NEMO Watershed Based Plan

Upper Gila 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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Executive Summary

The objective of this study was to develop a watershed based plan for the Upper Gila Watershed that includes a characterization and classification of the watershed features. This watershed based plan identifies areas that are susceptible to water quality problems and nonpoint pollution sources that need to be controlled, and management measures that should be implemented to improve water quality throughout the watershed.

The first part of the project focused on watershed characterization identifying physical, biological and social characteristics of the Upper Gila Watershed from publicly available information. ArcGIS (Environmental Systems Research Institute, Inc.) software was used to construct a spatial database including topography, land cover, soil types and characteristics, geology, vegetation, hydrologic features, and population characteristics.

After developing the geographic information system (GIS) spatial database, watershed classifications were performed to identify important resources and rank 10-digit HUC (hydrologic unit code) subwatershed areas based on likelihood of nonpoint source pollutant contribution to stream water quality degradation. A HUC is a means of subdividing watersheds into successively smaller hydrologic units of surface water drainage features.

To achieve the objective of developing a watershed classification, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types. Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized as a method by which to quantify common sense. This methodology has been selected as the basis by which subwatershed areas and stream reaches were prioritized for proposed implementation of Best Management Practices to assure load reductions of constituents of concern.

The water quality results reported in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), and EPA's (U.S. Environmental Protection Agency) revisions of Arizona's final 2004 303d List for water quality results were reviewed and summarized for each monitored stream reach in the Upper Gila Watershed. Based on exceedances of water quality standards in each reach and the designated use classification system, each stream reach was classified as extreme, high, medium or low risk of impairment. Each subwatershed was then ranked using a scale of 0-1 based on the stream reach condition in each 10-digit HUC and downstream reach condition.

Subwatershed classification ranking data were then created based on calculated parameters for each of the water quality constituent groups and by simulating hydrologic response using the GIS data. For each constituent group several parameters were calculated in each subwatershed and a fuzzy membership value (FMV) was developed in order to assign a ranked value (0-1) to each 10-digit HUC subwatershed. The FMV for each parameter and the ranked water quality assessment data were combined, and each subwatershed was ranked and categorized as either low or high risk for nonpoint source pollution problems.

The Revised Universal Soil Loss Equation (RUSLE) model (USDA, 1997) was used to estimate sediment yield due to land use or land use change. The Soil and Water Assessment Tool (SWAT) hydrologic model (Arnold et al., 1994) within the Automated Geospatial Watershed Assessment Tool (AGWA) (Burns et al., 2004) was also applied to simulate sediment yield and runoff for each 10-digit HUC subwatershed area.

Unique Waters of the state, mapped wilderness areas and preserves, riparian areas, and critical habitat for endangered species were used to identify important Natural Resource Areas (NRA) at the scale of 10-digit HUC subwatersheds in the Upper Gila Watershed. These were then used to recommend management actions specific to the conditions in each NRA.

Best Management Practices for each subwatershed were proposed based on the watershed assessment data and available ADEQ Total Maximum Daily Load (TMDL) reports. This section of the document includes general watershed management methods, recommended strategies for addressing existing impairment in the watershed, stream channel and riparian restoration, and proposed education programs.

As a result of this study, the primary sources for nonpoint source pollutant concerns in the Upper Gila Watershed were identified as abandoned mine sites, new development and increased urbanization, and new road construction. Apache Creek-Upper Gila River, Yuma Wash-Upper Gila River, Centerfire Creek-San Francisco River, Mule Creek-San Francisco River, Chase Creek-San Francisco River, and Stockton Wash subwatersheds are prioritized as high risk areas from nonpoint source pollutants (metals, sediment or organic constituents).

References:

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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)).

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. It is differentiated from point source pollution in that, for some states such as Arizona, there are no regulatory mechanisms by which to enforce clean up of nonpoint source pollution.

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, 2003) 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 where a TMDL has been developed and approved or is in the process of being developed, watershed-based plans must be designed to achieve the load reductions called for in the TMDL.

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. This 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.

- 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.

Watershed-based plans are holistic documents that are 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 will deliver proactive measures to protect water bodies. In watersheds where a TMDL has been developed and approved or is in the process of being developed, watershed-based plans must be designed to achieve the load reductions called for in the TMDL.

Purpose and Scope

This watershed based plan includes a characterization and classification for the Upper Gila Watershed to support pending water quality improvement projects and to provide educational outreach material to stakeholders and watershed partnerships. It provides an inventory of natural resources and environmental conditions that affect primarily surface water quality.

In addition to the classification, this plan provides methods and tools to identify problem sources and locations for implementation of Best Management Practices to mitigate nonpoint source pollution. Although these chapters are written based on current information, the tools developed can be used to update this report and reevaluate water quality concerns as new information becomes available.

The watershed characterization includes physical, biological, and social data in a geographic information system (GIS) database format, as both mapped and tabulated data, as collected from available existing and published data sources. No additional data were collected.

It also includes descriptions of environmental attributes and identification of water quality problems by incorporating water quality data reported in *The DRAFT Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report* (ADEQ, 2003), ADEQ's biennial report consolidating water quality reporting requirements under the federal Clean

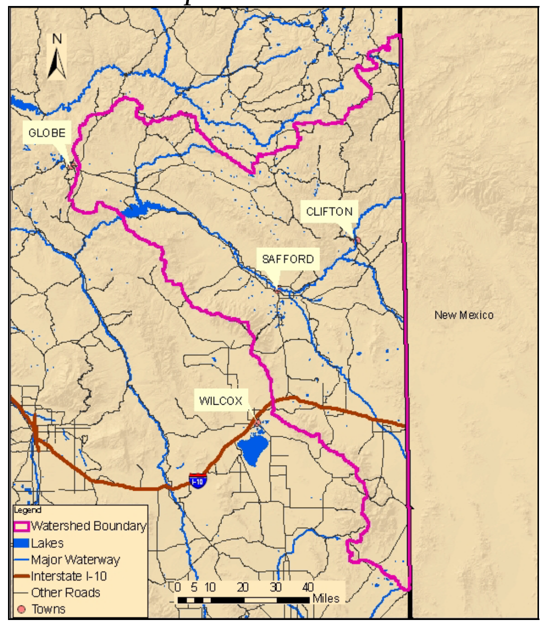
Water Act. The ADEQ water quality data, TMDL definitions, and further information for each stream reach and the surface water sampling sites across the state can be found at: www.adeq.state.az.us/environ/water/assessment/assess.html.

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

Following the classification, this watershed plan includes general discussions of recommended nonpoint source Best Management Practices (BMPs) that will need to be implemented to achieve load reductions, as well as to achieve other watershed goals. 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 appropriate and revise management activities as conditions within the watershed change.

The Upper Gila Watershed is located in the southeastern portion of the state of Arizona, bounded by the city of Globe to the east, and the state of New Mexico to the west, as shown in Figure 1-1.

Figure 1-1: Upper Gila Watershed Location Map.



Methods

GIS and hydrologic modeling were the major tools used to develop this watershed plan. Two types of information represent geographic features in a GIS: locational and descriptive data. Locational (spatial) data is stored using a vector or a raster 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, each of which is limited and defined by an equal amount of earth's surface. These units are of different shapes, i.e. triangular or hexagonal, but the most commonly used shape is the square, called a cell. Corresponding descriptive (attribute) data for each geographic feature are stored in a set of tables. The spatial and descriptive data are linked so that both sets of information are always available.

Planning and assessment in land and water resource management requires spatial modeling tools so as to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Upper Gila Watershed included 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, and to simulate sediment load in the 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 Revised Universal Soil Loss Equation (RUSLE) was also used to estimate soil loss from different land use types (Renard et al., 1997).

The watershed classifications incorporate 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, 2003), and simulate impacts due to mine sites (erosion and metals pollution) and grazing (erosion and pollutant nutrients).

The Upper Gila 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).

Within the six-digit HUC, subwatershed areas were delineated on the basis of the eight-digit cataloging HUC, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

Within this report, both HUC units and subwatershed names are used to clarify location. This watershed assessment uses the following HUC watersheds:

- The Upper Gila Watershed (150400)
  - Upper Gila (15040002)
    - Railroad Wash (1504000208)
    - Apache Creek (1504000207)
  - Animas Valley (15040003)
    - Animas Valley (1504000300)
  - San Francisco River (15040004)

Centerfire Creek (1504000403)
Upper Blue (1504000405)
Pueblo Creek (1504000406)
Lower Blue (1504000407)
Mule Creek (1504000408)
Chase Creek (1504000409)
Gila Valley (15040005)
Willow Creek (1504000501)
Upper Eagle (1504000502)
Lower Eagle (1504000503)
Bonita Creek (1504000504)
Yuma Wash (1504000505)
Stockton Wash (1504000506)
Cottonwood Wash (1504000507)
Black Rock Wash (1504000508)
Goodwin Wash (1504000509)
San Simon Creek (15040006)
San Simon River Headwaters (1504000601)
Cave Creek (1504000602)
Happy Camp (1504000603)
East Whitetail Creek (1504000604)
Hot Well Draw (1504000605)
Tule Wells Draw (1504000606)
Gold Gulch (1504000607)
Slick Rock Wash ((1504000608)
San Carlos River (15040007)
Ash Creek (1504000701)
Sevenmile Draw (1504000702)
Gilson Wash (1504000703)
San Carlos River (1504000704)

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 handle vagueness or uncertainty, and has been characterized 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. For example, one is either tall or short, 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 considered in the tall class, although he could not be considered 'not-tall'. This is not satisfactory, for example, if one has to describe or quantify 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, and in the case above, the degree of tallness was iteratively added in intervals of 0.2. An example of a continuous data set would be graphing heights of all individuals and correlating 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. Using the example above, a tall individual of the degree 0.2 would be 5' 8" tall.

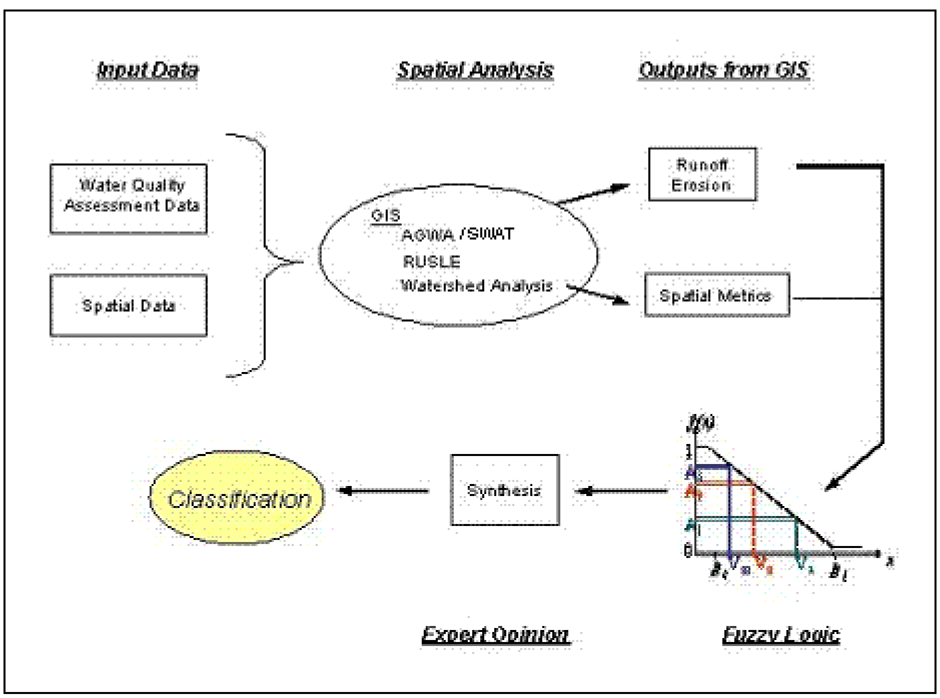
The development of a fuzzy membership function can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. Another benefit of this approach is that it provides for the use of different methods for combining individual factors 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.

Our general approach 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. 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 (in this example, dissolved / total metals water quality impairment to streams due to mine activity);

2. Assemble GIS data and other observational data;

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



3. Define watershed characteristics through:

    a. Water quality data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report;
    b. GIS mapping analysis; and
    c. Modeling / simulation of erosion vulnerability / 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 vulnerability / impairment metrics into fuzzy membership values; and

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

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 the watershed classification, the goal is to identify critical subwatersheds in which BMPs should be implemented to reduce nonpoint source pollution.

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), 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, turbidity/sediment, and nutrients. Two 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 exceedences in a constituent group and there are sufficient data to make a classification. Classifications were conducted at the 10-digit HUC subwatershed scale, resulting in the ranking of thirty-one subwatershed areas within the nearly 7,350 square mile area of the Upper Gila Watershed.

Structure of this Watershed Based Plan

This watershed based plan includes eight sections and four appendices. The watershed characterization, including physical, biological, and social characteristics, are discussed in Sections 2 through 4. Important environmental resources are discussed in Section 5, and 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, and the Watershed Plan is presented in Section 8.

The full tabulation of the ADEQ water quality data and assessment status is provided in Appendix A. Appendix B is a list of selected technical references applicable to the Upper Gila Watershed, Appendix C discusses the Revised Universal Soil Loss Equation used in the modeling, and Appendix D describes the AGWA tool.

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Section 2: Physical Features

The Gila River stretches from western New Mexico's Gila mountains to the Colorado River in Yuma, Arizona. The Upper Gila Watershed in Arizona is defined by the Gila River drainage area from where the river enters the state from New Mexico to Coolidge Dam (San Carlos Reservoir). Although the Gila River Watershed continues eastward and upstream into the state of New Mexico, this study is limited to the area within the state of Arizona, as shown on Figure 2-1. Downstream from Coolidge Dam the watershed area is designated the Middle Gila Watershed, and the river channel skirts the metropolitan Phoenix area.

Watershed Size

The Upper Gila Watershed area is approximately 7,350 square miles, which covers a little over 6% of the state of Arizona. The watershed has a maximum approximate width of 100 miles east-west, and a maximum length of 168 miles north-south. 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 7,820 square miles of Upper Gila Watershed is within the state of New Mexico.

The watershed was delineated by 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. This report will work with two levels, an eight-digit HUC, and a subdivision of these, a 10-digit HUC. The subwatershed areas were delineated on the basis of the eight-digit cataloging HUC, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

The eight-digit subwatershed HUCs of the Upper Gila 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.

Figure 2-1: Upper Gila Watershed.

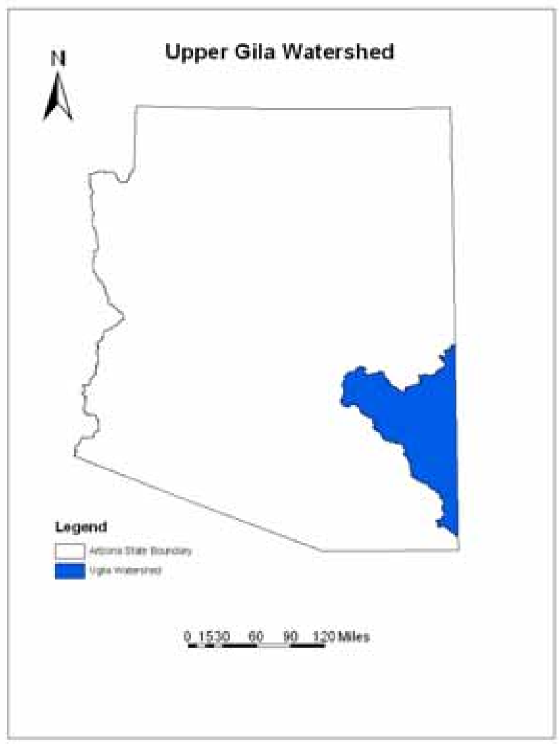


Table 2-1: Upper Gila Watershed HUCs and Subwatershed Areas in Arizona.

Subwatershed Name HUC	Area (square miles)
Upper Gila H15040002	**542**
Animas Valley H15040003	**17**
San Francisco River H15040004	**938**
Gila Valley H15040005	**2,779**
San Simon Creek H15040006	**2,004**
San Carlos River H15040007	**1,070**
Total Upper Gila Watershed	***7,350***

Figure 2-2: Upper Gila Watershed HUCs.

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

Topography

The land surface elevation of the Upper Gila Watershed ranges between 2,334 and 10,912 feet above mean sea level (msl). The tallest feature in the watershed is Escudilla Mountain in the Apache- Sitgreaves National Forest at 10,912 feet msl, within the San Francisco River subwatershed. The lowest elevation is at 2,334 feet at Coolidge Dam in the Gila Valley subwatershed. Mount Graham, at 10,717 feet msl, is found within the San Simon Creek subwatershed. Mean elevation for the whole Upper Gila Watershed is approximately 4,660 feet msl. Both the Animas Valley and the San Francisco River subwatersheds have a mean elevation greater than 5,000 feet msl, and both extend into New Mexico.

Figure 2-3: Upper Gila Watershed Topography.

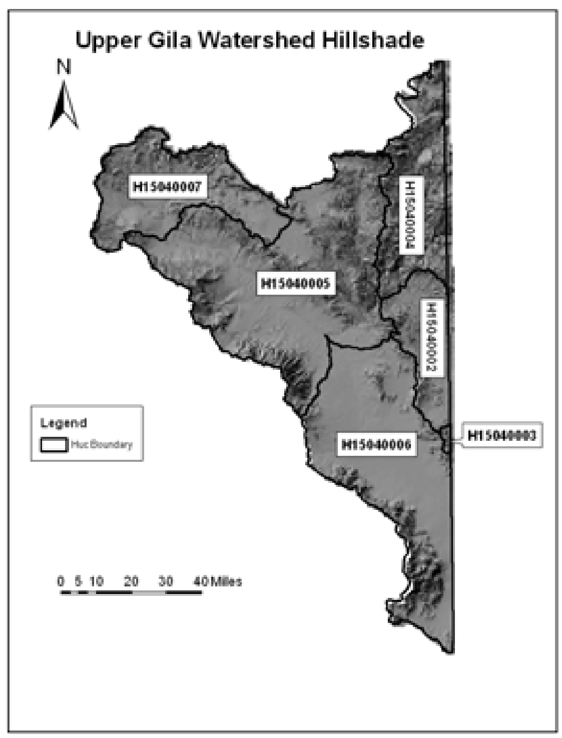


Table 2-2: Upper Gila Watershed Elevation Range (feet above mean sea level).

Subwatershed Name	Min Elev.	Max Elev.	Mean Elev.
Upper Gila H15040002	**3,279**	**7,489**	**4,317**
Animas Valley H15040003	**4,406**	**6,519**	**5,044**
San Francisco River H15040004	**3,279**	**10,749***	**6,291**
Gila Valley H15040005	**2,334**	**10,703**	**4,537**
San Simon Creek H15040006	**2,939**	**9,749**	**4,301**
San Carlos River H15040007	**2,495**	**7,533**	**4,383**
Upper Gila Watershed	***2,334***	***10,749***	***4,659***

*****Because of data resolution, this value is an average elevation within a 10 X 10 meter area around Escudilla Peak, elevation 10,912 feet msl.

The GIS was used to analyze the variation in slope and to determine slope classes. Slightly less than one-half of the Upper Gila Watershed has a slope of 15% or greater, while 34% of the watershed exhibits land slope between 0 to 5% (Figure 2-4). The rugged San Francisco River area is the only subwatershed that significantly deviates from this, with 80% of its area in the 15% or greater slope category, and only 5% of its area with a slope between 0 to 5%. Most areas in the other subwatersheds have a 15% or greater slope except the San Simon Creek subwatershed which exhibits a slope of 0 to 5% for most of the land area.

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

Figure 2-4: Upper Gila Watershed Slope Classes.

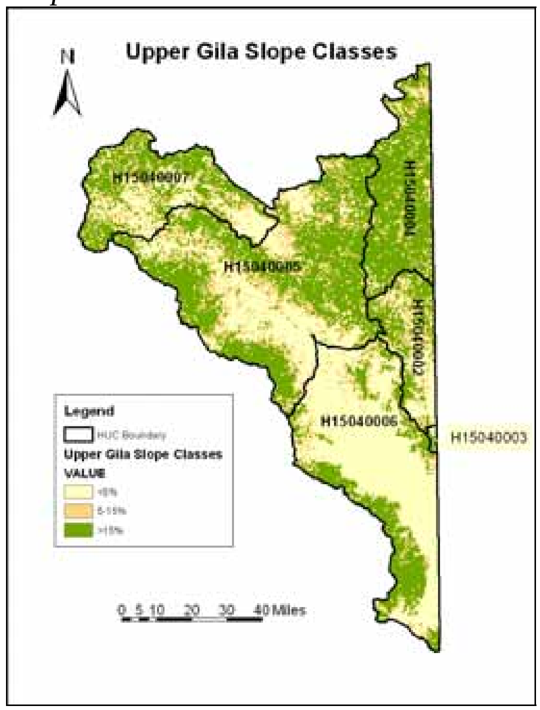


Table 2-3: Upper Gila Watershed Slope Classes.

Subwatershed Name	0-5%	5-15%	>15%
Upper Gila H15040002	**29%**	**25%**	**46%**
Animas Valley H15040003	**24%**	**22%**	**54%**
San Francisco River H15040004	**5%**	**15%**	**80%**
Gila Valley H15040005	**27%**	**20%**	**53%**
San Simon Creek H15040006	**63%**	**12%**	**25%**
San Carlos River H15040007	**29%**	**22%**	**49%**
Upper Gila Watershed	***34%***	***18%***	***48%***

Water Resources

The Gila River is relatively unique in that it has mostly unimpeded flow with only a few relatively small irrigation diversions until impoundment by the Coolidge Dam. The Coolidge Dam and reservoir system irrigates approximately 100,000 acres, half of which is found on the San Carlos Reservation Tribal lands. Built in 1927-28, the dam is 249 feet high and 920 feet long, and is named for the 29th president of the United States.

Two river segments within the Upper Gila Watershed are classified as Unique Waters of the State: Bonita Creek and Cave Creek. These waters were found to be outstanding state water resources 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.

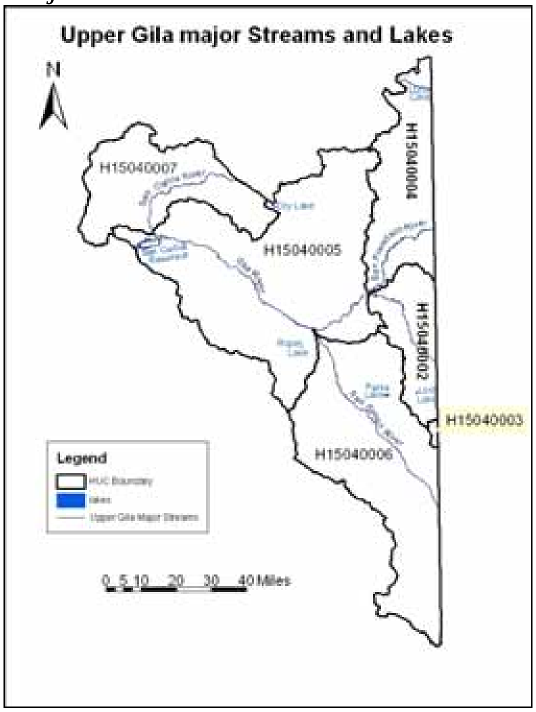
Lakes and Reservoirs

There are 230 lakes and 11 reservoirs within the Upper Gila Watershed. Among these, San Carlos Reservoir has the largest open surface water area within the watershed at about 8,475 acres. The San Carlos Reservoir forms behind the Coolidge Dam. Table 2-4 shows major lakes within the watershed and their associated surface water area.

Table 2-4: Upper Gila Watershed Lakes and Reservoirs.

Lake Name	Subwatershed	Surface Area (acre)	Elevation (feet above mean sea level)	Dam Name (if known)
San Carlos Reservoir	Gila Valley	8,475	2,497	Coolidge Dam
Parks Lake	San Simon Creek	427	3,521	not known
Dry Lake	Gila Valley	230	6,972	not known
Unnamed Lake	San Simon Creek	152	4,610	not known
Lost Lake	Upper Gila	124	4,416	not known
Luna Lake	San Francisco River	120	7,884	not known
Salt Shed Tank	Gila Valley	73	6,024	not known
Point of Pines Lake	Gila Valley	47	6,204	not known
Unnamed Reservoir	Gila Valley	35	2,920	Rogers Reservoir Dam
Big Tank	Upper Gila	28	4,282	Big Tank Detention Dam

Figure 2-5: Upper Gila Watershed Major Lakes and Streams.



Stream Type

The Upper Gila Watershed has a total channel length of 11,826 miles, and three different stream types: ephemeral, perennial, and intermittent.

- Perennial surface water means surface water that flows continuously throughout the year.
- Intermittent surface water means a stream or reach of a stream that flows continuously only at certain times of the year, as when it receives water from a seasonal spring or from another source, such as melting spring snow.
- An ephemeral stream is at all times above the ground water table, has no base flow, and flows only in direct response to precipitation.

Ninety five percent of the streams in the Upper Gila Watershed are ephemeral streams with a total accumulated length of 11,213 miles. Only approximately 5% of streams are perennial, mostly restricted to the main stem of the Gila River. The remaining intermittent drainages are found in the western region of the Gila Valley subwatershed.

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

Figure 2-6: Upper Gila Watershed Stream Types.

Table 2-5: Upper Gila Watershed Stream Type and Length.

Stream Type	Stream Length (miles)	Percent of Total Stream's Length
Intermittent	**5**	**<1%**
Perennial	**609**	**5%**
Ephemeral	**11,213**	**95%**
Total Length	***11,826***	***100%***

Table 2-6: Upper Gila Watershed Major Stream Lengths.

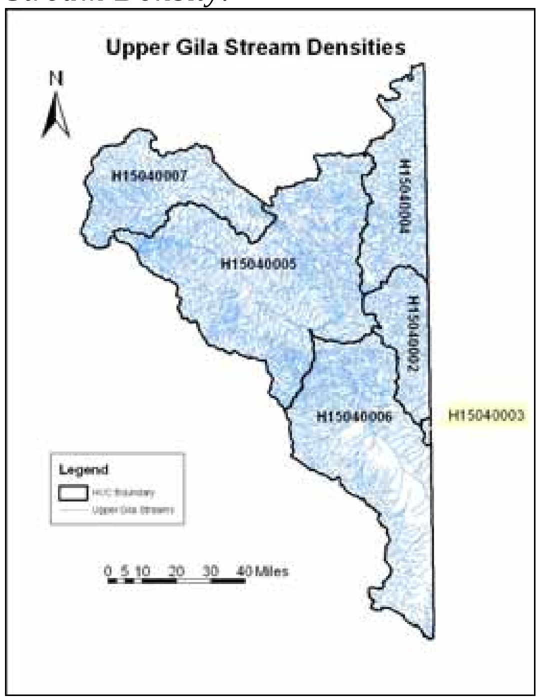
Tributary Name	Subwatershed	Stream Length(miles)
Gila River	**Upper Gila-Gila Valley**	**217**
San Francisco River	**San Francisco River**	**88**
San Simon River	**San Simon Creek**	**78**
Eagle Creek	**Gila Valley**	**64**
Bonita Creek	**Gila Valley**	**53**
Blue River	**San Francisco River**	**51**
San Carlos River	**San Carlos River**	**49**
Stockton Wash	**Gila Valley**	**33**
Gold Gulch	**San Simon Creek**	**33**
Sycamore Creek	**San Carlos River**	**28**

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 2-7 shows stream density for the Upper Gila Watershed, and Table 2-7 gives the stream density for each subwatershed in feet of stream length per acre. Stream density is similar throughout most of the Upper Gila Watershed, except for the very small portion of the Animas sub-watershed that occurs in Arizona.

Figure 2-7: Upper Gila Watershed Stream Density.



Annual Stream Flow

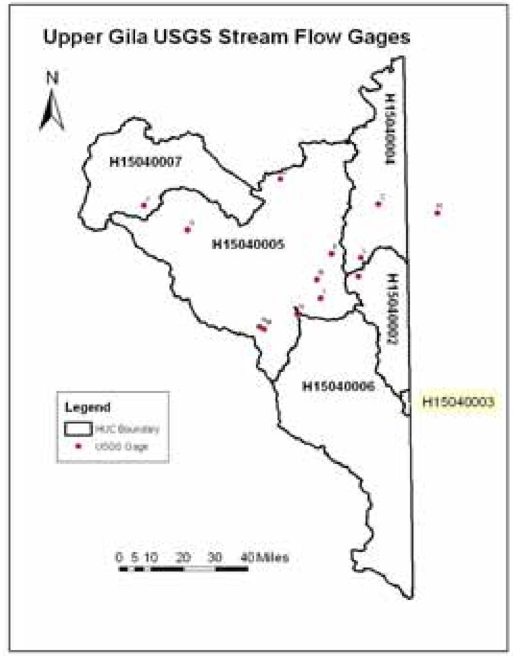
Annual stream flows for fourteen gages were calculated for the Upper Gila Watershed. These gages were selected based on their location, length of date record, and representativeness of watershed response. Figure 2-8 shows the location of these gages.

The Gila River at the head of Safford Valley gage has the highest measured mean annual stream flow with 465.4 cubic feet per second while Fry Creek near Thatcher has the lowest measured mean annual stream flow at 1.42 cubic feet per second.

Table 2-7: Upper Gila Watershed Stream Density.

Sub watershed	Area (acre)	Stream Length (feet)	Stream Density(ft/ac)
Upper Gila H15040002	**346,662**	**5,211,443**	**15.03**
Animas Valley H15040003	**11,031**	**78,741**	**7.14**
San Francisco River H15040004	**600,233**	**8,629,060**	**14.38**
Gila Valley H15040005	**1,778,441**	**29,252,845**	**16.45**
San Simon Creek H15040006	**1,282,351**	**15,232,372**	**11.88**
San Carlos River H15040007	**684,494**	**9,940,484**	**14.52**
Upper Gila Watershed	***4,703,215***	***68,344,945***	***14.53***

Figure 2-8: Upper Gila Watershed USGS Gages.



Figures 2-9, 2-10, and 2-11 show typical hydrographs for the watershed. Figure 2-12 is a 5-year moving average of stream flow of the Gila River at the head of Safford Valley, near Solomon.

Table 2-8: Upper Gila Watershed USGS Gages.

Map ID	Site Name	Begin Date	End Date	Annual Mean Stream Flow (cfs)
A	**Frye Creek near Thatcher**	**10/1/1989**	**9/30/2003**	**1.4**
B	**Bonita Creek near Morenci**	**8/1/1981**	**9/30/2003**	**13.2**
C	**Blue River near Clifton**	**11/7/1967**	**9/30/2003**	**69.6**
D	**Willow Creek Div from Black River**	**4/21/1945**	**9/30/2002**	**11.4**
E	**Eagle Creek abv Pumping Plant**	**4/1/1944**	**9/30/2003**	**67.5**
F	**Gila River Near Redrock**	**10/1/1930**	**9/30/2002**	**218.6**
G	**Gila River at Calva**	**10/1/1929**	**9/30/2003**	**375.5**
H	**San Francisco River near Glenwood**	**10/1/1927**	**9/30/2002**	**89.1**
I	**Gila River at Head of Safford Valley**	**10/1/1920**	**9/30/2003**	**465.4**
J	**San Carlos River near Peridot**	**4/1/1914**	**9/30/2003**	**60**
K	**Gila River near Clifton**	**11/1/1910**	**9/30/2003**	**204.1**
L	**San Francisco River at Clifton**	**10/23/1910**	**9/30/2003**	**220.5**

Map ID	Site Name	Begin Date	End Date	Annual Mean Stream Flow (cfs)
M	**Deadman Creek Near Safford**	**11/10/1966**	**9/30/1993**	**1.6**
N	**San Simon River near Solomon**	**6/1/1931**	**9/30/1982**	**11.6**

Figure 2-9: USGS Gage 09468500 (San Carlos River Near Peridot, AZ) Hydrograph.

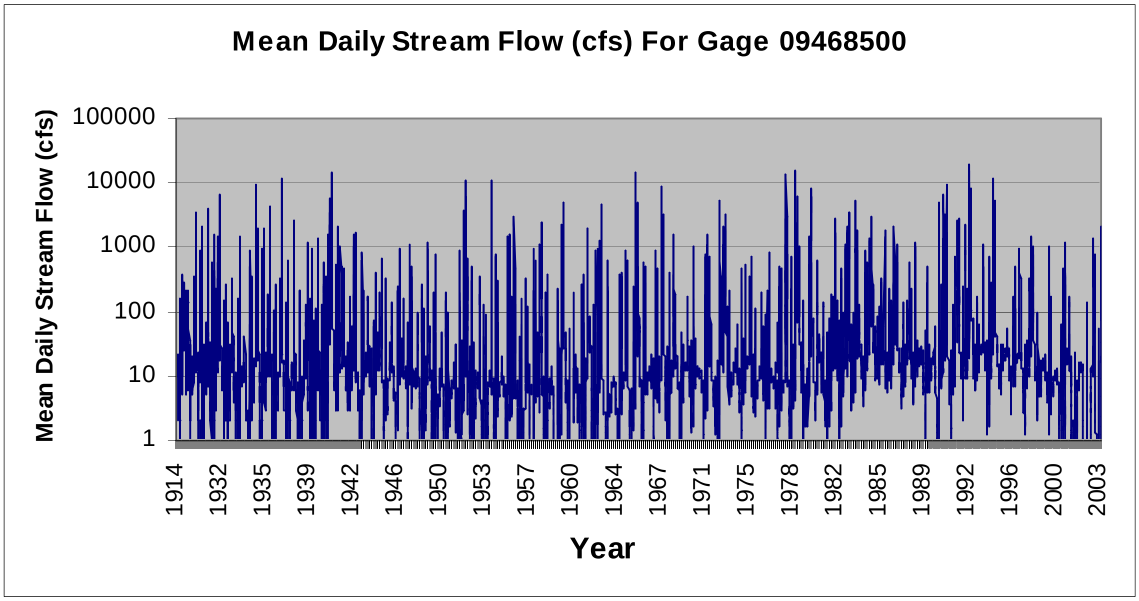


Figure 2-10: USGS Gage 09448500 (Gila River at Head of Safford Valley, Near Solomon) Hydrograph.

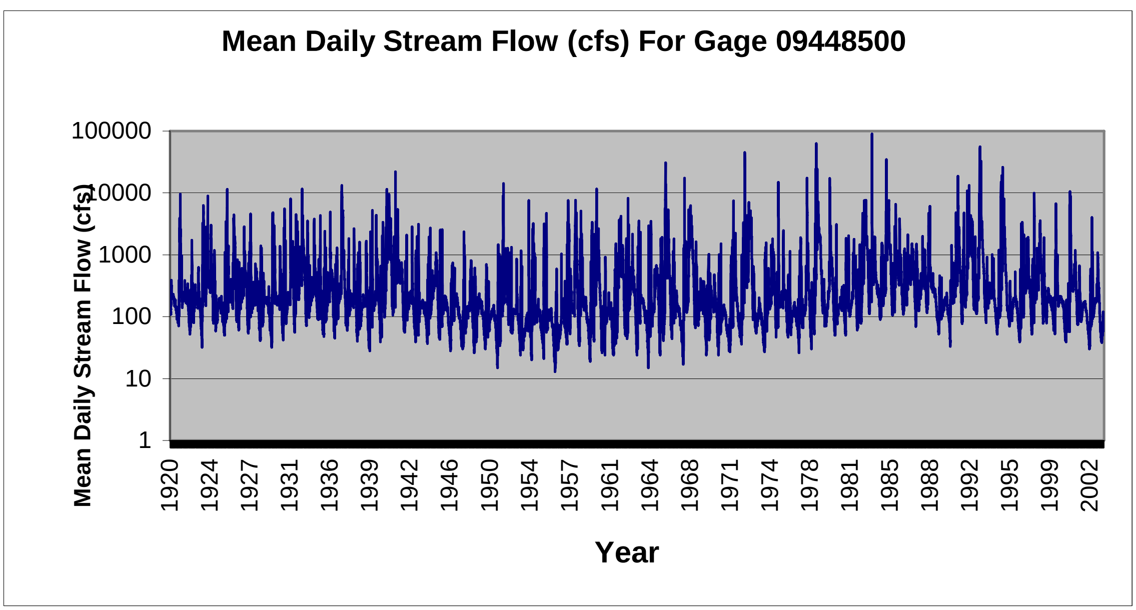


Figure 2-11: USGS Gage 09444500 (San Francisco River at Clifton) Hydrograph.

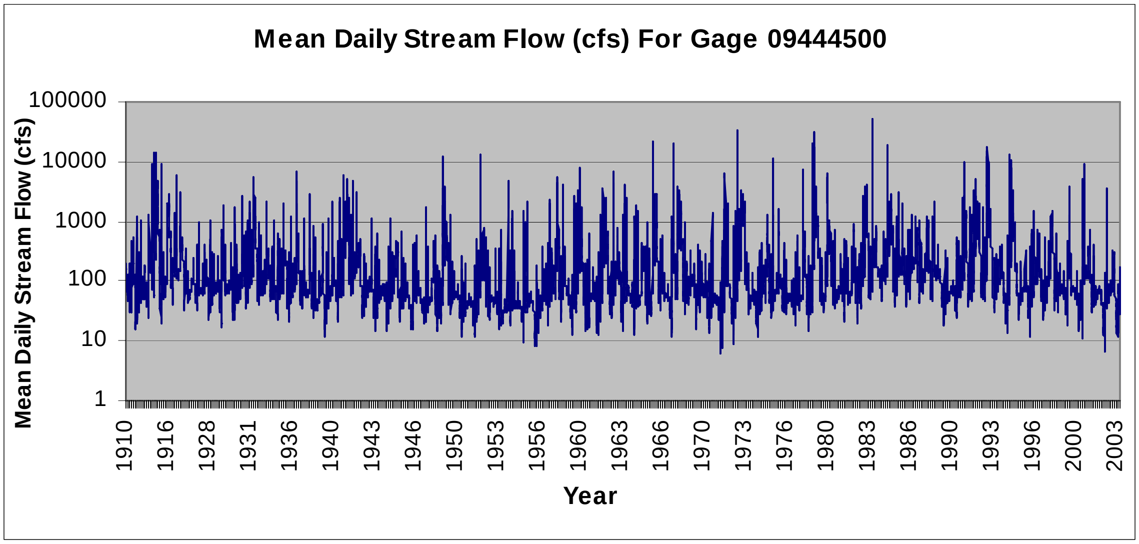
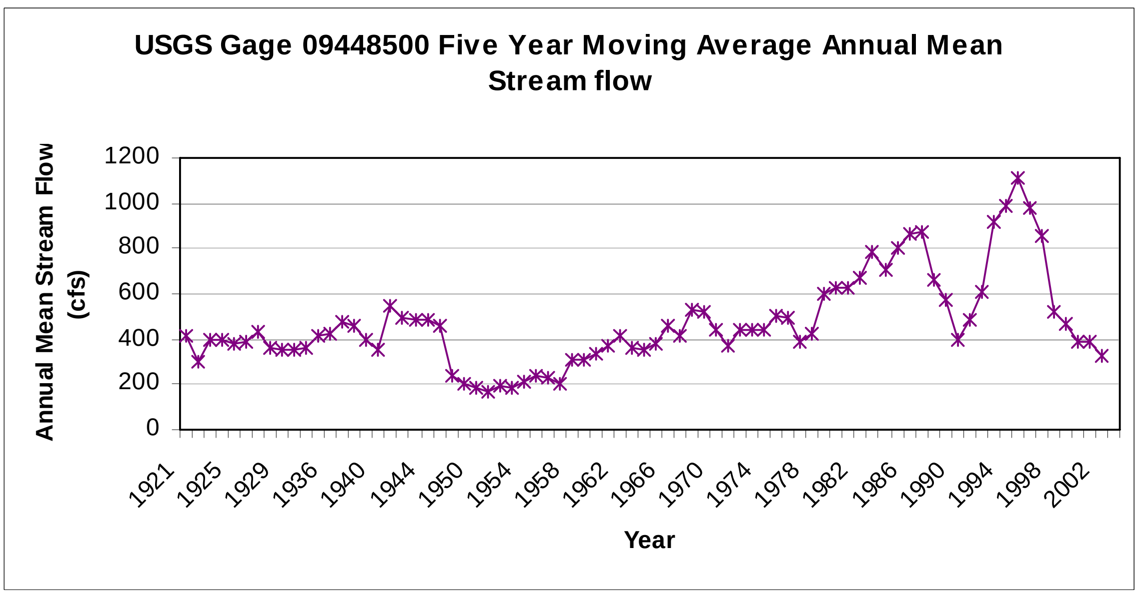


Figure 2-12: USGS Gage 09448500 (Gila River at Head of Safford Valley, Near Solomon) Five Year Annual Moving Average Stream Flow (cfs).



Water Quality

In the Upper Gila Watershed four stream reaches and one lake were listed as impaired in 2004 (ADEQ, 2005) (Figure 2-13):

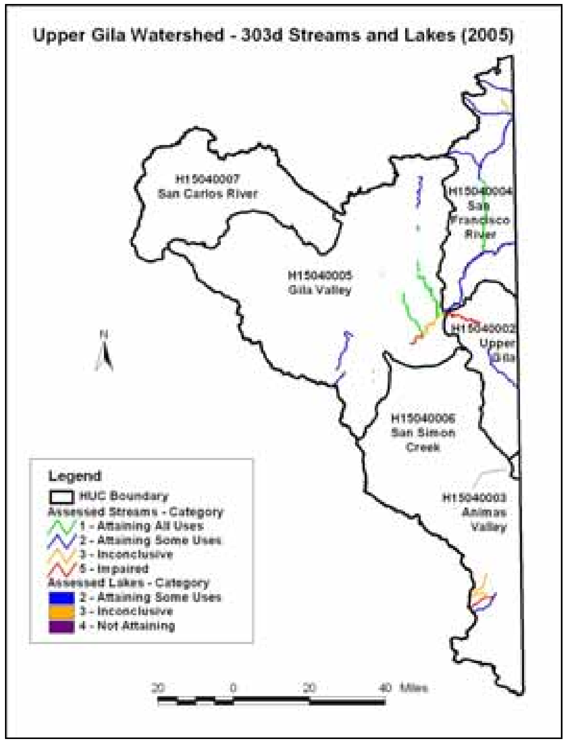
- Cave Creek from its headwaters to South Fork of Cave Creek, due to selenium;
- Gila River from Skully Creek to the San Francisco River due to selenium;
- Gila River between Bonita Creek and Yuma Wash due to bacterial contamination (*Escherichia coli*) and turbidity/suspended sediment;
- San Francisco River from its headwaters to the New Mexico border (Luna Lake area) due to turbidity; and
- Luna Lake due to excessive nutrients.

Several other streams and lakes are listed as inconclusive due to exceedances of standards, but further monitoring is needed to determine if the surface water is impaired or actually attaining its designated uses. Both Bonita Creek and Eagle Creek had reaches that were assessed as "attaining all uses." An explanation of the 303d listing process and a tabulation of the water quality attributes can be found in Section 6, Watershed Classification.

Geology

A majority of the Upper Gila Watershed area is located within the Central Highlands geologic and physiographic transition area between the Basin and Range and Plateau Uplands of Arizona. The San Simon Creek subwatershed lies within the Basin and Range Geologic Province.

Figure 2-13: Upper Gila Watershed 303d Streams and Lakes.

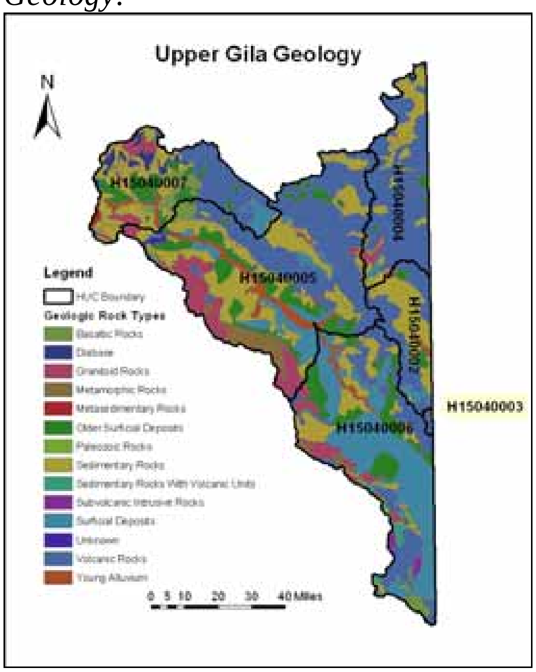


The mountainous Central Highlands lie in a diagonal band between the southern Arizona deserts and the Colorado Plateau. The fault-bound valleys are shallower and less broad than found to the south and flat-laying Precambrian and Paleozoic aged rocks are exposed, similar to what is found in the higher Plateau to the north.

Within the Basin and Range Province, thousands of feet of alluvial fill have eroded from nearly vertical, block-faulted mountains with metamorphic cores. As the deep basins filled with debris and volcanic eruptions dammed streams and isolated drainage basins, thick layers of salt accumulated in the layered sediments. As the basins filled and drainages connected, most southern Arizona streams joined together as tributaries of the Gila River.

Less than five million years ago when the Colorado River became the master drainage of the region, the Gila River drainage network began downcutting to balance with the Colorado system. Within the last two million years, and in response to alternating wet and dry climate cycles, complicated arrays of terraces were eroded along the upper Gila River and its tributaries. These land forms are evident throughout the San Simon Creek and Gila Valley subwatersheds.

Figure 2-14: Upper Gila Watershed Geology.



The geology of the Upper Gila Watershed consists of four major rock types: igneous, sedimentary, metamorphic, and alluvial surficial deposits. These geologic types make up approximately 45%, 24%, 2%, and 28% of the surficial geology. The surficial deposits are differentiated between younger, Holocene to middle Pleistocene, and older, middle Pleistocene to latest Pliocene, surficial deposits, with the older alluvium forming the broad valleys along the Gila River main drainage.

The major rock type for the entire watershed is igneous, except for the San Simon Creek subwatershed where the major rock type is classified as younger surficial deposits (Holocene to middle Pleistocene). The younger surficial deposits are found in isolated terraces along the mountain flanks, residuals of the downcutting that occurred when the regional drainage transferred from the Gila to the Colorado River system.

The igneous rocks are subdivided between extrusive lava flows and light-colored granitic intrusive magma. The igneous intrusions and volcanism permitted mineral-rich solutions to rise toward the land surface and solidify, resulting in most of Arizona's mineral deposits and rich mining history, and contributing to high concentrations of heavy metals in the water and sediments in these areas.

Table 2-9: Upper Gila Watershed Geology (percent by subwatershed).

Name	Geologic Code	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Water-shed*
SEDIMENTARY ROCKS WITH LOCAL VOLCANIC UNITS (Cretaceous to late Jurassic)	**KJs**	**-**	**-**	**-**	**-**	**2.17%**	**-**	***<1%***
SEDIMENTARY ROCKS (Cretaceous)	**Ks**	**-**	**-**	**0.14%**	**0.08%**	**-**	**-**	***<1%***
VOLCANIC ROCKS (late Cretaceous; early Tertiary near Safford)	**Kv**	**-**	**-**	**-**	**0.54%**	**0.63%**	**-**	***<1%***
SEDIMENTARY ROCKS (Mississippian to Cambrian)	**MC**	**0.21%**	**-**	**1.91%**	**1.33%**	**0.35%**	**1.12%**	***1%***
SEDIMENTARY ROCKS (Permian and Pennsylvanian)	**PP**	**-**	**-**	**-**	**-**	**1.27%**	**0.10%**	***<1%***
PALEOZOIC ROCKS (undifferentiated)	**Pz**	**-**	**-**	**-**	**0.29%**	**0.78%**	**-**	***<1%***
SURFICIAL DEPOSITS (Holocene to middle Pleistocene)	**Q**	**7.40%**	**0.12%**	**1.41%**	**7.35%**	**38.73%**	**5.10%**	***15%***
BASALTIC ROCKS (Holocene to late Pliocene; 0 to 4 Ma.)	**QTb**	**-**	**-**	**-**	**1.13%**	**1.99%**	**7.09%**	***2%***
OLDER SURFICIAL DEPOSITS (Middle Pleistocene to latest Pliocene)	**Qo**	**4.53%**	**12.55%**	**1.66%**	**11.51%**	**12.95%**	**13.68%**	***10%***
YOUNG ALLUVIUM (Holocene to latest Pleistocene)	**Qy**	**1.57%**	**-**	**-**	**4.33%**	**2.01%**	**3.07%**	***3%***
GRANITOID ROCKS (early Tertiary to late Cretaceous; 55 to 85 Ma.)	**TKg**	**-**	**-**	**0.84%**	**0.21%**	**0.11%**	**0.15%**	***<1%***
BASALTIC ROCKS (late to middle Miocene; 8 to 16 Ma.)	**Tb**	**-**	**-**	**-**	**-**	**-**	**0.24%**	***<1%***
GRANITOID ROCKS (early Miocene to Oligocene; 18 to 38 Ma.)	**Tg**	**-**	**-**	**-**	**4.36%**	**0.93%**	**-**	***2%***
SUBVOLCANIC INTRUSIVE ROCKS (Middle Miocene to Oligocene)	**Ti**	**-**	**-**	**-**	**-**	**1 %**	**-**	***<1%***
SEDIMENTARY ROCKS (Middle Miocene to Oligocene; 15 to 38 Ma.)	**Tsm**	**0.36%**	**-**	**0.16%**	**0.27%**	**-**	**-**	***<1%***
SEDIMENTARY ROCKS (Oligocene to Eocene or locally Paleocene)	**Tso**	**-**	**-**	**12.64%**	**-**	**-**	**0.00%**	***2%***
SEDIMENTARY ROCKS (Pliocene to middle Miocene)	**Tsy**	**42.59%**	**-**	**7.69%**	**23.47%**	**11.54%**	**17.22%**	***19%***
VOLCANIC ROCKS (Middle Miocene to Oligocene; 15 to 38 Ma.)	**Tv**	**42.99%**	**87.33%**	**71.61%**	**34.74%**	**19.77%**	**26.50%**	***35%***
Unknown	**W**	**-**	**-**	**-**	**0.60%**	**-**	**0.08%**	***<1%***

Name	Geologic Code	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Water-shed*
GRANITOID ROCKS (early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Xg**	**-**	**-**	**-**	**1.05%**	**-**	**-**	***<1%***
METAMORPHIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xm**	**-**	**-**	**0.19%**	**4.37%**	**1.45%**	**-**	***2%***
METASEDIMENTARY ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xms**	**-**	**-**	**-**	**0.52%**	**-**	**0.91%**	***<1%***
GRANITOID ROCKS (Middle or early Proterozoic; 1400 Ma or 1650 to 1750 Ma.)	**YXg**	**0.35%**	**-**	**1.76%**	**-**	**-**	**-**	***<1%***
DIABASE (Middle Proterozoic; 1100 Ma.)	**Yd**	**-**	**-**	**-**	**-**	**-**	**6.54%**	***<1%***
GRANITOID ROCKS (Middle Proterozoic; 1400 Ma.)	**Yg**	**-**	**-**	**-**	**3.73%**	**4.32%**	**6.51%**	***4%***
SEDIMENTARY ROCKS (Middle Proterozoic)	**Ys**	**-**	**-**	**-**	**0.10%**	**-**	**11.67%**	***2%***
Area (square miles)		***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

Table 2-10: Upper Gila Watershed – Rock Type (percent by subwatershed).

Rock Type	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Alluvium	**13.50%**	**12.67%**	**3.07%**	**23.20%**	**53.69%**	**21.86%**	***28.01%***
Igneous Rocks	**43.34%**	**87.33%**	**74.21%**	**45.76%**	**28.75%**	**47.03%**	***45.06%***
Metamorphic Rocks	**-**	**-**	**0.19%**	**4.89%**	**1.45%**	**0.91%**	***2.20%***
Sedimentary Rocks	**43.16%**	**-**	**22.53%**	**25.26%**	**15.33%**	**30.12%**	***24.17%***
Undifferentiated	**-**	**-**	**-**	**0.89%**	**0.78%**	**0.08%**	***0.56%***
Area (square miles)	***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

Soils

Soil characteristics were considered for the Upper Gila 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.

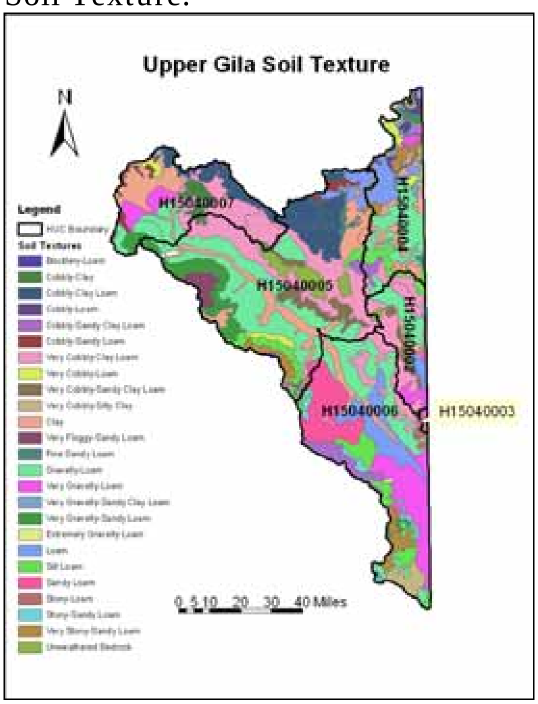
As shown in Figure 2-15, 25 different soil textures occur within the watershed. Table 2-11 presents percent soil texture by subwatershed and for the entire Upper Gila Watershed. For example, the gravelly-loam texture comprises 22% of the watershed, and the very cobbly – clay loam texture predominates over approximately 16% of the area.

The fine clays and silts are found in the flat-lying agricultural lands along the main stem of the Gila River. Thin soils overlaying bedrock are encountered in the highlands of the San Francisco River and portions of the San Simon Creek subwatersheds.

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.

Figure 2-15: Upper Gila Watershed Soil Texture.



Erosion caused by precipitation and running water and the factors affecting soil loss have been summarized in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The USLE 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 2-12 shows these values for each subwatershed.

The San Simon Creek subwatershed has the highest weighted mean for Soil Erodibility Factor, with K = 0.19, and the Animas Valley subwatershed has the lowest weighted mean at 0.09. The weighted mean K for the whole Upper Gila Watershed is 0.15.

Table 2-11: Upper Gila Watershed Soil Texture by Subwatershed (percent).

Soil Texture	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	Upper Gila Watershed
Bouldery-Loam	-	-	-	0.17%	-	-	*<1%*
Cobbly-Clay	-	-	-	0.37%	-	6.76%	*1%*
Cobbly-Clay Loam	-	-	-	11.21%	-	14.45%	*6%*
Cobbly-Loam	-	-	5.39%	0.06%	-	-	*<1%*
Cobbly-Sandy Clay Loam	-	-	2.80%	0.53%	5.10%	-	*2%*
Cobbly- Sandy Loam	-	-	0.20%	1.12%	-	3.69%	*1%*
Very Cobbly-Clay Loam	41.35%	1.78%	2.90%	17.20%	7.70%	27.14%	*16%*
Very Cobbly-Loam	-	-	7.51%	1.23%	-	1.81%	*2%*
Very Cobbly-Sandy Clay Loam	9.44%	-	-	4.60%	-	0.22%	*3%*
Very Cobbly-Silty Clay	-	-	-	-	3.85%	-	*1%*
Clay	4.08%	-	14.90%	11.60%	3.83%	17.44%	*10%*
Very Flaggy-Sandy Loam	-	-	-	2.82%	-	0.39%	*1%*
Fine Sandy Loam	-	-	3.91%	1.13%	0.20%	-	*1%*
Gravelly-Loam	21.97%	-	27.94%	24.65%	18.03%	15.07%	*22%*
Very Gravelly-Loam	8.61%	34.95%	2.93%	-	16.40%	8.93%	*7%*
Very Gravelly-Sandy Clay Loam	-	-	-	-	-	0.52%	*<1%*
Very Gravelly-Sandy Loam	-	-	1.39%	7.55%	0.63%	3.25%	*4%*
Extremely Gravelly-Loam	-	-	-	-	0.18%	-	*<1%*
Loam	6.44%	-	17.40%	3.51%	11.72%	-	*7%*
Silt Loam	4.27%	-	7.16%	5%	8.92%	-	*5%*
Sandy Loam	-	-	-	0.05%	15.39%	-	*5%*
Stony-Loam	2.25%	63.27%	-	-	1.33%	-	*<%*
Stony-Sandy Loam	-	-	-	0.07%	2.80%	-	*<1%*
Very Stony-Sandy Loam	-	-	5.57%	2.13%	3.93%	-	*3%*
Unweathered Bedrock	1.60%	-	-	4.99%	-	0.32%	*2%*
Area (square miles)	*542*	*17*	*938*	*2,779*	*2,004*	*1,070*	*7,350*

Figure 2-16: Upper Gila Watershed Soil Erodibility Factor.

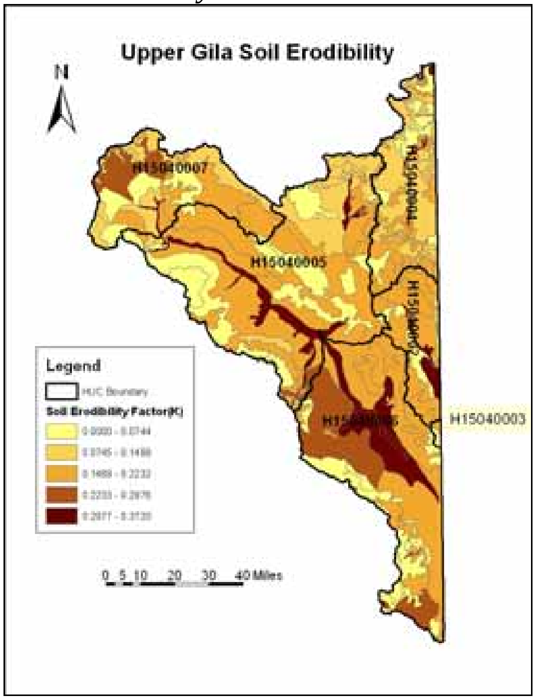


Table 2-12: Upper Gila Watershed Soil Erodibility Factor.

Subwatershed Name	Min	Max	Weighted Average
Upper Gila H15040002	**0**	**0.37**	**0.16**
Animas Valley H15040003	**0.05**	**0.16**	**0.09**
San Francisco River H15040004	**0.04**	**0.37**	**0.12**
Gila Valley H15040005	**0**	**0.34**	**0.13**
San Simon Creek H15040006	**0**	**0.37**	**0.19**
San Carlos River H15040007	**0**	**0.34**	**0.14**
Upper Gila Watershed	***0***	***0.37***	***0.15***

Climate

Precipitation

For the 30 years (1961-1990) of precipitation data, the average annual precipitation for the Upper Gila Watershed is 16.4 inches. Figure 2-17 and Table 2-13 show average annual precipitation. The San Francisco River subwatershed has the highest average rainfall per year (20 inches/year), while the Upper Gila and the San Simon Creek subwatersheds exhibit the lowest at 14 inches/year average rainfall. In the region around Mt. Graham in the San Simon Creek subwatershed, precipitation exceeds 40 inches/year, accumulating in the form of both rain and snow. The valley floor surrounding the main channel of the Gila River has the least localized rainfall at less than 13 inches/year. Irrigation is required to support agriculture in the region.

Temperature

Nine weather stations in the Upper Gila Watershed are shown in Figure 2-18. Data from these locations were used for watershed modeling. Although there are more weather stations in the watershed, these stations were selected for modeling because of the consistency and duration of the data.

Table 2-14 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).

Figure 2-17: Upper Gila Watershed Average Annual Precipitation (inches/year).

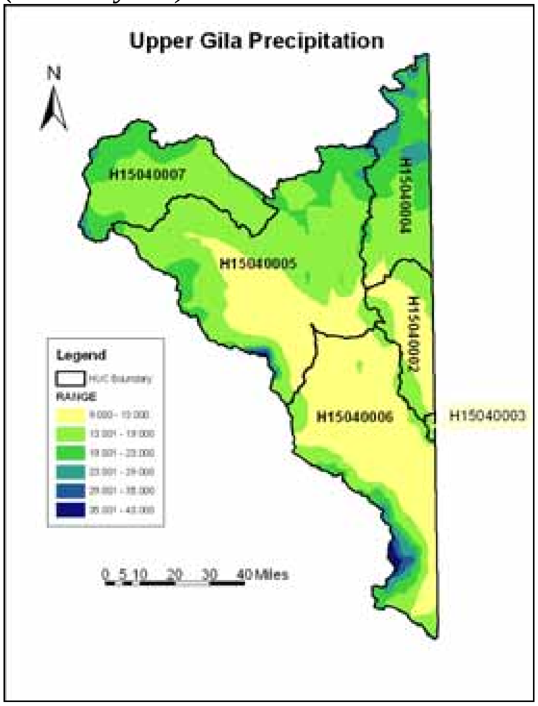


Figure 2-18: Upper Gila Watershed Weather Stations.

Table 2-13: Upper Gila Watershed Average Annual Precipitation.

Subwatershed Name	Min (inches /yr)	Max (inches /yr)	Avg. (inches /yr)
Upper Gila H15040002	**11**	**19**	**14**
Animas Valley H15040003	**13**	**17**	**15**
San Francisco River H15040004	**13**	**33**	**20**
Gila Valley H15040005	**9**	**39**	**16**
San Simon Creek H15040006	**9**	**43**	**14**
San Carlos River H15040007	**15**	**27**	**19**
Upper Gila Watershed	***9***	***43***	***16.4***

For the 30 years of temperature data, the average annual temperature for the Upper Gila Watershed is 58.4° Fahrenheit. San Simon Creek subwatershed has the highest annual average temperature (60.9 F). Table 2-15 shows the annual values for the other subwatersheds, and Figure 2-19 shows the annual average temperatures.

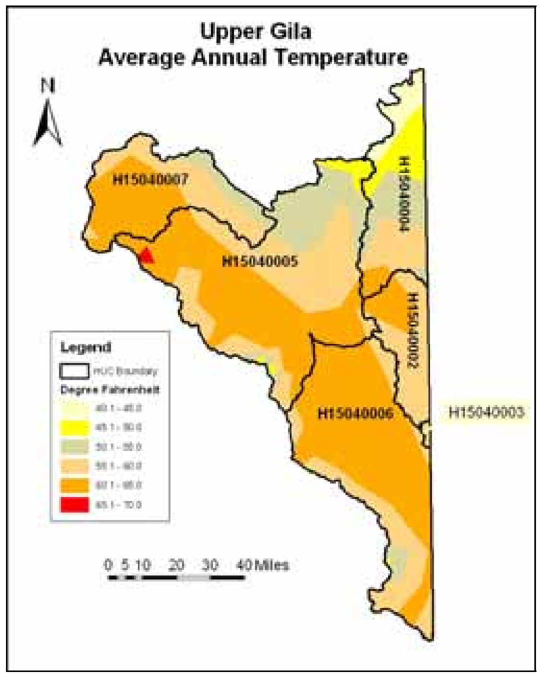
Table 2-14: Summary of Temperature Data for Eight Temperature Gages in the Upper Gila Watershed.

Gage	Average Annual Max. Temperature (ºF)	Average Annual Min. Temperature (ºF)	Average Annual Temperature (ºF)
Alpine	**61.3**	**27.4**	**44.4**
Alpine 8 SSE	**N/A**	**N/A**	**N/A**
Clifton	**80.1**	**50**	**65.1**
Fort Thomas 2 SW	**79.1**	**46.2**	**62.6**
Safford Agriculture Center	**80.1**	**46.6**	**63.4**
Duncan	**79.1**	**40.6**	**59.9**
Bowie	**79.5**	**48.3**	**63.9**
San Simon	**78.1**	**44.1**	**61.1**
Portal 4 SW	**69.9**	**37.5**	**53.7**

Table 2-15: Upper Gila Watershed Temperature.

Subwatershed Name	Average Annual Temperature (ºF)
Upper Gila H15040002	**58.9**
Animas Valley H15040003	**57.5**
San Francisco River H15040004	**51.6**
Gila Valley H15040005	**58.6**
San Simon Creek H15040006	**60.9**
San Carlos River H15040007	**59.3**
Upper Gila Watershed	***58.4***

Figure 2-19: Upper Gila Watershed Annual Average Temperature (ºF).



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Temperature data. July 15, 2004.

**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.

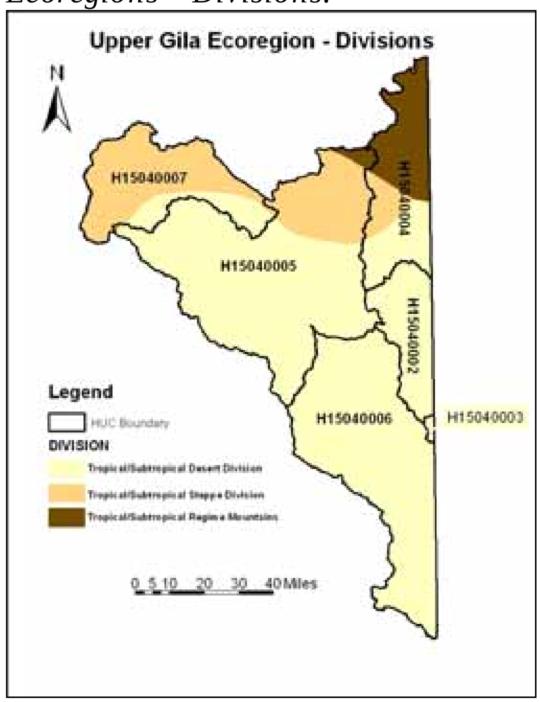
Because macroclimates are among the most significant factors affecting the distribution of life on earth, as the macroclimate changes, the other components of the ecosystem change in response. Bailey's Ecoregion classification (Bailey, 1976) provides a general description of the ecosystem geography of 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 Upper Gila Watershed in the dry domain. There are three different divisions of the dry domain within the watershed: Tropical/Subtropical Desert Division, which comprises 72% of the watershed; Tropical/Subtropical Steppe Division; and Tropical/Subtropical Regime Mountains, comprising 21% and 7% of the total area of the watershed respectively. 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, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

Figure 3-1: Upper Gila Watershed Ecoregions – Divisions.



Note: See Table 3-1 for subwatershed names.

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 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 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).

Figure 3-2: Upper Gila Watershed Ecoregions – Provinces.

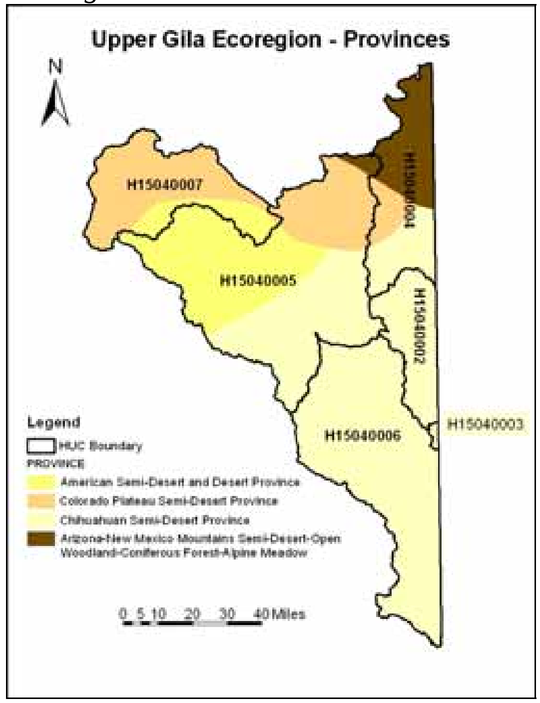


Figure 3-3: Upper Gila Watershed Ecoregions – Sections.

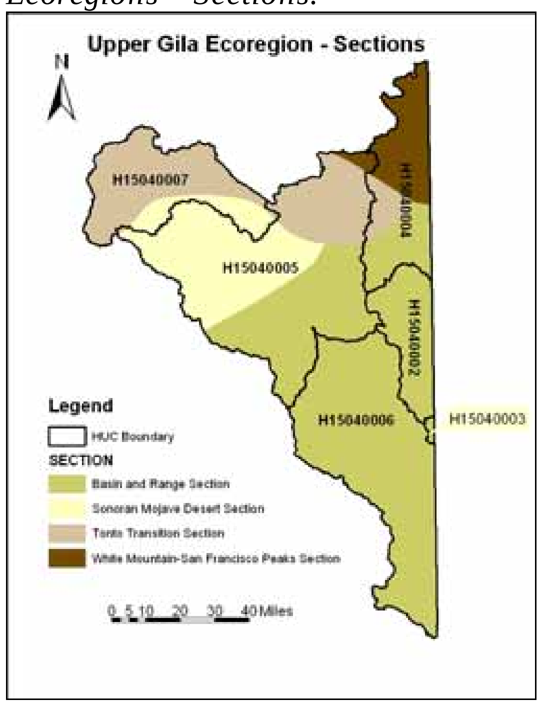


Table 3-1: Upper Gila Watershed Ecoregions - Divisions.

Division	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Tropical/Subtropical Regime Mountains	-0-	-0-	51%	2%	-0-	-0-	*7%*
Tropical/Subtropical Steppe Division	-0-	-0-	16%	20%	-0-	78%	*21%*
Tropical/Subtropical Desert Division	100%	100%	34%	78%	100%	22%	*72%*
Area (square miles)	*542*	*17*	*938*	*2,779*	*2,004*	*1,070*	*7,350*

Table 3-2: Upper Gila Watershed Ecoregions - Provinces.

Province	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Chihuahuan Semi-Desert Province	100%	100%	34%	38%	100%	-0-	*54%*
Colorado Plateau Semi-Desert Province	-0-	-0-	16%	20%	-0-	78 %	*21%*
American Semi-Desert and Desert Province	-0-	-0-	-0-	40%	-0-	22%	*18%*
Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest Alpine Meadow Province	-0-	-0-	51%	2%	-0-	-0-	*7%*
Area (square miles)	*542*	*17*	*938*	*2,779*	*2,004*	*1,070*	*7,350*

Table 3-3: Upper Gila Watershed Ecoregions - Sections.

Section	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Basin and Range Section	100%	100%	34%	-0-	100%	38%	*54%*
Tonto Transition Section	-0-	-0-	16%	-0-	-0-	20%	*21%*
Sonoran Mojave Desert Section	-0-	-0-	-0-	-0-	-0-	40%	*18%*
White Mountain-San Francisco Peaks Section	-0-	-0-	51%	-0-	-0-	2%	*7%*
Area (square miles)	*542*	*17*	*938*	*2,779*	*2,004*	*1,070*	*7,350*

Vegetation

Two different vegetation maps were created for the Upper Gila watershed, one based on biotic (vegetation) 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 ten different biotic communities in the Upper Gila Watershed. The two primary communities are Semi-Desert Grassland (25% of the Upper Gila Watershed), and Arizona Upland Sonoran Desert Scrub (18% of the watershed area). Table 3-4 shows the percentage of each biotic community in each subwatershed.

Figure 3-4: Upper Gila Watershed - Brown, Lowe and Pace Vegetation.

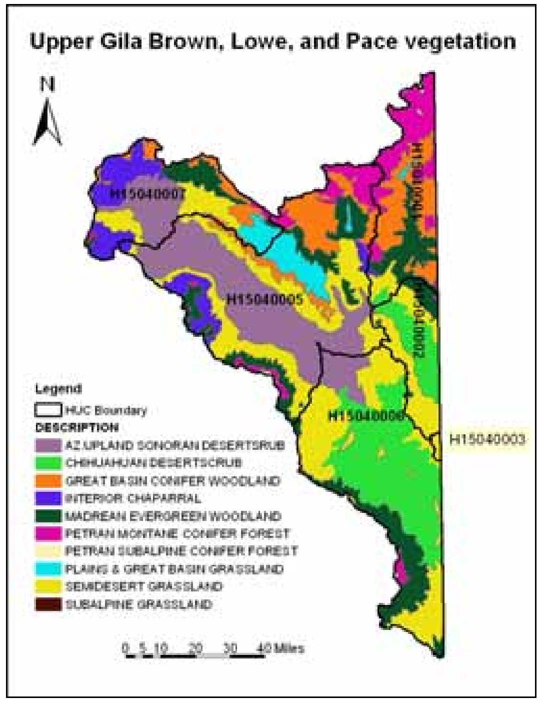


Table 3-4: Upper Gila Watershed - Brown, Lowe and Pace Biotic Communities.

Biotic Communities	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Arizona Upland Sonoran Desertscrub	**<1%**	**-0-**	**<1%**	**34%**	**7%**	**24%**	***18%***
Chihuahuan Desertscrub	**39%**	**-0-**	**1%**	**-0-**	**44%**	**-0-**	***15%***
Great Basin Conifer Woodland	**-0-**	**-0-**	**37%**	**12%**	**-0-**	**12%**	***11%***
Interior Chaparral	**-0-**	**-0-**	**1%**	**5%**	**-0-**	**25%**	***6%***
Madrean Evergreen Woodland	**12%**	**-0-**	**20%**	**11%**	**15%**	**11%**	***13%***
Petran Montane Conifer Forest	**<1%**	**-0-**	**33%**	**7%**	**1%**	**2%**	***8%***
Petran Subalpine Conifer Forest	**-0-**	**-0-**	**1%**	**<1%**	**<1%**	**-0-**	***<1%***
Plains & Great Basin Grassland	**-0-**	**-0-**	**1%**	**6%**	**-0-**	**7%**	***3%***
Semi-Desert Grassland	**49%**	**100%**	**6%**	**24 %**	**33%**	**19%**	***25%***
Subalpine Grassland	**-0-**	**-0-**	**<1%**	**-0-**	**-0-**	**-0-**	***<1%***
Area (square miles)	***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

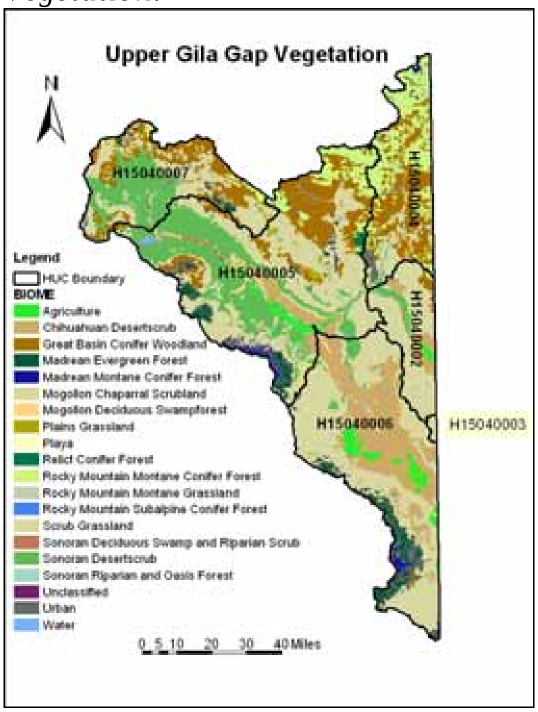
The second vegetation map was created based on the Gap Vegetation cover, which shows vegetation communities or land cover (Halvorson et al., 2001). Based on this map, twenty different vegetation cover types are found within the watershed, including: urban landscape, surface water features, and agriculture (Table 3-5). Two of the most common vegetation types over the entire watershed are Scrub Grassland and Great Basin Conifer Woodland, which comprise 35% and 16% of the Upper Gila Watershed area respectively.

Table 3-5: Upper Gila Watershed - GAP Vegetation.

Vegetation	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Agriculture	**3%**	**-0-**	**<1%**	**3%**	**4%**	**<1%**	***12%***
Chihuahuan Desertscrub	**12%**	**-0-**	**-0-**	**4%**	**33%**	**-0-**	***16%***
Great Basin Conifer Woodland	**3 %**	**-0-**	**41%**	**17%**	**<1%**	**29%**	***5%***
Madrean Evergreen Forest	**-0-**	**-0-**	**1%**	**4%**	**9%**	**3%**	***1%***
Madrean Montane Conifer Forest	**-0-**	**-0-**	**-0-**	**2%**	**2%**	**<1%**	***4%***
Mogollon Chaparral Scrubland	**1%**	**-0-**	**4%**	**4%**	**1%**	**15%**	***1%***
Mogollon Deciduous Swamp Forest	**<1%**	**-0-**	**<1%**	**1%**	**<1%**	**<1%**	***<1%***
Plains Grassland	**-0-**	**-0-**	**1%**	**1%**	**-0-**	**1%**	***<1%***
Playa	**-0-**	**-0-**	**-0-**	**-0-**	**-0-**	**-0-**	***<1%***
Relict Conifer Forest	**-0-**	**-0-**	**<1%**	**<1%**	**-0-**	**-0-**	***8%***
Rocky Mountain Montane Conifer Forest	**1%**	**-0-**	**40%**	**6%**	**-0-**	**2%**	***<1%***
Rocky Mountain Montane Grassland	**-0-**	**-0-**	**<1%**	**-0-**	**-0-**	**-0-**	***<1%***
Rocky Mountain Subalpine Conifer Forest	**-0-**	**-0-**	**<1%**	**<1%**	**-0-**	**-0-**	***35%***
Scrub Grassland	**73%**	**98%**	**7%**	**31%**	**49%**	**19%**	***<1%***
Sonoran Deciduous Swamp & Riparian Scrub	**<1%**	**-0-**	**<1%**	**1%**	**-0-**	**<1%**	***15%***
Sonoran Desertscrub	**5%**	**-0-**	**1%**	**25%**	**2%**	**31%**	***<1%***
Sonoran Riparian & Oasis Forest	**<1%**	**-0-**	**<1%**	**<1%**	**-0-**	**<1%**	***<1%***
Unclassified	**<1%**	**2%**	**<1%**	**-0-**	**<1%**	**-0-**	***<1%***
Urban	**<1%**	**-0-**	**3%**	**<1%**	**-0-**	**<1%**	***<1%***
Water	**<1%**	**-0-**	**<1%**	**<1%**	**<1%**	**<1%**	***12%***
Area (square miles)	***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

The most common vegetation type within the subwatersheds is Scrub Grassland except for San Francisco River and San Carlos River subwatersheds where Great Basin Conifer Woodland is the most common vegetation type. Figure 3-5 is a map of the GAP Vegetation for the Upper Gila Watershed.

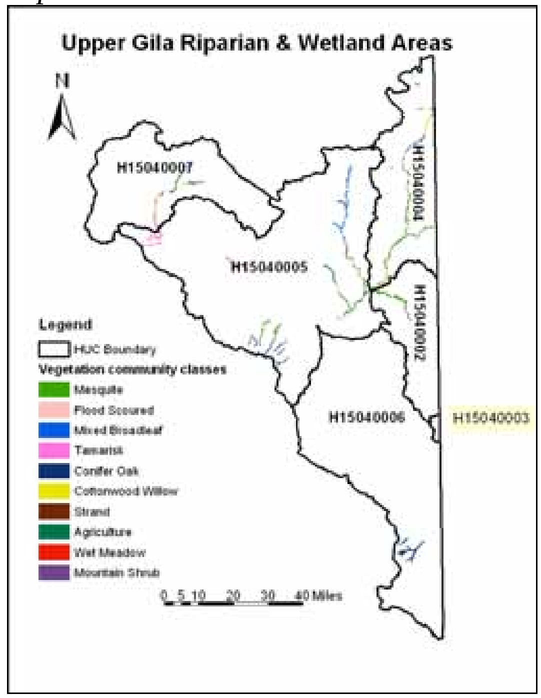
Figure 3-5: Upper Gila Watershed Gap Vegetation.



<u>Habitats (Riparian and Wetland Areas)</u>

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 Upper Gila Watershed (Figure 3-6).

Figure 3-6: Upper Gila Watershed Riparian and Wetland Areas.



There are ten different types of riparian areas within the watershed encompassing a total of 32.6 square miles, which comprises 0.44% of the whole watershed. Mesquite, Flood Scoured and Mixed Broadleaf groups make up the largest groups of riparian wetland areas in the watershed. In Upper Gila and San Francisco River subwatersheds, Mesquite is a significant riparian area type, while in Gila Valley and San Carlos River subwatersheds, Flood Scoured Riparian area is the most common type. In San Simon Creek subwatershed, Conifer Oak comprises about 76% of the total riparian area (Table 3-6).

<u>Major Land Resource Areas (MLRAs)</u>

There are four different MLRAs in the Upper Gila Watershed (Figure 3-7). The dominant MLRA is classified as the Southeastern Arizona Basin and Range. This area comprises 56% of the entire watershed. Arizona Interior Chaparral, and Arizona and New Mexico Mountains cover 24% and 20% of the watershed, respectively. New Mexico and Arizona Plateaus and Mesas comprise less than 1 percent of the entire watershed (Table 3-7).

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

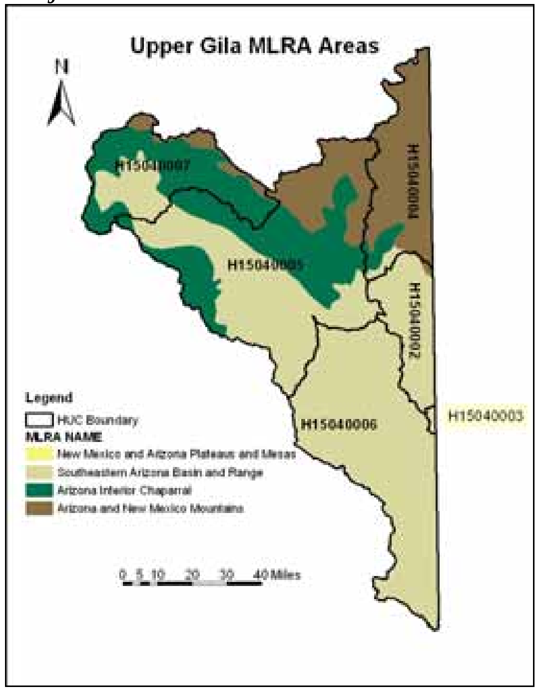


Table 3-6: Upper Gila Watershed Riparian and Wetland Areas (acres).

Vegetation Community	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Mesquite	**1,241**	**-0-**	**1,648**	**2,446**	**-0-**	**462**	***5,797***
Flood Scoured	**-0-**	**-0-**	**785**	**2,976**	**-0-**	**1,816**	***5,578***
Mixed Broadleaf	**13**	**-0-**	**454**	**1,943**	**183**	**528**	***3,120***
Tamarisk	**405**	**-0-**	**9**	**1,949**	**-0-**	**595**	***2,958***
Conifer Oak	**-0-**	**-0-**	**-0-**	**513**	**1,626**	**-0-**	***2,139***
Cottonwood Willow	**-0-**	**-0-**	**432**	**62**	**-0-**	**278**	***772***
Strand	**50**	**-0-**	**123**	**61**	**-0-**	**74**	***308***
Agriculture	**-0-**	**-0-**	**43**	**-0-**	**74**	**-0-**	***117***
Wet Meadow	**-0-**	**-0-**	**54**	**-0-**	**-0-**	**-0-**	***54***
Mountain Shrub	**-0-**	**-0-**	**15**	**-0-**	**-0-**	**-0-**	***15***
Total Riparian (acres)	***1,709***	***-0-***	***3,565***	***9,951***	***1,883***	***3,753***	***20,860***

Table 3-7: Upper Gila Watershed Major Land Resource Areas.

Major Land Resource Areas	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Southeastern Arizona Basin and Range	**98%**	**100%**	**4%**	**45%**	**100%**	**25%**	***56%***
Arizona Interior Chaparral	**-0-**	**-0-**	**8%**	**37%**	**-0-**	**64%**	***24%***
Arizona & New Mexico Mountains	**2%**	**-0-**	**89%**	**19%**	**-0-**	**12%**	***20%***
New Mexico & Arizona Plateaus & Mesas	**-0-**	**-0-**	**-0-**	**-0-**	**-0-**	**-0-**	***<1%***
Area (square miles)	***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

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U.S. Department of Agriculture, Natural Resources Conservation Service.
ftp-fc.sc.egov.usda.gov/NHQ/pub/land/arc_export/us48mlra.e00.zip
Major Land Resource Area Map. July 15, 2003.

**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.*

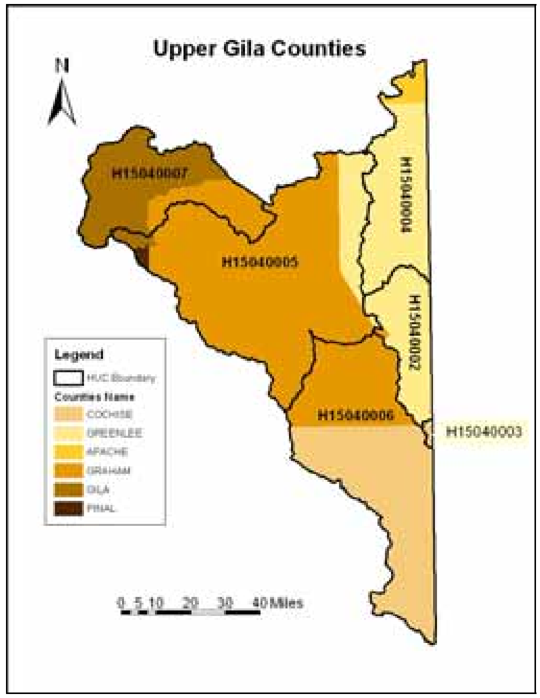
Section 4: Social/Economic Characteristics

County Governments

Understanding which governmental entities hold jurisdiction over the land in a given watershed helps a partnership understand the significance of each stakeholder's influence on the watershed. The Upper Gila Watershed is comprised of six counties: Apache, Cochise, Gila, Graham, Greenlee and Pinal, as shown in Figure 4-1. Among those, Graham County covers 47% of the watershed, while Pinal County covers less than 1% of the watershed area. In Upper Gila and San Francisco River subwatersheds, Greenlee County covers 98%, and 90% of the subwatershed areas, respectively. In Animas Valley and San Simon Creek subwatersheds, Cochise County covers 80%, and 65% of the area, respectively.

In Gila Valley, Graham County covers 86% of the subwatershed area, while in the San Carlos River subwatershed, Gila County covers 71% of the subwatershed area. Table 4-1 lists the percentage of each subwatershed in each county.

Figure 4-1: Upper Gila Watershed Counties.



Note: See Table 4-1 for subwatershed names.

Table 4-1: Upper Gila Watershed – Percent of Subwatershed in Each County.

Subwatershed and HUC	Area (square miles)	Apache	Cochise	Gila	Graham	Greenlee	Pinal
Upper Gila - H15040002	**542**	**-0-**	**<1%**	**-0-**	**2%**	**98%**	**-0-**
Animas Valley H15040003	**17**	**-0-**	**80%**	**-0-**	**-0-**	**20%**	**-0-**
San Francisco River H15040004	**938**	**10%**	**-0-**	**-0-**	**-0-**	**90%**	**-0-**
Gila Valley - H15040005	**2,779**	**-0-**	**-0-**	**2%**	**86%**	**11%**	**1%**
San Simon Creek H15040006	**2,004**	**-0-**	**65%**	**-0-**	**35%**	**<1%**	**-0-**
San Carlos River H15040007	**1,070**	**-0-**	**-0-**	**71%**	**29%**	**-0-**	**-0-**
Upper Gila Watershed	***7,350***	***1%***	***18%***	***11%***	***47%***	***23%***	***<1%***

Council of Governments (COGs)

Three Councils of Governments are present in the Upper Gila Watershed (Figure 4-2). The South Eastern Arizona Government Organization (SEAGO) governs 87% of the watershed, while 11% of the watershed is governed by the Central Arizona Association of Governments (CAAG), and 1% by the Northern Arizona Council of Governments (NACOG) (Table 4-2). The SEAGO Council is the dominant administrative group in all subwatersheds except for the San Carlos River subwatershed where the CAAG Council is responsible for governance of 71% of the subwatershed area.

Table 4-2: Upper Gila Watershed Council of Governments.

Subwatershed Name	Council Of Governments		
	CAAG	NACOG	SEAGO
Upper Gila - H15040002	**-0-**	**-0-**	**100%**
Animas Valley H15040003	**-0-**	**-0-**	**100%**
San Francisco River H15040004	**-0-**	**10%**	**90%**
Gila Valley - H15040005	**2%**	**-0-**	**98%**
San Simon Creek H15040006	**-0-**	**-0-**	**100%**
San Carlos River H15040007	**71%**	**-0-**	**29%**
Upper Gila Watershed	***11%***	***1%***	***87%***

Figure 4-2: Upper Gila Watershed Council of Governments.

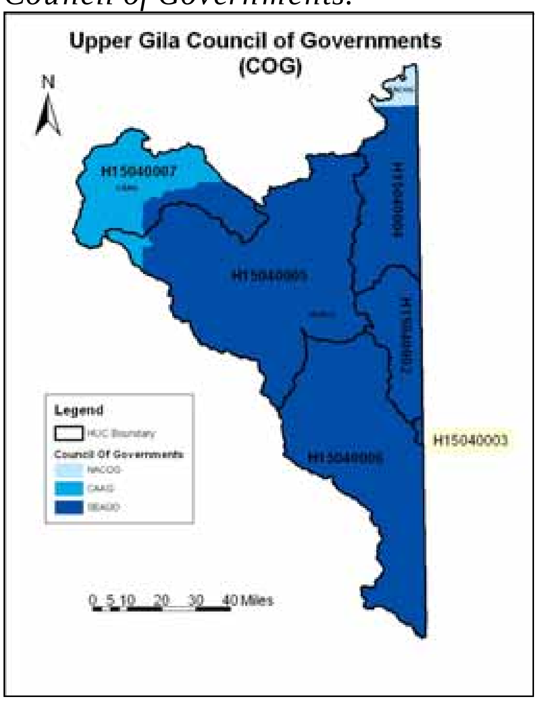
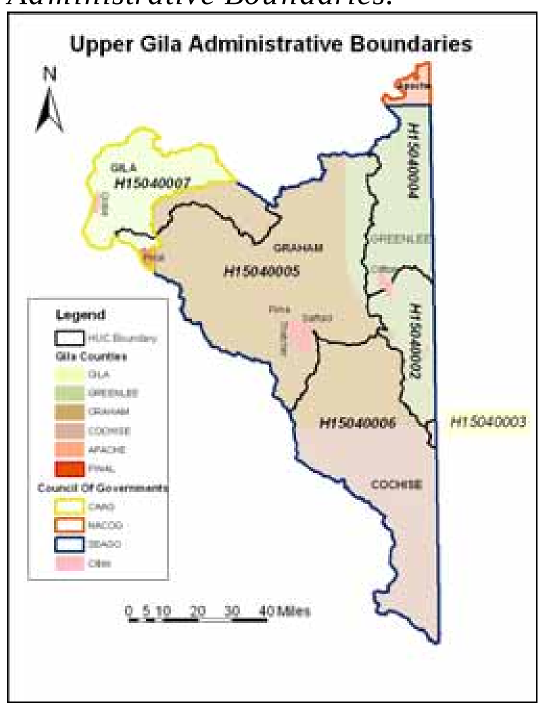


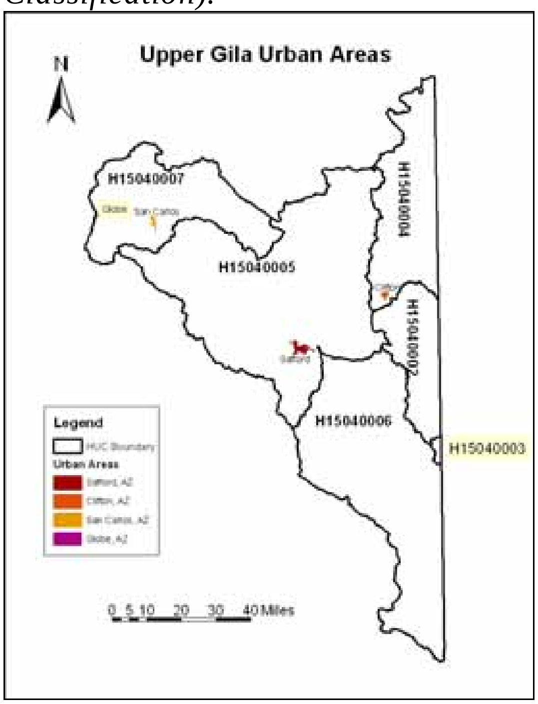
Figure 4-3: Upper Gila Watershed Administrative Boundaries.



Urban Areas

The U.S. Census Bureau defines Urbanized Areas as densely settled territory that contains 50,000 or more people. Based on that definition, there are four major urban areas within the Upper Gila Watershed: Safford, Clifton, San Carlos, and Globe (Figure 4-4). Safford is the largest urban area within the Upper Gila Watershed and comprises 61% (5,551 acres) of the urban areas. Gila Valley subwatershed has the highest percentage of urban areas, and there are no urban areas within Upper Gila, Animas Valley, and San Simon Creek subwatersheds (Table 4-3).

Figure 4-4: Upper Gila Watershed Urban Areas (Census Bureau Classification).



Another population density map was created for the Upper Gila Watershed based on 2000 census block population data. From this map, areas with a population density greater than 1,000 persons per square mile were designated as urban (Figure 4-5). The classification yielded three urban areas (Table 4-4). Results from this classification are compared to the Census Bureau Classification in Figure 4-6.

Table 4-3: Upper Gila Watershed Urbanized Areas.

Sub-watershed Name	Urban Area (acre)			
	Clifton	Globe	Safford	San Carlos
Upper Gila H15040002	**-0-**	**-0-**	**-0-**	**-0-**
Animas Valley H15040003	**-0-**	**-0-**	**-0-**	**-0-**
San Francisco River H15040004	**1,796**	**-0-**	**-0-**	**-0-**
Gila Valley H15040005	**-0-**	**-0-**	**5,551**	**-0-**
San Simon Creek H15040006	**-0-**	**-0-**	**-0-**	**-0-**
San Carlos River H15040007	**-0-**	**93**	**-0-**	**1,633**
Upper Gila Watershed	***1,796***	***93***	***5,551***	***1,633***

Table 4-4: Upper Gila Watershed Urban Areas Based on Population Density Data

Urban Areas (Density > = 1000 persons /square mile)	Area (acre)
Clifton	**761**
Safford	**2,395**
Thatcher	**424**
Total Urban Areas (acre)	***3,580***

Figure 4-5: Upper Gila Watershed Urban Areas (1,000 persons/square mile).

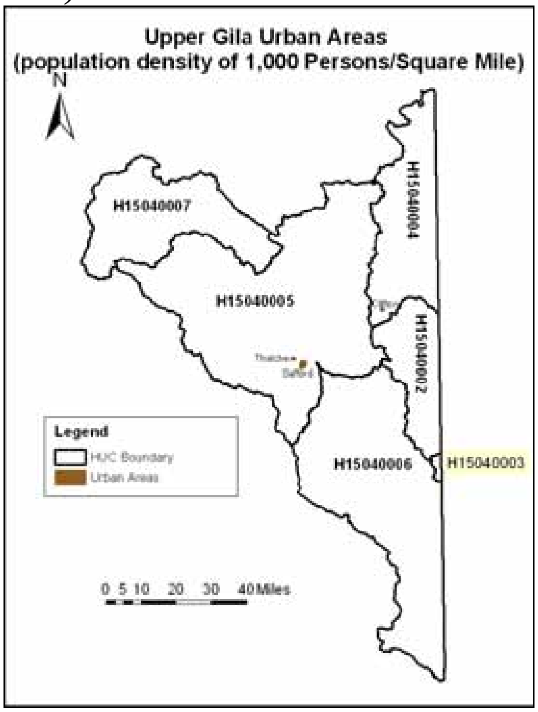
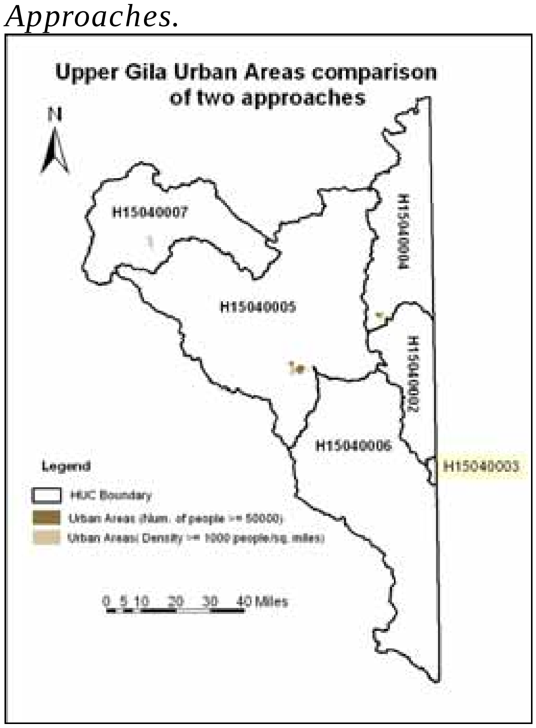


Figure 4-6: Upper Gila Watershed Urban Areas Comparison of Two Approaches.



Roads

The total road length in the Upper Gila Watershed is 1,213 miles, comprising approximately 7% of all roads in Arizona. The predominant road type, based on the Census Classification, is neighborhood roads with nearly 41% of the total roads length. The Gila Valley subwatershed has the greatest accumulated length of roads with 440 miles. Table 4-5 and Figure 4-7 show road types in each subwatershed.

Primary roads include Interstate 10. Secondary roads are usually undivided with single lane characteristics, such as U.S. Highway 60. Connecting roads are similar to secondary roads, and neighborhood roads are used for local traffic.

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

Table 4-5: Upper Gila Watershed Road Types.

Census Classification Code	Road Length (miles)	Percent of Total Length
Road	**11**	**1%**
Primary Road	**42**	**3%**
Secondary Road	**418**	**34%**
Connecting Road	**248**	**20%**
Neighborhood Road	**491**	**41%**
Special Road Features	**3**	**0%**
Total Road Length (miles)	***1,213***	***100%***

Figure 4-7: Upper Gila Watershed Road Types.

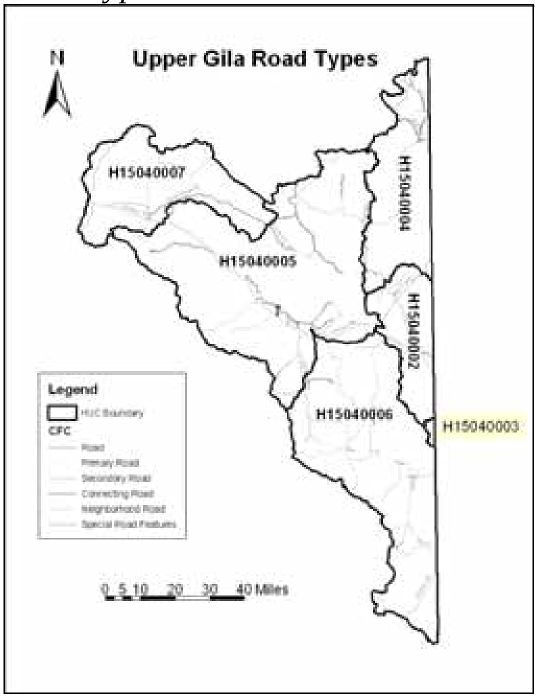


Table 4-6: Upper Gila Watershed Road Lengths by Subwatershed.

Subwatershed Name	Road Length (miles)	Percent of Total Length
Upper Gila - H15040002	**87**	**7%**
Animas Valley H15040003	**0**	**0%**
San Francisco River H15040004	**148**	**12%**
Gila Valley - H15040005	**440**	**36%**
San Simon Creek H15040006	**349**	**29%**
San Carlos River H15040007	**187**	**15%**
Upper Gila Watershed	***1,213***	***100%***

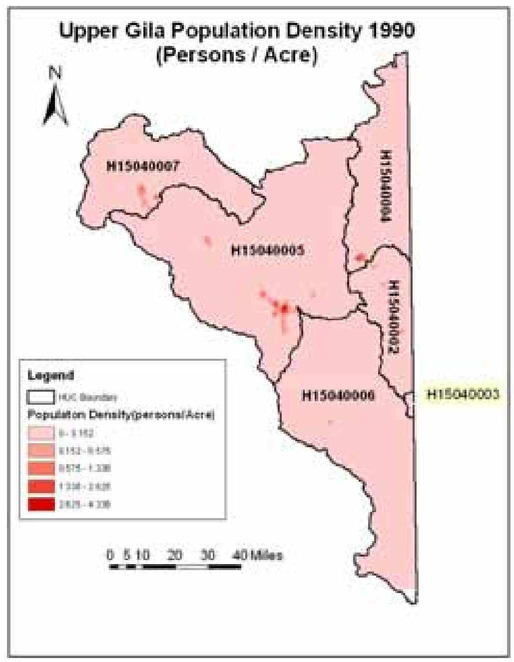
Population

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 4-8), which shows the number of individuals per acre. Table 4-7 shows the tabulated number of persons per acre.

Figure 4-8: Upper Gila Watershed Population Density 1990.



[Note: the southern tip of the watershed does not have 1990 population density information. This was a limitation of the dataset used.]

Table 4-7: Upper Gila Watershed Population Density 1990 (persons/acre).

Sub-watershed Name	Area (square miles	Min	Max	Mean
Upper Gila H15040002	**542**	**-0-**	**<1**	**-0-**
Animas Valley H15040003	**17**	**-0-**	**-0-**	**-0-**
San Francisco River H15040004	**938**	**-0-**	**3**	**-0-**
Gila Valley - H15040005	**2,779**	**-0-**	**4**	**<1**
San Simon Creek H15040006	**2,004**	**-0-**	**<1**	**<1**
San Carlos River H15040007	**1,070**	**-0-**	**1**	**<1**
Upper Gila Watershed	***7,350***	***-0-***	***4***	***<1***

Table 4-8: Upper Gila Watershed Population Density 2000 (persons/acre).

Subwatershed Name	Area (square miles)	Min	Max	Mean
Upper Gila - H15040002	**542**	**-0-**	**<1**	**<1**
Animas Valley H15040003	**17**	**-0-**	**-0-**	**-0-**
San Francisco River H15040004	**938**	**-0-**	**2**	**<1**
Gila Valley - H15040005	**2,779**	**-0-**	**4**	**<1**
San Simon Creek H15040006	**2,004**	**-0-**	**<1**	**<1**
San Carlos River H15040007	**1,070**	**-0-**	**1**	**<1**
Upper Gila Watershed	***7,350***	***-0-***	***4***	***<1***

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 are shown in Table 4-8. A population density map (Figure 4-9) was created from these data.

Population Change

The 1990 and 2000 population density maps were used to create a population density change map. The resulting map (Figure 4-10) shows population increase or decrease over the ten year time frame. Table 4-9 shows the change in population density from 1990 to 2000 in persons per acre.

Figure 4-9: Upper Gila Watershed Population Density 2000.

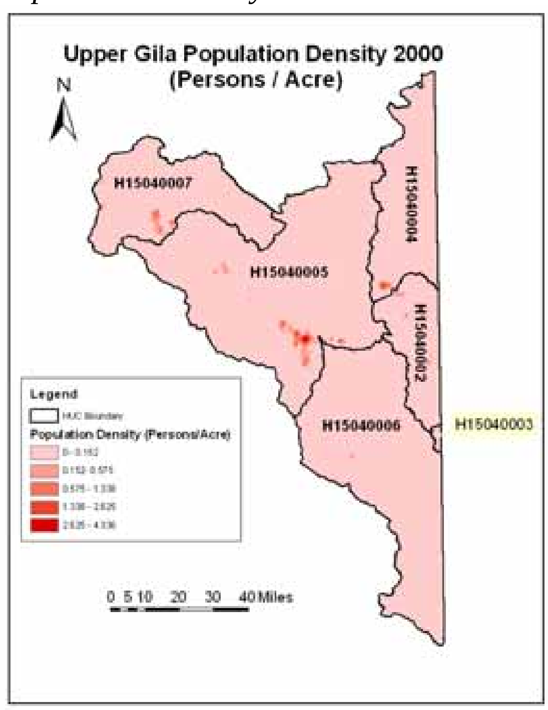
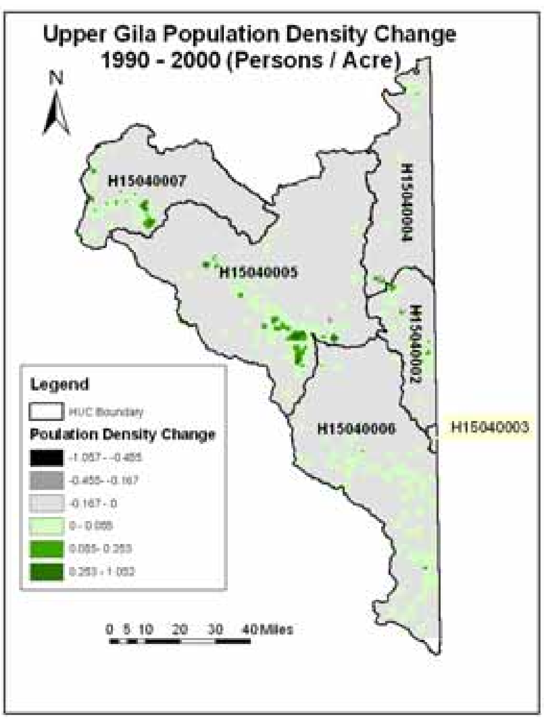


Table 4-9: Upper Gila Watershed Population Density Change 1990-2000 (persons/acre).

Subwatershed Name	Area (square mile)	Min	Max	Mean
Upper Gila - H15040002	**542**	**-<1**	**<1**	**<1**
Animas Valley H15040003	**17**	**-0-**	**-0-**	**-0-**
San Francisco River H15040004	**938**	**-<1**	**<1**	**-<1**
Gila Valley - H15040005	**2,779**	**-<1**	**1**	**<1**
San Simon Creek H15040006	**2,004**	**-<1**	**<1**	**-0-**
San Carlos River H15040007	**1,070**	**-1**	**<1**	**<1**
Upper Gila Watershed	***7,350***	***-1***	***1***	***<1***

Figure 4-10: Upper Gila Watershed Population Density Change 1990 - 2000.



Mines

There are 598 mineral extraction mines recorded with the Office of the Arizona State Mine Inspector in the Upper Gila Watershed. Gila Valley has the highest number of mines (189) while there are no mines reported within Animas Valley subwatershed. Ten different mine types are reported, of which 165 of them (27.6 %) are open-pit surface mines (Table 4-10 and Figure 4-11).

Mine activity status is tabulated under 6 different groups, which range between active and inactive production (Table 4-11 and Figure 4-12). The primary types of ore being mined are copper, silver and gold (Table 4-12 and Figure 4-13).

Figure 4-11: Upper Gila Watershed Mine Types.

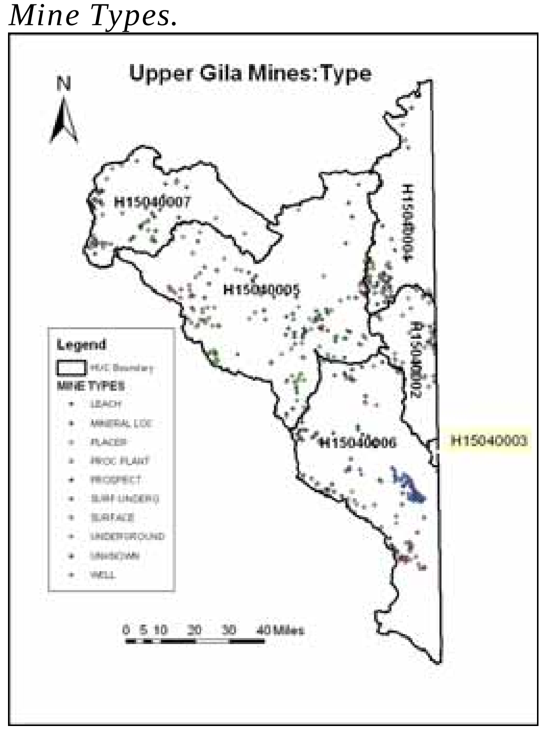


Figure 4-12: Upper Gila Watershed Mines - Status.

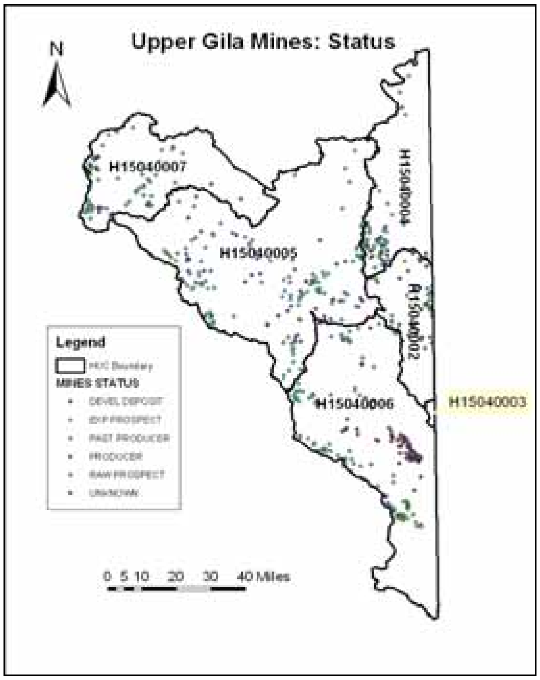


Figure 4-13: Upper Gila Watershed Mines - Primary Ore.

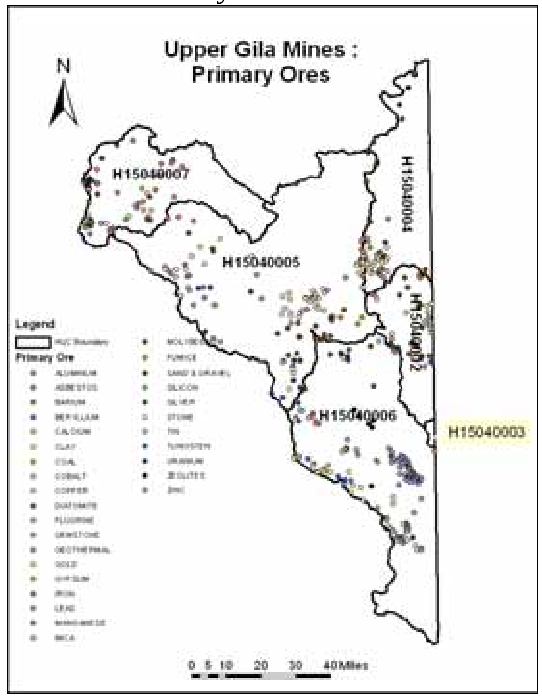


Table 4-10: Upper Gila Watershed Mine Types.

Mine Types	**Upper Gila H15040002**	**Animas Valley H15040003**	**San Francisco River H15040004**	**Gila Valley H15040005**	**San Simon Creek H15040006**	**San Carlos River H15040007**	***Upper Gila Watershed***
Leach	**-**	**-**	**-**	**2**	**-**	**-**	***2***
Mineral Locatable	**-**	**-**	**1**	**-**	**-**	**2**	***3***
Placer	**-**	**-**	**-**	**-**	**2**	**-**	***2***
Processing Plant	**-**	**-**	**2**	**1**	**-**	**1**	***4***
Prospect	**6**	**-**	**20**	**53**	**40**	**27**	***146***
Surface/ Under-ground	**8**	**-**	**8**	**18**	**18**	**21**	***73***
Surface	**25**	**-**	**26**	**76**	**17**	**21**	***165***
Under-ground	**19**	**-**	**16**	**34**	**35**	**17**	***121***
Unknown	**-**	**-**	**-**	**4**	**5**	**3**	***12***
Well	**-**	**-**	**-**	**1**	**68**	**1**	***70***
Total Mines	***58***	**-**	***73***	***189***	***185***	***93***	***598***

Table 4-11: Upper Gila Watershed Mines - Status.

Mine Status	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Developed Deposit	6	-	2	7	-	-	*15*
Explored Prospect	14	-	27	94	42	31	*208*
Past Producer	21	-	21	38	58	43	*181*
Producer	7	-	11	15	73	3	*109*
Raw Prospect	-	-	2	1	3	2	*8*
Unknown	10	-	10	34	9	14	*77*
Total Mines	*58*	-	*73*	*189*	*185*	*93*	*598*

Table 4-12: Upper Gila Watershed Mines – Ore Type.

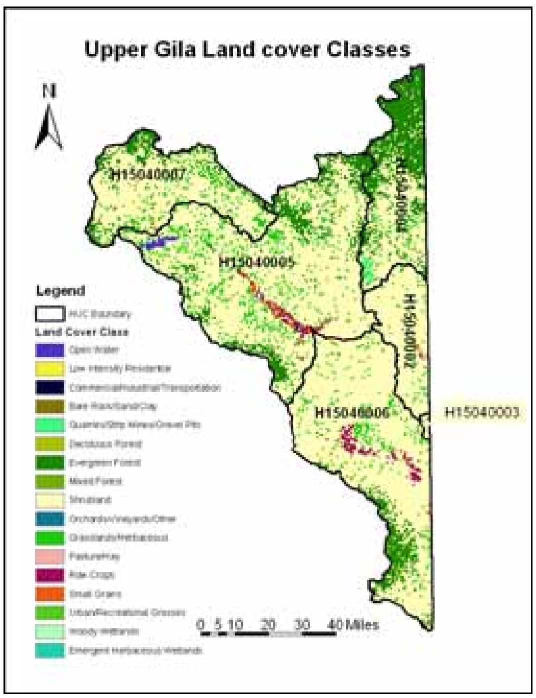
Ore Type	Total Number of Mines in Upper Gila Watershed	Ore Type	Total Number of Mines in Upper Gila Watershed
Copper	148	Gemstone	5
Silver	103	Gypsum	5
Gold	87	Beryllium	3
Geothermal	69	Clay	3
Manganese	67	Tin	3
Lead	61	Barium	2
Sand & gravel	56	Bismuth	2
Zinc	30	Cobalt	2
Asbestos	20	Mica	2
Fluorine	19	Nickel	2
Uranium	19	Thorium	2
Tungsten	16	Vanadium	2
Silicon	15	Aluminum	1
Iron	14	Antimony	1
Molybdenum	13	Arsenic	1
Diatomite	10	Coal	1
Pumice	10	Feldspar	1
Zeolites	8	Perlite	1
Calcium	6	Rare Earth	1
Stone	6		

Land Cover

The land cover condition in the early 1990's was determined using the National Land Cover Dataset (NLCD). The NLCD classification contains 21 different land cover categories from which 17 classes are represented within the Upper Gila watershed (Figure 4-14 and Table 4-13).

The most common land cover is Shrub-land which makes up 75% of the area. Evergreen Forests and Grassland/Herbaceous cover types are the next most common types with 14% and 8% coverage, respectively, over the total area.

Figure 4-14: Upper Gila Watershed Land Cover.



Land Ownership

In the Upper Gila Watershed, there are 12 different land ownership entities (Figure 4-15 and Table 4-14). The San Carlos Indian Reservation and the Bureau of Land Management (BLM) are the most significant land owners with nearly 30% and 23% of the watershed, respectively. The San Carlos Indian Reservation owns 89% of the San Carlos River subwatershed, and 43% of the Gila Valley subwatershed.

Most of the area in Animas Valley and San Simon Creek is owned by the BLM. The Apache-Sitgreaves National Forest owns 89% of the San Francisco River subwatershed and the State of Arizona owns 46% of the Upper Gila subwatershed

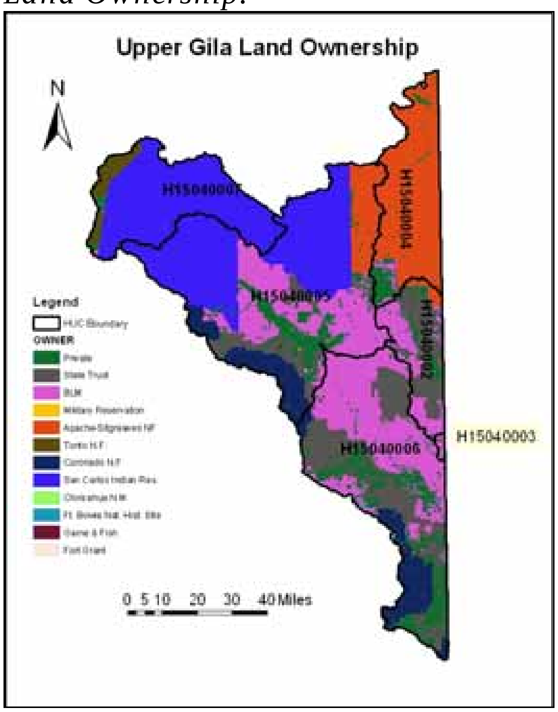
Table 4-13: Upper Gila Watershed Land Cover.

Land Cover	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Open Water	**<1%**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Low Intensity Residential	**<1%**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Commercial/ Industrial/ Transportation	**<1%**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Bare Rock/Sand/ Clay	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Quarries/Strip Mines/Gravel Pits	**-**	**-**	**1%**	**<1%**	**<1%**	**<1%**	**<1%**
Deciduous Forest	**<1%**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Evergreen Forest	**1%**	**-**	**45%**	**10%**	**7%**	**14%**	**14%**
Mixed Forest	**<1%**	**<1%**	**<1%**	**<1%**	**1%**	**<1%**	**<1%**
Shrub land	**91%**	**83%**	**47%**	**75%**	**83%**	**75%**	**75%**
Orchards/ Vineyards/ Other	**-**	**-**	**-**	**<1%**	**<1%**	**-**	**<1%**
Grasslands/ Herbaceous	**6%**	**17%**	**6%**	**11%**	**6%**	**10%**	**8%**
Pasture/Hay	**1%**	**-**	**<1%**	**<1%**	**1%**	**<1%**	**<1%**
Row Crops	**<1%**	**-**	**<1%**	**1%**	**2%**	**<1%**	**1%**
Small Grains	**1%**	**-**	**-**	**<1%**	**<1%**	**<1%**	**<1%**
Urban/ Recreational Grasses	**-**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Woody Wetlands	**<1%**	**-**	**<1%**	**<1%**	**<1%**	**<1%**	**<1%**
Emergent Herbaceous Wetlands	**-**	**-**	**<1%**	**<1%**	**-**	**<1%**	**<1%**
Total Area (square miles)	***542***	***17***	***938***	***2,779***	***2,004***	***1,070***	***7,350***

Table 4-14: Upper Gila Watershed Land Ownership.

Land Owner	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Private	12%	12%	7%	8%	18%	2%	*10%*
State Trust	46%	-	1 %	8%	28%	<1%	*14%*
BLM	36%	88%	3%	23%	41%	<1%	*23%*
Military Reservation	-	-	-	<1%	-	-	*<1%*
Apache-Sitgreaves N.F.	6%	-	89%	9%	-	-	*15%*
Tonto N.F.	-	-	-	-	-	9%	*1%*
Coronado N.F.	-	-	-	9%	13%	-	*7%*
San Carlos Indian Res.	-	-	-	43%	-	89%	*29%*
Chiricahua N.M.	-	-	-	-	<1%	-	*<1%*
Ft. Bowie N. Hist. Site	-	-	-	-	<1%	-	*<1%*
U.S. Fish & Wildlife Service	-	-	-	<1%	<1%	-	*<1%*
Fort Grant State Prison	-	-	-	<1%	-	-	*<1%*
Total Area (square miles)	*542*	*17*	*938*	*2,779*	*2,004*	*1,070*	*7,350*

Figure 4-15: Upper Gila Watershed Land Ownership.



Special Areas

Preserves:

There are 119,651 acres of preserve areas within the Upper Gila Watershed, which is less than 3% of the total watershed area. Upper Gila subwatershed has the greatest area of preserves within the Upper Gila Watershed.

Wilderness:

There are 10 different wilderness areas within the Upper Gila watershed which comprise a total of 497 square miles, or nearly 7% of the watershed. The largest wilderness area in the watershed is the Blue Range Primitive Area with approximately 283 square miles of area.

The Blue Range Primitive Area comprises 57% of all the wilderness areas in the watershed. The second largest area is the Chiricahua Wilderness Area which comprises 13% of the watershed. San Francisco River subwatershed has the greatest mapped wilderness area within the watershed with 283 square miles.

Figure 4-16: Upper Gila Watershed Preserve Areas.

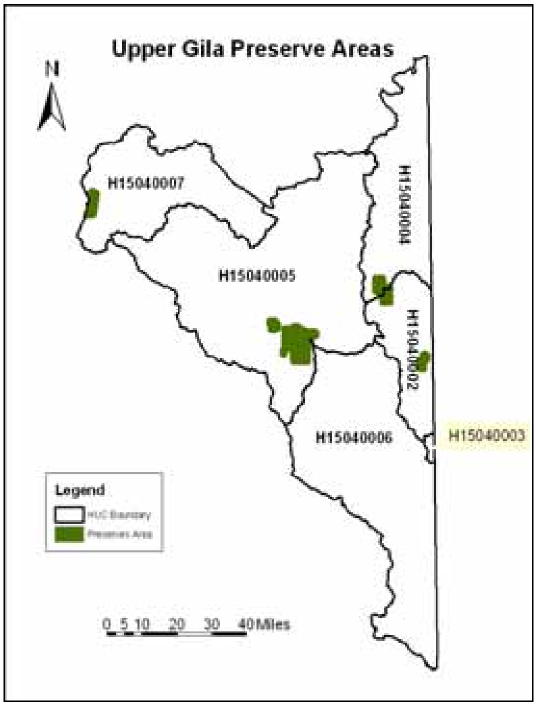


Figure 4-17: Upper Gila Watershed Wilderness Areas.

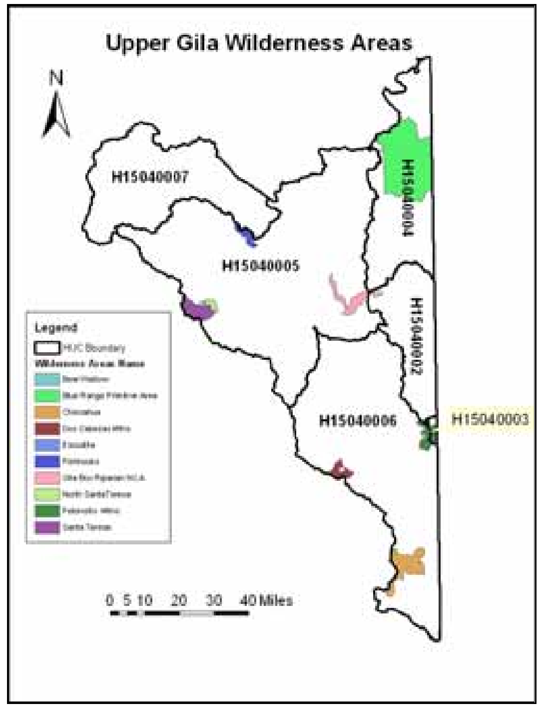


Table 4-15: Upper Gila Watershed Preserve Areas.

Subwatershed Name	Subwatershed Area (square miles)	Preserve Areas (acre)
Upper Gila H15040002	**542**	**21,238**
Animas Valley H15040003	**17**	**0**
San Francisco River H15040004	**938**	**14,356**
Gila Valley - H15040005	**2,779**	**6,801**
San Simon Creek H15040006	**2,004**	**59**
San Carlos River H15040007	**1,070**	**15,989**
Upper Gila Watershed	***7,350***	***119,651***

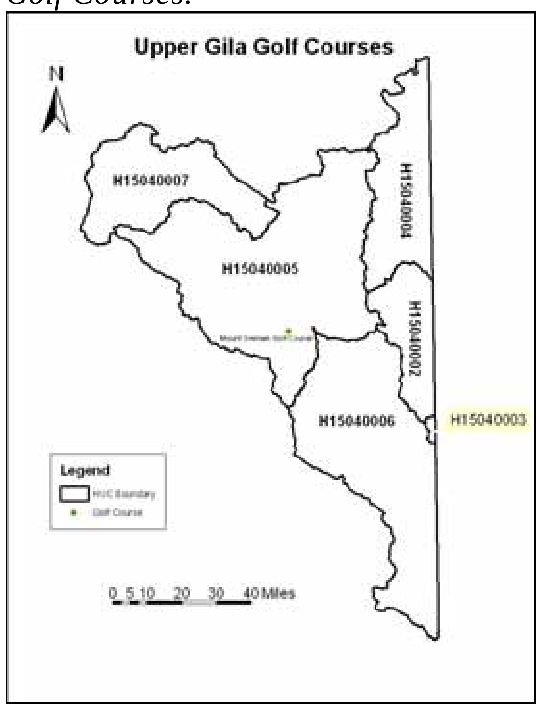
Table 4-16: Upper Gila Watershed Wilderness Areas (acres).

Wilderness Area	Upper Gila H15040002	Animas Valley H15040003	San Francisco River H15040004	Gila Valley H15040005	San Simon Creek H15040006	San Carlos River H15040007	*Upper Gila Watershed*
Escudilla	-	-	1,280	-	-	-	*1,316*
Blue Range Primitive Area	-	-	179,840	-	-	-	*180,039*
Bear Wallow	-	-	-	120	-	-	*124*
Fishhooks	-	-	-	10,498	-	26	*10,569*
Gila Box Riparian NCA	3,200	-	1,920	20,070	-	-	*23,364*
Santa Teresa	-	-	-	23,673	-	-	*23,781*
North Santa Teresa	-	-	-	5,792	-	-	*5,820*
Peloncillo Mtns.	640	6,400	-	-	11,872	-	*19,484*
Dos Cabezas Mtns.	-	-	-	-	11,802	-	*11,767*
Chiricahua	-	-	-	-	42,246	-	*42,113*
Total Wilderness Area (acre)	*3,840*	*6,400*	*181,120*	*60,154*	*65,920*	*26*	*318,377*

Golf Courses:

The only mapped golf course within the Upper Gila watershed is called the Mount Graham Golf Course (ESRI Data and Maps, 2001). This golf course is located within the Gila Valley subwatershed (Figure 4-18).

Figure 4-18: Upper Gila Watershed Golf Courses.



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Data Sources:*

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Preserve Areas. July 31, 2003.
Wilderness Areas. June 9, 2003.

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Landuse. July 21, 2003.

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 Upper Gila Watershed has extensive and important natural resources, with national, regional and local significance. The watershed contains critical riparian habitat for several rare and endangered species, including the Gila Chub, Razorback Sucker and Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004). The watershed also contains 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, and wilderness), the presence of perennial waters and riparian areas, recreational resources and local values.

The nine identified Natural Resource Areas (Figure 5-1) are:

Upper Gila River
Animas Valley
Happy Camp
Cave Creek
Centerfire Creek
Upper Blue River
Cottonwood
Chase Creek
Mule Creek

The NRAs have been categorized within the 10-digit HUC subwatershed area where they are located, and the significance of each area is discussed below.

<u>Upper Gila River NRA</u>

The Upper Gila River NRA (UGR-NRA) is one of the most significant natural resource areas in Arizona. The NRA includes two 10-digit HUC subwatersheds: Apache Creek-Upper Gila River and Yuma Wash-Upper Gila River. The UGR-NRA contains several wilderness areas, extensive riparian forests, important recreation areas and critical wildlife habitat. Many of the important resource values in this NRA are water dependent.

The 22,000 acre Gila Box Riparian National Conservation Area is located in the UGR-NRA and is managed by the Bureau of Land Management (BLM). On November 28, 1990, Congress created the Gila Box Riparian National Conservation Area (RNCA) through the Arizona Desert Wilderness Act to "conserve, protect, and enhance" the riparian and associated values of the area.

Four perennial waterways - the Gila River, Bonita Creek, Eagle Creek, and San Francisco River - are the lifeblood of this remarkable place. Not only does the RNCA hold one of the most significant riparian zones in the Southwest, it offers tremendous scientific, cultural, scenic, recreational, and other associated values. It is one of only two Riparian National Conservation Areas in the nation. A 15-mile segment of Bonita Creek and 23 miles of the Gila River have been included in this special natural area.

Bonita Creek, popular for birding and picnicking, is lined with large cottonwoods, sycamores and willows (U.S. Bureau of Land Management, 2004). Cliff dwellings, historic homesteads, Rocky Mountain bighorn sheep, and over 200 species of birds make this cool year-round desert oasis worth the short drive from Safford. The Gila River section, known as the Gila Box, is comprised of patchy mesquite woodlands, mature cottonwood trees, sandy beaches and grand buff colored cliffs (U.S. Bureau of Land Management, 2004).

The NRA also provides critical habitat for the Razorback Sucker (*Xyrauchen texanus)* which is listed as an Endangered Species (U.S. Fish & Wildlife Service, 2004).

Upper Gila River NRA Protection Needs

Most of the resource values in the Upper Gila River NRA depend on the protection and restoration of the Gila Box riparian area. The riparian area provides critical habitat for several protected wildlife species, as well as recreation opportunities. Nonpoint source pollutant management measures should be taken to protect and restore the channel and riparian systems.

As will be discussed in the classification section of this report (Section 6), the Upper Gila River NRA is listed as high priority for metals, sediment and organics. Based on Arizona's 303(d) List of Impaired Waters (ADEQ, 2003), the Gila River from Bonita Creek to the Yuma Wash is impaired due to E. coli exceedances and sediment exceedances(Craig, 2005).

The Gila River, from Skully Creek to the San Francisco River is impaired due to selenium exceedances.

<u>Animas Valley NRA</u>

The Animas Valley Natural Resource Area (AV-NRA) contains five 10-digit HUC subwatersheds: Railroad Wash-Upper Gila River, Animas Valley, East Whitetail Creek-San Simon River, Hot Well Draw-Hospital Flat and Tule Wells Draw-San Simon River. The East Whitetail Creek-San Simon River subwatershed contains critical habitat for the Mexican Spotted Owl.

The NRA also includes the 19,440 acre Peloncillo Mountains Wilderness located 9 miles northeast of San Simon, Arizona, in Graham, Greenlee and Cochise counties. The Peloncillo Mountains Wilderness lies within the rugged Peloncillo Range, which stretches from Mexico to the Gila River. This remote and primitive area flanking the Arizona-New Mexico state line shows little sign of human activity. The Peloncillo Mountain Wilderness offers outstanding opportunities for primitive recreation, including hiking, backpacking, rock scrambling, hunting and sight-seeing. The higher country offers long-distance views, and excellent scenery enhances wilderness values in the rugged mountains and canyons.

Desert bighorn sheep have been recently reintroduced to the region and share their home with peregrine falcons and four other sensitive animal species. Vegetation ranges

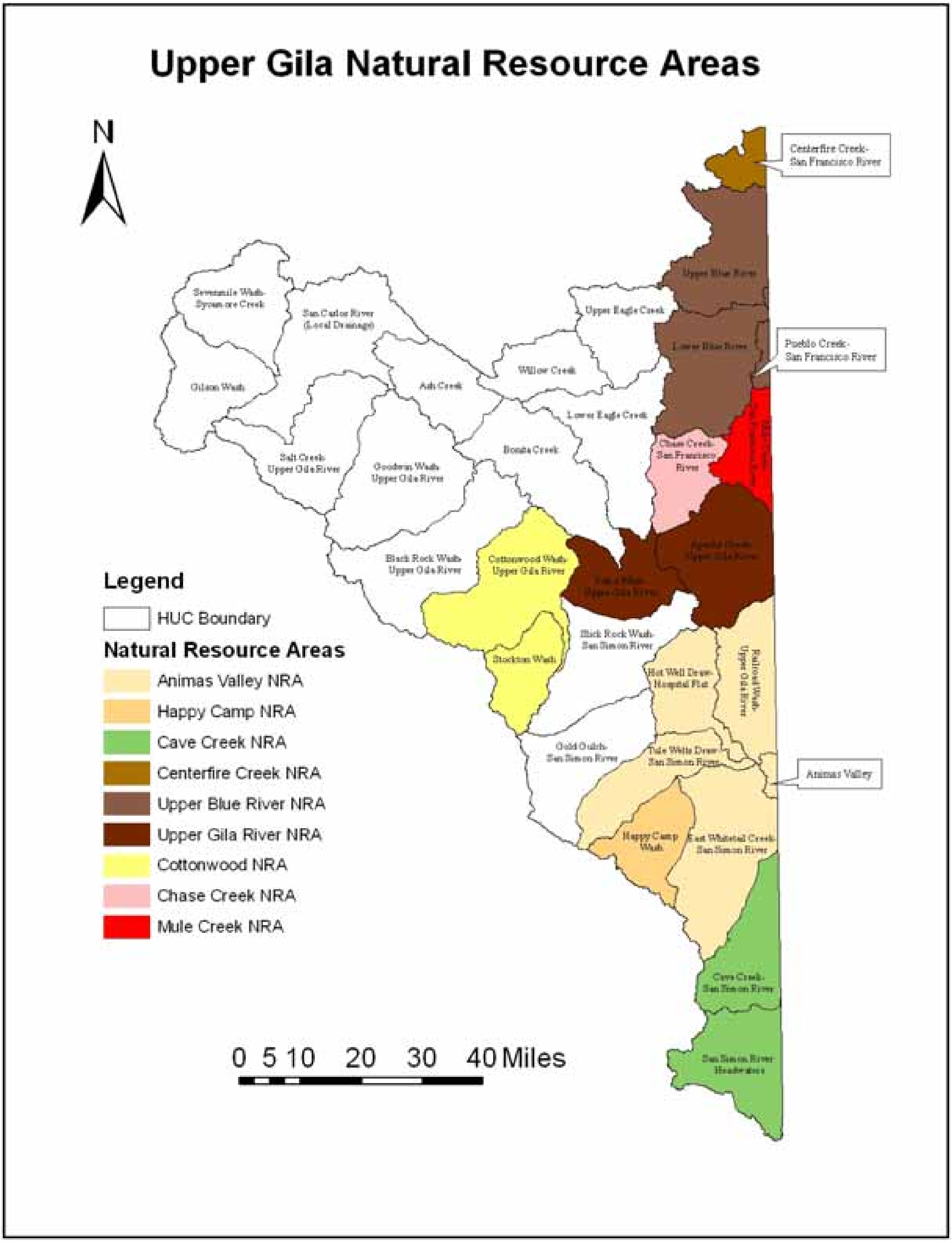

Figure 5-1: Natural Resource Areas in the Upper Gila Watershed.

from desert shrub grasslands in the surrounding flatlands to oak-juniper woodlands in the higher reaches. The area is also rich in archaeological sites with the historic Butterfield Stage route forming the southern boundary of the wilderness.

Animas Valley NRA Protection Needs

Based on current water quality monitoring information (ADEQ 2003), only one subwatershed has current monitoring data (Gila River from New Mexico border to Bitter Creek). No waters are currently listed as impaired within the Animas Valley NRA. Water quality monitoring should be expanded, especially where perennial water occurs, and appropriate Best Management Practices should be implemented to maintain water quality. Special attention should be given to protecting the riparian areas and critical habitat.

Happy Camp NRA

The Happy Camp Natural Resource Area (HC-NRA) contains one 10-digit HUC subwatershed called Happy Camp Wash. This area includes the Dos Cabezas Mountains Wilderness, a portion of which is located in the Tule Wells Draw subwatershed.

The 11,700-acre Dos Cabezas Mountains Wilderness lies 20 miles east of Willcox and seven miles south of Bowie, Arizona in Cochise County. The wilderness consists of the rugged slopes of the Dos Cabezas Mountains, with elevations ranging from 4,080 feet to 7,500 feet. This range allows for a variety of plant and animal life as well as excellent recreation opportunities. Visitors will find a diverse terrain of steep mountain slopes, granite outcroppings and vegetated canyon floors. This rugged and remote environment provides a rich wilderness experience, outstanding opportunities for hiking, backpacking, camping, rock scrambling and sightseeing. Sightseeing from the higher mountains and ridges offers outstanding long distance views of Sulphur Springs and San Simon Valleys and numerous mountain ranges (U.S. Bureau of Land Management, 2004).

Several developed and natural springs in the wilderness provide water for the abundant wildlife. White-tailed and mule deer, mountain lions, golden eagles, bald eagles and many other animals inhabit the Dos Cabezas Mountains. The beautiful and unusual collared lizard may be found in the upper portions of Buckeye Canyon. The peregrine falcon, a state and federally listed endangered species, migrates through the area. The majority of the wilderness contains mountain shrub, desert shrub and riparian vegetation (U.S. Bureau of Land Management, 2004).

Some parts of HC-NRA are also designated as critical habitat for the Mexican Spotted Owl.

Happy Camp NRA Protection Needs

There is no information regarding the status of surface water quality within this subwatershed.

Cave Creek NRA

The Cave Creek Natural Resource Area (CC-NRA) contains two 10-digit HUC subwatersheds: San Simon River Headwaters and Cave Creek-San Simon River.

The Chiricahua Wilderness is located within this area. It consists of 87,700 acres surrounding the 9,797 foot Chiricahua Peak. Steep canyons radiate from the high point. Travel is difficult in this area because of a heavy accumulation of dead and fallen trees. The only openings are old fire sites, rock outcroppings, and a few natural parks. No vehicles are permitted, and travel is limited to foot and horseback. The absence of motorized or mechanized vehicles, low trail maintenance, and limited signage provides a rugged, challenging and natural outdoor experience for hikers. This area is managed by the U.S. Forest Service.

The U.S. Fish & Wildlife Service has designated a portion of the NRA as critical habitat for the Mexican Spotted Owl. In addition, Cave Creek Headwaters and the South Fork of Cave Creek Headwaters are designated as Unique Waters of the state which provides special protection from water quality degradation.

Cave Creek NRA Protection Needs

Based on Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003) only five stream reaches have current water quality monitoring within this area. Cave Creek from the headwaters to the South Fork of Cave Creek is assessed as impaired due to selenium. Water quality monitoring should be continued for all constituents.

Centerfire Creek NRA

The Centerfire Creek Natural Resource Area (CFC-NRA) contains one 10 digit HUC subwatershed: Centerfire Creek-San Francisco River. It includes riparian and wilderness areas such as the 5,200 acre Escudilla Wilderness Area which is managed by the U.S. Forest Service.

Portions of the CFC-NRA are designated as critical habitat for the Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004).

Centerfire Creek NRA Protection Needs

Based on Arizona's 303(d) List of Impaired Waters (ADEQ, 2003), Luna Lake is listed as impaired for pH and dissolved oxygen, and is also on the TMDL list. San Francisco River, from its headwaters to the New Mexico border assessed as impaired due to sediment exceedances (Craig, 2005).

Best Management Practices for this NRA are recommended in the Management Section (Section 7).

Upper Blue River NRA

The Upper Blue River Natural Resource Area (UBR –NRA) includes three 10-digit HUC subwatersheds: Upper Blue River, Pueblo Creek-San Francisco River and Lower Blue River.

The Blue Range Primitive Area is located in UBR-NRA, although approximately half of it is located in the state of New Mexico. This area is managed by the U.S. Forest Service. This land of rugged mountains, steep canyons, and stark ridges is remote but accessible through an extensive trail system. Trails are open to non-motorized and non-mechanized use only.

In early 1998 Mexican wolves were released into part of the Blue Range under the Endangered Species Act. The Mexican Wolf Recovery Project is a cooperative effort currently administered by six primary agencies: U.S. Fish and Wildlife Service, Arizona Game and Fish Department, New Mexico Department of Game and Fish, White Mountain Apache Tribe, USDA – Wildlife Services, and USDA Forest Service. For more information, see http://www.azgfd.gov/w_c/wolf_reintroduction.shtml

The UBR-NRA also contains part of the critical habitat for the Mexican Spotted Owl.

Upper Blue River NRA Protection Needs

Based on the ADEQ Water Quality Assessment results (ADEQ, 2003), there are seven stream reaches within this area which are monitored by ADEQ. No exceedances were reported for any of the monitored constituents.

<u>Cottonwood NRA</u>

The Cottonwood Natural Resource Area (C-NRA) includes two 10-digit HUC Subwatersheds: Cottonwood Wash-Upper Gila River and Stockton Wash. This area provides important resources and riparian habitats, including critical habitat for the Gila Chub and Mexican Spotted Owl.

Cottonwood NRA Protection Needs

Because this area is a critical habitat for the Mexican Spotted Owl and Gila Chub, conservation measures should be chosen to prevent degradation of natural resources in this area.

The current water quality assessment report (ADEQ, 2003) indicates that monitoring has occurred on two stream reaches and three lakes in the Cottonwood NRA. Some exceedances of selenium and turbidity/suspended sediment standards were reported at Dankworth Ponds, and should continue to be monitored. No surface water is listed as impaired.

<u>Chase Creek NRA</u>

Chase Creek Natural Resource Area (CC-NRA) includes one 10-digit HUC subwatershed named Chase Creek-San Francisco River. This area provides riparian habitat for many plant and animal species.

Chase Creek NRA Protection Needs

There are two stream reaches within this area that are monitored by ADEQ. Some exceedances are reported for other constituents in other stream reaches. Water quality monitoring should be continued for this area.

<u>Mule Creek NRA</u>

The Mule Creek Natural Resource Area (M-NRA) includes one 10-digit HUC subwatershed: Mule Creek-San Francisco River.

The Mule Creek NRA contains critical habitat for the Gila Chub and Mexican Spotted Owl. It also provides riparian habitat for many plant and animal species.

Based on current water quality assessment results (ADEQ, 2003), one stream reach was monitored. Although insufficient suspended sediment concentration and flow records are available to assess sediment, the old turbidity standard was occasionally exceeded in the past.

Mule Creek NRA Protection Needs

The Mule Creek-San Francisco River subwatershed is classified as moderate risk for metals, and high risk for sediment (see Section 6). In addition, because this area is a critical habitat for the Gila Chub and Mexican Spotted Owl, conservation measures, water quality monitoring, and Best Management Practices should be implemented to maintain water quality.

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Section 6: Watershed Classification

In this section each 10-digit subwatershed in the Upper Gila is classified or ranked based on susceptibility to water quality problems and nonpoint pollution that need to be controlled through implementation of nonpoint source Best Management Practices (BMPs). The pollution sources were grouped into four major categories: metals, sediment, organics and selenium. This classification prioritizes all 31 subwatersheds for available water quality improvement grants, based on known water quality concerns.

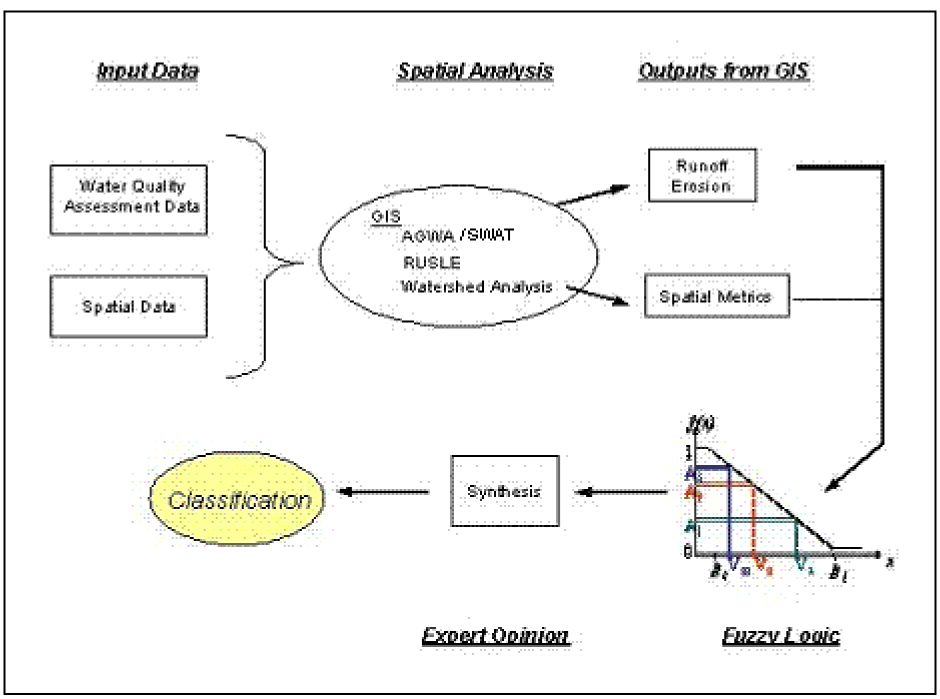
Methods

The general approach to classifying the 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:

- 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;

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



- Assemble GIS data and other observational data;

- Define watershed characteristics through:

  - ✓ Water quality assessment data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003);
  - ✓ GIS mapping analysis; and
  - ✓ 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).

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

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

Fuzzy Logic

The "fuzzy logic" method is used to integrate different types of data (Guertin et al., 2000; Reynolds, 2001). Using fuzzy logic, a watershed tool was developed that can be updated as new water quality information becomes available. In this tool, the "weight" or priority given a specific factor used in the classification can be changed or adjusted, making the tool more valuable because underlying bias in interpreting the data can be uncovered and evaluated.

Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized 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. For example, one is either tall or short, 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 considered in the tall class, although he could not be considered 'not-tall'. This is not satisfactory, for example, if one has to describe or quantify 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.

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 case above, the degree of tallness was iteratively added in intervals of 0.2. An example of a continuous data set would be graphing heights of all individuals and correlating 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.

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 Classifications

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 Upper Gila Watershed are:

- Metals (copper, lead, mercury), with copper used as an index since it is the most common parameter sampled in the subwatershed;
- Sediment (turbidity is used as an index since it was the previous standard and represents most of the sampling data);
- Organics (Escherichia coli, nutrients, high pH factors, and dissolved oxygen are concerns and are related to organic material being introduced into the aquatic system); and
- Selenium.
-

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

HUC 10	Subwatershed Name
1504000207	Railroad Wash-Upper Gila River
1504000208	Apache Creek-Upper Gila River
1504000300	Animas Valley
1504000403	Centerfire Creek-San Francisco River
1504000405	Upper Blue River
1504000406	Pueblo Creek-San Francisco River
1504000407	Lower Blue River
1504000408	Mule Creek-San Francisco River
1504000409	Chase Creek-San Francisco River
1504000501	Willow Creek
1504000502	Upper Eagle Creek
1504000503	Lower Eagle Creek
1504000504	Bonita Creek
1504000505	Yuma Wash-Upper Gila River
1504000506	Stockton Wash
1504000507	Cottonwood Wash-Upper Gila River
1504000508	Black Rock Wash-Upper Gila River
1504000509	Goodwin Wash-Upper Gila River
1504000510	Salt Creek-Upper Gila River
1504000601	San Simon River Headwaters
1504000602	Cave Creek-San Simon River
1504000603	Happy Camp Wash
1504000604	East Whitetail Creek-San Simon River
1504000605	Hot Well Draw-Hospital Flat
1504000606	Tule Wells Draw-San Simon River
1504000607	Gold Gulch-San Simon River
1504000608	Slick Rock Wash-San Simon River
1504000701	Ash Creek
1504000702	Sevenmile Wash-Sycamore Creek
1504000703	Gilson Wash
1504000704	San Carlos River (Local Drainage)

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

Water Quality Assessment Data

Data collected and used for Arizona's 2004 Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003) was used to define the current level of impairment based on water quality sampling results from several entities and volunteer groups in Arizona. In assigning fuzzy membership values the location of a subwatershed relative to an impaired water was considered. Appendix A Table 1 is a summary of the water quality monitoring and assessment data collected on the Upper Gila Watershed.

ADEQ's assessment criteria and assessment definitions are found in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003). Surface waters assessed as "impaired" are included in Arizona's 303(d) List of Impaired Waters and 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, 2004).

The water quality data were used to classify each monitored stream reach based on its relative risk of impairment for the constituent groups described above.

To classify each 10-digit subwatershed, based on its relative risk of impairment for the constituent groups described above, four levels of risk were defined: Extreme, High, Moderate, and Low.

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

- 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.

- Moderate risk – If either:
    - 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
    - There were no water quality measurements available for a constituent group at any site within the subwatershed.

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

For more information on ADEQ's Upper Gila Watershed Water Quality Assessment, see the ADEQ Website: http://www.adeq.state.az.us/environ/water/assessment/assess.html

Each 10-digit HUC subwatershed is assigned a fuzzy membership value (FMV) based on the water quality parameters and assessment results. Table 6-2 contains the FMVs used for

different watershed conditions based on the water quality classification results.
It should be noted that not every 10-digit HUC subwatershed contained a water quality measurement site.

The FMVs are based on two considerations: 1) relative risk of impairment (described above), and 2) assessed water quality status of downstream surface waters if the subwatershed has either "high" or "moderate" condition.

The status of downstream surface waters provides a way to evaluate the potential 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.

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

Reaches classified as either extreme or low risk were given precedence over high or moderate classified reaches in determining downstream water quality condition because of their ambiguity. For example, if a downstream water body was classified as extreme risk, it was used to define the downstream water quality condition. However, if a reach along the pathway was classified as low risk, then the low risk reach was used to define the downstream water quality condition.

Table 1 in Appendix A provides more clarification on the ADEQ Water Quality Assessment results, and defines the basis for classification as extreme, high, moderate, and low risk.

<u>Metals</u>

Metals are one of the most significant water quality problems in the Upper Gila Watershed because of the potential toxicity to aquatic life. Two stream reaches within the Apache Creek and Yuma Wash subwatersheds have high exceedances for copper and lead, and metals were found to exceed standards in several other reaches. However, some stream reaches have not been sampled for metals.

The primary sources for metals in the Upper Gila 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 Upper Gila 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, 2003) was used to define the current level of impairment for metals. The location of a subwatershed relative to an impaired water was considered when assigning fuzzy membership values. As noted previously, Table 6-2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results.
Table 6-3 contains the fuzzy membership values for metals assigned to each 10-digit HUC subwatershed, based on criteria defined in Table 6-2.

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

Subwatershed Name	FMV	Justification
Railroad Wash-Upper Gila River	0.6	Classified as moderate risk, drains into Apache Creek subwatershed that is classified as high risk.
Apache Creek-Upper Gila River	0.8	Classified as high risk, drains into Yuma Wash subwatershed that is classified as high risk.
Animas Valley	0.5	Classified as moderate risk (no data), and is along the Arizona-New Mexico state line.
Centerfire Creek-San Francisco River	0.5	Classified as moderate risk (limited data), drains into New Mexico.
Upper Blue River	0.6	Classified as moderate risk, drains into Yuma Wash that is classified as high risk.
Pueblo Creek-San Francisco River	0.5	Classified as moderate risk (no data).
Lower Blue River	0.6	Classified as moderate risk, drains into Yuma Wash that is classified as high risk.
Mule Creek-San Francisco River	0.6	Classified as moderate risk (limited data), drains into Yuma Wash that is classified as high risk.
Chase Creek-San Francisco River	0.6	Classified as moderate risk due to copper, lead and mercury exceedances, drains into Yuma Wash that is classified as high risk.
Willow Creek	0.6	Classified as moderate risk (no data), drains into Yuma Wash that is classified as high risk.
Upper Eagle Creek	0.6	Classified as moderate risk (limited data), drains into Yuma Wash that is classified as high risk.
Lower Eagle Creek	0.6	Classified as moderate risk, drains into Yuma Wash that is classified as high risk.
Bonita Creek	0.0	Classified as low risk.
Yuma Wash-Upper Gila River	0.7	Classified as high risk, drains into Cottonwood Wash that is classified as moderate risk.

Subwatershed Name	FMV	Justification
Stockton Wash	**0.5**	**Classified as moderate risk (limited data).**
Cottonwood Wash-Upper Gila River	**0.5**	**Classified as moderate risk (limited data).**
Black Rock Wash-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
Goodwin Wash-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
Salt Creek-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
San Simon River Headwaters	**0.5**	**Classified as moderate risk (no data).**
Cave Creek-San Simon River	**0.5**	**Classified as moderate risk.**
Happy Camp Wash	**0.5**	**Classified as moderate risk (no data).**
East Whitetail Creek-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Hot Well Draw-Hospital Flat	**0.5**	**Classified as moderate risk (no data).**
Tule Wells Draw-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Gold Gulch-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Slick Rock Wash-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Ash Creek	**0.5**	**Classified as moderate risk (no data).**
Sevenmile Wash-Sycamore Creek	**0.5**	**Classified as moderate risk (no data).**
Gilson Wash	**0.5**	**Classified as moderate risk (no data).**
San Carlos River (Local Drainage)	**0.5**	**Classified as moderate risk (no data).**

Note: This table is cross-referenced to Table 1 of Appendix A where the 10-digit HUC names are tabulated by subwatershed name.

Location of Mining Activities

Section 2 Physical Characteristics, and Section 4 Social Characteristics of the Upper Gila Watershed, contain a more thorough discussion of the geologic conditions and location of mine sites and mine types across the watershed. The subwatersheds were classified using the fuzzy logic methodology by incorporating the spatial data from Sections 2 and 4 with the tabulated ADEQ water quality assessment data.

The number of mines in a subwatershed and within the riparian zone (< = 250 m from a stream) were used to assess the relative impact of mining on the concentration of dissolved and total metals in the subwatershed. The fuzzy membership functions for both conditions are:

Number of mines/subwatershed:

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

Number of mines/riparian:

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.

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

Subwatershed Name	FMV #mines/ watershed	FMV #mines riparian
Railroad Wash-Upper Gila River	**1.00**	**1.0**
Apache Creek-Upper Gila River	**1.00**	**1.0**
Animas Valley	**0.00**	**0.0**
Centerfire Creek-San Francisco River	**0.00**	**0.0**
Upper Blue River	**0.25**	**0.4**
Pueblo Creek-San Francisco River	**0.00**	**0.0**
Pueblo Creek-San Francisco River	**0.00**	**0.0**
Lower Blue River	**0.50**	**0.4**
Mule Creek-San Francisco River	**0.00**	**0.4**
Chase Creek-San Francisco River	**1.00**	**1.0**
Willow Creek	**0.00**	**0.2**
Upper Eagle Creek	**0.38**	**0.8**
Lower Eagle Creek	**1.00**	**1.0**
Bonita Creek	**0.63**	**0.6**
Yuma Wash-Upper Gila River	**1.00**	**1.0**
Stockton Wash	**1.00**	**1.0**
Cottonwood Wash-Upper Gila River	**1.00**	**1.0**
Black Rock Wash-Upper Gila River	**1.00**	**1.0**
Goodwin Wash-Upper Gila River	**1.00**	**1.0**
Salt Creek-Upper Gila River	**1.00**	**1.0**
San Simon River Headwaters	**0.00**	**0.0**
Cave Creek-San Simon River	**1.00**	**1.0**
Happy Camp Wash	**1.00**	**0.4**
East Whitetail Creek-San Simon River	**1.00**	**1.0**
Hot Well Draw-Hospital Flat	**0.75**	**1.0**
Tule Wells Draw-San Simon River	**1.00**	**1.0**
Gold Gulch-San Simon River	**1.00**	**1.0**
Slick Rock Wash-San Simon River	**1.00**	**1.0**
Ash Creek	**0.00**	**0.0**
Sevenmile Wash-Sycamore Creek	**0.75**	**1.0**
Gilson Wash	**1.00**	**1.0**
San Carlos River (Local Drainage)	**1.00**	**1.0**

Potential Contribution of Mines to Sediment Yield

Based on RUSLE modeling (Renard et al., 1997; see Appendix C) the potential for erosion from mines to contribute to the sediment yield for a subwatershed was evaluated. The modeling results were reclassified into 6 categories. The first category represented zero potential for contribution (i.e. no mines) and was given a fuzzy membership value of 0.0. The fuzzy membership values were increased by increments of 0.2 for each higher erosion category. Table 6-5 contains the results.

Table 6-5: FMV Per Erosion Category.

Subwatershed	Category	FMV
Railroad Wash-Upper Gila River	**2**	**0.2**
Apache Creek-Upper Gila River	**2**	**0.2**
Animas Valley	**1**	**0.0**
Centerfire Creek-San Francisco River	**2**	**0.2**
Upper Blue River	**2**	**0.2**
Pueblo Creek-San Francisco River	**1**	**0.0**
Lower Blue River	**2**	**0.2**
Mule Creek-San Francisco River	**2**	**0.2**

Subwatershed	Category	FMV
Chase Creek-San Francisco River	6	1.0
Willow Creek	2	0.2
Upper Eagle Creek	2	0.2
Lower Eagle Creek	5	0.8
Bonita Creek	2	0.2
Yuma Wash-Upper Gila River	2	0.2
Stockton Wash	3	0.4
Cottonwood Wash-Upper Gila River	4	0.6
Black Rock Wash-Upper Gila River	2	0.2
Goodwin Wash-Upper Gila River	2	0.2
Salt Creek-Upper Gila River	2	0.2
San Simon River Headwaters	1	0.0
Cave Creek-San Simon River	2	0.2
Happy Camp Wash	2	0.2
East Whitetail Creek-San Simon River	2	0.2
Hot Well Draw-Hospital Flat	2	0.2
Tule Wells Draw-San Simon River	2	0.2
Gold Gulch-San Simon River	2	0.2
Slick Rock Wash-San Simon River	2	0.2
Ash Creek	2	0.2
Sevenmile Wash-Sycamore Creek	2	0.2
Gilson Wash	2	0.2
San Carlos River (Local Drainage)	2	0.2

Metals Results

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

Weights were developed in cooperation with ADEQ and were ranked to emphasize the proximity of mines to the riparian area, the susceptibility to erosion, and the ADEQ Water Quality Assessment results. The overall number of mines within the subwatershed (but removed from the riparian area) was not considered as pertinent to the classification. Therefore, the weight assigned was 0.1, as opposed to 0.3 for the other categories.

Each of the assigned weights were multiplied by the FMV, and then added to the result in the weighted ranking. Subwatershed areas were classified into two groups, 'high' or 'low', based on the natural breaks of the FMV results. Figure 6-2 shows the results of the weighted combination method classified into high and low priority for metals.

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

Subwatershed	WQA[1]	#Mines/ Subwatershed	#Mines/ Riparian	Erosion Category	FMV Weighted
Railroad Wash-Upper Gila River	0.6	1.000	1.000	0.200	0.640
Apache Creek-Upper Gila River	0.8	1.000	1.000	0.200	0.700
Animas Valley	0.5	0.000	0.000	0.000	0.150
Centerfire Creek-San Francisco River	0.5	0.000	0.000	0.200	0.210
Upper Blue River	0.6	0.250	0.400	0.200	0.385
Pueblo Creek-San Francisco River	0.5	0.000	0.000	0.000	0.150
Lower Blue River	0.6	0.500	0.400	0.200	0.410
Mule Creek-San Francisco River	0.6	0.000	0.400	0.200	0.360
Chase Creek-San Francisco River	0.6	1.000	1.000	1.000	0.880
Willow Creek	0.6	0.000	0.200	0.200	0.300
Upper Eagle Creek	0.6	0.375	0.800	0.200	0.518
Lower Eagle Creek	0.6	1.000	1.000	0.800	0.820
Bonita Creek	0.0	0.625	0.600	0.200	0.303
Yuma Wash-Upper Gila River	0.7	1.000	1.000	0.200	0.670
Stockton Wash	0.5	1.000	1.000	0.400	0.670
Cottonwood Wash-Upper Gila River	0.5	1.000	1.000	0.600	0.730
Black Rock Wash-Upper Gila River	0.5	1.000	1.000	0.200	0.610
Goodwin Wash-Upper Gila River	0.5	1.000	1.000	0.200	0.610
Salt Creek-Upper Gila River	0.5	1.000	1.000	0.200	0.610
San Simon River Headwaters	0.5	0.000	0.000	0.000	0.150
Cave Creek-San Simon River	0.5	1.000	1.000	0.200	0.610
Happy Camp Wash	0.5	1.000	0.400	0.200	0.430
East Whitetail Creek-San Simon River	0.5	1.000	1.000	0.200	0.610
Hot Well Draw-Hospital Flat	0.5	0.750	1.000	0.200	0.585
Tule Wells Draw-San Simon River	0.5	1.000	1.000	0.200	0.610
Gold Gulch-San Simon River	0.5	1.000	1.000	0.200	0.610
Slick Rock Wash-San Simon River	0.5	1.000	1.000	0.200	0.610
Ash Creek	0.5	0.000	0.000	0.200	0.210
Sevenmile Wash-Sycamore Creek	0.5	0.750	1.000	0.200	0.585
Gilson Wash	0.5	1.000	1.000	0.200	0.610
San Carlos River (Local Drainage)	0.5	1.000	1.000	0.200	0.610
Weights	*0.3*	*0.1*	*0.3*	*0.3*	

[1]WQA = Water Quality Assessment results

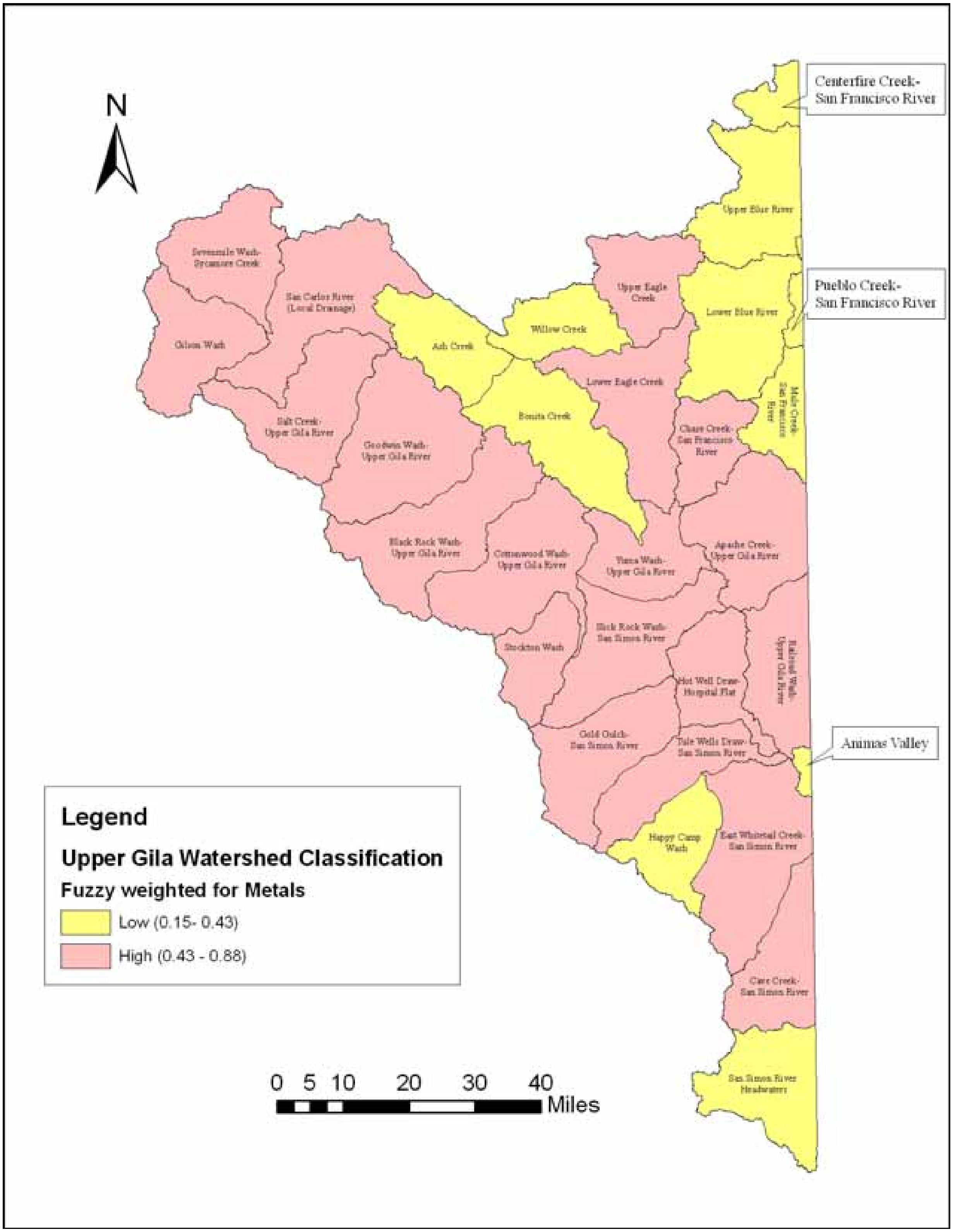


Figure 6-2: Results for the Fuzzy Logic Classification for Metals, Based on the Weighted Combination Approach.

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.

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

Water Quality Assessment Data - Sediment

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), 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, Table 6-2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results. Table 6-7 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on turbidity data.

Table 6-7: Fuzzy Membership Values for Sediment Assigned to each 10-digit HUC Subwatershed, Based on Water Quality Assessment Results.

Subwatershed Name	FMV	Justification
Railroad Wash-Upper Gila River	0.0	Classified as low risk.
Apache Creek-Upper Gila River	0.7	Classified as moderate risk for sediment, and drains to Yuma Wash subwatershed that is classified as extreme risk.
Animas Valley	0.5	Classified as moderate risk (no data), and is along the Arizona-New Mexico state line.
Centerfire Creek-San Francisco River	1.0	Classified as extreme risk.
Upper Blue River	0.3	Classified as moderate risk for sediment, and drains into Lower Blue River that is classified as low risk for sediment.
Pueblo Creek-San Francisco River	0.5	Classified as moderate risk (no data).
Lower Blue River	0.0	Classified as low risk for sediment.
Mule Creek-San Francisco River	1.0	Classified as high risk for sediment, and drains into Yuma Wash that is classified as extreme risk.
Chase Creek-San Francisco River	1.0	Classified as high risk, and drains into Yuma Wash that is classified as extreme risk.

Subwatershed Name	FMV	Justification
Willow Creek	0.7	Classified as moderate risk (no data), and drains into Yuma Wash that is classified as extreme risk.
Upper Eagle Creek	0.0	Classified as low risk.
Lower Eagle Creek	0.7	Classified as moderate risk, and drains into Yuma Wash that is classified as extreme risk.
Bonita Creek	0.7	Classified as moderate risk, and drains into Yuma Wash that is classified as extreme risk.
Yuma Wash-Upper Gila River	1.0	Classified as extreme risk.
Stockton Wash	0.7	Classified as high risk, and drains into Cottonwood Wash that is classified as moderate risk area.
Cottonwood Wash-Upper Gila River	0.5	Classified as moderate risk, and drains into Black Rock Wash that is classified as moderate risk.
Black Rock Wash-Upper Gila River	0.5	Classified as moderate risk (no data).
Goodwin Wash-Upper Gila River	0.5	Classified as moderate risk (no data).
Salt Creek-Upper Gila River	0.5	Classified as moderate risk (no data).
San Simon River Headwaters	0.5	Classified as moderate risk (no data).
Cave Creek-San Simon River	0.7	Classified as high risk.
Happy Camp Wash	0.5	Classified as moderate risk (no data).
East Whitetail Creek-San Simon River	0.6	Classified as moderate risk (no data).
Hot Well Draw-Hospital Flat	0.5	Classified as moderate risk (no data).
Tule Wells Draw-San Simon River	0.5	Classified as moderate risk (no data).
Gold Gulch-San Simon River	0.5	Classified as moderate risk (no data).
Slick Rock Wash-San Simon River	0.5	Classified as moderate risk (no data).
Ash Creek	0.5	Classified as moderate risk (no data).
Sevenmile Wash-Sycamore Creek	0.5	Classified as moderate risk (no data).
Gilson Wash	0.5	Classified as moderate risk (no data).
San Carlos River (Local Drainage)	0.5	Classified as moderate risk (no data).

Land Ownership

The principal land use in the Upper Gila 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, with cotton being the most common row crop. 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:

$$FMV = 0 \text{ if } (\%State + private <= 10)$$
$$FMV = (\%State + private - 10) / 15$$
$$FMV = 1 \text{ if } (\%State + private >= 25)$$

Table 6-8 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Upper Gila Watershed based on land ownership.

Table 6-8: Fuzzy Membership Values Based on Land Ownership.

Subwatershed Name	%State + Private	FMV
Railroad Wash-Upper Gila River	**63.32**	**1.00**
Apache Creek-Upper Gila River	**55.17**	**1.00**
Animas Valley	**12.25**	**0.15**
Centerfire Creek-San Francisco River	**12.02**	**0.13**
Upper Blue River	**1.10**	**0.00**
Pueblo Creek-San Francisco River	**0.00**	**0.00**
Lower Blue River	**0.22**	**0.00**
Mule Creek-San Francisco River	**0.58**	**0.00**
Chase Creek-San Francisco River	**46.78**	**1.00**
Willow Creek	**99.98**	**1.00**
Upper Eagle Creek	**36.48**	**1.00**
Lower Eagle Creek	**52.48**	**1.00**
Bonita Creek	**84.81**	**1.00**
Yuma Wash-Upper Gila River	**11.74**	**0.12**
Stockton Wash	**34.78**	**1.00**
Cottonwood Wash-Upper Gila River	**57.47**	**1.00**
Black Rock Wash-Upper Gila River	**58.04**	**1.00**
Goodwin Wash-Upper Gila River	**71.36**	**1.00**
Salt Creek-Upper Gila River	**100.00**	**1.00**
San Simon River Headwaters	**55.93**	**1.00**
Cave Creek-San Simon River	**54.43**	**1.00**
Happy Camp Wash	**61.92**	**1.00**
East Whitetail Creek-San Simon River	**43.26**	**1.00**
Hot Well Draw-Hospital Flat	**69.86**	**1.00**
Tule Wells Draw-San Simon River	**44.68**	**1.00**
Gold Gulch-San Simon River	**55.19**	**1.00**
Slick Rock Wash-San Simon River	**9.15**	**0.00**
Ash Creek	**99.98**	**1.00**
Sevenmile Wash-Sycamore Creek	**77.04**	**1.00**
Gilson Wash	**83.75**	**1.00**
San Carlos River (Local Drainage)	**100.00**	**1.00**

Human Use Index – Sediment Load

The Human Use Index (HUI) 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 Upper Gila Watershed, human use was based on developed areas as defined by the National Land Cover

Data as residential land use, mining, agricultural lands and roads (USGS, 2003). Human use was assessed at both the subwatershed and riparian scale (< = 250 meters from a stream). The fuzzy membership functions for these 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 6-9 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Upper Gila Watershed based on the Human Use Index.

Table 6-9: Fuzzy Membership Values Based on the Human Use Index.

Subwatershed	FMV HU Index /watershed	FMV HU Index /riparian
Railroad Wash-Upper Gila River	0.00	0.96
Apache Creek-Upper Gila River	0.00	0.06
Animas Valley	0.00	0.00
Centerfire Creek-San Francisco River	0.00	0.94
Upper Blue River	0.00	0.00
Pueblo Creek-San Francisco River	0.00	0.00
Lower Blue River	0.00	0.00
Mule Creek-San Francisco River	0.00	0.00
Chase Creek-San Francisco River	0.30	1.00
Willow Creek	0.00	0.00
Upper Eagle Creek	0.00	0.00
Lower Eagle Creek	0.00	0.00
Bonita Creek	0.00	0.00
Yuma Wash-Upper Gila River	0.00	0.77
Stockton Wash	0.00	0.45
Cottonwood Wash-Upper Gila River	0.29	1.00
Black Rock Wash-Upper Gila River	0.00	0.35
Goodwin Wash-Upper Gila River	0.00	0.07
Salt Creek-Upper Gila River	0.00	0.00
San Simon River Headwaters	0.00	0.00
Cave Creek-San Simon River	0.00	0.13
Happy Camp Wash	0.07	0.64
East Whitetail Creek	0.08	0.28
Hot Well Draw-Hospital Flat	0.00	0.00
Tule Wells Draw-San Simon River	0.39	1.00
Gold Gulch-San Simon River	0.00	0.00
Slick Rock Wash-San Simon River	0.00	0.06
Ash Creek	0.00	0.00
Sevenmile Wash-Sycamore Creek	0.00	0.00
Gilson Wash	0.00	0.00
San Carlos River (Local Drainage)	0.00	0.00

Runoff

Based on SWAT modeling (see Appendix D) the potential runoff for a subwatershed area was evaluated. The modeling results were reclassified into 5 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 erosion category, as shown in Table 6-10.

Table 6-10: Fuzzy Membership Values and Runoff Categories.

Subwatershed	Runoff Category	FMV
Railroad Wash-Upper Gila River	3	0.6
Apache Creek-Upper Gila River	3	0.6
Animas Valley	1	0.2
Centerfire Creek-San Francisco River	1	0.2
Upper Blue River	2	0.4
Pueblo Creek-San Francisco River	1	0.2
Lower Blue River	2	0.4
Mule Creek-San Francisco River	1	0.2
Chase Creek-San Francisco River	2	0.4
Willow Creek	2	0.4
Upper Eagle Creek	3	0.6
Lower Eagle Creek	2	0.4
Bonita Creek	4	0.8
Yuma Wash-Upper Gila River	5	1.0
Stockton Wash	1	0.2
Cottonwood Wash-Upper Gila River	4	0.8
Black Rock Wash-Upper Gila River	5	1.0
Goodwin Wash-Upper Gila River	5	1.0
Salt Creek-Upper Gila River	3	0.6
San Simon River Headwaters	2	0.4
Cave Creek-San Simon River	1	0.2
Happy Camp Wash	1	0.2
East Whitetail Creek-San Simon River	1	0.2
Hot Well Draw-Hospital Flat	1	0.2
Tule Wells Draw-San Simon River	1	0.2
Gold Gulch-San Simon River	1	0.2
Slick Rock Wash-San Simon River	1	0.2
Ash Creek	2	0.4
Sevenmile Wash-Sycamore Creek	5	1.0
Gilson Wash	2	0.4
San Carlos River (Local Drainage)	2	0.4

Erosion

Sediment yield is a measure of the rate of erosion, and depends on a combination of soil properties, topography, climate and land cover.

SWAT was used to evaluate the potential sediment yield for each subwatershed (see Appendix D). The modeling results were reclassified into 5 categories, with the first category given a fuzzy membership value of 0.2. The fuzzy membership values were increased incrementally by 0.2 for each higher erosion category based on modeled sediment yield, as shown in Table 6-11.

Sediment Results

The weighted combination approach was used to create combined fuzzy scores to rank sediment results, as shown in Table 6-12. The weights used in the classification are found at the bottom of Table 6-12.
Figure 6-3 shows the results of the weighted combination method for sediment classified into high and low priority.

Table 6-11: Fuzzy Membership Values and Erosion Categories.

Subwatershed	Erosion Category	FMV
Railroad Wash-Upper Gila River	2	0.4
Apache Creek-Upper Gila River	3	0.6
Animas Valley	1	0.2
Centerfire Creek-San Francisco River	1	0.2
Upper Blue River	1	0.2
Pueblo Creek-San Francisco River	1	0.2
Lower Blue River	1	0.2
Mule Creek-San Francisco River	1	0.2
Chase Creek-San Francisco River	3	0.6
Willow Creek	1	0.2
Upper Eagle Creek	3	0.6
Lower Eagle Creek	2	0.4
Bonita Creek	5	1.0
Yuma Wash-Upper Gila River	5	1.0
Stockton Wash	1	0.2
Cottonwood Wash-Upper Gila River	4	0.8
Black Rock Wash-Upper Gila River	4	0.8
Goodwin Wash-Upper Gila River	4	0.8
Salt Creek-Upper Gila River	3	0.6
San Simon River Headwaters	1	0.2
Cave Creek-San Simon River	1	0.2
Happy Camp Wash	1	0.2
East Whitetail Creek-San Simon River	1	0.2
Hot Well Draw-Hospital Flat	1	0.2
Tule Wells Draw-San Simon River	1	0.2
Gold Gulch-San Simon River	1	0.2

Subwatershed	Erosion Category	FMV
Slick Rock Wash-San Simon River	1	0.2
Ash Creek	1	0.2
Sevenmile Wash-Sycamore Creek	5	1.0
Gilson Wash	1	0.2
San Carlos River (Local Drainage)	1	0.2

Table 6-12: Summary Results for Sediment, Based on the Fuzzy Logic Approach - Weighted Combination Approach.

Subwatershed	WQA[1]	Owner	HU Index/ Watershed	HU Index/ Riparian	Runoff	Erosion	FMV Weighted
Railroad Wash-Upper Gila River	0.0	1.00	0.00	0.96	0.6	0.4	0.54
Apache Creek-Upper Gila River	0.7	1.00	0.00	0.06	0.6	0.6	0.46
Animas Valley	0.5	0.15	0.00	0.00	0.2	0.2	0.15
Centerfire Creek-San Francisco River	1.0	0.13	0.00	0.94	0.2	0.2	0.36
Upper Blue River	0.3	0.00	0.00	0.00	0.4	0.2	0.20
Pueblo Creek-San Francisco River	0.5	0.00	0.00	0.00	0.2	0.2	0.15
Lower Blue River	0.0	0.00	0.00	0.00	0.4	0.2	0.18
Mule Creek-San Francisco River	1.0	0.00	0.00	0.00	0.2	0.2	0.17
Chase Creek-San Francisco River	1.0	1.00	0.30	1.00	0.4	0.6	0.63
Willow Creek	0.7	1.00	0.00	0.00	0.4	0.2	0.27
Upper Eagle Creek	0.0	1.00	0.00	0.00	0.6	0.6	0.41
Lower Eagle Creek	0.7	1.00	0.00	0.00	0.4	0.4	0.33
Bonita Creek	0.7	1.00	0.00	0.00	0.8	1.0	0.63
Yuma Wash-Upper Gila River	1.0	0.12	0.00	0.77	1.0	1.0	0.81
Stockton Wash	0.7	1.00	0.00	0.45	0.2	0.2	0.30
Cottonwood Wash-Upper Gila River	0.5	1.00	0.29	1.00	0.8	0.8	0.78
Black Rock Wash-Upper Gila River	0.5	1.00	0.00	0.35	1.0	0.8	0.69
Goodwin Wash-Upper Gila River	0.5	1.00	0.00	0.07	1.0	0.8	0.63
Salt Creek-Upper Gila River	0.5	1.00	0.00	0.00	0.6	0.6	0.44
San Simon River Headwaters	0.5	1.00	0.00	0.00	0.4	0.2	0.26
Cave Creek-San Simon River	0.7	1.00	0.00	0.13	0.2	0.2	0.23
Happy Camp Wash	0.5	1.00	0.07	0.64	0.2	0.2	0.33
East Whitetail Creek-San Simon River	0.6	1.00	0.08	0.28	0.2	0.2	0.26
Hot Well Draw-Hospital Flat	0.5	1.00	0.00	0.00	0.2	0.2	0.20
Tule Wells Draw-San Simon River	0.5	1.00	0.39	1.00	0.2	0.2	0.43
Gold Gulch-San Simon River	0.5	1.00	0.00	0.00	0.2	0.2	0.20
Slick Rock Wash-San Simon River	0.5	0.00	0.00	0.06	0.2	0.2	0.16

Subwatershed	WQA[1]	Owner	HU Index/ Watershed	HU Index/ Riparian	Runoff	Erosion	FMV Weighted
Ash Creek	**0.5**	**1.00**	**0.00**	**0.00**	**0.4**	**0.2**	**0.26**
Sevenmile Wash-Sycamore Creek	**0.5**	**1.00**	**0.00**	**0.00**	**1.0**	**1.0**	**0.68**
Gilson Wash	**0.5**	**1.00**	**0.00**	**0.00**	**0.4**	**0.2**	**0.26**
San Carlos River (Local Drainage)	**0.5**	**1.00**	**0.00**	**0.00**	**0.4**	**0.2**	**0.26**
Weights	***0.05***	***0.05***	***0.1***	***0.2***	***0.3***	***0.3***	

[1]WQA = Water Quality Assessment results

Organics

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

Exceedances for Escherichia coli (E. coli) have been found on five monitoring reaches, and exceedances of dissolved oxygen have been found on four monitoring reaches. Among these reaches, the Gila River from Bonita Creek to the Yuma Wash was assessed as “impaired” for E. coli. Luna Lake assessed as “not attaining” due to high exceedances for dissolved oxygen and pH.

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, 2003) 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 6-13 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed for organics classification.

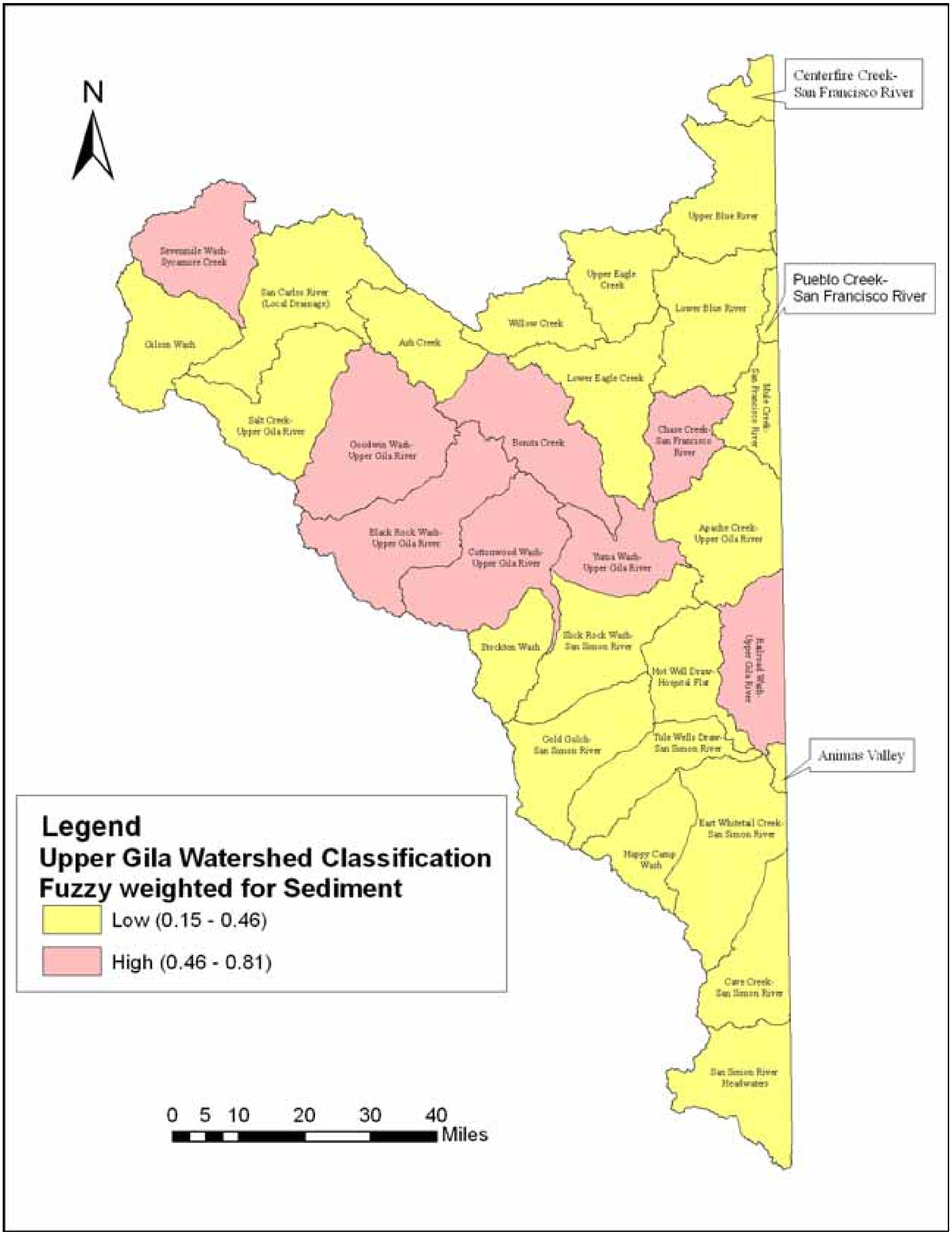


Figure 6-3: Results for the Fuzzy Logic Classification for Sediment, Based on the Weighted Combination Approach.

Table 6-13: Fuzzy Membership Values Assigned to each 10-digit HUC Subwatershed - Based on Water Quality Assessment Results for Organics.

Subwatershed Name	FMV	Justification
Railroad Wash-Upper Gila River	0.0	Classified as low risk.
Apache Creek-Upper Gila River	1.0	Classified as high risk for organics, and drains to Yuma Wash subwatershed that is classified as extreme risk.
Animas Valley	0.5	Classified as moderate risk (no data), and is along Arizona-New Mexico state line.
Centerfire Creek-San Francisco River	1.0	Classified as extreme risk.
Upper Blue River	0.3	Classified as moderate risk for organics, and drains to Lower Blue River subwatershed that is classified as low risk for organics.
Pueblo Creek-San Francisco River	0.5	Classified as moderate risk (no data).
Lower Blue River	0.0	Classified as low risk for organics.
Mule Creek-San Francisco River	0.0	Classified as low risk for organics.
Chase Creek-San Francisco River	0.7	Classified as moderate risk, and drains to Yuma Wash subwatershed that is classified as extreme risk.
Willow Creek	0.7	Classified as moderate risk (no data), and drains to Yuma Wash subwatershed that is classified as extreme risk.
Upper Eagle Creek	0.0	Classified as low risk.
Lower Eagle Creek	0.0	Classified as low risk.
Bonita Creek	0.0	Classified as low risk.
Yuma Wash-Upper Gila River	1.0	Classified as extreme risk.
Stockton Wash	0.5	Classified as moderate risk and drains into Black Rock Wash that is classified as moderate risk.
Cottonwood Wash-Upper Gila River	0.5	Classified as moderate risk, and drains into Black Rock Wash that is classified as moderate risk.
Black Rock Wash-Upper Gila River	0.5	Classified as moderate risk (no data).
Goodwin Wash-Upper Gila River	0.5	Classified as moderate risk (no data).
Salt Creek-Upper Gila River	0.5	Classified as moderate risk (no data).
San Simon River Headwaters	0.5	Classified as moderate risk (no data).
Cave Creek-San Simon River	0.5	Classified as moderate risk.
Happy Camp Wash	0.5	Classified as moderate risk (no data).
East Whitetail Creek-San Simon River	0.5	Classified as moderate risk (no data).
Hot Well Draw-Hospital Flat	0.5	Classified as moderate risk (no data).
Tule Wells Draw-San Simon River	0.5	Classified as moderate risk (no data).
Gold Gulch-San Simon River	0.5	Classified as moderate risk (no data).
Slick Rock Wash-San Simon River	0.5	Classified as moderate risk (no data).
Ash Creek	0.5	Classified as moderate risk (no data).
Sevenmile Wash-Sycamore Creek	0.5	Classified as moderate risk (no data).
Gilson Wash	0.5	Classified as moderate risk (no data).
San Carlos River (Local Drainage)	0.5	Classified as moderate risk (no data).

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 Upper Gila Watershed, human use is based on developed areas as defined by the National Land Cover Data as residential land use, mining, agriculture and roads (USGS, 2003).

Human activity can introduce organic material to a water body by disposal of organic compounds and sewage. Most of the residential development in the Upper Gila Watershed utilizes 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 6-14 contains the fuzzy membership values for organics for each 10-digit HUC subwatershed based on the Human Use Index.

Land Use - Organics

The principal land use in the Upper Gila 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 watershed 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.

Table 6-14: Fuzzy Membership Values for Organics, Based on the Human Use Index.

Subwatershed	FMV HUI/sub-watershed	FMV HUI/ riparian
Railroad Wash-Upper Gila River	**0.932**	**1.000**
Apache Creek-Upper Gila River	**0.070**	**0.311**
Animas Valley	**0.000**	**0.000**

Subwatershed	FMV HUI/sub-watershed	FMV HUI/ riparian
Centerfire Creek-San Francisco River	**0.533**	**1.000**
Upper Blue River	**0.000**	**0.224**
Pueblo Creek-San Francisco River	**0.000**	**0.000**
Lower Blue River	**0.000**	**0.056**
Mule Creek-San Francisco River	**0.000**	**0.063**
Chase Creek-San Francisco River	**1.000**	**1.000**
Willow Creek	**0.000**	**0.118**
Upper Eagle Creek	**0.000**	**0.098**
Lower Eagle Creek	**0.000**	**0.071**
Bonita Creek	**0.000**	**0.122**
Yuma Wash-Upper Gila River	**0.774**	**1.000**
Stockton Wash	**0.800**	**0.697**
Cottonwood Wash-Upper Gila River	**1.000**	**1.000**
Black Rock Wash-Upper Gila River	**0.605**	**0.597**
Goodwin Wash-Upper Gila River	**0.093**	**0.317**
Salt Creek-Upper Gila River	**0.000**	**0.086**
San Simon River Headwaters	**0.000**	**0.085**
Cave Creek-San Simon River	**0.409**	**0.374**
Happy Camp Wash	**1.000**	**0.888**
East Whitetail Creek-San Simon River	**1.000**	**0.529**
Hot Well Draw-Hospital Flat	**0.000**	**0.076**
Tule Wells Draw-San Simon River	**1.000**	**1.000**
Gold Gulch-San Simon River	**0.000**	**0.105**
Slick Rock Wash-San Simon River	**0.104**	**0.312**
Ash Creek	**0.000**	**0.034**
Sevenmile Wash-Sycamore Creek	**0.000**	**0.078**
Gilson Wash	**0.000**	**0.153**
San Carlos River (Local Drainage)	**0.000**	**0.238**

Nutrients

According to the ADEQ's water quality assessment data, no exceedances were reported for any of the stream reaches that are sampled for nutrients.

Five stream reaches and one lake were classified as moderate for nutrients due to lack of data, including: Turkey Creek (Head waters-Campbell Blue Creek), Gila River (Eagle Creek-Bonita Creek), Gila River (San Francisco River-Eagle Creek), East Turkey Creek from headwaters to unnamed tributary (15040006-873A), North Fork Cave Creek (headwaters to Cave Creek), and Cluff Pond #3.

Nutrients, specifically nitrogen and phosphorus, do not appear to be a problem within the Upper Gila Watershed. This analysis is 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 Upper Gila Watershed.

Another source of introduced nutrients is runoff from residential areas where landscapes are fertilized. The Upper Gila 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. There are also no known commercial activities within the watershed that would introduce nutrients into the system.

pH

Luna Lake is reported to be "not attaining" for high pH (caustic) levels. Caustic pH measurements can be an indication of lake eutrophication. Typical unpolluted flowing water will have pH values ranging from 6.5 to 8.5; however, where photosynthesis by aquatic organisms takes up dissolved carbon dioxide during daylight hours, a diurnal pH fluctuation may occur and the maximum pH value may sometimes reach as high as 9.0. Studies have found that in poorly buffered lake water, pH fluctuations occur with maximum pH values exceeding 12 (Hem, 1970). The fluctuation in pH has been found to be more pronounced in warm, arid lakes such as Luna Lake.

Organics Results

The weighted combination approach was used to create the combined fuzzy score for organics, and the results are found in Table 6-15. The weights used in the classification are found at the bottom of Table 6-15. Figure 6-4 shows the results of the weighted combination method classified into high and low priority for organics.

Table 6-15: Summary Results for Organics, Based on Weighted Combination Approach.

Subwatershed Name	WQA[1]	Owner	HUI/sub-watershed	HUI/ Riparian	FMV Weighted
Railroad Wash-Upper Gila River	0.000	1.000	0.932	1.000	0.686
Apache Creek-Upper Gila River	1.000	1.000	0.070	0.311	0.607
Animas Valley	0.500	1.000	0.000	0.000	0.350
Centerfire Creek-San Francisco River	1.000	1.000	0.533	1.000	0.907
Upper Blue River	0.300	1.000	0.000	0.224	0.357
Pueblo Creek-San Francisco River	0.500	1.000	0.000	0.000	0.350
Lower Blue River	0.000	1.000	0.000	0.056	0.217
Mule Creek-San Francisco River	0.000	1.000	0.000	0.063	0.219
Chase Creek-San Francisco River	0.700	1.000	1.000	1.000	0.910
Willow Creek	0.700	1.000	0.000	0.118	0.445
Upper Eagle Creek	0.000	1.000	0.000	0.098	0.229
Lower Eagle Creek	0.000	1.000	0.000	0.071	0.221
Bonita Creek	0.000	1.000	0.000	0.122	0.237
Yuma Wash-Upper Gila River	1.000	1.000	0.774	1.000	0.955
Stockton Wash	0.500	1.000	0.800	0.697	0.719
Cottonwood Wash-Upper Gila River	0.500	1.000	1.000	1.000	0.850
Black Rock Wash-Upper Gila River	0.500	1.000	0.605	0.597	0.650
Goodwin Wash-Upper Gila River	0.500	1.000	0.093	0.317	0.464
Salt Creek-Upper Gila River	0.500	1.000	0.000	0.086	0.376
San Simon River Headwaters	0.500	1.000	0.000	0.085	0.376
Cave Creek-San Simon River	0.500	1.000	0.409	0.374	0.544
Happy Camp Wash	0.500	1.000	1.000	0.888	0.816
East Whitetail Creek-San Simon River	0.500	1.000	1.000	0.529	0.709

Subwatershed Name	WQA[1]	Owner	HUI/sub-watershed	HUI/ Riparian	FMV Weighted
Hot Well Draw-Hospital Flat	**0.500**	**1.000**	**0.000**	**0.076**	**0.373**
Tule Wells Draw-San Simon River	**0.500**	**1.000**	**1.000**	**1.000**	**0.850**
Gold Gulch-San Simon River	**0.500**	**1.000**	**0.000**	**0.105**	**0.382**
Slick Rock Wash-San Simon River	**0.500**	**1.000**	**0.104**	**0.312**	**0.464**
Ash Creek	**0.500**	**1.000**	**0.000**	**0.034**	**0.360**
Sevenmile Wash-Sycamore Creek	**0.500**	**1.000**	**0.000**	**0.078**	**0.373**
Gilson Wash	**0.500**	**1.000**	**0.000**	**0.153**	**0.396**
San Carlos River (Local Drainage)	**0.500**	**1.000**	**0.000**	**0.238**	**0.421**
Weights	***0.300***	***0.200***	***0.200***	***0.300***	

[1]WQA = Water Quality Assessment results

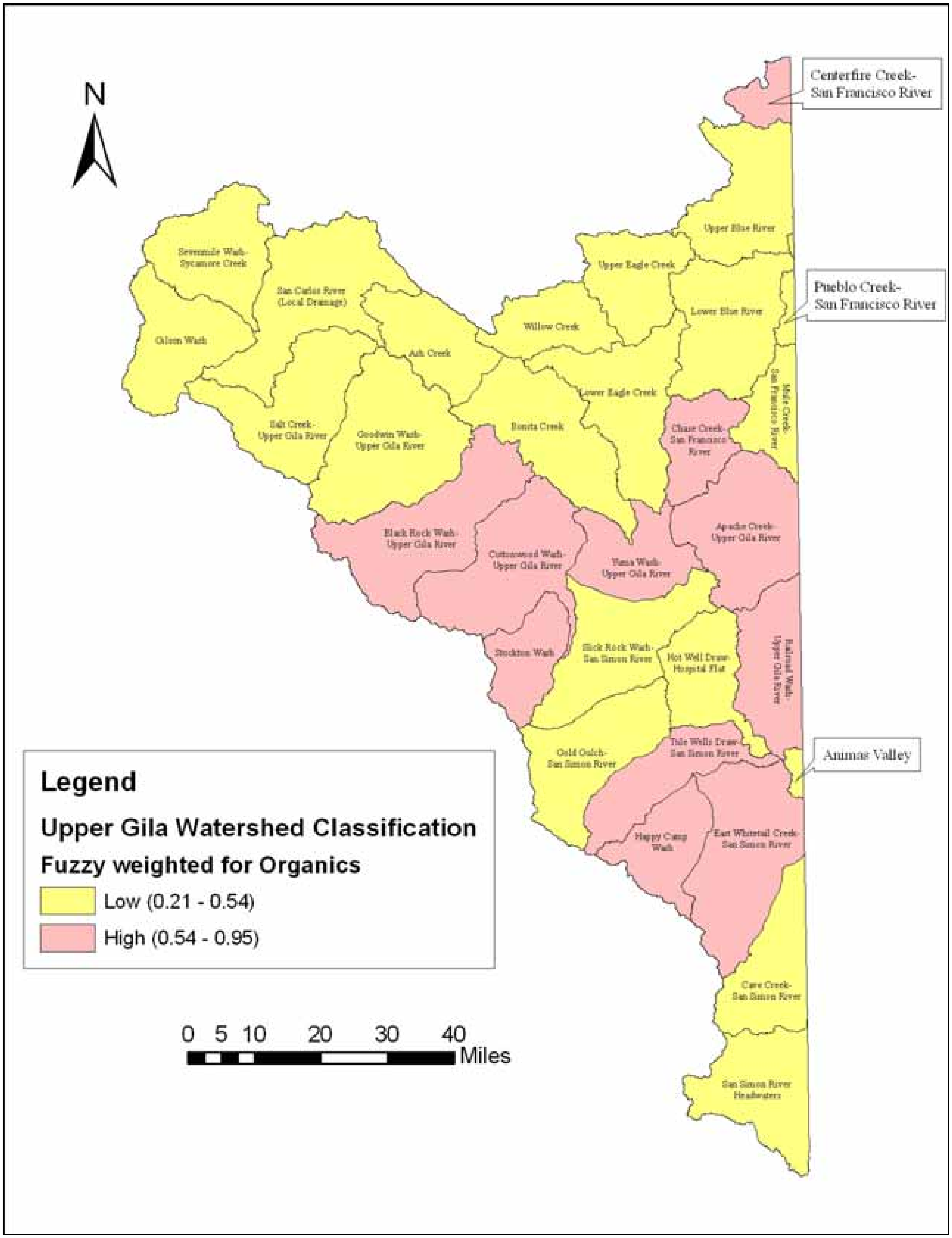


Figure 6-4: Results for the Fuzzy Logic Classification for Organics, Based on the Weighted Combination Approach.

Selenium

Two stream reaches within Upper Gila watershed assessed as “impaired” due to high selenium exceedances, including Gila River (Skully Creek-San Francisco River) and Cave Creek (headwaters – South Fork of Cave Creek). Gila River (New Mexico Border-Bitter Creek) and Dankworth Ponds also showed high exceedances for selenium and assessed as “inconclusive” in the ADEQ Water Quality report.

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 6-16 contains the fuzzy membership values for selenium for each subwatershed based on the water quality assessment results.

Table 6-16: Fuzzy Membership Values for Selenium Assigned to each Subwatershed, Based on Water Quality Assessment Results.

Subwatershed Name	FMV	Justification
Railroad Wash-Upper Gila River	1.0	Classified as high risk, and drains into Apache Creek subwatershed that is classified as extreme risk.
Apache Creek-Upper Gila River	1.0	Classified as extreme risk for selenium.
Animas Valley	0.5	Classified as moderate risk (no data), and is along the Arizona-New Mexico state line.
Centerfire Creek-San Francisco River	0.5	Classified as moderate risk (limited data), and drains into New Mexico.
Upper Blue River	0.5	Classified as moderate risk, and drains into Lower Blue River that is classified as moderate risk.
Pueblo Creek-San Francisco River	0.5	Classified as moderate risk (no data).
Lower Blue River	0.3	Classified as moderate risk, and drains into Chase Creek that is classified as low risk.
Mule Creek-San Francisco River	0.0	Classified as low risk.
Chase Creek-San Francisco River	0.0	Classified as low risk.
Willow Creek	0.3	Classified as moderate risk (no data), and drains into Lower Eagle Creek that is classified as low risk.
Upper Eagle Creek	0.73	Classified as moderate risk (limited data,) and drains into Lower Eagle Creek that is classified as low risk.
Lower Eagle Creek	0.0	Classified as low risk.
Bonita Creek	0.0	Classified as low risk.
Yuma Wash-Upper Gila River	0.5	Classified as moderate risk and drains into Cottonwood Wash that is classified as moderate risk.
Stockton Wash	0.7	Classified as high risk, and drains into Cottonwood Wash that is classified as moderate risk.

Subwatershed Name	FMV	Justification
Cottonwood Wash-Upper Gila River	**0.5**	**Classified as moderate risk (limited data).**
Black Rock Wash-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
Goodwin Wash-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
Salt Creek-Upper Gila River	**0.5**	**Classified as moderate risk (no data).**
San Simon River Headwaters	**0.5**	**Classified as moderate risk (no data).**
Cave Creek-San Simon River	**1.0**	**Classified as extreme risk.**
Happy Camp Wash	**0.5**	**Classified as moderate risk (no data).**
East Whitetail Creek-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Hot Well Draw-Hospital Flat	**0.5**	**Classified as moderate risk (no data).**
Tule Wells Draw-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Gold Gulch-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Slick Rock Wash-San Simon River	**0.5**	**Classified as moderate risk (no data).**
Ash Creek	**0.5**	**Classified as moderate risk (no data).**
Sevenmile Wash-Sycamore Creek	**0.5**	**Classified as moderate risk (no data).**
Gilson Wash	**0.5**	**Classified as moderate risk (no data).**
San Carlos River (Local Drainage)	**0.5**	**Classified as moderate risk (no data).**

Note: This table is cross-referenced to Table 1 of Appendix A where the 10-digit HUC names are tabulated with the subwatershed name.

Agricultural lands

The percentage of the agricultural lands in each 10-digit HUC subwatershed was calculated and a fuzzy membership function was defined as follows:

FMV = 0 if (% of Agricultural land = 0)
FMV = (% of Agricultural land / 10)
FMV = 1 if (% of Agric. land > = 10)

Selenium Results

Table 6-17 shows the fuzzy membership values for selenium for agricultural lands. The fuzzy membership values were used to create a combined fuzzy score for each subwatershed and were incorporated into the weighted combination method. These results are found in Table 6-18, and the weights are listed at the bottom of the table.

High values for selenium are most likely naturally occurring in the highly mineralized soils of the region. In addition, the high selenium 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 drainage water from seleniferous irrigated soils (Hem 1970). Figure 6-5 shows the results of the weighted fuzzy logic classification for selenium, and Figure 6-6 shows the results in relation to agricultural lands.

Table 6-17: Fuzzy Membership Values for Selenium Assigned to each Subwatershed, Based on the Percentage of Agricultural Lands.

Subwatershed Name	Percentage of Agricultural land	FMV for Agricultural lands
Railroad Wash-Upper Gila River	3.54%	0.354
Apache Creek-Upper Gila River	0.59%	0.059
Animas Valley	0.00%	0.000
Centerfire Creek-San Francisco River	1.86%	0.186
Upper Blue River	0.01%	0.001
Pueblo Creek-San Francisco River	0.00%	0.000
Lower Blue River	0.00%	0.000
Mule Creek-San Francisco River	0.06%	0.006
Chase Creek-San Francisco River	0.00%	0.000
Willow Creek	0.00%	0.000
Upper Eagle Creek	0.00%	0.000
Lower Eagle Creek	0.00%	0.000
Bonita Creek	0.00%	0.000
Yuma Wash-Upper Gila River	2.71%	0.271
Stockton Wash	2.62%	0.262
Cottonwood Wash-Upper Gila River	8.39%	0.839
Black Rock Wash-Upper Gila River	2.55%	0.255
Goodwin Wash-Upper Gila River	1.10%	0.110
Salt Creek-Upper Gila River	0.00%	0.000
San Simon River Headwaters	0.70%	0.070
Cave Creek-San Simon River	1.85%	0.185
Happy Camp Wash	5.68%	0.568
East Whitetail Creek-San Simon River	5.80%	0.580
Hot Well Draw-Hospital Flat	0.00%	0.000
Tule Wells Draw-San Simon River	10.37%	1.000
Gold Gulch-San Simon River	0.00%	0.000
Slick Rock Wash-San Simon River	0.83%	0.083
Ash Creek	0.00%	0.000
Sevenmile Wash-Sycamore Creek	0.00%	0.000
Gilson Wash	0.01%	0.001
San Carlos River (Local Drainage)	0.14%	0.014

Table 6-18: Weighted Combination Method Results for Selenium Based on the Fuzzy Logic Approach.

Subwatershed Name	WQA[1]	FMV for Agricultural Lands	FMV Weighted
Railroad Wash-Upper Gila River	**1.0**	**0.354**	**0.677**
Apache Creek-Upper Gila River	**1.0**	**0.059**	**0.530**
Animas Valley	**0.5**	**0.000**	**0.250**
Centerfire Creek-San Francisco River	**0.5**	**0.186**	**0.343**
Upper Blue River	**0.5**	**0.001**	**0.250**
Pueblo Creek-San Francisco River	**0.5**	**0.000**	**0.250**
Lower Blue River	**0.3**	**0.000**	**0.150**
Mule Creek-San Francisco River	**0.0**	**0.006**	**0.003**
Chase Creek-San Francisco River	**0.0**	**0.000**	**0.000**
Willow Creek	**0.3**	**0.000**	**0.150**
Upper Eagle Creek	**0.3**	**0.000**	**0.150**
Lower Eagle Creek	**0.0**	**0.000**	**0.000**
Bonita Creek	**0.0**	**0.000**	**0.000**
Yuma Wash-Upper Gila River	**0.5**	**0.271**	**0.385**
Stockton Wash	**0.7**	**0.262**	**0.481**
Cottonwood Wash-Upper Gila River	**0.5**	**0.839**	**0.670**
Black Rock Wash-Upper Gila River	**0.5**	**0.255**	**0.377**
Goodwin Wash-Upper Gila River	**0.5**	**0.110**	**0.305**
Salt Creek-Upper Gila River	**0.5**	**0.000**	**0.250**
San Simon River Headwaters	**0.5**	**0.070**	**0.285**
Cave Creek-San Simon River	**1.0**	**0.185**	**0.593**
Happy Camp Wash	**0.5**	**0.568**	**0.534**
East Whitetail Creek-San Simon River	**0.5**	**0.580**	**0.540**
Hot Well Draw-Hospital Flat	**0.5**	**0.000**	**0.250**
Tule Wells Draw-San Simon River	**0.5**	**1.000**	**0.750**
Gold Gulch-San Simon River	**0.5**	**0.000**	**0.250**
Slick Rock Wash-San Simon River	**0.5**	**0.083**	**0.292**
Ash Creek	**0.5**	**0.000**	**0.250**
Sevenmile Wash-Sycamore Creek	**0.5**	**0.000**	**0.250**
Gilson Wash	**0.5**	**0.001**	**0.250**
San Carlos River (Local Drainage)	**0.5**	**0.014**	**0.257**
Weights	***0.5***	***0.5***	

[1]WQA = Water Quality Assessment results

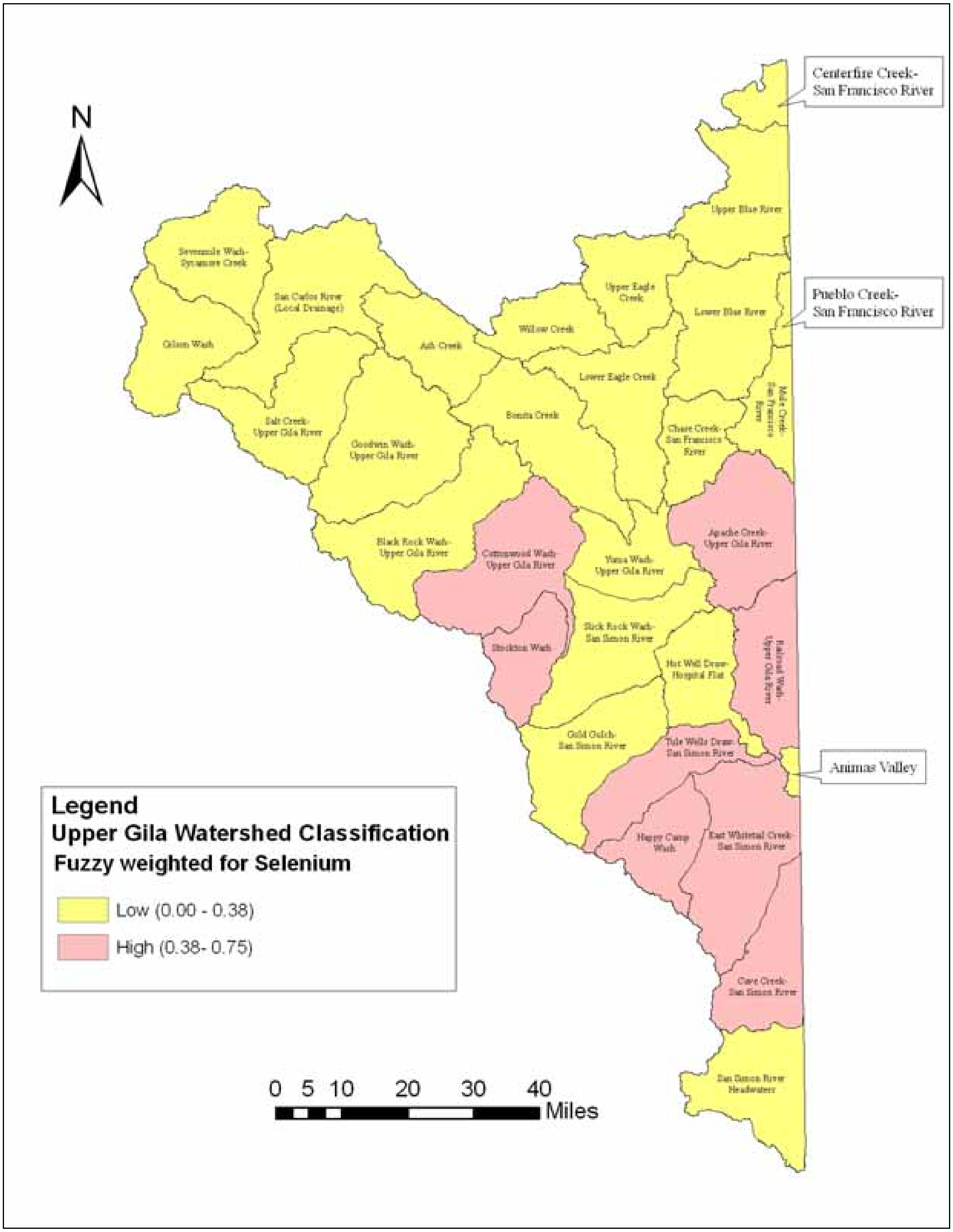


Figure 6-5: Results for the Fuzzy Logic Classification for Selenium, Based on the Weighted Combination Approach.

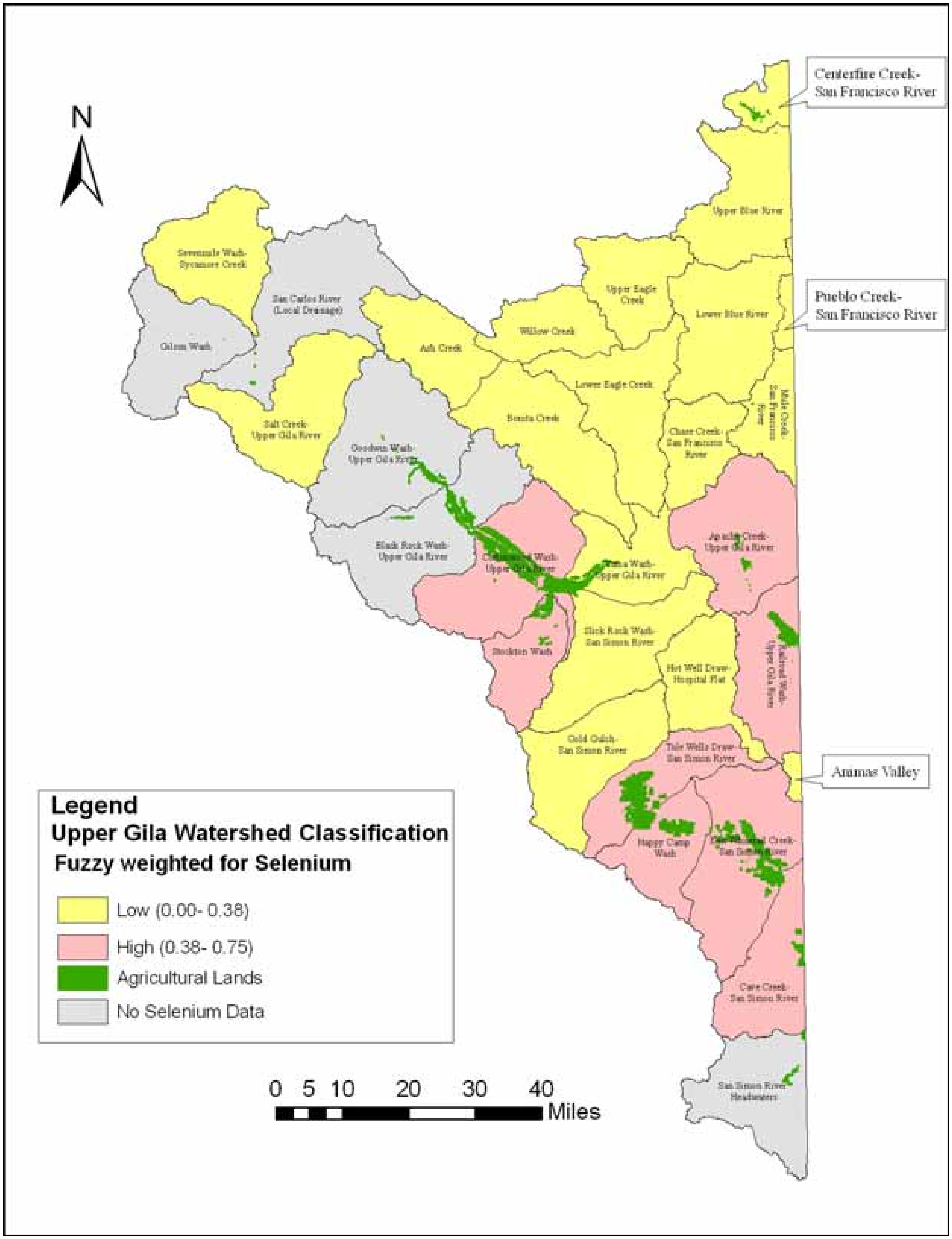


Figure 6-6: Results for the Fuzzy Logic Classification for Selenium, Based on the Weighted Combination Approach, Showing the Distribution of Agricultural Lands in each 10-digit HUC Subwatershed.

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Land use. July 21, 2003.

**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 7: Watershed Management

This section discusses the recommended watershed management activities to address nonpoint source pollution concerns in the Upper Gila 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 to allow land use decision makers and watershed stakeholders to conceptualize how best to address watershed management.

The Luna Lake TMDL Implementation Plan is 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 pollutant categories: metals, organics and nutrients.

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 Upper Gila Watershed include the mining industry, new housing developments and increased urbanization, and new road construction. The Cave Creek and Animas Valley Natural Resource Areas are particularly at risk to future housing development due to the large percentage of private land within the watershed (over 50% of the area, see table 7-2).

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 Upper Gila Watershed's waters.
- 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.

Strategy for Addressing Existing Impairment

The major sources of water quality impairment and environmental damage in the Upper Gila waters are elevated concentrations of dissolved and particulate metals, sediment and organics (ADEQ, 2004). 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 the impairment for each constituent group. The management measures discussed herein are brief and are 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 additional nonpoint source Best Management Practices (BMPs), can be found at the NEMO website, www.srnr.arizona.edu/nemo.

Metals

The primary nonpoint source of anthropogenic metals in the Upper Gila Watershed is abandoned 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; however, the Upper Gila Watershed has 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 Upper Gila Watershed, including federal, state and private lands, with a majority of the mines found on land administered by the private sector, Bureau of Land Management (BLM), 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 dependant on site specific conditions. Low costs could range from nominal to $20,000, medium costs could range between $10,000 and $500,000, and high costs could be anything greater than $250,000. Per-acre costs can range anywhere from $200 per acre, to $1,000,000 per acre depending on the location, toxicity of the contamination, or other factors. 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 as 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 onsite inventory to clarify the degree of risk the site exhibits towards discharging elevated concentrations of metals to a waterbody. 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 waterbody, 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 semiarid environments, revegetation of a disturbed site is relatively difficult even under optimal conditions. The amount of effort that is 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
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/awardwy.htm)

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 until the vegetation cover becomes established. Erosion control fabric and plant mulch are two short-term erosion 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. Load reduction potential, maintenance, cost and estimated life of erosion control treatments such as geotextile fabrics and mulches are found in Table 7-1.

Runoff and Sediment Capture:

The capture and containment of mine site runoff and sediment, and prevention of the waste rock and tailings from contact with a waterbody 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.

A long-term treatment is 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.

Rock Rip-Rap Sediment Control
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/ocphoto.htm)

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.

Removal:

The mine waste/tailing material can be excavated and removed. 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
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/ocphoto.htm)

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, the 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, Tribal entities).

Figure 7-1 identifies land ownership across the 10-digit HUCs, Figure 7-2 shows the 10-digit HUCs with major streams, and Table 7-2 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 than the brief discussion of land ownership in Section 4, Social and Economic Characteristics of the watershed.

Subwatershed areas prioritized for educational outreach on problems associated with abandoned mines include Railroad Wash, Apache Creek, Chase Creek-San Francisco River, Yuma Wash- Upper Gila River, Stockton Wash, Cottonwood Wash-Upper Gila River, Cave Creek- San Simon River, East Whitetail Creek – San Simon River, Hot Well Draw-Hospital Flat, Tule Wells Draw- San Simon River, Gold Gulch-San Simon River, Slick Rock Wash-San Simon River (See Figure 7-2).

Note that recommendations for those subwatersheds owned by tribal groups are not provided in this document.

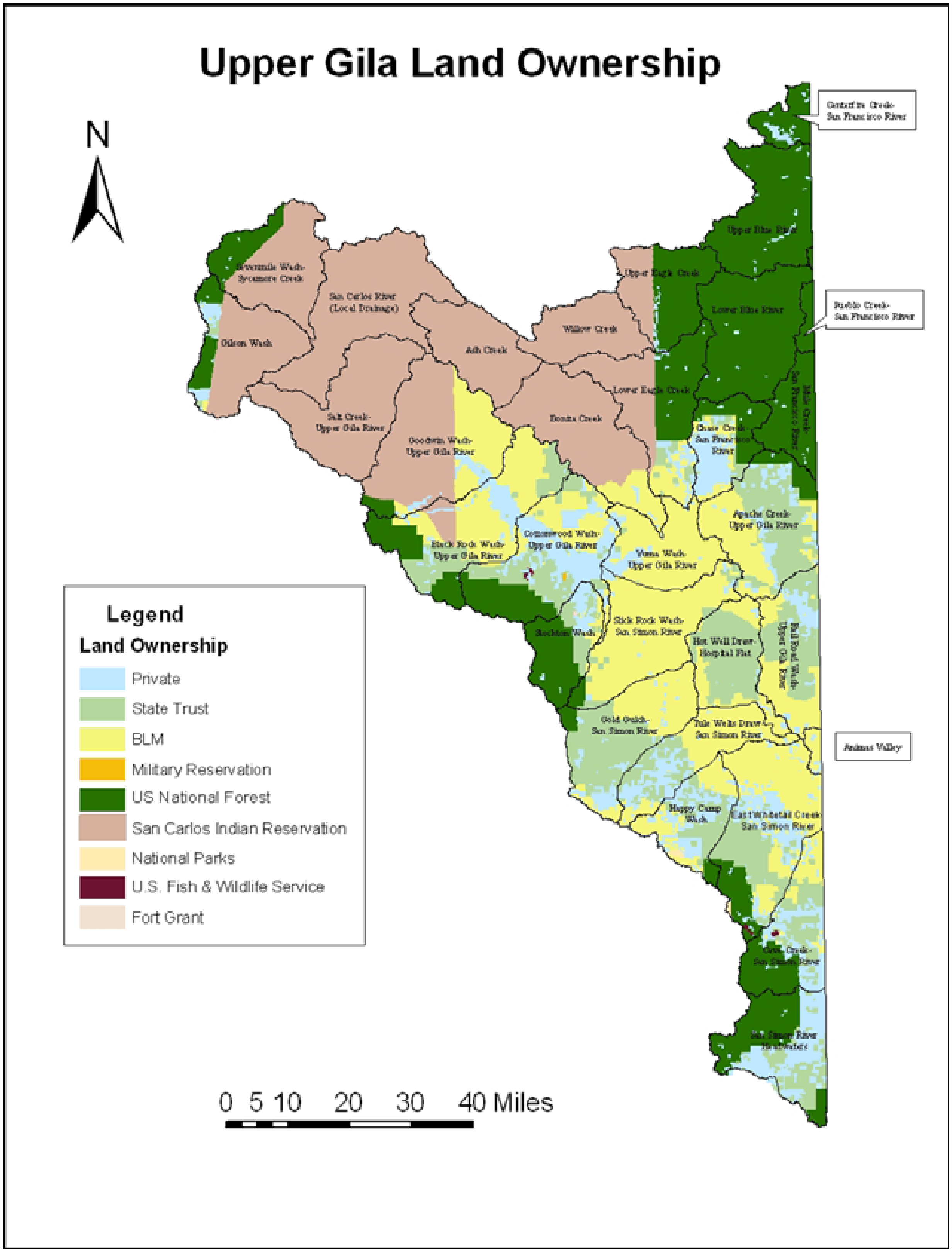

Figure 7-1: Upper Gila Watershed Land Ownership by Subwatershed.

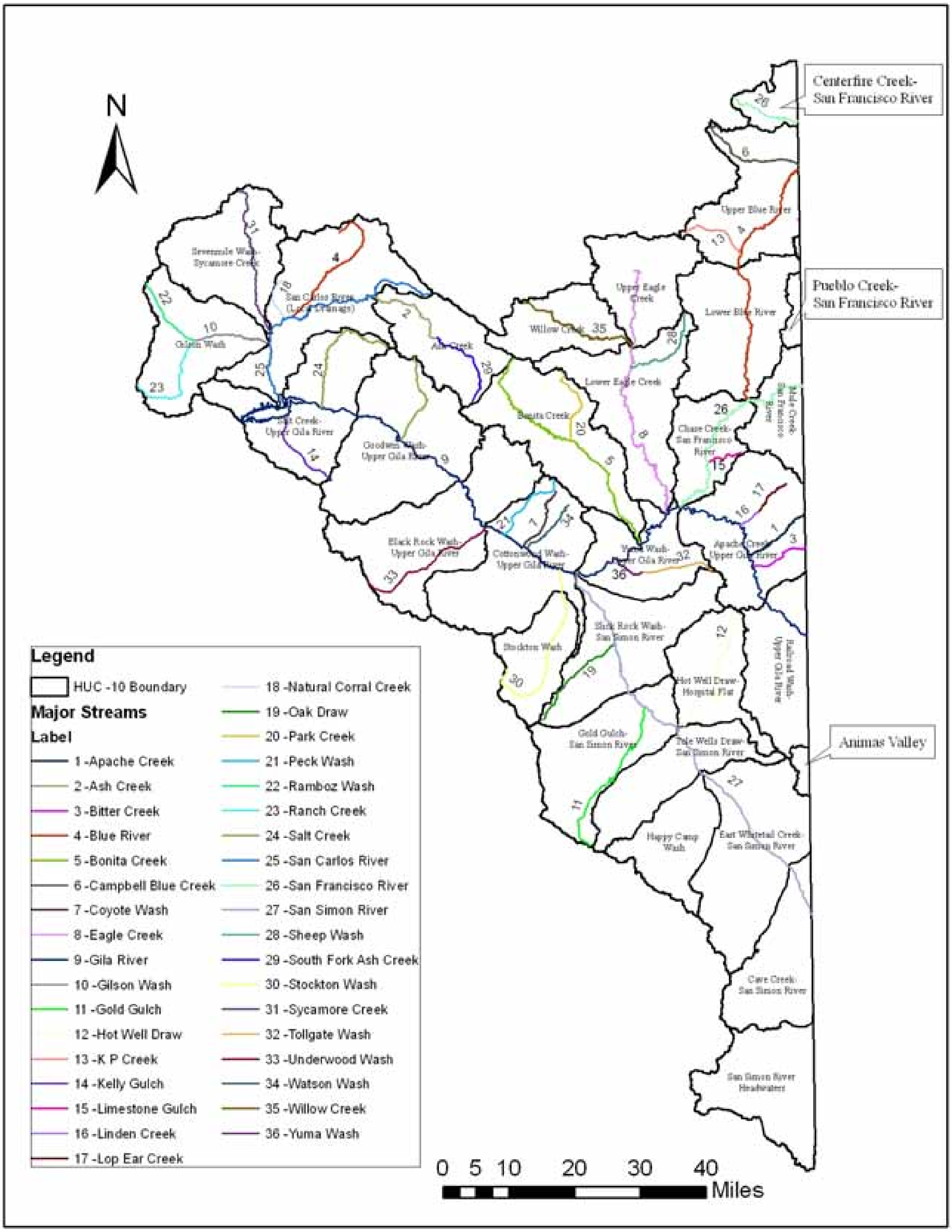

Figure 7-2: Upper Gila Watershed Major Streams with HUC-10 Boundaries.

Table 7-2: Percentage Land Ownership by Subwatershed.

Subwatershed	Private	State Trust Lands	U.S. Bureau of Land Mgmt	Military Reserv.	U.S. Forest Service	Indian Reserv	National Park Service	U.S. Fish & Wildlife Service	Fort Grant State Prison
Railroad Wash-Upper Gila River	11.40	51.61	36.99	0.00	0.00	0.00	0.00	0.00	0.00
Apache Creek-Upper Gila River	12.13	42.50	35.47	0.00	9.90	0.00	0.00	0.00	0.00
Animas Valley	12.21	0.00	87.79	0.00	0.00	0.00	0.00	0.00	0.00
Centerfire Creek-San Francisco River	12.05	0.00	0.00	0.00	87.95	0.00	0.00	0.00	0.00
Upper Blue River	1.10	0.00	0.00	0.00	98.90	0.00	0.00	0.00	0.00
Pueblo Creek-San Francisco River	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Lower Blue River	0.22	0.00	0.00	0.00	99.78	0.00	0.00	0.00	0.00
Mule Creek-San Francisco River	0.58	0.00	0.00	0.00	99.42	0.00	0.00	0.00	0.00
Chase Creek-San Francisco River	35.88	8.38	15.55	0.00	40.18	0.00	0.00	0.00	0.00
Willow Creek	0.00	0.00	0.00	0.00	0.02	99.98	0.00	0.00	0.00
Upper Eagle Creek	1.67	0.00	0.00	0.00	63.55	34.78	0.00	0.00	0.00
Lower Eagle Creek	6.96	4.83	10.12	0.00	39.15	38.94	0.00	0.00	0.00
Bonita Creek	0.67	0.02	15.19	0.00	0.00	84.12	0.00	0.00	0.00
Yuma Wash-Upper Gila River	10.58	1.15	88.27	0.00	0.00	0.00	0.00	0.00	0.00
Stockton Wash	14.43	19.91	7.59	0.00	57.84	0.00	0.00	0.00	0.24
Cottonwood Wash-Upper Gila River	30.21	23.99	23.94	0.18	21.34	0.00	0.00	0.35	0.00
Black Rock Wash-Upper Gila River	9.85	19.98	45.67	0.00	18.06	6.44	0.00	0.00	0.00
Goodwin Wash-Upper Gila River	4.26	0.05	29.39	0.00	3.13	63.18	0.00	0.00	0.00
Salt Creek-Upper Gila River	0.00	0.00	0.00	0.00	0.00	100	0.00	0.00	0.00
San Simon River Headwaters	35.48	20.44	0.00	0.00	44.08	0.00	0.00	0.00	0.00
Cave Creek-San Simon River	25.96	25.86	15.88	0.00	31.88	0.00	0.00	0.41	0.00
Happy Camp Wash	30.36	29.92	33.14	0.00	5.19	0.00	1.39	0.00	0.00
East Whitetail Creek-San Simon River	19.01	22.70	45.52	0.00	12.20	0.00	0.36	0.22	0.00
Hot Well Draw-Hospital Flat	2.26	67.14	30.60	0.00	0.00	0.00	0.00	0.00	0.00
Tule Wells Draw-San Simon River	22.02	22.41	55.57	0.00	0.00	0.00	0.00	0.00	0.00
Gold Gulch-San Simon River	8.68	46.50	41.23	0.00	3.59	0.00	0.00	0.00	0.00
Slick Rock Wash-San Simon River	2.86	5.94	88.05	0.00	3.15	0.00	0.00	0.00	0.00
Ash Creek	0.00	0.00	0.02	0.00		99.98	0.00	0.00	0.00
Sevenmile Wash-Sycamore Creek	0.09	0.00	0.00	0.00	22.96	76.95	0.00	0.00	0.00
Gilson Wash	6.45	1.95	0.62	0.00	15.68	75.31	0.00	0.00	0.00
San Carlos River (Local Drainage)	0.00	0.00	0.00	0.00	0.00	100	0.00	0.00	0.00
Percentage of Upper Gila	*10.03*	*14.21*	*23.02*	*0.01*	*23.30*	*29.33*	*0.05*	*0.04*	*0.005*

Sediment

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

The primary land uses in the Upper Gila Watershed that can contribute to sediment erosion are livestock grazing and mining (See Section 6-Sediment). Development is also increasing in some portions of the watershed, notably the Chase Creek and San Simon River subwatersheds with approximately 35% of the area under private land ownership. The increase in impervious land surface accelerates surface runoff, increases flow velocity, and exacerbates channel scour. Dirt roads are also a common feature in the watershed that can be an important source of sediment. The recommended sediment management actions (Table 7-3) are:

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

Grazing Management:

Livestock grazing is currently the primary land use in the Upper Gila Watershed. Implementing grazing management practices to improve or maintain the health and vigor of plant communities will help reduce 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 the land 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:

Creating a filter strip along a waterbody will retard the movement of sediment into the waterbody, and may remove pollutants from runoff before the material enters the body of water. Filter strips will reduce sedimentation of streams, lakes and other bodies of water, and 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.

Table 7-3: Proposed Treatments for Addressing Erosion and Sedimentation.

Action	Load Reduction Potential	Estimated Time - Load Reduction	Expected Maintenance	Expected Cost	Estimated Life
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**
Dirt Roads	**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.

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.

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 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 Livestock Watering Facility
(EC Bar Ranch http://www.ecbarranch.com)

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.

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 and Jute Matting Erosion Control along a stream.

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 along the down-slope edge that intercepts and redirects runoff water in areas of soil disturbance (tailings piles, 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.

If a road is adjacent to a stream, engineered road stabilization treatments may be necessary. The stabilization of roads and other embankments reduces sediment inputs from erosion and protects the related infrastructure. Traditional stabilization relied on expensive rock (riprap) treatments. Other options are available including the use of erosion control fabric, toe rock, and revegetation to stabilize banks.

Bank Stabilization and Erosion Control along a highway

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 the Chase Creek and San Simon River subwatersheds (35% private lands), educational programs should address stormwater management from land development, and target citizen groups, developers, and watershed partnerships.

Based on the sediment and erosion classification completed in Section 6, subwatershed areas prioritized for educational outreach to address erosion control include Railroad Wash, Chase Creek- San Francisco River, Yuma Wash-Upper Gila River, and Cottonwood Wash -Upper Gila River.

<u>Organics</u>

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

The nutrient-based Luna Lake TMDL plan is summarized within this section as it addresses excess organic loading in the headwaters to the San Francisco 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.

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

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

Filter Strip near Waterbody
U.S. E.P.A.
(http://www.epa.gov/owow/nps/ex-bmps.html)

Filter Strips:

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.

Fencing:

Restricting cattle access to riparian corridors with fencing will reduce the amount of organics from animal waste in the stream. Straw bale or silt fencing slows runoff and traps organics from sheet flow or channelized flow in areas of soil disturbance.

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.

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 status 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.

Educational programs should also be developed on residential septic system maintenance. These programs should promote 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 Railroad Wash, Apache Creek, Chase Creek-San Francisco River, Yuma Wash _ Upper Gila River, Stockton Wash, Cottonwood Wash-Upper Gila River, Happy Camp Wash, East Whitetail Creek-San Simon River, and Tule Wells Draw-San Simon River.

<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.

Luna Lake TMDL Implementation Plan:

In 1998, the ADEQ identified Luna Lake as not supporting its designated uses due to observed exceedances of water quality standards for pH, dissolved oxygen, and plant nutrients (excessive weeds) and occasional fish kills. A TMDL for pH and excessive nutrients was completed and approved by EPA in 2000 (ADEQ, 2001). Historic high external inputs of nutrients (nitrogen and phosphorous) to the lake, along with current in-lake nutrient cycling and many sunny days have resulted in a highly productive (eutrophic: rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae) system that has repeatedly failed to meet surface water quality standards.

The TMDL investigation indicated that the following nonpoint sources contribute nutrients that lead to the impairment: septic systems, forest runoff, agricultural runoff, residential and commercial runoff, decomposition of aquatic plants and ground water. To meet standards, the TMDL concluded that the following reductions from historic levels will need to be made:

- 46% less nitrogen - down to 69.4 pounds per day;
- 67% less phosphorous - down to 19 pounds per day; and
- 37% less chlorophyll (a measure of algal production).

Table 7-5 summarizes the TMDL recommended reductions for several nonpoint source categories.

Table 7-5: TMDL Recommended Reductions for Nonpoint Source Pollution in Luna Lake (ADEQ, 2001):

Sources	**Nitrogen**	**Phosphorous**
Septic systems	**50%**	**50%**
Residential	**50%**	**50%**
Livestock	**25%**	**25%**
Elk	**25%**	**25%**
Macrophyte decomposition	**60%**	**60%**

The TMDL identified the following implementation options to meet these reductions:

- Determine the number of remaining septic systems that are in use and the extent to which unused systems are continuing to leach nutrients to Luna Lake. If there are a large number of active improperly functioning systems, the community could consider extending sewer lines.

- Implement voluntary grazing Best Management Practices for pastures to reduce loading from domestic livestock and elk herds.

- Implement voluntary Best Management Practices that reduce runoff from residential areas. This runoff is generally caused by impervious surfaces and soil amendments such as fertilizers for lawns.

- Use dredging to remove the top meter of sediments in ponds that has accumulated most of the nutrients, and thereby reduce nutrient recycling (Baker and Farnsworth, 1995).

- Maintain a macrophyte harvesting schedule and/or biological controls of the macrophytes, as macrophytes will re-colonize Luna Lake within a short period of time after dredging has been completed.

- Increase irrigation system efficiency to reduce irrigation water withdrawals, and thereby provide higher quality lake water.

The goal of this TMDL is to incrementally improve water quality. ADEQ is working with the local community and cooperating agencies to implement some of these strategies and develop a monitoring program for Luna Lake to assess whether the management actions are being met.

Strategy for Channel and Riparian Protection and Restoration

Riparian areas are one of the most critical resources in the Upper Gila 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 U.S. Forest Service. In cooperation with responsible management agencies, riparian protection and restoration efforts should be implemented across the watershed, including the creation of filter strips surrounding all important water bodies and riparian systems within the six Natural Resource Areas (NRA's):

- Upper Gila River NRA
- Centerfire Creek NRA
- Upper Blue River NRA
- Mule Creek NRA
- Cottonwood NRA
- Cave Creek 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, develop and apply low impact riparian grazing systems where feasible.

In impaired stream reaches restoration treatments may be 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 to prioritize 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 conditions.

- Identifying the causes for the impairment, and determining 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 can also 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. These projects cannot be conducted in isolation from other watershed activities. If the root cause of channel and riparian impairment is upstream watershed conditions, onsite restoration efforts are likely to fail unless the overall watershed conditions are also improved. This requires an integrated approach that crosses the entire watershed.

Citizen groups also have a role in the restoration efforts. Volunteers can be used in tree planting and seeding treatments, or for grade control and bank stabilization construction projects. Education programs, such as 'Adopt A Stream', will 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 is supported by and partnered with the Arizona Department of Environmental Quality. 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

- *Abandoned Mines:* Educate land use decision makers and stakeholders on the problems associated with abandoned mines and the available treatments to mitigate the problems.

- *Grazing Management:* Develop education programs that address the impact of livestock grazing and promote the implementation of erosion control treatments.

- *Streamside Protection:* Develop education programs to promote the implementation of filter strips and alternative watering facilities.

- *Riparian Management:* Develop education programs focusing on the importance and management of riparian systems.

- *Septic Systems:* Develop education programs focusing on residential septic system maintenance, and encourage municipalities and counties to implement septic system licensing and inspection programs.

- *Stormwater Management:* Develop education programs focusing on nonpoint source management measures to control stormwater runoff from urbanized and developing areas.

- *Water Conservation:* Develop education programs on water conservation for private residents. As ground water withdrawals increase with increased land development, natural stream flow and riparian areas are at risk of dewatering.

- *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 septic systems, stormwater management and water conservation, will target the Chase Creek subwatershed. Development of an 'Adopt a Stream' Program will be considered.

References:

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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 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 watershed-based planning 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 6-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. 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 most susceptible to 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. This methodology ranked 31 subwatersheds for four key nonpoint source water quality concerns:

- metals originating from abandoned mine sites
- stream sedimentation due to land use activities
- organic and nutrient pollution due to land use activities
- selenium due to agricultural practices.

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

Summary of Weighted Fuzzy Membership Values for each Subwatershed				
Subwatershed Name	**Metals WFMV[1]**	**Sediment WFMV[2]**	**Organics WFMV[3]**	**Selenium WFMV[4]**
Railroad Wash-Upper Gila River	**0.640**	**0.54**	**0.686**	**0.677**
Apache Creek-Upper Gila River	**0.700**	0.46	**0.607**	**0.530**
Animas Valley	0.150	0.15	0.350	0.250
Centerfire Creek-San Francisco River	0.210	0.36	**0.907**	0.343
Upper Blue River	0.385	0.20	0.357	0.250
Pueblo Creek-San Francisco River	0.150	0.15	0.350	0.250
Lower Blue River	0.410	0.18	0.217	0.150
Mule Creek-San Francisco River	0.360	0.17	0.219	0.003
Chase Creek-San Francisco River	**0.880**	**0.63**	**0.910**	0.000
Willow Creek	0.300	0.27	0.445	0.150
Upper Eagle Creek	**0.518**	0.41	0.229	0.150
Lower Eagle Creek	**0.820**	0.33	0.221	0.000
Bonita Creek	0.303	**0.63**	0.237	0.000
Yuma Wash-Upper Gila River	**0.670**	**0.81**	**0.955**	**0.385**
Stockton Wash	**0.670**	0.30	**0.719**	**0.481**
Cottonwood Wash-Upper Gila River	**0.730**	**0.78**	**0.850**	**0.670**
Black Rock Wash-Upper Gila River	**0.610**	**0.69**	**0.650**	0.377
Goodwin Wash-Upper Gila River	**0.610**	**0.63**	0.464	0.305
Salt Creek-Upper Gila River	**0.610**	0.44	0.376	0.250
San Simon River Headwaters	0.150	0.26	0.376	0.285
Cave Creek-San Simon River	**0.610**	0.23	**0.544**	**0.593**
Happy Camp Wash	0.430	0.33	**0.816**	**0.534**
East Whitetail Creek-San Simon River	**0.610**	0.26	**0.709**	**0.540**
Hot Well Draw-Hospital Flat	**0.585**	0.20	0.373	0.250
Tule Wells Draw-San Simon River	**0.610**	0.43	**0.850**	**0.750**
Gold Gulch-San Simon River	**0.610**	0.20	0.382	0.250
Slick Rock Wash-San Simon River	**0.610**	0.16	0.464	0.292
Ash Creek	0.210	0.26	0.360	0.250
Sevenmile Wash-Sycamore Creek	**0.585**	**0.68**	0.373	0.250
Gilson Wash	**0.610**	0.26	0.396	0.250
San Carlos River (Local Drainage)	**0.610**	0.26	0.421	0.257

Notes:
1 Values greater than 0.43 indicate High Priority for Metals (shaded boxes), Table 6-6, Figure 6-2.
2 Values greater than 0.46 indicate High Priority for Sediment (shaded boxes), Table 6-12, Figure 6-3.
3 Values greater than 0.54 indicate High Priority for Organics (shaded boxes), Table 6-15, Figure 6-4.
4 Values greater than 0.38 indicate High Priority for Selenium (shaded boxes), Table 6-18, Figure 6-5.

Table 8-1 shows all 31 subwatersheds and their final weighted fuzzy membership value for each of these four constituents. Values highlighted in bold and with a shaded box indicate high risk for water quality degradation. The rankings range from a low risk of 0.0 to higher values approaching 1.0. See Section 6 for a full discussion on the derivation of these values.

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. Chase Creek – San Francisco River Subwatershed, for metals pollution;

2. Yuma Wash – Upper Gila River Subwatershed, for sediment pollution;

3. Yuma Wash-Upper Gila River Subwatershed, for pollutants due to organics and nutrients derived from land use; and

4. Tule Wells Draw – San Simon River, for selenium due to agricultural practices.

Example projects with best management practices to reduce sediment, metals, 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. Chase Creek – San Francisco River 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 Chase Creek subwatershed of the San Francisco River ranked as the most critical area in the Upper Gila Watershed impacted by metals related to an abandoned mine site (i.e. highest fuzzy membership value for metals), and a project to control the movement of metal-laden sediment is recommended. The land owners within this subwatershed include the U.S. Forest Service, U.S. Bureau of Land Management, State of Arizona, and private owners (Table 7-2). 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:
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 - 3. Yuma Wash – Upper Gila River Subwatershed Example Projects

Pollutant Type and Source: (1) Sediment pollution due to overgrazing, and (2) organic pollutants, specifically *E. coli*, assumed to originate from cattle watering in the stream channel.

The Yuma Wash subwatershed of the Upper Gila River ranked as the most critical area impacted by land use activities. It had the highest fuzzy membership values for both sediment and organics, both of which are highly correlated to land use activities (Table 8-1).

For this example project it will be assumed that grazing within the riparian area has exacerbated erosion (sediment pollution) and introduced fecal matter into the stream (organic pollution in the form of *E. coli*). The land owners within this subwatershed (Table 7-2) include the U.S. Bureau of Land Management, private owners, and some State Trust lands. 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 project is to reduce both sediment and bacterial (organic) pollution to the Yuma Wash subwatershed. Sediment load reductions can be calculated and documented using the Michigan DEQ (1999) methodology, available at the NEMO website, under BMP Manual, Links (www.ArizonaNEMO.org).

Prior to initiating a project to reduce E. coli bacteria pollution, it may benefit the watershed partnership to determine the source of the bacterial contamination. 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). For example, implementation of DNA fingerprinting technology will identify the actual sources of bacterial and clarify how best to target an implementation plan and project.

The results of a study funded from Section 319 Nonpoint Source Grant funds for Oak Creek Canyon within the Verde Watershed found that most of the fecal pollution came from natural animal populations in the canyon 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 Yuma Wash, pathogens and sediment are assumed to most likely originate from grazing practices because livestock grazing is the primary land use. Therefore, load reduction should concentrate on grazing management.

Management Measures:
Implementing grazing management practices to improve or maintain riparian health will help reduce excess surface runoff and accelerated erosion, and reduce the amount of bacterial pollution to the stream. Sustainable livestock grazing can be achieved in all plant communities by changing the duration, frequency and intensity of grazing.

In addition, livestock 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. Section 7 discusses these management measures. Tables 7-3 and 7-4 present load reduction potential, required maintenance and anticipated costs associated with various management options. 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 or the installation of an alternative water source may necessitate project design by a licensed engineer.

4. Tule Wells Draw – San Simon River Subwatershed Example Project

Pollutant Type and Source: Selenium pollution due to flood irrigation practices.

The Tule Wells Draw subwatershed of the San Simon River ranked as the most critical area impacted by agricultural land use practices that exacerbate the concentration of naturally occurring selenium (i.e. highest fuzzy membership values for Selenium, Table 8-1). For this example project it will be assumed that irrigation tail water has introduced elevated concentrations of selenium into the stream. The land owners within this subwatershed (Table 7-2) include the U.S. Bureau of Land Management, private owners, and some State Trust lands. 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:
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.

In some watersheds in California, agricultural drainage water contains 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 may be beyond the scope of a proposed best management practices project, and technologies are still in the research stage.

Section 7 outlines load reduction potential, maintenance, and anticipated costs associated with the installation of mechanized irrigation systems. 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. Mechanized irrigation, however, allows for improved water conservation and improved management of limited water resources.

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.

In the Upper Gila Watershed, the Gila Watershed Partnership has become an established stakeholder group that meets on a regular basis to plan water quality improvement projects and strategize funding opportunities. Education outreach is a regular part of their monthly meetings with their agenda usually including reports on the status of grant-funded projects. To compliment this outreach, the Partnership invites speakers to present a topic pertinent to a pending project. For example, in anticipation of developing a grant application to fund a wildcat dump cleanup along the Gila River, a representative of the Solid Waste Division of the Arizona Department of Environmental Quality was invited to speak before the Partnership. This outreach effort was complimented by a news paper article the next day, written by a reporter that had been invited to attend.

Other successful outreach and public education activities in the watershed include sponsoring a Partnership booth at the County Fair. Working with other Cooperative Extension programs, such as Project WET (Water Education for Teachers, K-12 classroom education), the Partnership booth provided displays, posters, and fact sheets on important water topics in addition to individual water quality improvement projects.

The NEMO program offers each watershed partnership the opportunity to post 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 Upper Gila Watershed, Chase Creek, Yuma Wash, and Tule Wells Draw 10-digit HUC subwatershed areas have been prioritized 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 discreet 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.

Table 8-2: Example Watershed Project Planning Schedule.

Watershed Project Planning Steps	Year				
	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

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, and Flood Plain), or organized into activity-based projects (Wildcat Dump Cleanup, Engineered Culverts, etc).

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.**
			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 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**

Management Measures and Implementation Schedule Streambank Stabilization and Estimated 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**
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**

Evaluation

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 on Table 8-2, 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.

Monitoring

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) Assessment Report (ADEQ, 2002), but the overall stakeholder group watershed plan will identify additional data collection activities that are tied to stakeholder concerns and goals. For the Upper Gila Watershed, the Chase Creek, Yuma Wash, and Tule Wells Draw subwatersheds are identified as vulnerable to water quality impairment due to metals, organics and nutrients, and selenium. Monitoring of stream reaches within the San Francisco River (Chase Creek), Gila River (Yuma Wash) and the San Simon (Tule Wells Draw) 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 8-2, 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 all thirty-one 10-digit HUC subwatersheds within the Upper Gila 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 Upper Gila Watershed (ADEQ, 2002).

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 31 subwatersheds included in this assessment, the four watersheds with the highest risk of water quality degradation are:

1. Chase Creek – San Francisco River Subwatershed, for metals pollution;

2. Yuma Wash – Upper Gila River Subwatershed, for sediment pollution;

3. Yuma Wash-Upper Gila River Subwatershed, for pollutants due to organics and nutrients derived from land use; and

4. Tule Wells Draw – San Simon River, for selenium due to agricultural practices.

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:

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ADEQ, Arizona Department of Environmental Quality. 2002. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Upper Gila Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/305-02/17ug.pdf

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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

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Appendix A

Table 1: Water Quality Data and Assessment Status, Upper Gila Watershed.

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td colspan="3">Railroad Wash – Upper Gila River Subwatershed
HUC 1504000207
Classification:
Moderate risk for metals;
Low risk for sediment;
Low risk for organics; and
High risk for selenium.</td></tr>
<tr><td rowspan="2">Gila River, from New Mexico border to Bitter Creek
15040002-004

One Site:
UGGLR205.35

Note: This reach flows through two subwatersheds HUCs:
1504000207
1504000208</td><td>Sampling</td><td>E. coli; temperature, pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium (1); beryllium; antimony; thallium (1); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t 1) (d 1); manganese (t); mercury (t) (d 1); selenium (t); silver (t 1) (d 1); zinc (t) (d); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: selenium (t) (1/1) assessed as “Inconclusive”.

Subwatershed risk classification:
Moderate risk for metals because of limited data;
Low risk for sediment;
Low risk for organics and other constituents;
High risk for selenium due to exceedances.</td></tr>
<tr><td colspan="3">Apache Creek – Upper Gila River Subwatershed
HUC 1504000208
Combined classification:
High risk for metals;
Moderate risk for sediment;
High risk for organics; and
Extreme risk for selenium.</td></tr>
<tr><td>Gila River, from Skully Creek to San Francisco River
15040002-001

One Site:
UGGLR197.26</td><td>Sampling</td><td>E. coli; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium (t 2); beryllium; antimony; thallium (2); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d 2); manganese (t); mercury (t) (d 2); selenium (t); silver (t 2) (d 2); zinc (t) (d); nickel (t 2) (d 2); nitrogen as ammonia; nitrite/nitrate; phosphorus; fluoride; and hardness.</td></tr>
</table>

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
	Status	Parameters exceeding standards: lead (t) (1/8) assessed as "Inconclusive"; former turbidity standard (2/10) assessed as "Attaining"; dissolved oxygen (1/9) assessed as "Inconclusive"; and selenium (t) (3/3) assessed as "Impaired". Subwatershed risk classification: • High risk for metals due to lead exceedance; • Moderate risk for sediment due to turbidity; • High risk for organics due to dissolved oxygen exceedance; low for other constituents groups; • Extreme risk for selenium because surface water is impaired due to selenium.
Gila River, from New Mexico border to Bitter Creek 15040002-004 One Site: UGGLR205.35 Note: This reach flows through two subwatersheds HUCs: 1504000207 1504000208	Sampling	*E. coli*; temperature, pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium (1); beryllium; antimony; thallium (1); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t 1) (d 1); manganese (t); mercury (t) (d 1); selenium (t); silver (t 1) (d 1); zinc (t) (d); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: selenium (t) (1/1) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Low risk for organics and other constituents; • High risk for selenium due to exceedances.
Animas Valley Subwatershed **HUC 1504000300** **No data collected.** **Classification:** • Moderate risk for all constituent categories due to lack of monitoring data.		
Centerfire Creek – San Francisco River Subwatershed **HUC 1504000403** **Combined classification:** • Moderate risk for metals; • Extreme risk for sediment; • Extreme risk for organics; and • Moderate risk for selenium.		
San Francisco River, from headwaters to New Mexico border[4] 15040004-023 One Site: UGSFR059.98	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
	Status	Parameters exceeding standards: Due to sediment exceedances assessed as “Impaired”; and dissolved oxygen (1/10) assessed “Attaining”. Subwatershed risk classification: • Low risk for metals; • Extreme risk for sediment ; • Extreme risk for organics because Luna Lake (in middle of this reach) is impaired due to excessive nutrients, low dissolved oxygen, and high pH; • Low risk for selenium.
Luna Lake 15040004-0840 Six Sites: UGLUN UGLUN-L1 UGLUN-L2 UGLUN-L3 UGLUN-A UGLUN-B	Sampling	*E. coli* (1); temperature; pH; dissolved oxygen; total dissolved solids; turbidity (1); secchi depth; arsenic (1); boron (1); cadmium (t 1); chromium (t 1); copper (t 1); lead (t 1); manganese (t 2); mercury (t 1); selenium (t 1); silver (t); nickel (t 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate (2); phosphorus; sulfate; chloride; fluoride (2); hardness; and total suspended solids.
	Status	Parameters exceeding standards: dissolved oxygen (14/43) assessed as “Not Attaining”; and pH (16/43) assessed as “Not Attaining”. On the planning list for monitoring turbidity, E. coli, dissolved metals (copper, cadmium, zinc) and total metals (mercury, copper and lead). Subwatershed risk classification: • Moderate risk for metals due to limited data; • Moderate risk for sediment because of limited data; • Extreme risk for organics because Luna Lake is impaired due to excessive nutrients, low dissolved oxygen, and extreme risk for pH; • Moderate risk for selenium due to limited data.
Upper Blue River Subwatershed HUC 1504000405 **Combined classification:** • Moderate risk for metals; • Moderate risk for sediment; • Moderate risk for organics; and • Moderate risk for selenium.		
Blue River, from KP Creek to Strayhorse Creek 15040004-025A One Site: UGBLR021.95	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic (1); barium (1); beryllium (1); antimony (1); thallium (1); boron (1); cadmium (t 1) (d 1); chromium(t 1) (d 1); copper (t 1)(d 1); lead (t 1) (d 1); manganese (t 1); mercury (t 1) (d 1); selenium (t 1); silver (t 1) (d 1); zinc (t 1) (d 1); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Note: This reach flows through two subwatersheds HUCs: 1504000405 1504000407	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Low risk for organics and other constituents groups; • Moderate risk for selenium because of limited data.
Blue River, from New Mexico border to KP Creek 15040004-026 Ten Sites: UGBLR043.03 UGBLR042.69 UGBLR041.93 UGBLR039.84 UGBLR039.67 UGBLR035.10 UGBLR034.75 UGBLR033.04 UGBLR030.42 UGBLR029.50	Sampling	*E. coli;* temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic (1); barium (1); beryllium (1); antimony (1); thallium (1); boron (1); cadmium (t 1) (d 1); chromium(t 1) (d 1); copper (t 1) (d 1); lead (t 1) (d 1); manganese (t 1); mercury (t 1) (d 1); selenium (t 1); silver (t 1) (d 1); zinc (t 1) (d 1); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: former turbidity standard (1/40) assessed as "Attaining"; and dissolved oxygen (2/22) assessed as "Attaining. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment based on turbidity exceedances; • Moderate risk for organics due to low dissolved oxygen and low for other constituents groups; • Moderate risk for selenium due to limited data.
Campbell Blue Creek, from headwaters to Blue River 15040004-028 Four Sites: UGCMB002.30 UGCMB002.16 UGCMB001.46 UGCMB000.16	Sampling	temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals due to missing core parameters, and low for other constituents groups; • Low risk for selenium.
KP Creek, from headwaters to Blue River 15040004-029 Two Sites: UG0KP065.54 UG0KP000.08	Sampling	temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration (2); arsenic; barium (2); beryllium; antimony; thallium (2); Boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d 2); manganese (t); mercury (t) (d 2); selenium (t); silver (t 2) (d 2); zinc (t) (d); nickel (t 2) (d 2); uranium (1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td></td><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classification:
• Moderate risk for metals because of limited data;
• Moderate risk for sediment because of limited data;
• Moderate risk for organics because of no data for E. coli and low for other constituents groups;
• Low risk for selenium.</td></tr>
<tr><td rowspan="2">Turkey Creek Headwaters- Campbell Blue Creek
15040004-060

One Site:
UGTRY000.17</td><td>Sampling</td><td>temperature; pH; dissolved oxygen; turbidity; and suspended sediment concentration (2).</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classification:
• Moderate risk for all constituents due to lack of or limited data.</td></tr>
<tr><td colspan="3">Pueblo Creek – San Francisco River Subwatershed
HUC 1504000406
No data collected.
Classification:
• Moderate risk for all constituent categories due to lack of monitoring data.</td></tr>
<tr><td colspan="3">Lower Blue River Subwatershed
HUC 1504000407
Combined classification:
• Moderate risk for metals;
• Low risk for sediment;
• Low risk for organics; and
• Moderate risk for selenium.</td></tr>
<tr><td>Blue River, from KP Creek to Strayhorse Creek
15040004-025A

One Site:
UGBLR021.95

Note: This reach flows through two subwatersheds HUCs:
1504000405
1504000407</td><td>Sampling</td><td>E. coli; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic (1); barium (1); beryllium (1); antimony (1); thallium (1); boron (1); cadmium (t 1) (d 1); chromium(t 1) (d 1); copper (t 1)(d 1); lead (t 1) (d 1); manganese (t 1); mercury (t 1) (d 1); selenium (t 1); silver (t 1) (d 1); zinc (t 1) (d 1); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.</td></tr>
</table>

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td></td><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classification:
• Moderate risk for metals because of limited data;
• Low risk for sediment;
• Low risk for organics and other constituents groups;
• Moderate risk for selenium because of limited data.</td></tr>
<tr><td rowspan="2">Blue River, from Strayhorse Creek to San Francisco River
15040004-025B

Three sites:
UGBLR008.07
UGBLR005.68
UGBLR005.59</td><td>Sampling</td><td>E. coli; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classification:
• Low risk for all constituents.</td></tr>
<tr><td colspan="3">Mule Creek – San Francisco River Subwatershed
HUC 1504000408
Classification:
• Moderate risk for metals;
• High risk for sediment;
• Low risk for organics; and
• Low risk for selenium.</td></tr>
<tr><td rowspan="2">San Francisco River, from New Mexico border to Blue River
15040004-004

One Site:
UGSFR017.66</td><td>Sampling</td><td>E. coli; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium (2); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d 2); manganese (t); mercury (t) (d); selenium (t); silver (t 2) (d 2); zinc (t) (d); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: former turbidity standard (1/6) assessed as “Inconclusive”.

Subwatershed risk classification:
• Moderate risk for metals because of limited data;
• High risk for sediment because of exceedance;
• Low risk for organics and other constituents groups;
• Low risk for selenium.</td></tr>
<tr><td colspan="3">Chase Creek – San Francisco River Subwatershed
HUC 1504000409
Combined classification:
• Moderate risk for metals;
• High risk for sediment;
• Moderate risk for organics; and
• Low risk for selenium.</td></tr>
</table>

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
San Francisco River, from Limestone Gulch to Gila River[4] 15040004-001 One Site: UGSFR003.04	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); sliver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: copper (d) (1/22) assessed as "Inconclusive" and lead (1 of 22) assessed as "Attaining"; former turbidity standard (4 of 21) assessed as "Inconclusive"; and *E. coli* (1/17) assessed as "Inconclusive" and dissolved oxygen (2/21) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals due to copper (d) and lead exceedances; • High risk for sediment due to turbidity; • Moderate risk for organics due to *E. coli* exceedance; and low risk for other constituents groups; • Low risk for selenium.
San Francisco River, from Blue River to Limestone Gulch[4] 15040004-003 One Site: UGSFR011.29	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: mercury (1/17) assessed as "Attaining"; former turbidity standard (3/16) assessed as "Attaining"; and *E. coli* (1/13) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals due to mercury exceedance; • Moderate risk for sediment due to turbidity exceedance; • Moderate risk for organics due to *E. coli* exceedance; and low risk for other constituents groups; • Low risk for selenium.
Willow Creek Subwatershed HUC 1504000501 **No data collected.** **Classification:** • Moderate risk for all constituent categories due to lack of monitoring data.		

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Upper Eagle Creek Subwatershed HUC 1504000502 **Classification** • Moderate risk for metals; • Low risk for sediment; • Low risk for organics; and • Moderate risk for selenium.		
Eagle Creek, from headwaters to unnamed tributary at 33 23 24/109 29 35 (latitude/longitude) 15040005-028A One Site: UGEAG035.99	Sampling	*E. coli*; temperature; pH; dissolved oxygen; turbidity; arsenic (2); barium (2); beryllium (2); antimony (2); thallium (2); boron (2); cadmium (t 2) (d 2); chromium (t 2) (d 2); copper (t 2) (d 2); lead (t 2); lead (d 2); manganese (t 2); mercury (t 2) (d 2); selenium (t 2); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals due to limited data; • Low risk for sediment; • Low risk for organics; and other constituents groups; • Moderate risk for selenium due to limited data.
Lower Eagle Creek Subwatershed HUC 1504000503 **Combined classification:** • Moderate risk for metals; • Moderate risk for sediment; • Low risk for organics; and • Low risk for selenium.		
Eagle Creek, from Sheep Wash to Gila River 15040005-025 One Site: UGEAG006.05	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids (2); turbidity; suspended sediment concentration (2); arsenic; barium (2); beryllium; antimony; thallium (2); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d 2); manganese (t); mercury (t) (d); selenium (t); silver (t 2); zinc (t) (d); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of limited data; • Low risk for organics; and other constituents groups; • Low risk for selenium.
Eagle Creek, from Willow Creek to Sheep Wash 15040005-027 One Site: UGEAG023.34	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration (2); arsenic; barium(2); beryllium; antimony; thallium(2); boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d 2); manganese (t); mercury (t) (d); selenium (t); silver (t 2); zinc (t) (d); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of limited data; • Low risk for organics and other constituents groups; • Low risk for selenium.
Bonita Creek Subwatershed HUC 1504000504 **Classification:** • Low risk for metals; • Moderate risk for sediment; • Low risk for organics; and • Low risk for selenium.		
Bonita Creek, from Park Cre to Gila River 15040005-030 Two Sites: UGBON011.31 UGBON000.20	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: former turbidity standard (1/11) assessed as "Attaining". Subwatershed risk classification: • Low risk for metals; • Moderate risk for sediment due to turbidity exceedance; • Low risk for organics and other constituents groups; • Low risk for selenium.
Yuma Wash – Upper Gila River Subwatershed HUC 1504000505 **Combined classification:** • High risk for metals; • Extreme risk for sediment; • Extreme risk for organics; and • Moderate risk for selenium.		

Reach **Sites**	**Results**	**Available Water Quality Data and Assessment Status[1,2,3]**
Gila River, from Bonita Creek to Yuma Wash[4] 15040005-022 One Site: UGGLR188.98	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); manganese (t); zinc(d); nickel (t) (d); uranium; nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; hardness; total solids; and total suspended solids.
	Status	Parameters exceeding standards: copper (d) (1/23) and lead (t) (4/21) are assessed as “Inconclusive”; suspended sediment concentration (1/3) and former turbidity standard (7/24) are assessed as “Inconclusive. Reach assessed as “Impaired” due to sediment; *E. coli* (3/23) assessed as “impaired”. Subwatershed risk classification: • High risk for metals due to lead (t) and copper (d) exceedances; • Extreme risk for sediment; • Extreme risk for organics due to *E. coli* and low risk for other constituents groups; • Low risk for selenium.
Gila River Eagle Creek- Bonita Creek[4] 15040005-023	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Added to the planning list in 2002 due to former turbidity standard exceedances (9/12) assessed as “Inconclusive”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • High risk for sediment due to exceedances of former turbidity standard; • Moderate risk for organics and other constituents groups because of limited data; • Moderate risk for selenium because of limited data.
Gila River San Francisco River	Sampling	No current monitoring data.

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td>Eagle Creek[4]
15040005-024</td><td>Status</td><td>Parameters exceeding standards: none. Added to the planning list in 2002 due to former turbidity standard exceedances (12/12) assessed as “Inconclusive”.
Subwatershed risk classification:
• Moderate risk for metals because of limited data;
• High risk for sediment due to exceedances of former turbidity standard;
• Moderate risk for organics and other constituents groups, because of limited data;
• Moderate risk for selenium because of limited data.</td></tr>
<tr><td colspan="3">Stockton Wash Subwatershed
HUC 1504000506
Combined classification:
• Moderate risk for metals;
• High risk for sediment;
• Moderate risk for organics; and
• High risk for selenium.</td></tr>
<tr><td rowspan="2">Dankworth Ponds
15040006-0440

Four Sites:
UGDAN-A
UGDAN-B
UGDAN-POND
UGDAN-SPR4</td><td>Sampling</td><td>temperature; pH; dissolved oxygen; total dissolved solids; turbidity; Secchi depth; arsenic; barium; beryllium; boron; cadmium (t); chromium (t); copper (t); lead (t); manganese (t); mercury (t); selenium (t); zinc (t); nitrogen as ammonia; n-kjeldahl; phosphorous; and fluoride.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Former turbidity standard (1/2) assessed as “Inconclusive”; and selenium (chronic standard-1/1) (acute standard- 1/4) assessed as “Inconclusive”.

Subwatershed risk classification:
• Moderate risk for metals due to limited data;
• High risk for sediment due to turbidity;
• Moderate risk for organics due to lack of data for E. coli; and low risk for other constituents groups;
• High risk for selenium due to exceedances.</td></tr>
<tr><td rowspan="2">Roper Lake
15040006-1250

Four Sites:
UGROP-A
UGROP-B
UGROP-Pond
UGROP-Canal</td><td>Sampling</td><td>temperature; pH; dissolved oxygen; total dissolved solids; Secchi depth; arsenic; barium; beryllium; antimony (1); boron; cadmium (t); chromium (t); copper (t); lead (t); manganese (t); mercury (t) (d); selenium (t); silver (t); zinc (t); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; chloride; fluoride; and hardness.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classification:
• Moderate risk for metals because of limited data;
• Moderate risk for sediment because of limited data;
• Moderate risk for organics because of limited data;
• Low risk for selenium.</td></tr>
</table>

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Cottonwood Wash – Upper Gila River Subwatershed **HUC 1504000507** **Combined classification:** • Moderate risk for metals; • Moderate risk for sediment; • Moderate risk for organics; and • Moderate risk for selenium.		
Ash Creek 15040005-040B One Site: UGA1H008.62	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; arsenic; barium (1); beryllium; antimony; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t)(d 1); manganese (t); mercury (t) (d 1); selenium (t); silver (t 1) (d 1); zinc (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Low risk for organics and other constituents groups; • Low risk for selenium.
Frye Canyon Creek, from headwaters to Frye Mesa Reservoir 15040005-988A One Site: UGFRY007.00	Sampling	temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic (1); barium (1); beryllium(1); antimony(1); thallium(1); boron(1); cadmium (t 1) (d 1); chromium (t 1) (d 1); copper (t 1) (d 1); lead (t 1) (d 1); manganese (t 1); mercury (t 1)(d 1); selenium (t 1); silver (t 1); zinc (t 1) (d 1); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Low risk for organics; and other constituents groups; • Moderate risk for selenium due to limited data.
Cluff Pond #3 15040005-0370 One Site: UGCRC-Mid	Sampling	Temperature (1); pH (1); dissolved oxygen (1); total dissolved solids (1); Secchi depth (1); copper (t 1); manganese (t 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrate (1); phosphorus (1); chloride (1); hardness (1); and total suspended solids (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for all constituents groups because of limited or lack of data.
Black Rock Wash – Upper Gila River Subwatershed **HUC 1504000508** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Goodwin Wash – Upper Gila River Subwatershed HUC 1504000509 No data collected. Classification: • Moderate risk for all constituents groups due to lack of monitoring data.		
Salt Creek – Upper Gila River Subwatershed HUC 1504000510 No data collected. Classification: • Moderate risk for all constituents groups due to lack of monitoring data.		
San Simon River Headwaters Subwatershed HUC 1504000601 No data collected. Classification: • Moderate risk for all constituents groups due to lack of monitoring data		
Cave Creek – San Simon River Subwatershed HUC 1504000602 Combined classification: • Moderate risk for metals; • High risk for sediment; • Moderate risk for organics; and • Extreme risk for selenium.		
East Turkey Creek, from headwaters to unnamed tributary at 31 58 22 / 109 12 17 (latitude / longitude) 15040006-837A One Site: UGETK007.70	Sampling	temperature (1); pH (1); dissolved oxygen(1); total dissolved solids (1);Turbidity (1); cadmium(d 1); copper (d 1); mercury (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrate/nitrite (1); phosphorus (1); and hardness (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for all constituents groups due to limited or lack of data.
Cave Creek, South Fork-headwaters-Cave Creek (Unique Water) 15040006-849 Three Sites: UGSCV002.45 UGSCV002.26 UGSCV000.12	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; sulfate (1); fluoride; and hardness.
	Status	Parameters exceeding standards: former turbidity standard (1/13) assessed as "Attaining"; *E. coli* (1/10) assessed as "Inconclusive", Subwatershed risk classification: • Low risk for metals; • Moderate risk for sediment due to turbidity exceedance; • Moderate risk for organics due to *E. coli* exceedance; and low risk for other constituents groups; • Low risk for selenium.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Cave Creek, from headwaters to South Fork of Cave Creek 15040006-852A Five Sites: UGCAV009.86 UGCOV008.92 UGCOV008.49 UGCOV007.70 UGCOV007.64	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d 1); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: former turbidity standard (1/18) assessed as “Attaining”; selenium (t) (2/2) assessed as “Impaired”. Subwatershed risk classification: • Low risk for metals; • Moderate risk for sediment due to turbidity exceedance; • Low risk for organics; and other constituents groups; • Extreme risk for selenium due to exceedances.
Cave Creek, from South Fork of Cave Creek to the USFS boundary 15040006-852B Two sites: UGCAV007.46 UGCOV006.55	Sampling	*E. coli*; temperature; pH; dissolved oxygen; total dissolved solids; turbidity; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrate/nitrate; phosphorus; fluoride; and hardness.
	Status	Parameters exceeding standards: former turbidity standard (1/9) assessed as “Inconclusive”; and *E. coli* (1/8) assessed as “Attaining”. Subwatershed risk classification: • Low risk for metals; • High risk for sediment due to turbidity exceedance; • Moderate risk for organics because of an *E. coli* exceedance, but no exceedances in the last three years of monitoring; • Low risk for selenium.
North Fork Cave Creek, from headwaters to Cave Creek 15040006-856 One Site: UGNCV000.03	Sampling	*E. coli* (1), temperature (1), pH (1), dissolved oxygen (1), total dissolved solids (1), turbidity (1), cadmium(d 1), copper (d 1), mercury (d 1), nitrogen as ammonia (1), n-kjeldahl (1), nitrate/nitrate (1), phosphorus (1), fluoride (1), and hardness (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for all constituents groups due to limited or lack of data.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Happy Camp Wash Subwatershed **HUC 1504000603** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
East Whitetail Creek – San Simon River Subwatershed **HUC 1504000604** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Hot Well Draw – San Simon River Subwatershed **HUC 1504000605** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Tule Wells Draw – San Simon River Subwatershed **HUC 1504000606** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Gold Gulch – San Simon River Subwatershed **HUC 1504000607** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Slick Rock Wash – San Simon River Subwatershed **HUC 1504000608** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data		
Ash Creek Subwatershed **HUC 1504000701** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Sevenmile Wash – Sycamore Creek Subwatershed **HUC 1504000702** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		
Gilson Wash Creek Subwatershed **HUC 1504000703** **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
San Carlos River Subwatershed HUC 1504000704 **No data collected.** **Classification:** • Moderate risk for all constituents groups due to lack of monitoring data.		

[1] 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.

[2] The number of samples that exceed a standard are 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.

[3] The acronyms used for the water quality parameters are defined below:

(t) = (t) metal or metalloid (before filtration)
(d) = dissolved fraction of the metal or metalloid (after filtration)
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: dissolved Oxygen
E. coli: Escherichia coli bacteria
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.
nitrate/nitrite: 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: total dissolved solids
total solids: (t) Solids
total suspended solids: (t) Suspended Solids
turbidity: Measurement of suspended matter in water sample.
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.

[4] ADEQ reports that this reach is expected to be added to the final 2004 303d list by Region 9 EPA.

Appendix B: Suggested Readings
Upper Gila Watershed

Hirsch, R.M., Walker, J.F., Day, J.C., Kallio, R. 1990. The influence of man on hydrologic systems. 329-359 in Wolman, M.G., Riggs, H.C., (eds.) Surface Water Hydrology. Geological Society of America, Boulder, Colorado.

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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:

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Van Remortel, R. 2004. Soil & Landform Metrics: Programs and U.S. Geodatasets Version 1.1. Environmental Protection Agency. Las Vegas, NV.

Data Sources*:

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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 Upper Gila 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: United States Geological Survey. July 21, 2003. http://landcover.usgs.gov/natllandcover.asp

- 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.

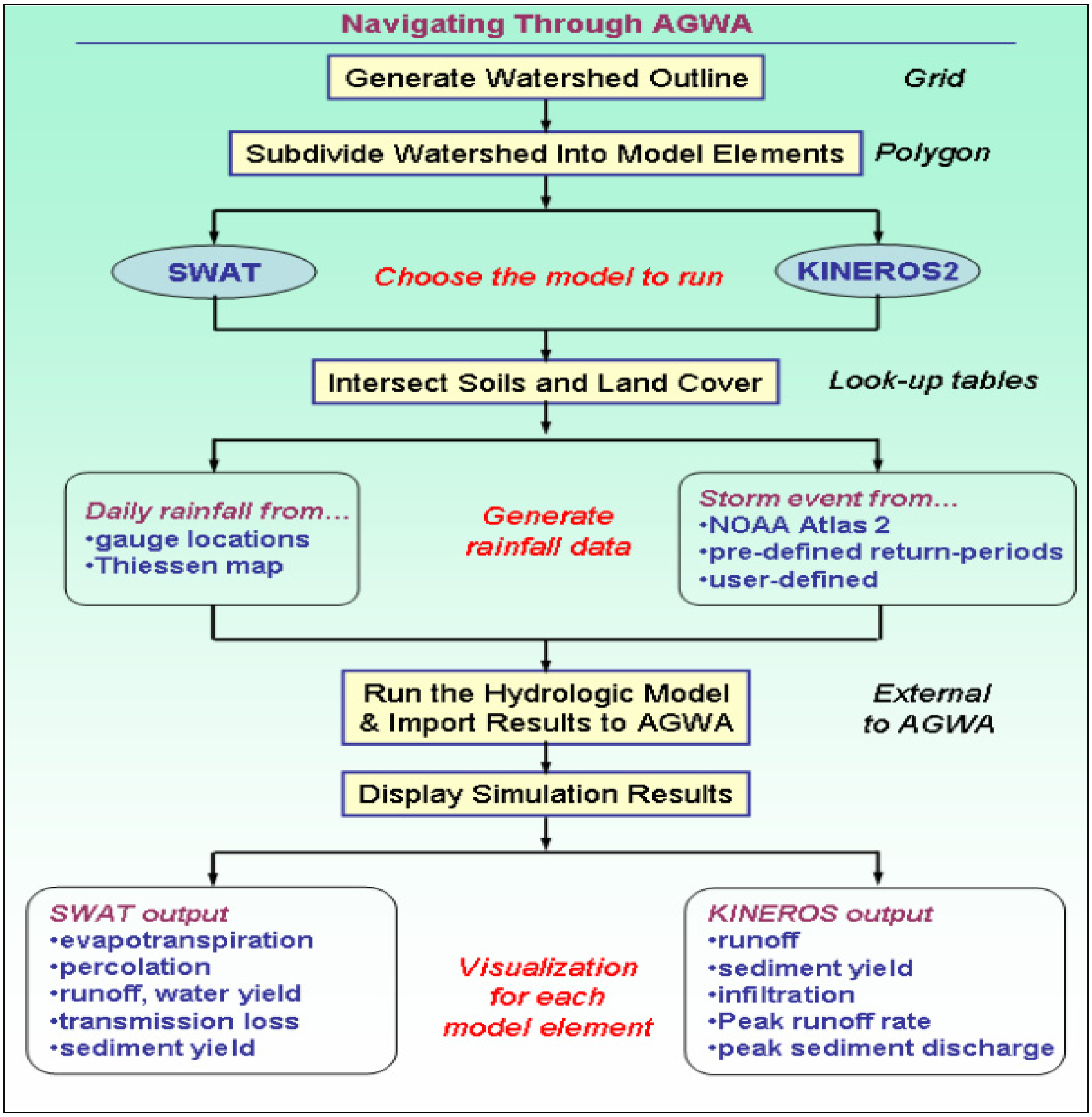

Figure D-1: Flow chart showing the general framework for using KINEROS2 and SWAT in AGWA.

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.

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