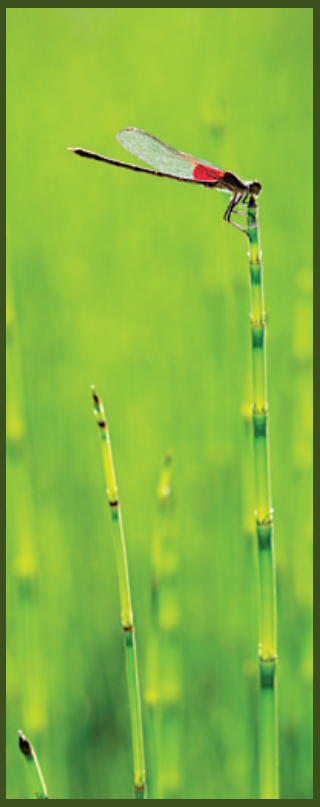
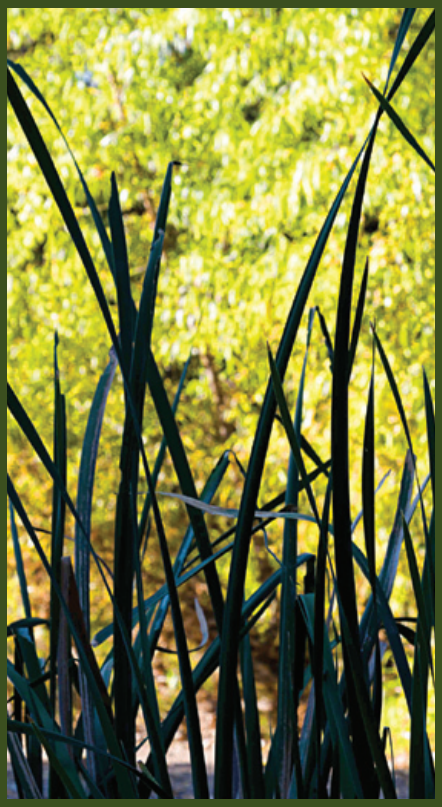
a living river

CHARTING WETLAND CONDITIONS OF THE LOWER SANTA CRUZ RIVER

2013 Water Year





CONTENTS

SONORAN INSTITUTE

PIMA COUNTY

This assessment is a sister series to the *Living River* reports completed for the Upper Santa Cruz River, downstream of the Nogales International Wastewater Treatment Plant (learn more at **www.tiny.cc/uscr**).

THE LOWER SANTA CRUZ RIVER
A LIVING ECOSYSTEM

Water: In an arid landscape, it is the essential resource for people, plants, and wildlife. In southern Arizona and northern Sonora, Mexico, the Santa Cruz River provided this vital life force. With its corridor of majestic cottonwood trees and waters teaming with ducks, fish, and frogs, the river attracted the first humans to its banks more than 12,000 years ago and has subsequently supported the longest continuous record of agriculture in the United States. The agricultural legacy along the Santa Cruz River Valley would not have been possible without a consistent supply of water.

As dry sections of riverbed demonstrate, however, even the Santa Cruz River has its limits. Dependable water in the river began to dwindle—and largely disappear—in the mid-20th century because of groundwater pumping to support agriculture, mines, and burgeoning communities. Today, most of the river flows only when it rains. The good news is that after taking and using the river's water for millennia, people are giving life back to the river.

Thanks to the release of *effluent*, or treated wastewater, into the river, many miles of the Lower Santa Cruz River from northwest Tucson through Marana flow year-round. Water in this stretch comes from two regional *water reclamation facilities*, or wastewater treatment plants, which have been supplying effluent to the river since the 1970s. This practice has not only formed Arizona's longest length of river ecosystem dominated by effluent, but also preserved one of the last living examples of the river heritage that has supplied numerous benefits to the community.

For more than four decades, the Clean Water Act has provided an expanding set of regulatory requirements to improve the quality of effluent discharged into the Lower Santa Cruz River. As a result, Pima County recently completed its largest public works project by investing over $600 million to upgrade the reclamation facilities along the river. The release of higher-quality water is a key ingredient in supporting a healthier environment, but how can we gauge conditions of this valuable ecosystem and community amenity? The Sonoran Institute pioneered the *Living River* report to track annual changes along the Upper Santa Cruz River, an upstream stretch also dominated by effluent. Now Pima County has partnered with the Sonoran Institute to develop a new series for the Lower Santa Cruz River.

By documenting how the Lower Santa Cruz River is changing from year to year, we gain insight into the river's health. This new *Living River* series is an assessment of the wetland conditions created and impacted by the effluent. This first report establishes baseline measures of 16 indicators of river health along a 23-mile stretch of the river. Setting these baselines for the 2013 water year (October 1, 2012–September 30, 2013) is important because it captures conditions in the year prior to completion of the facility upgrades. Therefore, this report is a firm foundation and benchmark for future assessments.

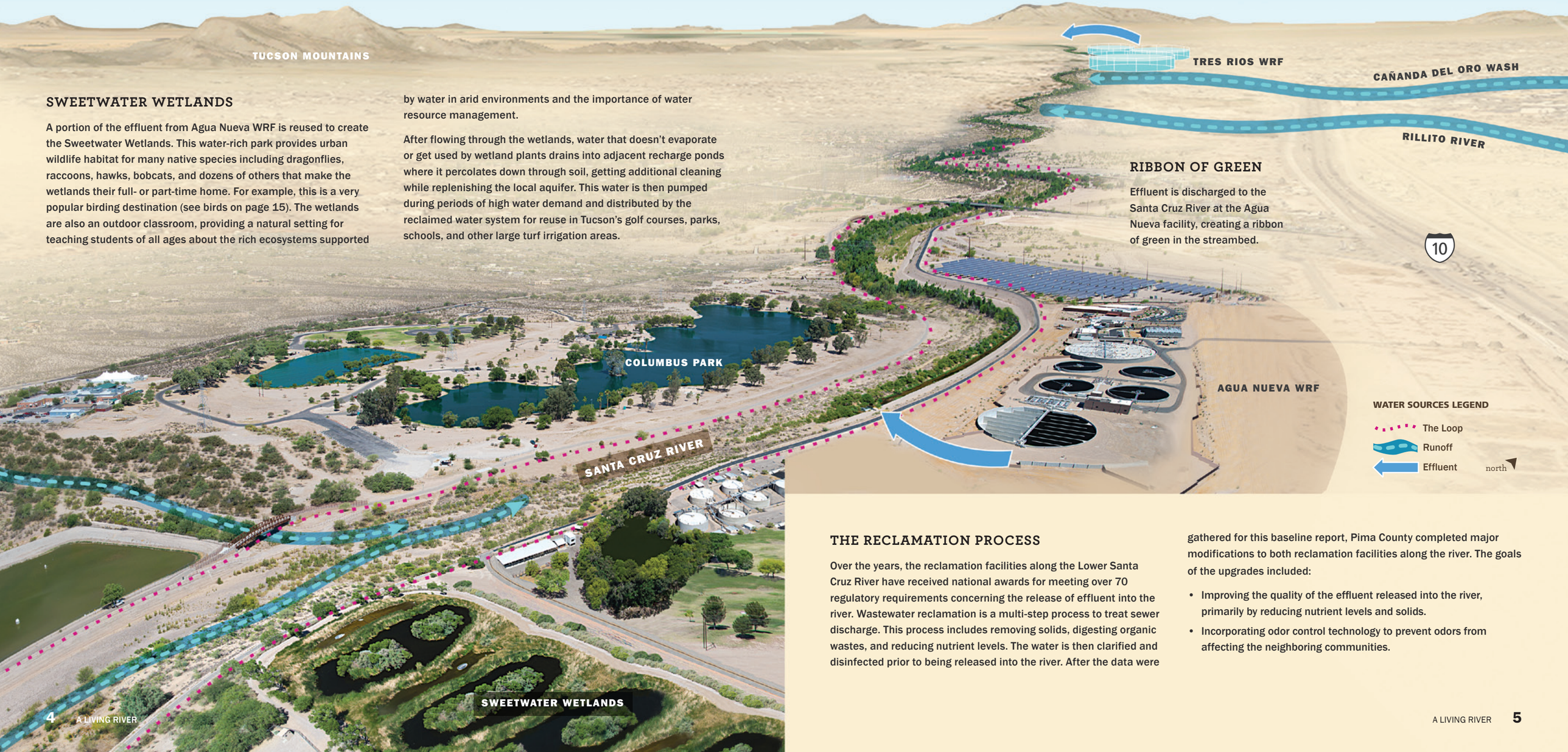
All *Living River* reports and associated documents for the Lower Santa Cruz River are available for download on the Sonoran Institute website at **www.tiny.cc/lscr**.

WATER SOURCES

Water flowing in the Lower Santa Cruz River primarily comes from effluent released by the Agua Nueva and Tres Rios water reclamation facilities (WRF). Effluent is water that has been pumped or diverted from one location, used by people, treated in a reclamation facility, and released in a new location—often rivers and desert washes. While there are challenges and uncertainties regarding the ecological benefits of effluent (e.g., high nutrient levels often found in effluent can lead to nutrient pollution, see page 13), research at Arizona's universities and agencies has shown that effluent can be an important human source of water for rivers and their associated vegetation and wildlife, and its discharge helps support the many benefits rivers provide to adjacent communities.

Additional water in the Lower Santa Cruz River comes from rainfall in the surrounding watershed. When it rains, water that doesn't evaporate, percolate into the soil, or get absorbed by plant roots becomes runoff that eventually flows into a wash or tributary and down to the river. Runoff from Tucson, Marana, Oro Valley, and Green Valley and from irrigated farmland in Marana flows toward the river and provides additional streamflow.

Historically, groundwater (water found in the layers of rock or earth that comprise an aquifer) was another source of water for some stretches of the Santa Cruz River (read more in the *State of the Santa Cruz River*, an online publication available at **www.tiny.cc/scrci**). However, groundwater does not contribute much, if any, streamflow along the Lower Santa Cruz River because the water table, or level of groundwater, is too deep below the surface.



SWEETWATER WETLANDS

A portion of the effluent from Agua Nueva WRF is reused to create the Sweetwater Wetlands. This water-rich park provides urban wildlife habitat for many native species including dragonflies, raccoons, hawks, bobcats, and dozens of others that make the wetlands their full- or part-time home. For example, this is a very popular birding destination (see birds on page 15). The wetlands are also an outdoor classroom, providing a natural setting for teaching students of all ages about the rich ecosystems supported by water in arid environments and the importance of water resource management.

After flowing through the wetlands, water that doesn't evaporate or get used by wetland plants drains into adjacent recharge ponds where it percolates down through soil, getting additional cleaning while replenishing the local aquifer. This water is then pumped during periods of high water demand and distributed by the reclaimed water system for reuse in Tucson's golf courses, parks, schools, and other large turf irrigation areas.

RIBBON OF GREEN

Effluent is discharged to the Santa Cruz River at the Agua Nueva facility, creating a ribbon of green in the streambed.

THE RECLAMATION PROCESS

Over the years, the reclamation facilities along the Lower Santa Cruz River have received national awards for meeting over 70 regulatory requirements concerning the release of effluent into the river. Wastewater reclamation is a multi-step process to treat sewer discharge. This process includes removing solids, digesting organic wastes, and reducing nutrient levels. The water is then clarified and disinfected prior to being released into the river. After the data were gathered for this baseline report, Pima County completed major modifications to both reclamation facilities along the river. The goals of the upgrades included:

- Improving the quality of the effluent released into the river, primarily by reducing nutrient levels and solids.
- Incorporating odor control technology to prevent odors from affecting the neighboring communities.

ASSESSING WETLAND CONDITIONS

The *Living River* report evaluates conditions of the Lower Santa Cruz River using 16 indicators (see diagram) organized into six categories: *flow extent*, *water quality*, *sediment transport*, *aquatic wildlife*, *riparian vegetation*, and *social impacts*. The indicators relate to the conditions in the river channel and in the adjacent riparian areas, the areas next to and affected by the river. Other important characteristics are being informally tracked. These are discussed throughout the report and include nutrient pollution, birds, amphibians and reptiles, and recreation.

The purpose of the *Living River* series is to monitor and report on the wetland and riparian conditions at various intervals downstream of the effluent discharge points. As the effluent flows downstream, it impacts and is impacted by the natural conditions of soils, vegetation, and surrounding environment created by the effluent. The selected indicators will be used to study these interactions. Guidelines for evaluation of these indicators were developed as described in the following paragraph.

Data collected by Pima County and by other organizations are evaluated for this report. Most water quality indicators are compared to standards set by the Arizona Department of Environmental Quality (ADEQ) that define water quality goals for streams and are designed to protect wildlife. For some standards, ADEQ defines goals for streams whose waters are dominated by effluent. However, for indicators where there are no such standards, data are evaluated with reference values established by historical data or other sources. For indicators without a clear reference value or standard, the 2013 *Living River* assessment becomes the baseline for tracking future change. Additional information about historical conditions along the river is summarized in *Historical Conditions of the Effluent-Dependent Lower Santa Cruz River*, available online at **www.tiny.cc/lscr**.

The following pages present the data collected in the 2013 water year (October 1, 2012–September 30, 2013), prior to reclamation facility upgrades. For the purposes of this report, the 23-mile stretch of river is divided into three sections, or reaches: Three Rivers, Cortaro Narrows, and Marana Flats. These reaches differ in geology, hydrology, and adjacent land use. To review all the data in more detail and see additional charts from the 2013 water year, please visit the Sonoran Institute website at **www.tiny.cc/lscr13**.

IMPORTANT NOTE: Facility upgrades at the Tres Rios WRF came online in phases between Fall 2012 and Fall 2013. However, the Agua Nueva WRF upgrades did not come online until December 2013. Therefore, the cumulative effect of all the upgrades is not reflected in the baseline information in this report. As this report was sent to the press, casual observation of the river suggests that the upgrades will significantly impact wetland conditions and flows in the Lower Santa Cruz River.

Riparian areas are the areas next to and affected by the water in wetlands, rivers, and desert washes. Wetlands are places where water saturates the soil, thereby shaping what can grow there. Riparian areas and wetlands are extraordinarily rare in the desert. They produce abundant wildlife, and people highly value them for recreation and relief from the heat.

Santa Cruz River near Ina Road, 2014

CATEGORY	PURPOSE	INDICATORS
FLOW EXTENT	General measure of water flowing in and out of the system, recharge, and available aquatic habitat.	• Miles of flow in each reach • Flow at Trico Road
SEDIMENT TRANSPORT	Measure of solid particles moving through the system, which can impact habitat and conditions for aquatic plants and animals.	• Total suspended solids • Turbidity • Percent fines
WATER QUALITY	Measure of chemical conditions necessary for sustaining the river's animal and plant communities.	• Total dissolved solids • Ammonia • Dissolved oxygen • Biochemical oxygen demand • Metals
AQUATIC WILDLIFE	Direct measure of river's wildlife which integrate many factors of the surrounding environment.	• Fish • Aquatic invertebrates
RIPARIAN VEGETATION	Direct measure of river's plant communities which reflect changes in water quantity and quality.	• Wetland indicator status • Nitrogen affinity score • Riparian tree cover
SOCIAL IMPACTS	Measure of aesthetic factors that directly impact people living or recreating along the river.	• Odor at reclamation facilities

STREAMFLOW, RAINFALL, AND WATER BUDGET

Streamflow, or the amount of water flowing in a river, provides an important context for the results of the indicators in the following pages. Reclamation facilities continuously release water into the river, which accounts for the majority of daily streamflow. However, streamflow also includes runoff, which is influenced by rainfall and the amount of impervious area (e.g., roadways) in the watershed. The Santa Cruz River Watershed includes all of the land whose runoff flows toward the river. Seasonal floods are important for recharging aquifers, dispersing seeds, inducing seed germination, and clearing natural debris.

We can develop a water budget for the Lower Santa Cruz River by estimating the water *inputs* and *outputs*. Inputs are **effluent** and **runoff**, while outputs are water that does one of the following: **flows past Trico Road** (see map on page 2), **evaporates or is used by wetland vegetation**, or sinks into the ground to **recharge local groundwater**. Volume of inputs and outputs over the year are totaled in acre-feet, the number of acres that would be covered with water 1 foot deep. The water budget is focused on the *water year* (October 1 to September 30), which includes the region's two rainy seasons. The *winter rainy season*, which lasts from December to March, brings gentle and widespread rain. Locally heavy thunderstorms occur during the *summer monsoon season*, which typically lasts from July to mid-September. Thus, the water year starts during the dry season before the winter rains and ends during the dry season after the summer monsoon.

2013 Rainfall

Rainfall is monitored for the region at the Tucson International Airport and near the Lower Santa Cruz River at Ina Road. Rainfall totals from these locations provide a general idea of when runoff may have increased streamflow.

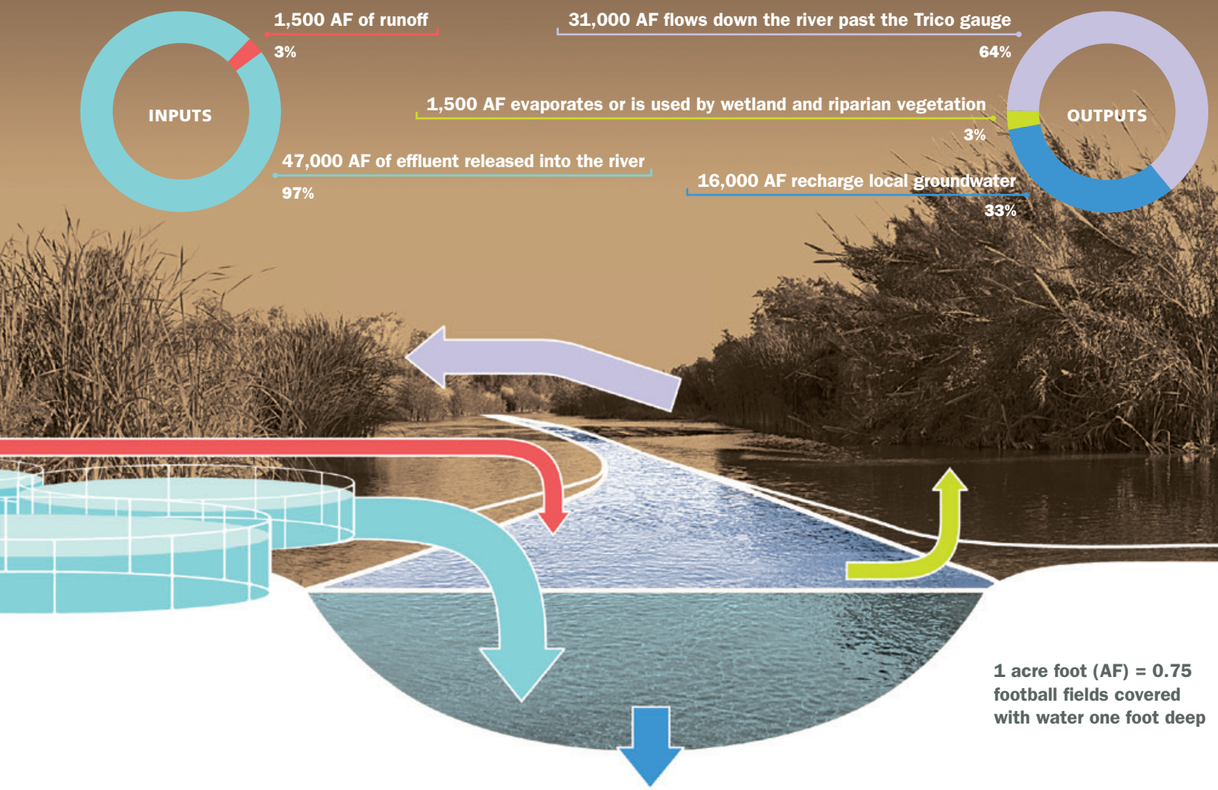
The Tucson International Airport recorded 6.59 inches of rain. This is below the historical average recorded at the airport (11.24 inches from 1949 to 2011).

- The winter rainy season brought over 2.7 inches of rain.
- The summer monsoon season brought over 3.7 inches of rain.

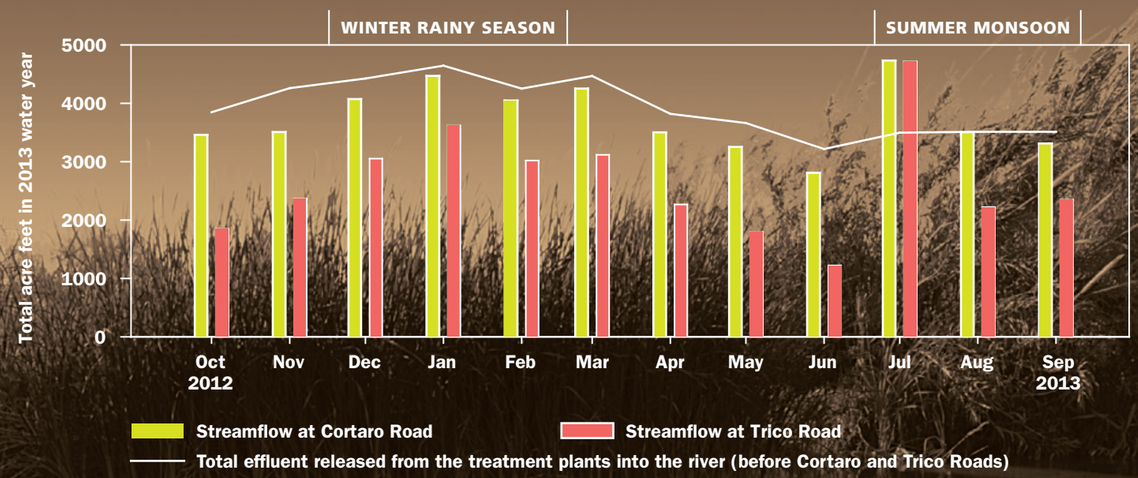
The weather station at Ina Road recorded 6.58 inches of rain. This is similar to the recent average recorded at this station (7.95 inches from 2002 to 2012).

- The winter rainy season brought nearly 2.6 inches of rain.
- The summer monsoon season brought over 3.7 inches of rain.

2013 Water Budget



1 acre foot (AF) = 0.75 football fields covered with water one foot deep



Data sources for streamflow, rainfall and water budget: National Weather Service, Pima County Regional Flood Control District, Pima County Regional Wastewater Reclamation Department, Tucson Water, and U.S. Geological Survey

2013 Streamflow

Streamflow is measured at Cortaro Road and Trico Road, which are downstream of the Agua Nueva and Tres Rios Reclamation Facilities (see map page 2). View additional streamflow data online at **www.tiny.cc/stream13**.

- On average, about 3,900 AF of effluent was released into the river every month, accounting for the majority of streamflow. Runoff contributed to streamflow during the rainy seasons, most noticeably in July when the total AF of streamflow at Cortaro and Trico Roads was greater than the total AF of effluent released into the river.
- Total monthly streamflow averaged about 3,700 AF at Cortaro Road and 2,600 AF at Trico Road.

INDICATOR RESULTS

FLOW EXTENT

Measuring flow extent, or the distance the river is flowing, is a quick visual way to track changes in the river's water budget while providing a rough measure of the quantity of aquatic habitat available. For example, high flow extent may indicate high availability of habitat for aquatic life. Low flow extent may indicate reduced water inputs, which could decrease aquatic habitat. Alternatively, low flow extent could indicate greater recharge of water into local aquifers.

Two indicators help track changes in flow extent:

Flow at Trico Road, located at the end of the study area, estimates daily changes in maximum flow extent through the three reaches by counting the "dry days" or days with no streamflow.

Miles of flow in each reach prior to the monsoon season determines the minimum extent of flow during the driest time of year. This is typically measured in mid-June.

2013 RESULTS

Streamflow extended through all three reaches, and there were no days when the river was dry at Trico Road. This matches recent flow extent, as all three reaches of the river have been flowing year-round since the mid-1990s.

Data source: Pima County Regional Flood Control District and U.S. Geological Survey

SEDIMENT TRANSPORT

Rivers naturally move sediments and other small particles of algae or detritus downstream. As these materials are swept away, others are deposited from upstream, bringing an influx of essential nutrients to the river ecosystem. Excess sediments result from natural and human impacts on the landscape, such as heavy rainfall, clearing of vegetation, and runoff from roads and urban areas. High sediment transport can be like a "sandstorm" in the water and may impact conditions for aquatic life. Under chronically high "sandstorm" conditions, sunlight doesn't travel as deep into the water. Thus, aquatic plants may not receive enough sunlight to conduct photosynthesis, and aquatic predators may not be able to see well enough to capture prey. Three indicators help track changes in sediment transport in the river.

Total suspended solids is an estimate of the number of particles in the water, or the intensity of the sandstorm. ADEQ does not have a standard for total suspended solids. The results from the 2013 water year will serve as a baseline.

Turbidity measures water clarity, or how far you can see through the sandstorm, and is reported in Nephelometric Turbidity Units (NTU). High NTU indicates the water is cloudy and hard to see through. The 1988–1993 median level of turbidity in the Cortaro Narrows reach was 15 NTU. ADEQ does not have a standard for turbidity, so this assessment uses 15 NTU as a historical reference value.

Percent fines is an estimate of the portion of the riverbed comprised of small sediments (≤2 mm in diameter). Fines or "muck" that settle out of the sandstorm onto the riverbed can become so abundant that they smother aquatic life and habitat. ADEQ does not have a standard for rivers dominated by effluent. This assessment uses the reference value for warm water rivers, <50% fines.

2013 RESULTS

Measures of sediment transport were collected throughout the year at several locations during normal times when the river was not flooding. Overall, all measures of sediment transport increased as the river flowed downstream. Turbidity often met the historical reference value, though was highest in Marana Flats. Except for the most upstream site in Three Rivers, all reaches had percent fines above the reference value. View all the data online at **www.tiny.cc/st13**.

Data source: Pima County, University of Arizona

WATER QUALITY

Aquatic ecosystems, such as streams, depend on particular water quality conditions (chemical, physical, and biological properties) to sustain plant and animal communities. Five indicators help track changes in water quality in the river: total dissolved solids, ammonia, dissolved oxygen, biochemical oxygen demand, and metals.

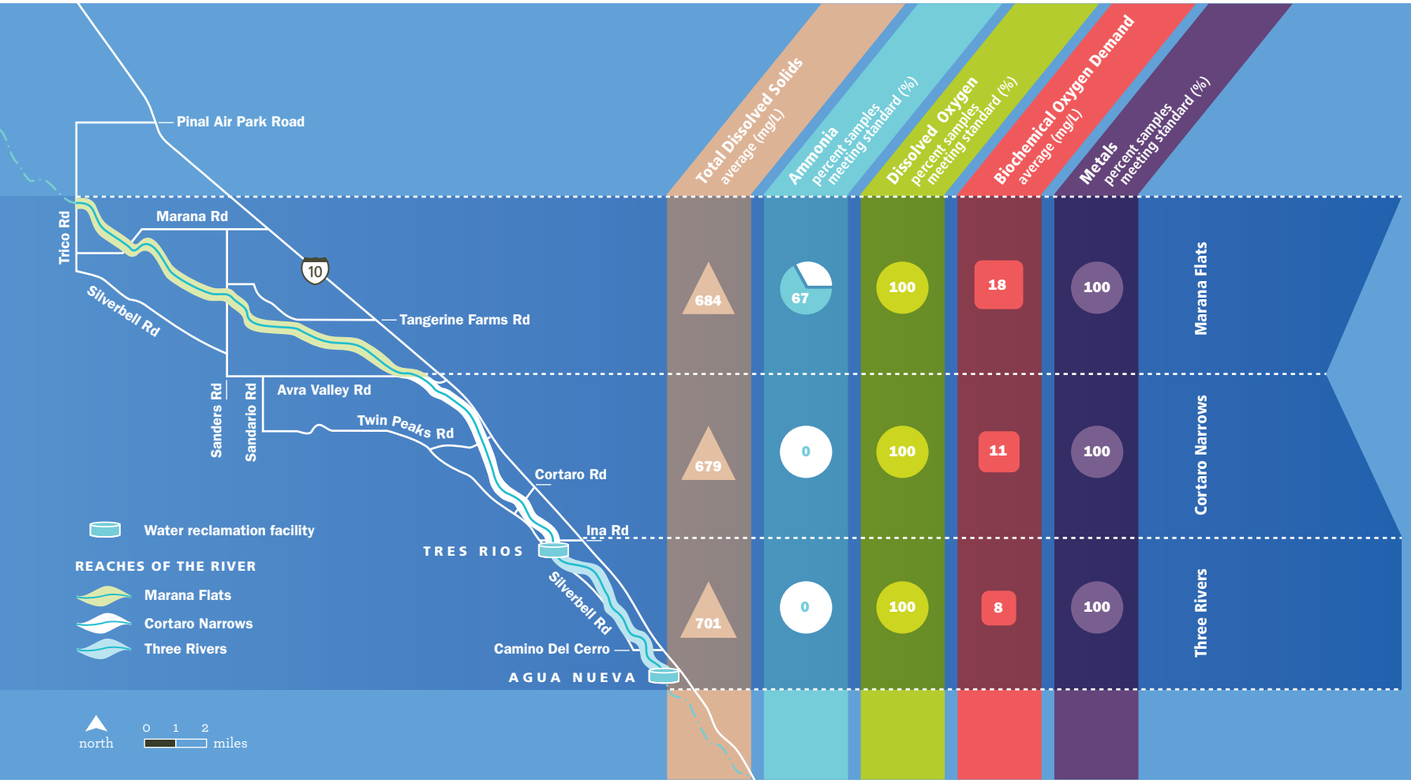
Many of the dissolved solids are essential nutrients for plants and animals, but when too abundant they can produce unhealthy conditions for aquatic life and riparian vegetation. Thus, measuring **total dissolved solids** (TDS) is commonly used to monitor excess salts in the water. TDS in the effluent has been rising with increased use of Colorado River water in the Tucson area. The Colorado River has greater TDS, mostly in the form of dissolved salts, than the local groundwater. Because there is no standard for TDS (often standards are for individual elements that contribute to TDS), the results from the 2013 water year will serve as a baseline.

Nitrogen is an essential nutrient for plant and animal life, but too much can contribute to nutrient pollution. **Ammonia** (NH_3) is one form of nitrogen that can be toxic to fish. Even at low concentrations, ammonia can reduce hatching success, among other impacts. ADEQ's chronic wildlife standard for ammonia levels in rivers dominated by effluent varies with pH (level of acidity) and temperature. As pH and temperature increase, the toxicity of ammonia increases, thus the acceptable level of ammonia decreases with high pH and temperature. During the 2013 water year, water temperature ranged from 62.6° F in the winter to nearly 92° F in the summer; pH was between 7.4 and 8.0. Based on the range of temperatures and pH in the reaches, the maximum amount of ammonia during the 2013 water year should be less than 0.9 to 2.5 milligrams per liter (mg/L) for ecosystem health.

Fish and other aquatic animals need **dissolved oxygen** to survive. Rivers absorb oxygen from the atmosphere, and aquatic plants and algae produce oxygen. Natural causes of variability in dissolved oxygen levels include nutrient levels, shading, water temperature, and time of day. ADEQ sets the minimum standard for dissolved oxygen in effluent-dependent streams at 3 milligrams per liter (mg/L) during the day.

Biochemical oxygen demand (BOD) is an estimate of how much dissolved oxygen is being used. Microorganisms in the river consume dissolved oxygen as they break down and use organic materials, such as leaves and woody debris, dead plants and animals, and animal wastes. If there are a lot of organic materials in the water, these microorganisms become so numerous that they consume a lot of dissolved oxygen and deprive other aquatic animals of the oxygen they need to survive. Though there are standards for BOD in the wastewater reclamation process, there is no standard for BOD in rivers. The results from the 2013 water year will serve as a baseline.

Metals in high concentrations endanger wildlife in aquatic ecosystems by lowering reproductive success, interfering with growth and development, and, in extreme cases, causing death. Most metals build up in aquatic food chains and may pose long-term threats to all organisms in the aquatic environment. Rivers are exposed to pollutant metals through numerous sources, including mine drainage, roadways, and by the release of metals naturally occurring in near-surface rocks and sediments. ADEQ has set standards for the protection of aquatic wildlife. Results for the following metals are compared to their appropriate standard: arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc.



2013 RESULTS

Measures of water quality were collected at several locations throughout the year. Total dissolved solids were similar across all reaches. With the exception of Marana Flats, ammonia levels were high and did not meet the ADEQ standard. Dissolved oxygen levels met the ADEQ standard. Biochemical oxygen demand tended to increase as the river flowed through the reaches. All the metals tested met the appropriate standard. View all the data online at www.tiny.cc/wq13.

Data source: Pima County Regional Wastewater Reclamation Department

NUTRIENT POLLUTION

Nutrient pollution, such as high levels of nitrogen and phosphorus, enters the river from air pollution, fertilizer, surface runoff, and release of effluent from wastewater treatment plants. While elevated nutrient levels can benefit growth of riparian plants, they can also lead to problems such as low levels of oxygen in the water (dissolved oxygen) and associated declines in fish habitat. High nutrient levels can also increase the number of microorganisms that break down and use these nutrients. These organisms live in the spaces between the sand and gravel in the streambed, and can become so numerous that they create an impermeable "clogging" layer that can reduce the amount of water that moves through the streambed, thereby decreasing infiltration of water into local aquifers. Under such conditions and without seasonal floods to scour the streambed and flush out the microorganisms, streamflow may continue without riparian plants being able to access water flowing in the river.


Western Mosquitofish

AQUATIC WILDLIFE

Though wetland and riparian areas are rare across the arid Southwest, they are critical for the region's wildlife and are used by 80% of all species at some point during their lives. Wildlife can be good indicators of river health because they integrate and reflect conditions of multiple factors in the surrounding environment, such as water quality and availability of habitat. Two indicators help track changes in aquatic wildlife.

Fish can serve as effective indicators of river health because they live for several years and vary in their tolerance to pollution. Historically, the Santa Cruz River supported several native fish species: Gila Topminnow, Gila Chub, Desert Sucker, Sonora Sucker, Longfin Dace, and a pupfish species that went extinct when the river ceased to flow year-round. There is no standard for abundance or diversity of fish. The results from the 2013 water year will serve as a baseline for measuring change in future years.

Aquatic invertebrates (aquatic animals that lack a spinal column or backbone) are an important biological component in streams. They break down organic materials and are important prey for fish and other species. They also differ in their tolerances to pollution. The presence of species that are pollution sensitive is a sign of good health. Ephemeroptera (mayflies) have exposed gills on the outside of their body, making them very pollution sensitive. Chironomidae (midges), are pollution tolerant and found in high numbers even with low oxygen levels and high organic matter. Amphipods, family Gammaridae, also thrive in high detritus environments.

Regardless of sensitivity to pollution, if a single species or group accounts for more than 50 percent of the invertebrate community, this lack of diversity suggests a stream is under environmental stress or impaired. Lastly, the ADEQ index of biological integrity defines standard conditions for aquatic invertebrates in warm-water streams: a value of >50 meets the standard, 40–49 is inconclusive, <39 is impaired. Although the index does not apply to effluent-dominated rivers, it can be used as a reference to track improvements over time. The 2013 water year will serve as a baseline for future years.


Sonora mud turtle

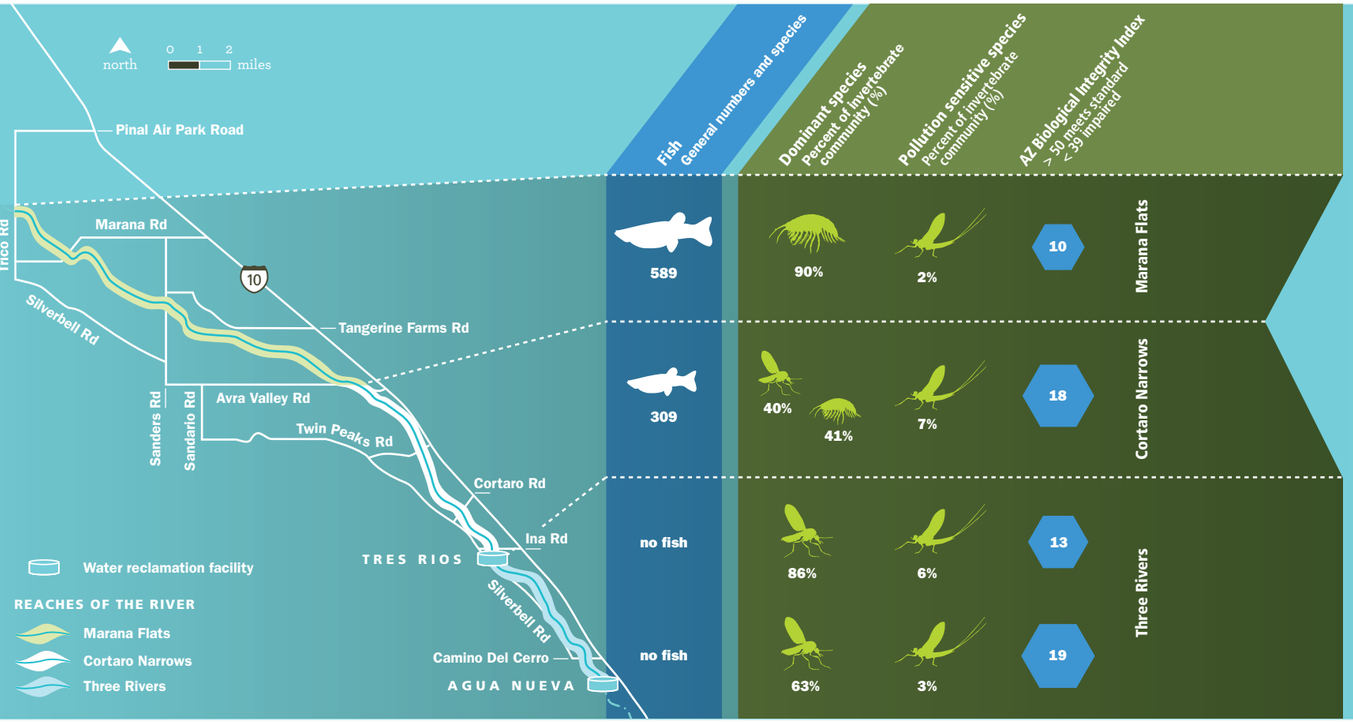
AMPHIBIANS AND REPTILES

Riparian areas are critical habitat for numerous amphibian and reptile species. Historically, the Santa Cruz River was home to a community of species commonly found along rivers and desert washes in southeastern Arizona. This community included leopard frogs, Sonora mud turtles, and Mexican Gartersnakes, among many others. Past surveys for amphibians found the following amphibians along the Lower Santa Cruz: Couch's spadefoot toad, Mexican spadefoot toad, Great Plains toad, Sonoran Desert toad, and the non-native American bullfrog. Amphibians and reptiles were not formally surveyed in the 2013 water year. However, an American bullfrog and a spiny softshell turtle, another non-native species, were both observed in the Three Rivers reach during the fish survey.

BIRDS

The birds of the Santa Cruz Valley attract thousands of visitors each year. Thus, the health of the river is not only important for wildlife, but also for the local economy. Many bird watchers record the species they see along the Santa Cruz River into an online database at **www.ebird.org**, a citizen-science program managed by the Cornell Lab of Ornithology. In the 2013 water year, there were 332 citizen-scientists who collected nearly 40,000 bird observations along the Lower Santa Cruz River. Though bird watchers made observations all along the three reaches, over 34,000 were from the Sweetwater Wetlands, demonstrating the importance of this site as a birding destination and valuable bird habitat. Overall, there were 218 unique species observed along the Lower Santa Cruz. The river is home to many local species, but observations of migratory species, like MacGillivray's Warbler, Townsend's Warbler, and Wilson's Warbler, demonstrate the importance of this wetland habitat for birds to stop and rest on their journey.


White-crowned sparrow



AQUATIC WILDLIFE KEY

Chironomidae (midges)

Gammaridae (amphipods or "scuds")

Ephemeroptera (mayflies)

Western Mosquitofish

2013 RESULTS

A spring 2013 survey of the aquatic invertebrate community was conducted at four locations along the river. The invertebrate community was generally dominated by one species, often pollution-tolerant midges from the family Chironomidae. Pollution-sensitive mayflies, Ephemeroptera, were found only in small numbers. The biological index scores were very low, ranging from 10 to 19, suggesting that river life is impaired. A fall 2013 fish survey was conducted at these same four locations with the aim to detect species and general fish numbers, but not population numbers. While no native fish were found, the non-native Western Mosquitofish increased in abundance as the river flowed through the three reaches. View all the data online at **www.tiny.cc/aw13**.

Data source: Pima County, Sonoran Institute, Arizona Game and Fish Department

Sonoran desert toad

RIPARIAN VEGETATION

Riparian vegetation represents a small percentage of the land cover in the Santa Cruz River watershed, but provides important benefits to the region and is a good visual indicator of river health. Riparian vegetation's many benefits include slowing flood flows, increasing groundwater recharge, reducing erosion potential along stream banks, providing habitat for wildlife, and providing recreational and spiritual enjoyment. Three indicators help track riparian vegetation conditions along the river: wetland indicator status, nitrogen affinity score, and riparian tree cover.

Wetland Indicator Status measures abundance of stream-side plants that vary in their need for permanent water in the river channel. Scores range from 1 to 5. Low scores (<3) indicate that the majority of plants at a given location are wetland plants like watercress and cattails, which depend on consistent presence of water in the river. High scores (>3) indicate that the majority of plants are upland plants like burrobrush and different grasses; these do not depend on consistent presence of water in the river and usually are not found in wetlands. Results from the 2013 water year will serve as a baseline to help track future changes in wetland plants.

Although nitrogen is an essential nutrient, too much can undermine plant growth or favor the growth of plants that thrive in high-nitrogen environments. **Nitrogen Affinity Score** measures the abundance of stream-side plants that vary in their tolerance of nitrogen. Scores range from 1 to 9. Low scores (<5) indicate that the majority of plants at a given location grow well with low levels of nitrogen, like burrobrush and different grasses. High scores (>5) indicate that the majority of plants grow well with high levels of nitrogen, like cattails and common sunflowers. Changes in nitrogen affinity scores likely reflect changes in water quality, either an increase or decrease in nutrients in the water. Results from the 2013 water year will serve as a baseline.

Riparian Tree Cover measures the abundance of adult trees along the river and in the adjacent floodplain. High tree cover indicates the presence of sufficient soil moisture to support riparian trees. Tree cover is commonly reported as basal area. Basal area, measured in square meters per hectare (m^2/ha), is the area covered by trees in one hectare (10,000 m^2 or approximately two football fields). In addition, riparian tree species differ in their tolerance to declines in soil moisture. Native cottonwoods and willows have shallow roots and are more sensitive to reductions in soil moisture. Non-native tamarix and saltcedar have deeper roots and can tolerate a greater range of soil moisture. Trees grow slowly, and amount of cover is not likely to change on an annual basis, unless vegetation is affected by sustained drying or large floods. Tree cover is thus measured every three years, and results from the 2013 water year will serve as a baseline.

2013 RESULTS

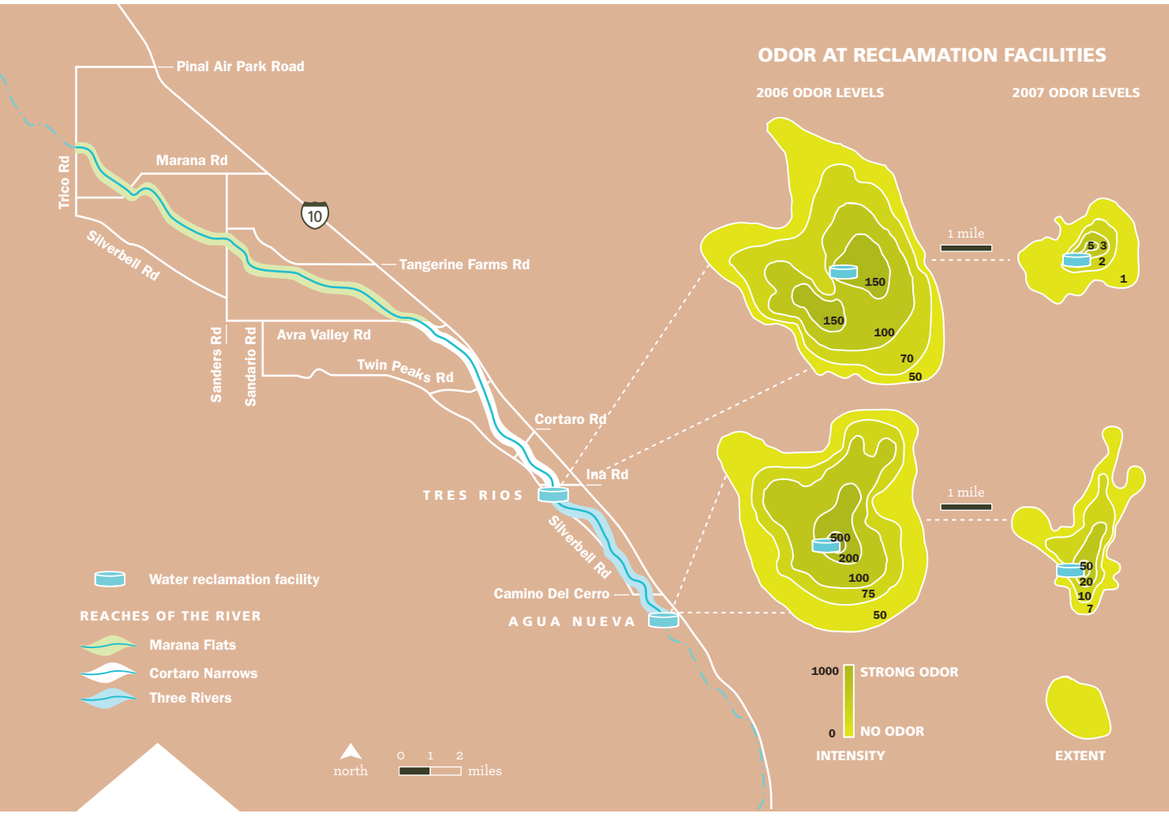
Measures of riparian vegetation were collected in the spring at seven sites along the river. Riparian vegetation varied from site to site. Overall, the abundance of wetland plants increased as the river flowed through the reaches. Stream-side plants that grow well in high nitrogen environments were most common immediately downstream of the reclamation facilities. Diversity and abundance of tree cover generally decreased as the river flowed through the reaches, with the exception of the last site in Marana Flats, which had the highest basal area. Native willow trees dominated the three sites with the highest basal area. View all the data online at **www.tiny.cc/rv13**.

Data source: Pima County, Harris Environmental

SOCIAL IMPACTS

In addition to ecological indicators, changes in the health and value of the river can be tracked with social indicators. While they often reflect ecological conditions, social indicators relate more to how people experience the river. That is, these indicators measure impacts on and behavior of people living or recreating near the river, rather than the natural environment itself. For example, studies have demonstrated that land value increases near lushly vegetated rivers and desert washes in Southern Arizona. People's demand for this property and the resulting rise in property values over time could reflect improving river conditions. Though many social indicators were considered, the level of odor coming from the reclamation facilities was the indicator chosen to help track changes in social impacts along the river.

Reclamation facilities are restoring a piece of the river heritage and supporting important wetland habitats by releasing effluent into the river. However, unpleasant odors often associated with the reclamation process can lead to negative perceptions of the river for those living near or recreating along the river. The most common offender is hydrogen sulfide or the "rotten egg" smell. **Odor at the reclamation facilities** estimates the extent and intensity of odors linked to the reclamation process. The goal is to minimize both, thus reducing the impact of disagreeable odors on adjacent areas. The results from the 2013 water year serve as a baseline.



2013 RESULTS

Odor is monitored at both reclamation facilities along the river. Data for the 2013 water year was unavailable at press time. However, odor was studied in 2006, in planning for the facility upgrades. Initial facility improvements made in 2007 significantly reduced odor levels. Additional reductions in odor levels are anticipated, particularly in the Three Rivers reach, when upgrades at the Agua Nueva facility are complete.

Data source: Pima County Regional Wastewater Reclamation Department

RIVER BENEFITS

A healthy river maintains its plant, animal, and physical composition, as well as its function. A healthy river also sustains human communities by supplying ecosystem services—the benefits that people obtain and receive from natural systems such as rivers, forests, and grasslands.

Ecosystem services supplied by the Santa Cruz River include:

- **Goods received, such as fresh water and sand and gravel for construction.**
- **Natural control of water flows and the reduction of hazards related to water flows. These include flood and erosion control, groundwater recharge, and improvement of water quality.**
- **Recreational, aesthetic, and spiritual interaction with nature.**
- **Habitat, or the necessary resources for plants and animals to survive.**
- **Nutrient cycling, or the transfer of nutrients from one place to another.**

RECREATION

Go enjoy the river! As noted in the bird section (see page 15), the Lower Santa Cruz River is a popular birding destination. You can find your favorite spot by traveling sections of The Loop, the recreational path along the river. Between 2011 and 2012, volunteers counted nearly 400 bicyclists and pedestrians on The Loop near Camino Del Cerro over several weekend and weekday traffic counts. In addition, there are seven parks between Tucson and Marana with access to the river and numerous bridge crossings where you can get a bird's eye view of this incredible wetland amenity. Go to **www.pima.gov/TheLoop** to find a detailed map and plan your visit. The river starts flowing near Columbus Park.

SUMMARY OF WETLAND CONDITIONS

This assessment of the 2013 water year provides a summary of the baseline conditions of the Lower Santa Cruz River that will help us assess changes over time, including those directly related to the reclamation facility upgrades.

High flow extent suggests that availability of aquatic habitat was good. However, fish were absent from Three Rivers, and the aquatic invertebrate communities were dominated by a single species group, suggesting that conditions are impaired for aquatic wildlife. Though dissolved oxygen levels and other water quality measures met standards, levels of ammonia did not meet the standard for protecting aquatic wildlife. The greatest number of fish were observed in Marana Flats, which had the lowest levels of ammonia. Nitrogen and ammonia levels are expected to decrease after the reclamation facility upgrades are complete.

CATEGORY	PURPOSE	2013 CONDITIONS
FLOW EXTENT	General measure of water flowing in and out of the system, recharge, and available aquatic habitat.	Water was always flowing through all three reaches (p. 10).
SEDIMENT TRANSPORT	Measure of solid particles moving through the system, which can impact habitat and conditions for aquatic plants and animals.	High amount of particles moving through all three reaches during normal, non-flooding conditions. Sediment in the water increased as the river flowed downstream (p. 11).
WATER QUALITY	Measure of chemical conditions necessary for sustaining the river's animal and plant communities.	High levels of ammonia posed a health risk to aquatic life. Other measures met standards or provided a baseline for comparison in future assessments (pp. 12–13).
AQUATIC WILDLIFE	Direct measure of river's wildlife which integrate many factors of the surrounding environment.	No fish in Three Rivers, but Western Mosquitofish in Cortaro Narrows and Marana Flats. Aquatic invertebrate communities in all three reaches suggest the river is impaired or under environmental stress (pp. 14–15).
RIPARIAN VEGETATION	Direct measure of river's plant communities which reflect changes in water quantity and quality.	Wetland plants increased through the reaches. Nitrogen-tolerant plants were more common near the reclamation facilities. With the exception of Marana Flats, riparian trees generally declined as the river flowed downstream (pp. 16–17).
SOCIAL IMPACTS	Measure of aesthetic factors that directly impact people living or recreating along the river.	Odor data unavailable at press; past efforts to reduce odor impact have resulted in significant reductions in odor levels (p. 18).

Sediment moving through the water increased in the downstream direction and could also be impacting aquatic wildlife. The river bed consisted of a high percentage of the fine sediments or "muck," which may be suffocating aquatic invertebrates or covering habitat.

The presence of both wetland plants and riparian trees suggests there is adequate water available for riparian vegetation. Wetland plants that thrive in high nitrogen environments were more common closer to the reclamation facilities. As water quality improves, and nitrogen is reduced, these wetland plants may decrease in abundance.

Though odor data was unavailable at the time this report went to press, earlier efforts to mitigate odor impact demonstrate significant reductions in odor levels at the reclamation facilities. Additional actions will be completed as part of the upgrade plan, which will improve conditions for neighboring communities and businesses, as well as for people recreating along the river.

OTHER EFFORTS

This assessment builds on the numerous conservation efforts all along the Santa Cruz River, many of which are identified in the *State of the Santa Cruz River—Conservation Inventory* (online at www.tiny.cc/scrci).

- Pima County Regional Flood Control District studies current and historical conditions of the Lower Santa Cruz River. www.webcms.pima.gov/cms/one.aspx?portalId=169&pageId=65418
- Pima County Regional Wastewater Reclamation Department is managing the efforts to upgrade Agua Nueva and Tres Rios Water Reclamation Facilities. www.webcms.pima.gov/government/wastewaterreclamation/romp_project
- Community Water Coalition provides leadership and guidance toward water policy that sustains healthy ecosystems and quality of life in the Tucson area and lower Santa Cruz River watershed. www.communitywatercoalition.org
- Tucson Bird Count, a citizen-science driven effort, is documenting how native birds use the habitat within and around Tucson. www.tucsonbirds.org
- The U. S. Environmental Protection Agency is using the Santa Cruz River as a case study to investigate how urban households value river ecosystems. www.epa.gov/region09/water/watershed/santacruz/santacruz-river-survey.html
- Sky Island Alliance conducts mammal tracking to identify wildlife corridors and assesses the conditions of springs in the Santa Cruz River Valley. www.skyislandalliance.org

Lower Santa Cruz River, Fall 2013 fish survey

GET INVOLVED

- Have your child enter Tucson's River of Words Youth Poetry and Art Contest. This program helps kids explore the region's natural and cultural history. www.tucsonpimaartscouncil.org/programs/arts-education/river-of-words
- Save water at your house or business and support Tucson's Conserve2Enhance (C2E). C2E connects conservation to community action. Your donations, based on water savings, provide funding to improve watershed health by enhancing Tucson's urban washes which ultimately flow into the Lower Santa Cruz River. www.conserve2enhance.org/Tucson

C2E™ conserve to enhance

PRODUCTION CREDITS AND REFERENCES

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Valuable oversight, assistance, and guidance are provided for the Living River Project by the following:

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The Sonoran Institute convened a Living River Technical Committee of ecology, hydrology, and wildlife experts to bring the best available science to bear on the development of the Living River health assessments. The Technical Committee provided guidance by selecting and aggregating indicators of river health, identifying reference values or standards for evaluating and tracking changes in river conditions, and reviewing this report. The information presented in this report grew out of discussions involving these experts and represents the product of a collective effort; it does not reflect the opinions or viewpoints of any individual member of the technical team. The viewpoints and opinions expressed in the discussions of the group and captured in this report also do not reflect the opinions or viewpoints of the agencies, institutions, or organizations with whom the technical team members and external reviewers are associated or employed. Any errors or omissions contained herein are solely those of the Sonoran Institute.

MEMBERS OF THE LIVING RIVER TECHNICAL COMMITTEE

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LEARN MORE

Request a presentation about the Living River Project. More information at www.tiny.cc/lscr.

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The Sonoran Institute inspires and enables community decisions and public policies that respect the land and people of western North America. Facing rapid change, communities in the West value their natural and cultural resources, which support resilient environmental and economic systems.

Founded in 1990, the Sonoran Institute helps communities conserve and restore those resources and manage growth and change through collaboration, civil dialogue, sound information, practical solutions and big-picture thinking.

The Sonoran Institute is a nonprofit organization with offices in Tucson and Phoenix, Arizona; Bozeman, Montana; Glenwood Springs, Colorado; and Mexicali, Baja California, Mexico.

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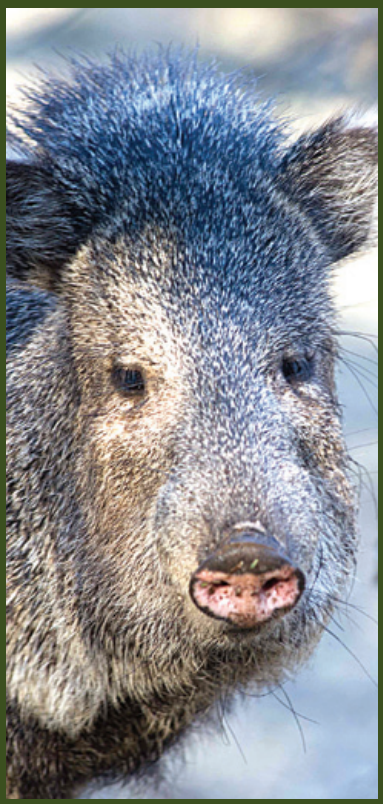

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Pima County Regional Flood Control District
www.pima.gov/government/flood_control

Pima County Wastewater Reclamation Department
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