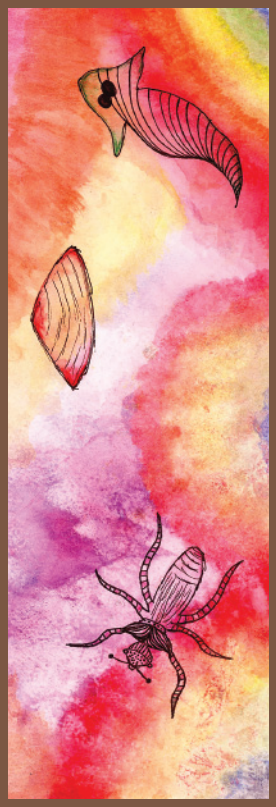
a living river

CHARTING WETLAND CONDITIONS OF THE LOWER SANTA CRUZ RIVER

Supplementary Data For 2013 to 2016 Water Years



25 SONORAN INSTITUTE

PIMA COUNTY

THE LOWER SANTA CRUZ RIVER
A LIVING ECOSYSTEM

The Lower 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, and 2016 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**

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:** Five species of fish 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

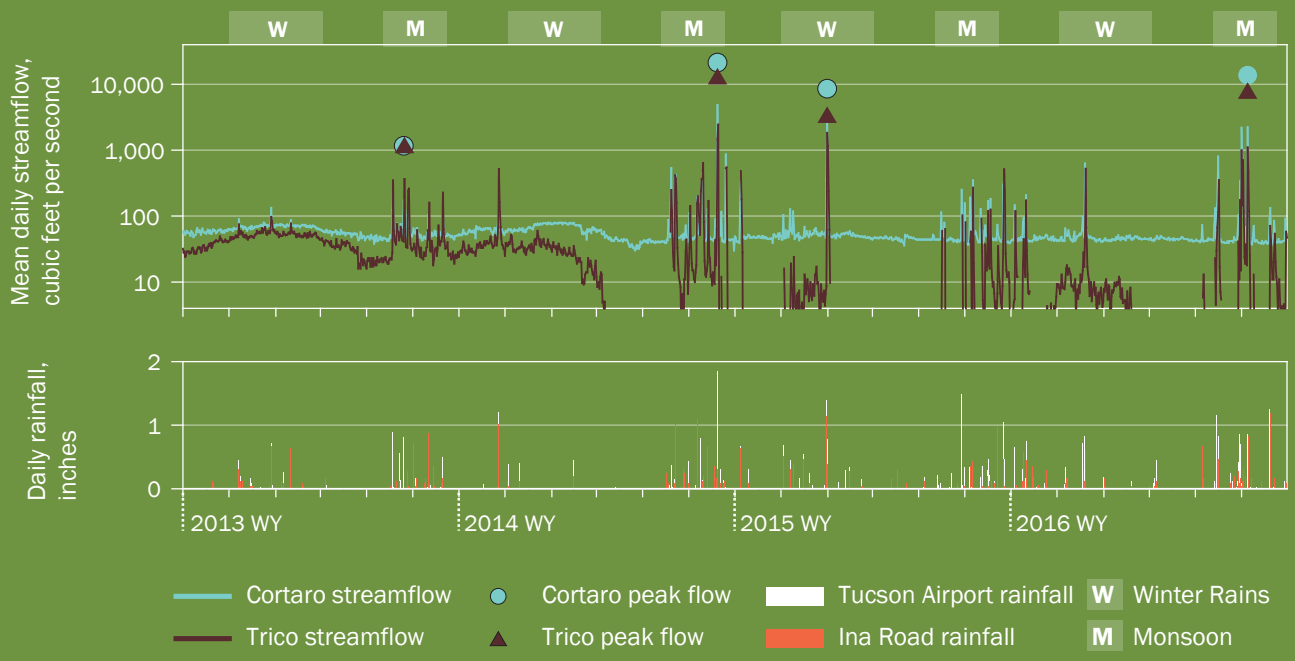
Common carp, *Cyprinus carpo*

OTHER OBSERVATIONS

- **Total effluent released to the river has decreased:** Releases of effluent have decreased 8-10% 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 has increased since 2013.
- **Increased infiltration rates and groundwater recharge:** The amount of water that recharged local aquifers more than doubled between 2013 and 2016. 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 provided the first contact with a flowing stream for hundreds of kids. The Lower Santa Cruz River provided meaningful inspiration for youth art and poetry projects, some of which are featured in this report.

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 - 2016 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 the most rain in 2016 and 2015 with 13 and 14 inches respectively. This is above the site's historical average (11.24 inches from 1949 to 2011).

- The winter rains averaged 3.0 inches of rain.
- The summer monsoon averaged 5.0 inches of rain.

Ina Road recorded the most rain in 2016 and 2015 with 11 and 9 inches respectively. This is above the recent average recorded here (7.95 inches from 2002 to 2012).

- The winter rains averaged 2.1 inches of rain.
- The summer monsoons averaged 4.1 inches of rain.

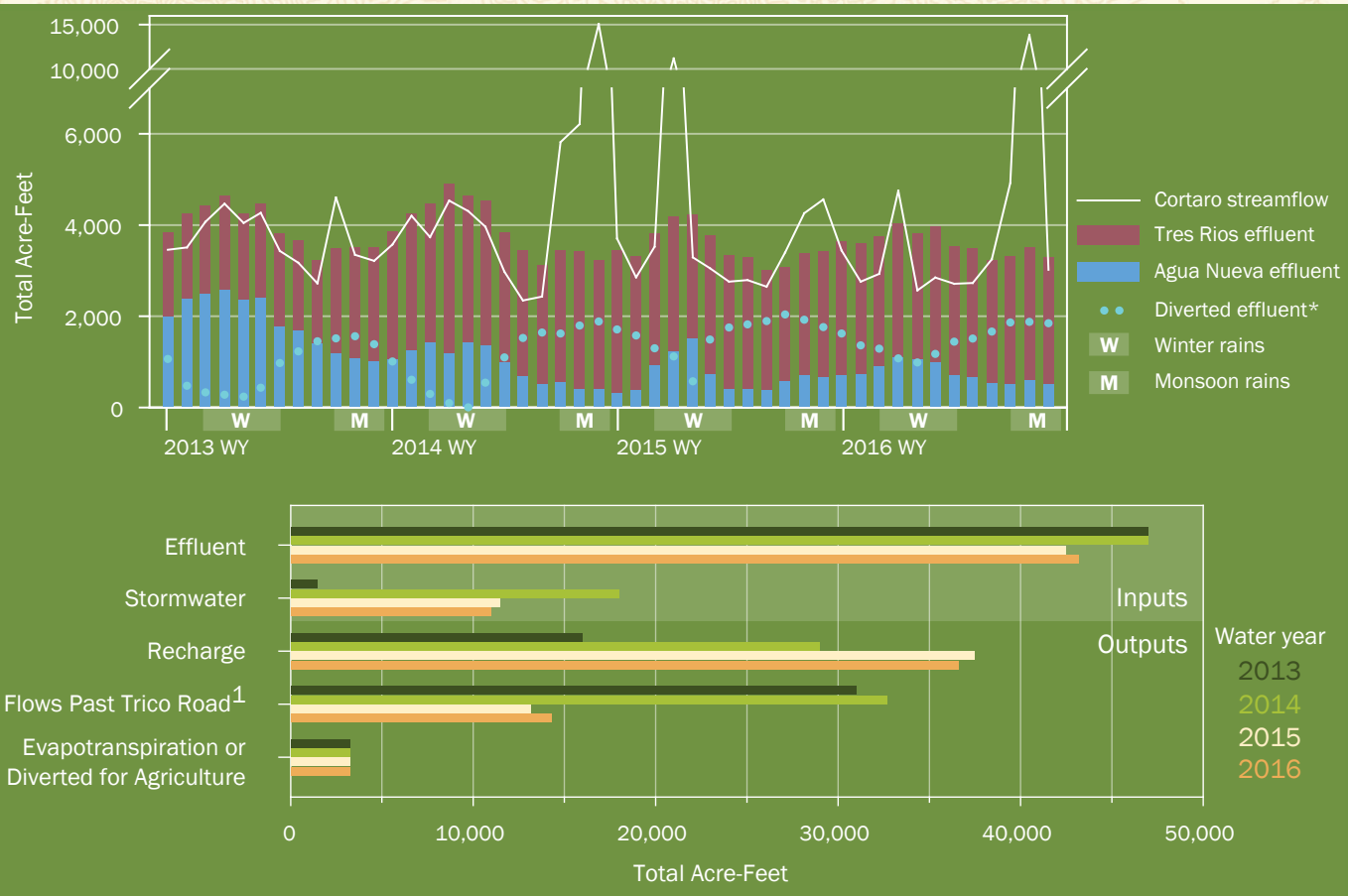
2013 - 2016 STREAMFLOW

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.
1 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 = 3,400AF

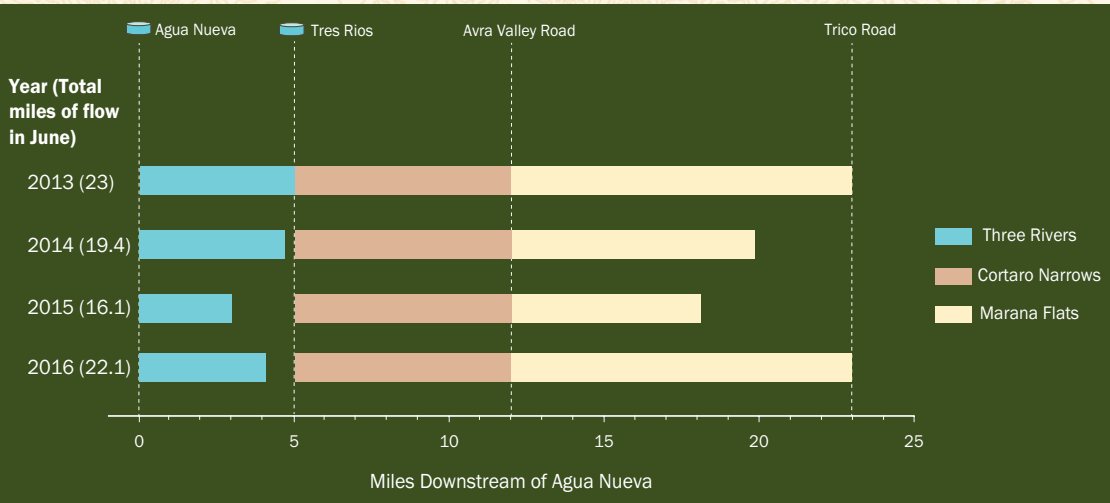
2013 - 2016 WATER BUDGET

Effluent provides most of the flow in the river. Effluent releases from Agua Nueva have decreased for two reasons. First, the 2014 facility upgrade 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 10% in 2015 and 8% in 2016 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

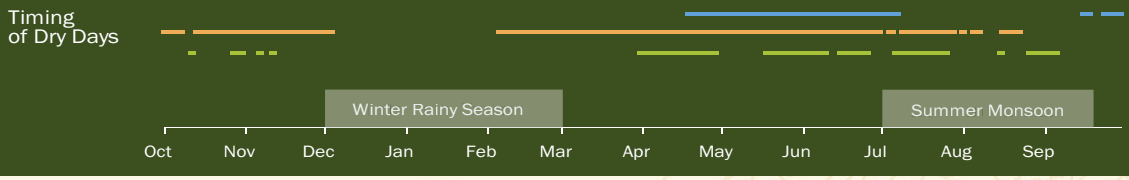
Measuring flow extent, or the distance the river is flowing, is a quick visual way to track changes in water inputs and outputs, while providing a rough measure of the quantity of aquatic habitat available. For example, high flow extent may indicate high inputs and high availability of habitat for aquatic 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.



Flow at Trico Road

	2013	2014	2015	2016
Number of Dry Days	0	94	244	109



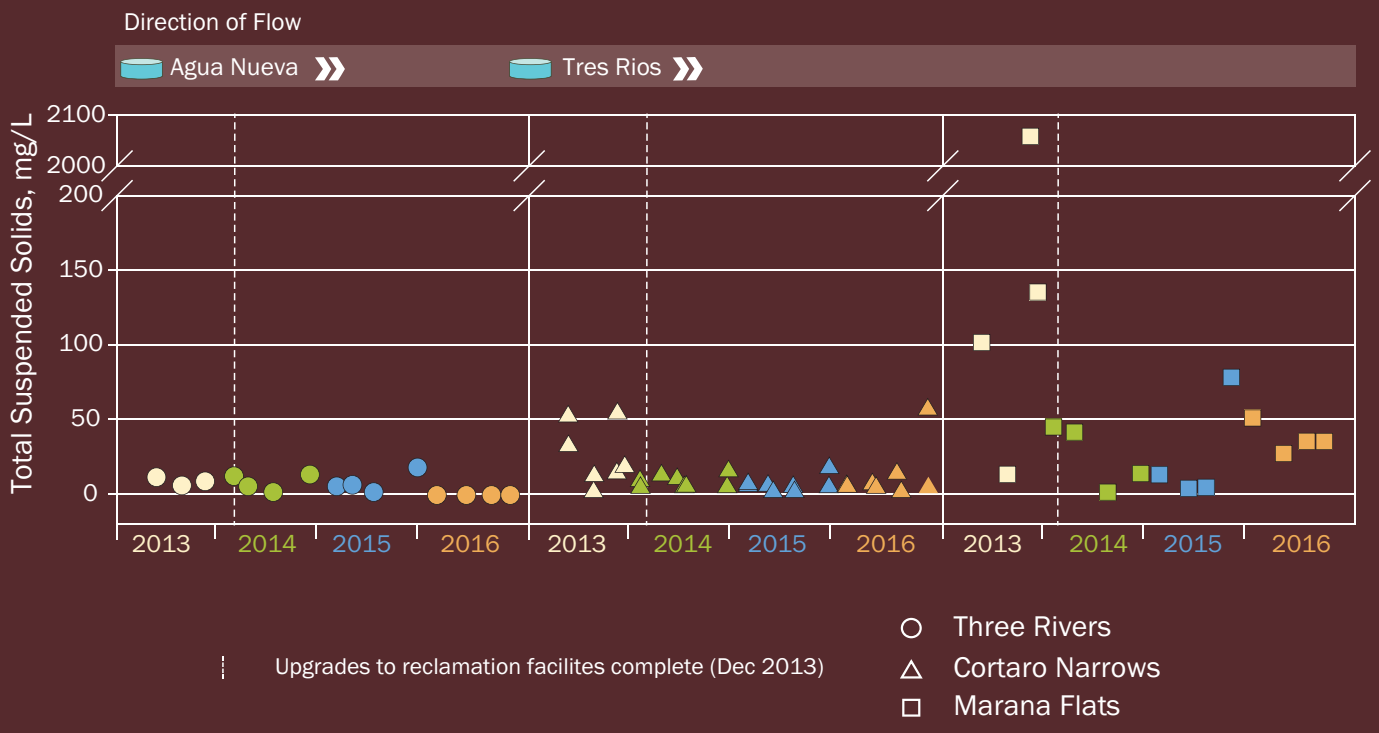
2013 - 2016 RESULTS

Flow extent decreased and varied seasonally after the 2014 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 by diverting flow into a pit. 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: Total Suspended Solids

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.

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

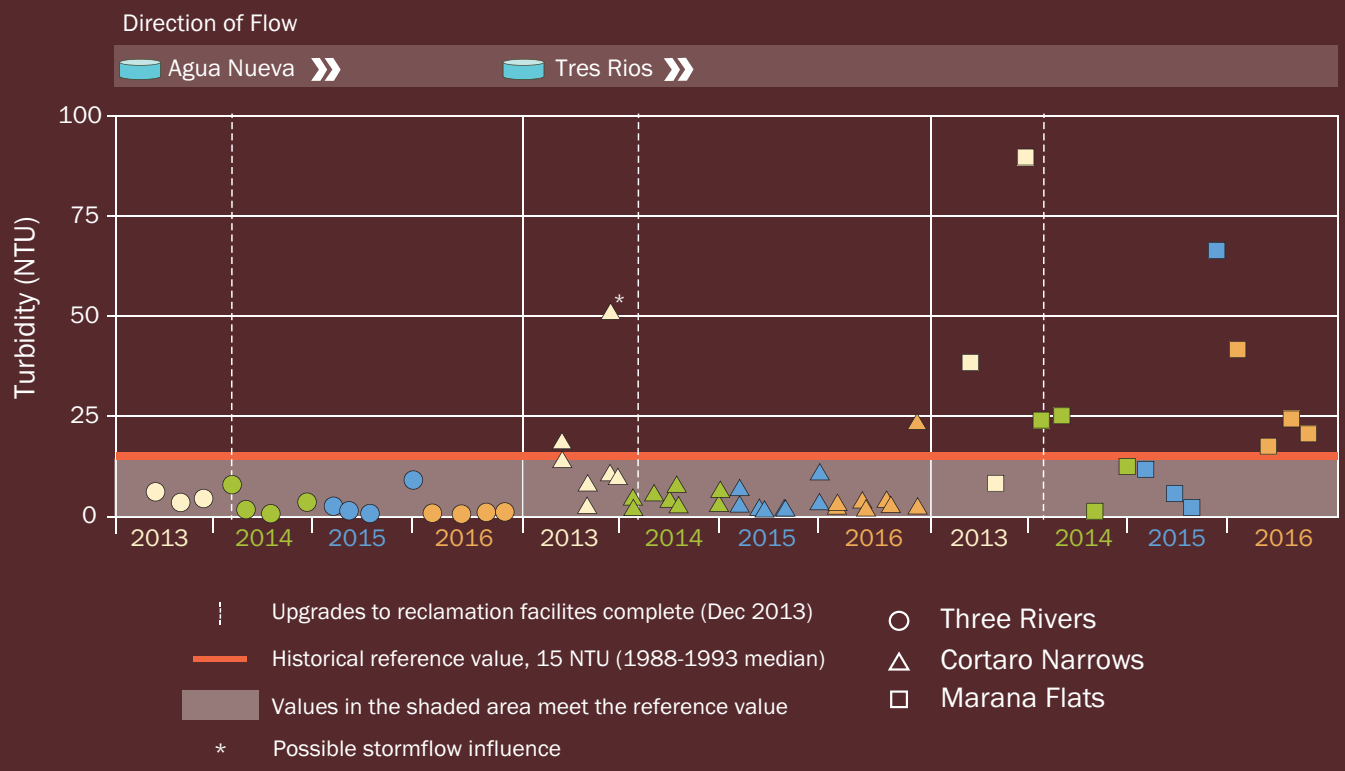


2013 - 2016 RESULTS

Total suspended solids (TSS) was measured a total of 62 times. Levels of TSS decreased in Cortaro Narrows and Marana Flats since the upgrades were complete. Levels of TSS were similar in all three reaches in 2014 and 2015. In 2016, Marana Flats saw an increase, though levels were still significantly lower than the 2013 baseline.

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.



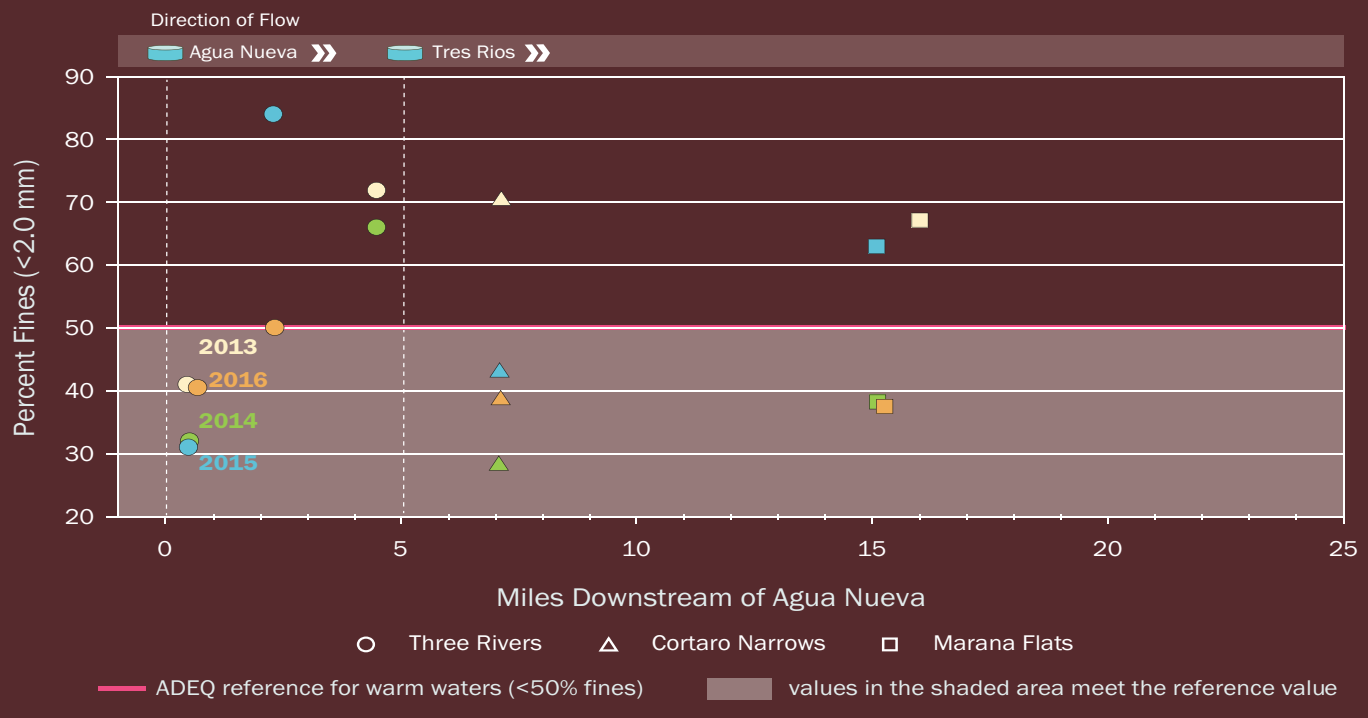
2013 - 2016 RESULTS

Turbidity was measured a total of 49 times. Overall, the reference value was met 61 times (80%). Turbidity decreased most notably in Marana Flats after the upgrade was complete, though it has been higher and more variable in the last year.

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 (≤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 assement uses the reference value for warm-water rivers, <50%.

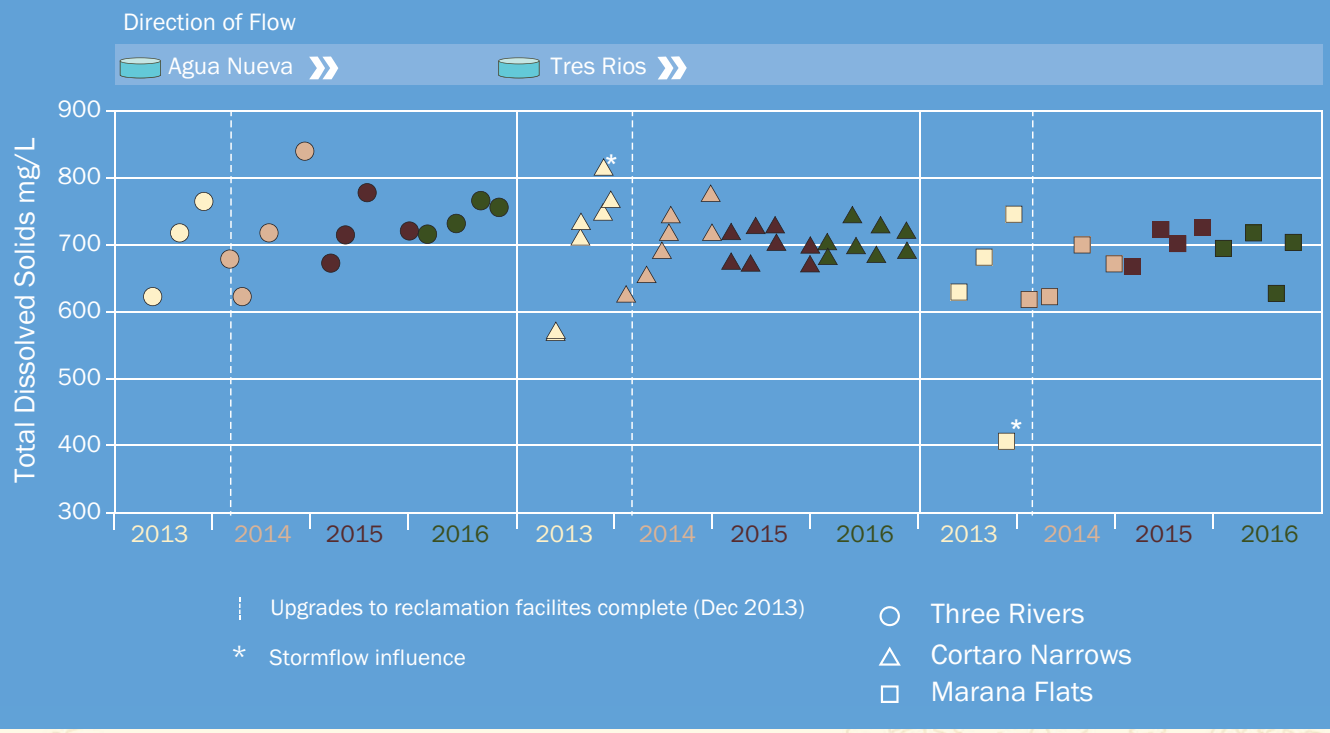


2013 - 2016 RESULTS

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.



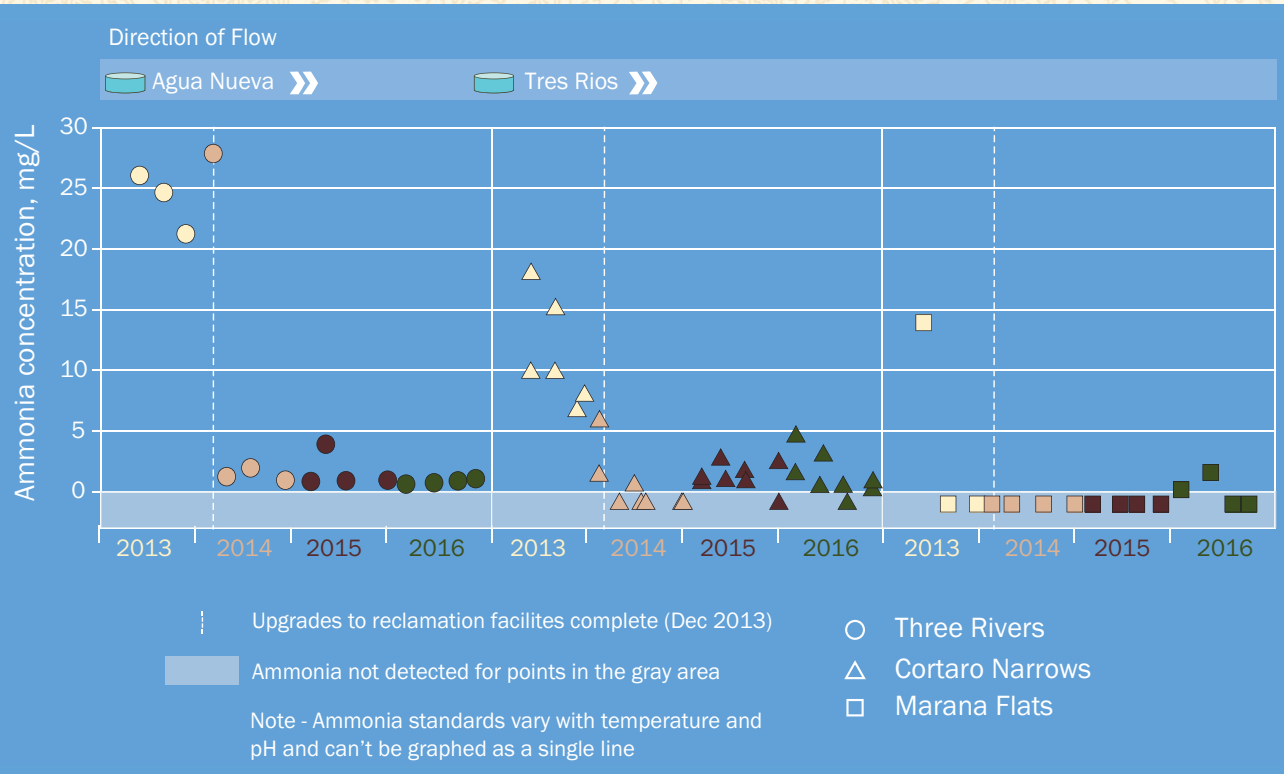
2013 - 2016 RESULTS

Total dissolved solids (TDS) were measured 61 times. Overall, levels of TDS were similar in all three reaches and didn't change much from 2013. 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 the Lower Santa Cruz River. Samples of stormwater are collected upstream of Agua Nueva when possible. Four samples collected (one each year during the summer monsoon) averaged 280 mg/L.

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 nitogen 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 (NH3) 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.

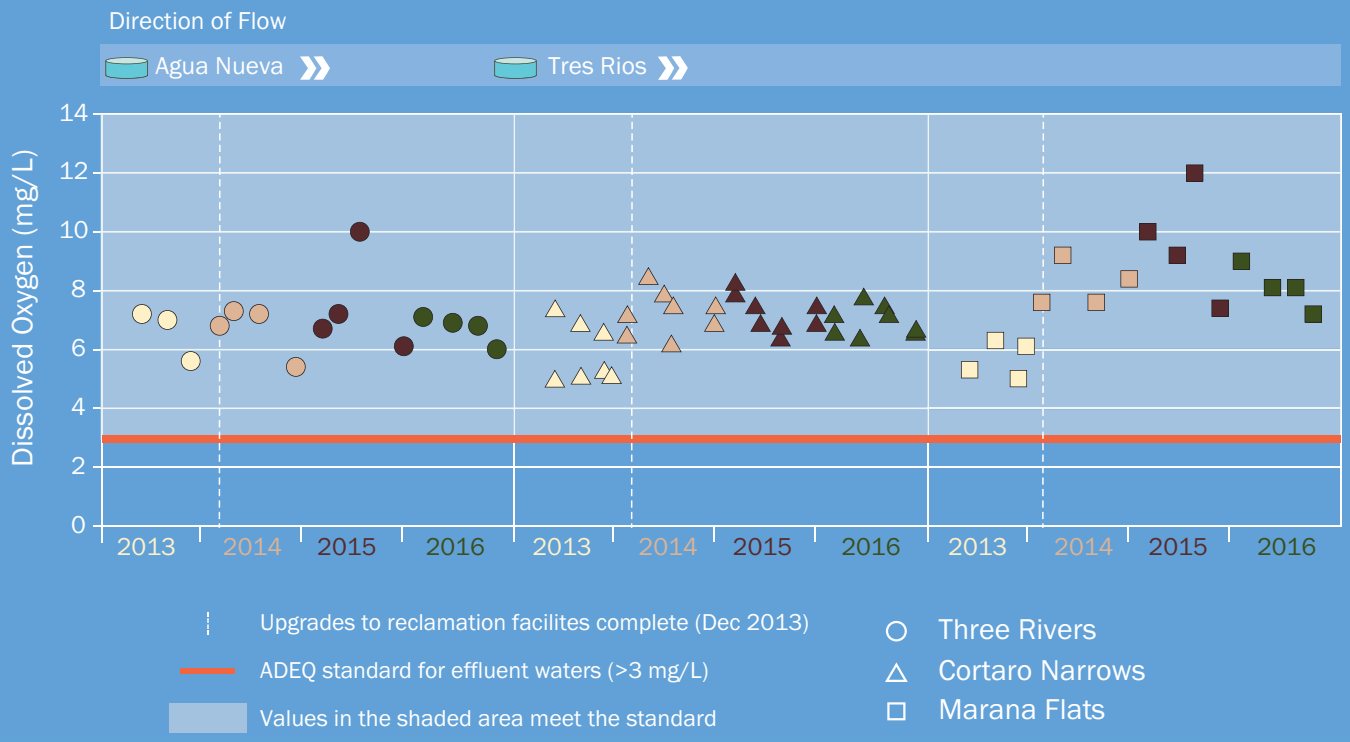


2013 - 2016 RESULTS

Ammonia was measured 60 times along the river. Overall the standard was met 39 of the 60 times (65%). 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*= 0.8 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: Dissolved Oxygen

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 streams dominated by effluent at 3 milligram per liter (mg/L) during the day (3 hrs after surise to sunset).

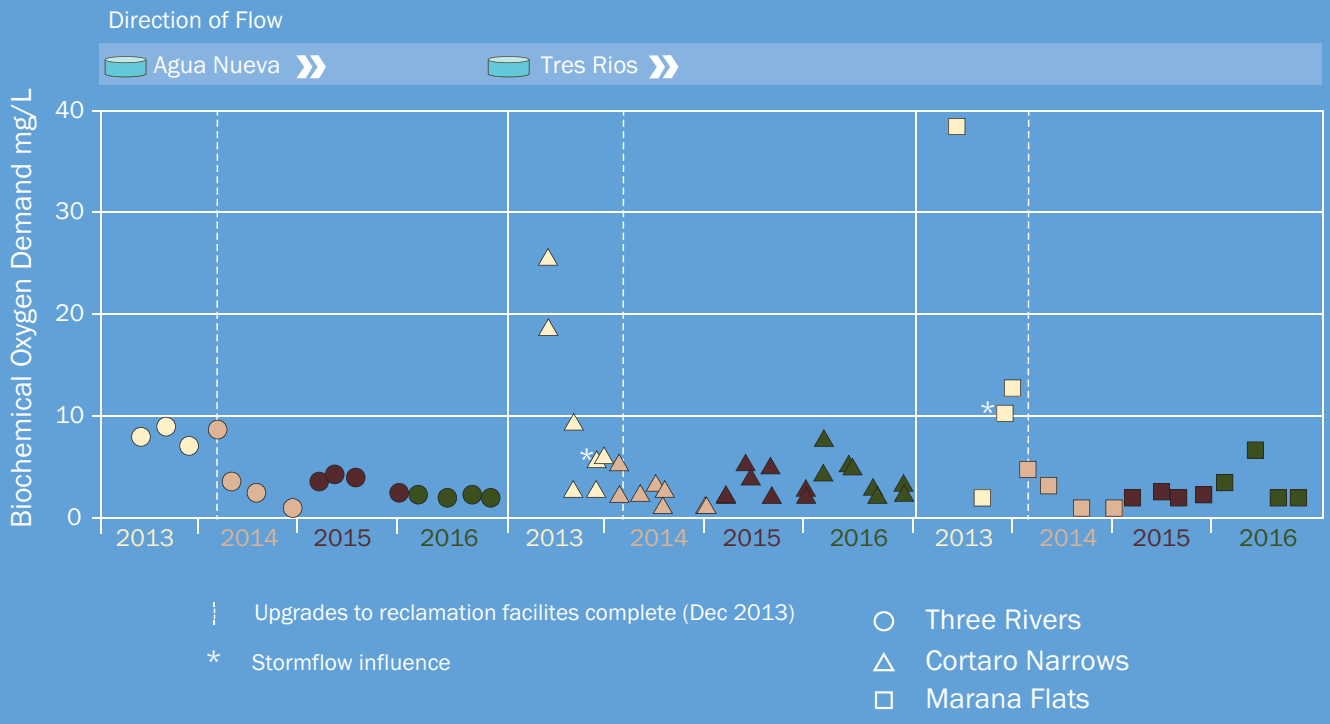


2013 - 2016 RESULTS

Dissolved oxygen was measured 62 times along the river. All of the samples met the standard for dissolved oxygen (100 %). Levels of dissolved oxygen stayed fairly constant in Three Rivers and Cortaro Narrows. However, Marana Flats saw an increase in dissolved oxygen after the facility upgrades were completed, even with drying conditions in this reach (some measures of dissolved oxygen had to be shifted upstream due to lack of flow at time of sampling).

WATER QUALITY: Biochemical Oxygen Demand

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 much of the 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.



2013 - 2016 RESULTS

Biochemical oxygen demand was measured 62 times along the river. BOD has decreased since the upgrades to the reclamation facilities were completed. The high levels observed in Cortaro Narrows and Marana Flats are absent after the 2013 water year, and all three reaches now have similar levels.

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)

	Agua Nueva		Tres Rios			Average Standard *standards for wildlife vary with water hardness*
Arsenic	3.9	3.1	3.3	3.8	3.4	3.9	150 ug/L*
Cadmium	ND	ND	ND	ND	ND	ND	2.1 ug/L
Chromium	0.7	0.6	0.5	0.3	0.4	0.7	11 ug/L
Copper	2.8	2.5	2.5	3.6	1.9	3.3	18 ug/L
Lead	0.3	0.2	0.3	0.3	0.5	0.3	6 ug/L
Mercury	ND	ND	ND	ND	ND	ND	0.01 ug/L
Zinc	50	51	50	36	41	36	233 ug/L

0 5 10 15 20 25

Miles Downstream of Agua Nueva

*set value, not an average

ND = Not Detected

2013 - 2016 RESULTS

All samples tested over the four years have met the appropriate standard for the following dissolved metals: arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc.

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 - 2016 RESULTS

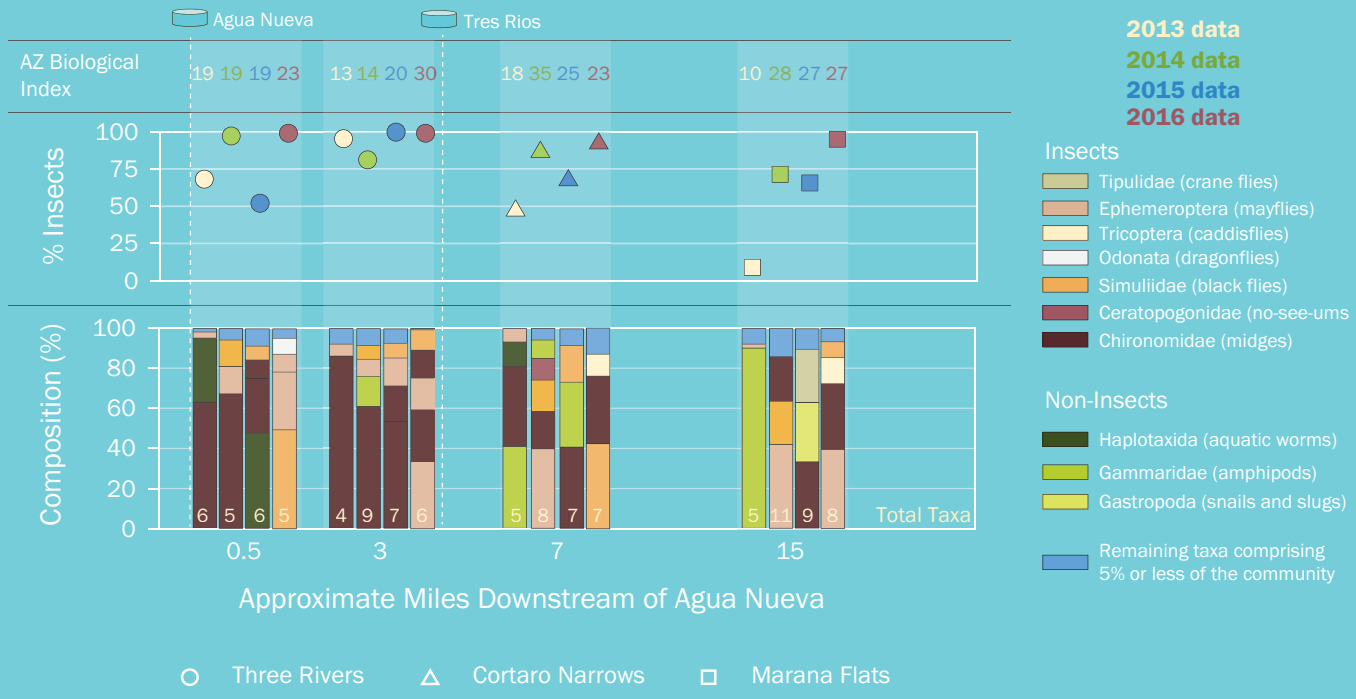
Fish surveys were conducted annually in the fall at the same four locations that macroinvertebrates were surveyed. The aim was to detect species and general fish numbers, but not population numbers. Improvements in water quality have allowed fish to thrive again. Cortaro Narrows may provide the best habitat for fish since the survey location in this reach has recorded the highest numbers of fish and species. Overall, number of fish species observed has increased from one to five. Though large fish, likely Common carp, were seen in spring of 2014, these larger species were not observed or captured until the 2015 survey. A large flood in September 2014 may have killed these species or washed them past Trico Road and beyond the study area. This flood may also explain the lower overall number of fish captured in 2014.

Fish presence has expanded upstream to Three Rivers, though only Western Mosquitofish were found in very low numbers in this reach. Flows in Three Rivers are often very shallow and may not provide habitat for the other larger species. In time, large floods may bring back native species, since the Longfin Dace and Gila Topminnow are found in the Upper Santa Cruz in Santa Cruz County.

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. 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% of the community, this lack of diversity suggests a stream is 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. The index does not apply to effluent-dominated rivers, but is a reference to track improvements over time.

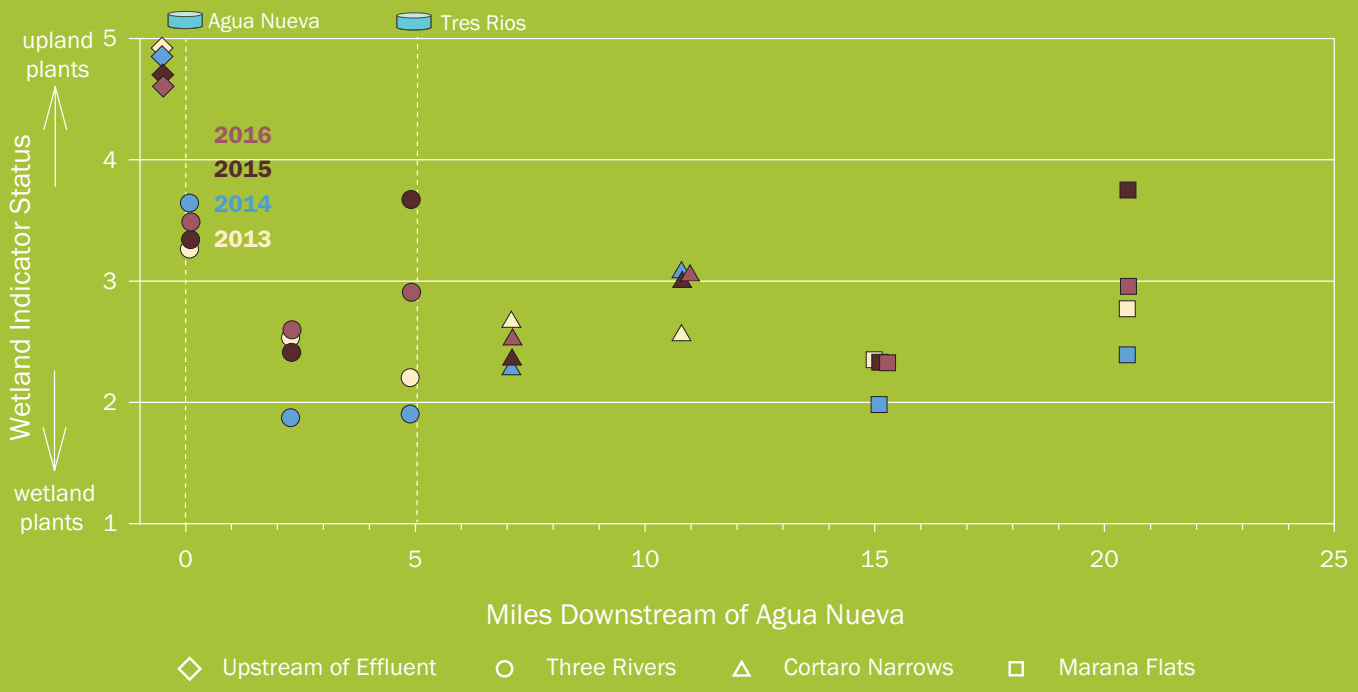


2013 - 2016 RESULTS

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. While this increased diversity is supported by an increase in the biological index scores, the scores remain below 39 and suggest that river life is impaired. Marana Flats may have shown the most change and most consistent improvement in terms of composition, % insects, and overall index. Continued monitoring will determine the level of improvements at all the sites.

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.

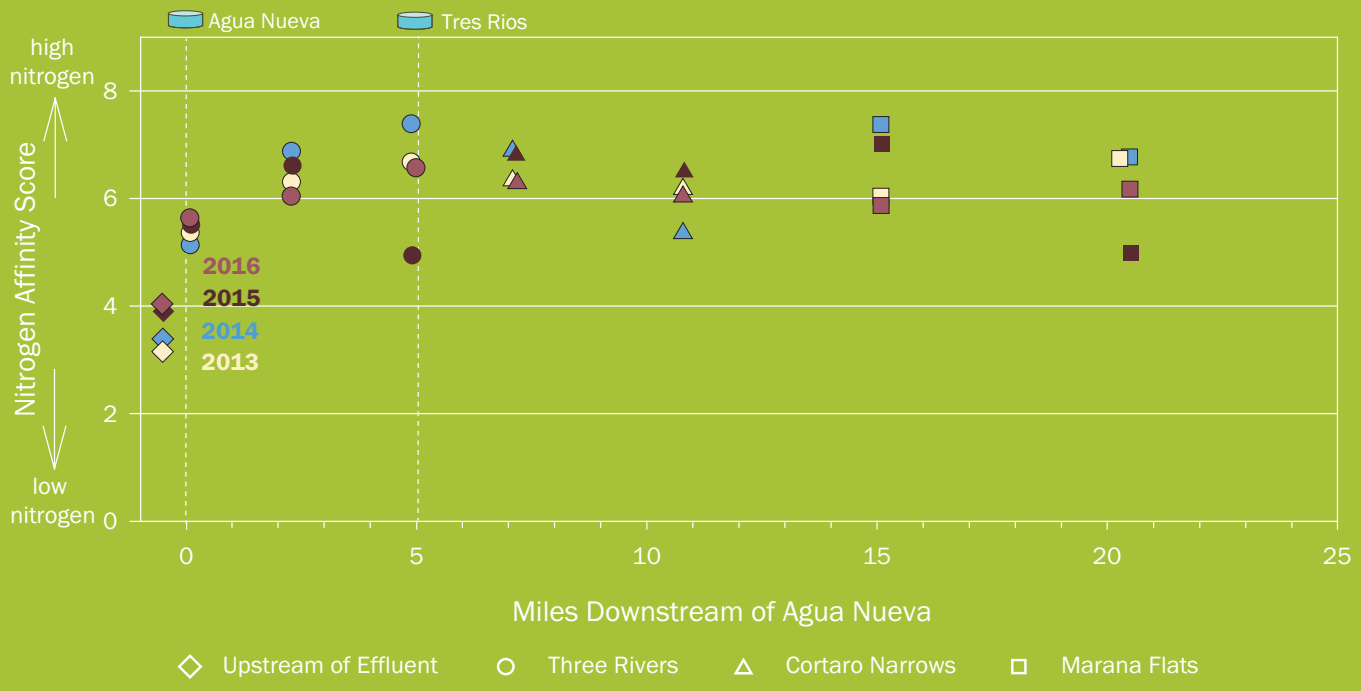


2013 - 2016 RESULTS

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.

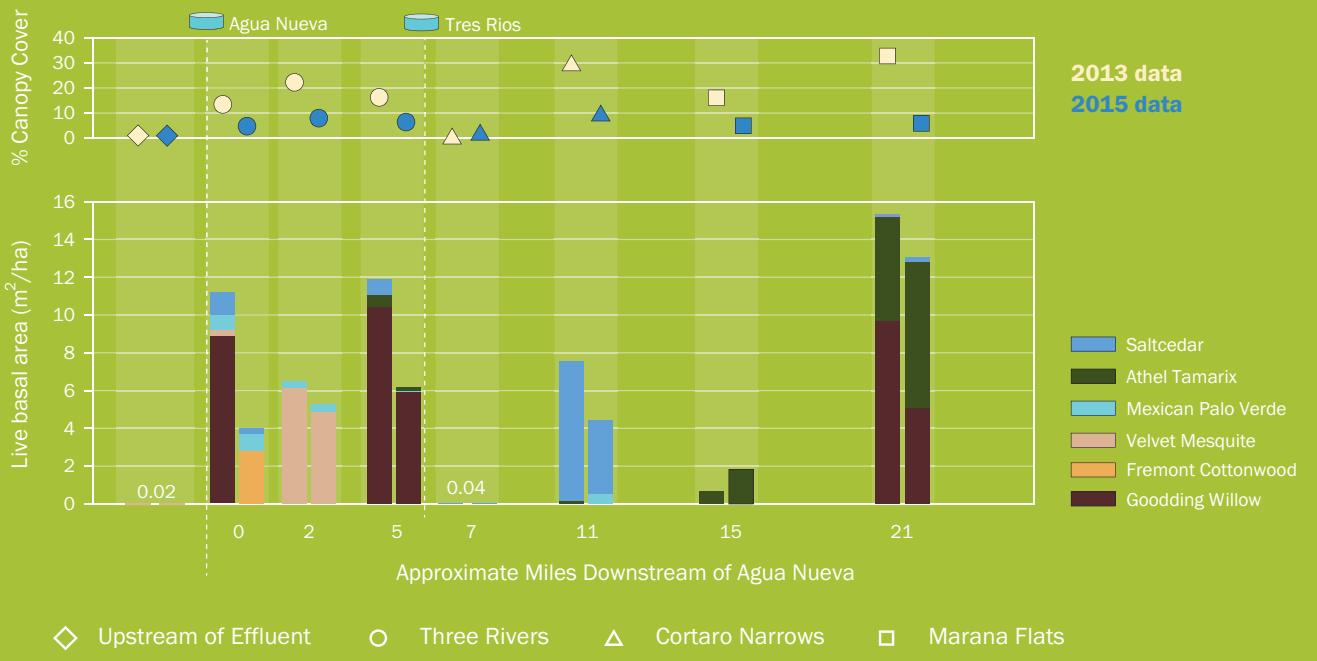


2013 - 2016 RESULTS

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^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. 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.

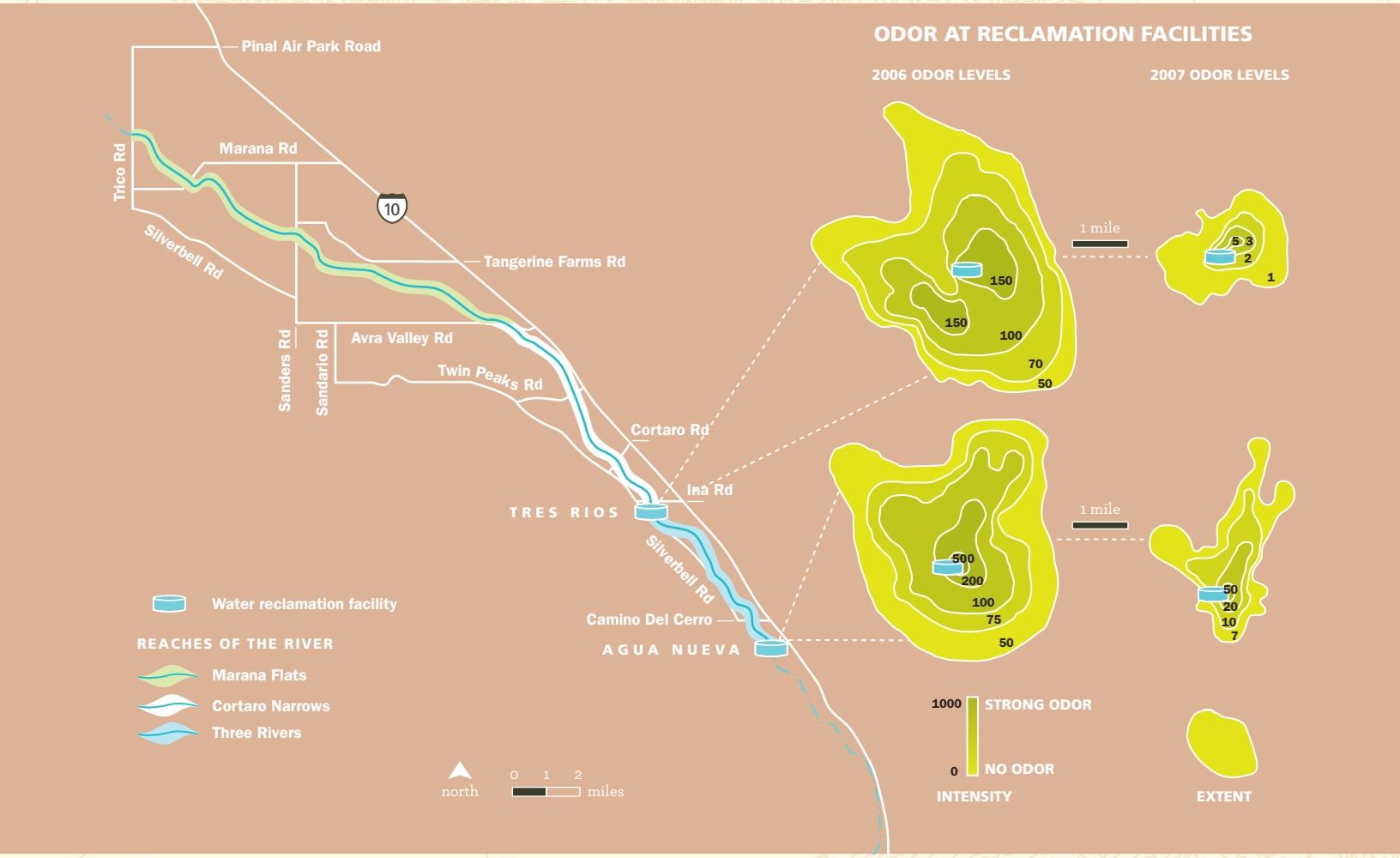


2013 - 2016 RESULTS

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_2S) 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 - 2016 RESULTS

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 fencelines. Levels of H_2S 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_2S 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_2S levels are not possible.

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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.

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Image Credits: all front and back cover art was created by Living River of Words students. Front left: **Katherine Daily**, age 17, Flowing Wells High School • Ms. Pechuzal; center: detail of painting by **Bianey Franco**, age 15, Tucson High Magnet School • Ms. Jenness; right: **Gabe Marcott**, age 16, Flowing Wells High School • Ms. Pechuzal. **2**: Santa Cruz River near Cortaro Road by **Pima County**; detail of Living River of Words painting by **Rylee Dankert**, age 7, Roadrunner Elemntary; Sandhill cranes at El Rio Preserve by **Craig Thayer**. **3**: cloudy and clear water photos by **Jennifer Duan**; Common carp by **Pima County**. **Back cover student art** left: **Elara Wallenmeyer**, age 14, Tucson High Magnet School • Ms. Jenness; right: **Bianey Franco**, age 15, Tucson High Magnet School • Ms. Jenness

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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.

The Sonoran Institute is a nonprofit organization with offices in Tucson and Phoenix, Arizona; and Mexicali, Baja California, Mexico. Visit our website to learn more www.sonoraninstitute.org.

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- **Attend the annual Santa Cruz River Research Days to learn about research and conservation efforts that pertain to the natural and cultural resources along the Santa Cruz River. Learn more at www.sonoraninstitute.org.**
- **Have your child enter the 2018 Living River of Words Youth Poetry and Art Contest. Sign up at www.pima.gov/nrpr.**
- **Save water, save rivers, and build community by joining Tucson's Conserve2Enhance (C2E) program. Help enhance urban washes that ultimately flow to the Santa Cruz River. Learn more at conserve2enhance.org/Tucson.**
- **Visit the Santa Cruz! See the river's "headwaters," where effluent is released into the river from Agua Nueva, just north of the Sweetwater Wetlands. From the west entrance, walk a half mile north along The Loop. Visit www.pima.gov/TheLoop for other access points.**

PIMA COUNTY

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