ARROYO

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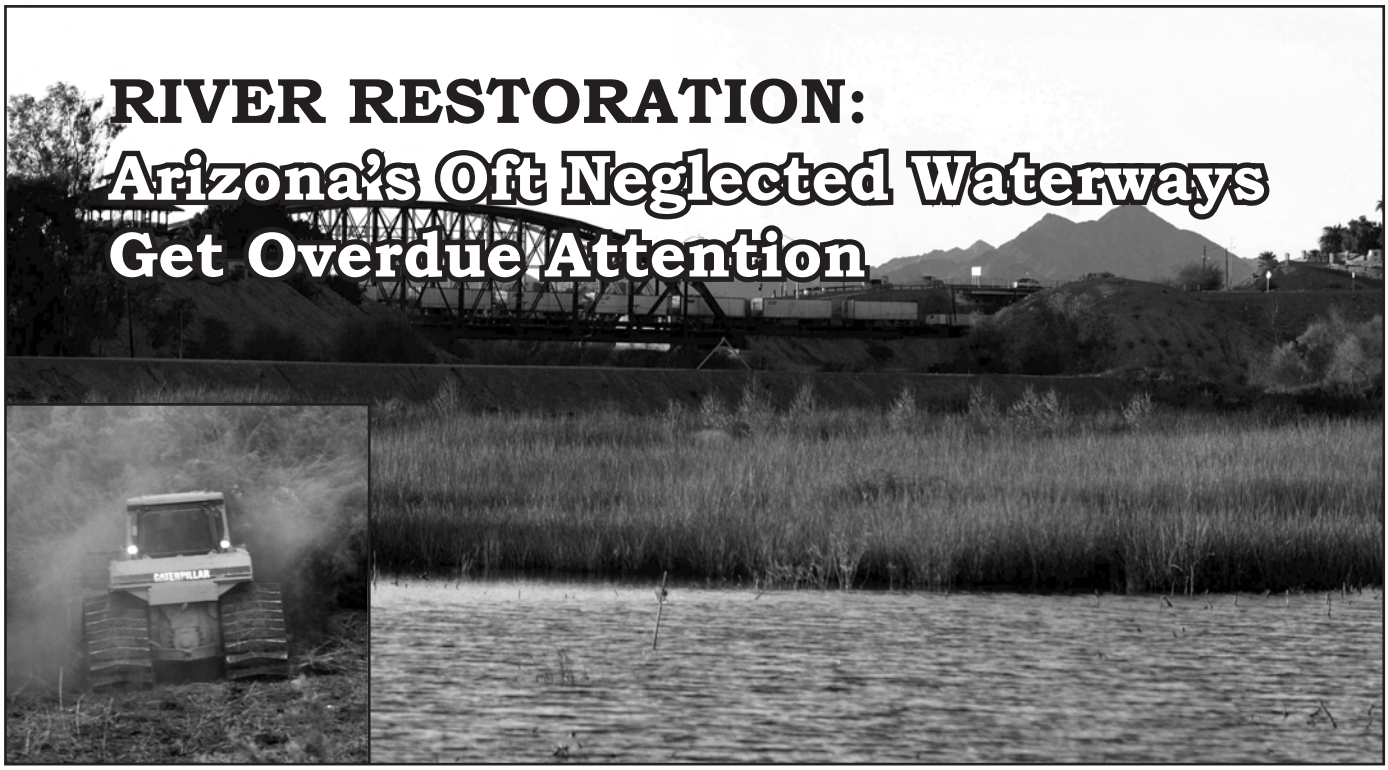
Water Resources Research Center • College of Agriculture and Life Sciences • The University of Arizona

RIVER RESTORATION: Arizona's Oft Neglected Waterways Get Overdue Attention



The inset shows land being cleared of exotic vegetation, a figurative and literal groundbreaking first step in many restoration projects. Before the wetlands in the main photo were restored, a thick growth of salt cedar was bulldozed from what was the historic confluence of the Gila and Colorado rivers. (Today's confluence is four miles upstream.) Part of the Yuma East Restoration Project, the channel was restored in 2005: bulrush grows in the foreground with cottonwood and willow in the background. The Yuma Clapper Rail, an endangered specie, has established habitat along the channel. The Yuma Territorial Prison and the Ocean to Ocean Bridge are in view. Photos: Fred Phillips

Urbanization, channelization, groundwater depletion, irrigated agriculture, and a variety of other activities have significantly affected many of Arizona's rivers, and citizens are awakening to the resulting problems. In contrast to their ecologically degraded counterparts, healthy, well-functioning rivers and wetlands are some of the most productive ecosystems in North America, providing habitat for wildlife, including many endangered species. They reduce flood peaks, are sinks for sediments and nutrients, provide water temperature control and groundwater recharge. Failure to protect the health of these systems can lead to loss of habitat and species, water quality degradation, storm water management problems, and loss of recreational amenities, among other issues.

Generally, there are three possible goals for efforts undertaken to improve the condition of a damaged ecosystem: restoration, rehabilitation, and replacement. Strictly speaking, "restoration" is defined as an attempt to create an ecosystem exactly like the one that was present prior to disturbance. Reestablishing the processes that sustained the predisturbance ecosystem is an important part of this definition. Given the severity of impacts and resulting ecological decline suffered by many of our rivers, true restoration is simply not possible, and many efforts to "fix" our rivers fall into the rehabilitation or replacement categories. However, the term "restoration" is widely used for any effort to improve ecosystem conditions, and we use this more general meaning in this issue of *Arroyo*.

At stake is more than just the hydrological workings of rivers; humans derive emotional satisfaction from healthy rivers. Although difficult to quantify, the satisfaction humans derive from viewing

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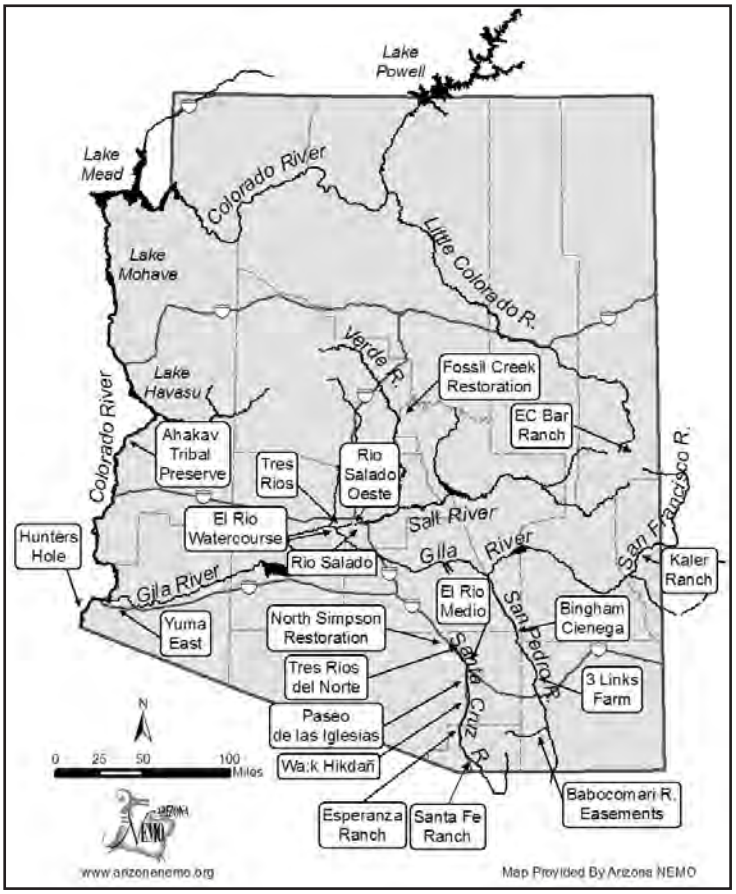


State map with locations of river restoration projects discussed in this publication.

the beauty of free-flowing water, rich with native vegetation and wildlife, should not be underestimated. Acknowledgement of this emotional connection, in addition to other benefits, is generating interest in river restoration. Efforts to restore Arizona rivers have been receiving more and more attention. The many projects completed and on-going in Arizona testify to a growing commitment to the health of the state's rivers and streams.

Fixing the Santa Cruz River

A stretch of the Santa Cruz River once flowed year-round as a shallow stream from San Xavier del Bac through Tucson across a wide floodplain. The braided, meandering channel was lined with cottonwood-willow woodlands and mesquite bosques. Remnants of the "Grand Mesquite Forest" upstream of Tucson, locally dense bosques downstream, and the cottonwood gallery forests survived into the 1960s, but later disappeared completely.

Human settlement wrought these changes. Irrigation diversions, groundwater pumping, construction projects, and flood control measures altered the relationship of the river with its floodplain. These changes, combined with the Southwest's dynamic climate (arid conditions punctuated by periodic floods) resulted in channel incision: the scouring of sediment from the river channel that changes the topography of the channel from broad and shallow to narrow and deep. Riparian vegetation bordering the incised channel was left high and dry. Now groundwater levels are too deep to support riparian vegetation even in the flood channel and only a few desert shrub species have become reestablished there.

Dumping compounded the problem. During the 1950s, one million tons of garbage was deposited in and around the river in cavities created by sand and gravel mining.

No longer a living river for most of the year, the Santa Cruz has served as a street, a shelter, even an illegal track for off-road vehicles. There is no better measure of the extent to which the natural conditions of this segment of the river have been altered than the fact that whatever water happens to flow within its banks is viewed as a novelty or worse yet, a nuisance. In an effort to remedy the situation, river restoration plans are afoot to reclaim sections of the river.

One such project, Paseo de las Iglesias encompasses almost 1,100 acres between Los Reales Road and Congress Street. The project proposes to reestablish mesquite and riparian shrubs in the historic floodplain of the river, and cottonwoods and willows at some tributaries, for an estimated cost of $97 million. Rainwater harvesting basins scattered throughout the project site will concentrate water on new plantings of cottonwoods and willows. Eventually, the new vegetation will serve as habitat for wildlife and shade for trails and seating areas. El Rio Medio and Tres Rios del Norte are two additional potential Santa Cruz River restoration projects which, if funded, would result in restoration from Congress Street in Tucson to Sanders Road in Marana.

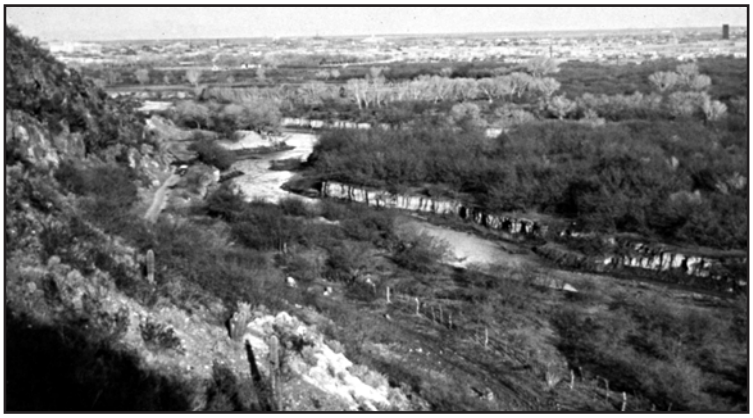
Such river restoration efforts to remedy degraded conditions are occurring more frequently throughout the state as citizens become increasingly aware of what is at stake — the health and survival of their waterways. This greater sensitivity about the natural conditions of rivers and the availability of new funding sources has prompted restoration projects in every major watershed in the state.

Restoration Projects Are Many and Varied

Like the rivers in the state, which vary in length, flow and quality, river restoration projects in Arizona vary greatly in size,

Many Arizona Projects Occur "Under the Radar"

The upsurge in river restoration activities nationwide has made cataloging projects an enormous task. The National River Restoration Science Synthesis is attempting to synthesize lessons from many thousands of projects completed in the recent past and currently underway. For the southwestern node of the NRRSS, which includes data on Arizona's projects, the database contains almost 600 projects (198 in Arizona), which may represent as little as 50 percent of the total number of projects in the region. The studies that provided the basic information for this issue of *Arroyo* describe about 30 projects in Arizona, some not included in the NRRSS database.



The Santa Cruz River in Tucson had a perennial flow with secondary growth of mesquite and cottonwood lining the channel when this picture was taken in the early 1900s. Photo: Arizona Historical Society/Tucson AHS no. 24868

scope and complexity. In one project, a rancher is managing his land to benefit the San Francisco River in the Upper Gila Watershed. In another, partners in the Lower Colorado River Multi-Species Conservation Program plan to create more than 8,100 acres of new or restored cottonwood-willow, mesquite, marsh and backwater habitat. This will benefit six federally listed endangered species as well as 20 additional species. Partners in the MSCP include five federal agencies, the three Lower Colorado Basin states, several Colorado River tribes, water and power contractors and other stakeholders with interests in Lower Colorado River management.

Although the main goals of river restoration efforts are the same — protecting Arizona's last, lush places, and returning others to their original splendor — projects take different paths to achieving their objectives. Many projects focus on reestablishing native trees and shrubs along a degraded riverbed, while others concentrate on pulling invasive plants out. Some are large-scale construction efforts, and some deal with the removal of previously installed structures or obsolete dams. Sponsors of restoration projects might have the goal of restoring the historical conditions of an area, or might take advantage of newly forming habitats.

Costs of projects described in this publication range from less than $100 thousand to more than $100 million; their sizes vary from less than 20 acres to several thousand. Some projects occur close to populated urban centers; others take place in remote areas that few people visit.

The many restoration projects, with their varied characteristics, might be viewed as chapters in the story of restoration work in the state. The following discussion focuses on specific projects — or individual chapters — to present an overview of the kind of restoration activities occurring within the state, each sharing the vision of securing a vital legacy for future generations.

Ranchers Take On Small-scale Projects

When Dick Kaler purchased his ranch in 2003 he was not aware of several environmental problems on the property. The ranch, located on the San Francisco River in Greeley County in the Upper Gila Watershed, had been used for livestock grazing for over 100 years. Primary grazing pastures were located along the San Francisco River. When it rained, runoff flowed across the pastures directly into the river carrying with it sediment and animal waste. To resolve the problem Kaler got an Environmental Quality Incentive program grant from the Natural Resources Conservation Service to level his fields to reduce runoff.

Another problem confronting Kaler were culverts, some large enough for a six-foot person to stand in upright, that drained a dirt road depositing the runoff onto his property. Although the culverts were installed to drain water to the river, they did not extend to the river's edge; instead the culverts drained across the ranch's livestock fields, washing soil and livestock waste into the river and breaking down river banks.

Kaler enlisted the support of the Gila Watershed Partnership to obtain various state grants, with the funds used to place the culverts underground and to extend them to drain directly into the river in areas where the banks are stable. With less sediment and cattle waste entering the river and greater bank stabilization, river conditions are improving. Improved water quality will ensure better habitat for the loach minnow, a threatened fish that lives in the river. Also the ranch will no longer be a major source of E. coli entering the river.

Since 1996 Nutrioso Creek in the White Mountains, which flows through the EC Bar Ranch, eventually reaching the Little Colorado River, has benefited from the management practices of ranch owner Jim Crosswhite. Originally homesteaded in 1882, the 400-acre ranch has a history of overgrazing. The riparian zone along the creek was non-functioning, and the turbid waters of the creek itself were officially classified as impaired by the Arizona Department of Environmental Quality.

Over the past decade, Crosswhite has completed numerous government-recommended Best Management Practices. He fenced off the riparian area from cattle and elk during the growing season, seeded the banks with grass, and installed bank-stabilizing structures. He also drilled water wells and installed a more efficient irrigation system, which allowed him to divert less water from the creek to irrigate upland pasture. His actions significantly improved the riparian area through the ranch.

Lower Colorado Program: A Vast Undertaking

The Lower Colorado River Multi-Species Conservation Program is a complex and multifaceted program. A coordinated, comprehensive, long-term multi-agency effort developed between 1996 and 2005, the MSCP proffers a 50-year plan with a very ambitious agenda. Its intent is to address

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the needs of threatened and endangered wildlife listed under the federal Endangered Species Act and reduce the likelihood that additional species will be listed. The project also ensures the continuation of existing Lower Colorado River water and power operations.

MSCP goals include creating more than 8,100 acres of riparian, marsh and backwater habitat along the lower Colorado River for native species. Further, MSCP partners will work together on species recovery programs for two listed fish species: the razorback sucker and bonytail.

The MSCP covers an extensive area, including the Colorado River and its historical floodplain from the U.S. - Mexican border up to and including the full-pool elevations of lakes Havasu, Mohave and Mead. This is a distance of about 400 river miles. Current conservation measures focus on the area from Hoover Dam to the international border; the Grand Canyon may be included in the future.

Yuma East Project: Collaboration Pays Off

Collaboration among varied organizations is often a key to the success of a project, as is demonstrated by the Yuma East Restoration Project. Begun in 1999 as a partnership between the City of Yuma and the Quechan Indian Nation, the project has since grown to include private landowners, federal commissions and public agencies, as well as architects, engineers and biologists. Project managers say gaining consensus among diverse stakeholders was as challenging as the restoration work itself.

Their common ground was the reedy, tamarisk-choked riverbank that runs through the city. Together, these groups created a project that stabilized the riverbanks, removed invasive species and established salt-tolerant native vegetation. To date, 200 acres of the project site along the Lower Colorado River has been restored. The sponsors are currently monitoring the return of wildlife and endangered birds to the riparian area.

The work at Yuma demonstrated that restoration projects not only benefit the environment, but also can provide a boost to the local economy. The project has provided $6 million dollars to Yuma's economy, as well as creating more than 100 permanent and part-time jobs over the past six years. A new growth industry is even being spawned. JSA Inc., a local landscaping company, is developing a new division specializing in native revegetation efforts. Revegetation could well become a major industry within the next few decades.

Surrounded by development, the Yuma East project focuses on improving the quality of life of Yuma's citizens. Before restoration work began, the 1,418-acre site had at least 20 illegal dump sites and almost as many transient encampments. Today, birdwatchers and dog walkers come daily to an area that, only three years ago, most citizens avoided. Hiking trails, picnic grounds and opportunities for other kinds of passive recreation have brought the community back to the river.

River Restoration, a Collective Effort

A wide range of parties undertake river restoration projects. Sponsors of projects include government, Native American tribes, non-profit organizations and universities. Projects are designed and implemented to reflect each organization's mission and goals.

In Arizona, County Flood Control Districts are responsible for stabilizing riverbanks and controlling erosion, and typically undertake restoration strategies to mitigate damage at project sites. Pima County Regional Flood Control District has been unusual in protecting and restoring functioning ecosystems separate from engineering projects. Non-profits like the Tucson Audubon Society and The Nature Conservancy, concerned with maintaining ecosystems and preserving the value of the natural environment, are usually project managers. Native American tribes frequently cite cultural and historical benefits as a major reason for initiating restoration work. Universities focus on scientific understanding and include strong research and education components when designing a restoration project.

Committed volunteers are often an important part of a collective river restoration effort. These volunteers are working at the North Simpson Restoration Project. *See page 11.*

Federal government agencies typically partner with local government entities or non-profit organizations when they undertake restoration work. This federal-local collaboration is a common characteristic of many of the projects in Arizona. State agencies also collaborate in the planning and implementation of projects.

Various entities provide funding for a range of projects. The Arizona Water Protection Fund supports riparian restoration projects in general, while the U.S. Bureau of Reclamation has money earmarked for the enhancement of wetlands. Arizona's Heritage Fund Program provides $20 million each year divided between the Arizona Game and Fish and State Parks Departments for parks, trails, wildlife conservation and the preservation of historic sites.

The Arizona Department of Environmental Quality has a grant program specifically for improving water quality through projects designed to control non-point source pollution. ADEQ conducts water quality monitoring after implementation of some projects to determine success, but otherwise its direct participation in projects is minimal.

The U.S Army Corps of Engineers is an unusual organization with both the ability to fund projects and the human resources to implement them. The Water Resources Development Act of 1986 authorizes the agency to participate in restoration projects that attempt to repair environmental damage done by previous Corps projects.

San Pedro River: Protecting the Flow

The San Pedro River in southern Arizona and the Verde River in the northern part of the state are among Arizona's most precious environmental resources. Last year, American Rivers placed both systems in its annual "Most Endangered Rivers" list. Groundwater pumping threatens river flow in both regions, because the aquifers that feed the San Pedro and Verde are critical water sources for nearby cities, towns and farms.

The San Pedro River flows from Mexico into the United States through the Madrean Archipelago, also known as the Sky Islands, running about 100 miles from its headwaters in Canenea, Mexico, north across the international border to its confluence with the Gila River near Winkelman. Influenced by the biology of both the Sierra Madre and the Rocky Mountains, the region has an unparalleled diversity of wildlife. Christened by The Nature Conservancy as one of the "Last Great Places," the San Pedro's riparian corridor is a haven for 350 species of birds, over 80 species of mammals, two native species and several introduced species of fish and more than 40 species of amphibians and reptiles.

One of the last free-flowing desert rivers in the Southwest, the San Pedro is threatened by groundwater pumping occurring within the Upper San Pedro watershed. "The narrows," a natural constriction in the San Pedro River Valley located about 10 miles downstream from the town of Benson, divides the upper and lower basins, with the U.S. portion of the Upper San Pedro Basin south of the narrows. Groundwater pumping and natural uses within the basin result in more water being taken out of the aquifer than is being naturally recharged. Compounding the problem is the ongoing multi-year drought. In July 2005, flow at the U.S. Geological Survey's gauge near Charleston, Arizona went dry for the first time in more than a century of record keeping.

United in their concern about the river, local governments, agencies and community members have banded together to form the Upper San Pedro Partnership, a voluntary watershed association. A consortium of 21 agencies and organizations, the USPP has adopted the goal of sustainable groundwater management for the Upper San Pedro. The organization has been successful in achieving an impressive degree of cooperation and consensus in addressing problems in the area.

The survival and health of desert river ecosystems largely depend on whether sufficient base flow — groundwater flow to the stream from its alluvial aquifer — is maintained during dry seasons. When a stream meets this criterion, its flow is "perennial". To maintain the San Pedro River's base flow, a collaborative effort is underway to reduce or cease groundwater pumping through purchases of property and conservation easements. Conservation easements are voluntary legal agreements that protect the land into perpetuity by limiting the property rights of current and subsequent owners.

In line with this strategy, TNC has recently purchased four conservation easements in partnership with the Bureau of Land Management, Fort Huachuca and landowners along the Babocomari River, a tributary to the San Pedro River. The U.S. Geological Survey identified the shallow aquifer underlying the Babocomari River as one of the most important contributors to the San Pedro aquifer in the Upper San Pedro Valley. The easements protect 1,411 acres and more than four miles of the river channel by restricting future development and water use. Funds for the easements, which cost $5.5 million, were provided by the National Park Service's Land and Water Conservation Fund and Fort Huachuca.

The Nature Conservancy projects along the San Pedro River. Map: Dan Marka, The Nature Conservancy

Fort Huachuca spent $830,000 for two ranch easements, adjacent to one another, to block development along the Babocomari River corridor. The Bureau of Land Management purchased a third ranch easement for $2.7 million that protects 674.6 acres, including three and one-half miles of the Babocomari River channel. The main objective of these purchases is to limit groundwater use. Another easement will protect 487.3 acres of grasslands that contain valuable wetland habitat by allowing the water table to remain at or near the surface.

Previously TNC had worked with Fort Huachuca to establish easements along the San Pedro River in the Palominas area, where the river crosses the border into the United States from Mexico. In that situation, TNC bought property and obtained an easement restricting groundwater pumping and development on other property along the river owned by the seller.

Purchasing and establishing easements are a form of "passive" restoration. Passive restoration seeks to remove disturbances such as excessive groundwater pumping that damaged the river system and have prevented it from returning to health. Where passive methods can be used, they are very cost-effective alternatives to more active restoration efforts involving excavation, construction, irrigation and other costly activities to accomplish project goals.

Along the San Pedro River, TNC also has been involved in projects taking a more active approach. One such major restoration project involved purchasing the Three Links Farm: more than 2,000 acres of ranchland north of Benson. The project was a four-million dollar undertaking: $2,770,000 for acquiring the land in 2002 and the remainder for restoration activities, including fencing off the property and reestablishing native vegetation in the old agricultural fields.

TNC is recouping the costs by dividing the land into five parcels for private purchase and establishing a conservation easement on the properties. The proposed five new properties can have only one house-

hold per parcel, and groundwater pumping for all five is limited to a maximum of 300 acre-feet per year. This means that nearly 4,200 acre-feet of water previously used each year by the farm has been "retired" and left in the ground to bolster the San Pedro's faltering supply.

At the time of purchase, the San Pedro flowed only intermittently on the farm and for miles downstream. TNC purchased the property intending to restore and enhance both groundwater levels and surface flows on about 20 miles of the river. Tom Collazo, TNC associate state director, says, "We turned off the pumps and we have seen dramatic recovery of stream flow, not only on the property but for quite a ways downriver as well, and subsequently a dramatic increase in cottonwood-willow habitat and willow flycatcher populations and a number of other riparian related species."

Other restoration projects on property acquired by TNC along the San Pedro River include the San Pedro Preserve and the Bingham Cienega Natural Preserve. The consistency of the plan is crucial. According to David Harris, Director of Land and Water at TNC, the rehabilitated areas will be vulnerable until the entire river is protected. Development upstream could threaten the progress made on the Three Links Farm, but by buying and restoring threatened land, TNC is creating a patchwork of protected places along the river corridor.

Santa Cruz River: Recovering a Lost Legacy

Work along the San Pedro is focused on protecting a functioning ecosystem. Most other restoration projects in the state don't have the luxury of working with a naturally flowing river. Most of the rivers that once provided green oases in the deserts of Southern and Central Arizona went dry long ago. Restoration projects in these areas often focus on bringing back what has been lost.

The Santa Cruz River has long been a troubled river. In 1910, G.E.P. Smith, a renowned University of Arizona hydrologist, reported that the Santa Cruz River was an "ever dwindling stream." By the time of statehood in 1912 the Santa Cruz River — a source of water for settlers, wildlife and vegetation for thousands of years — had mostly ceased to flow.

From its headwaters in the San Rafael Valley in Arizona, the Santa Cruz River loops south into Mexico before reentering Arizona about five miles east of Nogales. It then flows north-northwest to its confluence with the Gila River near Phoenix.

One of the efforts to restore a segment of the Santa Cruz River is the previously discussed Paseo de las Iglesias project. (See page 2) Another segment of the Santa Cruz River has benefited by what might be described as accidental restoration; it might also be described as a case of fortunate unintended consequences.

In the 1970s, no one intended to initiate an environmental restoration project on the typically dry Santa Cruz River north of the Roger and Ina Road wastewater treatment plants. But the area is now vibrant with life — the result of discharging effluent to a previously empty riverbed. Today, this river reach receives an almost constant flow of 50,000 to 60,000 acre-feet of effluent per year.

Impressive changes resulted. Willow and cottonwood have returned to line the banks of the river, their branches filled with birds' nests. Invasive species like tamarisk and buffelgrass have also taken advantage of the dependable flows. Floods scour the riverbed, depositing new sediment and sweeping away the thick algal mats that form in the nutrient rich water. Like a natural system, the river ebbs and flows with the seasons, a variability that supports habitat diversity.

Such heartening benefits, however, are offset by some drawbacks. The elevated ammonia and low oxygen levels in the water, as well as traces of chemicals that remain in the water after it is discharged from the treatment plant, make this river less than ideal habitat. Few invertebrates and almost no fish can survive. There are unanswered questions regarding the environmental effects of trace contaminants that remain in the water after it is discharged from the treatment plant — substances such as pharmaceuticals and estrogenic compounds. The band of riparian vegetation is narrow and crowds close to the water's edge in most places, diminishing its usefulness to wildlife. But the site is still a testament to what can be accomplished simply by allowing water to flow once again in river channels. Large-scale restoration projects are underway along the Santa Cruz through Tucson, with plans to improve and extend habitat along these effluent-dominated reaches (see page 11).

Wastewater also provides flow in the Upper Santa Cruz River. The Nogales International Wastewater Treatment Plant at Calabasas in Santa Cruz County processes sewage from Nogales, Arizona and Nogales, Sonora. About 20 percent of the effluent comes from Nogales and Rio Rico, Arizona, with 80 percent coming from Nogales, Sonora. A new treatment plant is being constructed at the same site as the older facility with completion expected in fall 2009. Treatment goals for the new plant include stringent secondary treatment standards, nitrification-denitrification and improved disinfection. While at present effluent discharges into the river average about 15 million gallons per day, effluent discharge rates vary widely. The discharged effluent flows north over shallow alluvium recharging aquifers, supporting a riparian corridor, attracting tourists and increasing land values along the way.

River Science — Interdisciplinary Study Promotes Restoration

Restoration projects being undertaken today stand to benefit from strides made in the field of river science in the last several decades. River restoration science has been defined as an interdisciplinary study, combining the sciences of hydrology, geomorphology and ecology and incorporating social sciences. River science teams study restoration projects to learn about the complex relationships among the many components of a living river. The understanding provided by river scientists helps protect existing healthy rivers and can be incorporated into design, implementation, maintenance and monitoring of projects to bring degraded rivers back to health.

Five miles upstream, however, the Santa Fe Ranch restoration project will need to pump groundwater to establish the corridor of historic vegetation planned to trap sediment and control erosion along this ephemeral 1,200-foot section of the Santa Cruz River. The project's sponsors hope to repair the damage from a 1967 flood and subsequent neglect, a goal made more challenging by drought and nearby water and land uses.

Rio Salado, Restoration in an Urban Landscape

Location has a lot to do with the values associated with a particular project. Designed generally to accommodate human interest and use, urban projects often have great quality-of-life value. Ecosystems within city boundaries, however, are often heavily degraded; completely revitalizing the river is neither practical nor possible given available water supplies. Moreover constructing restoration projects often depends on voter approval. As a result, such projects often include civic amenities and opportunities for passive recreation to attract voter interest, including hiking trails, picnic grounds, campsites, and river parks.

Examples of degraded urban rivers include the Santa Cruz in Tucson, the Salt in Phoenix, and the Lower Colorado where it flows through Yuma. All three rivers now have major restoration efforts underway. Sponsors at these sites, for the most part, are not tackling the Herculean task of bringing back the river's historical conditions. Instead, they are focusing on what the city's residents can gain from an improved riparian ecosystem. Consider, for example, work being done along the Salt River.

A Sept. 26, 2007 *Arizona Republic* editorial described the sad state of affairs that has afflicted many urban waterways: "For most of the Valley's modern history, we've turned our backs on rivers. We've seen them as hazards that overflow their banks or hindrances that restrict development with sprawling floodplains. ... We've seen them as unsightly blemishes on the landscape, a place fit only for the coarse business of sand and gravel or the dumping of old tires and radiators."

The Salt River was once perennial, swelling during the springtime as snow melted in the mountainous parts of its watershed. Before the Roosevelt Dam was constructed, gallery forests of cottonwood and willow lined its lower reaches for hundreds of miles. During the twentieth century, the river was harnessed by dams, and its water diverted for agricultural and urban uses in the growing Phoenix area. The river's flows became smaller, and then ceased; the water table dropped. Today, only isolated fragments of the original riparian corridor remain.

Rio Salado offers urban residents various kinds of recreation including hiking, horseback riding and birdwatching. Also Rio Salado enables children to investigate the fascinating qualities of water. The above children are observing fish.

The Rio Salado Project sought to bring back the historic woodlands of cottonwood, willow and mesquite. First conceived by James Elmore in the 1960s, the project evolved over two decades to include 23 miles of lakes, with a price tag of $2.5 billion. When brought to voters in 1987, it was overwhelming defeated. Today's project, encompassing five miles of river, and costing $100 million, is much scaled down.

Project sponsors had to obtain water to irrigate the new vegetation they planted along the riverbanks. (See more on obtaining project water on page 10.) Four years, 76,000 trees and nearly 100 government permits later, the area made a Cinderella transformation from garbage dump to nature park. The dedication ceremony on Nov. 5, 2006, was attended by 800 people. Hiking trails are open daily and frequented by varied users, from horseback riders to bicyclists to people in wheelchairs. Shaded by mesquite trees and willows, blackbirds build new nests among the cattails, while blue herons settle in pools of water. With the community's approval, the river restoration will continue in two subsequent projects, Rio Salado Oeste and Tres Rios.

A Phoenix urban area restoration project now in the works, El Rio Watercourse project will be an amenity in the newly developing West Valley along the Gila River. The plan is to develop a greenbelt by reclaiming a channel, restoring vegetation along the river and creating a wetlands area. Willow, ironwood and mesquite trees would line streambeds and two lakes would be located adjacent to the Estrella Mountain Regional Park. The purpose of the project is to create a natural and scenic area that will attract compatible development.

Bingham Cienega Natural Preserve, a Remote Location

Compared to planners of urban projects, sponsors of restoration projects located in remote areas are usually under less pressure to incorporate public use and economic goals into restoration projects and can give exclusive attention to environmental rehabilitation. Such projects might provide habitat for threatened and endangered species, improve the quality or increase the quantity of water for fish and wildlife, or prevent development from encroaching into a unique and beautiful area. The benefit people derive from such projects depend on their personal values and beliefs. Even if

they do not have direct access to the area, some people derive satisfaction from knowing that biodiversity and habitat are being restored, protected and preserved.

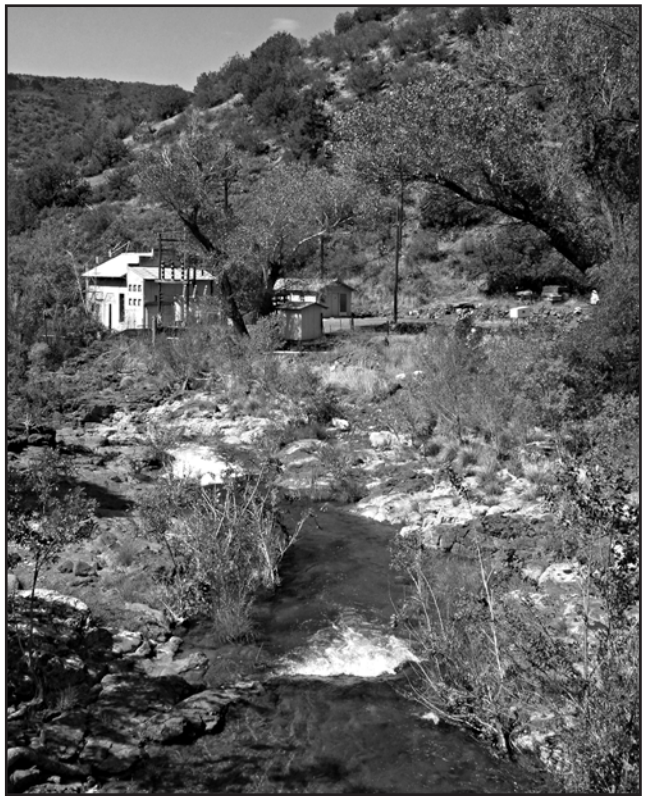
The Nature Conservancy, for example, undertakes restoration work with a clear mission in mind: To preserve threatened lands and waters for the sake of the life that depends on these resources. For TNC the functioning ecosystem along the San Pedro River provides a rare opportunity to undo previous damage and protect this endangered place from additional losses.

The remnants of five of the rarest habitat types in Arizona can be found on the Bingham Cienega Natural Preserve on the west side of the San Pedro River. This 285-acre parcel of land was purchased by Pima County Flood Control District in 1989 and given over to TNC's management. Historically used for ranching and farming, the fields lay fallow for over ten years, while the Bingham Cienega's wetlands, sacaton, mesquite bosques, and riparian forests retook the land. Efforts have succeeded in creating habitat for many of the federally listed endangered species that populate the river corridor, including the leopard frog and willow flycatcher.

Preserves like this one typically have limited public access. TNC offers field trips to the Bingham Cienega Preserve for students, local residents and members of TNC and other groups by prior arrangement; unlike urban restoration projects, this San Pedro site is not normally open to the public. (See map on page 5 for location of Bingham Cienega preserve.)

Fossil Creek Restored

Most projects are designed to achieve a balance of direct human benefits and benefits that accrue to the environment. Fossil Creek, near Strawberry in Central Arizona, is valuable both as a unique water system and as a recreational site for hikers and birdwatchers. Restoration work on Fossil Creek was initiated with the goal of restoring the ecosystem in this rare and beautiful place, a goal that resonates with both human and ecological values.



The Childs power plant along side Fossil Creek. Restoration of Fossil Creek began in 1999 when Arizona Public Service decided to decommission its two power plants operating along the river.

In its heyday, Fossil Creek was the fourth largest travertine system in the world. Fed by underground streams, it ran year-round into the Verde River, its waters rich with calcium carbonate from the limestone aquifer below. Mineral deposits, building up year by year, polished the walls of the canyon into a stepladder of waterfalls and pools. One observer noted the creek's waters were "so impregnated with mineral that they are constantly building great round basins for themselves, and for a long distance flow down over bowl and bowl."

But the creek's consistent flow, so necessary to its native fish populations, also made it perfect for dams. By 1900, Lew Turner, a rancher in the Verde Valley, had filed for the rights to the headwaters of the creek. Six years later, construction began on a power plant and a dam to divert the water. Construction of the diversion structures, accomplished in very rugged country, was an engineering feat of its day. When a second power plant was added downstream in 1916, so much of the water was diverted that the creek no longer flowed except during heavy rain.

Until the turn of this century, the Childs and Irving power plants' use of the creek reduced the previously quick-running water to a trickle. When the Arizona Public Service assessed damage at the site in 1981, they noted that without reliable flows the creek's unique travertine system was in danger of being lost.

In 1999, Arizona Public Service decided to voluntarily shut down the power plants, which generated only 7 megawatts of power at full capacity and were generating 4.2 megawatts at the time. Restoration work took many years. A partnership, headed up by the U.S. Forest Service and a Northern Arizona University research team planned and implemented a series of restoration activities needed before flow would be restored to the creek. Others agencies involved in the restoration effort included the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Arizona Game and Fish and the U.S. Forest Service. Their efforts included salvaging native fish, eradicating the exotic ones, and constructing a fish barrier to prevent exotics from re-colonizing the area. The dam was lowered and diversions ceased in June 2005, restoring full flows to the creek.

This is the first watercourse in Arizona to have a major water retention structure retired. Since diversions ceased, the creek's native fish population has increased tenfold. The Fossil Creek project is at the frontier of a growing movement to remove obsolete dams; lessons learned here are likely to be useful for projects around the United States and the world.

The Fossil Creek story, like the stories of other successful restoration projects, seems to have had a happy ending: a river brought back to life. Yet the natural and scenic conditions of the restored creek are attracting visitors, some of whom do not share the environmental values of the restorers. These users are careless and negligent of the natural setting; makeshift trails scar the landscape, and abandoned trash and human waste litter the area.

This has become an acute problem

along Fossil Creek, in part because the U.S. Forest Service is having difficulty managing isolated back-country areas. A management plan is needed to guide use. Forest Service officials plan to conduct a wide-ranging public input process to devise rules to balance protection of the natural area with human access and enjoyment.

Meanwhile Fossil Creek illustrates the need for continued care and vigilance to ensure the natural conditions of a restored river are not misused. As is being shown at Fossil Creek, the next step after renewing water flow and natural habitat is to organize efforts to monitor or protect what has been restored.

Tribal Projects: Preserving Cultural and Historical Sites

Another human benefit of restoration work is the preservation of culturally or historically significant sites. Projects sponsored by Native American tribes are often initiated for this reason, including restoration work along the Lower Colorado River.

Quechan Tribal Interest in Yuma East Project

The Lower Colorado River, which forms most of the border of Arizona and California, once supported 450,000 acres of riparian woodlands. The riparian corridor was characterized by mesquite bosques teaming with wildlife and cottonwood stands filled with birds. Dams, water channelization projects and invasive non-native plants dramatically altered the river's flow. Without the floods that once swept the riverbed clean, the backwater channels filled with sediment. Shallow wetlands dried up, invaded by tamarisk. Today, only 6,000 acres of cottonwood and willow remain.

The Quechan Indian Tribe depended on the Lower Colorado River for their livelihood long before settlers began building a town called Yuma there. When the river changed, the Quechan way of life changed as well. As a major sponsor of the Yuma East project, the Quechan Indian Nation hopes to bring back their heritage along with the willows.

'Ahakhav Tribal Preserve Project

A similar project is taking place 130 miles north of Yuma on the 'Ahakhav Tribal Preserve, a thousand-acre stretch of land established by the Colorado River Indian Tribes in 1995. In 1997, the Tribes began revitalizing the area, dredging out sediment-filled backwater channels and replanting trees. Their intent was to develop a template for environmental restoration work all along the Lower Colorado.

The 'Ahakhav Tribal Preserve incorporated monitoring and adaptive management into project design. For the first year of growth, staff took careful measurements of the young trees from the base to the tallest up-stretched leaf, and conducted monthly bird surveys as conspicuous indicators of environmental health. These consistent check-ups allowed flexibility as the project evolved and, equally important, gave the restoration team the satisfaction of seeing its efforts blossom and flourish before their eyes.

Reaching out to the community was an important aspect of the project. During the first year of restoration work, project organizers took over 300 youths canoeing on a river once sluggish with sediment, past fields that would soon hold stand after stand of young cottonwood trees. Today, the Preserve has expanded to 1,300 acres, and restoration focusing on the removal of invasive tamarisk and resurgence of native trees continues. The project has become an inspiration for others; the 'Ahakhav nursery now sells over 50,000 trees each year for restoration work along the Colorado.

Wa:k Hikdañ Site

Dramatic changes to Arizona's landscapes have occurred within living memory of Native American elders. Elders are anchors for tribal history, giving purpose and vision to restoration work. On the San Xavier reservation outside Tucson, the Tohono O'odham community restored a section of the Santa Cruz by recreating a wetland near the river channel and planting mesquite, hackberry and desert willow on the higher flood terrace. During the design of the project, tribal elders were consulted to gain insight into what the area looked like during their youth.

The work at the Wa:k Hikdañ site, completed in 2003, created a place for tribal members to walk, contemplate, and observe wildlife that once populated the river's banks in abundance. In a San Xavier District publication, Mark Briggs of Briggs Restoration said the Citizen's Steering Committee considered the restoration effort to be of paramount importance to elders and other community members who wanted to see a semblance of what the Santa Cruz River used to be. Bringing back the landscape also brought back a vital piece of their history.

Project Restores Riverbed, Secures Border

In what might seem an unlikely partnership, environmentalists and security officials are concerned about the blighted environmental conditions along the 23-mile stretch of Colorado River dividing Mexico from the United States south of Yuma.

Environmentalists view the dense, invasive, non-native, overgrown vegetation within the riverbed at Hunters Hole as preventing the growth of native mesquites and willows needed to provide crucial habitat for wildlife and endangered birds including the Yuma clapper rail, California black rail and bald eagle.

Security officials are concerned because the riverbed, thick with vegetative growth, offers good hiding spots for those seeking to avoid law enforcement authorities.

Restored Rivers Offer Varied Benefits

The benefits derived from environmental restoration are many and varied. Some projects provide services that benefit people directly, including flood management, erosion control, recreational opportunities, improved water quality, and scenic beauty. Other benefits are environmental, such as preserving fish and wildlife species by protecting and enhancing habitat. Revitalizing a river corridor can sometimes revitalize the local economy as well, bringing visitors and increasing the value of nearby properties. Places of cultural or historical significance can be preserved for future generations to visit. Additionally, river restoration provides opportunities for education and research. Different values may predominate in different projects.

Degraded environmental conditions have created a high-crime area where smuggling, banditry and sexual assault occur within concealing vegetation.

Where environmentalists desire a return to natural conditions, rich with native vegetation and birds and wildlife, Border Patrol officials want a safety zone with increased visibility to discourage illegal activities. In this instance of complementary objectives, environmentalists and security officials are working together to garner interest and support for the project.

In an unusual description of a river restoration project, Yuma Crossing National Heritage Area officials describe the project as a "security channel" and "an innovation in homeland security." They were highly successful in gaining support from a wide range of agencies and organizations, from the Environmental Defense Fund and the Sonoran Institute to the Border Patrol and the Department of Homeland Security.

Expected to cost between $7 and $9 million, the project would restore an approximately 2.2-mile segment of river including 435 acres of wetlands. Fund raising is expected to take about a year, with restoration work slated to begin within two years.

Water Sources for Restoration Projects

The essential ingredient of all river restoration projects is of course water. While some projects are designed to maintain themselves on existing sources of water, most require additional irrigation, with some tapping groundwater supplies. Some projects focus on protecting or augmenting available water supplies, while others depend on ephemeral flows and rain.

Surface Water and Central Arizona Project Water

The concept of leaving water in a river to support riparian habitat came late to Arizona's water policies, after most water rights had been claimed for other uses. Because Arizona's system of water laws treats each separate source differently, sponsors must sometimes work out complex arrangements to make use of groundwater, surface water or effluent for restoration. Obtaining this water is critical for many restoration projects because establishing new vegetation typically requires at least three years of irrigation.

Water from rivers and streams is allocated by prior appropriation, meaning the first user to divert water and put it to a beneficial use obtains a priority right, and that right is to be satisfied before any other user has access to the water. The definition of what constitutes a "beneficial use" has evolved. Although the Arizona Legislature added habitat for wildlife and fish as one of the beneficial uses in 1941, it wasn't until 1976 that the court ruled this included a right for instream flow, and the first instream flow permit was not issued until 1990. Obtaining a permit for instream flow allows users to leave their allocation of water in the river rather than diverting or consuming it.

Completed in 2003, the Wa:k Hikdañ site on the San Xavier Reservation was the first to use Central Arizona Project water in the Tucson basin for riparian restoration. In following years as much as 50,000 acre-feet of CAP water was put to restoration use on the reservation.

The Bureau of Reclamation purchased Three Links Farms easements as part of a plan, in partnership with The Nature Conservancy and the Salt River Project, to secure instream flow rights on the river. The partners hope to secure water no longer used on Three Links Farm with permits for instream flow in the San Pedro. The strategy will break new legal ground if it succeeds.

While securing flow in the river is one of the most effective ways to revitalize an ecosystem, project sponsors sometimes need to divert surface water for their restoration work. The Yuma East project, for example, drew Colorado River water from Yuma's surface water allocation to irrigate new plantings. The project design predicts the eradication of invasive species in the area will eventually leave more water in the river than was there before the project began.

Colorado River water delivered through the CAP canal is allocated by contracts with the CAP and the Bureau of Reclamation. The San Xavier Reservation has an allocation of CAP water as a result of the Southern Arizona Water Rights Settlement Act. They were the first in the Tucson basin to use water diverted from the CAP canal for environmental restoration. The water now flows through a created stream and wetland. The Tohono O'odham community hopes this water will percolate through the soil and mound on an impervious geologic layer near the surface, creating a "perched" groundwater source for the wetland and riparian vegetation. The reservation has continued to use CAP water for subsequent restoration efforts.

Groundwater

Unlike surface water, groundwater in Arizona is managed under the Reasonable Use doctrine. In effect groundwater users can pump as much water as they can use, as long as the use is not malicious.

Because the Reasonable Use doctrine was established before the hydraulic connection between groundwater and surface water was fully understood, legal groundwater pumping has at times dewatered rivers and created conditions restoration projects have set out to remedy. At the same time groundwater has been a source of water for some restoration work.

On the Bingham Cienega Natural Preserve, TNC worked out an agreement with a neighboring landowner to pump groundwater from his wells for use as temporary irrigation water. The pumped groundwater

WRRC Report Identifies Key Features of Restoration Projects

A Water Resources Research Center report provides complementary information to environmental enhancement studies and restoration project reports by describing 30 projects throughout Arizona. Release of the report, *Projects to Enhance Arizona's Environment: An Examination of Their Functions, Water Requirements and Public Benefits*, provided the impetus for devoting this *Arroyo* to river restoration.

The study focuses on certain fundamental characteristics of the enhancement projects— their drivers, sponsorship, benefits, water requirements and lessons learned. Drivers are the reasons projects were undertaken; most projects have multiple drivers. Drivers include providing habitat, economic development, flood protection, environmental education and water quality improvement.

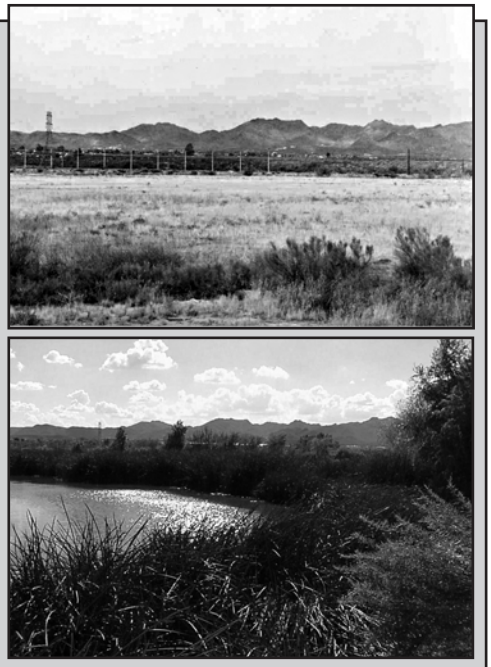
Sponsorship was determined to be an important factor in project design and implementation. Entities that sponsor projects, wholly or in part, include city, county, state and federal agencies, tribes, non-governmental organizations, private landowners and universities.

Varied benefits resulted from the projects — 16 different benefits are identified — with all projects listing more than one. All 30 projects included a habitat value benefit, with the next three most often cited benefits being public use, environmental education and flood protection.

Water use is an important part of the study. The authors asked: What is the source of the projects' water? Are unprotected instream flows a source? Are water rights purchased? If so, at what cost? What projects get by without importing water?

Finally there is a summary of lessons learned. These are not just research results; lessons learned are information, observations and comments that can qualify as advice. The authors identify the lessons as the six P's in the pond: preparation, persistence, partnership, progress, pests and post-construction.

Funded by the U.S. Department of the Interior, Bureau of Reclamation, the publication was written by WRRC Director Sharon B. Megdal and graduate students Kelly Mott Lacroix and Andrew Schwarz. It is available on the WRRC's web site: http://cals.arizona.edu/azwater/ Click "Recent Publications." CD version available upon request.



Above is a before-and-after depiction of Sweetwater Wetlands. A valuable component of a recharge facility, the Sweetwater Wetlands, located along the Santa Cruz River in Tucson, serves multiple uses including research, public education, recreation and wildlife habitat.

helped to establish sacaton and new riparian woodland vegetation including cottonwoods and willows planted close to the wetland where the depth to groundwater is only three feet.

The Preserve is located along the San Pedro River, a viable system with surface water flow and a shallow groundwater table. Understanding depth to groundwater helped guide plantings at the Preserve. Mesquites were planted in areas where depth to groundwater was more than nine feet below land surface. Between the riparian vegetation and the mesquites, restorers sowed sacaton grass seeds to create a band of rare grassland. These gradients of the restored habitat reflect nature, with depth to groundwater determining the species of plants that survive.

Restoration projects located within the state's Active Management Areas confront challenges unique to the AMAs. The 1980 Groundwater Management Act changed the groundwater laws in central Arizona, establishing AMAs where groundwater overdraft was a problem. The Reasonable Use doctrine was replaced by a statutorily defined permit system with rules on pumping, conservation, new wells, and permitted uses.

Located within the Phoenix AMA, the Rio Salado Project is located along the Salt River in an area where the water table has fallen well below the root zone of riparian plant species. To achieve its goal of restoring vegetation along a river despite the fact that it long ago lost its connection with the underlying aquifer, the project will have to rely on irrigation to support new riparian vegetation.

To obtain the needed water, the City of Phoenix worked out a creative strategy involving the Roosevelt Irrigation District. Phoenix provides effluent to the District, which allows the District to reduce the amount of groundwater it pumps for irrigation. Through this transaction, Phoenix acquires effluent "credits" that it can use to pump water from the "area of hydrologic impact" where the District's wells formerly pumped. Legally, this water is not considered groundwater. The aquifer is contaminated by agricultural and urban pollutants, and the water is not being used as a potable supply because the cost of treatment would be too high. Instead, it is treated to acceptable standards for irrigation and used to establish cottonwoods, willows, and mesquite along the Salt River riparian corridor.

Effluent, Rainwater Harvesting at the North Simpson Restoration Project

Usually considered a waste product, effluent is often discharged from wastewater treatment plants into convenient riverbeds. As described earlier (page 6), the result has been to the advantage of resurgent riparian vegetation. At the North Simpson site, 20 and more miles downstream from the discharge points of two treatment plants, a meandering Santa Cruz River flows with ef-

fluent. Historically an ephemeral section of the Santa Cruz, the area now has an almost constant flow, supporting cottonwoods and willows where none existed historically.

The goal of the North Simpson Restoration Project is to take advantage of the cottonwood-willow habitat developing along the riverbed and to augment and improve it by reestablishing meso and xeroriparian vegetation in the very wide floodplain at this location. This will widen the corridor of vegetation and increase its diversity and usefulness as habitat. Work began on the site in 2000, when the Tucson Audubon Society started planting new trees, fencing out cattle and monitoring the bird species. Over the past six years, the restoration team has seeded hundreds of acres along the riverbanks. Bell's vireo, Bullock's oriole and yellow-billed cuckoos, along with the ubiquitous white-crowned sparrows and many other species, have returned to the revitalized riparian area.

An agreement with the City of Tucson allows the Tucson Audubon Society to use up to ten acre-feet of water per year to establish native vegetation, but actual use is consistently less. Eventually, the groundwater irrigation system will be turned off and the newly planted riparian vegetation will be left to adapt on its own, dependent on variable effluent flows from the treatment plants, rain and periodic storm water flows.

Sponsors of restoration efforts take advantage of "free" water when they can, but the producer of the wastewater may choose to discontinue releasing it at any time. As cities threaten to grow beyond the available water supplies, perceptions of the value of effluent are changing. Eventually, as technology improves and demand increases, it will become a valuable commodity for many non-potable uses. Some cities are even considering advanced treatment of wastewater for potable use in the future.

If the effluent flows at North Simpson are ever diverted for another use, it is likely that many of the cottonwoods and willows will lose their tenuous hold on life. But Ann Audrey, the former project manager, points to the natural ephemerality of riparian corridors in the desert, where destructive floods and prolonged droughts are natural hazards. Audrey says, "Regardless of how changes might alter habitat in the future, the site right now is serving as a habitat for numerous birds and other wildlife." For her, the value of putting the effluent stream to good use, despite its transitory nature, outweighs whatever changes might occur later on. In addition, the floodplain plantings, a wide variety of meso and xero riparian vegetation, will remain viable even without effluent.

The Tucson Audubon Society supplemented the effluent supply at the site with rainwater harvesting. Staff and volunteers nestled newly planted trees into shallow basins and designed raised berms and swales to direct both temporary irrigation and periodic rainfall to the vegetation's best advantage. These earthworks increase the chances that the vegetation will survive after the irrigation is turned off.

Another Santa Cruz River restoration project, Esperanza Ranch, also flows with released effluent and storm water. According to an agreement entered into by the previous owners, both surface water diversions and groundwater pumping are prohibited on the site. As a result, the Tucson Audubon Society faces the challenge and opportunity of establishing new vegetation without the advantage of irrigation water. Seedlings, planted beginning in the fall of 2006, will depend on rainwater harvesting as the sole water source.

Conserve-to-Enhance

Recently, Andrew Schwarz, former University of Arizona student, and Sharon Megdal, director of the UA Water Resources Research Center, developed an innovative strategy to obtain water for environmental or restoration projects. The voluntary program involves municipal water customers paying for water they have conserved, with the funds then used to purchase water for environmental purposes. Still in the development stage, this "Conserve to Enhance" strategy would require the voluntary participation of water utilities. Program developers hope to implement the program through a pilot project.

U.S. BuRec Supports Newsletter
The WRRC thanks the U.S. Bureau of Reclamation for assistance in the preparation of this edition of *Arroyo*.

Conclusion

There is something tragic about a degraded river bereft of its natural features, its riparian vegetation, fish and wildlife greatly diminished or even lost. It is first of all an environmental tragedy when the natural bounty of our rivers is damaged or destroyed.

A human tragedy also unfolds because a vitalizing connection between people and nature is severed. This tragedy is especially poignant because humans are usually at the root of the destruction; their drive to control rivers for economic gain taking precedence over a desire to be stewards of ecological resources. In the best of all possible worlds, environmental and human values would not conflict; rather they would be complementary.

Natural resource management must contend with various interests, each with something at stake in an issue; the more seemingly divergent the interests, the greater the potential for conflict. Compromises, however, can always be reached. If the preceding discussion noted that rivers often get short changed, it also illustrated that many of Arizona's rivers are now benefitting from creative efforts to restore and enhance them. To use an aquatic metaphor — albeit one more suited to seaside than semi-arid Arizona — the tide is turning. Rivers and their ecosystems are receiving much needed attention in the western states.

Ibis in flight at the Yuma East Restoration Project.