

# a living river

CHARTING SANTA CRUZ RIVER CONDITIONS  
NORTHWEST TUCSON TO MARANA



SUPPLEMENTARY REPORT FOR 2013 TO 2017 WATER YEARS



SONORAN  
INSTITUTE



PIMA COUNTY

# THE SANTA CRUZ RIVER A LIVING ECOSYSTEM



The Santa Cruz River in northwest Tucson and Marana flows year-round and provides the principal wetland habitat in Pima County. River flows are sustained by the release of effluent—highly-treated wastewater—from two regional facilities. In December 2013, Pima County completed the largest public works project in southern Arizona by investing over \$600 million to upgrade the treatment process. Improved treatment affords the opportunity to enhance the aquatic environment along the river, reduce odors, and increase re-use of reclaimed water.

The *Living River* reports were developed to annually gauge conditions of this valuable ecosystem and track the impacts of our community investment. This supplementary report summarizes data from the 2013, 2014, 2015, 2016, and 2017 water years. The pages following this executive summary provide more details on the water context and data for 16 indicators of river health.

All *Living River* reports can be found on the Sonoran Institute website at [www.sonoraninstitute.org](http://www.sonoraninstitute.org)

## CHANGES IN WATER QUALITY AND WETLAND CONDITIONS

- **Ammonia no longer limiting life:** Ammonia, which can be toxic to aquatic organisms, was appreciably reduced to low levels.
- **Oxygen availability not a stressor:** Essential for aquatic life, dissolved oxygen remained at steady levels or increased. Biochemical oxygen demand (an indirect measure of pollutants that use up oxygen in the water) declined to nearly non-detectable levels, indicating that there is more oxygen available for organisms to thrive.
- **Water clarity much improved:** Sediments and other particles carried in the water decreased, resulting in clear river water on normal non-flooding days. Elevated sediment levels in the water can increase water temperature, thereby decreasing available dissolved oxygen.
- **More diverse life:** Six species of fish, including the endangered Gila topminnow, and increased diversity of aquatic invertebrates (which include insects, crustaceans, and worms) have been observed in the river, indicating that aquatic life is rebounding in the river.
- **Reduced flow extent:** The length of the flowing river has decreased due to a combination of factors, including increased water infiltration from reduced nutrient levels, scouring floods, and the natural and human management of water inputs.
- **Wetland plants reduced in drying sections:** The release of effluent supports wetland plants and trees. There is a decrease in willows and increased variability in streamside plants in the sections of reduced flow extent.
- **Very little odor escaped the reclamation facility boundary:** Odor levels are far below levels required by facility permits and anecdotal observations report odor as hardly noticeable near the facility boundaries.



Cloudy water, before upgrade



Clear water, after upgrade



Gila topminnow, *Poeciliopsis occidentalis*

## OTHER OBSERVATIONS

- **Total effluent released to the river has decreased:** Releases of effluent have decreased an average of 11% since 2013. However, effluent remains the primary source of water in the river. Stormwater is also an important source of flows and total volume of stormwater in the river has increased since 2013.
- **Increased infiltration rates and groundwater recharge:** The amount of water that recharged local aquifers more than doubled between 2013 and 2017. This is likely from increased rates of infiltration resulting in part from improved water quality.
- **Many kids are seeing a flowing river for the first time:** The Living River of Words youth art and science program continues to provide the first contact with a flowing stream for hundreds of kids. The Santa Cruz River from northwest Tucson to Marana provided meaningful inspiration for youth art and poetry projects. To date over 2,100 youth have visited the river since 2015.

# ASSESSING CONDITIONS

The Living River report evaluates conditions of the Santa Cruz River from northwest Tucson to Marana using indicators (see table below) organized into six categories that represent a breadth of biological, chemical, physical, and social properties

of the river. The indicators relate to conditions in the river channel and in the riparian areas, the areas next to and affected by the river.

The purpose of the Living River series is to monitor and report on wetland and riparian conditions at various intervals downstream of the effluent discharge points. As effluent flows downstream, it impacts and is impacted by the natural

CATEGORY		PURPOSE	INDICATORS
<b>Flow Extent</b>		Water flowing in and out of the system determines available aquatic habitat.	<ul style="list-style-type: none"> <li>• Miles of flow in June</li> <li>• Number of “dry days” at Trico Road</li> </ul>
<b>Water Clarity</b>		Solid particles in the water and on the riverbed can impact habitat and conditions for aquatic life.	<ul style="list-style-type: none"> <li>• Total suspended solids</li> <li>• Turbidity</li> <li>• Percent fines on riverbed</li> </ul>
<b>Water Quality</b>		Specific chemical conditions are necessary to sustain the river’s animal and plant communities.	<ul style="list-style-type: none"> <li>• Total dissolved solids</li> <li>• Ammonia</li> <li>• Dissolved oxygen</li> <li>• Biochemical oxygen demand</li> <li>• Metals</li> </ul>
<b>Aquatic Wildlife</b>		Wildlife in the river integrate and reflect conditions of many factors of the surrounding environment.	<ul style="list-style-type: none"> <li>• Fish</li> <li>• Aquatic invertebrates</li> </ul>
<b>Riparian vegetation</b>		Plant communities reflect changes in water quantity and quality.	<ul style="list-style-type: none"> <li>• Wetland indicator status</li> <li>• Nitrogen affinity score</li> <li>• Riparian tree cover</li> </ul>
<b>Social Impacts</b>		Aesthetic factors directly impact people living or recreating along the river.	<ul style="list-style-type: none"> <li>• Odor at reclamation facilities</li> </ul>

conditions of soils, vegetation, and the surrounding ecosystem. For the purposes of this study, the 23-mile stretch of river is divided into three sections, or reaches: Three Rivers, Cortaro Narrows, and Marana Flats. Reaches were delineated by their differing hydrology, geology, and adjacent land use.

Data is collected and summarized by water year (October 1–September 30) and compared to the baseline conditions observed in the 2013 water year. This supplemental report shares data from all the water years to enable an easy viewing of trends and long-term patterns.

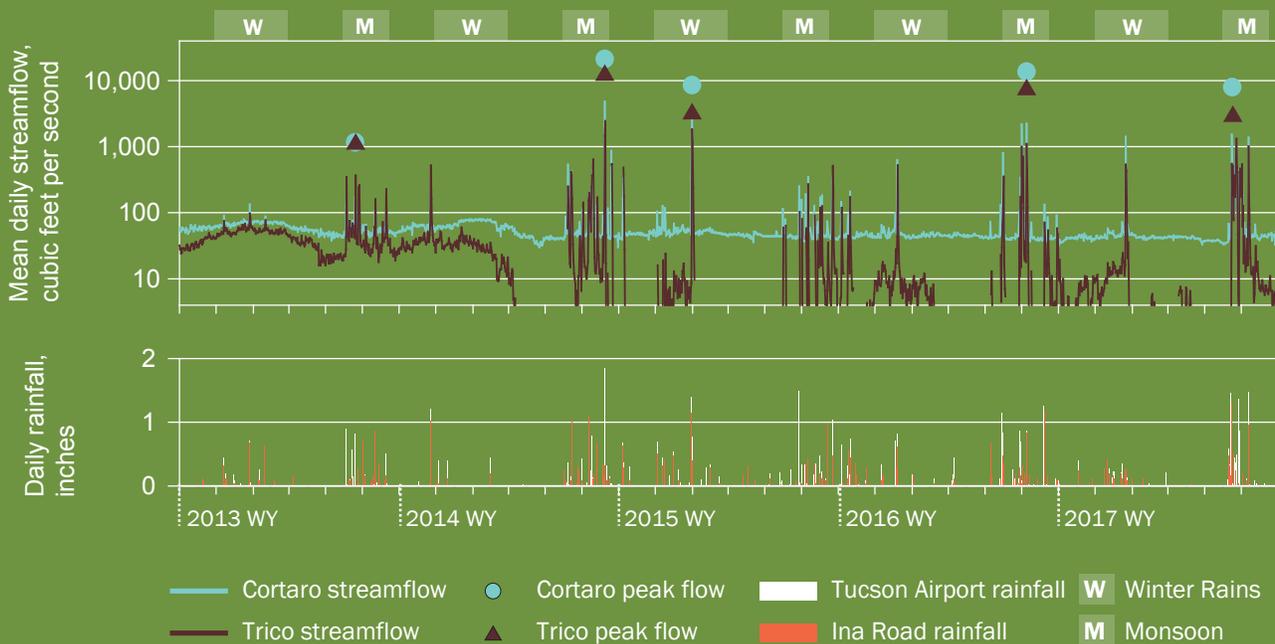
## Streamflow, Rainfall, and Water Budget

Streamflow, or the amount of water flowing in a river, provides an important context for the results of the indicators.

Reclamation facilities continuously release water into the river, which accounts for the majority of daily streamflow.

However, streamflow also includes stormwater, 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 stormwater flows toward the river. Seasonal floods are important for recharging aquifers, dispersing seeds, inducing seed germination, and clearing natural debris.



### 2013–2017 RAINFALL

Rainfall totals from the Tucson International Airport (TIA) and near the river at Ina Road provide a general idea of when stormwater may have increased streamflow.

**TIA** recorded an average of 11 inches of rain. The most rain fell in 2016 and 2015 with 13 and 14 inches respectively. The historical average is 11.2 inches from 1949 to 2011.

- The winter rains averaged 2.9 inches of rain.
- The summer monsoon averaged 5.7 inches of rain.

**Ina Road** recorded an average of 8 inches of rain. The most rain fell in 2016 and 2015 with 11 and 9 inches respectively. The recent average is 7.95 inches from 2002 to 2012.

- The winter rains averaged 2.2 inches of rain.
- The summer monsoons averaged 4.2 inches of rain.

### 2013–2017 STREAMFLOW

Streamflow is measured with gages at Cortaro Road and Trico Road, which are downstream of the Agua Nueva and Tres Rios Reclamation Facilities. Streamflow, measured in cubic feet per second (cfs), is the volume (cubic feet) of water flowing past a fixed point in a specific time period (1 second). Measuring streamflow daily tracks seasonal floods.

At Cortaro Road, mean daily streamflow has remained similar over the years, though flood peaks have been higher since 2013. Flows at Trico Road have changed significantly. Like Cortaro Road, the peak flows have increased. However, mean daily streamflow has declined since the facility upgrades were complete in December of 2013. By the 2015 water year, most flows passing by Trico Road are limited to the rainy seasons when there is additional stormwater.

## Streamflow, Rainfall, and Water Budget, cont.

A water budget estimates the water inputs and outputs. Inputs are effluent and stormwater, while outputs include water that does one of the following: flows past Trico Road (the end of the study area), evaporates or is used by wetland vegetation (a process called evapotranspiration), is diverted for agricultural use, or sinks into the riverbed to recharge local groundwater. Volumes are totaled in acre-feet (AF), the

number of acres that would be covered with water one foot deep. Total recharge volume is for effluent only and does not include stormwater. Totals for evapotranspiration and diversions are not directly measured. They are estimates and viewed as fairly constant from year to year in the calculations for the managed recharge projects located along the Lower Santa Cruz River.



\* Includes effluent that doesn't go to the river; either it is diverted to the reclaimed system for irrigation or to recharge basins located outside the river channel.

<sup>1</sup> Excluding days with stormwater, the volume of only effluent flowing past Trico Road is: 2013 = 26,800 AF; 2014 = 13,400 AF; 2015 = 2,100 AF; 2016 = 3,800AF; 2017 = 3,700AF

## 2013 – 2017 WATER BUDGET

Effluent provides most of the flow in the river. Effluent releases from Agua Nueva have decreased for two reasons. First, the facility upgrade completed in December of 2013 resulted in some wastewater being redirected to Tres Rios and released further downstream. Second, more effluent was diverted, before release into the river, into nearby basins to recharge local aquifers. Effluent inputs were reduced by an average of 11% from the 2013 baseline. Total inputs, however, have increased with higher volumes of stormwater. Even with greater inputs, recharge has increased significantly, likely from higher infiltration rates into the riverbed after improved water quality. Increased infiltration has also reduced the amount of water that flows past Trico Road. Exact volumes of water diverted for agriculture and used by wetland vegetation are not known. These volumes are treated as constants in the calculations of recharge that occurs along the river.



## FLOW EXTENT

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

**Miles of flow in June** in each reach prior to the monsoon season determines the minimum extent of flow during the driest time of year. This is typically measured on one morning in mid-June. **Flow at Trico Road**, located at the farthest 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.



## 2013–2017 RESULTS

Flow extent decreased and varied seasonally after the December 2013 upgrades. In June, prior to the start of the summer monsoon, only Cortaro Narrows flowed through the whole reach. Dry days at Trico Road have increased. Reduced flow extent is likely due to increased recharge, though water management is also an important factor. Agua Nueva released less effluent into the river, contributing to drying in Three Rivers. Marana Flats drying is more complex. In this reach, water is diverted by an earthen berm for irrigation of agriculture and for recharge at Marana High Plains, a constructed basin adjacent to the river. The berm failed just before the June 2016 survey, and likely increased miles of flow. Failure of this berm several times in 2016 may have also decreased the dry days at Trico Road. Conversely, failure of a different berm increased dry days in 2015. This occurred when a large flood in September 2014 moved the location of the low-flow channel and breached a berm along the El Rio Preserve, a former borrow pit near the start of Marana Flats. This allowed water to flow into the pit and form “Lake Marana.” The river stopped flowing into the lake in January 2015 when a flood moved the low-flow channel again, demonstrating nature’s contribution to water management.

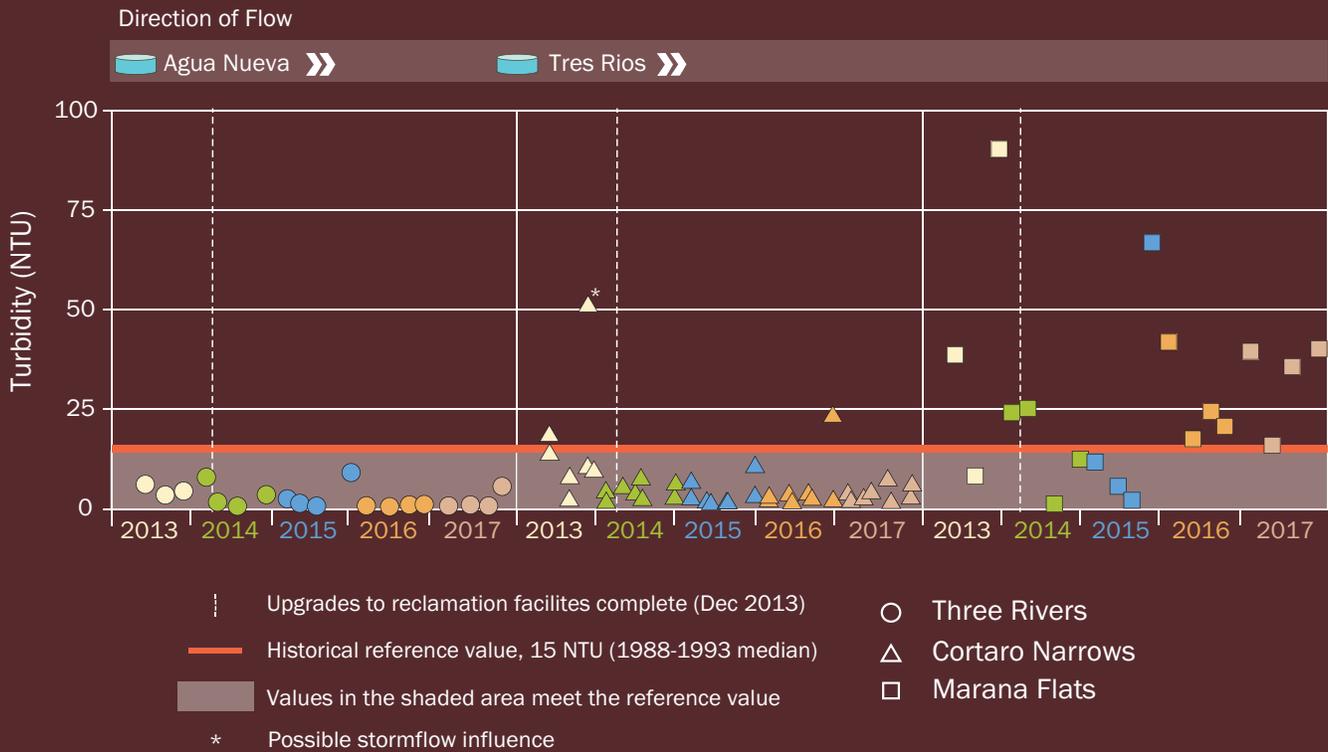




## WATER CLARITY: Turbidity

Rivers naturally move sediments and other small particles of algae or detritus downstream. High concentrations of materials in the water can create murky “dust storm” conditions and may impact conditions for aquatic life. Under chronically high “dust storm” 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. **Turbidity** measures water clarity, or how far you can see through the “dust storm,” 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.



### 2013–2017 RESULTS

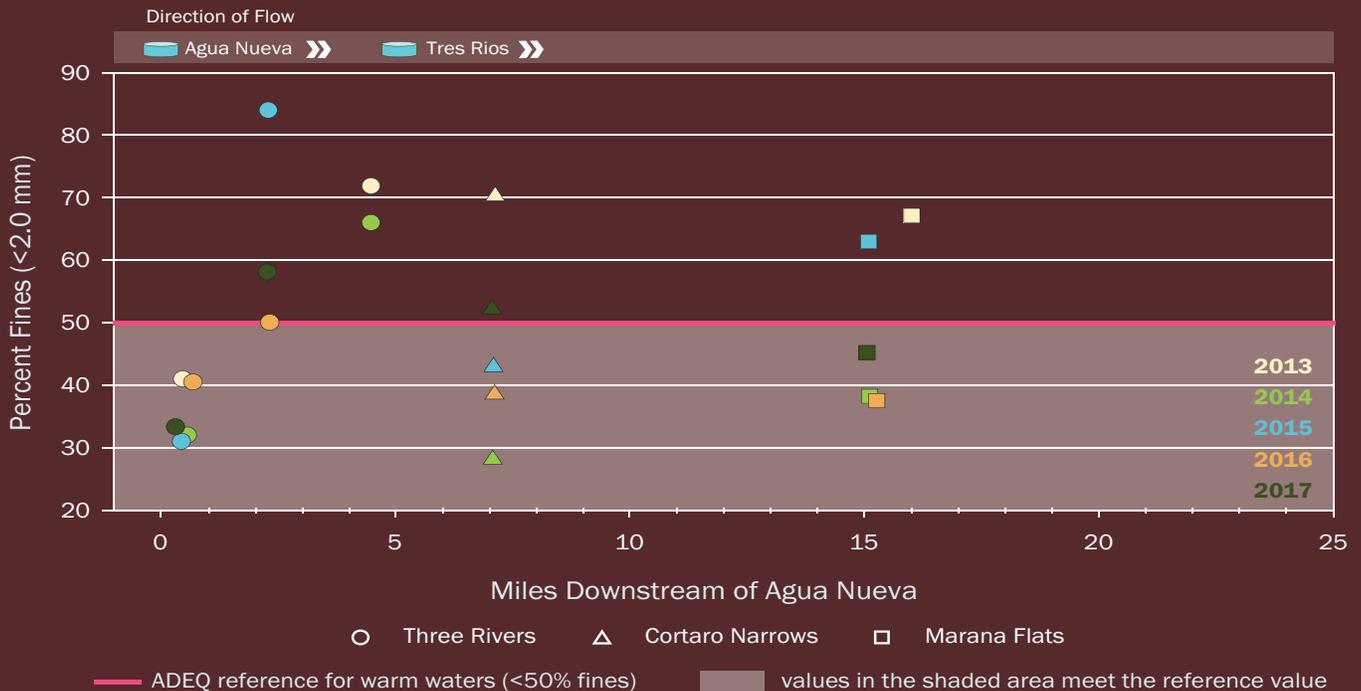
Turbidity was measured a total of 77 times. Overall, the reference value was met 61 times (79%). Turbidity decreased most notably in Marana Flats immediately after the upgrade was complete, though it has been higher and more variable in the last two years.



## WATER CLARITY: Percent Fines

Rivers naturally move sediments and other small particles of algae or detritus downstream. High concentrations of materials in the water can create murky “dust storm” conditions and may impact conditions for aquatic life. Under chronically high “dust storm” 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.

**Percent fines** is an estimate of the portion of the riverbed comprised of small sediments ( $\leq 2$  mm in diameter). Fines, or “muck,” that settle out of the storm 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%.



### 2013–2017 RESULTS

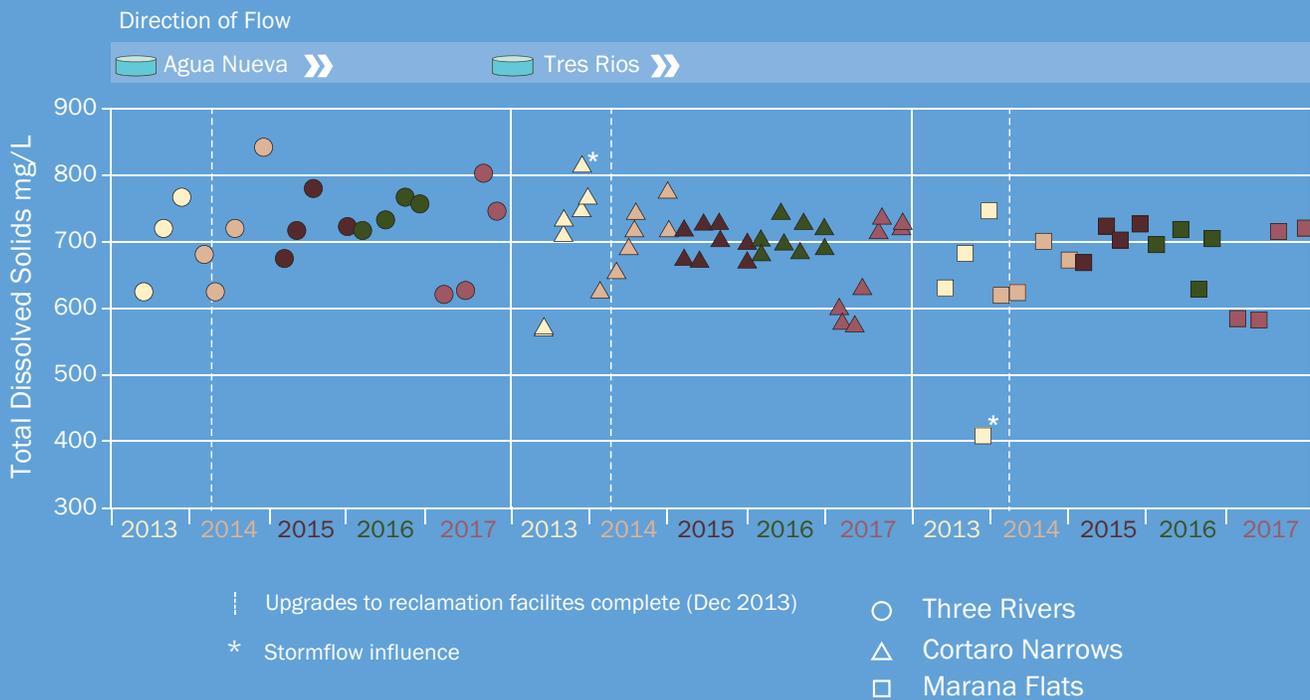
Percent fines were estimated at all of the sites where macroinvertebrate samples were collected. Overall there was a reduction in the percent fines covering the riverbed at these sites. Due to reductions in flow extent, survey sites located at around 4 miles and 16 miles downstream of Agua Nueva had to be shifted upstream to around 3 miles (in 2015) and 15 miles (in 2014) respectively. There was greater variability in levels of percent fines at these sites, perhaps due to variable flow conditions in these areas. For example, more particles may settle out of river flows that have slowed as extent has diminished.



## WATER QUALITY: Total Dissolved Solids

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 since the 1990s with increased use of

Colorado River water in the Tucson area. The Colorado River has greater TDS, mostly in 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.



### 2013–2017 RESULTS

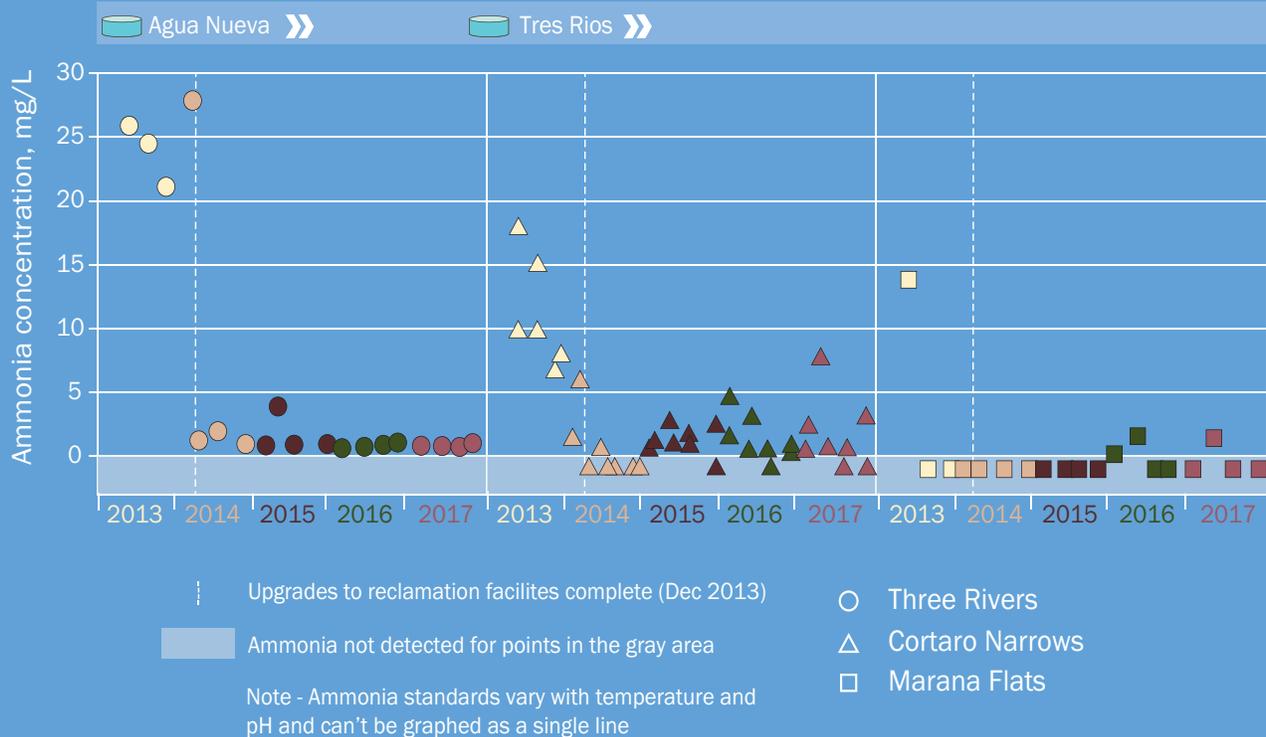
Total dissolved solids (TDS) were measured 77 times. Overall, levels of TDS were similar in all three reaches. Generally TDS hasn't changed very much, though variability in TDS levels has increased again in 2017 for unknown reasons. The lowest measure of TDS was in Marana Flats. This sample was collected on a day where there was possible stormwater influence. Thus, the addition of water with lower TDS levels may have diluted the levels in this reach of the Santa Cruz River. Samples of stormwater are collected upstream of Agua Nueva when possible. Four samples collected (one each year during the summer monsoon for 2013–2016) averaged 280 mg/L. No stormwater sample was collected in 2017.



## WATER QUALITY: Ammonia

Nitrogen is an essential nutrient for plant and animal life, but too much can contribute to nutrient pollution. Nutrient pollution, such as high levels of nitrogen and phosphorus, enters the river from air pollution, fertilizer, surface runoff, and the release of effluent. While elevated nutrient levels can benefit riparian plants, they can also lead to poor water quality conditions for aquatic wildlife.

**Ammonia** (NH<sub>3</sub>) is one form of nitrogen that can be toxic to fish. Even at low concentrations, ammonia can reduce hatching success, among other impacts. The ADEQ standard for ammonia 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.



### 2013–2017 RESULTS

Ammonia was measured 76 times along the river. Overall the standard was met 52 of the 70 times (68%). Levels of ammonia have dropped significantly after the upgrade was complete in 2013. Levels of ammonia also decreased with distance from the reclamation facilities, as it breaks down into other forms of nitrogen while moving downstream. Although there were exceedances of the ammonia standard before and after the upgrade, the magnitude of the average exceedance has dropped significantly (average exceedance above standard: *before upgrade* = 14 mg/L, *after upgrade* = 1.2 mg/L). Nitrogen removal is a complex process, and Pima County Regional Wastewater Reclamation Department is vigilantly investigating and working to eliminate ammonia exceedances.







## WATER QUALITY: Metals

**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, and zinc.

Average values for dissolved metals tested throughout the year concentrations in micrograms/liter (ug/L), also known as parts per billion (ppb)

Average Standard standards for wildlife vary with water hardness

	Agua Nueva	Tres Rios	Direction of Flow >>		
	Three Rivers	Cortaro Narrows	Marana Flats		
Arsenic	3.9	3.0	3.2	3.6	150 ug/L*
Cadmium	ND	ND	ND	ND	2.6 ug/L
Chromium	0.7	0.6	0.5	0.5	11 ug/L*
Copper	2.6	2.3	2.8	2.4	18 ug/L
Lead	0.3	0.2	0.3	0.4	6 ug/L
Mercury	ND	ND	ND	ND	0.01 ug/L*
Zinc	51	49	46	38	233 ug/L

\*set value, not an average

ND = Not Detected

### 2013–2017 RESULTS

All samples tested over the five years have met the appropriate standard for the following dissolved metals: arsenic, cadmium, chromium, copper, lead, mercury, and zinc. The samples taken within Marana Flats were from three different sites and averaged here. The sample location had to be moved several times due to drying and inconsistent flows following increased recharge rates.



## AQUATIC WILDLIFE: Fish

**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 subsequent years.



### 2013–2017 RESULTS

Fish surveys were conducted annually in the fall at the same four locations that macroinvertebrates were surveyed. Surveys aim to detect all fish species present at a location. Improvements in water quality have allowed fish to thrive. Overall, number of fish species observed increased from one to six. All are non-native, except for the endangered Gila topminnow, which was found in the river in 2017. Exactly how this native fish returned is unknown. Gila topminnow are found in the Santa Cruz near Nogales and may have been carried in large flood flows down to the Three Rivers reach. Although flood flows connected these two stretches of Santa Cruz River for two days in July 2017, initial genetic analysis suggests the Gila topminnow in the river near Tucson are most similar to fish found in the Cienega Creek watershed.

Cortaro Narrows may provide the best habitat for fish since the survey location in this reach has recorded the highest numbers of fish species. Fish presence has recently increased in Three Rivers. Flows in Three Rivers are often very shallow and may favor smaller fish like the Western mosquitofish and Gila topminnow. Though the media reported presence of large fish, likely common carp, in spring of 2014, these larger species were not observed or captured until the 2015 survey. A large flood in September 2014 may have washed them past Trico Road and beyond the study area.



## AQUATIC WILDLIFE: Aquatic Invertebrates

**Aquatic invertebrates** break down organic materials and are important prey for fish and other species. They also differ in their tolerances to pollution. Chironomidae (midges) are pollution tolerant and found in high numbers even with low oxygen levels and high organic matter. Ephemeroptera (mayflies) have exposed gills on the outside of their body, making them very pollution sensitive. The percent of the invertebrate community comprised of Ephemeroptera taxa

is commonly used to help track changes in water quality. Regardless of sensitivity to pollution, if a single species or group accounts for more than 50% of the community, this lack of diversity suggests a stream is impaired. Another way to look at diversity is simply looking at the total number of different invertebrate taxa found in the samples collected.



### 2013–2017 RESULTS

The aquatic invertebrate community was surveyed annually at the same four locations that fish were surveyed. Overall, there were signs of improvement. Diversity was higher after the upgrades were complete, with number of taxa at each site increasing. Increased diversity is also demonstrated by the smaller percentage of the community composed of a single group. If the dominant group is more than 50% of the community, river life is thought to be impaired. Improvements are also supported by the increase in the percent of the community comprised of pollution-sensitive species from the order Ephemeroptera. The 2017 water year reached the highest levels of diversity across all sites with the highest number of taxa recorded and the lowest recorded percentage of the dominant group.



## RIPARIAN VEGETATION: Wetland Indicator Status

**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 (<4) 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

(>4) 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.



### 2013–2016 RESULTS

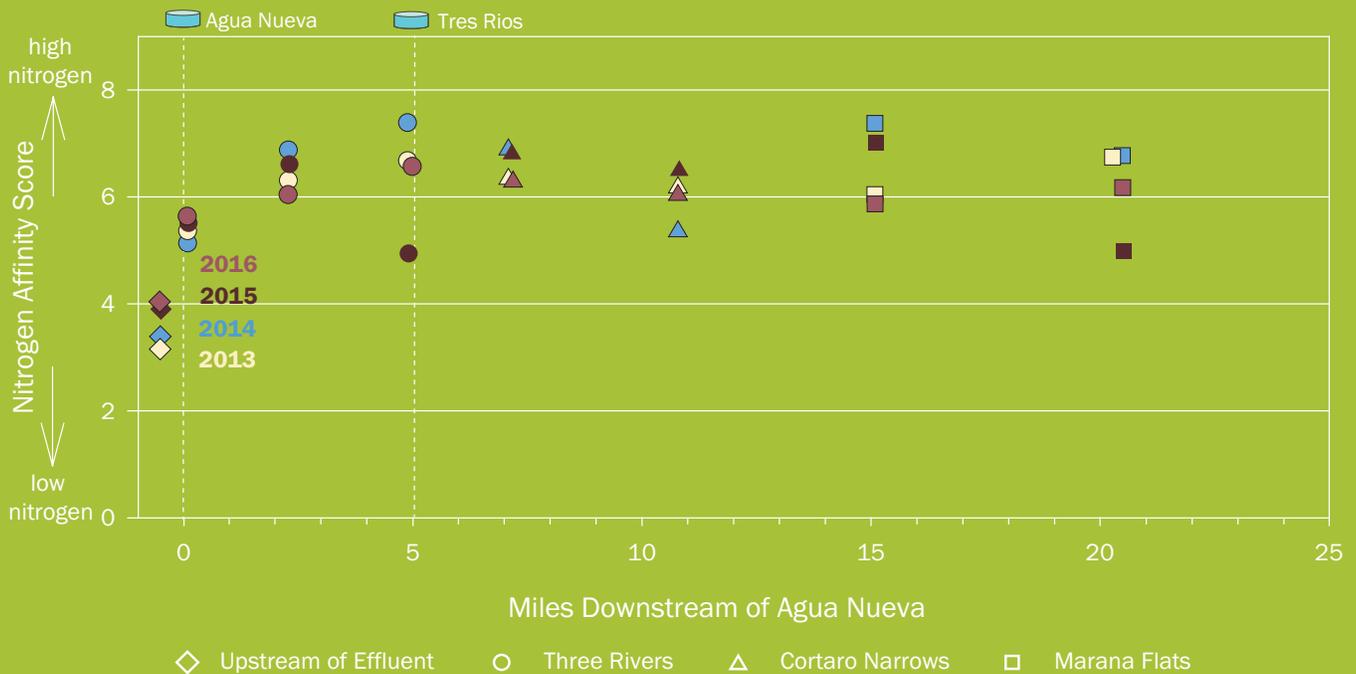
**Not measured in 2017.** Wetland indicator status (WIS) was determined for eight total locations along the river. Overall, scores have remained similar at most sites. Scores averaged 2.7 downstream of Agua Nueva. This suggests greater presence of wetland plants instead of upland plants as the river flowed away from the reclamation facilities. Just upstream of the study area, a reference site had the highest scores and was dominated by upland plants. Two sites (approximately 5 and 20 miles downstream) appeared to shift toward more upland plants with increased scores in 2015. This may be in part explained by changes in flow extent, as these sites experienced dry conditions more frequently in water year 2015. However, these same sites were wet again when surveyed in 2016, and stream-side plants shifted back toward wetland plants.



## RIPARIAN VEGETATION: Nitrogen Affinity Score

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.



### 2013–2016 RESULTS

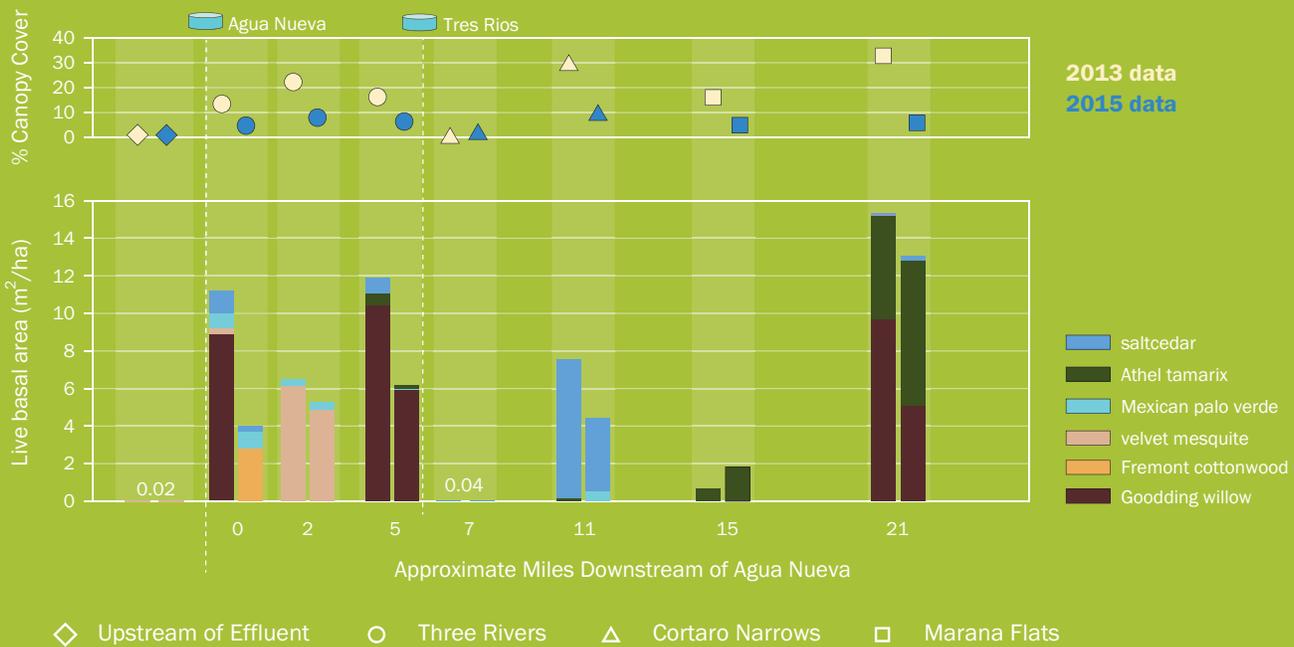
**Not measured in 2017.** Nitrogen affinity score was determined for eight total locations along the river. Overall, scores have remained similar at most sites. Scores averaged 6.2 downstream of Agua Nueva. This suggests that stream-side plants that grow well in high nitrogen environments were most common immediately downstream of the reclamation facilities. Just upstream of the study area a reference site had the lowest scores and was dominated by plants that grow well with low levels of nitrogen. Two sites (approximately 5 and 20 miles downstream) appeared to shift toward more low-nitrogen plants in 2015. Though we may expect this shift from reduced nutrient pollution, reduction in water presence and soil moisture may be the bigger factor. Both of these sites experienced dry conditions more frequently in water year 2015 and were dry at time of survey in 2015. These same sites shifted back towards nitrogen-loving plants in 2016, when water was present again at time of survey. So both nitrogen affinity and wetland indicator seem to indicate presence of permanent water in the channel or high soil moisture. This is supported by a high correlation of the nitrogen scores with wetland scores; plants with high nitrogen scores had very low wetland scores, or more simply, the wetland plants in our area love nitrogen.



## RIPARIAN VEGETATION: Riparian Tree Cover

**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<sup>2</sup>/ha), is the area covered by trees in one hectare (10,000 m<sup>2</sup>, 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. Velvet mesquite and non-native tamarix species, such as Athel 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 was measured in 2015, and results from the 2013 water year serve as a baseline.



### 2013–2016 RESULTS

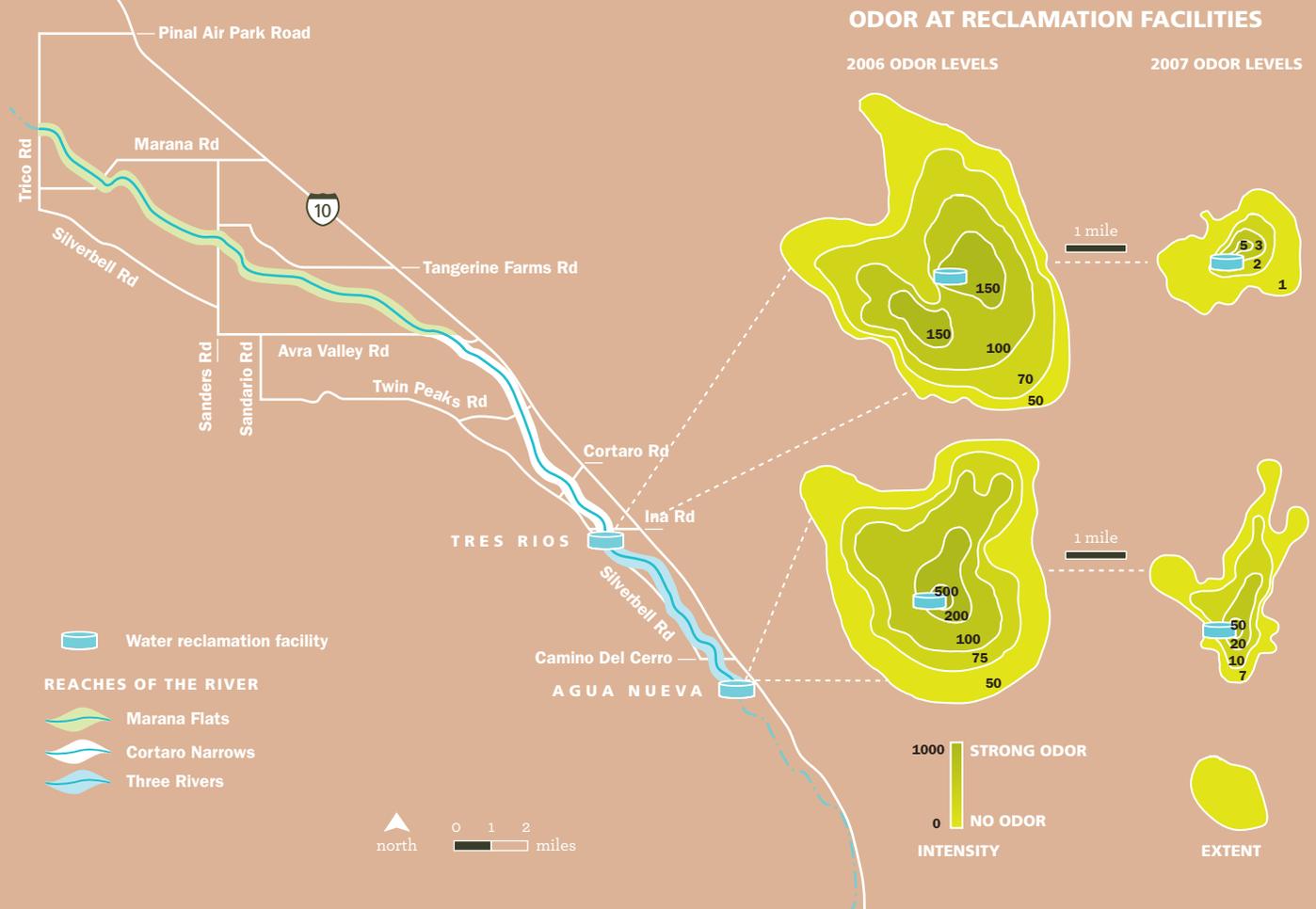
**Not measured in 2017.** Overall tree cover, as measured by basal area and percent canopy cover, decreased between 2013 and 2015 (trees were not measured in 2016). Most notable was the decrease in cover of Goodding’s willow. Decrease in cover of mature trees is likely the result of decreased flow extent. There may not have been enough moisture to support more shallow rooted trees like Goodding’s willow. More monitoring will be needed to determine if effluent continues to support mature riparian trees in all three reaches, and whether the community shifts to deeper rooted trees such as velvet mesquite and non-native tamarix species.



## SOCIAL IMPACTS: Odor at the Reclamation Facilities

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 (H<sub>2</sub>S) or the “rotten egg” smell. **Odor at the reclamation facilities** tracks changes in odors linked to the reclamation process. Minimizing both the extent and intensity of disagreeable odors coming from the facilities was one of the goals of the reclamation facility upgrades.



### 2013–2017 RESULTS

**Data not yet available for 2017.** Initial facility improvements in 2007 reduced both the extent and intensity of odor emanating from the reclamation facilities. Data to map extent and intensity of odors over the last three years is not available. However, anecdotal data from people recreating in the area indicate that odors are either gone or barely noticeable compared to past conditions. As of 2016, odor is monitored continuously at the facilities and at numerous points along the surrounding fence-lines. Levels of H<sub>2</sub>S at Agua Nueva remained very low in 2016, with an average of 0.03 parts per billion (ppb) for the over 4 million measures taken. Levels of H<sub>2</sub>S at Tres Rios were also low with an average of 0.69 ppb for over 3.5 million measures of odor. These concentrations are far less than the 10 ppb allowed by the facility permits. Detailed odor data of this kind is not available for years prior to the upgrades, thus comparisons to previous H<sub>2</sub>S levels are not possible.

## ACKNOWLEDGEMENTS

Sonoran Institute and Pima County prepared this report with generous funding from the U.S. Environmental Protection Agency, Pima County Regional Wastewater Reclamation Department, Pima County Regional Flood Control District, and community individuals. We are grateful for the expert guidance from our Living River Technical Committee, and for the support of our project partners, including Arizona Department of Environmental Quality, Arizona State University, Tucson Audubon Society, University of Arizona, and the U.S. Geological Survey.

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.



Jaime Moreno, age 11  
DeGrazia Elementary • Ms. Mirlocca

### THE SONG OF THE RIVER

The song of the river played endlessly  
through the night,  
As the small insects were chirping away,  
and the river was flowing,  
the owls hooting,  
the fish swimming through the water.  
These are the things that make up the song  
of the river,  
one of the most beautiful sounds in the world.

Alexander S. Frazier, age 11  
DeGrazia Elementary • Ms. Mirlocca

### RIVER BANK

The birds chirping up in a tree  
The green leaves rustling with the wind  
The feel of the cool mud below my shoes  
The smell of the moisture along the river  
Tells me I am home.

Quim Al-Fayed Musa, age 12  
DeGrazia Elementary • Ms. Mirlocca



McKenna Whisenant, age 11 | DeGrazia Elementary • Ms. Mirlocca

## MEMBERS OF THE LIVING RIVER TECHNICAL COMMITTEE

**Plácido Dos Santos**, retired water expert and member of the public

**Jennifer Duan**, University of Arizona

**Edward Curley**, Pima County Regional Wastewater Reclamation Department (retired)

**Eve Halper**, Bureau of Reclamation

**Akitsu Kimoto**, Stantec

**John Kmiec**, Town of Marana

**Kendall Kroesen**, Tucson Audubon Society (formerly)

**Michael F. Liberti**, City of Tucson, Water Department

**Christopher Magirl**, U. S. Geological Survey

**Jean E. McLain**, University of Arizona

**Brian Powell**, Pima County Office of Sustainability and Conservation

**E. Linwood Smith**, Consulting Ecologist

**Patrice Spindler**, Arizona Department of Environmental Quality

**Juliet Stromberg**, Arizona State University

**Robert Webb**, University of Arizona (retired)

**Claire Zucker**, University of Arizona

We wish to acknowledge additional reviewers who provided valuable knowledge, insight, and assistance:

**Daniel Bunting**, Harris Environmental Group, Inc.

**Jacob Prietto**, Pima County Regional Flood Control District

## LIVING RIVER PROJECT TEAM

**Evan Canfield**, Pima County Regional Flood Control District

**James DuBois** and **Anna Martin**, Pima County Regional Wastewater Reclamation Department

**Julia Fonseca** and **Brian Powell**, Pima County Office of Sustainability and Conservation

**Wendy Burroughs**, Pima County Natural Resources, Parks and Recreation

**Claire A. Zugmeyer**, **Ian Dowdy**, and **Amanda Smith**, Sonoran Institute

**Elizabeth Goldmann**, U. S. Environmental Protection Agency, Region 9

## PRODUCTION CREDITS

Data synthesis, writing, and production: **Claire A. Zugmeyer**, **Amanda Smith**, and **Anna Martin**

Editing: **Audrey Spillane**

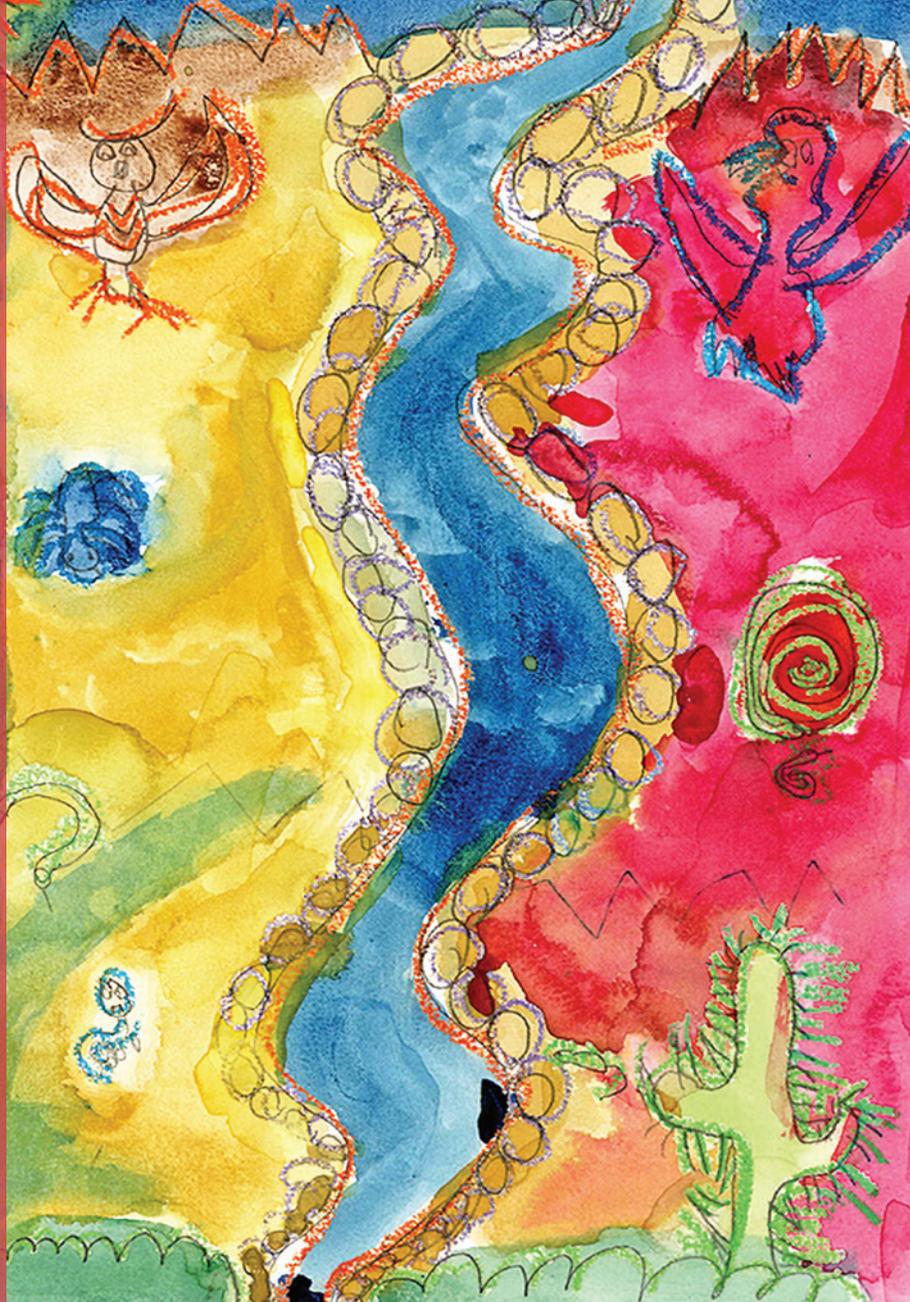
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Rylee Dankert, age 7 | Roadrunner Elementary • Ms. Carroll



Estevan Moreno, age 5 | Sewell Elementary • Ms. Dolan





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100 N. Stone Ave., Suite 400  
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The Sonoran Institute's mission is to connect people and communities with the natural resources that nourish and sustain them. We work at the nexus of commerce, community, and conservation to help people in the North American West build the communities they want to live in while preserving the values which brought them here. We envision a West where civil dialogue and collaboration are hallmarks of decision making, where people and wildlife live in harmony, and where clean water, air, and energy are assured.



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Sean Mergenthaler, age 7, Agua Caliente Elementary—Ms. Mansour



Andrea Sampson, age 15, Tucson High School—Ms. Jenness

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