NEMO Watershed Based Plan

Little Colorado Watershed

ADEQ Arizona Department of Environmental Quality

The University of Arizona Tucson Arizona

Arizona Cooperative Extension — The University of Arizona • College of Agriculture and Life Sciences

Water Resources Research Center

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The NEMO website is www.ArizonaNEMO.org.

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Section 1: Introduction

Background: Nonpoint Source Pollution and NEMO

The Southwestern United States, including the state of Arizona, is the fastest growing region in the country. Because the region is undergoing rapid development, there is a need to address health and quality of life issues that result from degradation of our water resources.

Water quality problems may originate from both “point” and “nonpoint” sources. The Clean Water Act (CWA) defines "point source” pollution as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged" (33 U.S.C. § 1362(14)). Point source discharge is regulated through provisions in the CWA.

Although nonpoint source pollution is not defined under the CWA, it is widely understood to be the type of pollution that arises from many dispersed activities over large areas, and is not traceable to any single discrete source. Nonpoint source pollution may originate from many different sources, usually associated with rainfall runoff moving over and through the ground, carrying natural and manmade pollutants into lakes, rivers, streams, wetlands and ground water. In contrast to point source pollution, nonpoint source pollution is addressed primarily through non-regulatory means under the CWA. Nonpoint source pollution is the leading cause of water quality degradation across the United States, and is the water quality issue that NEMO, the Nonpoint Education for Municipal Officials program, and this watershed based plan will address.

Nationally, NEMO has been very successful in helping to mitigate nonpoint source pollution. The goal of NEMO is to educate land-use decision makers to take proactive voluntary actions that will mitigate nonpoint source pollution and protect natural resources. In the eastern United States (where the NEMO concept originated), land use authority is concentrated in municipal (village, town and city) government. In Arizona, where nearly 80% of the land is managed by state, tribal and federal entities, land use authorities include county, state and federal agencies, in addition to municipal officials and private citizens.

In partnership with the Arizona Department of Environmental Quality (ADEQ) and the University of Arizona (U of A) Water Resources Research Center, the Arizona Cooperative Extension at the U of A has initiated the Arizona NEMO program. Arizona NEMO attempts to adapt the NEMO program to the conditions in the semiarid, western United States, where water supply is limited and many natural resource problems are related to the lack of water, as well as water quality.

Working within a watershed template, Arizona NEMO includes: comprehensive and integrated watershed planning support, identification and publication of Best Management Practices (BMP), and education on water conservation and riparian water quality restoration.

Arizona NEMO maintains a website, http://www.ArizonaNEMO.org that contains these watershed based plans, Best Management Practices fact sheets, and other educational materials.

Watershed Based Plans

Watershed-based plans are holistic documents designed to protect and restore a watershed. These plans provide a careful analysis of the sources of water quality problems, their relative contributions to the problems, and alternatives to solve those problems. Furthermore, watershed-based plans present proactive measures that can be applied to protect water bodies. In watersheds with developed or drafted Total Maximum Daily Load (TMDL) studies for specific waterbodies, the watershed-based plan must be designed to achieve the load reductions identified in the TMDL.

The CWA requires each state to perform a TMDL on waterbodies that are identified as impaired due to exceedances of state surface water quality standards. As point sources and nonpoint sources of pollution are determined through TMDL analysis, subsequent load reductions are assigned to each source as necessary for the purposes of improving water quality to meet state standards.

In collaboration with the local watershed partnerships and ADEQ, NEMO will help improve water quality by developing a realistic watershed-based plan to achieve water quality standards and protection goals. This plan will identify:

- Areas that are susceptible to water quality problems and pollution;
- Sources that need to be controlled; and
- Management measures that should be implemented to protect or improve water quality.

The first component of the planning process is to characterize the watershed by summarizing all readily available natural resource information and other data for that watershed. As seen in Sections 2 though 5 of this document, these data are at a broad-based, large watershed scale and include information on water quality, land use and cover, natural resources and wildlife habitat.

It is anticipated that stakeholder-groups will develop their own detailed planning documents. That document may cover a subwatershed area within the NEMO Watershed-based Plan, or include the entire watershed area. In addition, stakeholder-group local watershed-based plans will incorporate local knowledge and concerns gleaned from stakeholder involvement and will include:

- A description of the stakeholder / partnership process;
- A well-stated, overarching goal aimed at protecting, preserving, and restoring habitat and water

quality, and encouragement of land stewardship;

- A plan to coordinate natural resource protection and planning efforts;

- A detailed and prioritized description of natural resource management objectives; and

- A detailed and prioritized discussion of best management practices, strategies and projects to be implemented by the partnership.

Based on EPA's 2003 Guidelines for the Award of Section 319 Nonpoint Source Grants, a watershed-based plan should include all nine of the elements listed below. This NEMO watershed-based plan addresses each of these elements (except for Element 2: Expected Load Reductions); however, the watershed group must determine the final watershed plan and actions.

- Element 1: Causes and Sources - Clearly define the causes and sources of impairment (physical, chemical, and biological).

- Element 2: Expected Load Reductions - An estimate of the load reductions expected for each of the management measures or best management practices to be implemented (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

- Element 3: Management Measures - A description of the management measures or best management practices and associated costs that will need to be implemented to achieve the load reductions estimated in this plan and an identification (using a map or a description) of the critical areas where those measures are needed.

- Element 4: Technical and Financial Assistance - An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan.

- Element 5: Information / Education Component - An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing management measures.

- Element 6: Schedule - A schedule for implementing management measures identified in this plan that is reasonably expeditious.

- Element 7: Measurable Milestones - A schedule of interim, measurable milestones for determining whether the management measures, Best Management Practices, or other control actions are being implemented.

- Element 8: Evaluation of Progress - A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the plan needs to be revised or, if a Total Maximum Daily Load (TMDL) has been established, whether the TMDL needs to be revised.

- Element 9: Effectiveness Monitoring - A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established in the Evaluation of Progress element.

These nine elements help provide reasonable assurance that the nonpoint source of pollution will be managed to improve and protect water quality and to assure that public funds to address impaired waters are used effectively.

Purpose and Scope

This watershed-based plan includes a watershed characterization and a watershed classification for the Little Colorado Watershed.

The Little Colorado Watershed is located in the northeast portion of the state of Arizona, east of the city of Flagstaff, as shown in Figure 1- 1.

The watershed characterization in Sections 2 through 5 includes physical, biological, and social/economic data in a geographic information system (GIS) database format, as both mapped and tabulated data, that has been collected from available existing and published data sources. No new field data were collected for this plan. This characterization represents an inventory of natural resources and environmental conditions that affect primarily surface water quality. It provides educational outreach material to stakeholders and watershed partnerships.

The watershed classification identifies water quality problems by incorporating water quality data reported in The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), ADEQ's biennial report consolidating water quality reporting requirements under the federal Clean Water Act. The ADEQ water quality data, TMDL definitions, and further information for each stream reach and the surface water sampling sites across the state can be found at: www.adeq.state.az.us/environ/water/assessment/assess.html.

The watershed classification includes identifying and mapping important resources, and ranking 10-digit HUC (hydrologic unit codes) subwatersheds (discussed later in this section) based on the likelihood of nonpoint source pollutant contribution to stream water quality degradation.

In addition to the watershed characterization and classification, this plan includes general discussions of recommended nonpoint source Best Management Practices (BMP) that may be implemented to achieve pollutant load reductions and other watershed goals. It provides methods and tools to identify problem sources and locations for implementation of BMPs to mitigate nonpoint source pollution.

These watershed management activities are proposed with the understanding that the land-use decision makers and stakeholders within the watershed can select the BMPs they feel are most appropriate and revise management activities as conditions within the watershed change. Although these chapters are written based on current information, the tools developed can be used to update this plan and reevaluate water quality concerns as new information becomes available.

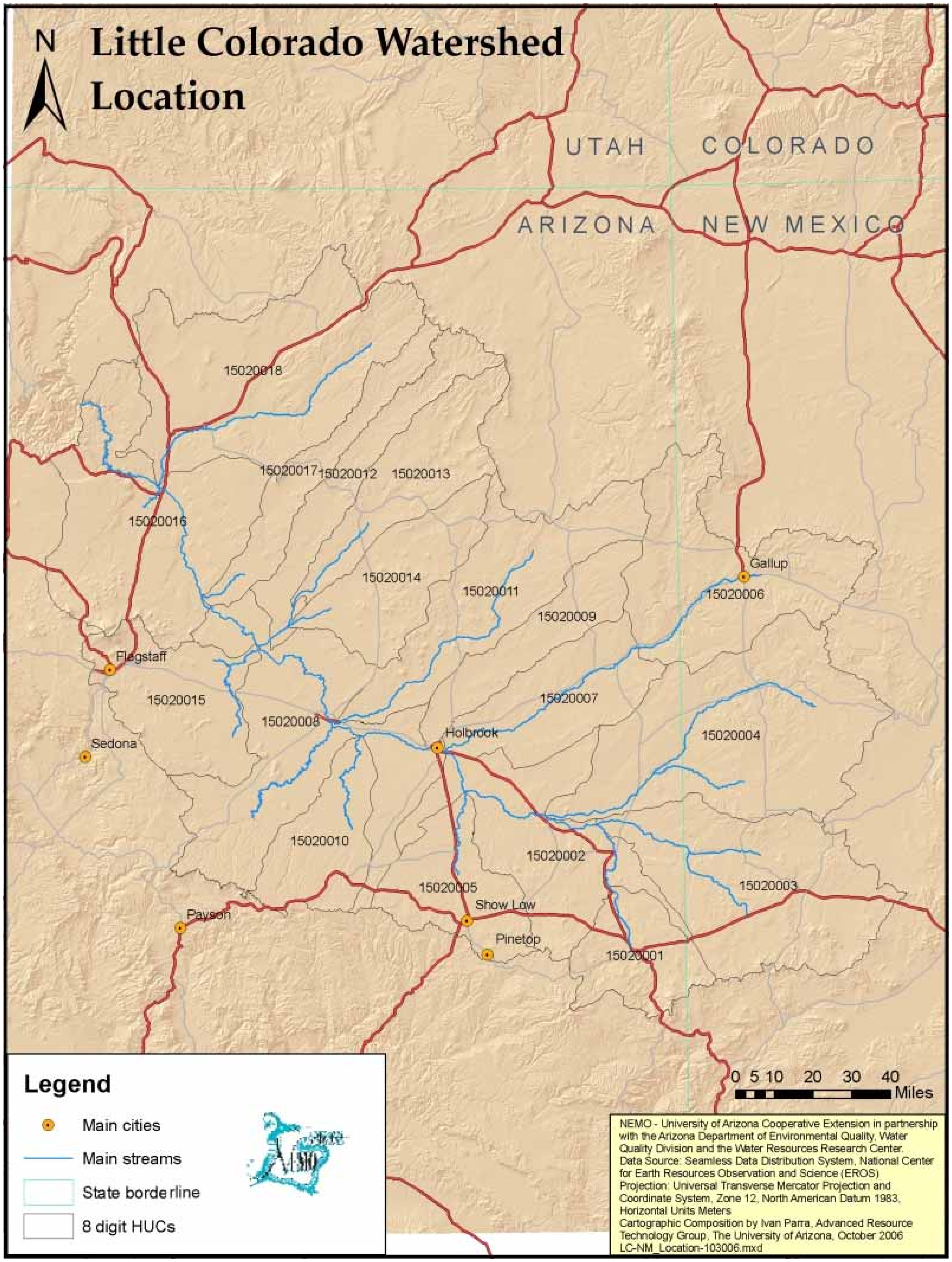

Figure 1-1: Little Colorado Watershed Location Map.

Methods

GIS and Hydrologic modeling

GIS and hydrologic modeling were the major tools used to develop this watershed-based plan. In a GIS, two types of information represent geographic features: locational and descriptive data. Locational (spatial) data are stored using a vector (line) or a raster (grid) data structure. Vector data are object based data models which show spatial features as points, lines, and/or polygons. Raster data models represent geographical space by dividing it into a series of units or cells, each of which is limited and defined by an equal amount of the earth's surface. These cells may be triangular or hexagonal, although the square is the most common. Corresponding descriptive (attribute) data for each geographic feature are stored in a set of tables. The spatial and descriptive data are linked in the GIS so that both sets of information are always available.

Planning and assessment in land and water resource management requires spatial modeling tools to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Little Colorado Watershed include AGWA, SWAT and RUSLE, as described below.

The Automated Geospatial Watershed Assessment Tool (AGWA) is a GIS-based hydrologic modeling tool designed to evaluate the effects of land use change (Burns et al., 2004). AGWA provides the functionality to conduct all phases of a watershed assessment. It facilitates the use of the Soil and Water Assessment Tool (SWAT), a hydrologic model, by preparing the inputs, running the model, and presenting the results visually in the GIS. AGWA has been used to illustrate the impacts of urbanization and other landscape changes on runoff and sediment load in a watershed.

AGWA was developed under a joint project between the Environmental Protection Agency (EPA), Agricultural Research Service (ARS), and the University of Arizona. SWAT was developed by the ARS, and is able to predict the impacts of land management practices on water, sediment and chemical yields in complex watersheds with varying soils, land use and management conditions (Arnold et al., 1994).

The SEDMOD model (Van Remortel et al., 2004), which uses the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), was applied in this plan to estimate soil erosion and sediment delivery from different land use types. This procedure involves a series of automated Arc Macro Language (AML) scripts and two supported programs that run in an ESRI ArcGIS 8.x Workstation platform.

The watershed classification within this plan incorporates GIS-based hydrologic modeling results and other data to describe watershed conditions upstream from an impaired stream reach identified within Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005). In addition, impacts due to mine sites (erosion and metals pollution) and grazing (erosion and pollutant nutrients) are analyzed using fuzzy logic (described below).

The Little Colorado Watershed is defined and mapped by the U.S. Geological Survey using the six-digit Hydrologic Unit Code (HUC). The United States is divided and sub-divided into successively smaller hydrologic units of surface water drainage features, which are classified into four levels, each identified by a unique hydrologic unit code consisting of two to eight digits: regions (2 digit), sub-regions (4 digit), accounting units (6 digit), and cataloging units (8 digit) (Seaber et al., 1987).

The Little Colorado is a six-digit HUC watershed, and within it smaller subwatershed areas are delineated using both the eight and ten digit cataloging HUC. Eight-digit HUCs were used for the characterizations while classifications and GIS modeling were done at the 10-digit level.

The following HUC units (and subwatershed names are used to clarify locations in this plan.

15020001 Little Colorado River Headwaters
1502000101-Nutrioso Creek
1502000102-South Fork Little Colorado River-Little Colorado River Headwaters
1502000103-Coyote Creek
1502000104-Carnero Creek-Little Colorado River Headwaters

15020002 Upper Little Colorado River
1502000201-Upper Little Colorado River, Lyman Lake to Big Hollow Wash
1502000202-Big Hollow Wash
1502000203-Concho Creek-Upper Little Colorado River
1502000204-Oso Draw
1502000205-Milky Wash
1502000206-Hay Hollow Draw-Upper Little Colorado River
1502000207-Washboard Wash-Upper Little Colorado River

15020003 Carrizo Wash
1502000306-Middle Carrizo Wash
1502000307-Lower Carrizo Wash

15020004 Zuni River
1502000406-Jaralosa Draw
1502000407-Middle Zuni River
1502000408-Hardscrabble Wash
1502000409-Lower Zuni River

15020005 Silver Creek
1502000501-Show Low Creek
1502000502-Upper Silver Creek
1502000503-Cottonwood Creek
1502000504-Lower Silver Creek

15020006 Upper Puerco River
1502000603-Upper Black Creek
1502000605-Whitewater Arroyo
1502000606-Lower Black Creek
1502000607-Manuelito Canyon-Upper Puerco River

15020007 Lower Puerco River
1502000701-Burntwater Wash-Lower Puerco River
1502000702-Morgan Canyon
1502000703-Dead Wash
1502000704-Dry Wash
1502000705-Ninemile Wash-Lower Puerco River
1502000706-Lithodendron Wash-Lower Puerco River

15020008 Middle Little Colorado River
1502000801-Phoenix Park Wash-Dry Lake
1502000802-Porter Tank Draw-Middle Little Colorado River
1502000803-Upper Clear Creek

1502000804-Lower Clear Creek
1502000805-Jacks Canyon
1502000806-McDonald Canyon-Middle Little Colorado River
1502000807-Rincon Basin Area-Middle Little Colorado River
1502000808-Coyote Wash-Middle Little Colorado River
1502000809-Cow Canyon-Middle Little Colorado River
1502000810-Middle Little Colorado River-Canyon Diablo to Grand Falls

15020009 Wide Ruin Wash-Leroux Wash
1502000901-Upper Wide Ruin Wash
1502000902-Lower Wide Ruin Wash
1502000903-Leroux Wash

15020010 Chevelon Canyon
1502001001-Upper Chevelon Canyon
1502001002-Black Canyon
1502001003-Lower Chevelon Canyon

15020011 Pueblo Colorado Wash-Cottonwood Wash
1502001101-Upper Pueblo Colorado Wash
1502001102-Steamboat Wash
1502001103-Middle Pueblo Colorado Wash
1502001104-Bidahochi Wash
1502001105-Lower Pueblo Colorado Wash
1502001106-Cottonwood Wash

15020012 Oraibi Wash
1502001201-Upper Oraibi Wash
1502001202-Middle Oraibi Wash
1502001203-Lower Oraibi Wash

15020013 Polacca Wash
1502001301-Upper Polacca Wash
1502001302-Wepo Wash
1502001303-Middle Polacca Wash
1502001304-Lower Polacca Wash

15020014 Jadito Wash
1502001401-Ha-whi-yalin Wash
1502001402-Upper Jadito Wash
1502001403-Coyote Wash
1502001404-Lower Jadito Wash

15020015 Canyon Diablo
1502001501-Rio de Flag
1502001502-Walnut Creek
1502001503-San Francisco Wash
1502001504-Canyon Diablo (Local Drainage)

15020016 Lower Little Colorado River
1502001601-Kana-a Wash-Lower Little Colorado River
1502001602-Deadman Wash
1502001603-Big Wash-The Big Lake Area
1502001604-Tohachi Wash
1502001605-Citadel Wash-Lower Little Colorado River
1502001606-Upper Cedar Wash
1502001607-Lower Cedar Wash
1502001608-Tonahakaad Wash-Lower Little Colorado River
1502001609-Lee Canyon-Lower Little Colorado River
1502001610-Sheep Wash-Lower Little Colorado River

15020017 Dinnebito Wash
1502001701-Upper Dinnebito Wash
1502001702-Middle Dinnebito Wash
1502001703-Lower Dinnebito Wash

15020018 Moenkopi Wash
1502001801-Moenkopi Wash Headwaters
1502001802-Shonto Wash
1502001803-Upper Begashibito Wash
1502001804-Crooked Ridge/Echo Cliffs Area
1502001805-Lower Begashibito Wash

1502001806-Wide Ruin Canyon-Moenkopi Wash
1502001807-Pasture Canyon
1502001808-Coal Mine Canyon-Moenkopi Wash
1502001809-Hamblin Wash
1502001810-Kerley Valley-Moenkopi Wash
1502001811-Fivemile Wash-Moenkopi Wash

Fuzzy Logic

To rank the 10-digit HUC subwatershed areas that are susceptible to water quality problems and pollution, and to identify sources that need to be controlled, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types (Guertin et al., 2000; Miller et al., 2002; Reynolds et al., 2001). This methodology has been selected as the basis by which subwatershed areas and stream reaches are prioritized for the implementation of BMPs to assure nonpoint source pollution is managed.

Fuzzy logic is an approach to set theory that handles vagueness or uncertainty, and has been described as a method by which to quantify common sense. In classical set theory, an object is either a member of the set or excluded from the set. Fuzzy logic allows for an object to be a partial member of a set.

For example, classical set theory might place a man into either the tall or short class, with the class of tall men being those over the height of 6'0". Using this method, a man who is 5' 11" tall would not be placed in the tall class, although he would not be considered 'not-tall'. This is unacceptable, for example, for describing or quantifying an object that may be a partial member of a set. In fuzzy logic, membership in a set is described as a value between 0 (non- membership in the set) and 1 (full membership in the set). For instance, the individual who is 5' 11" is not classified as short or tall, but is classified as tall to a degree of 0.8. Likewise, an individual of height 5' 10" would be tall to a degree of 0.6.

In fuzzy logic, the range in values between different data factors are converted to the same scale (0-1) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the characteristics of the input. In the illustration above, the degree of tallness was iteratively added in intervals of 0.2, creating a discrete data set. A continuous data set would graph the heights of all individuals and correlate a continuous fuzzy member value to that graph. A user defines their membership functions to describe the relationship between an individual factor and the achievement of the stated goal.

A benefit of using a fuzzy membership function is that it can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. Another benefit is that it provides for the use of different methods for combining individual factors to create the final classification, and the goal set. Fuzzy membership functions and weighting schemes can also be changed based on watershed concerns and conditions.

The general approach used in this plan was to integrate watershed characteristics, water quality measurements, and modeling results within a multi- parameter ranking system based on the fuzzy logic knowledge-based approach, as shown schematically in Figure 1-2.

This approach requires that a goal be defined according to the desired outcome and that the classification be defined as a function of the goal and is therefore reflective of the management objective. For this watershed classification, the goal is to identify critical subwatersheds in which BMPs should be implemented to reduce nonpoint source pollution.

The classification process was implemented within a GIS interface to create the subwatershed classifications using five primary steps:

- Define the goal of this watershed classification: Classify water quality impairment due to dissolved total metals from mining activity;

- Assemble GIS data and other observational data;

- Define watershed characteristics through:

    1. Water quality data provided in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005);

    2. GIS mapping analysis; and

    3. Modeling and simulation of erosion vulnerability and potential for stream impairment (i.e. from soils at mine sites and proximity to abandoned mine sites).

- Use fuzzy membership functions to transform the vulnerability and impairment metrics into fuzzy membership values; and

- Determine a composite fuzzy score representing the ranking of the combined attributes for each subwatershed, and interpret the results.

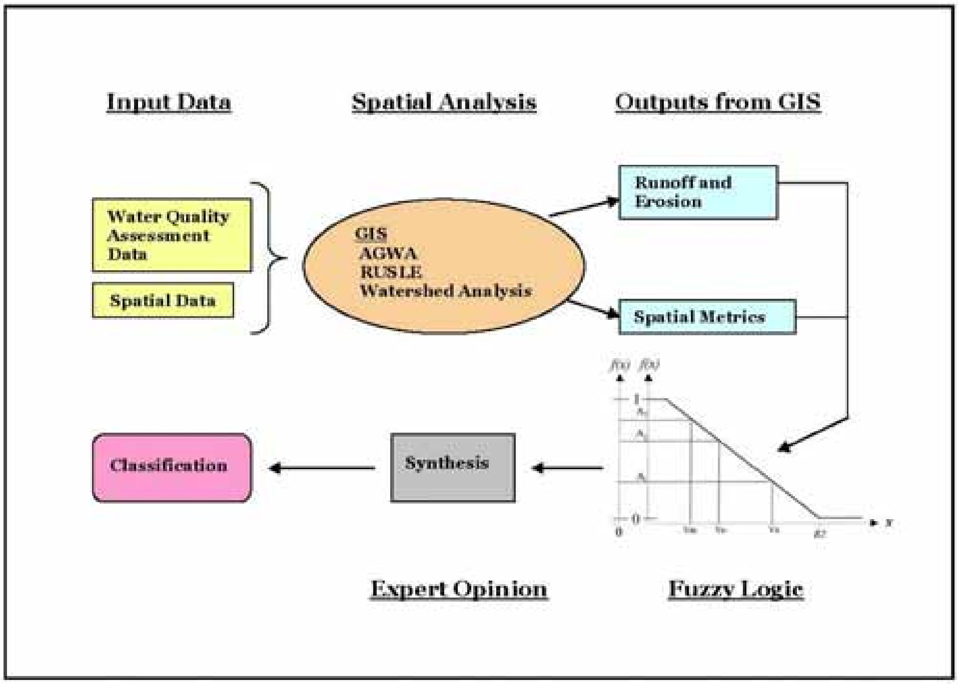

Figure 1-2: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), was used to classify each monitored stream reach based on its relative risk of impairment for each of the chemical constituent groups. The constituent groups include metals, organics, nutrients, and turbidity/sediment. Two final levels of risk were defined: high and low. For example, if elevated concentrations of metals, such as copper and mercury, are found above standards, the water body would be classified as "high" risk if ADEQ has currently assessed it as being "impaired" for that constituent group. Conversely, a water body is classified as "low" risk if there are no exceedances in a constituent group and there are sufficient data to make a classification.

Classifications were conducted at the 8-digit HUC subwatershed scale, for the Little Colorado Watershed, resulting in the ranking of the subwatershed areas.

Structure of this Plan

Watershed characterizations, including physical, biological, and social characteristics, are discussed in Sections 2 through 4. Important environmental resources are discussed in Section 5. These sections will address the entire Little Colorado Watershed (all 18 8-digit HUCs).

The subwatershed classifications based on water quality attributes including concentrations of metals, sediment/turbidity, organics, and nutrients are found in Section 6. Watershed management strategies and

BMPs are provided in Section 7, the Watershed Plan is presented in Section 8, and a summary of EPA's 9 Key Elements is provided in Section 9.

The full tabulation of the ADEQ water quality data and assessment status is provided in Appendix A. Suggested technical references of studies completed across the Little Colorado Watershed are included in Appendix B, a description of RUSLE is in Appendix C, and a description of AGWA is in Appendix D.

References

Arizona Department of Environmental Quality, ADEQ. 2005. The Status of Water Quality in Arizona - 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, 1110 West Washington Ave., Phoenix, Arizona, 85007, from http://www.azdeq.gov/environ/water/assessment/2004.html.

Arnold, J.G., J. R. Williams, R. Srinivasan, K.W. King, and R. H. Griggs. 1994. SWAT - Soil & Water Assessment Tool. USDA, Agricultural Research Service, Grassland, Soil and Water Research Laboratory, Temple, Texas.

Burns, I.S., S. Scott, L. Levick, M. Hernandez, D.C. Goodrich, S.N. Miller, D.J. Semmens, and W.G. Kepner. 2004. Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual Version 1.4, from http://www.tucson.ars.ag.gov/agwa/

Guertin, D.P., Fiedler, R.H., S.N. Miller, and D.C. Goodrich. 2000. Fuzzy logic for watershed assessment. Proceedings of the ASCE Conference on Science and Technology for the New Millennium: Watershed Management 2000, Fort Collins, CO, June 21-24, 2000.

Miller, S.N., W.G. Kepner, M.H. Mehaffrey, M. Hernandez, R.C. Miller, D.C. Goodrich, K.K. Devonald, D.T. Heggem, and W.P. Miller. 2002. Integrating Landscape Assessment and Hydrologic Modeling for Land Cover Change Analysis, in Journal of the American Water Resources Association, Vol. 38, No. 4, August. P. 915- 929.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), U. S. Department of Agriculture, Agriculture Handbook No. 703. 404 pp.

Reynolds, K.M. 2001. Fuzzy logic knowledge bases in integrated landscape assessment: Examples and possibilities. General Technical Report PNW-GTR-521. USDA Forest Service Pacific Northwest Research Station. 24 pp.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294. 63p.

Van Remortel, R., D. Heggem, and A. Pitchford. 2004. SEDMOD, Version 1.1 of Soil & Landform Metrics: Programs and U.S. Geodatasets (CD). U.S. Environmental Protection Agency, Environmental Sciences Division, Landscape Ecology Branch, Las Vegas, NV.

Section 2: Physical Features

The Little Colorado River Watershed stretches from the mountains in the Apache National Forest to the Colorado River in Grand Canyon National Park, east from the Walhalla Plateau in Arizona and southward down to the Mogollon Rim. This area is also the eastern most extent of the continental divide at the United States. The Little Colorado River Watershed in Arizona is defined by the Little Colorado River drainage area, which includes part of New Mexico. Although the Watershed continues eastward into the state of New Mexico, this study is limited to the area within the state of Arizona, as shown in Figure 2-1.

Watershed Size

The Little Colorado River Watershed area is approximately 27,051 square miles, covering a little over 19% of the state of Arizona. The watershed has a maximum approximate length of 160 miles north-south, and a maximum width of 246 miles east-west. It is located within both the state of Arizona and the western portion of New Mexico, but for the purposes of this study, only the Arizona portion is mapped. Nearly 21,729,820 square miles of Little Colorado Watershed are within the state of Arizona with an additional 5,321 square miles in New Mexico.

The watershed was delineated by the U.S. Geological Survey and has been subdivided into subwatershed or drainage areas. Each drainage area has a unique hydrologic unit code number, or HUC, and a name based on the primary surface water within the HUC. These drainage areas can be further subdivided as needed. The subwatershed areas were delineated on the basis of the eight-digit cataloging HUC as well as the classifications and GIS modeling.

The eight-digit subwatershed HUCs of the Little Colorado Watershed are listed in Table 2-1 and delineated in Figure 2-2. These six subwatersheds are identified with both the unique HUC digital classification and the subwatershed basin name in Table 2-1.

Topography

The land surface elevation of the Little Colorado Watershed ranges between 2,669 and 12,633 feet above mean sea level (msl). Twenty-nine of the 100 highest named summits in Arizona occur in the Little Colorado watershed. Humphreys Peak in the San Francisco Mountain (Coconino County) is the tallest at 12,633 feet msl. The second highest peak is Agassiz Peak, at 12,356 feet msl, found within the same subwatershed as Humphreys Peak.

The lowest elevation is at 2,334 feet msl at Cape Solitude in the Lower Little Colorado River subwatershed. Mean elevation for the whole Little Colorado Watershed is approximately 6,088 feet msl. All subwatersheds have a mean elevation greater than 5,000 feet msl. Table 2-2 shows the elevation ranges for each subwatershed, and Figure 2-3 shows the topography.

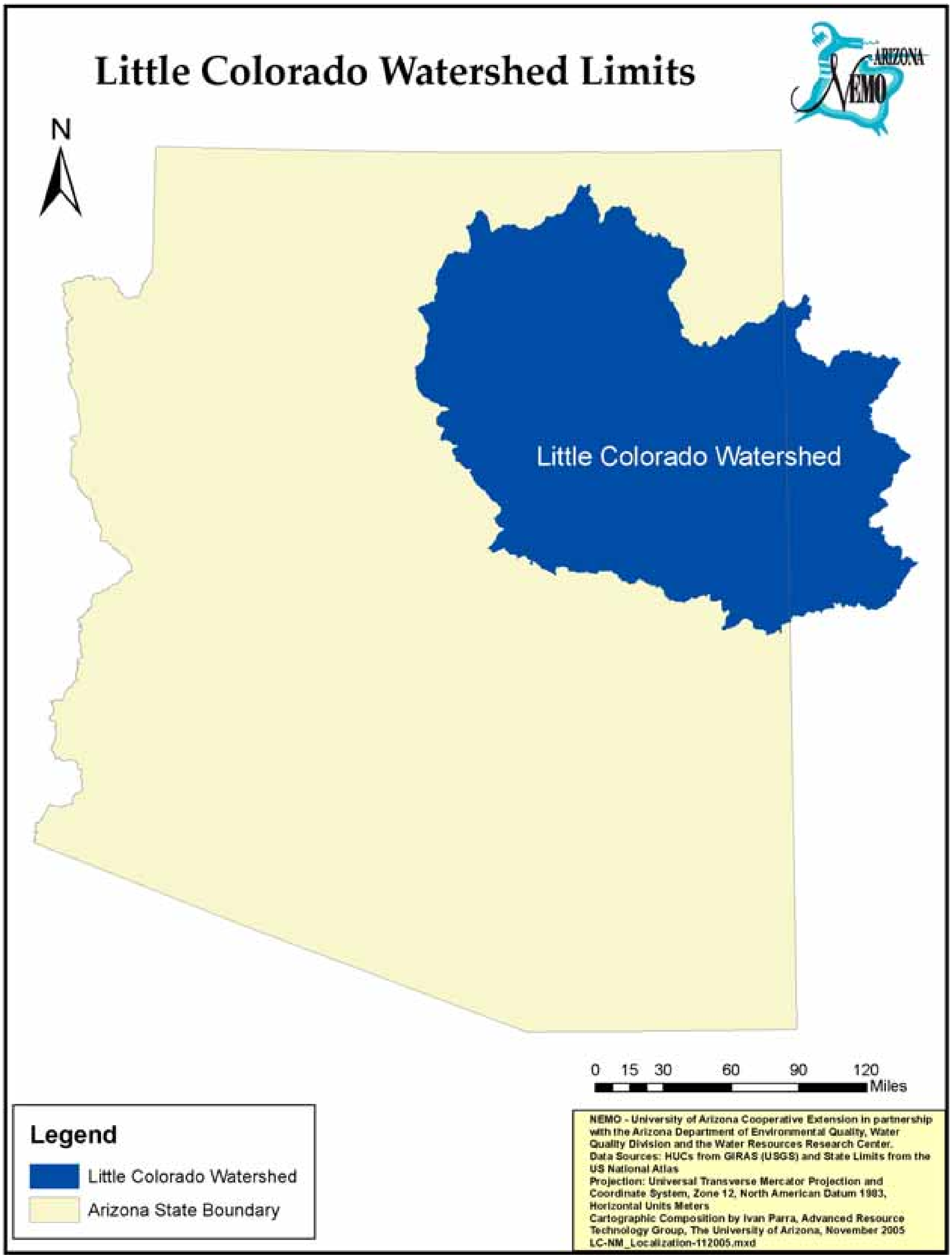

Figure 2-1 Little Colorado Watershed Location.

Table 2-1 Little Colorado Watershed HUCs and Subwatershed Areas in Arizona.

Subwatershed Name	Area (square miles)	Area (acres)
Little Colorado River Headwaters-15020001	**722**	**461,950**
Upper Little Colorado River-15020002	**1,609**	**1,029,683**
Carrizo Wash-15020003	**335**	**214,248**
Zuni River-15020004	**735**	**470,432**
Silver Creek-15020005	**947**	**606,263**
Upper Puerco River-15020006	**550**	**352,214**
Lower Puerco River-15020007	**1,119**	**715,931**
Middle Little Colorado River-15020008	**2,470**	**1,580,532**
Wide Ruin Wash-Leroux Wash-15020009	**807**	**516,277**
Chevelon Canyon-15020010	**844**	**540,420**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**1,607**	**1,028,494**
Oraibi Wash-15020012	**855**	**547,167**
Polacca Wash-15020013	**1,083**	**692,838**
Jadito Wash-15020014	**1,040**	**665,421**
Canyon Diablo-15020015	**1,204**	**770,704**
Lower Little Colorado River-15020016	**2,399**	**1,535,248**
Dinnebito Wash-15020017	**743**	**475,411**
Moenkopi Wash-15020018	**2,634**	**1,685,528**
Little Colorado River Watershed-150200	***21,703***	***13,888,761***

Figure 2- 2 Little Colorado Watershed HUCs.

Note: Subwatershed names are provided here but will not be included on subsequent maps due to space limitations.

Table 2-2 Little Colorado Watershed Elevation Range (feet above mean sea level).

Subwatershed Name	Min	Max	Mean
Little Colorado River Headwaters-15020001	**5,950**	**11,178**	**7,702**
Upper Little Colorado River-15020002	**5,098**	**10,135**	**6,057**
Carrizo Wash-15020003	**5,550**	**7,384**	**6,227**
Zuni River-15020004	**5,393**	**6,946**	**6,170**
Silver Creek-15020005	**5,179**	**8,842**	**6,308**
Upper Puerco River-15020006	**5,940**	**8,172**	**7,016**
Lower Puerco River-15020007	**5,102**	**7,110**	**5,832**
Middle Little Colorado River-15020008	**4,504**	**8,442**	**5,693**
Wide Ruin Wash-Leroux Wash-15020009	**5,055**	**7,766**	**6,144**
Chevelon Canyon-15020010	**4,900**	**7,940**	**6,468**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**4,853**	**8,303**	**6,203**
Oraibi Wash-15020012	**4,712**	**8,085**	**5,994**
Polacca Wash-15020013	**4,887**	**8,035**	**6,222**
Jadito Wash-15020014	**4,831**	**7,373**	**5,938**
Canyon Diablo-15020015	**4,687**	**12,335**	**6,524**
Lower Little Colorado River-15020016	**2,699**	**12,624**	**5,673**
Dinnebito Wash-15020017	**4,367**	**7,674**	**5,861**
Moenkopi Wash-15020018	**4,105**	**8,170**	**5,901**
Little Colorado River Watershed-150200	***2,699***	***12,624***	***6,088***

Note: Because of data resolution, this value is an average elevation within a 30 X 30 meter area around Humphreys Peak, elevation 12,633 feet msl

GIS was used to analyze the variation in slope and to determine slope classes. Slightly more than ten percent of the Little Colorado Watershed has a slope of 15% or greater, while 64% of the watershed exhibits land slope between 0 to 5%. Table 2-3 and Figure 2-4show the slope classes.

Most of the subwatersheds within the Little Colorado have more than half their area with an average slope of between 0-5%. These subwatersheds do contain more rugged topography (>15% slope) and have significant mountain areas, but due to their large size, every subwatershed has large portions within the central valley of the watershed.

Topography and land slope, as well as soil characteristics, are important when assessing the vulnerability of the subwatershed to erosion and pollutant transport, as will be discussed later in this document.

Figure 2-3 Little Colorado Watershed Topography.

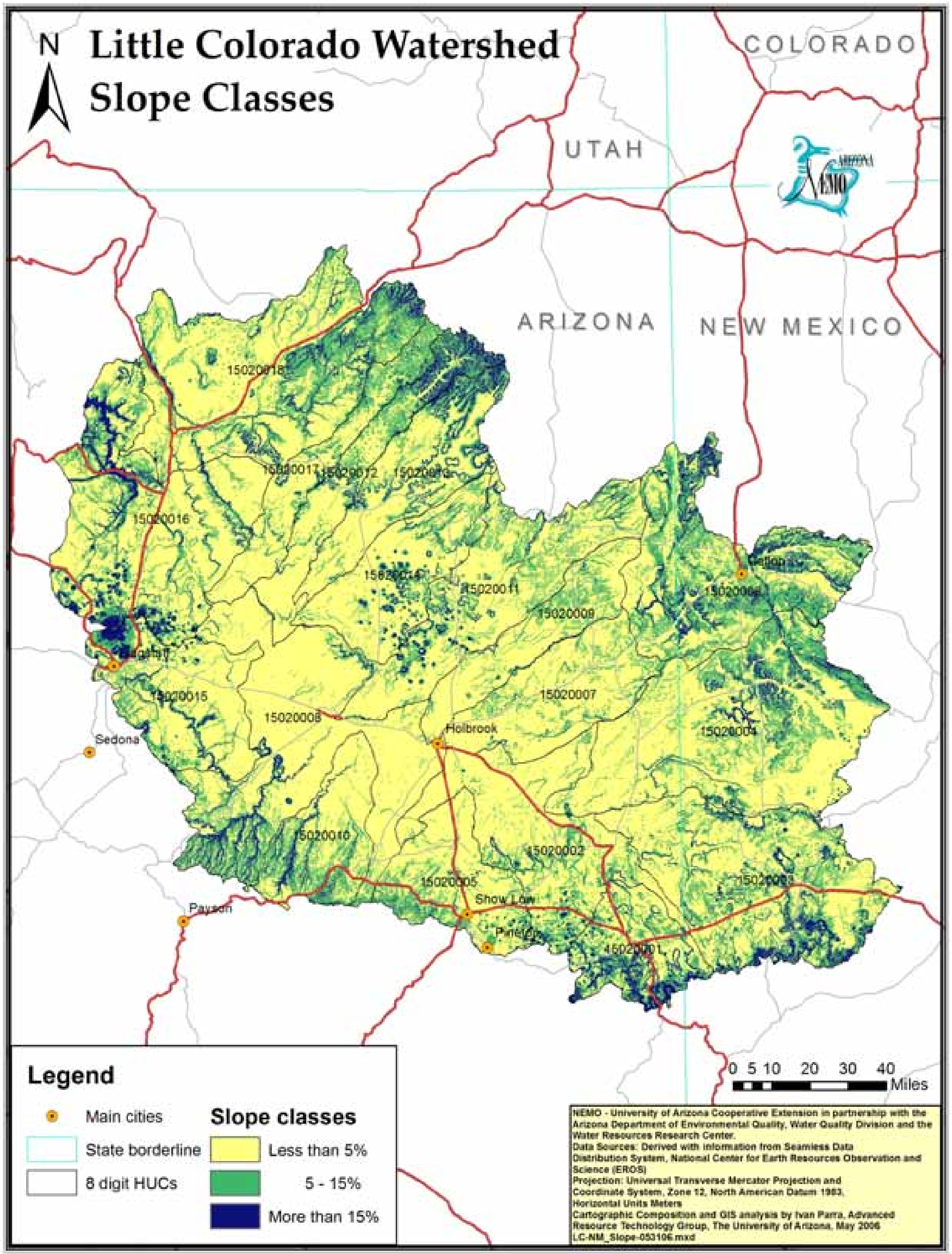

Figure 2-4 Little Colorado Watershed Slope Classes.

Table 2-3 Little Colorado Watershed Slope Classes.

Subwatershed Name	0-5%	5-15%	>15%
Little Colorado River Headwaters-15020001	46%	30%	24%
Upper Little Colorado River-15020002	72%	22%	6%
Carrizo Wash-15020003	78%	19%	3%
Zuni River-15020004	78%	20%	2%
Silver Creek-15020005	64%	28%	8%
Upper Puerco River-15020006	48%	37%	14%
Lower Puerco River-15020007	75%	21%	4%
Middle Little Colorado River-15020008	75%	16%	9%
Wide Ruin Wash-Leroux Wash-15020009	68%	26%	5%
Chevelon Canyon-15020010	56%	29%	16%
Pueblo Colorado Wash-Cottonwood Wash-15020011	62%	29%	9%
Oraibi Wash-15020012	53%	25%	22%
Polacca Wash-15020013	60%	25%	15%
Jadito Wash-15020014	68%	23%	9%
Canyon Diablo-15020015	65%	22%	12%
Lower Little Colorado River-15020016	60%	25%	15%
Dinnebito Wash-15020017	58%	31%	11%
Moenkopi Wash-15020018	56%	30%	14%
Little Colorado River Watershed-150200	64%	25%	11%

Water Resources

One river segment within the Little Colorado Watershed is classified as a "Unique Water of the State": the West Fork of the Little Colorado River, above Government Springs. This river reach was found to be an outstanding state water resource based on:

- Perennial flow;
- Lack of hydrological modifications such as impoundments, diversions and channelization;
- Good water quality, meeting or exceeding applicable surface water quality standards; and,
- Exceptional recreational or ecological significance because of unique attributes (geology, flora, fauna, aesthetic values or wilderness characteristics); or federally listed threatened or endangered species are known to be associated with the surface water.

Unique Waters are offered special water quality protection, strictly restricting activities within the drainage areas so that water quality degradation will not occur.

Both surface and ground water are important water supplies for municipal, industrial, and agricultural uses in the Little Colorado Watershed, but due to recent drought conditions many municipalities have turned to more reliable ground water supplies. It is estimated that ground water satisfies 90% of the water demand in the area (ADWR, 2006). Ground water is pumped from several large regional aquifers of sedimentary formations of sandstone and limestone, stacked on top of one another and generally separated by impermeable shales and siltstones. In descending order, the regional aquifers are the D-, N-, and C-aquifers.

The cities of Holbrook and Winslow rely entirely on ground water pumped from the C-aquifer. Ground water from the C-aquifer and from shallow local aquifers is also the principal water supply for municipal use along the Mogollon Rim, including the communities of Heber, Pinetop-Lakeside, Show Low, Snowflake, Springerville, Eagar, St. Johns, and Flagstaff. (ADWR, 2006).

Stream Type

The Little Colorado Watershed has a total stream channel length of 923,748 miles, with two predominant stream types: perennial and ephemeral/intermittent. Figure 2-5 shows the stream types and Table 2-4 tabulates the total length for each stream type.

The definitions for the three different stream types are below:

- Perennial surface water means surface water that flows continuously throughout the year, with baseflow maintained by ground water discharged into the channel.
- Intermittent surface water means a stream or reach of a stream that flows continuously only at certain times of the year; such as when it receives water from a seasonal rainfall, a spring, or from another source, such as melting spring snow.
- Ephemeral streams are at all times above the elevation of the ground water table, has no base flow, and flows only in direct response to precipitation.

Ninety six percent of the streams in the Little Colorado River Watershed are ephemeral/intermittent streams with a total accumulated length of 890,557 miles. Only approximately 4% of streams are perennial, mostly in the White Mountains in the southern portion of the watershed.

Most streams in Arizona are intermittent or ephemeral. Some of the stream channels in the Little Colorado Watershed are dry for years at a time, but are subject to flash flooding during high-intensity storms (Gordon et al., 1992).

The Little Colorado Watershed has approximately 1,414 miles of streams that are considered major streams. These streams are tabulated in Table 2-5.

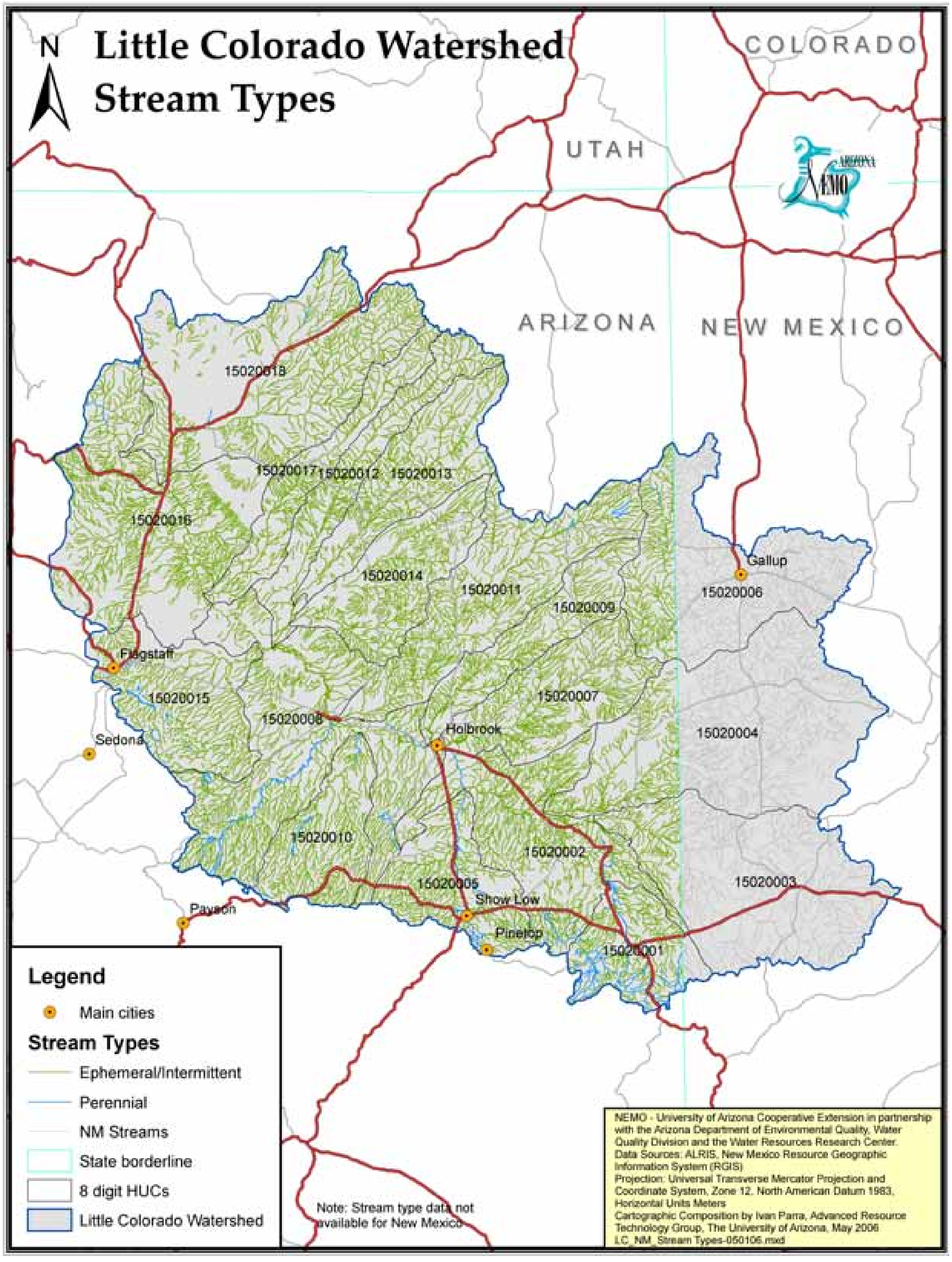

Figure 2-5 Little Colorado Watershed Stream Types.

Table 2-4 Little Colorado Watershed Stream Type and Length.

Type	Stream Length (miles)	Percent of Total Stream's Length
Intermittent	890,557	96%
Perennial	33,191	4%
Total	923,748	100%

Table 2-5 Little Colorado Watershed Major Stream Lengths.

Tributary Name	Subwatershed	Stream Length (miles)
Little Colorado River	Lower Little Colorado River-15020016	419
Dinnebito Wash	Dinnebito Wash-15020017	141
Oraibi Wash	Oraibi Wash-15020012	134
Moenkopi Wash	Moenkopi Wash-15020018	129
Puerco River	Upper Puerco River-15020006	114
Polacca Wash	Polacca Wash-15020013	106
Chevelon Canyon	Middle Little Colorado River-15020008	99
Pueblo Colorado Wash	Pueblo Colorado Wash-Cottonwood Wash-15020011	99
Cottonwood Wash	Pueblo Colorado Wash-Cottonwood Wash-15020011	97
Canyon Diablo	Canyon Diablo-15020015	81

Stream Density

The density of channels in the landscape is a measure of the dissection of the terrain. The stream density is defined as the length of all channels in the watershed divided by the watershed area. Areas with high stream density are associated with high flood peaks and high sediment production, due to increased efficiency in the routing of water from the watershed. Since the ability to detect and map streams is a function of scale, stream densities should only be compared at equivalent scales (Dunne and Leopold, 1978).

Figure 2-6 shows stream density for the Little Colorado Watershed, and Table 2-6 gives the stream density for each subwatershed in feet of stream length per acre. Stream density is similar throughout most of the Little Colorado Watershed going from 6.39 ft/ac in the Moenkopi Wash subwatershed to 11.11 ft/ac in the Little Colorado River Headwaters subwatershed.

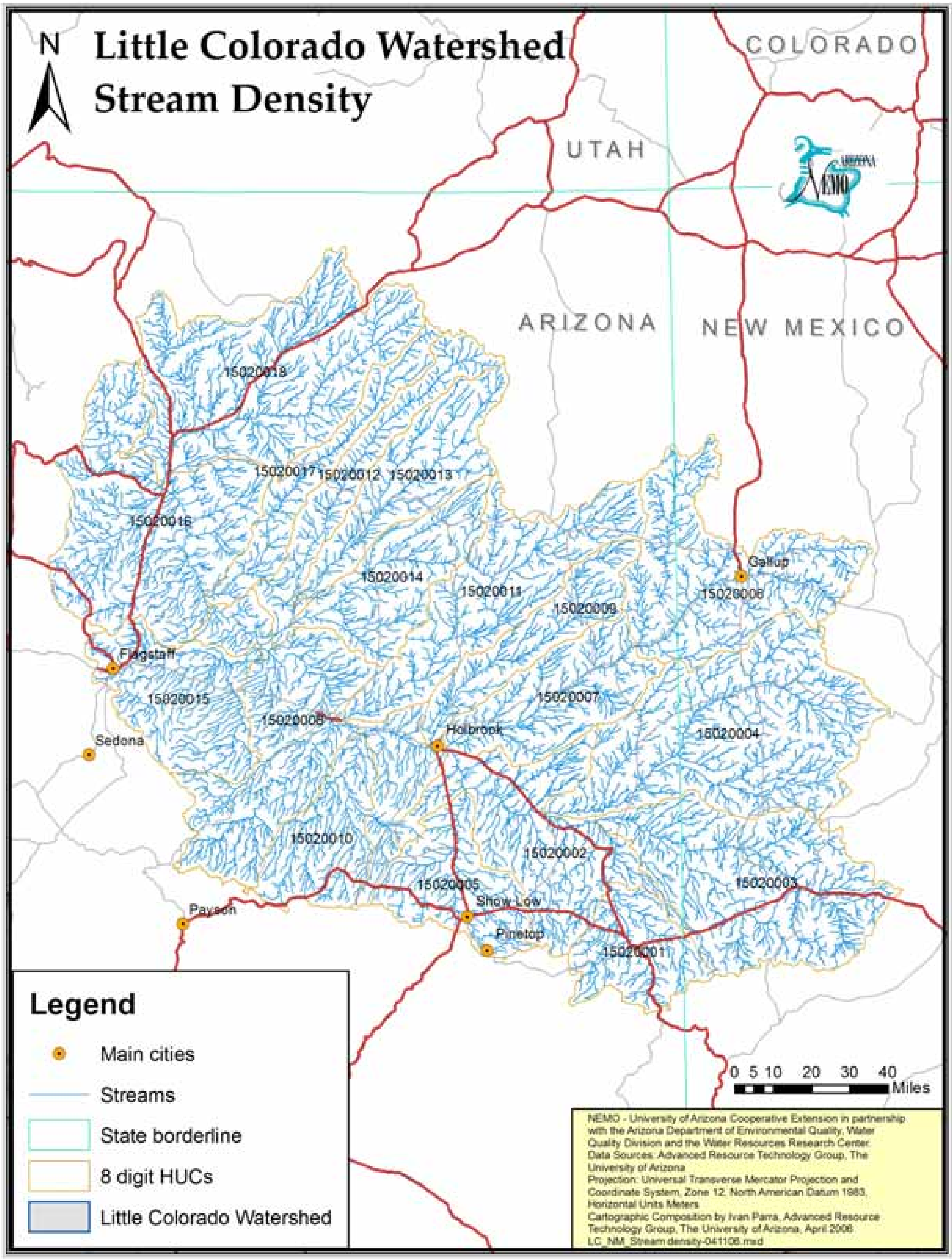

Figure 2-6 Little Colorado Watershed Stream Density.

Table 2-6 Little Colorado Watershed Stream Density.

Subwatershed	Stream Length (feet)	Area (acres)	Stream Density (ft/ac)
Little Colorado River Headwaters-15020001	5,131,464	461,950	11.11
Upper Little Colorado River-15020002	10,620,133	1,029,683	10.31
Carrizo Wash-15020003	1,878,262	214,248	8.77
Zuni River-15020004	3,723,995	470,432	7.92
Silver Creek-15020005	5,805,337	606,263	9.58
Upper Puerco River-15020006	3,390,207	352,214	9.63
Lower Puerco River-15020007	7,189,486	715,931	10.04
Middle Little Colorado River-15020008	14,564,936	1,580,532	9.22
Wide Ruin Wash-Leroux Wash-15020009	4,887,290	516,277	9.47
Chevelon Canyon-15020010	5,410,968	540,420	10.01
Pueblo Colorado Wash-Cottonwood Wash-15020011	9,877,042	1,028,494	9.60
Oraibi Wash-15020012	4,365,767	547,167	7.98
Polacca Wash-15020013	6,166,892	692,838	8.90
Jadito Wash-15020014	5,853,747	665,421	8.80
Canyon Diablo-15020015	6,531,632	770,704	8.47
Lower Little Colorado River-15020016	13,050,771	1,535,248	8.50
Dinnebito Wash-15020017	4,295,300	475,411	9.03
Moenkopi Wash-15020018	10,777,216	1,685,528	6.39

Annual Stream Flow

Annual stream flows for eight USGS gages were calculated for the Little Colorado Watershed. These gages were selected based on their location, length of date record, and representativeness of watershed response. Table 2-7 lists these gages with their mean annual stream flow (cubic feet per second, cfs). Figure 2-7 shows the location of all gages in the watershed.

The “Little Colorado River above the mouth near Desert View” gage (very close to the location where the Little Colorado drains into the Colorado River, northwest limit of watershed) has the highest measured mean annual stream flow with 310 cubic feet per second, while Show Low Creek (near Lakeside) has one of the lowest measured mean annual stream flow at 13.39 cubic feet per second.

Figures 2- 8, 2- 10, 2- 12 and 2- 14 show typical hydrographs for the watershed.

Figures 2- 9, 2- 11, 2- 13 and 2- 15 show 5-year moving averages of stream flow with an estimated linear trend line.

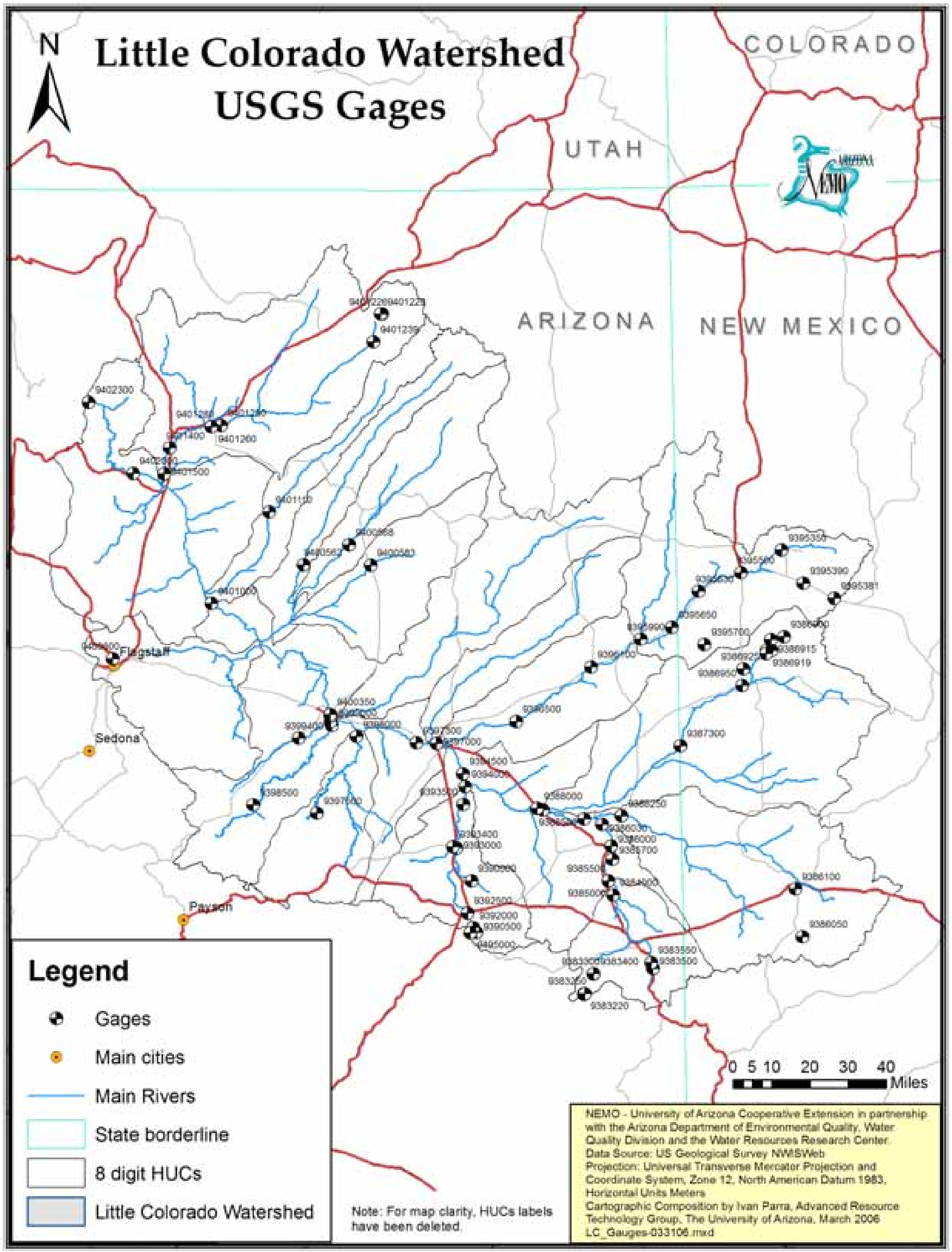

Figure 2-7 Little Colorado Watershed USGS Stream Gages.

Table 2-7 Little Colorado Watershed USGS Stream Gages.

Gage Number	Name	Begin Date	End Date	Number of days in Record	Mean Annual Flow (CFS)
9402300	Little Colorado River Abv Mouth Nr Desert View, AZ	5/4/1990	9/30/2005	1581	310.00
9402000	Little Colorado River Near Cameron, AZ	6/1/1947	9/30/2005	21307	219.28
9401000	Little Colo. River at Grand Falls, AZ	11/15/1925	9/30/1994	13508	274.05
9399000	Clear Creek Near Winslow, AZ	6/1/1906	12/31/1982	19259	83.87
9398500	Clear Creek Below Willow Creek, N Winslow, AZ	6/1/1947	9/30/1991	16193	81.87
9394500	Little Colorado River At Woodruff, AZ	3/16/1905	9/30/2005	28528	49.50
9390500	Show Low Creek Near Lakeside, AZ	5/1/1953	9/30/2005	19146	13.39
9384000	Little Colorado R Abv Lyman Lake Nr St. Johns, AZ	10/1/1940	9/30/2005	23741	21.53

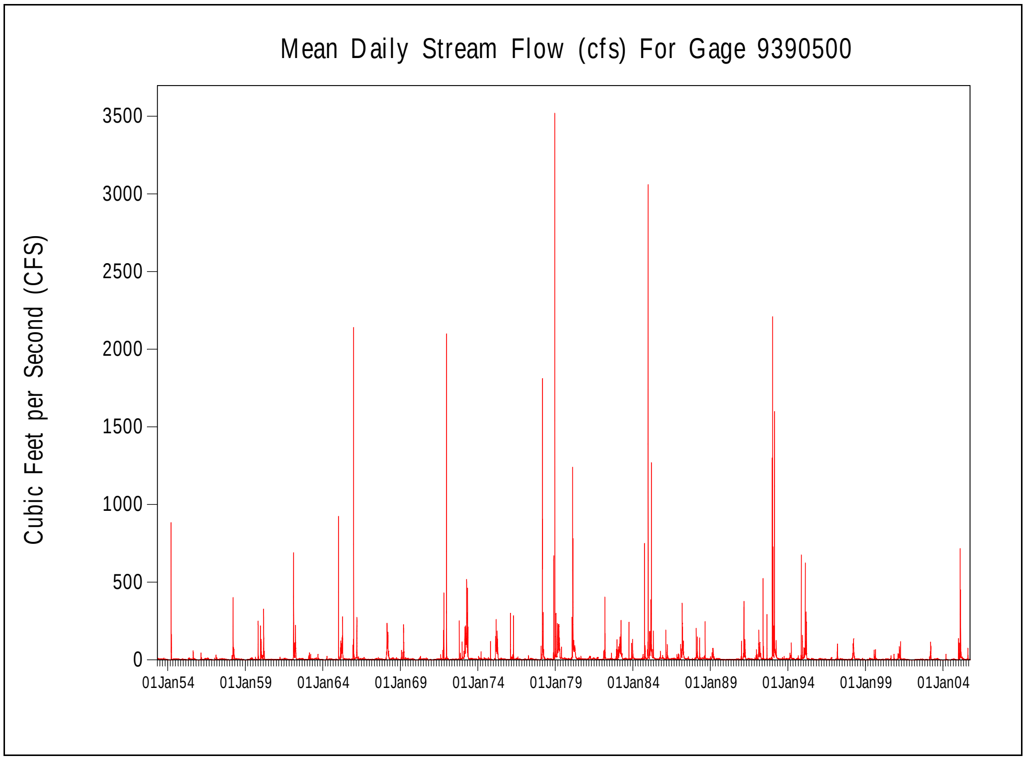

Figure 2-8 USGS Gage 09390500 (Show Low Creek Near Lakeside, AZ) Hydrograph.

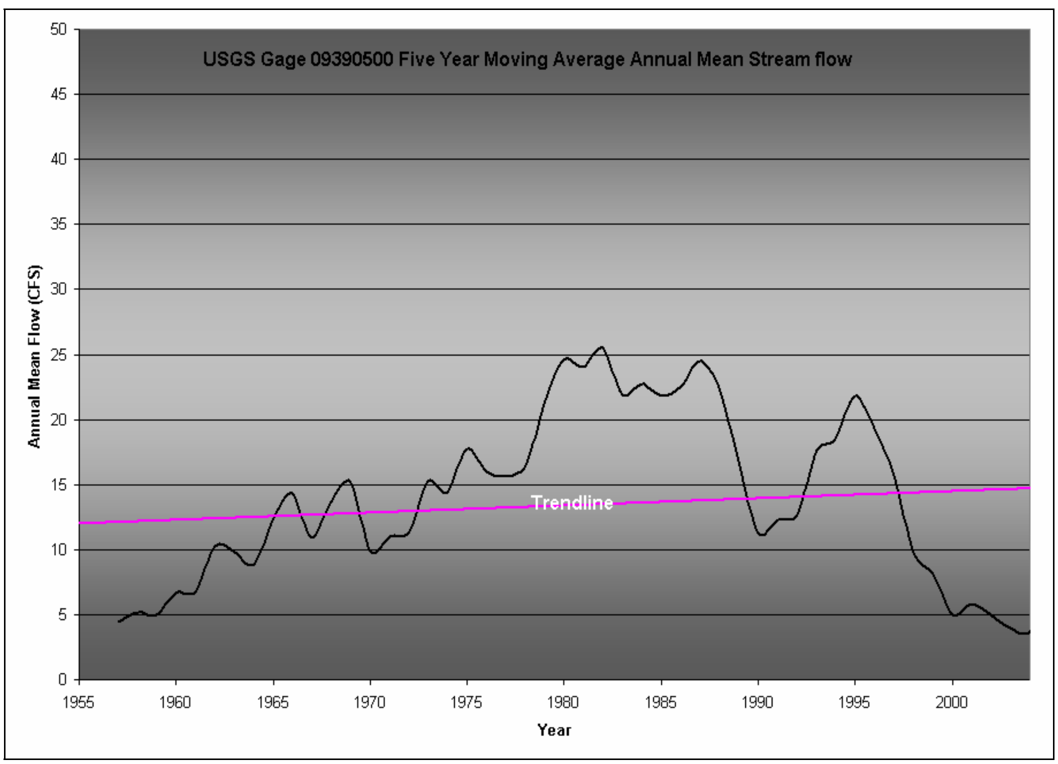

Figure 2-9 USGS Gage 09390500 (Show Low Creek Near Lakeside, AZ) Five Year Annual Moving Average Stream Flow (cfs).

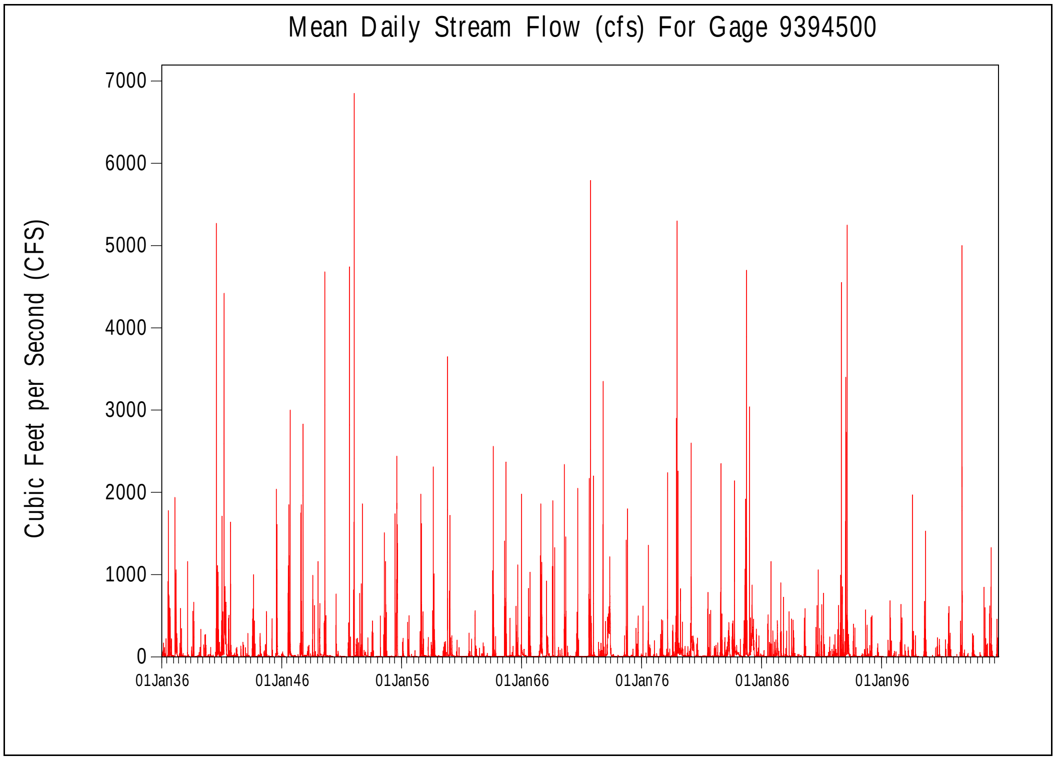

Figure 2-10 USGS Gage 09394500 (Little Colorado River at Woodruff, AZ) Hydrograph.

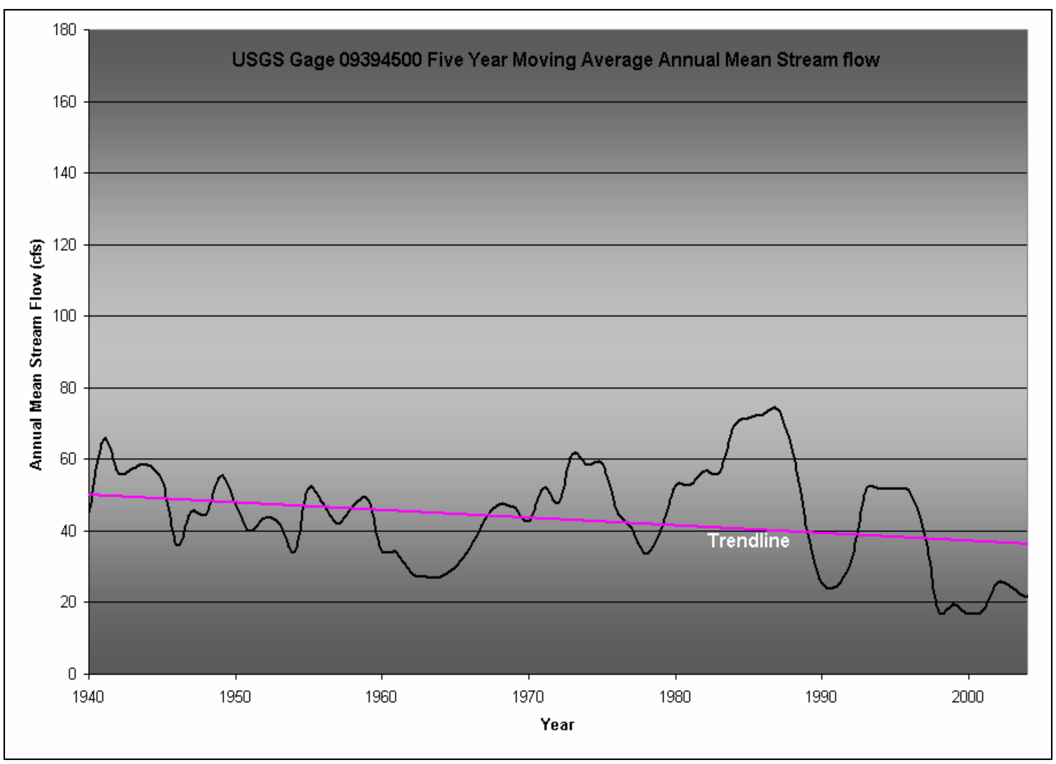

Figure 2-11 USGS Gage 09394500 (Little Colorado River at Woodruff, AZ) Five Year Annual Moving Average Stream Flow (cfs).

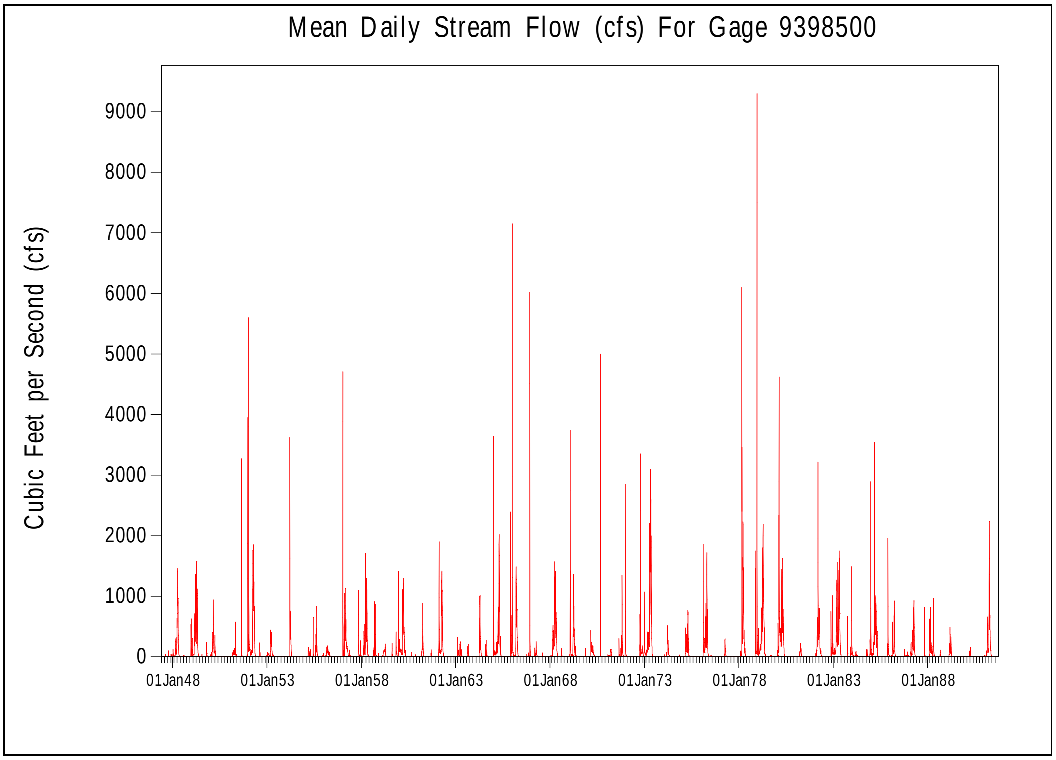

Figure 2-12 USGS Gage 09398500 (Clear Creek Below Willow Creek, N Winslow, AZ) Hydrograph.

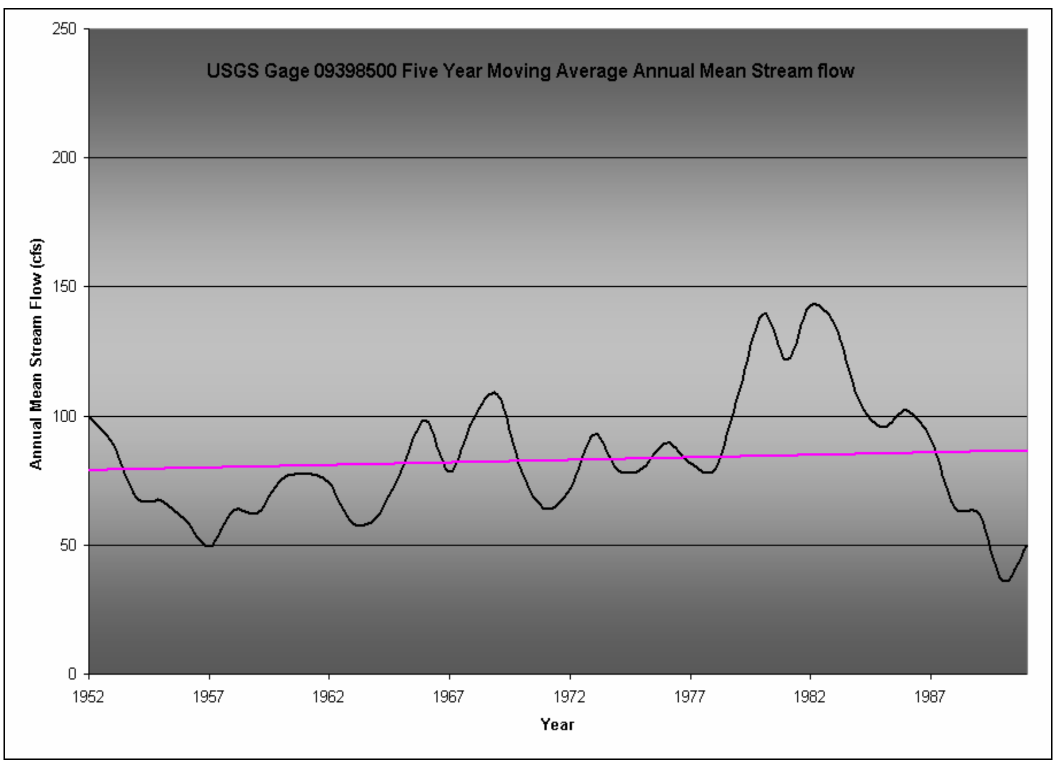

Figure 2-13 USGS Gage 09398500 (Clear Creek Below Willow Creek, N Winslow, AZ) Five Year Annual Moving Average Stream Flow (cfs).

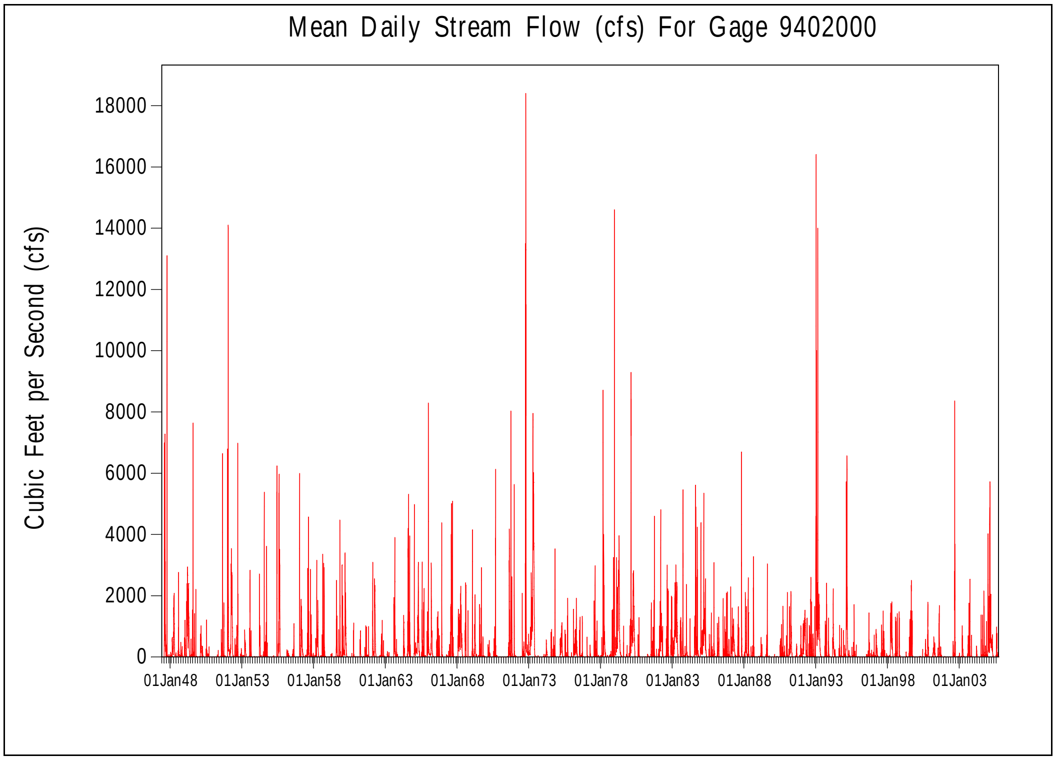

Figure 2-14 USGS Gage 09402000 (Little Colorado River Near Cameron, AZ) Hydrograph.

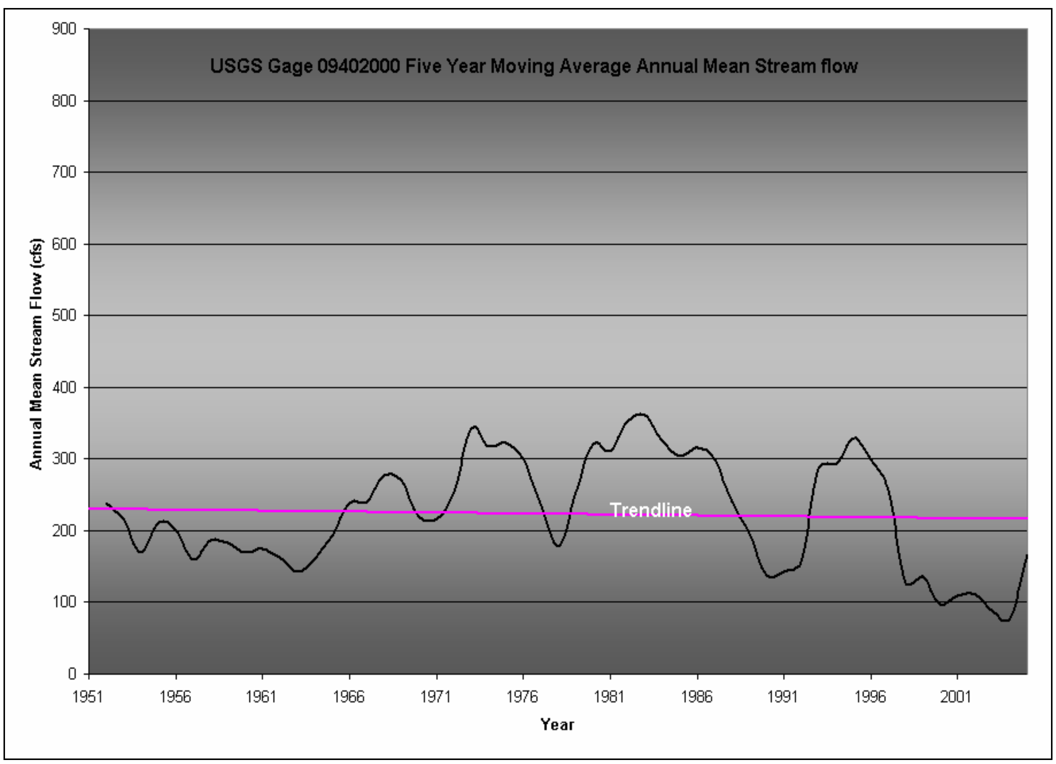

Figure 2-15 USGS Gage 09402000 (Little Colorado River Near Cameron, AZ) Five Year Annual Moving Average Stream Flow (cfs).

Lakes and Reservoirs

There are 465 lakes and 26 reservoirs within the Little Colorado Watershed. Among these, Mormon Lake has the largest open surface water area within the watershed at about 3,097 acres, located southeast from Flagstaff.

Figure 2- 16 shows major lakes within the watershed and Table 2- 8 shows their associated surface water areas.

Table 2- 8 Little Colorado Watershed Lakes and Reservoirs.

Lake Name	Subwatershed	Surface Area (acres)	Elevation (feet above sea level)	Dam name (if known)
Mormon Lake	**Canyon Diablo-15020015**	**3,097**	**7,184**	**not known**
Dry Lake	**Middle Little Colorado River-15020008**	**1,675**	**5,883**	**not known**
Mormon Lake	**Canyon Diablo-15020015**	**1,372**	**7,184**	**not known**
Lyman Lake	**Little Colorado River Headwaters-15020001**	**1,308**	**5,990**	**not known**
Upper Lake Mary	**Canyon Diablo-15020015**	**861**	**6,825**	**Upper Lake Mary Dam**
Lower Lake Mary	**Canyon Diablo-15020015**	**764**	**6,805**	**Lower Lake Mary Dam**
Zion Reservoir	**Upper Little Colorado River-15020002**	**555**	**5,543**	**Zion Dam**
Hay Lake	**Middle Little Colorado River-15020008**	**456**	**6,694**	**Hay Lake Dam**
Tremaine Lake	**Middle Little Colorado River-15020008**	**421**	**6,716**	**not known**
Long Lake	**Silver Creek-15020005**	**397**	**6,346**	**not known**

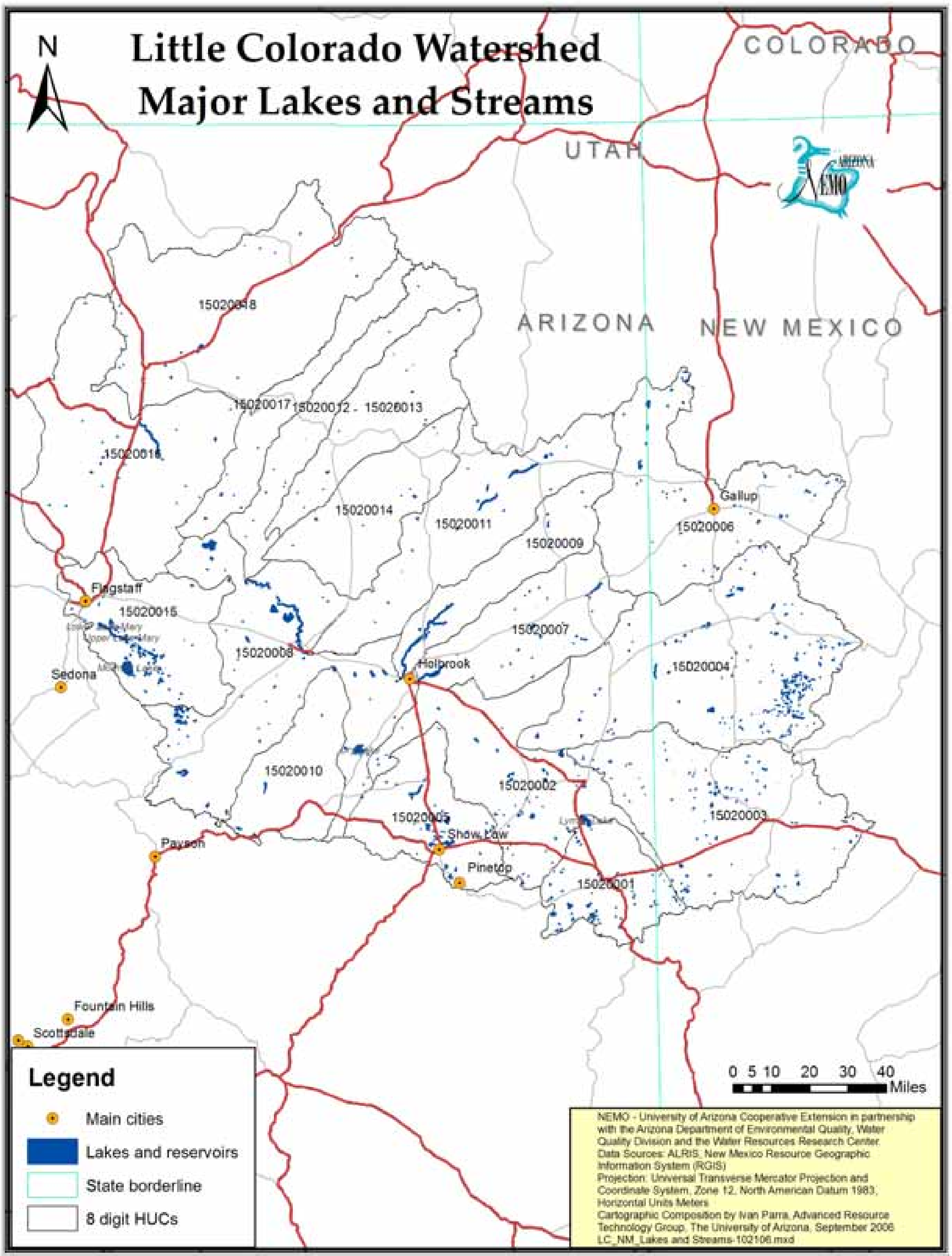

Figure 2-16 Little Colorado Watershed Major Lakes and Streams.

Water Quality

In the Little Colorado Watershed, eight stream reaches and eight lakes were listed as impaired in 2004 (ADEQ, 2005) (Figure 2-17), among them:

- Nutrioso Creek, from headwaters to Picnic Creek due to turbidity (prior TMDL)
- Nutrioso Creek from Picnic Creek to Little Colorado River due to turbidity (prior TMDL)
- Little Colorado River from West Fork of the Little Colorado River to Water Canyon Creek due to Turbidity (prior TMDL)
- Little Colorado River from Water Canyon Creek to Nutrioso Creek due to Turbidity (prior TMDL)
- Little Colorado River unnamed reach to Lyman Lake, due to turbidity (prior TMDL)
- Little Colorado River from Nutrioso Creek to Carnero Wash, due to turbidity (prior TMDL)
- Little Colorado River from Silver Creek to Car Wash, due to bacterial contamination (*Escherichia coli*) and suspended sediment
- Little Colorado River from Porter Tank Draw to McDonalds Wash, due to past copper and silver concentration exceedances
- Upper Lake Mary, due to mercury in fish tissue
- Lower Lake Mary, due to mercury in fish tissue
- Long Lake (lower), due to mercury in fish tissue
- Rainbow Lake, due to nutrients - past TMDL
- Bear Canyon Lake, due to low pH
- Soldier's Annex Lake, due to the presence of mercury in fish tissue
- Soldier's Lake, due to the presence of mercury in fish tissue
- Lyman Lake, due to the presence of mercury in fish tissue

Several other streams and lakes are listed by ADEQ as "inconclusive water quality status", due to exceedances of standards, but further monitoring is needed to determine if the surface water is impaired or actually attaining its designated uses. An explanation of the 303d listing process and a tabulation of the water quality attributes can be found in Section 6, Watershed Classification as well as in Appendix A Table 1.

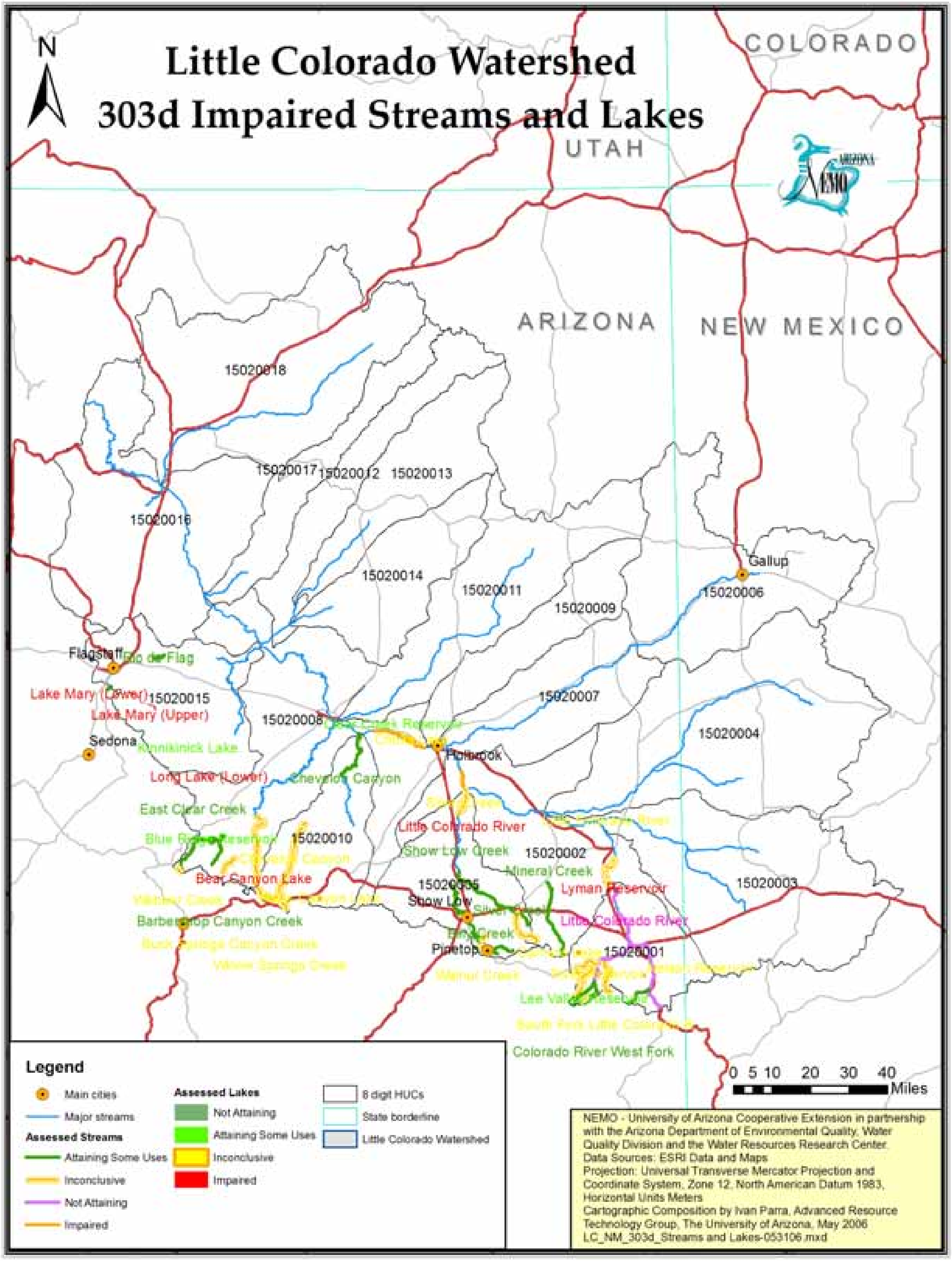

Figure 2-17 Little Colorado Watershed 303d Streams and Lakes.

Geology

The Little Colorado Watershed is in the northeastern corner of the state within the Colorado Plateau Uplands physiographic province. This province covers the northern 2/5 of the state of Arizona and is characterized by mostly level, horizontally stratified sedimentary rocks that have been eroded into canyons and plateaus, and by some high volcanic mountains.

Major mountain ranges are the San Francisco Peaks near Flagstaff, the White Mountains along the southeastern ridge of the watershed, and the Chuskas and Lukachukai mountains located along the Arizona-New Mexico border (ADWR, 2006).

Compared with the rest of Arizona geology, the Plateau Uplands seems easy to understand: the rocks are flat-lying sedimentary strata set in sequences of oldest to youngest. canyons cut through the flat plateau surfaces, exposing the layered rocks below, with the Grand Canyon to the north and west of the watershed cutting though to the Precambrian basement rock.

Figure 2-18 shows the geology of the Little Colorado Watershed. Table 2- 9 lists the geologic units by subwatershed, and Table 2- 10 lists the percentage of each rock type.

The watershed is bounded on the south by the Mogollon Rim, an escarpment almost 2,000 feet high in some locations, extending from central Arizona to the Mogollon Mountains in New Mexico. Quaternary and Tertiary aged lava flows along the margins of the White Mountains cover most of the watershed, and many flows have filled paleovalleys, protecting them from erosion that wore away surrounding unprotected paleoridges, so that now what was a valley has become a ridge, and what were ridges have become eroded valleys.

Hundreds of volcanic cinder cones and craters are found across the landscape. The White Mountain volcanic field rises towards a central volcano, Mt. Baldy (11,490 feet) where the volcanic rocks are reported to be nearly 4,000 feet thick (Chronic, 1983). Humphreys Peak (12,633 feet) in the San Francisco Mountains is the highest point in Arizona, and is one of three other peaks (the Agassiz and Fremont) that remained after a Mt. St. Helens-like sideward explosion of a larger volcano.

The San Francisco Mountains resulted from eruptions from 2.8 million to 200,000 year ago, and are still considered a potentially active volcanic hazard (Kamilli and Richard, 1998). The youngest volcanic activity in the watershed formed Sunset Crater, with eruptions that began in 1064 or 1065 AD (Chronic, 1983). The lava surface along this boundary of the watershed characteristically has no organized drainage patterns and is pocked with irregular hills and poorly drained depressions. Along the San Francisco Peaks and the White Mountains, Pleistocene glaciers carved into the peaks and left smoothed valleys and moraine deposits.

Jurassic age Navajo sandstone, and the older Triassic age Chinle Formation are exposed across the watershed. Shaly siltstones, mudstone, conglomerates, and the Kaibab limestone overlay the Permian age Coconino Sandstone, and the older red siltstone and fine sandstone rocks of the Supai Formation are exposed in the deep canyon cut by the Little Colorado as it enters the Colorado River northwest of Cameron.

The Painted Desert, northeast of Holbrook, is shaped by erosion of the soft, limy mudstone layers of the Chinle Formation. The Chinle Formation contains bentonite, a clay formed from volcanic ash that swells when wet and dries into a crust that erodes easily. The Formation is famous for fossil trees and the great logs of the Petrified Forest. Nearly 20 species of fossil ferns and other plants have been found in the region (Chronic, 1983).

Geologic resources of note in the watershed include deposits of economically important Black Mesa Coal, uranium near Cameron, and helium east of Holbrook. Black Mesa coal was mined for pottery firing as early as 900 A.D., and more than 100,000 tons were mined between 1300 and 1600 (Nations, et al, 1998). Coal is found in the lands of the Navajo Nation and the Hopi Tribe within the Cretaceous age Mesa Verde Group, and overlay the Mancos Shale. Coal seams average 4-8 feet in thickness, some are as much as 20 feet thick, and multiple beds range in cumulative thickness from 24-91 feet.

Arizona at one time was the nations' richest source of uranium, and deposits were formed in breccia pipes, a depositional setting unique to the geology of the Colorado Plateau. These pipes were formed as rock collapsed into solution caves created in the underlying Mississippian Redwall Limestone. Deposits of uranium were formed by geochemical reaction about 230 to 200 million years ago from saline ground water that flowed upward between the breccia fragments, and uranium was concentrated in the Permian Coconino Sandstone, Hermit Shale, and Supai Group rocks (Kamilli and Richard, 1998)

Helium is found in natural gas deposits within the Permian age Coconino Sandstone (Fellows, 1999). In addition to being an important source of geologic resources, the Coconino Sandstone is an important water supply aquifer, as discussed below.

Although alluvial deposits are important aquifers in other parts of the state, the shallow alluvium in the Little Colorado Watershed provides the only local sources of shallow ground water. Figure 2-19 shows the alluvial geology of the Little Colorado watershed, and differentiates between the younger alluvium deposited along current drainage features and the older alluvial materials that may also consist of windblown aeolian and glacial deposits. Table 2-11 tabulates the older and younger alluvium by subwatershed.

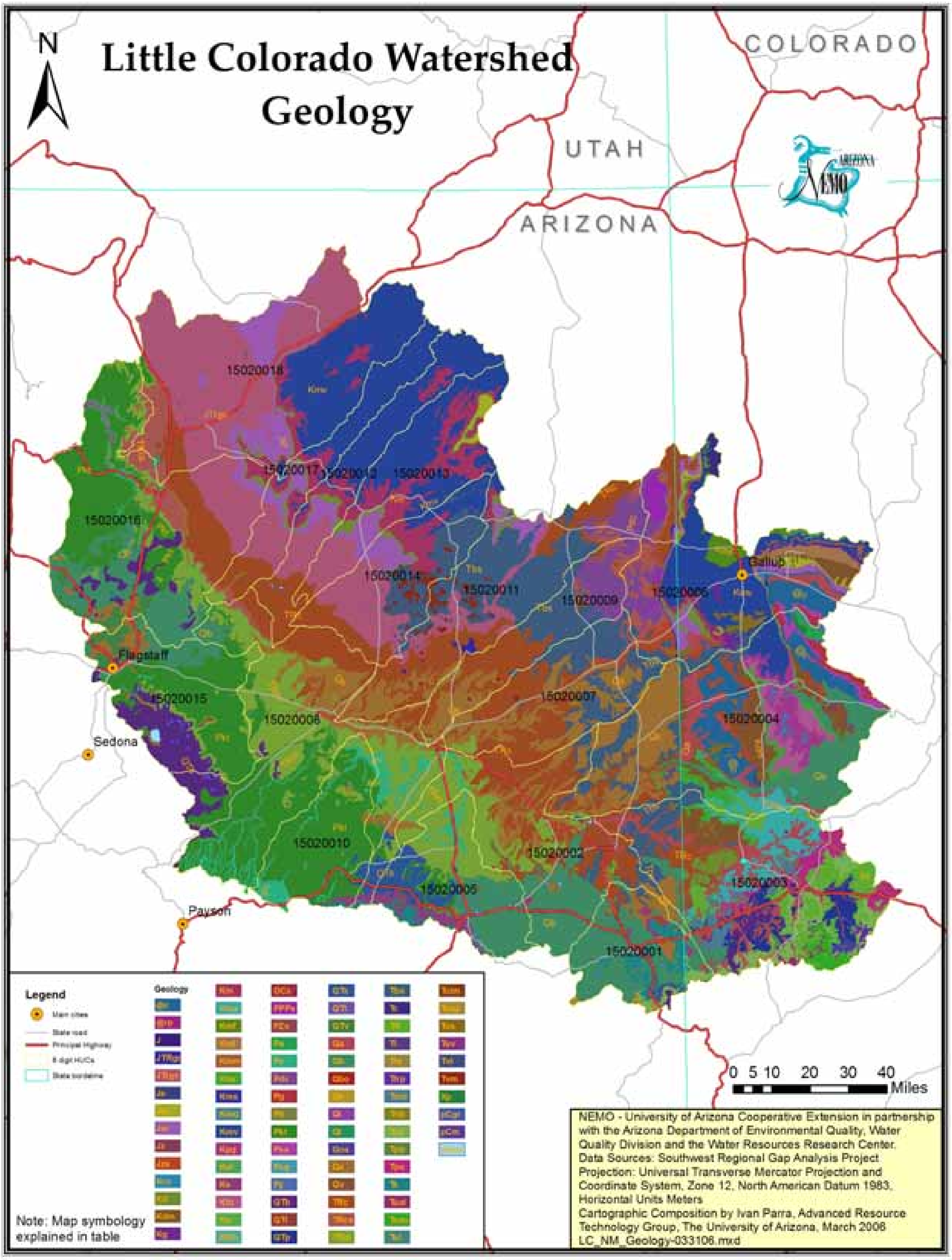

Figure 2-18 Little Colorado Watershed Geology.

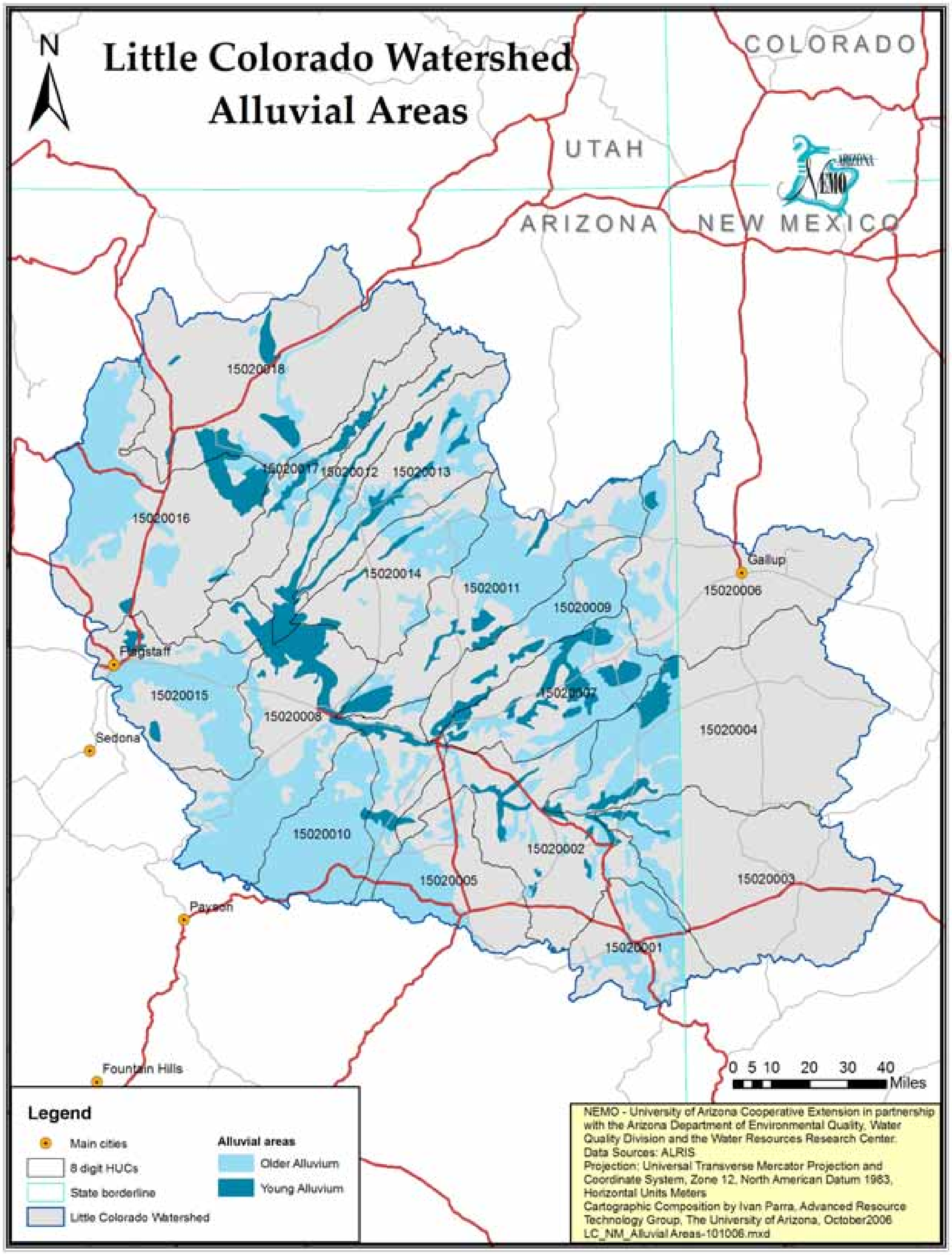

Figure 2-19 Little Colorado Watershed Alluvium.

Table 2- 9 Little Colorado Watershed Geology (percent by subwatershed) part 1 of 3.

Geology	LCR Head-waters-15020001	Upper LCR - 15020002	Carrizo Wash-15020003	Zuni River-15020004	Silver Creek-15020005	Upper Puerco River-15020006	Lower Puerco River-15020007
Glen Canyon Group (Early Jurassic)	0%	0%	0%	0%	0%	0%	0%
Sedimentary Rocks (Permian)	0%	1%	0%	0%	3%	3%	0%
Chinle Formation (Late Triassic)	1%	18%	2%	4%	0%	6%	15%
Moenkopi Formation (Middle[?] and Early Triassic)	0%	21%	0%	0%	14%	0%	1%
San Rafael Group (Late to Middle Jurassic)	0%	0%	0%	0%	0%	8%	0%
Morrison Formation (Late Jurassic)	0%	0%	0%	0%	0%	0%	0%
Sedimentary Rocks (Permian and Pennsylvanian)	0%	0%	0%	0%	0%	36%	0%
Sedimentary Rocks (Cretaceous)	3%	1%	1%	4%	10%	2%	0%
Mesa Verde Group (Late Cretaceous)	0%	0%	0%	0%	0%	1%	0%
Sedimentary Rocks (Mississippian to Cambrian)	0%	0%	0%	0%	0%	0%	0%
Surficial Deposits (Holocene to Middle Pleistocene)	0%	3%	3%	5%	0%	0%	2%
Older Surficial Deposits (Middle Pleistocene to Latest Pliocene)	0%	2%	0%	21%	0%	3%	44%
Young Alluvium (Holocene to Latest Pleistocene)	0%	11%	0%	1%	0%	0%	10%
Shinarum Formation (Late Triassic)	0%	0%	0%	0%	0%	16%	0%
Basaltic Rocks (Holocene to Late Pliocene: 0 to 4 Ma.)	20%	18%	2%	0%	17%	0%	0%
Sedimentary Rocks (Pliocene to Middle Miocene)	2%	10%	8%	15%	5%	1%	16%
Subvolcanic Intrusive Rocks (Middle Miocene to Oligocene)	0%	0%	0%	0%	0%	100%	0%

Geology	LCR Head-waters-15020001	Upper LCR -15020002	Carrizo Wash-15020003	Zuni River-15020004	Silver Creek-15020005	Upper Puerco River-15020006	Lower Puerco River-15020007
Basaltic Rocks (Pliocene to Late Miocene; 4 to 8 Ma.)	0%	0%	0%	1%	0%	0%	0%
Granitoid Rocks (Middle Or Early Proterozoic; 1400 Ma Or 1650 to 1750 Ma.)	0%	0%	0%	0%	0%	100%	0%
Volcanic Rocks (Quaternary to Late Pliocene)	0%	0%	0%	0%	0%	0%	0%
Basaltic Rocks (Late to Middle Miocene; 8 Ro 16 Ma.)	0%	0%	0%	0%	0%	0%	0%
Sedimentary Rocks (Oligocene to Eocene Or Locally Paleocene)	77%	1%	0%	0%	14%	0%	0%
Volcanic Rocks (Pliocene to Middle Miocene; 4 to 15 Ma.	100%	0%	0%	0%	0%	0%	0%
Volcanic Rocks (Middle Miocene to Oligocene; 15-38 Ma.)	100%	0%	0%	0%	0%	0%	0%

Table 2- 9 Little Colorado Watershed Geology (percent by subwatershed) part 2 of 3.

Geology	Middle LCR -15020008	Wide Ruin Wash-Leroux Wash-15020009	Chevelon Canyon-15020010	Pueblo Colorado Wash-Cottonwood Wash-15020011	Oraibi Wash-15020012	Polacca Wash-15020013
Glen Canyon Group (Early Jurassic)	0%	0%	0%	7%	4%	6%
Sedimentary Rocks (Permian)	27%	5%	21%	0%	0%	0%
Chinle Formation (Late Triassic)	8%	11%	0%	14%	1%	1%
Moenkopi Formation (Middle [?]And Early Triassic)	42%	0%	3%	0%	0%	0%
San Rafael Group (Late to Middle Jurassic)	0%	0%	0%	6%	8%	11%
Morrison Formation (Late Jurassic)	0%	0%	0%	13%	0%	87%
Sedimentary Rocks (Permian And Pennsylvanian)	0%	2%	0%	51%	0%	0%

Geology	Middle LCR -15020008	Wide Ruin Wash-Leroux Wash-15020009	Chevelon Canyon-15020010	Pueblo Colorado Wash-Cottonwood Wash-15020011	Oraibi Wash-15020012	Polacca Wash-15020013
Sedimentary Rocks (Cretaceous)	**1%**	**0%**	**1%**	**7%**	**8%**	**30%**
Mesa Verde Group (Late Cretaceous)	**0%**	**0%**	**0%**	**2%**	**21%**	**23%**
Sedimentary Rocks (Mississippian to Cambrian)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Surficial Deposits (Holocene to Middle Pleistocene)	**17%**	**7%**	**1%**	**10%**	**1%**	**7%**
Older Surficial Deposits (Middle Pleistocene to Latest Pliocene)	**2%**	**3%**	**0%**	**1%**	**0%**	**0%**
Young Alluvium (Holocene to Latest Pleistocene)	**31%**	**0%**	**0%**	**9%**	**13%**	**17%**
Shinarum Formation (Late Triassic)	**12%**	**9%**	**0%**	**8%**	**0%**	**0%**
Basaltic Rocks (Holocene to Late Pliocene: 0 to 4 Ma.)	**3%**	**0%**	**0%**	**0%**	**0%**	**0%**
Sedimentary Rocks (Pliocene to Middle Miocene)	**3%**	**8%**	**1%**	**24%**	**0%**	**0%**
Subvolcanic Intrusive Rocks (Middle Miocene to Oligocene)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Basaltic Rocks (Pliocene to Late Miocene; 4 to 8 Ma.)	**15%**	**0%**	**0%**	**18%**	**0%**	**0%**
Granitoid Rocks (Middle Or Early Proterozoic; 1400 Ma Or 1650 to 1750 Ma.)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Volcanic Rocks (Quaternary to Late Pliocene)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Basaltic Rocks (Late to Middle Miocene; 8 Ro 16 Ma.)	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**
Sedimentary Rocks (Oligocene to Eocene Or Locally Paleocene)	**4%**	**0%**	**4%**	**0%**	**0%**	**0%**
Volcanic Rocks (Pliocene to Middle Miocene; 4 to 15 Ma.	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

Geology	Middle LCR -15020008	Wide Ruin Wash-Leroux Wash-15020009	Chevelon Canyon-15020010	Pueblo Colorado Wash-Cottonwood Wash-15020011	Oraibi Wash-15020012	Polacca Wash-15020013
Volcanic Rocks (Middle Miocene to Oligocene; 15-38 Ma.)	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

Table 2- 9 Little Colorado Watershed Geology (percent by subwatershed) part 3 of 3.

Geology	Jadito Wash-15020014	Canyon Diablo-15020015	Lower LCR -15020016	Dinnebito Wash-15020017	Moenkopi Wash-15020018	Total
Glen Canyon Group (Early Jurassic)	**13%**	**0%**	**6%**	**7%**	**56%**	***10%***
Sedimentary Rocks (Permian)	**0%**	**16%**	**24%**	**0%**	**0%**	***15%***
Chinle Formation (Late Triassic)	**4%**	**0%**	**8%**	**5%**	**3%**	***13%***
Moenkopi Formation (Middle [?]and Early Triassic)	**0%**	**4%**	**14%**	**1%**	**1%**	***8%***
San Rafael Group (Late to Middle Jurassic)	**14%**	**0%**	**1%**	**5%**	**47%**	***2%***
Morrison Formation (Late Jurassic)	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***
Sedimentary Rocks (Permian And Pennsylvanian)	**0%**	**0%**	**10%**	**0%**	**0%**	***1%***
Sedimentary Rocks (Cretaceous)	**11%**	**0%**	**1%**	**10%**	**11%**	***4%***
Mesa Verde Group (Late Cretaceous)	**4%**	**0%**	**0%**	**14%**	**36%**	***10%***
Sedimentary Rocks (Mississippian to Cambrian)	**0%**	**0%**	**100%**	**0%**	**0%**	***0%***
Surficial Deposits (Holocene to Middle Pleistocene)	**2%**	**2%**	**16%**	**11%**	**12%**	***4%***
Older Surficial Deposits (Middle Pleistocene to Latest Pliocene)	**0%**	**6%**	**4%**	**0%**	**13%**	***2%***
Young Alluvium (Holocene to Latest Pleistocene)	**4%**	**0%**	**0%**	**2%**	**1%**	***3%***
Shinarum Formation (Late Triassic)	**0%**	**0%**	**31%**	**1%**	**22%**	***2%***
Basaltic Rocks (Holocene to Late Pliocene: 0 to 4 Ma.)	**0%**	**11%**	**30%**	**0%**	**0%**	***9%***

Geology	Jadito Wash-15020014	Canyon Diablo-15020015	Lower LCR -15020016	Dinnebito Wash-15020017	Moenkopi Wash-15020018	Total
Sedimentary Rocks (Pliocene to Middle Miocene)	**6%**	**0%**	**1%**	**0%**	**0%**	***12%***
Subvolcanic Intrusive Rocks (Middle Miocene to Oligocene)	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***
Basaltic Rocks (Pliocene to Late Miocene; 4 to 8 Ma.)	**18%**	**47%**	**0%**	**0%**	**0%**	***3%***
Granitoid Rocks (Middle Or Early Proterozoic; 1400 Ma Or 1650 to 1750 Ma.)	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***
Volcanic Rocks (Quaternary to Late Pliocene)	**0%**	**56%**	**44%**	**0%**	**0%**	***1%***
Basaltic Rocks (Late to Middle Miocene; 8 Ro 16 Ma.)	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***
Sedimentary Rocks (Oligocene to Eocene Or Locally Paleocene)	**0%**	**0%**	**0%**	**0%**	**0%**	***1%***
Volcanic Rocks (Pliocene to Middle Miocene; 4 to 15 Ma.	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***
Volcanic Rocks (Middle Miocene to Oligocene; 15 to 38 Ma.)	**0%**	**0%**	**0%**	**0%**	**0%**	***0%***

Table 2- 10 Little Colorado Watershed Rock Type (percent by subwatershed).

Subwatershed Name	Sedimentary	Alluvium	Volcanic	Granitic	*Total (sq miles)*
Little Colorado River Headwaters-15020001	**43%**	**0%**	**57%**	**0%**	***744***
Upper Little Colorado River-15020002	**72%**	**6%**	**21%**	**0%**	***1,614***
Carrizo Wash-15020003	**80%**	**8%**	**12%**	**0%**	***331***
Zuni River-15020004	**79%**	**20%**	**1%**	**0%**	***695***
Silver Creek-15020005	**65%**	**0%**	**35%**	**0%**	***945***
Upper Puerco River-15020006	**97%**	**2%**	**1%**	**0%**	***551***
Lower Puerco River-15020007	**77%**	**23%**	**0%**	**0%**	***1,115***
Middle Little Colorado River-15020008	**81%**	**13%**	**6%**	**0%**	***2,519***
Wide Ruin Wash-Leroux Wash-15020009	**91%**	**9%**	**0%**	**0%**	***813***
Chevelon Canyon-15020010	**99%**	**1%**	**0%**	**0%**	***819***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**85%**	**9%**	**6%**	**0%**	***1,670***
Oraibi Wash-15020012	**88%**	**12%**	**0%**	**0%**	***730***
Polacca Wash-15020013	**85%**	**15%**	**0%**	**0%**	***1,151***

Subwatershed Name	Sedimentary	Alluvium	Volcanic	Granitic	*Total (sq miles)*
Jadito Wash-15020014	**84%**	**4%**	**12%**	**0%**	***939***
Canyon Diablo-15020015	**52%**	**3%**	**45%**	**0%**	***1,189***
Lower Little Colorado River-15020016	**67%**	**7%**	**26%**	**0%**	***2,369***
Dinnebito Wash-15020017	**88%**	**12%**	**0%**	**0%**	***818***
Moenkopi Wash-15020018	**94%**	**6%**	**0%**	**0%**	***2,619***
Little Colorado River Watershed-150200	***79%***	***9%***	***12%***	***0%***	***21,633***

Table 2- 11 Little Colorado Watershed Alluvial Area by Subwatershed (acres).

Subwatershed Name and HUC	Older Alluvium	Young Alluvium
Little Colorado River Headwaters-15020001	**306**	**171**
Upper Little Colorado River-15020002	**191,786**	**65,184**
Carrizo Wash-15020003	**129,943**	**16,601**
Zuni River-15020004	**271,658**	**88,866**
Silver Creek-15020005	**233,897**	**0**
Upper Puerco River-15020006	**135,456**	**7,998**
Lower Puerco River-15020007	**260,520**	**165,272**
Middle Little Colorado River-15020008	**637,281**	**216,984**
Wide Ruin Wash-Leroux Wash-15020009	**234,119**	**47,020**
Chevelon Canyon-15020010	**488,283**	**4,980**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**489,838**	**92,610**
Oraibi Wash-15020012	**47,851**	**54,769**
Polacca Wash-15020013	**185,620**	**106,876**
Jadito Wash-15020014	**161,987**	**25,192**
Canyon Diablo-15020015	**348,037**	**22,783**
Lower Little Colorado River-15020016	**532,380**	**98,713**
Dinnebito Wash-15020017	**61,687**	**64,069**
Moenkopi Wash-15020018	**78,027**	**104,039**
Little Colorado River Watershed-150200 (Total)	***4,683,943***	***1,182,127***

Alluvial Aquifers

The three regional aquifers in the Little Colorado Watershed consist of sedimentary formations of sandstone and limestone, separated from impermeable shales and siltstones. In descending order, the regional aquifers are the D-, N-, and C-aquifers, and each has a very large areal extent across the watershed. These formations gain thickness towards the center of the basin, resulting in artesian conditions. It is estimated that there are about 508 million acre-feet of storage in the Little Colorado River Plateau aquifers (ADWR, 1994).

The C-aquifer is the largest and most productive aquifer with an areal extent of nearly 22,000 square miles, and is named for its primary water-bearing unit, the Coconino Sandstone. It is used as the water supply of the cities of Flagstaff, Show Low, Snowflake, and Concho. North of the Little Colorado River the C-aquifer is too deep to be economically useful or is unsuitable for most uses because of high concentrations of total dissolved solids (ADWR, 2006).

The N-aquifer is an important water supply north of the Little Colorado River and has an areal extent of a little over 6,000 square miles. Jurassic age Navajo Sandstone and the Wingate Sandstone are the main water-bearing unites of the aquifer. It is generally unconfined but there are artesian conditions in the Black Mesa area. The water quality is good and is a source of water supply for the Navajo and Hopi Tribal lands (ADWR, 2006).

The D-aquifer is the smallest in areal extent, occurring over about 3,000 square miles. The aquifer is composed of the Jurassic age sandstones immediately under the Cretaceous Mancos Shale. There is some hydraulic connection with the underlying N-aquifer, the Navajo Sandstone. Water quality is poor due to high concentrations of dissolved solids (ADWR, 2006).

Local aquifers are important for domestic uses where the regional aquifers are too deep or have unsuitable water quality. Local aquifers include alluvial deposits that occur along washes and stream channels, including along the Little Colorado River and its tributaries. The Tertiary age Bidahochi formation forms a local aquifer in the central part of Apache and Navajo Counties. In the southeastern part of Navajo County, saturated basaltic rocks together with underlying sedimentary rocks are locally known as the Lakeside-Pinetop aquifer, which is an important supply for the area (ADWR, 2006).

Delineated Ground Water Basins

Three ground water administrative basins have been delineated by the Arizona Department of Water Resources in the Little Colorado Watershed:

- Coconino Plateau, with close to 7% of the total watershed area;
- Joseph City Irrigation Non-Expansion Areas (INA) with the least coverage representing about 1% of the total watershed; and
- Little Colorado River Plateau, covering most of the Little Colorado River subwatershed (92%).

Their locations can be found in parts of three counties contained within the three administrative basins: Apache, Coconino and Navajo counties (Figure 2-20). Other than municipal water supply, there are a large number of industrial water uses due to several electrical generating stations, large coal mining operations, and a paper mill. Agricultural irrigation is relatively small-scale in terms of acreage but is a large water use sector. The Joseph City Irrigation Non-expansion Area (INA) is an area designated as having insufficient ground water to provide a reasonable safe supply for irrigation (ADWR, 2006).

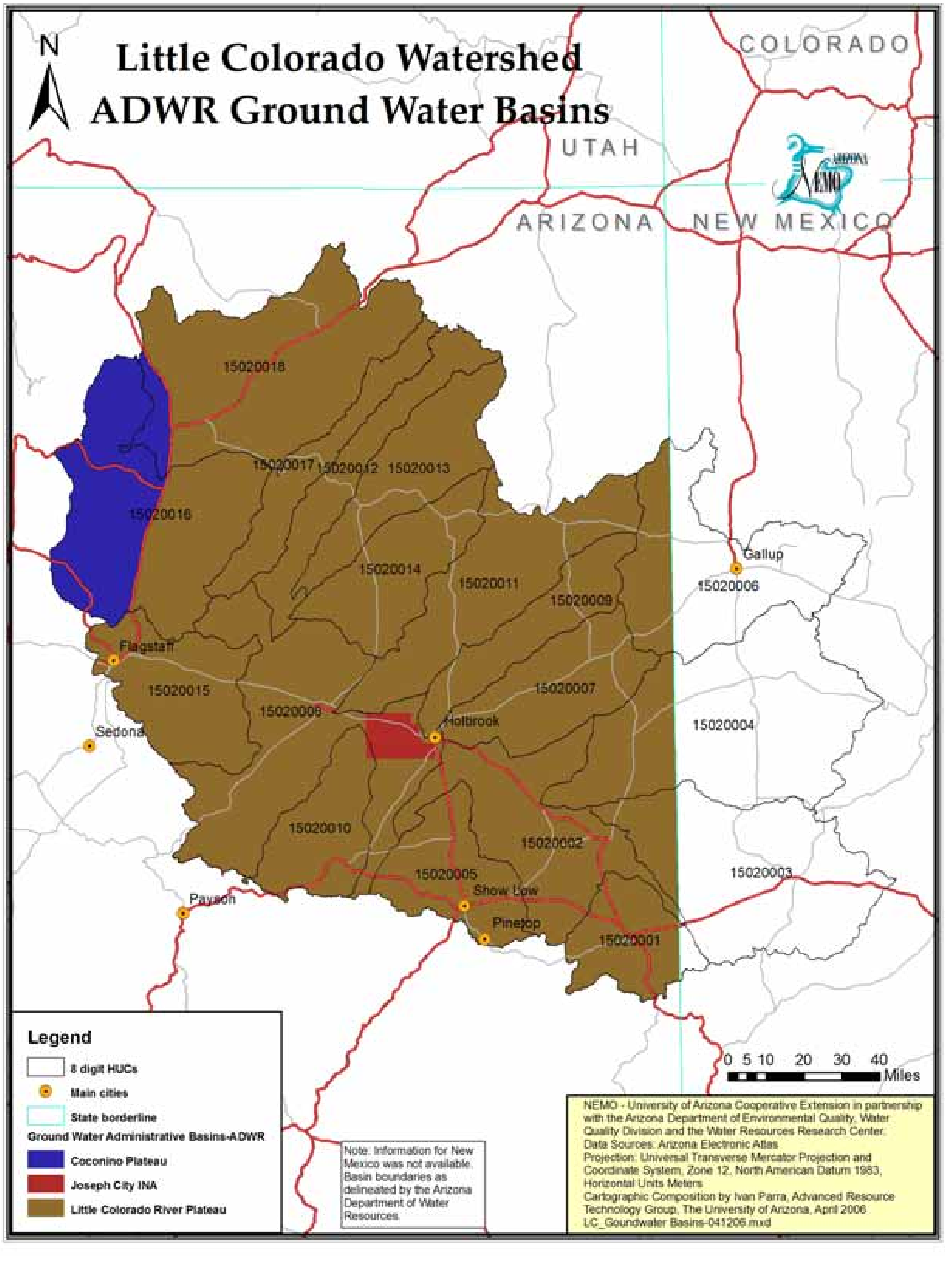

Figure 2-20 Little Colorado Watershed ADWR Ground Water Basins.

Soils

Soil characteristics were reviewed for the Little Colorado Watershed and two types of maps were created: a soil texture map and a soil erodibility factor map. Soil erodibility is generated from the soil texture characteristics, as discussed below.

As shown in Figure 2-21, nineteen different soil textures occur within the watershed. Table 2-12 presents percent soil texture by subwatershed and for the entire Little Colorado Watershed. For example, the Flaggy silt loam texture comprises 23% of the watershed, and the Loamy fine sand texture predominates over approximately 16% of the area. The fine clays and silts are found around Holbrook and North of Show Low.

Soil erosion is a naturally occurring process; however, accelerated erosion occurs when soils are disturbed by agriculture, mining, construction, and when natural ground cover is removed and the soil is left unprotected. Soils differ in their susceptibility to disturbance by water due to different inherent physical, chemical, and mineralogical properties.

Properties known to affect erodibility include particle size distribution, organic matter content, soil structure, texture, moisture content, vegetation cover, and precipitation amount and intensity.

Erosion caused by precipitation and running water and the factors affecting soil loss have been summarized in the Revised Universal Soil Loss Equation (RUSLE). The RUSLE is a model for predicting long-term average soil losses based in part on factors of slope and erosive energy. Within the equation, the Soil Erodibility Factor (K), is estimated in the units of mass/unit area, and is based on soil texture, with a range of values between 0.0 (no erosion potential) to 1.0 (USDA, 1997). Table 2-13 shows these values for each subwatershed, and Figure 2-22 is a Soil Erodibility map for the watershed.

The Wide Ruin Wash – Leroux Wash subwatershed has the highest weighted mean for Soil Erodibility Factor, with K = 0.296, and the Chevelon Canyon subwatershed has the lowest weighted mean at 0.07. The weighted mean K for the whole Little Colorado Watershed is 0.189.

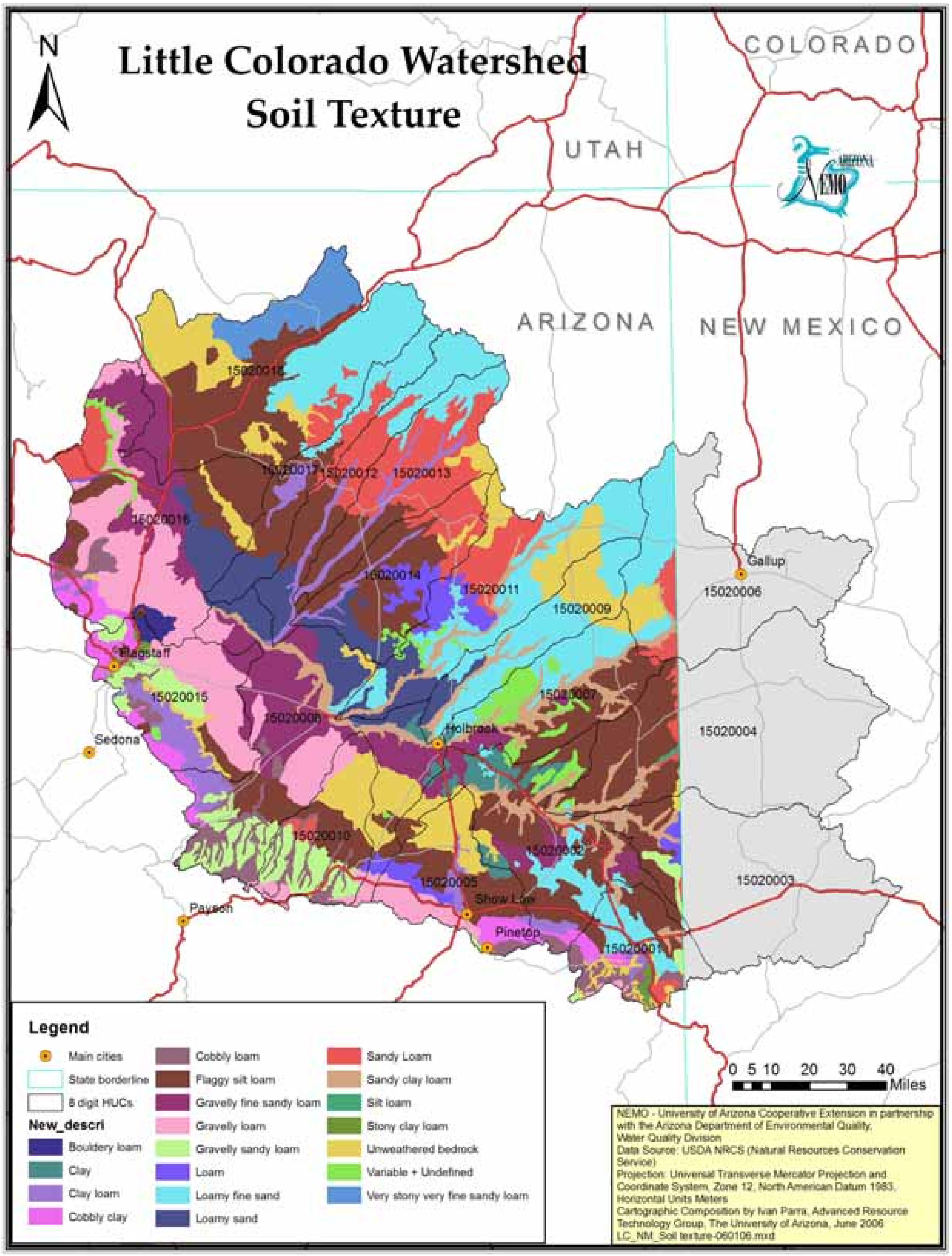

Figure 2-21 Little Colorado Watershed Soil Texture.

Table 2- 12 Little Colorado Watershed Soil Texture by Subwatershed (percent) (part 1 of 2).

Subwatershed Name	Bouldery loam	Clay	Clay loam	Cobbly clay	Cobbly loam	Flaggy silt loam	Gravelly fine sandy loam	Gravelly loam	Gravelly sandy loam	Loam
Little Colorado River Headwaters-15020001	0%	0%	4%	6%	16%	22%	0%	1%	3%	0%
Upper Little Colorado River-15020002	0%	11%	2%	2%	1%	40%	13%	0%	0%	0%
Carrizo Wash-15020003	0%	0%	0%	0%	0%	50%	0%	0%	13%	11%
Zuni River-15020004	0%	0%	0%	0%	0%	77%	0%	0%	0%	0%
Silver Creek-15020005	0%	2%	7%	10%	3%	31%	0%	18%	1%	8%
Upper Puerco River-15020006	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
Lower Puerco River-15020007	0%	1%	0%	0%	0%	30%	6%	0%	0%	0%
Middle Little Colorado River-15020008	0%	1%	2%	1%	8%	9%	29%	14%	8%	1%
Wide Ruin Wash-Leroux Wash-15020009	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Chevelon Canyon-15020010	0%	0%	0%	0%	14%	19%	3%	10%	26%	1%
Pueblo Colorado Wash-Cottonwood Wash-15020011	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%
Oraibi Wash-15020012	0%	0%	7%	0%	0%	24%	0%	0%	0%	0%
Polacca Wash-15020013	0%	0%	11%	0%	0%	21%	0%	0%	0%	0%
Jadito Wash-15020014	0%	0%	6%	0%	0%	45%	0%	0%	0%	13%
Canyon Diablo-15020015	2%	0%	15%	13%	4%	6%	4%	33%	15%	0%
Lower Little Colorado River-15020016	2%	0%	1%	4%	3%	17%	18%	33%	1%	0%
Dinnebito Wash-15020017	0%	0%	8%	0%	0%	30%	0%	0%	0%	0%
Moenkopi Wash-15020018	0%	0%	0%	0%	0%	31%	6%	1%	0%	0%
Little Colorado River Watershed-150200	*0%*	*1%*	*3%*	*2%*	*3%*	*23%*	*8%*	*8%*	*3%*	*2%*

Table 2-12 Little Colorado Watershed Soil Texture by Subwatershed (percent) (part 2 of 2).

Subwatershed Name	Loamy fine sand	Loamy sand	Sandy clay loam	Sandy Loam	Silt loam	Stony clay loam	Unweathered bedrock	Variable + Undefined	Very stony very fine sandy loam
Little Colorado River Headwaters-15020001	27%	0%	4%	4%	1%	2%	10%	0%	0%
Upper Little Colorado River-15020002	10%	0%	11%	0%	0%	0%	6%	4%	0%
Carrizo Wash-15020003	0%	0%	21%	1%	0%	0%	2%	0%	0%

Subwatershed Name	Loamy fine sand	Loamy sand	Sandy clay loam	Sandy Loam	Silt loam	Stony clay loam	Unweathered bedrock	Variable + Undefined	Very stony very fine sandy loam
Zuni River-15020004	**0%**	**0%**	**13%**	**5%**	**1%**	**0%**	**1%**	**1%**	**0%**
Silver Creek-15020005	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**21%**	**0%**	**0%**
Upper Puerco River-15020006	**59%**	**0%**	**6%**	**17%**	**0%**	**0%**	**17%**	**0%**	**0%**
Lower Puerco River-15020007	**24%**	**0%**	**19%**	**0%**	**0%**	**0%**	**3%**	**17%**	**0%**
Middle Little Colorado River-15020008	**1%**	**13%**	**6%**	**0%**	**0%**	**0%**	**7%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**60%**	**8%**	**8%**	**0%**	**0%**	**0%**	**21%**	**1%**	**0%**
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**4%**	**0%**	**0%**	**23%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**36%**	**9%**	**9%**	**17%**	**0%**	**0%**	**17%**	**2%**	**0%**
Oraibi Wash-15020012	**38%**	**4%**	**0%**	**27%**	**0%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**14%**	**2%**	**0%**	**46%**	**0%**	**0%**	**6%**	**0%**	**0%**
Jadito Wash-15020014	**0%**	**16%**	**0%**	**15%**	**0%**	**0%**	**3%**	**2%**	**0%**
Canyon Diablo-15020015	**0%**	**0%**	**0%**	**0%**	**0%**	**3%**	**5%**	**1%**	**0%**
Lower Little Colorado River-15020016	**0%**	**9%**	**0%**	**6%**	**0%**	**0%**	**3%**	**3%**	**0%**
Dinnebito Wash-15020017	**26%**	**23%**	**0%**	**12%**	**0%**	**0%**	**1%**	**0%**	**0%**
Moenkopi Wash-15020018	**25%**	**0%**	**0%**	**4%**	**0%**	**0%**	**18%**	**0%**	**15%**
Little Colorado River Watershed-150200	***16%***	***5%***	***5%***	***8%***	***0%***	***0%***	***9%***	***2%***	***2%***

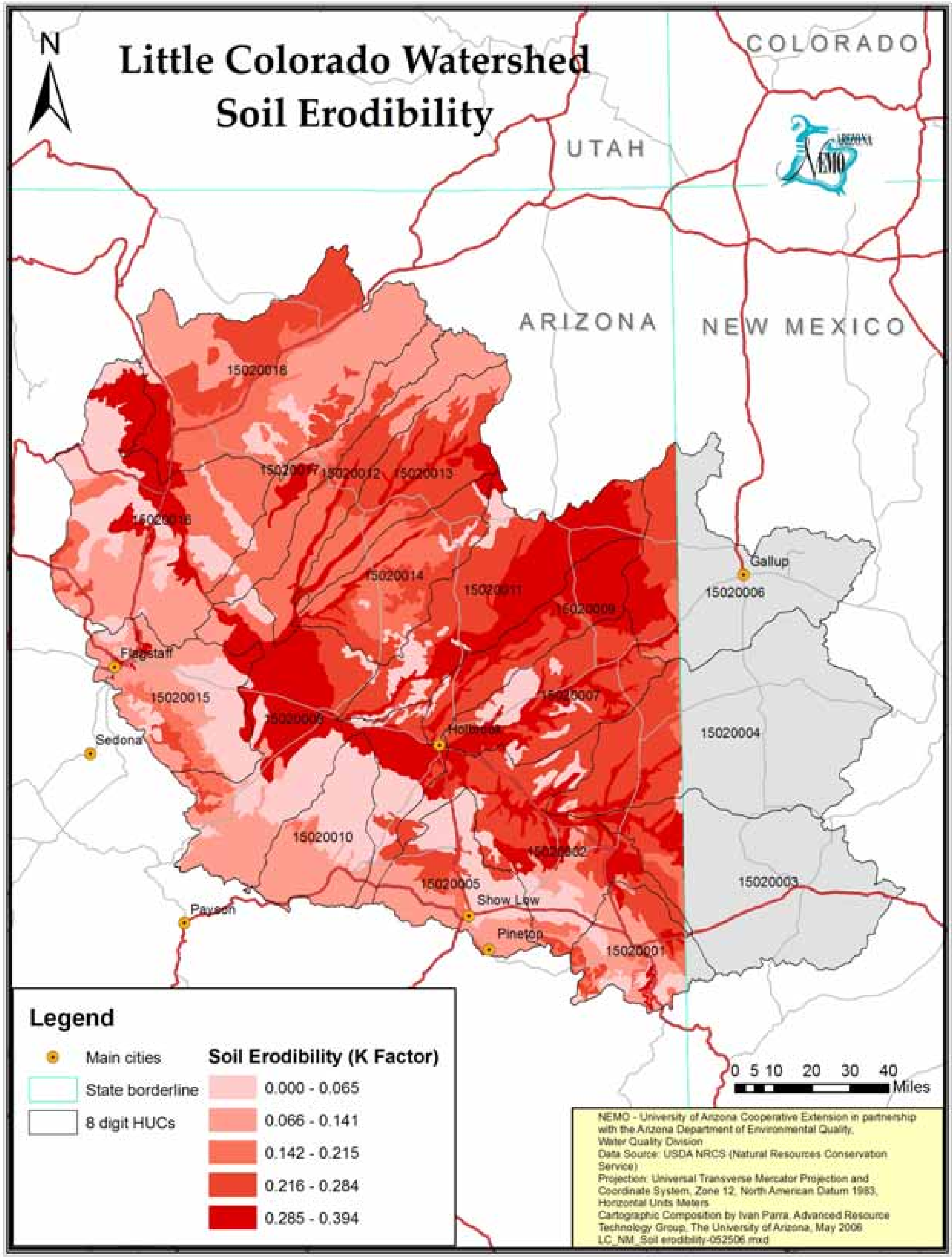

Figure 2-22 Little Colorado Watershed Soil Erodibility Factor.

Table 2-13 Little Colorado Watershed Soil Erodibility Factor (K).

Subwatershed Name	Min K	Max K	Weighted Average K
Little Colorado River Headwaters-15020001	**0.000**	**0.338**	**0.146**
Upper Little Colorado River-15020002	**0.000**	**0.338**	**0.206**
Carrizo Wash-15020003	**0.051**	**0.338**	**0.267**
Zuni River-15020004	**0.015**	**0.394**	**0.261**
Silver Creek-15020005	**0.000**	**0.338**	**0.094**
Upper Puerco River-15020006	**0.199**	**0.366**	**0.283**
Lower Puerco River-15020007	**0.015**	**0.366**	**0.234**
Middle Little Colorado River-15020008	**0.000**	**0.338**	**0.189**
Wide Ruin Wash-Leroux Wash-15020009	**0.015**	**0.366**	**0.296**
Chevelon Canyon-15020010	**0.000**	**0.338**	**0.071**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0.000**	**0.366**	**0.260**
Oraibi Wash-15020012	**0.020**	**0.304**	**0.172**
Polacca Wash-15020013	**0.020**	**0.366**	**0.222**
Jadito Wash-15020014	**0.000**	**0.366**	**0.219**
Canyon Diablo-15020015	**0.000**	**0.338**	**0.118**
Lower Little Colorado River-15020016	**0.000**	**0.338**	**0.149**
Dinnebito Wash-15020017	**0.000**	**0.304**	**0.170**
Moenkopi Wash-15020018	**0.000**	**0.338**	**0.170**
Little Colorado River Watershed-150200	***0.000***	***0.394***	***0.189***

Climate

Precipitation

For the 30 years (1961-1990) of published precipitation data (NCDC, 2002), the average annual precipitation for the Little Colorado Watershed is 12.1 inches. Figure 2-23 and Table 2-14 show average annual precipitation across the watershed area. The Canyon Diablo subwatershed has the highest average annual rainfall (18.6 inches/year), while the Moenkopi Wash and Dinnebito Wash subwatersheds exhibit the lowest at 9.3 and 9.2 inches/year average rainfall, respectively. In the region around the White Mountains in the southern portion of the watershed, precipitation is at the greatest value of 37.5 inches/year, accumulating in the form of both rain and snow. The valley floor surrounding the main channel of the Little Colorado River has the least localized rainfall at less than eight inches/year.

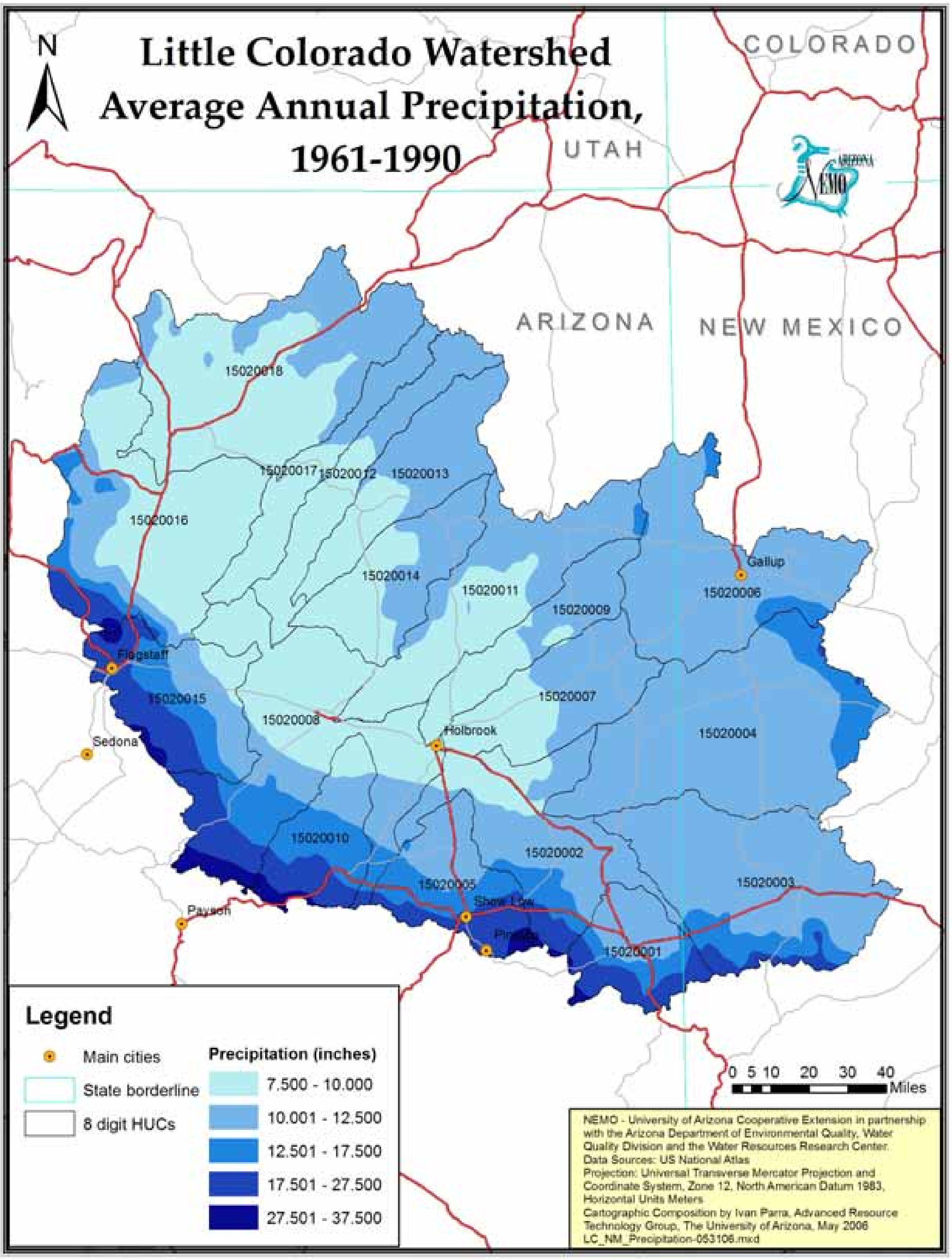

Figure 2-23 Little Colorado Watershed Average Annual Precipitation (inches/year).

Table 2-14 Little Colorado Watershed Average Annual Precipitation (in/yr).

Subwatershed Name	Min (inches/year)	Max (inches/year)	Average (inches/year)
Little Colorado River Headwaters-15020001	**12.5**	**32.5**	**17.6**
Upper Little Colorado River-15020002	**7.5**	**32.5**	**12.9**
Carrizo Wash-15020003	**12.5**	**12.5**	**12.5**
Zuni River-15020004	**7.5**	**12.5**	**12.5**
Silver Creek-15020005	**12.5**	**32.5**	**18.1**
Upper Puerco River-15020006	**12.5**	**17.5**	**12.5**
Lower Puerco River-15020007	**7.5**	**12.5**	**10.5**
Middle Little Colorado River-15020008	**7.5**	**37.5**	**12.5**
Wide Ruin Wash-Leroux Wash-15020009	**7.5**	**17.5**	**10.2**
Chevelon Canyon-15020010	**7.5**	**37.5**	**18.2**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**7.5**	**17.5**	**10.2**
Oraibi Wash-15020012	**7.5**	**12.5**	**9.9**
Polacca Wash-15020013	**7.5**	**12.5**	**10.6**
Jadito Wash-15020014	**7.5**	**12.5**	**9.9**
Canyon Diablo-15020015	**7.5**	**37.5**	**18.6**
Lower Little Colorado River-15020016	**7.5**	**37.5**	**10.4**
Dinnebito Wash-15020017	**7.5**	**12.5**	**9.2**
Moenkopi Wash-15020018	**7.5**	**12.5**	**9.3**
Little Colorado River Watershed-150200	***7.5***	***37.5***	***12.40***

Temperature

Weather stations in the Little Colorado Watershed are shown in Figure 2-24. Data from some of these locations were used for watershed modeling as discussed in section 6. Although there are more weather stations in the watershed, stations were selected for modeling because of the consistency and duration of the data.

Table 2-15 shows a summary of temperature data for the eight weather stations for which we were able to obtain summary data within the watershed during the 1971-2000 period (WRCC, 2004).

For the 30 years of temperature data, the average annual temperature for the Little Colorado River Watershed is 50.9° Fahrenheit. The Lower Little Colorado River subwatershed has the highest annual average temperature at 54.3 °F. Little Colorado River Headwaters subwatershed showed the lowest average annual temperature reporting 46.4 °F. Table 2-16 shows the annual values for the other subwatersheds, and Figure 2-25 shows the annual average temperatures.

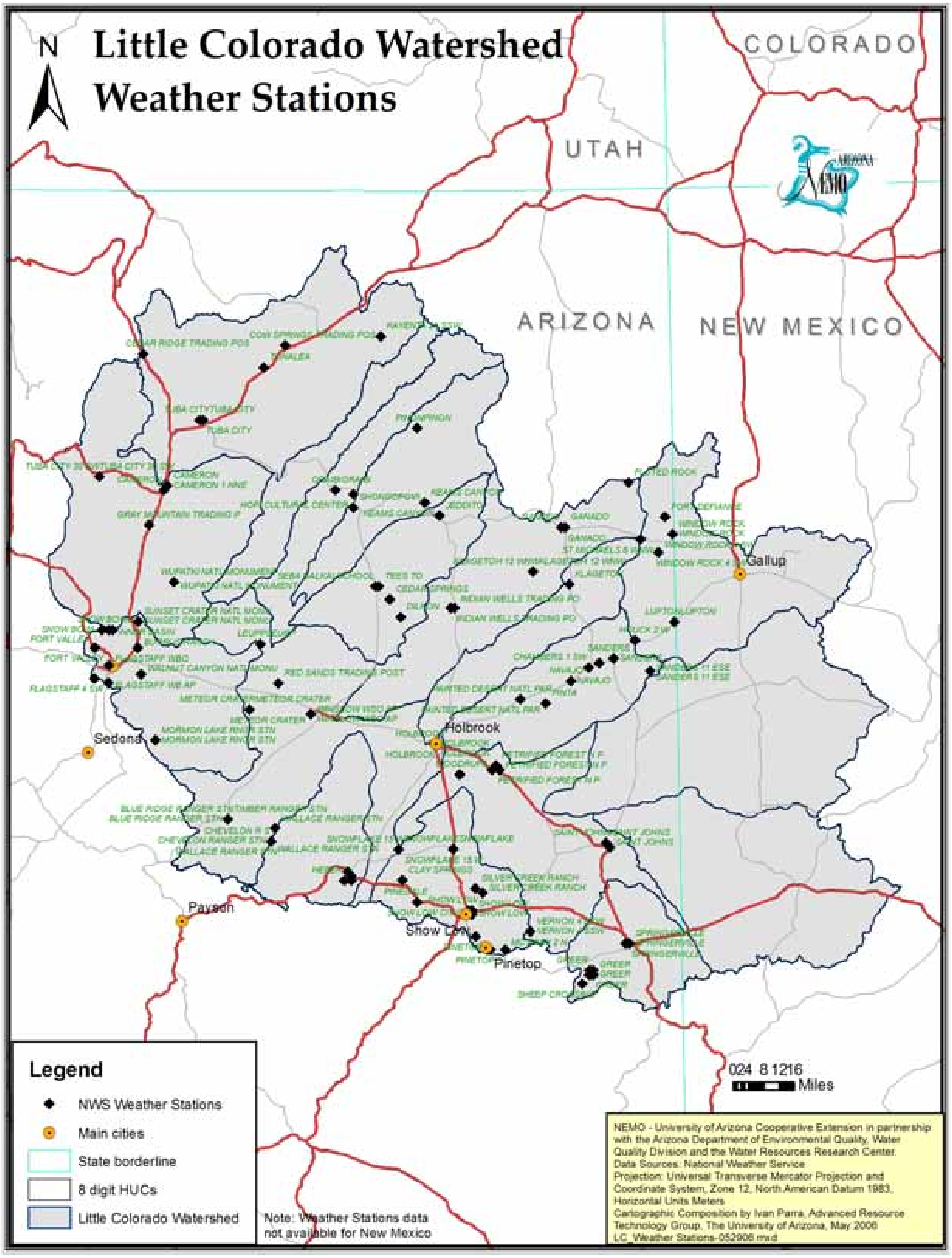

Figure 2-24 Little Colorado Watershed Weather Stations.

Table 2-15 Summary of Temperature Data for Nine Temperature Stations in the Little Colorado Watershed.

Station Name	Average Annual Max. Temperature (°F)	Average Annual Min. Temperature (°F)	Average Annual Temperature (°F)
Flagstaff Pulliam Airport	61.4	30.9	46.2
Holbrook	73.6	38.6	56.1
Show Low Airport	67.1	39.7	53.4
Tuba City	69.6	40.9	55.3
Ganado	65.2	34.7	49.9
Sanders	68.5	35.6	52.1
Springerville	65.5	31	48.3
Snowflake	69.6	35.9	52.8
Chevelon Ranger Station	60.9	35.4	48.1

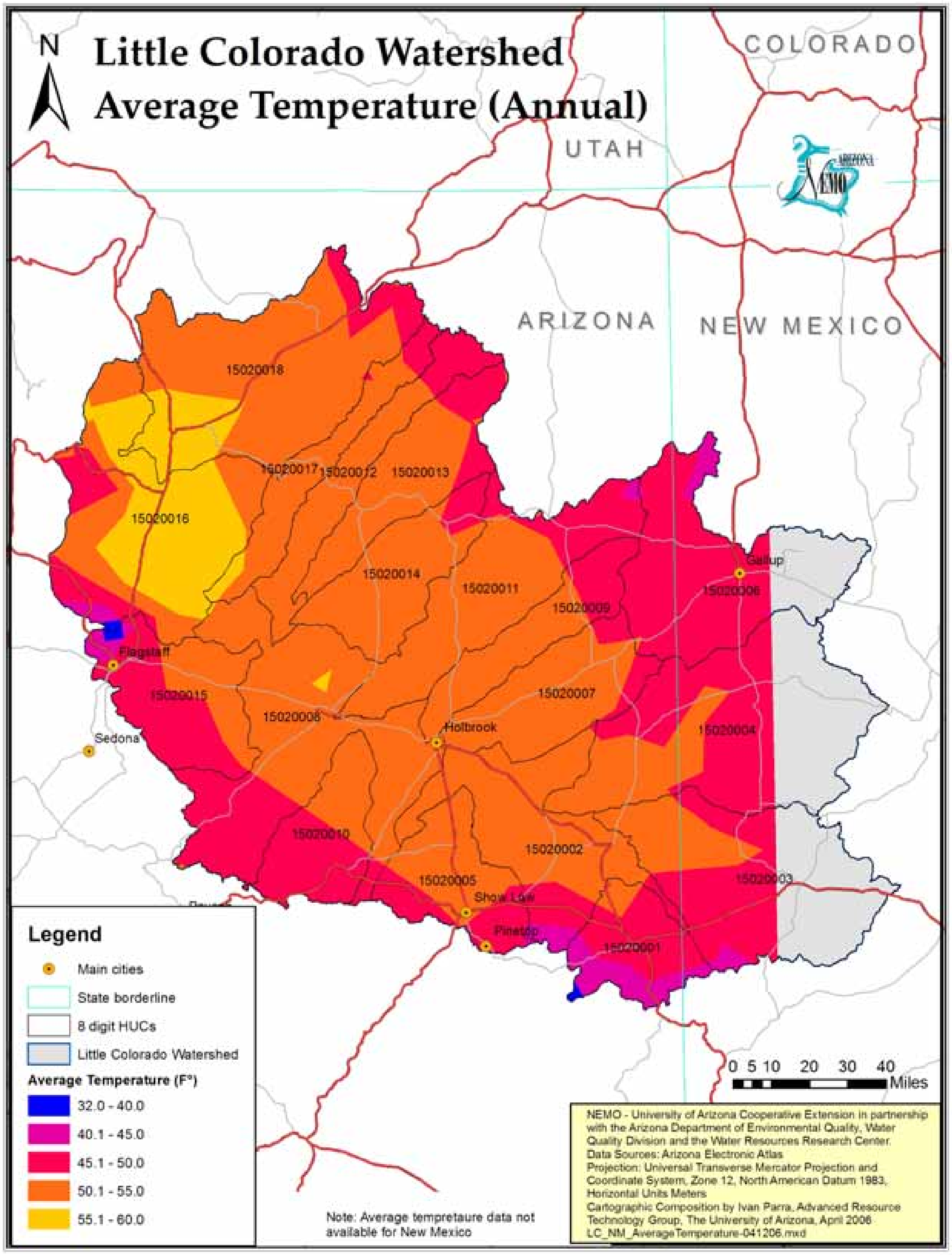

Figure 2-25 Little Colorado Watershed Annual Average Temperature (°F).

Table 2-16 Little Colorado Watershed Average Annual Temperature.

Subwatershed Name	Average Annual Temperature (°F)
Little Colorado River Headwaters-15020001	46.4
Upper Little Colorado River-15020002	51.4
Carrizo Wash-15020003	51.7
Zuni River-15020004	50.8
Silver Creek-15020005	50.6
Upper Puerco River-15020006	47.5
Lower Puerco River-15020007	51.8
Middle Little Colorado River-15020008	51.3
Wide Ruin Wash-Leroux Wash-15020009	50.9
Chevelon Canyon-15020010	49.4
Pueblo Colorado Wash-Cottonwood Wash-15020011	51.1
Oraibi Wash-15020012	51.2
Polacca Wash-15020013	51.4
Jadito Wash-15020014	52.1
Canyon Diablo-15020015	48.9
Lower Little Colorado River-15020016	54.3
Dinnebito Wash-15020017	52.2
Little Colorado River Watershed-150200	50.9

References

Arizona Department of Environmental Quality, ADEQ. 2005. The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, 1110 West Washington Ave., Phoenix, Arizona, 85007. EQR0501. http://www.azdeq.gov/environ/water/assessment/2004.html

Arizona Department of Water Resources (ADWR), 1994. Arizona Water Resources Assessment, August 1994. Phoenix, Arizona

Arizona Department of Water Resources (ADWR), 2006. DRAFT Arizona Water Atlas, Vol. 2, web published at http://www.azwater.gov/dwr/

Chronic, Halka, 1983. Roadside Geology of Arizona. Mountain Press Publishing Company, Missoula, Montana.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York.

Fellows, Larry D. 1999. Oil and Gas in Arizona: Good News and Bad News. Arizona Geology, Spring 1999 - Vol. 29, No. 1.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology; Chapter 4 - Getting to know your stream. John Wiley & Sons, New York, New York.

J.D. Nations, R.L. Swift and H.H. Haven, 1998. Arizona Coal. Arizona Geology, Winter 1998 - Vol. 28, No. 4.

Kamilli, R. J. and Richard, S. M. Editors, 1998. Geologic Highway Map of Arizona: Tucson, Arizona Geological Society and Arizona Geological Survey.

USDA. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook No. 703. USDA Washington D.C.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting Rainfall-Erosion Losses. Agricultural Handbook No. 537. USDA SEA Washington, D.C.

<u>Data sources</u>

Advanced Resource Technology Group, The University of Arizona
AZ Streams, March 2005
AZ Lakes, March 2005
AZ Geology, March 2005
AZ 303d Streams and Lakes, March 2006
AZ Delineated Ground Water Basins, March 2006
AZ Weather Stations (NWS)

Arizona Electronic Atlas
http://atlas.library.arizona.edu/atlas/
Mean Daily Average Temperature–Annual, September 19, 2005
Mean Total Precipitation-Annual, September 19, 2005
Groundwater Basins, September 26, 2005

National Climatic Data Center (NCDC). 2002. Cooperative Summary of the Day (Technical Data 3200) POR-2001 CD ROM, Ash ville, North Carolina.

New Mexico Resource Geographic Information System (RGIS)
http://rgis.unm.edu/intro.cfm
New Mexico Counties, June 20, 2005
New Mexico Streams, June 20, 2005
New Mexico Geology, June 20, 2005
Evaporation Isopleths, September 19, 2005

Seamless Data Distribution System, National Center for Earth Resources Observation and Science (EROS)
http://seamless.usgs.gov/
National Elevation Dataset (NED) 1 Arc Second, May 23-June 16, 2005

Southwest Regional Gap Analysis Project
http://www.gis.usu.edu/docs/projects/swgap/index.html
Arizona and New Mexico Soils Classes, December 05, 2005

USDA NRCS (Natural Resources Conservation Service)
http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/data/az.html
Arizona Soils Classes (STATSGO), December 05, 2005

USGS (United States Geological Survey) NWIS Web Data for the Nation
http://waterdata.usgs.gov/nwis
Calendar Year Streamflow Statistics for New Mexico, July 26, 2005
Calendar Year Streamflow Statistics for Arizona, July 26, 2005

USGS Water Resources Maps and GIS Information
http://water.usgs.gov/maps.html
1:250,000-scale Hydrologic Units of the United States, June 17, 2005

US National Atlas, http://nationalatlas.gov/index.html
Cities and Towns of the United States, May 18, 2005
State Boundaries of the United States, March 30, 2005
1:2,000,000-Scale Hydrologic Unit Boundaries, May 18, 2005
Major Roads of the United States, May 18, 2005

Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization and general description of the data.

Section 3: Biological Resources

Ecoregions

The effects of latitude, continental position, and elevation, together with other climatic factors, combine to form the world's ecoclimatic zones, which are referred to as an ecosystem region or ecoregion. Ecoregion maps show climatically determined ecological units.

Because macroclimates are among the most significant factors affecting the distribution of life on earth, as the macroclimate changes, the other components of the ecosystem change in response. Bailey's Ecoregion classification (Bailey, 1976) provides a general description of the ecosystem geography of the United States.

In Bailey's classification system, there are four "domain" groups. Three of the groups are humid, thermally differentiated, and are named Polar, Humid Temperate and Humid Tropical. The Dry Domain, which is defined on the basis of moisture alone, is the fourth domain. Each domain is divided into divisions, which are further subdivided into provinces, on the basis of macrofeatures of the vegetation.

This classification places all of the Little Colorado Watershed in the Dry Domain. There are two different divisions of the Dry Domain within the watershed:

1. Tropical/Subtropical Desert Division, which comprises close to 23% of the watershed; and

2. Tropical/Subtropical Steppe Division, comprising over 77% of the total area of the watershed.

The watershed can also be further subdivided into "provinces" and "sections" using the Bailey's ecological classification, as shown in Figures 3-1, 3-2 and 3- 3, and Tables 3-1, 3-2 and 3-3 below.

The subwatersheds are identified using the USGS Hydrologic Unit Codes (HUC). Subwatershed areas were delineated on the basis of the eight-digit cataloging HUC, as well as the classifications and GIS modeling.

The essential feature of a dry climate is that annual losses of water through evaporation at the earth's surface exceed annual water gain from precipitation. Dry climates occupy one-fourth or more of the earth's total land surface.

Commonly, two divisions of dry climates are recognized: the arid desert and the semi-arid steppe. Generally, the steppe is a transitional belt surrounding the desert, separating it from the humid climates beyond (Bailey, 1995). The boundary between arid and semi-arid climates is arbitrary but is commonly defined as one-half the amount of precipitation separating steppe from humid climates (Bailey 1995). Steppes typically are grasslands of short grasses and other herbs and with locally developed shrub and woodland. Soils are commonly Mollisols and Aridisols containing some humus.

In desert areas xerophytic plants provide negligible ground cover. In dry periods, visible vegetation is limited to small hard-leaved or spiny shrubs, cacti, or hard grasses. Many species of small annuals may be present, but they appear only after the rare but heavy rains have saturated the soil (Bailey, 1995).

Soils in the Little Colorado Watershed are mostly Aridisols (dry, high in calcium-carbonate, clays and salts, not suitable for agriculture without irrigation), and dry Entisols (young, diverse, some suitable for agriculture). The dominant pedogenic (soil-forming) process is salinization which produces areas of salt crust where only salt-loving plants can survive. Salinization occurs in areas where evapotranspiration exceeds precipitation. Calcification, the accumulation of calcium carbonate in soil surface layers, is conspicuous on well drained uplands (Bailey, 1995).

The Tropical/Subtropical Steppe Division has only one province represented in the Little Colorado region, named the “Colorado Plateau Semi-Desert Province”. The Tropical/Subtropical Steppe Regime Mountains Division is represented by the “Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province”.

The “Arizona-New Mexico Mountains Semi-Desert -Open Woodland-Coniferous Forest -Alpine Meadow Province” is divided into three different sections in the Little Colorado watershed: Grand Canyon Lands, Navajo Canyonlands, and the Painted Desert.

The White Mountain-San Francisco Peaks Section is the only representative of the “Colorado Plateau Semi-Desert Province”.

Figure 3-1 Little Colorado Watershed Ecoregions – Divisions.

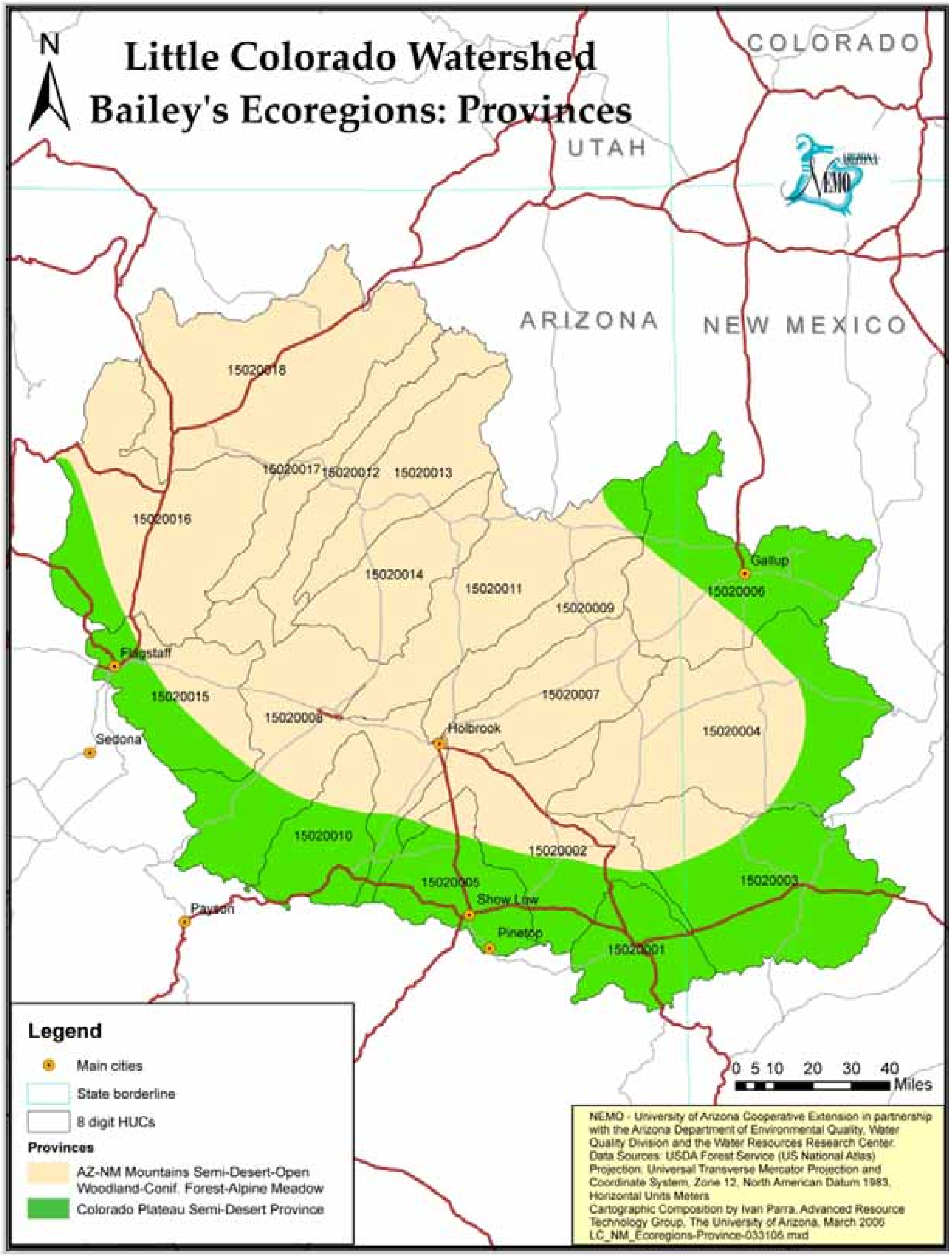

Figure 3-2 Little Colorado Watershed Ecoregions – Provinces

Figure 3-3 Little Colorado Watershed Ecoregions – Sections.

Table 3-1 Little Colorado Watershed Ecoregions - Divisions.

Subwatershed Name	Tropical/Subtropical Steppe Division	Tropical/Subtropical Steppe Regime Mountains Division	Total Area (square miles)
Little Colorado River Headwaters-15020001	**0%**	**100%**	***1,197,445***
Upper Little Colorado River-15020002	**66%**	**34%**	***2,598,145***
Carrizo Wash-15020003	**81%**	**19%**	***532,513***
Zuni River-15020004	**100%**	**0%**	***1,119,410***
Silver Creek-15020005	**12%**	**88%**	***1,520,492***
Upper Puerco River-15020006	**61%**	**39%**	***886,543***
Lower Puerco River-15020007	**100%**	**0%**	***1,794,870***
Middle Little Colorado River-15020008	**69%**	**31%**	***4,054,677***
Wide Ruin Wash-Leroux Wash-15020009	**100%**	**0%**	***1,308,472***
Chevelon Canyon-15020010	**26%**	**74%**	***1,317,534***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**93%**	**7%**	***2,687,116***
Oraibi Wash-15020012	**100%**	**0%**	***1,175,519***
Polacca Wash-15020013	**100%**	**0%**	***1,851,900***
Jadito Wash-15020014	**100%**	**0%**	***1,510,428***
Canyon Diablo-15020015	**47%**	**53%**	***1,914,114***
Lower Little Colorado River-15020016	**84%**	**16%**	***3,812,932***
Dinnebito Wash-15020017	**100%**	**0%**	***1,317,201***
Moenkopi Wash-15020018	**100%**	**0%**	***4,215,480***
Little Colorado River Watershed-150200	***77%***	***23%***	***34,814,791***

Table 3-2 Little Colorado Watershed Ecoregions - Provinces.

Subwatershed Name	Colorado Plateau Semi-Desert Province	Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province	Total Area (square miles)
Little Colorado River Headwaters-15020001	**0%**	**100%**	***1,197,445***
Upper Little Colorado River-15020002	**66%**	**34%**	***2,598,145***
Carrizo Wash-15020003	**81%**	**19%**	***532,513***
Zuni River-15020004	**100%**	**0%**	***1,119,410***
Silver Creek-15020005	**12%**	**88%**	***1,520,492***
Upper Puerco River-15020006	**61%**	**39%**	***886,543***
Lower Puerco River-15020007	**100%**	**0%**	***1,794,870***
Middle Little Colorado River-15020008	**69%**	**31%**	***4,054,677***

Subwatershed Name	Colorado Plateau Semi-Desert Province	Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province	Total Area (square miles)
Wide Ruin Wash-Leroux Wash-15020009	**100%**	**0%**	***1,308,472***
Chevelon Canyon-15020010	**26%**	**74%**	***1,317,534***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**93%**	**7%**	***2,687,116***
Oraibi Wash-15020012	**100%**	**0%**	***1,175,519***
Polacca Wash-15020013	**100%**	**0%**	***1,851,900***
Jadito Wash-15020014	**100%**	**0%**	***1,510,428***
Canyon Diablo-15020015	**47%**	**53%**	***1,914,114***
Lower Little Colorado River-15020016	**84%**	**16%**	***3,812,932***
Dinnebito Wash-15020017	**100%**	**0%**	***1,317,201***
Moenkopi Wash-15020018	**100%**	**0%**	***4,215,480***
Little Colorado River Watershed-150200	***77%***	***23%***	***34,814,791***

Table 3- 3 Little Colorado Watershed Ecoregions - Sections.

Subwatershed Name	Grand Canyon Lands Section	Navajo Canyonlands Section	White Mountain-San Francisco Peaks Section	Painted Desert Section	Total Area (square miles)
Little Colorado River Headwaters-15020001	**0%**	**0%**	**100%**	**0%**	***1,197,445***
Upper Little Colorado River-15020002	**0%**	**0%**	**34%**	**66%**	***2,598,145***
Carrizo Wash-15020003	**0%**	**0%**	**19%**	**81%**	***532,513***
Zuni River-15020004	**0%**	**6%**	**0%**	**94%**	***1,119,410***
Silver Creek-15020005	**0%**	**0%**	**88%**	**12%**	***1,520,492***
Upper Puerco River-15020006	**0%**	**61%**	**39%**	**0%**	***886,543***
Lower Puerco River-15020007	**0%**	**30%**	**0%**	**70%**	***1,794,870***
Middle Little Colorado River-15020008	**0%**	**0%**	**31%**	**69%**	***4,054,677***
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**65%**	**0%**	**35%**	***1,308,472***
Chevelon Canyon-15020010	**0%**	**0%**	**74%**	**26%**	***1,317,534***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**69%**	**7%**	**24%**	***2,687,116***
Oraibi Wash-15020012	**0%**	**78%**	**0%**	**22%**	***1,175,519***
Polacca Wash-15020013	**0%**	**80%**	**0%**	**20%**	***1,851,900***
Jadito Wash-15020014	**0%**	**46%**	**0%**	**54%**	***1,510,428***
Canyon Diablo-15020015	**0%**	**0%**	**53%**	**47%**	***1,914,114***
Lower Little Colorado River-15020016	**27%**	**5%**	**16%**	**52%**	***3,812,932***
Dinnebito Wash-15020017	**0%**	**55%**	**0%**	**45%**	***1,317,201***

Subwatershed Name	Grand Canyon Lands Section	Navajo Canyonlands Section	White Mountain-San Francisco Peaks Section	Painted Desert Section	Total Area (square miles)
Moenkopi Wash-15020018	**4%**	**96%**	**0%**	**0%**	***4,215,480***
Little Colorado River Watershed-150200	***3%***	***34%***	***23%***	***40%***	***34,814,791***

Vegetation

Two different vegetation maps were created for the Little Colorado watershed, one based on biotic communities and the other based on vegetative cover.

The first map is based on the classification of biotic communities that was published by Brown, Lowe, and Pace (Brown et al., 1979). These biotic zones are general categories indicating where vegetation communities would most likely exist (Figure 3- 4). Under this classification there are seven different biotic communities in the Little Colorado Watershed. The two primary communities are “Plains and Great Basin Grassland” (41% of the watershed), and “Great Basin Conifer Woodland” (29% of the watershed area). Table 3- 4 shows the percentage of each biotic community in each subwatershed.

The second vegetation map was created based on the Southwest Regional Gap Vegetation cover, which shows vegetation communities or land cover (Halvorson et al., 2001). Based on this map, 19 different vegetation cover types are found within the watershed, including: urban landscape, playa and surface water features (Table 3-5). Two of the most common vegetation types over the entire watershed are Plains and Great Basin Conifer Woodland, which comprise 36% and 33% of the Little Colorado.

Figure 3-5 is a map of the GAP Vegetation for the Little Colorado Watershed.

Habitats (Riparian and Wetland Areas)

The Arizona Game & Fish Department has identified riparian vegetation associated with perennial waters and has mapped the data in response to the requirements of the state Riparian Protection Program. This map was used to identify riparian areas in the Little Colorado Watershed (Figure 3-6).

There are ten different types of riparian areas within the watershed encompassing a total of 5,226 acres, which comprises 0.04% of the whole watershed. Wet Meadow, Conifer Oak, and Tamarisk groups make up the largest groups of riparian wetland areas in the watershed. In the Little Colorado River Headwaters, Wet Meadow is a significant riparian area type, while in the Middle Little Colorado River, Conifer Oak is the most important (in terms of coverage). The Little Colorado River Headwaters subwatershed has the greatest amount of wetland with 2,041 acres (Table 3- 5).

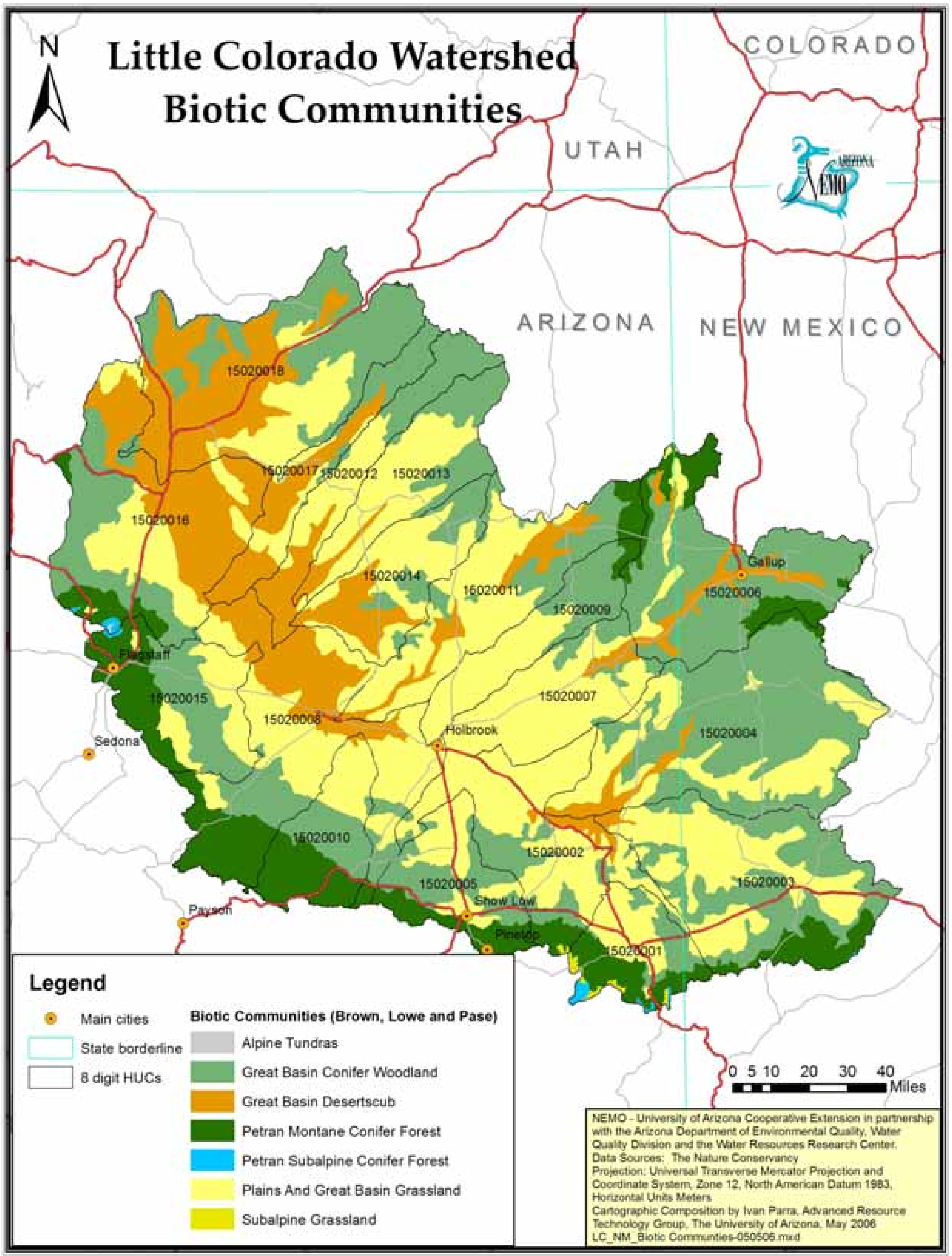

Figure 3-4 Little Colorado Watershed - Brown, Lowe and Pace Biotic Communities.

Table 3-4 Little Colorado Watershed - Brown, Lowe and Pace Biotic Communities, Percent of Subwatershed.

Subwatershed Name	Great Basin Conifer Woodland	Plains And Great Basin Grassland	Petran Montane Conifer Forest	Great Basin Desertscrub	Petran Subalpine Conifer Forest	Alpine Tundras	Subalpine Grassland	Total Area (square miles)
Little Colorado River Headwaters-15020001	18%	42%	32%	0%	4%	0%	4%	*1,197,445*
Upper Little Colorado River-15020002	22%	67%	5%	5%	0%	0%	0.3%	*2,598,145*
Carrizo Wash-15020003	32%	62%	0%	6%	0%	0%	0%	*532,513*
Zuni River-15020004	31%	50%	0%	18%	0%	0%	0%	*1,119,410*
Silver Creek-15020005	41%	34%	25%	0%	0%	0%	0%	*1,520,492*
Upper Puerco River-15020006	56%	14%	17%	13%	0%	0%	0%	*886,543*
Lower Puerco River-15020007	14%	82%	0%	5%	0%	0%	0%	*1,794,870*
Middle Little Colorado River-15020008	14%	43%	16%	26%	0%	0%	0%	*4,054,677*
Wide Ruin Wash-Leroux Wash-15020009	38%	56%	5%	0%	0%	0%	0%	*1,308,472*
Chevelon Canyon-15020010	32%	25%	42%	1%	0%	0%	0%	*1,317,534*
Pueblo Colorado Wash-Cottonwood Wash-15020011	25%	54%	5%	16%	0%	0%	0%	*2,687,116*
Oraibi Wash-15020012	43%	43%	0%	14%	0%	0%	0%	*1,175,519*
Polacca Wash-15020013	34%	56%	0%	10%	0%	0%	0%	*1,851,900*
Jadito Wash-15020014	22%	50%	0%	28%	0%	0%	0%	*1,510,428*
Canyon Diablo-15020015	36%	27%	36%	1%	0%	0%	0%	*1,914,114*

Subwatershed Name	**Great Basin Conifer Woodland**	**Plains And Great Basin Grassland**	**Petran Montane Conifer Forest**	**Great Basin Desertscrub**	**Petran Subalpine Conifer Forest**	**Alpine Tundras**	**Subalpine Grassland**	**Total Area (square miles)**
Lower Little Colorado River-15020016	**28%**	**25%**	**7%**	**39%**	**1%**	**0.1%**	**0%**	***3,812,932***
Dinnebito Wash-15020017	**27%**	**18%**	**0%**	**55%**	**0%**	**0%**	**0%**	***1,317,201***
Moenkopi Wash-15020018	**38%**	**20%**	**0%**	**42%**	**0%**	**0%**	**0%**	***4,215,480***
Little Colorado River Watershed-150200	***29%***	***41%***	***10%***	***19.5%***	***0.2%***	***0.01%***	***0.2%***	***34,814,791***

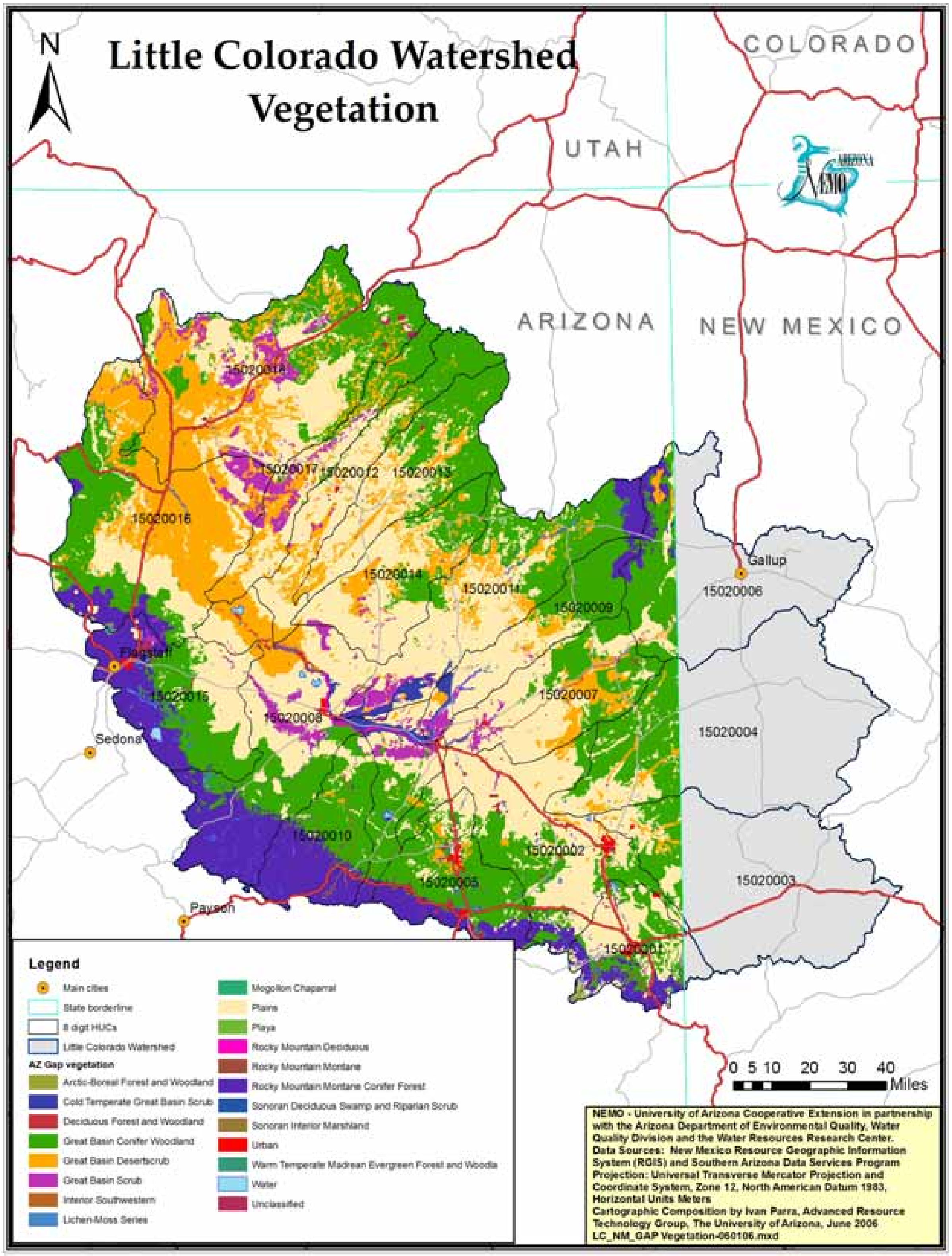

Figure 3-5 Little Colorado Watershed GAP Vegetation.

Table 3-5 Little Colorado Watershed GAP Vegetation, Percent of Subwatershed (pt 1/3).

Subwatershed Name	Great Basin Conifer Woodland	Plains	Great Basin Desertscrub	Rocky Mountain Montane Conifer Forest	Great Basin Scrub	Water	Deciduous Forest and Woodland
Little Colorado River Headwaters-15020001	**27%**	**48%**	**0%**	**18%**	**0%**	**1%**	**0%**
Upper Little Colorado River-15020002	**31%**	**61%**	**3%**	**3%**	**0%**	**0%**	**0%**
Carrizo Wash-15020003	**52%**	**40%**	**7%**	**0%**	**0%**	**0%**	**0%**
Zuni River-15020004	**62%**	**31%**	**7%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**55%**	**14%**	**4%**	**23%**	**0%**	**0%**	**0%**
Upper Puerco River-15020006	**62%**	**15%**	**6%**	**16%**	**0%**	**0%**	**0%**
Lower Puerco River-15020007	**29%**	**51%**	**16%**	**0%**	**2%**	**0%**	**1%**
Middle Little Colorado River-15020008	**23%**	**38%**	**9%**	**19%**	**6%**	**1%**	**1%**
Wide Ruin Wash-Leroux Wash-15020009	**38%**	**42%**	**7%**	**4%**	**5%**	**1%**	**0%**
Chevelon Canyon-15020010	**43%**	**7%**	**1%**	**46%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**35%**	**41%**	**11%**	**5%**	**4%**	**0%**	**0%**
Oraibi Wash-15020012	**36%**	**49%**	**13%**	**0%**	**1%**	**0%**	**0%**
Polacca Wash-15020013	**42%**	**42%**	**15%**	**0%**	**0%**	**0%**	**0%**
Jadito Wash-15020014	**21%**	**59%**	**19%**	**0%**	**2%**	**0%**	**0%**
Canyon Diablo-15020015	**36%**	**24%**	**1%**	**35%**	**1%**	**1%**	**0%**
Lower Little Colorado River-15020016	**26%**	**22%**	**41%**	**6%**	**4%**	**0%**	**0%**
Dinnebito Wash-15020017	**23%**	**39%**	**27%**	**0%**	**11%**	**0%**	**0%**
Moenkopi Wash-15020018	**28%**	**32%**	**33%**	**0%**	**7%**	**0%**	**0%**
Little Colorado River Watershed-150200	***33%***	***36.5%***	***15%***	***9%***	***3%***	***0.3%***	***0.2%***

Table 3-5 Little Colorado Watershed GAP Vegetation (part 2 of 3).

Subwatershed Name	Urban	Rocky Mountain Montane	Rocky Mountain Deciduous	Arctic-Boreal Forest and Woodland	Sonoran Deciduous Swamp and Riparian Scrub	Mogollon Chaparral
Little Colorado River Headwaters-15020001	**2%**	**2%**	**0%**	**2%**	**0%**	**0.1%**
Upper Little Colorado River-15020002	**1%**	**0%**	**0%**	**0%**	**0%**	**0%**
Carrizo Wash-15020003	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**3%**	**0%**	**0%**	**0%**	**0%**	**0%**
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**0%**	**0.2%**
Lower Puerco River-15020007	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Middle Little Colorado River-15020008	**0%**	**0%**	**1%**	**0%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**0%**	**0%**	**0%**	**0.2%**	**0%**
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Jadito Wash-15020014	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Canyon Diablo-15020015	**1%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lower Little Colorado River-15020016	**0%**	**0%**	**0%**	**0.2%**	**0%**	**0%**
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Moenkopi Wash-15020018	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Little Colorado River Watershed-150200	***0.4%***	***0.1%***	***0.4%***	***0.1%***	***0.01%***	***0.01%***

Table 3-5 Little Colorado Watershed Gap Vegetation (part 3 of 3).

Subwatershed Name	Lichen-Moss Series	Cold Temperate Great Basin Scrub	Interior Southwestern	Playa	Warm Temperate Madrean Evergreen Forest and Woodland	Sonoran Interior Marshland
Little Colorado River Headwaters-15020001	**0%**	**0%**	**0%**	**0%**	**0.4%**	**0.1%**
Upper Little Colorado River-15020002	**0%**	**0%**	**0.1%**	**0%**	**0%**	**0%**
Carrizo Wash-15020003	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lower Puerco River-15020007	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Middle Little Colorado River-15020008	**0%**	**2%**	**0.2%**	**0.02%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**3%**	**0%**	**0%**	**0%**	**0%**
Chevelon Canyon-15020010	**0%**	**0%**	**3%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**4%**	**0%**	**0%**	**0%**	**0%**
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Jadito Wash-15020014	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Canyon Diablo-15020015	**0.1%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lower Little Colorado River-15020016	**0.1%**	**0%**	**0%**	**0%**	**0%**	**0%**
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Moenkopi Wash-15020018	**0%**	**0%**	**0.1%**	**0%**	**0%**	**0%**
Little Colorado River Watershed-150200	***0.2%***	***1%***	***0.7%***	***0%***	***0.01%***	***0%***

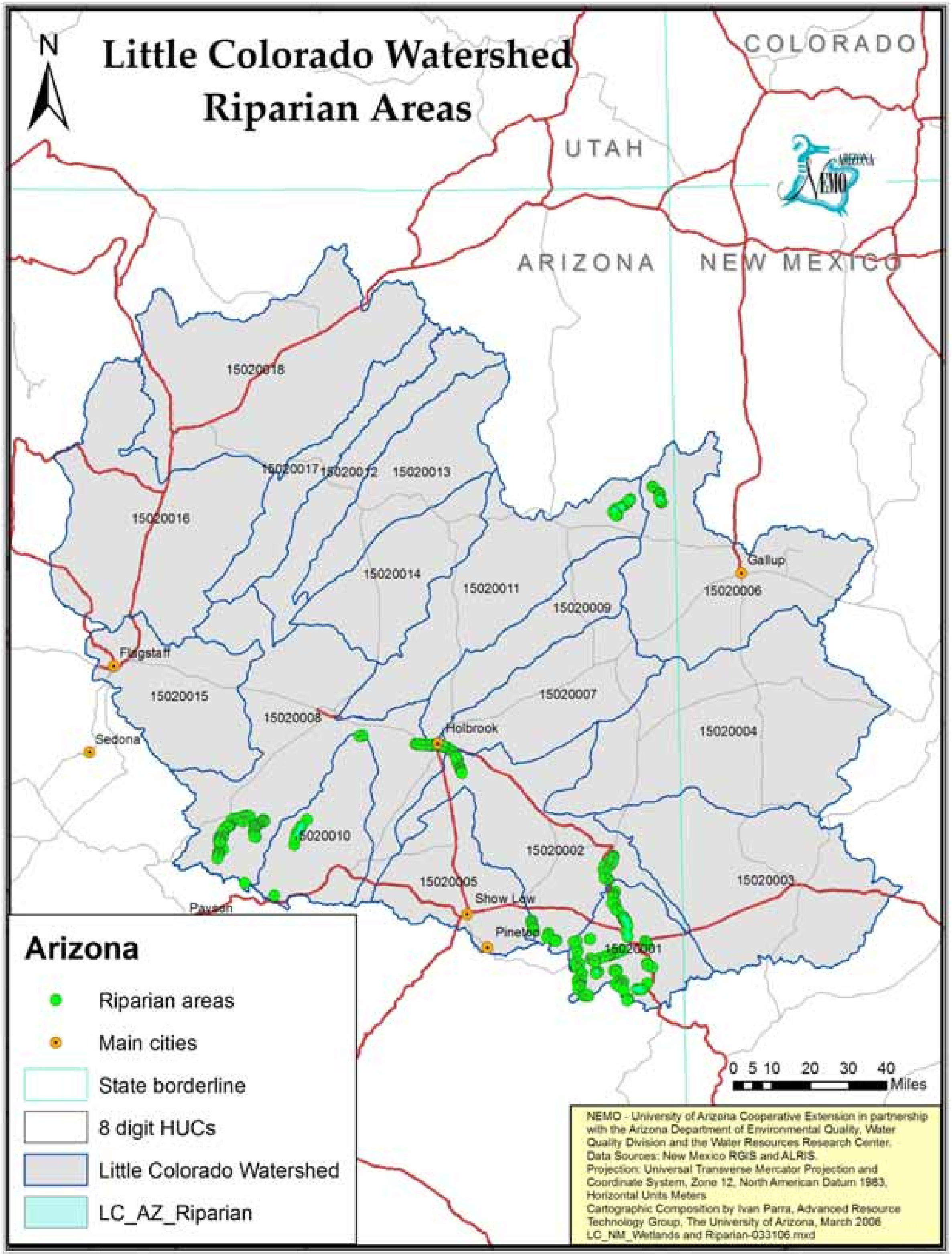

Figure 3-6 Little Colorado Watershed Riparian Areas.

Table 3-6 Little Colorado Watershed Types of Riparian and Wetland Areas (acres) (part 1 of 2).

Subwatershed Name	Wet Meadow	Mountain Shrub	Conifer Oak	Cottonwood Willow	Russian Olive
Little Colorado River Headwaters-15020001	**985**	**122**	**356**	**0**	**0**
Upper Little Colorado River-15020002	**185**	**0**	**119**	**0**	**0**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**
Zuni River-15020004	**0**	**0**	**0**	**0**	**0**
Silver Creek-15020005	**0**	**0**	**0**	**0**	**0**
Upper Puerco River-15020006	**223**	**16**	**0**	**0**	**0**
Lower Puerco River-15020007	**0**	**0**	**0**	**0**	**0**
Middle Little Colorado River-15020008	**0**	**0**	**867**	**0**	**5**
Wide Ruin Wash-Leroux Wash-15020009	**0**	**0**	**0**	**0**	**0**
Chevelon Canyon-15020010	**57**	**75**	**0**	**0**	**0**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**8**	**57**	**112**	**8**	**11**
Oraibi Wash-15020012	**0**	**0**	**0**	**0**	**0**
Polacca Wash-15020013	**0**	**0**	**0**	**0**	**0**
Jadito Wash-15020014	**0**	**0**	**0**	**0**	**0**
Canyon Diablo-15020015	**0**	**0**	**0**	**0**	**0**
Lower Little Colorado River-15020016	**0**	**0**	**0**	**0**	**0**
Dinnebito Wash-15020017	**0**	**0**	**0**	**0**	**0**
Moenkopi Wash-15020018	**0**	**0**	**0**	**0**	**0**
Little Colorado River Watershed-150200	**0**	**0**	**0**	**0**	**0**
Total Riparian (acres)	***1,459***	***269***	***1,454***	***8***	***16***

Table 3- 6 Little Colorado Watershed Types of Riparian and Wetland Areas (acres) (part 2 of 2).

Subwatershed Name	Tamarisk	Mesquite	Strand	Mixed Broadleaf	Marsh
Little Colorado River Headwaters-15020001	**91**	**43**	**12**	**424**	**9**
Upper Little Colorado River-15020002	**502**	**139**	**0**	**60**	**0**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**
Zuni River-15020004	**0**	**0**	**0**	**0**	**0**
Silver Creek-15020005	**0**	**0**	**0**	**0**	**0**

Subwatershed Name	Tamarisk	Mesquite	Strand	Mixed Broadleaf	Marsh
Upper Puerco River-15020006	**0**	**0**	**0**	**0**	**0**
Lower Puerco River-15020007	**5**	**0**	**0**	**0**	**0**
Middle Little Colorado River-15020008	**436**	**0**	**90**	**2**	**0**
Wide Ruin Wash-Leroux Wash-15020009	**16**	**0**	**0**	**0**	**0**
Chevelon Canyon-15020010	**162**	**6**	**0**	**26**	**0**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0**	**0**	**0**	**0**	**0**
Oraibi Wash-15020012	**0**	**0**	**0**	**0**	**0**
Polacca Wash-15020013	**0**	**0**	**0**	**0**	**0**
Jadito Wash-15020014	**0**	**0**	**0**	**0**	**0**
Canyon Diablo-15020015	**0**	**0**	**0**	**0**	**0**
Lower Little Colorado River-15020016	**0**	**0**	**0**	**0**	**0**
Dinnebito Wash-15020017	**0**	**0**	**0**	**0**	**0**
Moenkopi Wash-15020018	**0**	**0**	**0**	**0**	**0**
Little Colorado River Watershed-150200	**0**	**0**	**0**	**0**	**0**
Total Riparian (acres)	***1,212***	***188***	***102***	***511***	***9***

Major Land Resource Areas

According to the US Department of Agriculture (1981), Major Land Resource Areas (MLRA) are defined as "A geographic area, usually several thousand acres in extent, that is characterized by a particular pattern of soils, climate, water resources, land uses, and type of farming".

There are four different MLRAs in the Little Colorado Watershed (Figure 3-7). The dominant MLRA is classified as "Colorado and Green River Plateaus". This area comprises over 67% of the entire watershed. "New Mexico and Arizona Plateaus and Mesas" and "Arizona and New Mexico Mountains" cover 11% and 21% of the watershed, respectively. "Sonoran Basin and Range" comprise less than 1 percent of the entire watershed (Table 3- 7).

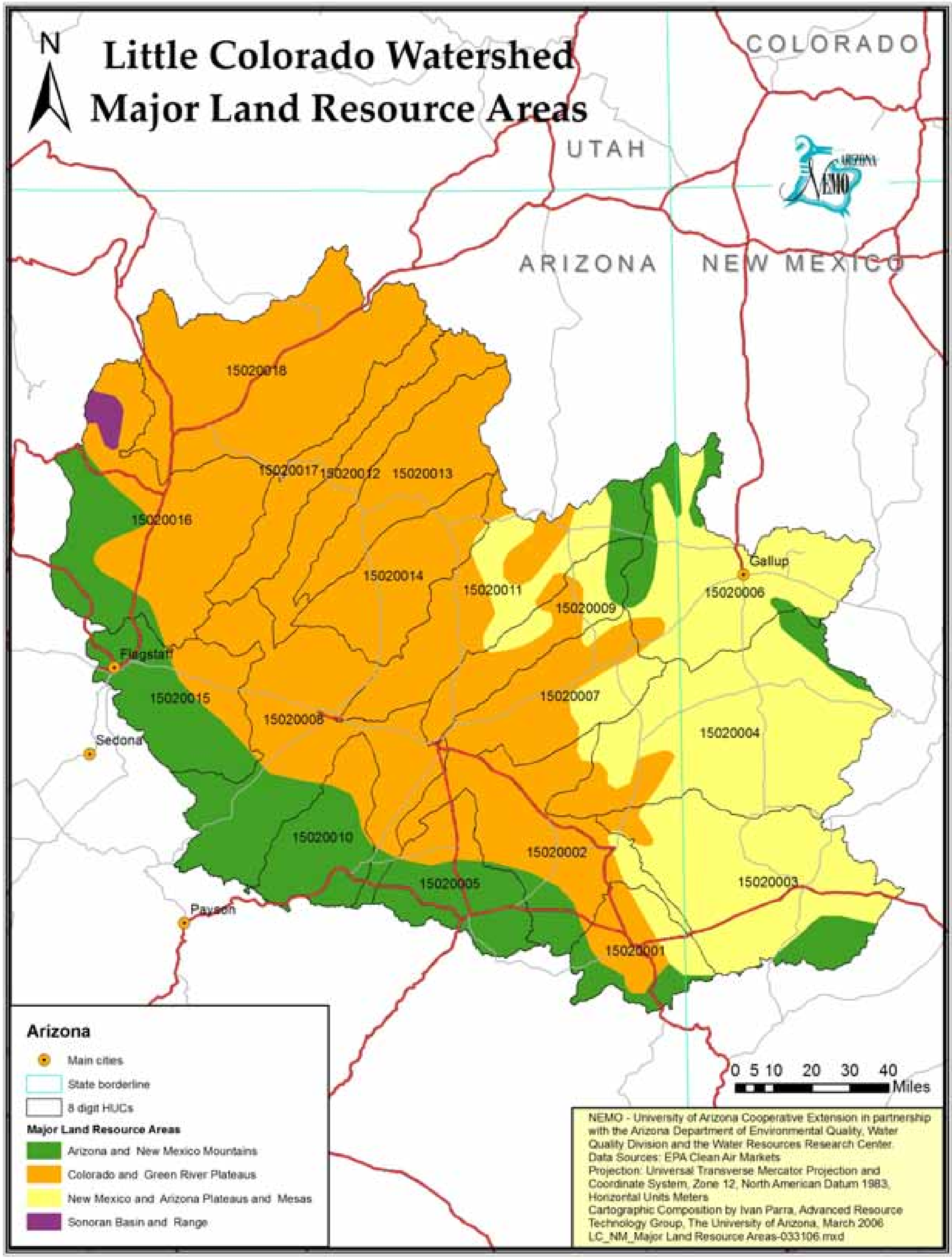

Figure 3- 7 Upper Gila Watershed Major Land Resource Areas.

Table 3-7 Little Colorado Watershed Major Land Resource Areas.

Subwatershed Name	Colorado and Green River Plateaus	Sonoran Basin and Range	New Mexico and Arizona Plateaus and Mesas	Arizona and New Mexico Mountains	Total Area (square miles)
Little Colorado River Headwaters-15020001	**52%**	**0%**	**18%**	**30%**	***1,197,445***
Upper Little Colorado River-15020002	**74%**	**0%**	**12%**	**14%**	***2,598,145***
Carrizo Wash-15020003	**23%**	**0%**	**77%**	**0%**	***532,513***
Zuni River-15020004	**40%**	**0%**	**60%**	**0%**	***1,119,410***
Silver Creek-15020005	**26%**	**0%**	**0%**	**74%**	***1,520,492***
Upper Puerco River-15020006	**9%**	**0%**	**54%**	**37%**	***886,543***
Lower Puerco River-15020007	**72%**	**0%**	**28%**	**0%**	***1,794,870***
Middle Little Colorado River-15020008	**70%**	**0%**	**0%**	**30%**	***4,054,677***
Wide Ruin Wash-Leroux Wash-15020009	**58%**	**0%**	**28%**	**13%**	***1,308,472***
Chevelon Canyon-15020010	**22%**	**0%**	**0%**	**78%**	***1,317,534***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**60%**	**0%**	**32%**	**8%**	***2,687,116***
Oraibi Wash-15020012	**100%**	**0%**	**0%**	**0%**	***1,175,519***
Polacca Wash-15020013	**100%**	**0%**	**0%**	**0%**	***1,851,900***
Jadito Wash-15020014	**100%**	**0%**	**0%**	**0%**	***1,510,428***
Canyon Diablo-15020015	**27%**	**0%**	**0%**	**73%**	***1,914,114***
Lower Little Colorado River-15020016	**67%**	**4%**	**0%**	**28%**	***3,812,932***
Dinnebito Wash-15020017	**100%**	**0%**	**0%**	**0%**	***1,317,201***
Moenkopi Wash-15020018	**100%**	**0%**	**0%**	**0%**	***4,215,480***
Little Colorado River Watershed-150200	***68%***	***0%***	***11%***	***21%***	***34,814,791***

References

Bailey, R.G. 1976. "Ecoregions of the United States" map, Aug. 17, 2001, unnumbered publication. Intermountain Region, USDA Forest Service, Ogden, Utah, from http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html

Bailey, R.G. 1995. Description of the Ecoregions of the United States, Aug. 17, 2001. U.S. Forest Service, USDA. http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html

Bailey, R.G. 1996. Ecosystem Geography. Springer-Verlag. New York. 204 p.

Bailey, R.G. 2002. Ecoregion-Based Design for Sustainability. Springer-Verlag. New York. 222 p.

Brown, D.E., C.H. Lowe, and C.P. Pace. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest, J. Arizona-Nevada Acad. Sci., 14 (Suppl. 1), 1–16, 1979

Halvorson, W.L., K. Thomas, L. Graham, M.R. Kunzmann, P.S. Bennett, C. van Riper, C. Drost. 2001. The Arizona GAP Analysis Project: Final Report. Tucson, Arizona: U.S. Geological Survey Sonoran Desert Field Station.

US Department of Agriculture. 1981. Land resource regions and major land resource areas of the United States. Agricultural Handbook 296, Soil Conservation Service, Washington, DC.

Data Sources

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/alrishome.html
Habitats (Riparian & Wetland Areas). June 12, 2003.

US National Atlas, http://nationalatlas.gov/index.html
Ecoregions and Subregions of the United States, Puerto Rico, and the U.S. Virgin Islands (2004). May 01, 2005.
Cities and Towns of the United States, May 18, 2005
State Boundaries of the United States, March 30, 2005
Major Roads of the United States, May 18, 2005

New Mexico Resource Geographic Information System (RGIS), http://rgis.unm.edu/intro.cfm
New Mexico Wetlands, June 20, 2005
New Mexico General Vegetation, June 20, 2005

The Nature Conservancy's GIS Website, http://gis.tnc.org/
TNC Ecoregions, June 14, 2005

EPA Clean Air Markets
http://www.epa.gov/airmarkets/cmap/data/index.html

Major Land Resource Areas, May 15, 2005
Southern Arizona Data Services Program

Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, its geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.

Section 4: Social/Economic Characteristics

County Governments

Understanding which governmental entities hold jurisdiction over the land in a given watershed helps a watershed partnership understand the significance of each stakeholder’s influence on the watershed. The Little Colorado Watershed is comprised of three counties in Arizona: Apache (28%), Coconino (36%) and Navajo (36%), as shown in Figure 4-1.

The Little Colorado River Headwaters, Carrizo Wash, Zuni River and Upper Puerco River subwatersheds are completely within Apache County. The Canyon Diablo and Lower Little Colorado River subwatersheds are completely within Coconino County and the Jadito Wash subwatershed is almost completely (96%) located in Navajo County.

Oraibi Wash, Polacca Wash and Jadito Wash subwatersheds have at least a portion of their area within all three counties.

Council of Governments (COGs)

All three Arizona counties in the Little Colorado Watershed belong to one Council of Governments: the Northern Arizona Council of Governments (Figure 4-2).

An illustration of which counties belong to which Council of Governments in both Arizona and New Mexico is shown in Figure 4-3, Administrative Boundaries..

Urban Areas

The U.S. Census Bureau defines Urbanized Areas as densely settled territory that contains 50,000 or more people.

Based on data from ALRIS, there are ten major urban areas within the Little Colorado Watershed: the communities of Eagar; Flagstaff; Holbrook; Pinetop-Lakeside; Show Low; Snowflake; Springerville; St. Johns; Taylor and “Urban Lands Outside of Flagstaff” (Figure 4-4).

Flagstaff and its surroundings represent the largest urban area within the Little Colorado Watershed and comprise 28% of the urban areas. The Silver Creek subwatershed has the highest percentage of urban areas, and there are no urban areas within Carrizo Wash, Zuni River, Upper Puerco River, Chevelon Canyon, Pueblo Colorado Wash-Cottonwood Wash, Oraibi Wash, Polacca Wash, Jadito Wash, Lower Little Colorado River, Dinnebito Wash and Moenkopi Wash subwatersheds (Table 4-2).

Figure 4-1 Little Colorado Watershed Counties.

Table 4- 1 Little Colorado Watershed – Percent of Subwatershed in Each County.

Subwatershed and HUC	Area (square miles)	Apache	Coconino	Navajo
Little Colorado River Headwaters-15020001	**755**	**100%**	**0%**	**0%**
Upper Little Colorado River-15020002	**1,617**	**74%**	**0%**	**26%**
Carrizo Wash-15020003	**331**	**100%**	**0%**	**0%**
Zuni River-15020004	**696**	**100%**	**0%**	**0%**
Silver Creek-15020005	**948**	**11%**	**0%**	**89%**
Upper Puerco River-15020006	**552**	**100%**	**0%**	**0%**
Lower Puerco River-15020007	**1,115**	**84%**	**0%**	**16%**
Middle Little Colorado River-15020008	**2,523**	**0%**	**59%**	**41%**
Wide Ruin Wash-Leroux Wash-15020009	**813**	**65%**	**0%**	**35%**
Chevelon Canyon-15020010	**819**	**0%**	**29%**	**71%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**1,676**	**48%**	**0%**	**52%**
Oraibi Wash-15020012	**731**	**8%**	**15%**	**77%**
Polacca Wash-15020013	**1,155**	**16%**	**6%**	**79%**
Jadito Wash-15020014	**939**	**2%**	**2%**	**96%**
Canyon Diablo-15020015	**1,199**	**0%**	**100%**	**0%**
Lower Little Colorado River-15020016	**2,393**	**0%**	**100%**	**0%**
Dinnebito Wash-15020017	**819**	**0%**	**57%**	**43%**
Moenkopi Wash-15020018	**2,650**	**0%**	**67%**	**33%**
Little Colorado River Watershed-150200	***21,729***	***28%***	***36%***	***36%***

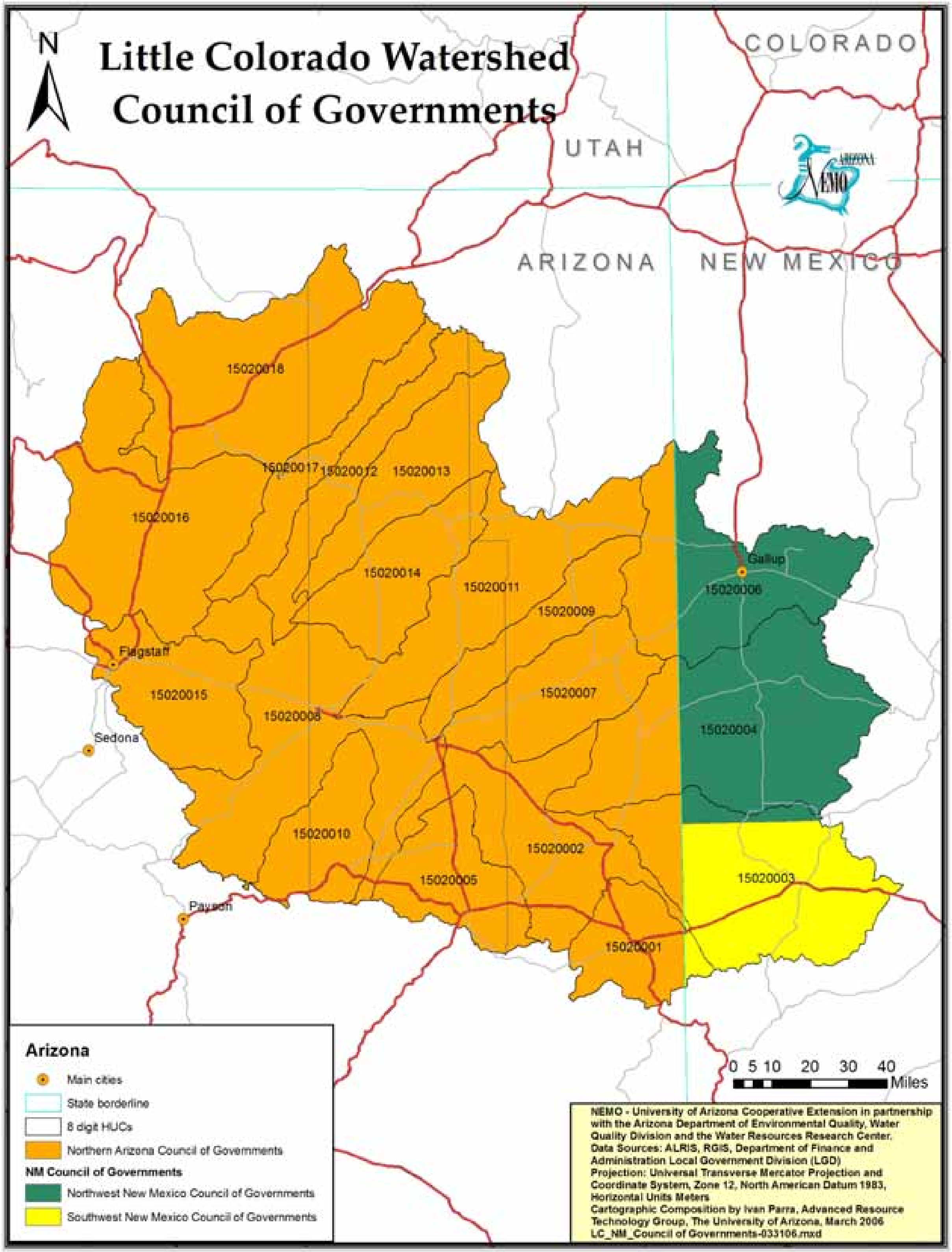

Figure 4-2 Little Colorado Watershed Council of Governments.

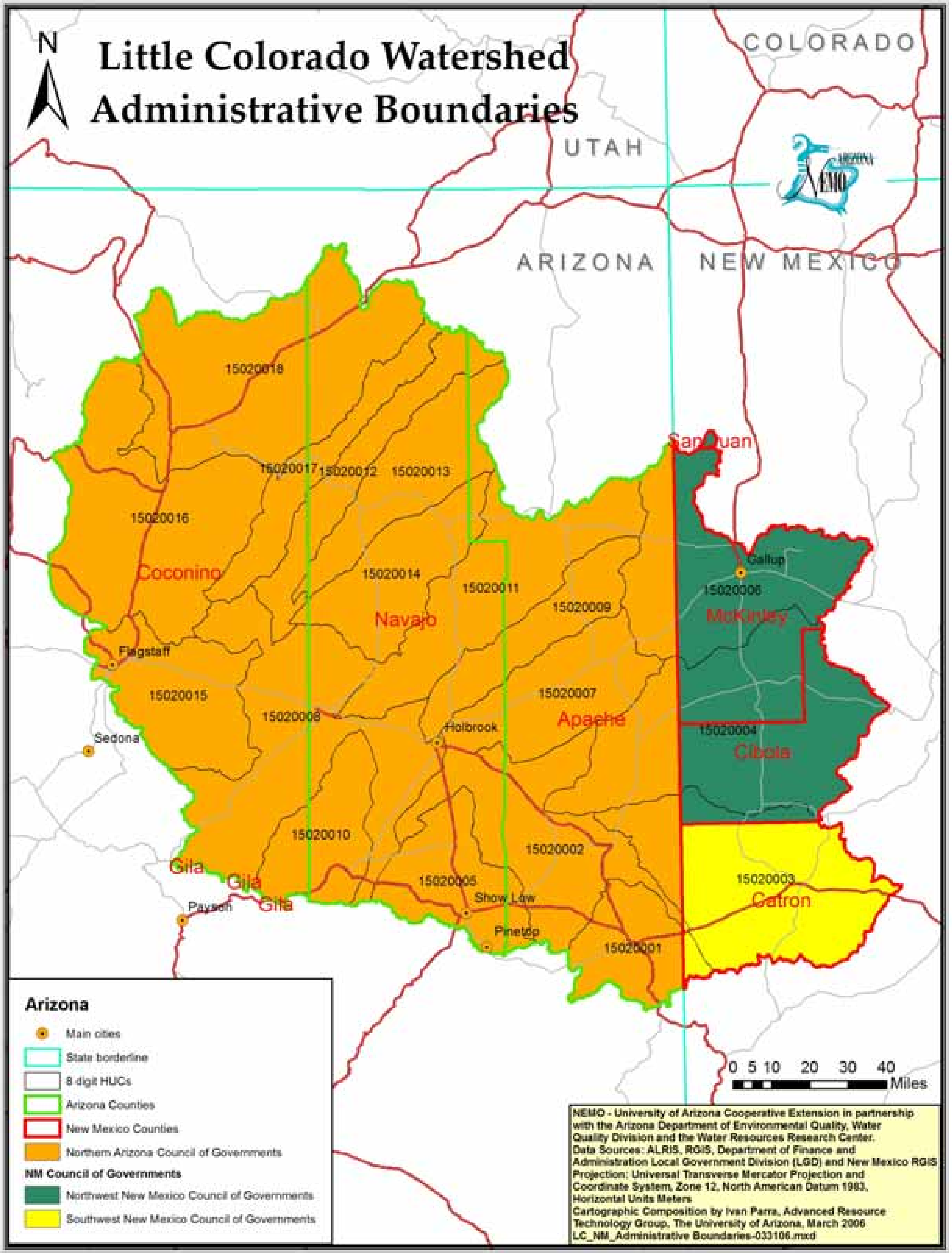

Figure 4-3 Little Colorado Watershed Administrative Boundaries.

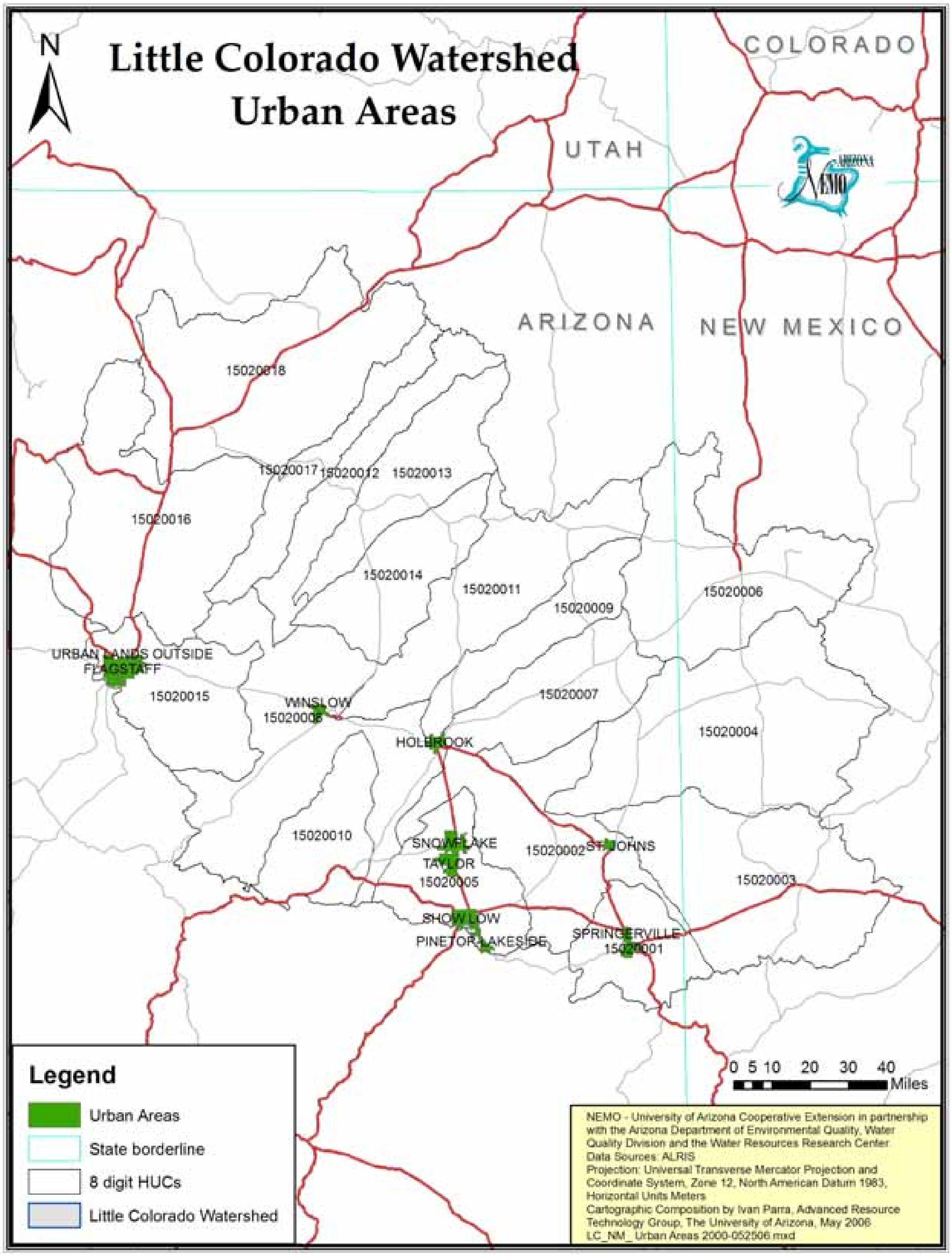

Figure 4-4 Little Colorado Watershed Urban Areas.

Table 4-2 Little Colorado Watershed Urbanized Areas (part 1 of 2).

Subwatershed Name	Flagstaff	Urban Lands Outside Flagstaff	Winslow	Holbrook	Snowflake	St. Johns
Little Colorado River Headwaters-15020001	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Upper Little Colorado River-15020002	**0%**	**0%**	**0%**	**0%**	**0%**	**100%**
Carrizo Wash-15020003	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**0%**	**4%**	**0%**	**0%**	**31%**	**0%**
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lower Puerco River-15020007	**0%**	**0%**	**0%**	**100%**	**0%**	**0%**
Middle Little Colorado River-15020008	**0%**	**0%**	**54%**	**46%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**0%**	**0%**	**100%**	**0%**	**0%**
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Jadito Wash-15020014	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Canyon Diablo-15020015	**96%**	**4%**	**0%**	**0%**	**0%**	**0%**
Lower Little Colorado River-15020016	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Moenkopi Wash-15020018	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Little Colorado River Watershed-150200	***28%***	***3%***	***6%***	***7%***	***14%***	***3%***

Table 4-2 Little Colorado Watershed Urbanized Areas (part 2 of 2).

Subwatershed Name	Taylor	Show Low	Springerville	Pinetop-Lakeside	Eagar	Total (sq miles)
Little Colorado River Headwaters-15020001	**0%**	**0%**	**51%**	**0%**	**49%**	***14,815***
Upper Little Colorado River-15020002	**0%**	**0%**	**0%**	**0%**	**0%**	***4,392***
Carrizo Wash-15020003	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Silver Creek-15020005	**25%**	**29%**	**0%**	**11%**	**0%**	***61,918***
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Lower Puerco River-15020007	**0%**	**0%**	**0%**	**0%**	**0%**	***463***
Middle Little Colorado River-15020008	**0%**	**0%**	**0%**	**0%**	**0%**	***15,353***
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**0%**	**0%**	**0%**	**0%**	***2,163***
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Jadito Wash-15020014	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Canyon Diablo-15020015	**0%**	**0%**	**0%**	**0%**	**0%**	***40,930***
Lower Little Colorado River-15020016	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Moenkopi Wash-15020018	**0%**	**0%**	**0%**	**0%**	**0%**	***0***
Little Colorado River Watershed-150200	***11%***	***13%***	***5%***	***5%***	***5%***	***140,033***

Roads

Roads are important to consider in a watershed classification because they can affect water quality by increasing runoff and, especially in timber-harvesting areas, can increase sediment yield.

Table 4-3 and Figure 4-5 show road types in each subwatershed. Primary Highways include US Route 60 and US Route 69. The famous Route 66, which as the song said, passes from Gallup New Mexico through Flagstaff, Arizona, and is now known as Interstate Route 40.

The total road length in the Little Colorado Watershed is 1,247 miles, comprising over 7% of all roads in Arizona. The predominant road type, based on the Census Classification, is “Other Through Highway” with nearly 46% of the total roads length.

The Middle Little Colorado River subwatershed has the greatest accumulated length of roads with 175 miles. Table 4-4 shows the total length of roads for each subwatershed.

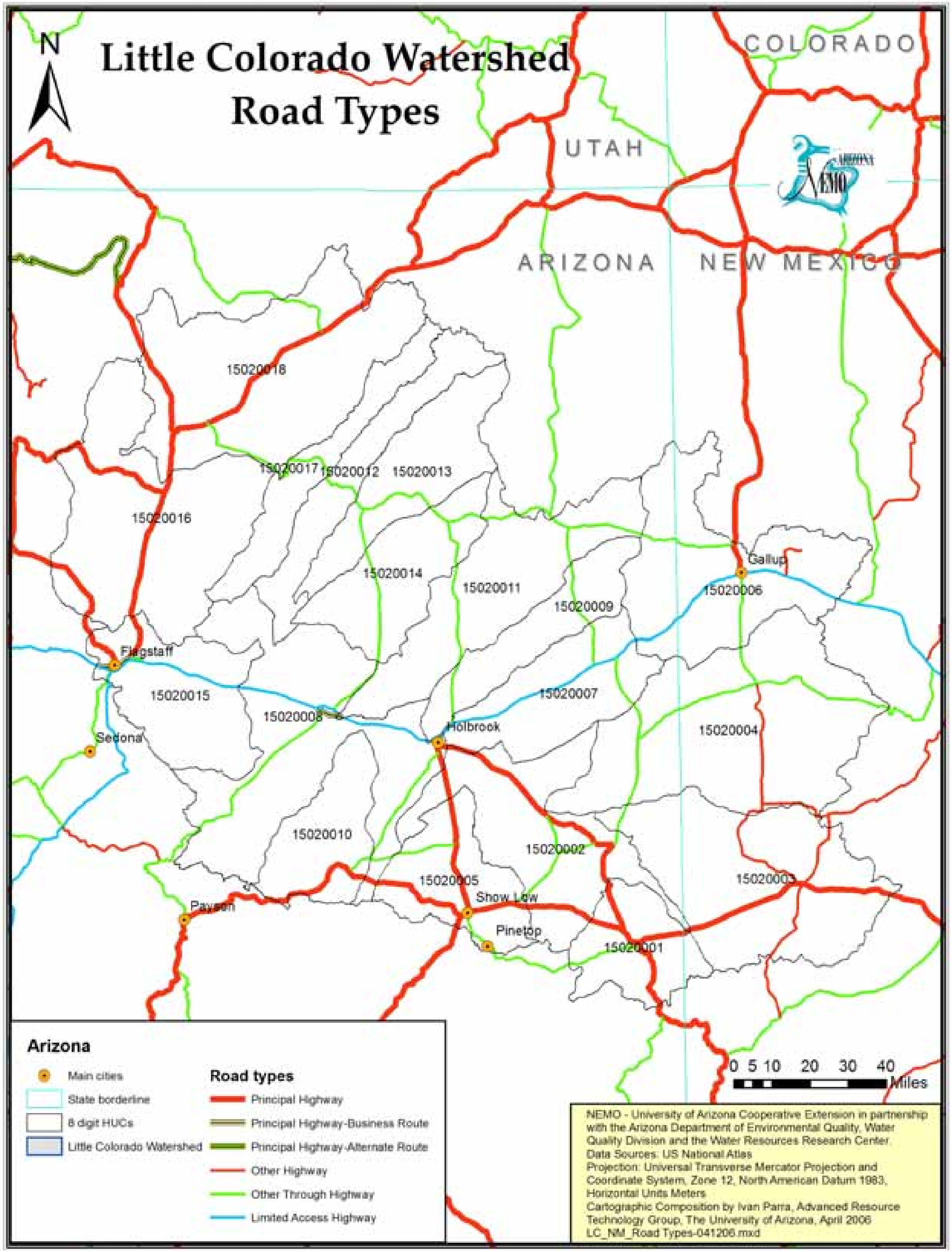

Figure 4-5 Little Colorado Watershed Road Types.

Table 4-3 Little Colorado Watershed Road Types.

Road Type	Road Length (miles)	Percent of Total Length
Limited Access Highway	**172**	**14%**
Other Through Highway	**573**	**46%**
Principal Highway	**481**	**39%**
Principal Highway Alternate Route	**1**	**0%**
Principal Highway Business Route	**20**	**2%**

Table 4- 4 Little Colorado Watershed Road Lengths by Subwatershed.

Subwatershed Name	Road Length (miles)	Percent of Total Length
Little Colorado River Headwaters-15020001	**86**	**7%**
Upper Little Colorado River-15020002	**124**	**10%**
Carrizo Wash-15020003	**7**	**1%**
Zuni River-15020004	**41**	**3%**
Silver Creek-15020005	**114**	**9%**
Upper Puerco River-15020006	**22**	**2%**
Lower Puerco River-15020007	**82**	**7%**
Middle Little Colorado River-15020008	**175**	**14%**
Wide Ruin Wash-Leroux Wash-15020009	**39**	**3%**
Chevelon Canyon-15020010	**32**	**3%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**86**	**7%**
Oraibi Wash-15020012	**13**	**1%**
Polacca Wash-15020013	**35**	**3%**
Jadito Wash-15020014	**53**	**4%**
Canyon Diablo-15020015	**85**	**7%**
Lower Little Colorado River-15020016	**95**	**8%**
Dinnebito Wash-15020017	**16**	**1%**
Moenkopi Wash-15020018	**141**	**11%**
Little Colorado River Watershed-150200 (total)	***1,247***	***100%***

Population

Census Population Densities in 1990

Census block statistics for 1990 were compiled from a CD prepared by Geo-Lytics (Geo- Lytics, 1998). These data were linked with census block data and used to create a density map (Figure 4-6) through a normalization process in 7 Km squares, which shows the number of individuals per square mile.

Table 4-5 shows the tabulated number of persons per square mile, which was calculated using the original census block data.

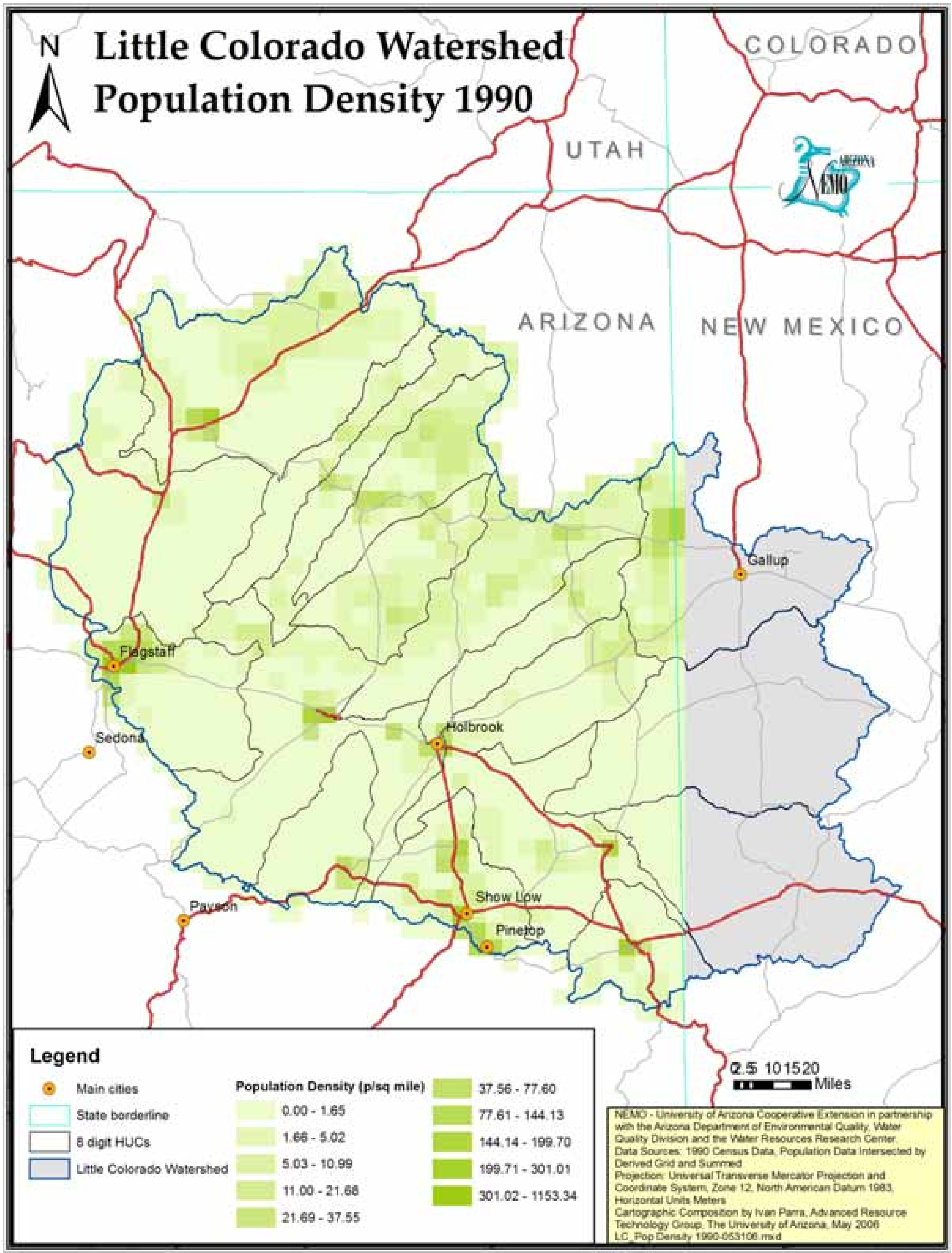

Figure 4-6 Little Colorado Watershed Population Density 1990.

Table 4-5 Colorado Watershed Population Density 1990 (persons/sq mile).

Subwatershed Name	Area (sq miles)	Min	Max	Mean
Little Colorado River Headwaters-15020001	722	0	289.04	9.17
Upper Little Colorado River-15020002	1,609	0	176.71	3.68
Carrizo Wash-15020003	335	0	5.94	0.11
Zuni River-15020004	735	0	2.76	0.25
Silver Creek-15020005	947	0	244.94	20.12
Upper Puerco River-15020006	550	0	191.15	19.60
Lower Puerco River-15020007	1,119	0	126.73	3.11
Middle Little Colorado River-15020008	2,470	0	280.51	6.56
Wide Ruin Wash-Leroux Wash-15020009	807	0	126.73	3.27
Chevelon Canyon-15020010	844	0	44.32	2.32
Pueblo Colorado Wash-Cottonwood Wash-15020011	1,607	0	280.51	4.92
Oraibi Wash-15020012	855	0	67.06	3.65
Polacca Wash-15020013	1,083	0	67.06	7.86
Jadito Wash-15020014	1,040	0	28.30	4.38
Canyon Diablo-15020015	1,204	0	1,153.34	43.80
Lower Little Colorado River-15020016	2,399	0	37.55	0.76
Dinnebito Wash-15020017	743	0	52.59	2.04
Moenkopi Wash-15020018	2,634	0	301.01	5.88
Little Colorado River Watershed-150200 (total)	*21,703*	*0*	*1,153.34*	*7.27*

Census Population Densities in 2000

The Census Block 2000 statistics data were downloaded from the Environmental Systems Research Institute (ESRI) website (ESRI Data Products, 2003) and population density was calculated by unit. Statistics per subwatershed are shown in Table 4-6. A population density map (Figure 4-7) was created from these data following the same procedure used for the 1990 census data.

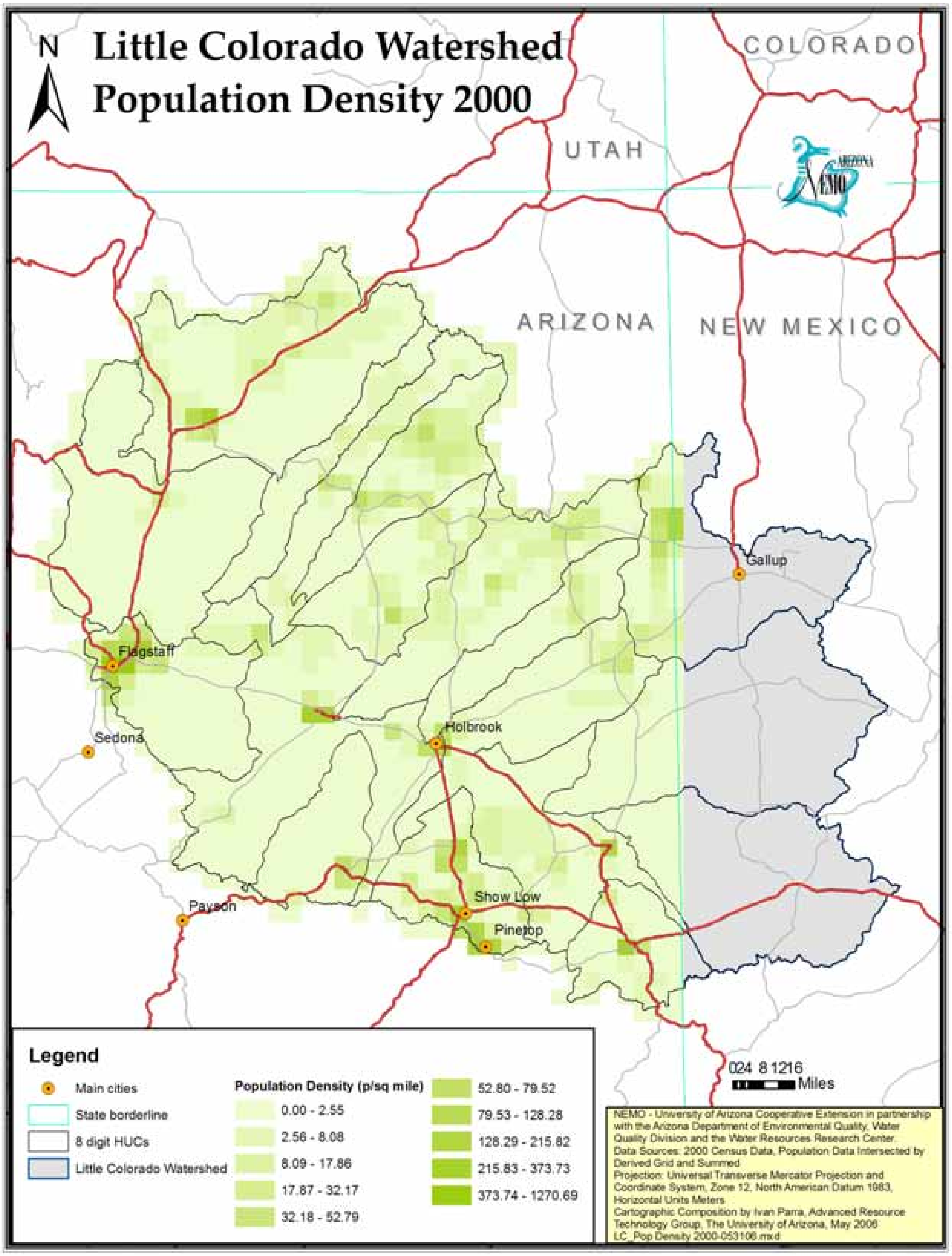

Figure 4-7 Little Colorado Watershed Population Density 2000.

Table 4- 6 Little Colorado Watershed Population Density 2000 (persons/sq mile).

Subwatershed Name	Area (sq miles)	Min	Max	Mean
Little Colorado River Headwaters-15020001	**722**	**0**	**281.53**	**9.76**
Upper Little Colorado River-15020002	**1,609**	**0**	**175.25**	**4.75**
Carrizo Wash-15020003	**335**	**0**	**3.22**	**0.09**
Zuni River-15020004	**735**	**0**	**7.01**	**0.25**
Silver Creek-15020005	**947**	**0**	**373.73**	**30.64**
Upper Puerco River-15020006	**550**	**0**	**178.51**	**19.55**
Lower Puerco River-15020007	**1,119**	**0**	**128.28**	**4.06**
Middle Little Colorado River-15020008	**2,470**	**0**	**267.43**	**7.12**
Wide Ruin Wash-Leroux Wash-15020009	**807**	**0**	**128.28**	**3.47**
Chevelon Canyon-15020010	**844**	**0**	**79.52**	**4.07**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**1,607**	**0**	**267.43**	**5.36**
Oraibi Wash-15020012	**855**	**0**	**60.36**	**4.11**
Polacca Wash-15020013	**1,083**	**0**	**60.36**	**9.37**
Jadito Wash-15020014	**1,040**	**0**	**57.51**	**5.46**
Canyon Diablo-15020015	**1,204**	**0**	**1,270.69**	**52.50**
Lower Little Colorado River-15020016	**2,399**	**0**	**44.33**	**0.83**
Dinnebito Wash-15020017	**743**	**0**	**46.85**	**1.94**
Moenkopi Wash-15020018	**2,634**	**0**	**327.92**	**6.54**
Little Colorado River Watershed-150200 (total)	***21,703***	***0***	***1,270.69***	***8.69***

Population Change

The 1990 and 2000 population density maps were used to create a population density change map. The resulting map (Figure 4-8) shows population increase or decrease over the ten-year period. Table 4-7 shows the change in population density from 1990 to 2000 in persons per square mile, derived from original census block data.

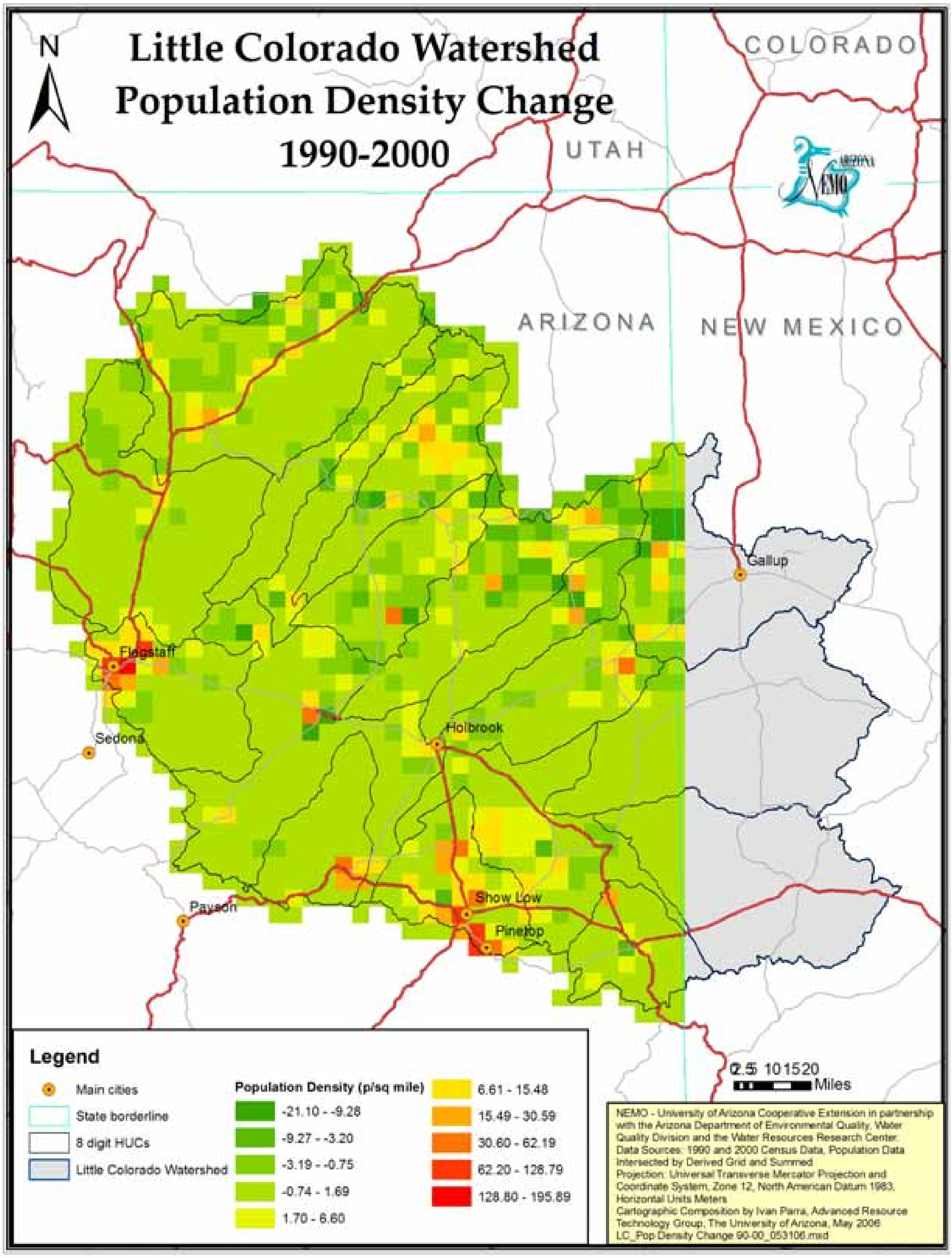

Figure 4-8 Little Colorado Watershed Population Density Change 1990 -2000.

Table 4- 7 Little Colorado Watershed Population Density Change 1990-2000 (persons/sq mile).

Subwatershed Name	Area (sq miles)	Min	Max	Mean
Little Colorado River Headwaters-15020001	**722**	**-7.51**	**18.67**	**0.59**
Upper Little Colorado River-15020002	**1,609**	**-7.76**	**18.67**	**1.07**
Carrizo Wash-15020003	**335**	**-2.71**	**0.24**	**-0.02**
Zuni River-15020004	**735**	**-1.59**	**4.25**	**0.00**
Silver Creek-15020005	**947**	**-4.01**	**128.79**	**10.53**
Upper Puerco River-15020006	**550**	**-13.47**	**30.59**	**-0.06**
Lower Puerco River-15020007	**1,119**	**-5.76**	**32.11**	**0.96**
Middle Little Colorado River-15020008	**2,470**	**-21.10**	**49.51**	**0.57**
Wide Ruin Wash-Leroux Wash-15020009	**807**	**-17.21**	**20.40**	**0.20**
Chevelon Canyon-15020010	**844**	**-1.50**	**35.21**	**1.75**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**1,607**	**-13.08**	**23.84**	**0.44**
Oraibi Wash-15020012	**855**	**-6.70**	**9.92**	**0.46**
Polacca Wash-15020013	**1,083**	**-14.64**	**29.00**	**1.51**
Jadito Wash-15020014	**1,040**	**-9.45**	**32.38**	**1.08**
Canyon Diablo-15020015	**1,204**	**-2.31**	**195.89**	**8.70**
Lower Little Colorado River-15020016	**2,399**	**-2.96**	**13.53**	**0.07**
Dinnebito Wash-15020017	**743**	**-5.74**	**4.56**	**-0.10**
Moenkopi Wash-15020018	**2,634**	**-9.86**	**26.91**	**0.66**
Little Colorado River Watershed-150200 (total)	***21,703***	***-21.1***	***195.89***	***0.075***

Mines

There are 527 mineral extraction mines recorded with the Office of the Arizona State Mine Inspector in the Little Colorado Watershed. The Lower Little Colorado River subwatershed (HUC 15020016) has the highest number of mines (75) while there are only two mines reported within the Carrizo Wash subwatershed. Eight different mine types are reported, of which 343 of them (65 %) are open-pit surface mines (Table 4-8 and Figure 4-9).

Mine activity status is tabulated under five different groups, which range between active and inactive production (Table 4-9 and Figure 4-10). The primary types of ore being mined are sand and gravel, pumice and uranium (Table 4-10 and Figure 4-11).

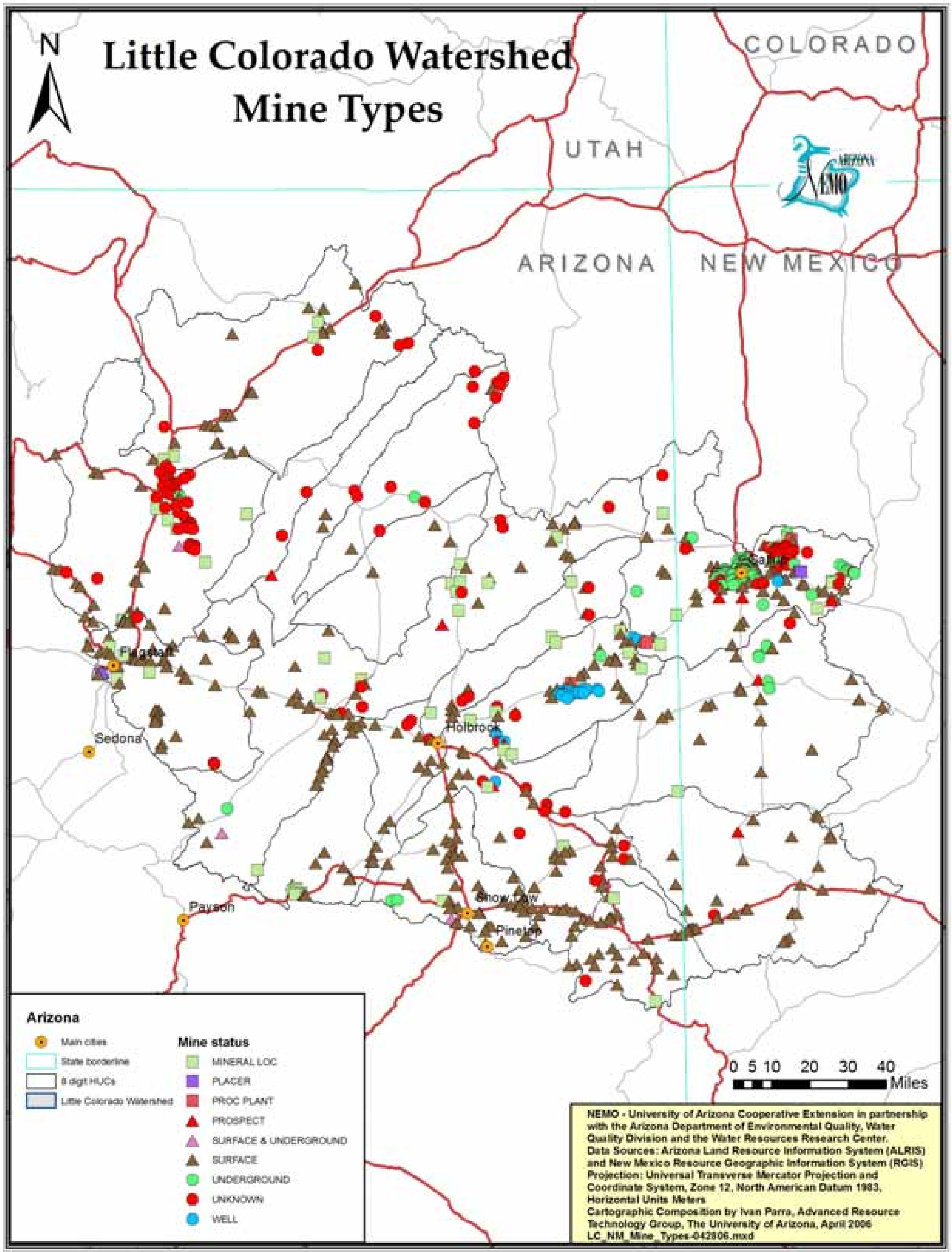

Figure 4-9 Little Colorado Watershed Mine Types.

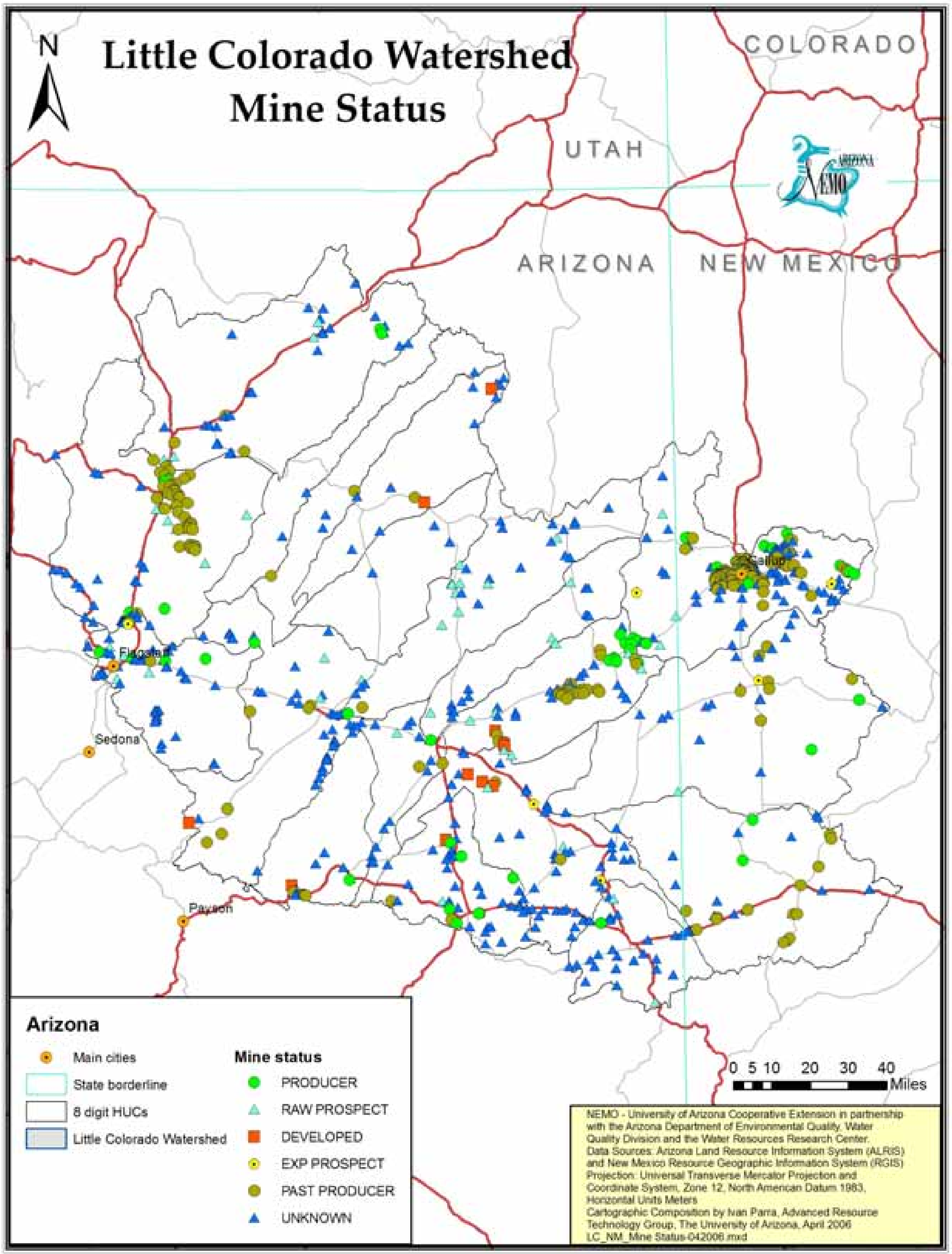

Figure 4-10 Little Colorado Watershed Mines - Status.

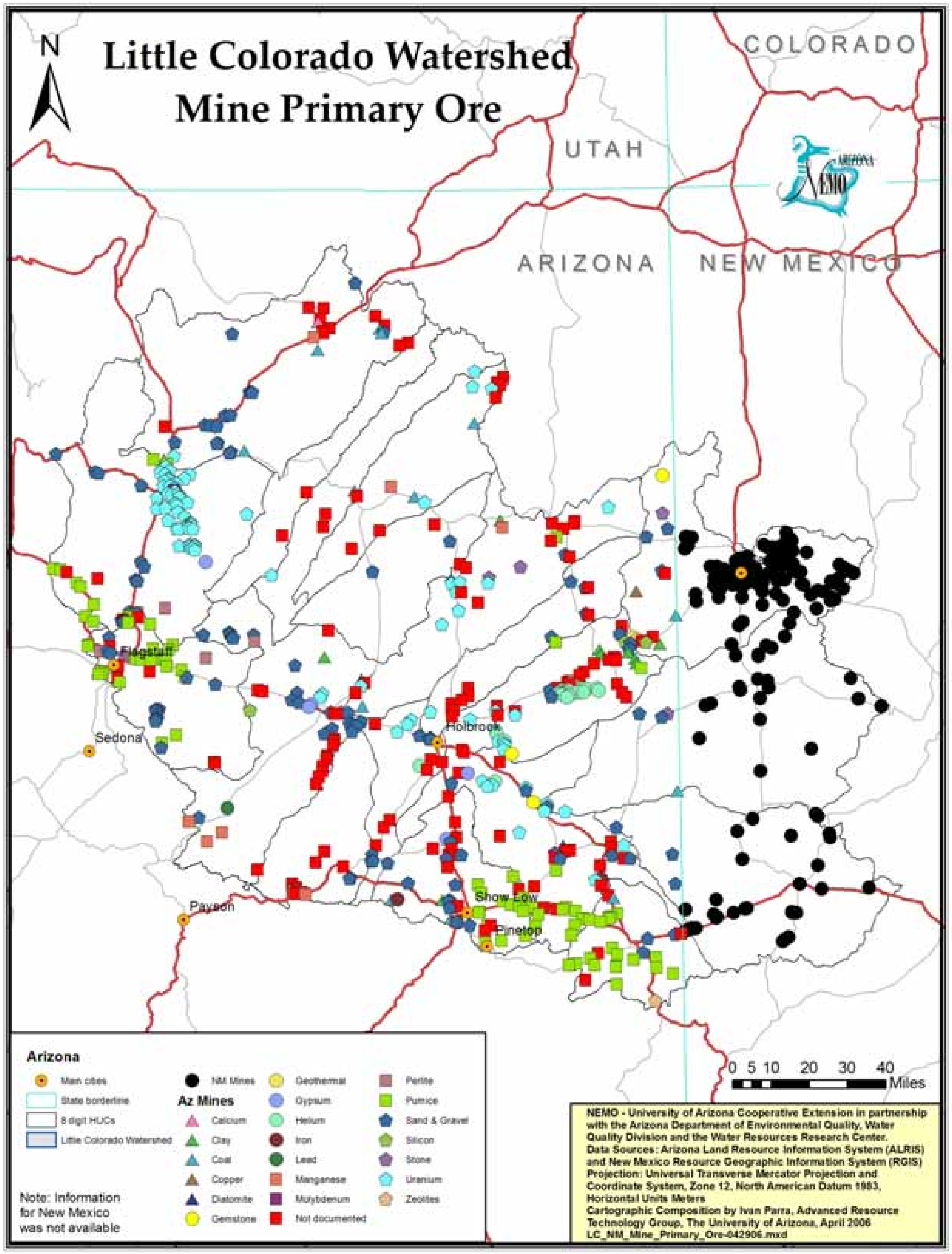

Figure 4- 11 Little Colorado Watershed Mines - Primary Ore.

Table 4- 8 Little Colorado Watershed Mine Types.

Subwatershed Name	Mineral loc	Placer	Proc plant	Prospect	Surf-underg	Surface	Under-ground	Unknown	Well
Little Colorado River Headwaters-15020001	**2**	**0**	**0**	**0**	**0**	**26**	**0**	**1**	**0**
Upper Little Colorado River-15020002	**3**	**0**	**0**	**1**	**0**	**35**	**0**	**7**	**1**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**
Zuni River-15020004	**1**	**0**	**0**	**0**	**0**	**4**	**0**	**2**	**0**
Silver Creek-15020005	**1**	**0**	**0**	**0**	**1**	**42**	**2**	**0**	**0**
Upper Puerco River-15020006	**3**	**0**	**1**	**0**	**0**	**7**	**1**	**1**	**1**
Lower Puerco River-15020007	**7**	**0**	**1**	**3**	**0**	**29**	**1**	**3**	**20**
Middle Little Colorado River-15020008	**4**	**0**	**0**	**0**	**1**	**53**	**1**	**4**	**0**
Wide Ruin Wash-Leroux Wash-15020009	**3**	**0**	**0**	**0**	**0**	**9**	**0**	**5**	**0**
Chevelon Canyon-15020010	**4**	**0**	**0**	**0**	**1**	**10**	**0**	**0**	**0**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**7**	**0**	**0**	**1**	**0**	**15**	**0**	**6**	**0**
Oraibi Wash-15020012	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**2**	**0**
Polacca Wash-15020013	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**10**	**0**
Jadito Wash-15020014	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**
Canyon Diablo-15020015	**4**	**1**	**0**	**0**	**0**	**47**	**0**	**3**	**0**
Lower Little Colorado River-15020016	**7**	**0**	**0**	**0**	**1**	**30**	**1**	**36**	**0**
Dinnebito Wash-15020017	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**0**
Moenkopi Wash-15020018	**4**	**0**	**1**	**0**	**0**	**27**	**0**	**8**	**0**
Little Colorado River Watershed-150200	***50***	***1***	***3***	***6***	***4***	***343***	***7***	***91***	***22***

Table 4-9 Little Colorado Watershed Mines - Status.

Watershed and HUC Name	Devel deposit	Exp prospect	Past producer	Producer	Raw prospect	Unknown
Little Colorado River Headwaters-15020001	**0**	**0**	**0**	**1**	**2**	**26**
Upper Little Colorado River-15020002	**3**	**2**	**2**	**0**	**3**	**37**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**	**2**
Zuni River-15020004	**0**	**0**	**0**	**0**	**1**	**6**
Silver Creek-15020005	**1**	**0**	**3**	**7**	**1**	**34**
Upper Puerco River-15020006	**0**	**1**	**0**	**2**	**3**	**8**
Lower Puerco River-15020007	**3**	**0**	**25**	**10**	**7**	**19**
Middle Little Colorado River-15020008	**1**	**0**	**8**	**1**	**4**	**49**
Wide Ruin Wash-Leroux Wash-15020009	**0**	**0**	**0**	**1**	**3**	**13**
Chevelon Canyon-15020010	**1**	**0**	**4**	**1**	**0**	**9**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0**	**0**	**1**	**1**	**8**	**19**
Oraibi Wash-15020012	**0**	**0**	**1**	**0**	**0**	**3**
Polacca Wash-15020013	**2**	**0**	**1**	**0**	**0**	**10**
Jadito Wash-15020014	**0**	**0**	**0**	**0**	**0**	**3**
Canyon Diablo-15020015	**0**	**1**	**2**	**4**	**4**	**44**
Lower Little Colorado River-15020016	**0**	**0**	**39**	**4**	**5**	**27**
Dinnebito Wash-15020017	**0**	**0**	**1**	**0**	**0**	**3**
Moenkopi Wash-15020018	**0**	**0**	**7**	**2**	**4**	**27**
Little Colorado River Watershed-150200	***11***	***4***	***94***	***34***	***45***	***339***

Table 4- 10 Little Colorado Watershed Mines – Ore Type (part 1 of 2).

Subwatershed Name	Calcium	Clay	Coal	Copper	Diatomite	Gemstone	Geothermal	Gypsum	Helium	Iron	Lead
Little Colorado River Headwaters-15020001	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Upper Little Colorado River-15020002	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**1**	**0**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Zuni River-15020004	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Silver Creek-15020005	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**
Upper Puerco River-15020006	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**
Lower Puerco River-15020007	**0**	**7**	**0**	**0**	**0**	**1**	**1**	**0**	**20**	**0**	**0**

Subwatershed Name	Calcium	Clay	Coal	Copper	Diatomite	Gemstone	Geothermal	Gypsum	Helium	Iron	Lead
Middle Little Colorado River-15020008	0	2	0	0	0	0	0	2	1	0	1
Wide Ruin Wash-Leroux Wash-15020009	0	0	0	0	0	0	0	0	0	0	0
Chevelon Canyon-15020010	0	0	0	0	0	0	0	0	0	0	0
Pueblo Colorado Wash-Cottonwood Wash-15020011	0	1	1	0	0	0	0	0	0	0	0
Oraibi Wash-15020012	0	0	1	0	0	0	0	0	0	0	0
Polacca Wash-15020013	0	0	2	0	0	0	0	0	0	0	0
Jadito Wash-15020014	0	0	0	0	0	0	0	0	0	0	0
Canyon Diablo-15020015	0	0	0	0	0	0	0	0	0	0	0
Lower Little Colorado River-15020016	0	0	0	0	0	0	0	1	0	0	0
Dinnebito Wash-15020017	0	0	0	0	0	0	0	0	0	0	0
Moenkopi Wash-15020018	1	1	4	0	0	0	0	0	0	0	0
Little Colorado River Watershed-150200	*1*	*13*	*13*	*1*	*1*	*3*	*2*	*5*	*22*	*2*	*1*

Table 4- 10 Little Colorado Watershed Mines – Ore Type (part 2 of 2).

Subwatershed Name	Man-ganese	Molyb-denum	Not docu-mented	Perlite	Pumice	Sand & Gravel	Silicon	Stone	Uranium	Zeolites
Little Colorado River Headwaters-15020001	0	0	4	0	20	3	0	0	0	1
Upper Little Colorado River-15020002	0	0	16	0	10	7	0	0	9	0
Carrizo Wash-15020003	0	0	0	0	0	2	0	0	0	0
Zuni River-15020004	0	0	0	0	0	3	0	1	2	0
Silver Creek-15020005	0	0	13	0	17	11	0	0	0	0
Upper Puerco River-15020006	0	0	4	0	0	3	1	1	0	0
Lower Puerco River-15020007	0	0	20	0	2	5	1	0	7	0

Subwatershed Name	Man-ganese	Molyb-denum	Not docu-mented	Perlite	Pumice	Sand & Gravel	Silicon	Stone	Uranium	Zeolites
Middle Little Colorado River-15020008	**3**	**0**	**23**	**1**	**0**	**23**	**1**	**0**	**6**	**0**
Wide Ruin Wash-Leroux Wash-15020009	**0**	**0**	**9**	**0**	**0**	**7**	**0**	**0**	**1**	**0**
Chevelon Canyon-15020010	**4**	**0**	**8**	**0**	**0**	**3**	**0**	**0**	**0**	**0**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**1**	**0**	**12**	**0**	**1**	**3**	**0**	**2**	**8**	**0**
Oraibi Wash-15020012	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**1**	**0**
Polacca Wash-15020013	**1**	**0**	**7**	**0**	**0**	**0**	**0**	**0**	**3**	**0**
Jadito Wash-15020014	**0**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**
Canyon Diablo-15020015	**0**	**0**	**7**	**3**	**27**	**17**	**0**	**1**	**0**	**0**
Lower Little Colorado River-15020016	**0**	**1**	**4**	**2**	**10**	**14**	**0**	**0**	**43**	**0**
Dinnebito Wash-15020017	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**1**	**0**
Moenkopi Wash-15020018	**1**	**0**	**10**	**0**	**1**	**16**	**0**	**0**	**6**	**0**
Little Colorado River Watershed-150200	***10***	***1***	***143***	***6***	***88***	***119***	***3***	***5***	***87***	***1***

Land use

The land cover conditions from data obtained during the early 1990's were obtained using the National Land Cover Dataset (NLCD). The NLCD classification contains 21 different land cover categories from which 18 classes are represented within the Little Colorado watershed (Figure 4-12 and Table 4-11).

The most common land cover across the watershed is shrub-land, which makes up 63% of the area. Evergreen forests and grassland/herbaceous cover types are the next most common types with 22% and 13% coverage, respectively, over the total area.

Figure 4-12 Little Colorado Watershed Land Cover.

Table 4- 11 Little Colorado Watershed Land Cover (part 1 of 3)

Subwatershed Name	Bare Rock/ Sand/Clay	Commercial /Industrial /Transport	Deciduous Forest	Emergent Herbaceous Wetlands	Evergreen Forest	Grasslands/ Herbaceous
Little Colorado River Headwaters-15020001	**1%**	**0%**	**0%**	**0.1%**	**36%**	**6%**
Upper Little Colorado River-15020002	**1%**	**0%**	**0%**	**0%**	**14%**	**4%**
Carrizo Wash-15020003	**2%**	**0%**	**0%**	**0%**	**17%**	**14%**
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**29%**	**9%**
Silver Creek-15020005	**0%**	**0%**	**0%**	**0%**	**53%**	**7%**
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**56%**	**3%**
Lower Puerco River-15020007	**2%**	**0.3%**	**0%**	**0%**	**12%**	**6%**
Middle Little Colorado River-15020008	**2%**	**0%**	**0%**	**0%**	**21%**	**9%**
Wide Ruin Wash-Leroux Wash-15020009	**3%**	**0%**	**0%**	**0%**	**21%**	**6%**
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**0%**	**53%**	**10%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**4%**	**0%**	**0%**	**0%**	**14%**	**9%**
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**21%**	**14%**
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**15%**	**15%**
Jadito Wash-15020014	**5%**	**0%**	**0%**	**0%**	**5%**	**14%**
Canyon Diablo-15020015	**0%**	**0.3%**	**0%**	**0%**	**44%**	**11%**
Lower Little Colorado River-15020016	**2%**	**0%**	**0%**	**0%**	**16%**	**16%**
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**15%**	**16%**
Moenkopi Wash-15020018	**0%**	**0%**	**0%**	**0%**	**8%**	**33%**
Little Colorado River Watershed-150200 (total)	***1%***	***0.1%***	***0%***	***0%***	***22%***	***13%***

Table 4- 11 Little Colorado Watershed Land Cover (part 2 of 3)

Subwatershed Name	Low Intensity Residential	Mixed Forest	Open Water	Orchards/ Vineyards/ Other	Pasture/Hay	Quarries/Strip Mines/Gravel Pit
Little Colorado River Headwaters-15020001	**0%**	**0%**	**1%**	**0%**	**1%**	**0%**
Upper Little Colorado River-15020002	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Carrizo Wash-15020003	**0%**	**0%**	**0%**	**0%**	**0%**	**0.4%**
Zuni River-15020004	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**
Upper Puerco River-15020006	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lower Puerco River-15020007	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Middle Little Colorado River-15020008	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Chevelon Canyon-15020010	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Oraibi Wash-15020012	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Jadito Wash-15020014	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Canyon Diablo-15020015	**0.4%**	**2%**	**1%**	**0%**	**0%**	**0%**
Lower Little Colorado River-15020016	**0%**	**1%**	**0%**	**0%**	**0%**	**0%**
Dinnebito Wash-15020017	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Moenkopi Wash-15020018	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Little Colorado River Watershed-150200 (total)	***0.1%***	***0.2%***	***0%***	***0%***	***0.1%***	***0.1%***

Table 4- 11 Little Colorado Watershed Land Cover (part 3 of 3)

Subwatershed Name	Row Crops	Shrubland	Small Grains	Transitional	Urban/ Recreational Grasses	Woody Wetlands
Little Colorado River Headwaters-15020001	**0%**	**55%**	**0%**	**0%**	**0%**	**0%**
Upper Little Colorado River-15020002	**0%**	**79%**	**0%**	**0%**	**0%**	**0%**
Carrizo Wash-15020003	**0%**	**67%**	**0%**	**0%**	**0%**	**0%**
Zuni River-15020004	**0%**	**61%**	**0%**	**0%**	**0%**	**0%**
Silver Creek-15020005	**0.1%**	**37%**	**0.1%**	**0%**	**0.1%**	**0%**
Upper Puerco River-15020006	**0%**	**40%**	**0%**	**0%**	**0%**	**0%**

Subwatershed Name	Row Crops	Shrubland	Small Grains	Transitional	Urban/ Recreational Grasses	Woody Wetlands
Lower Puerco River-15020007	**0%**	**80%**	**0%**	**0%**	**0%**	**0%**
Middle Little Colorado River-15020008	**0%**	**68%**	**0%**	**0%**	**0%**	**0%**
Wide Ruin Wash-Leroux Wash-15020009	**0%**	**70%**	**0%**	**0%**	**0%**	**0%**
Chevelon Canyon-15020010	**0%**	**37%**	**0%**	**0%**	**0%**	**0%**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0%**	**72%**	**0%**	**0%**	**0%**	**0%**
Oraibi Wash-15020012	**0%**	**64%**	**0%**	**0%**	**0%**	**0%**
Polacca Wash-15020013	**0%**	**69%**	**0%**	**0%**	**0%**	**0.5%**
Jadito Wash-15020014	**0%**	**76%**	**0%**	**0%**	**0%**	**0%**
Canyon Diablo-15020015	**0%**	**41%**	**0%**	**0%**	**0%**	**0%**
Lower Little Colorado River-15020016	**0%**	**66%**	**0%**	**0%**	**0%**	**0%**
Dinnebito Wash-15020017	**0%**	**69%**	**0%**	**0%**	**0%**	**0%**
Moenkopi Wash-15020018	**0%**	**58%**	**0%**	**0%**	**0%**	**0%**
Little Colorado River Watershed-150200 (total)	***0%***	***63%***	***0%***	***0%***	***0%***	***0.1%***

Land Ownership

In the Little Colorado Watershed, there are 22 different land ownership entities (Figure 4-13 and Table 4-12). Forty-six percent of the total watershed is owned by Native American Tribes. As individual categories, the Navajo Indian Reservation and Private are the most significant land owners with nearly 35% and 19% of the watershed, respectively.

The Navajo Indian Reservation owns 93.5% of the Upper Puerco River subwatershed, 82.8% Pueblo Colorado Wash-Cottonwood Wash subwatershed, and 74% of the Wide Ruin Wash-Leroux Wash subwatershed. More than half of Upper Little Colorado River (59%) is privately owned.

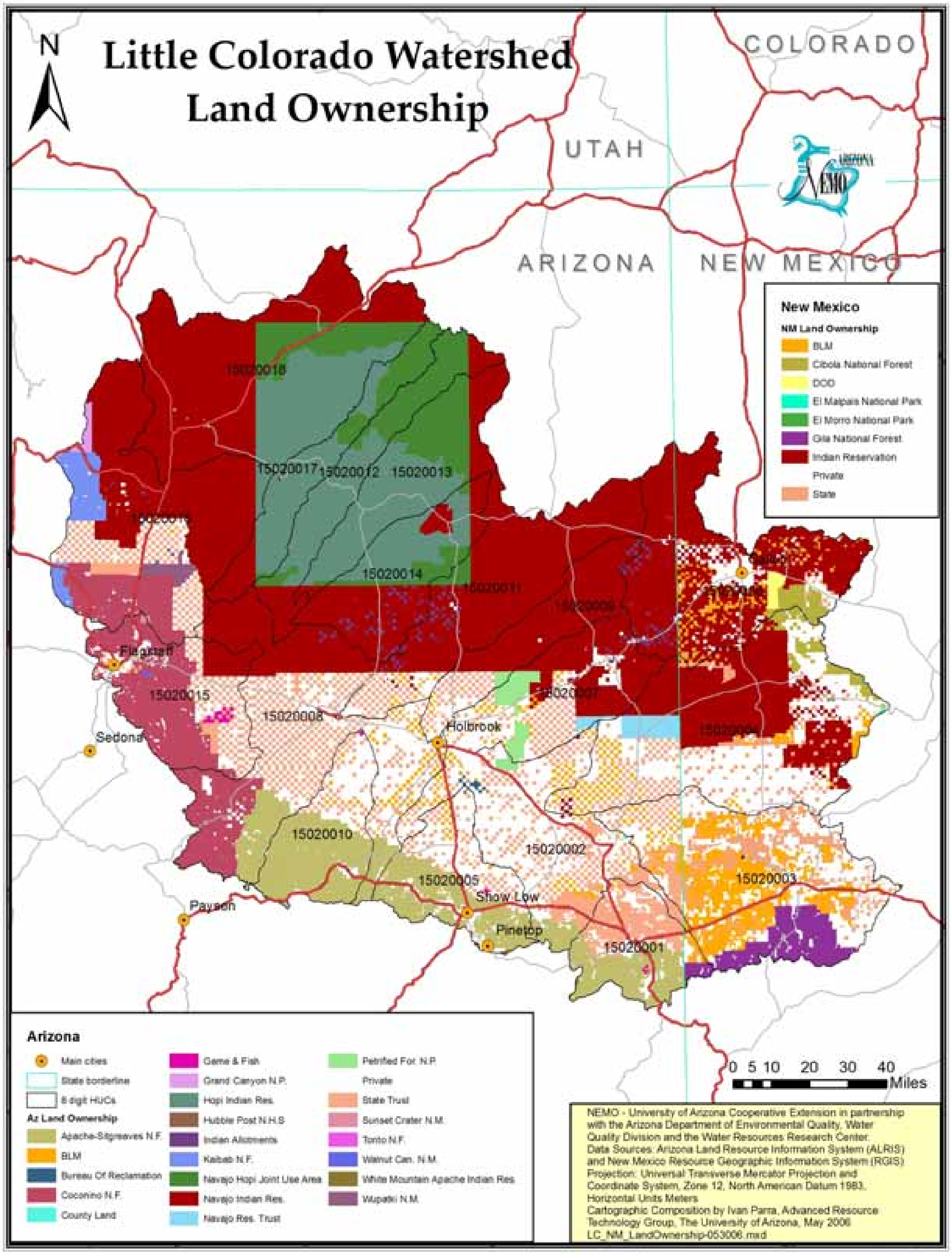

Figure 4-13 Little Colorado Watershed Land Ownership.

Table 4- 12 Little Colorado Watershed Land Ownership (part 1 of 3).

Owner	LCR Headwaters -15020001	Upper LCR -15020002	Carrizo Wash- 15020003	Zuni River- 15020004	Silver Creek- 15020005	Upper Puerco River- 15020006
Private	**16.7**	**59.4**	**44.8**	**43.3**	**41.1**	**0.8**
State Trust	**38.1**	**29.1**	**39.2**	**16.5**	**10.4**	**0.0**
BLM	**0.3**	**4.6**	**15.9**	**9.3**	**1.7**	**0.0**
Apache-Sitgreaves NF	**44.0**	**4.7**	**0.0**	**0.0**	**46.1**	**0.0**
Kaibab N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Tonto N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Coconino N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Hopi Indian Res.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Navajo Indian Res.	**0.0**	**0.2**	**0.0**	**18.5**	**0.0**	**93.5**
White Mountain Apache Indian Res.	**0.3**	**0.0**	**0.0**	**0.0**	**0.5**	**0.0**
Grand Canyon N.P.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Petrified Forest N.P.	**0.0**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**
Sunset Crater N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Wupatki N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Walnut Canyon N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Hubble Post N.H.S	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Game & Fish	**0.5**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**
County Land	**0.0**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**
Navajo Res. Trust	**0.0**	**0.2**	**0.0**	**12.5**	**0.0**	**0.0**
Indian Allotments	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**5.8**
Bureau Of Reclamation	**0.0**	**0.5**	**0.0**	**0.0**	**0.1**	**0.0**
Navajo Hopi Joint Use Area	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total (square miles)	***722***	***1,609***	***335***	***735***	***947***	***550***

Table 4- 12 Little Colorado Watershed Land Ownership (part 2 of 3).

Owner	Lower Puerco River- 15020007	Middle LCR -15020008	Wide Ruin Wash- Leroux Wash- 15020009	Chevelon Canyon- 15020010	Pueblo Colorado Wash- Cottonwood Wash- 15020011	Oraibi Wash- 15020012
Private	**29.3**	**33.6**	**14.6**	**28.6**	**7.7**	**0.0**
State Trust	**10.7**	**17.6**	**8.3**	**7.4**	**4.1**	**0.0**
BLM	**2.8**	**2.1**	**0.8**	**1.2**	**0.8**	**0.0**
Apache-Sitgreaves NF	**0.0**	**10.8**	**0.0**	**62.6**	**0.0**	**0.0**
Kaibab N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Tonto N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Coconino N.F.	**0.0**	**15.2**	**0.0**	**0.0**	**0.0**	**0.0**

Owner	Lower Puerco River-15020007	Middle LCR -15020008	Wide Ruin Wash-Leroux Wash-15020009	Chevelon Canyon-15020010	Pueblo Colorado Wash-Cottonwood Wash-15020011	Oraibi Wash-15020012
Hopi Indian Res.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**44.1**
Navajo Indian Res.	**44.4**	**20.5**	**73.8**	**0.0**	**82.8**	**19.6**
White Mountain Apache Indian Res.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Grand Canyon N.P.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Petrified Forest N.P.	**10.3**	**0.0**	**1.8**	**0.0**	**0.0**	**0.0**
Sunset Crater N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Wupatki N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Walnut Can. N.M.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Hubble Post N.H.S	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Game & Fish	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
County Land	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Navajo Res. Trust	**1.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Indian Allotments	**0.7**	**0.2**	**0.7**	**0.0**	**2.0**	**0.0**
Bureau Of Reclamation	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Navajo Hopi Joint Use Area	**0.0**	**0.0**	**0.0**	**0.0**	**2.6**	**36.3**
Total (square miles)	***1,119***	***2,470***	***807***	***844***	***1,607***	***855***

Table 4- 12 Little Colorado Watershed Land Ownership (part 3 of 3).

Owner	Polacca Wash-15020013	Jadito Wash-15020014	Canyon Diablo-15020015	Lower LCR -15020016	Dinnebito Wash-15020017	Moenkopi Wash-15020018
Private	**0.0**	**0.0**	**20.0**	**9.7**	**0.0**	**0.0**
State Trust	**0.0**	**0.0**	**15.2**	**9.3**	**0.0**	**0.0**
BLM	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
Apache-Sitgreaves NF	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Kaibab N.F.	**0.0**	**0.0**	**0.0**	**8.5**	**0.0**	**0.0**
Tonto N.F.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Coconino N.F.	**0.0**	**0.0**	**54.1**	**15.4**	**0.0**	**0.0**
Hopi Indian Res.	**52.9**	**33.8**	**0.0**	**1.7**	**56.3**	**25.5**
Navajo Indian Res.	**17.6**	**51.6**	**8.9**	**51.1**	**15.2**	**60.7**
White Mountain Apache Indian Res.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Grand Canyon N.P.	**0.0**	**0.0**	**0.0**	**1.5**	**0.0**	**0.0**
Petrified Forest N.P.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Sunset Crater N.M.	**0.0**	**0.0**	**0.3**	**0.1**	**0.0**	**0.0**
Wupatki N.M.	**0.0**	**0.0**	**0.0**	**2.4**	**0.0**	**0.0**
Walnut Canyon N.M.	**0.0**	**0.0**	**0.2**	**0.0**	**0.0**	**0.0**

Owner	Polacca Wash-15020013	Jadito Wash-15020014	Canyon Diablo-15020015	Lower LCR - 15020016	Dinnebito Wash-15020017	Moenkopi Wash-15020018
Hubble Post N.H.S	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Game & Fish	**0.0**	**0.0**	**1.3**	**0.0**	**0.0**	**0.0**
County Land	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Navajo Res. Trust	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Indian Allotments	**0.0**	**3.3**	**0.0**	**0.3**	**0.0**	**0.0**
Bureau Of Reclamation	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Navajo Hopi Joint Use Area	**29.5**	**11.3**	**0.0**	**0.0**	**28.5**	**13.8**
Total (square miles)	***1,083***	***1,040***	***1,204***	***2,399***	***743***	***2,634***

Special Areas

Preserves

Preserves listed here are part of the Arizona Preserve Initiative (API). The API was passed by the Arizona State Legislature as HB 2555 and signed into law by the Governor in the spring of 1996. It is designed to encourage the preservation of select parcels of state Trust land in and around urban areas for open space to benefit future generations. The law lays out a process by which Trust land can be leased for up to 50 years or sold for conservation purposes. Leases and sales must both occur at a public auction (http://www.land.state.az.us/programs/operations/api.htm).

Figure 4-14 shows the boundaries of the preserve lands within the Little Colorado Watershed. The State Trust lands within these 369,698 acres are eligible to be designated as Arizona Preserve Initiative land. Table 4-13 show the API areas for each subwatershed.

The Silver Creek subwatershed has the greatest area of API land within the Little Colorado Watershed with a total of 119,773 acres.

Wilderness

There are six different wilderness areas within the Little Colorado watershed, which comprise a total of 3,922 acres, or nearly 3% of the watershed (Figure 4-15 and Table 4-14). The largest wilderness area in the watershed is the Petrified Forest National Park with approximately 51,036 acres of area, which comprises 55% of all the wilderness areas in the watershed. The second largest area is the Kachina Peaks Wilderness Area, which comprises 18% of the watershed. The Lower Puerco River subwatershed has the greatest mapped wilderness area within the watershed with 38,681 acres.

Golf Courses

Although existing databases do not record golf courses, it is understood that several golf courses have been developed across the watershed. The basis of our information is ESRI Data and Maps (2001).

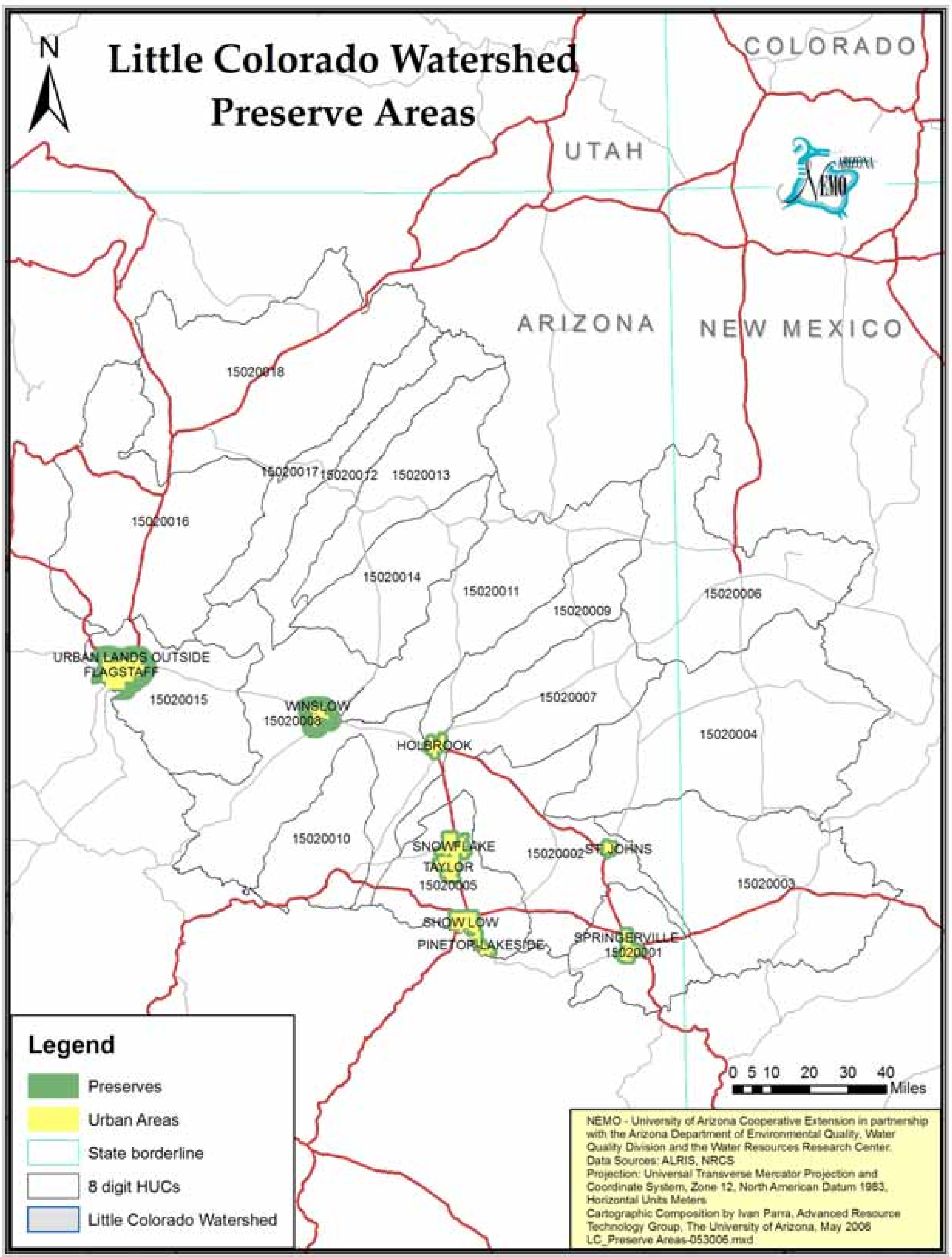

Figure 4- 14 Little Colorado Watershed Preserve Areas.

Table 4- 13 Little Colorado Watershed Preserve Areas.

Subwatershed Name	Preserve Area (sq miles)	Preserve Area (acre)
Little Colorado River Headwaters-15020001	722	35,518
Upper Little Colorado River-15020002	1,609	14,277
Carrizo Wash-15020003	335	0
Zuni River-15020004	735	0
Silver Creek-15020005	947	119,773
Upper Puerco River-15020006	550	0
Lower Puerco River-15020007	1,119	2,842
Middle Little Colorado River-15020008	2,470	77,899
Wide Ruin Wash-Leroux Wash-15020009	807	7,003
Chevelon Canyon-15020010	844	0
Pueblo Colorado Wash-Cottonwood Wash-15020011	1,607	1,425
Oraibi Wash-15020012	855	0
Polacca Wash-15020013	1,083	0
Jadito Wash-15020014	1,040	0
Canyon Diablo-15020015	1,204	110,961
Lower Little Colorado River-15020016	2,399	0
Dinnebito Wash-15020017	743	0
Moenkopi Wash-15020018	2,634	0
Little Colorado River Watershed-150200 (total)	*21,701*	*369,698*

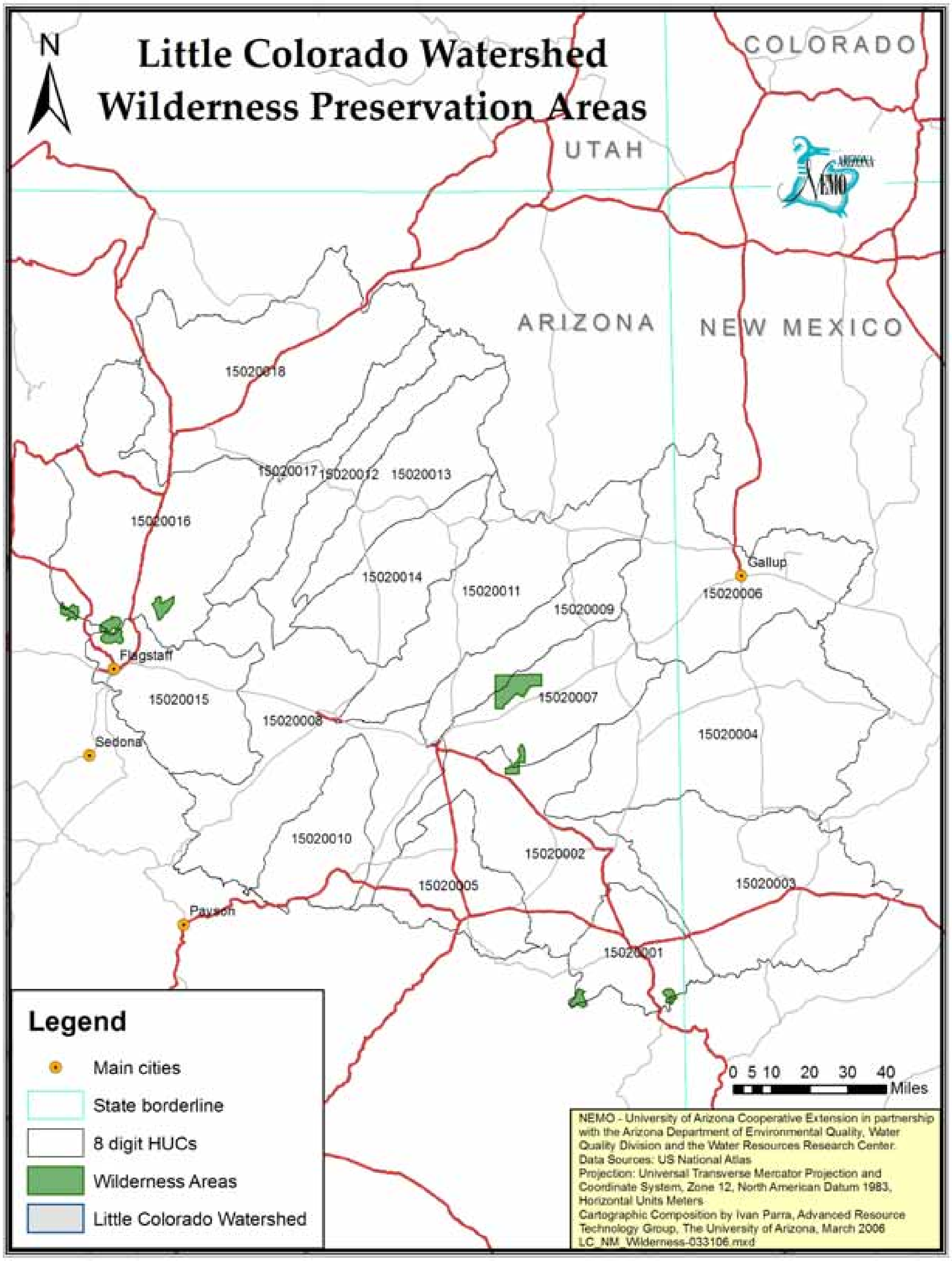

Figure 4- 15 Little Colorado Watershed Wilderness Areas.

Table 4- 14 Little Colorado Watershed Wilderness Areas (acres).

Subwatershed Name	Strawberry Crater	Kendrick Mountain	Kachina Peaks	Petrified Forest National Park	Mount Baldy	Escudilla
Little Colorado River Headwaters-15020001	**0**	**0**	**0**	**0**	**7,295**	**3,922**
Upper Little Colorado River-15020002	**0**	**0**	**0**	**4,382**	**0**	**0**
Carrizo Wash-15020003	**0**	**0**	**0**	**0**	**0**	**0**
Zuni River-15020004	**0**	**0**	**0**	**0**	**0**	**0**
Silver Creek-15020005	**0**	**0**	**0**	**0**	**0**	**0**
Upper Puerco River-15020006	**0**	**0**	**0**	**0**	**0**	**0**
Lower Puerco River-15020007	**0**	**0**	**0**	**38,681**	**0**	**0**
Middle Little Colorado River-15020008	**0**	**0**	**0**	**0**	**0**	**0**
Wide Ruin Wash-Leroux Wash-15020009	**0**	**0**	**0**	**7,974**	**0**	**0**
Chevelon Canyon-15020010	**0**	**0**	**0**	**0**	**0**	**0**
Pueblo Colorado Wash-Cottonwood Wash-15020011	**0**	**0**	**0**	**0**	**0**	**0**
Oraibi Wash-15020012	**0**	**0**	**0**	**0**	**0**	**0**
Polacca Wash-15020013	**0**	**0**	**0**	**0**	**0**	**0**
Jadito Wash-15020014	**0**	**0**	**0**	**0**	**0**	**0**
Canyon Diablo-15020015	**0**	**0**	**8,621**	**0**	**0**	**0**
Lower Little Colorado River-15020016	**11,268**	**3,079**	**8,430**	**0**	**0**	**0**
Dinnebito Wash-15020017	**0**	**0**	**0**	**0**	**0**	**0**
Moenkopi Wash-15020018	**0**	**0**	**0**	**0**	**0**	**0**
Little Colorado River Watershed-150200 (total)	***11,268***	***3,079***	***17,051***	***51,036***	***7,295***	***3,922***

<u>References</u>

GeoLytics, Inc. 1998. Census 1990. Census CD + Maps. Release 3.0.

<u>Data Sources*</u>

Advanced Resource Technology Group, The University of Arizona
Arizona Land Ownership, March 2005

EPA Clean Air Markets, http://www.epa.gov/airmarkets/cmap/data/index.html
Major Land Resource Areas, May 15, 2005

ESRI Data and Maps, http://www.esri.com/data/index.html
Arizona Urban Areas (U.S. Bureau of the Census, Census 2000 TIGER/Line® Data), July 27, 2005
New Mexico Urban Areas (U.S. Bureau of the Census, Census 2000
Arizona Census Blocks 2000 data layer, Dec 05 2005
Arizona Census Blocks 1990 data layer, Dec 05 2005
New Mexico Census Blocks 1990 data layer, Dec 05 2005
New Mexico Census Blocks 2000 data layer, Dec 05 2005
AZ Census Block Demographics (SF1), Dec 05 2005
NM Census Block Demographics (SF1), Dec 05 2005

ESRI Data and Maps. 2001. 7 CD set: CD 3, no.85913.
Golf Courses. 2003

NRCS Data Gateway, http://datagateway.nrcs.usda.gov/
2002 Arizona Tiger Census Blocks, August 16, 2005
2002 New Mexico Tiger Census Blocks, August 16, 2005

New Mexico Resource Geographic Information System (RGIS), http://rgis.unm.edu/intro.cfm
New Mexico Counties, June 20, 2005
New Mexico Land Ownership, June 20, 2005
New Mexico Minerals Industry Locator System (MILS), August 16, 2005

US National Atlas, http://nationalatlas.gov/index.html
Cities and Towns of the United States, May 18, 2005
State Boundaries of the United States, March 30, 2005
Major Roads of the United States, May 18, 2005
Wilderness Preservation System Areas, July 11, 2005

US Census Bureau, Cartographic Boundary Files http://www.census.gov/geo/www/cob/metadata.html
Census 1990 Urbanized Areas, September 19, 2005
Census 2000 Urbanized Areas, September 19, 2005
AZ and NM 1990 Census of Population and Housing. December 5 2005

**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and a general description of the data.*

Section 5: Important Resources

The Little Colorado Watershed contains many important natural resources, with national, regional and local significance. It is home to Grand Canyon National Park, Painted Desert National Park, the Petrified Forest and Wupatki National Monuments, Sunset Crater, Kachina Peaks, Kendrick Mountain and Mount Baldy Wilderness areas. Mormon Lake, the largest natural fresh water body in Arizona is located in this watershed. The little Colorado Watershed also includes a significant portion of the Navajo and Hopi Reservations. The watershed contains critical habitat for the Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004) and important recreational resources including extensive wilderness areas with hiking, bird watching and fishing.

As a result of our analysis, nine Natural Resource Areas (NRAs) have been identified for protection based on the combination of natural resource values. Factors that were considered in delineating these areas include: legal status (unique waters, critical habitat for threatened and endangered species, national monuments and wilderness areas), the presence of perennial waters, riparian areas, state parks, forests, recreational resources and local values.

The nine identified Natural Resource Areas consist of the following groupings of 10-digit HUCS:

1. *Lower Little Colorado River NRA:* Sheep Wash-Lower Little Colorado River, Lee Canyon-Lower Little Colorado River.

2. *Black Creek Colorado River NRA:* Upper Black Creek, Lower Black Creek, Upper Pueblo Colorado Wash, Middle Pueblo Colorado Wash.

3. *Clear Creek Chevelon Canyon NRA:* Jacks Canyon, Lower Clear Creek, Upper Clear Creek, Upper Chevelon Canyon, Lower Chevelon Canyon, Black Canyon, Phoenix Park Wash-Dry Lake, Cottonwood Creek.

4. *Walnut Canyon NRA:* Citadel Wash-Lower Little Colorado River, Deadman Wash, Kana-a Wash-Lower Little Colorado River, Rio de Flag, San Francisco Wash, Walnut Creek, Canyon Diablo.

5. *McDonald Canyon-Middle Little Colorado River NRA:* McDonald Canyon-Middle Little Colorado River.

6. *Cedar Wash NRA:* Lower Cedar Wash, Upper Cedar Wash.

7. *Oraibi Wash NRA:* Moenkopi Wash Headwaters, Upper Dinnebito Wash, Upper Oraibi Wash, Upper Polacca Wash.

8. *Puerco River Wash NRA:* Leroux Wash, Lithodendron Wash-Lower Puerco River, Washboard Wash-Upper Little Colorado River, Ninemile Wash-Lower Puerco River, Dry Wash, Milky Wash.

9. *Upper Little Colorado River, Lyman Lake to Big Hollow Wash NRA:* Lower Silver Creek, Show Low Creek, Upper Silver Creek,

Oso Draw, Big Hollow Wash, Carnero Creek-Little Colorado River Headwaters, Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Coyote Creek, Nutrioso Creek, South Fork Little Colorado River-Little Colorado River Headwaters.

The NRAs have been categorized within the 10-digit HUC subwatershed area where they are located. Several 10-digit contiguous HUCs have been combined to form a unique NRA based on criteria such as State Parks, Forests, National Monuments, Wilderness and endangered species areas they have in common. The significance of each area is discussed in the following paragraphs.

Lower Little Colorado River NRA

This NRA includes two 10-digit HUC subwatersheds: Sheep Wash-Lower Little Colorado River and Lee Canyon-Lower Little Colorado River. The Lower Little Colorado River-NRA contains a portion of the Grand Canyon National Park, a portion of the Kaibab National Forest, and a section of the Little Colorado River.
The Grand Canyon National Park is 277 miles long, an average of 10 miles wide and nearly 1 mile deep. The Grand Canyon is widely proclaimed as one of the wonders of the natural world. Since Grand Canyon was set aside as a National Monument by Theodore Roosevelt in 1908, and achieved official park status by Congress in 1919, millions of visitors have journeyed to see this awe-inspiring site. The very southeastern section of the Grand Canyon National Park is found in the Lower Little Colorado River NRA (a portion of the south rim). The South Rim of Grand Canyon averages 7,000 feet above sea level (National Park Service, 2006). The southeastern portion of the Kaibab National Forest, Tusayan, is located in the Lower Little Colorado River NRA. The Tusayan sits on the south rim of the Grand Canyon and is made up of aspen groves and lush pine forests. In 1934, the Tusayan National Forest south of the Grand Canyon was consolidated into the Kaibab National Forest.
The Lower Little Colorado River NRA also contains a portion of the Little Colorado River. The Little Colorado River is a tributary of the Colorado River, approximately 315 mi (507 km) long. The river provides the principal drainage for the Painted Desert. It rises in eastern Arizona, in southeastern Apache County, and flows northwest, through a series of deep gorges, past the towns of St. Johns, Holbrook, and Winslow. It joins the Colorado in the Grand Canyon, approximately 70 mi (113 km) north of Flagstaff (http://en.wikipedia.org/wiki/Little_Colorado_River).

Black Creek Colorado River NRA

This NRA includes four 10-digit HUC subwatersheds: Upper Black Creek, Lower Black Creek, Upper Pueblo Colorado Wash and Middle Pueblo Colorado Wash. The Black Creek Colorado River NRA includes Mexican Spotted Owl habitat and several ADEQ designated unique waters, as well as critical riparian zones.

Ganado Lake, which has fishing, camping, hiking and picniking opportunities, is also located in this NRA.

This NRA contains a portion of Mexican Spotted Owl habitat. The Mexican spotted owl was listed as a threatened species on 15 April 1993 (U.S. Fish & Wildlife Service, 2004).

The Hubbell Trading Post National Historic Site is located on the Navajo Reservation. The trading post was purchased by John Lorenzo Hubbell in 1878, and the Hubbell family operated the post until it was sold to the National Park Service in 1967. The trading post is still active, and operated by a non-profit organization that maintains the trading traditions the Hubbell family established. The site consists of the original 160 acre homestead, with the trading post, family home and visitor center as the primary attractions (National Park Service, 2005).

Clear Creek Chevelon Canyon NRA

This NRA contains eight 10-digit HUC subwatersheds: Jacks Canyon, Lower Clear Creek, Upper Clear Creek, Upper Chevelon Canyon, Lower Chevelon Canyon, Black Canyon, Phoenix Park Wash-Dry Lake and Cottonwood Creek. The Clear Creek Chevelon Canyon NRA includes several perennial streams, lakes, two national forests, Mexican Spotted Owl habitat, the Mogollon Rim Botanical Area, the Chevelon Canyon Ranch Wildlife area, and a Wildcat Research Natural Area (RNA).

This NRA contains portions of the Coconino and Apache-Sitgreaves National Forest. The Mormon Lake Ranger District of the Coconino National Forest occurs within this NRA. It contains ponderosa pine forests and pinyon, juniper woodlands clustered around broad prairies and small lakes.

The Apache-Sitgreaves National Forest encompasses magnificent mountain country in the eastern portion of the NRA along the Mogollon Rim and the White Mountains. On the Sitgreaves, the major attractions for visitors from the hot valleys of Phoenix or Tucson are the Mogollon Rim and strings of man-made lakes. From the Rim's 7,600-foot elevation, vista points provide inspiring views of the low country to the south and west. The Mogollon Rim, a 2,000-foot (600 m) escarpment, cuts across the central section of the state and marks the southwestern edge of the Colorado Plateau (Source Wikipedia).

The Chevelon Canyon Ranch Wildlife area is managed by Arizona Game and Fish. This area provides great opportunities to enjoy the cool mountain weather atop the Mogollon Rim, as well as possibilities to view wildlife, including mule deer, elk, turkey, falcons, hawks, bats and reptiles. The excellent stream, meadow and upland pine habitats attract many species of wildlife (Arizona Game and Fish, 2006).

Dry Lake, Hay Lake and Tremaine Lake, all man made lakes, are found in the Clear Creek Chevelon Canyon NRA.

Walnut Canyon NRA

This NRA is made up of seven 10-digit HUC subwatersheds: Citadel Wash-Lower Little Colorado River, Deadman Wash, Kana-a Wash-Lower Little Colorado River, Rio de Flag, San Francisco Wash, Walnut Creek, and Canyon Diablo. It contains portions of a National Forest, several wilderness areas, several national monuments, endangered species habitat, lakes, perennial streams and a historic park.

Wupatki National Monument is one of several sites preserving pueblos (houses) of ancient peoples, but unlike the Tonto, Montezuma, Casa Grande and Tuzigoot monuments where there is only one main building, here there are many ruins scattered over a large area of desert northeast of Flagstaff. The pueblos all have a distinctive red color and were made from the local Moenkopi sandstone. All the houses were inhabited by the Anasazi and Sinagua Indians during the 12th and 13th centuries. The settlement of this region was influenced by the eruption of nearby Sunset Volcano during the winter of 1064-5, as the resulting ash and lava made the surrounding land infertile and so the residents of that area moved further afield into land previously considered too dry and barren. In the early 13th century all the pueblos were abandoned, as were most other settlements in this part of the Southwest, although it is believed that the present day Hopi are descended from the former inhabitants of this region (www.americansouthwest.net).

Sunset Crater Volcano National Monument is located northeast of Flagstaff and contains the results of much volcanic activity including several colorful cinder cones formed by extinct volcanoes, and large expanses of lava and ash. The dominant peak is Sunset Crater; as with the other cones it has distinctive dusky red-brown patches formed by oxidized iron and sulphur - this caused John Wesley Powell, who was the first modern-day explorer of the area in 1887, to name the mountain 'Sunset Peak'. The contrasting colors of the cinders provide the most striking aspect of the Monument but the buckled and twisted lava fields are also very dramatic (www.americansouthwest.net).

Walnut Canyon National Monument, an Arizona National Park Service historical site is located in densely-wooded country southeast of Flagstaff. The small seasonal stream, Walnut Creek, has carved a 600 foot deep canyon into the local Kaibab limestone as it flows east, eventually joining the Little Colorado River en route to the Grand Canyon. The exposed rocks in the canyon walls occur in various layers, of slightly differing hardness, some of which have eroded more rapidly forming shallow caves. During the 12th to 13th centuries the caves were used by the local Sinagua Indians who constructed many cave-dwellings along the steep well-protected ledges, high above the canyon floor. Many of the dwellings were built around a U-shaped meander in Walnut Canyon, where the creek circles around 3 sides of a high rocky plateau, almost creating an 'island', and this region now forms the central attraction of the National Monument (www.americansouthwest.net).

The Kachina Peaks Wilderness Area is located just north of Flagstaff. This Wilderness is part of a large, heavily vegetated composite volcano 7,400 to 12,643 feet high including Humphreys Peak, the highest point in Arizona. Kachina Peaks was designated as a wilderness area in 1984 and has a total of 18,616 acres which is managed by the Forest Service. The "Peaks" exhibit a rich diversity of past geologic events such as lava flows, violent volcanic explosions, glaciation, erosion, and frost action. The only Arctic-Alpine vegetation in the state is found on the Peaks in a fragile 2-square mile zone and contains a threatened plant, Senecio Franciscanus, a dwarf perennial alpine plant.

The Peaks are outstanding examples of past volcanic activity and preserve the best example of Ice Age glaciation in Arizona in lateral and medial moraines and former stream beds. The Peaks are sacred to several western Indian tribes including the Zuni, Havasupai, Hopi and Navajo. A number of religious shrines have been documented that have historic and religious value and are currently in use. (http://gorp.away.com/gorp/resource/us_wilderness_area/az_kachi.htm)

Strawberry Crater, a Wilderness area designated by the United States Congress in 1984 is managed by the Forest Service and is comprised of 10,743 acres. Part of the huge San Francisco volcanic field, Strawberry Crater is one of its roughly 600 craters and cones, between 50,000 to 100,000 years old. The crater once sent lava flowing across the northwestern corner of this Wilderness, and low cinder cones dominate the southern end. Strawberry Crater is made up of gently rolling hills covered in pinyon and juniper, cinder-strewn terrain ranging in elevation from 5,500 feet to 6,000 feet. From the tops of many of the cinder cones you can see the Painted Desert, Hopi Buttes, and mesas of the valley of the Little Colorado River. Game animals and smaller mammals may be seen throughout the area (www.wilderness.net).

Arizona's largest natural lake, Mormon Lake, is located here. The area is also known for its plentiful wildlife. Large herds of elk roam the forests and edgelands. Bald eagles and ospreys live and hunt around the lakes. Pronghorn antelope graze the prairies. Lakes Mary, Ashurst, Indian, Ducksnest, Vail, Upper Tank, BigFill and Long are also found in the Walnut Canyon NRA.

This NRA also contains the nation's first United States Forest Service Experiment Station, Fort Valley, and the Raymond Ranch Wildlife Area (RRWA). Eighty-five to 90 bison are maintained at RRWA. Fifty to 100 elk use the wildlife area at one time or another during the year, along with pronghorn antelope and mule deer. Waterfowl, shorebirds and other wildlife are known or believed to occur seasonally, including several special status species (Arizona Game and Fish, 2006).

Mexican Spotted Owl habitat is also found throughout the Walnut Canyon NRA.

McDonald Canyon-Middle Little Colorado River NRA

This NRA is made up of one 10-digit HUC subwatershed: McDonald Canyon-Middle Little Colorado River. The NRA contains several lakes including Obed Meadow and McDonalds Canyon.

The Tanner Wash Area of Critical Environmental Concern (ACEC) is found within this NRA. An ACEC is defined as a place within Bureau of Land Management public lands where special management attention is required to protect and prevent irreparable damage to important historic, cultural, or scenic values; fish and wildlife resources; or other natural systems or processes or to protect life and safety from natural hazards.

Cedar Wash NRA

This NRA includes two 10-digit HUC subwatersheds: Lower Cedar Wash and Upper Cedar Wash. The Cedar Wash NRA includes portions of two national forests, the Coconino and Kaibab, Mexican Spotted Owl habitat, a wilderness area and a lake, Cedar Wash.

Kendrick Mountain Wilderness encompasses Kendrick Peak, one of the many peaks of the vast San Francisco mountain volcanic field located on the Coconino Plateau in north-central Arizona. Reaching an elevation of 10,418, the summit affords excellent views of the surrounding plateau, including the San Francisco Peaks to the east, the distant red rock of the Oak Creek-Sycamore Canyon country, Sitgreaves and Bill Williams Mountains to the south, Red Butte and distant views of the north rim of the Grand Canyon to the north. In 2000 a majority of the wilderness was involved in a large wildfire. Dramatic vegetation patterns were created by burn intensities ranging from light to very severe, most evident on the west, north, and east slopes. On-going natural recovery processes may be observed, with early seral species becoming established in the severely burned areas.

Characteristic montane coniferous forests, aspen stands, and high mountain meadow grasslands will re-establish with time. Unstable volcanic soils have undergone recurring severe erosion on the steeper slopes within burned areas, causing damage to the trails and access roads. Soils in the burn area will take many more years to re-stabilize. (http://www.fs.fed.us/r3/coconino/recreation/peaks/kentrick-mtn-wild.shtml)

Oraibi Wash NRA

This NRA contains four 10-digit HUC subwatersheds: Moenkopi Wash Headwaters, Upper Dinnebito Wash, Upper Oraibi Wash and Upper Polacca Wash. The Oraibi Wash NRA contains a significant portion of Mexican Spotted Owl habitat.

Puerco River Wash NRA

This NRA is made up of seven 10-digit HUC subwatersheds: Leroux Wash, Lithodendron Wash-Lower Puerco River, Porter Tank Draw-Middle Little Colorado, Washboard Wash-Upper Little Colorado River, Ninemile Wash-Lower Puerco River, Dry Wash and Milky Wash. The Puerco River Wash NRA contains the Petrified Forest National Park, Painted Desert National Park, Little Colorado River and Silver Creek (both of which are perennial streams).

Petrified Forest National Park is a surprising land of scenic wonders and fascinating science. The park contains one of the world's largest and most colorful concentrations of petrified wood, multi-hued badlands of the Chinle Formation, portions of the Painted Desert, historic structures, archeological sites, and displays of 225 million year old fossils. Petrified Forest National Park features some of the best fossil records and rock formations from the Late Triassic (225 million years ago) in the world. The park is 93,533 acres, with a recently expanded boundary increasing the acreage to 218,533 acres (National Park Service, 2006).

Upper Little Colorado River, Lyman Lake to Big Hollow Wash NRA

This NRA includes ten 10-digit HUC subwatersheds: Lower Silver Creek, Show Low Creek, Upper Silver Creek, Oso Draw, Big Hollow Wash, Carnero Creek-Little Colorado River Headwaters, Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Coyote Creek, Nutrioso Creek and South Fork Little Colorado River-Little Colorado River Headwaters.

This NRA is home to portions of a national forest, several wilderness areas and state parks, endangered species habitat, several lakes, and perennial streams.

The United States Congress designated the Escudilla Wilderness in 1984 and it now has a total of 5,200 acres managed by the Forest Service. Escudilla Mountain is the third highest mountain in Arizona at 10,912 feet. Escudilla sits on the third smallest Wilderness area in the state, home to acres of mountain meadows. The Wilderness encompasses the upper reaches of the mountain, and aspen cover about 40 percent of the area, regrowth from a terrible fire in 1953 (www.wilderness.net).

The United States Congress designated the Mount Baldy Wilderness in 1970 and it now has a total of 7,079 acres managed by the Forest Service. It is one of the most popular hiking areas in Arizona. An extinct volcano rising to 11,403 feet, Mount Baldy stands within the White Mountain Apache Reservation; the Wilderness occupies its eastern slope.

Most of the forest covering the mountain is mixed conifers with ponderosa pine in the lower elevations and fir and spruce higher up. Large meadows break open the forest, carpeted in summer with wildflowers such as Indian paintbrush, columbine, penstemon, iris, and lupine. Until winter cloaks the area in snow, elk and deer are commonly seen. Beavers, mountain lions, coyotes, bobcats, and black bears live here with a variety of smaller mammals. Bald eagles, falcons, and hawks are also found here (www.wilderness.net).

The Apache-Sitgreaves National Forest makes up a little over 25% of this NRA. The Upper Little Colorado River, Lyman Lake to Big Hollow Wash NRA also includes several important perennial rivers and streams: Little Colorado River, Silver Creek, Nutrioso Creek, Big Ditch, Water Canyon Creek, Mineral Creek, Show Low Creek, Benny Creek, Fish Creek, Coyote Creek and Lyman Lake.

This NRA contains the Grasslands Wildlife area, Wenima Wildlife Area, and the Sipe White Mountain Wildlife Area. These wildlife areas are managed by U.S. Fish & Wildlife.

Also included in this NRA is Lyman Lake State Park. The Park was created as an irrigation reservoir by damming the Little Colorado River. This 1,200-acre park encompasses the shoreline of a 1,500-acre reservoir at an elevation of 6,000 feet. Because of its size, Lyman Lake is one of the few bodies of water in northeastern Arizona with no size restrictions on boats. The fishery consists of walleye, channel catfish and largemouth bass.

References:

Arizona Game and Fish Department
Grasslands Wildlife Area, Lyman Lake State Park, Wenima Wildlife Area, Sipe White Mountain Wilderness,
http://www.azgfd.gov/outdoor_recreation/wildlife_area_sipe.shtml
Last Updated: 2006

Experiment Station
Fort Valley, http://www.rms.nau.edu/fortvalley/history.html

Little Colorado River
http://travel.mongabay.com/grand_canyon/grandcan_0617_little_colorado.htm
Last Updated: 2006

National Monuments, Wupatki, Sunset Crater and Walnut Canyon
http://www.americansouthwest.net/arizona/sunset_crater_volcano/national_monument.html

U.S. Bureau of Land Management
Cienega and Bonita Creek
http://www.blm.gov/nhp/news/releases/pages/1996/pr960606.html
Last updated: 04/04/03

U.S. Fish & Wildlife Service. 2004.
Mexican Spotted Owl, http://www.fws.gov/ifw2es/mso/recovery_plan.htm

U.S. Forest Service

Coconino National Forest, Sitgreaves National Forest,
http://www.fs.fed.us/r3/coconino/recreation/mormon_lake/index.shtml
Last Updated: Wednesday, 12 July 2006

Kaibab National Forest
http://gorp.away.com/gorp/resource/us_**national_forest**/az_kaiba.htm
Last Updated: 2006

Mogollon Rim
http://www.travelmagazineusa.com/arizona.asp Last Updated: 2006
http://www.gf.state.az.us/outdoor_recreation/wildlife_area_chevelon_canyon.shtml Last Updated: 2006

Kendrick Mountain Wilderness
http://www.fs.fed.us/r3/coconino/recreation/peaks/kentrick-mtn-wild.shtml
Last Updated: Tuesday, 30 May 2006

U.S. National Park Service

Grand Canyon National Park, http://www.nps.gov/grca/grandcanyon/south-rim/index.htm Last updated: 19-Apr-2006

Hubbell Trading Post NHS,
http://www.nps.gov/hutr/home.htm, Last Updated: May 2005

Petrified Forest, http://www.nps.gov/pefo/

Kachina Peaks,
http://gorp.away.com/gorp/resource/us_wilderness_area/az_kachi.htm
Last Updated: 2006

Section 6: Watershed Classification

In this watershed classification, each 10-digit subwatershed in the Little Colorado Watershed is classified or ranked based on susceptibility to water quality problems and pollution sources that need to be controlled through implementation of nonpoint source Best Management Practices (BMPs). This classification also prioritizes subwatersheds for available water quality improvement grants, based on known water quality concerns.

Methods

The general approach to classifying subwatersheds was to integrate watershed characteristics, water quality measurements, and results from modeling within a multi- parameter ranking system based on the fuzzy logic knowledge-based approach (described below), as shown schematically in Figure 6- 1.

The process was implemented within a GIS interface to create the subwatershed classifications using five primary steps:

1. Define the goal of the watershed classification: to prioritize which 10-digit HUC subwatersheds are most susceptible to known water quality concerns, and therefore, where BMPs should be implemented to reduce nonpoint source pollution;
2. Assemble GIS data and other observational data;
3. Define watershed characteristics through:
   a. Water quality assessment data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005);
   b. GIS mapping analysis; and
   c. Modeling / simulation of erosion vulnerability and potential for stream impairment (in this case, from soils in mine site areas and proximity to abandoned mine sites).

4. Use fuzzy membership functions to transform the potential vulnerability / impairment metrics into fuzzy membership values with scales from 0 to 1; and

5. Determine a composite fuzzy score representing the ranking of the combined attributes, and interpret the results.

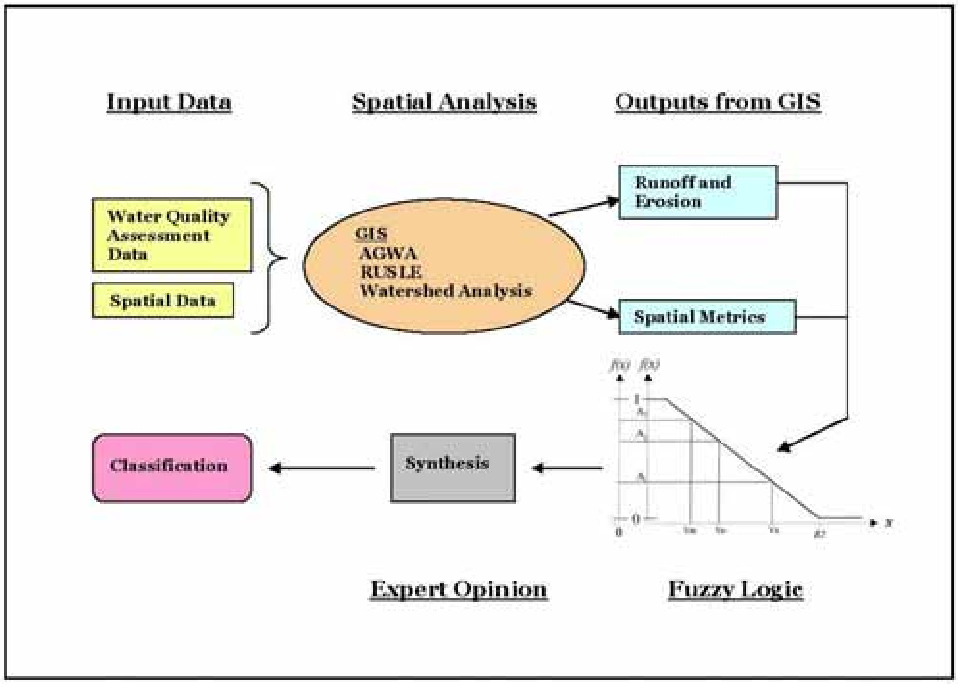

Figure 6-1 Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.

GIS and Hydrologic Modeling

GIS and hydrologic modeling were the major tools used to develop this watershed-based plan. Planning and assessment in land and water resource management require spatial modeling tools so as to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Little Colorado Watershed include AGWA, SWAT, and SEDMOD/RUSLE, as described below and in Appendices C and D.

The Automated Geospatial Watershed Assessment Tool (AGWA) is a GIS-based hydrologic modeling tool designed to evaluate the effects of land use change (Burns et al., 2004). AGWA provides the functionality to conduct all phases of a watershed assessment. It facilitates the use of the Soil and Water Assessment Tool (SWAT), a hydrologic model, by preparing the inputs, running the model, and presenting the results visually in the GIS. AGWA has been used to illustrate the impacts of urbanization and other landscape changes on runoff and sediment load in a watershed. AGWA was developed under a joint project between the Environmental Protection Agency (EPA), Agricultural Research Service (ARS), and the University of Arizona.

SWAT was developed by the ARS, and is able to predict the impacts of land management practices on water, sediment and chemical yields in complex watersheds with varying soils, land use and management conditions (Arnold et al., 1994). The SEDMOD model (Van Remortel et al., 2004), which uses the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), was used to estimate soil erosion and sediment delivery from different land use types.

The watershed classification within this plan incorporates GIS-based hydrologic modeling results and other data to describe watershed conditions upstream from an impaired stream reach identified within Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005). In addition, impacts due to mine sites (e.g. erosion and metals pollution) and grazing (e.g. erosion and pollutant nutrients) are simulated.

Fuzzy Logic

To rank the 10-digit HUC subwatershed areas that are susceptible to water quality problems and pollution, and to identify sources that need to be controlled, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types (Guertin et al., 2000; Miller et al., 2002; Reynolds et al., 2001). This methodology has been selected as the basis by which subwatershed areas and stream reaches are prioritized for the implementation of BMPs to assure nonpoint source pollution is managed.

Fuzzy logic is an approach to set theory that handles vagueness or uncertainty, and has been described as a method by which to quantify common sense. In classical set theory, an object is either a member of the set or excluded from the set. Fuzzy logic allows for an object to be a partial member of a set, and converts the range in values between different data factors to the same scale (0.0 -1.0) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the input characteristics.

The development of a fuzzy membership function can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. A benefit of this approach is that it provides for the use of different methods for combining individual factors to create the final classification and the goal set. Fuzzy membership functions and weighting schemes can also be changed based on watershed concerns and conditions.

Subwatershed Classification

This classification was conducted at the 10-digit HUC subwatershed scale. Table 6- 1 lists the HUC numerical identification and subwatershed name. Classifications were conducted for individual or groups of water quality parameters, and potential for impairment for a water quality parameter based on the biophysical characteristics of the watershed.

Constituent groups evaluated for the Little Colorado Watershed are:

1. Metals, including arsenic, barium, beryllium, thorium, antimony, mercury, cadmium, chromium, copper, lead, nickel, silver, zinc, and magnesium;

2. Sediment (turbidity is used as an index since it was the previous standard and represents most of the sampling data);

3. Organics (Escherichia coli, nutrients, pH, and dissolved

oxygen are concerns and are related to organic material being introduced into the aquatic system); and

4. Selenium.

The development of the fuzzy logic approach for each constituent is described below.

Water Quality Assessment Data

ADEQ's water quality assessment criteria and assessment definitions are found in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005). These data were used to define the current level of impairment of each HUC-10 subwatershed using fuzzy membership values. For more information see the ADEQ website: http://www.azdeq.gov/environ/water/assessment/2004.html.

Surface waters assessed as "impaired" and included in the 303(d) List of Impaired Waters are scheduled for completion of a Total Maximum Daily Load (TMDL) quantitative and analysis plan. A TMDL is the maximum amount (load) of a water quality parameter which can be carried by a surface water body, on a daily basis, without causing an exceedance of surface water quality standards (ADEQ, 2006). Although all monitored water bodies will be reviewed in this watershed-based plan, only those assessed as impaired will be discussed for best management practices (Section 7 of this Watershed-Based Plan).

Appendix A Table 1 is a summary of the ADEQ water quality monitoring data (ADEQ, 2005) and 10-digit HUC subwatershed classification results for the entire Little Colorado Watershed. The water quality data were used to classify each monitored stream reach or water body based on its relative risk of impairment for the constituent groups. It should be noted that not every 10-digit HUC subwatershed contained a water quality sampling site.

The four levels of risk used to classify each water body are: Extreme, High, Moderate and Low. These are described below:

1. Extreme risk --If a surface water within the subwatershed is currently assessed as being "impaired" by ADEQ for one of the constituent groups.

2. High risk – If a surface water within the subwatershed is assessed as "inconclusive" because of limited data, but the available sampling indicates water quality exceedances occurred.

3. Moderate risk – If either:
    a. A surface water within the subwatershed was assessed as "inconclusive" or "attaining," but there are still a low number of samples exceeding standards for a constituent group; or
    b. There were no water quality measurements available for a constituent group at any site within the subwatershed.

4. Low risk -- If no exceedances exist in a constituent group and there were sufficient data to make an assessment.

An overall risk classification is assigned to the HUC 10-digit subwatershed based on the worst case risk classification of the water bodies in that subwatershed. Fuzzy membership values (FMV) were assigned to each subwatershed using the criteria in Table 6- 2.

The FMVs in Table 6- 2 are based on two considerations: 1) Subwatershed relative risk of impairment (described above), and 2) Downstream subwatershed risk of impairment.

The status of downstream surface waters provides a way to evaluate the possibility that the subwatershed is contributing to downstream water quality problems. This is particularly important where water quality data is limited and few surface water quality samples may have been collected within the subwatershed.

Water bodies classified as either extreme (impaired) or low (no exceedances) risk had a higher influence than high or moderate classified water bodies in determining downstream water quality condition because they were less ambiguous than the other levels of risk. For example, if a water body was classified as extreme risk, it was used to define the water quality condition, and the subwatershed was given an FMV of 1.0. Likewise, if a water body along the pathway was classified as low risk, then that water body was used to define the downstream water quality condition (see Table 6- 2). Overall, during the Little Colorado River assessment 473 miles of stream reach were evaluated.

Table 6- 1 HUC 10-Digit Numerical Designation and Subwatershed Name.

HUC 10	Subwatershed Name
1502000101	Nutrioso Creek
1502000102	South Fork Little Colorado River-Little Colorado River Headwaters
1502000103	Coyote Creek
1502000104	Carnero Creek-Little Colorado River Headwaters
1502000201	Upper Little Colorado River, Lyman Lake to Big Hollow Wash
1502000202	Big Hollow Wash
1502000203	Concho Creek-Upper Little Colorado River
1502000204	Oso Draw
1502000205	Milky Wash
1502000206	Hay Hollow Draw-Upper Little Colorado River
1502000207	Washboard Wash-Upper Little Colorado River
1502000306	Middle Carrizo Wash
1502000307	Lower Carrizo Wash
1502000406	Jaralosa Draw
1502000407	Middle Zuni River
1502000408	Hardscrabble Wash
1502000409	Lower Zuni River
1502000501	Show Low Creek
1502000502	Upper Silver Creek
1502000503	Cottonwood Creek
1502000504	Lower Silver Creek
1502000603	Upper Black Creek
1502000605	Whitewater Arroyo
1502000606	Lower Black Creek
1502000607	Manuelito Canyon-Upper Puerco River
1502000701	Burntwater Wash-Lower Puerco River
1502000702	Morgan Canyon
1502000703	Dead Wash
1502000704	Dry Wash
1502000705	Ninemile Wash-Lower Puerco River
1502000706	Lithodendron Wash-Lower Puerco River
1502000801	Phoenix Park Wash-Dry Lake
1502000802	Porter Tank Draw-Middle Little Colorado River
1502000803	Upper Clear Creek

HUC 10	Subwatershed Name
1502000804	Lower Clear Creek
1502000805	Jacks Canyon
1502000806	McDonald Canyon-Middle Little Colorado River
1502000807	Rincon Basin Area-Middle Little Colorado River
1502000808	Coyote Wash-Middle Little Colorado River
1502000809	Cow Canyon-Middle Little Colorado River
1502000810	Middle Little Colorado River-Canyon Diablo to Grand Falls
1502000901	Upper Wide Ruin Wash
1502000902	Lower Wide Ruin Wash
1502000903	Leroux Wash
1502001001	Upper Chevelon Canyon
1502001002	Black Canyon
1502001003	Lower Chevelon Canyon
1502001101	Upper Pueblo Colorado Wash
1502001102	Steamboat Wash
1502001103	Middle Pueblo Colorado Wash
1502001104	Bidahochi Wash
1502001105	Lower Pueblo Colorado Wash
1502001106	Cottonwood Wash
1502001201	Upper Oraibi Wash
1502001202	Middle Oraibi Wash
1502001203	Lower Oraibi Wash
1502001301	Upper Polacca Wash
1502001302	Wepo Wash
1502001303	Middle Polacca Wash
1502001304	Lower Polacca Wash
1502001401	Ha-whi-yalin Wash
1502001402	Upper Jadito Wash
1502001403	Coyote Wash
1502001404	Lower Jadito Wash
1502001501	Rio de Flag
1502001502	Walnut Creek
1502001503	San Francisco Wash
1502001504	Canyon Diablo (Local Drainage)
1502001601	Kana-a Wash-Lower Little Colorado River
1502001602	Deadman Wash
1502001603	Big Wash-The Big Lake Area
1502001604	Tohachi Wash
1502001605	Citadel Wash-Lower Little Colorado River
1502001606	Upper Cedar Wash
1502001607	Lower Cedar Wash
1502001608	Tonahakaad Wash-Lower Little Colorado River
1502001609	Lee Canyon-Lower Little Colorado River
1502001610	Sheep Wash-Lower Little Colorado River
1502001701	Upper Dinnebito Wash
1502001702	Middle Dinnebito Wash
1502001703	Lower Dinnebito Wash
1502001801	Moenkopi Wash Headwaters
1502001802	Shonto Wash
1502001803	Upper Begashibito Wash
1502001804	Crooked Ridge/Echo Cliffs Area
1502001805	Lower Begashibito Wash
1502001806	Wide Ruin Canyon-Moenkopi Wash
1502001807	Pasture Canyon
1502001808	Coal Mine Canyon-Moenkopi Wash
1502001809	Hamblin Wash
1502001810	Kerley Valley-Moenkopi Wash
1502001811	Fivemile Wash-Moenkopi Wash

Table 6- 2 Fuzzy Membership Values (FMV) for HUC-10 Subwatersheds Based on ADEQ Water Quality Assessment Results.

Reach Condition	Downstream Condition	FMV
Extreme	N/A	1.0
High	Extreme	1.0
High	High	0.8
High	Moderate /Low	0.7
Moderate	Extreme	0.7
Moderate	High	0.6
Moderate	Moderate	0.5
Moderate	Low	0.3
Low	N/A	0.0

Metals

Metals are one of the most significant water quality problems in the Little Colorado Watershed because of the potential toxicity to aquatic life. Two reaches within the watershed showed sampling with exceedances in standards for metal: a) West Fork Little Colorado River (South Fork of the Little Colorado River subwatershed) with copper, and b) Fish Creek (headwaters of the Little Colorado River subwatershed) with mercury. It is important to note that in Fish Creek sampling was not sufficient to reach a conclusion.

Several waterbodies in the Little Colorado watershed have been assessed as impaired, due to the presence of high quantities of mercury in fish tissue: Upper Lake Mary and Lower Lake Mary (Walnut Creek subwatershed), Long Lake (Lower Canyon Diablo subwatershed), Lyman Lake (Carnero Creek subwatershed), and Soldier's Lake and Soldier's Annex Lake (Jacks Canyon subwatershed).

The primary sources for metals in the Little Colorado Watershed are probably runoff and erosion from active and abandoned mines. Developed urban areas should also be considered a nonpoint source for metals pollutants; however, the Little Colorado Watershed is mostly rural and has little industry besides mining. Because of the sparse population density, urban development is not foreseen as a major source of metals, and “development” was not used as a classification factor.

The factors used for the metals classification were:

- ADEQ water quality assessment results;
- Presence of mines within a subwatershed;
- Presence of mines within the riparian zone; and
- Potential contribution of mines to sediment yield.

Water Quality Assessment Data - Metals

Arizona’s Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) was used to define the current level of impairment for metals for each stream reach. Each subwatershed was then assigned a risk level based on the worst case stream reach. The FMV was assigned based on the location of the subwatershed relative to an impaired water.

Table 6- 2 lists the fuzzy membership values used for different watershed conditions based on watershed location and water quality assessment results. Table 6- 3 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed for metals, based on the criteria defined in Table 6- 2. The justification used to determine the FMV is also included in Table 6- 3.

Location of Mining Activities

The type and location of a mine within a watershed and in relation to a riparian zone determines its potential for impact on nearby water quality. Mining generally causes soil disturbance, which results in erosion and sediment yield to streams. In addition, since mines by definition occur in mineralized areas, it is assumed that the eroded soil is also high in metals. More thorough discussions of the geologic conditions and location of mine sites and mine types across the watershed are found in Section 2, Physical Characteristics and Section 4, Social/Economic Characteristics. The spatial data described in those sections were used along with the ADEQ water quality assessment data to classify each subwatershed for susceptibility to erosion and risk for metals pollution using the methodology described below.

The number of mines in a subwatershed and within the riparian zone (<= 250 m from a stream) were determined in the GIS. The results were used to assign an FMV to each subwatershed based on the following criteria.

Number of mines per watershed:

FMV = 0 if (# of mines <= 2)
FMV = (# of mines – 2) / 8
FMV = 1 if (# of mines >= 10)

Number of mines in riparian zone:

FMV = 0 if (# of mines < 1)
FMV = (# of mines) / 5
FMV = 1 if (# of mines >= 5)

Table 6- 4 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on the number of and location of mines. These values were used in the summary analysis to assess the relative impact of mining on the concentration of dissolved and total metals in the subwatershed.

Table 6- 3 Fuzzy Membership Values (FMV) Assigned to each 10-digit HUC Subwatershed, Based on Water Quality Assessment Results for Metals.

Subwatershed	FMV	Justification
Nutrioso Creek	0.0	Classified as low risk
South Fork Little Colorado River-Little Colorado River Headwaters	0.7	Classified as moderate risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as extreme risk
Coyote Creek	0.7	Classified as moderate risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as extreme risk
Carnero Creek-Little Colorado River Headwaters	1.0	Classified as extreme risk
Upper Little Colorado River, Lyman Lake to Big Hollow Wash	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Big Hollow Wash	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Concho Creek-Upper Little Colorado River	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Oso Draw	0.0	Classified as low risk
Milky Wash	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Hay Hollow Draw-Upper Little Colorado River	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Washboard Wash-Upper Little Colorado River	1.0	Classified as extreme risk
Middle Carrizo Wash	0.5	Classified as moderate risk, drains into Lower Carrizo Wash that is classified as moderate risk

Subwatershed	FMV	Justification
Lower Carrizo Wash	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Jaralosa Draw	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Middle Zuni River	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Hardscrabble Wash	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Lower Zuni River	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Show Low Creek	0.0	Classified as low risk
Upper Silver Creek	0.0	Classified as low risk
Cottonwood Creek	0.5	Classified as moderate risk, drains into Lower Silver Creek that is classified as moderate risk
Lower Silver Creek	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Upper Black Creek	0.5	Classified as moderate risk, drains into Lower Black Creek that is classified as moderate risk
Whitewater Arroyo	0.5	Classified as moderate risk, drains into Manuelito Canyon-Upper Puerco River that is classified as moderate risk
Lower Black Creek	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Manuelito Canyon-Upper Puerco River	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Burntwater Wash-Lower Puerco River	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Morgan Canyon	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Dead Wash	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Dry Wash	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Ninemile Wash-Lower Puerco River	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Lithodendron Wash-Lower Puerco River	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Phoenix Park Wash-Dry Lake	0.5	Classified as moderate risk, drains into Black Canyon that is classified as moderate risk
Porter Tank Draw-Middle Little Colorado River	0.5	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk
Upper Clear Creek	0.0	Classified as low risk
Lower Clear Creek	0.5	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk
Jacks Canyon	1.0	Classified as extreme risk
McDonald Canyon-Middle Little Colorado River	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Rincon Basin Area-Middle Little Colorado River	0.5	Classified as moderate risk, drains into Coyote Wash-Middle Little Colorado River that is classified as moderate risk
Coyote Wash-Middle Little Colorado River	0.5	Classified as moderate risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk
Cow Canyon-Middle Little Colorado River	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Middle Little Colorado River-Canyon Diablo to Grand Falls	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk

Subwatershed	FMV	Justification
Upper Wide Ruin Wash	0.5	Classified as moderate risk, drains into Lower Wide Ruin Wash that is classified as moderate risk
Lower Wide Ruin Wash	0.5	Classified as moderate risk, drains into Leroux Wash that is classified as moderate risk
Leroux Wash	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Upper Chevelon Canyon	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Black Canyon	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Lower Chevelon Canyon	0.0	Classified as low risk
Upper Pueblo Colorado Wash	0.5	Classified as moderate risk, drains into Middle Pueblo Colorado Wash that is classified as moderate risk
Steamboat Wash	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Middle Pueblo Colorado Wash	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Bidahochi Wash	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Lower Pueblo Colorado Wash	0.5	Classified as moderate risk, drains into Cottonwood Wash that is classified as moderate risk
Cottonwood Wash	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Upper Oraibi Wash	0.5	Classified as moderate risk, drains into Middle Oraibi Wash that is classified as moderate risk
Middle Oraibi Wash	0.5	Classified as moderate risk, drains into Lower Oraibi Wash that is classified as moderate risk
Lower Oraibi Wash	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Upper Polacca Wash	0.5	Classified as moderate risk, drains into Middle Polacca Wash that is classified as moderate risk
Wepo Wash	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Middle Polacca Wash	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Lower Polacca Wash	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Ha-whi-yalin Wash	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Upper Jadito Wash	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Coyote Wash	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Lower Jadito Wash	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Rio de Flag	0.0	Classified as low risk
Walnut Creek	0.5	Classified as moderate risk, drains into San Francisco Wash that is classified as moderate risk
San Francisco Wash	0.5	Classified as moderate risk, drains into Canyon Diablo (Local Drainage) that is classified as moderate risk
Canyon Diablo (Local Drainage)	0.5	Classified as moderate risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk
Kana-a Wash-Lower Little Colorado River	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk
Deadman Wash	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk

Subwatershed	FMV	Justification
Big Wash-The Big Lake Area	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Tohachi Wash	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Citadel Wash-Lower Little Colorado River	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Upper Cedar Wash	0.5	Classified as moderate risk, drains into Lower Cedar Wash that is classified as moderate risk
Lower Cedar Wash	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Tonahakaad Wash-Lower Little Colorado River	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Lee Canyon-Lower Little Colorado River	0.5	Classified as moderate risk, drains into Sheep Wash-Lower Little Colorado River that is classified as moderate risk
Sheep Wash-Lower Little Colorado River	0.5	Classified as moderate risk
Upper Dinnebito Wash	0.5	Classified as moderate risk, drains into Middle Dinnebito Wash that is classified as moderate risk
Middle Dinnebito Wash	0.5	Classified as moderate risk, drains into Lower Dinnebito Wash that is classified as moderate risk
Lower Dinnebito Wash	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk
Moenkopi Wash Headwaters	0.5	Classified as moderate risk, drains into Wide Ruin Canyon-Moenkopi Wash that is classified as moderate risk
Shonto Wash	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk
Upper Begashibito Wash	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk
Crooked Ridge/Echo Cliffs Area	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Lower Begashibito Wash	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Wide Ruin Canyon-Moenkopi Wash	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Pasture Canyon	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Coal Mine Canyon-Moenkopi Wash	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Hamblin Wash	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Kerley Valley-Moenkopi Wash	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Fivemile Wash-Moenkopi Wash	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk

Table 6- 4 FMV for each Subwatershed Based on the Number and Location of Mines.

Subwatershed Name	FMV #mines /watershed	FMV #mines riparian
Nutrioso Creek-1502000101	4.75	0
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	1	0.6
Coyote Creek-1502000103	3.75	0
Carnero Creek-Little Colorado River Headwaters-1502000104	1	0.8
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	1	1
Big Hollow Wash-1502000202	3.75	0.2
Concho Creek-Upper Little Colorado River-1502000203	7.75	0.6
Oso Draw-1502000204	7.75	0.6
Milky Wash-1502000205	0	0
Hay Hollow Draw-Upper Little Colorado River-1502000206	4.75	0.6
Washboard Wash-Upper Little Colorado River-1502000207	1	0.2
Middle Carrizo Wash-1502000306	0	0
Lower Carrizo Wash-1502000307	0	0
Jaralosa Draw-1502000406	0	0
Middle Zuni River-1502000407	0	0.2
Hardscrabble Wash-1502000408	0	0.2
Lower Zuni River-1502000409	3.75	0.2
Show Low Creek-1502000501	1	0.8
Upper Silver Creek-1502000502	1	0
Cottonwood Creek-1502000503	8.75	0.4
Lower Silver Creek-1502000504	5.75	0.4
Upper Black Creek-1502000603	0	0.2
Whitewater Arroyo-1502000605	0	0
Lower Black Creek-1502000606	5.75	0.8
Manuelito Canyon-Upper Puerco River-1502000607	4.75	0.2
Burntwater Wash-Lower Puerco River-1502000701	1	1
Morgan Canyon-1502000702	4.75	0
Dead Wash-1502000703	0	0
Dry Wash-1502000704	6.75	0.2
Ninemile Wash-Lower Puerco River-1502000705	1	0.6
Lithodendron Wash-Lower Puerco River-1502000706	5.75	0.2
Phoenix Park Wash-Dry Lake-1502000801	5.75	0.2
Porter Tank Draw-Middle Little Colorado River-1502000802	4.75	0.4
Upper Clear Creek-1502000803	2.75	0.4
Lower Clear Creek-1502000804	7.75	0.2
Jacks Canyon-1502000805	2.75	0.2
McDonald Canyon-Middle Little Colorado River-1502000806	1	0.6
Rincon Basin Area-Middle Little Colorado River-1502000807	6.75	0.6
Coyote Wash-Middle Little Colorado River-1502000808	5.75	0.2

Subwatershed Name	FMV #mines /watershed	FMV #mines riparian
Cow Canyon-Middle Little Colorado River-1502000809	4.75	0.4
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	6.75	0.2
Upper Wide Ruin Wash-1502000901	4.75	0.6
Lower Wide Ruin Wash-1502000902	0	0
Leroux Wash-1502000903	1	1
Upper Chevelon Canyon-1502001001	1	0.4
Black Canyon-1502001002	2.75	0.6
Lower Chevelon Canyon-1502001003	0	0.2
Upper Pueblo Colorado Wash-1502001101	0	0.4
Steamboat Wash-1502001102	4.75	0.4
Middle Pueblo Colorado Wash-1502001103	7.75	0.6
Bidahochi Wash-1502001104	8.75	1
Lower Pueblo Colorado Wash-1502001105	0	0
Cottonwood Wash-1502001106	4.75	0.4
Upper Oraibi Wash-1502001201	0	0
Middle Oraibi Wash-1502001202	0	0.2
Lower Oraibi Wash-1502001203	0	0.2
Upper Polacca Wash-1502001301	6.75	0.2
Wepo Wash-1502001302	0	0
Middle Polacca Wash-1502001303	0	0.4
Lower Polacca Wash-1502001304	0	0
Ha-whi-yalin Wash-1502001401	0	0
Upper Jadito Wash-1502001402	0	0
Coyote Wash-1502001403	0	0
Lower Jadito Wash-1502001404	0	0.2
Rio de Flag-1502001501	1	1
Walnut Creek-1502001502	1	0.4
San Francisco Wash-1502001503	1	0.8
Canyon Diablo (Local Drainage)-1502001504	2.75	0.4
Kana-a Wash-Lower Little Colorado River-1502001601	0	0
Deadman Wash-1502001602	1	1
Big Wash-The Big Lake Area-1502001603	0	0
Tohachi Wash-1502001604	0	0
Citadel Wash-Lower Little Colorado River-1502001605	1	0.6
Upper Cedar Wash-1502001606	6.75	0
Lower Cedar Wash-1502001607	0	0
Tonahakaad Wash-Lower Little Colorado River-1502001608	1	1
Lee Canyon-Lower Little Colorado River-1502001609	4.75	0.4
Sheep Wash-Lower Little Colorado River-1502001610	0	0
Upper Dinnebito Wash-1502001701	0	0
Middle Dinnebito Wash-1502001702	0	0

Subwatershed Name	FMV #mines /watershed	FMV #mines riparian
Lower Dinnebito Wash-1502001703	0	0.2
Moenkopi Wash Headwaters-1502001801	5.75	0
Shonto Wash-1502001802	7.75	0.2
Upper Begashibito Wash-1502001803	0	0
Crooked Ridge/Echo Cliffs Area-1502001804	0	0
Lower Begashibito Wash-1502001805	0	0.2
Wide Ruin Canyon-Moenkopi Wash-1502001806	0	0.2
Pasture Canyon-1502001807	2.75	0.4
Coal Mine Canyon-Moenkopi Wash-1502001808	8.75	0.2
Hamblin Wash-1502001809	0.75	0
Kerley Valley-Moenkopi Wash-1502001810	2.75	0.2
Fivemile Wash-Moenkopi Wash-1502001811	6.75	0.8

Potential Contribution of Mines to Sediment Yield

Gross soil erosion in Kg/ha/yr was determined for each subwatershed using the SEDMOD model (Van Remortel et al., 2004), which is based on RUSLE (Renard et al., 1997; see Appendix C). Since this watershed based plan assumes that mine sites contribute to erosion and the resulting sediments are high in metals, the potential for erosion from mines to contribute to the risk for metals impairment for a subwatershed was evaluated.

The model results for soil loss (RUSLE “A” value) were imported into the GIS and reclassified into six categories. Table 6- 5 tabulates the values for soil loss in Kg/ha/yr for each subwatershed, and Figure 6- 2 shows these results.

Metals Results

Table 6- 6 shows the erosion category and fuzzy membership value for each subwatershed. The range of erosion values were classified into six erosion categories, where category “1” represents zero potential for metals contribution (i.e. low sediment yield), and category “6” represents a high potential (i.e. high sediment yield). The fuzzy membership values ranged from 0.0 to 1.0, and were increased by 0.2 for each higher erosion category.

The fuzzy membership values for the number of mines and for the erosion category were used to create a combined fuzzy score for each subwatershed using the weighted combination method.

This method uses a weighting scheme (weighted combination method) which was developed in cooperation with ADEQ. The weights consider the proximity of mines to the riparian area, the susceptibility to erosion, and the ADEQ water quality results. The overall number of mines within the subwatershed (but removed from the riparian area) was not considered as pertinent to the classification, so this weight was set at 0.1, as opposed to 0.3 for the other conditions.

The summary results are found in Table 6- 7, and the weights are listed at the bottom of the table. Each of the assigned weights were multiplied with the FMV, and then added to produce the weighted FMV ranking.

Using the weighted FMV values, the subwatershed areas were classified into ‘high’ or ‘low” risk for impairment due to metals based on natural breaks. Figure 6- 3 shows the results of the weighted combination method classified into high and low risk for metals.

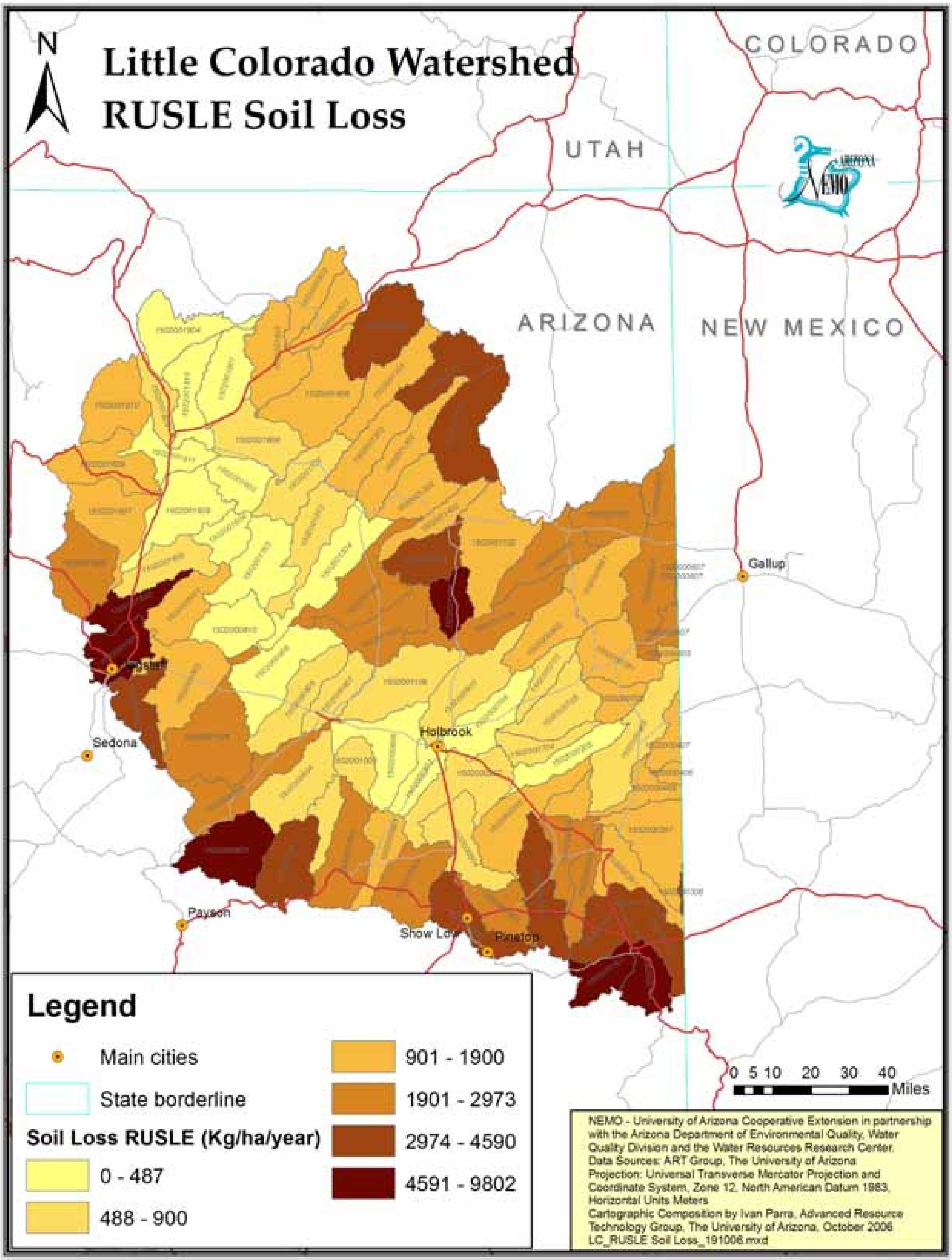

Figure 6- 2 RUSLE Soil Loss "A" (Kg/ha/yr) by Subwatershed.

Table 6- 5 RUSLE Calculated Soil Loss "A" (Kg/ha/yr).

Subwatershed	RUSLE Soil Loss "A" Kg/ha/yr
Nutrioso Creek-1502000101	9,802
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	9,477
Coyote Creek-1502000103	4,590
Carnero Creek-Little Colorado River Headwaters-1502000104	3,246
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	1,745
Big Hollow Wash-1502000202	2,973
Concho Creek-Upper Little Colorado River-1502000203	2,139
Oso Draw-1502000204	3,394
Milky Wash-1502000205	467
Hay Hollow Draw-Upper Little Colorado River-1502000206	1,097
Washboard Wash-Upper Little Colorado River-1502000207	529
Middle Carrizo Wash-1502000306	3,365
Lower Carrizo Wash-1502000307	1,155
Jaralosa Draw-1502000406	1,608
Middle Zuni River-1502000407	1,120
Hardscrabble Wash-1502000408	693
Lower Zuni River-1502000409	1,118
Show Low Creek-1502000501	3,408
Upper Silver Creek-1502000502	2,232
Cottonwood Creek-1502000503	2,911
Lower Silver Creek-1502000504	607
Upper Black Creek-1502000603	2,465
Whitewater Arroyo-1502000605	1,614
Lower Black Creek-1502000606	2,420
Manuelito Canyon-Upper Puerco River-1502000607	2,606
Burntwater Wash-Lower Puerco River-1502000701	1,157
Morgan Canyon-1502000702	1,222
Dead Wash-1502000703	500
Dry Wash-1502000704	530
Ninemile Wash-Lower Puerco River-1502000705	794
Lithodendron Wash-Lower Puerco River-1502000706	346
Phoenix Park Wash-Dry Lake-1502000801	1,172
Porter Tank Draw-Middle Little Colorado River-1502000802	397
Upper Clear Creek-1502000803	5,986
Lower Clear Creek-1502000804	889
Jacks Canyon-1502000805	2,321
McDonald Canyon-Middle Little Colorado River-1502000806	297
Rincon Basin Area-Middle Little Colorado River-1502000807	704

Subwatershed	RUSLE Soil Loss "A" Kg/ha/yr
Coyote Wash-Middle Little Colorado River-1502000808	**574**
Cow Canyon-Middle Little Colorado River-1502000809	**244**
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	**246**
Upper Wide Ruin Wash-1502000901	**1,749**
Lower Wide Ruin Wash-1502000902	**1,409**
Leroux Wash-1502000903	**900**
Upper Chevelon Canyon-1502001001	**3,732**
Black Canyon-1502001002	**2,148**
Lower Chevelon Canyon-1502001003	**790**
Upper Pueblo Colorado Wash-1502001101	**2,448**
Steamboat Wash-1502001102	**1,703**
Middle Pueblo Colorado Wash-1502001103	**2,310**
Bidahochi Wash-1502001104	**6,356**
Lower Pueblo Colorado Wash-1502001105	**2,639**
Cottonwood Wash-1502001106	**611**
Upper Oraibi Wash-1502001201	**3,939**
Middle Oraibi Wash-1502001202	**1,508**
Lower Oraibi Wash-1502001203	**560**
Upper Polacca Wash-1502001301	**3,069**
Wepo Wash-1502001302	**1,462**
Middle Polacca Wash-1502001303	**1,900**
Lower Polacca Wash-1502001304	**323**
Ha-whi-yalin Wash-1502001401	**3,470**
Upper Jadito Wash-1502001402	**1,851**
Coyote Wash-1502001403	**2,400**
Lower Jadito Wash-1502001404	**2,209**
Rio de Flag-1502001501	**7,443**
Walnut Creek-1502001502	**4,246**
San Francisco Wash-1502001503	**1,703**
Canyon Diablo (Local Drainage)-1502001504	**2,117**
Kana-a Wash-Lower Little Colorado River-1502001601	**1,844**
Deadman Wash-1502001602	**7,157**
Big Wash-The Big Lake Area-1502001603	**248**
Tohachi Wash-1502001604	**456**
Citadel Wash-Lower Little Colorado River-1502001605	**588**
Upper Cedar Wash-1502001606	**2,422**
Lower Cedar Wash-1502001607	**1,295**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**436**
Lee Canyon-Lower Little Colorado River-1502001609	**1,775**
Sheep Wash-Lower Little Colorado River-1502001610	**1,240**

Subwatershed	RUSLE Soil Loss "A" Kg/ha/yr
Upper Dinnebito Wash-1502001701	1,636
Middle Dinnebito Wash-1502001702	858
Lower Dinnebito Wash-1502001703	289
Moenkopi Wash Headwaters-1502001801	3,042
Shonto Wash-1502001802	1,465
Upper Begashibito Wash-1502001803	1,334
Crooked Ridge/Echo Cliffs Area-1502001804	293
Lower Begashibito Wash-1502001805	1,094
Wide Ruin Canyon-Moenkopi Wash-1502001806	1,539
Pasture Canyon-1502001807	280
Coal Mine Canyon-Moenkopi Wash-1502001808	645
Hamblin Wash-1502001809	621
Kerley Valley-Moenkopi Wash-1502001810	243
Fivemile Wash-Moenkopi Wash-1502001811	487

Table 6- 6 Fuzzy Membership Values per Erosion Category.

Subwatershed	Erosion Category	FMV
Nutrioso Creek-1502000101	6	1
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	6	1
Coyote Creek-1502000103	5	0.8
Carnero Creek-Little Colorado River Headwaters-1502000104	5	0.8
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	3	0.4
Big Hollow Wash-1502000202	4	0.6
Concho Creek-Upper Little Colorado River-1502000203	4	0.6
Oso Draw-1502000204	5	0.8
Milky Wash-1502000205	1	0
Hay Hollow Draw-Upper Little Colorado River-1502000206	3	0.4
Washboard Wash-Upper Little Colorado River-1502000207	2	0.2
Middle Carrizo Wash-1502000306	5	0.8
Lower Carrizo Wash-1502000307	3	0.4
Jaralosa Draw-1502000406	3	0.4
Middle Zuni River-1502000407	3	0.4
Hardscrabble Wash-1502000408	2	0.2
Lower Zuni River-1502000409	3	0.4
Show Low Creek-1502000501	5	0.8
Upper Silver Creek-1502000502	4	0.6
Cottonwood Creek-1502000503	4	0.6
Lower Silver Creek-1502000504	2	0.2

Subwatershed	Erosion Category	FMV
Upper Black Creek-1502000603	4	0.6
Whitewater Arroyo-1502000605	3	0.4
Lower Black Creek-1502000606	4	0.6
Manuelito Canyon-Upper Puerco River-1502000607	4	0.6
Burntwater Wash-Lower Puerco River-1502000701	3	0.4
Morgan Canyon-1502000702	3	0.4
Dead Wash-1502000703	2	0.2
Dry Wash-1502000704	2	0.2
Ninemile Wash-Lower Puerco River-1502000705	2	0.2
Lithodendron Wash-Lower Puerco River-1502000706	1	0
Phoenix Park Wash-Dry Lake-1502000801	3	0.4
Porter Tank Draw-Middle Little Colorado River-1502000802	1	0
Upper Clear Creek-1502000803	6	1
Lower Clear Creek-1502000804	2	0.2
Jacks Canyon-1502000805	4	0.6
McDonald Canyon-Middle Little Colorado River-1502000806	1	0
Rincon Basin Area-Middle Little Colorado River-1502000807	2	0.2
Coyote Wash-Middle Little Colorado River-1502000808	2	0.2
Cow Canyon-Middle Little Colorado River-1502000809	1	0
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	1	0
Upper Wide Ruin Wash-1502000901	3	0.4
Lower Wide Ruin Wash-1502000902	3	0.4
Leroux Wash-1502000903	2	0.2
Upper Chevelon Canyon-1502001001	5	0.8
Black Canyon-1502001002	4	0.6
Lower Chevelon Canyon-1502001003	2	0.2
Upper Pueblo Colorado Wash-1502001101	4	0.6
Steamboat Wash-1502001102	3	0.4
Middle Pueblo Colorado Wash-1502001103	4	0.6
Bidahochi Wash-1502001104	6	1
Lower Pueblo Colorado Wash-1502001105	4	0.6
Cottonwood Wash-1502001106	2	0.2
Upper Oraibi Wash-1502001201	5	0.8
Middle Oraibi Wash-1502001202	3	0.4
Lower Oraibi Wash-1502001203	2	0.2
Upper Polacca Wash-1502001301	5	0.8
Wepo Wash-1502001302	3	0.4
Middle Polacca Wash-1502001303	3	0.4
Lower Polacca Wash-1502001304	1	0
Ha-whi-yalin Wash-1502001401	5	0.8

Subwatershed	Erosion Category	FMV
Upper Jadito Wash-1502001402	3	0.4
Coyote Wash-1502001403	4	0.6
Lower Jadito Wash-1502001404	4	0.6
Rio de Flag-1502001501	6	1
Walnut Creek-1502001502	5	0.8
San Francisco Wash-1502001503	3	0.4
Canyon Diablo (Local Drainage)-1502001504	4	0.6
Kana-a Wash-Lower Little Colorado River-1502001601	3	0.4
Deadman Wash-1502001602	6	1
Big Wash-The Big Lake Area-1502001603	1	0
Tohachi Wash-1502001604	1	0
Citadel Wash-Lower Little Colorado River-1502001605	2	0.2
Upper Cedar Wash-1502001606	4	0.6
Lower Cedar Wash-1502001607	3	0.4
Tonahakaad Wash-Lower Little Colorado River-1502001608	1	0
Lee Canyon-Lower Little Colorado River-1502001609	3	0.4
Sheep Wash-Lower Little Colorado River-1502001610	3	0.4
Upper Dinnebito Wash-1502001701	3	0.4
Middle Dinnebito Wash-1502001702	2	0.2
Lower Dinnebito Wash-1502001703	1	0
Moenkopi Wash Headwaters-1502001801	5	0.8
Shonto Wash-1502001802	3	0.4
Upper Begashibito Wash-1502001803	3	0.4
Crooked Ridge/Echo Cliffs Area-1502001804	1	0
Lower Begashibito Wash-1502001805	3	0.4
Wide Ruin Canyon-Moenkopi Wash-1502001806	3	0.4
Pasture Canyon-1502001807	1	0
Coal Mine Canyon-Moenkopi Wash-1502001808	2	0.2
Hamblin Wash-1502001809	2	0.2
Kerley Valley-Moenkopi Wash-1502001810	1	0
Fivemile Wash-Moenkopi Wash-1502001811	1	0

Table 6- 7 Summary Results for Metals, Based on the Fuzzy Logic Approach – Weighted Combination Approach.

Subwatershed	WQA[1]	#Mines/ Subwatershed	#Mines/ Riparian	Erosion Category	FMV Weighted
Nutrioso Creek-1502000101	0	0.375	0.000	1.000	0.338
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.7	1.000	0.600	1.000	0.790
Coyote Creek-1502000103	0.7	0.250	0.000	0.800	0.475
Carnero Creek-Little Colorado River Headwaters-1502000104	1	1.000	0.800	0.800	0.880
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	1.000	1.000	0.400	0.670
Big Hollow Wash-1502000202	0.5	0.250	0.200	0.600	0.415
Concho Creek-Upper Little Colorado River-1502000203	0.5	0.750	0.600	0.600	0.585
Oso Draw-1502000204	0	0.750	0.600	0.800	0.495
Milky Wash-1502000205	0.7	0.000	0.000	0.000	0.210
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.7	0.375	0.600	0.400	0.548
Washboard Wash-Upper Little Colorado River-1502000207	1	1.000	0.200	0.200	0.520
Middle Carrizo Wash-1502000306	0.5	0.000	0.000	0.800	0.390
Lower Carrizo Wash-1502000307	0.5	0.000	0.000	0.400	0.270
Jaralosa Draw-1502000406	0.5	0.000	0.000	0.400	0.270
Middle Zuni River-1502000407	0.5	0.000	0.200	0.400	0.330
Hardscrabble Wash-1502000408	0.5	0.000	0.200	0.200	0.270
Lower Zuni River-1502000409	0.5	0.250	0.200	0.400	0.355
Show Low Creek-1502000501	0	1.000	0.800	0.800	0.580
Upper Silver Creek-1502000502	0	1.000	0.000	0.600	0.280
Cottonwood Creek-1502000503	0.5	0.875	0.400	0.600	0.538
Lower Silver Creek-1502000504	0.7	0.500	0.400	0.200	0.440
Upper Black Creek-1502000603	0.5	0.000	0.200	0.600	0.390
Whitewater Arroyo-1502000605	0.5	0.000	0.000	0.400	0.270
Lower Black Creek-1502000606	0.5	0.500	0.800	0.600	0.620
Manuelito Canyon-Upper Puerco River-1502000607	0.5	0.375	0.200	0.600	0.428
Burntwater Wash-Lower Puerco River-1502000701	0.5	1.000	1.000	0.400	0.670
Morgan Canyon-1502000702	0.5	0.375	0.000	0.400	0.308
Dead Wash-1502000703	0.5	0.000	0.000	0.200	0.210
Dry Wash-1502000704	0.5	0.625	0.200	0.200	0.333
Ninemile Wash-Lower Puerco River-1502000705	0.5	1.000	0.600	0.200	0.490
Lithodendron Wash-Lower Puerco River-1502000706	0.5	0.500	0.200	0.000	0.260
Phoenix Park Wash-Dry Lake-1502000801	0.5	0.500	0.200	0.400	0.380
Porter Tank Draw-Middle Little Colorado River-1502000802	0.5	0.375	0.400	0.000	0.308
Upper Clear Creek-1502000803	0	0.125	0.400	1.000	0.433

Subwatershed	WQA[1]	#Mines/ Subwatershed	#Mines/ Riparian	Erosion Category	FMV Weighted
Lower Clear Creek-1502000804	0.5	0.750	0.200	0.200	0.345
Jacks Canyon-1502000805	1	0.125	0.200	0.600	0.553
McDonald Canyon-Middle Little Colorado River-1502000806	0.5	1.000	0.600	0.000	0.430
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	0.625	0.600	0.200	0.453
Coyote Wash-Middle Little Colorado River-1502000808	0.5	0.500	0.200	0.200	0.320
Cow Canyon-Middle Little Colorado River-1502000809	0.5	0.375	0.400	0.000	0.308
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	0.625	0.200	0.000	0.273
Upper Wide Ruin Wash-1502000901	0.5	0.375	0.600	0.400	0.488
Lower Wide Ruin Wash-1502000902	0.5	0.000	0.000	0.400	0.270
Leroux Wash-1502000903	0.5	1.000	1.000	0.200	0.610
Upper Chevelon Canyon-1502001001	0.3	1.000	0.400	0.800	0.550
Black Canyon-1502001002	0.3	0.125	0.600	0.600	0.463
Lower Chevelon Canyon-1502001003	0	0.000	0.200	0.200	0.120
Upper Pueblo Colorado Wash-1502001101	0.5	0.000	0.400	0.600	0.450
Steamboat Wash-1502001102	0.5	0.375	0.400	0.400	0.428
Middle Pueblo Colorado Wash-1502001103	0.5	0.750	0.600	0.600	0.585
Bidahochi Wash-1502001104	0.5	0.875	1.000	1.000	0.838
Lower Pueblo Colorado Wash-1502001105	0.5	0.000	0.000	0.600	0.330
Cottonwood Wash-1502001106	0.5	0.375	0.400	0.200	0.368
Upper Oraibi Wash-1502001201	0.5	0.000	0.000	0.800	0.390
Middle Oraibi Wash-1502001202	0.5	0.000	0.200	0.400	0.330
Lower Oraibi Wash-1502001203	0.5	0.000	0.200	0.200	0.270
Upper Polacca Wash-1502001301	0.5	0.625	0.200	0.800	0.513
Wepo Wash-1502001302	0.5	0.000	0.000	0.400	0.270
Middle Polacca Wash-1502001303	0.5	0.000	0.400	0.400	0.390
Lower Polacca Wash-1502001304	0.5	0.000	0.000	0.000	0.150
Ha-whi-yalin Wash-1502001401	0.5	0.000	0.000	0.800	0.390
Upper Jadito Wash-1502001402	0.5	0.000	0.000	0.400	0.270
Coyote Wash-1502001403	0.5	0.000	0.000	0.600	0.330
Lower Jadito Wash-1502001404	0.5	0.000	0.200	0.600	0.390
Rio de Flag-1502001501	0	1.000	1.000	1.000	0.700
Walnut Creek-1502001502	0.5	1.000	0.400	0.800	0.610
San Francisco Wash-1502001503	0.5	1.000	0.800	0.400	0.610
Canyon Diablo (Local Drainage)-1502001504	0.5	0.125	0.400	0.600	0.463
Kana-a Wash-Lower Little Colorado River-1502001601	0.5	0.000	0.000	0.400	0.270
Deadman Wash-1502001602	0.5	1.000	1.000	1.000	0.850
Big Wash-The Big Lake Area-1502001603	0.5	0.000	0.000	0.000	0.150
Tohachi Wash-1502001604	0.5	0.000	0.000	0.000	0.150

Subwatershed	WQA[1]	#Mines/ Subwatershed	#Mines/ Riparian	Erosion Category	FMV Weighted
Citadel Wash-Lower Little Colorado River-1502001605	**0.5**	**1.000**	**0.600**	**0.200**	**0.490**
Upper Cedar Wash-1502001606	**0.5**	**0.625**	**0.000**	**0.600**	**0.393**
Lower Cedar Wash-1502001607	**0.5**	**0.000**	**0.000**	**0.400**	**0.270**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**0.5**	**1.000**	**1.000**	**0.000**	**0.550**
Lee Canyon-Lower Little Colorado River-1502001609	**0.5**	**0.375**	**0.400**	**0.400**	**0.428**
Sheep Wash-Lower Little Colorado River-1502001610	**0.5**	**0.000**	**0.000**	**0.400**	**0.270**
Upper Dinnebito Wash-1502001701	**0.5**	**0.000**	**0.000**	**0.400**	**0.270**
Middle Dinnebito Wash-1502001702	**0.5**	**0.000**	**0.000**	**0.200**	**0.210**
Lower Dinnebito Wash-1502001703	**0.5**	**0.000**	**0.200**	**0.000**	**0.210**
Moenkopi Wash Headwaters-1502001801	**0.5**	**0.500**	**0.000**	**0.800**	**0.440**
Shonto Wash-1502001802	**0.5**	**0.750**	**0.200**	**0.400**	**0.405**
Upper Begashibito Wash-1502001803	**0.5**	**0.000**	**0.000**	**0.400**	**0.270**
Crooked Ridge/Echo Cliffs Area-1502001804	**0.5**	**0.000**	**0.000**	**0.000**	**0.150**
Lower Begashibito Wash-1502001805	**0.5**	**0.000**	**0.200**	**0.400**	**0.330**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.5**	**0.000**	**0.200**	**0.400**	**0.330**
Pasture Canyon-1502001807	**0.5**	**0.125**	**0.400**	**0.000**	**0.283**
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**0.875**	**0.200**	**0.200**	**0.358**
Hamblin Wash-1502001809	**0.5**	**0.750**	**0.000**	**0.200**	**0.285**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**0.125**	**0.200**	**0.000**	**0.223**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**0.625**	**0.800**	**0.000**	**0.453**
Weights	***0.3***	***0.100***	***0.300***	***0.300***	

[1]WQA = Water Quality Assessment Data

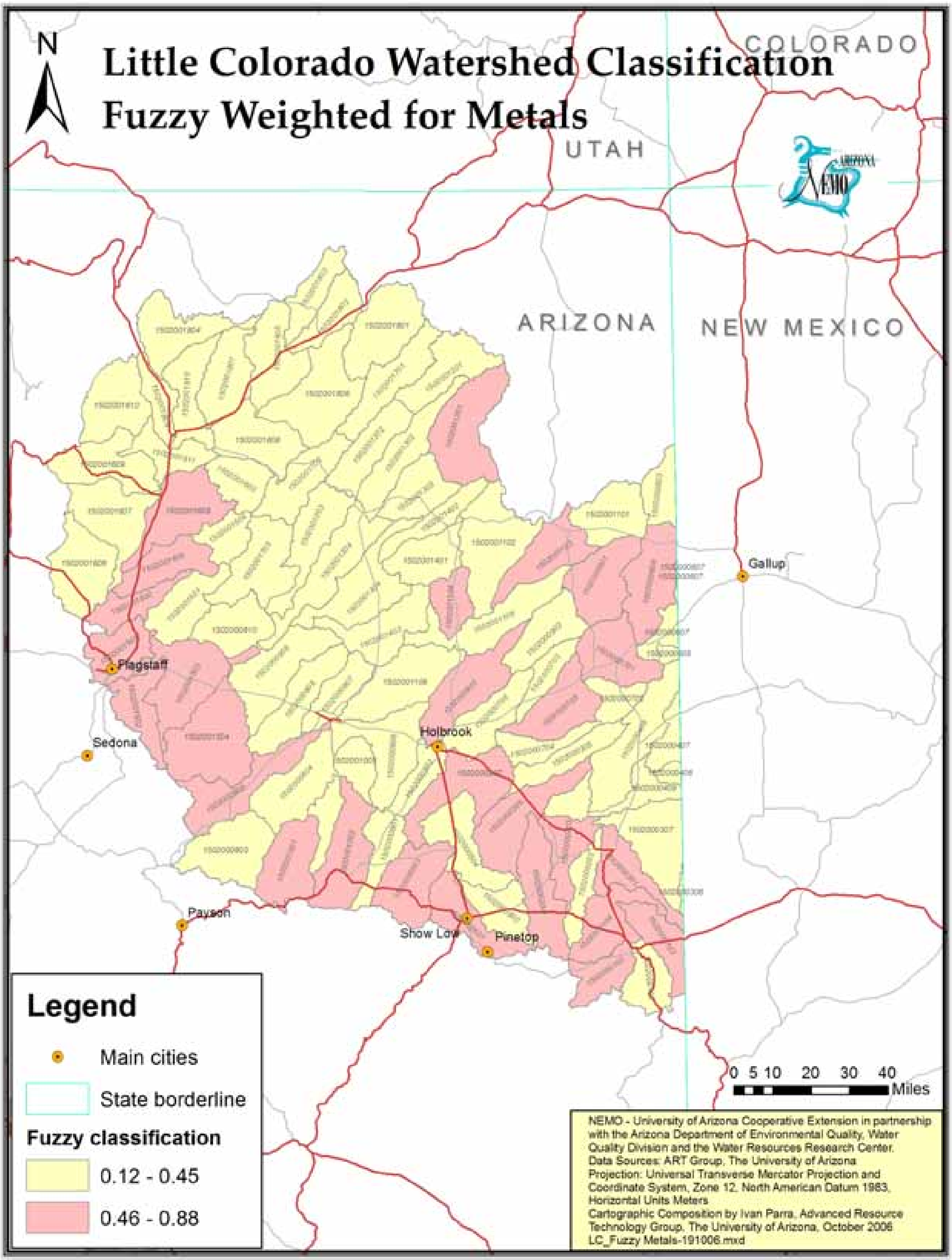

Figure 6- 3 Results for the Fuzzy Logic Classification for Metals, Based on the Weighted Combination Approach.

Sediment

Erosion and sedimentation are major environmental concerns in arid and semiarid environments. Sediment is the chief source of impairment in the southwestern United States, not only to our few aquatic systems, but also to our riparian systems which are at risk from channel degradation.

The factors used for the sediment classification are:

- ADEQ water quality assessment results (note that turbidity data is used where sediment results are not available);
- Estimated current runoff and sediment yield;
- Human use within a subwatershed and riparian area; and
- Land ownership.

Because available water quality data was limited, more weight was placed on subwatershed characteristics and modeling results when performing the classification.

Water Quality Assessment Data - Sediment

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), was used to define the current water quality based on water monitoring results. In assigning fuzzy membership values, the location of a subwatershed relative to an impaired water was considered. As discussed under the metals classification section, an overall risk classification is assigned to the HUC 10-digit subwatershed based on the worst case risk classification of the water bodies in that subwatershed. Fuzzy membership values (FMV) were assigned to each subwatershed using the criteria in Table 6- 2. The FMVs in Table 6- 2 are based on two considerations: 1) Subwatershed relative risk of impairment (described above), and 2) Downstream subwatershed risk of impairment.

The status of downstream surface waters provides a way to evaluate the possibility that the subwatershed is contributing to downstream water quality problems. This is particularly important where water quality data is limited and few surface water quality samples may have been collected within the subwatershed.

Water bodies classified as either extreme (impaired) or low (no exceedances) risk had a higher influence than high or moderate classified water bodies in determining downstream water quality condition because they were less ambiguous than the other levels of risk. For example, if a water body was classified as extreme risk, it was used to define the water quality condition, and the subwatershed was given an FMV of 1.0. Likewise, if a water body along the pathway was classified as low risk, then that water body was used to define the downstream water quality condition (see Table 6- 2).

Table 6- 2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results. Table 6- 8 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on turbidity data.

Table 6- 8 Fuzzy Membership Values for Sediment Assigned to each 10-digit HUC Subwatershed, Based on Water Quality Assessment Results.

Subwatershed	FMV	Justification
Nutrioso Creek-1502000101	1.0	Classified as extreme risk
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	1.0	Classified as extreme risk
Coyote Creek-1502000103	0.7	Classified as moderate risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as extreme risk
Carnero Creek-Little Colorado River Headwaters-1502000104	1.0	Classified as extreme risk
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Big Hollow Wash-1502000202	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Concho Creek-Upper Little Colorado River-1502000203	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Oso Draw-1502000204	0.0	Classified as low risk
Milky Wash-1502000205	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Washboard Wash-Upper Little Colorado River-1502000207	1.0	Classified as extreme risk
Middle Carrizo Wash-1502000306	0.5	Classified as moderate risk, drains into Lower Carrizo Wash that is classified as moderate risk
Lower Carrizo Wash-1502000307	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Jaralosa Draw-1502000406	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Middle Zuni River-1502000407	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Hardscrabble Wash-1502000408	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Lower Zuni River-1502000409	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Show Low Creek-1502000501	0.7	Classified as high risk, drains into Lower Silver Creek that is classified as moderate risk
Upper Silver Creek-1502000502	0.7	Classified as high risk, drains into Lower Silver Creek that is classified as moderate risk
Cottonwood Creek-1502000503	0.5	Classified as moderate risk, drains into Lower Silver Creek that is classified as moderate risk
Lower Silver Creek-1502000504	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Upper Black Creek-1502000603	0.5	Classified as moderate risk, drains into Lower Black Creek that is classified as moderate risk

Subwatershed	FMV	Justification
Whitewater Arroyo-1502000605	0.5	Classified as moderate risk, drains into Manuelito Canyon-Upper Puerco River that is classified as moderate risk
Lower Black Creek-1502000606	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Manuelito Canyon-Upper Puerco River-1502000607	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Burntwater Wash-Lower Puerco River-1502000701	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Morgan Canyon-1502000702	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Dead Wash-1502000703	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Dry Wash-1502000704	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Ninemile Wash-Lower Puerco River-1502000705	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Lithodendron Wash-Lower Puerco River-1502000706	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Phoenix Park Wash-Dry Lake-1502000801	0.5	Classified as moderate risk, drains into Black Canyon that is classified as moderate risk
Porter Tank Draw-Middle Little Colorado River-1502000802	0.7	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as extreme risk
Upper Clear Creek-1502000803	0.5	Classified as moderate risk, drains into Lower Clear Creek that is classified as moderate risk
Lower Clear Creek-1502000804	0.7	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as extreme risk
Jacks Canyon-1502000805	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
McDonald Canyon-Middle Little Colorado River-1502000806	1.0	Classified as extreme risk
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	Classified as moderate risk, drains into Coyote Wash-Middle Little Colorado River that is classified as moderate risk
Coyote Wash-Middle Little Colorado River-1502000808	0.5	Classified as moderate risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk
Cow Canyon-Middle Little Colorado River-1502000809	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk
Upper Wide Ruin Wash-1502000901	0.5	Classified as moderate risk, drains into Lower Wide Ruin Wash that is classified as moderate risk
Lower Wide Ruin Wash-1502000902	0.5	Classified as moderate risk, drains into Leroux Wash that is classified as moderate risk

Subwatershed	FMV	Justification
Leroux Wash-1502000903	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Upper Chevelon Canyon-1502001001	0.6	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as high risk
Black Canyon-1502001002	0.6	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as high risk
Lower Chevelon Canyon-1502001003	1.0	Classified as high risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as extreme risk
Upper Pueblo Colorado Wash-1502001101	0.5	Classified as moderate risk, drains into Middle Pueblo Colorado Wash that is classified as moderate risk
Steamboat Wash-1502001102	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Middle Pueblo Colorado Wash-1502001103	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Bidahochi Wash-1502001104	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Lower Pueblo Colorado Wash-1502001105	0.5	Classified as moderate risk, drains into Cottonwood Wash that is classified as moderate risk
Cottonwood Wash-1502001106	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Upper Oraibi Wash-1502001201	0.5	Classified as moderate risk, drains into Middle Oraibi Wash that is classified as moderate risk
Middle Oraibi Wash-1502001202	0.5	Classified as moderate risk, drains into Lower Oraibi Wash that is classified as moderate risk
Lower Oraibi Wash-1502001203	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Upper Polacca Wash-1502001301	0.5	Classified as moderate risk, drains into Middle Polacca Wash that is classified as moderate risk
Wepo Wash-1502001302	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Middle Polacca Wash-1502001303	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Lower Polacca Wash-1502001304	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Ha-whi-yalin Wash-1502001401	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Upper Jadito Wash-1502001402	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Coyote Wash-1502001403	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Lower Jadito Wash-1502001404	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Rio de Flag-1502001501	0.7	Classified as high risk, drains into San Francisco Wash that is classified as moderate risk
Walnut Creek-1502001502	0.5	Classified as moderate risk, drains into San Francisco Wash that is classified as moderate risk
San Francisco Wash-1502001503	0.6	Classified as moderate risk, drains into Canyon Diablo (Local Drainage) that is classified as high risk

Subwatershed	FMV	Justification
Canyon Diablo (Local Drainage)-1502001504	0.7	Classified as high risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk
Kana-a Wash-Lower Little Colorado River-1502001601	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk
Deadman Wash-1502001602	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk
Big Wash-The Big Lake Area-1502001603	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Tohachi Wash-1502001604	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Citadel Wash-Lower Little Colorado River-1502001605	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Upper Cedar Wash-1502001606	0.5	Classified as moderate risk, drains into Lower Cedar Wash that is classified as moderate risk
Lower Cedar Wash-1502001607	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Lee Canyon-Lower Little Colorado River-1502001609	0.5	Classified as moderate risk, drains into Sheep Wash-Lower Little Colorado River that is classified as moderate risk
Sheep Wash-Lower Little Colorado River-1502001610	0.5	Classified as moderate risk
Upper Dinnebito Wash-1502001701	0.5	Classified as moderate risk, drains into Middle Dinnebito Wash that is classified as moderate risk
Middle Dinnebito Wash-1502001702	0.5	Classified as moderate risk, drains into Lower Dinnebito Wash that is classified as moderate risk
Lower Dinnebito Wash-1502001703	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk
Moenkopi Wash Headwaters-1502001801	0.5	Classified as moderate risk, drains into Wide Ruin Canyon-Moenkopi Wash that is classified as moderate risk
Shonto Wash-1502001802	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk
Upper Begashibito Wash-1502001803	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk
Crooked Ridge/Echo Cliffs Area-1502001804	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Lower Begashibito Wash-1502001805	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Pasture Canyon-1502001807	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk

Subwatershed	FMV	Justification
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk**
Hamblin Wash-1502001809	**0.5**	**Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk**

Land ownership - Sediment

The principal land use in the Little Colorado Watershed is livestock grazing. Livestock grazing occurs primarily on land owned by the federal government (Bureau of Land Management (BLM) and U.S. Forest Service (USFS)) which comprises approximately 46% of the total watershed area. The remaining lands where grazing occurs are Arizona State Trust Land (approximately 14%), and privately owned land (approximately 10%). An estimated 1.72% of the watershed is under agricultural production.

Section 4, Social Characteristics, contains a brief discussion of land ownership, with more detail provided in Section 7, Watershed Management, where individual management practices and target stakeholders are discussed. Given that Federal lands must have management plans that include Best Management Practices, the following classification will highlight State and private lands that may not have a water management plan in place. The fuzzy membership function for the percentage of land in State or private ownership within a 10-digit HUC subwatershed is below.

State and Private ownership over the subwatershed area:

FMV = 0 if (%State + private < = 10)
FMV = (%State + private – 10) / 15
FMV = 1 if (%State + private > = 25)

Table 6- 9 contains the fuzzy membership values assigned to each 10- digit HUC subwatershed in the Little Colorado Watershed based on land ownership.

Table 6- 9 Fuzzy Membership Values Based on Land Ownership.

Subwatershed	% State + Private	FMV
Nutrioso Creek-1502000101	22.15	0.81
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	20.71	0.71
Coyote Creek-1502000103	75.83	1.00
Carnero Creek-Little Colorado River Headwaters-1502000104	87.62	1.00
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	94.90	1.00
Big Hollow Wash-1502000202	88.13	1.00
Concho Creek-Upper Little Colorado River-1502000203	92.08	1.00
Oso Draw-1502000204	78.68	1.00
Milky Wash-1502000205	92.68	1.00
Hay Hollow Draw-Upper Little Colorado River-1502000206	95.37	1.00
Washboard Wash-Upper Little Colorado River-1502000207	87.97	1.00
Middle Carrizo Wash-1502000306	82.34	1.00
Lower Carrizo Wash-1502000307	83.78	1.00
Jaralosa Draw-1502000406	100.00	1.00
Middle Zuni River-1502000407	93.43	1.00
Hardscrabble Wash-1502000408	80.84	1.00
Lower Zuni River-1502000409	84.28	1.00
Show Low Creek-1502000501	23.84	0.92
Upper Silver Creek-1502000502	54.63	1.00
Cottonwood Creek-1502000503	31.68	1.00
Lower Silver Creek-1502000504	90.92	1.00
Upper Black Creek-1502000603	0.00	0.00
Whitewater Arroyo-1502000605	0.00	0.00
Lower Black Creek-1502000606	0.00	0.00
Manuelito Canyon-Upper Puerco River-1502000607	0.02	0.00
Burntwater Wash-Lower Puerco River-1502000701	40.34	1.00
Morgan Canyon-1502000702	91.26	1.00
Dead Wash-1502000703	47.93	1.00
Dry Wash-1502000704	68.20	1.00
Ninemile Wash-Lower Puerco River-1502000705	88.72	1.00
Lithodendron Wash-Lower Puerco River-1502000706	64.48	1.00
Phoenix Park Wash-Dry Lake-1502000801	53.81	1.00
Porter Tank Draw-Middle Little Colorado River-1502000802	79.98	1.00
Upper Clear Creek-1502000803	8.25	0.00
Lower Clear Creek-1502000804	77.07	1.00
Jacks Canyon-1502000805	43.57	1.00
McDonald Canyon-Middle Little Colorado River-1502000806	93.89	1.00
Rincon Basin Area-Middle Little Colorado River-1502000807	75.81	1.00
Coyote Wash-Middle Little Colorado River-1502000808	71.30	1.00
Cow Canyon-Middle Little Colorado River-1502000809	37.23	1.00
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	4.86	0.00
Upper Wide Ruin Wash-1502000901	0.00	0.00
Lower Wide Ruin Wash-1502000902	0.00	0.00
Leroux Wash-1502000903	59.54	1.00
Upper Chevelon Canyon-1502001001	1.25	0.00
Black Canyon-1502001002	33.61	1.00
Lower Chevelon Canyon-1502001003	79.63	1.00
Upper Pueblo Colorado Wash-1502001101	0.00	0.00
Steamboat Wash-1502001102	0.00	0.00
Middle Pueblo Colorado Wash-1502001103	0.00	0.00
Bidahochi Wash-1502001104	0.00	0.00
Lower Pueblo Colorado Wash-1502001105	0.00	0.00
Cottonwood Wash-1502001106	54.72	1.00
Upper Oraibi Wash-1502001201	0.00	0.00
Middle Oraibi Wash-1502001202	0.00	0.00
Lower Oraibi Wash-1502001203	0.00	0.00
Upper Polacca Wash-1502001301	0.00	0.00
Wepo Wash-1502001302	0.00	0.00
Middle Polacca Wash-1502001303	0.00	0.00
Lower Polacca Wash-1502001304	0.00	0.00
Ha-whi-yalin Wash-1502001401	0.00	0.00
Upper Jadito Wash-1502001402	0.00	0.00
Coyote Wash-1502001403	0.00	0.00
Lower Jadito Wash-1502001404	0.00	0.00
Rio de Flag-1502001501	32.43	1.00
Walnut Creek-1502001502	5.40	0.00

Subwatershed	% State + Private	FMV
San Francisco Wash-1502001503	23.15	0.88
Canyon Diablo (Local Drainage)-1502001504	54.02	1.00
Kana-a Wash-Lower Little Colorado River-1502001601	44.60	1.00
Deadman Wash-1502001602	3.62	0.00
Big Wash-The Big Lake Area-1502001603	0.00	0.00
Tohachi Wash-1502001604	0.00	0.00
Citadel Wash-Lower Little Colorado River-1502001605	34.24	1.00
Upper Cedar Wash-1502001606	49.09	1.00
Lower Cedar Wash-1502001607	12.08	0.14
Tonahakaad Wash-Lower Little Colorado River-1502001608	25.95	1.00
Lee Canyon-Lower Little Colorado River-1502001609	0.34	0.00
Sheep Wash-Lower Little Colorado River-1502001610	0.00	0.00
Upper Dinnebito Wash-1502001701	0.00	0.00
Middle Dinnebito Wash-1502001702	0.00	0.00
Lower Dinnebito Wash-1502001703	0.00	0.00
Moenkopi Wash Headwaters-1502001801	0.00	0.00
Shonto Wash-1502001802	0.00	0.00
Upper Begashibito Wash-1502001803	0.00	0.00
Crooked Ridge/Echo Cliffs Area-1502001804	0.00	0.00
Lower Begashibito Wash-1502001805	0.00	0.00
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.00	0.00
Pasture Canyon-1502001807	0.00	0.00
Coal Mine Canyon-Moenkopi Wash-1502001808	0.00	0.00
Hamblin Wash-1502001809	0.00	0.00
Kerley Valley-Moenkopi Wash-1502001810	0.00	0.00
Fivemile Wash-Moenkopi Wash-1502001811	0.00	0.00

Human Use Index - Sediment Load

The Human Use Index was used to assess the relative impact of urban development on sediment load in streams. The Human Use Index is defined as the percentage of a subwatershed that is characterized as developed for human use. In the Little Colorado Watershed, human use consists of developed areas as defined by the NLCD cover data set as residential land use, agriculture, mining and roads (RS/GIS Laboratory, 2004).

Human use was assessed at both the subwatershed and riparian scale (<= 250 meters from a stream). The fuzzy membership functions for both conditions are:

Human Use Index/subwatershed:
FMV = 0 if (HUI <= 5%)
FMV = (HUI – 5) / 15
FMV = 1 if (HUI >= 20%)

Human Use Index/riparian:
FMV = 0 if (HUI <= 1%)
FMV = (HUI - 1) / 4
FMV = 1 if (HUI >= 5%)

Table 6- 10 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Little Colorado Watershed based on the Human Use Index.

Table 6- 10 Fuzzy Membership Values Based on the Human Use Index.

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Nutrioso Creek-1502000101	0.00	0.65
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.00	1.00
Coyote Creek-1502000103	0.00	0.00
Carnero Creek-Little Colorado River Headwaters-1502000104	0.00	0.58
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.01	1.00
Big Hollow Wash-1502000202	0.00	0.00
Concho Creek-Upper Little Colorado River-1502000203	0.00	0.05
Oso Draw-1502000204	0.00	0.00
Milky Wash-1502000205	0.00	0.00
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.00	0.05
Washboard Wash-Upper Little Colorado River-1502000207	0.00	0.00
Middle Carrizo Wash-1502000306	0.00	0.00
Lower Carrizo Wash-1502000307	0.00	0.00
Jaralosa Draw-1502000406	0.00	0.00
Middle Zuni River-1502000407	0.00	0.00
Hardscrabble Wash-1502000408	0.00	0.00
Lower Zuni River-1502000409	0.00	0.00
Show Low Creek-1502000501	0.00	0.71
Upper Silver Creek-1502000502	0.00	0.44
Cottonwood Creek-1502000503	0.00	0.59
Lower Silver Creek-1502000504	0.00	1.00
Upper Black Creek-1502000603	0.00	0.00
Whitewater Arroyo-1502000605	0.00	0.00
Lower Black Creek-1502000606	0.00	0.00
Manuelito Canyon-Upper Puerco River-1502000607	0.00	0.12
Burntwater Wash-Lower Puerco River-1502000701	0.00	0.11
Morgan Canyon-1502000702	0.00	0.00
Dead Wash-1502000703	0.00	0.00
Dry Wash-1502000704	0.00	0.00
Ninemile Wash-Lower Puerco River-1502000705	0.00	0.00
Lithodendron Wash-Lower Puerco River-1502000706	0.00	0.00
Phoenix Park Wash-Dry Lake-1502000801	0.00	0.22
Porter Tank Draw-Middle Little Colorado River-1502000802	0.00	0.05
Upper Clear Creek-1502000803	0.00	0.00
Lower Clear Creek-1502000804	0.00	0.00
Jacks Canyon-1502000805	0.00	0.25
McDonald Canyon-Middle Little Colorado River-1502000806	0.00	0.15
Rincon Basin Area-Middle Little Colorado River-1502000807	0.00	0.85
Coyote Wash-Middle Little Colorado River-1502000808	0.00	0.00

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Cow Canyon-Middle Little Colorado River-1502000809	0.00	0.00
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.00	0.00
Upper Wide Ruin Wash-1502000901	0.00	0.00
Lower Wide Ruin Wash-1502000902	0.00	0.00
Leroux Wash-1502000903	0.00	0.00
Upper Chevelon Canyon-1502001001	0.00	0.00
Black Canyon-1502001002	0.00	0.00
Lower Chevelon Canyon-1502001003	0.00	0.00
Upper Pueblo Colorado Wash-1502001101	0.00	0.00
Steamboat Wash-1502001102	0.00	0.00
Middle Pueblo Colorado Wash-1502001103	0.00	0.00
Bidahochi Wash-1502001104	0.00	0.00
Lower Pueblo Colorado Wash-1502001105	0.00	0.00
Cottonwood Wash-1502001106	0.00	0.00
Upper Oraibi Wash-1502001201	0.00	0.00
Middle Oraibi Wash-1502001202	0.00	0.00
Lower Oraibi Wash-1502001203	0.00	0.00
Upper Polacca Wash-1502001301	0.00	0.00
Wepo Wash-1502001302	0.00	0.00
Middle Polacca Wash-1502001303	0.00	0.00
Lower Polacca Wash-1502001304	0.00	0.00
Ha-whi-yalin Wash-1502001401	0.00	0.00
Upper Jadito Wash-1502001402	0.00	0.00
Coyote Wash-1502001403	0.00	0.00
Lower Jadito Wash-1502001404	0.00	0.00
Rio de Flag-1502001501	0.00	1.00
Walnut Creek-1502001502	0.00	1.00
San Francisco Wash-1502001503	0.00	0.14
Canyon Diablo (Local Drainage)-1502001504	0.00	0.00
Kana-a Wash-Lower Little Colorado River-1502001601	0.00	0.00
Deadman Wash-1502001602	0.00	0.00
Big Wash-The Big Lake Area-1502001603	0.00	0.00
Tohachi Wash-1502001604	0.00	0.00
Citadel Wash-Lower Little Colorado River-1502001605	0.00	0.00
Upper Cedar Wash-1502001606	0.00	0.00
Lower Cedar Wash-1502001607	0.00	0.00
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.00	0.00
Lee Canyon-Lower Little Colorado River-1502001609	0.00	0.00
Sheep Wash-Lower Little Colorado River-1502001610	0.00	0.00
Upper Dinnebito Wash-1502001701	0.00	0.00
Middle Dinnebito Wash-1502001702	0.00	0.00
Lower Dinnebito Wash-1502001703	0.00	0.00

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Moenkopi Wash Headwaters-1502001801	0.00	0.00
Shonto Wash-1502001802	0.00	0.00
Upper Begashibito Wash-1502001803	0.00	0.00
Crooked Ridge/Echo Cliffs Area-1502001804	0.00	0.00
Lower Begashibito Wash-1502001805	0.00	0.00
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.00	0.00
Pasture Canyon-1502001807	0.00	0.00
Coal Mine Canyon-Moenkopi Wash-1502001808	0.00	0.00
Hamblin Wash-1502001809	0.00	0.00
Kerley Valley-Moenkopi Wash-1502001810	0.00	0.00
Fivemile Wash-Moenkopi Wash-1502001811	0.00	0.00

AGWA/SWAT Modeling

Runoff

Based on SWAT modeling (see Appendix D) the potential runoff for a subwatershed area was evaluated. The modeling results were reclassified (using Jenks method under ArcGIS 9.1) into five categories, with the first category given a fuzzy membership value of 0.2. The fuzzy membership values were increased by 0.2 for each higher runoff category, as shown in Table 6- 11.

Erosion and Sediment Yield

AGWA/SWAT was used to evaluate the potential runoff and sediment yield (see Appendix D for a description of AGWA/SWAT) for a subwatershed area. Runoff can be used to evaluate potential sediment yield, which is a measure of the rate of erosion. Both runoff and sediment yield depend on a combination of soil properties, topography, climate and land cover.

The modeling results were reclassified into five categories, with the first category given a fuzzy membership value of 0.2. The fuzzy membership values were increased by 0.2 for each higher category. Table 6- 12 shows the erosion categories and associated FMV.

Sediment Results

The weighted combination approach was used to create combined fuzzy scores to rank sediment results, as shown in Table 6- 13. Figure 6- 4 shows the results of the weighted combination method classified into high and low priority for sediment. The weights used in the classification are also found in Table 6- 13.

Table 6- 11 Fuzzy Membership Values and Runoff Categories.

Subwatershed	Runoff Category	FMV
Nutrioso Creek-1502000101	3	0.6
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	3	0.6
Coyote Creek-1502000103	3	0.6
Carnero Creek-Little Colorado River Headwaters-1502000104	3	0.6
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	3	0.6
Big Hollow Wash-1502000202	3	0.6
Concho Creek-Upper Little Colorado River-1502000203	3	0.6
Oso Draw-1502000204	4	0.8
Milky Wash-1502000205	3	0.6
Hay Hollow Draw-Upper Little Colorado River-1502000206	3	0.6
Washboard Wash-Upper Little Colorado River-1502000207	4	0.8
Middle Carrizo Wash-1502000306	2	0.4
Lower Carrizo Wash-1502000307	2	0.4
Jaralosa Draw-1502000406	2	0.4
Middle Zuni River-1502000407	1	0.2
Hardscrabble Wash-1502000408	2	0.4
Lower Zuni River-1502000409	3	0.6
Show Low Creek-1502000501	5	1
Upper Silver Creek-1502000502	5	1
Cottonwood Creek-1502000503	3	0.6
Lower Silver Creek-1502000504	4	0.8
Upper Black Creek-1502000603	1	0.2
Whitewater Arroyo-1502000605	2	0.4
Lower Black Creek-1502000606	1	0.2
Manuelito Canyon-Upper Puerco River-1502000607	2	0.4
Burntwater Wash-Lower Puerco River-1502000701	2	0.4
Morgan Canyon-1502000702	2	0.4
Dead Wash-1502000703	2	0.4
Dry Wash-1502000704	2	0.4
Ninemile Wash-Lower Puerco River-1502000705	2	0.4
Lithodendron Wash-Lower Puerco River-1502000706	2	0.4
Phoenix Park Wash-Dry Lake-1502000801	4	0.8
Porter Tank Draw-Middle Little Colorado River-1502000802	4	0.8
Upper Clear Creek-1502000803	1	0.2
Lower Clear Creek-1502000804	2	0.4
Jacks Canyon-1502000805	3	0.6
McDonald Canyon-Middle Little Colorado River-1502000806	4	0.8
Rincon Basin Area-Middle Little Colorado River-1502000807	3	0.6
Coyote Wash-Middle Little Colorado River-1502000808	3	0.6
Cow Canyon-Middle Little Colorado River-1502000809	3	0.6

Subwatershed	Runoff Category	FMV
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	3	0.6
Upper Wide Ruin Wash-1502000901	2	0.4
Lower Wide Ruin Wash-1502000902	2	0.4
Leroux Wash-1502000903	2	0.4
Upper Chevelon Canyon-1502001001	1	0.2
Black Canyon-1502001002	3	0.6
Lower Chevelon Canyon-1502001003	4	0.8
Upper Pueblo Colorado Wash-1502001101	2	0.4
Steamboat Wash-1502001102	1	0.2
Middle Pueblo Colorado Wash-1502001103	1	0.2
Bidahochi Wash-1502001104	1	0.2
Lower Pueblo Colorado Wash-1502001105	1	0.2
Cottonwood Wash-1502001106	1	0.2
Upper Oraibi Wash-1502001201	2	0.4
Middle Oraibi Wash-1502001202	2	0.4
Lower Oraibi Wash-1502001203	2	0.4
Upper Polacca Wash-1502001301	1	0.2
Wepo Wash-1502001302	2	0.4
Middle Polacca Wash-1502001303	2	0.4
Lower Polacca Wash-1502001304	2	0.4
Ha-whi-yalin Wash-1502001401	1	0.2
Upper Jadito Wash-1502001402	1	0.2
Coyote Wash-1502001403	1	0.2
Lower Jadito Wash-1502001404	2	0.4
Rio de Flag-1502001501	5	1
Walnut Creek-1502001502	5	1
San Francisco Wash-1502001503	4	0.8
Canyon Diablo (Local Drainage)-1502001504	4	0.8
Kana-a Wash-Lower Little Colorado River-1502001601	4	0.8
Deadman Wash-1502001602	4	0.8
Big Wash-The Big Lake Area-1502001603	3	0.6
Tohachi Wash-1502001604	4	0.8
Citadel Wash-Lower Little Colorado River-1502001605	4	0.8
Upper Cedar Wash-1502001606	5	1
Lower Cedar Wash-1502001607	2	0.4
Tonahakaad Wash-Lower Little Colorado River-1502001608	4	0.8
Lee Canyon-Lower Little Colorado River-1502001609	3	0.6
Sheep Wash-Lower Little Colorado River-1502001610	3	0.6
Upper Dinnebito Wash-1502001701	2	0.4
Middle Dinnebito Wash-1502001702	3	0.6
Lower Dinnebito Wash-1502001703	3	0.6

Subwatershed	Runoff Category	FMV
Moenkopi Wash Headwaters-1502001801	2	0.4
Shonto Wash-1502001802	2	0.4
Upper Begashibito Wash-1502001803	2	0.4
Crooked Ridge/Echo Cliffs Area-1502001804	3	0.6
Lower Begashibito Wash-1502001805	2	0.4
Wide Ruin Canyon-Moenkopi Wash-1502001806	2	0.4
Pasture Canyon-1502001807	3	0.6
Coal Mine Canyon-Moenkopi Wash-1502001808	3	0.6
Hamblin Wash-1502001809	3	0.6
Kerley Valley-Moenkopi Wash-1502001810	3	0.6
Fivemile Wash-Moenkopi Wash-1502001811	3	0.6

Table 6- 12 Fuzzy Membership Values and Erosion Categories.

Subwatershed	Erosion Category	FMV
Nutrioso Creek-1502000101	4	0.8
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	4	0.8
Coyote Creek-1502000103	3	0.6
Carnero Creek-Little Colorado River Headwaters-1502000104	3	0.6
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	3	0.6
Big Hollow Wash-1502000202	3	0.6
Concho Creek-Upper Little Colorado River-1502000203	4	0.8
Oso Draw-1502000204	1	0.2
Milky Wash-1502000205	1	0.2
Hay Hollow Draw-Upper Little Colorado River-1502000206	1	0.2
Washboard Wash-Upper Little Colorado River-1502000207	1	0.2
Middle Carrizo Wash-1502000306	2	0.4
Lower Carrizo Wash-1502000307	1	0.2
Jaralosa Draw-1502000406	1	0.2
Middle Zuni River-1502000407	2	0.4
Hardscrabble Wash-1502000408	1	0.2
Lower Zuni River-1502000409	2	0.4
Show Low Creek-1502000501	1	0.2
Upper Silver Creek-1502000502	1	0.2
Cottonwood Creek-1502000503	2	0.4
Lower Silver Creek-1502000504	1	0.2
Upper Black Creek-1502000603	2	0.4
Whitewater Arroyo-1502000605	3	0.6
Lower Black Creek-1502000606	1	0.2
Manuelito Canyon-Upper Puerco River-1502000607	3	0.6
Burntwater Wash-Lower Puerco River-1502000701	1	0.2

Subwatershed	Erosion Category	FMV
Morgan Canyon-1502000702	1	0.2
Dead Wash-1502000703	1	0.2
Dry Wash-1502000704	1	0.2
Ninemile Wash-Lower Puerco River-1502000705	1	0.2
Lithodendron Wash-Lower Puerco River-1502000706	1	0.2
Phoenix Park Wash-Dry Lake-1502000801	1	0.2
Porter Tank Draw-Middle Little Colorado River-1502000802	1	0.2
Upper Clear Creek-1502000803	2	0.4
Lower Clear Creek-1502000804	1	0.2
Jacks Canyon-1502000805	1	0.2
McDonald Canyon-Middle Little Colorado River-1502000806	1	0.2
Rincon Basin Area-Middle Little Colorado River-1502000807	1	0.2
Coyote Wash-Middle Little Colorado River-1502000808	1	0.2
Cow Canyon-Middle Little Colorado River-1502000809	1	0.2
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	1	0.2
Upper Wide Ruin Wash-1502000901	5	1
Lower Wide Ruin Wash-1502000902	1	0.2
Leroux Wash-1502000903	1	0.2
Upper Chevelon Canyon-1502001001	1	0.2
Black Canyon-1502001002	1	0.2
Lower Chevelon Canyon-1502001003	1	0.2
Upper Pueblo Colorado Wash-1502001101	3	0.6
Steamboat Wash-1502001102	4	0.8
Middle Pueblo Colorado Wash-1502001103	2	0.4
Bidahochi Wash-1502001104	1	0.2
Lower Pueblo Colorado Wash-1502001105	1	0.2
Cottonwood Wash-1502001106	1	0.2
Upper Oraibi Wash-1502001201	5	1
Middle Oraibi Wash-1502001202	3	0.6
Lower Oraibi Wash-1502001203	3	0.6
Upper Polacca Wash-1502001301	5	1
Wepo Wash-1502001302	4	0.8
Middle Polacca Wash-1502001303	4	0.8
Lower Polacca Wash-1502001304	3	0.6
Ha-whi-yalin Wash-1502001401	4	0.8
Upper Jadito Wash-1502001402	4	0.8
Coyote Wash-1502001403	4	0.8
Lower Jadito Wash-1502001404	3	0.6
Rio de Flag-1502001501	3	0.6
Walnut Creek-1502001502	3	0.6
San Francisco Wash-1502001503	1	0.2
Canyon Diablo (Local Drainage)-1502001504	1	0.2

Subwatershed	Erosion Category	FMV
Kana-a Wash-Lower Little Colorado River-1502001601	1	0.2
Deadman Wash-1502001602	1	0.2
Big Wash-The Big Lake Area-1502001603	2	0.4
Tohachi Wash-1502001604	1	0.2
Citadel Wash-Lower Little Colorado River-1502001605	1	0.2
Upper Cedar Wash-1502001606	2	0.4
Lower Cedar Wash-1502001607	2	0.4
Tonahakaad Wash-Lower Little Colorado River-1502001608	1	0.2
Lee Canyon-Lower Little Colorado River-1502001609	5	1
Sheep Wash-Lower Little Colorado River-1502001610	5	1
Upper Dinnebito Wash-1502001701	3	0.6
Middle Dinnebito Wash-1502001702	2	0.4
Lower Dinnebito Wash-1502001703	2	0.4
Moenkopi Wash Headwaters-1502001801	4	0.8
Shonto Wash-1502001802	5	1
Upper Begashibito Wash-1502001803	5	1
Crooked Ridge/Echo Cliffs Area-1502001804	3	0.6
Lower Begashibito Wash-1502001805	4	0.8
Wide Ruin Canyon-Moenkopi Wash-1502001806	4	0.8
Pasture Canyon-1502001807	3	0.6
Coal Mine Canyon-Moenkopi Wash-1502001808	4	0.8
Hamblin Wash-1502001809	3	0.6
Kerley Valley-Moenkopi Wash-1502001810	3	0.6
Fivemile Wash-Moenkopi Wash-1502001811	3	0.6

Table 6- 13 Summary Results for Sediment, Based on the Fuzzy Logic Approach - Weighted Combination Approach.

Subwatershed	WQA	Land Ownership	HUI/ Subwatershed	HUI/ Riparian	Runoff	Erosion	FMV Weighted
Nutrioso Creek-1502000101	0.7	0.810	0.000	0.648	0.600	1.000	0.685
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.7	0.714	0.000	1.000	0.600	1.000	0.751
Coyote Creek-1502000103	0.5	1.000	0.000	0.000	0.600	0.800	0.495
Carnero Creek-Little Colorado River Headwaters-1502000104	0.5	1.000	0.000	0.578	0.600	0.800	0.611
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	1.000	0.014	1.000	0.600	0.400	0.576
Big Hollow Wash-1502000202	0.5	1.000	0.000	0.000	0.600	0.600	0.435
Concho Creek-Upper Little Colorado River-1502000203	0.5	1.000	0.000	0.045	0.600	0.600	0.444
Oso Draw-1502000204	0.7	1.000	0.000	0.000	0.800	0.800	0.565

Subwatershed	WQA	Land Ownership	HUI/ Subwatershed	HUI/ Riparian	Runoff	Erosion	FMV Weighted
Milky Wash-1502000205	0.7	1.000	0.000	0.000	0.600	0.000	0.265
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.7	1.000	0.000	0.045	0.600	0.400	0.394
Washboard Wash-Upper Little Colorado River-1502000207	1	1.000	0.000	0.000	0.800	0.200	0.400
Middle Carrizo Wash-1502000306	0.5	1.000	0.000	0.000	0.400	0.800	0.435
Lower Carrizo Wash-1502000307	0.5	1.000	0.000	0.000	0.400	0.400	0.315
Jaralosa Draw-1502000406	0.5	1.000	0.000	0.000	0.400	0.400	0.315
Middle Zuni River-1502000407	0.5	1.000	0.000	0.000	0.200	0.400	0.255
Hardscrabble Wash-1502000408	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Lower Zuni River-1502000409	0.5	1.000	0.000	0.000	0.600	0.400	0.375
Show Low Creek-1502000501	1	0.923	0.000	0.710	1.000	0.800	0.778
Upper Silver Creek-1502000502	0.7	1.000	0.000	0.440	1.000	0.600	0.653
Cottonwood Creek-1502000503	0.5	1.000	0.000	0.585	0.600	0.600	0.552
Lower Silver Creek-1502000504	0.7	1.000	0.000	1.000	0.800	0.200	0.585
Upper Black Creek-1502000603	0.5	0.000	0.000	0.000	0.200	0.600	0.265
Whitewater Arroyo-1502000605	0.5	0.000	0.000	0.000	0.400	0.400	0.265
Lower Black Creek-1502000606	0.5	0.000	0.000	0.000	0.200	0.600	0.265
Manuelito Canyon-Upper Puerco River-1502000607	0.5	0.000	0.000	0.118	0.400	0.600	0.349
Burntwater Wash-Lower Puerco River-1502000701	0.5	1.000	0.000	0.110	0.400	0.400	0.337
Morgan Canyon-1502000702	0.5	1.000	0.000	0.000	0.400	0.400	0.315
Dead Wash-1502000703	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Dry Wash-1502000704	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Ninemile Wash-Lower Puerco River-1502000705	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Lithodendron Wash-Lower Puerco River-1502000706	0.5	1.000	0.000	0.000	0.400	0.000	0.195
Phoenix Park Wash-Dry Lake-1502000801	0.5	1.000	0.000	0.223	0.800	0.400	0.480
Porter Tank Draw-Middle Little Colorado River-1502000802	0.5	1.000	0.000	0.050	0.800	0.000	0.325
Upper Clear Creek-1502000803	1	0.000	0.000	0.000	0.200	1.000	0.410
Lower Clear Creek-1502000804	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Jacks Canyon-1502000805	0.5	1.000	0.000	0.245	0.600	0.600	0.484
McDonald Canyon-Middle Little Colorado River-1502000806	0.5	1.000	0.000	0.150	0.800	0.000	0.345
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	1.000	0.000	0.850	0.600	0.200	0.485
Coyote Wash-Middle Little Colorado River-1502000808	0.5	1.000	0.000	0.000	0.600	0.200	0.315
Cow Canyon-Middle Little Colorado River-1502000809	0.5	1.000	0.000	0.000	0.600	0.000	0.255
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	0.000	0.000	0.000	0.600	0.000	0.205
Upper Wide Ruin Wash-1502000901	0.5	0.000	0.000	0.000	0.400	0.400	0.265

Subwatershed	WQA	Land Ownership	HUI/ Subwatershed	HUI/ Riparian	Runoff	Erosion	FMV Weighted
Lower Wide Ruin Wash-1502000902	0.5	0.000	0.000	0.000	0.400	0.400	0.265
Leroux Wash-1502000903	0.5	1.000	0.000	0.000	0.400	0.200	0.255
Upper Chevelon Canyon-1502001001	0.3	0.000	0.000	0.000	0.200	0.800	0.315
Black Canyon-1502001002	0.3	1.000	0.000	0.000	0.600	0.600	0.425
Lower Chevelon Canyon-1502001003	0	1.000	0.000	0.000	0.800	0.200	0.350
Upper Pueblo Colorado Wash-1502001101	0.5	0.000	0.000	0.000	0.400	0.600	0.325
Steamboat Wash-1502001102	0.5	0.000	0.000	0.000	0.200	0.400	0.205
Middle Pueblo Colorado Wash-1502001103	0.5	0.000	0.000	0.000	0.200	0.600	0.265
Bidahochi Wash-1502001104	0.5	0.000	0.000	0.000	0.200	1.000	0.385
Lower Pueblo Colorado Wash-1502001105	0.5	0.000	0.000	0.000	0.200	0.600	0.265
Cottonwood Wash-1502001106	0.5	1.000	0.000	0.000	0.200	0.200	0.195
Upper Oraibi Wash-1502001201	0.5	0.000	0.000	0.000	0.400	0.800	0.385
Middle Oraibi Wash-1502001202	0.5	0.000	0.000	0.000	0.400	0.400	0.265
Lower Oraibi Wash-1502001203	0.5	0.000	0.000	0.000	0.400	0.200	0.205
Upper Polacca Wash-1502001301	0.5	0.000	0.000	0.000	0.200	0.800	0.325
Wepo Wash-1502001302	0.5	0.000	0.000	0.000	0.400	0.400	0.265
Middle Polacca Wash-1502001303	0.5	0.000	0.000	0.000	0.400	0.400	0.265
Lower Polacca Wash-1502001304	0.5	0.000	0.000	0.000	0.400	0.000	0.145
Ha-whi-yalin Wash-1502001401	0.5	0.000	0.000	0.000	0.200	0.800	0.325
Upper Jadito Wash-1502001402	0.5	0.000	0.000	0.000	0.200	0.400	0.205
Coyote Wash-1502001403	0.5	0.000	0.000	0.000	0.200	0.600	0.265
Lower Jadito Wash-1502001404	0.5	0.000	0.000	0.000	0.400	0.600	0.325
Rio de Flag-1502001501	0	1.000	0.000	1.000	1.000	1.000	0.850
Walnut Creek-1502001502	0.5	0.000	0.000	1.000	1.000	0.800	0.765
San Francisco Wash-1502001503	0.3	0.877	0.000	0.138	0.800	0.400	0.446
Canyon Diablo (Local Drainage)-1502001504	0	1.000	0.000	0.000	0.800	0.600	0.470
Kana-a Wash-Lower Little Colorado River-1502001601	0.5	1.000	0.000	0.000	0.800	0.400	0.435
Deadman Wash-1502001602	0.5	0.000	0.000	0.000	0.800	1.000	0.565
Big Wash-The Big Lake Area-1502001603	0.5	0.000	0.000	0.000	0.600	0.000	0.205
Tohachi Wash-1502001604	0.5	0.000	0.000	0.000	0.800	0.000	0.265
Citadel Wash-Lower Little Colorado River-1502001605	0.5	1.000	0.000	0.000	0.800	0.200	0.375
Upper Cedar Wash-1502001606	0.5	1.000	0.000	0.000	1.000	0.600	0.555
Lower Cedar Wash-1502001607	0.5	0.139	0.000	0.000	0.400	0.400	0.272
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.5	1.000	0.000	0.000	0.800	0.000	0.315
Lee Canyon-Lower Little Colorado River-1502001609	0.5	0.000	0.000	0.000	0.600	0.400	0.325
Sheep Wash-Lower Little Colorado River-1502001610	0.5	0.000	0.000	0.000	0.600	0.400	0.325

Subwatershed	WQA	Land Ownership	HUI/ Subwatershed	HUI/ Riparian	Runoff	Erosion	FMV Weighted
Upper Dinnebito Wash-1502001701	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.400**	**0.265**
Middle Dinnebito Wash-1502001702	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.200**	**0.265**
Lower Dinnebito Wash-1502001703	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.000**	**0.205**
Moenkopi Wash Headwaters-1502001801	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.800**	**0.385**
Shonto Wash-1502001802	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.400**	**0.265**
Upper Begashibito Wash-1502001803	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.400**	**0.265**
Crooked Ridge/Echo Cliffs Area-1502001804	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.000**	**0.205**
Lower Begashibito Wash-1502001805	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.400**	**0.265**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.5**	**0.000**	**0.000**	**0.000**	**0.400**	**0.400**	**0.265**
Pasture Canyon-1502001807	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.000**	**0.205**
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.200**	**0.265**
Hamblin Wash-1502001809	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.200**	**0.265**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.000**	**0.205**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**0.000**	**0.000**	**0.000**	**0.600**	**0.000**	**0.205**
Weights	***0.05***	***0.050***	***0.100***	***0.200***	***0.300***	***0.300***	

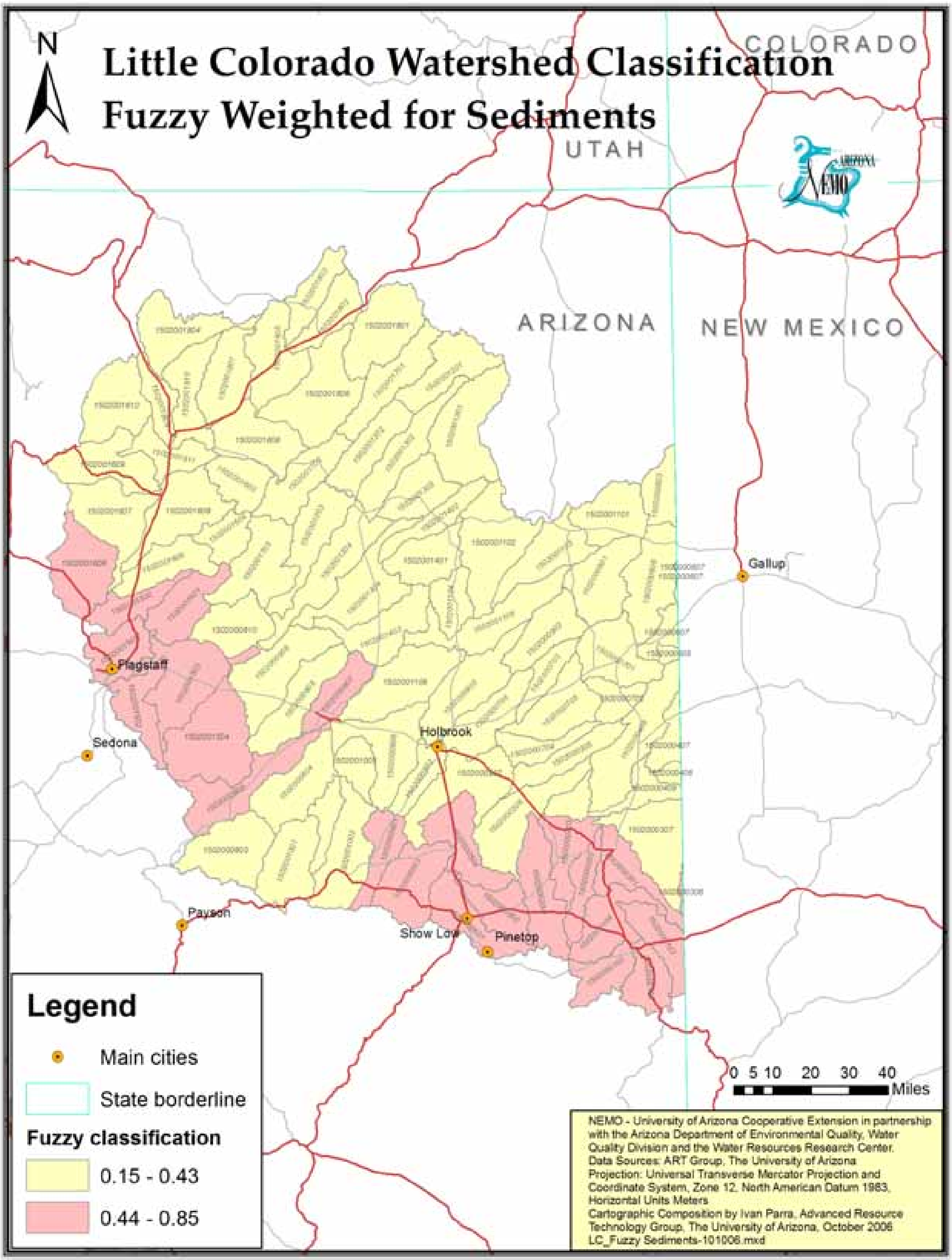

Figure 6- 4 Results for the Fuzzy Logic Classification for Sediment, Based on the Weighted Combination Approach.

Organics

Several water quality parameters that have been identified as concerns in the Little Colorado Watershed are related to the introduction of organic material to a water body. For this section, organics will include nutrients and pH.

Three reaches and two lakes had exceedances that were considered important enough to cause changes in the assessment:

- Little Colorado River (Washboard Draw subwatershed) was evaluated as impaired due to exceedances in *Escherichia coli*.
- Clear Creek Reservoir (Lower Clear Creek subwatershed) and Blue Ridge Reservoir (Black Canyon subwatershed) were assessed as "Attaining some uses" due to low dissolved oxygen.
- Bear Canyon Lake (Upper Clear Creek subwatershed) was assessed by EPA as impaired due to low pH.
- Rainbow Lake was assessed as impaired due to nutrient and pH exceedences.

The factors that were used for the organic material classification are:

- ADEQ water quality assessment results for organic parameters, including dissolved oxygen, E. coli, pH, nutrients and TDS;
- Human use index within both the overall subwatershed and within the riparian area; and
- Land use, including grazing and agriculture.

Water Quality Assessment Data - Organics

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) was used to define the current water quality conditions based on water quality measurements. In assigning fuzzy membership values, the location of the 10-digit HUC subwatershed relative to an impaired water or reach was considered.

Table 6- 2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results. Table 6- 14 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed for organics classification.

Table 6- 14 Fuzzy Membership Values Assigned to each 10- digit HUC Subwatershed - Based on Water Quality Assessment Results for Organics.

Subwatershed	FMV	Justification
Nutrioso Creek-1502000101	0.7	Classified as high risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as moderate risk
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.7	Classified as high risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as moderate risk
Coyote Creek-1502000103	0.5	Classified as moderate risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as moderate risk
Carnero Creek-Little Colorado River Headwaters-1502000104	0.5	Classified as moderate risk, drains into Upper Little Colorado River, Lyman Lake to Big Hollow Wash that is classified as moderate risk
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Big Hollow Wash-1502000202	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Concho Creek-Upper Little Colorado River-1502000203	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Oso Draw-1502000204	0.7	Classified as high risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Milky Wash-1502000205	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Washboard Wash-Upper Little Colorado River-1502000207	1.0	Classified as extreme risk
Middle Carrizo Wash-1502000306	0.5	Classified as moderate risk, drains into Lower Carrizo Wash that is classified as moderate risk
Lower Carrizo Wash-1502000307	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Jaralosa Draw-1502000406	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Middle Zuni River-1502000407	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Hardscrabble Wash-1502000408	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Lower Zuni River-1502000409	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Show Low Creek-1502000501	1.0	Classified as extreme risk
Upper Silver Creek-1502000502	0.7	Classified as high risk, drains into Lower Silver Creek that is classified as moderate risk
Cottonwood Creek-1502000503	0.5	Classified as moderate risk, drains into Lower Silver Creek that is classified as moderate risk
Lower Silver Creek-1502000504	0.7	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as extreme risk
Upper Black Creek-1502000603	0.5	Classified as moderate risk, drains into Lower Black Creek that is classified as moderate risk
Whitewater Arroyo-1502000605	0.5	Classified as moderate risk, drains into Manuelito Canyon-Upper Puerco River that is classified as moderate risk
Lower Black Creek-1502000606	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Manuelito Canyon-Upper Puerco River-1502000607	0.5	Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk
Burntwater Wash-Lower Puerco River-1502000701	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Morgan Canyon-1502000702	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk

Subwatershed	FMV	Justification
Dead Wash-1502000703	0.5	Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk
Dry Wash-1502000704	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Ninemile Wash-Lower Puerco River-1502000705	0.5	Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk
Lithodendron Wash-Lower Puerco River-1502000706	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Phoenix Park Wash-Dry Lake-1502000801	0.5	Classified as moderate risk, drains into Black Canyon that is classified as moderate risk
Porter Tank Draw-Middle Little Colorado River-1502000802	0.5	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk
Upper Clear Creek-1502000803	1.0	Classified as moderate risk
Lower Clear Creek-1502000804	0.5	Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk
Jacks Canyon-1502000805	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
McDonald Canyon-Middle Little Colorado River-1502000806	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	Classified as moderate risk, drains into Coyote Wash-Middle Little Colorado River that is classified as moderate risk
Coyote Wash-Middle Little Colorado River-1502000808	0.5	Classified as moderate risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk
Cow Canyon-Middle Little Colorado River-1502000809	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk
Upper Wide Ruin Wash-1502000901	0.5	Classified as moderate risk, drains into Lower Wide Ruin Wash that is classified as moderate risk
Lower Wide Ruin Wash-1502000902	0.5	Classified as moderate risk, drains into Leroux Wash that is classified as moderate risk
Leroux Wash-1502000903	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Upper Chevelon Canyon-1502001001	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Black Canyon-1502001002	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Lower Chevelon Canyon-1502001003	0.0	Classified as low risk
Upper Pueblo Colorado Wash-1502001101	0.5	Classified as moderate risk, drains into Middle Pueblo Colorado Wash that is classified as moderate risk
Steamboat Wash-1502001102	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Middle Pueblo Colorado Wash-1502001103	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Bidahochi Wash-1502001104	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Lower Pueblo Colorado Wash-1502001105	0.5	Classified as moderate risk, drains into Cottonwood Wash that is classified as moderate risk
Cottonwood Wash-1502001106	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Upper Oraibi Wash-1502001201	0.5	Classified as moderate risk, drains into Middle Oraibi Wash that is classified as moderate risk
Middle Oraibi Wash-1502001202	0.5	Classified as moderate risk, drains into Lower Oraibi Wash that is classified as moderate risk
Lower Oraibi Wash-1502001203	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk

Subwatershed	FMV	Justification
Upper Polacca Wash-1502001301	0.5	Classified as moderate risk, drains into Middle Polacca Wash that is classified as moderate risk
Wepo Wash-1502001302	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Middle Polacca Wash-1502001303	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Lower Polacca Wash-1502001304	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Ha-whi-yalin Wash-1502001401	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Upper Jadito Wash-1502001402	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Coyote Wash-1502001403	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Lower Jadito Wash-1502001404	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Rio de Flag-1502001501	0.0	Classified as low risk
Walnut Creek-1502001502	0.5	Classified as moderate risk, drains into San Francisco Wash that is classified as moderate risk
San Francisco Wash-1502001503	0.3	Classified as moderate risk, drains into Canyon Diablo (Local Drainage) that is classified as low risk
Canyon Diablo (Local Drainage)-1502001504	0.0	Classified as low risk
Kana-a Wash-Lower Little Colorado River-1502001601	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk
Deadman Wash-1502001602	0.5	Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk
Big Wash-The Big Lake Area-1502001603	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Tohachi Wash-1502001604	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Citadel Wash-Lower Little Colorado River-1502001605	0.5	Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk
Upper Cedar Wash-1502001606	0.5	Classified as moderate risk, drains into Lower Cedar Wash that is classified as moderate risk
Lower Cedar Wash-1502001607	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk
Lee Canyon-Lower Little Colorado River-1502001609	0.5	Classified as moderate risk, drains into Sheep Wash-Lower Little Colorado River that is classified as moderate risk
Sheep Wash-Lower Little Colorado River-1502001610	0.5	Classified as moderate risk
Upper Dinnebito Wash-1502001701	0.5	Classified as moderate risk, drains into Middle Dinnebito Wash that is classified as moderate risk
Middle Dinnebito Wash-1502001702	0.5	Classified as moderate risk, drains into Lower Dinnebito Wash that is classified as moderate risk
Lower Dinnebito Wash-1502001703	0.5	Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk
Moenkopi Wash Headwaters-1502001801	0.5	Classified as moderate risk, drains into Wide Ruin Canyon-Moenkopi Wash that is classified as moderate risk
Shonto Wash-1502001802	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk
Upper Begashibito Wash-1502001803	0.5	Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk

Subwatershed	FMV	Justification
Crooked Ridge/Echo Cliffs Area-1502001804	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Lower Begashibito Wash-1502001805	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.5	Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk
Pasture Canyon-1502001807	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Coal Mine Canyon-Moenkopi Wash-1502001808	0.5	Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk
Hamblin Wash-1502001809	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Kerley Valley-Moenkopi Wash-1502001810	0.5	Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk
Fivemile Wash-Moenkopi Wash-1502001811	0.5	Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk

Human Use Index - Organics

The Human Use Index was used to assess the relative impact of urban development on the presence of organics in stream water. The Human Use Index is defined as the percentage of a subwatershed that is disturbed by development and human use. In the Little Colorado Watershed, human use is based on developed areas as defined by the National Land Cover Data as residential land use, mining, agriculture and roads.

Human activity can introduce organic material to a water body by disposal of organic compounds and sewage. This can be a problem in areas where residential developments utilize on-site septic sewage systems. Currently, the construction of new septic systems requires a permit from ADEQ in the State of Arizona (some exemptions apply), and an inspection of the septic system is required when a property is sold if it was originally approved for use on or after Jan. 1, 2001 by ADEQ or a delegated county agency (http://www.azdeq.gov/environ/water/permits/wastewater.html). However, there are no requirements for regular inspections of older septic systems and as a result, rural areas may have a significant impact on the introduction of organic material to the environment.

Human use has been assessed at both the subwatershed and riparian area scale (< = 250 meters from a stream). The fuzzy membership functions for organics for both conditions are as follows:

Human Use Index (HUI)/subwatershed:

FMV = 0 if (HUI < = 1%)
FMV = (HUI – 1) / 3
FMV = 1 if (HUI > = 4%)

Human Use Index/Riparian:

FMV = 0 if (HUI < = 0%)
FMV = (HUI - 0) / 4
FMV = 1 if (HUI > = 4%)

Table 6- 15 contains the fuzzy membership values for organics for each 10-digit HUC subwatershed based on the Human Use Index.

Each 10-digit HUC subwatershed was assigned a fuzzy membership value based on its primary land use relative to livestock grazing. All subwatersheds were initially assigned a value of 1.0, representing land assumed to be primarily used for livestock grazing.

Land Use - Organics

The principal land use in the Little Colorado Watershed is livestock grazing. Livestock grazing occurs primarily on land owned by the federal government (BLM and the USFS), or on Arizona State Trust Land.

Each 10-digit HUC was assigned a fuzzy membership value based on its primary land use relative to livestock grazing. Subwatersheds that are largely wilderness were assigned a value of 0.0 because its wilderness designation suggests that the land is managed and non-point source pollution is controlled. All other subwatersheds were assigned a value of 1.0 as the land was assumed to be used primarily for livestock grazing.

Table 6- 15 Fuzzy Membership Values for Organics, Based on the Human Use Index.

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Nutrioso Creek-1502000101	0.00	0.65
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.00	1.00
Coyote Creek-1502000103	0.00	0.00
Carnero Creek-Little Colorado River Headwaters-1502000104	0.00	0.58
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.01	1.00
Big Hollow Wash-1502000202	0.00	0.00
Concho Creek-Upper Little Colorado River-1502000203	0.00	0.05
Oso Draw-1502000204	0.00	0.00
Milky Wash-1502000205	0.00	0.00
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.00	0.05
Washboard Wash-Upper Little Colorado River-1502000207	0.00	0.00
Middle Carrizo Wash-1502000306	0.00	0.00
Lower Carrizo Wash-1502000307	0.00	0.00
Jaralosa Draw-1502000406	0.00	0.00
Middle Zuni River-1502000407	0.00	0.00
Hardscrabble Wash-1502000408	0.00	0.00
Lower Zuni River-1502000409	0.00	0.00
Show Low Creek-1502000501	0.00	0.71
Upper Silver Creek-1502000502	0.00	0.44
Cottonwood Creek-1502000503	0.00	0.59
Lower Silver Creek-1502000504	0.00	1.00
Upper Black Creek-1502000603	0.00	0.00
Whitewater Arroyo-1502000605	0.00	0.00
Lower Black Creek-1502000606	0.00	0.00
Manuelito Canyon-Upper Puerco River-1502000607	0.00	0.12

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Manuelito Canyon-Upper Puerco River-1502000607	0.00	0.12
Manuelito Canyon-Upper Puerco River-1502000607	0.00	0.12
Burntwater Wash-Lower Puerco River-1502000701	0.00	0.11
Morgan Canyon-1502000702	0.00	0.00
Dead Wash-1502000703	0.00	0.00
Dry Wash-1502000704	0.00	0.00
Ninemile Wash-Lower Puerco River-1502000705	0.00	0.00
Lithodendron Wash-Lower Puerco River-1502000706	0.00	0.00
Phoenix Park Wash-Dry Lake-1502000801	0.00	0.22
Porter Tank Draw-Middle Little Colorado River-1502000802	0.00	0.05
Upper Clear Creek-1502000803	0.00	0.00
Lower Clear Creek-1502000804	0.00	0.00
Jacks Canyon-1502000805	0.00	0.25
McDonald Canyon-Middle Little Colorado River-1502000806	0.00	0.15
Rincon Basin Area-Middle Little Colorado River-1502000807	0.00	0.85
Coyote Wash-Middle Little Colorado River-1502000808	0.00	0.00
Cow Canyon-Middle Little Colorado River-1502000809	0.00	0.00
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.00	0.00
Upper Wide Ruin Wash-1502000901	0.00	0.00
Lower Wide Ruin Wash-1502000902	0.00	0.00
Leroux Wash-1502000903	0.00	0.00
Upper Chevelon Canyon-1502001001	0.00	0.00
Black Canyon-1502001002	0.00	0.00
Lower Chevelon Canyon-1502001003	0.00	0.00
Upper Pueblo Colorado Wash-1502001101	0.00	0.00
Steamboat Wash-1502001102	0.00	0.00
Middle Pueblo Colorado Wash-1502001103	0.00	0.00
Bidahochi Wash-1502001104	0.00	0.00
Lower Pueblo Colorado Wash-1502001105	0.00	0.00
Cottonwood Wash-1502001106	0.00	0.00
Upper Oraibi Wash-1502001201	0.00	0.00
Middle Oraibi Wash-1502001202	0.00	0.00
Lower Oraibi Wash-1502001203	0.00	0.00
Upper Polacca Wash-1502001301	0.00	0.00
Wepo Wash-1502001302	0.00	0.00
Middle Polacca Wash-1502001303	0.00	0.00
Lower Polacca Wash-1502001304	0.00	0.00
Ha-whi-yalin Wash-1502001401	0.00	0.00
Upper Jadito Wash-1502001402	0.00	0.00
Coyote Wash-1502001403	0.00	0.00
Lower Jadito Wash-1502001404	0.00	0.00
Rio de Flag-1502001501	0.00	1.00

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Walnut Creek-1502001502	0.00	1.00
San Francisco Wash-1502001503	0.00	0.14
Canyon Diablo (Local Drainage)-1502001504	0.00	0.00
Kana-a Wash-Lower Little Colorado River-1502001601	0.00	0.00
Deadman Wash-1502001602	0.00	0.00
Big Wash-The Big Lake Area-1502001603	0.00	0.00
Tohachi Wash-1502001604	0.00	0.00
Citadel Wash-Lower Little Colorado River-1502001605	0.00	0.00
Upper Cedar Wash-1502001606	0.00	0.00
Lower Cedar Wash-1502001607	0.00	0.00
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.00	0.00
Lee Canyon-Lower Little Colorado River-1502001609	0.00	0.00
Sheep Wash-Lower Little Colorado River-1502001610	0.00	0.00
Upper Dinnebito Wash-1502001701	0.00	0.00
Middle Dinnebito Wash-1502001702	0.00	0.00
Lower Dinnebito Wash-1502001703	0.00	0.00
Moenkopi Wash Headwaters-1502001801	0.00	0.00
Shonto Wash-1502001802	0.00	0.00
Upper Begashibito Wash-1502001803	0.00	0.00
Crooked Ridge/Echo Cliffs Area-1502001804	0.00	0.00
Lower Begashibito Wash-1502001805	0.00	0.00
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.00	0.00
Pasture Canyon-1502001807	0.00	0.00
Coal Mine Canyon-Moenkopi Wash-1502001808	0.00	0.00
Hamblin Wash-1502001809	0.00	0.00
Kerley Valley-Moenkopi Wash-1502001810	0.00	0.00
Fivemile Wash-Moenkopi Wash-1502001811	0.00	0.00

Nutrients

Most of the Little Colorado watershed is lacking data, especially in reservation areas which cover most of the area.

Exceedances of organics were present in different waterbodies, without the impact of impairment: Little Colorado River South Fork of the Little Colorado River Subwatershed) showed low dissolved oxygen, Little Colorado River (Camero Creek subwatershed) exceedances of E.coli, Carnero Creek (Carnero Creek subwatershed) low dissolved oxygen, Carnero Lake (Carnero Creek subwatershed) low dissolved oxygen and high pH, McKay Reservoir (Nutrioso Creek subwatershed) low dissolved oxygen and high pH, Bunch Reservoir and Tunnel Reservoir (South Fork of the Little Colorado River Subwatershed) low dissolved oxygen, Mineral Creek (Oso Draw subwatershed), Billy Creek

(Show Low Creek) E. coli, Silver Creek (Upper Silver Creek subwatershed) low dissolved oxygen, and Buck Springs Canyon Creek (Upper Clear Creek subwatershed).

Nutrients, specifically nitrogen and phosphorus, do not appear to be a problem within the Little Colorado Watershed, a conclusion supported by the lack of potential sources for nutrients within the system. The application of commercial fertilizers to support agriculture is the most common source of introduced nutrients, but this is largely absent in the watershed.

Another source of introduced nutrients is runoff from residential areas where landscapes are fertilized. The Little Colorado Watershed not only has a low density of urban development, but most of the home sites in the area are likely to use natural landscaping due to the lack of water resources available for irrigation.

pH

Bear Canyon Lake (Upper Clear Creek subwatershed) was assessed by EPA as impaired due to low pH, but ADEQ sampling was deemed as "Inconclusive" with 4 out of 5 samples with low values (ranging from 6.6 to 8, being >7 the acceptable standard).

Organics Results

The weighted combination approach was used to create the combined fuzzy score for organics, and the results are found in Table 6-16. The weights used in the classification are found at the bottom of the table. Figure 6- 5 shows the results of the weighted combination method classified into high and low priority for organics.

Table 6- 16 Summary Results for Organics, Based on the Fuzzy Logic - Weighted Combination Approach.

Subwatershed	WQA[1]	Owner	HUI Subws	HUI Riparian	Weighted FMV
Nutrioso Creek-1502000101	0.7	1.000	0.000	0.648	0.604
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.7	1.000	0.000	1.000	0.710
Coyote Creek-1502000103	0.5	1.000	0.000	0.000	0.350
Carnero Creek-Little Colorado River Headwaters-1502000104	0.5	1.000	0.000	0.578	0.523
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	1.000	0.014	1.000	0.653
Big Hollow Wash-1502000202	0.5	1.000	0.000	0.000	0.350
Concho Creek-Upper Little Colorado River-1502000203	0.5	1.000	0.000	0.045	0.364
Oso Draw-1502000204	0.7	1.000	0.000	0.000	0.410
Milky Wash-1502000205	0.7	1.000	0.000	0.000	0.410
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.7	1.000	0.000	0.045	0.424
Washboard Wash-Upper Little Colorado River-1502000207	1	1.000	0.000	0.000	0.500
Middle Carrizo Wash-1502000306	0.5	1.000	0.000	0.000	0.350
Lower Carrizo Wash-1502000307	0.5	1.000	0.000	0.000	0.350

Subwatershed	WQA[1]	Owner	HUI Subws	HUI Riparian	Weighted FMV
Jaralosa Draw-1502000406	0.5	1.000	0.000	0.000	0.350
Middle Zuni River-1502000407	0.5	1.000	0.000	0.000	0.350
Hardscrabble Wash-1502000408	0.5	1.000	0.000	0.000	0.350
Lower Zuni River-1502000409	0.5	1.000	0.000	0.000	0.350
Show Low Creek-1502000501	1	1.000	0.000	0.710	0.542
Upper Silver Creek-1502000502	0.7	1.000	0.000	0.440	0.542
Cottonwood Creek-1502000503	0.5	1.000	0.000	0.585	0.526
Lower Silver Creek-1502000504	0.7	1.000	0.000	1.000	0.710
Upper Black Creek-1502000603	0.5	1.000	0.000	0.000	0.350
Whitewater Arroyo-1502000605	0.5	1.000	0.000	0.000	0.350
Lower Black Creek-1502000606	0.5	1.000	0.000	0.000	0.350
Manuelito Canyon-Upper Puerco River-1502000607	0.5	1.000	0.000	0.118	0.385
Burntwater Wash-Lower Puerco River-1502000701	0.5	1.000	0.000	0.110	0.383
Morgan Canyon-1502000702	0.5	1.000	0.000	0.000	0.350
Dead Wash-1502000703	0.5	1.000	0.000	0.000	0.350
Dry Wash-1502000704	0.5	1.000	0.000	0.000	0.350
Ninemile Wash-Lower Puerco River-1502000705	0.5	1.000	0.000	0.000	0.350
Lithodendron Wash-Lower Puerco River-1502000706	0.5	1.000	0.000	0.000	0.350
Phoenix Park Wash-Dry Lake-1502000801	0.5	1.000	0.000	0.223	0.417
Porter Tank Draw-Middle Little Colorado River-1502000802	0.5	1.000	0.000	0.050	0.365
Upper Clear Creek-1502000803	1	1.000	0.000	0.000	0.500
Lower Clear Creek-1502000804	0.5	1.000	0.000	0.000	0.350
Jacks Canyon-1502000805	0.5	1.000	0.000	0.245	0.424
McDonald Canyon-Middle Little Colorado River-1502000806	0.5	1.000	0.000	0.150	0.395
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	1.000	0.000	0.850	0.605
Coyote Wash-Middle Little Colorado River-1502000808	0.5	1.000	0.000	0.000	0.350
Cow Canyon-Middle Little Colorado River-1502000809	0.5	1.000	0.000	0.000	0.350
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	1.000	0.000	0.000	0.350
Upper Wide Ruin Wash-1502000901	0.5	1.000	0.000	0.000	0.350
Lower Wide Ruin Wash-1502000902	0.5	1.000	0.000	0.000	0.350
Leroux Wash-1502000903	0.5	1.000	0.000	0.000	0.350
Upper Chevelon Canyon-1502001001	0.3	1.000	0.000	0.000	0.290
Black Canyon-1502001002	0.3	1.000	0.000	0.000	0.290
Lower Chevelon Canyon-1502001003	0	1.000	0.000	0.000	0.200
Upper Pueblo Colorado Wash-1502001101	0.5	1.000	0.000	0.000	0.350
Steamboat Wash-1502001102	0.5	1.000	0.000	0.000	0.350
Middle Pueblo Colorado Wash-1502001103	0.5	1.000	0.000	0.000	0.350
Bidahochi Wash-1502001104	0.5	1.000	0.000	0.000	0.350
Lower Pueblo Colorado Wash-1502001105	0.5	1.000	0.000	0.000	0.350
Cottonwood Wash-1502001106	0.5	1.000	0.000	0.000	0.350
Upper Oraibi Wash-1502001201	0.5	1.000	0.000	0.000	0.350

Subwatershed	WQA[1]	Owner	HUI Subws	HUI Riparian	Weighted FMV
Middle Oraibi Wash-1502001202	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Oraibi Wash-1502001203	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Upper Polacca Wash-1502001301	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Wepo Wash-1502001302	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Middle Polacca Wash-1502001303	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Polacca Wash-1502001304	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Ha-whi-yalin Wash-1502001401	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Upper Jadito Wash-1502001402	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Coyote Wash-1502001403	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Jadito Wash-1502001404	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Rio de Flag-1502001501	**0**	**1.000**	**0.000**	**1.000**	**0.500**
Walnut Creek-1502001502	**0.5**	**1.000**	**0.000**	**1.000**	**0.650**
San Francisco Wash-1502001503	**0.3**	**1.000**	**0.000**	**0.138**	**0.331**
Canyon Diablo (Local Drainage)-1502001504	**0**	**1.000**	**0.000**	**0.000**	**0.200**
Kana-a Wash-Lower Little Colorado River-1502001601	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Deadman Wash-1502001602	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Big Wash-The Big Lake Area-1502001603	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Tohachi Wash-1502001604	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Citadel Wash-Lower Little Colorado River-1502001605	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Upper Cedar Wash-1502001606	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Cedar Wash-1502001607	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lee Canyon-Lower Little Colorado River-1502001609	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Sheep Wash-Lower Little Colorado River-1502001610	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Upper Dinnebito Wash-1502001701	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Middle Dinnebito Wash-1502001702	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Dinnebito Wash-1502001703	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Moenkopi Wash Headwaters-1502001801	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Shonto Wash-1502001802	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Upper Begashibito Wash-1502001803	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Crooked Ridge/Echo Cliffs Area-1502001804	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Lower Begashibito Wash-1502001805	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Pasture Canyon-1502001807	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Hamblin Wash-1502001809	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**1.000**	**0.000**	**0.000**	**0.350**
Weights	***0.3***	***0.200***	***0.200***	***0.300***	

WQA[1] = Water Quality Assessment Data

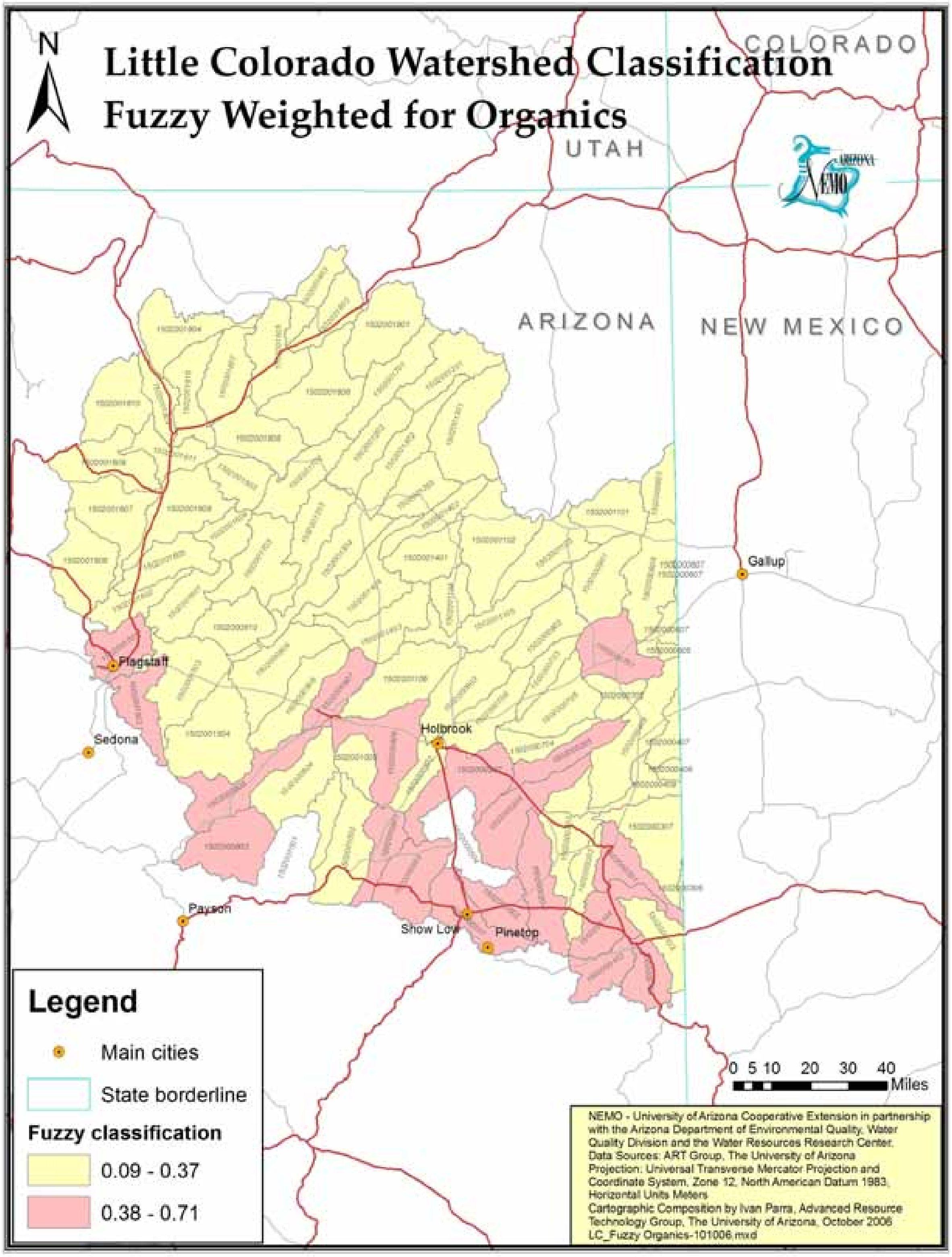

Figure 6- 5 Results for the Fuzzy Logic Classification for Organics, Based on the Weighted Combination Approach.

Selenium

There were insufficient selenium data to assess most waterbodies and none were impaired due to selenium exceedances. In two places high selenium values were recorded without effect in impairment: Bear Canyon Lake (Upper Clear Creek Subwatershed) and Kinnikinick Lake (Canyon Diablo subwatershed).

High values for selenium may be associated with high values for metals, and are likely to be naturally occurring in highly mineralized soils. In addition, high values may be associated with mining evaporation or tailing ponds, where evaporation would increase the relative concentration of selenium, as well as other constituents. One common source of elevated selenium in the western United States is agricultural drainage water ("tail water") from seleniferous irrigated soils (Hem, 1970).

Water Quality Assessment Data - Selenium

The ADEQ Water Quality Assessment results were used to define the current water quality based on water monitoring results. In assigning fuzzy membership values, the location of a subwatershed relative to an impaired water was considered. Table 6-17 contains the fuzzy membership values for selenium for each subwatershed based on the water quality assessment results.

Agricultural Lands

The percentage of the agricultural lands in each 10-digit HUC subwatershed was calculated as shown in Table 6- 18. Since the percentage of agricultural land in each subwatershed is small, this result shows that there is no correlation between the percentage of agricultural land and selenium impairment in the watershed. Therefore another index based on prevalence of metalliferous mines within the subwatershed was used to represent the relationship.

Number of Mines per Watershed

Elevated concentrations of selenium in the waters of the Little Colorado Watershed are likely due to naturally occurring selenium in the metal-rich soils and rocks. To classify subwatersheds likely to exhibit exceedance in selenium, the number of mines allowed in each 10-digit HUC was assigned a fuzzy membership value, as shown in Table 6-19. The actual number of mines in each 10-digit HUC subwatershed was then calculated, and each subwatershed was assigned a fuzzy membership value based on Table 6-19. The results are shown in Table 6- 20.

Selenium Results

The fuzzy membership values were used to create a combined fuzzy score for each subwatershed and were incorporated into the weighted combination method (Figure 6- 6). These results are found in Table 6- 21, and the weights are listed at the bottom of the table.

Table 6- 17 Fuzzy Membership Values for Selenium Assigned to each Subwatershed, Based on Water Quality Assessment Results.

Subwatershed	FMV	Justification
Nutrioso Creek-1502000101	0.0	Classified as low risk
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.0	Classified as low risk
Coyote Creek-1502000103	0.3	Classified as moderate risk, drains into Carnero Creek-Little Colorado River Headwaters that is classified as low risk
Carnero Creek-Little Colorado River Headwaters-1502000104	0.0	Classified as low risk
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Big Hollow Wash-1502000202	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Concho Creek-Upper Little Colorado River-1502000203	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Oso Draw-1502000204	0.0	Classified as low risk
Milky Wash-1502000205	0.3	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as low risk
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.3	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as low risk
Washboard Wash-Upper Little Colorado River-1502000207	0.0	Classified as low risk
Middle Carrizo Wash-1502000306	0.5	Classified as moderate risk, drains into Lower Carrizo Wash that is classified as moderate risk
Lower Carrizo Wash-1502000307	0.5	Classified as moderate risk, drains into Concho Creek-Upper Little Colorado River that is classified as moderate risk
Jaralosa Draw-1502000406	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Middle Zuni River-1502000407	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Hardscrabble Wash-1502000408	0.5	Classified as moderate risk, drains into Lower Zuni River that is classified as moderate risk
Lower Zuni River-1502000409	0.5	Classified as moderate risk, drains into Hay Hollow Draw-Upper Little Colorado River that is classified as moderate risk
Show Low Creek-1502000501	0.0	Classified as low risk
Upper Silver Creek-1502000502	0.0	Classified as low risk
Cottonwood Creek-1502000503	0.5	Classified as moderate risk, drains into Lower Silver Creek that is classified as moderate risk
Lower Silver Creek-1502000504	0.3	Classified as moderate risk, drains into Washboard Wash-Upper Little Colorado River that is classified as low risk
Upper Black Creek-1502000603	0.5	Classified as moderate risk, drains into Lower Black Creek that is classified as moderate risk
Whitewater Arroyo-1502000605	0.5	Classified as moderate risk, drains into Manuelito Canyon-Upper Puerco River that is classified as moderate risk

Subwatershed	FMV	Justification
Lower Black Creek-1502000606	**0.5**	**Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk**
Manuelito Canyon-Upper Puerco River-1502000607	**0.5**	**Classified as moderate risk, drains into Burntwater Wash-Lower Puerco River that is classified as moderate risk**
Burntwater Wash-Lower Puerco River-1502000701	**0.5**	**Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk**
Morgan Canyon-1502000702	**0.5**	**Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk**
Dead Wash-1502000703	**0.5**	**Classified as moderate risk, drains into Ninemile Wash-Lower Puerco River that is classified as moderate risk**
Dry Wash-1502000704	**0.5**	**Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk**
Ninemile Wash-Lower Puerco River-1502000705	**0.5**	**Classified as moderate risk, drains into Lithodendron Wash-Lower Puerco River that is classified as moderate risk**
Lithodendron Wash-Lower Puerco River-1502000706	**0.5**	**Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk**
Phoenix Park Wash-Dry Lake-1502000801	**0.5**	**Classified as moderate risk, drains into Black Canyon that is classified as moderate risk**
Porter Tank Draw-Middle Little Colorado River-1502000802	**0.5**	**Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk**
Upper Clear Creek-1502000803	**0.5**	**Classified as moderate risk, drains into Lower Clear Creek that is classified as moderate risk**
Lower Clear Creek-1502000804	**0.5**	**Classified as moderate risk, drains into McDonald Canyon-Middle Little Colorado River that is classified as moderate risk**
Jacks Canyon-1502000805	**0.5**	**Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk**
McDonald Canyon-Middle Little Colorado River-1502000806	**0.5**	**Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk**
Rincon Basin Area-Middle Little Colorado River-1502000807	**0.5**	**Classified as moderate risk, drains into Coyote Wash-Middle Little Colorado River that is classified as moderate risk**
Coyote Wash-Middle Little Colorado River-1502000808	**0.5**	**Classified as moderate risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk**
Cow Canyon-Middle Little Colorado River-1502000809	**0.5**	**Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk**
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	**0.5**	**Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk**
Upper Wide Ruin Wash-1502000901	**0.5**	**Classified as moderate risk, drains into Lower Wide Ruin Wash that is classified as moderate risk**
Lower Wide Ruin Wash-1502000902	**0.5**	**Classified as moderate risk, drains into Leroux Wash that is classified as moderate risk**

Subwatershed	FMV	Justification
Leroux Wash-1502000903	0.5	Classified as moderate risk, drains into Porter Tank Draw-Middle Little Colorado River that is classified as moderate risk
Upper Chevelon Canyon-1502001001	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Black Canyon-1502001002	0.3	Classified as moderate risk, drains into Lower Chevelon Canyon that is classified as low risk
Lower Chevelon Canyon-1502001003	0.0	Classified as low risk
Upper Pueblo Colorado Wash-1502001101	0.5	Classified as moderate risk, drains into Middle Pueblo Colorado Wash that is classified as moderate risk
Steamboat Wash-1502001102	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Middle Pueblo Colorado Wash-1502001103	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Bidahochi Wash-1502001104	0.5	Classified as moderate risk, drains into Lower Pueblo Colorado Wash that is classified as moderate risk
Lower Pueblo Colorado Wash-1502001105	0.5	Classified as moderate risk, drains into Cottonwood Wash that is classified as moderate risk
Cottonwood Wash-1502001106	0.5	Classified as moderate risk, drains into Rincon Basin Area-Middle Little Colorado River that is classified as moderate risk
Upper Oraibi Wash-1502001201	0.5	Classified as moderate risk, drains into Middle Oraibi Wash that is classified as moderate risk
Middle Oraibi Wash-1502001202	0.5	Classified as moderate risk, drains into Lower Oraibi Wash that is classified as moderate risk
Lower Oraibi Wash-1502001203	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Upper Polacca Wash-1502001301	0.5	Classified as moderate risk, drains into Middle Polacca Wash that is classified as moderate risk
Wepo Wash-1502001302	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Middle Polacca Wash-1502001303	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Lower Polacca Wash-1502001304	0.5	Classified as moderate risk, drains into Middle Little Colorado River-Canyon Diablo to Grand Falls that is classified as moderate risk
Ha-whi-yalin Wash-1502001401	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Upper Jadito Wash-1502001402	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Coyote Wash-1502001403	0.5	Classified as moderate risk, drains into Lower Jadito Wash that is classified as moderate risk
Lower Jadito Wash-1502001404	0.5	Classified as moderate risk, drains into Lower Polacca Wash that is classified as moderate risk
Rio de Flag-1502001501	0.0	Classified as low risk

Subwatershed	FMV	Justification
Walnut Creek-1502001502	**0.5**	**Classified as moderate risk, drains into San Francisco Wash that is classified as moderate risk**
San Francisco Wash-1502001503	**0.6**	**Classified as moderate risk, drains into Canyon Diablo (Local Drainage) that is classified as high risk**
Canyon Diablo (Local Drainage)-1502001504	**0.7**	**Classified as high risk, drains into Cow Canyon-Middle Little Colorado River that is classified as moderate risk**
Kana-a Wash-Lower Little Colorado River-1502001601	**0.5**	**Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk**
Deadman Wash-1502001602	**0.5**	**Classified as moderate risk, drains into Citadel Wash-Lower Little Colorado River that is classified as moderate risk**
Big Wash-The Big Lake Area-1502001603	**0.5**	**Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk**
Tohachi Wash-1502001604	**0.5**	**Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk**
Citadel Wash-Lower Little Colorado River-1502001605	**0.5**	**Classified as moderate risk, drains into Tonahakaad Wash-Lower Little Colorado River that is classified as moderate risk**
Upper Cedar Wash-1502001606	**0.5**	**Classified as moderate risk, drains into Lower Cedar Wash that is classified as moderate risk**
Lower Cedar Wash-1502001607	**0.5**	**Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**0.5**	**Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk**
Lee Canyon-Lower Little Colorado River-1502001609	**0.5**	**Classified as moderate risk, drains into Sheep Wash-Lower Little Colorado River that is classified as moderate risk**
Sheep Wash-Lower Little Colorado River-1502001610	**0.5**	**Classified as moderate risk**
Upper Dinnebito Wash-1502001701	**0.5**	**Classified as moderate risk, drains into Middle Dinnebito Wash that is classified as moderate risk**
Middle Dinnebito Wash-1502001702	**0.5**	**Classified as moderate risk, drains into Lower Dinnebito Wash that is classified as moderate risk**
Lower Dinnebito Wash-1502001703	**0.5**	**Classified as moderate risk, drains into Kana-a Wash-Lower Little Colorado River that is classified as moderate risk**
Moenkopi Wash Headwaters-1502001801	**0.5**	**Classified as moderate risk, drains into Wide Ruin Canyon-Moenkopi Wash that is classified as moderate risk**
Shonto Wash-1502001802	**0.5**	**Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk**
Upper Begashibito Wash-1502001803	**0.5**	**Classified as moderate risk, drains into Lower Begashibito Wash that is classified as moderate risk**
Crooked Ridge/Echo Cliffs Area-1502001804	**0.5**	**Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk**

Subwatershed	FMV	Justification
Lower Begashibito Wash-1502001805	**0.5**	**Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.5**	**Classified as moderate risk, drains into Coal Mine Canyon-Moenkopi Wash that is classified as moderate risk**
Pasture Canyon-1502001807	**0.5**	**Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk**
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**Classified as moderate risk, drains into Kerley Valley-Moenkopi Wash that is classified as moderate risk**
Hamblin Wash-1502001809	**0.5**	**Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**Classified as moderate risk, drains into Fivemile Wash-Moenkopi Wash that is classified as moderate risk**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**Classified as moderate risk, drains into Lee Canyon-Lower Little Colorado River that is classified as moderate risk**

Table 6- 18 Percentage of Agricultural Lands in each Subwatershed.

Subwatershed	Percentage of Agricultural Area
Nutrioso Creek-1502000101	**1.42**
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	**1.35**
Coyote Creek-1502000103	**0.03**
Carnero Creek-Little Colorado River Headwaters-1502000104	**0.51**
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	**3.75**
Big Hollow Wash-1502000202	**0.01**
Concho Creek-Upper Little Colorado River-1502000203	**0.46**
Oso Draw-1502000204	**0.26**
Milky Wash-1502000205	**0.01**
Hay Hollow Draw-Upper Little Colorado River-1502000206	**0.77**
Washboard Wash-Upper Little Colorado River-1502000207	**0.67**
Middle Carrizo Wash-1502000306	**0.000**
Lower Carrizo Wash-1502000307	**0.000**
Jaralosa Draw-1502000406	**0.000**
Middle Zuni River-1502000407	**0.000**
Hardscrabble Wash-1502000408	**0.000**
Lower Zuni River-1502000409	**0.000**
Show Low Creek-1502000501	**1.19**
Upper Silver Creek-1502000502	**0.61**
Cottonwood Creek-1502000503	**1.48**
Lower Silver Creek-1502000504	**2.25**

Subwatershed	Percentage of Agricultural Area
Upper Black Creek-1502000603	0.02
Whitewater Arroyo-1502000605	0.000
Lower Black Creek-1502000606	0.25
Manuelito Canyon-Upper Puerco River-1502000607	0.00
Burntwater Wash-Lower Puerco River-1502000701	0.01
Morgan Canyon-1502000702	0.000
Dead Wash-1502000703	0.00
Dry Wash-1502000704	0.000
Ninemile Wash-Lower Puerco River-1502000705	0.00
Lithodendron Wash-Lower Puerco River-1502000706	0.02
Phoenix Park Wash-Dry Lake-1502000801	0.01
Porter Tank Draw-Middle Little Colorado River-1502000802	0.19
Upper Clear Creek-1502000803	0.01
Lower Clear Creek-1502000804	0.000
Jacks Canyon-1502000805	0.38
McDonald Canyon-Middle Little Colorado River-1502000806	0.07
Rincon Basin Area-Middle Little Colorado River-1502000807	0.52
Coyote Wash-Middle Little Colorado River-1502000808	0.000
Cow Canyon-Middle Little Colorado River-1502000809	0.01
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.000
Upper Wide Ruin Wash-1502000901	0.28
Lower Wide Ruin Wash-1502000902	0.000
Leroux Wash-1502000903	0.02
Upper Chevelon Canyon-1502001001	0.00
Black Canyon-1502001002	0.02
Lower Chevelon Canyon-1502001003	0.000
Upper Pueblo Colorado Wash-1502001101	0.000
Steamboat Wash-1502001102	0.00
Middle Pueblo Colorado Wash-1502001103	0.01
Bidahochi Wash-1502001104	0.000
Lower Pueblo Colorado Wash-1502001105	0.000
Cottonwood Wash-1502001106	0.000
Upper Oraibi Wash-1502001201	0.000
Middle Oraibi Wash-1502001202	0.26
Lower Oraibi Wash-1502001203	0.17
Upper Polacca Wash-1502001301	0.00
Wepo Wash-1502001302	0.07
Middle Polacca Wash-1502001303	0.03
Lower Polacca Wash-1502001304	0.06
Ha-whi-yalin Wash-1502001401	0.000
Upper Jadito Wash-1502001402	0.000

Subwatershed	Percentage of Agricultural Area
Coyote Wash-1502001403	0.00
Lower Jadito Wash-1502001404	0.000
Rio de Flag-1502001501	0.29
Walnut Creek-1502001502	0.01
San Francisco Wash-1502001503	0.01
Canyon Diablo (Local Drainage)-1502001504	0.00
Kana-a Wash-Lower Little Colorado River-1502001601	0.000
Deadman Wash-1502001602	0.000
Big Wash-The Big Lake Area-1502001603	0.000
Tohachi Wash-1502001604	0.000
Citadel Wash-Lower Little Colorado River-1502001605	0.000
Upper Cedar Wash-1502001606	0.000
Lower Cedar Wash-1502001607	0.000
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.000
Lee Canyon-Lower Little Colorado River-1502001609	0.000
Sheep Wash-Lower Little Colorado River-1502001610	0.000
Upper Dinnebito Wash-1502001701	0.000
Middle Dinnebito Wash-1502001702	0.20
Lower Dinnebito Wash-1502001703	0.000
Moenkopi Wash Headwaters-1502001801	0.000
Shonto Wash-1502001802	0.01
Upper Begashibito Wash-1502001803	0.00
Crooked Ridge/Echo Cliffs Area-1502001804	0.000
Lower Begashibito Wash-1502001805	0.000
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.000
Pasture Canyon-1502001807	0.01
Coal Mine Canyon-Moenkopi Wash-1502001808	0.000
Hamblin Wash-1502001809	0.03
Kerley Valley-Moenkopi Wash-1502001810	0.07
Fivemile Wash-Moenkopi Wash-1502001811	0.000

Table 6- 19 Fuzzy Membership Values Based on Number of Mines in each 10-digit HUC Subwatershed.

Number of Mines in each Subwatershed	FMV
0-10	0.00
11-25	0.33
26-50	0.66
>50	1.00

Table 6- 20 Fuzzy Membership Values for Selenium for each 10-digit HUC Subwatershed Based on the Number of Mines.

Subwatershed Name	Number of Mines	FMV for mines/HUC
Nutrioso Creek-1502000101	5	0.00
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	10	0.00
Coyote Creek-1502000103	4	0.00
Carnero Creek-Little Colorado River Headwaters-1502000104	10	0.00
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	11	0.33
Big Hollow Wash-1502000202	4	0.00
Concho Creek-Upper Little Colorado River-1502000203	8	0.00
Oso Draw-1502000204	8	0.00
Milky Wash-1502000205	0	0.00
Hay Hollow Draw-Upper Little Colorado River-1502000206	5	0.00
Washboard Wash-Upper Little Colorado River-1502000207	11	0.33
Middle Carrizo Wash-1502000306	0	0.00
Lower Carrizo Wash-1502000307	2	0.00
Jaralosa Draw-1502000406	0	0.00
Middle Zuni River-1502000407	1	0.00
Hardscrabble Wash-1502000408	2	0.00
Lower Zuni River-1502000409	4	0.00
Show Low Creek-1502000501	19	0.33
Upper Silver Creek-1502000502	12	0.33
Cottonwood Creek-1502000503	9	0.00
Lower Silver Creek-1502000504	6	0.00
Upper Black Creek-1502000603	2	0.00
Whitewater Arroyo-1502000605	1	0.00
Lower Black Creek-1502000606	6	0.00
Manuelito Canyon-Upper Puerco River-1502000607	5	0.00
Burntwater Wash-Lower Puerco River-1502000701	20	0.33
Morgan Canyon-1502000702	5	0.00
Dead Wash-1502000703	2	0.00
Dry Wash-1502000704	7	0.00
Ninemile Wash-Lower Puerco River-1502000705	24	0.33
Lithodendron Wash-Lower Puerco River-1502000706	6	0.00
Phoenix Park Wash-Dry Lake-1502000801	6	0.00
Porter Tank Draw-Middle Little Colorado River-1502000802	5	0.00
Upper Clear Creek-1502000803	3	0.00
Lower Clear Creek-1502000804	8	0.00
Jacks Canyon-1502000805	3	0.00
McDonald Canyon-Middle Little Colorado River-1502000806	13	0.33
Rincon Basin Area-Middle Little Colorado River-1502000807	7	0.00
Coyote Wash-Middle Little Colorado River-1502000808	6	0.00

Subwatershed Name	Number of Mines	FMV for mines/HUC
Cow Canyon-Middle Little Colorado River-1502000809	5	0.00
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	7	0.00
Upper Wide Ruin Wash-1502000901	5	0.00
Lower Wide Ruin Wash-1502000902	1	0.00
Leroux Wash-1502000903	11	0.33
Upper Chevelon Canyon-1502001001	10	0.00
Black Canyon-1502001002	3	0.00
Lower Chevelon Canyon-1502001003	2	0.00
Upper Pueblo Colorado Wash-1502001101	2	0.00
Steamboat Wash-1502001102	5	0.00
Middle Pueblo Colorado Wash-1502001103	8	0.00
Bidahochi Wash-1502001104	9	0.00
Lower Pueblo Colorado Wash-1502001105	0	0.00
Cottonwood Wash-1502001106	5	0.00
Upper Oraibi Wash-1502001201	1	0.00
Middle Oraibi Wash-1502001202	1	0.00
Lower Oraibi Wash-1502001203	2	0.00
Upper Polacca Wash-1502001301	7	0.00
Wepo Wash-1502001302	2	0.00
Middle Polacca Wash-1502001303	2	0.00
Lower Polacca Wash-1502001304	2	0.00
Ha-whi-yalin Wash-1502001401	1	0.00
Upper Jadito Wash-1502001402	1	0.00
Coyote Wash-1502001403	0	0.00
Lower Jadito Wash-1502001404	1	0.00
Rio de Flag-1502001501	26	0.66
Walnut Creek-1502001502	15	0.33
San Francisco Wash-1502001503	11	0.33
Canyon Diablo (Local Drainage)-1502001504	3	0.00
Kana-a Wash-Lower Little Colorado River-1502001601	2	0.00
Deadman Wash-1502001602	12	0.33
Big Wash-The Big Lake Area-1502001603	0	0.00
Tohachi Wash-1502001604	1	0.00
Citadel Wash-Lower Little Colorado River-1502001605	13	0.33
Upper Cedar Wash-1502001606	7	0.00
Lower Cedar Wash-1502001607	1	0.00
Tonahakaad Wash-Lower Little Colorado River-1502001608	34	0.66
Lee Canyon-Lower Little Colorado River-1502001609	5	0.00
Sheep Wash-Lower Little Colorado River-1502001610	0	0.00
Upper Dinnebito Wash-1502001701	1	0.00
Middle Dinnebito Wash-1502001702	1	0.00
Lower Dinnebito Wash-1502001703	2	0.00

Subwatershed Name	Number of Mines	FMV for mines/HUC
Moenkopi Wash Headwaters-1502001801	6	0.00
Shonto Wash-1502001802	8	0.00
Upper Begashibito Wash-1502001803	1	0.00
Crooked Ridge/Echo Cliffs Area-1502001804	0	0.00
Lower Begashibito Wash-1502001805	1	0.00
Wide Ruin Canyon-Moenkopi Wash-1502001806	1	0.00
Pasture Canyon-1502001807	3	0.00
Coal Mine Canyon-Moenkopi Wash-1502001808	9	0.00
Hamblin Wash-1502001809	1	0.00
Kerley Valley-Moenkopi Wash-1502001810	3	0.00
Fivemile Wash-Moenkopi Wash-1502001811	7	0.00

Table 6- 21 Weighted Combination Method Results for Selenium Based on the Fuzzy Logic Approach.

Subwatershed	WQA[1]	FMV mines/HUC	FMV Weighted
Nutrioso Creek-1502000101	0.0	0.00	0.00
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.0	0.00	0.00
Coyote Creek-1502000103	0.3	0.00	0.15
Carnero Creek-Little Colorado River Headwaters-1502000104	0.0	0.00	0.00
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.5	0.33	0.42
Big Hollow Wash-1502000202	0.5	0.00	0.25
Concho Creek-Upper Little Colorado River-1502000203	0.5	0.00	0.25
Oso Draw-1502000204	0.0	0.00	0.00
Milky Wash-1502000205	0.3	0.00	0.15
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.3	0.00	0.15
Washboard Wash-Upper Little Colorado River-1502000207	0.0	0.33	0.17
Middle Carrizo Wash-1502000306	0.5	0.00	0.25
Lower Carrizo Wash-1502000307	0.5	0.00	0.25
Jaralosa Draw-1502000406	0.5	0.00	0.25
Middle Zuni River-1502000407	0.5	0.00	0.25
Hardscrabble Wash-1502000408	0.5	0.00	0.25
Lower Zuni River-1502000409	0.5	0.00	0.25
Show Low Creek-1502000501	0.0	0.33	0.17
Upper Silver Creek-1502000502	0.0	0.33	0.17
Cottonwood Creek-1502000503	0.5	0.00	0.25
Lower Silver Creek-1502000504	0.3	0.00	0.15
Upper Black Creek-1502000603	0.5	0.00	0.25
Whitewater Arroyo-1502000605	0.5	0.00	0.25
Lower Black Creek-1502000606	0.5	0.00	0.25
Manuelito Canyon-Upper Puerco River-1502000607	0.5	0.00	0.25

Subwatershed	WQA[1]	FMV mines/HUC	FMV Weighted
Burntwater Wash-Lower Puerco River-1502000701	0.5	0.33	0.42
Morgan Canyon-1502000702	0.5	0.00	0.25
Dead Wash-1502000703	0.5	0.00	0.25
Dry Wash-1502000704	0.5	0.00	0.25
Ninemile Wash-Lower Puerco River-1502000705	0.5	0.33	0.42
Lithodendron Wash-Lower Puerco River-1502000706	0.5	0.00	0.25
Phoenix Park Wash-Dry Lake-1502000801	0.5	0.00	0.25
Porter Tank Draw-Middle Little Colorado River-1502000802	0.5	0.00	0.25
Upper Clear Creek-1502000803	0.5	0.00	0.25
Lower Clear Creek-1502000804	0.5	0.00	0.25
Jacks Canyon-1502000805	0.5	0.00	0.25
McDonald Canyon-Middle Little Colorado River-1502000806	0.5	0.33	0.42
Rincon Basin Area-Middle Little Colorado River-1502000807	0.5	0.00	0.25
Coyote Wash-Middle Little Colorado River-1502000808	0.5	0.00	0.25
Cow Canyon-Middle Little Colorado River-1502000809	0.5	0.00	0.25
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	0.5	0.00	0.25
Upper Wide Ruin Wash-1502000901	0.5	0.00	0.25
Lower Wide Ruin Wash-1502000902	0.5	0.00	0.25
Leroux Wash-1502000903	0.5	0.33	0.42
Upper Chevelon Canyon-1502001001	0.3	0.00	0.15
Black Canyon-1502001002	0.3	0.00	0.15
Lower Chevelon Canyon-1502001003	0.0	0.00	0.00
Upper Pueblo Colorado Wash-1502001101	0.5	0.00	0.25
Steamboat Wash-1502001102	0.5	0.00	0.25
Middle Pueblo Colorado Wash-1502001103	0.5	0.00	0.25
Bidahochi Wash-1502001104	0.5	0.00	0.25
Lower Pueblo Colorado Wash-1502001105	0.5	0.00	0.25
Cottonwood Wash-1502001106	0.5	0.00	0.25
Upper Oraibi Wash-1502001201	0.5	0.00	0.25
Middle Oraibi Wash-1502001202	0.5	0.00	0.25
Lower Oraibi Wash-1502001203	0.5	0.00	0.25
Upper Polacca Wash-1502001301	0.5	0.00	0.25
Wepo Wash-1502001302	0.5	0.00	0.25
Middle Polacca Wash-1502001303	0.5	0.00	0.25
Lower Polacca Wash-1502001304	0.5	0.00	0.25
Ha-whi-yalin Wash-1502001401	0.5	0.00	0.25
Upper Jadito Wash-1502001402	0.5	0.00	0.25
Coyote Wash-1502001403	0.5	0.00	0.25
Lower Jadito Wash-1502001404	0.5	0.00	0.25
Rio de Flag-1502001501	0.0	0.66	0.33
Walnut Creek-1502001502	0.5	0.33	0.42

Subwatershed	WQA[1]	FMV mines/HUC	FMV Weighted
San Francisco Wash-1502001503	**0.6**	**0.33**	**0.47**
Canyon Diablo (Local Drainage)-1502001504	**0.7**	**0.00**	**0.35**
Kana-a Wash-Lower Little Colorado River-1502001601	**0.5**	**0.00**	**0.25**
Deadman Wash-1502001602	**0.5**	**0.33**	**0.42**
Big Wash-The Big Lake Area-1502001603	**0.5**	**0.00**	**0.25**
Tohachi Wash-1502001604	**0.5**	**0.00**	**0.25**
Citadel Wash-Lower Little Colorado River-1502001605	**0.5**	**0.33**	**0.42**
Upper Cedar Wash-1502001606	**0.5**	**0.00**	**0.25**
Lower Cedar Wash-1502001607	**0.5**	**0.00**	**0.25**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**0.5**	**0.66**	**0.58**
Lee Canyon-Lower Little Colorado River-1502001609	**0.5**	**0.00**	**0.25**
Sheep Wash-Lower Little Colorado River-1502001610	**0.5**	**0.00**	**0.25**
Upper Dinnebito Wash-1502001701	**0.5**	**0.00**	**0.25**
Middle Dinnebito Wash-1502001702	**0.5**	**0.00**	**0.25**
Lower Dinnebito Wash-1502001703	**0.5**	**0.00**	**0.25**
Moenkopi Wash Headwaters-1502001801	**0.5**	**0.00**	**0.25**
Shonto Wash-1502001802	**0.5**	**0.00**	**0.25**
Upper Begashibito Wash-1502001803	**0.5**	**0.00**	**0.25**
Crooked Ridge/Echo Cliffs Area-1502001804	**0.5**	**0.00**	**0.25**
Lower Begashibito Wash-1502001805	**0.5**	**0.00**	**0.25**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.5**	**0.00**	**0.25**
Pasture Canyon-1502001807	**0.5**	**0.00**	**0.25**
Coal Mine Canyon-Moenkopi Wash-1502001808	**0.5**	**0.00**	**0.25**
Hamblin Wash-1502001809	**0.5**	**0.00**	**0.25**
Kerley Valley-Moenkopi Wash-1502001810	**0.5**	**0.00**	**0.25**
Fivemile Wash-Moenkopi Wash-1502001811	**0.5**	**0.00**	**0.25**
Weights	***0.5***	***0.5***	

[1]WQA = Water Quality Assessment Data

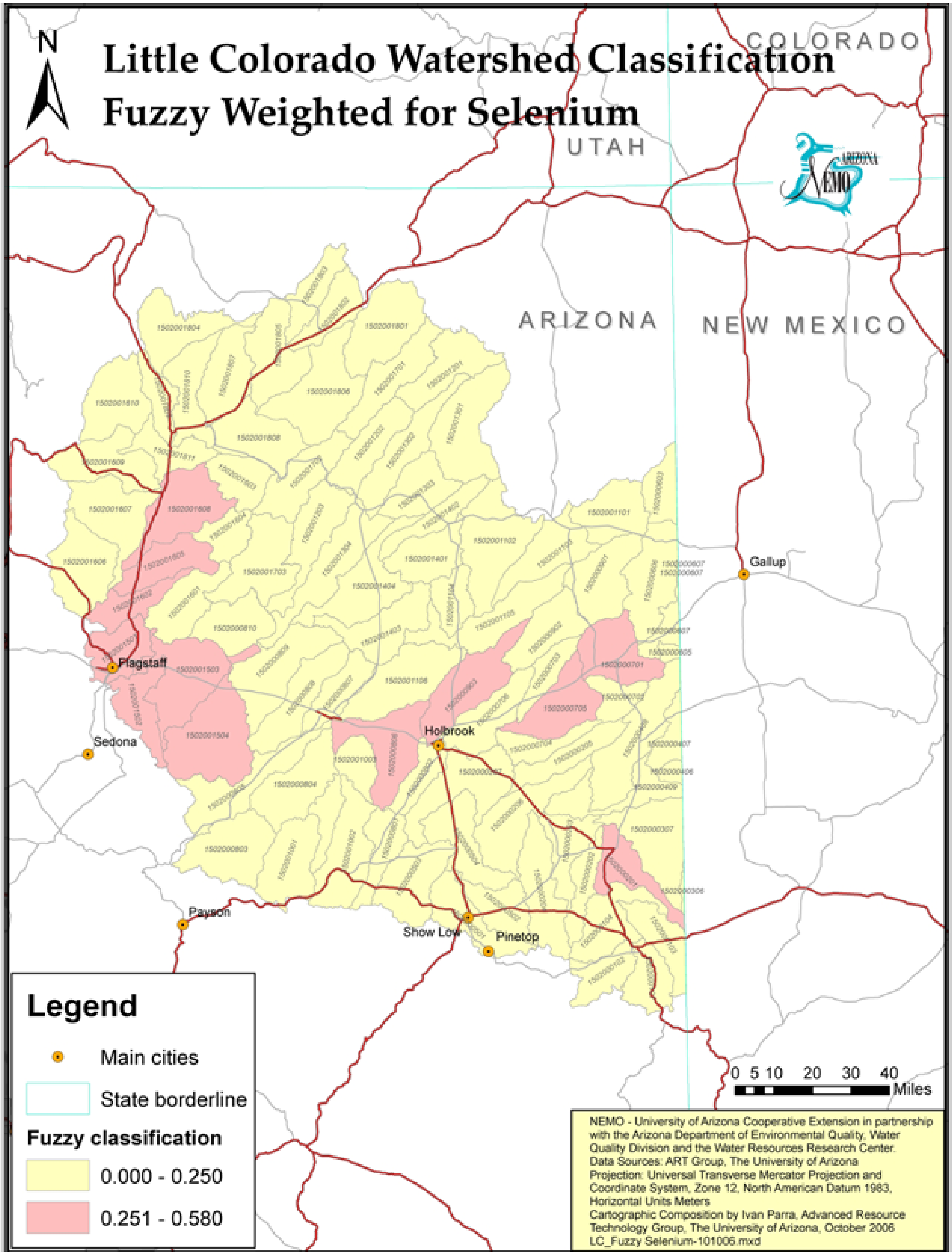

Figure 6- 6 Results for the Fuzzy Logic Classification for Selenium, Based on the Weighted Combination Approach.

References

Arizona Department of Environmental Quality, ADEQ. DRAFT 2005, Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, 1110 West Washington Ave., Phoenix, Arizona, 85007 http://www.adeq.state.az.us/environ/water/assessment/assess.html

Arizona Department of Environmental Quality, ADEQ. July 19, 2004. ADEQ TMDL Program website. http://www.azdeq.gov/environ/water/assessment/tmdl.html (Feb. 22, 2005).

Guertin, D.P., R.H. Fiedler, S.N. Miller, and D.C. Goodrich. 2000. Fuzzy Logic for Watershed Assessment. Proceedings of the ASCE Conference on Science and Technology for the New Millennium: Watershed Management 2000, Fort Collins, CO, June 21-24, 2000.

Hem, J.D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water, 2nd Edition. U.S. Geological Survey Water-Supply Paper 1473.

Reynolds, K.M. 2001. Fuzzy Logic Knowledge Bases in Integrated Landscape Assessment: Examples and Possibilities. General Technical Report PNW-GTR-521. USDA Forest Service, Pacific Northwest Research Station. 24 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), U. S. Department of Agriculture, Agriculture Handbook No. 703. 404 pp.

Data Sources*

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/index.html
Landownership. February 7, 2002.
Mines. February 7, 2002.

National Land Cover Database 2001 (NLCD 2001)
http://www.mrlc.gov/mrlc2k_nlcd.asp
Land use. September 12, 2006

** Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, its geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Section 7: Watershed Management

This section discusses the recommended watershed management activities to address nonpoint source pollution concerns in the Little Colorado Watershed. These recommendations are subject to revision by land use decision makers and stakeholders, and may be revised based on new data as it becomes available. It is understood that the application of any management activities will require site-specific design and may require licensed engineering design. These recommendations are only general in nature and are presented herein so as to allow land use decision makers and watershed stakeholders to conceptualize how best to address watershed management.

The Nutrioso Creek TMDL Implementation Plan and the Rainbow Lake TMDL are also summarized within this section. A TMDL plan is a study for an impaired water body that defines the maximum amount of a specified water quality parameter or pollutant that can be carried by a waterbody without causing an exceedance of water quality standards.

Management Methods

This section includes general watershed management methods, recommended strategies for addressing existing impairment in the watershed, stream channel and riparian restoration, and proposed education programs. The general watershed management methods include:

- Site management on new development;
- Monitoring and enforcement activities;
- Water quality improvement and restoration projects; and
- Education.

Each of these methods is defined further below, and is addressed within each of the three classifications: metals, organics, and nutrient nonpoint source pollutant water quality concerns.

Site Management on New Development

Control the quantity and quality of water run-off from new development sites. The primary sources for future development in the Little Colorado Watershed include the mining industry, new housing developments and increased urbanization, and new road construction. Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Concho Creek-Upper Little Colorado River, Oso Draw, Milky Wash, Hay Hollow Draw-Upper Little Colorado River, Washboard Wash-Upper Little Colorado River, Lower Carrizo Wash, Jaralosa Draw, Lower Zuni River, Upper Silver Creek, Lower Silver Creek, Dry Wash, Lithodendron Wash-Lower Puerco River, Phoenix Park Wash-Dry Lake, Porter Tank Draw-Middle Little Colorado River, Lower Clear Creek, McDonald Canyon-Middle Little Colorado River, Rincon Basin Area-Middle Little Colorado River, Coyote Wash-Middle Little Colorado River, Leroux Wash and Lower Chevelon Canyon subwatersheds are particularly at risk to future housing development due to the large percentage of private land within the watershed (over 35% of the area, see Table 7- 3).

Although it is recognized that ADEQ requires Aquifer Protection Permitting and the issuance of Stormwater Management Plans for active mine sites, new mine developments in the watershed should continue to be monitored. It is important to promote the application of nonpoint source management measures on all new development sites through cooperation with local government, developers and private land owners.

Monitoring and Enforcement Activities

- Continue and expand water quality monitoring programs in the watershed to measure the effectiveness of management practices on protecting and restoring the waters of the Little Colorado Watershed.
- Promote septic tank inspections and certification of septic systems by local government entities.
- Promote construction site inspection and enforcement action for new development.

Water Quality Improvement and Restoration Projects

- Promote efforts to protect and restore the natural functions and characteristics of impaired water bodies. Potential projects are discussed below.
- Integrate adaptive management methods and activities across the watershed to address existing and future problems.

Education

- Develop programs to increase the awareness and participation of citizens, developers and local decision makers in the watershed management efforts. Education programs are discussed below.

<u>Strategy for Addressing Existing Impairment</u>

The major sources of water quality impairment and environmental damage in the Little Colorado waters are elevated concentrations of dissolved and particulate metals, sediment and organics. The high priority 10-digit HUC subwatersheds were identified for each constituent group in the previous section on Watershed Classification (Section 6).

The goal of this section is to describe a strategy for dealing with the sources of impairment for each constituent group. The management measures discussed herein are brief and meant to provide initial guidance to the land use decision makers and watershed stakeholders.

Detailed descriptions of the following management measures, in addition to a manual of nonpoint source best management practices (BMPs), can be found at the NEMO website www.ArizonaNEMO.org.

Metals

The primary nonpoint source of anthropogenic metals in the Little Colorado Watershed is abandoned or inactive mines, although it is recognized that naturally occurring metals originating from local highly mineralized soils may contribute to elevated background concentrations in streams and lakes. Industrial and urban sources of metals are generally insignificant in this type of rural area. Portions of the Little Colorado Watershed have a long history of mining, with many abandoned and several active mines found across the watershed. In most cases the original owner or responsible party for an abandoned mine is unknown and the responsibility for the orphaned mine falls to the current landowner.

Abandoned / orphaned mines are found on all classes of land ownership in the Little Colorado Watershed, including federal, state and private lands, with a majority of the mines located on land administered by the Federal government and the State of Arizona.

Surface runoff and erosion from mine waste / tailings is the principal source of nonpoint source contamination. Subsurface drainage from mine waste / tailings can also be a concern. The recommended actions include:

- Inventory of existing abandoned mines;
- Revegetation of disturbed mined lands;
- Erosion control;
- Runoff and sediment capture;
- Tailings and mine waste removal; and
- Education.

Load reduction potential, maintenance, cost and estimated life of revegetation and erosion control treatments are found in Table 7- 1.

Table 7- 1 Proposed Treatments for Addressing Metals from Abandoned Mines.

Action	Load Reduction Potential	Estimated Time Load Reduction	Expected Maintenance	Expected Cost	Estimated Life of Treatment
Revegetation	**Medium**	**< 2 years**	**Low**	**Low-Medium**	**Long**
Erosion Control Fabric	**High**	**Immediate**	**Low**	**Low-Medium**	**Short**
Plant Mulch	**Low**	**Immediate**	**Low**	**Low**	**Short**
Rock Mulch	**High**	**Immediate**	**Medium**	**Low-High**	**Long**
Toe Drains	**High**	**Immediate**	**Medium**	**Medium**	**Medium**
Detention Basin	**High**	**Immediate**	**High**	**High**	**Medium- Long**
Silt Fence	**Medium**	**Immediate**	**Medium**	**Low**	**Short- Medium**
Straw Roll/bale	**Medium**	**Immediate**	**High**	**Low**	**Short**
Removal	**High**	**Immediate**	**Low**	**High**	**Long**

NOTE: The actual cost, load reduction, or life expectancy of any treatment is dependent on site specific conditions. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Inventory of Existing Abandoned Mines

All existing abandoned mines are not equal sources for elevated concentrations of metals. One of the difficulties in developing this assessment is the lack of thorough and centralized data on abandoned mine sites. Some of the mapped abandoned mine sites are prospector claims with limited land disturbance, while others are remote and disconnected from natural drainage features and represent a low risk pollutant source.

At sites where water and oxygen are in contact with waste rock containing sulfates, sulfuric acid is formed. As the water becomes more acidic, metals are leached from the soils and rock, generating toxic concentrations of heavy metals in the water. Acid rock drainage, also known as acid mine drainage, can be a significant water quality concern. Management of this important source of watershed impairment begins with compiling available information from the responsible agencies. This information can be used to conduct an on-site inventory to clarify the degree of risk the site exhibits towards discharging elevated concentrations of metals to a water body.

Risk factors to be assessed include: area and volume of waste/tailings; metal species present and toxicity; site drainage features and metal transport characteristics (air dispersion, sediment transport, acid mine drainage, etc.); distance to a water body; and evidence of active site erosion. Abandoned mine sites can then be ranked and prioritized for site management and restoration.

Revegetation

Revegetation of the mine site is the only long-term, low maintenance restoration alternative in the absence of funding to install engineered site containment and capping. In semi-arid environments, revegetation of a disturbed site is relatively difficult even under optimal conditions. The amount of effort required to revegetate an abandoned mine site depends on the chemical composition of the mine waste/tailings, which may be too toxic to sustain growth.

The addition of soil amendments, buffering agents, or capping with top soil to sustain vegetation often approaches the costs associated with engineered capping. If acid mine drainage is a significant concern, intercepting and managing the acidic water may necessitate extensive site drainage control systems and water treatment, a significant increase in cost and requiring on-going site operation and maintenance.

Reclaimed Mine Site (DOI, Office of Surface Mining, http://www.osmre.gov/scripts/album.pl)

Erosion Control

If revegetation of the mine site is impractical, site drainage and erosion control treatments are alternatives. Erosion control actions can also be applied in combination with revegetation to control erosion as the vegetation cover is established. Erosion control fabric and plant mulch are two short-term treatments that are usually applied in combination with revegetation.

Rock mulch (i.e. rock riprap) is a long-term treatment, but can be costly and impractical on an isolated site. Rock mulch can be an inexpensive acid buffering treatment if carbonate rocks (limestone) are locally available. As the acidic mine drainage comes in contact with the rock mulch, the water looses it's acidity and dissolved metals precipitate out of the water column. A disadvantage of erosion control treatments is that they do not assist in dewatering a site and may have little impact on subsurface acidic leaching.

Runoff and Sediment Capture

The capture and containment of site runoff and sediment, and prevention of the waste rock and tailings from contact with a water body are other management approaches. Short-term treatments include installing straw roll/bale or silt fence barriers at the toe of the source area to capture sediment.

Long-term treatments include trenching the toe of the source area to capture the runoff and sediment. If the source area is large, the construction of a detention basin may be warranted.

Disadvantages of runoff and sediment capture and containment treatments are that they may concentrate the contaminated material, especially if dissolved metals are concentrated by evaporation in retention ponds. Structural failure can lead to downstream transport of pollutants. The retention / detention of site runoff can also escalate subsurface drainage problems by ponding water.

Load reduction potential, maintenance, cost and estimated life of runoff and sediment control treatments such as toe drains, basins, and silt fences are found in Table 7- 2.

Sediment Pond (DOI, Office of Surface Mining, http://www.osmre.gov/scripts/album.pl)

Table 7- 2 Proposed Treatments for Addressing Erosion and Sedimentation.

Action	Load Reduction Potential	Estimated Time to Load Reduction	Expected Maintenance	Expected Cost	Estimated Life of Treatment
Grazing Mgt.	**Medium**	**< 2 years**	**Low**	**Low**	**Long**
Filter Strips	**High**	**< 2 years**	**Low**	**Low**	**Long**
Fencing	**Low**	**Immediate**	**Low**	**Low**	**Medium**
Watering Facility	**Medium**	**Immediate**	**Low**	**Low-Medium**	**Medium**
Rock Riprap	**High**	**Immediate**	**Medium**	**Medium-High**	**Long**
Erosion Control Fabric	**High**	**Immediate**	**Low**	**Low-Medium**	**Short**
Toe Rock	**High**	**Immediate**	**Low**	**Medium**	**Long**
Water Bars	**Medium**	**Immediate**	**Medium**	**Medium**	**Medium**
Road Surface	**High**	**Immediate**	**Medium**	**High**	**Long**

Note: The actual cost, load reduction, or life expectancy of any treatment is dependant on site specific conditions. Low costs could range from nominal to $10,000, medium costs could range between $5,000 and $50,000, and high costs could be anything greater than $25,000. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Removal

The mine waste/tailing material can be excavated and removed for pollution control. This treatment is very expensive and infeasible for some sites due to lack of accessibility or due to the large volume of material.

Rock Structure for Runoff Control (DOI, Office of Surface Mining, http://www.osmre.gov/scripts/album.pl)

Education

Land use decision makers and stakeholders need to be educated on the problems associated with abandoned mines and the available treatments to mitigate the problems. In addition, abandoned mine sites are health and safety concerns and the public should be warned about entering open shafts that may collapse, or traversing unstable slopes. Due to the financial liability associated with site restoration, legal and regulatory constraints must also be addressed.

The target audiences for education programs are private land owners, watershed groups, local officials and land management agencies (U.S. Forest Service, Bureau of Land Management, and Tribal entities).

Figure 7- 1 shows land ownership across the 10-digit HUCs, figure 7-2

shows the 10-digit HUCs with major streams, and Table 7- 3 provides a listing of percentage of land ownership as distributed across the subwatershed areas. This table provides a basis from which to identify stakeholders pertinent to each subwatershed area, and is repeated here in more detail after a brief discussion of land ownership in Section 4, Social and Economic Characteristics of the watershed.

The 28 subwatershed areas prioritized for educational outreach on problems associated with abandoned mines include: Upper Polacca Wash, Tonahakaad Wash-Lower Little Colorado River, Middle Pueblo Colorado Wash, Lower Black Creek, Citadel Wash-Lower Little Colorado River, Upper Wide Ruin Wash, Bidahochi Wash, Deadman Wash, Burntwater Wash-Lower Puerco River, Rio de Flag, Leroux Wash, San Francisco Wash, Canyon Diablo (Local Drainage), Ninemile Wash-Lower Puerco River, Walnut Creek, Jacks Canyon, Washboard Wash-Upper Little Colorado River, Hay Hollow Draw-Upper Little Colorado River, Black Canyon, Oso Draw, Concho Creek-Upper Little Colorado River, Upper Chevelon Canyon, Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Cottonwood Creek, Show Low Creek, Carnero Creek-Little Colorado River Headwaters, Coyote Creek and South Fork Little Colorado River-Little Colorado River Headwaters (See Figure 7-2).

There are no TMDL Implementation plans that have been developed to address metal contamination, since few concerns have been detected in water sampling.

Note that recommendations for those subwatersheds owned by tribal groups are not provided in this document although they represent most of the total area in the watershed.

Sediment

Erosion and sedimentation are major environment problems in the western United States, including the Little Colorado Watershed. In semiarid regions, the primary source of sediment is from channel scour. Excessive channel scour and down-cutting can lead to deterioration of riparian systems' extent and condition. Increases in channel scour are caused by increased surface runoff produced by changing watershed conditions. Restoration of impaired channel riparian areas can also mitigate erosion damage.

The primary land uses in the Little Colorado Watershed that can contribute to sediment erosion are livestock grazing and mining (See Section 6-Sediment). Development, which also contributes to erosion, is increasing in some portions of the watershed, notably in Lower Black Creek, Coyote Wash, Burntwater Wash-Lower Puerco River, Rio de Flag, Rincon Basin Area-Middle Little Colorado River, Walnut Creek, Black Canyon, Lower Silver Creek, Show Low Creek and Upper Silver Creek subwatersheds, which showed portions with a high increase in population density from 1990 to 2000 (see Section 4 - Population Density Change 1990-2000).

Impervious land surfaces accelerate surface runoff, increase flow velocity, and exacerbates channel scour. Dirt roads can be an important source of sediment as well. The recommended sediment management actions (Table 7-2 above) are:

- Grazing Management
- Filter Strips
- Fencing
- Watering Facilities
- Rock Riprap
- Erosion Control Fabrics
- Toe Rock
- Water Bars
- Erosion Control on Dirt Roads
- Education

The turbidity-based Little Colorado TMDL plan is summarized within this section as it addresses excess sediment loading in the headwaters to the Little Colorado River. A TMDL is a study for an impaired waterbody that defines the maximum amount of a specified water quality parameter or pollutant that can be carried by a waterbody without causing an exceedance of water quality standards.

<u>Grazing Management</u>

Livestock grazing is currently the primary land use in the Little Colorado Watershed. Implementing grazing management practices to improve or maintain the health and vigor of plant communities leads to reduction in surface runoff and erosion. Sustainable livestock grazing can be achieved in all plant communities by changing the duration, frequency and intensity of grazing.

Management may include exclusion of land, such as riparian areas, from grazing, seasonal rotation, rest, or some combination of these options. Proper grazing land management provides for a healthy riparian plant community that stabilizes stream banks, creates habitat and slows flood velocities.

Filter Strips

A filter strip along a stream, lake or other waterbody will retard the movement of sediment, and may remove pollutants from runoff before the material enters the body of water. Filter strips will protect channel and riparian systems from livestock grazing and tramping. Fencing the filter strip is usually required when livestock are present. Filter strips and fencing can be used to protect other sensitive ecological resources.

Fencing

Restricting access to riparian corridors by fencing will allow for the reestablishment of riparian vegetation. Straw bale fencing slows runoff and traps sediment from sheet flow or channelized flow in areas of soil disturbance.

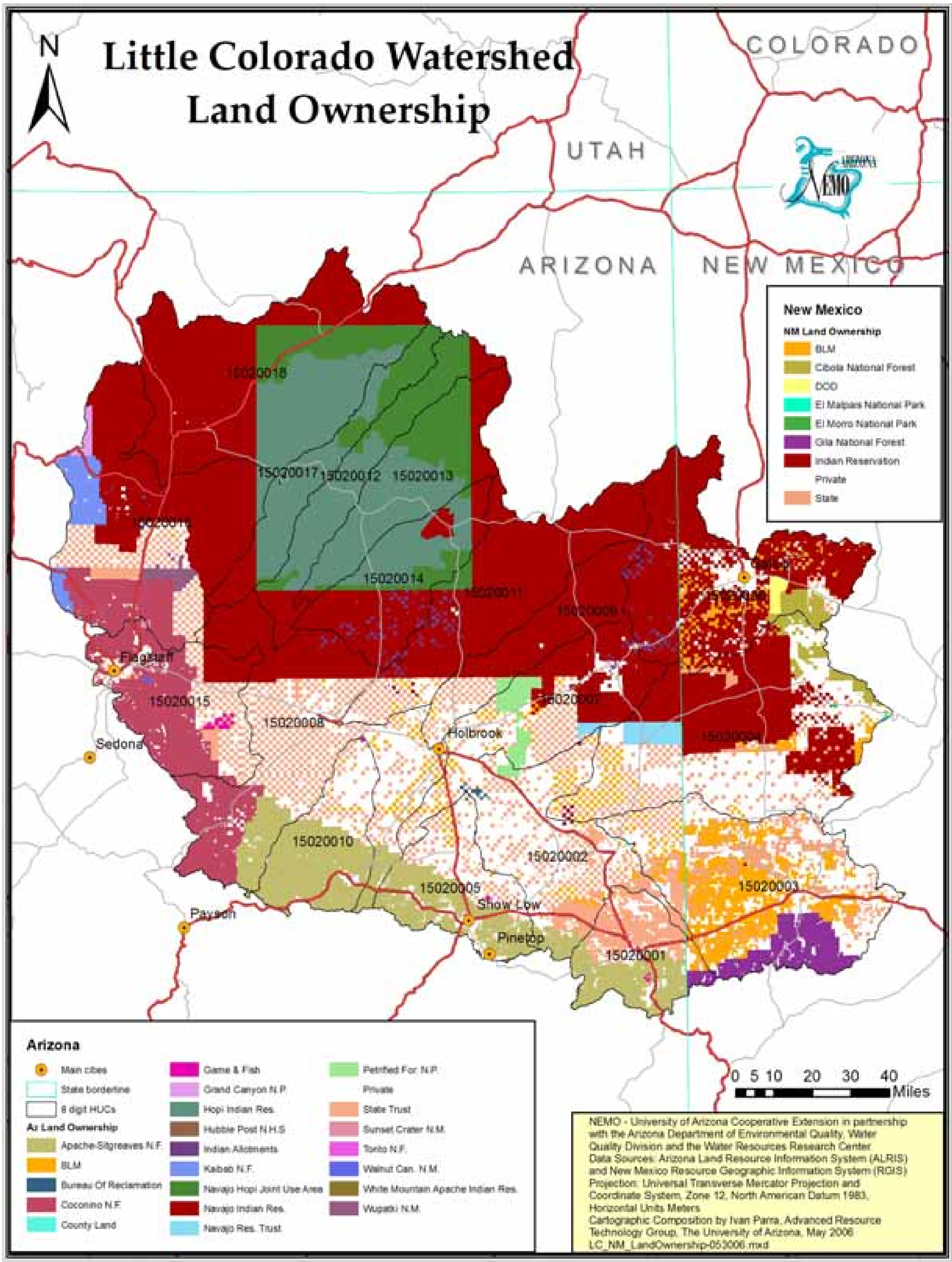

Figure 7- 1 Little Colorado Land Ownership by Subwatershed.

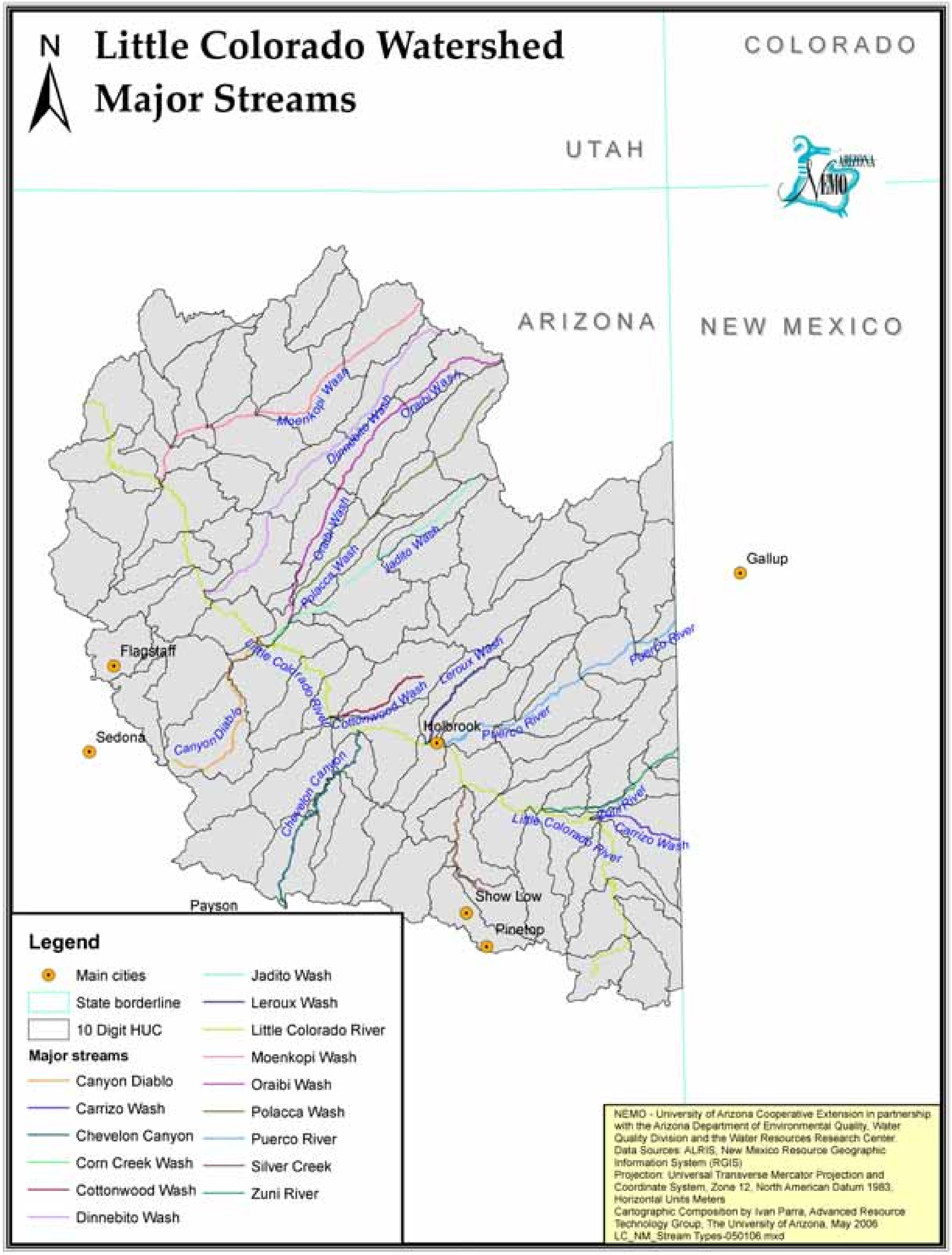

Figure 7- 2 Little Colorado Watershed Major Streams with HUC-10 Boundaries.

Table 7- 3 Percentage Land Ownership by Subwatershed (part 1 of 3).

Subwatershed	Navajo Indian Res.	Navajo Hopi Joint Use Area	Hopi Indian Res.	Grand Canyon N.P.	Private	Kaibab N.F.	Indian Allotments
Nutrioso Creek-1502000101	0.00%	0.00%	0.00%	0.00%	18.19%	0.00%	0.00%
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.00%	0.00%	0.00%	0.00%	13.62%	0.00%	0.00%
Coyote Creek-1502000103	0.00%	0.00%	0.00%	0.00%	15.07%	0.00%	0.00%
Carnero Creek-Little Colorado River Headwaters-1502000104	0.00%	0.00%	0.00%	0.00%	17.30%	0.00%	0.00%
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	0.00%	0.00%	0.00%	0.00%	49.29%	0.00%	0.00%
Big Hollow Wash-1502000202	0.00%	0.00%	0.00%	0.00%	34.16%	0.00%	0.00%
Concho Creek-Upper Little Colorado River-1502000203	1.47%	0.00%	0.00%	0.00%	63.63%	0.00%	0.00%
Oso Draw-1502000204	0.00%	0.00%	0.00%	0.00%	52.30%	0.00%	0.00%
Milky Wash-1502000205	0.56%	0.00%	0.00%	0.00%	64.47%	0.00%	0.00%
Hay Hollow Draw-Upper Little Colorado River-1502000206	0.00%	0.00%	0.00%	0.00%	77.83%	0.00%	0.00%
Washboard Wash-Upper Little Colorado River-1502000207	0.00%	0.00%	0.00%	0.00%	66.40%	0.00%	0.00%
Middle Carrizo Wash-1502000306	0.00%	0.00%	0.00%	0.00%	16.49%	0.00%	0.00%
Lower Carrizo Wash-1502000307	0.00%	0.00%	0.00%	0.00%	45.44%	0.00%	0.00%
Jaralosa Draw-1502000406	0.00%	0.00%	0.00%	0.00%	87.76%	0.00%	0.00%
Middle Zuni River-1502000407	21.00%	0.00%	0.00%	0.00%	30.24%	0.00%	0.00%
Hardscrabble Wash-1502000408	30.24%	0.00%	0.00%	0.00%	31.46%	0.00%	0.00%
Lower Zuni River-1502000409	2.69%	0.00%	0.00%	0.00%	58.60%	0.00%	0.00%
Show Low Creek-1502000501	0.00%	0.00%	0.00%	0.00%	27.29%	0.00%	0.00%
Upper Silver Creek-1502000502	0.00%	0.00%	0.00%	0.00%	37.31%	0.00%	0.00%
Cottonwood Creek-1502000503	0.00%	0.00%	0.00%	0.00%	25.70%	0.00%	0.00%
Lower Silver Creek-1502000504	0.00%	0.00%	0.00%	0.00%	73.14%	0.00%	0.00%
Upper Black Creek-1502000603	99.89%	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%

Subwatershed	Navajo Indian Res.	Navajo Hopi Joint Use Area	Hopi Indian Res.	Grand Canyon N.P.	Private	Kaibab N.F.	Indian Allotments
Whitewater Arroyo-1502000605	91.77%	0.00%	0.00%	0.00%	0.00%	0.00%	8.23%
Lower Black Creek-1502000606	93.69%	0.00%	0.00%	0.00%	0.90%	0.00%	5.41%
Manuelito Canyon-Upper Puerco River-1502000607	82.43%	0.00%	0.00%	0.00%	1.62%	0.00%	15.95%
Burntwater Wash-Lower Puerco River-1502000701	82.51%	0.00%	0.00%	0.00%	13.17%	0.00%	3.13%
Morgan Canyon-1502000702	86.78%	0.00%	0.00%	0.00%	10.42%	0.00%	0.00%
Dead Wash-1502000703	75.22%	0.00%	0.00%	0.00%	8.64%	0.00%	0.00%
Dry Wash-1502000704	0.04%	0.00%	0.00%	0.00%	39.34%	0.00%	0.00%
Ninemile Wash-Lower Puerco River-1502000705	34.04%	0.00%	0.00%	0.00%	33.87%	0.00%	0.00%
Lithodendron Wash-Lower Puerco River-1502000706	2.89%	0.00%	0.00%	0.00%	55.14%	0.00%	0.00%
Phoenix Park Wash-Dry Lake-1502000801	0.00%	0.00%	0.00%	0.00%	38.39%	0.00%	0.00%
Porter Tank Draw-Middle Little Colorado River-1502000802	0.00%	0.00%	0.00%	0.00%	66.48%	0.00%	0.00%
Upper Clear Creek-1502000803	0.00%	0.00%	0.00%	0.00%	4.19%	0.00%	0.00%
Lower Clear Creek-1502000804	0.00%	0.00%	0.00%	0.00%	43.39%	0.00%	0.00%
Jacks Canyon-1502000805	0.00%	0.00%	0.00%	0.00%	25.26%	0.00%	0.00%
McDonald Canyon-Middle Little Colorado River-1502000806	0.00%	0.00%	0.00%	0.00%	74.46%	0.00%	0.00%
Rincon Basin Area-Middle Little Colorado River-1502000807	24.12%	0.00%	0.00%	0.00%	47.64%	0.00%	0.00%
Coyote Wash-Middle Little Colorado River-1502000808	28.31%	0.00%	0.00%	0.00%	38.55%	0.00%	0.00%
Cow Canyon-Middle Little Colorado River-1502000809	61.57%	0.00%	0.00%	0.00%	19.93%	0.00%	1.20%
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	94.56%	0.00%	0.00%	0.00%	2.96%	0.00%	0.00%
Upper Wide Ruin Wash-1502000901	98.02%	0.00%	0.00%	0.00%	0.00%	0.00%	1.98%
Lower Wide Ruin Wash-1502000902	99.54%	0.00%	0.00%	0.00%	0.46%	0.00%	0.00%
Leroux Wash-1502000903	33.96%	0.00%	0.00%	0.00%	37.72%	0.00%	0.00%
Upper Chevelon Canyon-1502001001	0.00%	0.00%	0.00%	0.00%	1.08%	0.00%	0.00%
Black Canyon-1502001002	0.00%	0.00%	0.00%	0.00%	27.08%	0.00%	0.00%

Subwatershed	Navajo Indian Res.	Navajo Hopi Joint Use Area	Hopi Indian Res.	Grand Canyon N.P.	Private	Kaibab N.F.	Indian Allotments
Lower Chevelon Canyon-1502001003	0.00%	0.00%	0.00%	0.00%	61.76%	0.00%	0.00%
Upper Pueblo Colorado Wash-1502001101	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Steamboat Wash-1502001102	89.77%	3.66%	6.57%	0.00%	0.00%	0.00%	0.00%
Middle Pueblo Colorado Wash-1502001103	99.84%	0.00%	0.00%	0.00%	0.06%	0.00%	0.00%
Bidahochi Wash-1502001104	63.07%	26.11%	0.00%	0.00%	1.44%	0.00%	9.38%
Lower Pueblo Colorado Wash-1502001105	96.51%	0.00%	0.00%	0.00%	0.00%	0.00%	3.49%
Cottonwood Wash-1502001106	40.55%	0.00%	0.00%	0.00%	34.53%	0.00%	2.21%
Upper Oraibi Wash-1502001201	22.55%	77.45%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Oraibi Wash-1502001202	0.00%	41.56%	58.41%	0.00%	0.03%	0.00%	0.00%
Lower Oraibi Wash-1502001203	12.54%	0.02%	87.44%	0.00%	0.00%	0.00%	0.00%
Upper Polacca Wash-1502001301	47.07%	50.18%	2.76%	0.00%	0.00%	0.00%	0.00%
Wepo Wash-1502001302	0.07%	45.98%	53.94%	0.00%	0.01%	0.00%	0.00%
Middle Polacca Wash-1502001303	0.00%	4.40%	95.60%	0.00%	0.00%	0.00%	0.00%
Lower Polacca Wash-1502001304	28.59%	2.80%	68.61%	0.00%	0.00%	0.00%	0.00%
Ha-whi-yalin Wash-1502001401	3.10%	32.13%	64.77%	0.00%	0.00%	0.00%	0.00%
Upper Jadito Wash-1502001402	40.41%	5.84%	53.75%	0.00%	0.00%	0.00%	0.00%
Coyote Wash-1502001403	88.84%	1.81%	0.00%	0.00%	0.00%	0.00%	9.35%
Lower Jadito Wash-1502001404	53.23%	7.92%	35.87%	0.00%	0.00%	0.00%	2.98%
Rio de Flag-1502001501	0.00%	0.00%	0.00%	0.00%	29.15%	0.00%	0.00%
Walnut Creek-1502001502	0.00%	0.00%	0.00%	0.00%	4.96%	0.00%	0.00%
San Francisco Wash-1502001503	17.14%	0.00%	0.00%	0.00%	13.11%	0.00%	0.00%
Canyon Diablo (Local Drainage)-1502001504	4.96%	0.00%	0.00%	0.00%	27.08%	0.00%	0.00%
Kana-a Wash-Lower Little Colorado River-1502001601	21.75%	0.00%	0.00%	0.00%	23.21%	0.00%	0.00%
Deadman Wash-1502001602	0.00%	0.00%	0.00%	0.00%	3.46%	0.00%	0.00%
Big Wash-The Big Lake Area-1502001603	78.00%	0.00%	22.00%	0.00%	0.00%	0.00%	0.00%
Tohachi Wash-1502001604	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Subwatershed	Navajo Indian Res.	Navajo Hopi Joint Use Area	Hopi Indian Res.	Grand Canyon N.P.	Private	Kaibab N.F.	Indian Allotments
Citadel Wash-Lower Little Colorado River-1502001605	**28.37%**	**0.00%**	**0.00%**	**0.00%**	**17.68%**	**0.00%**	**0.73%**
Upper Cedar Wash-1502001606	**1.44%**	**0.00%**	**0.00%**	**0.00%**	**22.28%**	**12.44%**	**0.00%**
Lower Cedar Wash-1502001607	**57.37%**	**0.00%**	**0.00%**	**0.00%**	**6.68%**	**26.15%**	**1.50%**
Tonahakaad Wash-Lower Little Colorado River-1502001608	**73.69%**	**0.00%**	**0.00%**	**0.00%**	**13.45%**	**0.00%**	**0.09%**
Lee Canyon-Lower Little Colorado River-1502001609	**65.93%**	**0.00%**	**0.00%**	**6.13%**	**0.52%**	**27.13%**	**0.28%**
Sheep Wash-Lower Little Colorado River-1502001610	**93.23%**	**0.00%**	**0.00%**	**6.77%**	**0.00%**	**0.00%**	**0.00%**
Upper Dinnebito Wash-1502001701	**0.51%**	**75.54%**	**23.95%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Dinnebito Wash-1502001702	**0.30%**	**4.11%**	**95.59%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Dinnebito Wash-1502001703	**41.71%**	**9.99%**	**48.29%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Moenkopi Wash Headwaters-1502001801	**43.10%**	**33.74%**	**23.16%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Shonto Wash-1502001802	**67.48%**	**32.45%**	**0.07%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Begashibito Wash-1502001803	**87.82%**	**12.18%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Crooked Ridge/Echo Cliffs Area-1502001804	**99.92%**	**0.08%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Begashibito Wash-1502001805	**22.15%**	**42.78%**	**35.07%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Wide Ruin Canyon-Moenkopi Wash-1502001806	**0.05%**	**13.34%**	**86.61%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Pasture Canyon-1502001807	**99.65%**	**0.32%**	**0.00%**	**0.00%**	**0.02%**	**0.00%**	**0.00%**
Coal Mine Canyon-Moenkopi Wash-1502001808	**45.94%**	**0.00%**	**54.06%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hamblin Wash-1502001809	**99.88%**	**0.00%**	**0.00%**	**0.00%**	**0.12%**	**0.00%**	**0.00%**
Kerley Valley-Moenkopi Wash-1502001810	**99.56%**	**0.00%**	**0.00%**	**0.00%**	**0.44%**	**0.00%**	**0.00%**
Fivemile Wash-Moenkopi Wash-1502001811	**100.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Total	***34.69%***	***6.30%***	***11.23%***	***0.16%***	***18.73%***	***0.89%***	***0.57%***

Table 7- 3 Percentage Land Ownership by Subwatershed (part 2 of 3).

Subwatershed	State Trust	Hubble Post N.H.S	BLM	Wupatki N.M.	Coconino N.F.	Sunset Crater N.M.	Game & Fish
Nutrioso Creek-1502000101	**3.23%**	**0.00%**	**0.03%**	**0.00%**	**0.00%**	**0.00%**	**1.49%**
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	**8.00%**	**0.00%**	**0.01%**	**0.00%**	**0.00%**	**0.00%**	**0.40%**
Coyote Creek-1502000103	**60.61%**	**0.00%**	**0.19%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Carnero Creek-Little Colorado River Headwaters-1502000104	**70.48%**	**0.00%**	**2.10%**	**0.00%**	**0.00%**	**0.00%**	**0.17%**
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	**45.61%**	**0.00%**	**4.53%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Big Hollow Wash-1502000202	**52.94%**	**0.00%**	**4.03%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Concho Creek-Upper Little Colorado River-1502000203	**28.41%**	**0.00%**	**6.29%**	**0.00%**	**0.00%**	**0.00%**	**0.20%**
Oso Draw-1502000204	**26.20%**	**0.00%**	**0.59%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Milky Wash-1502000205	**25.25%**	**0.00%**	**4.49%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hay Hollow Draw-Upper Little Colorado River-1502000206	**17.59%**	**0.00%**	**4.58%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Washboard Wash-Upper Little Colorado River-1502000207	**19.07%**	**0.00%**	**7.12%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Carrizo Wash-1502000306	**65.97%**	**0.00%**	**17.54%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Carrizo Wash-1502000307	**38.31%**	**0.00%**	**16.14%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Jaralosa Draw-1502000406	**12.24%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Zuni River-1502000407	**22.28%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hardscrabble Wash-1502000408	**10.17%**	**0.00%**	**10.91%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Zuni River-1502000409	**25.72%**	**0.00%**	**12.99%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Show Low Creek-1502000501	**0.69%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.20%**
Upper Silver Creek-1502000502	**15.11%**	**0.00%**	**0.16%**	**0.00%**	**0.00%**	**0.00%**	**0.72%**
Cottonwood Creek-1502000503	**5.60%**	**0.00%**	**0.24%**	**0.00%**	**0.00%**	**0.00%**	**0.01%**
Lower Silver Creek-1502000504	**20.27%**	**0.00%**	**6.22%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Black Creek-1502000603	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Whitewater Arroyo-1502000605	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Black Creek-1502000606	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Manuelito Canyon-Upper Puerco River-1502000607	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Burntwater Wash-Lower Puerco River-1502000701	**0.87%**	**0.00%**	**0.32%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Subwatershed	State Trust	Hubble Post N.H.S	BLM	Wupatki N.M.	Coconino N.F.	Sunset Crater N.M.	Game & Fish
Morgan Canyon-1502000702	**0.01%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Dead Wash-1502000703	**0.59%**	**0.00%**	**4.58%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Dry Wash-1502000704	**23.64%**	**0.00%**	**2.08%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Ninemile Wash-Lower Puerco River-1502000705	**24.02%**	**0.00%**	**3.27%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lithodendron Wash-Lower Puerco River-1502000706	**9.29%**	**0.00%**	**6.10%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Phoenix Park Wash-Dry Lake-1502000801	**14.40%**	**0.00%**	**2.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Porter Tank Draw-Middle Little Colorado River-1502000802	**13.32%**	**0.00%**	**19.44%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Clear Creek-1502000803	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**54.41%**	**0.00%**	**0.02%**
Lower Clear Creek-1502000804	**33.14%**	**0.00%**	**0.16%**	**0.00%**	**2.58%**	**0.00%**	**0.00%**
Jacks Canyon-1502000805	**18.83%**	**0.00%**	**0.01%**	**0.00%**	**55.90%**	**0.00%**	**0.00%**
McDonald Canyon-Middle Little Colorado River-1502000806	**19.53%**	**0.00%**	**5.96%**	**0.00%**	**0.00%**	**0.00%**	**0.04%**
Rincon Basin Area-Middle Little Colorado River-1502000807	**28.23%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Coyote Wash-Middle Little Colorado River-1502000808	**32.81%**	**0.00%**	**0.34%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Cow Canyon-Middle Little Colorado River-1502000809	**17.30%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	**2.16%**	**0.00%**	**0.32%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Wide Ruin Wash-1502000901	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Wide Ruin Wash-1502000902	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Leroux Wash-1502000903	**21.80%**	**0.00%**	**2.03%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Chevelon Canyon-1502001001	**0.25%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.07%**
Black Canyon-1502001002	**5.30%**	**0.00%**	**1.33%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Chevelon Canyon-1502001003	**17.53%**	**0.00%**	**2.50%**	**0.00%**	**0.00%**	**0.00%**	**0.41%**
Upper Pueblo Colorado Wash-1502001101	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Steamboat Wash-1502001102	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Pueblo Colorado Wash-1502001103	**0.00%**	**0.10%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Bidahochi Wash-1502001104	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Pueblo Colorado Wash-1502001105	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Subwatershed	State Trust	Hubble Post N.H.S	BLM	Wupatki N.M.	Coconino N.F.	Sunset Crater N.M.	Game & Fish
Cottonwood Wash-1502001106	18.84%	0.00%	3.87%	0.00%	0.00%	0.00%	0.00%
Upper Oraibi Wash-1502001201	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Oraibi Wash-1502001202	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Oraibi Wash-1502001203	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Polacca Wash-1502001301	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wepo Wash-1502001302	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Polacca Wash-1502001303	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Polacca Wash-1502001304	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ha-whi-yalin Wash-1502001401	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Jadito Wash-1502001402	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coyote Wash-1502001403	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Jadito Wash-1502001404	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rio de Flag-1502001501	6.19%	0.00%	0.00%	0.00%	63.09%	1.40%	0.17%
Walnut Creek-1502001502	0.14%	0.00%	0.00%	0.00%	93.43%	0.00%	0.00%
San Francisco Wash-1502001503	11.68%	0.00%	0.00%	0.00%	58.03%	0.00%	0.00%
Canyon Diablo (Local Drainage)-1502001504	27.02%	0.00%	0.01%	0.00%	37.60%	0.00%	3.32%
Kana-a Wash-Lower Little Colorado River-1502001601	20.75%	0.00%	0.73%	3.85%	28.98%	0.72%	0.00%
Deadman Wash-1502001602	0.00%	0.00%	0.00%	6.55%	89.74%	0.26%	0.00%
Big Wash-The Big Lake Area-1502001603	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tohachi Wash-1502001604	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Citadel Wash-Lower Little Colorado River-1502001605	15.32%	0.00%	0.00%	18.51%	19.39%	0.00%	0.00%
Upper Cedar Wash-1502001606	26.62%	0.00%	0.00%	0.00%	37.22%	0.00%	0.00%
Lower Cedar Wash-1502001607	6.19%	0.00%	0.00%	0.00%	2.10%	0.00%	0.00%
Tonahakaad Wash-Lower Little Colorado River-1502001608	12.47%	0.00%	0.31%	0.00%	0.00%	0.00%	0.00%
Lee Canyon-Lower Little Colorado River-1502001609	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheep Wash-Lower Little Colorado River-1502001610	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Dinnebito Wash-1502001701	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Subwatershed	State Trust	Hubble Post N.H.S	BLM	Wupatki N.M.	Coconino N.F.	Sunset Crater N.M.	Game & Fish
Middle Dinnebito Wash-1502001702	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Dinnebito Wash-1502001703	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Moenkopi Wash Headwaters-1502001801	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shonto Wash-1502001802	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Begashibito Wash-1502001803	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Crooked Ridge/Echo Cliffs Area-1502001804	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Begashibito Wash-1502001805	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pasture Canyon-1502001807	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal Mine Canyon-Moenkopi Wash-1502001808	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hamblin Wash-1502001809	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kerley Valley-Moenkopi Wash-1502001810	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fivemile Wash-Moenkopi Wash-1502001811	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	*10.38%*	*0.00%*	*1.52%*	*0.26%*	*6.39%*	*0.02%*	*0.10%*

Table 7- 3 Percentage Land Ownership by Subwatershed (part 3 of 3).

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
Nutrioso Creek-1502000101	0.00%	0.00%	0.00%	0.00%	0.00%	77.06%	0.00%	0.00%
South Fork Little Colorado River-Little Colorado River Headwaters-1502000102	0.00%	0.00%	0.00%	0.00%	0.00%	77.06%	0.00%	0.90%
Coyote Creek-1502000103	0.00%	0.00%	0.00%	0.00%	0.00%	24.13%	0.00%	0.00%
Carnero Creek-Little Colorado River Headwaters-1502000104	0.00%	0.00%	0.00%	0.00%	0.00%	9.95%	0.00%	0.00%

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
Upper Little Colorado River, Lyman Lake to Big Hollow Wash-1502000201	**0.00%**	**0.00%**	**0.00%**	**0.57%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Big Hollow Wash-1502000202	**0.00%**	**0.00%**	**0.00%**	**0.02%**	**0.00%**	**8.85%**	**0.00%**	**0.00%**
Concho Creek-Upper Little Colorado River-1502000203	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Oso Draw-1502000204	**0.00%**	**0.00%**	**0.00%**	**0.14%**	**0.00%**	**20.74%**	**0.00%**	**0.03%**
Milky Wash-1502000205	**0.00%**	**1.86%**	**3.37%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hay Hollow Draw-Upper Little Colorado River-1502000206	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Washboard Wash-Upper Little Colorado River-1502000207	**0.00%**	**4.83%**	**0.00%**	**0.00%**	**2.57%**	**0.00%**	**0.00%**	**0.00%**
Middle Carrizo Wash-1502000306	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Carrizo Wash-1502000307	**0.00%**	**0.00%**	**0.00%**	**0.11%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Jaralosa Draw-1502000406	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Zuni River-1502000407	**0.00%**	**0.00%**	**26.48%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hardscrabble Wash-1502000408	**0.00%**	**0.00%**	**17.21%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Zuni River-1502000409	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Show Low Creek-1502000501	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**71.41%**	**0.00%**	**0.41%**
Upper Silver Creek-1502000502	**0.00%**	**0.00%**	**0.00%**	**0.09%**	**0.00%**	**46.61%**	**0.00%**	**0.00%**
Cottonwood Creek-1502000503	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**68.44%**	**0.00%**	**0.01%**
Lower Silver Creek-1502000504	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.37%**	**0.00%**	**0.00%**	**0.00%**
Upper Black Creek-1502000603	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Whitewater Arroyo-1502000605	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Black Creek-1502000606	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Manuelito Canyon-Upper Puerco River-1502000607	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
Burntwater Wash-Lower Puerco River-1502000701	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Morgan Canyon-1502000702	**0.00%**	**0.00%**	**2.79%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Dead Wash-1502000703	**0.00%**	**10.98%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Dry Wash-1502000704	**0.00%**	**23.98%**	**10.92%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Ninemile Wash-Lower Puerco River-1502000705	**0.00%**	**3.47%**	**1.32%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lithodendron Wash-Lower Puerco River-1502000706	**0.00%**	**26.58%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Phoenix Park Wash-Dry Lake-1502000801	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**45.21%**	**0.00%**	**0.00%**
Porter Tank Draw-Middle Little Colorado River-1502000802	**0.00%**	**0.00%**	**0.00%**	**0.76%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Clear Creek-1502000803	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**41.38%**	**0.00%**	**0.00%**
Lower Clear Creek-1502000804	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**20.72%**	**0.00%**	**0.00%**
Jacks Canyon-1502000805	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
McDonald Canyon-Middle Little Colorado River-1502000806	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Rincon Basin Area-Middle Little Colorado River-1502000807	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Coyote Wash-Middle Little Colorado River-1502000808	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Cow Canyon-Middle Little Colorado River-1502000809	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Middle Little Colorado River-Canyon Diablo to Grand Falls-1502000810	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Upper Wide Ruin Wash-1502000901	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Lower Wide Ruin Wash-1502000902	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
Leroux Wash-1502000903	0.00%	4.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Chevelon Canyon-1502001001	0.00%	0.00%	0.00%	0.00%	0.00%	98.60%	0.00%	0.00%
Black Canyon-1502001002	0.00%	0.00%	0.00%	0.00%	0.00%	66.29%	0.00%	0.00%
Lower Chevelon Canyon-1502001003	0.00%	0.00%	0.00%	0.00%	0.00%	17.81%	0.00%	0.00%
Upper Pueblo Colorado Wash-1502001101	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Steamboat Wash-1502001102	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Pueblo Colorado Wash-1502001103	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bidahochi Wash-1502001104	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Pueblo Colorado Wash-1502001105	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cottonwood Wash-1502001106	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Oraibi Wash-1502001201	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Oraibi Wash-1502001202	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Oraibi Wash-1502001203	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Polacca Wash-1502001301	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wepo Wash-1502001302	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Polacca Wash-1502001303	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Polacca Wash-1502001304	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ha-whi-yalin Wash-1502001401	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Jadito Wash-1502001402	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coyote Wash-1502001403	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Jadito Wash-1502001404	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rio de Flag-1502001501	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Walnut Creek-1502001502	1.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
San Francisco Wash-1502001503	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Canyon Diablo (Local Drainage)-1502001504	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kana-a Wash-Lower Little Colorado River-1502001601	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Deadman Wash-1502001602	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Big Wash-The Big Lake Area-1502001603	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tohachi Wash-1502001604	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Citadel Wash-Lower Little Colorado River-1502001605	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Cedar Wash-1502001606	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Cedar Wash-1502001607	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tonahakaad Wash-Lower Little Colorado River-1502001608	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lee Canyon-Lower Little Colorado River-1502001609	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheep Wash-Lower Little Colorado River-1502001610	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Dinnebito Wash-1502001701	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middle Dinnebito Wash-1502001702	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Dinnebito Wash-1502001703	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Moenkopi Wash Headwaters-1502001801	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shonto Wash-1502001802	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Begashibito Wash-1502001803	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Crooked Ridge/Echo Cliffs Area-1502001804	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lower Begashibito Wash-1502001805	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Subwatershed	Walnut Canyon N.M.	Petrified Forest N.P.	Navajo Res. Trust	County Land	Bureau Of Reclamation	Apache-Sitgreaves N.F.	Tonto N.F.	White Mountain Apache Indian Res.
Wide Ruin Canyon-Moenkopi Wash-1502001806	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pasture Canyon-1502001807	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal Mine Canyon-Moenkopi Wash-1502001808	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hamblin Wash-1502001809	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Kerley Valley-Moenkopi Wash-1502001810	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fivemile Wash-Moenkopi Wash-1502001811	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.01%	0.68%	0.53%	0.01%	0.04%	7.46%	0.00%	0.01%

Watering Facilities

Alternative watering facilities, such as a tank, trough, or other watertight container at a location removed from the waterbody, can provide animal access to water, protect and enhance vegetative cover, provide erosion control through better management of grazing stock and wildlife, and protect streams, ponds and water supplies from biological contamination. Providing alternative water sources is usually required when creating filter strips.

Alternative cattle watering facilities (http://www.2gosolar.com/typical_installations.htm)

Rock Riprap

Large diameter rock riprap reduces erosion when installed along stream channels and in areas subject to head cutting. Regrading may be necessary before placing the rocks, boulders or coarse stones, and best management practices should be applied to reduce erosion during regrading.

Erosion Control Fabric

Geotextile filter fabrics reduce the potential for soil erosion as well as volunteer (weed) vegetation, and are often installed beneath rock riprap.

Rock riprap for erosion control (CONAFOR).

Toe Rock

Placement of rock and riprap along the toe of soil slopes reduces erosion and increases slope stability.

Water Bars

A water bar is a shallow trench with mounding long the down-slope edge that intercepts and redirects runoff water in areas of soil disturbance. This erosion control method is most frequently used at tailings piles or on dirt roads.

Erosion Control on Dirt Roads

In collaboration with responsible parties, implement runoff and erosion control treatments on dirt roads and other disturbed areas. Dirt roads can contribute significant quantities of runoff and sediment if not properly constructed and managed. Water bars and surfacing are potential treatments. When a road is adjacent to a stream, it may be necessary to use engineered road stabilization treatments.

The stabilization of roads and embankments reduces sediment input from erosion and protects the related infrastructure. Traditional stabilization relied on expensive rock (riprap) treatments. Other options to stabilize banks include the use of erosion control fabric, toe rock and revegetation.

Slope stabilization and erosion control along highway
(Photo: Ivan Parra).

Channel and Riparian Restoration

Restoration or reconstruction of a stream reach is used when the stream reach has approached or crossed a threshold of stability from which natural recovery may take too long or be unachievable. This practice significantly reduces sediment input to a system and will promote the riparian recovery process. Channel and riparian restoration will be discussed in more detail below.

Education

The development of education programs will help address the impact of livestock grazing and promote the implementation of erosion control treatments. In addition, because of the growth potential in several of the subwatersheds, educational programs should address stormwater management from land development, and target citizen groups, developers, and watershed partnerships. These subwatersheds include the Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Concho Creek-Upper Little Colorado River, Oso Draw, Milky Wash, Hay Hollow Draw-Upper Little Colorado River, Washboard Wash-Upper Little Colorado River, Lower Carrizo Wash, Jaralosa Draw, Lower Zuni River, Upper Silver Creek, Lower Silver Creek, Dry Wash, Lithodendron Wash-Lower Puerco River, Phoenix Park Wash-Dry Lake, Porter Tank Draw-Middle Little Colorado River, Lower Clear Creek, McDonald Canyon-Middle Little Colorado River, Rincon Basin Area-Middle Little Colorado River, Coyote Wash-Middle Little Colorado River, Leroux Wash and Lower Chevelon Canyon (35% private lands).

Based on the sediment and erosion classification completed in Section 6, subwatershed areas prioritized for educational outreach to address erosion control include Lower Black Creek, Coyote Wash, Burntwater Wash-Lower Puerco River, Rio de Flag, Rincon Basin Area-Middle Little Colorado River, Walnut Creek, Black Canyon, Lower Silver Creek, Show Low Creek and Upper Silver Creek.

Little Colorado River TMDL for Turbidity

According to the Arizona Department of Environmental Quality (ADEQ, 2002b) "The Little Colorado River (LCR) is located in southern Apache County, AZ near the border with New Mexico. Its headwaters originate in the White Mountains along the northern and eastern slopes of Mount Baldy (11,043 feet). The river flows east-northeast until it reaches Eagar, AZ where it turns to a more northerly course. Two segments, totaling 16 miles, of the LCR, near Springerville, AZ, were listed as impaired due to violations of the turbidity standard for Aquatic and Wildlife coldwater streams, which is 10 NTU. The first segment, Water Canyon Creek to Nutrioso Creek (HUC 15020001-010), is 4 miles long. The second segment, Nutrioso Creek to Carnero Creek (HUC 15020001-009), is 12 miles long." Those segments are included in the Nutrioso Creek and Carnero Creek subwatersheds.

Monitoring developed from 1991 to 1996 led to inclusion of the Little Colorado River in the 303(d) listing of the Clean Water Act and further sampling collected in 2000 was used to pinpoint the source/start of high turbidity values. In 2000, the TMDL for turbidity in Nutrioso Creek was developed (ADEQ, 2000) but was later included in the wider Little Colorado River TMDL in 2002.

Results from this sampling indicate that turbidity impairment is a result of upstream activities. No point sources were identified and several non-point sources were identified as relevant:

a. cattle grazing and wildlife activity;
b. lack of riparian vegetation that cause stream channel instabilities;
c. existing road systems (including non-system roads);
d. natural conditions; and
e. the construction of a golf course.

A TMDL is comprised of the sum of individual waste load allocations within the receiving water body for point sources (which are null for this subwatersheds), load allocations for nonpoint sources, and natural background levels. In the TMDL analysis, a targeted loading capacity is first calculated, which is the maximum pollutant load (sediment in this case) that the system can handle and still meet the surface water quality standards. Then this load is allocated among all sources, including an allocation set aside as a margin of safety to handle natural variation.

Strategies that are included in the implementation of this TMDL include education, monitoring and evaluation, restoration and soil conservation practices and the use of best management practices (BMP). BMPs have been found to be one of the best strategies when dealing with non-point pollution sources.

Trager load capacity was defined by season, in order to respond to natural changes due to precipitation regimes. The TMDL is summarized in the following table, taken from ADEQ (2002b). Activities are focused in reducing sediment contribution during high flow events.

WINTER-SPRING FLOWS (FEB-MAY)		**SUMMER-FALL FLOWS (JUN-SEP)**	
Designed for 28.9 cfs (18.9 mgd)		**Designed for 13.1 cfs (8.5 mgd)**	
Background, lbs./day TSS	**354**	**Background, lbs./day TSS**	**354**
Waste Load Allocation, lbs./day TSS	**0**	**Waste Load Allocation, lbs./day TSS**	**0**
Load Allocation, lbs./day TSS	**1,225**	**Load Allocation, lbs./day TSS**	**262**
Margin of Safety, lbs./day TSS	**123**	**Margin of Safety, lbs./day TSS**	**65**
TMDL, lbs./day TSS	**1,702**	**TMDL, lbs./day TSS**	**681**
Measured Load, lbs./day TSS	**6,959**	**Measured Load, lbs./day TSS**	**2,509**
Load Reduction, lbs./day TSS	**5,257**	**Load Reduction, lbs./day TSS**	**1,828**

<u>Organics</u>

At some locations within the Little Colorado Watershed, water quality problems associated with the introduction of animal waste were observed. The two primary sources of animal waste in the watershed are livestock grazing in riparian areas and failing septic systems. Livestock grazing is common across the entire watershed.

The Rainbow Lake nutrient TMDL, discussed in this section, addresses nitrogen and phosphorus load in pounds attributed to both internal and external nutrient loading.

The recommended actions (see Table 7-4) for management of organics are:

- Filter Strips
- Fencing
- Watering Facilities
- Dredging
- Septic System Repair
- Education

Filter Strips

Filter strips are grass or vegetated areas along a water body used to intercept and slow runoff, to prevent sediment and other pollutants from entering the water body. Creating a filter strip along a waterbody will reduce and may remove pollutants from runoff before the material enters a body of water. Filter strips have been found to be very effective in removing animal waste due to livestock grazing, allowing the organics to bio- attenuate (i.e. be used by the plants) and degrade. Fencing the filter strip is usually required when dealing with livestock.

Filter strip near waterbody
(http://jasperswcd.org/practices.htm)

Fencing

Restricting access to riparian corridors by fencing will allow for the reestablishment of riparian vegetation. Straw bale or silt fencing slows runoff and traps organics from sheet flow or channelized flow in areas of soil disturbance.

Riparian fencing
(http://nycd.scc.wa.gov)

Table 7- 4 Proposed Treatments for Addressing Organics.

Action	Load Reduction Potential	Estimated Time Load Reduction	Expected Maintenance	Expected Cost	Estimated Life
Filter Strips	**High**	**< 2 years**	**Low**	**Low**	**Long**
Fencing	**Low**	**Immediate**	**Low**	**Low**	**Medium**
Watering Facilities	**Medium**	**Immediate**	**Low**	**Low-Medium**	**Medium**
Septic System Repair	**High**	**Medium**	**High**	**High**	**Medium**

Note: The actual cost, load reduction, or life expectancy of any treatment is dependant on site specific conditions. Low costs could range from nominal to $10,000, medium costs could range between $5,000 and $20,000, and high costs could be anything greater than $15,000. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Watering Facilities

Alternative watering facilities, such as a tank, trough, or other watertight container at a location removed from the waterbody, can provide animal access to water and protect streams, ponds and water supplies from biological contamination by grazing cattle. Providing alternative water sources is usually required when creating filter strips.

Dredging

Dredging may be used to improve water quality by removing sediments and plant roots in lake or stream bottoms. These sediments and roots may have absorbed nutrients such as phosphorus, resulting in eutrophication. Removal will break the nutrient cycle, allowing natural processes to resume. Care must be taken that the dredged materials are disposed of properly, and that the action will not harm any sensitive aquatic ecosystems by releasing toxic chemicals (heavy metals or PCBs) or excess sediments into the water column.

Septic System Repair

One of the difficulties in assessing the impact of failing septic systems to streams is the lack of thorough and centralized data on septic systems. Although it can be assumed that residential development in areas not served by sanitary sewers will rely on private, on-site septic systems, the condition of the systems are usually unknown until failure is obvious to the home owner.

Currently, the construction of new septic systems requires a permit from ADEQ in the State of Arizona (some exemptions apply). In addition, ADEQ requires that the septic system be inspected when a property is sold if it was originally approved for use on or after Jan. 1, 2001 by ADEQ or a delegated county agency. This is to help selling and buying property owners understand the physical and operational condition of the septic system serving the home or business. The ADEQ website http://www.azdeq.gov/environ/water/permits/wastewater.html contains more information on permitting septic systems.

Although not required by ADEQ, older septic systems should be inspected when purchasing a home with an existing system.

At a minimum, conduct an inventory of locations where private septic systems occur to clarify the degree of risk a stream reach may exhibit due to failure of these systems. Risk factors can be assessed with GIS mapping tools, such as: proximity to a waterbody, soil type, depth to the water table, and density of development. Septic system sites can then be ranked and prioritized for further evaluation.

Education

Develop educational programs that explain the sources of organics, address the impacts of livestock grazing, and promote the implementation of filter strips, fencing and alternative watering facilities. In addition, the programs should promote residential septic system maintenance, septic tank inspections and certification of septic systems by local municipalities or government entities.

Based on the results of the organics classification and ranking in Section 6, subwatershed areas that are prioritized for educational outreach to address organics include Burntwater Wash-Lower Puerco River, Rio de Flag, Rincon Basin Area-Middle Little Colorado River, Walnut Creek, McDonald Canyon-Middle Little Colorado River, Milky Wash, Jacks Canyon, Washboard Wash-Upper Little Colorado River, Hay Hollow Draw-Upper Little Colorado River, Lower Silver Creek, Phoenix Park Wash-Dry Lake, Oso Draw, Upper Little Colorado River, Lyman Lake to Big Hollow Wash, Cottonwood Creek, Show Low Creek, Upper Silver Creek, Carnero Creek-Little Colorado River Headwaters, Nutrioso Creek and South Fork Little Colorado River-Little Colorado River Headwaters.

Rainbow Lake TMDL for nutrients

Rainbow Lake was included in the 303(d) List of Impaired waters due to exceedances of surface water quality standards for pH and narrative nutrients (excessive aquatic plants and algae). Historically, high external inputs of nutrients (nitrogen and phosphorus) to the lake, as well as in-lake nutrient cycling, have resulted in a highly productive (eutrophic) system (http://www.azdeq.gov/environ/water/assessment/download/rainbow.pdf).

ADEQ has developed a TMDL for phosphorus and nitrogen. The TMDL plan was completed in 2000, and identified historic agricultural runoff, historic septic, and internal nutrient cycling as the sources of the exceedances.

Susan Fitch, ADEQ Lakes Specialist, is developing a proposal to monitor Rainbow Lake to support several ADEQ objectives:
1) Collection of data to support current 305 (b) Assessment (using Matrix for implementation of the Narrative Nutrient Standard in Lakes);
2) BMP effectiveness monitoring for the implementation of buffer strips, harvesting, and dredging;
3) TMDL resolution. Monitoring will commence prior to installation of select BMPs and continue through final BMP implementation.

The proposal includes one year of monitoring for every BMP selected and may be revised to include multiple treatments. Parameters to be analyzed bimonthly include chlorophyll-a, secchi depth, total phosphorus, total nitrogen, total kjeldahl nitrogen, blue-green algae species, percent coverage by aquatic species, percent invasives, diel dissolved oxygen and pH. Deep cores will be analyzed for nutrient deposition and will support bmp effectiveness in addition to supporting plans for dredging. A nutrient budget will be estimated through inflow/outflow, vegetation and sediment measurements. This ADEQ Rainbow Lake monitoring effort will support the "Rainbow Lake Water Quality Enhancement" project proposal's required BMP effectiveness monitoring component.

A TMDL is comprised of the sum of individual waste load allocations within the receiving water body for point sources (which are null for this subwatersheds), load allocations for nonpoint sources, and natural background levels. In the TMDL analysis, a targeted loading capacity is first calculated, which is the maximum pollutant load (sediment in this case) that the system can handle and still meet the surface water quality standards. Then this load is allocated among all sources, including an allocation set aside as a margin of safety to handle natural variation.

<u>Selenium</u>

Selenium occurs naturally in the environment; however, it can enter groundwater or surface water from hazardous waste-sites or irrigated farmland. The recommended action for the management of selenium is to avoid flood irrigation of croplands, and install a mechanized irrigation system.

Mechanized irrigation systems include center pivot, linear move, gated pipe, wheelline or drip irrigation. Based on a 1998 study (Hoffman and Willett, 1998) costs range from a low of $340 per acre for the PVC gated pipe to a high of $1,095 per acre for the linear move. The center pivot cost per acre is $550, and wheelline is $805 per acre.

Education

Develop educational programs that explain the sources of selenium, and illustrate the various alternative irrigation systems.

Agriculture represents a very small portion of the land use in the Little Colorado Watershed. Based on the results of the selenium classification and ranking in Section 6, the subwatershed areas that are prioritized for educational outreach to address selenium are Tonahakaad Wash-Lower Little Colorado River, Citadel Wash-Lower Little Colorado River, Deadman Wash, Burntwater Wash-Lower Puerco River, Rio de Flag, Leroux Wash, San Francisco Wash, Canyon Diablo (Local Drainage), Ninemile Wash-Lower Puerco River, Walnut Creek, McDonald Canyon-Middle Little Colorado River and Upper Little Colorado River, Lyman Lake to Big Hollow Wash.

<u>Strategy for Channel and Riparian Protection and Restoration</u>

Riparian areas are one of the most critical resources in the Little Colorado Watershed. Healthy riparian areas stabilize stream banks, decrease channel erosion and sedimentation, remove pollutants from surface runoff, create wildlife habitat, slow flood velocities, promote aquifer recharge and provide recreational opportunities.

As ground water resources are tapped for water supply, many riparian areas across the watershed are in danger of being dewatered as the water table drops below the base of the stream channel. A large portion of the riparian systems in the watershed are managed by federal agencies, principally the Bureau of Land Management and the Forest Service. In cooperation with responsible management agencies, riparian protection and restoration efforts should be implemented across the watershed.

The creation of filter strips should be considered surrounding all important water bodies and riparian systems within the three natural resource areas, including the extensive riparian forests and perennial streams of the Lower Little Colorado River NRA, Black Creek Colorado River NRA, Clear Creek Chevelon Canyon NRA, Walnut Canyon NRA, McDonald Canyon-Middle Little Colorado River NRA, Cedar Wash NRA, Oraibi Wash NRA, Puerco River Wash NRA and Upper Little Colorado River, Lyman Lake to Big Hollow Wash NRA.

This will require fencing and, in many cases, providing alternative water sources for livestock and wildlife. Riparian areas have been an important source of forage for most livestock growers, but to protect these delicate ecosystems, low impact riparian grazing systems should be developed and applied where feasible.

In impaired stream reaches restoration treatments maybe necessary. Treatments may involve engineered channel re-alignment, grade control and bank stabilization structures and a variety of revegetation and other bio-engineering practices.

Additional information will need to be collected on the existing impairment of stream reaches and riparian areas to better understand which stream segments should be prioritized for restoration projects. Data needs include:

- Studying the existing stream corridor structure, function and disturbances.
- Determining the natural stream conditions before disturbance. This entails identifying a "reference site" that illustrates the potential pristine stream condition.
- Identifying the causes for the impairment and restoration alternatives.
- Identifying stream reaches that have a high potential to successfully respond to restoration treatments.

This watershed classification is one method used to identify stream impairment and restoration alternatives, but other data needs may also include identifying important issues, examining historic conditions, evaluating present conditions and processes, and determining the effects of human activities. It can mean describing the parts and processes of the whole watershed and analyzing their functions in general or relative to some standard (such as a water quality standard or historic condition). It also can mean focusing on particular concerns about human activities, conditions or processes in the watershed.

Stream and riparian restoration projects are costly and should be viewed as a long-term endeavor. Stream and riparian restoration projects cannot be conducted in isolation from other watershed activities. If the root cause of channel and riparian impairment is due to upstream watershed conditions, onsite restoration efforts are likely to fail unless the overall watershed conditions are also improved. This requires an integrated approach that addresses the entire watershed.

Citizen groups also have a role in the restoration efforts. Volunteers can be used in the tree planting and seeding treatments, and can also be used for grade control and bank stabilization construction. Education programs, such as “Adopt A Stream”, should be developed to encourage public understanding of the importance of maintaining natural riparian systems and restoration of degraded streams.

Education Programs

The education effort will be partly conducted by the Arizona Nonpoint Education of Municipal Officials (NEMO) program. Arizona NEMO works through the University of Arizona Cooperative Extension Service, in partnership with the Arizona Department of Environmental Quality (ADEQ) Water Quality Division, and the Water Resources Research Center. The goal of Arizona NEMO is to educate land use decision-makers to take voluntary actions that will mitigate nonpoint source pollution and protect our natural resources.

Education Needs

Education programs need to be developed for land use decision makers and stakeholders that will address the various sources of water quality degradation and present management options. The key sources of concern for educational programs are:

- Abandoned Mines (control of runoff and sediment).
- Grazing Management (erosion control treatments and riparian area protection).
- Streamside Protection (filter strips and alternative watering facilities).
- Riparian Management (bank stabilization, filter strips and livestock fencing).
- Septic Systems (residential septic system maintenance, licensing and inspection programs).
- Stormwater Management (control of stormwater runoff from urbanized and developing areas).
- Water Conservation (for private residents and to prevent dewatering of natural stream flow and riparian areas).

Target Audiences

The targeted audiences will include developers, private land owners and managers, livestock growers, home owners and citizen groups. Several programs, including those addressing mine reclamation, septic systems, stormwater management and water conservation, will be considered. Development of an “Adopt a Stream” Program will also be considered.

References

ADEQ, Arizona Department of Environmental Quality. 2000. Nutrioso Creek TMDL for Turbidity. 19 pp. http://www.azdeq.gov/environ/water/assessment/download/nutrioso.pdf

ADEQ, Arizona Department of Environmental Quality. 2002a. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Little Colorado Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/303-04/lcr.pdf

ADEQ, Arizona Department of Environmental Quality. 2002b. Little Colorado River TMDL for Turbidity. 35 pp. http://www.azdeq.gov/environ/water/assessment/download/lcrtmdl.pdf

ADEQ, Arizona Department of Environmental Quality. 2004. The 2004 water quality assessment of streams and lakes by watershed (The Little Colorado Watershed). http://www.azdeq.gov/environ/water/assessment/download/305-04/ch4elcr.pdf

Baker, L.A., and L. Farnsworth. 1995. Feasibility of management options to improve water quality in Rainbow Lake. Prepared for Arizona Department of Environmental Quality. 53 pp.

Hoffman, T.R. and G.S. Willett. 1998. The Economics Of Alternative Irrigation Systems In The Kittitas Valley Of Washington State. Cooperative Extension, Washington State University, pub. EB1875. http://cru84.cahe.wsu.edu/cgi-bin/pubs/EB1875.html

Data Sources

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/index.html
Land ownership. February 7, 2002.

Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.

Section 8: Local Watershed Planning

The first component of the watershed-based planning process is to summarize all readily available natural resource information and other data for a given watershed. As seen in Sections 2 though 5 of this document, these data are at a broad-based, large watershed scale and include information on water quality, land use and cover, natural resources and wildlife habitat.

It is anticipated that stakeholder-groups will develop their own planning documents. The stakeholder-group watershed-based plans may cover a subwatershed area within the NEMO Watershed-based Plan, or include the entire 8-digit HUC watershed area.

In addition, stakeholder-group local watershed-based plans should incorporate local knowledge and concerns gleaned from stakeholder involvement and could include:

- A description of the stakeholder / partnership process;
- A well-stated, overarching goal aimed at protecting, preserving, and restoring habitat and water quality, and encouragement of land stewardship;
- A plan to coordinate natural resource protection and planning efforts;
- A detailed and prioritized description of natural resource management objectives; and
- A detailed and prioritized discussion of best management practices, strategies and projects to be implemented by the partnership.

EPA's *2003 Guidelines for the Award of Section 319 Nonpoint Source Grants* (EPA, 2003) suggests that a watershed-based plan should include all nine elements listed in Section 1 of this document to be considered for funding. These elements are discussed again in Section 9 and the corresponding sections in the Plan are noted. The nine planning elements help provide reasonable assurance that the nonpoint source of pollution will be managed to improve and protect water quality, and to assure that public funds to address impaired waters are used effectively.

<u>Potential Water Quality Improvement Projects</u>

GIS, hydrologic modeling and fuzzy logic were used to rank and prioritize the 10-digit HUC subwatersheds for known water quality concerns (Section 6, Watershed Classification). These rankings are used to identify where water quality improvement projects should be implemented to reduce nonpoint source pollution in the Little Colorado Watershed. This methodology ranked ninety-two subwatersheds for four key nonpoint source water quality concerns:

1. Metals originating from abandoned mine sites;
2. Stream sedimentation due to land use activities;
3. Organic and nutrient pollution due to land use activities; and

4. Selenium due to agricultural practices.

Table 8-1 lists the ninety-two subwatersheds and their final weighted fuzzy membership value for each of these four constituents. Values highlighted with a shaded box indicate high risk for water quality degradation. The highest ranking value in each category is highlighted with a bold cell outline. The rankings range from a low risk of 0.0 to higher risk values approaching 1.0. See Section 6 for a full discussion on the derivation of these values.

Table 8-1. Summary of Weighted Fuzzy Membership Values for each Subwatershed

Subwatershed	FMV Weighted			
	Metals	**Sediment**	**Organics**	**Selenium**
Nutrioso Creek - 1502000101	**0.338**	**0.685**	**0.566**	**0.00**
South Fork Little Colorado River – Little Colorado River Headwaters - 1502000102	**0.790**	**0.751**	**0.653**	**0.00**
Coyote Creek - 1502000103	**0.475**	**0.495**	**0.350**	**0.15**
Carnero Creek – Little Colorado River Headwaters - 1502000104	**0.880**	**0.611**	**0.523**	**0.00**
Upper Little Colorado River, Lyman Lake to Big Hollow Wash - 1502000201	**0.670**	**0.576**	**0.653**	**0.42**
Big Hollow Wash - 1502000202	**0.415**	**0.435**	**0.350**	**0.25**
Concho Creek – Upper Little Colorado River - 1502000203	**0.585**	**0.444**	**0.364**	**0.25**
Oso Draw - 1502000204	**0.495**	**0.565**	**0.410**	**0.00**
Milky Wash - 1502000205	**0.210**	**0.265**	**0.410**	**0.15**
Hay Hollow Draw – Upper Little Colorado River - 1502000206	**0.548**	**0.394**	**0.424**	**0.15**
Washboard Wash – Upper Little Colorado River - 1502000207	**0.520**	**0.400**	**0.500**	**0.17**
Middle Carrizo Wash - 1502000306	**0.390**	**0.435**	**0.350**	**0.25**
Lower Carrizo Wash - 1502000307	**0.270**	**0.315**	**0.350**	**0.25**
Jaralosa Draw - 1502000406	**0.270**	**0.315**	**0.350**	**0.25**
Middle Zuni River - 1502000407	**0.330**	**0.255**	**0.350**	**0.25**
Hardscrabble Wash - 1502000408	**0.270**	**0.255**	**0.350**	**0.25**
Lower Zuni River - 1502000409	**0.355**	**0.375**	**0.350**	**0.25**
Show Low Creek - 1502000501	**0.580**	**0.778**	**0.698**	**0.17**
Upper Silver Creek - 1502000502	**0.280**	**0.653**	**0.542**	**0.17**
Cottonwood Creek - 1502000503	**0.538**	**0.552**	**0.526**	**0.25**
Lower Silver Creek - 1502000504	**0.440**	**0.585**	**0.710**	**0.15**
Upper Black Creek - 1502000603	**0.390**	**0.265**	**0.150**	**0.25**
Whitewater Arroyo - 1502000605	**0.270**	**0.265**	**0.150**	**0.25**
Lower Black Creek - 1502000606	**0.620**	**0.265**	**0.150**	**0.25**
Manuelito Canyon – Upper Puerco River - 1502000607	**0.428**	**0.349**	**0.185**	**0.25**

Subwatershed	FMV Weighted			
	Metals	Sediment	Organics	Selenium
Burntwater Wash – Lower Puerco River - - 1502000701	0.670	0.337	0.383	0.42
Morgan Canyon - 1502000702	0.308	0.315	0.350	0.25
Dead Wash - 1502000703	0.210	0.255	0.350	0.25
Dry Wash - 1502000704	0.333	0.255	0.350	0.25
Ninemile Wash – Lower Puerco River - 1502000705	0.490	0.255	0.350	0.42
Lithodendron Wash – Lower Puerco River - 1502000706	0.260	0.195	0.350	0.25
Phoenix Park Wash – Dry Lake - 1502000801	0.380	0.480	0.417	0.25
Porter Tank Draw-Middle Little Colorado River - 1502000802	0.308	0.325	0.365	0.25
Upper Clear Creek - 1502000803	0.433	0.410	0.300	0.25
Lower Clear Creek - 1502000804	0.345	0.255	0.350	0.25
Jacks Canyon - 1502000805	0.553	0.484	0.424	0.25
McDonald Canyon – Middle Little Colorado River - 1502000806	0.430	0.345	0.395	0.42
Rincon Basin Area – Middle Little Colorado River - 1502000807	0.453	0.485	0.605	0.25
Coyote Wash – Middle Little Colorado River - 1502000808	0.320	0.315	0.350	0.25
Cow Canyon – Middle Little Colo4rado River - 1502000809	0.308	0.255	0.350	0.25
Middle Little Colorado River – Canyon Diablo to Grant Falls - 1502000810	0.273	0.205	0.150	0.25
Upper Wide Ruin Wash - 1502000901	0.488	0.265	0.150	0.25
Lower Wide Ruin Wash - 1502000902	0.270	0.265	0.150	0.25
Leroux Wash - 1502000903	0.610	0.255	0.350	0.42
Upper Chevelon Canyon - 1502001001	0.550	0.315	0.090	0.15
Black Canyon - 1502001002	0.463	0.425	0.290	0.15
Lower Chevelon Canyon - 1502001003	0.120	0.350	0.200	0.00
Upper Pueblo Colorado Wash - 1502001101	0.450	0.325	0.150	0.25
Steamboat Wash - 1502001102	0.428	0.205	0.150	0.25
Middle Colorado Wash - 1502001103	0.585	0.265	0.150	0.25
Bidahochi Wash - 1502001104	0.838	0.385	0.150	0.25
Lower Pueblo Colorado Wash - 1502001105	0.330	0.265	0.150	0.25
Cottonwood Wash - 1502001106	0.368	0.195	0.360	0.25
Upper Oraibi Wash - 1502001201	0.390	0.385	0.150	0.25
Middle Oraibi Wash - 1502001202	0.330	0.265	0.150	0.25
Lower Oraibi Wash - 1502001203	0.270	0.205	0.150	0.25
Upper Polacca Wash - 1502001301	0.513	0.325	0.150	0.25
Wepo Wash - 1502001302	0.270	0.265	0.150	0.25
Middle Polacca Wash - 1502001303	0.390	0.265	0.150	0.25
Lower Polacca Wash - 1502001304	0.150	0.145	0.150	0.25

Subwatershed	FMV Weighted			
	Metals	Sediment	Organics	Selenium
Ha-whi-yalin Wash - 1502001401	0.390	0.325	0.150	0.25
Upper Jadito Wash - 1502001402	0.270	0.205	0.150	0.25
Coyote Wash - 1502001403	0.330	0.265	0.150	0.25
Lower Jadito Wash - 1502001404	0.390	0.325	0.150	0.25
Rio De Flag - 1502001501	0.700	0.850	0.500	0.33
Walnut Creek - 1502001502	0.610	0.765	0.450	0.42
San Francisco Wash - 1502001503	0.610	0.446	0.307	0.47
Canyon Diablo (Local Drainage) – 1502001504	0.463	0.470	0.200	0.35
Kana-a Wash – Lower Little Colorado River - 1502001601	0.270	0.435	0.350	0.25
Deadman Wash - 1502001602	0.850	0.565	0.150	0.42
Big Wash – The Big Lake Area - 1502001603	0.150	0.205	0.150	0.25
Tohachi Wash - 1502001604	0.150	0.265	0.150	0.25
Citadel Wash – Lower Little Colorado River - 1502001605	0.490	0.375	0.350	0.42
Upper Cedar Wash - 1502001606	0.393	0.555	0.350	0.25
Lower Cedar Wash - 1502001607	0.270	0.272	0.178	0.25
Tonahakaad Wash – Lower Little Colorado River - 1502001608	0.550	0.315	0.350	0.58
Lee Canyon – Lower Little Colorado River - 1502001609	0.428	0.325	0.150	0.25
Sheep Wash – Lower Little Colorado River - 1502001610	0.270	0.325	0.150	0.25
Upper Dinnebito Wash - 1502001701	0.270	0.265	0.150	0.25
Middle Dinnebito Wash - 1502001702	0.210	0.265	0.150	0.25
Lower Dinnebito Wash - 1502001703	0.210	0.205	0.150	0.25
Moenkopi Wash Headwaters - 1502001801	0.440	0.385	0.150	0.25
Shonto Wash - 1502001802	0.405	0.265	0.150	0.25
Upper Begashibito Wash - 1502001803	0.270	0.265	0.150	0.25
Crooked Ridge / Echo Cliffs Area - 1502001804	0.150	0.205	0.150	0.25
Lower Begashibito Wash - 1502001805	0.330	0.265	0.150	0.25
Wide Ruin Canyon – Moenkopi Wash - 1502001806	0.330	0.265	0.150	0.25
Pasture Canyon - 1502001807	0.283	0.205	0.150	0.25
Coal Mine Canyo0n – Moenkopi Wash - 1502001808	0.358	0.265	0.150	0.25
Hamblin Wash - 1502001809	0.285	0.265	0.150	0.25
Kerley Valley – Moenkopi Wash - 1502001810	0.223	0.205	0.150	0.25
Fivemile Wash – Moenkopi Wash - 1502001811	0.453	0.205	0.150	0.25

Based on these fuzzy membership values, the subwatershed that ranked the highest for each of the nonpoint sources was selected for an example water quality improvement project.

The four example subwatershed projects that will be discussed here are:

1. Carnero Creek – Little Colorado River Headwaters Subwatershed, for metals pollution;

2. Rio De Flag Subwatershed, in the Flagstaff area, for sediment pollution derived from land use;

3. Lower Silver Creek Subwatershed, for organics pollution due to failing septic systems and livestock grazing; and

4. Tonahakaad Wash – Lower Little Colorado River - Subwatershed, for selenium due to elevated naturally occurring selenium.

Example projects with best management practices to reduce metals, sediment, organic, nutrient and selenium pollution are discussed below. Management measures and their associated costs must be designed and calculated based on site-specific conditions; however, sample costs are included in Section 7.

Methods for calculating and documenting pollutant reductions for sediment, sediment-borne phosphorus and nitrogen, feedlot runoff, and commercial fertilizer, pesticides and manure utilization can be found on the NEMO web site in the Best Management Practices (BMP) Manual, under Links (www.ArizonaNEMO.org). It is expected that the local stakeholder partnership watershed-based plan will identify projects and locations important to their community, and may differ from the example project locations proposed here.

1. Carnero Creek – Little Colorado River Headwaters Subwatershed Example Project

Pollutant Type and Source:
Metal-laden sediment originating from an abandoned tailings or spoil pile at an assumed abandoned mine site within the riparian area.

The Carnero Creek Subwatershed of the Little Colorado Headwaters ranked as the most critical area in the Little Colorado Watershed impacted by metals related to abandoned mine sites (i.e. highest fuzzy membership value for metals), and a project to control the movement of metal-laden sediment is recommended. The major land owner within this subwatershed is State Trust (70.48%), Private Lands (17.30%), Apache-Sitgreaves National Forest (9.95%), Bureau of Land Management (2.10%) and Arizona Game and Fish (0.17%). Projects implemented on federal or state lands must obtain the permission of the owner and must comply with all local, state and federal permits.

Load Reductions:
Calculate and document sediment delivery and pollutant reductions for sediment-borne metals using Michigan DEQ (1999) methodology (found in the NEMO BMP Manual under "Links"). Although this manual addresses sediment reduction with respect to

nutrients, the methods can be applied when addressing metals. Particulate metals that generate dissolved metals in the water column and dissolved metals have a tendency to behave like nutrients in the water column.

Management Measures:
Various options are available to restore a mine site, ranging from erosion control fabrics and revegetation to the removal and relocation of the tailings material. Section 7 and Table 7-1 present these management measures along with associated load reduction potential, maintenance, and anticipated costs. It should be recognized that only after a site-specific evaluation can the best treatment option be identified and that the installation of engineered erosion control systems and/or the relocation of the tailings will necessitate project design by a licensed engineer.

2. Rio De Flag Subwatershed, in the Flagstaff area, Example Project

Pollutant Type and Source:
Sediment pollution presumed to be due to increased urbanization and associated land use activities.

The Rio De Flag Subwatershed of the Little Colorado River ranked as the most critical subwatershed impacted by land use activities, and for the purposes of outlining an example project, implementation of best management practices related to stormwater management is recommended. In rapidly growing urban areas, such as Flagstaff, new construction and increasing population growth result in increased soil disturbance and stormwater sediment loading.

The land owners within this subwatershed (Table 7-3) include the Coconino National Forest (63.09%), Private Land (29.15%), State Trust (6.19), the Sunset Crater National Monument (1.4%), and Arizona Game and Fish (0.17%). Projects implemented on private, federal or state lands must obtain the permission of the owner and must comply with all local, state and federal permits.

Load Reductions:
The goal of this example is to reduce sediment pollution to the Rio De Flag subwatershed. Because increased sediment load is assumed to be the result of increased urban stormwater concerns, some background information on current stormwater regulations is necessary.

The Environmental Protection Agency (EPA) has estimated that about 30 percent of known pollution to our nation's waters is attributable to stormwater runoff. In 1987, Congress directed EPA to develop a regulatory program to address the stormwater problem. EPA issued regulations in 1990 authorizing the creation of a National Pollution Discharge Elimination System (NPDES) permitting system for stormwater discharges. In Arizona, this program is called AZPDES, which stands for Arizona Pollutant Discharge Elimination System. Because stormwater runoff can transport pollutants to either a municipal storm sewer system or to a water of the United States, permits are required for those discharges.

Stormwater Phase II Regulations established by EPA in 1999 required some smaller municipalities to obtain a permit for their municipal stormwater discharges (Phase I regulations addressed large metropolitan cities, such as Phoenix). Flagstaff is a regulated municipality as designated by ADEQ Phase II Stormwater Regulations (see 20 CFR 122.32(a) (2)). Flagstaff was the only municipality in the Little Colorado River Watershed required to submit their Notice of Intent and Stormwater Management Program to ADEQ by December 2003.

Stormwater discharges generated during construction activities can also cause an array of physical, chemical, and biological water quality impacts. Water quality impairment occurs, in part, because a number of pollutants are preferentially absorbed onto mineral or organic particles found in fine sediment. The interconnected process of erosion (detachment of soil particles) and sediment transport during storm events results in water quality degradation. Stormwater runoff from construction sites can include pollutants other than sediment, which may become mobilized when land surfaces are disturbed. These include phosphorous, nitrogen, pesticides, petroleum derivatives, construction chemical and solid wastes.

ADEQ stormwater regulations address both small and large construction sites. Large construction activity refers to the disturbance of 5 or more acres. It also refers to the disturbance of less than 5 acres of total land area that is a part of a larger common plan of development or sale if the large common plan will ultimately disturb five acres or more (see 40 CFR 122.26(b)(14)(x)).

Small construction activity refers to the disturbance of 1 or more, but less than 5, acres of land. It also refers to the disturbance of less than 1 acre of total land area that is part of a larger common plan of development of sale if the larger common plan will ultimately disturb 1 or more, but less than 5 acres (see 40 CFR 122.26(b0(15)).

To obtain authorization for discharges of stormwater associated with construction activity, the operator must comply with all the requirements of the general permit and submit a Notice of Intent (NOI) and a Stormwater Management Plan (SWMP). More information about Arizona Stormwater Regulations and permitting can be found at http://azdeq.gov/environ.water/permits/stormwater.html.

Management Measures:
Municipal Ordinances addressing stormwater retention / detention, construction site management, housing density, drainage buffers, impermeable surfaces, and grading are the most effective management measures to address sediment pollution due to stormwater runoff. New ordinance proposals can be initiated by citizen groups within the jurisdiction of the municipality, such as the stakeholder-group local watershed partnership.

The City of Flagstaff enacted the Stormwater Utility Fee effective July 1, 2003. This utility fee is necessary for compliance with the federally mandated stormwater and pollution control standards as specified in the

National Pollutant Discharge Elimination System (NPDES) Phase II, and funds the operation of the Stormwater Group. Its scope of responsibility includes review of construction site and development proposals, as they impact public infrastructure, grading plans, management of City construction projects, inspections related to abandonment of private sewer systems and connections to the City wastewater collection system, and overseeing the implementation of stormwater management projects.

Generally, properly implemented and enforced construction site ordinances effectively reduce sediment pollution. In many areas, however, the effectiveness of ordinances in reducing pollutants is limited due to inadequate information or incomplete compliance with local ordinances by construction site operators. Report of obvious construction site violations or local ordinances, for example, failure to manage site waste (messy housekeeping) and tracking of mud onto roadway can be performed by local citizens.

In addition to ordinances as a best management practices to address stormwater sediment, the ADEQ Phase II Stormwater Regulations require an outreach education component of the Stormwater Management Plans. Stakeholder-group local watershed partnerships can play an important role in educating the public about individual property owner responsibilities in protecting stream water quality.

3. Lower Silver Creek Subwatershed Example Project

Pollutant Type and Source:
Organics pollution due to failing septic systems and livestock grazing.

The rural homesteads surrounding and downstream from Show Low generally do not have access to public waste water treatment and for this reason organic pollutants are assumed to originate from failing septic systems. However, livestock grazing and cattle watering in the stream channel may also contribute to the pollution concern.

Land owners within this subwatershed (Table 7-3) include Private lands (73.14%), Navajo Indian Reservation (20.27%), Hopi Indian Reservation (6.22%) and Bureau of Reclamation (0.37%). Projects implemented on private, federal, or tribal lands must obtain the permission of the owner and must comply with all local, state and federal permits.

Load Reductions:
Prior to initiating a project to address bacteria pollution, it may benefit the watershed partnership to determine the source of bacterial contamination. Implementation of DNA fingerprinting technology will identify the actual sources of bacteria and clarify how best to target an implementation plan and project.

The field of bacteria source tracking continues to evolve rapidly and there are numerous methods available, each of which has its limitations and benefits. Despite the rapid and intensive research into existing methods, EPA recommends that bacteria source tracking "should be used by federal and state agencies to address sources of fecal pollution in water… [because it] represents the best tools available to determine pathogen TMDL load allocations and TMDL implementation plan development" (EPA, 2001).

As an example, the results of a study funded from Section 319 Nonpoint Source Grant funds for Oak Creek Canyon within the Verde Watershed to the west of the Little Colorado Watershed found that most of the fecal pollution came from natural animal populations with sporadic and seasonal impacts from human, dog, cattle, house and llama sources (NAU, 2000). The Oak Creek Task Force (a locally led watershed group) suggested implementing locally approved grazing modifications to decrease the inflow of sediment carrying fecal material, as well as public education and increased toilet facilities within the canyon to reduce nonpoint source bacterial pollutants.

In the Lower Silver Creek Subwatershed, pathogens are assumed to most likely originate from a combination of failing septic systems and /or grazing practices because rangeland livestock grazing is observed in the area. Load reductions can be calculated and documented for grazing runoff using Michigan DEQ (1999) methodology (see the NEMO BMP Manual).

Management Measures:
Implementing grazing management practices to improve or maintain riparian health will help reduce organic pollutants. Management may include exclusion of the land from grazing and/or restricting access to riparian corridors by fencing, which will also reduce the introduction of fecal matter to the stream.

Alternative watering facilities at a location removed from the waterbody may be necessary. Tables 7-2 and 7-4 present load reduction potential, required maintenance and anticipated costs associated with each project option. It should be recognized that only after a site-specific evaluation can the best treatment option be identified.

Failing septic systems can also result in partially treated or untreated surface wastewater containing fecal coliform bacteria and nutrients, causing nonpoint source pollution in drainage ways, streams, and lakes. The only practical long-term best management practice would be to either upgrade individual septic systems by redesigning and replacing part or all of them, or requiring hook-up to a public wastewater treatment facility. This work must be done by a registered contractor or a business licensed to design and install individual sewage treatment systems, but the greatest constraint to this practice is the significant cost to the homeowner. The Arizona Water Infrastructure Finance Authority (WIFA) could be a source of low interest financing to rural communities seeking to upgrade their waste water disposal systems to protect water supply, however requiring hook-up still results in costs to the homeowner.

Some locations experiencing rapid development across the state are putting into place ordinances requiring new development to install waste water treatment facilities, but this does little to address existing systems.

Constructed wetland systems have been successfully applied in more humid regions of the country, and may be applicable to the Dodson Wash area where shallow ground water can be found in locations near the river. Shallow ground water would be necessary to sustain a constructed wetland treatment system.

The constructed wetland system would consist of two shallow basins about 1 foot in depth and containing gravel, which supports emergent vegetation. The first of the two cells is lined to prevent seepage, while the second is unlined and acts as a disposal field. The water level is maintained below the gravel surface, thus preventing odors, public exposure, and vector problems. In an alternative design, a standard septic drain-tile field drain system could be used in place of the second cell.

4. Tonahakaad Wash – Lower Little Colorado River Subwatershed Example Project

Pollutant Type and Source:
Selenium, naturally occurring.

The Tonahakaad Wash - Lower Little Colorado River Subwatershed area ranked as the most critical subwatershed impacted by selenium, however agricultural land use is limited throughout the watershed. Because selenium is naturally occurring, no best management practice is recommended to address selenium in this watershed. It should be understood, however, that flood irrigation will exacerbate selenium loading in the stream and for this reason it should be avoided.

The land owners within the Tonahakaad Wash subwatershed (Table 7-3) are primarily Navajo Tribal Lands (73.69%), Private land (13.45%), State Trust Lands (12.47%) and the Bureau of Land Management (0.31%).

Load Reductions:
Naturally occurring selenium is concentrated in water by evaporation, and also when irrigation water leaches selenium from the soil. To calculate the load reduction resulting from implementation of a best management practice, an estimate of the reduction in volume of irrigation tail water that returns to the stream is required.

Support for calculating load reductions can be obtained from the local Agricultural Research Service or County Cooperative Extension office (http://cals.arizona.edu/extension/).

Management Measures:
Implementing agricultural irrigation practices to reduce tail water pollution will necessitate dramatic changes from the typical practice of flood irrigation. This may involve the installation of mechanized irrigation systems or on-site treatment.

As an example of a situation where drainage water must be managed, some watersheds in California have agricultural drainage water containing levels of selenium that approach the numeric criterion defining hazardous waste (above 1,000 parts per billion). This situation is being considered for permit regulation to manage drainage at the farm level (San Joaquin Valley Drainage Implementation Program, 1999).

Currently, Arizona is not considering such extreme measures, but selenium remains an important nonpoint source contaminant and a known risk to wildlife. The use of treatment technologies to reduce selenium concentrations include ion exchange, reverse osmosis, solar ponds, chemical reduction with iron, microalgal-bacterial treatment, biological precipitation, and constructed wetlands. Engineered water treatment systems, however, may be beyond the scope of a proposed best management practices project, and technologies are still in the research stage.

Section 7 briefly discusses load reduction potential, maintenance, and anticipated costs associated with the installation of mechanized irrigation systems. These types of systems allow for improved water conservation and improved management of limited water resources. It should be recognized that only after a site-specific evaluation can the best treatment option be identified and that the installation of mechanized irrigation systems involve capital expense and may necessitate project design by a licensed engineer.

Technical and Financial Assistance

Stakeholder-group local watershed-based plans should identify specific projects important to their partnership, and during the planning process should estimate the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement the plan. Technical support sources include NEMO, University of Arizona Cooperative Extension, government agencies, engineering contractors, volunteers, and other environmental professionals. Funding sources may include:

- Clean Water Act Section 319(h) funds;
- State revolving funds though the Arizona Department of Environmental Quality;
- Central Hazardous Materials Fund;
- USDA Environmental Quality Incentives Program and Conservation Security Program;
- Arizona Water Protection Fund through the Arizona Department of Water Resources;
- Water Infrastructure Finance Authority;
- Arizona Heritage Fund though Arizona State Parks and Arizona Game and Fish; and
- Private donations or non-profit organization donations.

In addition to the extensive listing of funding and grant sources on the NEMO web site (www.ArizonaNEMO.org), searchable grant funding databases can be found at the EPA grant opportunity web site www.grants.gov or www.epa.gov/owow/funding.html.

In Arizona, Clean Water Act Section 319(h) funds are managed by ADEQ and the funding cycle and grant application data can be found at: http://www.azdeq.gov/environ/water/watershed/fin.html

The Arizona legislature allocates funding to the Arizona Water Protection Fund. In addition, the fund is supplemented by income generated by water-banking agreements with the Central Arizona Project. Information can be found at http://www.awpf.state.az.us/

Most grants require matching funds in dollars or in-kind services. In-kind services may include volunteer labor, access to equipment and facilities, and a reduction on fee schedules / rates for subcontracted tasks. Grant matching and cost share strategies allow for creative management of limited financial resources to fund a project.

Education and Outreach

An information/education component is an important aspect of the Stakeholder-group local watershed-based plan that will be used to enhance public understanding of the project and encourage early and continued participation in selecting, designing and implementing management measures.

Both the Pinetop / Lakeside and the Little Colorado Watershed Partnerships have become established stakeholder groups that meet on a regular basis to plan water quality improvement projects and strategize funding opportunities. Education outreach is a regular part of each of their monthly meetings with their agenda usually including reports on the status of grant-funded projects. Other Watershed based groups in the area include the Little Colorado River Watershed Coordinating Council, Show Low Creek Watershed Enhancement Partnership, and the Upper Little Colorado River Watershed Partnership. Information as to how to contact these partnerships will be posted on the NEMO web page when available.

The NEMO program offers each watershed partnership the opportunity to post information, fact sheets and status reports on the NEMO web site, and to announce important events on the NEMO calendar (www.ArizonaNEMO.org). In addition, a partnership can obtain guidance and technical support in designing an outreach program through the University of Arizona Cooperative Extension.

Implementation Schedules & Milestones

Necessary to the watershed planning process is a schedule for project selection, design, funding, implementation, reporting, operation and maintenance, and project closure. In the Little Colorado Watershed, 10-digit HUC subwatershed areas have been prioritized in this plan for potential water quality improvement projects, but other locations across the watershed may hold greater interest by the stakeholders for project implementation. Private land owners, or partnerships of stakeholders, may propose specific projects to respond to immediate water quality concerns, such as stream bank erosion exacerbated by a recent flooding event.

After project selection, implementation may be dependent on the availability of funds, and because of this most watershed partnerships find themselves planning around grant cycles. Table 8-2 depicts the planning process, and suggests that the stakeholder group may want to revisit the listing and ranking of proposed projects on a regular basis, giving the group the opportunity to address changing conditions.

As shown in the table, a 'short' one-year project actually may take as many as three years from conception, to implementation, and ultimate project closure. With the number of grants currently available in Arizona for water quality improvement projects, the watershed partnership may find themselves in a continual cycle of grant writing and project reporting, overlapping and managing several aspects of several projects simultaneously.

Most funding agencies operate on a reimbursement basis and will require reporting of project progress and reimbursement on a percent completion basis. In addition, the individual project schedule should be tied to important measurable milestones which should include both project implementation milestones and pollutant load reduction milestones. Implementation milestones may include interim tasks, such as shown in Table 8-3, and can be tied to grant funding-source reporting requirements.

Based on funding availability, the activities outlined in Table 8-3 could be broken down into three separate projects based on location (Stream Channel, Stream Bank or Flood Plain), or organized into activity-based projects (Wildcat Dump Cleanup, Engineered Culverts, etc).

Table 8-2: Example Watershed Project Planning Schedule.

	Year				
Watershed Project Planning Steps	**1**	**2**	**3**	**4**	**5**
Stakeholder-Group 319 Plan Development	X				
Identify and rank priority projects	X				
Grant Cycle Year 1: Select Project(s)	X				
Project(s) Design, Mobilization, and Implementation	X	X			
Project(s) Reporting and Outreach		X			
Project(s) Operation and Maintenance, Closure		X	X		
Grant Cycle Year 2: Select Project(s)		X			
Project(s) Design, Mobilization, and Implementation		X	X		
Project(s) Reporting and Outreach			X		
Project(s) Operation and Maintenance, Closure			X	X	
Revisit Plan, Identify and re-rank priority projects			X		
Grant Cycle Year 3: Select Project(s)			X		
Project(s) Design, Mobilization, and Implementation			X	X	
Project(s) Reporting and Outreach				X	
Project(s) Operation and Maintenance, Closure				X	X

Table 8-3: Example Project Schedule

Management Measures and Implementation Schedule Streambank Stabilization and Estimated Load Reduction					
			Water Quality Milestone Target Load Reduction: 100% Hazardous Materials / 75% Sediment Load		
Milestone	**Date**	**Implementation Milestone**	**Area 1 Stream Channel**	**Area 2 Stream Bank**	**Area 3 Flood Plain**
Task 1: **Contract Administration**	**04/01/05 Thru 09/31/06**	**Contract signed Quarterly reports Final report**			
Task 2: **Wildcat Dump Clean-up**	**04/01/05 Thru 07/05/05**	**Select & Advertise Clean-up date Schedule Containers and removal**	**Remove hazardous materials from stream channel 100% hazardous material removal**	**Remove tires and vehicle bodies from streambank 100% hazardous material removal**	
Task 3: **Engineering Design**	**04/01/05 Thru 08/15/05**	**Conceptual design, select final design based on 75% load reduction**		**Gabions, culverts, calculate estimated load reduction**	**Re-contour, regrade, berms, water bars, gully plugs: calculate estimated load reduction.**
Task 4: **Permits**	**04/01/05 Thru 09/01/05**	**Confirm permit requirements and apply for necessary permits**	**US Army Corps of Engineers may require permits to conduct projects within the stream channel**	**Local government ordinances as well as the US Army Corps and State Historical Preservation permits may be needed.**	**In addition to local and State permits, the presence of listed or Endangered Species will require special permitting and reporting.**
Task 5: **Monitoring**	**07/05/05 thru 10/31/06**	**Establish photo points and water quality sample locations**	**Turbidity sampling, baseline and quarterly, compare to anticipated 75% Sediment load reduction**	**Photo points, baseline and quarterly, Calculate Sediment load reduction**	**Photo points, baseline and quarterly, Calculate Sediment load reduction**
Task 6: **Revegetation**	**08/15/05 thru 09/15/05**	**Survey and select appropriate vegetation**			**Willows, native grasses, cotton wood, mulch**
Task 7: **Mobilization**	**09/01/05 thru 10/31/05**	**Purchase, delivery and installation of engineered structures and revegetation material**		**Install gabions, resized culverts / professional and volunteer labor**	**Regrade, plant vegetation with protective wire screens around trees / install gully plugs and water bars, volunteer labor**

Milestone	Date	Implementation Milestone	Water Quality Milestone Target Load Reduction: 100% Hazardous Materials / 75% Sediment Load Area 1 Stream Channel	Area 2 Stream Bank	Area 3 Flood Plain
Task 8: Outreach	04/01/05 thru 10/31/06	Publication of news articles, posters, monthly reports during stakeholder-group local watershed meetings			
Task 9: Operation and Maintenance	09/01/05 thru 10/31/06	Documentation of routine operation and maintenance in project quarterly reports during contract period, continued internal record keeping after contract / project closure		Maintenance and routine repair of engineered structures	Maintenance / irrigation of new plantings until established, removal of weeds and invasive species

<u>Evaluation</u>

The evaluation section of a watershed plan will provide a set of criteria that can be used to determine whether progress towards individual project goals is being achieved and/or the effectiveness of implementation is meeting expectations. These criteria will help define the course of action as milestones and monitoring activities are being reviewed.

The estimate of the load reductions expected for each of the management measures or best management practices to be implemented is an excellent criterion against which progress can be measured. Prior to project implementation, baselines should be established to track water quality improvements, and standard measurement protocols should be established so as to assure measurement methodology does not change during the life of the project.

To evaluate the example project outlined in Table 8-3, the following key evaluation attributes must be met:

- Schedule and timeliness: Grant applications, invoices and quarterly reports must be submitted to the funding source when due or risk cancellation of contracts. If permits are not obtained prior to project mobilization, the project crew may be subject to penalties or fines.
- Compliance with standards: Engineered designs must meet the standards of the Engineering Board of Licensing; water quality analytical work must be in compliance with State of Arizona Laboratory Certification.

Excellent evaluation criteria would include engineer-stamped 'as-built' construction diagrams and documentation of laboratory certification, for example. Methods for estimating load reduction must be consistent with established methodology, and the means by which load reductions are calculated throughout the life of the plan must be maintained.

- Consistency of measurement: The plan should identify what is being measured, the units of measurement, and the standard protocol for obtaining measurements. For example, turbidity can be measured in 'Nephlometric Units' or more qualitatively with a Siche disk. Water volume can be measured as acre/feet, gallons, or cubic feet. Failure to train project staff to perform field activities consistently and to use comparable units of measure can result in project failure.

- Documentation and reporting: Field note books, spread sheets, and data reporting methodology must remain consistent throughout the project. Photo point locations must be permanently marked so as to assure changes identified over the life of the project are comparable. If the frequency of data collection changes or the methodology of reporting changes in the midst of the project, the project and overall plan looses credibility.

The project is a near success if the reports are on time, the engineered structures do not fail, data are reported accurately, and an independent person reviewing your project a year after project closure understands what was accomplished. The project is a full success if water quality improvement and load reductions have been made.

The criteria for determining whether the overall watershed plan needs to be revised are an appropriate function of the evaluation section as well. For example, successful implementation of a culvert redesign may reduce the urgency of a stream bank stabilization project downstream from the culvert, allowing for reprioritization of projects.

It is necessary to evaluate the progress of the overall watershed plan to determine effectiveness, project suitability, or the need to revise goals, BMPs or management measures. The criteria used to determine whether there has been success, failure or progress will also determine if objectives, strategies or plan activities need to be revised, as well as the watershed-based plan itself.

<u>Monitoring</u>

Monitoring of watershed management activities is intrinsically linked to the evaluation performed within the watershed because both track effectiveness. While monitoring evaluates the effectiveness of implementation measures over time, the criteria used to judge success/failure/progress is part of the evaluation process.

Watershed monitoring will include the water quality data reported in Arizona's Integrated 305(b) Water Quality

Assessment and 303(d) Listing Report, Little Colorado Watershed Assessment (ADEQ, 2005), but the overall stakeholder group watershed plan will identify additional data collection activities that are tied to stakeholder concerns and goals.

For the Little Colorado Watershed, Carnero Creek – Little Colorado River Headwaters Subwatershed, Rio De Flag Subwatershed, Lower Silver Creek Subwatershed, and Tonahakaad Wash – Lower Little Colorado River subwatersheds are identified as vulnerable to water quality impairment due to metals, organics and nutrients, and selenium. Monitoring of stream reaches for these constituents require standard water sample collection methodology and sample analysis by a certified laboratory. If routine monitoring of these reaches is to be conducted, sample collection and analysis must be consistent with data collection by the ADEQ to support the 305(b) Assessment Report.

Following the example of the project outlined in Table 8-3, other water quality and watershed health constituents to be monitored include:

- Turbidity. Measuring stream turbidity before, during and after project implementation will allow for quantification of load reduction.

- Stream flow and volume, presence or absence of flow in a wash following precipitation. Monitoring of these attributes is important especially after stream channel hydromodification.

- Presence / absence of waste material. This can be monitored with photo-points.

- Riparian health, based on diversity of vegetation and wildlife. Monitoring can include photo-points, wildlife surveys and plant mapping.

The monitoring section will determine if the partnership's watershed strategies/management plan is successful, and/or the need to revise implementation strategies, milestones or schedule. It is necessary to evaluate the progress of the plan to determine effectiveness, unsuitability, or need to revise goals or BMPs.

Water quality monitoring for chemical constituents that may expose the sampler to hazardous conditions will require appropriate health and safety training and the development of a Quality Assurance Project Plan (QAPP). Monitoring for metals derived from abandoned mine sites, pollutants due to organics, nutrients derived from land use, and selenium will require specialized sample collection and preservation techniques, in addition to laboratory analysis. Monitoring for sediment load reduction may be implemented in the field without extensive protocol development.

Resources to design a project monitoring program can be found at the EPA water quality and assessment web site: www.epa.gov/owow/monitoring/ as well as through the Master Watershed Steward Program available through the local county office of University of Arizona Cooperative Extension. In addition, ADEQ will provide assistance in reviewing a QAPP and monitoring program.

Conclusions

This watershed-based plan ranked or classified four, non-urban 10-digit HUC subwatersheds within the Little Colorado Watershed for vulnerability to water quality degradation from nonpoint source pollutants (Section 6 and Table 8-1). This ranking was based on Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, for the Little Colorado-San Juan Watershed (ADEQ, 2005).

In addition to the subwatershed classifications, this plan contains information on the natural resources and socio-economic characteristics of the watershed (Sections 2 through 5). Based on the results of the Classification in Section 6, example best management practices and water quality improvement projects to reduce nonpoint source pollutants are also provided (Section 7).

The subwatershed rankings were determined for the four major constituent groups (metals, sediment, organics and selenium) using fuzzy logic (see Section 6 for more information on this methodology and the classification procedure). The final results are summarized in this section and are shown in Table 8-1. In addition, technical and financial assistance to implement the stakeholder-group local watershed-based plans are outlined in this section.

Of the ninety-two subwatersheds included in this assessment, the four watersheds with the highest risk of water quality degradation are:

1. Carnero Creek – Little Colorado River Headwaters Subwatershed, for metals pollution;

2. Rio De Flag Subwatershed, in the Flagstaff area, for sediment pollution derived from land use;

3. Lower Silver Creek Subwatershed, for organics pollution due to failing septic systems and livestock grazing; and

4. Tonahakaad Wash – Lower Little Colorado River - Subwatershed, for selenium due to elevated naturally occurring selenium.

This NEMO Watershed-Based Plan is consistent with EPA guidelines for CWA Section 319 Nonpoint Source Grant funding. The nine planning elements required to be eligible for 319 grant funding are discussed, including education and outreach, project scheduling and implementation, project evaluation, and monitoring.

Some basic elements are common to almost all forms of planning: data gathering, data analysis, project identification, implementation and monitoring. It is expected that local stakeholder groups and communities will identify specific projects important to their partnership, and will rely on the NEMO Plan in developing their own plans.

References:

ADEQ, Arizona Department of Environmental Quality. 2005. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Little Colorado-San Juan Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/303-04/lcr.pdf

EPA (U.S. Environmental Protection Agency). January 2001. Protocol for Developing Pathogen TMDLs, First Edition. United States Environmental Protection Agency, Office of Water, Washington DC. EPA 841-R-00-002.

EPA (U.S. Environmental Protection Agency). 2003. Clean Water Act Section 319, Nonpoint Source Program and Grants Guidelines for States and Territories. http://www.epa.gov/owow/nps/Section319/319guide03.html

Michigan Department of Environmental Quality (Michigan DEQ). 1999. Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual. Surface Water Quality Division, Nonpoint Source Unit. http://www.deq.state.mi.us/documents/deq-swq-nps-POLCNTRL.pdf

Northern Arizona University (NAU). November 8, 2000. The Oak Creek Canyon *Escherichia coli* Genotyping Project. Submitted to Arizona Department of Environmental Quality, Nonpoint Source Unit, Phoenix, Arizona.

San Joaquin Valley Drainage Implementation Program. February 1999. Drainage Water Treatment Final Report. Drainage Water Treatment Technical Committee. Sacramento, California. http://wwwdpla.water.ca.gov/agriculture/drainage

Section 9: Summary of EPA's 9 Key Elements for Section 319 Funding

Introduction

All projects that apply for Section 319 funding under the Clean Water Act and administered through the Arizona Department of Environmental Quality must include nine key elements in their watershed-based plans. These elements are listed in Section 1 of this Watershed-Based Management Plan and are also discussed in the Nonpoint Source Guidance Document by the US EPA (http://www.epa.gov/owow/nps/319/index.html).

The nine key elements are described below and the corresponding sections of this NEMO Watershed-Based Management Plan are noted. Information and data to support this requirement can be found in these sections of this Plan.

Element 1: Causes and Sources.
NEMO Sections 6 and 7

The watershed-based plan must identify the sources that will need to be controlled to achieve load reductions established in the nonpoint source TMDL.

In addition, pollutants of concern must be identified, and the causes and sources (primary and secondary) of waterbody impairment (physical, chemical, and biological, both point and non-point sources) must be linked to each pollutant of concern.

Section 6 of the NEMO Watershed-based management plan prioritizes the subwatersheds for risk of impairment due to metals, sediment, organics and selenium nonpoint source pollution. In addition, the potential causes for each constituent are described so that the watershed group can begin identifying the source of the risk.

Section 7 of the NEMO plan discusses existing TMDLs in the watershed that identify known sources of waterbody impairment.

Element 2: Expected Load Reductions.
Not included in NEMO Plan

The plan must contain an overview of TMDL load reductions expected for each Best Management Practice, linked to an identifiable source (only required for sediment (tons/yr), nitrogen or phosphorus (lbs/yr)).

Element 3: Management Measures.
NEMO Sections 7 and 8

The plan must contain a description of the nonpoint source Best Management Practices or management measures and associated costs needed to achieve load reductions for the critical areas identified in which the measures will need to be implemented to achieve the nonpoint source TMDL.

Section 7 of the NEMO plan describes a variety of nonpoint source BMPs that may be applied for load reduction and management of metals, sediment, organics and selenium pollution.

Section 8 includes an example water quality improvement project for each of the four constituents (metals, sediment, organics and selenium) with specific example management measures.

Element 4: Technical and Financial Assistance.
NEMO Sections 7 and 8, and NEMO website www.ArizonaNEMO.org

The plan must include an estimate of the technical and financial assistance needed, including associated costs, and funding strategy (funding sources), and authorities the state anticipates having to rely on to implement the plan.

Section 7 includes several tables that include various management measures and their relative costs, life expectancy and load reduction potential.

Section 8 includes a list of possible funding sources and links for water quality improvement projects. In addition, the NEMO website (www.ArizonaNEMO.org) has an extensive list of links to a wide variety of funding sources.

Element 5: Information / Education Component.
NEMO Section 8

This is the information/education component intended to enhance public understanding and participation in selecting, designing, and implementing the nonpoint source management measures, including the outreach strategy with long and short term goals, and funding strategy.

Section 8 lists local resources that may be valuable in education and outreach to the local community or other targeted audiences. In addition, examples of local educational outreach projects are presented.

Element 6: Schedule.
NEMO Section 8

The plan must include a schedule for implementing, operating and maintaining the nonpoint source Best Management Practices identified in the plan.

Section 8 describes the importance of schedules in a water quality improvement project and presents an example schedule.

Element 7: Measurable Milestones.
NEMO Section 8

The plan must include a schedule of interim, measurable milestones for determining whether nonpoint source Best Management Practices or other control actions are being implemented and water quality improvements are occurring.

Section 8 describes some measurable milestones and presents an example schedule that includes milestones.

Element 8: Evaluation of Progress.
NEMO Section 8

The plan must contain a set of criteria used to determine whether load reductions are being achieved and substantial progress is being made towards attaining water quality standards, including criteria for determining whether the plan needs to be revised or if the Total Maximum Daily Load (TMDL) needs to be revised.

Section 8 describes how to evaluate the progress and success of a water quality improvement project and describes the key attributes that must be met for a successful project.

Element 9: Effectiveness Monitoring. Section 8

The plan must include a monitoring plan to evaluate the effectiveness of implementation efforts over time, measured against the set of criteria established in the Evaluation of Progress element (8).

Section 8 discusses the importance of project monitoring, and presents several example water quality and health constituents that should be monitored.

Conclusions

The NEMO Watershed based plans are structured to be a watershed wide, broad evaluation of the nine key elements. The community watershed groups, as they apply for 319 Grant Funds to implement projects, will need to readdress each of these 9 key elements for their specific watershed project.

Table 1: Subwatershed Classification for Risk of Impairment, Little Colorado Watershed.

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) includes water quality data and assessments of water quality in several surface waterbodies across the Little Colorado watershed. This table summarizes the surface waterbody data used to assess the risk of impairment for each 10-digit HUC subwatershed; some HUCs may have more than one surface waterbody assessed within the watershed, some have none. The table includes the ADEQ water quality data (sampling and assessment status) and the NEMO risk classification assigned to individual surface waterbodies within each subwatershed. It also includes the NEMO risk classification for each subwatershed, which is determined by the highest risk level of the surface waterbodies within that subwatershed.

The four levels of NEMO risk classification are defined in Section 6: extreme; high; moderate; and, low. This table is organized to determine the relative risk of nonpoint source water quality degradation due to metals, sediment, organics and selenium for each 10-digit HUC subwatershed based on existing ADEQ water quality data. See the footnotes at the end of the table for more information and definitions of abbreviations, and Section 6 for the NEMO ranking values assigned to each risk classification.

Subwatershed		
Nutrioso Creek Subwatershed **HUC 1502000101** **Combined Classification for Risk of Impairment:** • **Metals:** Low • **Sediment:** Extreme due to exceedances at Nutrioso Creek; • **Organics:** High due to insufficient data at McKay Reservoir • **Selenium:** Low		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status**[i],[ii],[iii]	
Nutrioso Creek from headwaters to Picnic Creek ADEQ ID: 15020001-017 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td4); barium (td4); beryllium (td4); thorium (td4); antimony (td4); mercury (td4); cadmium (td4); chromium (td4); copper (td4); lead (td4); nickel (td4); silver (td4); zinc (td4); magnesium (4t); fluoride(4); boron (4); • **Sediment:** Total dissolved solids (4) and turbidity (4) • **Organics:** *E. coli* (4); • **Selenium:** selenium (4);
	Status	Parameters exceeding standards: Turbidity (1/1). Currently assessed as "Impaired". Surface Waterbody risk classification: • **Metals:** Low • **Sediment:** Moderate due to insufficient data • **Organics:** Extreme due to exceedance • **Selenium:** Low

Nutrioso Creek from Picnic Creek to Little Colorado River ADEQ ID: 15020001-015	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: Turbidity (1/1). Currently assessed as "Impaired" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** High risk due to exceedances • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Colter Creek headwaters to Nutrioso Creek ADEQ ID: 15020001-293 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td4); barium (td4); beryllium (td4); thorium (td4); antimony (td4); selenium (td4); mercury (td4); cadmium (td4); chromium (td4); copper (td4); lead (td4); nickel (td4); silver (td4); zinc (td4); magnesium (t4); fluoride; boron • **Sediment:** turbidity (4), total dissolved solids • **Organics:** dissolved oxygen; pH, nitrogen; phosphorus; ammonia (4); *E. coli* (4) • **Selenium:** Selenium (4)
	Status	Parameters exceeding standards: None. Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Low risk
McKay Reservoir ADEQ ID: 15020001-1007	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: Low dissolved oxygen; high pH (2-4). Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Nelson Reservoir ADEQ ID: 15020001-1000 One sampling site at this surface waterbody.	Sampling	• **Metals:** none • **Sediment:** none • **Organics:** (1) dissolved oxygen; pH, nitrogen; phosphorus; NH3 • **Selenium:** none
	Status	Parameters exceeding standards: None. Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

South Fork LCR Subwatershed
HUC 1502000102

Combined Classification for Risk Impairment:

- **Metals:** Moderate due to due to exceedances at **Little Colorado River**
- **Sediment:** Extreme due to exceedances at **Little Colorado River**
- **Organics:** High due to exceedances in **Bunch Reservoir**
- **Selenium:** Low risk

Surface Waterbody	Water Quality Data: Sampling and Assessment Status [i, ii, iii]	
Lee Valley Creek, from Lee Valley Res to East Fork of Little Colorado River ADEQ ID: 15020001-232B One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td1) (1); barium(td1); beryllium(td1); thorium(td1); antimony(td1); selenium(td1); mercury(td1); cadmium(td1); chromium(td1); copper; lead(td1); nickel(td1); silver(td1); zinc(td1); magnesium(t1) • **Sediment:** Turbidity (1) and total dissolved solids(1) and total dissolved solids(1) • **Organics:** Nitrogen(t1); phosphorus(t1); ammonia(t1); dissolved oxygen(t1); pH(t1); E. coli(1); fluoride(1); boron(1) • **Selenium:** Selenium(1)
	Status	Parameters exceeding standards: None. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Little Colorado River from West Fork Little Colorado River to Water Canyon Creek ADEQ ID: 15020001-011 Five sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic(td4); barium(td4); beryllium(td4); thorium(TD4); antimony(TD4); selenium(TD4); mercury(TD4); cadmium; chromium(td4); copper(td4); lead(TD4); nickel(td4); silver(td4); zinc(td4); magnesium(t); fluoride(t4); boron(t4); • **Sediment:** turbidity (50) and total dissolved solids(t4) • **Organics:** dissolved oxygen (t50); pH(t50); nitrogen(t4); phosphorus(t4); ammonia(t4); *E. coli*(T4); • **Selenium:** selenium(t4)
	Status	Parameters exceeding standards: Turbidity (18/50), dissolved oxygen (1/50) Currently assessed as “Impaired” Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** High risk due to exceedances • **Organics:** Moderate due to exceedances (1/15) • **Selenium:** Low risk

Little Colorado River from Water Canyon Creek to Nutrioso Creek ADEQ ID: 15020001-010	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: Turbidity. Currently assessed as “Impaired” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Hall Creek headwaters to Little Colorado River ADEQ ID: 15020001-012 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic(td1); barium(td1); beryllium(td1); thorium(td1); antimony(td1); selenium(td1); mercury(td1); cadmium(td1); chromium(td1); copper(td1); lead(td1); nickel(td1); silver(td1); zinc(td1); magnesium(t); fluoride(1); boron(1) • **Sediment:** turbidity(1) and total dissolved solids(1) • **Organics:** nitrogen(1); phosphorus(1); ammonia(1); dissolved oxygen(1); pH(1) and *E. coli*(1); • **Selenium:** Selenium(1);
	Status	Parameters exceeding standards: Dissolved Oxygen[1]. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
East Fork Little Colorado River headwaters to Halls Creek ADEQ ID: 15020001-230 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), fluoride (t4), boron (t4) and magnesium (t4) • **Sediment:** Turbidity and total dissolved solids • **Organics:** Dissolved oxygen (t4), pH, nitrogen (t4), phosphorus (t4), ammonia (t4), *E. coli* (t4) • **Selenium:** Selenium (t4)
	Status	Parameters exceeding standards: None. Currently assessed as “Attaining some uses” Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** Low risk • **Selenium:** Low risk

[1] Due to natural causes

Fish Creek headwaters to Little Colorado River ADEQ ID: 15020001-211 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1) and magnesium (t1), fluoride (1) and boron (1) • **Sediment:** turbidity (1) total dissolved solids (1) • **Organics:** nitrogen (1), phosphorus (1), ammonia (1), dissolved oxygen (1), pH (1), E. coli (1) • **Selenium:** Selenium (1)
	Status	Parameters exceeding standards: Mercury (1/1) Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
South Fork Little Colorado River headwaters to Little Colorado River ADEQ ID: 15020001-027 One sampling site at this surface waterbody.	Sampling	• **Metals:** selenium (d1), mercury (d1), cadmium (d1), copper (d1) • **Sediment:** turbidity (1) • **Organics:** nitrogen, phosphorus(1), ammonia (1), dissolved oxygen (1), pH (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: None. Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
West Fork Little Colorado River from headwaters to Government Springs ADEQ ID: 15020001-013A Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4), fluoride (4), boron (1) • **Sediment:** turbidity (4), TDS (4) • **Organics:** dissolved oxygen (5); pH (5), nitrogen (5), phosphorus (5), ammonia (5), *E. Coli* (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: None. Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** Low risk • **Selenium:** Low risk

West Fork Little Colorado River From Government Springs to Little Colorado River ADEQ ID: 15020001-013B One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td13), barium (td13), beryllium (td13), thorium (td13), antimony (td13), selenium (td13), mercury (td13), cadmium (td13), chromium (td13), copper (td13), lead (td13), nickel (td13), silver (td13), zinc (td13), Magnesium (t13), fluoride(13), boron(13) • **Sediment:** turbidity (13), TDS (13) • **Organics:** Dissolved Oxygen (13), pH (13), Nitrogen (13), P (13), NH3 (13), *E. Coli* (13) • **Selenium:** selenium (13)
	Status	Parameters exceeding standards: Copper (1/1) and Dissolved Oxygen[2] (2/11) . Currently assessed as “Attaining some uses” Surface Waterbody risk classification: • **Metals:** High risk due to exceedances • **Sediment:** Low risk • **Organics:** Low risk • **Selenium:** Low risk
Bunch Reservoir ADEQ ID: 15020001-0230 One sampling site at this surface waterbody.	Sampling	• **Metals:** copper (t3), iron (t3), manganese (t3), zinc (t3) • **Sediment:** total dissolved solids (3) • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), ammonia (3) • **Selenium:** none
	Status	Parameters exceeding standards: Low dissolved oxygen (2/3). Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Lee Valley Reservoir ADEQ ID: 15020001-0770 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (3td), barium (3td), beryllium (3td), thorium (3td), antimony (3td), selenium (3td), mercury (3td), cadmium (3td), chromium (3td), copper (3td), lead (3td), nickel (3td), silver (3td), zinc (3td), magnesium (t13) • **Sediment:** Turbidity (3), total dissolved solids (3) • **Organics:** dissolved oxygen (6) ,nitrogen (6), phosphorus (6), ammonia (6), pH (6), *E. coli*(3), fluoride (3), boron (3) • **Selenium:** selenium (3)

[2] Due to natural causes

	Status	Parameters exceeding standards: None. Currently assessed as “Attaining some uses” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Low risk • **Selenium:** Moderate due to insufficient data
River Reservoir ADEQ ID: 15020001-1170 One sampling site at this surface waterbody.	Sampling	• **Metals:** copper (3), iron (3), manganese (3), zinc (3) • **Sediment:** total dissolved solids (3) • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), ammonia(3) • **Selenium:** none
	Status	Parameters exceeding standards: None. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Tunnel Reservoir ADEQ ID: 15020001-1550 One sampling site at this surface waterbody.	Sampling	• **Metals:** copper (3), iron (3), manganese (3), zinc (3) • **Sediment:** none • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3); NH3 (3) • **Selenium:** none
	Status	Parameters exceeding standards: Low dissolved oxygen (1/3). Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

Coyote Creek Subwatershed
HUC 1502000103
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Camero Creek Subwatershed
HUC 1502000104

Combined Classification for Risk Impairment:

- **Metals:** Extreme for metals[3] at Lyman Lake
- **Sediment:** Extreme for sediment due to exceedances at **Little Colorado River**
- **Organics:** Moderate for organics due to exceedances at **Carnero Lake**
- **Selenium:** Low risk

<table>
<tr><th>Surface Waterbody</th><th colspan="2">Water Quality Data:
Sampling and Assessment Status [i, ii, iii]</th></tr>
<tr><td rowspan="2">Little Colorado River, unnamed reach to Lyman Lake

ADEQ ID: 15020001-005

One sampling site at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4)
• Sediment: Turbidity (3)
• Organics: dissolved oxygen (4), nitrogen (4), phosphorus (4), ammonia (4), pH (4), E. Coli (4)
• Selenium: selenium (4)</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Turbidity (3/3), E. coli (1/3).

Currently assessed as “Impaired”

Surface Waterbody risk classification:
• Metals: Moderate due to insufficient data
• Sediment: Moderate due to insufficient data
• Organics: Moderate due to insufficient data
• Selenium: Moderate due to insufficient data</td></tr>
<tr><td rowspan="2">Little Colorado River from Nutrioso Creek to Carnero Wash

ADEQ ID: 15020001-009

One sampling site at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic (td13) (td13), barium (td13), beryllium (td13), thorium (td13), antimony (td13), selenium (td13), mercury (td13), cadmium (td13), chromium (td13), copper (td13), lead (td13), nickel (td13), silver (td13), zinc (td13), magnesium (t13)
• Sediment: Turbidity (12), total dissolved solids (13)
• Organics: samples dissolved oxygen(13), nitrogen (13), phosphorus (13), ammonia (13), pH (13), E. coli (12); fluoride (13), boron (13), pH (13)
• Selenium: Selenium (13)</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Turbidity (9/12), E. coli (1/12).

Currently assessed as “Impaired”

Surface Waterbody risk classification:
• Metals: Moderate due to insufficient data
• Sediment: High risk due to exceedances
• Organics: Moderate risk due to exceedances
• Selenium: Moderate due to insufficient data</td></tr>
</table>

[3] Mercury in fish tissue

Carnero Lake ADEQ ID: 15020001-0260 One sampling site at this surface waterbody.	Sampling	• **Metals:** copper (t3), iron (t3), manganese (t3), zinc (t3) • **Sediment:** none • **Organics:** dissolved oxygen (3), nitrogen (3), phosphorus (3), ammonia (3), pH (3) • **Selenium:** none
	Status	Parameters exceeding standards: Low dissolved oxygen (1/3), high pH (2/3). Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Lyman Lake ADEQ ID: 15020001-0850 One sampling site at this surface waterbody.	Sampling	• **Metals:** none • **Sediment:** none • **Organics:** dissolved oxygen (1); pH (1), nitrogen (1), phosphorus (1), NH3 (1) • **Selenium:** none
	Status	Parameters exceeding standards: None. Currently assessed as "Impaired" because of mercury in fish tissue. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

Lyman Lake Subwatershed
HUC 1502000201

Combined Classification for risk impairment:

- **Metals:** Moderate due to insufficient data at Little Colorado River
- **Sediment:** Moderate due to insufficient data at Little Colorado River
- **Organics:** Moderate due to insufficient data at Little Colorado River
- **Selenium:** Moderate due to insufficient data at Little Colorado River

Surface Waterbody	Water Quality Data: Sampling and Assessment Status [i, ii, iii]	
Little Colorado River from 15020001 HUC boundary to unnamed tributary (15020002-025) ADEQ ID: 15020002-024	Sampling	• **Metals:** chromium (t2), copper (t2), iron (t2), lead (t2), manganese (t2), zinc (t2) • **Sediment:** none • **Organics:** dissolved oxygen (2), nitrogen (2), phosphorus (2), ammonia (2), pH (2) • **Selenium:** none

One sampling site at this surface waterbody.	Status	Parameters exceeding standards: None. Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

Big Hollow Wash Subwatershed
HUC 1502000202
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Concho Creek Wash Subwatershed
HUC 1502000203

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Surface Waterbody	Water Quality Data: Sampling and Assessment Status [i, ii, iii]	
Little Colorado River, Zion Reservoir to Concho Creek ADEQ ID: 15020002-016 One sampling site at this surface waterbody.	Sampling	• **Metals:** none • **Sediment:** Suspended sediment concentration (39) • **Organics:** none • **Selenium:** none
	Status	Parameters exceeding standards: Suspended sediment concentration annual means exceeded (1/3). Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed		
Oso Draw Wash Subwatershed **HUC 1502000204** **Combined Classification for Risk Impairment:** • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** High risk due to exceedances • **Selenium:** Low risk		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Mineral Creek from headwaters to Concho Creek ADEQ ID: 15020002-648 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4) • **Sediment:** Turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen(4), pH (4), nitrogen (4), phosphorus (4), ammonia (4), *E. coli* (4), fluoride (4), boron (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Dissolved oxygen (1/4). Currently assessed as "Attaining some" Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** High risk due to exceedances • **Selenium:** Low risk
Subwatershed		
Milky Wash Subwatershed **HUC 1502000205** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data		
Subwatershed		
Hay Hollow Draw Wash Subwatershed **HUC 1502000206** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data .		

Subwatershed		
Washboard Draw Subwatershed **HUC 1502000207** **Combined Classification for Risk Impairment:** • **Metals:** Extreme due to exceedances • **Sediment:** Extreme due to exceedances • **Organics:** Extreme due to exceedances • **Selenium:** Low risk		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Little Colorado River from Silver Creek to Car Wash ADEQ ID: 15020002-004 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td10-12), barium (td10-12), beryllium (td10-12), thorium (td10-12), antimony (td10-12), selenium (td10-12), mercury (td10-12), cadmium (td10-12), chromium (td10-12), copper (td10-12), lead (td10-12), nickel (td10-12), silver (td10-12), zinc (td10-12), magnesium (t10-12) • **Sediment:** Turbidity (8), total dissolved solids (11) • **Organics:** dissolved oxygen (11), nitrogen (11), phosphorus (11), ammonia (11), pH (11), *E. coli* (9), fluoride (11), boron (11), pH (11) • **Selenium:** selenium (td10-12)
	Status	Parameters exceeding standards: As (1/11), Ba (2/10), Be (2/12), Cr (1/12), dissolved oxygen (1/11), *E coli* (2/9), Pb (3/12), Mn (2/12), Hg (1/12), nickel1/10), turbidity (8/8). Currently assessed as “Impaired” Surface Waterbody risk classification: • **Metals:** High risk due to exceedances • **Sediment:** High risk due to exceedances • **Organics:** High risk due to exceedances • **Selenium:** Low risk
Subwatershed		
Middle Carrizo Wash Subwatershed **HUC 1502000306** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Moderate risk due to insufficient data • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		

Subwatershed

Lower Carrizo Wash Subwatershed
HUC 1502000307
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Jaraloso Draw Subwatershed
HUC 1502000406
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Middle Zuni River Subwatershed
HUC 1502000407
HALF ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Hardscrabble Wash Subwatershed
HUC 1502000408
HALF ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Lower Zuni River Subwatershed
HUC 1502000409
SOME ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

<table>
<tr><td colspan="3">Subwatershed</td></tr>
<tr><td colspan="3">Show Low Creek Subwatershed
HUC 1502000501
Combined Classification for Risk Impairment:
• Metals: Low risk
• Sediment: High due to exceedances at Show Low Creek
• Organics: Extreme due to previous TMDL at Rainbow lake and exceedances at Billy Creek
• Selenium: Low risk</td></tr>
<tr><td>Surface Waterbody</td><td colspan="2">Water Quality Data:
Sampling and Assessment Status [i, ii, iii]</td></tr>
<tr><td rowspan="2">Show Low Creek from headwaters to Linden Wash

ADEQ ID: 15020005-012

Three sampling sites at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic(td4) (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4)
• Sediment: turbidity (4), total dissolved solids (4)
• Organics: dissolved oxygen (6); pH (6), nitrogen (6), phosphorus (6), ammonia (6), E. coli (4), fluoride (4), boron (4)
• Selenium: selenium (4)</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Turbidity (3/5).

Currently assessed as “attaining some uses”

Surface Waterbody risk classification:
• Metals: Low risk
• Sediment: High risk due to exceedances
• Organics: High risk due to exceedances
• Selenium: Low risk</td></tr>
<tr><td rowspan="2">Billy Creek from headwaters to Show Low Creek

ADEQ ID: 15020005-019

Two sampling sites at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic (td8), barium (td8), beryllium (td8), thorium (td8), antimony (td8), selenium (td8), mercury (td8), cadmium (td8), chromium (td8), copper (td8), lead (td8), nickel (td8), silver (td8), zinc (td8), magnesium (t8)
• Sediment: turbidity (8), total dissolved solids (8)
• Organics: dissolved oxygen (8); pH (8), nitrogen (8), phosphorus (8), ammonia (8), E. coli (8), 8 fluoride (8) , boron (8)
• Selenium: selenium (8)</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: E coli (1/4), turbidity (3/8).

Currently assessed as “attaining some uses”

Surface Waterbody risk classification:
• Metals: Low risk
• Sediment: High risk due to exceedances
• Organics: High risk due to exceedances
• Selenium: Low risk</td></tr>
</table>

Porter Creek, from headwaters to Show Low Creek ADEQ ID: 15020005-246 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1), magnesium (t1) • **Sediment:** Turbidity (1), total dissolved solids (1) • **Organics:** nitrogen (2) , phosphorus (2), ammonia (2), dissolved oxygen (2), pH (2), *E. coli* (1), fluoride (1), boron (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: Turbidity (1/1). Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Rainbow Lake ADEQ ID: 15020005-1170 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic(td1) (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1), magnesium (t1) • **Sediment:** turbidity (1), total dissolved solids (1) • **Organics:** nitrogen (1), phosphorus (1), ammonia (1), dissolved oxygen (1), pH (1), *E. coli* (1); fluoride (1), boron (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: None. Currently assessed as "Impaired" due to nutrients over TMDL (previous). Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed		
Upper Silver Creek Subwatershed **HUC 1502000502** **Combined Classification for Risk Impairment:** • **Metals:** Low risk • **Sediment:** High risk due to exceedances at **Silver Creek** • **Organics: :** High risk due to exceedances at **Silver Creek** • **Selenium:** Low risk		
Surface Waterbody	**Water Quality Data:** **Sampling and Assessment Status** i, ii, iii	
Silver Creek from headwaters to Show Low Creek ADEQ ID: 15020005-013 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), Magnesium (t4) • **Sediment:** turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH (4), nitrogen(4), phosphorus (4), ammonia (4), *E. coli* (4), fluoride (4), boron (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Turbidity (1/4), dissolved oxygen (1/4). Currently assessed as “attaining some uses” Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** High risk due to exceedances • **Organics:** High risk due to exceedances • **Selenium:** Low risk
Brown Creek from headwaters to Show Low Creek ADEQ ID: 15020005-016 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** Arsenic (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1), Magnesium (t1) • **Sediment:** turbidity (1), total dissolved solids (1) • **Organics:** Nitrogen (1), phosphorus (1), ammonia (1), dissolved oxygen (1), pH (1), *E. coli* (1), fluoride (1), boron (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: None. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed		
Cottonwood Creek Subwatershed **HUC 1502000503** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Moderate risk due to insufficient data • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		
Subwatershed		
Lower Silver Creek Subwatershed **HUC 1502000504** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Moderate risk due to exceedances • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Silver Creek from Seven-Mile Draw to LCR ADEQ ID: 15020005-001 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1), magnesium(t1) • **Sediment:** turbidity (1), total dissolved solids (1) • **Organics:** Nitrogen (1), phosphorus (1), ammonia (1), dissolved oxygen (1), pH (1), *E. coli* (1), fluoride (1), boron (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: turbidity (1/1) Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate risk due to exceedances • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Subwatershed		
Upper Black Creek Subwatershed **HUC 1502000603** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Moderate risk due to insufficient data • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		

Subwatershed

HUC 1502000605
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

HUC 1502000606
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

HUC 1502000607
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Burntwater Wash Subwatershed
HUC 1502000701
HALF ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Morgan Canyon Subwatershed
HUC 1502000702
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Dead Wash Subwatershed
HUC 1502000703
HALF ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Dry Wash Subwatershed
HUC 1502000704
PART ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Ninemile Wash Subwatershed
HUC 1502000705
HALF ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Lithodendron Wash Subwatershed
HUC 1502000706
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Phoenix Park Wash Subwatershed
HUC 1502000801
NO SAMPLES COLLECTED

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed		
Porter Tank Draw Subwatershed **HUC 1502000802** **NO SAMPLES COLLECTED** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Moderate risk due to insufficient data • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		

Subwatershed		
Upper Clear Creek Subwatershed **HUC 1502000803** **Combined Classification for Risk Impairment:** • **Metals:** Low risk • **Sediment:** Moderate due to exceedances at Buck Springs Canyon Creek • **Organics:** Extreme due to "Impaired" classification at **Bear Canyon Lake** • **Selenium:** Moderate due to exceedances at **Bear Canyon Lake**		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
East Clear Creek from headwaters to Yeager Canyon ADEQ ID: 15020008-009 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium; (t4) • **Sediment:** turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH(4), nitrogen (4), phosphorus (4), ammonia (4), *E. coli* (4), fluoride (4), boron (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: dissolved oxygen (2/4). Currently assessed as "Attaining some uses"[4] Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** High risk due to exceedances • **Selenium:** Low risk

[4] There is a discrepancy in designation between the report posted online (inconclusive) and tabular data from ADEQ (attaining some).

Barbershop Canyon Creek from headwaters to East Clear Creek ADEQ ID: 15020008-537 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4), fluoride (4), boron (4) • **Sediment:** turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4); pH (4), nitrogen (4); phosphorus (4); ammonia (4), *E. coli* (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Dissolved Oxygen (1/4)[5]. Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** Low risk • **Organics:** Low risk • **Selenium:** Low risk
Buck Springs Canyon Creek headwaters to Leonard Canyon ADEQ ID: 1020008-557	Sampling	Old data
	Status	Parameters exceeding standards: Turbidity (1/1), low pH (1/1). Currently assessed as "Inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to exceedances • **Organics:** Moderate due to exceedances • **Selenium:** Moderate due to insufficient data
Bear Canyon Lake ADEQ ID: 15020008-0130 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** (1) dis and (3) total: arsenic; barium; beryllium; thorium; antimony; selenium; mercury; cadmium; chromium; copper; lead; nickel; silver; zinc; Total only: magnesium; (3) fluoride, boron • **Sediment:** (3) turbidity and total dissolved solids • **Organics:** (3) dissolved oxygen; pH, nitrogen; phosphorus; ammonia; 2 *E. coli* • **Selenium:** (3) selenium
	Status	Parameters exceeding standards: Low dissolved oxygen (2/5), Selenium (1/4). Currently assessed as "impaired"[6] Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to exceedances • **Selenium:** Moderate due to exceedances

[5] Due to natural causes

[6] There is a discrepancy in designation between the report posted online (inconclusive) and tabular data from ADEQ (impaired).

<table>
<tr><td colspan="3">Subwatershed</td></tr>
<tr><td colspan="3">Lower Clear Creek Subwatershed
HUC 1502000804
Combined Classification for Risk Impairment:
• Metals: Moderate risk due to insufficient data
• Sediment: Moderate risk due to insufficient data
• Organics: Moderate risk due to exceedances
• Selenium: Moderate risk due to insufficient data</td></tr>
<tr><td>Surface Waterbody</td><td colspan="2">Water Quality Data:
Sampling and Assessment Status [i, ii, iii]</td></tr>
<tr><td rowspan="2">Clear Creek Reservoir

ADEQ ID: 15020008-0340

Two sampling sites at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic (t3), cadmium (t3), chromium (t3), copper (t3), iron (t3), lead (t3), manganese (t3), mercury (t3), selenium (t3), silver (t3), zinc (t3)
• Sediment:
• Organics: dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), ammonia (3)
• Selenium: Selenium (3)</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Low dissolved oxygen (1/5).

Currently assessed as “Attaining some uses”

Surface Waterbody risk classification:
• Metals: Moderate due to insufficient data
• Sediment: Moderate due to insufficient data
• Organics: Moderate due to exceedances
• Selenium: Moderate due to insufficient data</td></tr>
<tr><td colspan="3">Subwatershed</td></tr>
<tr><td colspan="3">Jacks Canyon Subwatershed
HUC 1502000805: Note that the 10-digit HUC boundary is wrong here. It shows it in 1502001504, but it is not. That would cut across a piece of drainage.
Combined Classification for Risk Impairment:
• Metals: Extreme due to “Impaired” designation due to mercury in fish tissue at Soldier’s Lake
• Sediment: Moderate due to insufficient data
• Organics: Moderate due to exceedances
• Selenium: Moderate due to insufficient data</td></tr>
<tr><td>Surface Waterbody</td><td colspan="2">Water Quality Data:
Sampling and Assessment Status [i, ii, iii]</td></tr>
<tr><td>Soldier's Annex Lake

ADEQ ID: 15020008-1430

One sampling site at this surface waterbody.</td><td>Sampling</td><td>• Metals: none
• Sediment: none
• Organics: dissolved oxygen (1), pH (1), nitrogen (1), phosphorus (1), NH3 (1)
• Selenium: none</td></tr>
</table>

	Status	Parameters exceeding standards: None. Currently assessed as “impaired” due to mercury in fish tissue. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Soldier's Lake ADEQ ID: 15020008-1440	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: None. Currently assessed as “impaired” due to mercury in fish tissue. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Subwatershed		
McDonald Canyon Subwatershed **HUC 1502000806** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Extreme due to exceedances at **Little Colorado River** • **Organics:** Moderate risk due to insufficient data • **Selenium:** Moderate risk due to insufficient data		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Little Colorado River from Porter Tank Draw to McDonalds Wash ADEQ ID: 15020008-017 One sampling site at this surface waterbody.	Sampling	• **Metals:** none • **Sediment:** Suspended Sediment Concentration (27) • **Organics:** none • **Selenium:** none
	Status	Parameters exceeding standards: Annual Suspended Sediment Concentration (3/3). Currently assessed as “impaired” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** High due to exceedances • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Cholla Lake ADEQ ID: 15020008-0320 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (t3), cadmium (t3), chromium (t3), copper (t3), iron (t3), lead (t3), manganese (t3), mercury (t3), selenium (t3), silver (t3), zinc (t3) • **Sediment:** none • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), ammonia (3) • **Selenium:** Selenium (3)
	Status	Parameters exceeding standards: Fish kill in 2002 related to suspended sediments. Currently assessed as "inconclusive" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

Rincon Basin Area Subwatershed
HUC 1502000807
PART ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Coyote Wash Subwatershed
HUC 1502000808
PART ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Cow Canyon Subwatershed
HUC 1502000809
PART ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Canyon Diablo to Grand Falls Subwatershed
HUC 1502000810
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Upper Wide Ruin Subwatershed
HUC 1502000901
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Lower Wide Ruin Subwatershed
HUC 1502000902
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed

Leroux Wash Subwatershed
HUC 1502000903
PART ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk due to insufficient data
- **Sediment:** Moderate risk due to insufficient data
- **Organics:** Moderate risk due to insufficient data
- **Selenium:** Moderate risk due to insufficient data

Subwatershed		
Upper Chevelon Canyon Subwatershed **HUC 1502001001** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk due to insufficient data • **Sediment:** Low risk • **Organics:** Moderate risk due to insufficient data • **Selenium:** Low risk		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Chevelon Canyon from headwaters to West Chevelon Creek ADEQ ID: 15020010-006	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: No new data. Inconclusive on last assessment due to low dissolved oxygen and missing core parameters. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Woods Canyon Creek from headwaters to Chevelon Canyon Creek ADEQ ID: 15020010-084	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: No current data. Dissolved oxygen in past assessment. Currently assessed as “Inconclusive” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Woods Canyon Lake ADEQ ID: 15020010-1700 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (d1t3), barium (d1t3), beryllium (d1t3), thorium (d1t3), antimony (d1t3), selenium (d1t3), mercury (d1t3), cadmium (d1t3), chromium (d1t3), copper (d1t3), lead (d1t3), nickel (d1t3), silver (d1t3), zinc (d1t3), magnesium (t3), fluoride (4), boron (4) • **Sediment:** Turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH (4), nitrogen (4); phosphorus (4), ammonia (4), *E. coli* (2) • **Selenium:** Selenium (4)
	Status	Parameters exceeding standards: None. Currently assessed as “Attaining some” Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Low risk • **Organics:** Low risk • **Selenium:** Low risk

Subwatershed		
Black Canyon Subwatershed **HUC 1502001002** **Combined Classification for Risk Impairment:** • **Metals:** Moderate for metals due to insufficient data • **Sediment:** Moderate for sediment due to insufficient data • **Organics:** Moderate for organics due to exceedances • **Selenium:** Moderate for selenium due to insufficient data		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]	
Blue Ridge Reservoir ADEQ ID: 15020008-0200 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (d1+J170st3), barium (d1+J170st3), beryllium (d1+J170st3), thorium (d1+J170st3), antimony (d1+J170st3), selenium (d1+J170st3), mercury (d1+J170st3), cadmium (d1+J170st3), chromium (d1+J170st3), copper (d1+J170st3), lead (d1+J170st3), nickel (d1+J170st3), silver (d1+J170st3), manganese (d1+J170st3), zinc (d1+J170st3), fluoride (3), boron(3) • **Sediment:** turbidity (3), total dissolved solids (3) • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), ammonia (3), *E. coli* (1) • **Selenium:** selenium (3)
	Status	Parameters exceeding standards: Low dissolved oxygen (2/3). Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to exceedances • **Selenium:** Moderate due to insufficient data

Subwatershed	
Lower Chevelon Canyon Subwatershed **HUC 1502001003** **Combined Classification for Risk Impairment:** • **Metals:** Low risk • **Sediment:** High risk due to exceedances • **Organics:** Low risk • **Selenium:** Low risk	
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** [i, ii, iii]

Chevelon Canyon from Black Canyon to LCR ADEQ ID: 15020010-001 One sampling site at this surface waterbody.	Sampling	• **Metals:** Arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), magnesium (t4), fluoride (4), boron (4) • **Sediment:** turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH(4), nitrogen (4), phosphorus (4), ammonia (4), *E. coli* (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Turbidity (4/4). Currently assessed as "Attaining some uses"[7] Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** High due to exceedances • **Organics:** Low risk • **Selenium:** Low risk

Subwatershed

Upper Pueblo Colorado Wash Subwatershed
HUC 1502001101
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001102
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001103
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

[7] There is a discrepancy in designation between the report posted online (inconclusive) and tabular data from ADEQ (Attaining some uses).

Subwatershed

HUC 1502001104
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001105
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001106
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001201
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001202
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001203
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001301
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001302
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001303
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001304
ON INDIAN LAND

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001401
ON INDIAN LAND

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001402
ON INDIAN LAND

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001403
ON INDIAN LAND

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

HUC 1502001404
ON INDIAN LAND

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Rio de Flag Subwatershed
HUC 1502001501

Combined Classification for Risk Impairment:
- **Metals:** Low risk
- **Sediment:** High due to exceedances
- **Organics:** Low risk
- **Selenium:** Low risk

Surface Waterbody	Water Quality Data: Sampling and Assessment Status [i, ii, iii]

Rio de Flag from Flagstaff WWTP to San Francisco Wash ADEQ ID: 15020015-004B One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (td4), barium (td4), beryllium (td4), thorium (td4), antimony (td4), selenium (td4), mercury (td4), cadmium (td4), chromium (td4), copper (td4), lead (td4), nickel (td4), silver (td4), zinc (td4), Magnesium (t4), fluoride (4), boron (4) • **Sediment:** turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH (4), nitrogen (4), phosphorus (4), ammonia (4), *E. coli* (4) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Turbidity (1/4). Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** High due to exceedances • **Organics:** Low risk • **Selenium:** Low risk

Subwatershed

Walnut Creek Subwatershed
HUC 1502001502

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to exceedances in **Upper Lake Mary**
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Surface Waterbody	Water Quality Data: Sampling and Assessment Status [i, ii, iii]	
Upper Lake Mary ADEQ ID: 15020015-0900 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (td1), barium (td1), beryllium (td1), thorium (td1), antimony (td1), selenium (td1), mercury (td1), cadmium (td1), chromium (td1), copper (td1), lead (td1), nickel (td1), silver (td1), zinc (td1), Magnesium (t1), fluoride (1), boron (1) • **Sediment:** turbidity (1), total dissolved solids (1) • **Organics:** dissolved oxygen (1), pH (1), nitrogen (1), phosphorus (1), ammonia (1) • **Selenium:** selenium (1)
	Status	Parameters exceeding standards: turbidity (1/1), fish consumption advisory due to mercury. Currently assessed as "Impaired"[8] Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to exceedances • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

[8] There is a discrepancy in designation between the report posted online (inconclusive) and tabular data from ADEQ (Impaired).

Lower Lake Mary ADEQ ID: 15020015-0890	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: fish consumption advisory due to mercury. Currently assessed as "Impaired" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Subwatershed		
San Francisco Wash Subwatershed **HUC 1502001503** **Combined Classification for Risk Impairment:** • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due to insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** i, ii, iii	
Ashurst Lake ADEQ ID: 15020015-0090 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** Arsenic (td3), barium (td3), beryllium (td3), manganese (td3), antimony (td3), selenium (td3), mercury (td3), cadmium (td3), chromium (td3), copper (td3), lead (td3), nickel (td3), silver (td3), zinc (td3), fluoride (3), boron (3) • **Sediment:** turbidity (3) • **Organics:** Dissolved Oxygen (3), *E. coli* (2), total dissolved solids (3) • **Selenium:** selenium (3)
	Status	Parameters exceeding standards: Turbidity (4/4). Currently assessed as "Attaining some uses" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data
Subwatershed		
Canyon Diablo Subwatershed **HUC 1502001504** **Combined Classification for Risk Impairment:** • **Metals:** Moderate due to insufficient data • **Sediment:** High due to exceedances at **Kinnikinick Lake** • **Organics:** Low risk • **Selenium:** High due to exceedances at **Kinnikinick Lake**		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status** i, ii, iii	

Kinnikinick Lake ADEQ ID: 15020015-0730 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (d1t3), barium (d1t3), beryllium (d1t3), thorium (d1t3), antimony (d1t3), selenium (d1t3), mercury (d1t3), cadmium (d1t3), chromium (d1t3), copper (d1t3), lead (d1t3), nickel (d1t3), silver (d1t3), manganese (d1t3), zinc (d1t3), fluoride (4), boron (4) • **Sediment:** Turbidity (4), total dissolved solids (4) • **Organics:** dissolved oxygen (4), pH (4), nitrogen (4), phosphorus (4), ammonia (4), *E. coli* (2) • **Selenium:** selenium (4)
	Status	Parameters exceeding standards: Turbidity (7/7), Selenium (1/4). Currently assessed as "Attaining some uses"[9] Surface Waterbody risk classification: • **Metals:** Low risk • **Sediment:** High due to exceedances • **Organics:** Low risk • **Selenium:** High due to exceedances
Long Lake (lower) ADEQ ID: 15020015-0820[10] Two sampling sites at this surface waterbody.	Sampling	• **Metals:** none • **Sediment:** none • **Organics:** dissolved oxygen (3), pH (3), nitrogen (3), phosphorus (3), NH3 (3) • **Selenium:** none
	Status	Parameters exceeding standards: fish consumption advisory due to mercury. Currently assessed as "Impaired" Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data • **Sediment:** Moderate due insufficient data • **Organics:** Moderate due to insufficient data • **Selenium:** Moderate due to insufficient data

Subwatershed

Kana-a Wash Subwatershed
HUC 1502001601

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

[9] There is a discrepancy in designation between the report posted online (inconclusive) and tabular data from ADEQ (Attaining some uses).
[10] Listed as AZL15020008-0820 in ADEQ online document

Subwatershed
Deadman Wash Subwatershed **HUC 1502001602** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed
Big Wash Subwatershed **HUC 1502001603** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed
Tohachi Wash Subwatershed **HUC 1502001604** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed
Citadel Wash Subwatershed **HUC 1502001605** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed
Upper Cedar Wash Subwatershed **HUC 1502001606** **Combined Classification for Risk Impairment:** • **Metals:** Moderate risk for metals due to insufficient data • **Sediment:** Moderate risk for sediment due to insufficient data • **Organics:** Moderate risk for organics due to insufficient data • **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Lower Cedar Wash Subwatershed
HUC 1502001607

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Tonahakaad Wash Subwatershed
HUC 1502001608

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Lee Canyon Subwatershed
HUC 1502001609

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Sheep Wash Subwatershed
HUC 1502001610

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Upper Dinnebito Wash Subwatershed
HUC 1502001701

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Middle Dinnebito Wash Subwatershed
HUC 1502001702

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Lower Dinnebito Wash Subwatershed
HUC 1502001703

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Moenkopi Wash Headwaters Subwatershed
HUC 1502001801

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Shonto Wash Subwatershed
HUC 1502001802

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Upper Begashibito Wash Subwatershed
HUC 1502001803

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Crooked Ridge/Echo Cliffs Area Subwatershed
HUC 1502001804

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Lower Begashibito Wash Subwatershed
HUC 1502001805

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Wide Ruin Canyon-Moenkopi Wash Subwatershed
HUC 1502001806

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Pasture Canyon Subwatershed
HUC 1502001807

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Coal Mine Canyon-Moenkopi Wash Subwatershed
HUC 1502001808

Combined Classification for Risk Impairment:

- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Hamblin Wash Subwatershed
HUC 1502001809

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Kerley Valley-Moenkopi Wash Subwatershed
HUC 1502001810

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

Subwatershed

Fivemile Wash-Moenkopi Wash Subwatershed
HUC 1502001811

Combined Classification for Risk Impairment:
- **Metals:** Moderate risk for metals due to insufficient data
- **Sediment:** Moderate risk for sediment due to insufficient data
- **Organics:** Moderate risk for organics due to insufficient data
- **Selenium:** Moderate risk for selenium due to insufficient data

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[i] All water quality constituents had a minimum of three samples unless otherwise indicated by numbers in parenthesis. For example, arsenic (2) indicates two samples have been taken for arsenic on this reach.

[ii] The number of samples that exceed a standard is described by a ratio. For example, the statement "Exceedances reported for E. coli (1/2)," indicates that one from two samples has exceeded standards for E. coli.

[iii] The acronyms used for the water quality parameters are defined below:
(d) = dissolved fraction of the metal or metalloid (after filtration), ug/L
(t) = total metal or metalloid (before filtration), ug/L
cadmium (d): Filtered water sample analyzed for dissolved cadmium.
cadmium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) cadmium content.
chromium (d): Filtered water sample analyzed for dissolved chromium.
chromium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) chromium content.
copper (d): Filtered water sample analyzed for dissolved copper.
copper (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) copper content.
dissolved oxygen: O2 (mg/L)
E. coli: Escherichia coli bacteria (CFU/100mL)
lead (d): Filtered water sample analyzed for dissolved lead.
lead (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) lead content.

manganese (d): Filtered water sample analyzed for dissolved manganese.
manganese (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) manganese content.
mercury (d): Filtered water sample analyzed for dissolved mercury.
mercury (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) mercury content.
nickel (d): Filtered water sample analyzed for dissolved nickel.
nickel (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) nickel content.
nitrite/nitrate: Water sample analyzed for Nitrite/Nitrate content.
n-kjeldahl: Water sample analyzed by the Kjeldahl nitrogen analytical method which determines the nitrogen content of organic and inorganic substances by a process of sample acid digestion, distillation, and titration.
pH: Water sample analyzed for levels of acidity or alkalinity.
selenium (d): Filtered water sample analyzed for dissolved selenium.
selenium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) selenium content.
silver (d): Filtered water sample analyzed for dissolved silver.
silver (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) silver content.
suspended sediment concentration: Suspended Sediment Concentration
temperature: Sample temperature
total dissolved solids: tds, (mg/L)
total solids: (t) Solids
total suspended solids: (t) Suspended Solids
turbidity: Measurement of suspended matter in water sample (NTU)
zinc (d): Filtered water sample analyzed for dissolved zinc.
zinc (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) zinc content.

Designated Uses:
Agl: Agricultural Irrigation. Surface water is used for the irrigation of crops.
AgL: Agricultural Livestock Watering. Surface water is used as a supply of water for consumption by livestock.
A&Ww: Aquatic and Wildlife Warm water Fishery. Surface water used by animals, plants, or other organisms (excluding salmonid fish) for habitation, growth, or propagation, generally occurring at elevations less than 5000 feet.
FC: Fish Consumption. Surface water is used by humans for harvesting aquatic organisms for consumption. Harvestable aquatic organisms include, but are not limited to, fish, clams, crayfish, and frogs.
FBC: Full Body Contact. Surface water use causes the human body to come into direct contact with the water to the point of complete submergence (e.g., swimming). The use is such that ingestion of the water is likely to occur and certain sensitive body organs (e.g., eyes, ears, or nose) may be exposed to direct contact with the water.

References

Arizona Department of Environmental Quality, ADEQ. 2005. The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, 1110 West Washington Ave., Phoenix, Arizona, 85007, from http://www.azdeq.gov/environ/water/assessment/2004.html.

Appendix B - Selected References
Little Colorado River Watershed

Northern Arizona University, Center for Environmental Science and Education, Forest ERA webpage: forestera.nau.edu/index.htm

Show Low Creek Watershed Enhancement Partnership. 2007. Watershed management plan.

Upper Little Colorado River Watershed Partnership. 2004. Watershed based action and management plan.

Appendix C: Revised Universal Soil Loss Equation (RUSLE) Modeling

The Revised Universal Soil Loss Equation (RUSLE) was used to model erosion potential. RUSLE computes average annual erosion from field slopes as (Renard, 1997):

$$A = R*K*L*S*C*P$$

Where:

A = computed average annual soil loss in tons/acre/year.
R = rainfall-runoff erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover-management factor
P = Conservation Practice

The modeling was conducted in the ArcInfo Grid environment using Van Remortel's (2004) Soil & Landform Metrics program. This is a series of Arc Macro Language (AML) programs and C++ executables that are run sequentially to prepare the data and run the RUSLE model. A 30-meter cell size was used to correspond to the requirements of the program.

All of the required input spatial data layers were converted to the projection required by the program (USGS Albers NAD83) and placed in the appropriate directories. The input data layers include:

- USGS Digital Elevation Model (DEM). The DEM was modified by multiplying it by 100 and converting it to an integer grid as prescribed by the program.
- Master watershed boundary grid (created from USGS DEM).
- National Land Cover Dataset (NLCD) land cover grid.
- Land mask grid for open waters, such as oceans or bays, derived from the NLCD land cover data. No oceans or bays are present in this watershed, so no cells were masked.

The first component AML of the program sets up the 'master' soil and landform spatial datasets for the study area. This includes extracting the STATSGO soil map and attributes as well as the R, C, and P factors, from datasets that come with the program. The R-factor is rainfall-runoff erosivity, or the potential of rainfall-runoff to cause erosion. The C-factor considers the type of cover or land management on the land surface. The P-factor looks at conservation practices, such as conservation tillage.

Additionally, a stream network is delineated from the DEM using a user specified threshold for contributing area. A threshold of 500 30x30 meter cells was specified as the contributing area for stream delineation. This number was chosen based on consultation with the program author. The AML also created the K factor grid. The K factor considers how susceptible a soil type is to erosion.

The second component AML sets up additional directory structures for any defined subwatersheds. In this use of the model the entire Upper Gila watershed was done as a single unit.

The third component AML iteratively computes a set of soil parameters derived from the National Resource Conservation Service's State Soil Geographic (STATSGO) Dataset.

The fourth component AML calculates the LS factor according to the RUSLE criteria using DEM-based elevation and flow path. The L and S factors take into account hill slope length and hill slope steepness.

The fifth component AML runs RUSLE and outputs R, K, LS, C, P factor grids and an A value grid that contains the modeled estimate of erosion in tons/acre/year for each cell.

References:

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook No. 703. USDA, Washington D.C.

Van Remortel, R. 2004. Soil & Landform Metrics: Programs and U.S. Geodatasets Version 1.1. Environmental Protection Agency. Las Vegas, NV.

Data Sources*:

U.S. Department of Agriculture, Natural Resources Conservation Service.
Major Land Resource Area Map, National Land Cover Dataset (NLCD). July 15, 2003. ftp-fc.sc.egov.usda.gov/NHQ/pub/land/arc_export/us48mlra.e00.zip

State Soils Geographic (STATSGO) Dataset. April 17, 2003. http://www.ncgc.nrcs.usda.gov/branch/ssb/products/statsgo/

U.S. Geological Survey.
National Elevation Dataset 30-Meter Digital Elevation Models (DEMs). April 8, 2003. http://gisdata.usgs.net/NED/default.asp

**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, its geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Appendix D: Automated Geospatial Watershed Assessment Tool – AGWA

The Automated Geospatial Watershed Assessment (AGWA) tool is a multipurpose hydrologic analysis system for use by watershed, water resource, land use, and biological resource managers and scientists in performing watershed- and basin-scale studies (Burns et al., 2004). It was developed by the U.S.D.A. Agricultural Research Service's Southwest Watershed Research Center. AGWA is an extension for the Environmental Systems Research Institute's (ESRI) ArcView versions 3.x, a widely used and relatively inexpensive geographic information system (GIS) software package.

AGWA provides the functionality to conduct all phases of a watershed assessment for two widely used watershed hydrologic models: the Soil and Water Assessment Tool (SWAT); and the KINematic Runoff and EROSion model, KINEROS2.

The watershed assessment for the Little Colorado River Watershed was performed with the Soil and Water Assessment Tool. SWAT (Arnold et al., 1994) was developed by the USDA Agricultural Research Service (ARS) to predict the effect of alternative land management decisions on water, sediment and chemical yields with reasonable accuracy for ungaged rural watersheds. It is a distributed, lumped-parameter model that will evaluate large, complex watersheds with varying soils, land use and management conditions over long periods of time (> 1 year). SWAT is a continuous-time model, i.e. a long-term yield model, using daily average input values, and is not designed to simulate detailed, single-event flood routing. Major components of the model include: hydrology, weather generator, sedimentation, soil temperature, crop growth, nutrients, pesticides, groundwater and lateral flow, and agricultural management. The Curve Number method is used to compute rainfall excess, and flow is routed through the channels using a variable storage coefficient method developed by Williams (1969). Additional information and the latest model updates for SWAT can be found at http://www.brc.tamus.edu/swat/.

Data used in AGWA include Digital Elevation Models (DEMs), land cover grids, soil data and precipitation data.

For this study data were obtained from the following sources:

- DEM: United States Geological Survey National Elevation Dataset, 30-Meter Digital Elevation Models (DEMs). April 8, 2003. http://gisdata.usgs.net/NED/default.asp
- Soils: USDA Natural Resource Conservation Service, STATSGO Soils. April 17, 2003. http://www.ncgc.nrcs.usda.gov/branch/ssb/products/statsgo/
- Land cover: Southwest GAP Analysis Project Regional Provisional Land Cover dataset. September, 2004. http://earth.gis.usu.edu/swgap/

- Precipitation Data: Cooperative Summary of the Day TD3200: Includes daily weather data from the Western United States and the Pacific Islands. Version 1.0. August 2002. National Oceanic and Atmospheric Administration/National Climatic Data Center, Asheville, North Carolina.

The AGWA Tools menu is designed to reflect the order of tasks necessary to conduct a watershed assessment, which is broken out into five major steps, as shown in Figure 1 and listed below:

1. Watershed delineation and discretization;
2. Land cover and soils parameterization;
3. Writing the precipitation file for model input;
4. Writing the input parameter file and running the chosen model; and
5. Viewing the results.

When following these steps, the user first creates a watershed outline, which is a grid based on the accumulated flow to the designated outlet (pour point) of the study area. The user then specifies the contributing area for the establishment of stream channels and subwatersheds (model elements) as required by the model of choice.

From this point, the tasks are specific to the model that will be used, which in this case is SWAT. If internal runoff gages for model validation or ponds/reservoirs are present in the discretization, they can be used to further subdivide the watershed.

The application of AGWA is dependent on the presence of both land cover and soil GIS coverages. The watershed is intersected with these data, and parameters necessary for the hydrologic model runs are determined through a series of look-up tables. The hydrologic parameters are added to the watershed polygon and stream channel tables.

For SWAT, the user must provide daily rainfall values for rainfall gages within and near the watershed. If multiple gages are present, AGWA will build a Thiessen polygon map and create an area-weighted rainfall file. Precipitation files for model input are written from uniform (single gage) rainfall or distributed (multiple gage) rainfall data.

In this modeling process, the precipitation file was created for a 10-year period (1990-2000) based on data from the National Climatic Data Center. In each study watershed multiple gages were selected based on the adequacy of the data for this time period. The precipitation data file for model input was created from distributed rainfall data.

After all necessary input data have been prepared, the watershed has been subdivided into model elements, hydrologic parameters have been determined for each element, and rainfall files have been prepared, the user can run the hydrologic model of choice. SWAT was used in this application.

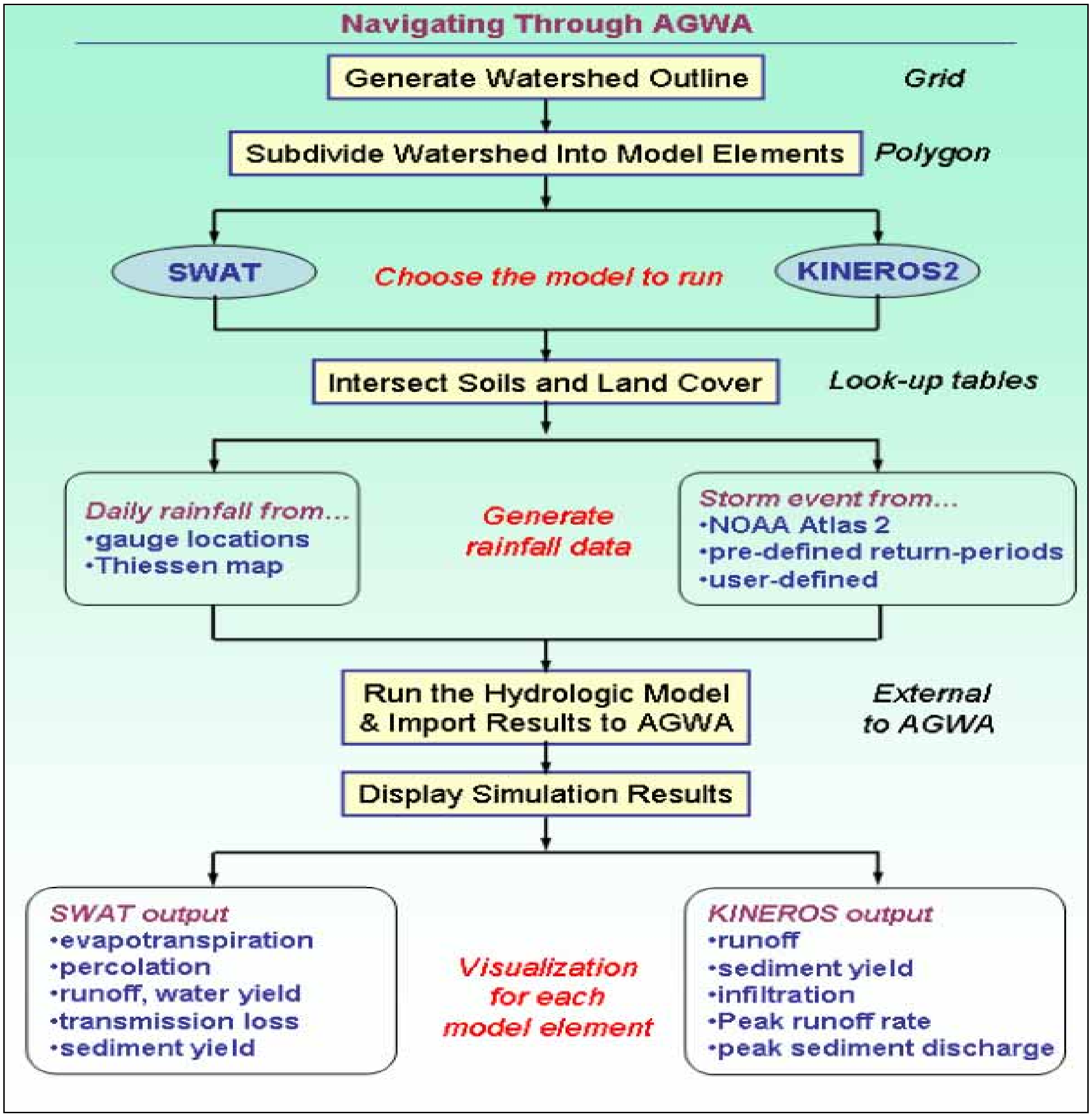

Figure D-1: Flow chart showing the general framework for using KINEROS2 and SWAT in AGWA.

After the model has run to completion, AGWA will automatically import the model results and add them to the polygon and stream map tables for display. A separate module within AGWA controls the visualization of model results. The user can toggle between viewing the total depth or accumulated volume of runoff, erosion, and infiltration output for both upland and channel elements. This enables problem areas to be identified visually so that limited resources can be focused for maximum effectiveness. Model results can also be overlaid with other digital data layers to further prioritize management activities.

Output variables available in AGWA/SWAT are:

- Channel Discharge (m^3/day);
- Evapotranspiration (ET) (mm);
- Percolation (mm);
- Surface Runoff (mm);
- Transmission loss (mm);
- Water yield (mm);
- Sediment yield (t/ha); and
- Precipitation (mm).

It is important to note that AGWA is designed to evaluate relative change and can only provide qualitative estimates of runoff and erosion. It cannot provide reliable quantitative estimates of runoff and erosion without careful calibration. It is also subject to the assumptions and limitations of its component models, and should always be applied with these in mind.

References:

Arnold, J.G., J. R. Williams, R. Srinivasan, K.W. King, and R. H. Griggs. 1994. SWAT-Soil & Water Assessment Tool. USDA, Agricultural Research Service, Grassland, Soil and Water Research Laboratory, Temple, Texas.

Burns, I.S., S. Scott, L. Levick, M. Hernandez, D.C. Goodrich, S.N. Miller, D.J. Semmens, and W.G. Kepner. 2004. Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual *Version 1.4*. http://www.tucson.ars.ag.gov/agwa/

RS/GIS Laboratory, 2004. Southwest Gap Regional Provisional Landcover. http://earth.gis.usu.edu/swgap Land cover / land use. Sept. 24, 2004.

Williams, J.R. 1969. Flood routing with variable travel time or variable storage coefficients. Trans. ASAE 12(1):100-103.