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Upper Gila River Watershed Assessment

PREPARED FOR

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GWP Watershed Assessment

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PAST AND PRESENT PARTNERS

Arizona Game and Fish Department
Arizona Department of Environmental Quality
Arizona Department of Agriculture
Arizona Department of Transportation
Arizona Department of Forestry and Fire Management
Arizona State Land Department
Arizona Conservation Corps
Borderlands Restoration, L3C
Boulder Creek Construction
City of Safford
Conservation Legacy
Coronado RC&D
E-Quality Inc.
U.S. Natural Resource Conservation Service
U.S. Fish and Wildlife Service
U.S. Bureau of Land Management
U.S. Forest Service
U.S. Bureau of Reclamation
Graham County
Greenlee County
Southeast Arizona Clean and Beautiful
Sky Island Alliance
Sky Island Restoration Cooperative
Stillwater Sciences
Southwest Decision Resources
Town of Thatcher
Town of Pima
Town of Duncan
Town of Clifton
Tamarisk Coalition
Freeport-McMoRan, Inc.
Graham County Chamber of Commerce
Greenlee county Chamber of Commerce
Rivers Edge West
United Way of Graham & Greenlee Counties
University of Arizona – Cooperative Extension
University of Arizona – Water Resource Research Center
Walton Family Foundation
Numerous Private Citizens

LIST OF ACRONYMS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ANSAC	Arizona Navigable Stream Adjudication Commission
BLM	Bureau of Land Management
CES	Cooperative Extension Services
CWA	Clean Water Act
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESP	Enhancement of Survival Permit
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
GPM	Gallon per minute
GWP	Gila Watershed Partnership
GVID	Gila Valley Irrigation District
ITP	Incidental Take Permit
NEPA	National Environmental Policy Act
NOI	Notice of Intent
NRCS	Natural Resources Conservation Service
UA	University of Arizona
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
WIP	Watershed Improvement Program
WOTUS	Waters of the United States
WRRC	Water Resources Research Center

EXECUTIVE SUMMARY

The Gila Watershed Partnership's (GWP) Watershed Assessment provides a summary of the primary resources and issues in the watershed, with specific and general recommendations for the Upper Gila River Watershed in Arizona. This document was compiled through a process involving the following tasks:

- Review the five-year watershed planning initiative, led by the University of Arizona Water Resources Research Center.
- Compile and synthesize relevant feedback from stakeholders.
- Assess current status of natural resources since completion of the *2014 Atlas of the Upper Gila River Watershed* (WRRC 2014).
- Provide updated maps of the watershed depicting resources and key analysis results.
- Conduct public presentations and review of plan with stakeholders.
- Develop recommendations to achieve the GWP's short-term and long-term goals.

The goals, data, and recommendations in this report are built upon a strong foundation of experiences and expertise of GWP's Board of Directors, staff, and stakeholders, supported by collaboration with Stillwater Sciences and the University of Arizona Water Resources Research Center (WRRC). This plan was developed as part of a project funded by the Walton Family Foundation.

General Management Recommendations include:

1. **Convene decision-makers around watershed issues.** Watershed management is strengthened with the participation of local decision-makers, experts, and community members. The GWP is best positioned to convene disparate groups and host critical dialogues about the health of the region in order to build common understanding of the issues and develop solutions.
2. **Prioritize areas most vulnerable to fire.** The Upper Gila River Watershed's patchwork of property ownership and land management create potential hazards for property and wildlife in the region. GWP will work with landowners and agencies to standardize management practices and develop a multi-jurisdictional plan for fire risk reduction.
3. **Identify infrastructure at risk from natural disasters.** Aged erosion control structures and outdated engineering over the last century has left the Upper Gila River Watershed at risk for flooding and other natural disasters. A concerted effort is necessary to identify and target compromised structures that pose the greatest threat to people, property, and the natural system.
4. **Cultivate next generation of watershed stewards.** Youth engagement, which has been found to be highly effective, will serve as a primary method for outreach and education in the communities in the Upper Gila River Watershed.
5. **Support conservation practices and policies.** Boost initiatives to install more efficient water-related infrastructure in homes, fix leaks, provide education on money savings, and get people to buy-in to conserving water. These types of programs could play a continuing role into the future, particularly in areas where new residential and commercial growth would create increased water demand. These programs may be

particularly important in areas where proposed conservation measures and programs have not yet been adopted.

6. **Establish Best Management Practices for Uplands.** Using resources from the Bureau of Land Management and other federal agencies, develop a set of practices customized for the region and reflective of the major stressors that impact upland health and, in turn, influence riparian and watershed health.
7. **Delineate River Management Segments.** Based on land ownership and aligned management objectives, delineate the management network and segments of the river corridor to prioritize management actions and the responsible entities.

SECTION 1: INTRODUCTION

The communities of the Upper Gila River Watershed have witnessed threshold moments in which decision-making at particular points in time resulted in substantial shifts in the future development and land use of the Valley. These threshold moments demonstrate how a collective choice or series of choices can result in long-term effects for residents and resources throughout the watershed. Land surveys and ownership arrangements established in the late 19th century impacted access to important resources like surface water and mineral rights. Site selections for new roadways and railways have had spillover effects for those communities included or excluded from such projects. In other cases, when expensive public projects were constrained by limited budgets, decisions were required to weigh community support. An early 20th century referendum led to the construction of a highway from Safford to Duncan instead of a dam in the area of the Gila Box. A long-term, anti-wildfire policy on federal forest lands has been shown to have counterproductive results, as the reduction in frequent, small-intensity fires is replaced by infrequent but tremendously destructive high-intensity blazes like the Wallow Fire in 2011. New plant species were introduced into the landscape during these waves of settlement; most notably contributing to the colonization of the Upper Gila River riparian zone by the invasive tamarisk tree. Decisions and policies regarding land use and resource management can have lasting, long-term cumulative impacts on the watershed.

From historical examples to the present, the sustainability of water supplies in the face of fluctuating precipitation levels has remained a constant theme in the life of residents of the Upper Gila River Watershed. This variability requires innovative and collaborative approaches to management of the land and water resources. The Gila Watershed Partnership (GWP) has taken on these challenges for the last three decades and persists in creating an ever more robust framework for future management decisions.

GILA
WATERSHED
PARTNERSHIP
OF ARIZONA

WATERSHED ASSESSMENT GOALS AND OBJECTIVES

This document is intended to draw together past and current watershed-focused planning efforts with stakeholder feedback in order to identify priority activities that will best address the major watershed challenges. It will provide guidance for future GWP projects and actions which support the efforts of partnering land and resource managers.

Objectives

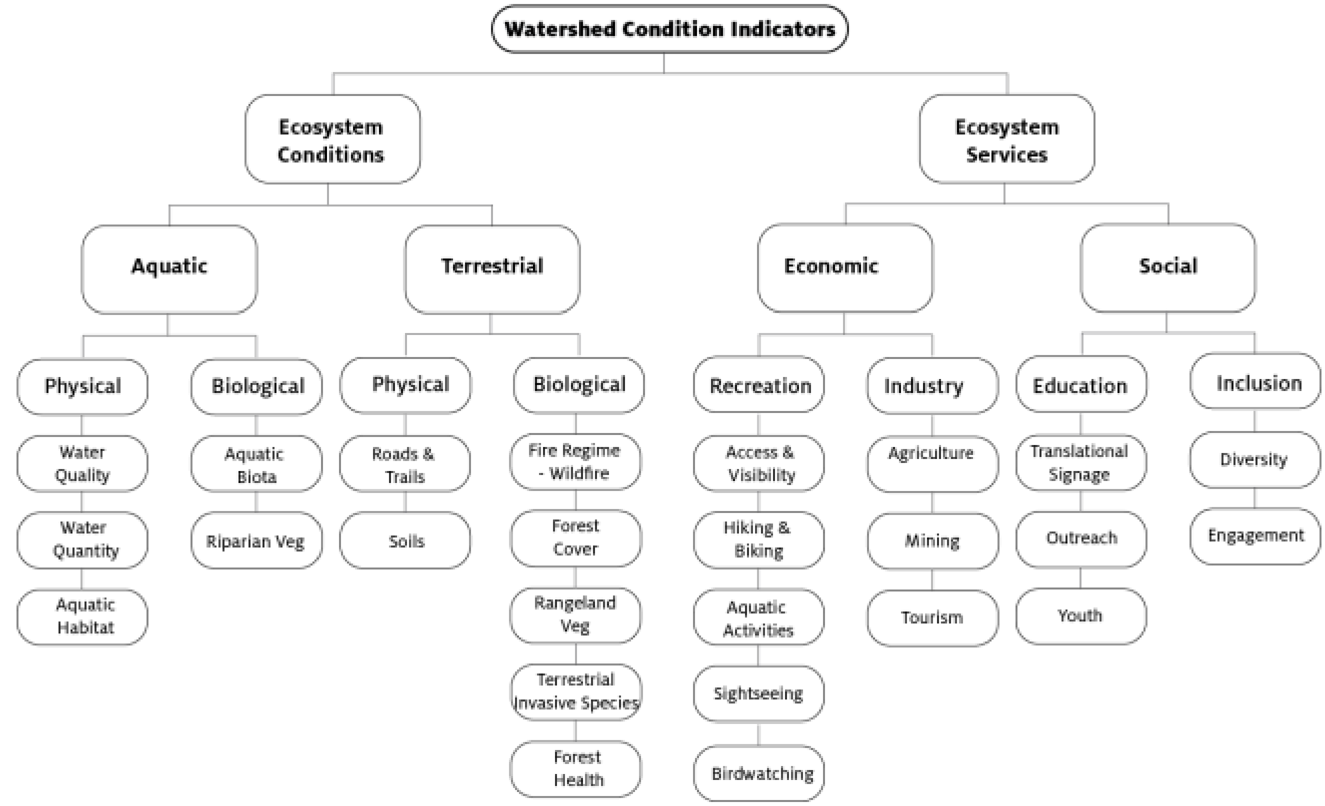
The main objectives of the Watershed Assessment are to:

- Characterize the existing resource conditions in the river-riparian corridor and upland areas throughout the watershed.
- Identify the greatest stressors affecting resources and functions of the physical, hydrological, and ecological systems in the watershed.
- Integrate the information on resource conditions and stressors to develop one or more watershed condition indicators.
- Identify data gaps and areas of greatest uncertainty.
- Provide recommendations for actions to improve watershed conditions and beneficial human uses.
- Identify metrics with which to measure progress toward GWP’s goals and objectives.

Watershed Condition

The greater the departure from the natural “pristine” state, the more impaired the watershed conditions are likely to be. Watershed condition refers to the physical and biological processes that impact the soil and hydrologic functions supporting ecosystems and a healthy environment. These conditions can reflect a range of variability from "natural pristine" (functioning properly) to "degraded" (severely altered state or impaired) (U.S. Forest Service 2011). Watersheds that are functioning properly have ecosystems that capture, store, and release water, sediment, wood, and nutrients within a natural range. This proper functioning can create and sustain functional habitats that are capable of supporting diverse populations of native aquatic- and riparian-dependent species, providing substantial economic, recreational, aesthetic, and other benefits.

In sum, a well-functioning watershed is a healthy watershed. While the Upper Gila River Watershed is sparsely populated and not heavily developed, certain activities such as agriculture, ranching, recreation, and mining can alter natural functioning of the watershed. This Watershed Assessment describes various indicators and variables that may impact watershed function. A framework for evaluating watershed condition is depicted in Figure 1. The example depicted here uses a suite of "indicators" and corresponding attributes related to watershed processes to determine watershed condition (U.S. Forest Service 2011). This and similar watershed condition frameworks typically are best suited for evaluating watershed condition relative to other watersheds within a region or state, to help resource managers plan and prioritize watershed protection and restoration efforts (EPA 2017).



(Adapted from US Forest Service Model)

Figure 1. Watershed Condition Indicators Model, adapted from the U.S. Forest Service Watershed Condition Classification Technical Guide (2011).

To gain a better understanding of which watershed indicators are being evaluated or have been evaluated in the past, GWP is soliciting input from stakeholders using the Watershed Condition Indicators Worksheet included herein as Appendix A. The information obtained by those working in the watershed will provide helpful context for deciding which watershed indicators should be addressed by GWP, which are already being addressed by partners, and which could be addressed by GWP supporting partners.

CONSISTENCY WITH PREVIOUS PLANNING EFFORTS

This Watershed Assessment is intended for use alongside the GWP *Watershed Conservation Plan*, *Riparian Restoration Plan*, and *Restoration Framework Report*, along with other technical reports that were assessed for the development of this document.

This report is also aligned with local planning considerations of Towns, Cities, Counties, and Federal Agencies (Table 1).

Table 1. Aligned planning and resources management reports.

Source	Related Sections or Documents
Graham County Multi-Jurisdictional Hazard Mitigation Plan (2010)	• 5.3. Hazard Risk Profiles (5.3.1-7: Dam Failure, Drought, Fissure, Flood/Flash Flood, Severe Wind, Wildfire)
Graham County Comprehensive Plan (1996)	• All goal statements, especially 1 and 2: 1.) To allow and provide for growth which has positive benefits to county residents and that is compatible with the natural environment and to insure economic security; 2.) To conserve natural resources, preserve scenic beauty and to promote recreational opportunities • 2.4.3 Environmental Impact Review (EIR)
Greenlee County Comprehensive Plan (2003)	• Vision Statement • Plan Element C. Environmental
U.S. Forest Service	• Watershed Condition Assessment Criteria • Land management Plan for the Apache-Sitgreaves National Forests (2016)
U.S. Bureau of Land Management	• Resource Management Plan • BMPs that address uplands
Arizona Department of Environmental Quality	• Five Year Non-point Source Management Plan (2015-2019): Identify impairments to surface and groundwater quality; Prevent and reduce NPS pollution discharges to protect and restore surface or groundwater resources; Coordinate efforts of various programs within ADEQ and with other agencies and partners to prevent and reduce NPS impacts to surface and groundwater
City of Safford General Plan (2016)	• Environmental Planning and Water Resources Element • Parks, Recreation, Trails, and Open Space
Town of Thatcher General Plan (2008)	• II.A.3. The General Plan recognizes the need for parks, recreational areas and open areas, which add to the attractiveness of the community, the quality of life of the residents and the expectation that park sites will be reserved and developed within new development projects." • II.A.4. Land use Considerations • II.A.5. Goals and Objectives – Goal 1: Proactively manage and direct growth to suitable areas for residential, commercial, and industrial uses
Town of Clifton (1985)	• Community Development Objectives and Policies – Provide the environment and improve the quality of life in the community
Town of Pima (2016)	• Future Changes in Land Use: Development Goal: Encourage the character of development in Town to be consistent with Pima's vision; associated Policy: Promote the use of landscaping that is appropriate for Pima, its natural setting and climate. • Future Changes in Public Services: all Water Goals

WATERSHED ASSESSMENT DEVELOPMENT AND ADAPTATION

This Watershed Assessment is intended to be a "living" document that is updated as environmental and land use conditions change, and/or GWP mission and goals adapt. The purpose of this document is to present a holistic view of the watershed conditions in order to assess the most effective and pragmatic ways to address those conditions under current and potential circumstances.

The Watershed Assessment will be periodically reviewed and revised in order to re-assess the watershed condition and respond to opportunities and challenges in a timely manner. The GWP Science and Technical Advisory Committee will review the Watershed Assessment once every 3 years from the time of completion. In cases where there are relevant changes in the plans of partnering organizations or dramatic changes in watershed conditions, review and revisions may occur on a more frequent basis.

PAST AND PRESENT GWP PROJECTS

Riparian Restoration Projects

The GWP has identified and begun riparian restoration at five discrete sites along the Upper Gila River in the Safford Valley, near the communities of Pima and Fort Thomas (Figure 2). The purpose of the riparian restoration projects is to re-establish native habitat for the Southwestern Willow Flycatcher (SWFL) and to control ecological, social, and economic threats from invasive tamarisk and other associated invasive species. The restoration sites were identified by GWP and their restoration-planning science team as part of a comprehensive ecohydrological assessment that evaluated restoration suitability throughout the river corridor in the Safford and Duncan valleys (Orr et al. 2014). This process entailed consideration of numerous environmental factors, each influencing suitability of SWFL-focused restoration in light of the imminent arrival of the tamarisk leaf beetle. Environmental factors included flood-scour risk, vegetation character, water and soil-moisture availability, soil salinity, and SWFL-nesting habitat suitability. The five restoration sites range in size from 2.9 to 24.6 acres, and total approximately 54.3 acres. Additional restoration is being planned at sites in the river-riparian corridor of the mainstem Gila River in and near the Safford Valley.

Other Ongoing GWP Projects

- Eastern Arizona College Discovery Park Campus Pollinator Garden
- Upper Gila River Watershed Riparian Restoration
- San Francisco and Blue River *E.coli* Reduction
- Upper Gila River Fuels Reduction
- Point of Pines Restoration

Past GWP Projects

Over 25 years, the GWP and partners have undertaken a variety of watershed projects, spanning from restoration to water quality improvement in the San Francisco River sub-basin and the removal of abandoned automobiles.

Tamarisk Removal and Restoration

- Zorilla Street Bridge Restoration
- Gila River Restoration at Apache Grove
- Point of Pines Restoration

Water Quality

- Central Retention Dam Rehabilitation
- Gila River Clean Up

- Abandoned Vehicle Removal Project – Crushed Vehicles Loaded for Removal
- Kaler Ranch Erosion Control Project, Phase I
- *E.coli* Reduction through Alternative Livestock Water on Kaler Ranch, Phases I, II, and III
- Buzzard Roost Clean Up
- Peterson Wash Stabilization
- Syfert Wildlife Watering Facility – Wildlife Watering Hole at Ten Ranch
- Ely Fence Replacement Project
- Salt Water Wells Closures
- Bellman Well Closure
- Thatcher Well Closure
- Groundwater Quality Project with ADEQ

Education

- Gila River Water Conservation Education Project
- Dzil Nchaa Si'An/Mt. Graham Youth Practicum Education Project Grant
- Upper Gila River Watershed Master Watershed Steward Class
- San Francisco River Master Watershed Steward Class
- Apache Grove Program
- GWP Monthly Speaker Series
- Discovery Park Earth Day

Water Conservation

- Graham County Fairgrounds Project
- Water Counts Program

Research

- Upper Gila River Fluvial Geomorphology Study
- San Simon Legacy Database
- Measuring the Flow of the San Francisco River

Economic Development & Tourism

- Growing Greenlee County as a Birding Destination
- The Buildings on Chase Creek in Clifton - Facade Improvement

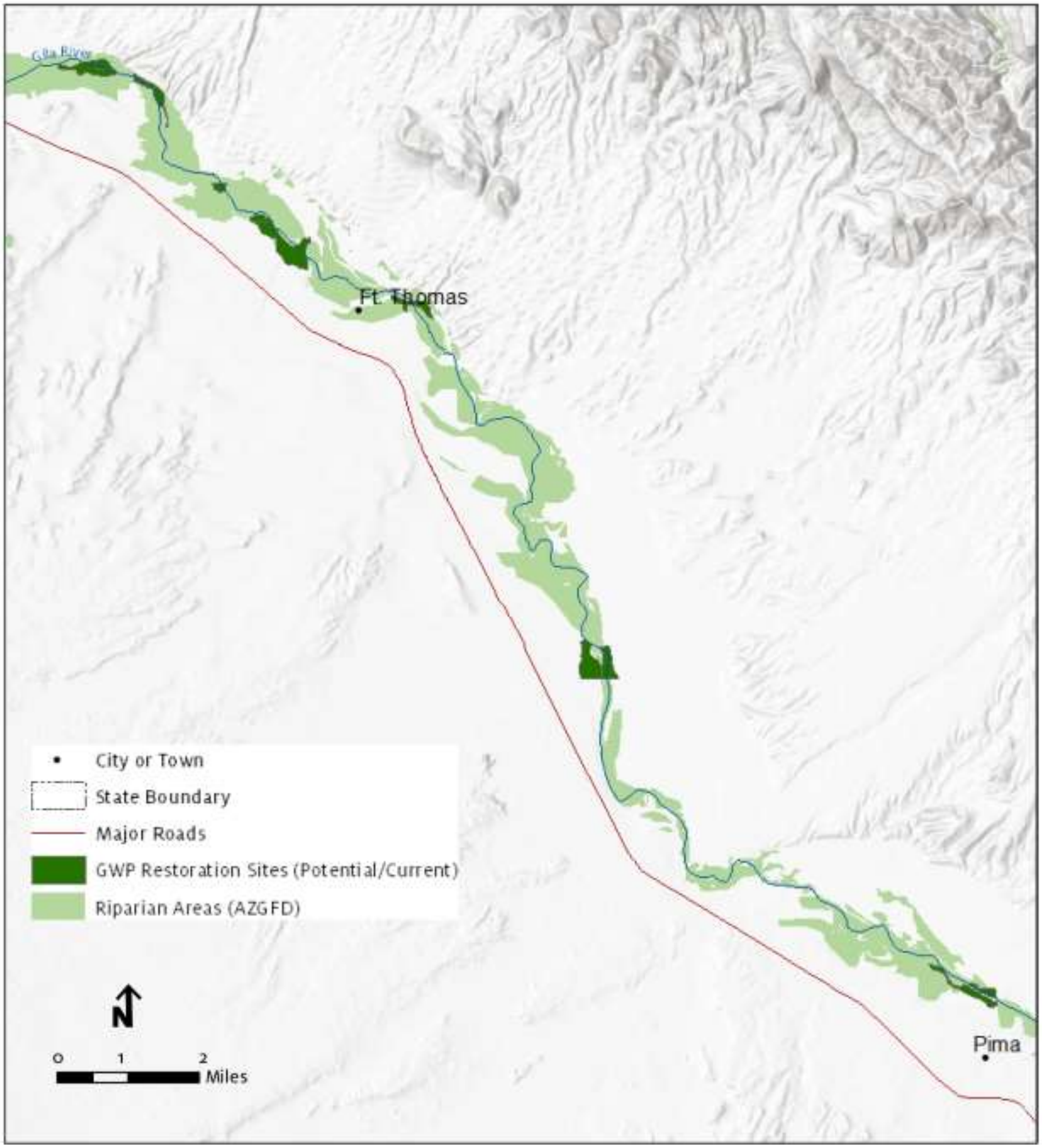


Figure 2. Locations of completed and ongoing GWP riparian restoration.

GEOGRAPHIC EXTENT OF THE WATERSHED ASSESSMENT

This Watershed Assessment is focused on the large expanse of southeastern Arizona within the Upper Gila River Watershed upstream of San Carlos Dam (Figure 3). The Watershed Assessment describes resources, uses, and stressors occurring in the mainstem Upper Gila River corridor from the Arizona-New Mexico border downstream to San Carlos Reservoir, and in the tributaries and upslope areas of the watershed. Because the inputs and processes acting throughout the watershed naturally propagate downstream to the drainage network, historical and current water and land management throughout the watershed shape the structure, function, and stressors acting on the river-riparian system. Understanding the resource conditions and relative magnitude of these influences will help define and prioritize future watershed management opportunities and constraints.

Reaches and Sub-basins

Between San Carlos Dam and the Arizona-New Mexico border, the Gila River flows through two broad alluvial valleys (the Duncan-Virden Valley and the Safford Valley) separated by the Gila Box, a much narrower, bedrock- confined system. Between York and the Duncan Valley, the Gila River is semi-confined with valley width ranging from 500-700 ft, until the valley widens significantly just downstream of Duncan.

Previous studies have delineated reaches and sub-basins for purposes of analysis and management. Orr et al. (2014) sub-divided the Gila River between Coolidge Dam and the lower Gila Box into three hydrogeomorphic reaches (the Reservoir-influenced Reach, The Gila (Safford) Valley, and the lower Gila Box. The U.S. Bureau of Reclamation (2003) identified 14 discontinuous reaches in the Duncan and Safford Valleys as part of an erosion study. The Safford Valley was further subdivided into 10 reaches based on floodplain width, vegetation, degree of braiding, land use, and tributary confluences.

Because this Watershed Assessment has a much larger study area than Orr et al. (2014) and the Reclamation (2003) erosion study, we have divided the Gila River into six reaches and include six large tributaries as separate sub-basins. The reaches and sub-basins are indicated by number in Figures 3, 4, and 5.

Gila River Mainstem Reaches

1. The Duncan Valley Reach from the New Mexico Border to Highway 191 (about 18 river miles)
2. The Gila Box Reach from Highway 191 to Bonita Creek (about 33 river miles)
3. The Upper Safford Valley Reach from Bonita Creek to the Smithville Diversion Dam (about 18 river miles)
4. The Lower Safford Valley Reach from Smithville Diversion Dam to the east boundary of the San Carlos Apache Reservation (about 34 river miles)
5. The Bylas Reach from the east boundary of the San Carlos Apache Reservation to the upstream limit of the reservoir backwater (defined by Orr et al. (2014) as the confluence with Bone Spring Canyon) (15.6 river miles)

6. San Carlos Reservoir and Backwater Reach from Bone Spring Canyon to Coolidge Dam (about 24 river miles).

Tributary Sub Basins

1. San Francisco River
2. Blue River
3. Eagle Creek
4. Bonita Creek
5. San Simon River
6. San Carlos River

Upland Zones

In mountain upland areas, there are unique blends of climate, geology, hydrology, soils, and vegetation shaping the landscape, with waterways often cutting down steep slopes to lower elevations and major drainages (washes, ephemeral streams, the mainstem Gila River). These factors, and more, influence the overall health of water resources: chemicals from the mineral weathering of rocks, from the decay of vegetation, and groundwater.

Delineating zones for the uplands would help with their management and aid in wrapping in the upland Best Management Practices from the Arizona Department of Environmental Quality (ADEQ) and the Bureau of Land Management (BLM). For instance, it would be important to identify material contribution areas, or small headwater catchments in the uppermost reaches of the watershed, as well as upland areas immediately adjacent to streams and rivers that are not floodplain, terrace, or riparian area. Material contribution areas provide food and energy (e.g., falling leaves) to aquatic organisms that is then transported downstream through ecological processes. The results of a proper functioning condition (PFC) analysis, such as those conducted by BLM for streams and rivers in the Upper Gila River Watershed, can be combined with other types of watershed assessments for a better understanding of how the riparian and upland areas interact. A PFC analysis is also often used as a screening level assessment to determine whether or not more intensive, quantitative analyses are necessary.

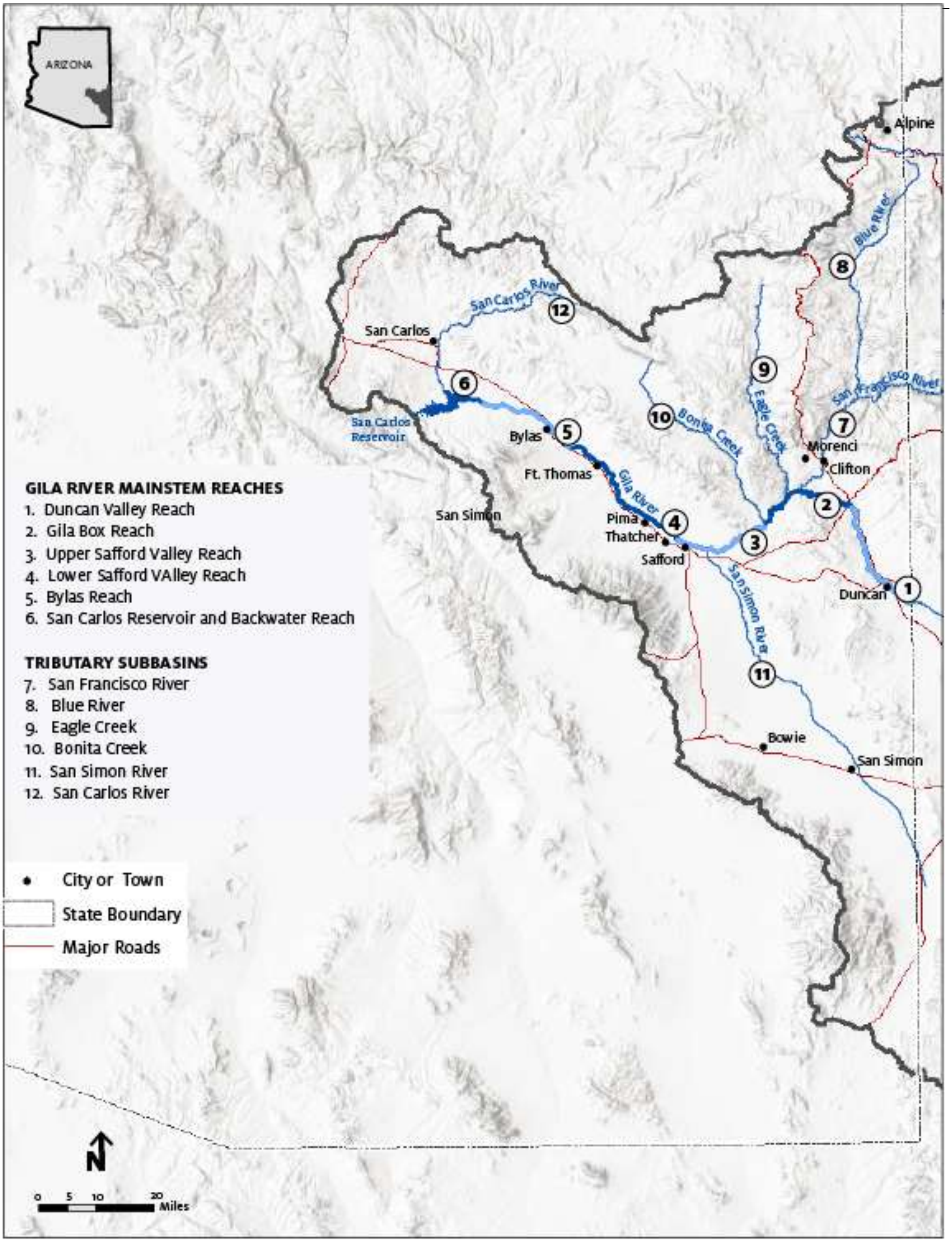


Figure 3. Geographic extent of the Watershed Assessment Plan with reaches.

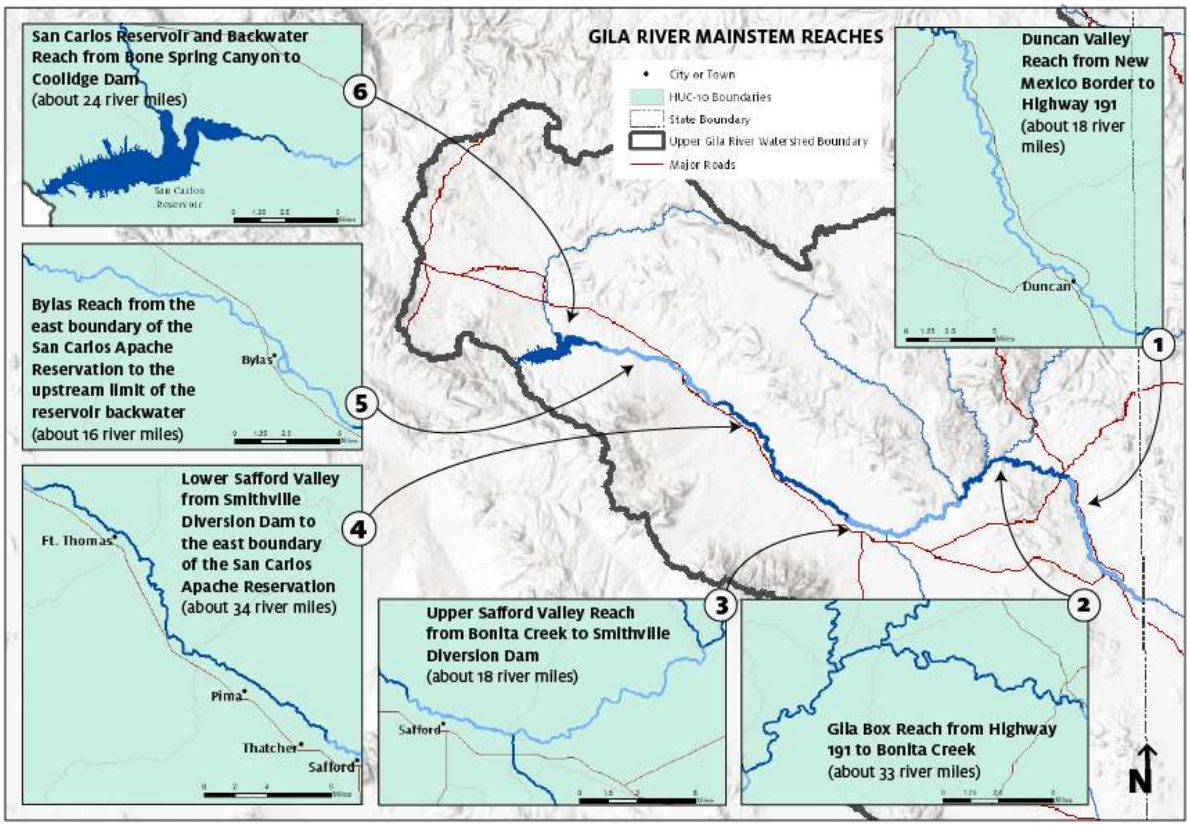


Figure 4. Mainstem reaches with description.

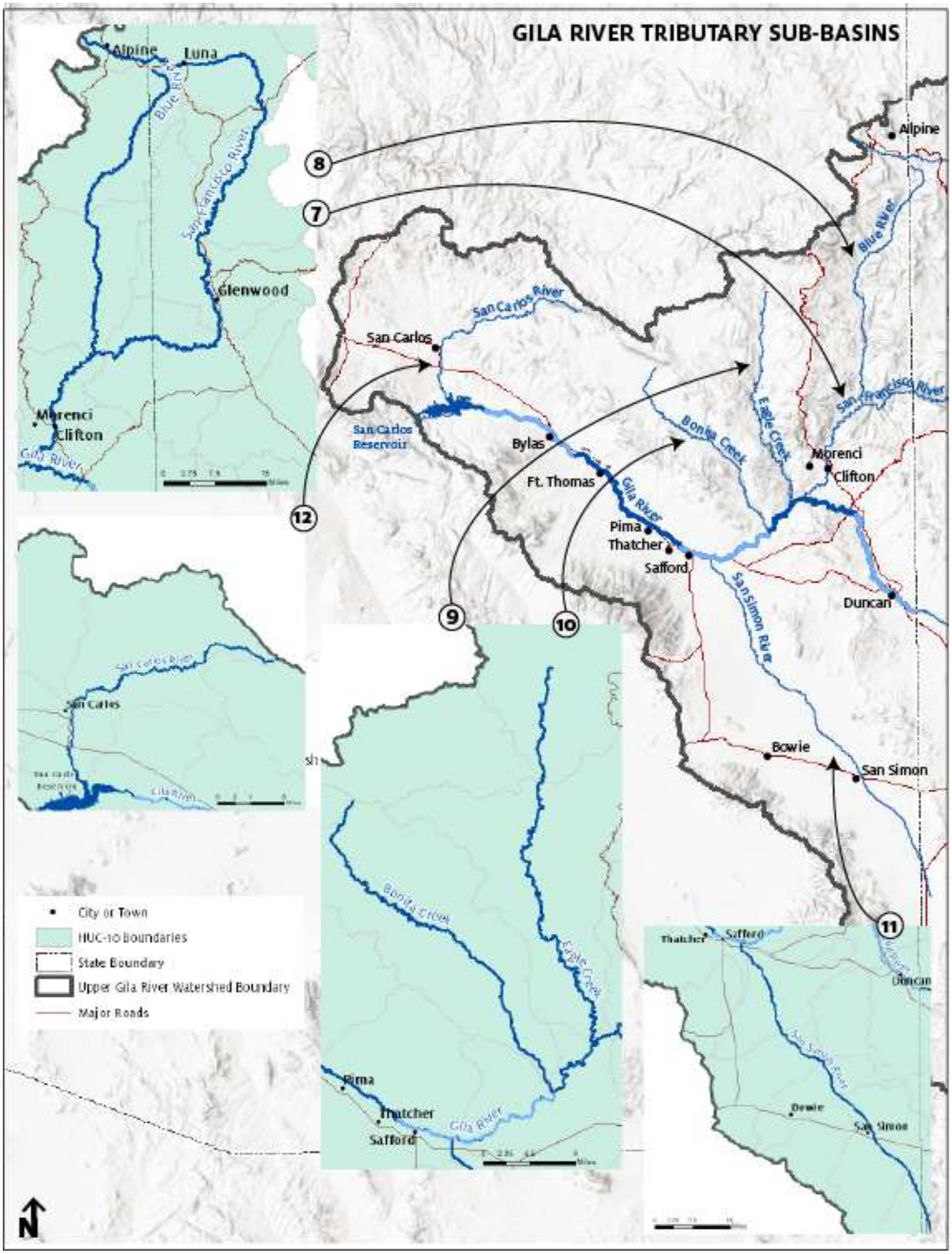


Figure 5. Upper Gila River Tributary Sub-basins.

SECTION 2: RECOMMENDATIONS

This section was developed with the participation of the GWP in order to identify and prioritize recommendations that are consistent with the mission, goals, and outlook of the organization, with specific recommendations pertaining to these priorities. These recommendations can be further refined and prioritized by means of prioritization exercises conducted by GWP with stakeholders. This section also describes data gaps and uncertainties that should be prioritized and developed into recommended actions.

1. Relationship Building - Engagement

Community engagement, recreation, and economy

- Seek opportunities to work with municipalities on the restoration/water quality/education portions of recreation and economic development initiatives.
- Seek available opportunities to purchase goods and services locally and hire local labor.
- Seek to improve workforce and education opportunities.

Farmer engagement and upland management

- Work with landowners to find mutually beneficial opportunities and projects.
- Work with land owners and aid agencies in decreasing erosion and *E.coli* through restoration and incentive programs.
- Work with land owners and agencies to identify and grow plants needed to restore damaged rangeland.

2. Recommended Actions

Infrastructure and fire/flood management

- Develop a fire management plan in cooperation with rural fire management districts.
- Prioritize vegetation management in fire prone areas of the watershed, including riparian corridors and in proximity to habitation, to reduce risk of wildfire and loss of life and property.
- In riparian corridors prioritize removal of tamarisk, which is extremely flammable, and revegetation with native species.
- Evaluate the degree to which sediment derived from fires impacts infrastructure, water quality, and aquatic and riparian habitat.
- Evaluate sediment control structures (check dams) to identify those which may be failing or full and unable to store additional sediment.
- Identify and prioritize sediment control structures to be maintained or abandoned.

Water quality, water supply, and water demand

- Seek opportunities to improve water quality through outreach and education to landowners and recreational users, especially in heavily trafficked areas such as the Gila Box and private lands.
- Partner with irrigators and other water users, including municipalities and mining interests, to reduce water demand by improving use of gray/recycled water, improving infrastructure efficiency, and implementing conservation efforts.

- Continue to monitor and update water supply and demand figures, provided by ADWR, every five years.
- Continue to work toward improving water quality and removing rivers from the 303d list.
- Reduce surface runoff and improve groundwater recharge by promoting low impact design (LID) practices that reduce impermeable area (roofs and pavement), dissipate runoff, and collect storm runoff in small impoundments (retention basins) for purposes of groundwater recharge, where appropriate.
- Quantify the sediment load from abandoned erosion control structures.

Geology, hydrology, and geomorphology

Although there have been studies of individual watersheds, few quantitative data of sediment sources and sinks are available for the Upper Gila. A geomorphological study of the Upper Gila Watershed including the tributaries would greatly help to prioritize restoration actions for riparian and aquatic species and assess the potential for aggradationally-induced flooding.

This study would include:

- updating maps of levees, potentially identifying levees with limited functionality;
- identifying levees that exacerbate rather than mitigate flooding in developed areas;
- assessing the potential for sediment delivery from failing sediment control structures in the San Simon watershed and other locations draining gullied Quaternary sediment deposits;
- assessing channel impacts from wildfire; and
- developing a sediment budget for the watershed to identify problem sediment sources and quantify current and potential sediment inputs throughout the watershed.

These studies can then be used to focus management actions. For example, the San Simon River has historically been a large sediment source to the Gila River and is a candidate for further evaluation and actions to control sediment.

Stream and riparian ecosystem health

- Fence or otherwise control livestock from accessing streams and streambanks, to help improve water quality, reduce erosion, and reduce impacts to native aquatic and riparian species. Consult state and federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.
- Encourage landowners to plant native riparian vegetation along perennial and ephemeral streams where vegetation removal, grazing, recreation, or other uses have caused erosion and compromised riparian functions. Consult state and federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.
- Continue establishing and maintaining exclusion fencing or otherwise manage livestock to prevent access to streams and streambanks, to help improve water quality, reduce erosion, and reduce impacts to native aquatic and riparian species. Consult state and

federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.

- Seek opportunities for private landowners to partner with state and federal resource agencies, conservation groups, volunteer organizations, and other entities to conduct aquatic habitat inventory, restoration, and monitoring efforts. Information obtained from baseline inventory and monitoring will help identify and prioritize the most suitable areas for conservation and possibly reintroduction of native fishes and other aquatic/riparian species.
- Recognizing that alterations to watershed hydrology (e.g., increased peak flow frequency and magnitude; lower baseflows) adversely affect native species, minimize existing and future hydrologic modification by promoting low impact design (LID) practices that reduce impermeable area (roofs and pavement) and dissipate runoff, by implementing modern stormwater and erosion control measures, and by encouraging native-species revegetation of bare soil caused by all types of land use.
- In cooperation with land owners, continue to conduct riparian restoration in the potentially suitable areas identified by Orr et al. (2014) and other areas, particularly burned areas, to pre-emptively maintain and enhance SWFL habitat prior to defoliation of tamarisk by the tamarisk beetle. Riparian restoration will also maintain and enhance ecosystem services and human uses, including recreation and aesthetic enjoyment, and may also increase water quantity in the river.
- Expand the ecohydrological assessment used by Orr et al. (2014) to other riparian corridors in the watershed, to identify additional areas with the greatest potential for effective and successful native vegetation restoration. Absent more detailed information, suitable areas for active restoration included those lying within the 0–4 m elevation range above the low-flow channel.
- More immediate restoration prioritization should be given to the most suitable locations within recently burned riparian parcels (e.g., following the Clay Fire and the Bee Town burn area near Bylas). The riparian vegetation, mostly tamarisk, was highly impacted during the fire, thus priming it for rapid, cost-effective restoration action specifically involving herbicide treatment of the re-sprouting tamarisk and then replanting with native species.
- More intensive active riparian restoration should involve a phased, patch-work ("Propagule Islands") approach to: preserve much of the existing taller SWFL-suitable tamarisk structure (to minimize disturbances to existing viable SWFL-nesting habitat); remove/treat lower tamarisk structure (in patches) and replace with native plantings well suited to site conditions; and gradually expand treatment and revegetation footprint before and following beetle colonization.
- Lower effort restoration strategies should also be considered throughout the remainder of the Planning Area following disturbance from fires or floods that have removed much of the tamarisk biomass. Mechanical removal and fire-contingent restoration actions such as herbicide applications on re-sprouting tamarisk and/or active planting of native species should be planned for Priority Areas downstream of Thatcher. Post-flood-scour

restoration actions can follow a similar approach taking advantage of newly cleared areas to treat remaining tamarisk and/or revegetate with native species.

- Given the greater occurrences of native trees and shrubs, as well as nearly all occurrences of floodplain wetland, that appear to be highly influenced by channelized tributary and/or agricultural return flows, active restoration actions should attempt to take advantage of such conditions through selection of sites with a known steady runoff supply or coordination with land managers to negotiate a viable water supply where natural sources are insufficient. Such sites should have higher success rates for both revegetation of native riparian species (i.e., higher survival and growth rates for planted trees and shrubs) and for creating or enhancing SWFL habitat (i.e., presence of surface water or saturated soils during the breeding season).
- In future riparian restoration planning and prioritization efforts, consider other factors including landowner willingness, existing conservation easements or related land use requirements, presence of key infrastructure, water rights, and initial and long-term costs and maintenance requirements.
- Prior to any treatment/removal activity, coordination with the Phoenix office of the USFWS will be necessary to first secure the prerequisite permits for carrying out such work that could potentially be considered an unauthorized "take" of SWFL or other federally listed fish or wildlife in the implementation area, or to determine that activities can safely be undertaken without risking take.
- Pre- and post-implementation monitoring is recommended to evaluate restoration success (see Appendix G in Orr et al. 2014). Restoration site monitoring plans should focus on factors such as: vegetation composition, density, and structure; physical and chemical soil properties; soil moisture/depth to groundwater; and avian/wildlife occupation and re-occupation.

3. Data Gaps and Uncertainties

Topics for which little or no information is available or those for which the availability or status of information is uncertain include:

- Effects of water diversion structures on sediment dynamics and channel morphology in the mainstem Gila River to address gaps in previous research.
- Quantification of sediment sources to the Upper Gila Watershed.
- Sediment supply from failed or filled sediment retention basins in the San Simon watershed and other watersheds with sediment retention structures.
- Amount of groundwater pumping by domestic wells.
- Impacts (positive and negative) of managed grazing on riparian areas.
- Uplands management practices customized for the conditions and context of the Upper Gila Watershed.
- Engage with land owners on cooperative projects and quantify benefits to land owners.
- Establishment of a Community Fire Protection and Response District to provide coordinated wildland fire prevention and post-fire planning, monitoring, and restoration support.

SECTION 3: METRICS FOR MEASURING PROGRESS

This section describes some of the metrics that can be used to measure success of priority actions (i.e., "Are the actions resulting in watershed improvement?") and progress toward achievement of GWP's short-term and long-term goals. Priority actions may include those intended to improve watershed conditions such as the aquatic and terrestrial indicators included in the Watershed Condition Indicators framework (see Section 1, Figure 1).

Geomorphology and hydrology metrics

Geomorphology and hydrology set physical structure that provides aquatic and riparian habitats. Metrics used in wetter watersheds such as wood loading are not as important in the Upper Gila River Watershed. Fluvial geomorphic metrics used elsewhere (e.g., US Forest Service 2011) include LWD loading, width-to-depth ratio, bed elevation changes, and floodplain connectivity. Because much of the watershed is sparsely vegetated, LWD should naturally be rare in those areas but in confined reaches of the Gila River and tributaries it may provide important functions including aquatic habitat complexity and flood energy attenuation. Additionally, the widespread braided morphology in the alluvial valleys means that while width-depth ratio is a useful metric to track, high width-depth ratios do not necessarily reflect impairment. Moreover, width-depth ratio in braided rivers is less stable from year to year than in single-thread rivers because width-depth ratio is often tied to the magnitude and duration of the last high flow and because bankfull depth is difficult to assess in braided rivers. Similarly, even in a pristine reach of the Upper Gila River, low wood loading levels relative to the Pacific Northwest might also be expected because forest density and wood recruitment dynamics are much different in arid watersheds such as the Upper Gila River. Width-depth ratio might also be expected to increase as tamarisk (which limits bank erosion) is replaced by native willows and cottonwoods as the dominant riparian vegetation. Metrics of the success of management actions include quantitative measures of channel characteristics such as bed elevation changes, channel width, valley, width, sediment transport, and sediment supply. Management targeted at geomorphology is likely most relevant in terms of changes to habitat, including habitat maintenance for native fish and riparian species once the tamarisk beetle reaches the Upper Gila. This can be quantified using changes to bed elevation. Metrics to consider for the Upper Gila River Watershed include:

- Bed elevation of the mainstem and tributary streams to track aggradation and incision
- Width-depth ratio/Width changes
- Levee extent and condition
- Spatial variations in sediment supply

Care must be taken in assessing the degree to which the metrics reflect the natural state of the channel rather than impairment.

Water quantity metrics

Groundwater levels:

- Relative change over time, as determined by groundwater well monitoring (refer to ADWR's data: https://new.azwater.gov/sites/default/files/WL_Change_Report_Final.pdf

Stream discharge:

- Achievement (% of time) of continuous flow target at selected locations, based on historical hydrograph analysis
- Index of Hydrologic Alteration (IHA; The Nature Conservancy 2009)

Wildfire metrics

- Change over time (in acres and fuel type) to the arrangement of the fuel, taking it from a vertical arrangement to a horizontal arrangement while also reducing fuel loading.
- Identified breaks in uniform continuity of fuel, aiming for a patchy dispersal.
- Potential wildfire fuel is reduced and structure of remaining fuel is horizontal rather than vertical.

Water quality

- Percentage of the surface water (e.g., acres or stream miles) in the watershed listed as water quality impaired (303d-listed).
- Annual number or frequency of water quality exceedances, as determined by long-term or event-specific water quality monitoring/testing

Terrestrial vegetation and wildlife metrics

- Terrestrial habitat fragmentation (edge/area ratio, road density, or other measure); metrics may be derived or modified from criteria used in BLM's Proper Functioning Condition assessments.
- Land use patterns, land cover changes; metrics may be derived or modified from criteria used in BLM's Proper Functioning Condition assessments.
- Relative abundance (% of total species or other measure) of native wildlife species
- Relative number of listed and sensitive species, by taxonomic group (e.g., birds)
- Area (e.g., acres) of replaced or created suitable SWFL habitat elsewhere in the Safford Valley, such as upstream of Thatcher. This metric would help quantify and track the trend in the existing areal extent of viable SWFL habitat and provide additional resiliency to the system following beetle colonization (Orr et al. 2014). However, it is recognized that such an effort would require some combination of earthmoving, soil conditioning, and/or irrigation to support active plantings and creation of suitable breeding habitat, thus necessitating more detailed site designs, grading plans, and environmental permits (e.g., USACE Section 404).

Aquatic and riparian metrics

- Index of Biotic Integrity (IBI) for fish and/or macroinvertebrates (a multi-metric index, e.g., Karr and Chu 1997).
- Relative abundance or canopy coverage (stem density, % cover, or other measure) of native riparian vegetation (by reach and sub-basin); data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.
- Increasing trend in the number of reaches and extent of stream monitoring.
- Evidence of natural recruitment of native riparian vegetation; site- or reach-based, as indicated by presence of seedlings/saplings of a specified height (e.g., 1 meter); data for

the Gila Box and elsewhere may be available from BLM’s Proper Functioning Condition assessments.

- Floodplain presence and function (e.g., % of channel length, by reach, with hydrologically connected floodplain; area of floodplain and degree of hydrologic connectivity); data for the Gila Box and elsewhere may be available from BLM’s Proper Functioning Condition assessments.
- Relative abundance (% of total species or other measure) of native aquatic species; data for the Gila Box and elsewhere may be available from BLM’s Proper Functioning Condition assessments.
- Relative number of listed and sensitive species, by taxonomic group (e.g., fish); data for the Gila Box and elsewhere may be available from BLM’s Proper Functioning Condition assessments.
- Hydrologic alteration/hydrologic connectivity (fish barriers/mile of stream length, other measures); data for the Gila Box and elsewhere may be available from BLM’s Proper Functioning Condition assessments.

Diversity and engagement metrics

- Jobs created performing riparian restoration or other activities (type and number of jobs; average length of employment):
    - Jobs performed by at-risk and underserved individuals
    - Internships
    - Monitoring
    - Local hires
    - Number of staff continuing education in relevant social or physical sciences
- Youth communication and engagement activities
    - Number of events
    - Attendance
- Working group activities
    - Number and type of working groups
    - Milestones
    - Membership (attendance, diversity of affiliations)
- Public meetings
    - Number and type of meetings
    - Attendance (number, diversity of affiliations)
- Engagement of private land owners
- Online presence (measured by analytics tools)
    - Social media (followers, post engagement)
    - Website traffic

PROGRESS TOWARD GWP GOALS

Metrics to evaluate progress in achieving GWP’s short-term and long-term goals are described in Table 2. It is expected that metrics will be modified in coordination with GWP (e.g., the Science Advisory Committee) as goals are revised, to select those that provide the best and most feasible measure of progress.

The GWP's short-term goals are those intended to be achieved within 5 years. Short-term goals are focused on riparian restoration at discrete sites, which includes removal of tamarisk and other invasive riparian vegetation and restoration through revegetation with native species. These actions will provide and enhance habitat for native wildlife, especially in areas dominated by tamarisk where existing habitat provided by tamarisk is expected to be reduced with the arrival of the tamarisk beetle and subsequent defoliation and mortality of tamarisk.

Long-term GWP goals are to be achieved within 10–30 years, and include larger-scale removal of tamarisk and other non-native invasive riparian plant species and revegetation through natural (passive) recruitment. Sites at which long-term riparian restoration will be focused include the following:

- High priority sites that normal river flooding processes are unlikely to naturally remove tamarisk as identified in the ecohydrologic assessment (Orr et al. 2014),
- Sites where private property and high-value vegetation (e.g., cottonwood groves) could be damaged by wildfire,
- Sites with willing landowners who are in agreement with approaches to re-establish native vegetation, and/or
- Sites where the tamarisk leaf beetle, when established, would not be an effective approach.

Long-term goals also include addressing other high-priority stressors in the watershed such as water quality impairment and adverse impacts resulting from intensive livestock grazing. A future iteration of this report and recommended next step is to broaden goals and metrics to include upland management.

Table 2. GWP goals and metrics to measure attainment of goals.

Goal	Metric	Comments
Short-term (5 yrs)		
Through active tamarisk control and re-vegetation projects, establish a minimum of 20 sites composed of willow/cottonwood plant communities of a minimum of 6 acres each for a total area not less than 200 acres.	Number of treatment sites ≥ 6 acres composed of willow/cottonwood Combined total acreage of treatment sites composed of willow/cottonwood, relative to 200 acre short-term target and long-term targets, expressed as a percentage Post-treatment survey results documenting SWFL nests or nesting potential (habitat suitability) Post-treatment survey results	These sites, identified through the eco-hydrologic study and other science-based activities, will provide potential nesting sites (refuge) for the SWFL as probable defoliation from the tamarisk leaf beetle occurs. These sites, known as propagule islands, will also provide native seed sources that are critical for re-establishing riparian plants throughout the watershed during flooding events. Also consider revegetation with giant sacaton (*Sporobolus wrightii*), a native grass which may have been a historically important

Goal	Metric	Comments
	documenting seed production by native riparian species (willow, cottonwood, others)	component of the riparian vegetation community.
Provide plant materials suitable for the Upper Gila River Watershed by developing a native plant nursery composed of a greenhouse, shade structure, plantation fields, and coppice fields.	Number of plants of each species produced and used for restoration/revegetation in the watershed	Consider propagating giant sacaton for use in riparian revegetation.
Assess and track success of restoration actions through the development and implementation of rapid and long-term monitoring protocols.	Allocation of funding for development of rapid and long-term monitoring protocols Completion of monitoring manual that includes final rapid and long-term monitoring protocols	Final monitoring manual should incorporate review comments by GWP Science Advisory Committee, funding entity, and other appropriate expert reviewers
Long-term (10–30 yrs)		
Reduce the relative canopy cover of tamarisk to less than 10% through active control measures and through the expected establishment of the tamarisk leaf beetle.	Relative canopy cover (%) of tamarisk, relative to 10% goal	Based on annual monitoring and mapping results Consider reporting on a reach-or site-specific basis
Reduce the relative canopy cover of other invasive species to less than 15%.	Relative canopy cover (%) of invasive riparian plant species other than tamarisk, relative to 15% goal	
Through primarily passive revegetation, increase native and desirable vegetation to levels that provide a riparian plant community composed of overstory and understory vegetation. Native species will be dominant and resilient through natural processes.	Riparian vegetation species and structural composition	Based on annual monitoring and mapping results Consider reporting on a reach-or site-specific basis Consider adding giant sacaton to the list of desirable native riparian vegetation included in revegetation goals.
Where possible, reduce stressors beyond invasive species to the river system – namely water quality and grazing pressures.	Water quality metrics: - Percentage of the watershed listed as water quality impaired (303d-listed). - Annual number or frequency of water quality exceedances, as determined by long-term or event-specific water quality monitoring/testing Metrics for grazing pressure and other stressors TBD, with input from GWP and stakeholders	If other high-priority stressors are identified, other metrics can be developed or added as appropriate

SECTION 4: WATERSHED CHARACTERIZATION

River-riparian ecosystems are interactive and deeply linked products of their landscape context (Figure 6). At broad scales in the landscape, there are several key factors that affect the fluvial and geomorphic processes and attributes that shape the structure and composition of riparian zones in alluvial river systems. These factors include climate (precipitation and temperature patterns), parent material (lithology), topography (slope, aspect, upslope drainage patterns), and input rates of water, sediment, nutrients, energy, woody debris, and chemical constituents from the watershed into the river. At finer scales within the watershed, key fluvial and geomorphic processes and attributes then shape riverine and riparian habitats, which in turn affect the biotic responses of aquatic and terrestrial populations and communities (Figure 6). Natural and anthropogenic disturbances (e.g., floods, fire, landslides, human land and water use, climate change) influence the system at all levels, from climate, watershed inputs, fluvial and geomorphic attributes and processes, to habitat (structure, complexity, connectivity), and biotic responses (Downs et al. 2011). Recognizing how broad-scale process differences interact with drivers and stressors (such as natural disturbance and human land use and flow regulation) is an important first step in assessing riparian condition and planning trajectories for functional recovery or enhancement of resilient riparian ecosystems.

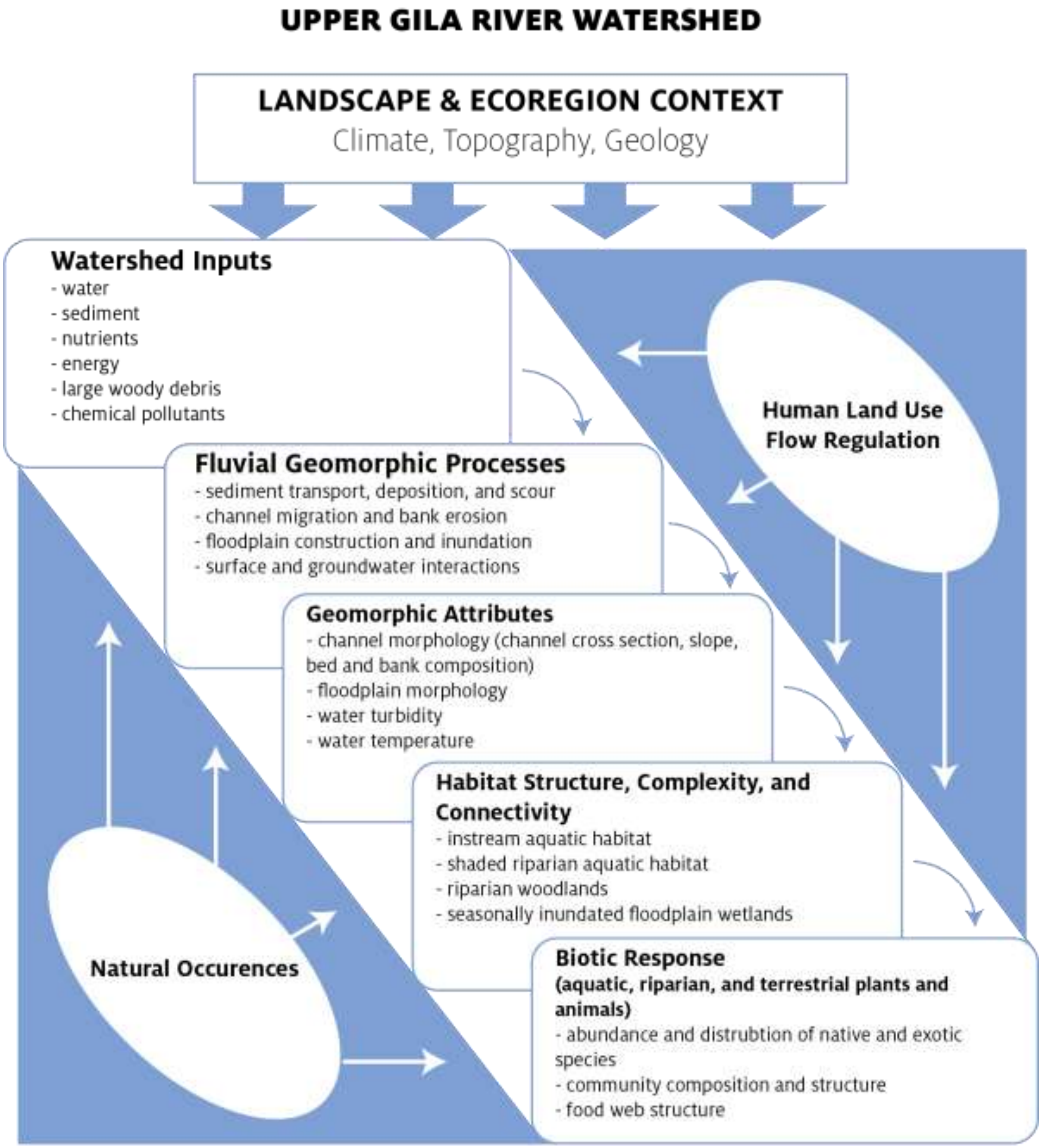


Figure 6. Ecosystem process linkages that influence habitat and biotic response (adapted from Stillwater Sciences conceptual diagram).

LOCATION OF THE UPPER GILA WATERSHED

Watersheds have physical boundaries that do not always align with political boundaries. The Upper Gila River Watershed has an area of approximately 9.7 million acres (15,193 mi^2) that straddles the Arizona-New Mexico border, with 48.4% of that total area located in Arizona, and the remaining 51.6% in New Mexico (Figure 7). The Arizona portion of the Upper Gila Watershed is approximately 7,354 square miles.

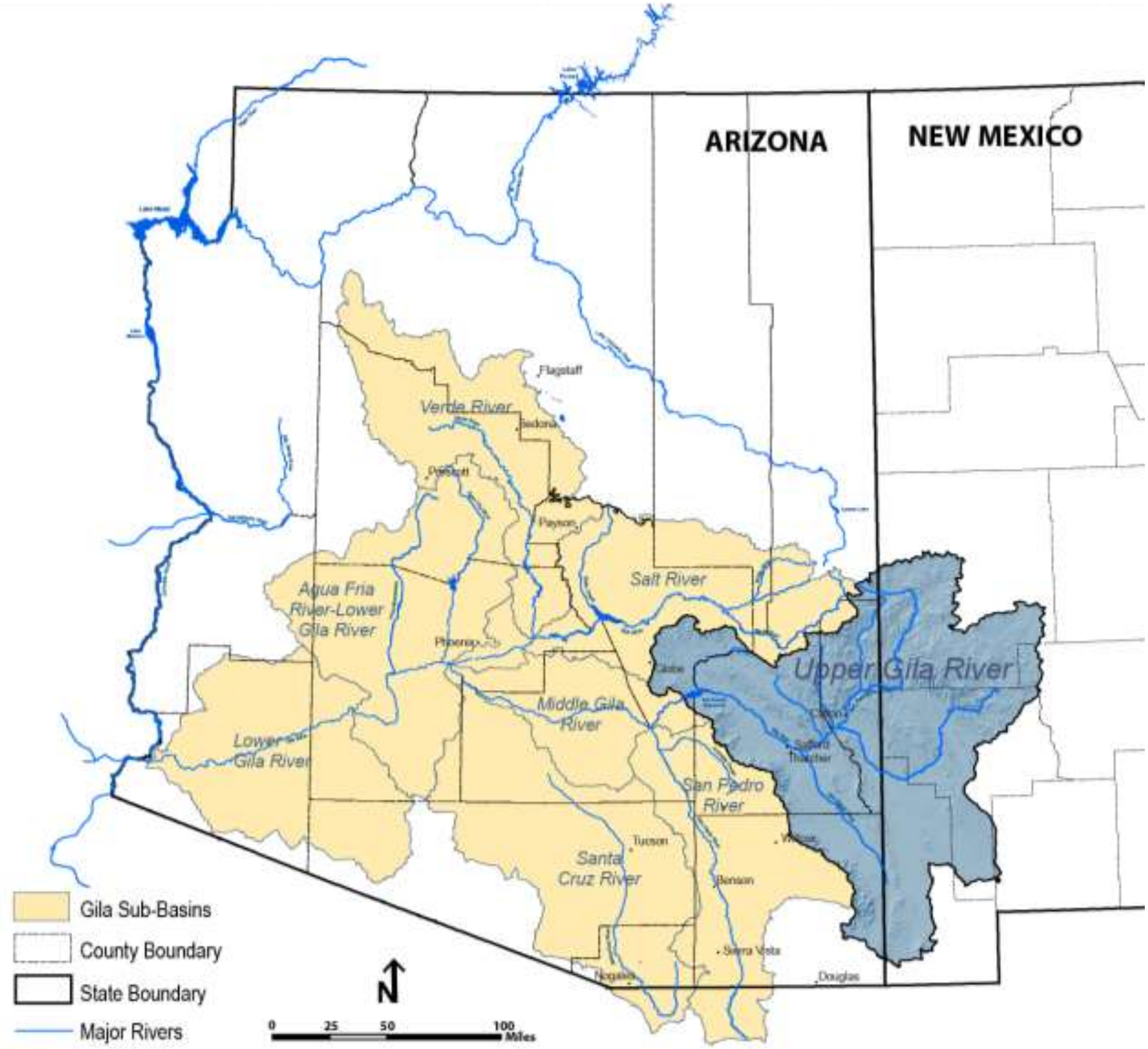


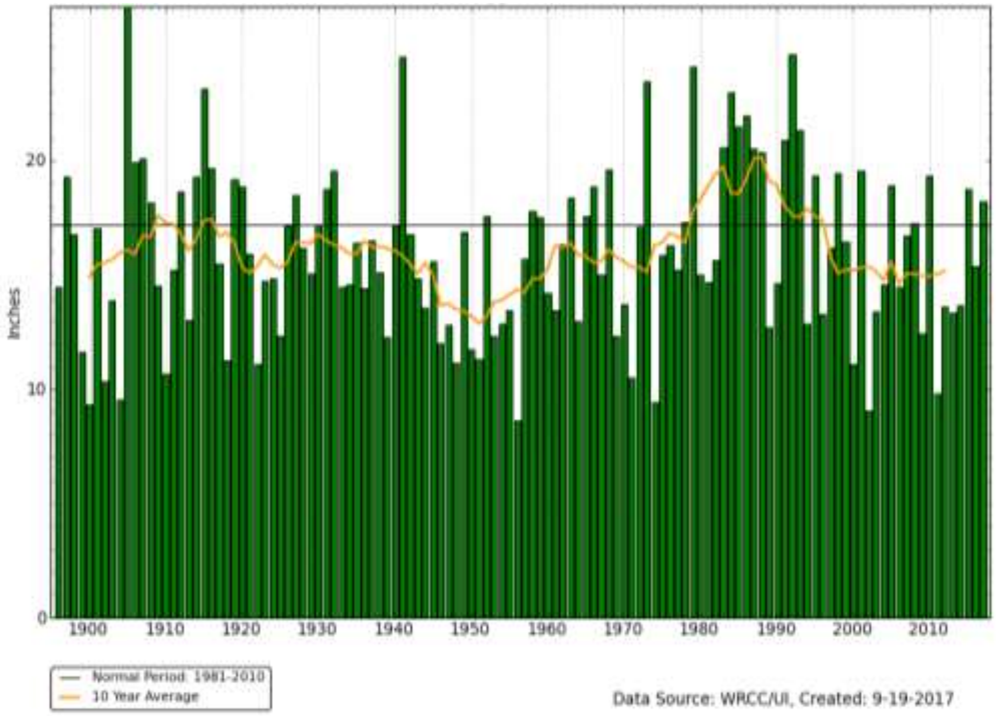
Figure 7. Upper Gila River Watershed in context of the entire Gila River watershed.

CLIMATE AND WILDFIRE

Arizona and the southwestern United States are built for drought. However, as temperatures are consistently warmer in recent years, the effects of longer-term warming are compounded. If observing rain gauge data (SPI) and historical averages, short-term predictions can be favorable or average, but when combined with warmer temperatures, we lose temporary gains in precipitation and drought creeps back in (Figures 8 and 9). The most high-risk areas must be considered with constant stress on trees, soil water balance, and variability or declining snowpack in upper elevation areas, while lower elevation areas may be more adapted to water stress as long as the timing of precipitation persists.

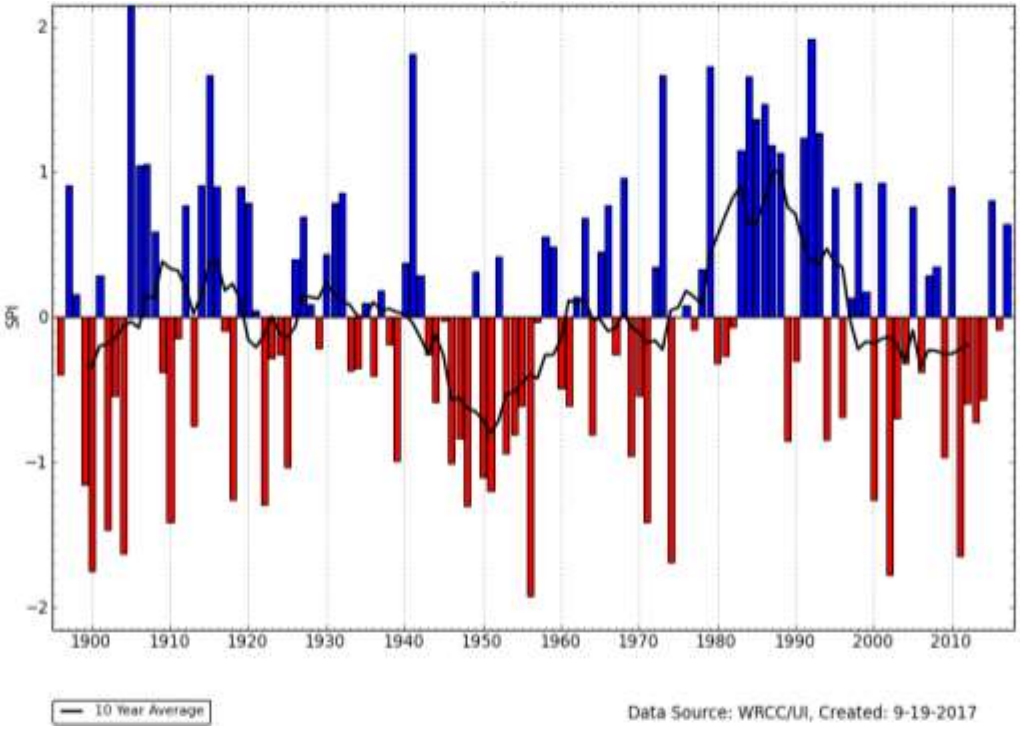
KEY TAKEAWAYS

- Rainfall in the Upper Gila Watershed is strongly tied to elevation with higher precipitation in the mountains (up to 40 inches per year) and the lowest precipitation in the valleys (about 8-10 inches per year).
- Rain occurs primarily during winter storms and summer monsoons; however drought has negatively affected the amount of long soaking rain in the winter, and it is predicted that the area will receive less, but more intense monsoon events.
- The Upper Gila River Watershed has experienced several large fires since 2011, including the largest fires on record in Arizona and New Mexico.
- These fires can result in direct mortality for fish and wildlife.
- The fires also increased runoff and sediment supply to the Upper Gila Watershed.
- The largest fires tend to be in the uplands, where vegetation is the densest. Effects of fire subsequently propagate downstream and can severely impact habitat for fish and other native species.
- The high flammability of tamarisk has contributed to the severity of fires in the riparian corridor of the lower Safford Valley.
- Major disasters, such as floods, can seriously degrade or destroy much of the infrastructure in relation to the river.
- Federal disaster relief programs made some funds available for the repair or reconstruction of flood-affected areas. These federal programs often added restrictions regarding the type of construction that could be funded, with the result that some potential upgrades to infrastructure may not be permitted.



Data Source: WRCC/UI, Created: 9-19-2017

Figure 8. Precipitation patterns in the Upper Gila River Watershed, by decade ending in August, over the last 100 years.



Data Source: WRCC/UI, Created: 9-19-2017

Figure 9. Standardized Precipitation Index for the Upper Gila River Watershed by decade, ending in August; blue bars indicate “above average” rainfall, while the red bars “below average” or “drought” patterns.

Precipitation and drought

Observing the last 100 years of precipitation patterns in the Upper Gila River Watershed, patterns of extended drought or “below average” precipitation (Figure 8) can put stress on both biological communities and the economic reliance on farming and ranching in the region. As shown in Figure 8, the majority of average precipitation (depicted with the yellow line) has fallen below the established “normal” period set defined between 1981 and 2010 (depicted with the black line). Climate Assessment for the Southwest (CLIMAS) predicts an overall drier and warmer future, which requires decision making at local, national, and global levels (Trenberth et al 2013). Southeastern Arizona is predicted to receive less precipitation in fewer, more extreme events in the future as the overall precipitation average continues to decrease in this region (Figure 9). The degree of wet and dry years contributes to a high degree of uncertainty and affects how communities, watershed practitioners, agriculturists, and others can plan for extreme events.

A 30-year record of annual rainfall measurements from precipitation stations were averaged and spatially-extrapolated by the PRISM Climate Group at Oregon State University to create a precipitation map (Figure 10). More precipitation falls at higher elevation in the ‘sky island’ region of Southeastern Arizona, creating wetter and more vegetated ecosystems separated by desert ‘seas’. The regional topography of these isolated mountain systems, known more generally as the Basin and Range Province, include deep sediment-filled valleys between mountain ranges. The mountains in Southeast Arizona receive precipitation flows via regional flow paths to recharge groundwater in the basin sediment.

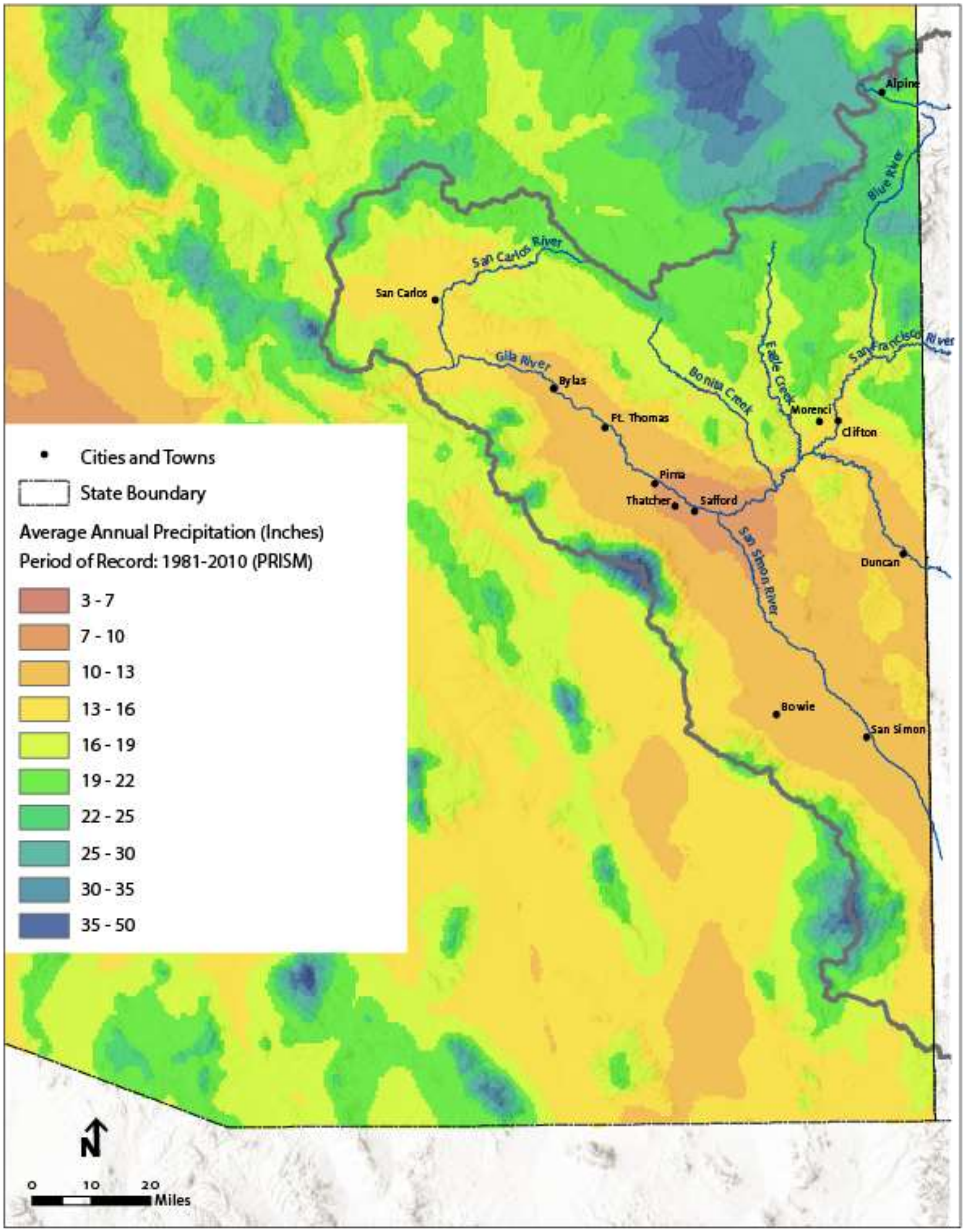


Figure 10. Regional map of average annual precipitation between 1981 and 2010 (PRISM 2017).

Lower elevation areas in the Upper Gila River Watershed, such as the Safford Valley and the San Simon Valley, receive the least rainfall, generally between 8 and 10 inches. The highest peaks in the Pinaleño and Chiricahua mountains receive more than 40 inches.

Recent fires (in the Chiricahuas, on Mount Graham, the Wallow, and Whitewater-Baldy Complex Fire), particularly those with high burn severity, will impact soils and may result in less infiltration of precipitation. This would increase surface flow and decrease the amount of mountain front recharge. The recent history and effects of wildfire in the Upper Gila River Watershed are described in the following section.

Global climate models predict the region will receive precipitation in fewer, larger events. Winter precipitation tends to arrive in blankets of clouds lingering over states for days, delivering moisture in drizzles. This gentle rain is more likely than the pounding summer storms to soak into the ground. As a result, winter precipitation tends to influence regional water supplies more than summer rains.

Winter precipitation also plays an important role in forest health. The growth rings of high-elevation southwestern trees typically reflect cool-season precipitation, with more growth occurring in years of abundant snow and rain. Because of this, researchers can use tree rings to reconstruct winter precipitation patterns far beyond the instrumental record, which goes back only about 100 years in the West. Winter and spring precipitation also exerts a large influence on when the wildfire season starts and whether grasslands or forests are more susceptible to ignition. A lack of cool-season precipitation can make forests more vulnerable to wildfires. Meanwhile, wet winters actually can spur fires in grasslands made lush by cool rains and then cured into kindling during a subsequent dry heat.

The monsoon season arrives in the summer, often around mid- to late June. Roughly half of the annual rainfall comes during the summer monsoon in southern Arizona and New Mexico. Monsoon rainfall events tend to be short and spotty, with intense, local storms drenching some areas and neighborhoods but not others. The water from these storms quickly flows off the landscape into streets and rivers, with most remnant moisture soon evaporating in the summer sun. In recent decades, the observed trend has leaned toward more extreme weather events that can damage property and lives. During the “wet period” of the 1980s and early 1990s, a series of floods caused tremendous amounts of damage to infrastructure in the valley.

Wildfire

The accumulation of combustible materials, such as leaf litter and dead vegetation following a major disturbance such as disease or insect infestation, combined with low water levels and hot, dry conditions can result in substantial fires. While vegetation removal can lead to temporarily increased surface flows due to less transpiration, evaporation rates can increase from the loss of shade-cover. New plants, sometimes not the same species as those removed by the fire, will establish as part of the post-fire recovery process. A fire-denuded riparian buffer is also typically subject to greater erosion.

Fire risk can be exacerbated by the interplay of other drivers in the watershed. Extended drought will result in critical water stress on plants, leading to large areas of dead or dying vegetation. Land management practices, such as forest thinning, can lessen the risk of large fires. Such efforts are particularly resource- and time-intensive, however, and these efforts are complicated by a patchwork of public and private land ownership as well as the often-challenging terrain in the watershed.

There have been five significant fires within the Upper Gila River Watershed since 2001: the Nuttall Complex, Horseshoe I, Horseshoe II, Wallow, and the Whitewater-Baldy Complex (Figure 11). These fires occurred where fuel was available at higher elevations within the watershed, and therefore near the watershed boundary. Of these, only the smaller Horseshoe I and the Whitewater- Baldy Complex were entirely contained within the Upper Gila River Watershed. The statistics shown in Figure 11 represent the severity of the burn area in the Upper Gila River Watershed only. Other than the Horseshoe I fire, which was almost entirely a low-severity fire, the four other major fires had severe burn intensities in 9–13% of their area in the Upper Gila River Watershed. The 2012 Whitewater-Baldy Complex fire burned over 292,000 acres in the San Francisco River watershed and was the largest wildfire recorded in New Mexico. Both the Wallow Fire and the Horseshoe II fire occurred in 2011, and were two of the five largest fires in Arizona history. The Wallow fire was the largest fire on record in Arizona (Meyer 2011), burning over 500,000 acres, 156,678 acres of which were in the Blue River watershed (Banister et al. 2014). The Wallow Fire dramatically increased stream discharge relative to rainfall (Wagenbrenner 2013) and also increased bedload supply to channels (Wagenbrenner and Robichaud 2014). Approximately 196 miles of perennial streams in the San Francisco and Blue River watersheds and 38 miles of perennial stream in the Gila River watershed were impacted by the Wallow Fire (Meyer 2011). The Wallow fire resulted in widespread fish mortality (AGFD 2012a), likely due to contamination of the water by ash. The high sediment supply from post-fire erosion degrades stream habitat by filling pools and simplifying and aggrading the stream bed.

Wildfire is an increasingly common disturbance in western river corridors owing, in part, to infestation by tamarisk. For example, two fires burned the Gila River floodplain in the Lower Safford Valley in 2013: the Clay Fire near Ft. Thomas and the Bee Town fire near Bylas. The Bee Town fire burned 1200 acres. A third fire burned about 230 acres in March 2018 near two GWP restoration sites near Ft. Thomas.

Comparison of the effects of the 2018 fire in areas dominated by native vegetation (left) and areas dominated by tamarisk (right). *Photo credit: Daniel Bove*

Riparian areas are considered to be barriers to wildfire spread due to the typical dominance by fire-resistant native vegetation with relatively high moisture content (e.g., willows and cottonwoods), but the replacement of the fire-resistant native vegetation by the more flammable tamarisk has reversed this relationship, with tamarisk-dominated areas burning approximately 10 times more frequently than native-dominated counterparts (Busch 1995). A site visit after the 2018 fire revealed that areas where tamarisk had been cleared or native vegetation dominated the fire burned with a lower intensity than in reaches dominated by tamarisk (see photos above, D. Bove, personal communication). Defoliation by the leaf beetle would appear to exacerbate this situation, but studies in Nevada show that tamarisk is highly flammable regardless of whether it is “browned-out” by defoliation or in a “healthy green” state (Dudley and Brooks 2011). Escaped fire from land-clearing on adjacent agricultural areas has become a serious concern for land managers in the Lower Safford Valley, particularly where weedy forbs next to fields carry fire into the arid, tamarisk-dominated riparian edges, and then into the mixed native/tamarisk vegetation along the river. This establishes a feedback loop in which fire promotes tamarisk, which recovers readily from burning by resprouting to become even more abundant, eventually displacing native elements in the stand. Biocontrol by the tamarisk beetle eventually reduces tamarisk volume, and after 3+ years of repeat defoliation can lead to mortality (Bean et al. 2013), thereby gradually reducing fire risk over the long term, although active restoration efforts are needed to speed up the process of reducing riparian fire risk in critical areas.

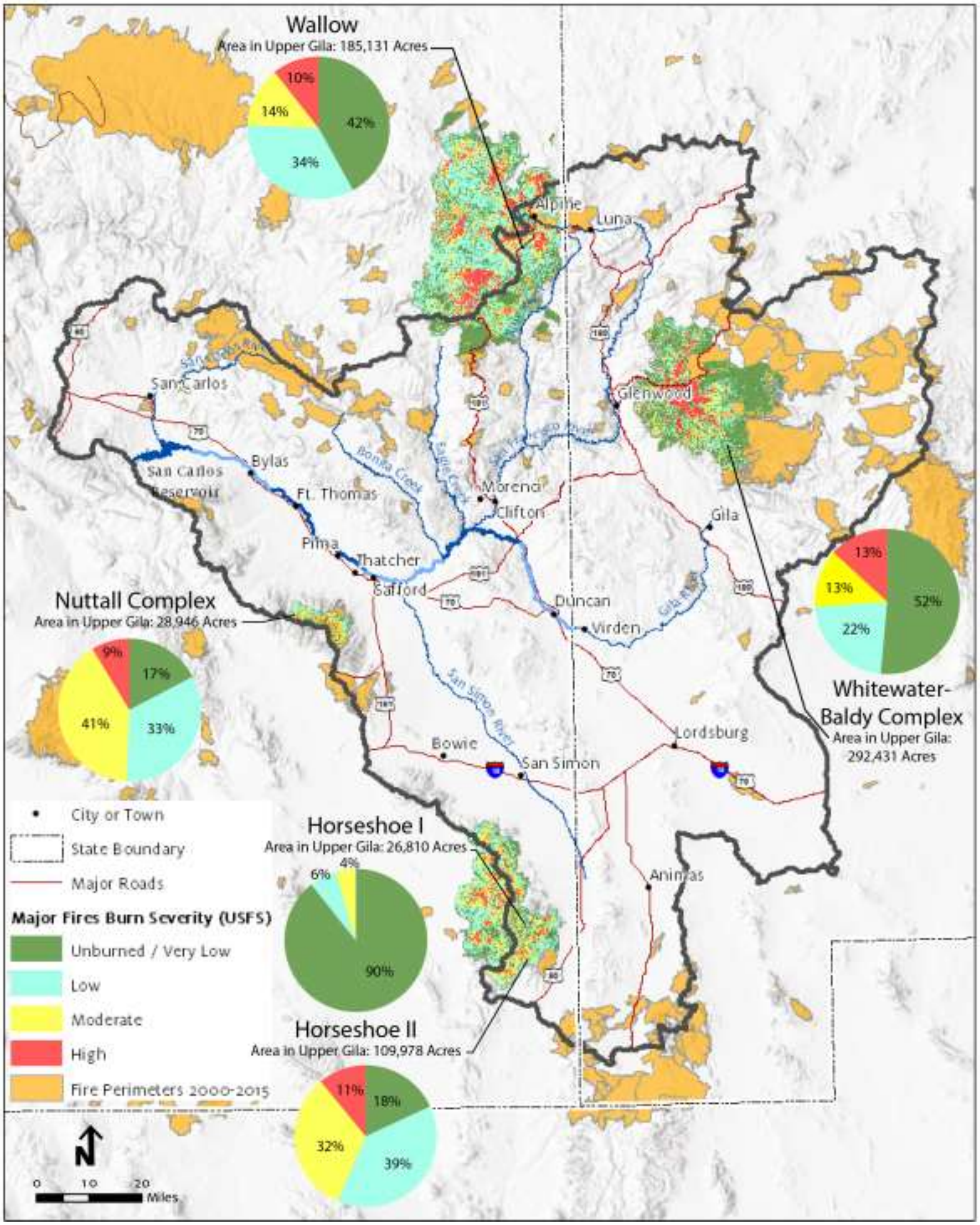


Figure 11. Significant fires in the Upper Gila River Watershed in both Arizona and New Mexico portions of the watershed (2000-2015).

In sum, the primary concern of water and land managers related to the fire regime within the Gila River Watershed concerns actions that might change a historic trend of fast-moving, high-intensity fires. Primary considerations include:

a. Fuel loading caused by tamarisk and how much of this fuel is present (measured in tons per acre)
b. Availability of this fuel to burn, based on time of year, time of day, and atmospheric conditions (directly affecting fuel moisture content and fuel temperature).
c. Vertical arrangement of fuel, which allows fires to get from the surface to the canopy causing dependent crown fires
d. Uniformity across the landscape, which allows fires to continue to burn with no breaks.

Working with partners, the emphasis must revolve around answering the question: What does it mean to change the way that fires respond to environmental factors and human intervention? How do we accomplish changing the fire regime in a patchwork of land ownerships and in the face of the challenges listed above?

GEOLOGY, HYDROLOGY, & GEOMORPHOLOGY

Watershed management is most effective when it considers the physical characteristics of the watershed. Below we describe the geology, hydrology, and geomorphology of the Upper Gila River Watershed.

KEY TAKEAWAYS

- The Gila River and its tributaries are subjected to very large floods that reset the morphology of the channel and floodplain. The width of the river expanded dramatically in 1915 and again in 1983 after large floods.
- Tamarisk has likely constrained the channel and floodplain in the mainstem Gila River since the early 20th century.
- Levees in the Safford and Duncan valleys constrain the flooded width and may exacerbate erosion and deposition during large floods.
- Channel incision and wildfire supply very high sediment loads to the Gila River and its tributaries, but the effects of the supply on the morphology of the river channel and floodplain have not been systematically evaluated.
- Removal of tamarisk either as part of stream restoration or due to the arrival of the tamarisk beetle is likely to lead to increased bank mobility and lateral channel erosion, primarily during smaller floods.
- There are many erosion control structures in the tributaries to the Gila River that have exceeded their design life and are failing, potentially increasing the supply to downstream reaches as eroded sediment from the retention basins is added to other sediment from the uplands. These retention basins could cause particular problems during large floods.
- Large sediment sources to the Gila River likely include the Blue River, San Simon River, and other smaller tributaries where the valleys are filled with thick deposits of relatively recent river and lake sediments.
- The effects of sediment supply on the mainstem Gila River have not been thoroughly investigated.

Geology

With the exception of the San Francisco River watershed, the Upper Gila River watershed is primarily located in the Mexican Highland section of the Basin and Range Province; a geographic region with a unique topography created by a period of tectonic extension (stretching) during the Miocene Epoch (17 million years ago). This region is generally characterized by a series of roughly parallel mountain ranges that trend northeast-southwest and are separated by broad flat valleys (Nations and Stump 1996). The San Francisco River watershed primarily lies within the Central Highlands Transition Zone between the Basin and Range Province and the Colorado Plateau.

The Gila River originates in the Mogollon Mountains of New Mexico. The mountain ranges bordering the valleys are made of consolidated volcanic, metamorphic, and sedimentary rocks (Figure 12). The Gila, Peloncillo and Chiricahua Mountains are made of rocks from mostly volcanic origin. The Piňaleno Mountains, to the south of the Safford Valley, are formed by Precambrian metamorphic rocks, while the Santa Teresa Mountains are comprised of granitic rocks. The uplands of the Duncan Valley are primarily comprised of Tertiary conglomerates and sandstones. The upper portions of the San Carlos River Watershed are comprised of Proterozoic granitic and sedimentary rocks.

Several drainages (e.g., the lower San Carlos River, San Simon River, Goodwin Wash, Tripp Wash, and Underwood Wash) are composed of Quaternary lake and river sediments (sand and gravel). These drainages are often lined by river terraces and are often large sediment sources.

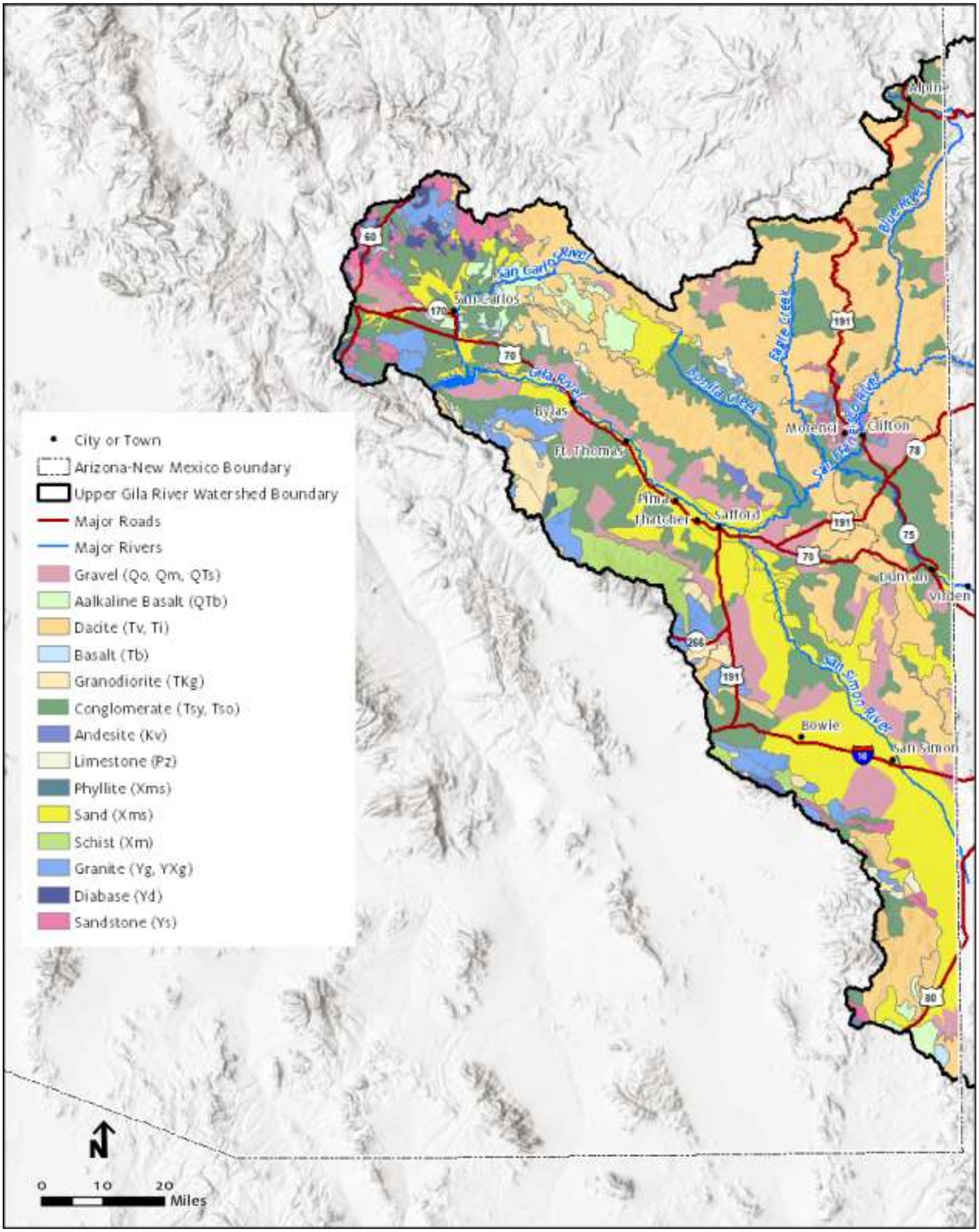


Figure 12. Geology of the Upper Gila River Watershed. Source: Atlas of the Upper Gila River Watershed (Banister et al. 2014).

Hydrology

The Upper Gila River Watershed experiences a warm, high desert climate with air temperatures varying seasonally. The average monthly maximum temperature occurs in June (99 °F) and minimum temperature occurs in December (29 °F), as recorded at the Safford Agricultural Center from 1981–2010 (NCDC 2013). Annual precipitation is generally bi-seasonal, with cold, winter frontal storms arriving between December through March and tropical monsoons arriving in July through October. The wettest month is typically August (1.9 inches) while the driest month is May (0.25 inches), based on rainfall measurements in Safford from 1981–2010 (NCDC 2013).

The arid climate in eastern Arizona is interrupted by periods of intense winter and late-summer storms that often flood the rivers and streams. Streamflow data from seven long-term gaging stations along the mainstem upper Gila River, San Francisco River, Blue River, and San Simon River were obtained from the USGS's National Water Information System website: http://waterdata.usgs.gov/nwis. These spatially distributed stations provide a reliable characterization of the average daily river flows in the watershed, as well as the episodic hydrologic regime responsible for driving the flood-scour processes and geomorphic expression. Basic information for the gages is summarized in Table 3.

Table 3 also shows the normalized mean discharge (the mean daily discharge divided by the drainage area). The normalized mean discharge is a useful metric for comparing the mean stream flows among gages with differing drainage areas. There are many differences between the gages, with normalized discharge in the Gila River generally decreasing downstream due to losses from diversions and groundwater. The mean discharge in the mainstem Gila River does increase downstream of the junctions with the San Francisco River, Eagle Creek, and Bonita Creek (the Gila River near Clifton gage is upstream of the San Francisco River junction). The San Francisco River watershed, and in particular the Blue River gage, has a higher mean discharge than all of the Gila gages reported here, reflecting the high elevation of the San Francisco basin, relative to the average elevation of the Gila River watershed. The mean normalized discharge at the San Simon gage is about 10% of the normalized discharge of the Gila River at the head of Safford Valley (USGS Gage 099448500). This reflects the lower elevation and hence much lower precipitation in the San Simon watershed.

Table 3. USGS discharge gaging stations in the Upper Gila River Watershed.

USGS gaging station [a] [upstream to downstream]	Total period of record in water years [b, c]	Drainage Area (mi^2)	Maximum peak discharge (cfs)	Mean daily discharge (cfs)	Mean daily discharge (inch/year)[d]	Reach/ Sub-basin
09432000 Gila River below Blue Creek, near Virden, NM	1927–2013	3,203	52,700 [Dec 19,1978]	210	0.89	Gila River upstream of the AZ/NM border
09442000 Gila River near Clifton, AZ	1911–1917, 1928–1946, 1948–2013	4,010	57,000 [Dec 19, 1978]	194	0.66	Gila Box
09444200 Blue River Near Clifton, AZ	1967 - 1980, 1998 - 2018	506	30,000 [Oct 20, 1972]	60	1.61	Blue River
09444500 San Francisco River at Clifton, AZ	1891, 1905–1907, 1911–2013	2,763	90,900 [Oct 2, 1983]	215	1.06	San Francisco River
09447800 Bonita Creek near Morenci	1981-2018	302	19,500 [Oct 2, 1983]	7.3	0.33	Bonita Creek
099448500 Gila River at head of Safford Valley, near Solomon, AZ	1914–2013	7,896	132,000 [Oct 2, 1983]	453	0.78	Gila Upper Safford Valley
09457000 San Simon Near Solomon, AZ	1931-1932, 1935-1982	2,192	27,500 [Aug 9, 1931]	13	0.08	San Simon River
09466500 Gila River at Calva, AZ	1916, 1930–2013	11,470	150,000 [Oct 3, 1983]	363	0.43	Gila River Bylas Reach
09468500 San Carlos River Near Peridot, AZ	1914-present	1,026	54,800 [Jan 8, 1993]	56	0.74	San Carlos River

[a] Weblinks to source data:

[1] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09432000
[2] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09442000
[3] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09444200
[4] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09444500
[5] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09448500
[6] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09447800
[7] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09466500
[8] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09457000
[9] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09468500

[b] Water year (WY) is the 12-month period from October 1 through September 30.

[c] Period of records utilized in the flood-frequency and daily-duration analyses slightly differ from the total period of record due to data gaps and/or unreliable historical data:

[1] Flood-frequency analysis: Virden=WY 1927–2013; Clifton=WY 1911–1917, 1928–1946, 1948–2013; SF at Clifton=WY 1911–2013; Solomon=1914–2013; and Calva=1930–2013.

[2] Daily-duration analysis: Virden=July 1, 1927–Sept 30, 2013; Clifton=Nov 1, 1910–Sept 30, 2013; SF at Clifton=Oct 23, 1910–Sept 30, 2013-09-30; Solomon=Oct 1, 1920–Sept 30, 2013; and Calva=Oct 1, 1929–Sept 30, 2013.

[d] Calculated as mean annual discharge divided by the drainage area.

The mainstem Gila River has flashy peak flows that dwarf the mean daily flows (e.g., 132,000 cfs peak flow versus 453 cfs mean daily flow in the Safford Valley) but usually span only a few hours to days. The 10 largest floods recorded to date in the valley occurred in water years (WY) 1915, 1916, 1917, 1973, 1979, 1984, 1985, 1993, 1995, and 2005, based on gage data from the Solomon and Calva stations (Figure 13). These records highlight the flood period initially observed in the early 20th century, a relatively quiescent 50-year period up through the mid-1960s, and a 40-year period of larger, more frequent flood events since the late 1960s.

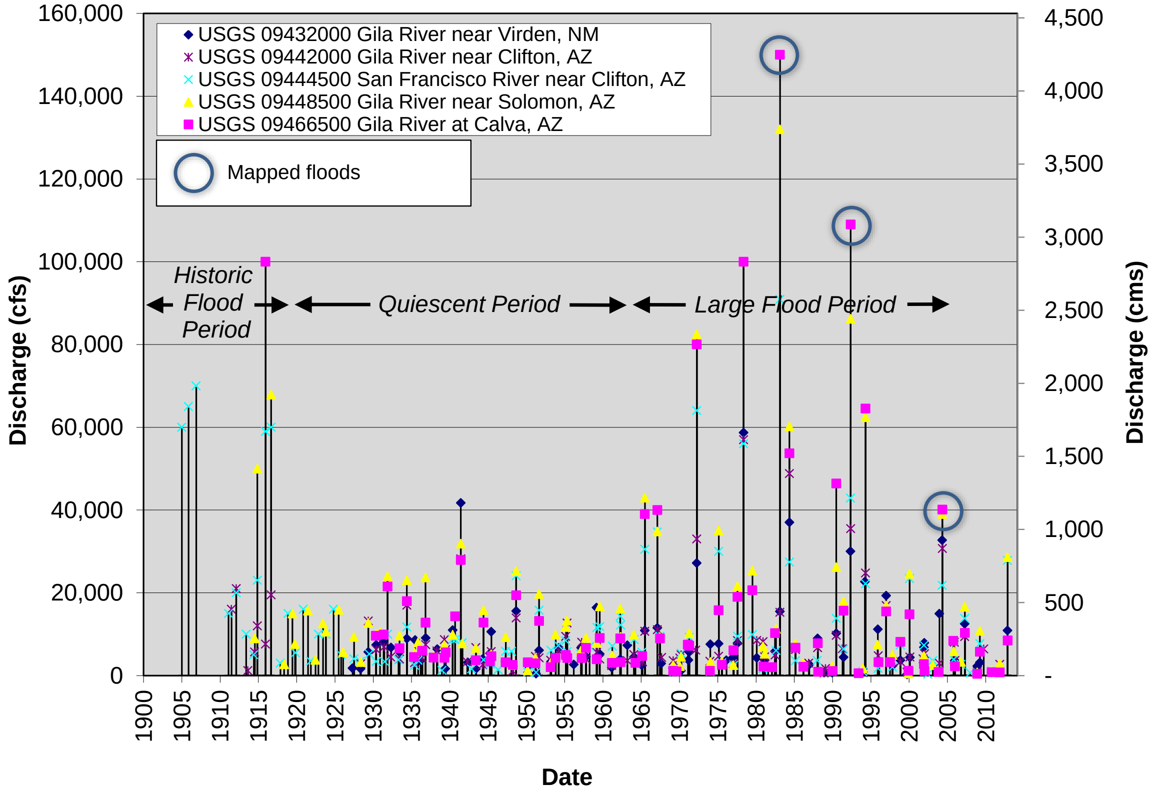


Figure 13. Historical flood peaks through water year 2013 at five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River. Flood-scour mapping by Orr et al. (2014) focused on three of the most recent large flood peaks, as indicated with blue circles.

While the data shown in Figure 13 suggest that the recent large-flood period has been waning since the 1990s, it should be cautioned that the potential for channel-scouring floods to occur in the near-future remains high.

In summary, the upper Gila River naturally experiences a wide variation of flows, punctuated episodically by short-duration but intensive high-flow events. These flashy discharge dynamics, which are common to large, dryland riverine systems, periodically result in dramatic geomorphic change (Graf 1978). The hydrology of the Gila River is likely to adjust due to climate change. And while climate models predict less total precipitation for the southwest region, increased frequency of intense storms and more precipitation falling as rain versus snow are expected to make southwest rivers more susceptible to flooding (USGCRP 2009). Thus, any restoration planning effort on the upper Gila River demands consideration of flood dynamics to best ensure long-term success.

Groundwater

Understanding basin-wide groundwater trends requires a general knowledge of the morphology of the basin as well as an understanding of the subsurface geology that underlies the aquifer units. The Upper Gila River Watershed is composed of five groundwater basins; Bonita Creek, Morenci, Duncan Valley, San Simon, and Safford. The Bonita Creek groundwater basin is entirely contained within the Upper Gila River Watershed and drains to Bonita Creek. The Bonita Creek aquifers include recent stream alluvium, basin fill, and volcanic bedrock (ADWR 2009) Aquifers in the Morenci groundwater basin consist of recent stream alluvium and volcanic rocks. The Morenci groundwater basin contains the drainage area of Eagle Creek, Blue River, and the San Francisco River. The Duncan Valley groundwater basin follows the Gila River from the New Mexico Border to just upstream of the confluence with the San Francisco River. The primary groundwater source in the Duncan Valley groundwater basin is recent stream alluvium, and additional groundwater is stored in Gila Formation sedimentary rocks (ADWR 2009). Groundwater elevations at two example wells evaluated by ADWR in the Duncan Valley were quasi-steady since 1975 (ADWR 2009). The Morenci and Duncan Valley groundwater basins are bounded by the New Mexico border, though the physical boundary contributing to the headwaters of these watersheds extends into New Mexico. The Safford groundwater basin is comprised of three smaller sub-basins: the San Simon sub-basin, Gila Valley sub-basin, and the San Carlos sub-basin.

Groundwater in the San Simon Valley has been primarily pumped from a deep confined aquifer, rather than the shallow aquifer that occurs there. The two aquifers are separated by a relatively impermeable Blue Clay layer (aquitard) whose depth varies across the basin. Groundwater pumping in the San Simon watershed increased from 1951-1983, then experienced a sharp decline as demand decreased, and the groundwater level has been declining at an average rate of 1.7 ft/yr from 2007 to 2015 (ADWR 2015). The principle aquifer for the San Carlos and Safford sub-basins is the younger basin fill (ADWR 2009).

The Groundwater conditions map (Figure 14) shows water levels of 309 shallow groundwater wells. Depth to water and well elevation were measured initially between 1987 and 1992, and then again in 2007 during the winter and early spring (December through March) for all measurements. The initial (1987–1992) water level was subtracted from the newer (2007) water level to calculate the change at each well. Positive change values indicate a rise in groundwater level, and negative values indicated a drop in water level. The overall range of the water level change is -91.2 to +76.8 feet, which indicates localized withdrawal and recharge effects. During this period, groundwater elevations decreased the most along the San Simon River, just south of Interstate Highway 10, which is surprising given that the lower aquifer is the primary groundwater source (ADWR 2015). Groundwater elevations increased the most in wells north of the confluence of the Gila and the San Simon rivers.

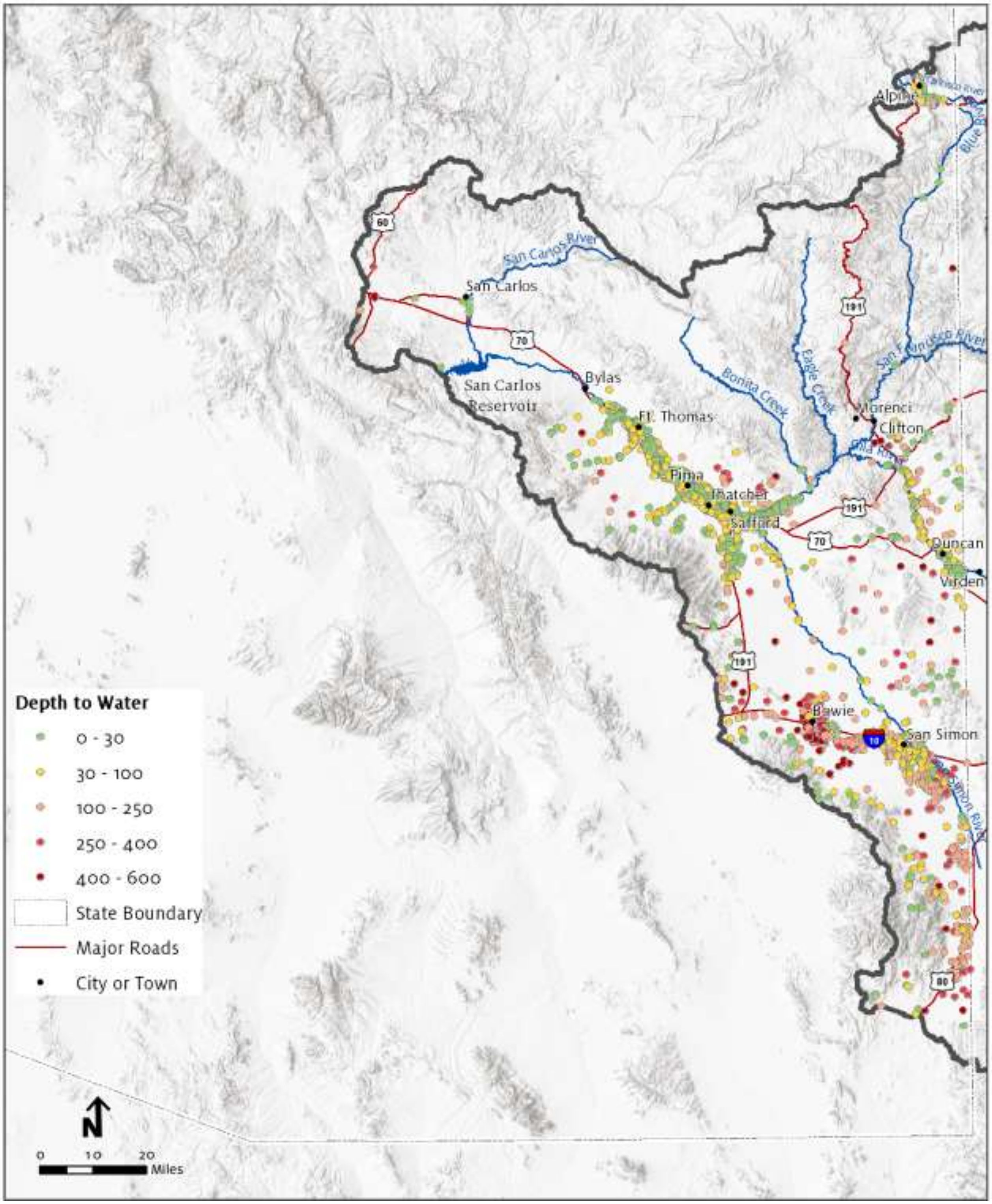


Figure 14. Groundwater level change between initial measurements in 1987-1992 and 2007. Source: Atlas of the Upper Gila River Watershed (Banister et al. 2014).

Geomorphology

The Upper Gila River

The upper Gila River between San Carlos Reservoir and the Arizona-New Mexico Border alternates between a multi-thread morphology (often single-threaded at low flow) with a wide floodplain confined by levees in the Safford and Duncan valleys, to a single-thread channel in a valley confined between high bedrock cliffs in the Gila Box. The slope is typically about 0.002 (0.2%) and relatively uniform. The bed is predominantly sand with lesser amounts of gravel, although the grain size distribution of the bed has not been systematically explored. The river has been altered by encroachment of tamarisk on the floodplain, which began in the early 20th century (Burkham 1972). A series of diversion dams in the Safford Valley divert water and trap sediment in the reaches immediately upstream of the diversion, leading to local aggradation and in places, long-term sediment management operations. Tributaries with high sediment loads tend to be those with easily erodible soils (Figure 15) (i.e., San Simon watershed, Blue River watershed, Rainville Wash, and the North Slope of Mt. Graham), rather than the steepest watersheds, which tend to have greater rock strength.

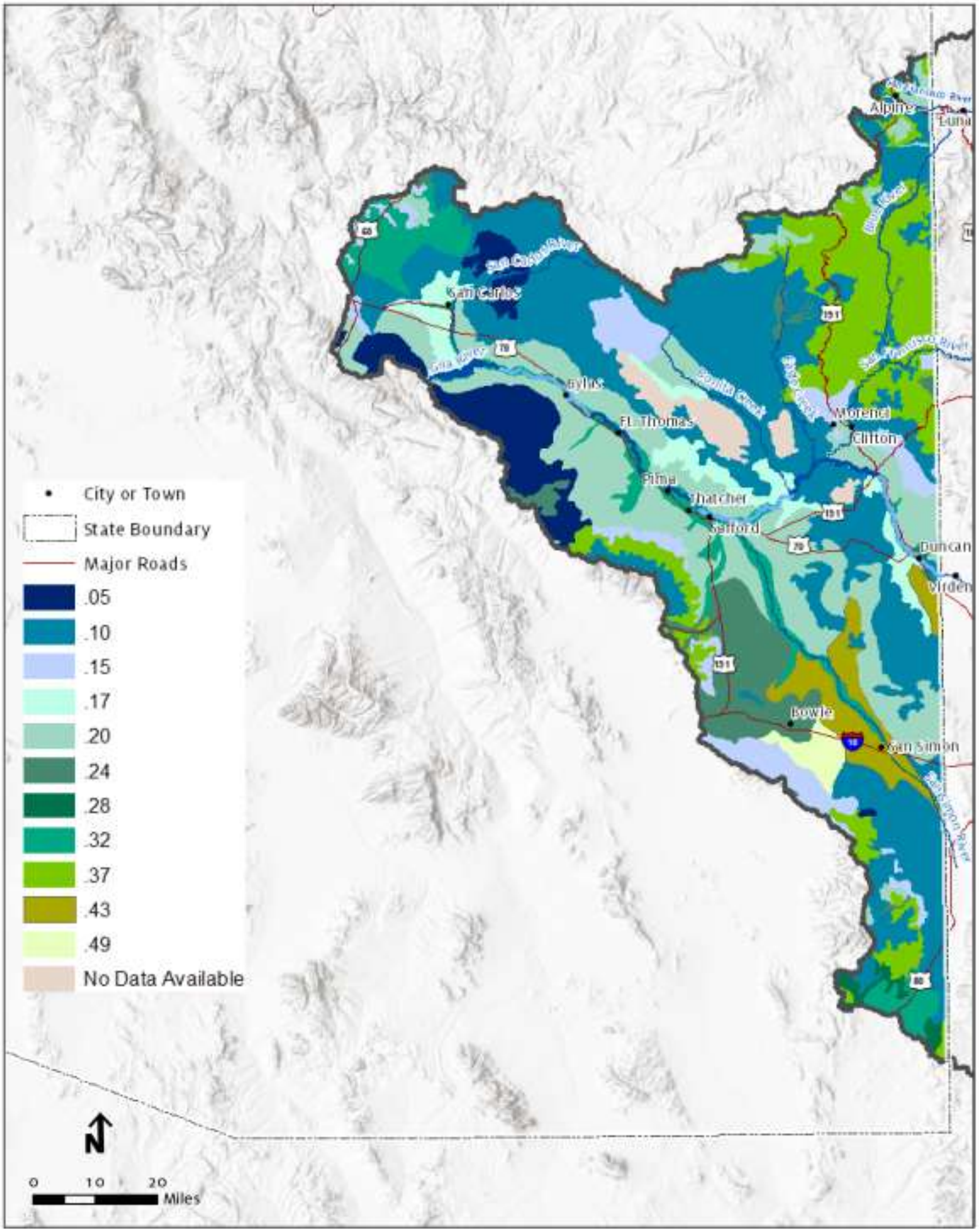


Figure 15. Soil erodibility (NRCS 2011).

Downstream of Pima, the valley narrows somewhat and the channel transitions to a wetter, fine-grained, braided/ meandering channel system composed of a narrow single-thread channel during lower flows that is encroached upon by dense riparian vegetation (mostly tamarisk), which is in turn bordered by a broad, cultivated floodplain with few developments. During high-flow events, side-channels also convey flow giving a more pronounced braided appearance to the river corridor. The entire corridor and some portion of its floodplain become inundated during the largest floods.

The natural flow and sediment-transport regime in the Safford Valley is altered by the presence of in-channel irrigation diversions, bridge crossings, and agricultural levees. A total of six irrigation canal diversion dams span at least part of the river corridor downstream of the Gila Box (listed from upstream to downstream): the Brown, San Jose, Graham, Smithville, Curtis, and Ft. Thomas diversion dams. The BOR (2004) mapped numerous occurrences of historical and existing levees and pilot channels, all of which appear to have been constructed in response to flooding, many of which are poorly managed and failing. Sediments accumulate upstream of the diversion structures, and some have historically been dredged (BOR 2004) to maintain functionality of the structures. The amount of sediment removed from the structures is not known, and the effect of the structures on sediment supply to downstream reaches has not been investigated.

The Gila River is subjected to large flood-scouring flows (Orr et al. 2014, BOR 2004), which tend to fill the entire valley and scour much of the floodplain. During these events, the low-flow channel position can change rapidly as the main thread of the channel migrates and switches position While the low flow channel boundary shifts during these floods, the boundary of the broader active-valley area changes less frequently. The flood-scour width is generally greater above Pima, and lower below. Levees likely exacerbate lateral erosion and land loss outside of the channel corridor (BOR 2004). Comparison of early maps and aerial photographs suggest that the channel widened significantly following the 1905 flood and that width has been subsequently maintained, and that many of the tributaries began incising while the Gila River widened, but the causal mechanism is unknown (Burkham 1972). It is possible that historical grazing destabilized the mainstem Gila and its tributaries and increased the sediment load.

Dense stands of tamarisk along the mainstem Gila River provide greater stability to the river and floodplain substrates than do native vegetation (e.g., willows and cottonwoods) and, as an unintended consequence, progressively narrow the active channel thereby increasing the frequency of floodplain inundation (Graf 1978). Bank erosion may increase following the removal of tamarisk either as part of stream restoration or due to the arrival of the tamarisk beetle.

Orr et al. (2014) identified a “Flood Reset Zone” downstream of the Gila Box as a flood risk assessment tool to inform restoration area prioritization and strategy selection (i.e., passive versus active revegetation) as part of the ecohydrological assessment. This zone includes areas having both 100% flood-scour frequency (i.e., scoured in 3 out of the 3 mapped events [1983, 1993, and 2005]) *and* “high” flood-disturbance activity—areas severely disturbed by flow, typically scoured to bare substrate retaining <10% apparent riparian vegetative cover—during the most recent flood of 2005. The size of the Flood Reset Zone progressively decreases in the downstream direction in the Safford Valley. The mapped flood reset accounts for over 80% of the riparian corridor near the upstream end of the Valley and only about 20% near the downstream end. The BOR (2004) documented widespread levee failure throughout the reach during these large floods, due to lateral erosion enhanced by overly confining flow with levees. The morphology of reaches of the Upper Gila River from upstream to downstream is described below, followed by the major tributaries.

Gila River upstream of the New Mexico State Line

Although it is outside of the plan area, the Gila River upstream of the New Mexico border acts as a source of water and sediment to the Gila River in Arizona and stressors upstream of the New Mexico border are among the important considerations for conservation and management of the Gila River in the plan area. The Gila River in New Mexico is mostly confined by bedrock on both banks, with some wider valleys (i.e., near Gila, NM). The lowermost seven miles of this reach is part of the Duncan Valley, but is outside of the plan area. The Upper Gila Total Maximum Daily Load (TMDL) (ADEQ 2011) identified the reach of the Gila from the Arizona border downstream to Bitter Creek as impaired for sediment. This impairment was for low flows only (when sediment transport is comparatively small) but suggests that sediment supply could be high from the Gila River upstream of the New Mexico border. Extensive sparsely vegetated desert areas coupled with easily erodible soils lead to relatively high background levels of sediment loading (ADEQ 2011). A water diversion project, to divert water from the Gila and San Francisco rivers in New Mexico, is proposed as part of the Arizona Water Settlements Act. The proposed project involves water diversions and groundwater wells on the Gila River near Cliff, New Mexico and water storage ponds near Virden, New Mexico at the upstream end of the Duncan Valley. Three diversion structures and a reservoir are proposed on the San Francisco River between Pleasanton, New Mexico (~11 miles upstream of the Arizona-New Mexico Border) upstream to about 0.4 miles upstream of the confluence with Pueblo Creek (~26 miles upstream of the border). The project is currently under deliberation and may affect hydrology and channel morphology downstream of the diversion depending on the design and implementation.

Duncan Valley Reach (New Mexico Border to Highway 191)

The Duncan Valley Reach extends downstream about 18 miles from the New Mexico Border to Highway 191. The upper 6 miles of the reach flows through the Duncan Valley. The Duncan Valley ranges from 3,600–4,000 feet wide and is dominated by agriculture on the floodplain and is morphologically similar to the Safford Valley. The slope in this reach is approximately 0.002 (0.2%). Confined reaches (~ 500 ft valley width) are interspersed with wider valleys up to 2000 ft wide (e.g., the York Valley) in the lower 18 miles of the reach.

Brandau et al. (2013) identified the Rainville/Railroad Wash as a large potential source of sediment to the Gila River in the Duncan Valley. Rainville Wash enters the Gila River immediately upstream of Duncan. The surficial geology of the watershed is dominated by Quaternary terraces and fans deposited over former lakebed sediments (Brandau et al. 2013). This geologic type often has very high soil erodibility and high sediment loads in the Upper Gila Watershed. The channels are highly incised and 32 sediment retention structures in the tributaries are designed to trap sediment from channel incision (Brandau et al. 2013). The contribution of sediment from Rainville Wash to the upper Gila has not been quantified. Brandau et al. (2013) identified several other retention basins in tributaries draining to the Duncan Valley. These structures are in various states of disrepair and may be acting as a sediment source to the upstream portion of the Duncan Valley. In addition, Goat Camp Canyon has one sediment retention structure that failed in the early 2000s and sediment from the retention basin is moving downstream into the Gila River (Brandau et al. 2013). Levee breaches along the Gila River near Railroad Wash led to extensive property loss between 1978 and 2000 within the former active flood zone (BOR 2004).

Gila Box Reach (Highway 191 to Bonita Creek)

The Gila Box Reach extends from Highway 191 about 33 miles downstream to the confluence with Bonita Creek through the Gila Box National Riparian Conservation Area. Within the Gila Box National Riparian Conservation Area, three major tributaries join the Gila River including the San Francisco River, Eagle Creek, and Bonita Creek. Cliffs composed of the Miocene to Pliocene-age Gila Conglomerate confine the channel and extend up to 1,000 ft above the valley floor. The BLM has conducted two desktop analyses of the Gila Box (Cockman and Sexton 2016, Cockman and Caldwell 2016) and completed several Proper Functioning Condition evaluations in the Gila Box. A recent Properly Functioning Condition report for 3.9 miles of the Gila Box upstream of the confluence of the San Francisco and Gila Rivers (Martin et al. 2017a) noted that while the outside banks were stabilized by vegetation, vegetation could be sparse on bars. In addition, they observed widespread sediment deposition in their 3.9-mile long study reach and that the floodplain had occasional boulders and overflow channels. In the downstream end of the Gila Box, Orr et al. (2014) described the channel as confined and gravel bedded with willow-cottonwood riparian forests.

Downstream views of the Gila River: mouth of Gila Box *(top)*; in the upper Safford Valley *(middle)*; and the lower Safford Valley *(bottom)* (Photos by Stillwater Sciences).

Upper Safford Valley (Bonita Creek to Smithville Diversion Dam)

In the Upper Safford Valley Reach, the Gila River is generally a vegetated, low-gradient (Slope = 0.0018), braided river corridor bordered by a broad floodplain. The character of the channel changes from upstream to downstream in this reach. Downstream of the Gila Box, the valley gradually widens to the San Jose Diversion Dam. Downstream of the San Jose Diversion Dam, the Gila River is a wide, braided/meandering channel with sparse to moderately dense riparian vegetation (mostly tamarisk) bordered by a broad, cultivated and developed floodplain. The floodplain supports agriculture and some urban developments. The Brown Canal Diversion Dam is 3.5 miles downstream of Bonita Creek, and is currently damaged (L. Opall, personal communication). Disconnected levees along towns and agricultural lands constrain the active floodplain width. The braided corridor generally ranges in width from 1,000 to 4,600 ft.

Lower Safford Valley (Smithville Diversion Dam to San Carlos Apache Reservation boundary)

The Gila River in the lower Safford Valley has valley widths that range from about 900 ft to 4,000 ft. The valley is generally narrower downstream of the town of Ft. Thomas, with narrow points often corresponding to bajadas[1]. For most of the reach length, agriculture occurs on both banks, but is limited to the southwest bank downstream of the town of Ft. Thomas. The river valley is braided, with a single-thread low flow channel confined by tamarisk. In some places the river corridor is confined by levees.

Several tributaries that enter the Gila from the south between Stockton Wash to Goodwin Wash historically have been large sources of sediment. Structures were built in the 1950s in this reach, many of which are currently failing (Brandau et al. 2013). The surficial geology is typical of rapidly eroding areas in the Upper Gila River watershed, with surficial Quaternary sediments including river deposits, former lake sediments, and fluvial terraces. The Sinuosity in this reach is generally 1.1-1.2 (Hooke 2000).

Bylas Reach (San Carlos Apache Reservation boundary to Bone Spring Canyon)

The Bylas Reach is the narrowest reach of the Gila River Valley downstream of the Gila Box. The valley in this reach is typically about 2,500 ft wide. The river in this reach is densely vegetated with tamarisk, with a braided pattern through the valley, although at low flows the channel is confined to a single thread. Levees have not been mapped in this reach, but aerial photographic inspection suggests that they may occur near the town of Bylas.

San Carlos Reservoir Reach (Bone Spring Canyon to Coolidge Dam)

This reach contains San Carlos Reservoir and the backwater reach of the Gila River. The backwater reach has dense tamaraisk stands that line a single-thread channel with a sinuosity of about 1.3. The San Carlos River enters the Gila just upstream of the reservoir within this reach. The valley width ranges from 1,600 ft to 4,800 ft in the backwater reach.

Tributaries

San Francisco River

The San Francisco River is the largest tributary to the upper Gila River, with a drainage area of 2,800 mi^2, and joins the Gila River from the north 2.6 mi upstream of Eagle Creek in the Gila Box National Riparian Area. The watershed contains the San Francisco and Blue Rivers in Arizona and New Mexico. The Blue River watershed is described separately below. The San Francisco

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[1] A bajada is an alluvial plain formed at the base of a mountain by the coalescing of several alluvial fans.

River is confined within a bedrock canyon for most of its length, with bedrock hillslopes abutting the channel in several places. Within the canyon, floodplain deposits supporting riparian vegetation occur throughout the river. Riparian areas are dominated by cottonwoods, native willows, sedges and grasses (Gila Watershed Partnership 2012).

Downstream of the confluence with the Blue River, the valley width is 300–600 ft, and generally decreases downstream. The San Francisco River was identified as impaired for suspended sediment in the Gila River TMDL (ADEQ 2011). Similar to the Duncan Valley reach sediment impairment is identified only at low flows, and available information is insufficient to characterize the sediment supply during high flows. The Gila Watershed Partnership has identified vegetation changes associated with grazing in riparian areas, particularly near Clifton, and grazing impacts are a major sediment source in the San Francisco watershed (Gila Watershed Partnership 2012). Other sources of sediment to the channel include recreation, off-road vehicles, and recent fires. Additionally, there is concern about sediment loads associated with lateral erosion of river terraces in the upper San Francisco River (NRCS, no date). The Morenci Mine, a copper mine located upstream of the towns of Clifton and Morenci, is operated under federal and state laws, which require that no water leaves the mine property and include strict measures to control sediment production. There are at least seven dams in the San Francisco River watershed (NRCS, no date) but, to our knowledge, their impact on water and sediment supply have not been quantified.

Martin et al. (2017b) completed a Proper Functioning Condition Study in the downstream-most 6 miles of the San Francisco River. They found that the reach had a slope of 0.004, with an average depth of 3.4 ft and average channel width of 72 ft (Martin et al. 2017b). They also observed that vegetation was absent on some point bars and observed some large wood on the channel banks and floodplain. Mid-channel bars and lateral point bars were observed in this lowest reach of the San Francisco River. They also observed direct effects of off-road vehicle use on the channel banks and floodplain.

Blue River

The Blue River watershed has a drainage area of 618 mi^2 and joins the San Francisco River approximately 18 miles upstream of Clifton. The Blue River drains mountainous terrain and the river valley is confined by bedrock cliffs. The soil characteristics of the Blue River watershed (Figure 15) lead to relatively high sediment loads, much of it from landslides (ADEQ 2011). Sediment loads were also very high following the Wallow Fire (Gila Watershed Partnership 2012).

Eagle Creek

Eagle Creek is a perennial stream that joins the Gila River 9.4 miles upstream of Bonita Creek in the Gila Box National Riparian Area. Eagle Creek has a drainage area of 654 mi^2 and primarily drains Miocene-Oligocene volcanic rocks. The sinuous creek is confined by bedrock and has a valley width of 350–500 ft. The Morenci Mine is along the eastern end of the drainage between Eagle Creek and the San Francisco River. Eagle Creek has not been identified as a significant sediment source to the Gila River. Since 1944 water has been diverted from the Black River (a Tributary to the Salt River) to Eagle Creek for use by the Morenci Mine.

Bonita Creek

Bonita Creek joins the Gila River from the north near the downstream end of the Gila Box. Bonita Creek is a perennial river with a drainage area of 312 mi^2 (808 km^2). Bonita Creek drains primarily resistant Miocene Conglomerate and Miocene-Oligocene Volcanic Rocks. The Bonita Creek Basin drains the Gila Mountains to the south and the Nantac Rim to the north. The creek is confined between bedrock valley walls but has a 200–230 ft wide vegetated alluvial valley. An infiltration gallery located on Bonita Creek approximately 5-6 miles above the mouth collects water for the City of Safford's water supply pipeline.

San Simon River

The San Simon River is an ephemeral river that joins the Gila River from the south near the town of Solomon. The San Simon River has a drainage area of 1,606 mi^2 (4,159 km^2) and drains relatively erodible loamy soils (Banister et al. 2014). Unlike the other sub-basins described herein, the San Simon watershed is relatively flat. The San Simon Valley is wide and is composed of extensive Quaternary river and lake deposits on the valley floor with Quaternary terrace deposits, particularly downstream of the town of Rodeo, New Mexico (near the Arizona-New Mexico border). As a consequence of the basin geology, the San Simon watershed has the highest soil erodibility of any of the other reaches or sub-basins in the Upper Gila River Watershed (Figure 13). The river is incised in a single thread, with large sediment deposits upstream of many sediment retention dams (described below). There is little agriculture except near the towns of Bowie and San Simon. Vegetation cover is limited in the basin and soil erosion is common.

The best available evidence suggests that widespread arroyo formation in the San Simon Watershed began in the early 20th century, with more than 100 miles of gullies exceeding 10 feet in depth (Burkham 1972). Arroyos are entrenched ephemeral streams found in the southwest that undergo periodic erosion (gullying) and filling (Waters and Haynes 2001). The cause of the arroyo formation is not certain, but Olmstead (1919) reported that incision in the San Simon originated following excavation of a 4 ft deep and 20 ft wide drainage ditch near the confluence with the Gila in the 1880s. Gullying, however, occurred in many of the tributaries to the Gila River following several years of drought and a large storm in 1915 (Burkham 1972), suggesting that the drainage ditch may not be the sole cause of gullying. Arroyos formed throughout the Southwest in the early 20th Century (Waters and Haynes 2001). The degree to which the gullying and arroyo formation was exacerbated by grazing is unknown, but given the timing of surface erosion and evidence from other basins, a change in vegetation perhaps in combination with the ditch excavation were the likely driver of the transition from a quasi-stable landscape to one with widespread erosion. The gullying extends from the mainstem up into the tributaries. The large volumes of sediment from surface erosion are retained and partially mitigated by numerous check dams in the tributaries and mainstem San Simon. Due to incision in the early 20th century the BLM installed at least 19 major detention dams in the San

Simon watershed (Brandau et al. 2003). In a subsequent study, Brandau (2013) identified 931 sediment control structures of various sizes and design in the San Simon Watershed. Of the 931 structures, 283 appeared to be breached. These breached dams are likely providing high sediment loads to the San Simon River and the upper Gila River. The San Simon is likely the largest sediment source to the Gila River downstream of the Gila Box (Brandau et al. 2013).

San Carlos River

The San Carlos River enters the Gila River form the north and has a drainage area of 1,054 mi^2. The river primarily drains the San Carlos Reservation and the San Carlos River and its tributaries are primarily multi-threaded, braided streams. The Talkalai Lake Reservoir has partially regulated discharge since 1979 (Webb and Boyer 2001). The valley is up to 2,600 ft wide in the lower reaches of the watershed. The lower portions of the watershed have a broadly similar geology to the San Simon Watershed. To our knowledge, the amount of 20th century arroyo cutting and gullying in the San Carlos Watershed has not been quantified, but a brief aerial photographic survey suggests that the degree of gullying is much less than the San Simon River. We are not aware of a systematic study of sedimentation in the San Carlos Watershed.

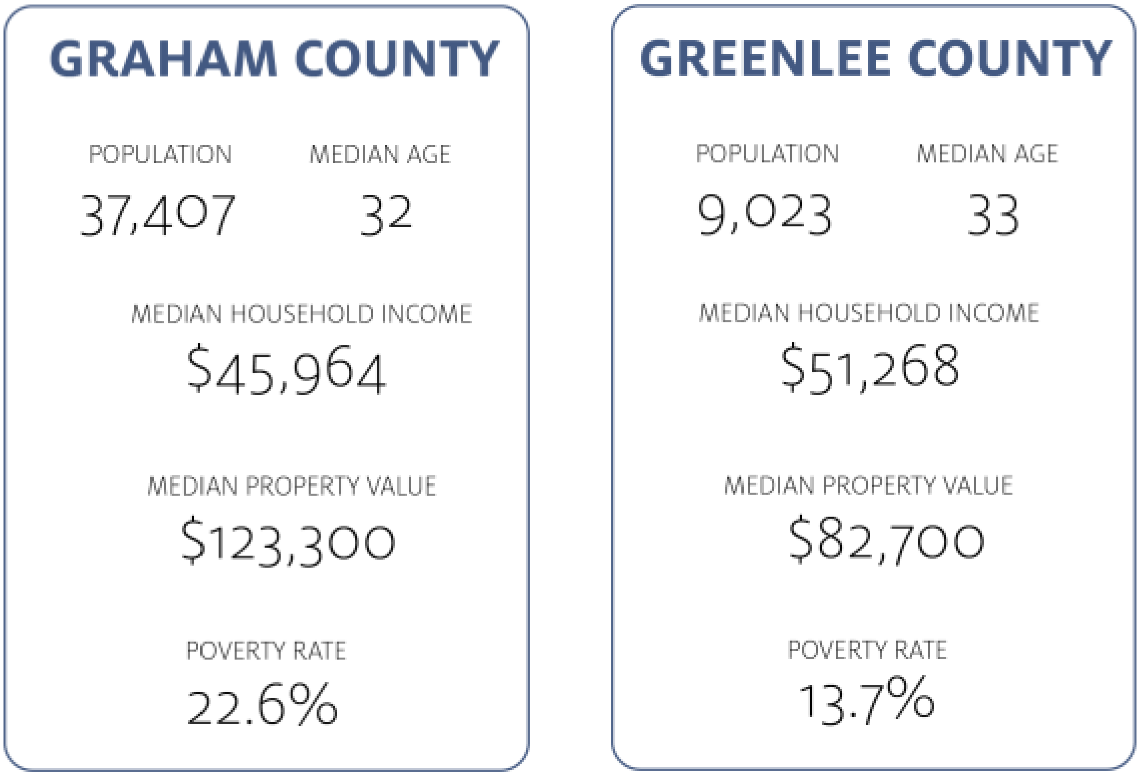
LAND USE & PEOPLE

Healthy communities are part of a healthy watershed. Economic and cultural context in the watershed are an important consideration in the work of GWP and partners. Understanding how humans have made an impact on the landscape, going back thousands of years, and recent patterns of settlement and land use will help us understand changes in the watershed.

Residents of the watershed largely value this vast landscape for its scenery and sense of place. In many instances, stakeholders have communicated the desire to preserve this rural lifestyle that has disappeared from many other places in the West. The GWP has even incorporated this value into their mission statement. However, the dispersed nature of the population can be a challenge for a watershed partnership seeking to connect stakeholders with projects in their region. See Figure 16 for snapshots of population and economic indicators in Graham and Greenlee Counties.

KEY TAKEAWAYS

- Dispersed and small populations can make engaging stakeholders in water and land management decisions difficult. These population characteristics also have implications for how water is obtained, treated, regarded (i.e. well owners vs municipal water utilities)
- Increased aging populations can have economic impacts, both positive and negative. Retirement populations can provide economic stimulus to a region, but economic growth requires an active labor force.
- An estimated 70% of the population of the Upper Gila Watershed lives within five miles of the Upper Gila or the San Francisco rivers. Maintained infrastructure is especially important in proximity to waterways. If there is a decrease in the amount of funds made available by federal agencies to local government, an increasing amount of the burden of maintaining this infrastructure falls on county and city/town governments.
- While agriculture and mining remain important sectors in many rural economies including the Upper Gila Watershed, service and retail industries have accounted for most job growth in rural America over the past few decades. Job opportunities available to the rural labor force is a key consideration for education of the youth.
- Increasing the area covered by homes, businesses and roads increases stormwater runoff, which can lead to flooding and/or water quality concerns.



GRAHAM COUNTY

POPULATION 37,407

MEDIAN AGE 32

MEDIAN HOUSEHOLD INCOME $45,964

MEDIAN PROPERTY VALUE $123,300

POVERTY RATE 22.6%

GREENLEE COUNTY

POPULATION 9,023

MEDIAN AGE 33

MEDIAN HOUSEHOLD INCOME $51,268

MEDIAN PROPERTY VALUE $82,700

POVERTY RATE 13.7%

Figure 16. Snapshots of population and economic data for Graham and Greenlee Counties, AZ (U.S. Census Bureau 2015).

Population growth, age distribution, and demographics

Graham and Greenlee Counties make up most of the Upper Gila Watershed. This 7,354 square mile watershed is occupied by only 47,500 people (2015), mostly living in the Safford and Clifton areas. Within these counties, the population density is widely dispersed with approximately 8 people for every square mile in Graham County and 5 people for every square mile in Greenlee County (ACS 2015, 5-Year Estimates)—some of the lowest rates of population density in the state.

The population within the watershed has changed dramatically over the last thirty years and can experience dramatic shifts based on largely economic trends. The 2018 total population estimate of Graham County is 37,407 people, and 9,023 people in Greenlee County. Since 2000, the population in Graham County has increased 9% (from 33,997 people), while the population of Greenlee County has increased 5% (from 8,584 people) (U.S. Census Bureau 2017) (Figures 17 and 18). However, as Figures 17 and 18 indicate, the population can fluctuate dramatically according to different economic and environmental factors, both regionally and nationally.

An estimated 70% of the population of the Upper Gila Watershed lives within five miles of the Upper Gila or the San Francisco rivers. With the exception of Peridot and San Carlos, the largest municipalities are all located along these two rivers. The region's settlement from the mid-1800s onward was concentrated along these corridors to take advantage of the water for human uses, particularly agriculture. Infrastructure similarly is closely associated with the river. Public and private actors are responsible for a variety of infrastructure in the region, from irrigation ditches and diversion dams to roads and bridges. Much of the costs associated with maintaining the public infrastructure is carried by local governments, with some assistance from state and federal entities. In recent years, there has been a marked decrease in the amount of funds made available by these levels of government. As a result, an increasing amount of the burden of maintaining this infrastructure falls on county and city/town governments. In addition, compliance costs regarding certain state or federal regulations (such as the National Historic Preservation Act, the National Environmental Planning Act, or the Endangered Species Act) increases the expenses born by governmental entities.

For Graham and Greenlee Counties, approximately 23–26% of the population is between the ages of 18 and 34 years old (Figure 16). The population of 65 years and over is 11–12% in these counties. A society is considered relatively old when the proportion of the population age 65 and over exceeds 8 to 10%. By this standard the proportion of elderly people in the United States was 12.6% in 2000, compared with only 4.1% in 1900. Elderly populations are projected nationwide to increase by 27% between 2012 and 2050 (Ortman et al 2014).

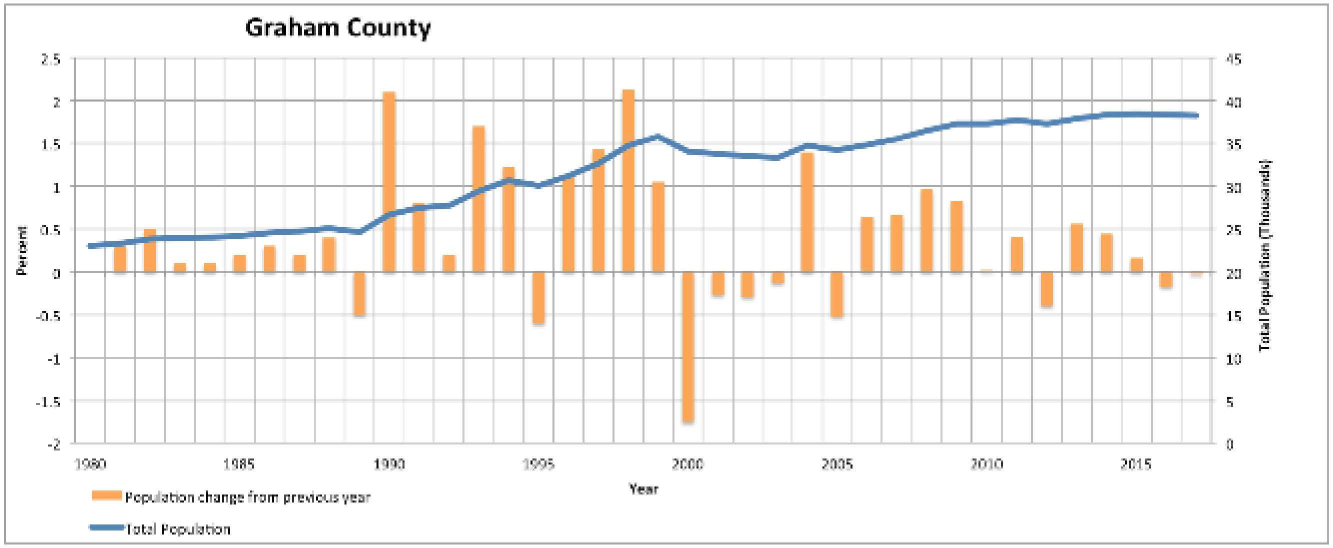


Figure 17. Graham County population between 1980 and 2017.

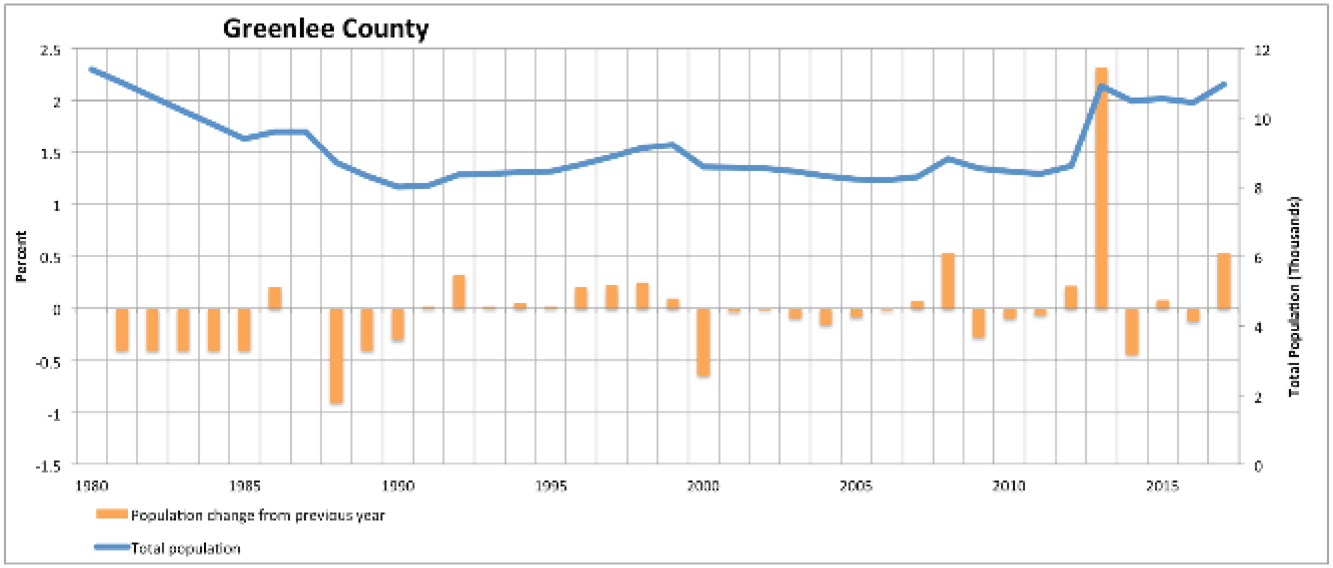


Figure 18. Greenlee County population between 1980 and 2017.

Economy and industry

Changes in technology have resulted in modifications to farming and land use patterns throughout the course of the Gila River's history of human occupation. From a market-driven perspective, the arrival of the railroad – and later, paved surface roads—led to the integration of the local farm economy into national and international markets. Instead of selling crops to the nearby towns, new sellers were suddenly available. Choice of crops by local farmers then became influenced by opportunities to participate in distant commodity markets. Cotton became popular among farmers in the Valley, and it remains a staple crop today.

Cotton is the primary crop grown in the Upper Gila Watershed, providing a strong cultural and economic base in Graham County communities, while ranching and livestock sales dominate in Greenlee County. According to the 2012 USDA Census of Agriculture, crop sales in Graham County accounted for $170 million (97% of all ag sales in the county) and livestock sales accounted for $414,000 (3% of all ag sales in the county). Meanwhile, crop sales in Greenlee County accounted for $2.4 million (25% of all ag sales in the county) and livestock sales accounted for $7.3 million (75% of all ag sales in the county) (USDA 2012). In 2012, 412 farms were located in Graham County (an increase from 343 farms in 2007) consisting of 1.25 million acres (USDA 2012)[2]. In the same year, 159 farms were located in Greenlee County (an increase from 127 farms in 2007), consisting of 52,000 acres[3]. There are also seven wheat farms in Graham County and zero in Greenlee, while there are six barley farms in Graham and zero in Greenlee (Kerna et al. 2016).

The economy of Graham County, AZ employs 11,954 people. The largest economic impacts are from Mining, Oil, Gas Extraction[4]; Management of Companies & Enterprises; and Public Administration, which employ respectively 18.64; 6.32; and 1.77 times more people than what would be expected in a location of this size. The largest industries in Graham County are Retail trade (1,605), Educational Services (1,596), and Healthcare & Social Assistance (1,391), and the highest paying industries are Utilities ($75,446), Mining, Quarrying, Oil, Gas Extraction ($61,453), and Professional, Scientific, Tech Services ($54,000).

The economy of Greenlee County, AZ employs 3,346 people. This area specializes in Mining, Quarrying, Oil, Gas Extraction; Management of Companies & Enterprises; and Agriculture, Forestry, Fishing, Hunting, which employ respectively 69.12; 6.77; and 2.37 times more people than what would be expected in a location of this size. The largest industries in Greenlee County, AZ are Mining, Quarrying, Oil, Gas Extraction (1,398), Construction (344), and Educational Services (270), and the highest paying industries are Mining, Quarrying, Oil, Gas Extraction ($59,116), Professional, Scientific, Tech Services ($55,043), and Transportation & Warehousing ($34,896).

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[2] This figure accounts for both farming and ranching land, including federal rangeland.

[3] This figure accounts for both farming and ranching land, including federal rangeland.

[4] US Bureau of Reclamation defined category. There is no known oil or gas extraction in Graham or Greenlee Counties.

“Mining, Quarrying, Oil, Gas Extraction” is one of the most common employment sectors for those who live in both Greenlee County and Graham County. However it is important to remember that of these residents may live in either of those counties and work somewhere else. Census data is tagged to a residential address, not a work address.

Land use

Land under different ownership is managed in different ways. The San Carlos Apache are a sovereign nation with an independent system of land management and water rights reserved prior to most others in the watershed. The U.S. Forest Service, BLM, and Arizona State Land Department lease lands to private citizens for uses such as grazing, mining, recreation, and rights of way for transportation and utilities (Figure 19, Table 4). The harvest and collection of forest products is also permitted on U.S. Forest Service land. The State Trust Lands are often interspersed with federally managed land and privately owned land, and may be sold into private ownership in the future. Several small areas in the watershed are managed for wildlife and recreation by the Bureau of Reclamation, the Salt River Project, the National Park Service and the Arizona Department of Game and Fish. Private ownership on the remaining parts of the watershed is primarily used for farming, ranching, mining, and housing.

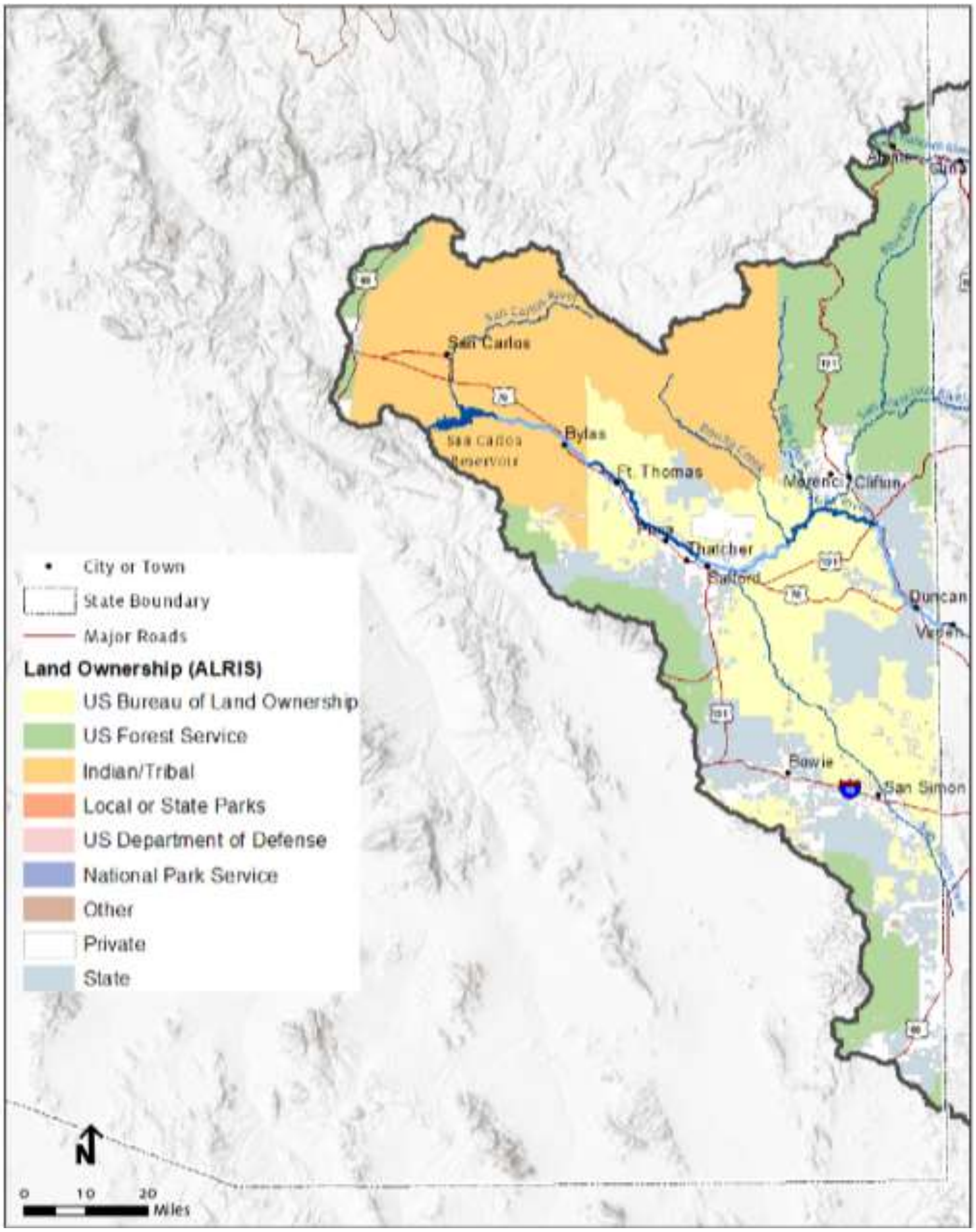


Figure 19. Land ownership in the Upper Gila Watershed (Source: ARLIS 2010).

Table 4. **Land ownership in the Watershed.**

Ownership	% Total Area
BLM	23%
Indian Lands	29%
Private	10%
State	14%
U.S. Forest Service	23%
Other (NPS, Military)	1%

Changes in land cover, such as the conversion of agricultural lands to houses and businesses, can impact the water quantity and quality. Figure 20 depicts a simplified land cover change analysis using information from the National Land Cover Database (NLCD). Datasets were developed for 1992, 2001, 2006, and 2011 using satellite imagery (Landsat TM/ETM+) with a spatial resolution of 30 meters. Though all four datasets were produced as part of the same program, changes in methodologies and input between the NLCD datasets makes it so that these datasets cannot all be directly compared to one another, although techniques have been created to correlate the datasets. Overall accuracy of the 1992 NLCD varied by region, but was 70% for the Southwest (Wickham et al. 2004). Overall accuracies for the entire 2001 and 2006 NLCD were 79% and 78%, respectively (Wickham et al. 2013).

To analyze land cover change, 1992 and 2006 land cover were compared (Table 5, Figure 20). The two original maps had different land classifications, so it was necessary to change both to more general categories that matched.

2006 Results: The differences in the original datasets make it difficult to examine change in specific areas, however it is possible to look at the landscape as a whole, and the relative proportion of each land cover class reveals interesting trends of land cover change in the watershed. For example, the percentage of land used for agriculture (2%) remained constant between 1992 and 2006 whereas the land for “urban” or houses, commercial use, and roads increased from 0.1% of the land area to 1%. While it is still a very small fraction of the total area this represents a 580% increase in land used for roads, homes, or businesses. Similarly, the area covered by “riparian” plants, which includes both native cottonwoods and willows as well as tamarisk, increased from 0.1% of the land to 0.5%. While riparian area remains only a tiny fraction of the land cover in the watershed, it increased 330% between 1992 and 2006. Finally, although it is notable that the area of forest land increased from 14% to 20%, the data represent conditions prior to several major forest fires and may not accurately reflect current conditions. It is also possible that the increase in forest land in particular is due, at least in part, to the different classification schemes from the original data.

Table 5. Land cover change in the Upper Gila River Watershed, 1992-2006.

Land cover	Area 1992	Area 2006
Agriculture	2%	2%
Barren	0.5%	0.3%
Forest	14%	20%
Open Water	0.3%	0.2%
Riparian	0.1%	0.5%
Shrubland and Grassland	83%	76%
Urban	0.1%	1%

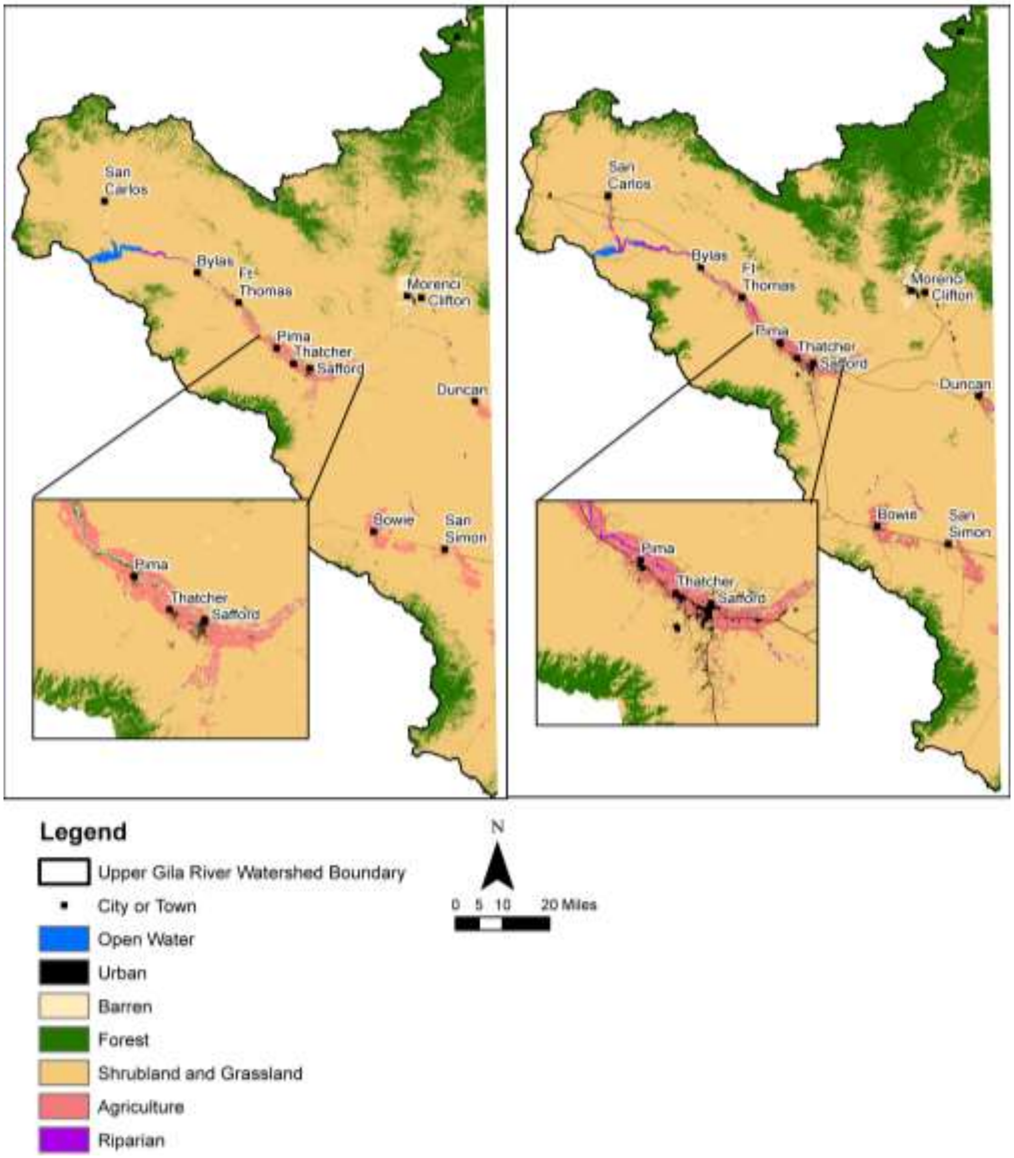


Figure 20. Land cover change (NRCS 1992-2006).

WATER USE AND SUPPLIES

In our water-scarce state, the Gila River has and will continue to be a valuable and highly sought after water source. Its surface water supplies and underlying groundwater allow the existence of robust farming, ranching, and mining, while providing a ribbon of green to the arid landscape. However, as much as these water resources have shaped the history of the watershed, a variety of legal uncertainties will influence future water supplies, potentially in a drastic way. The GWP can contribute to acquiring knowledge of the area's water limits and aiding in more efficiently managing water usage in order to cope with these uncertainties and maintain a secure water supply. These contributions are aligned with the GWP's long-term mission and goals to improve community health and preserve the rural lifestyle so central to the region.

Throughout Arizona, surface water rights are established by the doctrine of prior appropriation, commonly referred to as "first in time, first in right." Water that was first put to "beneficial use" is prioritized by state law as the imminent water right. During drought, whoever owns senior water rights are satisfied before those with more junior rights. Surface and groundwater use in the Upper Gila Watershed are also affected by a number of state and federal laws, court orders, and Congressionally-mandated settlements, namely the 1935 Globe Equity Decree No. 59, the San Carlos Apache Water Rights Settlements Act of 1992, Arizona Water Settlements Act of 2004, and the ongoing Gila River Stream Adjudication, which will adjudicate water rights not included in the aforementioned existing decrees or settlements (Mott Lacroix 2016)

Understanding water supplies in the region is difficult because of (1) lack of groundwater data and (2) complex regulations that do not apply uniformly across the watershed. Future water supplies are highly uncertain and affected by multiple variables (Figure 21). Most of the watershed could have either a deficit or surplus in their available water supplies, depending on the method used to calculate future supplies and demands. Through the study led by the University of Arizona Water Resources Research Center, stakeholders participated in the Water Supply and Demand Working Group, contributing data and expertise to the study in 2015. Participation in the Water Supply and Demand Working Group was open to all and included water users with expertise in municipal, farming, ranching, and mining water demand. This group did not, however, include representation from the San Simon region, making the figures presented for this region, particularly demand projections, speculative.

KEY TAKEAWAYS

- No feasible additional long-term supplies, except for *transfers between basins*; e.g., Morenci to Safford, however, there would not be a significant amount of extra water available through that avenue.
- Farming system is especially constrained, and the strict rules governing water use do not allow much room for flexibility or creative solutions. Of particular concern are the lack of return flow credits and the dis-incentives for water efficiency.
- Water use for many municipal, industrial, and irrigation wells in the watershed is capped based on the Arizona Water Rights Settlement Act. This limits the area's legally available water.
- Water use by domestic wells could be significant and is underreported.
- While water use by one does not necessarily mean the water is unavailable to another, affordable and high-quality water are increasingly questioned, considering uncertainty.
- Cooperation will be necessary in order to close the gap between water supplies and demands. The GWP is a well-placed and –equipped organization to play a crucial role.

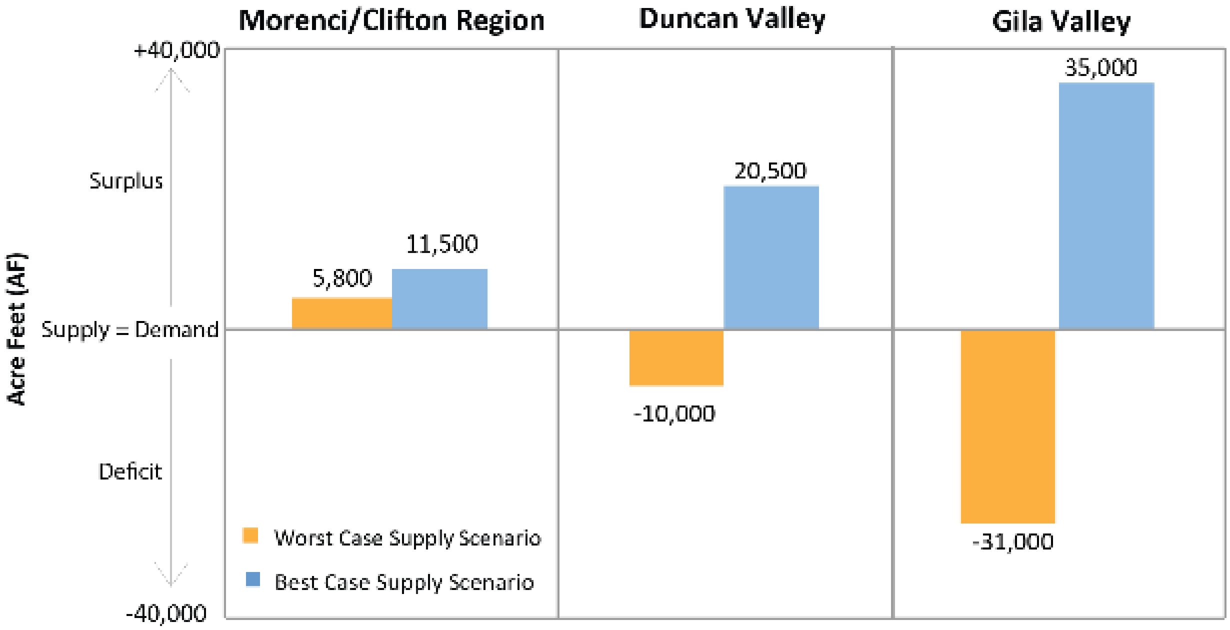


Figure 21. Water supply deficits looking 30 years into the future.

Water supplies

Quantifying the region's water supply proved to be a complex task requiring multiple strategies during the 2015 Water Supply and Demand Study led by the UA Water Resources Research Center. The approach used to calculate water supply can greatly impact the projected gap between water supply and demand. The estimations were based on four approaches: (1) Physically available water supply, (2) Legally available water supply, (3) Recently available water supply, and (4) 20% decrease in water supply. An approach that focused on *Physically Available Water Supply* would be based on stream gages for the determination of surface water (available through publicly released information from the Gila Water Commissioner's office), and for the determination of ground water based on 2009–2013 average pumping reports.

An approach informed by the *Legally Available Water Supply* would hone in on key components like the Globe Equity Decree, Arizona Water Settlements Act of 2004, and any other existing restrictions on diversions. Consideration of *Recently Available Water Supply* would also be a complicating factor, given the impact of the long drought. The Arizona Water Resource Development Commission's report offers insight into this situation. Potential impacts of different events, like the operationalization of the New Mexico CAP Unit or the varied consequences of a catastrophic flood, have been anticipated through an assumption of a *20% Decrease in Water Supply* (based on the Recently Available Water Supply estimate as a baseline). These four Water Supply approaches were taken in order to provide detailed and differentiated perspectives on water availability.

However, there can be a difference between "paper water" and "wet water"; one may have a legal water right, but whether that resource is actually available in the river or stream, or accessible from a groundwater well, may be a different story. The water supply data produced by WRRC quantify the estimated surface water and groundwater available in the watershed, compared with water that is legally available for use after accounting for regional water rights and obligations to downstream users. In addition to physically and legally available water, the amount of water recently available in the watershed was considered to account for the drought conditions of the past 16 years, as was a 20% reduction in water supply to account for uncertain impacts to water availability, such as persistent or worsening drought.

Water demand

Water use in the Upper Gila River Watershed is dominated by agricultural activities, especially in the Gila Valley where cotton production is highly active (Figures 22 and 23). The overall distribution of water demand among municipal, industrial, and agricultural water users resembles statewide water demand trends, with agricultural demand being somewhat higher compared to the statewide average of 74% (ADWR 2016). Between 2001 and 2006, an average of 91% of the surface water diversions and groundwater pumping were to meet agricultural water needs (ADWR 2016). Depending on the irrigation method, much of this water can return to the river or infiltrate through the soil into the aquifer. The more efficient the irrigation method, the less water will return to the river or aquifer. Water demand for industrial purposes, predominantly mining, makes up 4.5% of the demand in the watershed, the remaining 4% is used for municipal demand (Figure 22). In contrast to agriculture, industrial and municipal water uses are generally considered consumptive, as they return less water to the river or aquifer. An acre-foot of water for mining uses may, however, be used many times over. The amount of demand from domestic wells are not reported and therefore their contribution to overall water demand in the watershed is not well understood. The number of wells in the watershed have increased more than threefold over the last 60 years.

Overall, in the Upper Gila River Watershed water demand did not change significantly between 1991 and 2009, but there is year-to-year variability in the water demand by agricultural and mining users in particular (Bannister et al 2013). The proportion of groundwater versus surface water used in the watershed has fluctuated over time, with increased surface water use when it is more available and increased groundwater use when surface water is scarce.

Much of the watershed is subject to the provisions of the Arizona Water Right's Settlement Act. The full implications of this Act on water supply availability are too complex for this report. However, it is notable that most of the municipal, industrial and agricultural wells in the watershed are metered and the use of water from those wells is capped—e.g., no more than six acre-feet of water per acre for agricultural lands within the Act's decreed area.

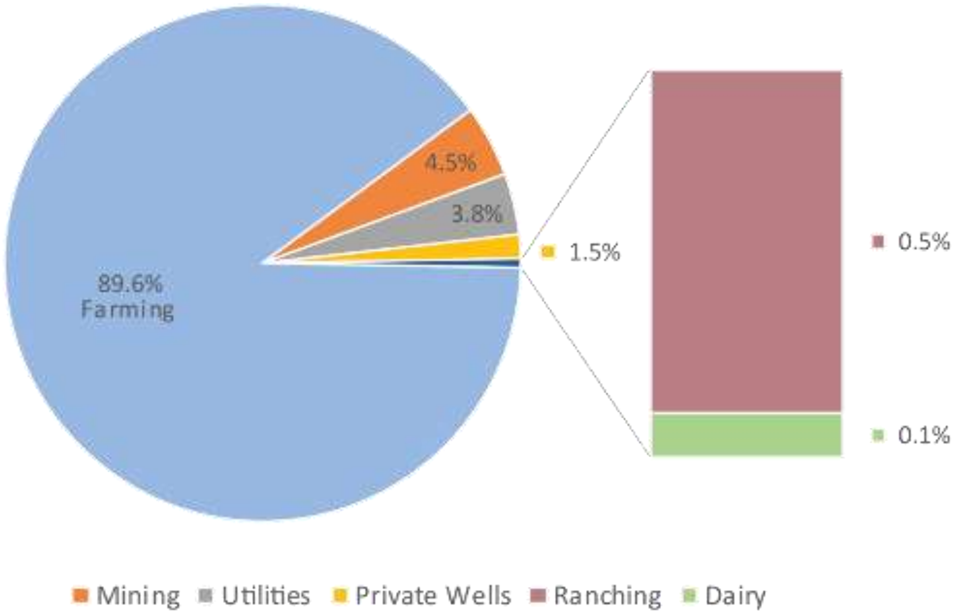


Figure 22. Water use defined by sector.

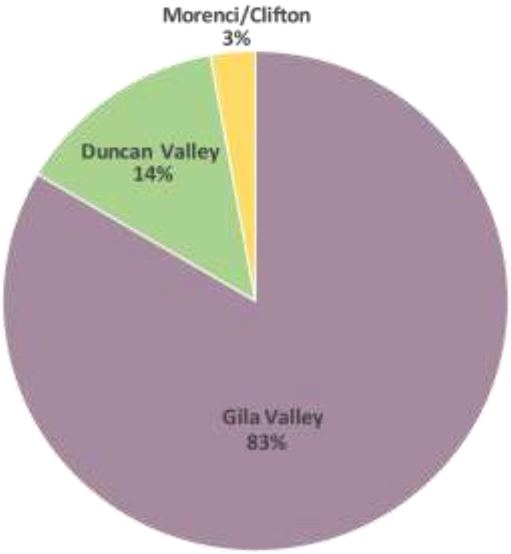


Figure 23. Water use defined by geographic areas.

WATER QUALITY

Access to reliable and reasonably clean supplies of water has been crucial to sustained human presence in the Upper Gila River Watershed for millennia. Particularly because of the arid climate and the long dry periods between the annual cycle of summer and winter rainfall, water has been a limiting factor on population growth and development. Modern technology has expanded the availability of water, with improved abilities to drill for water and transport it. As a result, certain areas have been settled and even irrigated when their former uses were more seasonal or transient in nature. Even so, the substantial cost of modern efforts to procure clean and reliable water supplies continues to influence land uses, underscoring the high value of water resources. The GWP has been successful in addressing water quality in the watershed with certain projects. This section will consider that success in context of the watershed-wide conditions.

KEY TAKEAWAYS

- The 2012 Watershed Improvement Plan for the San Francisco-Blue Rivers, produced by the GWP and partners, is an ongoing source of water quality information and instruction for the region.
- Fire continues to be an uncertain, but potentially devastating, threat to surface water quality in the region.
- While seeking to increase recreational opportunities, continued efforts must focus on waste disposal facilities at those sites.
- Public education must be ongoing to remind people that their water supplies are not completely self-cleaning, especially considering the level and types of activity around the river.
- Salinity continues to be an issue for farmers and residents of the area.
- More frequent and consistent testing of surface water chemical data is necessary to better characterize waters, particularly those designated ‘inconclusive’ by ADEQ in its 2016 report.
- The designation of impaired waters needs to be adjusted in order to remove stretches of the Gila River and its tributaries from the 303 list.

Surface Water

The ADEQ uses five categories to evaluate the status of a given water source, four of which have been observed in the Upper Gila River Watershed. These categories depend on the parameters tested and the frequency of testing. Attaining all uses (category 1) indicates that a full suite of parameters were tested a sufficient number of times with no exceedances reported at any time. Attaining some uses (category 2) is given for a water that recorded at least one exceedance, but in repeated sampling the exceedance was not consistent. Inconclusive (category 3) is given for a water which was not tested for enough parameters or frequently enough to determine water quality status. Impaired (category 5) is given for a waters that exceed criteria repeatedly. There were no waters with a Not Attaining Waters (category 4) status in the watershed. Surface water quality is designated impaired on the Gila in two places: just upstream of the confluence with the San Francisco and just downstream of the confluence with Bonita Creek. Cave Creek, in the San Simon Watershed in the Chiricahua Mountains is also designated impaired for selenium.

The Gila, San Francisco, Blue and San Simon Rivers as well as Bonita and Eagle Creek waterways make up a good portion of the water supply for the watershed's municipalities, industries, ranchers, farmers, and its wildlife that rely on riparian areas. Many of these rivers have seen a drop in seasonal flow due to lower winter snowpack levels as well as an increase in water quality issues over the years. The Blue, San Francisco, and Gila Rivers are all listed on the federal 303(d) impaired waters list due to *E. coli* exceedances and some are listed for sediment and lead. Although recreation is a large economic driver for our communities, there is risk for people who swim, fish and boat due to the water impairments seen throughout the watershed. The watershed has third highest miles of *E. coli* impaired rivers in the State of Arizona with a total of 56.9 miles (ADEQ - Water Quality Program 2016).

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)). In the past, 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 (Ajami et al 2005). 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) (Ajami et al 2005).

ADEQ placed river reaches of the San Francisco and Blue Rivers on the Clean Water Act 303(d) Impaired Waters List as impaired for the bacterium *Escherichia coli* (*E. coli*), based on testing results accumulated over years. Water quality monitoring professionals commonly use *E. coli* as an indicator for other waterborne pathogens that may pose more serious health risks to people (ADEQ 2012). Some members of the public are aware of waterborne pathogens and bacteria as well as parasites, amoebas and viruses. Salmonella is a well known for causing serious illness in humans; this bacteria is found in the intestinal tracts of animals and humans, as well as in contaminated water. Cryptosporidium and Giardia are parasites found in contaminated water that often cause gastro-intestinal and other illness (GWP 2012).

Typical sources of *E. coli* contamination:

- Recreation: Without toilet facilities or trash disposal, river stretches are vulnerable
- Livestock: Although widely restricted, cattle and sheep may frequent natural watering holes, which can affect some reaches
- Wildlife: Many kinds of wildlife visit the streams, accumulating in the uplands and washing into waterways during precipitation events
- Faulty or substandard septic systems: Most likely an issue during periods of heavy rainfall and resulting runoff

- Fire: For example, the 2011 Wallow Fire devastated 535,000 acres in Arizona and New Mexico, exacerbating later flooding and high loading of fine grasses and other sediments, also leading to higher levels of *E. coli*

The *E. coli* impairments along the San Francisco and Blue Rivers are attributed primarily to human and bovine fecal matter in the rivers (GWP 2012). These *E. coli* sources were confirmed by DNA testing completed in 2008 by the University of Arizona. A Watershed Improvement Plan (WIP) for the San Francisco and Blue Rivers was completed in 2012 with the guidance of the ADEQ and Watershed Improvement Council that included GWP (GWP 2012). As GWP finalizes two projects addressing human contributions of *E. coli* and other enteric pathogens, as were outlined in the WIP, we are looking ahead at the next steps in improving the water quality in this region. *E. coli* is identified by ADEQ as a pollutant for several reaches in the Upper Gila Watershed with primary sources identified by reach (Table 6). More testing is necessary to more accurately identify the primary source of contamination.

Table 6. Upper Gila Water Quality Monitoring (updated by ADEQ, 2017).

Reach	**Pollutant(s)**	**Common Primary Sources**	**Status**
Bonita Creek to Yuma Wash	E. coli, suspended sediment concentration (SSC)	agriculture, logging, septic systems, road crossings, permitted sources, grazing, others	E. coli and SSC TMDLs completed and approved by EPA in 2012 and 2013
New Mexico Border to Bitter Creek	E. coli and sediment	agriculture, logging, septic systems, road crossings, permitted sources, grazing, others	E. coli and SSC TMDLs completed and approved by EPA in 2012 and 2013
San Francisco River/Blue River	E. coli	recreation, livestock, wildlife, septic systems	WIP completed in 2012

Groundwater

The valleys of the Gila River and its tributaries are primarily made up of alluvial materials up to several thousand feet thick. A coarse, 100-foot thick, highly permeable aquifer lies under and along the main river channel (ADWR 2009). Beneath this younger alluvium is a finer grained material with locally concentrated salt (evaporite) deposits. Natural subsurface flow through the aquifer systems transmits salts to the Gila River, consequently increasing salinity in the water column; salinity levels are a major concern for water users in the Gila Watershed. Many statistically significant groundwater quality patterns were found between younger alluvium recharged by the Gila River and older alluvium and/or hard rock recharged by local precipitation. Total dissolved solids (TDS), major ions, nitrate, and boron concentrations were higher in younger alluvium than older alluvium and/or hard rock, while pH levels were lower in the younger materials and higher in the older materials. There were no noteworthy patterns involving arsenic and fluoride, the two most frequent constituents in exceedance in the watershed (ADEQ 2009).

The quality of groundwater has been studied in the Upper Gila River Watershed by the Arizona Department of Water Resources (ADWR) and ADEQ. These reports are inconsistent regarding the source of high levels of TDS, which is the main threat to water quality in the basin. The sources of TDS in the Safford Basin could be weathered dissolved geologic materials (particularly evaporites present in the Lower Basin Fill and Upper Basin Fill) or water where the TDS has been concentrated via evaporation (reducing the volume of water while leaving behind the dissolved materials). Additional theories include a lower artesian aquifer has high TDS which flows upward through faults to concentrate TDS in the Lower Basin Fill and Upper Basin Fill as well as downward migration of high TDS waters from irrigation runoff (data, summarized by Gootee (2012), do not show any correlation between depth of well and TDS). While the scale of riparian fires is very different, such fires can have direct and immediate impacts on water quality of shallow aquifer systems.

Chemical parameters that have exceeded minimum quality criteria for groundwater in the basin are: TDS, arsenic, fluoride, lead and nitrite. Many of these exceedances are located near the Safford-Pima corridor, upstream along the Gila as well as south along Highway 191. Many wells have more than one parameter with an exceedance value. Two wells were closed due to these contaminants, including Belleman and Thatcher Wells in 2000. The Wallen water report displayed improvement in groundwater quality since the records in the 1950 Hemp report.

Groundwater sample results for the Upper Gila Watershed are compared with the Safe Drinking Water Act (SDWA) water quality standards. Public water systems must meet these enforceable, health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. Primary MCLs are based on a daily lifetime (70 years) consumption of two liters of water (ADEQ 2009). While domestic well-owners are responsible for testing their own water, municipal and community supplies are tested regularly to comply with the SDWA. In the Upper Gila Watershed, targeted outreach and education efforts are best directed at private domestic well-owners so they are aware of risk factors and available information about their water.

TERRESTRIAL VEGETATION AND WILDLIFE

Vegetation in the Upper Gila River watershed influences and is influenced by a variety of biotic and abiotic factors. Vegetation provides habitat for terrestrial and riparian species, influences aquatic habitat quality, and helps control sediment delivery rates. Nine different biotic communities, or vegetation types classified according to Brown et al. (1979), have been mapped in the Arizona portion of the Upper Gila River Watershed (Banister et al. 2014; Table 7 and Figure 24). Slope, position, elevation, moisture, and temperature are the primary environmental factors affecting the distribution of these vegetation types within the watershed. The entire river-riparian corridor falls within the Sonoran Desert scrub and Chihuahuan Desert scrub communities, which occur on the river terraces and uplands. Riparian vegetation occurs along the river corridor and montane conifer forests are found in the higher-altitude mountain ranges (Orr et. al. 2014). Only 10% of the Arizona portion of the watershed is privately owned; large areas of the remaining land are managed by the U.S. Forest Service and BLM. Grazing is a major economic activity in the watershed, and in many areas wildlife shares the largely undeveloped land with cattle.

KEY TAKEAWAYS

- Special-status species protection may conflict with other land uses, including human water needs, development, agriculture, and recreation.
- Increased stressors on special-status species due to local extirpations in heavily developed areas outside the watershed may result in further restrictions on development in less developed portions of the watershed.
- Habitat destruction and fragmentation, non-native invasive species, and competing land uses restrict the movement and successful reproduction of wildlife species.
- Preserving habitat and wildlife corridors will maintain and improve dispersal, access to suitable habitat, population structure, and genetic diversity.
- Long term drought, land use conversion, non-native invasive species, wildfire, climate variability and increases in the number and severity of wildfires may affect habitat for plants and wildlife.

Table 7. Major vegetation types in the Upper Gila River Watershed in Arizona.[1]

Vegetation type	Percent of project area
Woodlands	
Great Basin Conifer Woodland	11.0%
Madrean Evergreen Woodland	13.5%
Petran Montane Conifer Forest	7.5%
Petran Subalpine Conifer Forest	0.1%
Shrublands	
Chihuahuan Desert Scrub	15.1%
Interior Chaparral	5.7%
Sonoran Desert Scrub	18.2%
Grasslands	
Plains and Great Basin Grassland	3.4%
Semidesert grassland	25.4%

[1] Source: Banister et al. 2014

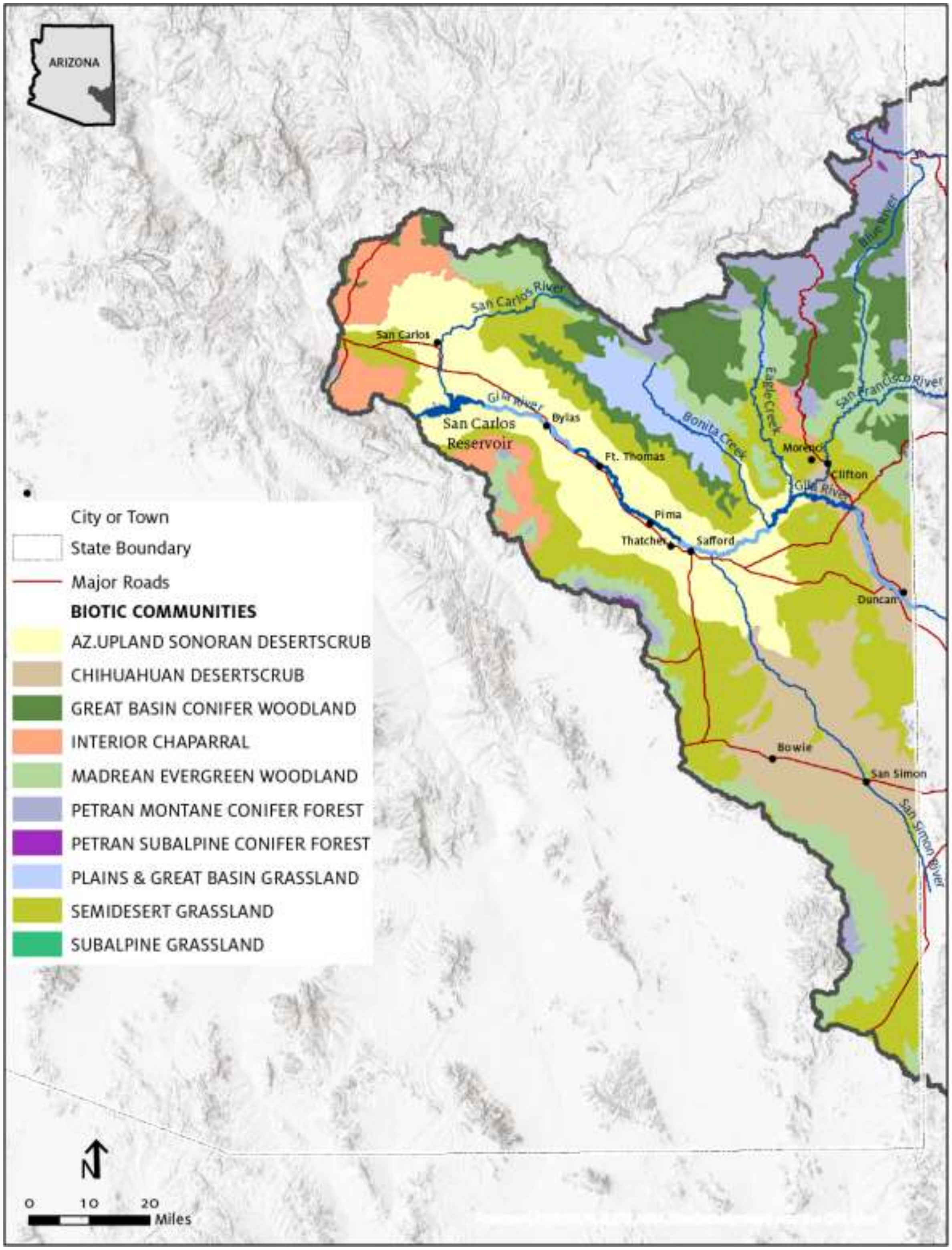


Figure 24. Biotic communities in the Upper Gila River Watershed in Arizona (Arizona Electronic Atlas 2009).

Each of the mapped vegetation types provides habitat for a rich assemblage of plants and wildlife, including native terrestrial and aquatic species listed as threatened or endangered under the Endangered Species Act. Twenty-one federally listed plant and wildlife species have the potential to occur in the Upper Gila River Watershed (Appendix B; USFWS 2018a). The U.S. Fish and Wildlife Service designates critical habitat (areas considered essential for survival) for each species listed as threatened or endangered; twelve species have designated critical habitat in the watershed: Gila chub, loach minnow, razorback sucker, spikedace, Chiricahua leopard frog, narrow-headed garter snake, northern Mexican garter snake, Mexican spotted owl, southwestern willow flycatcher, Mount Graham red squirrel, jaguar, and yellow-billed cuckoo. In addition, numerous plant and wildlife species are considered state-listed special-status species and have the potential to occur in the watershed; these species are listed in Appendix B (AGFD 2018). Descriptions of the vegetation types are provided in the following sections, including reference to any potentially associated federally-listed plant and wildlife species. Special-status species associated with riparian and aquatic habitats along the Upper Gila River mainstem are described in Appendix C.

Great Basin Conifer Woodland

Great Basin Conifer (pinyon-juniper) Woodlands cover large areas at elevations from about 5,000 to 7,500 feet (Arizona Department of Water Resources 2009) that receive about 12 to 20 inches of annual precipitation. Found mostly in northern Arizona and scattered parts of southeastern Arizona (McClaran and Brady 1994), the pinyon-juniper woodland zone is adjacent to and surrounds montane conifer forests in Arizona; in southern Arizona these woodlands merge with the chaparral zone (Arizona Department of Water Resources 2009). Dominant tree species include one-seed juniper (*Juniperus monosperma*), Utah juniper (*J. osteosperma*), and pinyon pine (*Pinus edulis*) (McClaran and Brady 1994); other pines and junipers may be present depending on geography. The understory may consist of grassland, chaparral, or desert scrub (Arizona Department of Water Resources 2009). This vegetation type provides habitat for the Mexican wolf which uses mid- to high-elevation woodlands of mixed conifers, oaks, and pinyon pines for foraging. Areas with perennial bunch grass in the understory and canyon topography may also support the Federally Threatened New Mexican ridge-nosed rattlesnake.

In the Upper Gila River Watershed, Great Basin Conifer Woodland covers 11% of land and is found north of the Gila River. The Federally Threatened Zuni fleabane (*Erigeron rhizomatus*) is found in Great Basin Conifer Woodlands at elevations from 7,300 to 8,000 feet on usually north-facing slopes (occasionally east- or west-facing) up to 40 degrees (USFWS 1988).

Madrean Evergreen Woodland

Madrean Evergreen Woodlands range widely from the mountains of southeastern Arizona (and northwest to Yavapai County), to southwestern New Mexico, the Trans-Pecos Texas, and southward into the Sierra Madre of Mexico. Species composition varies greatly depending on geography and elevation, but typically includes evergreen and deciduous oaks (*Quercus* spp.), alligatorbark (*Juniperus deppeanal*), one-seed juniper, and Mexican pinyon (*Pinus cembroides*). At higher elevations, other oak species as well as any of several Madrean pines (such as Apache pine [*Pinus engelmannii*], Chihuahua pine [*P. leiophylla*], Arizona pine [*P. arizonica* var. *arizonica*], pino triste [*P. lumholtzii*], Durango pine [*P. duranensis*], and Cooper's pine [*P. cooperi*]) become co-dominant or replace those from lower elevations. The vegetation type supports the Federally Threatened Mexican spotted owl which is generally found in dense, multi storied forests of mixed conifers and evergreens. It also provides habitat for the Mexican wolf.

In the Upper Gila River Watershed, Madrean Evergreen Woodland covers 13.5% of land, generally at elevations from 4,200 to 8,000 feet. Oak species characteristic of this community in southeast Arizona include silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Q. rugosa*) (Brown 1982). The Federally Endangered Arizona hedgehog cactus (*Echinocereus triglochidiatus* var. *arizonicus*) may be found in Madrean Evergreen Woodland where it is adjacent to Interior Chaparral, with a more open canopy. The hedgehog cactus is threatened by multiple human uses including road and utility construction, off-road vehicle use, and illegal collecting (Fletcher 1984).

Petran Montane Conifer Forest

Petran Montane (Rocky Mountain) Conifer Forests commonly occur between about 6,500 to 10,000 feet where moisture is relatively limited. At lower elevations, the forest may be exclusively ponderosa pine (*Pinus ponderosa*). At higher elevations, the forest contains a mix of conifers that may include Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), blue spruce (*Picea pungens*), and southwestern white pine (*Pinus strobiformis*), with ponderosa pine on warmer slopes. Aspen (*Populus tremuloides*) and Gambel oak (*Quercus gambelii*) are prominent in these forests following disturbances. (Brown 1982). Many stands of ponderosa pine are relatively open, with an understory of grasses, forbs, shrubs and broadleaf trees (Hendricks 1985). This vegetation type provides habitat for the Federally Endangered Mount Graham red squirrel which requires old-growth montane conifer forests and woodland.

In the Upper Gila River Watershed, Petran Montane Conifer Forest covers 7.5% of land and is most prevalent in the northeast portion, with small patches in the southern portion on the slopes surrounding Mt. Graham, Flys Peak, and Chiricahua Peak.

Petran Subalpine Conifer Forest

Petran Subalpine Conifer Forests are found at high elevations, from approximately 8,000 to 12,500 feet. These forests are typically composed of Engelmann spruce (*Picea engelmannii*), with subalpine/corkbark fir (*Abies lasiocarpa*) co-dominant. Aspen may be found in lower elevation areas following disturbance, and blue spruce is occasionally common in canyons and other lower-elevation locations. Limber pine and bristlecone pine (*Pinus aristata*) may be found on higher ridges, while wetter sites may contain Rocky Mountain maple (*Acer glabrum*), Bebb willow (*Salix bebbiana*), Scouler's willow (*Salix scouleriana*), blue elderberry (*Sambucus nigra* ssp. *cerulea*), thin-leaved alder (*Alnus incana* ssp. *tenuifolia*), or bitter cherry (*Prunus emarginata*) (Brown 1982). This vegetation type provides habitat for the Mexican wolf.

In the Upper Gila River Watershed, Petran Subalpine Conifer Forest accounts for just 0.1% of the area and is found in the mountains surrounding the community of Alpine in the northeast portion of the watershed, as well as in the southeast around Mt. Graham and between Flys Peak and Chiricahua Peak.

Chihuahuan Desert Scrub

The Chihuahuan Desert Scrub covers large expanses of land from southeast Arizona to southwest Texas and south to north-central Mexico. Generally found at elevations from 1,300 to 5,000 feet throughout its range (Brown 1982), but mostly above 3,500 feet in Arizona (Hendricks 1985), the most common species are creosote bush (*Larrea tridentata*), tarbush (*Flourensia cernua*), whitethorn acacia (*Acacia neovernicosa*) (Brown 1982), and sandpaperbush (*Mortonia scabrella*), often forming nearly pure stands of each (Hendricks 1985). Various agave (*Agave* spp.), beargrass (*Nolina* spp.), yucca (*Yucca* spp.), and a variety of woody shrubs may be present (Brown 1982), as well as a diverse assemblage of herbaceous perennials and small cacti (Hendricks 1985). This vegetation type provides habitat for northern aplomado falcon and the Federally Endangered jaguar which both hunt in the desert scrublands of southeastern Arizona. Ocelots, a Federally Endangered species, are also known to use this vegetation type in areas where stand density is high providing adequate cover for foraging.

In the Upper Gila River Watershed, Chihuahuan Desert Scrub is near its northwestern extent, and may occasionally grade into Sonoran Desert vegetation types. It is found throughout the upstream end of the Gila Box, as well as large expanses of the southern portion of the watershed, covering a total of 15.1% of the area.

Interior Chaparral

Interior Chaparral is found throughout Arizona to Texas and south into Mexico, growing at elevations ranging from 3,000 to 8,000 feet, below woodland or coniferous forest and above grassland or desert scrub. Interior Chaparral consists of deep-rooted evergreen shrubs and trees that have broad, sclerophyllous leaves. Of the over 50 shrub species in this community, the most common include shrub live oak (*Quercus turbinella*), sugar sumac (*Rhus ovata*), hollyleaf buckthorn (*Rhamnus crocea*), manzanitas (*Arctostaphylos* spp.), birchleaf mountain mahogany (*Cercocarpus breviflorus*), yellowleaf silktassel (*Garrya flavescens*), brickellbush (*Brickellia californica*), California flannelbush (*Fremontodendron californicum*), and ceanothus (*Ceanothus* spp.) (Brown 1982). Shrub canopy cover ranges from 80% or more on wetter sites, to 40% on dryer sites, where annual and perennial grasses and forbs may be found more commonly (Hendricks 1985).

In the Upper Gila River Watershed, Interior Chaparral covers 5.7% of the land, and is primarily found in the northwestern portion with an additional patch stretching northwest from Morenci Mine, at elevations from 3,400 to 7,000 feet. The Federally Endangered Arizona hedgehog cactus (*Echinocereus triglochidiatus* var. *arizonicus*) may be found in Interior Chaparral where it has a more open canopy, adjacent to Madrean Evergreen Woodland.

Sonoran Desert Scrub

Where it occurs in Arizona, Sonoran Desert Scrub is sparsely vegetated, composed of low-growing trees, shrubs, cacti, and perennial herbs. Common species include saguaro (*Carnegiea gigantea*), palo verde (*Cercidium spp.*), bursage (*Ambrosia spp.*), and creosote bush (McClaran and Brady 1994). This vegetation type provides habitat for the lesser long-nosed bat and the Mexican long-nosed bat which are both Federally Endangered and both feed on the saguaro cactus and other desert scrub plants. In addition, the northern aplomado falcon and Federally Endangered jaguar use desert shrublands for foraging.

In the Upper Gila River Watershed, Sonoran Desert Scrub is found from 2,350 to 4,700 feet in elevation. It occupies 18.2% of land in the watershed and is the dominant vegetation type along the Gila River in the lower half of the upstream end of the Gila Box and throughout the downstream end to below the reservoir. The Federally Endangered Arizona cliffrose (*Purshia subintegra*) is found in Sonoran Desert Scrub, and is threatened by grazing, urbanization, pesticides, inundation, off-road vehicle use, and development activities associated with petroleum and mineral exploration, roads, and utility corridors (USFWS 1995). Wright’s marsh thistle (*Cirsium wrightii*) is a Candidate Species for listing as Federally Endangered or Threatened and has the potential to occur in Sonoran Desert Scrub, though it is thought to now be extirpated from Arizona. It is typically found in seeps, marshes, and edges of streams and ponds, and is threatened by loss of habitat due to alteration of hydrology, introduced plants, drought, and cattle impacts (USFWS 2018b).

Plains and Great Basin Grassland

Plains and Great Basin Grasslands are scattered throughout the southwest, from southern Colorado and northwestern Texas to west-central Arizona and south into Chihuahua, Mexico (Brown 1982). Primarily composed of mixed or short-grass communities, Plains and Great Basin Grasslands are widespread at elevations generally from 5,000 to 7,000 feet that receive an average of 17 inches of rain per year (Hendricks 1985). Eurasian annual species such as cheatgrass (*Bromus tectorum*) have largely replaced the native bunchgrasses, and portions of the grasslands are being colonized by shrubs due to grazing and fire-suppression practices (Grahame and Sisk 2002). In Arizona, plains grasslands consist primarily of short grama grasses (*Bouteloua* spp.), blue oat grass (*Helictotrichon sempervirens*), and black oat (*Avena strigose*), with shrub species absent or nearly absent (Hendricks 1985). The grasslands of southeastern Arizona provide hunting habitat for the northern aplomado falcon which also inhabits oak savannah and desert shrublands.

In the Upper Gila River Watershed, Plains and Great Basin Grasslands are found on 3.4% of the land at elevations from 4,800 to 6,700 feet. The largest segment is in the San Carlos Reservation; several smaller segments are located to the northeast.

Semidesert Grassland

Semidesert Grasslands are found from Trans-Pecos Texas to southeast Arizona and south into Mexico. These grasslands are located at higher elevations than desert scrub, and lower elevations than evergreen woodland, chaparral, or plains grassland. Semidesert Grasslands were originally dominated by perennial bunchgrasses (Brown 1982). However, drought and heavy grazing by cattle, sheep, and goats have contributed to the evolution of these grasslands into semi-arid mixed high desert (Gila Watershed Partnership 2012), while elsewhere the grasslands face competition from a variety of tree, shrub, and cactus life-forms. The most characteristic perennial grass species are tobosa grass (*Pleuraphis mutica*) and black grama (*Bouteloua eriopoda*) (Brown 1982). The grasslands of southeastern Arizona provide hunting habitat for the northern aplomado falcon which also inhabits oak savannah and desert shrublands.

In the Upper Gila River Watershed, Semidesert Grassland is the most abundant vegetation type, occupying 25.4% of the land. It is found at elevations from 3,300 to 6,200 feet in large patches throughout the watershed, except it is not found in the northeast portion. Wright's marsh thistle (*Cirsium wrightii*) is a Candidate Species for listing as Federally Endangered or Threatened, and has the potential to occur in Semidesert Grassland, though it is thought to now be extirpated from Arizona.

Invasive species

Certain non-native invasive species are of particular concern due to their potential to spread explosively and ability to impact wildlands, which may cause serious ecological impacts to plant and animal communities. Within the Upper Gila River Watershed, particularly noxious terrestrial plants include non-native annual grasses, buffel grass (*Pennisetum ciliaris*), bull thistle (*Cirsium vulgare*), giant reed (*Arundo donax*), musk thistle (*Carduus nutans*), onion weed (*Asphodelus fistulosus*), Russian knapweed (*Acroptilon repens*), Russian thistle (*Salsola tragus*), Sahara mustard (*Brassica tournefortii*), Scotch thistle (*Onopordum acanthium*), sweet resin bush (*Euryops multifidus*), tocalote or Maltese star-thistle (*Centaurea melitensis*), and yellow star-thistle (*Centaurea solstitialis*) (AGFD 2012b and Brandau, personal communication). Information on these documented plant species is provided in Table 8 as well as the *Riparian habitat* section for tamarisk.

Table 8. Noxious terrestrial plants known to occur within Upper Gila River Watershed.

Scientific name	Common name	Status[1] (Arizona/USDA)	Family	Lifeform	Location within Upper Gila River Watershed	Ecological threat[2]
Acroptilon repens	Russian knapweed	PNW, RNW/–	Asteraceae	perennial herb		Can cause chewing disease in horses. Native to Eurasia; introduced into the United States in the early 1900s.
Arundo donax	giant reed	–/–	Poaceae	perennial grass		Invades wetlands; competes for water, nutrients and radiation; suppresses and excludes native vegetation which degrades wildlife habitat, increases fire risks, and interferes with flood control. Native to India; introduced into the United States in the early 1800s for ornamental purposes.
Asphodelus fistulosus	onion weed	–/noxious	Asphodelaceae	annual to short-lived perennial herb		Found in roadsides, pastures, disturbed areas, grasslands, and suburban settings; drought resistant and prefers sandy or gravelly soils. Native to the Mediterranean region and from western Asia to northern India.
Brassica tournefortii	Sahara mustard	–/–	Brassicaceae	annual herb		Prefers disturbed areas such as roadsides and abandoned fields. Native to Africa, Asia, and Europe.
Carduus nutans	musk thistle	–/–	Asteraceae	biennial herb		Invades a variety of disturbed areas. Unpalatable to livestock. Once established, can spread rapidly due to high seed production (120,000 seeds/plant). Native to Western Europe; accidentally introduced into the United States in the early 1900s.
Centaurea melitensis	tocalote or Maltese star-thistle	–/–	Asteraceae	annual herb		Prefers disturbed areas such as grasslands, open woodlands, roadsides, fields, and pastures. Native to Europe and North America.
Centaurea solstitialis	yellow star-thistle	PNW, RNW/–	Asteraceae	annual herb		Invades woodlands, fields, pastures and roadsides.

Scientific name	**Common name**	**Status[1] (Arizona/USDA)**	**Family**	**Lifeform**	**Location within Upper Gila River Watershed**	**Ecological threat[2]**
Cirsium vulgare	bull thistle	–/–	Asteraceae	annual or biennial herb		Invades disturbed areas including forest clearcuts, riparian areas, and pastures. Can form dense thickets, displacing other vegetation. Unpalatable to wildlife and livestock and reduces the forage potential of pastures. Native to Europe, western Asia, and northern Africa; thought to have been introduced to the eastern United States during colonial times and the western United States in the late 1800s.
Euryops multifidus	sweet resin bush	RNW/–	Asteraceae	shrub		Displaces native plants and forms monospecific stands. Native to Africa; introduced to the United States in 1930s (Invasive Species Specialist Group 2015).
Onopordum acanthium	Scotch thistle	PNW, RNW/–	Asteraceae	biennial herb		Major agricultural weed in western United States. With enough moisture, it can resprout from roots cut up during cultivation. Produces over 20,000 seeds that can be dispersed by wind, water, or animal fur.
Pennisetum ciliare (also referred to as *Cenchrus ciliaris*)	buffel grass	PNW, RGNW/–	Poaceae	perennial grass		Can form extensive dense monocultures excluding native species and promoting intense and frequent fires. Native to Africa, Asia, and Europe (Invasive Species Specialist Group 2015).
Salsola tragus	Russian thistle	–/–	Chenopodiaceae	annual herb		After matures, detaches from the root system and tumbles in the wind, spreading seed. Native to Eurasia.
Tamarix ramosissima and other *Tamarix* species or hybrids	tamarisk	–/–	Tamaricaceae	Shrub		Invades stream banks, sandbars, lake margins, wetlands, moist rangelands, and saline environments. Can crowd out native riparian species, diminish early successional habitat, and reduce water tables; interferes with hydrologic process.

Scientific name	Common name	Status[1] (Arizona/USDA)	Family	Lifeform	Location within Upper Gila River Watershed	Ecological threat[2]
n/a	non-native annual grasses	Various/–	Poaceae	annual grass	widespread	Replace native grassland and shrublands, increase fire risk, reduce diversity

[1] Status

–	Not rated
Arizona	
PNW	Prohibited noxious weed
RGNW	Regulated noxious weed
RNW	Restricted noxious weed
U.S. Department of Agriculture (USDA) federal noxious weed list	
noxious	Listed on the federal noxious weed list

[2] Source: Swearingen and Bargeron 2016 (unless otherwise cited).

RIPARIAN AND AQUATIC HABITATS

Riparian areas in Arizona and throughout the southwest are important habitats for wildlife and are considered the most productive and ecologically diverse habitats in the state (AZGFD 2012). Riparian areas provide fish and wildlife habitat, water supply to livestock, serve as wildlife movement corridors, and provide a variety of ecological functions and ecosystem services such as moderating local air temperature and humidity, stabilizing stream banks, contributing nutrients to streams, attenuating flood waters, and providing recreational opportunities and aesthetic enjoyment for humans. Riparian communities and aquatic habitat make up less than 2% of the total land area in the arid western United States, but in Arizona 70% of all threatened and endangered vertebrate species (AGFD 2012b) and up to 80% of all species depend on riparian areas.

KEY TAKEAWAYS

- Riparian and aquatic habitats are unique and valuable ecosystems that warrant special protection, conservation, and in some cases restoration to preserve their ecological functions and ecosystem services that benefit fish, wildlife, and humans.
- Special-status species protection may conflict with other land uses, including human water needs, development, agriculture, and recreation.
- Particular threats to riparian and aquatic systems include drought, recreational use, water diversion, and non-native invasive species.
- Fish are disproportionately at risk in the watershed, as evidenced by the occurrence of designated critical habitat for four native fish species.
- Streams in the watershed are "free-flowing" but aquatic habitat connectivity is interrupted by many small dams.
- The watershed may bear a disproportionately large portion of the burden of protecting endangered species; i.e., development in the relatively pristine portions of the watershed might be limited because species have previously suffered extirpation in more heavily developed areas.
- Preserving riparian habitat will maintain and improve dispersal, access to suitable habitat, population structure, and genetic diversity of a variety of species and will provide valuable ecosystem services that benefit humans.
- Invasive species, such as tamarisk (salt cedar) and Russian knapweed, compete with native species for resources in the watershed and can negatively impact human uses.
- The recently introduced tamarisk leaf beetle is projected to reach the watershed in the near future but, based on data through 2017, has not yet done so. It is expected to defoliate tamarisk trees leading to some mortality, a decrease in cover, and a reduction in flower/seed production. The beetle also poses a potential threat to the Southwestern Willow flycatcher (SWFL), a Federally Endangered bird species that uses the non-native trees as habitat. Defoliation of tamarisk may also impact ecosystem services including human recreational use and aesthetic enjoyment.
- Because high quality SWFL habitat corresponds strongly with vegetation density and the riparian vegetation is mostly composed of tamarisk, it is anticipated that these areas will experience the greatest impact initially following beetle colonization unless strategic planting of native vegetation is undertaken prior to arrival of the beetle.
- Declining groundwater levels will eventually reduce the amount of surface water available for fish, wildlife, and human uses.

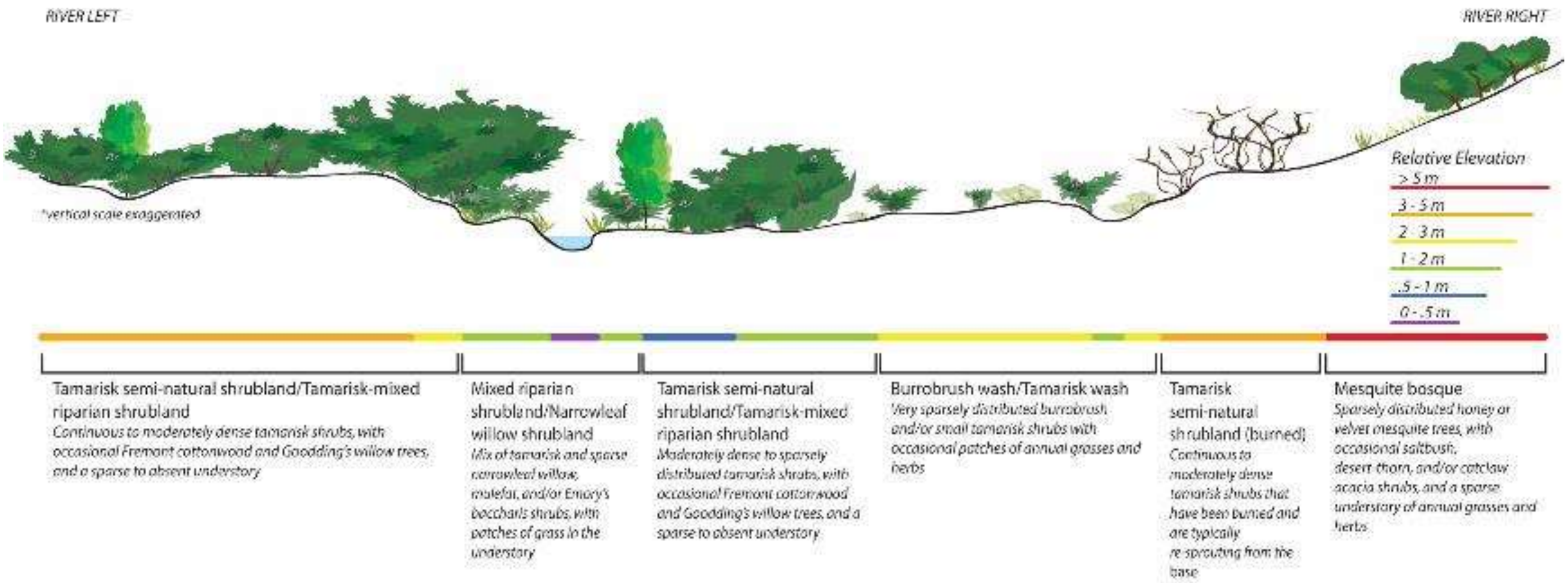
Riparian and aquatic habitats in Arizona have been changed considerably from their pre-settlement condition. Among the major sources of impact are persistent drought, impacts to riparian areas and uplands from livestock management, and introduction of non-native species (AGFD 2012b). Other landscape changes and land/water uses that have impacted riparian and aquatic systems include wildfire, stream diversions and impoundments, vegetation removal, pollution, and recreational activities. Drought conditions in Arizona have recently been at their most extreme within recorded history, resulting in the drying of formerly perennial springs and reduced surface water supply and groundwater recharge (AGFD 2012b). The reduced availability of water resources substantially impacts aquatic and riparian habitat functions and the species that depend on them.

Despite widespread impacts to aquatic and riparian systems in Arizona, the Upper Gila River Watershed contains areas of these habitats that remain relatively unaltered and continue to support native species and provide important ecological functions.

Riparian habitat

The Gila River flows free of large dams above the San Carlos Reservoir and sustains several perennial stretches that provide riparian and aquatic habitat for numerous plants and animals. Generally, riparian areas in portions of the upper watershed are richly vegetated with cottonwoods, native willows, sedges and grasses while other areas are dominated by the invasive tamarisk (*Tamarix ramosissima* and other *Tamarix* species or hybrids, herein referred to as "tamarisk") (Gila Watershed Partnership 2012). In the riparian communities within the Upper Gila River watershed, variation in vegetation composition and structure occurs both along the river length and across the valley width. The description of riparian habitat provided here is based largely on information for the mainstem Gila River corridor in the upper portion of the watershed, as little information is available on riparian habitat in the tributaries.

The densest riparian vegetation along the upper Gila River is generally found at downstream locations due to the agricultural return flows and areas in closest proximity to the river due to the availability of surface water or shallow groundwater. Historically, the river bottom was lined with willow (*Salix* spp.), cottonwood (*Populus* spp.), and mesquite (*Prosopis* spp.) based on surveys made in the mid- to late-1800s (Burkam 1972, Turner 1974, Webb et al. 2007). Recent research by the BLM suggests that giant sacaton (*Sporobolus wrightii*) may have also been a dominant plant species in some riparian bottomlands. Most of the native riparian vegetation was severely scoured during the 1905–1909 flood period and subsequently replaced by tamarisk soon after its introduction in the early 1920s (Burkham 1972). Tamarisk was planted along the river channel to control riverbank erosion and protect adjacent cultivated fields. In the Safford Valley, tamarisk has replaced most of the native riparian vegetation and associated habitat over the last century and continues to be the dominant tree species in the riparian corridor (Figure 25). Tamarisk can change the soil under the trees by increasing the soil salinity, reducing the ability of other plant species to grow there. Tamarisk density in riparian areas can range widely, from nearly continuous to only 10% tamarisk cover, and canopy heights are typically no more than 16 feet (Stillwater Sciences 2014). Some isolated stands of native species, including Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), narrowleaf (coyote) willow (*Salix exigua*), mulefat (*Baccharis salicifolia*), desert broom (*B. sarothroides*), Emory's baccharis (*B. emoryi*), and mesquite (*Prosopis glandulosa* and/or *P. velutina*) persist at low cover densities (Orr et al. 2014).



Tamarisk semi-natural shrubland/Tamarisk-mixed riparian shrubland
Continuous to moderately dense tamarisk shrubs, with occasional Fremont cottonwood and Gooddings's willow trees, and a sparse to absent understory

Mixed riparian shrubland/Narrowleaf willow shrubland
Mix of tamarisk and sparse narrowleaf willow, mulefat, and/or Emory's baccharis shrubs, with patches of grass in the understory

Tamarisk semi-natural shrubland/Tamarisk-mixed riparian shrubland
Moderately dense to sparsely distributed tamarisk shrubs, with occasional Fremont cottonwood and Gooddings's willow trees, and a sparse to absent understory

Burrobrush wash/Tamarisk wash
Very sparsely distributed burrobrush and/or small tamarisk shrubs with occasional patches of annual grasses and herbs

Tamarisk semi-natural shrubland (burned)
Continuous to moderately dense tamarisk shrubs that have been burned and are typically re-sprouting from the base

Mesquite bosque
Sparsely distributed honey or velvet mesquite trees, with occasional saltbush, desert thorn, and/or catclaw acacia shrubs, and a sparse understory of annual grasses and herbs

Figure 25. Illustration of the typical cross-sectional distribution of vegetation in the Gila River valley downstream of Pima, looking downstream (illustration by Stillwater Sciences).

There are also stands of cottonwood-Goodding's willow woodland in the Upper Gila River, typically along the outer margin of the riparian corridor and the banks of abandoned and/or high flow channels, which form a dense, high canopy 15–30 ft tall. Most cottonwood and Goodding's willow trees are mature or decadent, appearing to have been established soon after the 1983 and 1993 flood events, and there appears to be very little to no recent natural recruitment of either species. Tamarisk, and less often mesquite, still dominates the sub-canopy in these stands. In general, the herbaceous layer is very sparse to absent and the ground layer has a moderate cover of downed wood and other organic litter. Cottonwood-Goodding's willow woodland typically occurs where substrates are silty or sandy and generally dry, and at elevations where they are frequently inundated by floods of lower magnitude but are not subject to intense scouring (Stillwater Sciences 2014).

Riparian vegetation provides habitat for many species in the watershed including seven federally listed species: Chiricahua leopard frog, narrow-headed garter snake, northern Mexican garter snake, least tern, southwestern willow flycatcher, yellow-billed cuckoo, and New Mexico meadow jumping mouse. Each of these species is dependent on the habitat features provided by riparian vegetation during some or all of its life cycle. The relatively large number of special-status species in this vegetation type highlights the importance of riparian habitat for conservation of biodiversity. Further information regarding species of special concern for riparian restoration in mainstem portions of the Upper Gila River can be found in Appendix C.

Aquatic habitat

Aquatic habitat in the Upper Gila River Watershed occurs mainly as flowing water in rivers and streams, but springs, seeps, cienegas, stock ponds, and natural ponds and lakes (including beaver ponds) also provide habitat for aquatic species in the watershed. Perennial and intermittent waters above 5,000 ft elevation may be designated by ADEQ as providing cold water aquatic and wildlife uses, whereas waters below 5,000 ft elevation can be designated for warm water aquatic and wildlife uses. The majority of surface waters in the upper Gila River with designated aquatic and wildlife uses are in the warm water category. Cold water aquatic and wildlife uses in the watershed are designated only in the highest elevation headwater streams. A surface water (e.g., stream) may be designated as an Outstanding Arizona Water if it is free flowing, has good water quality, and is of exceptional recreational or ecological significance and/or provides essential habitat to support a threatened or endangered species. The lowermost 14.7 miles of Bonita Creek and the entirety of KP Creek, a headwater tributary of the Blue River, are designated Outstanding Arizona Waters in the Upper Gila River Watershed.

The mainstem Upper Gila River downstream of the Gila Box is characterized by a wide, low gradient channel composed predominantly of sand and lesser amounts of gravel substrate. Several agricultural diversions are located within this section of the Gila River that partially contribute to decreased flows in downstream sections of the river. The river in this area provides perennial aquatic habitat that supports fish and other aquatic and semi-aquatic species. Streamflow is typically greatest in the winter and lowest in the summer, but high intensity and short-duration high flow events often occur during the summer when flows rise quickly and can exceed 50,000 cfs or more for a few hours to a few days. Within the Gila Box, the river becomes more confined with coarser gravel substrate (Orr et al. 2014). Perennial flows persist year-round in the Gila Box reach, with a similar seasonal pattern as described in the downstream reach. Three large perennial tributaries enter the Gila in this section including Bonita Creek, Eagle Creek, and the San Francisco River. Upstream of the Gila Box the river flows through the Duncan Valley where the channel is relatively wide with primarily sand substrate. Several diversions are located within this reach and flows often become intermittent during the summer months with all surface flow diverted during dry years (ADEQ 2002).

Major tributaries to the Upper Gila River include San Simon River, Bonita Creek, Eagle Creek, and the San Francisco River. Although considered a major tributary, the San Simon River provides little to no flow during the summer. The San Simon River is a low gradient ephemeral river that enters the Gila downstream of the Gila Box near the town of Solomon. Because it is often dry it is expected to provide little if any aquatic habitat for fish. Bonita Creek is a perennial tributary that enters the Gila River at the downstream end of the Gila Box about ten miles upstream of the Safford Valley. Bonita Creek flows for approximately 48 miles before joining the Gila River. Infiltration galleries for a public water system are located in Bonita Creek approximately four miles above its confluence with the Gila River (Hem 1950, as cited in ADEQ 2002). Bonita Creek is recognized as one of the state's outstanding resource waters and it is designated as a "Unique Water" (ADEQ 2002). Stream flows in Bonita Creek are largely perennial with some intermittent stretches. Bonita Creek has a similar seasonal pattern as most other streams in the Upper Gila River Watershed, with low summer flows and higher winter flows. Eagle Creek, another perennial tributary, empties into the Gila River about two miles downstream from the confluence of the San Francisco River. Flow in Eagle Creek is supplemented by a water transfer from the Black River, a tributary to the Salt River. The water is subsequently pumped from Eagle Creek to Morenci and Clifton, Arizona where it is used for mining purposes and municipal supply (Hem 1950, as cited in ADEQ 2002). The San Francisco River watershed is the largest tributary to the Gila River, with perennial flows averaging 200 cfs to 400 cfs during the winter and 50 cfs to 100 cfs during the summer. The Blue River is a major tributary to the San Francisco River which enters approximately 18 miles upstream of the town of Clifton. Numerous tributaries to the San Francisco River and the Blue River provide coldwater habitat that supports trout and other native fish species (USFWS 2011).

Aquatic Species

Aquatic habitat within the Upper Gila Watershed supports numerous native and non-native fish species. Five threatened or endangered fish species occur within the upper Gila River, four of which have designated critical habitat in the watershed: Gila chub (*Gila intermedia*), loach minnow (*Tiaroga cobitis*), spikedace (*Meda fulgida*), and desert pupfish (*Cyprinodon macularius*). Although no longer found in the Upper Gila River, critical habitat has been designated for the endangered razorback sucker (*Xyrauchen texanus*). One additional listed fish species, the Gila topminnow (*Poeciliopsis occidentalis*) also occurs in the Upper Gila River Watershed on land managed by BLM (H. Blasius, BLM, pers. comm., June 2018). Gila trout (*Oncorhynchus gilae*) do not currently occur in the mainstem Gila River or its tributaries, but there are plans to stock them in some tributaries to the Blue River (H. Blasius, BLM, pers. comm., June 2018). . Listing status and a brief description of their habitat association for these species is included in Appendix B. Other native fish species found in the Upper Gila Watershed include roundtail chub (*Gila robusta*), desert sucker (*Pantosteus clarkii*), Sonora sucker (*Catostomus insignis*), longfin dace (*Agosia chrysogaster*), and speckled dace (*Rhinichthys* o*sculus*).

Numerous non-native primarily warm water fish species also occur within the Upper Gila River Watershed. Channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and sunfish (*Lepomis* spp.) have been documented in San Carlos Reservoir (BOR 2004). and likely occur throughout most of the upper Gila River based on other observations reported in the San Francisco River (USFWS 2011). Fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), bullheads (*Ameiurus* spp.), and rainbow trout (*Oncorhynchus mykiss*) are also reported to occur in the San Francisco River (USFWS 2011). Western mosquitofish (*Gambusia affinis*) are also expected to occur throughout most of the mainstem and lower sections of most tributaries based on Whittier et al. (2011), although observations were not reported in San Carlos Reservoir or in the San Francisco River (BOR 2004 and USFWS 2011).

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Appendices

Appendix A

Watershed Condition Indicators Worksheet

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
Water quality – impaired waters	University of Arizona (Natalie Brassill, Dr. Channah Rock)	Water sample collection to detect E. coli bacteria and turbidity as well as other water quality health components, river clean ups, education and outreach and planting of native species to slow overland flow	4	San Francisco - Blue confluence (impaired from E. coli bacteria)	Ongoing (combine efforts with native plantings to reduce erosion and allow more water infiltration to help reduce E. coli bacteria)
	ADEQ Water Quality Unit				
	BLM	Suspended sediment monitoring		San Simon River	Past and Future
Water quality – other	BLM	Water Quality Monitoring; salinity monitoring of soils and groundwater wells in San Simon River valley; salinity monitoring of suspended sediment in San Simon (future).		Gila Box, San Simon	Ongoing
		Suggested: UA (N. Brassill) can provide DNA source tracking to identify which species maybe causing impairments			
Water quantity – flow characteristics	USGS				
		Suggested: UA (N. Brassill) can measure flow when taking water samples using a flow meter and referencing USGS meters			
	BLM	Proper Functioning Condition Assessments; Stream gage (San Simon);		Through out the field office: Perennial and intermittent	Ongoing

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
		Rosgen classifications of streams including stream characteristics, flows, profiles, etc		streams; Springs/seeps supporting riparian biodiversity.	
Aquatic habitat – fragmentation					
Aquatic habitat – large woody debris	BLM	Proper Functioning Condition assessments			Ongoing
Aquatic habitat – channel shape and function	BLM	Proper Functioning Condition assessments			Ongoing
Aquatic biota - life form presence	BLM	Fish Surveys		Gila Box San Simon	Ongoing
Riparian vegetation – vegetation condition	BLM	Proper Functioning Condition assessments			Ongoing
Roads & trails – open road density	BLM	Travel Management Planning Resource Review		Gila San Simon	Ongoing
Roads & trails – road maintenance					
Roads & trails – proximity to water	BLM	Travel Management Planning Resource Review		Gila San Simon	Ongoing
Roads & trails – mass wasting					
Soils – soil productivity		Suggested: Plant native veg to help infiltrate water and bacteria			

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
Soils – soil erosion	BLM	Sediment traps and erosion monitoring		San Simon River Valley; Field Office Jurisdiction	Ongoing
	BLM	Suspended sediment monitoring			Past and future
	BLM	San Simon channel cross-sections			Ongoing
	BLM	Rangeland monitoring including soils			Ongoing
	BLM	Proper Functioning Condition Assessments			Ongoing
Soils – soil contamination					
Fire regime or wildfire – fire condition class					
Fire regime or wildfire – wildfire effects					
Forest cover – loss of forest cover					
Rangeland vegetation – vegetation condition	BLM	Rangeland health monitoring		Field Office	Ongoing
Terrestrial invasive species – extent and rate of spread	BLM	NISIMS data collection-National Invasive Species Information Management System (geospatial database for invasive species treatments,		Field Office	Ongoing

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
		occurrence and extent)			
Other watershed condition indicator	BLM	Recording rain gages for watershed characteristics: runoff, sediment monitoring in San Simon, etc.		Field Office	Ongoing
Other watershed condition indicator					

Appendix B

Special-status Species and Critical Habitat with Potential to Occur in the Upper Gila River Watershed

Table B-1. **Special-status species with potential to occur or with critical habitat designated within the upper Gila River Watershed Assessment Plan Area.**

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Fish			
Razorback sucker *Xyrauchen texanus*	E	Y	Razorback sucker has been extirpated from the Upper Gila River Watershed but critical habitat for the species is designated within the watershed. Occupies a variety of habitat types from mainstem channels to slow backwaters of medium and large streams and rivers.[1] Spawns over gravelly substrates in lakes and rivers.[2]
Gila chub *Gila intermedia*	E	Y	Pools in smaller streams, springs, and cienegas (desert wetlands). Can survive in small artificial impoundments. Prefer quiet, deeper waters, especially pools, or remaining near cover including terrestrial vegetation, boulders, and fallen logs.[3]
Gila trout *Oncorhynchus gilae*	T	N	Occupies moderate- to high-gradient perennial mountain streams above 5,400 ft elevation, typically in narrow, steep-sided canyons and valleys. Requires water temperatures below 77°F. Cover needs include woody debris, undercut banks, boulders, deep water, overhanging vegetation.[4]
Spikedace *Meda fulgida*	E	Y	Mid-water habitats of runs, pools, and swirling eddies at depths less than 3.3 ft (1 m).[5] In larger streams they are often found near the mouth of tributary streams.[6]
Gila topminnow *Poeciliopsis occidentalis*	E	N	Headwater springs and vegetated margins and backwater areas of intermittent and perennial streams and rivers. Prefer shallow warm water habitat with moderate velocity and dense aquatic vegetation or algae mats.[7]
Desert pupfish *Cyprinodon macularius*	E	Y	Desert pupfish occur occupy a variety of aquatic habitats and can persist in a wide range of temperature and salinity conditions. They are found at elevations up to 4,000 feet. The desert pupfish was historically extirpated from Arizona but has been reintroduced at multiple locations including the upper Gila River watershed on BLM managed lands.[8]
Loach minnow *Tiaroga cobitis*	E	Y	Small to large perennial streams; shallow, turbulent riffles with primarily cobble substrate and swift currents. Uses rocks for resting and spawning but fine sediment

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
			must be absent from interstitial spaces. Distribution: portions of the Gila River and its tributaries—the West, Middle, and East forks.[9]

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Amphibians			
Chiricahua leopard frog *Lithobates chiricahuensis*	T	Y	Occupies a variety of valley and montane aquatic habitats like springs, pools, lakes, cattle tanks, reservoirs, streams, and rivers. Currently limited to headwater streams and springs and livestock tanks [10]; typically found at elevations between 3,281 and 8,890 feet.
Reptiles			
Narrow-headed garter snake *Thamnophis rufipunctatus*	T	P	Strongly associated with clear, rocky streams, primarily uses pool and riffle habitat deeper containing cobbles and boulders. Elevations between 2,300–8,200 ft in Petran Montane Conifer Forest, Great Basin Conifer Woodland, Interior Chaparral, and the Arizona Upland subdivision of Sonoran Desert scrub communities
Northern Mexican gartersnake *Thamnophis eques megalops*	T	P	Strongly associated with permanent water with vegetation, including stock tanks, ponds, lakes, cienegas, cienega streams, and riparian woods. In Arizona it is usually found in or near water in highland canyons with pine-oak forest and pinyon-juniper woodland, sometimes in mesquite grassland and desert areas, especially along valleys and stream courses.
New Mexican ridge-nosed rattlesnake *Crotalus willardi obscurus*	T	Y	Uses rock shelters and perennial bunch grasses for cover in montane woodlands, bottoms of steep, rocky canyons with intermittent streams or talus slopes. Elevations between 5,000–8,500 feet.
Birds			
Northern aplomado falcon *Falco femoralis septentrionalis*	EX	N	A non-essential experimental population is listed for Arizona. Experimental populations are a designation under the ESA applied to a population of a threatened or endangered species prior to reestablishing it in an unoccupied portion of its former range. Mainly found in palm and oak savannahs, yucca-mesquite and other desert grassland/shrub associations.
Least tern *Sterna antillarum*	E	N	Beaches and islands sparsely vegetated due to tidal and river action, near shallow waters. Primarily coastal, but also breeds along inland rivers of the U.S., including Arizona.

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Yellow-billed cuckoo *Coccyzus americanus*	PT	P	Nests in low to moderate elevation riparian woodlands, primarily in willows. Habitat in Arizona includes box elder (*Acer negundo*), Arizona walnut (*Juglans major*), Arizona sycamore (*Platanus wrightii*), oak, netleaf hackberry, velve ash, Mexican elderberry, tamarisk, and seepwillow, mesquite, Fremont cottonwood.
Mexican spotted owl *Strix occidentalis lucida*	T	Y	Dense, multi storied montane forests of mixed conifer and madrean evergreens. Deep, cool, fractured canyons.
Southwestern willow flycatcher *Empidonax traillii extimus*	E	Y	Breeds in areas from near sea level to over 8,500 ft elevation (Durst et al. 2008) in riparian vegetation or other wetlands. Establishes nesting territories, builds nests, and forages where mosaics of relatively dense and expansive growths of trees and shrubs are established, near or adjacent to surface water or underlain by saturated soil (Sogge et al. 2010).
Mammals			
Mount Graham red squirrel *Tamiasciurus hudsonicus grahamensis*	E	Y	Mature to old-growth montane forests containing mixed conifer, spruce-fir [1] and less often in Douglas-fir [2]. Requires full forested canopy cover for travel and protection from predators [1] and is seldom found below 9,500 ft elevation [2]
New Mexico meadow jumping mouse *Zapus hudsonius luteus*	E	Y	Endemic to New Mexico, western Arizona, and southern Colorado. Nests in dry soils, but uses moist, dense riparian and wetland vegetation. Depends on two riparian communities: persistent emergent herbaceous wetlands (i.e., beaked sedge and reed canary grass alliances); and scrub-shrub wetlands (i.e., riparian areas along perennial streams that are composed of willows and alders).
Lesser long-nosed bat *Leptonycteris curasoae yerbabuena*	E	N	Requirements include caves and mines for roosting and healthy stands of saguaro cactus and paniculate agaves for foraging. In southwestern Arizona, the Sonoran desert scrub vegetation community provides early summer forage base. In southeastern Arizona, the semi-desert grassland and oak woodlands provide late summer agave.

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Mexican long-nosed bat *Leptonycteris nivalis*	E	N	Desert scrub, wooded elevations at higher elevations. Require caves or abandoned mines and tunnels. Feeds on agave and cactus nectar and pollen.
Jaguar *Panthera onca*	E	Y	Marginal habitat in open arid areas of northwestern Mexico and the southwestern U.S., includes habitat containing thornscrub, desert scrub, lowland desert, mesquite grassland, Madrean oak woodland, and pine-oak woodland communities.
Ocelot *Leopardus pardalis*	E	N	Dense vegetation cover is required, generally recorded in subtropical and tropical thornscrub, and tropical deciduous forests. A depleted population exists in southeastern Arizona.
Grey wolf *Canis lupus*	PEX	N	Currently extirpated from Arizona, but a non-essential proposed experimental population is listed for Arizona. Occupies a wide range of habitats including temperate forests, mountains, tundra, taiga, and grasslands.
Mexican wolf *Canis lupus baileyi*	EX	N	A non-essential experimental population is listed for parts of Arizona, where the only known populations exist. Most often recorded in mid- to high-elevation woodlands, including oak, pinyon pine, juniper, ponderosa pine and mixed conifer forests. May be dependent on ungulate populations more than vegetation types. Most historical records occur above 4,500 ft elevation.
Plants			
Arizona cliffrose *Purshia subintegra*	E	N	Gravelly clay or loam soils over limestone located in low rolling hills found in desert formations often dominated by creosote bush (*Larrea tridentata*), rabbit brush (*Chrysothamnus nauseosus*), false palo verde (*Canotia holocantha*), and catclaw acacia (*Senegalia greggii*).
Arizona hedgehog cactus *Echinocereus triglochidiatus* var. *arizonicus*	E	N	Dacite or granite bedrock, open slopes, in narrow cracks between boulders, and in the understory of shrubs in the ecotone between Madrean Evergreen Woodland and Interior Chaparral[11].

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Wright's marsh thistle *Cirsium wrightii*	C	N	Springs, seeps, marshes, stream banks, often in alkaline soil[11].
Zuni fleabane *Erigeron rhizomatus*	T	N	Chinle shale and associated soils in pinyon-juniper association.

[A.] Federal Listing Status: E = Endangered; Listed in the Federal Register as being in danger of extinction; T = Threatened; Listed as likely to become endangered within the foreseeable future; C = Candidate for listing; PEX = Proposed Experimental Population, Non-Essential; EX = Experimental Population, Non-Essential.

[B.] Critical Habitat: Y = Yes; N = No; P = Proposed

[C.] Habitat association information comes from the USFWS Environmental Conservation Online System (ECOS), or NatureServe Explorer databases, unless otherwise noted

[1] AGFD. 2002a. *Xyrauchen texanus*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

[2] USFWS. 1998. Razorback sucker (*Xyrauchen texanus*) Recovery Plan. Denver, Colorado.

[3] https://www.federalregister.gov/articles/2002/08/09/02-19872/endangered-and-threatened-wildlife-and-plants-listing-the-gila-chub-as-endangered-with-critical#h-8

[4] https://www.federalregister.gov/articles/2005/05/11/05-9121/endangered-and-threatened-wildlife-and-plants-reclassification-of-the-gila-trout-oncorhynchus-gilae; and USFWS 2002. Gila trout recovery plan (third revision). Albuquerque, New Mexico. 60 pages.

[5] AGFD. 2002b. *Meda fulgida*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

[6] USFWS. 1990. Spikedace recovery plan. Prepared by P. C. Marsh, Arizona State University, Tempe for USFWS, Region 2, Albuquerque, New Mexico.

[7] AGFD. 2001. *Poeciliopsis occidentalis occidentalis*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 6 pp.

[8] https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=E044#crithab; and H. Blasius, BLM, pers. comm., June 2018.

[9] http://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/Spikedace/SD-LM_pCH_FR_pub_10-28-10.pdf

[10] http://www.gpo.gov/fdsys/pkg/FR-2011-03-15/pdf/2011-4997.pdf

[11] https://www.fws.gov/southwest/es/arizona/Documents/Redbook/Arizona%20Hedgehog%20RB.pdf

[12] http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=250066407

Appendix C

Native Species of Primary Concern for Riparian Restoration in the Mainstem Upper Gila River

Species of Concern for Riparian Restoration

The following sections describe several species of concern for riparian restoration along the mainstem of the upper Gila River, including the non-native invasive tamarisk as well as several special-status species (southwestern willow flycatcher, western yellow-billed cuckoo, and razorback sucker). Other invasive plant species affect waterways and restoration areas including giant reed (*Arundo donax*), giant salvinia (*Salvinia molesta*), hydrilla (*Hydrilla verticillata*), and Eurasian water-milfoil (*Myriophyllum spicatum*), kochia (*Kochia scoparia),* tree tobacco (*Nicotiana glauca*), and Johnson grass (*Sorghum halepense*). Additional invasive aquatic wildlife species are known to have devastating effects on native aquatic fish and wildlife species – for example, quagga mussels impacts to the food web, crayfish impacts to native gartersnakes, turtles, mollusks, and fish, and bullfrog predation on a wide variety of reptiles and amphibians (AGFD 2012b).

Tamarisk

Native plants face extreme competitive pressure in tamarisk-dominated stands where woody material from dead cottonwoods and willows is often present. Tamarisk is highly flammable – tamarisk dominated areas burn approximately ten times more frequently than native plant-dominated counterparts (Busch 1995)—and has fueled a number of fires in the riparian corridor. For example, in areas burned by the Clay Fire in March 2013 near Fort Thomas, nearly all tamarisk biomass was burned away—later in 2013 only the main trunks and branches remained. However, nearly all burnt tamarisk trees were observed to be re-sprouting vigorously from the base in November 2013, indicating there is only a limited window of opportunity to establish native species before tamarisk biomass once again dominates the site. Escaped fire from land-clearing on adjacent agricultural areas is a concern for land managers in the Safford Valley, particularly where weedy forbs next to fields carry fire into the arid, tamarisk-dominated riparian edges, and then into the mixed native/tamarisk vegetation along the river. This establishes a feedback loop in which fire promotes tamarisk, which recovers readily from burning to become even more abundant, eventually displacing native elements in the stand (Orr et al. 2014). In addition, native vegetation along the upper Gila River currently lacks the spatial distribution and inherent growth rates to rapidly reestablish.

A key concern in the watershed is the anticipated arrival of the tamarisk leaf beetle (*Diorhabda elongata* and *sublineata* species groups) which has the potential to disturb existing riparian habitat conditions, particularly for southwestern willow flycatchers (see Section 3.8). The tamarisk leaf beetle (*Diorhabda elongata* and *sublineata* species groups), which was released in portions of Colorado, Nevada, Texas, Utah, and Wyoming during 2001–2009 by the U.S. Department of Agriculture (USDA) for biological control of tamarisk, is expected to arrive in the upper Gila River valley in the next 2 to 3 years and result in the defoliation and ultimate mortality of large tracts of tamarisk, as has been observed elsewhere in the southwest region (Tracy and Robbins 2009; J. Tracy, pers. comm., 2014, as cited in Orr et al. 2014). The beetle has not yet reached the Gila River Watershed from the east as expected, but in 2017, neared the upper reaches of the watershed near Silver City, New Mexico (Tamarisk Coalition 2017). Defoliation by the leaf beetle does not exacerbate the risk of wildfire, as tamarisk is highly flammable regardless of whether it is “browned-out” by defoliation or in a “healthy green” state (Dudley and Brooks 2011). Biocontrol eventually reduces tamarisk volume, and after 3+ years, repeated defoliation can lead to mortality (Bean et al. 2013).

Southwestern Willow Flycatcher

Endangered southwestern willow flycatchers (SWFL; *Empidonax traillii extimus*), listed as endangered in 1995, are present in the plan area, including designated critical habitat. They typically establish nesting territories, build nests, and forage where mosaics of relatively dense and expansive growths of trees and shrubs are established near or adjacent to surface water and/or underlain by saturated soil (Sogge et al. 2010). Many areas where the SWFL was formerly locally abundant now support few or none. Two riparian areas continue to support substantial numbers of SWFL, one of which is the Gila River (AGFD unpubl. Data; Magill et al. 2005; Dockens et al. 2007; Dockens and Ashbeck 2009, 2012; Graber and Koronkiewicz 2009a, 2009b, 2011, and 2012), where SWFLs have been known since the early 1900s (Willett 1912, Phillips 1948). SWFL along the upper Gila River now nest in tamarisk, due to the ubiquity of the plant and its suitable nesting structure, and when these trees and shrubs are defoliated they will become unsuitable for nesting. In other southwestern U.S. rivers, large areas of SWFL nesting habitat have been adversely affected as a result of defoliation from tamarisk leaf beetle, such as along the Virgin River in Arizona, Nevada, and Utah (R. Dobbs, pers. comm., 2013; BOR 2014).

USFWS (2013) has determined that the primary constituent elements (PCEs) of habitat essential to the conservation of SWFL are:

1. Riparian vegetation in a dynamic river or lakeside, natural or manmade successional environment that is comprised of trees, shrubs, vines, and herbs and some combination of:
    a. Dense riparian vegetation with thickets of trees and shrubs that can range in height from about 6 to 98 feet. Lower-stature thickets (6 to 13 ft tall) are found at higher elevation riparian forests and tall-stature thickets are found at middle- and lower-elevation riparian forests; and/or
    b. Areas of dense riparian foliage at least from the ground level up to approximately 13 ft above ground or dense foliage only at the shrub or tree level as a low, dense canopy; and/or
    c. Sites for nesting that contain a dense (about 50 to 100%) tree or shrub (or both) canopy (the amount of cover provided by tree and shrub branches measured from the ground); and/or
    d. Dense patches of riparian forests that are interspersed with small openings of open water or marsh or areas with shorter and sparser vegetation that creates a variety of habitat that is not uniformly dense. Patch size may be as small as 0.25 acre or as large as 175 acres.

2. A variety of insect prey populations found within or adjacent to riparian floodplains or moist environments.

SWFL may use a larger area than their initial territory after their young are fledged, and use non-riparian habitats adjacent to the breeding area (Durst et al. 2006). Even during the nesting stage, adult SWFL sometimes fly outside of their territory, often through an adjacent SWFL territory, to gather food for their nestlings.

Western Yellow-billed cuckoo (WYBC)

The western yellow-billed cuckoo (WYBC) is a federally threatened species (USFWS 2014a) and critical habitat was proposed in 2014 (USFWS 2014b). Critical habitat for WYBC in the upper Gila River extends from near the Bonita Creek confluence downstream to San Carlos reservoir.

Primary constituent elements (PCEs) of critical habitat for WYBC include: (1) riparian woodlands > 325-feet wide and ≥ 200 acres in extent, (2) an adequate prey base (e.g., large insects and insect larvae and tree frogs), and (3) dynamic river processes that maintain riparian vegetation patches at a variety of successional stages (USFWS 2014b).

WYBC nest in large (10–40 acres) patches of structurally complex riparian habitat with tall trees and a dense understory of woody vegetation, such as is often found in cottonwood-Goodding's willow woodlands (Hughes 1999, Laymon et al. 1997). Nests—typically a loose platform of twigs on a horizontal branch—are typically located in dense vegetation under 70 ft high near surface water where humidity is high and temperatures are cooler (Launer et al. 1990, as cited in Laymon 1998; Gaines and Laymon 1984, as cited in Suckling et al. 1998). Occasionally the nest of another species is used (Jay 1911, Bent 1940). In California and Arizona, cottonwood trees are an important habitat (Laymon et al. 1997, Holmes et al. 2008, Johnson et al. 2010). Nesting in the western states occurs almost exclusively near water, leading to some researchers hypothesizing that sufficient humidity may be necessary for successful reproduction (Hamilton and Hamilton 1965, Rosenberg et al. 1991).

The main nest-tree species in Arizona are Goodding's willow (*S. gooddingii*), cottonwood (*P. deltoides*), and tamarisk, although other trees or large shrubs, such as mesquite and seep willow (*Baccharis salicifolia*), may also be used (McNeil et al. 2012). In Arizona, Johnson et al. (2010) found WYBC detection rates to be highest in cottonwood-willow-ash (*Fraxinus* species [spp.]) and mesquite bosque–hackberry (*Celtis* spp.) habitats and much lower in Arizona sycamore (*Platanus wrightii)*–cottonwood habitat, sycamore-alder (*Alnus* spp.) habitat, and areas with more than 75% tamarisk cover. Aerial-photo and satellite models applied on the lower Colorado River found that important features associated with WYBC breeding habitat included: (1) a 4.5-ha core area of dense cottonwood-willow, (2) a large native forest (72 ha) surrounding the core, and (3) moderately rough topography. In contrast, the odds of WYBC occurrence decreased rapidly as the amount of tamarisk cover increased or when cottonwood-willow vegetation was scarce (Johnson et al. 2012).

Razorback Sucker

A member of the sucker family (*Catostomidae*), razorback suckers can reach sizes of up to 3 feet and may live 40 years or more. They are endemic to the Colorado River basin and historically occurred throughout much of the Gila River. By the 1950s the razorback sucker was extirpated from the Gila River and its tributaries (USFWS 1998). A number of factors led to the decline of this species, but the primary threats are considered to be habitat alteration from dams and diversions, and predation by non-native fish species (USFWS 1998). Efforts to reintroduce razorback suckers in the watershed took place from 1981 through 1990 but proved unsuccessful in establishing a self-sustaining population (Desert Fishes Team 2003), likely as a result of predation by non-native fish species such as channel catfish (*Ictalurus punctatus*) and flathead catfish (*Pylodictis olivaris*) (Marsh and Brooks 1989 and Maddux et al. 1993, as cited in USFWS 2002d).

In rivers where they occur, razorback suckers can be found in a variety of habitat types, from mainstem channels to slow backwaters of medium and large streams and rivers (AGFD 2002a). Adults tolerate water temperatures ranging from near freezing up to 90°F, with preferred temperatures between 72 and 77°F (AGFD 2002a). Spawning occurs from late winter through early summer over gravely substrates in lakes and rivers, when flows are typically high and the water column is generally highly turbid (USFWS 1998). Young razorback suckers require quiet, warm, shallow water nursery areas typical of tributary mouths, backwaters, or inundated floodplains (USFWS 2002). The diet of razorback suckers is similar to other members of the sucker family and includes algae, plankton, insect larvae, and detritus (AGFD 2002a).

The razorback sucker was listed as endangered in 1991 (USFWS 1991) and critical habitat was designated in 1994 (USFWS 1994). In the Gila River, critical habitat for razorback sucker is designated from the Arizona/New Mexico border to Coolidge Dam, where water quantity and quality are suitable (USFWS 1998). Although razorback suckers are not present in the Upper Gila River Watershed, the upper Gila River is still designated critical habitat. Despite intensive water diversion in this area and reaches that go intermittently dry, pools in the mainstem channel and tributaries can provide suitable water quality, water quantity, and other habitat features for this species during low flow periods (USFWS 1998).

Appendix D

Stakeholder Feedback from 2015 Water Supply and Demand Alternatives Workshop

The following information was developed in the 2015 Water Supply and Demand Alternatives Workshop.

Demand Reduction:

- A combination of potential approaches was thought to be most effective in decreasing water demand.
- Priorities should include *public education*, *coordination of water conservation activities*, *building codes/conservation ordinances*, and *conservation pricing.*

Small-scale Supply Alternatives:

- *Educating the community is important* - creating a sense of urgency, while avoiding a sense of panic, by focusing on specific education topics like greywater reuse, encouraging research into the ability to capture stormwater in canal systems, and targeting specific "early-adopter" groups like millennials.
- *Diversifying crops to promote efficiency and resilience* – in support of maintaining or improving the local agricultural economy.
- S*upporting already-existing teaching models like "Ag in the Classroom"* - an ongoing Farm Bureau initiative that includes lessons on water usage/conservation.
- Make continuous efforts to learn about best practices and effective models elsewhere
- Collect and publicize stories of water trends and challenges and creative responses
- Be aware of water conservation and public education "fatigue"
- Appreciate the particular social ethic in the watershed
- Develop a "Dynamic Education" model/process
- Prepare for strategic and frequent engagement with regional decision-makers
- Find opportunities for pilot projects
- Support coordinated education efforts
- Be aware of how new technology and shifts in the affordability of different conservation strategies will affect opportunities
- Explore ways of realizing the Mission Statement and evaluate what specific concerns or threats exist regarding regional water availability and determine how a coordinated response can bring people together to address these problems

The technology for automatic meters is readily available. Cost of installing a ¾" water meter is about $6,000. Farmers could consider installing automatic meters, which can improve measurements substantially and reduce labor costs over the long-term. Each farmer would need to perform his/her own cost analysis to determine if this is feasible. Similarly, drip irrigation would be more supported if funding issues and salinity problems were addressed.

Water efficiency for large (commercial, industrial) water users was also reviewed. Sheet flow is being lost unnecessarily in many parking lots and on slopes. Better design could allow this water to be utilized. For example, FMI has designed its parking lots to direct water into the canal. Recommendations include implementing urban watershed restoration, rainwater harvesting, and setting in place erosion control measures.

Increased use of reclaimed water was viewed by source and potential use. Use of reclaimed water for agriculture may be viable, depending on the crop. Questions were raised about the current incentive structures for municipal reuse of reclaimed water, and what kinds of fit-for-purpose options would make the most sense economically. Some effluent from Clifton and Morenci is used at FMI's Morenci mining operation, but it was unclear whether all was reused and whether other fit-for-purpose options were also available. Recommendations included exploring the possibility of transfers between jurisdictions or basins as well as maximizing the use of Clifton/Morenci effluent to the mine.

The group also discussed the development and treatment of lower quality sources. There is currently no incentive for agricultural users to use, store, or transfer reclaimed water. Agricultural users have a "use it or lose it" mentality because of uncertainty and the pressure to maintain their water rights. According to participants, some water transfers from agriculture to municipal sources are in the works in Graham County (such as for open space). Greenlee County has been involved in short-term transfer agreements. These depend on price point, and, again, there are concerns about losing water rights. Also, participants wondered whether there was a feasible way to store the extra water within the canal systems to rectify the problem of lost water when the canals sometimes overflow. Questions were also asked about the uncertainty regarding laws/regulations on use and storage of water. Recommendations included investigating the suitability and feasibility of evaporation ponds and permits for wells, encouraging short-term transfers (to help get around the "use it or lose it" mentality of water rights), building storage into canal systems (e.g., San Joaquin Valley – ponds interspersed to catch overflow water running through canals), and considering the sealing of canals. Overall, a desire to conserve water over the long-term was expressed, however, this conservation could only occur in the context of maintaining water rights.

Increased Agricultural Efficiency Measures were addressed in the context of Installing pumps at the end of agricultural fields and finding broader support for research into using desert adapted, low-water-use species in agriculture. Participants also reviewed water restrictions and enforcement options in the context of farming. Agricultural water use in the valley is limited to 28,000 irrigated acres at 6 AF/acre of surface water. This is allocated per canal, per farmer. Farmers can make agreements to adjust the amount of water they use on a shared canal. They cannot, however, use canals they are not assigned to. The estimated cost of water is about $2,600–$2,800 AF/acre. Under current use, drip irrigation methods uses at most 3 AF/acre, which offers substantial water conservation potential depending on other factors. Challenges to widespread adoption of such water conservation tools are varied. There is little incentive (and some disincentive) to use less water. This can help explain farmers' reluctance to use drip irrigation. Also, such conservation comes at a significant cost to farmers. Although conservation is a general best practice, farmers have reasons to use as much of their 6AF as possible under the current system. Municipal leaders have voiced a preference for reducing water use by a small amount versus returning large amounts back to the system. There have also been tenuous relationships between judicial bodies and the agricultural sector, where legal proceedings have been very expensive, and have resulted in controversial rulings. Recommendations included encouraging the transfer of excess water and supporting programs that encourage/incentivize drip irrigation while also including provisions for salinity management.

Rebate programs are currently not in use in the region for residential water use. There had been an incentive program in the past, but it was unsuccessful because residential users did not make much use of it. The point was made that most people in the region probably agree in the abstract that water conservation is important, but the behavior is difficult to change, particularly without incentives. One recommendation centered on the creation of a proposal that evaluated different conservation incentives at a broad-based, regional scale. This proposal could then be presented to various leaders and decision-makers in different water sectors to develop wider support and potentially a more extensive base for securing funding.

Further, efforts to document and publicize how water management works here in the Upper Gila region continues to be a challenge. There is probably a different social ethic in Safford than other municipalities, so there is value in accounting for those unique demographics (renters, etc.).

There was also a discussion of how other similarly-situated regions have looked at managing water. While there have been efforts in the past to look at other regions' approaches to water management, no formal investigations or documents have been created. By way of example, the Upper San Pedro Partnership (USPP) in Cochise County conducted a study of which methods would be effective at getting people to conserve water; now the USPP has successfully implemented some of these methods. It was recommended that there be further use made of GWP's connections to different groups in order to get agreement among different sectors on the problems and possible solutions of water.