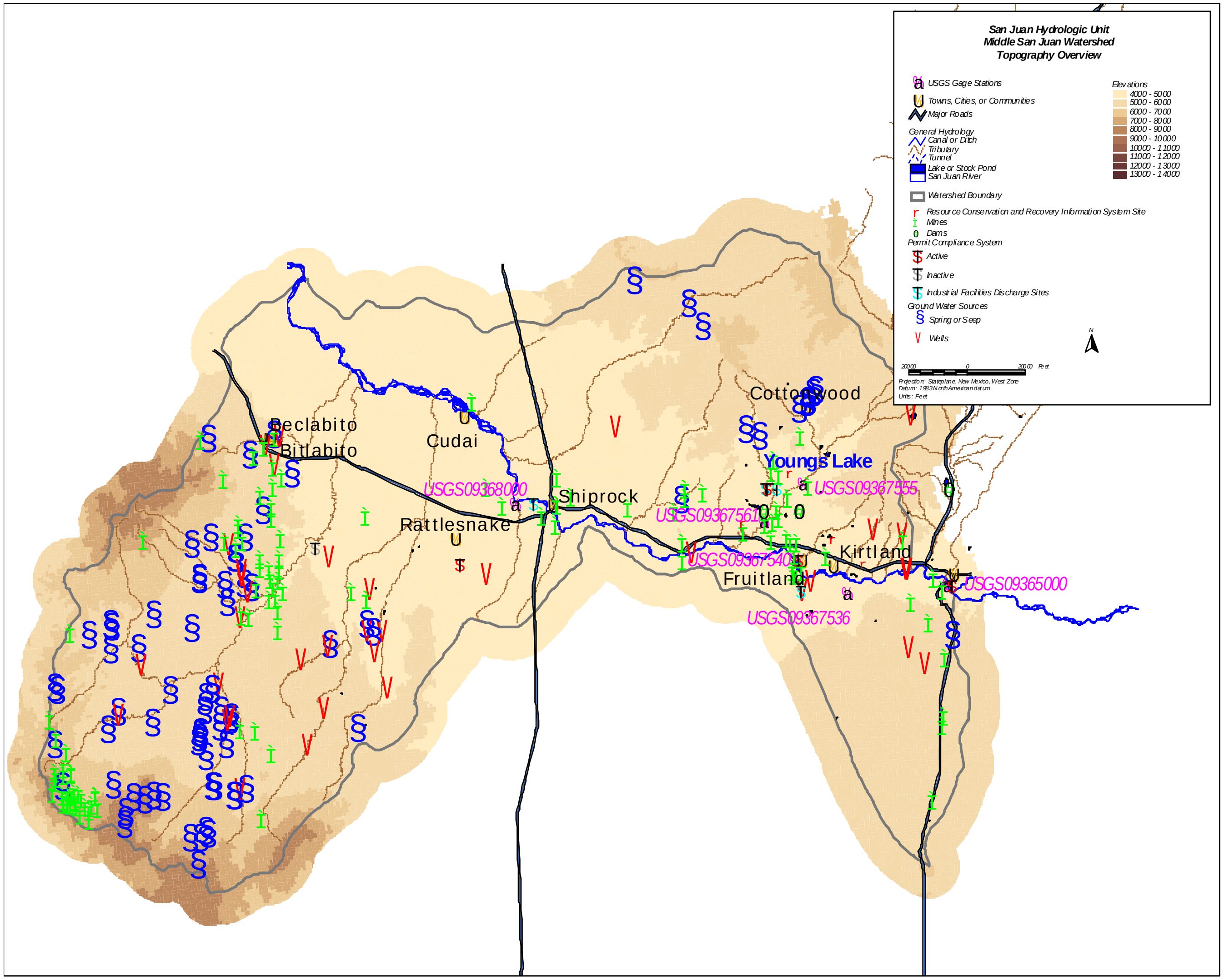
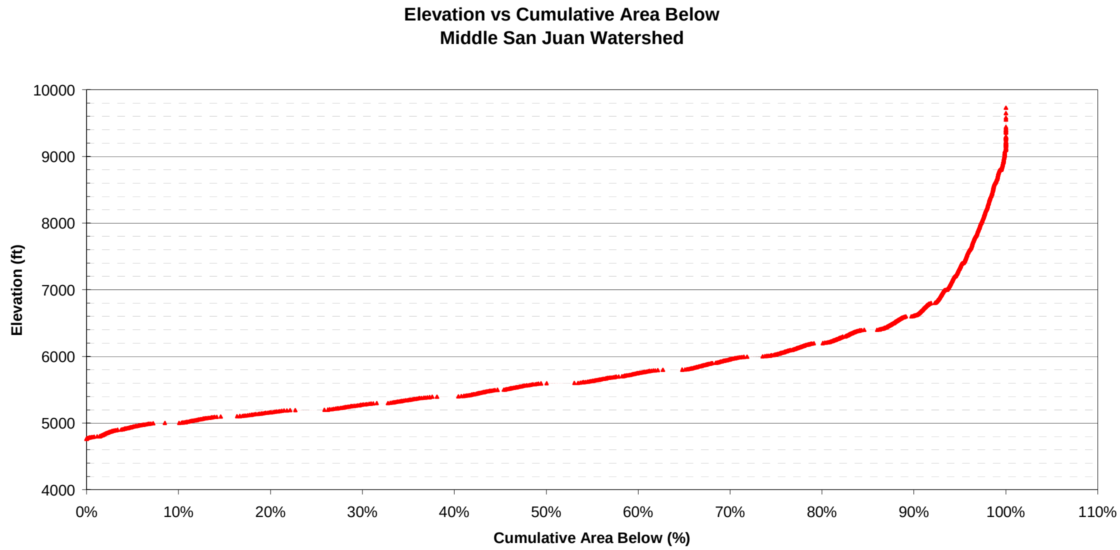


Figure 2-24: Elevation distribution in the Middle San Juan Watershed



There are eight communities within the Middle San Juan Watershed. There are two wastewater treatment plants within the watershed that discharge into the San Juan River. The wastewater treatment plants are:

1. Farmington wastewater treatment plant
2. Shiprock wastewater treatment plant

2.5.3. Water supply

2.5.3.1. Surface water

2.5.3.1.1. Stream Flow data

The San Juan River flows have historically been measured at several locations within the Middle San Juan Watershed. Table 2-25 provides the station identification number, the name, and the period of record for the USGS gage stations with available records that have been used to meter the San Juan River.

Table 2-25: USGS Gage Stations on the San Juan River within the Middle San Juan Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9365000	San Juan River near Farmington, NM	10/1930	9/1999
9367540	San Juan River near Fruitland, NM	10/1977	9/1980
9368000	San Juan River at Shiprock, NM	10/1934	9/2000

In addition to the flow measurements taken on the San Juan River, the USGS also obtained flow data on some of the tributaries to the San Juan River. The station identification number, the name, and the period of record for these gage stations are provided in Table 2-26. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-5. The locations for USGS gage stations listed in Table 2-25 and Table 2-26 are shown on Figure 2-22.

Table 2-26: USGS Gage Stations on tributaries of the San Juan River within the Middle San Juan Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9367536	Ojo Amarillo Canyon at NIIP near Fruitland, NM	10/1993	9/1994
9357555	Shumway Arroyo near Fruitland, NM	1/1976	9/1982
9357561	Shumway Arroyo near Waterflow, NM	10/1974	4/1990

2.5.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumption is specific for the Middle San Juan Watershed:

> the available monthly water supply for the Middle San Juan Watershed cannot be measured. It has to be calculated. The measured flows include flows that have already been considered as available flows for the watersheds located upstream of the gaging station for the Middle San Juan Watershed. The calculated available flows for the Middle San Juan Watershed are based on the measured flows at the USGS gaging station identified as 9365000, San Juan River at Farmington, NM. The watersheds contributing flow to this gage in the Middle San Juan Watershed are the Animas Watershed and the Upper San Juan Watershed. Therefore, the flows in these two watersheds are subtracted from the measured flows within the Middle San Juan Watershed. As a result of these deductions, the remaining flows (yield) in the Middle San Juan Watershed are negative values. Therefore, the actual flows and the computed negative supplies are both shown on Figure 2-25.

The surface water yields that were calculated for the Middle San Juan Watershed are shown on Figure 2-25. The results presented include average flows and 90% probability flows for the period of record and for 1985 – 1999. The differences between the annual averages for these two periods are presented in Table 2-27.

Table 2-27: Comparison of flows for the Middle San Juan Watershed

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1954 – 1999	(86,300)	0%	(143,500)	0%
1985 – 1999	(60,800)	+ 30%	(141,600)	+ 1%

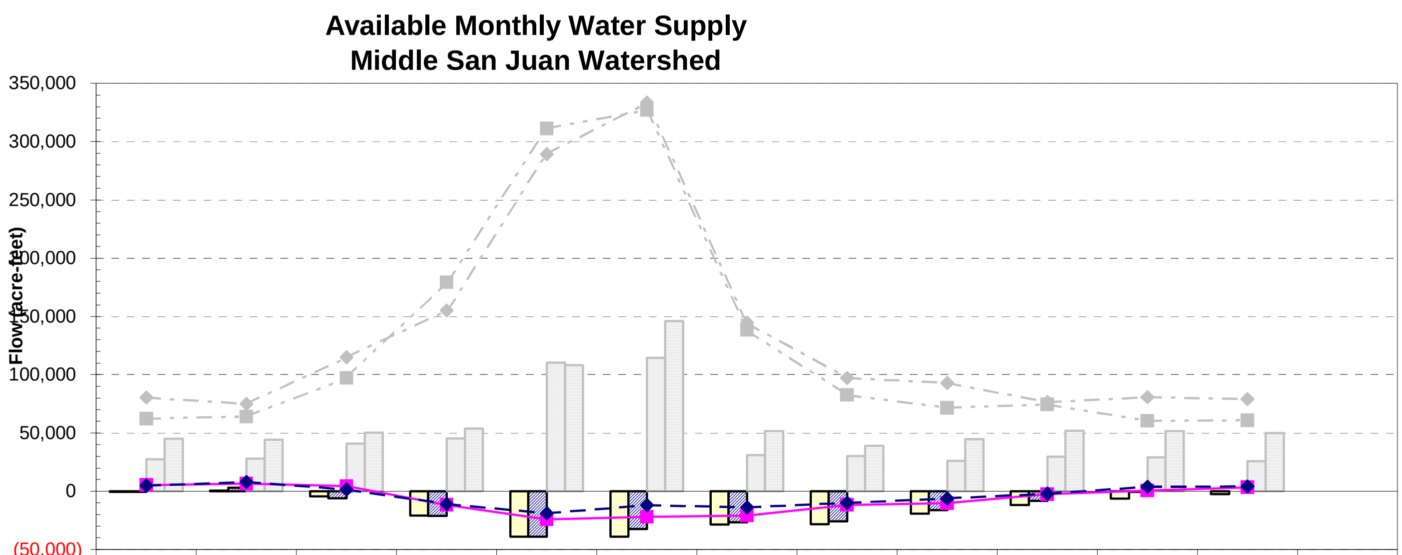
Figure 2-25: Surface Water Yields for the Middle San Juan Watershed

NOTE: The available water supply for the Middle San Juan Watershed has to be calculated, it can not be measured.

The available water supply is calculated as:

the measured flow at the USGS gaging station 9365000, San Juan River at Farmington, NM minus the Animas Watershed Supply minus Upper San Juan Watershed Supply.

Quantities were calculated for the entire period of record for the gage and separately for the last 15 years. The current operations of Navajo Dam over the past 15 years is assumed to be representative of the future available water supply for the Upper San Juan Watershed.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Calculated 90% Probability	(700)	500	(4,600)	(20,900)	(38,900)	(39,000)	(28,700)	(28,300)	(19,400)	(11,600)	(6,300)	(2,700)	(143,500)
Calculated 1985 - 1999 90% Probability	(800)	2,800	(6,000)	(21,000)	(38,900)	(32,300)	(26,600)	(25,900)	(16,300)	(8,200)	(800)	0	(141,600)
90% Probability	27,300	28,100	41,000	45,300	110,400	114,500	31,100	30,100	26,100	29,800	29,100	25,900	741,900
1985 - 1999 90% Probability	45,000	44,100	50,400	54,000	108,300	146,100	51,500	39,100	44,900	51,900	51,600	50,100	809,100
Calculated Average	5,400	6,400	4,400	(11,600)	(24,100)	(21,900)	(20,700)	(11,800)	(10,200)	(2,700)	400	3,400	(86,300)
Calculated 1985 - 1999 Average	4,700	7,900	1,400	(11,000)	(18,900)	(11,900)	(13,800)	(10,100)	(6,100)	(2,100)	3,900	4,200	(60,800)
Average	62,300	64,000	97,100	179,400	311,300	327,100	138,400	82,500	71,500	74,400	60,400	60,900	1,525,600
1985 - 1999 Average	80,400	74,900	115,000	155,100	289,200	333,400	144,700	97,200	93,000	76,400	80,700	79,100	1,598,400

Most of the time, the available water supply is negative. This indicates that the water supply for the Middle San Juan Watershed is provided through either the Upper San Juan Watershed or the Animas Watershed or a combination of both. The positive values during the non-irrigation season indicate that there are some accretion flows in the Animas Watershed and/or the Upper San Juan Watershed that contribute to the water supply in the Middle San Juan Watershed.

2.5.3.1.3. Storage Reservoirs

There are not any major storage reservoirs within the Middle San Juan Watershed, however, information was available for some of the smaller ones. Table 2-28 provides information relevant to the water supply.

Table 2-28: Middle San Juan Watershed Storage Reservoir Summary

Reservoir name:	San Juan Power Generation	Lower Valley Raw Water Supply
Date completed:	1972	Unknown
Primary purpose:	Hydroelectric	Water Supply
Owner / Operator:	Public Service Company of New Mexico	Lower Valley Water Users Association
Maximum storage:		47 acre-feet
Surface area at maximum storage:	66 acres	
Normal storage:	2,700 acre-feet	45.75 acre-feet

2.6. **Upper San Juan Watershed**

The Upper San Juan Watershed, as defined by the USGS Hydrologic Unit Code, is the second largest watershed in the San Juan Hydrologic Unit. It includes a total area of approximately 3,400 square miles. For the purposes of this study, the USGS' defined Upper San Juan Watershed was divided into two sub-watersheds. The boundary between the two watersheds is Navajo Dam. The watershed below Navajo Dam is called the Upper San Juan Watershed. The other watershed is called Upper San Juan above Navajo Dam.

2.6.1. Historical weather data

2.6.1.1. Precipitation

Table 2-29 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the Upper San Juan Watershed. Figure 2-26 shows the locations of the weather stations within and around the Upper San Juan Watershed and provides a graph of the information included in Table 2-29.

Table 2-29: Average Precipitation for weather stations within the Upper San Juan Watershed

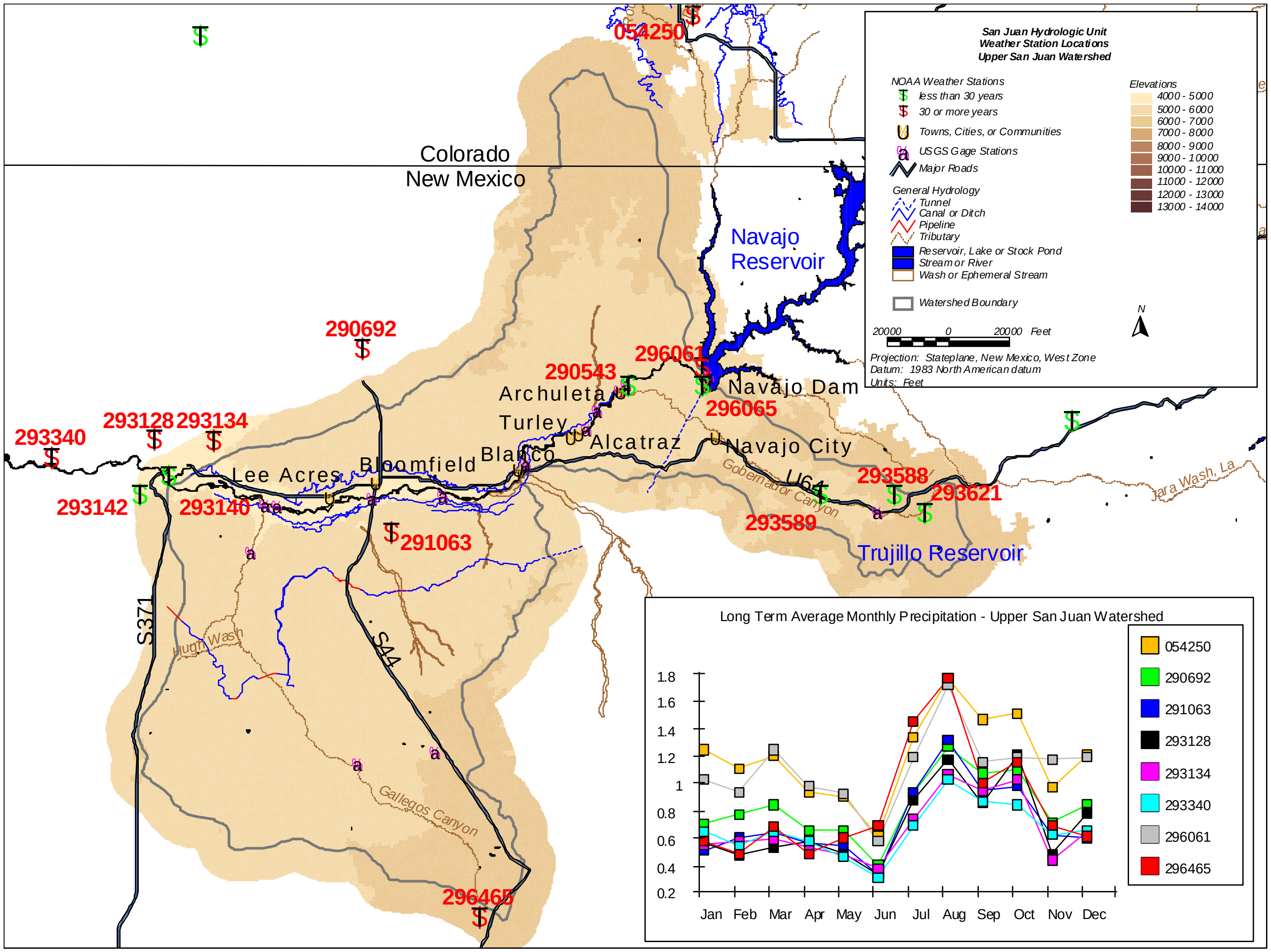
Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
054250	63	1.25	1.11	1.2	0.94	0.9	0.61	1.34	1.77	1.47	1.51	0.97	1.21	14.79
290692	68	0.71	0.77	0.85	0.66	0.66	0.41	0.93	1.27	1.08	1.1	0.72	0.85	9.95
291063	67	0.51	0.6	0.64	0.57	0.55	0.34	0.94	1.32	0.95	0.98	0.63	0.6	8.51
293128	31	0.57	0.48	0.53	0.58	0.49	0.34	0.88	1.18	0.86	1.21	0.49	0.79	8.1
293134	51	0.56	0.58	0.59	0.53	0.48	0.38	0.74	1.06	0.95	1.03	0.44	0.65	7.89
293340	61	0.65	0.54	0.65	0.58	0.46	0.32	0.7	1.03	0.87	0.84	0.63	0.66	8.06
296061	35	1.03	0.94	1.25	0.98	0.93	0.58	1.19	1.72	1.16	1.19	1.18	1.19	13.32
296465	41	0.58	0.49	0.68	0.49	0.6	0.69	1.45	1.76	1.01	1.16	0.69	0.61	10.09

To determine the average precipitation for the Upper San Juan Watershed, the precipitation values presented in Table 2-29 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-30.

Table 2-30: Calculated Average Precipitation within the Upper San Juan Watershed

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0.67	0.62	0.73	0.60	0.56	0.36	0.81	1.14	0.87	0.90	0.66	0.73	8.73

Figure 2-26: NOAA Weather Stations within the Upper San Juan Watershed



2.6.2. Drainage basins and watersheds

The extent of the Upper San Juan Watershed is presented in Figure 2-27. It covers a total area of 905 square miles, of which 870 square miles are in New Mexico. The primary source of water for this watershed is the San Juan River, which is controlled by releases from Navajo Reservoir.

Agriculture is found along both sides of the San Juan River. Approximately 6,500 acres are currently being irrigated within the Upper San Juan Watershed, excluding the NIIP. Areas of Echo Ditch lie within this watershed, are included in this total, but are supplied from the Animas River. The locations of the irrigated acreage are identified on Figure 2-27.

The topography of the Upper San Juan Watershed ranges from an elevation of approximately 5,250 feet to an elevation of approximately 7,600 feet. Figure 2-28 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-29 shows an elevation distribution for the watershed.

There are eight communities within the Upper San Juan Watershed. There are two wastewater treatment plants within the watershed that discharge into the San Juan River (See Figure 2-28). The wastewater treatment plants are:

1. Bloomfield wastewater treatment plant
2. Blanco wastewater treatment plant

There are two surface water treatment plants that divert water from the San Juan River within the Upper San Juan Watershed (See Figure 2-28). The diversions supply the following surface water treatment plants:

1. Farmington water treatment plant
2. Bloomfield water treatment plant – The Bloomfield water treatment plant diverts from a water supply pond that is supplied by the San Juan River.

Figure 2-27: Upper San Juan Watershed

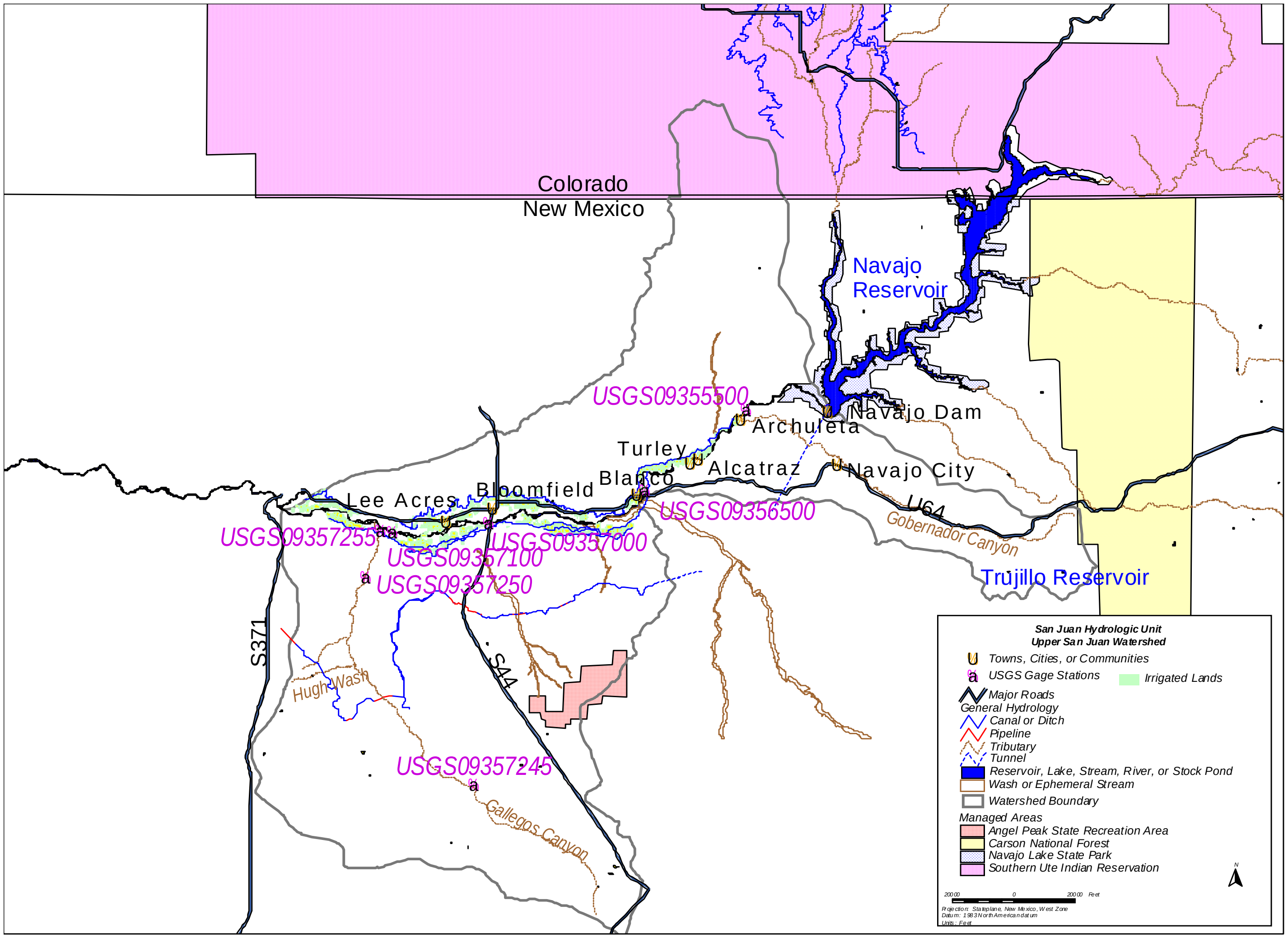


Figure 2-28: Topography Overview of the Upper San Juan Watershed

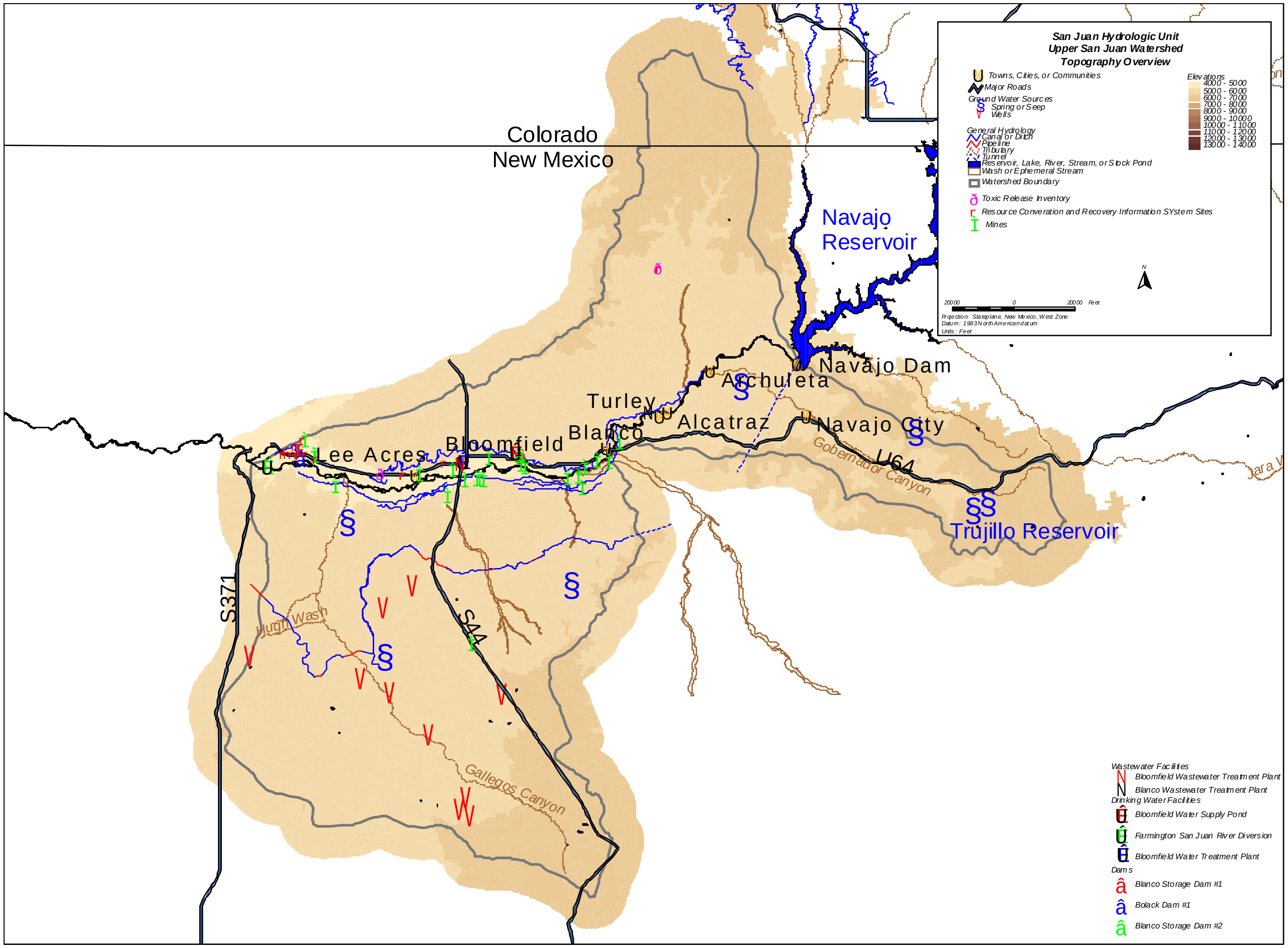
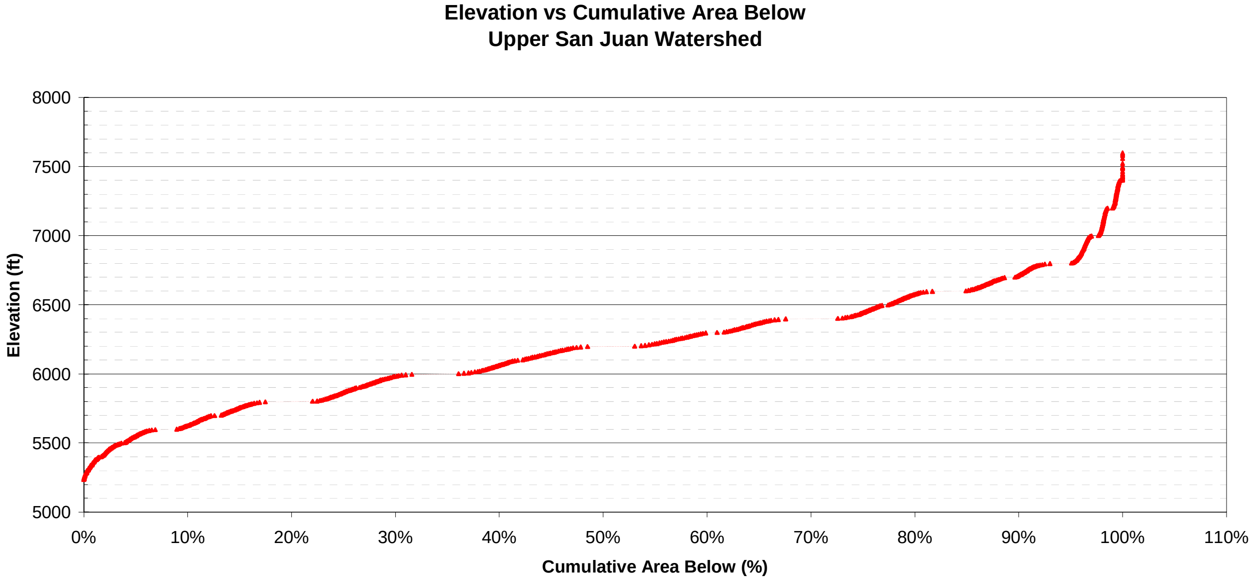


Figure 2-29: Elevation distribution in the Upper San Juan Watershed



2.6.3. Water supply

2.6.3.1. Surface water

2.6.3.1.1. Stream Flow data

The San Juan River flows have historically been measured at several locations within the Upper San Juan Watershed. Table 2-31 provides the station identification number, the name, and the period of record for the USGS gage stations with available records that have been used to meter the San Juan River.

Table 2-31: USGS Gage Stations on the San Juan River within the Upper San Juan Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9355500	San Juan River near Archuleta, NM	12/1954	9/2000
9356500	San Juan River near Blanco, NM	10/1930	12/1954
9357000	San Juan River near Bloomfield, NM	10/1955	12/1963
9357100	San Juan River at Hammond Bridge near Bloomfield, NM	10/1977	9/1981

In addition to the flow measurements taken on the San Juan River, the USGS also obtained flow data on some of the tributaries to the San Juan River. The station identification number, the name, and the period of record for these gage stations are provided in Table 2-32. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-6. The locations for the USGS gage stations listed in Table 2-31 and Table 2-32 are shown on Figure 2-27.

Table 2-32: USGS Gage Stations on tributaries of the San Juan River within the Upper San Juan Watershed.

Station ID	Station Name	Beginning Date	Ending Date
9357245	Gallegos Canyon at NIIP near Carson Trading Post, NM	9/1993	9/1994
9357250	Gallegos Canyon near Farmington, NM	10/1977	9/1981
9357255	Gallegos Canyon at NIIP near Farmington, NM	10/1993	9/1994

2.6.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumptions are specific for the Upper San Juan Watershed:

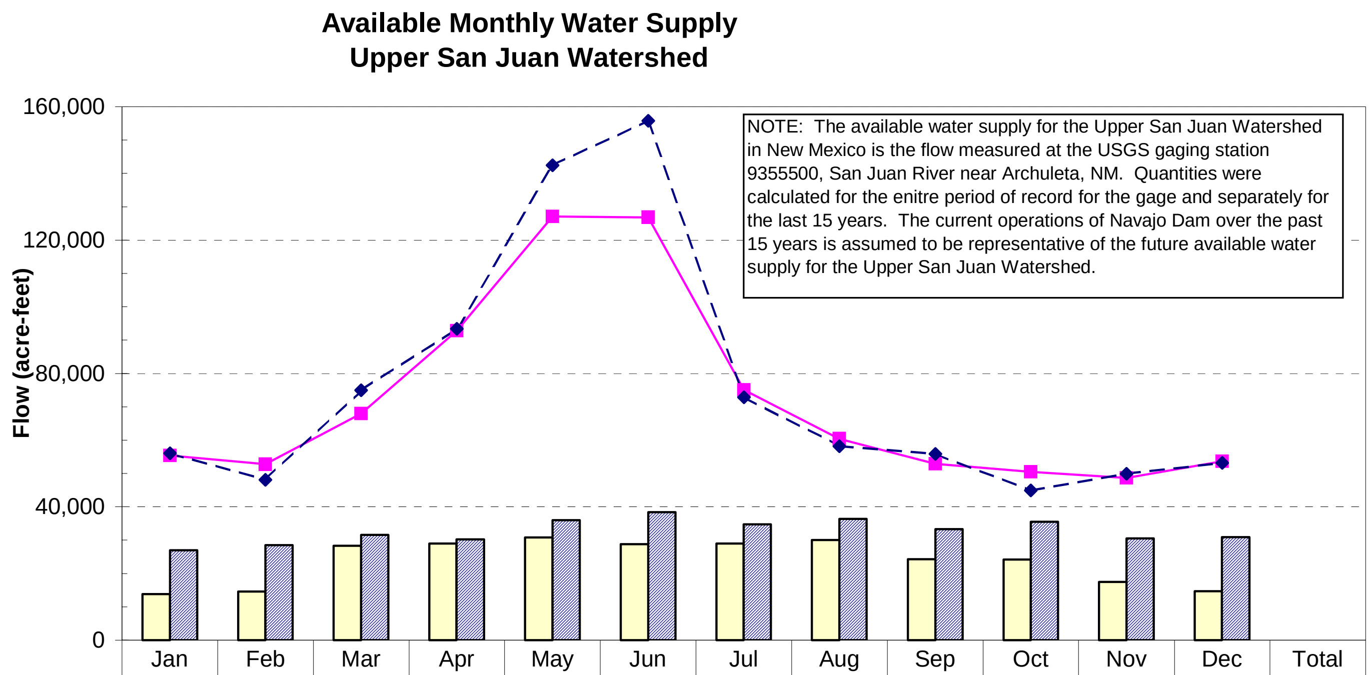
1. measured flows at the USGS gaging station identified as 9355500, San Juan River near Archuleta, NM was estimated as the available flow to the watershed.

The surface water yields that were calculated for the Upper San Juan Watershed are shown on Figure 2-30. The results presented include average flows and 90% probability flows for the entire period of record and for 1985 – 2000. The differences between the annual averages for these two periods are presented in Table 2-33.

Table 2-33: Comparison of flows for the Upper San Juan Watershed

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1954 – 2000	872,200	0%	415,600	0%
1985 – 2000	930,800	+ 7%	453,800	+ 9%

Figure 2-30: Surface Water Yields for the Upper San Juan Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	13,800	14,600	28,300	29,000	30,800	28,800	29,000	30,000	24,300	24,200	17,400	14,700	415,600
1985 - 2000 90% Probablility	27,000	28,500	31,600	30,200	36,000	38,400	34,700	36,400	33,300	35,500	30,500	30,900	453,800
Average	55,400	52,700	67,900	92,800	127,100	126,800	75,000	60,400	52,900	50,500	48,700	53,600	872,200
1985 - 2000 Average	56,000	48,100	74,900	93,400	142,400	155,800	72,900	58,200	55,900	44,900	49,900	53,100	930,800

2.6.3.1.3. Storage Reservoirs

The major storage reservoir suppling the Upper San Juan Watershed is Navajo Reservoir. Table 2-34 provides information relevant to the water supply.

Table 2-34: Upper San Juan Watershed Storage Reservoir Summary

Reservoir name:	Navajo Reservoir
Date completed:	1963
Primary purpose:	Irrigation
Owner / Operator:	Department of Interior, Bureau of Reclamation
Maximum storage:	1,986,600 acre-feet
Surface area at Maximum storage:	19,000 acre
Minimum pool:	Elevation 5,775 *(need stage vs storage curve)*
Normal storage:	1,708,600 acre-feet
Average surface area:	
Net evaporation rate:	16.4 inches per year[3]
Average total evaporation:	26,000 acre-feet [1] per year
Normal earliest release date:	N/A
Normal latest release date:	N/A
Average release per year:	930,300 acre-feet [2]
Firm yield of reservoir (1 or 5 year intervals):	453,800 acre-feet [4]

[1] Average evaporation for Navajo Reservoir based on NMISC letter dated June 13, 1997, Subject: Baseline Depletions from the San Juan River Basin authored by John Whipple.

[2] 1985 – 2000 average flow in the San Juan River near Archuleta, NM.

[3]Net Evaporation calculated from Average total evaporation and the surface area at design capacity.

[4]1985 – 2000 90% Probability Annual Flow

2.7. **Upper San Juan Watershed Above Navajo Dam**

The Upper San Juan Watershed, as defined by the USGS Hydrologic Unit Code, is the second largest watershed in the San Juan Hydrologic Unit. It includes a total area of approximately 3,400 square miles. For the purposes of this study, the USGS' defined Upper San Juan Watershed is divided into two sub-watersheds. The boundary between the two watersheds is Navajo Dam. The watershed upstream of Navajo Dam is called the Upper San Juan Watershed above Navajo Dam. The other watershed is called the Upper San Juan Watershed.

2.7.1. Historical weather data

2.7.1.1. Precipitation

Table 2-35 presents the monthly and annual averages for the weather stations that contributed to the precipitation within the Upper San Juan Watershed Above Navajo Dam. Figure 2-31 shows the locations of the weather stations within and around the Upper San Juan Watershed Above Navajo Dam and provides a graph of the information included in Table 2-35.

Table 2-35: Average Precipitation for weather stations within the Upper San Juan Watershed Above Navajo Reservoir

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
052432	92	1.61	1.50	1.74	1.40	1.12	0.80	1.94	2.34	1.85	1.91	1.36	1.73	19.45
053951	67	0.82	0.69	1.08	1.18	1.10	0.91	2.14	2.32	1.52	1.63	0.99	1.00	15.57
054250	63	1.25	1.11	1.20	0.94	0.90	0.61	1.34	1.77	1.47	1.51	0.97	1.21	14.79
056258	58	1.97	1.30	1.57	1.28	1.24	0.94	1.66	2.51	1.93	2.07	1.43	1.73	19.76
056271	36	1.87	1.7	2.33	1.62	1.55	1.62	3.12	3.33	2.67	2.11	1.82	2.20	26.11
057656	91	1.73	1.76	2.44	1.78	1.53	1.45	2.72	3.04	2.68	2.35	1.52	1.79	24.96
058154	39	1.60	1.42	1.68	1.37	1.37	1.05	2.57	2.78	2.23	2.20	1.66	1.98	21.33
058582	58	2.46	1.90	2.33	1.75	1.54	1.07	2.47	3.25	2.39	2.49	1.99	2.37	25.81
059181	40	3.68	3.87	5.02	3.17	2.12	1.81	3.45	4.46	4.51	4.42	4.22	4.49	43.40
059183	38	5.26	4.66	5.88	3.61	2.05	1.38	2.92	3.61	3.05	3.23	3.48	4.80	43.17
291664	68	1.92	1.74	1.78	1.33	1.39	1.03	1.87	2.70	2.07	1.75	1.44	1.76	21.12
292608	70	1.47	1.36	1.42	1.07	1.18	0.77	1.71	2.52	1.58	1.40	1.30	1.43	17.74
292837	63	1.07	0.84	1.07	0.95	1.04	0.86	1.71	2.36	1.55	1.23	0.92	0.99	14.71
293505	42	1.09	1.29	1.19	1.07	1.09	0.92	2.21	2.76	1.78	1.23	0.94	1.25	16.99
296061	35	1.03	0.94	1.25	0.98	0.93	0.58	1.19	1.72	1.16	1.19	1.18	1.19	13.32

To determine the average precipitation for the Upper San Juan Watershed Above Navajo Dam, the precipitation values presented in Table 2-35 were distributed over the entire watershed using the Thiessen Polygon. The results are presented in Table 2-36.

Figure 2-31: NOAA Weather Stations within the Upper San Juan Watershed Above Navajo Dam

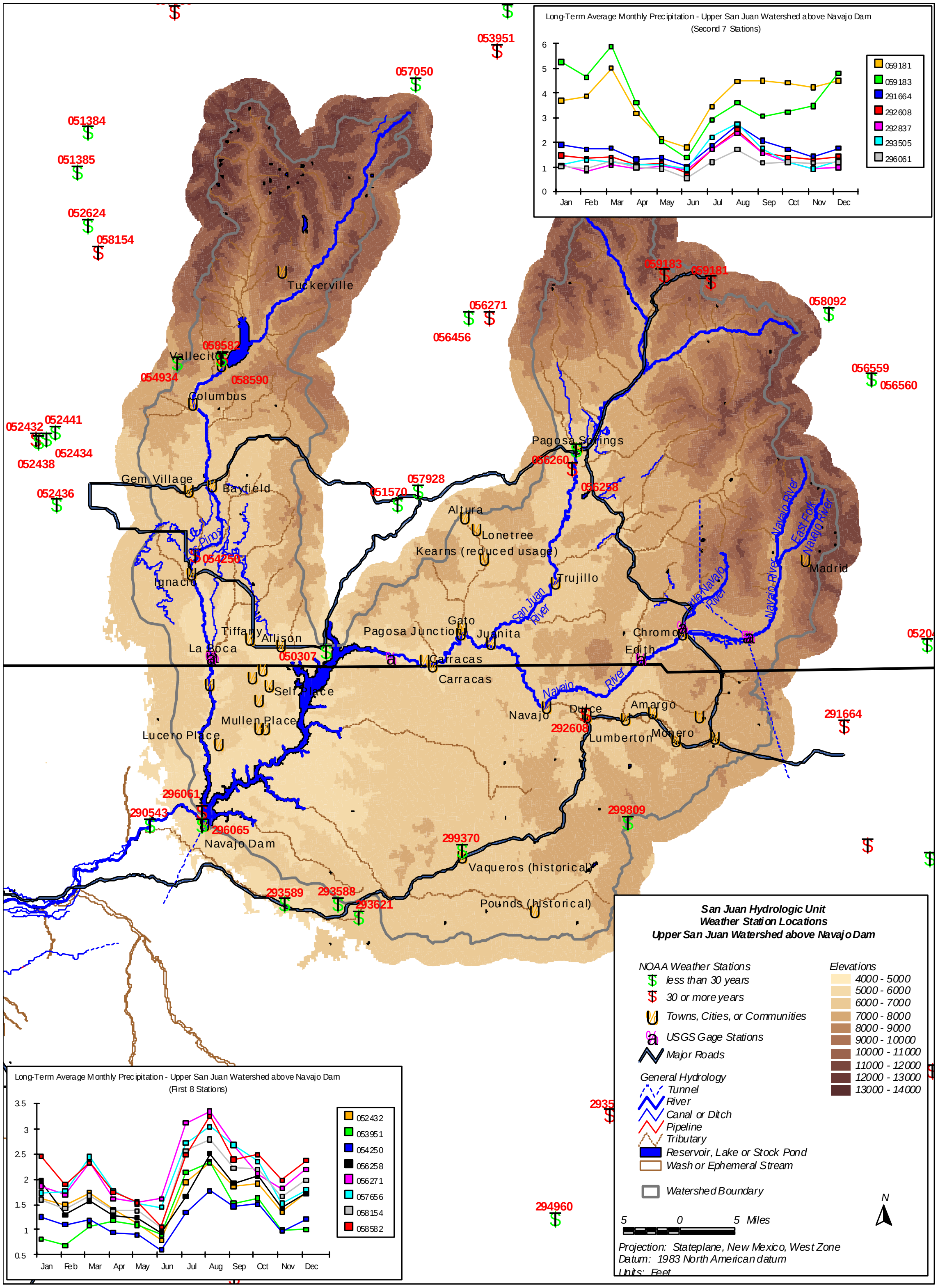


Table 2-36: Calculated Average Precipitation within the Upper San Juan Watershed Above Navajo Dam

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.75	1.60	1.93	1.44	1.29	1.01	2.09	2.68	2.06	1.93	1.58	1.84	21.20

2.7.2. Drainage basins and watersheds

The extent of the Upper San Juan Watershed Above Navajo Dam is presented in Figure 2-32. It covers a total area of approximately 2,540 square miles, of which only 930 square miles are in New Mexico. Of the 930 square miles in New Mexico, approximately 350 square miles are within the Jicarilla Apache Nation. The primary source of water for the principal demands in the New Mexico portion of this watershed is the Navajo River.

The Interstate Stream Commission reports approximately 200 acres of irrigated lands within the New Mexico portion of the watershed.

The topography of the Upper San Juan Watershed Above Navajo Dam ranges from an elevation of approximately 5,240 feet to an elevation of approximately 13,600 feet. Figure 2-33 provides an elevation-shaded relief that identifies the areas of lower and higher elevations within the watershed. Figure 2-34 shows an elevation distribution for the watershed.

There are several small communities within the New Mexico portion of the Upper San Juan Watershed above Navajo Dam. There are at least eight wastewater treatment facilities within the watershed; however, there is only one wastewater facility within the New Mexico portion of the watershed that discharges into a tributary of the Navajo River (See Figure 2-33). The wastewater facility is located at Dulce.

There are no surface water treatment facilities located in the New Mexico portion of the Upper San Juan Watershed above Navajo Dam.

Figure 2-32: Upper San Juan Watershed above Navajo Dam

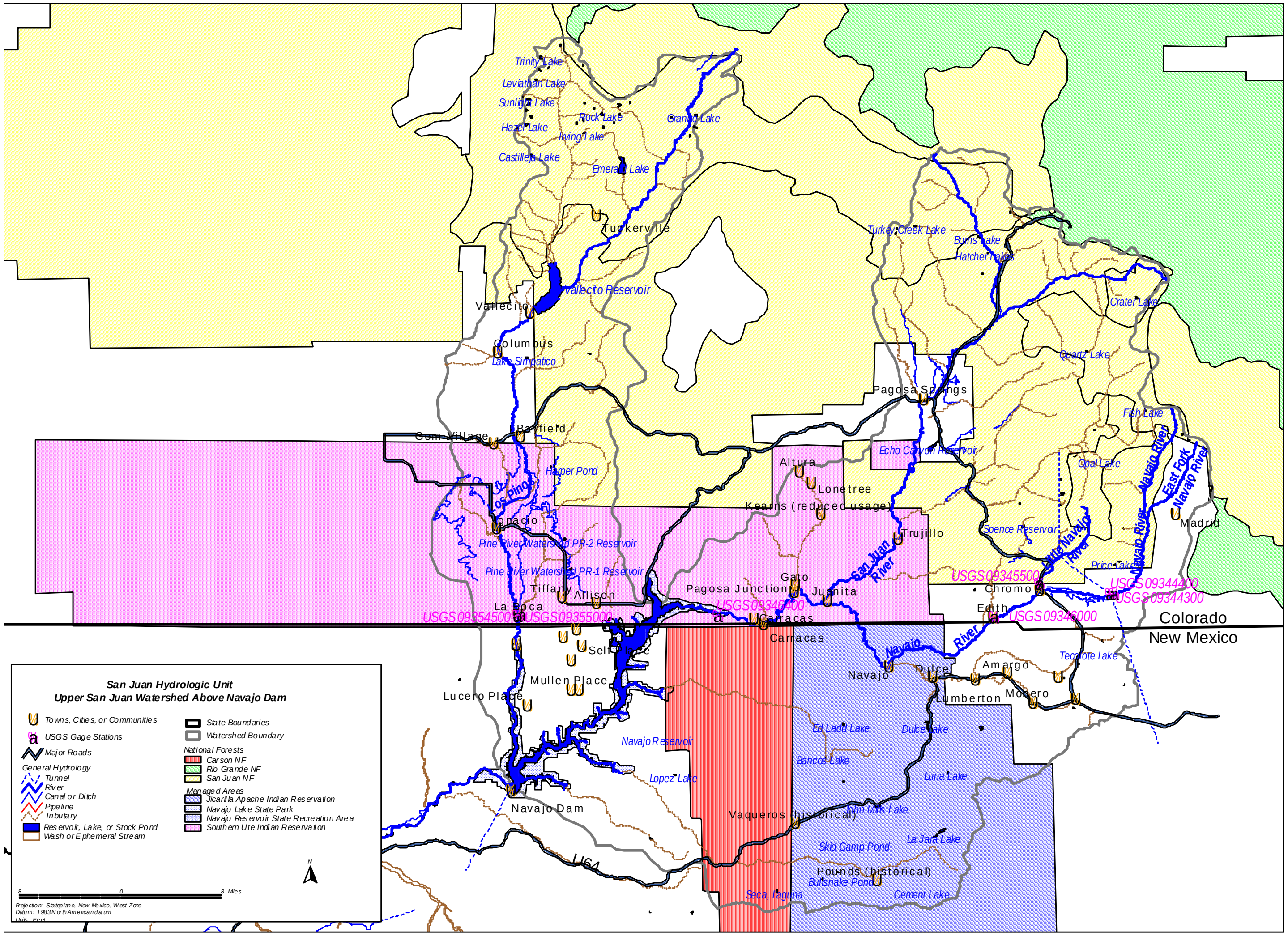


Figure 2-33: Topography Overview of the Upper San Juan Watershed above Navajo Dam

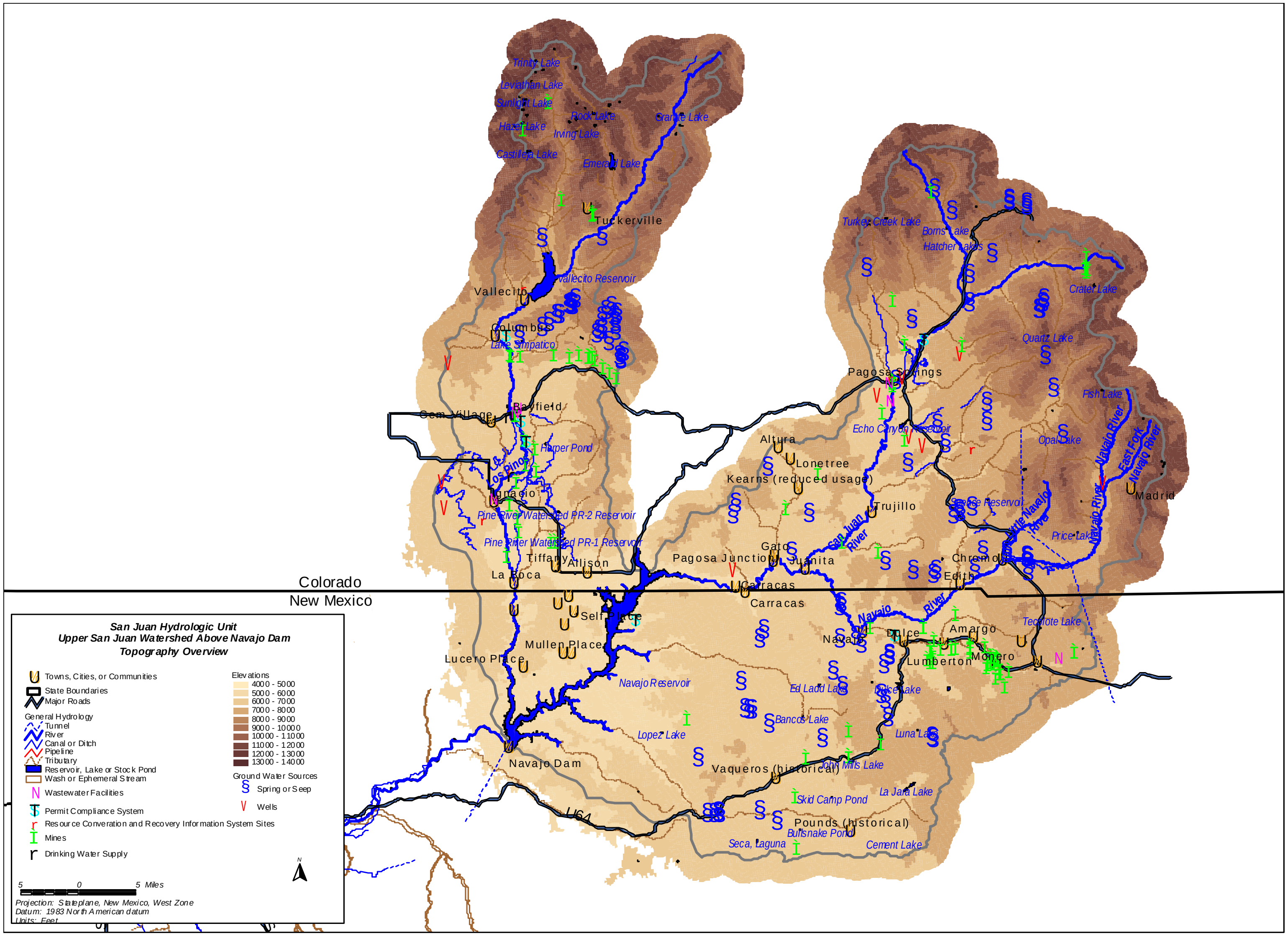
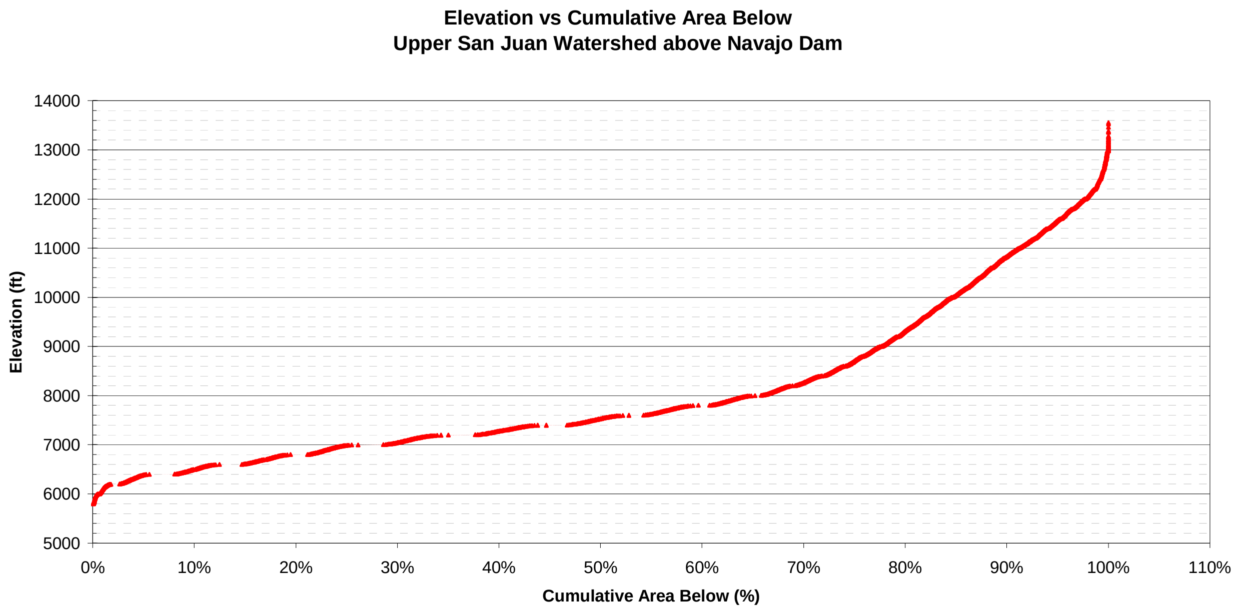


Figure 2-34: Elevation distribution in the Upper San Juan Watershed Above Navajo Dam



2.7.3. Water supply

2.7.3.1. Surface water

2.7.3.1.1. Stream Flow data

The Upper San Juan Watershed above Navajo Dam has two rivers that supply Navajo Reservoir located at the bottom of the watershed. They are the San Juan River and the Los Pinos River. Communities within New Mexico obtain surface water from the Navajo River, which is a tributary to the San Juan River (See Figure 2-32).

River flows have historically been measured at several locations along the Colorado – New Mexico Border within the Upper San Juan Watershed above Navajo Dam. In order to determine the available water supply for New Mexico communities within the Upper San Juan Watershed above Navajo Dam, as well as the available water supply from Navajo Reservoir, the USGS gages along the border were evaluated. Table 2-37 provides the station identification number, the name, and the period of record for the USGS gage stations with available records that have been used to meter the flows across the Colorado – New Mexico state line. The monthly data and graphs of the average monthly and 90% probability flows for these stations are provided in Appendix C-7. The locations for the USGS gage stations listed in Table 2-37 are shown on Figure 2-32.

Table 2-37: USGS Gage Stations along the Colorado – New Mexico state line within the Upper San Juan Watershed above Navajo Dam.

Station ID	Station Name	Beginning Date	Ending Date
9344300	Navajo River above Chromo, CO	10/1956	9/1970
9344400	Navajo River below Oso Diversion Dam near Chromo, CO	3/1971	9/1998
9345500	Little Navajo River at Chromo, CO	6/1935	9/1952
9346000	Navajo River at Edith, CO	10/1912	4/1996
9346400	San Juan River near Carracas, CO	11/1961	9/2000
9354500	Los Pinos River at La Boca, CO	1/1951	9/2000
9355000	Spring Creek at La Boca, CO	1/1951	9/2000

2.7.3.1.2. Surface water yields

The general assumptions used to determine the surface water yields for each watershed are listed in Section 1.1.2. The following assumptions are specific for the Upper San Juan Watershed above Navajo Dam:

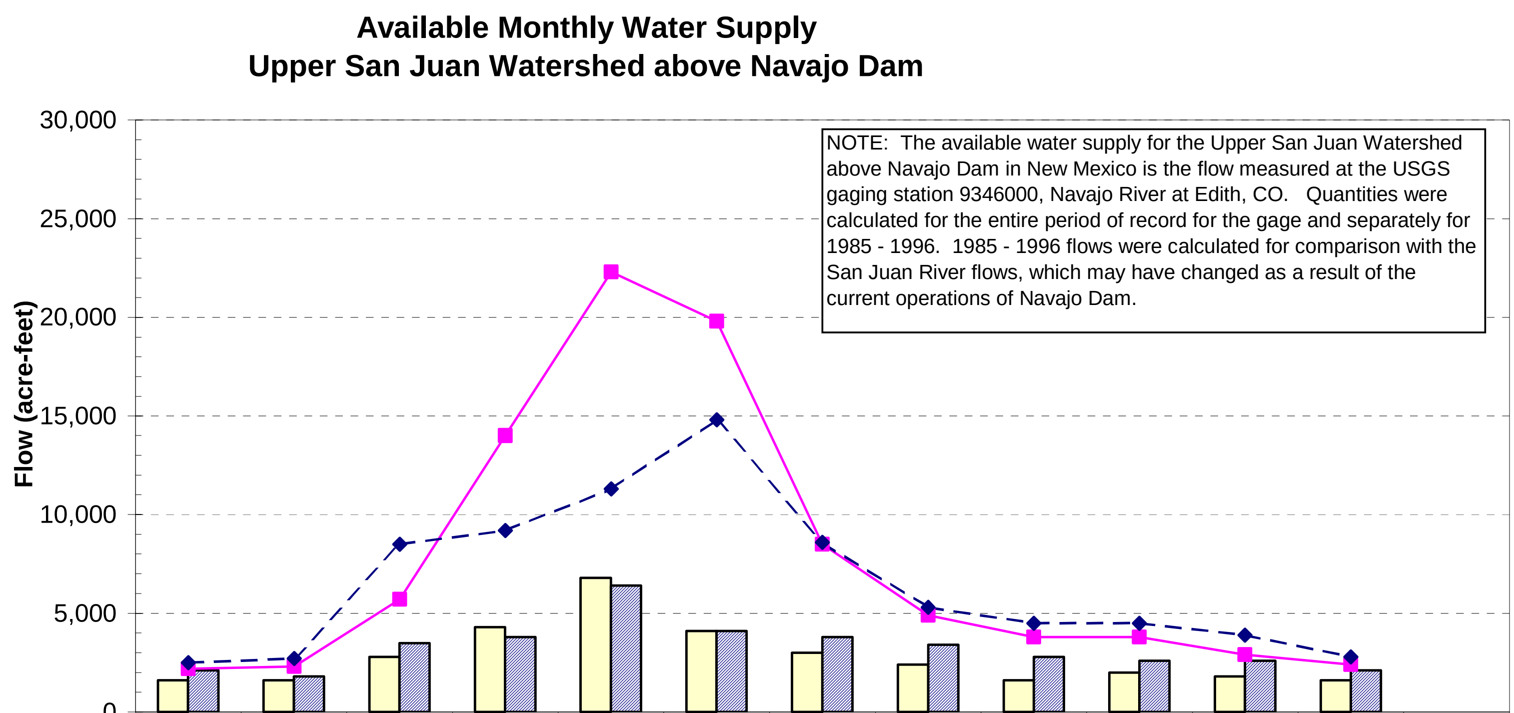
1. measured flows at the USGS gaging station identified as 9346000, Navajo River at Edith, CO was estimated as the available flow to the watershed. The Jicarilla Apache Nation is currently completing a study that will quantify the accretion flows that occur between the gaging station at Edith and their diversion.

The surface water yields that were calculated for the New Mexico portion of the Upper San Juan Watershed above Navajo Dam are shown on Figure 2-35. The results presented include average flows and 90% probability flows for the period of record and for 1985 – 1996. The differences between the annual averages for these two periods are presented in Table 2-38.

Table 2-38: Comparison of flows for the New Mexico portion of the Upper San Juan Watershed above Navajo Dam

Period	Average Annual Flow (ac-ft)	% difference	90% Probability Annual Flow (ac-ft)	% difference
1912 – 1996	92,800	0%	41,500	0%
1985 – 1996	79,700	-14%	50,000	20%

Figure 2-35: Surface Water Yields for the Upper San Juan Watershed



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
90% Probablility	1,600	1,600	2,800	4,300	6,800	4,100	3,000	2,400	1,600	2,000	1,800	1,600	41,500
1985 - 1996 90% Probablility	2,100	1,800	3,500	3,800	6,400	4,100	3,800	3,400	2,800	2,600	2,600	2,100	50,000
Average	2,200	2,300	5,700	14,000	22,300	19,800	8,500	4,900	3,800	3,800	2,900	2,400	92,800
1985 - 1996 Average	2,500	2,700	8,500	9,200	11,300	14,800	8,600	5,300	4,500	4,500	3,900	2,800	79,700

2.7.3.1.3. Storage Reservoirs

There are no storage reservoirs located on the Navajo River.

2.7.3.1.4. Transbasin Diversions

There is one transbasin diversion project that diverts water out of the Upper San Juan Watershed above Navajo Dam. This project is the San Juan – Chama Project. It diverts water from the Navajo, Little Navajo, and Blanco Rivers into the Rio Grande Basin. Historical diversions have been included in the reported stream gages in the San Juan Basins. Future increased diversions will need to be addressed as future demands on the water supply.

2.8. **Legal Limitations and Issues**

Refer to Volume I, Section 6, San Juan Hydrologic Unit Regional Water Plan

2.9. Summary of the Available Water Supply

The available water supply for each watershed was evaluated. As indicated in Section 1.1.2. the surface water supply for each watershed was evaluated for the entire period of record and for 1985 – 2000. The only exceptions were the Chaco and the Blanco Canyon Watersheds. Their period of record did not include 1985 – 2000. However, since their flows are insignificant when compared to the flows from the other watersheds, the results presented in Table 2-39 are still representative of the current available water supply for the Upper San Juan Hydrologic Unit within New Mexico.

Table 2-39: Summary of the Available Surface Water Supply for the New Mexico Portion of the Upper San Juan Hydrologic Unit

Surface Water Supply under Current Operating Criteria

Watershed	Average Annual (acre-feet)	90% Probability (acre-feet)
Animas	735,600	481,200
Blanco Canyon	15,900	5,500
Chaco	4,200	2,000
La Plata	29,000	11,500
Middle San Juan	(60,800)	(141,600)
Upper San Juan	930,800	453,800
Upper San Juan above Navajo Dam	79,700	50,000
Total Surface Water Supply[1]	**1,734,400**	**862,400**

[1] The total does not include the flows for the Upper San Juan above Navajo Dam. These flows are accounted for in the flows for the Upper San Juan.

The 1988 Hydrologic Determination allows New Mexico to deplete up to 669,400 acre-feet per year.

3.0 BIBLIOGRAPHY

CIELO Corp., Engineering Report, Prepared in Defense of Applications to Divert ALP Contract Water, January 1995.

Freeze, R. Allan, Cherry, John A., Groundwater, Englewood Cliffs, New Jersy, 1979.

Leedshill-Herkenhoff, Inc., John W. Shomaker, Inc., DuMars, Charles T., 40-Year Regional Water Plan, New Mexico State Planning and Development District 1, San Juan, McKinley, Cibola Counties, March 1994.

Phillips, Fred M., Tansey, Michael K., An Integrated Isotopic/Physical Approach to a Numerical Model of Groundwater Flow in the San Juan Basin, New Mexico Water Resources Research Institute, Las Cruces, New Mexico, December 1984.

State of New Mexico, Water Supply Regulations, Drinking Water Program, New Mexico Environment Department, April 1991.

State of New Mexico, Standards for Interstate and Intrastate Surface Waters, New Mexico Water Quality Control Commission, Santa Fe, New Mexico, January 2000.

Stone, William J., Lyford, Forest P., Frenzel, Peter F., Mizell, Nancy H., Padgett, Elizabeth T., Hydrology and Water Resources of San Juan Basin, New Mexico, Hydrologic Report 6, New Mexico Bureau of Mines and Mineral Resources, Socorro, 1983.

U.S. Environmental Protection Agency, National Recommended Water Quality Criteria - Correction, EPA 822-Z-99-001, April 1999.

U.S. Environmental Protection Agency, National Primary Drinking Water Standards, EPA 816-F-01-007, www.epa.gov/safewater, March 2001.

U.S. Geological Survey, Geochemistry of Ground Water in the Gallup, Dakota, and Morrison Aquifers, San Juan Basin, New Mexico, Water-Resources Investigations Report 94-4253, Albuquerque, New Mexico, 1995.

U.S. Geological Survey, Hydrogeology and Steady-State Simulation of Ground-Water Flow in the San Juan Basin, New Mexico, Colorado, Arizona, and Utah, Water-Resouces Investigations Report 95-4187, Albuquerque, New Mexico, 1996.

U.S. Geological Survey, Summary of the San Juan Structural Basin Regional Aquifer-System Analysis, New Mexico, Colorado, Arizona, and Utah, Water-Resources Investigations Report 95-4188, Albuquerque, New Mexico, 1996.