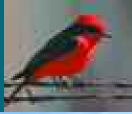
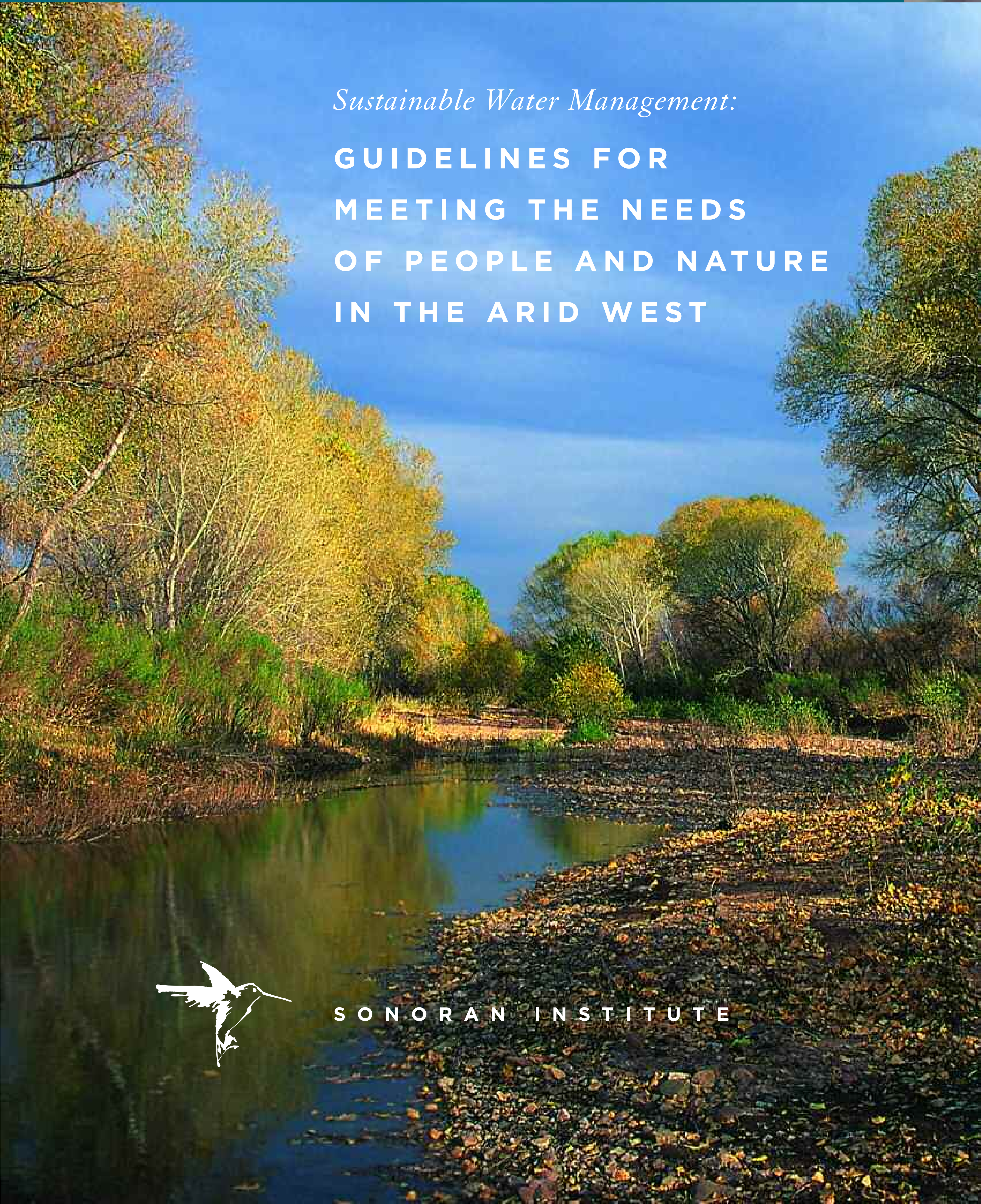


Sustainable Water Management:

GUIDELINES FOR MEETING THE NEEDS OF PEOPLE AND NATURE IN THE ARID WEST



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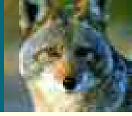


UNDERSTANDING RIVERS & STREAMS

During the last decade, five of the six fastest growing states were in the western United States. This growth has brought many challenges, not the least of which is reconciling the water needs of current and future residents, agriculture, and industry with the preservation of the West's remaining rivers and streams and the survival of the plants and animals that depend upon them.

"I think there are many that believe that the finite availability of water resources is not going to present a problem any time soon, but I think we are going to face some real tough decisions in the next few decades unless we start getting a better handle on things today. At some level, continued growth at what's projected and the sustainability of water resources are currently incompatible."

TOM RUNYON, STAKEHOLDER, ARIZONA'S SAN PEDRO RIVER

Highly valued for its biological diversity and its importance for neotropical migrating birds, Arizona's San Pedro River is a natural treasure.

Access to water is a basic necessity of life, especially in an arid environment like the West. Early settlements were normally located in close proximity to year-round flowing rivers, streams and springs. For these early settlers, water was accessed through extensive irrigation systems, which diverted surface water using small dams, flumes and hand-dug canals, or they pumped water from shallow wells using windmills or hand pumps. This changed significantly in the early 1900s with the onset of the Reclamation period in the western United States, when large dams and irrigation projects funded by federal, state and private sources began to regulate, store and divert surface water on a large scale to support human enterprises, principally agriculture.

The Hoover Dam on the Colorado River is one of the earliest, large Reclamation projects.

In the 1940s and 1950s, water use across the West took another quantum leap with the introduction of the electric-turbine pump. For the first time, large amounts of underground water (groundwater) could be easily and affordably accessed both deeper and farther from traditional surface water sources, dramatically increasing demand on groundwater and allowing communities to grow anywhere groundwater resources could be located.

The increased use of surface water and groundwater that resulted from these developments has generated tremendous prosperity, helping to transform the arid West from a sparsely settled territory with small populations clustered in a few areas to a region with a number of large, rapidly urbanizing population centers.

These same transformations have had substantial consequences for the West's rivers and streams. Dam construction, streambed channelization, floodplain development and large-scale groundwater pumping have significantly altered or destroyed many natural river systems. In the Southwest, once large desert rivers – such as the Salt, Santa Cruz and Gila rivers, with shallow groundwater that supported year-round flows and abundant vegetation and wildlife – have been reduced to dry channels where water flows only after large storms, considerably changing the types and amounts of vegetation and wildlife supported by them.

Truck-mounted groundwater wells have made water extraction in previously inaccessible locations possible.

Since the early 1970s, there has been a tremendous increase in awareness of the importance of rivers and streams and associated plants and wildlife. The protection of rivers and streams is a high priority among government agencies and conservation organizations, and many communities have engaged in significant restoration efforts to recreate lost vegetation and wildlife resources. Large-scale dam building across the West is largely a thing of the past, and floodplain development and flood-control projects routinely consider protecting natural river conditions.

Despite this increased awareness, these efforts to protect the rivers and streams of the arid West have largely focused on the impacts of surface activities. However, the health of rivers and streams is integrally related to the health of the entire hydrologic system. Groundwater use remains a significant threat to the continued existence of surface water

Volunteers re-vegetate the banks of Arizona's Santa Cruz River in the San Xavier District of the Tohono O'odham Nation (tribal permission required to visit this site).

"We need to take a broader view of how water should be managed… There are some possibilities that if we look at a bigger regional picture that we have a better chance of solving some local problems in a more sustainable, cost-effective way."

ERIC HOLLER, STAKEHOLDER, ARIZONA'S SAN PEDRO RIVER

flow in rivers and streams. Population growth and recent drought conditions in many communities have brought increased attention to the problems of unregulated or poorly regulated groundwater pumping as groundwater levels have declined, wells have gone dry, and streamflows have decreased and in some instances disappeared.

While the problems associated with groundwater pumping are significant, improvements in technology, advances in hydrology and ecology, progress in the understanding of natural systems, and increasing public awareness, interest and actions, all suggest that the future impacts to the West's rivers and streams are neither inevitable nor necessary. Quite to the contrary, maintaining the health of rivers and streams is an important part of maintaining the natural beauty, recreational opportunities, quality of life and the continued prosperity that draws so many people to the arid West.

THE ROLE OF GROUNDWATER

At the most basic level, rivers and streams exist as a result of precipitation. Rainwater and melting snow that do not immediately evaporate or are not used by plants, flows downhill over (or slightly below) the land surface and collects in these natural waterways. This water is known as **surface runoff.**

Along mountain fronts and across valley floors, rain and snow melt also infiltrates deep into the ground. This water is stored in bedrock cracks and fissures or in the porous sands and gravels in the valley bottoms forming an **aquifer.** The infiltration of water into an aquifer is known as **recharge.** The uppermost surface of the aquifer is known as the **water table.**

Where geology permits, water in an aquifer will flow underground by the force of gravity from areas of higher elevation to lower elevations. Where this underground water intersects the land surface, it emerges as a spring or seep or within a stream channel as **groundwater discharge.** As a general rule, where the water table in the aquifer is at or above the level of the stream channel, gravity will cause groundwater to emerge in the stream channel, increasing flow. Streams that receive groundwater discharge are **gaining streams.** If the water table is below the level of the stream, water from the stream will infiltrate into the streambed and lose water. Streams that lose water to the aquifer are **losing streams.** In an arid environment, it is not unusual for a river to have alternating gaining and losing stream reaches.

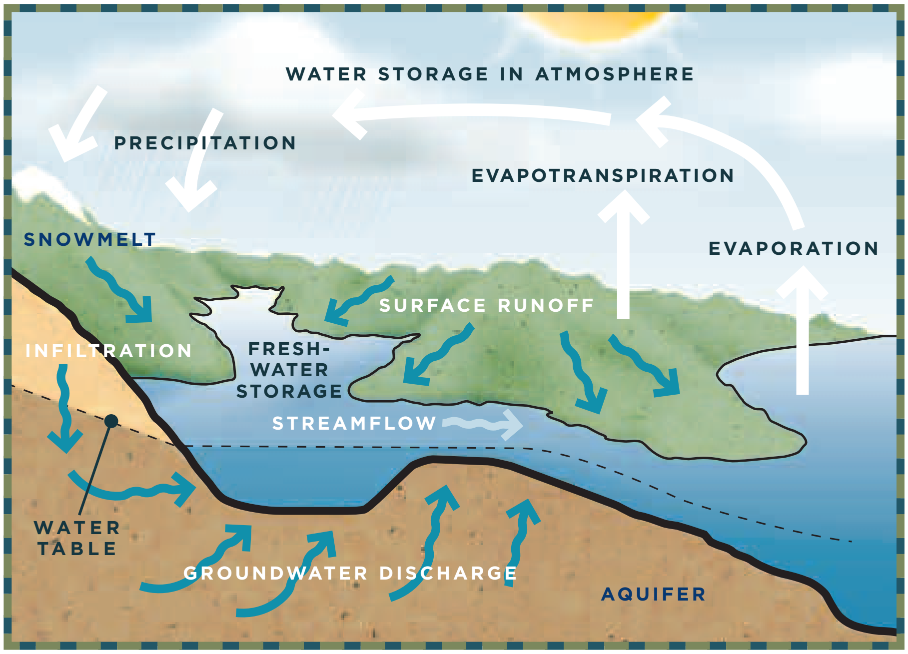


FIG. 1 **The hydrologic cycle.**

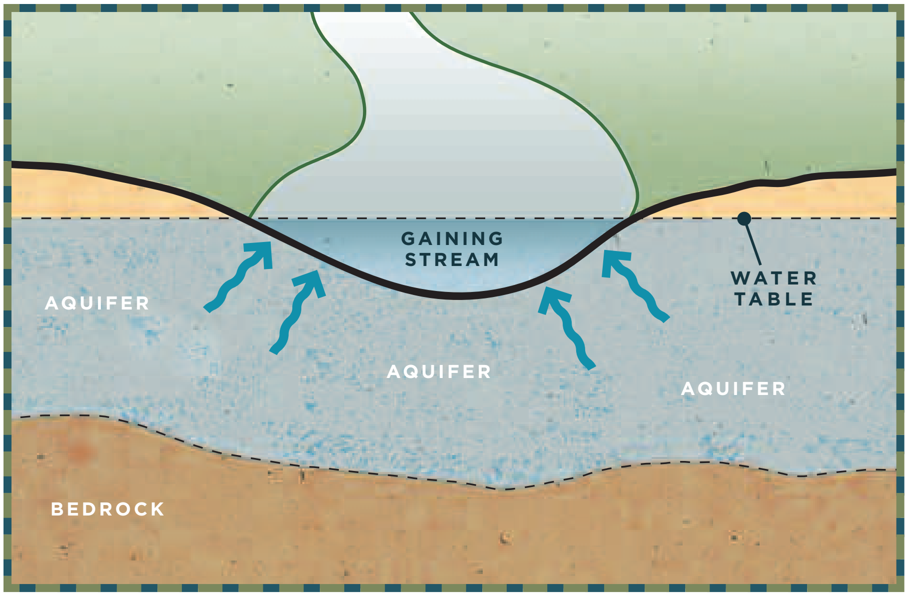


FIG. 2 Gaining streams — streams that receive groundwater discharge.

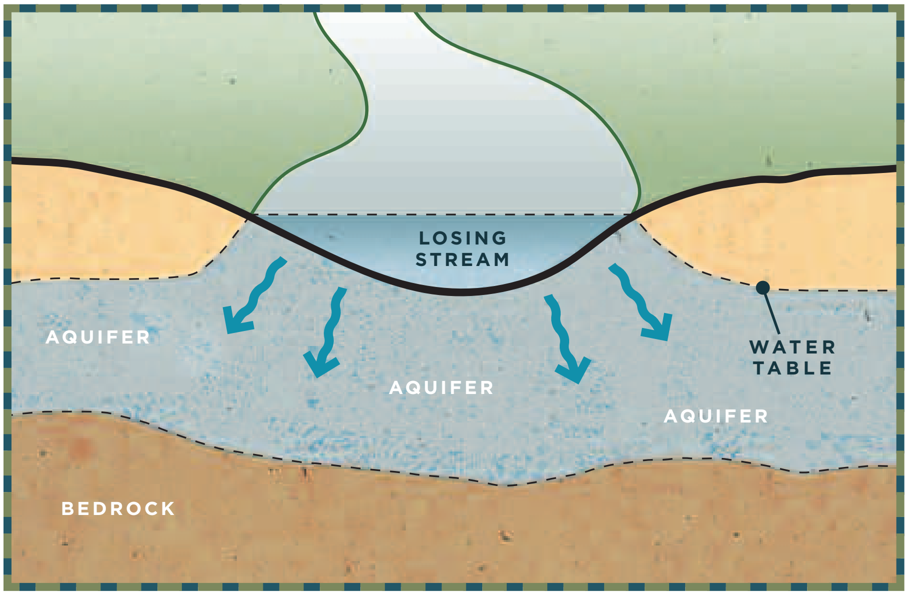


FIG. 3 Losing streams — streams that lose water to the aquifer.

In gaining stream reaches, the greater the difference in elevation between the water table and the point where groundwater is discharged into the stream channel, the greater the water pressure generated by the force of gravity. Thus, a small difference in elevation will result in a lower rate of groundwater discharge than a large difference in elevation – much as a siphon from one container to another will flow faster or slower depending on the difference in elevation between the two containers. The rate of flow of groundwater through the aquifer and of groundwater discharge relates both to the elevation gradient between the water table and the discharge point and to the physical characteristics of the aquifer, such as the type of material the water must travel through. Depending on these aquifer conditions, which can vary within an aquifer as well as among aquifers, a molecule of water may take anywhere from days or months if not hundreds or thousands of years to move from the point where it first disappears underground to the point where it re-emerges to the land surface.

Water that flows in rivers and streams thus has two basic components: surface runoff and groundwater discharge. The time and distance that water in a stream channel flows above ground under natural conditions is related to the total quantity of water delivered to the stream channel from upstream surface runoff and groundwater discharge, the amount of water taken up by plants growing along the stream channel, and whether the stream is gaining or losing water.

The contribution of groundwater to streamflow varies widely, but hydrologists suggest that groundwater contributes on the order of 40-to-50 percent of the water to small- and medium-sized streams. The portion of total streamflow supported by groundwater discharge is termed **baseflow.** In arid regions that have fewer and smaller rain and snowfall events, baseflow may be the only flow in a river or stream during many months of the year. Because the baseflow in these rivers and streams is dependent on groundwater discharge from an aquifer, these systems are most at risk from unregulated pumping of groundwater.

THE IMPORTANCE OF RIPARIAN HABITAT

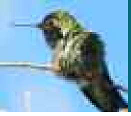
Adjoining rivers and streams is usually a noticeable band of vegetation, which is often quite distinct from the vegetation found on the surrounding landscape. This ribbon of green is integrally related to the river or stream and is dependent on the water that flows in the stream or in the underlying aquifer when the water table is close enough to the surface for plant roots to access. This band of distinct vegetation is known as a **riparian area.**

"We have a lot of other species that have to coexist and if we harvest all the water for human uses, there is never going to be enough for the plants and animals. The issue that I see is that there's a need to acknowledge other species."

CHARLES J. HAVRANEK, STAKEHOLDER, ARIZONA'S RIVERS

While riparian areas are a small part of the landscape, they are more structurally diverse and more productive in plant and animal material than adjacent upland areas. Riparian areas supply food, cover and water for a large diversity of animals and serve as migration routes and connectors between habitats for a variety of wildlife.

Riparian areas also provide many other benefits. They are important in mitigating or controlling water pollution, as riparian vegetation removes excess nutrients and sediment from surface runoff and shallow



groundwater. Riparian vegetation provides shade for fish and other aquatic wildlife. It is also effective in stabilizing stream banks by helping to slow and reduce flood flows, increase recharge, and prevent stream-bank erosion. Riparian areas also have important recreation and scenic values for hunting, fishing, boating, swimming, hiking, camping, picnicking and bird watching.

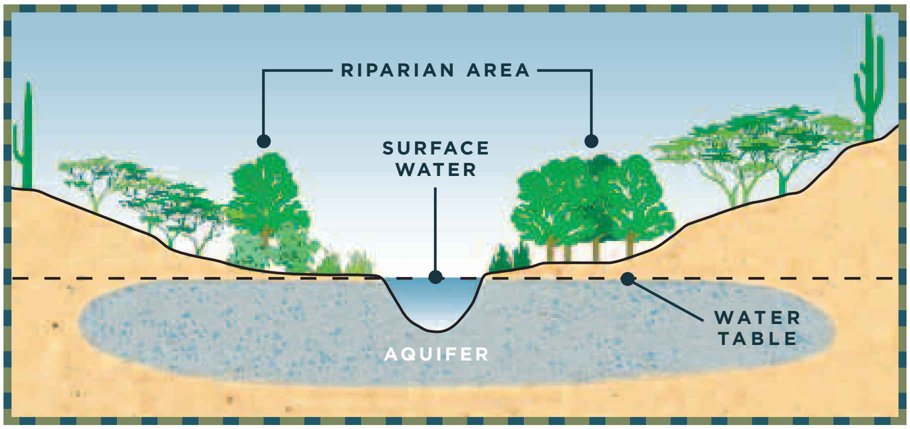


FIG. 4 Riparian areas — distinct vegetation adjoining and integrally related to rivers and streams.

Throughout the arid West, riparian ecosystems have been heavily impacted by human activities, including highway, bridge and pipeline construction, water development, channel modifications for flood control, recreation, industrial and residential development, agriculture, irrigation, grazing, logging and mining. Since the early 1970s, increased attention has been given to the importance of riparian areas, and many changes in management have occurred to minimize the impact of human activities. While improvements are still required, the dependence of these ecosystems on streamflow and shallow groundwater indicate that unregulated groundwater pumping may be the greatest threat to the future existence of these critical parts of the western landscape.

THE IMPACTS OF GROUNDWATER PUMPING

A fundamental organizing principle of hydrologic systems is that under natural conditions there is a balance between the water that flows into the aquifer and stream system – from precipitation, surface flow from upstream areas, and underground flow from upstream aquifers – and the water that flows out of the system as surface flow, groundwater discharge, underground flow to downstream aquifers, evaporation and plant use. Removing water from an aquifer by pumping from a groundwater well alters this balance by creating an additional point of groundwater discharge.

As such, a cardinal rule is that **for any river or stream that has a baseflow component, groundwater that is removed from an aquifer via a well and consumed will reduce the amount of water that is ultimately available to a stream and its associated riparian plants.** The amount of time that passes before this effect manifests itself will depend on how much water is pumped, how far the pumping location is from the stream channel, and the rate at which water flows through the aquifer.

Netting fish at Los Fresnos on the Upper San Pedro River in Mexico.

When pumping begins, groundwater starts to flow toward the well to replace the removed water, forming a **cone of depression.** As pumping from a well or cluster of wells continues, the resulting cone of depression will increase in size until it reaches a steady state, capturing enough water from other parts of the aquifer to replace the pumped water.

Initially, the cone of depression intercepts water flowing toward the stream from the upstream portion of the aquifer. This reduces the amount of water that would have otherwise reached the stream and thus reduces the baseflow of the stream. Continued or increased pumping from a cluster of wells may eventually extend the cone of depression to the stream itself, further reducing baseflow by reversing the gradient in groundwater flow such that water flows directly from the stream to the aquifer instead of the other way around.

Prolonged pumping during this stage can lower near-stream water tables to below the level of the stream. In the extreme, water table elevations can decline so greatly that they cannot be restored by natural recharge from surface runoff, and a complete separation occurs between the stream channel and the underlying aquifer, resulting in a permanent loss of baseflow. In this situation the portion of the stream affected by the pumping changes from a gaining reach to a losing reach.

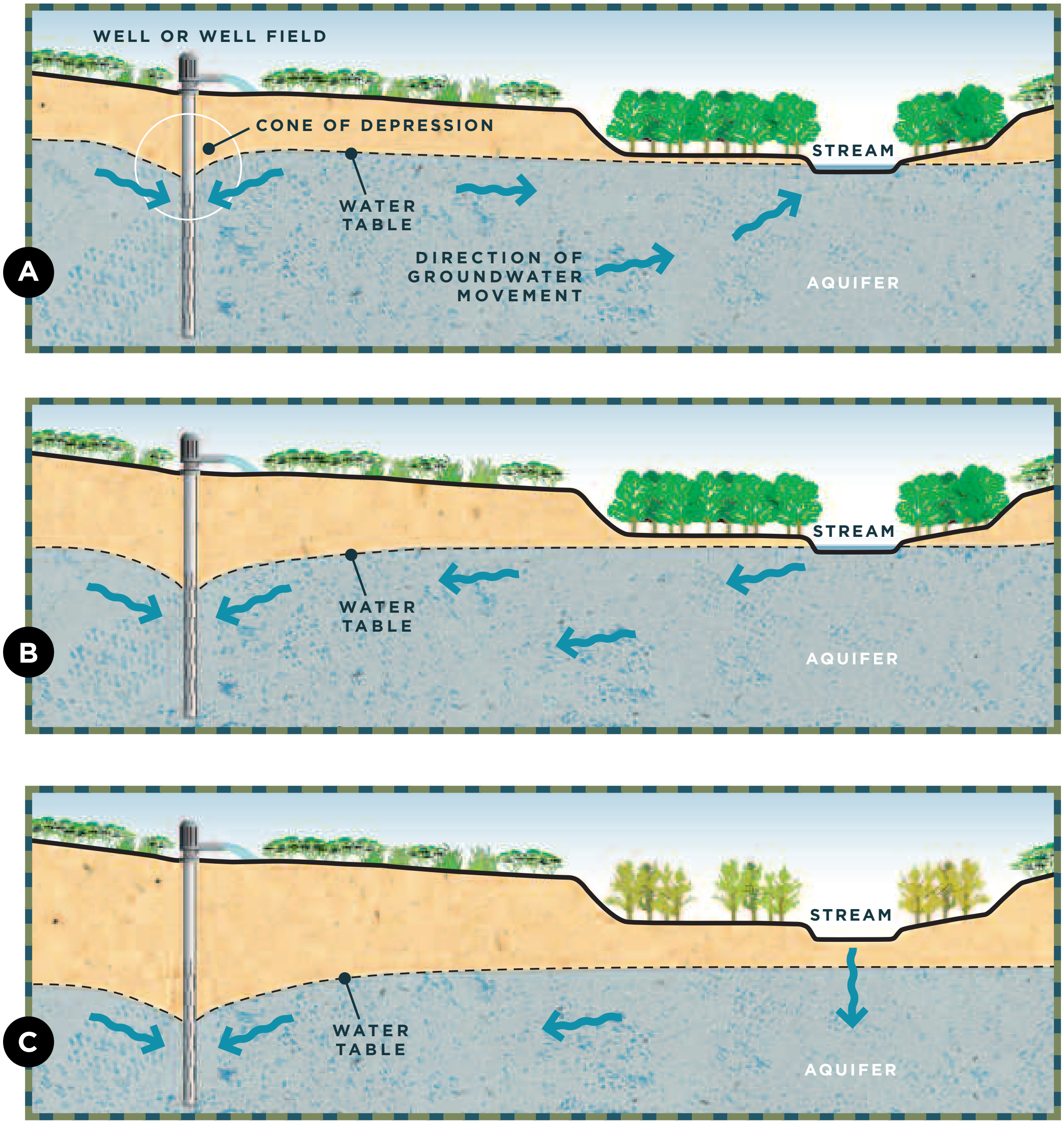


FIG. 5 Impact of Groundwater Capture on Riparian Area & Stream

A. At onset of pumping, water comes from storage around well and stream; aquifer system functions as before.

B. Substantial pumping causes movement of water away from stream and floodplain. Stream shifts from gaining to losing.

C. After pumping in excess of rate of flow from upgradient areas, stream and aquifer are disconnected, causing stream to go dry.

SUSTAINABLE WATER RESOURCES MANAGEMENT

This report identifies a series of recommendations for the sustainable management of water resources. Borrowing from the work of the Upper San Pedro Partnership (USPP) in Arizona, **sustainable management of water resources is defined as managing the development and use of surface water and groundwater in a manner that can be maintained for an indefinite time, without causing unacceptable environmental, economic or social consequences.**

This overall goal can be translated into three primary management objectives:

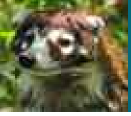
➤ **Provide for the needs of current and future residents of the area as well as the needs of downstream users, both natural and human.**

➤ **Protect aquifer-stream system conditions sufficient to maintain acceptable baseflow and associated aquatic, wetland and riparian habitats.**

Arizona's Santa Cruz River has its headwaters in the grasslands of the San Rafael Valley.

➤ **Protect restorative flood flows to maintain the stream channel and the aquatic, wetland and riparian habitat conditions necessary for plants and animals to reproduce and grow.**

It is important to note that efforts to further define these conditions will invariably require that decisions be made about the acceptable level of social, economic, hydrological or ecological consequences for water-resource use. These recommendations are not an attempt to judge the point at which these consequences become unacceptable, but rather they are intended to provide a set of water-management tools to meet these basic objectives. How these consequences of meeting these objectives are balanced in a given system must be defined by discussions at local, state and in some instances federal levels.



A FRAMEWORK FOR SUSTAINABLE WATER MANAGEMENT

"…I think the big challenge will be to get everybody on board. To me the plan fails if you don't have everyone on board. I've heard some people talking about safe yield, but not really addressing the environment or riparian issues. And then there are people who don't want to do anything. So, I think the challenge comes of trying to get all those people educated and on board with the concept of sustainability. There's a lot to do."

BOB HARDY, STAKEHOLDER, ARIZONA'S VERDE RIVER

Sustainable management of a common resource like water requires public dialogue. However, issues surrounding water management are technically and legally complicated, presenting challenges to using this information to develop sound public policies. In an effort to facilitate public dialogue and assist decision making, this report proposes a framework for sustainable water management. The application of this framework will lead to a comprehensive set of strategies that collectively will enable sustainable water management that meets the needs of people and nature.

Verde River, Arizona

1. MODEL THE SYSTEM:

Based upon the best available information, define and quantify hydrological and ecological processes both spatially and temporally, including human uses, and identify data gaps.

• On at least a conceptual basis, identify the relationships among streamflows, flood flows, aquifer conditions, aquatic, wetland and riparian plant and animal populations, and human water uses.

• Gather information necessary to better quantify elements of the system model, including groundwater models that account for the relationship of local aquifer conditions to surface water flows, interrelationships between areas, and effects of existing groundwater-pumping centers on aquifer

conditions. The development of the model should be an iterative process that is responsive to changing management needs. The development of a sophisticated model (such as a computer model) is not necessarily required; even simple models can assist resource management efforts.

• Conceptual understandings and models should consider past and future changes in climate, vegetation and stream morphology and inherent uncertainties about future hydrologic conditions, including the potential effects of climate change.

➤ 2. DEFINE GOALS:

Based upon the best available understanding of the hydrological and ecological system, develop management objectives that are explicitly tied to desired conditions and outcomes, recognizing that objectives may differ from place to place within the system and over time.

• Quantify water supplies needed to meet the needs of current and future residents, based on an analysis and juxtaposition of projected future demand (projected population times daily usage per person).

• Develop clear objectives for streamflows, flood flows and aquifer conditions that are tied to ecological objectives related to aquatic, wetland and riparian habitat. These should be a set of spatially explicit conditions for maintaining the system.

• Quantify water outflows from the management area to meet the needs of downstream users (human and natural).

A mesquite bosque is a highly-productive woodland riparian habitat that develops adjacent to desert streams and rivers.

➤ 3. ESTABLISH THE BASELINE:

Quantify existing uses and/or water rights and define their current and future impact on the system conditions spatially, temporally and in relationship to management objectives, accounting for the dynamic nature of the hydrologic system.

• Settle local surface-water-right claims; if this is not feasible, account for existing surface-water claims and diversions in relationship to other uses.

• Quantify all existing human and natural water uses (through measurement or estimate), including groundwater and surface water.

• Identify localized impacts of existing uses on the system over time.

• Develop localized and system-wide water budgets for all water inputs to and outputs from the system.

➤ 4. CONTROL NEW USES:

Quantify and regulate new uses in a manner that achieves management objectives.

• Establish limitations on new uses with regard to their location and amount of water use, including the possible establishment of groundwater rights that can be integrated with surface-water rights, recognizing that approaches may differ among the types of uses (e.g. agricultural, residential, commercial) and must account for variability in water supplies due to drought or long-term climate changes (e.g. additional conservation requirements, limits on lower priority uses, or pricing incentives that discourage use).

Sycamore Creek, Arizona.

➤ 5. REDUCE, REUSE OR REALLOCATE EXISTING USES:

Reduce, reuse or reallocate existing surface and groundwater uses as necessary to achieve management objectives.

• Define mechanisms for reducing existing uses, reusing water and/or transferring existing uses to new uses, including the establishment of a system of groundwater rights that can be integrated with surface water rights, recognizing that approaches may differ among the types of uses (e.g. agricultural, residential, commercial) and must account for variability in water supplies due to drought or long-term climate changes (e.g. additional conservation requirements, limits on lower priority uses, or pricing incentives that discourage use).

Verde River, Arizona

➤ 6. IDENTIFY & ALLOCATE ADDITIONAL SUPPLIES:

Define and evaluate future water supply needs to meet management objectives that cannot be met through the control of new uses or the reduction, reuse or reallocation of existing uses.

• If necessary, identify and implement actions to augment existing water supplies.

• If necessary, identify and secure new water supplies.

➤ 7. IMPLEMENT ADAPTIVE MANAGEMENT:

Monitor progress and re-evaluate management program over time to ensure achievement of management objectives.

• Establish mechanisms to monitor hydrological conditions, ecological conditions and water uses, and to fill data gaps.

• Establish trigger points for hydrological conditions, ecological conditions and water uses, building in adequate time for management responses, including enforcement of water-use restrictions and the establishment of additional monitoring to document and evaluate trends.

• Periodically review monitoring data and modify management strategies and objectives as needed.

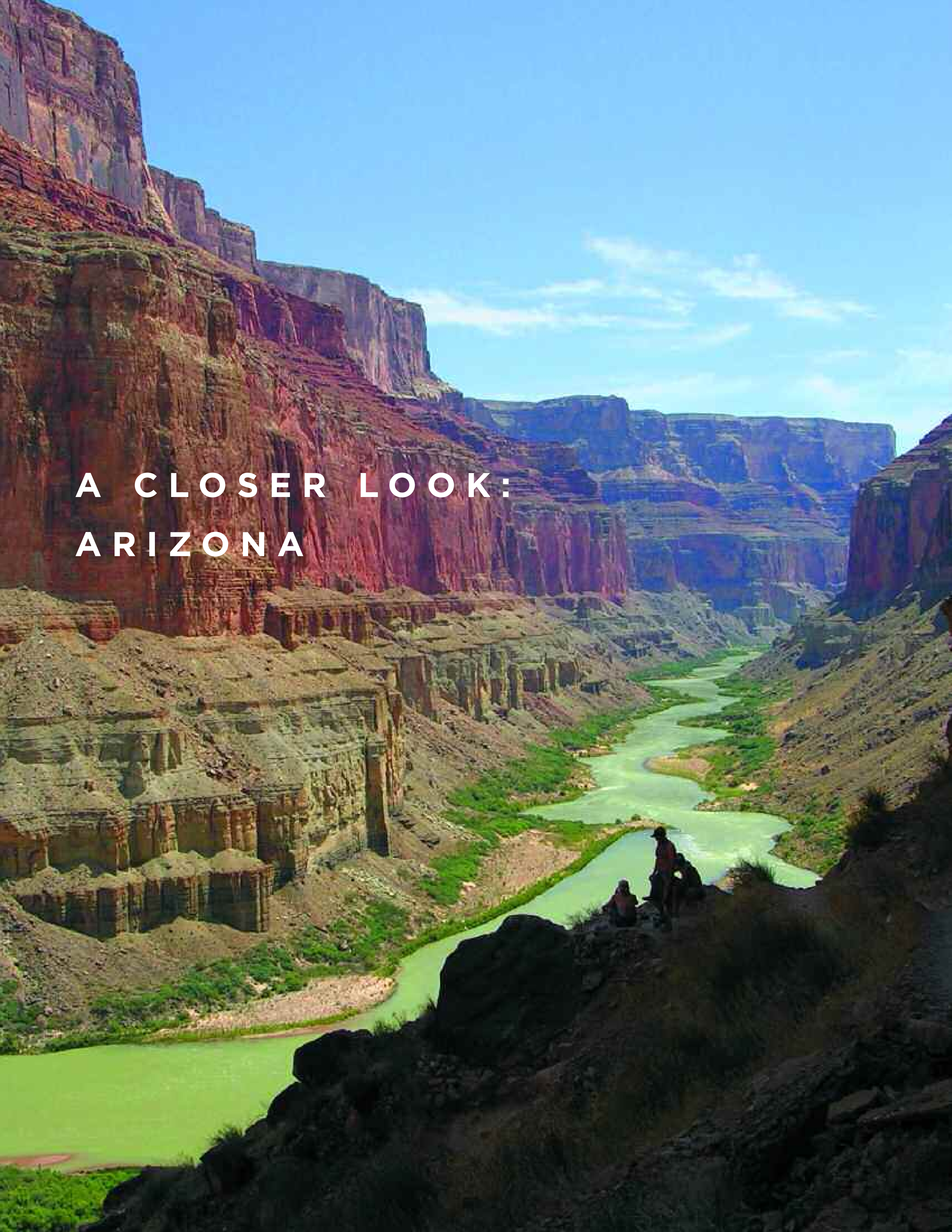
• Provide institutional support for long-term monitoring and management.

• Establish mechanisms for oversight and public and stakeholder involvement, such as technical advisory committees, watershed councils or similar entities.

"…I think often times in state government people look for the easy, clean, one-size-fits-all, here's our set of rules that we're going to apply them statewide as a solution to things. I think there has to be an opportunity for different goals and objectives, different rules given your geographic location… I think that it's a real key point to acknowledge that that is a process, not a destination…I think it's going to have to be a living, breathing process as we move forward."

GARY BRASHER, STAKEHOLDER, ARIZONA'S SANTA CRUZ RIVER

A CLOSER LOOK: ARIZONA



Like many states across the West, Arizona's population has grown significantly over the past several decades. In the last decade alone, Arizona has been either the first or second fastest-growing state in the nation. With the exception of Nevada, Arizona has the fewest number and miles of rivers and streams with year-round surface flow of any U.S. state. While this posed significant challenges during the early European settlement period, technological advances to store and divert surface water, to import water from remote locations, and to access groundwater has allowed development to occur far from rivers and streams and has generated tremendous economic prosperity for Arizona. However, these advances have not been without environmental consequences.

"Protecting stream flows is not only good for the ecological and biological systems, but it's also good for the economic security of the state. I've always kind of typified Arizona as the Arizona Highways *state. It's the rivers and streams and natural history and wildlife that attract people to this state. If we allow our rivers and streams to dry, we're going to see a negative impact on our economies."*

DAN CAMPBELL, STAKEHOLDER, ARIZONA'S VERDE RIVER

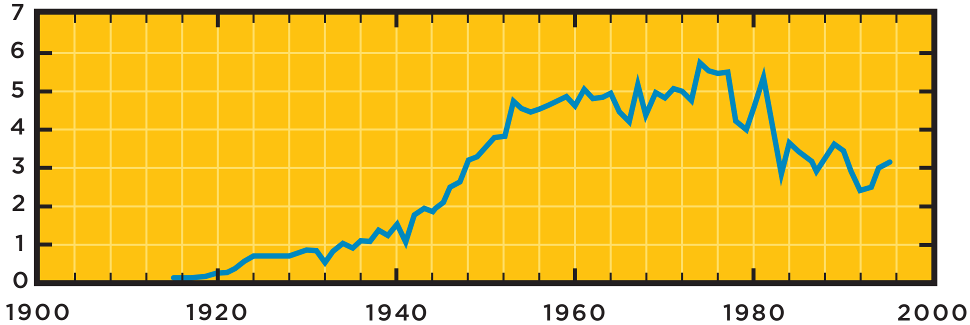


FIG. 6 Total groundwater withdrawals, annual million acre-feet, in Arizona, 1915-1995. Data for 1915 through 1990 is from Anning and Duet (1994); data for 1991 through 1995 is from M.T. Anderson (U.S. Geological Survey, unpublished data, 2003).

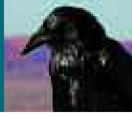
SURFACE AND GROUNDWATER MANAGEMENT IN ARIZONA

Two views of the same reach of the Santa Cruz River in 1942 (top) with well-established vegetation on the river banks, and 1989 (bottom) without year-round flow and loss of riparian habitat.

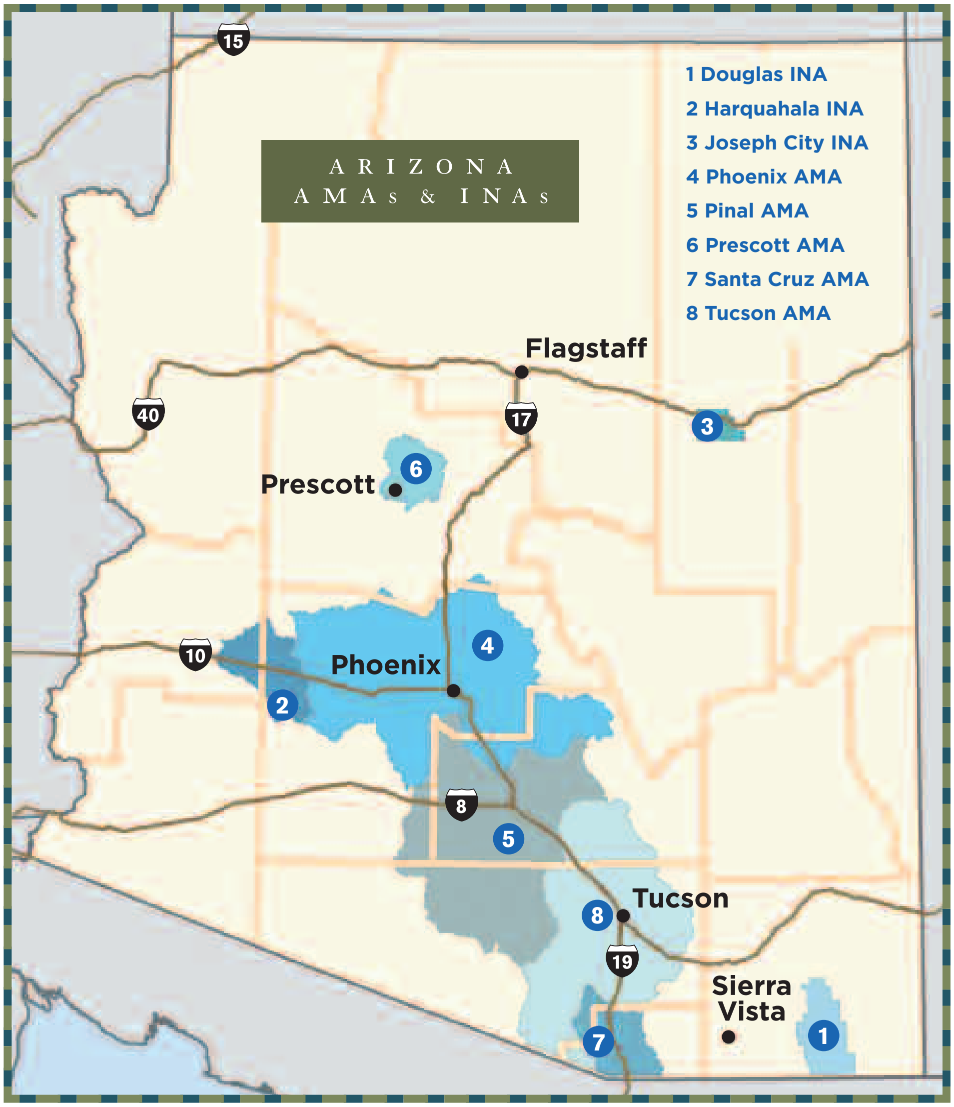
Historically, hydrologists understood surface water in rivers and streams to be physically distinct from groundwater. Early hydrologists recognized that streams could flow underground even when they appeared to be dry on the surface, but it was assumed that this effect was confined to an underground portion of the stream channel. Groundwater found at a distance from the stream was assumed to be unconnected with flows in the stream. As a result, the laws governing groundwater use in Arizona evolved separately from the laws governing surface water use.

In Arizona and much of the West, surface water is governed by the law of **prior appropriation** – in essence, a rule of "first in time, first in right." Under the prior appropriation system, the first user to divert water from a stream and put it to beneficial use obtains a right to continue such diversions and has priority senior to all subsequent diverters. A junior appropriator may only exercise her water rights to the extent that all senior rights have been satisfied first – even if this means that she must forgo her use of water.

By contrast, groundwater in most parts of Arizona is managed under the doctrine of **reasonable use** – effectively allowing a groundwater user to pump as much water as he may reasonably use. Under current Arizona law, the groundwater user may continue to pump even though, over the long term, his pumping may result in the loss of surface flows that support valid prior appropriation rights.



There is one key exception to this legal separation known as the **subflow doctrine.** In partial recognition of the need to connect these systems, the Arizona courts attempted a compromise by ruling that groundwater that has a "direct and appreciable" effect on a stream should be regulated as surface water under the prior appropriation system. Because the subflow doctrine is a legal concept that has little or no relationship to hydrologic reality, identifying the precise point at which groundwater (subject only to reasonable use) ends and subflow (subject to prior appropriation) begins remains an issue of controversy. Although the Arizona courts have refined this relationship, the final determination of what constitutes subflow in any particular river system and how the use of subflow should be administrated remains unsettled today. The uncertainties created by this legal doctrine have greatly complicated efforts to manage both surface water and groundwater resources in Arizona.



These issues are further complicated by the fact that most users of surface water have not had their rights under the prior appropriation system quantified or legally validated to the satisfaction of all water users. The Gila River General Stream Adjudication, a legal proceeding which is intended to quantify and settle the thousands of claims to the surface water of the greater Gila River watershed (and within which

Restoration efforts have begun in the San Xavier District of the Tohono O'odham Nation (tribal permission required to visit this site).

"I actually think the insanity of water law in this state — due to groundwater being completely separate from surface water, the idea of sustainability not being in the law at all, and how that has brought a tremendous number of problems…that's the issue."

SHERRY SASS, STAKEHOLDER, ARIZONA'S SANTA CRUZ RIVER

the three Arizona case study areas in this report occur), has been proceeding for more than 30 years. Apart from several settlements involving Indian reservations, and despite several important decisions by the Arizona Supreme Court that have clarified key legal issues, there remains little prospect that the Gila River General Stream Adjudication will conclude anytime soon. Further complicating the water-management situation, the Gila River General Stream Adjudication is still considering whether to exempt certain small uses as "de minimis" uses of surface water that are not subject to adjudication. Unfortunately, in many areas these small individual uses of water can collectively have a significant impact on hydrological systems.

Despite these legal uncertainties, Arizona has taken steps to manage groundwater more effectively in a few areas of the state. In 1980, in response to widespread concerns of groundwater overdraft in the Phoenix and Tucson metropolitan areas and several key agricultural regions, Governor Bruce Babbitt led an effort to develop groundwater management legislation, which culminated in the passage of the Arizona Groundwater Management Act (GMA). The GMA has a threefold goal: 1) control severe groundwater depletion occurring in certain parts of the state; 2) provide the means for allocating Arizona's limited groundwater resources in those areas to most effectively meet changing water needs; and 3) augment Arizona's groundwater through water supply development.

The GMA limits groundwater use in a series of defined metropolitan and agricultural areas known as Active Management Areas (AMAs) and Irrigation Non-Expansion Areas (INAs) by: quantifying existing uses of groundwater and extending grandfathered rights to these uses; requiring conservation programs and regulation and limitation of new groundwater uses except under defined circumstances; and providing the Arizona Department of Water Resources (ADWR) with administrative authority to implement the law. In addition, the GMA provides necessary incentives to encourage greater use of non-AMA groundwater, effluent, surface water (such as from the Salt, Verde, Agua Fria and Gila rivers), and Colorado River water delivered by the Central Arizona Project in Arizona's metropolitan areas.

Importantly, the GMA was not designed to protect groundwater-dependent rivers and streams. However, in 1994, the southern portion of the Tucson AMA was re-designated as the Santa Cruz AMA and a new management goal was developed: to prevent "…long-term declines in local water table conditions." This language represents an improvement in AMA goals by explicitly recognizing local water table declines rather than a basin-wide water balance. It also allows for the establishment of a more spatially limited set of hydrologic conditions including water table elevations that sustain river flow and riparian habitat.

It is generally acknowledged that the landmark GMA legislation greatly improved groundwater management in Arizona's AMAs and INAs, particularly in the Tucson and Phoenix metropolitan areas. However, the GMA has not been extended to any other areas of the state and does not resolve issues regarding the quantification and protection of surface-water uses.

Recent drought conditions have brought increased attention to the lack of water management in many rural areas of Arizona. As population growth continues in the rural areas of the state, growing groundwater use has resulted in groundwater declines in many rural and semirural communities, causing wells to go dry and threatening future economic prosperity. Attention is also being brought to several of Arizona's remaining rivers and streams where unregulated groundwater pumping is threatening life-sustaining streamflows. These include the San Pedro and Verde rivers, which are now listed among America's "Most Endangered" rivers.

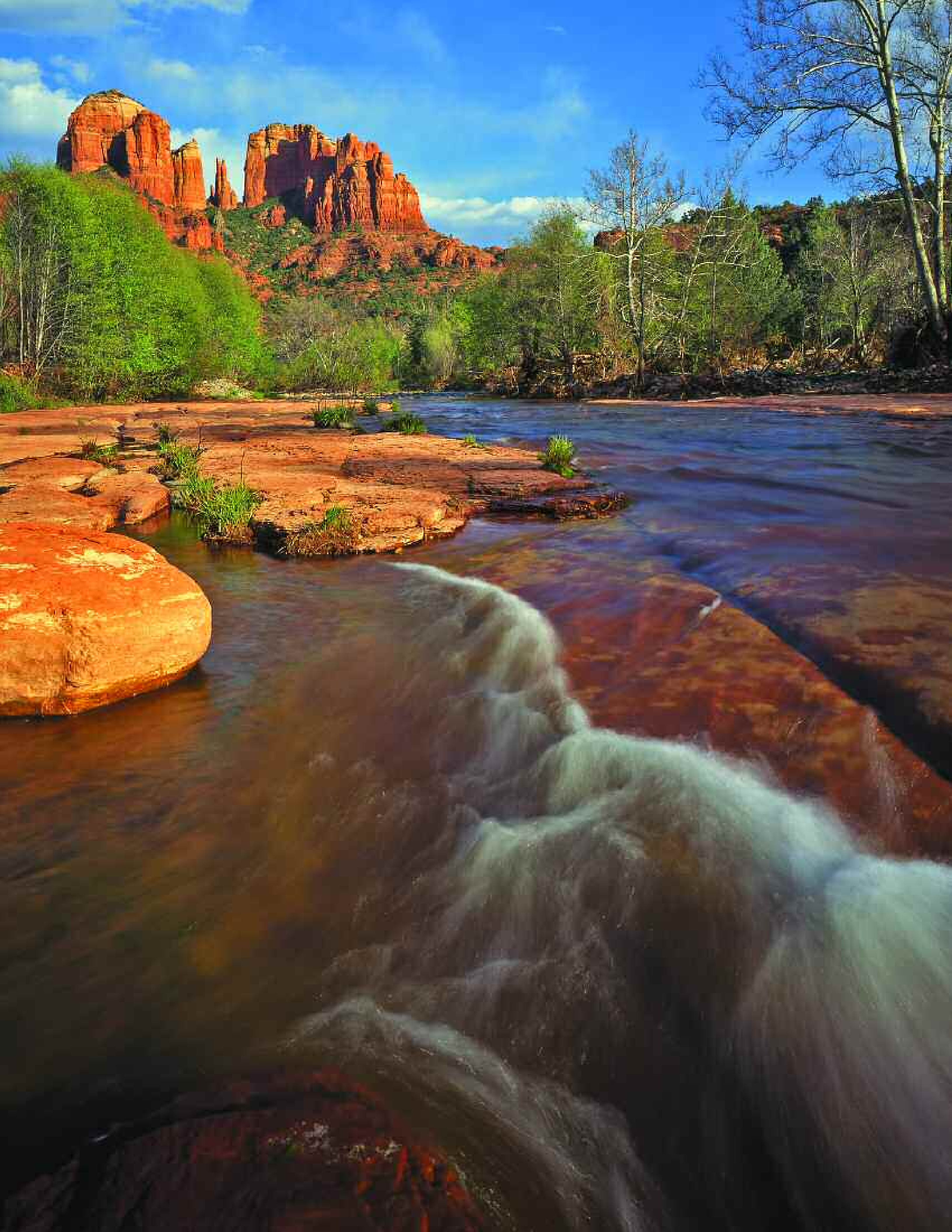
Making The American Rivers List

Arizona's San Pedro & Verde Rivers designated "Most Endangered"

Since 1986, American Rivers and dozens of partners have released ***America's Most Endangered Rivers*** — an annual report that spotlights rivers across the country facing critical and near-term threats, including confronting decisions in the coming year that could determine their future. Arizona's Verde River and San Pedro River joined the most endangered rivers list in 2006 and 1999 respectively.

Verde River: As a critical source of drinking water for rapidly growing Phoenix, Prescott and other communities, as well as a haven for boating, fishing and bird watching, the Verde is a jewel in the desert. However, the Verde could find itself diminished if plans move forward on a proposed 30-mile pipeline to increase pumping of water out of the underground aquifer — the Big Chino — that feeds the river. **www.americanrivers.org/site/DocServer/ MER_final.pdf?docID=3781**

Upper San Pedro River: Highly valued for its biological diversity and its importance for neotropical migrating birds, the Upper San Pedro River is a natural treasure. However, the increasing needs of the rapidly growing Sierra Vista region, including the U.S. Army's Fort Huachuca, are pumping water out of the regional aquifer faster than it can be replenished. Despite ongoing efforts, the failure of the region to bring the groundwater deficit into balance directly threatens the river's year-round flows and its vast ribbon of riparian habitat and diversity of species. **www.americanrivers.org/ site/DocServer/ MER_1999_Web.pdf?docID=2163**



APPLYING THE SUSTAINABLE WATER MANAGEMENT FRAMEWORK IN ARIZONA

Three case study assessments of Arizona river systems are presented which characterize the physical system, identify the current or potential impacts of groundwater pumping, and evaluate current water management efforts in light of the sustainable water management framework. The three case study areas are the San Pedro River in the vicinity of Sierra Vista and Fort Huachuca (Upper San Pedro River); the Verde River system in the areas around Cottonwood, Camp Verde and Clarkdale (Middle Verde River), as well as in the vicinity of Prescott, Prescott Valley and the Big and Little Chino Valleys (Upper Verde River); and the Santa Cruz River Valley in Santa Cruz County between the U.S.-Mexico border and Pima and Santa Cruz county line (Santa Cruz Active Management Area). While these case study areas are where population pressures and groundwater use are of most concern, other rivers like the Hassayampa, Agua Fria, Upper Gila and the Big Sandy can expect to join the list of Arizona's endangered rivers as groundwater pumping in these areas continues to increase without adequate management.

"I know that in some growing cities, developers and realtors are concerned that protecting the stream flows is protecting wildlife and habitat over the needs of human beings and economic development. I really think that there's a balance and that there's a point where you're not going to have any economic development when you lose your wildlife habitat."

JANE MOORE, STAKEHOLDER, ARIZONA'S VERDE RIVER

Visitor on the banks of the Verde River, Arizona.

Case Study #1:

UPPER SAN PEDRO RIVER

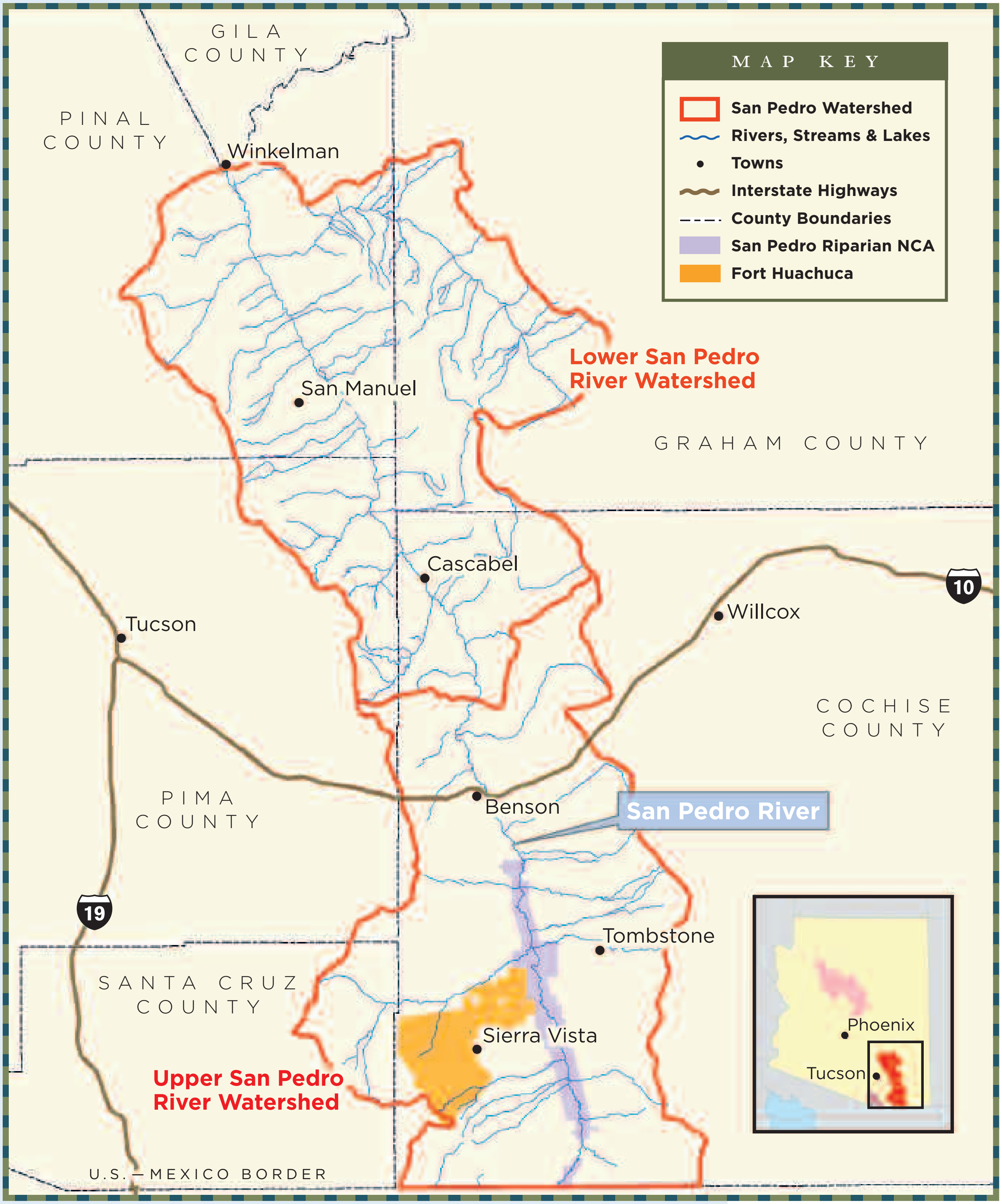
The San Pedro River runs approximately 100 miles from its headwaters in Canenea, Mexico, north across the U.S.-Mexico border to its confluence with the Gila River near Winkleman, Arizona. Along its course, the San Pedro flows between a series of mountain ranges that define the river basin. The upper and lower basins of the San Pedro River are divided by a natural constriction in the San Pedro River Valley known as "the narrows" about 10 miles downstream from the town of Benson, Arizona. The U.S. portion of the Upper San Pedro Basin, located to the south of the narrows, is divided into the Sierra Vista and Benson sub-watersheds. This report focuses on the Sierra Vista sub-watershed.

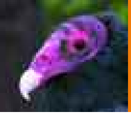
Located in a basin-and-range setting in southern Arizona, the Sierra Vista sub-watershed lies in a broad, sediment-filled valley surrounded by high-elevation, north-south trending mountains, often referred to as "sky islands." Within the valley is a large, deep aquifer that, in combination with surface runoff, sustains year-round flow in much of the river within the Sierra Vista sub-watershed, although small portions of the river can go dry for brief periods. This large, single aquifer system sustains base-flow in this portion of the Upper San Pedro River. A portion of the surface runoff entering the Sierra Vista sub-watershed is derived from Mexico, along with a small amount of groundwater inflow from the groundwater aquifer in Mexico.

With a regional population of about 72,500, groundwater pumping and natural uses in the Sierra Vista sub-watershed already exceeds the sustainable capacity of the basin. Estimates of the net deficit run as high as 10,000 acre-feet per year. The vast majority of human groundwater use supports residential and commercial development in and around Sierra Vista and the activities of the U.S. Army Garrison at Fort Huachuca. While Fort Huachuca is not expected to grow substantially, the population of Sierra Vista and the surrounding unincorporated areas continues to grow about 1.5 percent per year. With this growth, groundwater pumping by local water providers and individual well owners is increasing in Sierra Vista and further south in the unincorporated Palominas-Hereford area .

This pumping has led to declines in water-table elevations in portions of the aquifer west of the river. In addition, two large, distinct cones of depression resulting from clusters of groundwater wells have formed in the Palominas-Hereford area and in the vicinity of Sierra Vista and Fort Huachuca. In both cases, groundwater flow to the river has been intercepted; in the Palominas-Hereford area, there are indications that groundwater pumping has reversed the flow gradient away from the river during dry periods of the year.

The Upper San Pedro River system is highly variable. Climate data indicate that the river has experienced periodic, extended drought conditions and that the timing of rainfall has changed over time. In addition, changes in climate along with changes in


MAP KEY
San Pedro Watershed
Rivers, Streams & Lakes
Towns
Interstate Highways
County Boundaries
San Pedro Riparian NCA
Fort Huachuca
GILA COUNTY
PINAL COUNTY
Winkelman
San Manuel
Lower San Pedro River Watershed
GRAHAM COUNTY
Cascabel
Tucson
Willcox
10
COCHISE COUNTY
PIMA COUNTY
Benson
San Pedro River
19
Tombstone
SANTA CRUZ COUNTY
Sierra Vista
Upper San Pedro River Watershed
U.S. — MEXICO BORDER
Phoenix
Tucson



Case Study #1: Upper San Pedro River

"Protecting stream conditions is extremely important and needs to be shared across artificial boundaries of governance and really looked at holistically from a watershed perspective."

GRETCHEN KENT, STAKEHOLDER, ARIZONA'S SAN PEDRO RIVER

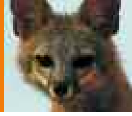
Beaver dams such as this one on the San Pedro River contribute to the health of riparian areas by widening the riparian strip, lessening erosion, slowing flood waters, and by providing new habitat for wildlife and fish.

floodplain geology have altered the composition and density of the river's wetland/riparian vegetation. However, groundwater pumping is recognized as the most significant risk to the river system and has likely contributed to declines in baseflow at two, long-term stream-gauge sites. Although there is uncertainty about the relative importance of groundwater pumping versus other factors (such as riparian forest expansion or climate changes) on the baseflow declines, there is widespread agreement that increased pumping without additional management will cause longer and longer segments of the river to go dry for periods of time.

Much of the perennial portion of the Upper San Pedro River is located within the San Pedro Riparian National Conservation Area (SPRNCA). SPRNCA was established by an Act of Congress in 1988, with the express purpose of protecting the San Pedro River and its riparian resources. The Act also granted the Bureau of Land Management an explicit federal reserved water right sufficient to fulfill the purposes of SPRNCA. Because SPRNCA's federal reserved water rights include rights to both surface water and groundwater necessary to support flows in the river, the prospect of enforcement of federal water rights by the Department of Justice remains a significant concern to local and state decision makers in the absence of more effective local water management.

The Congressional Act that created SPRNCA acknowledged that without adequate and purposeful management of water resources to meet the needs of a growing population in the Sierra Vista sub-watershed, the continued health and viability of the San Pedro's riparian system, as well as that of local communities, could be at risk. There is little formal structure to govern water management in the Sierra Vista sub-watershed. Surface water uses, other than the federal reserved right to surface water within the SPRNCA, are small in number. There has been no final adjudication of surface water rights, including subflow uses via groundwater pumping in the area, so the number of groundwater wells that are pumping surface water is unknown. Regardless, for the foreseeable future, the majority of water use in the area is likely to continue to be unregulated groundwater pumping.

Despite the lack of formal regulation, local governments, agencies and community members have formed a voluntary watershed association called the Upper San Pedro Partnership (USPP). Comprised of a consortium of 21 agencies and organizations, the USPP has expressly adopted a goal of sustainable groundwater management for the Upper San Pedro, linking water management to the achievement of specific hydrological and ecological objectives designed to maintain the health of the river. The long-term efforts of the USPP have produced a remarkable degree of cooperation and consensus regarding the problems facing the area, even in the absence of a formal management authority. The USPP has developed a great deal of scientific information about the river system, including threats to the river system, and they



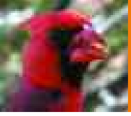
have identified a number of actions that will move them toward sustainable water management, some of which have been implemented. In addition, the relatively small number of surface-water rights in the Upper San Pedro simplifies efforts to manage the system in the face of legal uncertainties associated with the use of surface water and groundwater.

The barriers to moving forward in the Upper San Pedro River are largely problems of implementation due to the shortcomings of the current legal authorities to manage water outside of AMAs and INAs. There is agreement on the need for additional local authority to effectively manage the water resources within the Sierra Vista sub-watershed. However, at present, there is no legal authority to establish a system of groundwater rights, making it difficult if not impossible to quantify existing uses, to utilize market-driven reduction, reuse and reallocation, and to control new uses. Funding and corresponding financing mechanisms are needed to implement key solution elements, including potential importation of water supplies that may be needed to eliminate existing deficits and provide for new growth.

Legally permissible regulatory approaches such as mandatory water conservation or limitations on new uses have only seen modest implementation. Although local land-use authorities have undertaken some efforts to link land use to water-management objectives in the Upper San Pedro, their ability to do so is legally uncertain under current state law, and the USPP has identified the need for expanded local authority in this area. However, increased local land-use authority alone may not be sufficient to guide appropriate groundwater management; other formal mechanisms for regional water management may be needed to formalize the interagency cooperative relationships developed in the USPP, inform local decision making, and guide regional collaboration.

Javelinas are a common sight along Arizona's rivers and creeks during spring and summer.

Of the three case studies, the Upper San Pedro probably faces the smallest challenge from the lack of an adjudicated system of surface-water rights given that there are few direct surface-water diversions on the Upper San Pedro and the boundaries of SPRNCA have limited the number of wells near the river that pump subflow. Nonetheless, prompt adjudication of these rights would likely assist management efforts insofar as defining the legal character of the rights associated with subflow wells, the area of the subflow zone around the river (which would limit new well installations in the vicinity of the river outside the boundaries of the SPRNCA), and the rights of the federal government to surface water to maintain streamflow and riparian habitat in the SPRNCA and groundwater use associated with Fort Huachuca Army Garrison. A complicating factor is the presence of federally listed endangered species associated with the San Pedro River. This may result in additional water management imperatives in response to Endangered Species Act compliance issues for Fort Huachuca as well as other water users in the basin.



Case Study #2:

UPPER SANTA CRUZ RIVER

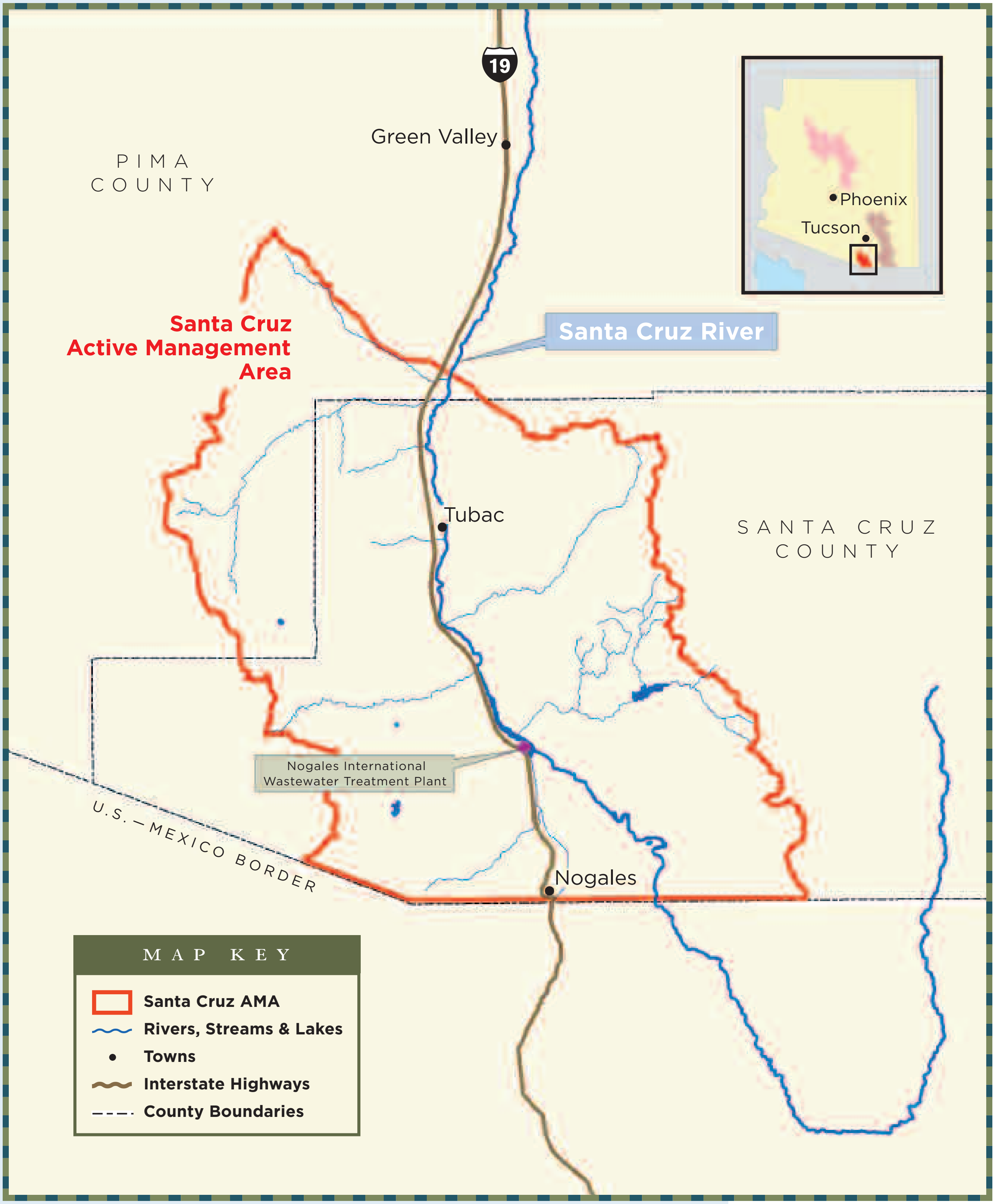
From its headwaters in the San Rafael Valley, the Santa Cruz River flows south into Mexico where it completes a 25-mile U-turn and flows north back into the United States through Santa Cruz, Pima and Pinal Counties before joining the Gila River in Maricopa County. This report focuses on the portion of the Santa Cruz River watershed within the Santa Cruz Active Management Area (SCAMA) and includes that portion of river from the U.S.-Mexico border to Santa Cruz-Pima County line.

Visitors to the Santa Cruz River.

Within the SCAMA, groundwater can be found in three relatively distinct aquifers. The first aquifer, the Younger Alluvium, fills a series of micro-basins immediately bordering the stream channel that have low storage capacity, although water moves easily through it, and ranges in depth from 40-to-150 feet. Generally, the Younger Alluvium aquifers increase in thickness and width downstream up to the northern SCAMA boundary, where the Younger Alluvium joins the very broad and deep Tucson basin. The second aquifer, known as the Older Alluvium, is found primarily beneath the foothills of the valley and beneath the Younger Alluvium and ranges from a few feet in thickness to over 4,800 feet. There is large storage capacity in the Older Alluvium, but water moves poorly through the aquifer because of its physical characteristics. The third aquifer, known as the Nogales Formation, underlies the Older Alluvium and has extremely poor water-bearing characteristics.

In the northern half of the SCAMA, the Santa Cruz River channel also receives effluent discharges from the Nogales International Wastewater Treatment Plant (NIWWTP) of roughly 15,000 gallons a day with two-thirds of the wastewater generated in Mexico. Santa Cruz River streamflows are maintained by surface runoff, groundwater discharge from the Younger Alluvium, and direct discharge of effluent from the NIWWTP to the stream channel. The nature of the groundwater in the Older Alluvium and Nogales Formation is poorly understood but it is not believed to contribute significantly to the water found in the Younger Alluvium.

Within the SCAMA, the majority of water use is associated with wells located in the Younger Alluvium micro-basins. These micro-basins can be depleted quickly by pumping in times of drought but can refill rapidly during large storms. Extensive pumping upstream from the NIWWTP to support municipal uses in Nogales, Mexico, and Nogales, U.S., has depleted much of the groundwater in the southernmost micro-


19
Green Valley
PIMA COUNTY
Phoenix
Tucson
Santa Cruz Active Management Area
Santa Cruz River
Tubac
SANTA CRUZ COUNTY
Nogales International Wastewater Treatment Plant
U.S. – MEXICO BORDER
Nogales
MAP KEY
Santa Cruz AMA
Rivers, Streams & Lakes
Towns
Interstate Highways
County Boundaries

Case Study #2: Upper Santa Cruz River

basins. Because of this, water table elevations in this section of the river are usually lower than the stream channel, and baseflow has been disrupted such that the river no longer flows perennially from the U.S.-Mexico border to the point of effluent discharge at the NIWWTP. While recharge from large storms can temporarily restore water table elevations, these storms are not sufficient to offset long-term pumping impacts, and perennial streamflows have not returned to this portion of the river.

An aerial view of a portion of Arizona's Santa Cruz River basin.

Downstream from the NIWWTP, however, groundwater levels in the micro-basins are higher as a result of the discharge of effluent from the NIWWTP. Unlike the other case studies addressed in this report, effluent discharges along with surface runoff and groundwater discharge maintain streamflow and high water table elevations that together sustain perennial streamflow and high-quality riparian habitat. In the Santa Cruz River, this effluent has mitigated the decreases in groundwater discharge that have occurred as a result of pumping. In the absence of effluent flows, groundwater pumping in the Younger Alluvium would likely have the same effect on baseflow as the pumping in the upstream portions of the river, which are now dry for portions of the year. Streamflow records from periods prior to the construction of the NIWWTP indicate that perennial flow had been eliminated in the effluent-dominated sections of the river by the mid-1970s.

While groundwater-table elevations downstream from the NIWWTP are usually high enough to sustain year-round flow and rich riparian habitats, water-table elevations can vary tremendously as a result of changes in aquifer recharge rates due to natural fluctuations in surface runoff from drought. Reductions in the frequency and size of flood events reduce the amount of surface runoff and also reduce the streambed scouring that occurs.

This latter effect is particularly important in the Santa Cruz's effluent-dependent system, as high nitrogen levels in the effluent produce significant amounts of algae, which forms thick mats on the bottom of the stream channel. If these algal mats remain in place for long periods, they essentially seal the bottom of the stream channel, preventing the infiltration of water into the aquifer and reducing recharge.

This can create an unusual situation where water continues to flow in the stream channel even as local water tables drop to the point that riparian plants can no longer access the groundwater and thus begin to suffer from drought conditions. Wetland and riparian vegetation vary in their response depending on how far the local water table declines, the duration of water table declines, the specific plant species, and the time of year when declines occur (as plants generally need less water in the winter than in the summer).

The SCAMA is a groundwater-management authority under the jurisdiction of ADWR and has a dual management goal: a) to maintain safe-yield in the basin and b) to prevent long-term declines in local water tables. The SCAMA goal of safe yield seeks to maintain a long-term balance between the amount of groundwater withdrawn in an AMA and the annual amount of natural and artificial recharge in the AMA. The second part of the SCAMA management goal was developed specifically to recognize the unique hydrological character of the SCAMA (i.e. a series of micro-basins) and thus seeks to prevent local water table declines (as opposed to seeking a water-use balance within the AMA as a whole). This provision is also intended to protect the stream and its associated resources. However, even short-term declines in groundwater-table conditions can result in significant riparian habitat loss depending on the factors described above. These short-term declines may nevertheless be consistent with the AMA management goal (since they may be offset by future recharge from surface runoff and effluent discharge) and meet the stated goal of preventing "long-term declines in local water tables."

Although the majority of water users draw from wells and are therefore subject to the regulations imposed by the SCAMA, the use of this water is also potentially governed by the surface-water-rights system, since recent court decisions have established that water drawn from wells in the Younger Alluvium is generally considered subflow. In anticipation of this fact, most of the groundwater wells in the SCAMA are dual-filed as both groundwater rights and as surface-water claims. As part of the Gila River General Stream Adjudication, claimants to surface-water rights in the Santa Cruz AMA are in the process of adjudicating these rights and have also entered into settlement discussions. However, until these rights are finally resolved, they remain uncertain and complicate efforts to integrate surface-water rights with the SCAMA rules and regulations. Since most of the water used in SCAMA is groundwater pumped from the Younger Alluvium that may be subflow, the amount of water being used by the majority of existing users cannot be effectively regulated through the SCAMA alone to the extent that their right to pump water derives from surface-water-rights claims. However, it should be noted that because AMA authority extends to water withdrawn from wells, the AMA does have some ability to regulate surface-water use in the form of subflow for purposes of some AMA programs, such as conservation requirements.

Case Study #2: Upper Santa Cruz River

Management of the Upper Santa Cruz River system is further complicated by the ownership of the effluent discharge from the NIWWTP, which as previously noted is the main source of recharge to offset groundwater-table declines associated with drought and pumping. As stated in the current SCAMA management plan, effluent "generated by the treatment plant is one of the most important renewable water supplies in the Santa Cruz AMA." A recent study on the implications of sustained drought in the Upper Santa Cruz has found that, "achieving safe yield would likely be impossible if the effluent from Mexico was not included." However, under Arizona law and U.S.-Mexico border agreements, effluent from the NIWWTP is owned by Mexico and the City of Nogales; as such, neither party is obligated to continue to discharge effluent to the stream channel.

Given the importance of this effluent to the health of the river system downstream from the NIWWTP and the uncertainty of the legal rights associated with the users of surface water (the vast majority of pumpers), the most important input (effluent) and output (well pumping) to the system are not under the complete control of the SCAMA. These shortcomings in the water-management system, coupled with population growth in the Santa Cruz River Valley, will continue to place tremendous pressure on limited water supplies and threaten the future vitality of the river corridor.

Many of the elements needed for a comprehensive management system in the Upper Santa Cruz River are already in place as a result of the authorities granted to the SCAMA. However, most of the necessary management programs are not yet fully implemented within the SCAMA framework, and many implementation challenges remain.

Building on the ADWR groundwater modeling for the area, there is a need for additional research to define the relationship between the local hydrologic system and streamflow and riparian habitat goals, which may require more information on ecological requirements. Data gathering in SCAMA has produced significant amounts of information about water uses in the Upper Santa Cruz.

SCAMA also provides for a system of groundwater rights and regulation that controls new uses and reduces existing uses. ADWR initiatives currently underway, including the development of assured water-supply rules and well-spacing criteria, will improve this management framework.

From a larger perspective, several key obstacles appear to stand in the way of effective, comprehensive management of water resources in the Upper Santa Cruz. First, and perhaps most critically given the central importance of continued effluent flows from the NIWWTP to the Santa Cruz River, is the necessity of securing a legal commitment or binding agreement with Mexico and the City of Nogales that ensures a quantifiable amount of effluent flows into the system.

While a guarantee of continued effluent flows will not in itself solve the problems facing the river, the protection of some level of effluent flows is likely an essential precondition to the protection of the river, as it currently represents the primary source of baseflow and recharge below the NIWWTP and is universally recognized as critical to sustainable water management in the Upper Santa Cruz River. Without this type of commitment, the goals of the SCAMA likely cannot be met. Related concerns are the need for additional nitrate removal from the effluent and the necessity of disrupting the formation of algal mats during periods of infrequent flood events to enable recharge to occur. Mechanisms to effectively accomplish algal mat removal are unknown.

The fact that surface-water rights are not yet adjudicated also significantly complicates management in this system. For several years, a group of surface-water rights holders have been actively engaged in settlement discussions because without a surface-water-rights settlement or prompt adjudication of surface-water rights, meaningful regulation of water use in the Santa Cruz will be difficult (since most of the groundwater users in the Upper Santa Cruz are likely pumping subflow and will be subject to the prior appropriation system). Similar to the effluent issue, the implementation of assured water-supply rules will require certain assumptions regarding future use by surface-water-right claimants, and surface-water uses will need to be subject to consistency with the SCAMA management goal under assured water-supply rules. The development of a SCAMA recharge program is likely necessary as well.

A final significant issue is associated with the AMA management goal itself. As discussed previously in this report, the current dual goals of maintaining a safe yield condition in the AMA and preventing local water tables from experiencing long-term declines allows for consideration of water-table conditions that will sustain baseflow in the river. However, ambiguity remains around the issue of long-term declines, as water-table declines that persist for relatively short periods of time can be very destructive to aquatic and riparian habitats. Absent a change in the AMA's goal, it is essential that management actions strive to minimize even short-term water-table declines.

"Protecting flood flows to maintain stream channels and habitat conditions is important, as long as it's balanced. We don't want to have all the streams running. We live in the desert and the natural conditions are not for the streams to be constantly full of water. The balance, in my opinion, there are some areas that the streams are going to be flowing part of the year, or most of the year, and some areas are going to be dry. That has been the natural condition for many, many years – balance is key."

ALEJANDRO BÁRCENES, STAKEHOLDER, ARIZONA'S SANTA CRUZ RIVER

Case Study #3:

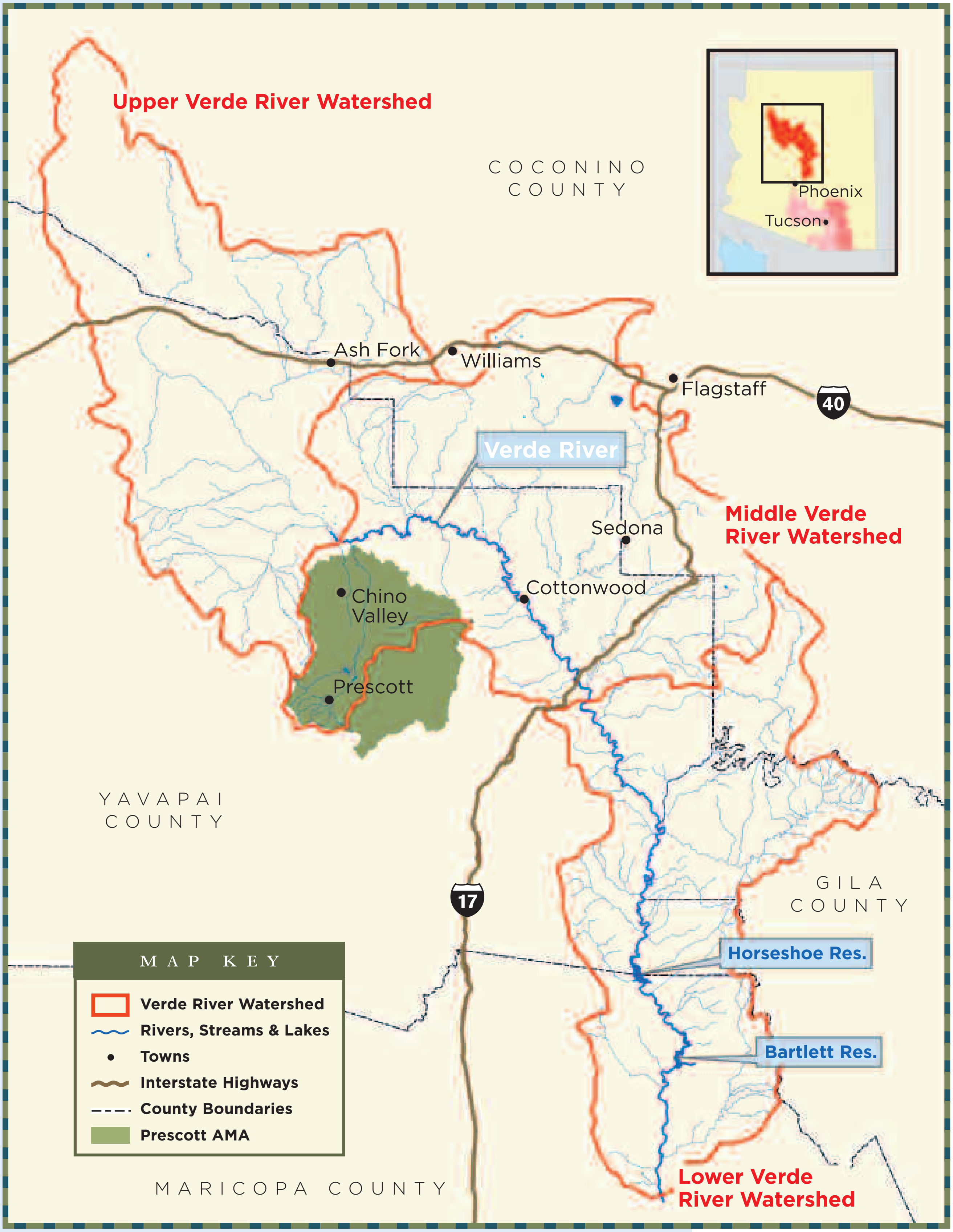
UPPER & MIDDLE VERDE RIVER

The Upper and Middle Verde River watersheds include an area that drains approximately 6,188-square-miles in north-central Arizona. Traversing a total distance of about 175 miles, the Verde River flows freely through this area for 125 miles before encountering Horseshoe and Bartlett Reservoirs en route to the Salt River. The river flows through lands managed by the U.S. Forest Service and private and tribal lands and the main population centers of Cottonwood, Clarkdale and Camp Verde. Within the Upper and Middle Verde River watersheds are multiple aquifers that play a significant role in sustaining streamflows: Big Chino, Little Chino, Redwall-Muav, C, and Verde Valley aquifers.

The Upper Verde River (that portion of the river in the upper watershed) flows intermittently through the Big Chino Valley, becoming perennial just upstream from its confluence with Granite Creek. Baseflow in the Upper Verde River is sustained primarily by groundwater discharge from the Big Chino Valley, which occurs as springs in and adjacent to the river immediately downstream from Sullivan Lake. These springs account for approximately 80-to-86 percent of total Verde River baseflow in the first 24 miles of the perennial flow. The remainder is derived from baseflow from Granite Creek originating in the Little Chino Aquifer and from groundwater discharge to the Verde River originating on Big Black Mesa and the Coconino Plateau.

The Little Chino aquifer is located within the Prescott Active Management Area (PrAMA) which has a safe yield management goal that seeks to achieve and thereafter maintain a long-term balance between the amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge in the AMA.

When the PrAMA was established in 1980, data was insufficient to determine if the groundwater basin was out of safe yield. By 1999, ADWR had acquired the necessary information to determine that pumping in the Little Chino sub-basin was exceeding its recharge and that groundwater mining was occurring. Unfortunately, the out-of-safe-yield declaration of the PrAMA was preceded by local government approval of approximately 32,000 residential units, casting doubt that safe yield could ever be obtained without a new water source. Widespread groundwater-level declines have continued within the PrAMA, resulting in continued declines in groundwater discharge from the Little Chino sub-basin to the Verde River via discharge from Del Rio Springs and Granite Creek.



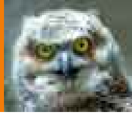
Upper Verde River Watershed
COCONINO COUNTY
Phoenix
Tucson
Ash Fork
Williams
Flagstaff
40
Verde River
Sedona
Middle Verde River Watershed
Cottonwood
Chino Valley
Prescott
YAVAPAI COUNTY
17
GILA COUNTY
Horseshoe Res.
Bartlett Res.
MAP KEY
Verde River Watershed
Rivers, Streams & Lakes
Towns
Interstate Highways
County Boundaries
Prescott AMA
MARICOPA COUNTY
Lower Verde River Watershed

Case Study #3: Upper & Middle Verde River

When the PrAMA was established, grandfathered groundwater rights for existing uses, withdrawal permits and approved subdivisions already exceeded safe yield. The 1999 declaration that the PrAMA was out of safe yield prohibits most new withdrawal of groundwater, thus requiring that new subdivisions be supported by a renewable source of water. However, new subdivisions have largely used treated sewage effluent to meet this requirement, which does not resolve the existing overdraft of the PrAMA. In addition, pumpage from unregulated wells (small wells that pump less than 35 gallons per minute, usually owned by individuals) has increased significantly since 1999 and continues to grow. This has exacerbated problems associated with overpumping of groundwater since the establishment of the PrAMA. There are approximately 9,400 exempt wells in the PrAMA, representing an estimated 14 percent of the total annual groundwater withdrawn.

The Prescott area was the fastest-growing rural area in the United States between 1990 and 2000, and comparable levels of growth are anticipated over the next two decades. Continued growth in the PrAMA, and the 1999 declaration that the PrAMA is out of safe yield, has forced communities to augment their water supplies from areas outside of the PrAMA. One area that is being actively investigated is the transfer of water from the Big Chino Valley (specifically permitted under state law), which is located outside of the PrAMA but within the Upper Verde River watershed. Groundwater pumping to support population growth in the Big Chino subwatershed, combined with the exportation of groundwater to PrAMA communities, is expected to result in the Big Chino Valley aquifer being pumped in excess of natural recharge. So while pumping in the Big Chino Valley will assist efforts to attain safe yield in the PrAMA, the end result could be reduced groundwater discharge to the Upper Verde River. Ironically, given the importance of the Big Chino Valley to Upper Verde River baseflow, the water needed by the PrAMA to attain safe yield is likely to exacerbate the impacts of groundwater pumping on the baseflow of the Verde River.

Steamflow in the Middle Verde River (that portion of the Verde River that flows through the Middle Verde watershed) is sustained by surface runoff, baseflow from the Upper Verde River, baseflow in the mainstream Verde River canyon at Perkinsville and Mormon Pocket, groundwater discharge from the Verde Basin aquifer, and con-



tributions from the major tributaries within the Middle Verde River watershed (e.g. Sycamore, Oak, Wet Beaver and West Clear creeks). The latter are, in turn, largely comprised of groundwater discharge from the C aquifer at the Mogollon Escarpment and Coconino Plateau. The flow of the Verde River increases significantly as it passes through this portion of the watershed.

Diversions of the Verde River for agricultural uses constitute the largest use of water within the Middle Verde watershed. Currently, there are approximately 50 irrigation companies and ditch associations located in the Verde Valley. The amount of river water that is diverted and applied by these users is not accurately measured (if it is measured at all), and uses are not currently reported. This unregulated diversion of surface water by water-right holders for irrigation has the unintended consequence of reducing flows in the Verde River during the late spring and summer months when baseflow is typically at its lowest.

Most of the groundwater pumping that occurs in the Verde Valley aquifer is associated with individual well owners, several large private and municipal water providers, and irrigation companies and ditch associations (largely supporting agricultural uses). Most of this pumping occurs in proximity to the Middle Verde River. Agricultural use is anticipated to remain steady or decline slightly over the next 25 years; over the same period, groundwater use associated with residential, commercial and industrial developments is anticipated to double, which may result in significant reductions in baseflow to the Verde River. Because of the proximity of groundwater use to the river, the impacts of pumping in this area are likely to be more immediate than the anticipated impacts of pumping in the Upper Verde River watershed. However, because Middle Verde River baseflow is significantly greater than that in the Upper Verde, these pumping impacts will reduce baseflow but are not likely to completely dry up any portions of the river for the foreseeable future.

The Verde River is unique among Arizona rivers in that approximately 90-to-95 percent of the water in the river is obligated to downstream, senior water-rights holders, including the Salt River Project, the City of Phoenix, the Salt River Pima-Maricopa Indian Community, and the Fort McDowell Indian Community. The Salt River Project captures and manages this water in the Horseshoe and Bartlett Lakes. The majority of uses in the Middle Verde River watershed (both surface-water-right diversions and much of the groundwater pumping) is or is likely to be considered surface water or subflow and thus subject to the prior appropriation system and the Gila River General Stream Adjudication; however, these rights have yet to be adjudicated or quantified. The lack of a mechanism for downstream surface-water-right holders to prohibit or limit junior upstream uses results in expensive, time-consuming, and uncertain legal challenges by downstream, senior surface-water-right holders to restrain diversions and pumping on lands with junior water rights. In addition, since

Case Study #3: Upper & Middle Verde River

many users are small-well owners, a de-minimis ruling in the Gila River General Stream Adjudication would likely exempt these users from the prior appropriation system, thus limiting the effectiveness of future efforts to control upstream use.

Of the three case studies, the Upper and Middle Verde River probably represents the most complex system and also the system in which progress toward comprehensive management is most tenuous in the short term. Understanding of this system is still in its early stages, although progress is being made toward the development of groundwater models for the larger Verde River basin and an ecological needs assessment for the Upper Verde River.

Understanding of existing uses in the Verde is similarly limited in that a significant amount of existing water use is not monitored. Although a portion of the Upper Verde watershed is subject to groundwater management via the PrAMA, the PrAMA includes only one of the two sub-basins that comprise the Upper Verde. Recent information suggests that groundwater discharge from the Big Chino Basin (which is not under management) provides as much as 86 percent of the groundwater that sustains Upper Verde River baseflow.

Although the PrAMA establishes a groundwater rights system within its limited boundaries, the PrAMA was well beyond safe yield before it was designated. The groundwater-rights system is thus protecting a large quantity of grandfathered rights, withdrawal permits and approved subdivision uses that will be difficult to reduce. Achievement of safe yield has only been further complicated by the fact that local governments permitted some 32,000 residential units within the PrAMA just prior to determining that the system had exceeded safe yield.

Even if safe yield can be achieved within the PrAMA, the safe yield management goal will not protect baseflow in the Upper Verde River. This is because it will still effectively eliminate groundwater discharge from the Little Chino by balancing discharge from pumping and recharge within the boundaries of the PrAMA, leaving no excess natural groundwater discharge available to support baseflow in Granite Creek at its confluence with the Verde River. Perhaps more importantly, the safe yield goal only seeks to balance the water equation within the PrAMA; it does not relate to the achievement and maintenance of aquifer conditions in the Big Chino to provide for continued groundwater discharge to sustain baseflow in the Upper Verde River. Ironically, the PrAMA safe-yield goal will serve to increase actual and potential pumping in the Big Chino Valley as a means of balancing water needs in the PrAMA, in turn bringing greater pressure on the Big Chino aquifer.

As in the San Pedro, the lack of local authority to link water use and land use outside of the PrAMA is a significant impediment to sustainable water management as groundwater pumping continues unabated outside the PrAMA. While the USPP has managed to offset some of the potential impacts of this pumping through a cooperative, regional coordination of various water management activities, the Upper and Middle Verde watersheds include a multitude of jurisdictions, including tribal entities, that make similar voluntary cooperative efforts more challenging, highlighting yet another reason for additional regional water management authority beyond the PrAMA.

Another critical issue facing the Middle Verde watershed is the continued uncertainty associated with the lack of adjudicated surface-water rights. Much of the water withdrawn from wells in this area is likely to be adjudicated as surface water, which (in light of the significant downstream water rights held by the Salt River Project and other senior appropriators) would result in at least some limited protection for the river if these uses are called out by downstream senior water users. The expansion of local authority to link land use and water use could and should be implemented to triage water-management problems and perhaps introduce a precautionary principle into water management. However, in the absence of adjudicated rights, it is difficult to see how comprehensive water management can effectively occur. At a minimum, some sort of assessment and quantification of existing surface-water and groundwater uses is essential to help manage water in the interim using current information about the likely outcome of a future adjudication. Any management regime will also need to ensure that, once surface-water rights are adjudicated, these rights are effectively enforced – something that does not always occur.

Lastly, throughout the Upper and Middle Verde Rivers, small-well owners are exempt from regulation within the PrAMA and may well prove to be exempt from the prior appropriation system, if the courts decide to institute a de-minimus ruling for small users of surface water. Although these wells individually have only minimal impacts on the system, their cumulative impact is significant. New legal authority will be required to regulate both current and future exempt well users.

RECOMMENDATIONS FOR SUSTAINABLE WATER MANAGEMENT IN ARIZONA

Because Arizona water laws and policies do not closely align with hydrological realities, there will continue to be uncertainty about the legal status of groundwater resources in many parts of the state until ongoing general stream adjudications are completed. Even then, integrated management of groundwater and surface water will likely continue to be challenged by this artificial separation. Nonetheless, it is critical for the State to develop a holistic regulatory strategy that can compensate for the disconnections created by Arizona's legal system.

While recognizing that each watershed presents unique challenges and barriers to implementation, a review of the case studies suggests four primary recommendations for these three river systems. These recommendations are not intended to challenge the existing system of surface-water rights, influence the continued legal controversy over how these rights should be adjudicated, or challenge the distinction that has been drawn between surface water and groundwater under existing Arizona law. As such these recommendations focus on approaches to managing groundwater that can accommodate a separate system of surface water regulation. These recommendations are likely to have application to other groundwater-dependent river systems in Arizona.

Upper Verde River, Arizona.

"We're not going to stop growing and we can't wait around. We need to expedite these settlements, but people are still going to be developing while these settlements are ongoing. I think the key to this is to clearly identify the data that's going to be needed to manage our water supplies and then we can plan for future based on known issues rather than hope."

TOM O'HALLERAN, STAKEHOLDER, ARIZONA'S VERDE RIVER

➤ 1. Resolve uncertainty over surface water rights.

In all three river systems, it will be difficult to reduce or reallocate existing uses to serve new demand unless uncertainties regarding the nature, quantity and priority of surface-water rights or claims are resolved – until this occurs, no one knows precisely what rights to water they have. This uncertainty will also complicate efforts to understand the availability

of water for future allocation, since the amount of use that will be allowed under an adjudicated right remains uncertain. Although less critical in the San Pedro due to the smaller number of privately held surface-water rights or claims, this is a critical concern in both the Santa Cruz and the Middle Verde rivers.

In the Santa Cruz, surface-water-right settlement discussions have been underway for a number of years. These discussions should be completed expeditiously, and whatever resources can be brought to bear to overcome remaining barriers should be deployed without delay. In the Middle Verde, these discussions have yet to begin, and the likelihood of reaching a comprehensive settlement seems remote at this point.

In the absence of local settlement, some type of effort must be undertaken to either (a) accelerate the course of the general stream adjudication, or else (b) reach some sort of pre-determination of water rights that will allow management efforts to account for surface-water uses in the interim until a formal adjudication is concluded. For the latter to occur, some preliminary process (with new statutory guidance) by which water rights could be estimated – perhaps a more limited version of the process used by the ADWR to evaluate, sever and transfer applications or to prepare a hydrographic survey report under existing adjudication statutes. Regardless, additional funding will need to be directed to ADWR to advance the process of adjudication and the definition of surface water rights in Arizona.

➤ 2. Create new water-management authorities that can define water available for allocation, allocate water resources among new and existing users, and pursue supply augmentation strategies.

In all three river systems, state legislation is required to establish new water-management authorities that can implement elements of the sustainable management framework. In essence, these authorities would need to accomplish four discrete tasks: (1) determine the availability of existing supply consistent with new sustainable management goals that have been adopted for the area; (2) provide mechanisms to reduce, reuse and reallocate existing uses; (3) allocate remaining available supply to new uses; and (4) facilitate the planning, financing and development of water projects necessary to achieve management goals. It should be noted that both the Upper Santa Cruz and the Upper Verde already have some of these functions in place as a result of the SCAMA and the PrAMA, although neither entity is currently in a position to fully implement sustainable management.

Little Colorado River, Arizona.

These new authorities could be vested at either the state or local level, or some combination thereof. However, these functions should ideally be provided by separate entities to ensure that purely technical issues (such as available water budgets) are appropriately objective, are consistently applied, and are appropriately separated from decisions about the allocation of water supplies and investments in recharge projects, re-use projects or water-supply augmentation. In light of the large amount of resources necessary to make appropriate technical investigations and the need for statewide consistency in determining water availability, technical functions should be lodged at the state level in the ADWR, although participation in developing technical information through a locally organized technical committee may help to increase community support for adequacy determinations (the USPP provides an excellent example of this).

The management of existing uses, controls on new uses and the allocation of water supplies that have been determined technically available could be vested at either the state level or the local level. However, the entity or entities responsible for this decision making must have an adequate level of authority to regulate existing uses, approve or deny new water uses, and control the development of all wells throughout the water management area in a consistent and enforceable manner. Implementation of water-allocation controls will require new statutory authority to allow for the denial of land uses based on water availability, to allow implementation of a system of groundwater rights for the reduction and transfer of existing uses, and to allow regulation of new uses through well spacing, mandatory conservation requirements and other measures.

In light of the large financial burden associated with large water projects and the potential for inter-jurisdictional competition for limited water supplies, legislation is needed to provide for the establishment of a regional entity with financing powers to implement water recharge, supply augmentation and similar projects that may be necessary to achieve local management goals. This entity could be the same one that regulates water use as described above; regardless, establishing a clear linkage between these two management tasks is essential so that any augmentation of supply is first used to offset existing use as necessary to achieve management goals – not to support continued unsustainable growth in new uses within the management area. For example, in the San Pedro, it is clear that offsetting the impacts of current uses will be necessary in the long run to protect the river and overcome the current pumping deficit. As such, any augmentation of water supplies in the basin should be tied to the implementation of water-use controls sufficient to ensure that augmentation results in the reduction or elimination of this deficit – not just further expansion in new uses.

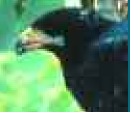
Once abundant, the razorback sucker has been listed as an endangered species since 1991.

The need for these new water-management authorities is most critical in the Upper San Pedro and Upper and Middle Verde rivers where two potential management structures merit consideration:

• Additional county- and city-level authority to regulate existing and new uses based on water availability that is tied explicitly to technical determinations undertaken by ADWR; or

• Establishment of a new water-management entity that can regulate existing and new uses, with governance vested at either the state or local level.

The challenge at hand is most straightforward in the Upper San Pedro where, although no water management authority currently exists, consensus has been reached about the water management boundary area (the Sierra Vista sub-watershed), and the surface-water-rights claims are few in number. Moreover, the Sierra Vista sub-watershed is located entirely within Cochise County and only four cities are in this portion of the county. As such, new county authority to regulate uses and a requirement that the cities follow suit in consistent fashion may serve to effectively manage water in a sustainable fashion.



The Verde presents a more complicated picture for new water-management authority. Because of the existence of the PrAMA and the greater number of independent jurisdictions, multiple entities with different management interests exist within the basin, including both Yavapai and Coconino counties. As such, relying on increased county authority becomes more challenging. As noted elsewhere, even if the PrAMA ultimately achieves its current safe-yield goal, it will still deprive the rest of the watershed of the base flows out of the Little Chino, and in the meantime, the existence of the PrAMA may encourage additional development of groundwater in the Big Chino Valley. All of this suggests that in the Verde, the creation of a new water-management entity will likely be necessary. This could potentially occur in one of two ways:

• Expand the PrAMA to include Big Chino sub-watershed and add an additional management goal that requires protection of adequate base-flow and flood flows at Paulden gauge; and establish a separate Middle Verde River management entity with a management goal that requires protection of adequate baseflow and flood flow requirements at several compliance points in the Middle Verde sub-watershed, including Sycamore Creek, Cottonwood and below Camp Verde, as well as protection of water supplies for current and future residents.

• Establish a management entity that includes all the areas outside of the PrAMA with a management goal that requires protection of adequate baseflow and flood-flow requirements at several compliance points in the Upper and Middle Verde sub-watersheds, including Paulden, Sycamore Creek, Cottonwood and below Camp Verde, as well as protection of water supplies for current and future residents.

In the Santa Cruz, an expansion of the activities and authorities of the SCAMA may be adequate to meet the need for a comprehensive water-allocation authority. Adoption of assured water-supply rules and incorporation of adjudicated surface-water rights, new well-spacing rules tied to AMA management goals, tailored recharge project criteria that promote micro-basin recharge as well as projects to increase storage in deep aquifers like Potrero Canyon, and strategic use of effluent would go a long way toward comprehensive regulation in this area. Notable loopholes in the assured water-supply rules (e.g. dry-lot subdivisions, exemption of certain lot splits and small wells) will require additional state or local authority to control.

➤ 3. Pursue recharge and re-use projects to encourage more effective use of existing water resources, including municipal effluent.

At the present time, certain water resources in all three watersheds are not allocated in a manner that ensures that they will contribute to the long-term sustainability of water management. For example, entities that control effluent that is available for re-use or recharge do not necessarily have an incentive to use this water in a manner that benefits the system as a whole – or may in fact be prohibited from using water for this purpose. As previously discussed, this issue is probably most critical in the Upper Santa Cruz River. Efforts must be undertaken by the International Boundary and Water Commission (IBWC), U.S. Environmental Protection Agency (EPA), ADWR, or other appropriate entities to secure and commit at least a portion of these effluent flows to the river.

Significant opportunities are being lost in the Verde as well. In the Verde, substantial quantities of municipal effluent (i.e. City of Sedona) are being deliberately evaporated to avoid the need for compliance with Clean Water Act discharge limitations on effluent. While this reduces the cost that would otherwise be associated with effluent treatment, it is not in the best interest of the river system. Both regulatory and financial incentives are needed to encourage re-use to offset existing water uses and/or for aquifer recharge. An effluent exchange program that made this water available for agricultural use thereby retiring existing uses of natural flows could significantly benefit the river system and help offset inevitable impacts that will otherwise occur as a result of groundwater development.

Similarly, in all three river systems, the implementation of new septic rules by the Arizona Department of Environmental Quality (ADEQ) will effectively require septic water that currently contributes to recharge be consumed at the surface. While this is intended to address water-quality concerns, the tradeoffs between water quality and water quantity concerns may not have been fully considered.

"…Is the purpose of reuse and recycle to restore a system or to make sure that a natural resource system recovers, or do we expect the citizens to conserve and reuse water just so we can accommodate more growth? I think citizens would be willing to make sacrifices if they knew what they were sacrificing for, but if the sacrifice is just to accommodate more growth and development then I don't think we're too willing to sacrifice for that purpose."

CHIP DAVIS, STAKEHOLDER, ARIZONA'S VERDE RIVER

Visitors along the Verde River, Arizona.

"I think there is a lot more that we could get done on both sides of the border with an increase in communication and collaboration and I think there's a lot of projects that could be beneficial, such as waste water that could be recharged that could help human health down there as well as water quantity here. I think those kinds of win-win projects are just sitting there waiting to be done, but there's no collaborative process to do them"

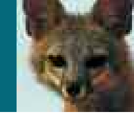
HOLLY RICHTER, STAKEHOLDER, ARIZONA'S SAN PEDRO RIVER

Septic systems are most often associated with individual small-well owners that already present a significant water-use challenge. Up until now, one mitigating factor for these small-well owners has been that their associated septic systems provided recharge to the aquifer, reducing their net impact on the system. Implementation of the new rules will exacerbate the impact of small-well owners throughout each of the case study areas. By contrast, projects to encourage shared sewer systems that can produce effluent available for recharge, or relaxation of septic rules to encourage recharge, could contribute to reducing impacts from new growth on these river systems.

Addressing these issues will require cooperation from both water-supply and water-quality agencies, and the establishment of a state-wide task force involving the EPA, ADEQ, ADWR, local jurisdictions and stakeholders to examine the issue of effluent use to meet future water needs and water-quality standards is recommended.

➤ 4. International and/or Regional Cooperation

In the Santa Cruz and the San Pedro, the presence of the international boundary in the midst of these watersheds complicates management efforts and draws an artificial line between management regimes. Water use in Mexico has already impacted flows in the Upper Santa Cruz, and recent information suggests that groundwater pumping to support mining activity around Cananea, Mexico, may be influencing water table conditions in the U.S. As previously discussed, discharge of Mexican-owned effluent is an important component of streamflows in the Upper Santa Cruz. Nonetheless, water management is not currently well-coordinated on a transboundary basis. In this environment, engaging existing international institutions such as IBWC as well as EPA and Mexican institutions in efforts to implement sustainable water-management programs will be critical to ensure that both countries work toward a common set of management goals. While the authority of the IBWC and EPA are clear with regard to their lead authority in coordinating with Mexico governments on water resource issues in the border region, the creation of a position within the Governor's Office that is charged with facilitating discussions on cross-border water resources issues could help stimulate more productive approaches.



MEETING THE NEEDS OF PEOPLE AND NATURE: A CALL TO ACTION

In all three of these river systems, continued uncertainty and lack of information remain critical concerns, including the number and volume of existing uses, the legal status of groundwater uses, the lack of adjudicated surface-water rights, and limited understanding of river systems. These issues, combined with insufficient management authority at either the local or state level, have served to retard and, in some cases, paralyze efforts to implement sustainable water management.

This uncertainty cannot stand in the way of efforts to improve water management as there is a critical need to do something to address these problems now if we are to protect our few remaining free flowing rivers and streams. Legal, scientific and economic uncertainty in the context of these complex hydrological regimes is inevitable and unavoidable; indeed, new factors – such as the anticipated impacts of climate change – may only serve to increase these uncertainties. These concerns, coupled with the inherent variability of natural river systems in an arid region, make it incumbent on water managers to introduce a precautionary principle into water resources management: management objectives must be defined to account for this uncertainty and provide sufficient buffers against future variations in water supply so that neither natural ecosystems nor human users lose life-sustaining water supplies when circumstances change.

While continued study of these systems is essential, time is also of the essence as the question is not if Arizona's remaining rivers and streams will go dry but when. We need to plan more comprehensively to effectively meet the needs of people and nature. Concerted, cooperative local, state and federal efforts to confront and overcome these problems by empowering all levels of government to consider water issues in growth and land-use decisions, implementation of additional management authorities, regional cooperation, and adaptive management are the best means of ensuring that Arizona's critical water resources will be protected for the benefit of future generations.

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Figure 1: Don Hammond. 2007.

Figures 2 & 3: Don Hammond, adapted from illustrations by Julia Laurenzi. 2007.

Figure 4: Don Hammond, adapted from illustration by Arizona Riparian Council, Global Institute of Sustainability, Arizona State University. 2004. Fact Sheet No. 3: Water. Tempe, AZ.

Figures 5 & 6: Don Hammond, adapted from figures by Webb, R.H., and Leake, S.A. 2006. Ground-water surface-water interactions and long-term change in riverine riparian vegetation in the southwestern United States. Journal of Hydrology 320: 302-323.

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Members of the Technical Team

Dr. Kyle Blasch, Scientist, United States Geological Survey

Mr. Mark K. Briggs, Restoration Ecologist & Private Consultant

Mr. Peter Culp, Attorney, Squire, Sanders & Dempsey

Mr. Robert J. Glennon, Morris K. Udall Professor of Law & Public Policy, College of Law, University of Arizona

Dr. Jim M. Holway, Associate Director, Global Institute of Sustainability, Arizona State University

Ms. Katherine L. Jacobs, Executive Director, Arizona Water Institute

Mr. Greg Kornrumph, Senior Analyst, Salt River Project

Mr. Andy Laurenzi, Program Director, Sonoran Institute

Dr. Thomas Maddock III, Professor, Department of Hydrology & Water Resources, University of Arizona

Mr. William Meyer, Retired District Chief, United States Geological Survey

Mr. Don Pool, Scientist, United States Geological Survey

Dr. Abe Springer, Associate Professor, Department of Geology, Northern Arizona University

Dr. Julie Stromberg, Associate Professor, Plant Biology Department, Arizona State University

Production Credits

Research: Amy McCoy

Editors: Jennifer A. Barefoot & Victoria Collier

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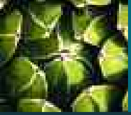

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