a living river

CHARTING THE HEALTH OF THE UPPER SANTA CRUZ RIVER

2009 Water Year

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THE UPPER SANTA CRUZ RIVER A LIVING ECOSYSTEM

The Upper Santa Cruz River is a culturally, historically, and ecologically important river that has sustained human communities for more than 3,500 years. From its headwaters in the San Rafael Valley in Arizona, the Santa Cruz River flows south into Mexico where it completes a 25-mile U-turn and flows north back into the United States through Santa Cruz County, Arizona. Constituting just a tiny fraction of the overall land area, the Upper Santa Cruz River supports among the highest density and abundance of life in the region. Along with plants and animals, the river sustains people living in the area by replenishing the groundwater aquifer that provides their primary source of water. Santa Cruz County highlighted the importance of the Upper Santa Cruz River in the 2004 Comprehensive Plan and specified that "*the Santa Cruz River and its watershed should be conserved and managed as a Living Ecosystem.*"

Recognizing the river's importance to the region, numerous groups and individuals have been involved for almost 20 years in research and monitoring efforts to track conditions along the Upper Santa Cruz River. The annual *Living River* report builds on these ongoing efforts, with a goal to promote a better understanding of the health of the Upper Santa Cruz River among watershed residents, land managers, and policymakers. We aim to understand how elements of the system are changing from year to year, how those changes may be affecting the ability of the system to function, and what stewardship efforts are required to help achieve and maintain a healthy river ecosystem.

Beginning with the 2008 water year (October 1, 2007–September 30, 2008), we conducted a baseline study to assess the health of a 20-mile stretch of the river in Santa Cruz County, Arizona, from Rio Rico to Amado. The baseline study indicated that poor water quality degraded the health of the river during that period. The complete *Living River* report for the 2008 water year is available to download at www.sonoraninstitute.org. A technical document detailing the development of the *Living River* series will be available at www.sonoraninstitute.org in fall 2010. This *Living River* report follows up on the baseline study and summarizes results from the 2009 water year (October 1, 2008–September 30, 2009).

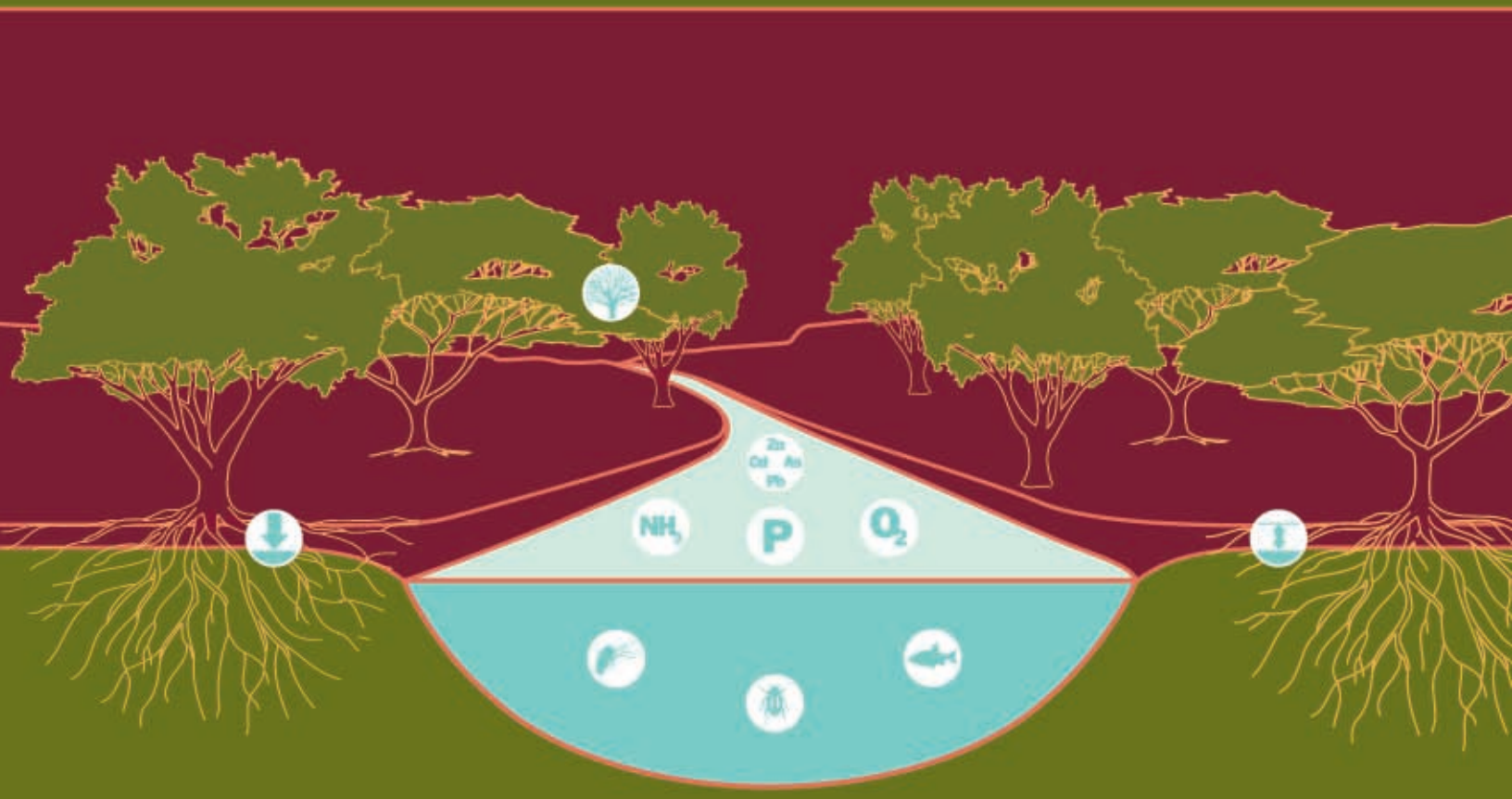
ASSESSING THE HEALTH OF THE UPPER SANTA CRUZ RIVER

A healthy natural system is one that persists in a stable and sustainable state. Therefore, a healthy river maintains its plant, animal, and physical composition; its organization; and its function. It is also able to sustain human communities through the provision of ecosystem services (i.e., the benefits that people obtain and receive from natural systems such as rivers, forests, and grasslands).

Ecosystem services can be broadly organized into four categories:

- ***Provisioning services*** provide goods such as food, fresh water, timber, and fiber for direct human use.
- ***Regulating services*** maintain processes that ensure the survival of life, such as pollination of crops, flood mitigation, erosion control, groundwater recharge, and climate stabilization.
- ***Cultural services*** provide recreational, aesthetic, and spiritual benefits.
- ***Supporting services*** are the underlying processes that produce the direct services above, such as soil formation, photosynthesis, and nutrient cycling.

This annual *Living River* report tracks the health of the Upper Santa Cruz River using 10 indicators (see diagram) that are grouped in two categories: *aquatic* and *riparian*. Riparian indicators relate to the plant and animal communities in areas adjacent to and affected by the surface water or groundwater of the river. Monitoring data from numerous agencies and organizations are evaluated against appropriate standards set by state agencies, federal agencies, or the scientific community. Most water quality indicators are compared to Arizona Department of Environmental Quality (ADEQ) surface water quality standards, which define water



1 Arizona Administrative Code. (2003). *Title 18. Environmental Quality, Chapter 11. Department of Environmental Quality, Water Quality Standards.* Arizona Administrative Code Supp. 03-1, pp. 1-85.

2 Arizona Department of Environmental Quality. (2008). *Notice of Final Rule Making Title 18. Environmental Quality, Chapter 11. Department of Environmental Quality, Water Quality Standards.*

quality goals for streams in the region and are designed to protect wildlife and/or human health. For some indicators, ADEQ defines a standard for streams that are effluent-dominated, such as the Upper Santa Cruz River in the Rio Rico, Tubac, and Amado reaches (stretches of river). For other indicators, the scientific community has determined scientific standards or benchmarks. Some indicators, such as aquatic animals and riparian vegetation, do not have defined standards for either abundance or diversity. For those indicators, the 2008 *Living River* assessment provides baseline data to which they can be compared.

The Arizona Department of Water Resources divides the roughly 20-mile stretch of river from Rio Rico to Amado in Santa Cruz County, Arizona, into three reaches: Rio Rico, Tubac, and Amado (see map on page 2). These reaches are delineated based on differences in geology and hydrology that have historically resulted in perennial (year-round) flow, with portions of the river alternating between *gaining* and *losing* stream conditions. There is a close connection between surface water and groundwater that can influence both the aquatic and riparian ecosystems in these reaches.

The following pages summarize the data collected by multiple agencies and organizations for the 10 indicators. For each indicator, a brief description is provided and a chart shows the data collected during the 2009 water year (October 1, 2008–September 30, 2009) and the appropriate standard for each indicator. Information about precipitation, streamflow, and other aspects of the aquatic and riparian ecosystems is also included. Results from the 2008 water year are provided as a reference. However, in general, there is not enough data to allow for a statistical comparison of the 2008 and 2009 water years. To view a side-by-side comparison of the data from the 2008 and 2009 water years, please visit the Sonoran Institute website.

Category	Indicators and Standards	Standard Source and Type
aquatic	**Dissolved oxygen:** > 1 mg/L	**ADEQ:** standard for wildlife in effluent[1]
	Ammonia: varies with temperature & pH	**ADEQ:** standard for wildlife in effluent[2]
	Total phosphorus: < 5 mg/L	**Historical (1992–1999 median)[3]**
	E. coli: < 235 CFU/100mL	**ADEQ:** standard for human health[1]
	Metals: varies by specific metal	**ADEQ:** standard for wildlife[2]
	Aquatic invertebrates: baseline	2008 Baseline information
	Fish: baseline	2008 Baseline information
riparian	**Depth to groundwater:** < 5.1 m	Scientific standard[4]
	Groundwater variability: < 0.8 m/yr	Scientific standard[4]
	Riparian vegetation: baseline	2006 Baseline information

(Effective January 31, 2009). Retrieved April 5, 2010, from http://www.azsos.gov/public_services/Register/2008/52/final.pdf

3 Friends of the Santa Cruz River. Unpublished data.

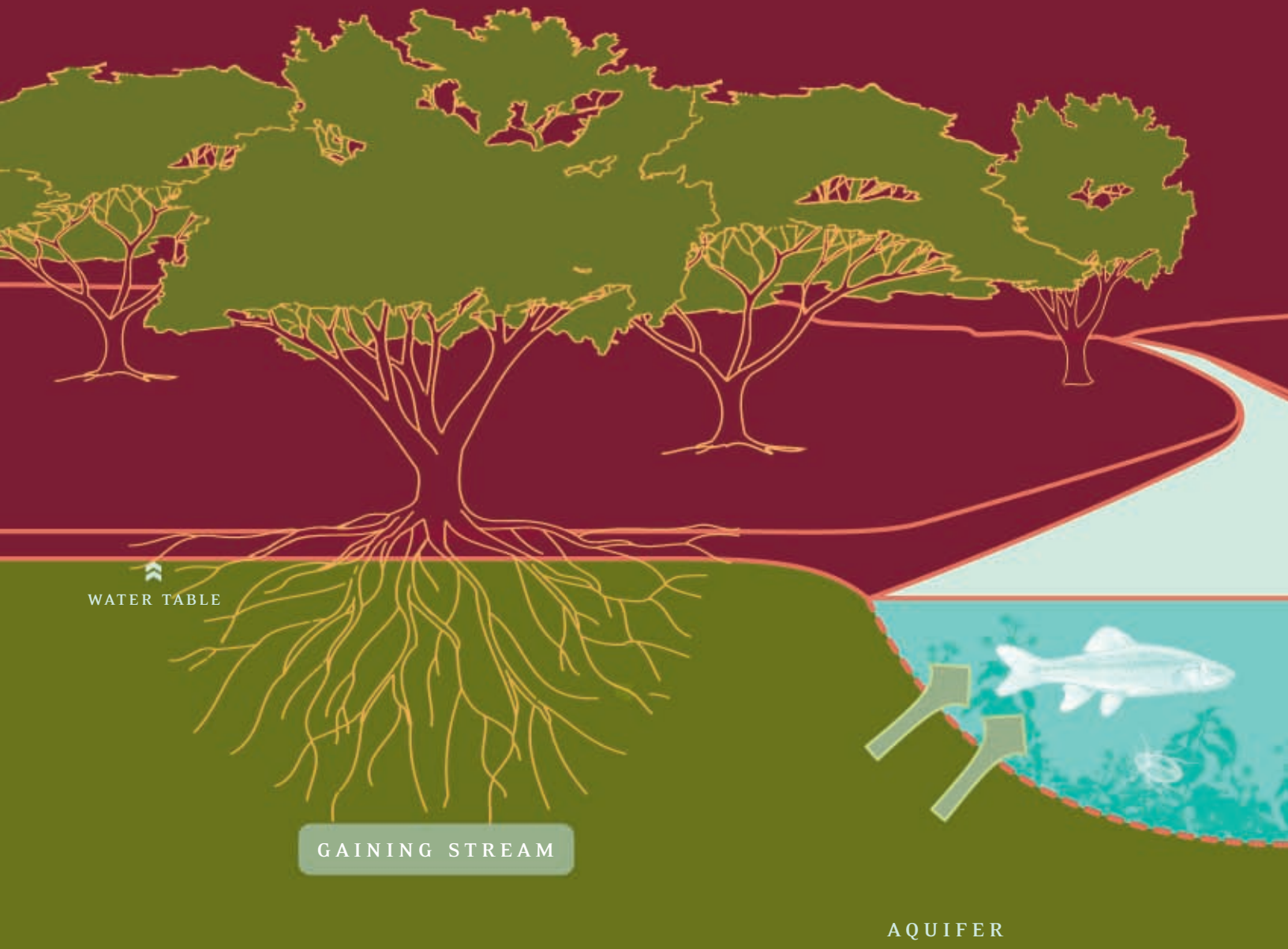
4 Lite, S. J., and J. C. Stromberg. (2005). Surface water and ground-water thresholds for maintaining Populus-Salix forests, San Pedro River, Arizona. *Biological Conservation* 125:153-167.

WATER SOURCES

A finite amount of water supports the human and natural environments along the Upper Santa Cruz River. This water comes from two sources: precipitation and groundwater. A third source of water, effluent, is water that has been pumped from one location, used by humans, treated in a wastewater facility, and discharged (returned to the river) in a new location. Thus, effluent is really the movement and use of water, and represents an important human "source" of water. While there are challenges and uncertainties regarding the ecological benefits of effluent, recent research at Arizona's universities and agencies has shown that effluent can be an important additional water source for the river and associated riparian vegetation. All three sources of water contribute to streamflows in the Upper Santa Cruz River.

Variability in streamflow (i.e., flood peaks) is influenced both by precipitation events throughout the watershed and by groundwater levels. As a general rule, when the water table in the aquifer is above the level of the stream, groundwater will emerge or discharge from the aquifer into the stream channel and augment flow. A stream that receives groundwater from the aquifer is referred to as a *gaining stream*. If the water table is below the level of the stream, water from the stream will infiltrate through the streambed to raise the water table in local aquifers, consequently lessening flow. A stream that loses water to the aquifer is referred to as a *losing stream*. Effluent discharged into the stream can therefore augment both streamflow and local aquifers as the water infiltrates through the streambed.

Historically, streamflow through many stretches of the Upper Santa Cruz River was perennial. As the human population



grew, the demand for water resulted in increased pumping of groundwater. As pumping lowered the water table, groundwater discharge to the stream decreased and streamflow became more dependent on effluent and precipitation.

Currently, effluent from the Nogales International Wastewater Treatment Plant (NIWTP) in Rio Rico, Arizona, provides the majority of the flow in the Rio Rico, Tubac, and Amado reaches, according to the Arizona Department of Environmental Quality and the Arizona Department of Water Resources. Effluent is discharged into the streambed at a rate of up to 15 million gallons per day from the NIWTP. The International Boundary and Water Commission stipulates that the treatment plant is permitted to treat 9.9 million gallons per day from Nogales, Sonora, Mexico, and 5.1 million gallons per day from Nogales, Arizona. Though the majority of flow downstream of the NIWTP is effluent, the variability of the flow is influenced by precipitation events. In contrast, upstream of the NIWTP, near Nogales, Arizona, the precipitation that falls in the watershed is the primary source of the streamflow in the river.

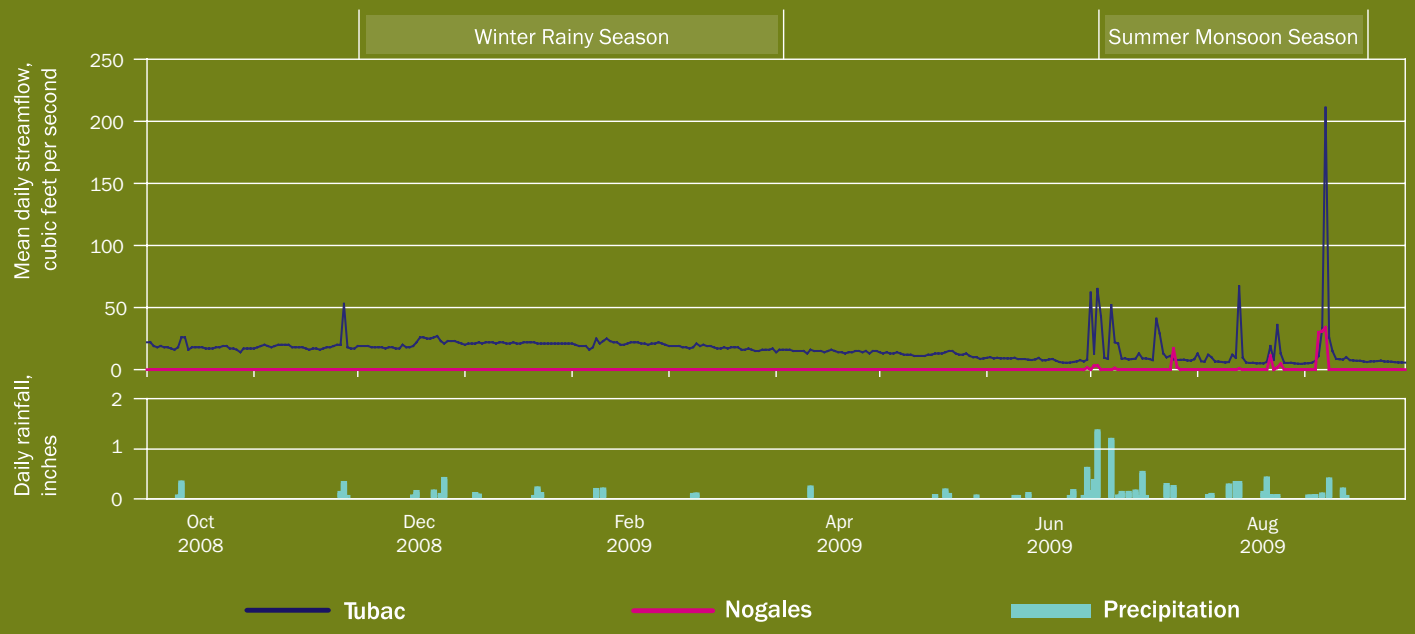
Recent upgrades to the NIWTP were completed in summer 2009. The upgrades included substantial changes to the sewage treatment process. According to the NIWTP, the new process, which includes removal of nitrogen compounds, has significantly improved clarity and lowered the concentrations of ammonia in the discharged effluent. The NIWTP began testing the system upgrades and directing all sewage flows through the new process on March 10, 2009. The system was officially completed on July 23, 2009.

As a result of the three sources of water, the Upper Santa Cruz River offers numerous ecosystem services: riparian vegetation naturally slows flood flows; tree roots control erosion; floodplain soil filters water as it recharges local aquifers that provide water to watershed residents; and the riparian area provides important wildlife habitat and contributes to the culture and heritage of the region.

PRECIPITATION AND STREAMFLOW

The “water year” (October 1 to September 30) is linked to annual precipitation patterns. Precipitation typically falls during two seasons. The *winter rainy season*, which lasts from December to March, brings the occasional gentle and widespread rain. Frequent but locally violent thunderstorms occur during the *summer monsoon season*, which typically lasts from July to mid-September. The two rainy seasons do not occur completely within one calendar year, and the water year starts during the dry season before the winter rains and ends during the dry season after the summer monsoon.

The variability of streamflow is influenced by precipitation events throughout the watershed. Seasonal floods are important for recharging aquifers, dispersing seeds, inducing seed germination, and clearing natural debris from the riparian forest floor.



Data Source: National Weather Service and U. S. Geological Survey

2009 Precipitation

Weather is monitored at the Nogales International Airport in Nogales, Arizona.

- During the 2009 water year, the station recorded 9.73 inches of rain. This was the lowest amount of rainfall since the 2001 water year.
  - Just under 1.5 inches of rain fell during the winter rainy season.
  - The summer monsoon brought just over 6 inches of rain.

2009 Streamflow

Streamflow, also called discharge, is measured with gages upstream of the NIWTP near Nogales, Arizona, and downstream of NIWTP at Tubac, Arizona. Streamflow is the volume (e.g., cubic feet) of water flowing past a fixed point in a specific amount of time (e.g., 1 second).

- Mean daily discharge averaged just under 0.5 cubic feet per second (cfs) near Nogales and around 16 cfs at Tubac.
- Mean daily discharge peaked at 34 cfs near Nogales and at 211 cfs at Tubac on September 7, 2009.

CUBIC FEET PER SECOND

1 cubic foot per second = 7.48 gallons per second

aquatic

Aquatic ecosystems, such as streams, depend on particular water quality conditions (chemical, physical, and biological properties) to sustain plant and animal communities. Water temperature and pH provide important context for river conditions. During the 2009 water year, water temperature ranged from 36° F in the winter to nearly 88° F in the summer; and pH was typically between 7.5 and 8.1, with a maximum pH of 8.6.

Nutrient pollution, such as elevated levels of nitrogen and phosphorus, can come from numerous sources: fertilizer, overflow from septic systems, surface runoff, and discharge of nitrogen and phosphorus from wastewater treatment plants. While high levels of nutrients can allow faster and larger growth for riparian plants, it can also lead to problems such as low levels of dissolved oxygen and associated declines in fish and aquatic wildlife habitat.

FISH

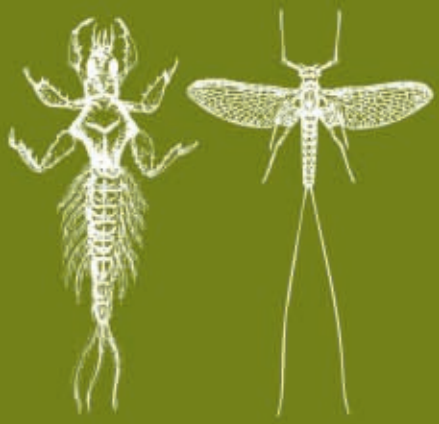
Fish can serve as effective indicators of ecological conditions because they live for several years and differ from one another in their tolerance to pollution. Historically, the Santa Cruz River supported several native fish species: Gila Topminnow, Desert Sucker, Sonora Sucker, and Longfin Dace. Long-term monitoring by the Friends of the Santa Cruz River and state and federal agencies has shown a decline in the number of native fish species present and the number of individual fish in the Upper Santa Cruz River. Three non-native fish species (the Western Mosquitofish, Green Sunfish, and Largemouth Bass) were found during an inventory of Tumacácori National Historical Park (2000–2003). The 2008 baseline documented only Longfin Dace, in very low numbers (2 individual fish caught).

2009 Results

In the fall of 2009 a fish survey was conducted along the Upper Santa Cruz River. Survey methods determined presence and general numbers of fish, but did not estimate total population numbers. More fish were caught and observed in 2009 than in 2008.

- **Rio Rico:** 70 Longfin Dace. *2008 = No fish*
- **Tubac:** 46 Longfin Dace and 109 Western Mosquitofish. *2008 = 1 Longfin Dace*
- **Amado:** 26 Longfin Dace and 47 Western Mosquitofish. *2008 = 1 Longfin Dace*

Stonefly larva and adult



Mayfly larva and adult

Caddisfly larva and adult

AQUATIC INVERTEBRATES

Aquatic invertebrates (animals that lack a spinal column or backbone) are an important biological component in streams. They also are a good indicator of watershed health because they differ in their tolerances to pollution and typically live for more than a year. ADEQ has developed a biological standard for aquatic invertebrates for cold and warm water streams. At this time there is no standard for effluent-dependent streams. In general, aquatic invertebrates with high tolerances to pollution, like those in the Chironomidae family (midges), are found in higher numbers in polluted streams. In contrast, scientists consider the following orders (groups of families) of aquatic invertebrates to be sensitive to pollution and found in lower numbers in polluted streams: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). In addition, if a single species or group accounts for more than 50 percent of the invertebrate community or assemblage, the stream may be under environmental stress.

2009 Results

The National Park Service Sonoran Desert Network monitors aquatic invertebrates at Tumacácori National Historical Park (Tubac reach). Unfortunately, results from their samples were not available at press. The Sonoran Institute initiated aquatic invertebrate sampling in the Amado reach in 2009. The Amado information serves as a baseline to which future assessments will be compared. Though the assemblage in Amado contained only a small percentage of pollution tolerant species, the dominance by one family still suggests that this reach is under environmental stress.

- **Rio Rico:** No samples were collected. *2008 = No data*
- **Tubac:** Results not available. *2008 = Dominated by Chironomidae family*
- **Amado:** The Erpobdellidae family (leeches) dominated the sample and accounted for 67% of the aquatic invertebrate assemblage. The Chironomidae family accounted for 3% of the aquatic invertebrate assemblage while the Ephemeroptera order accounted for 7%. *2008 = No data*

Sonora Sucker

NH_3 AMMONIA

Ammonia (NH_3), a form of nitrogen, is known to be toxic to fish. Even at low concentrations ammonia can cause reduction in hatching success, among other impacts. The toxicity of ammonia varies with several factors such as pH, temperature, and dissolved oxygen concentration. The Arizona Department of Environmental Quality's standard for ammonia varies by pH and temperature. As pH and temperature increase, the toxicity of ammonia increases, thus the acceptable level of ammonia decreases with high pH and temperature. Based on the range of temperatures and pH in the reaches, the applicable standard for the maximum amount of ammonia during the 2009 water year should be less than 0.28 to 4.36 milligrams per liter (mg/L) for ecosystem health.

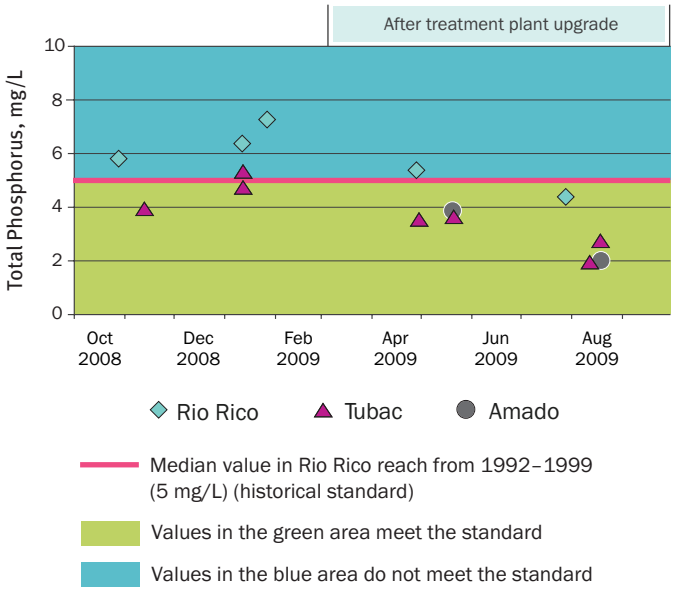
2009 Results

Ammonia was monitored a total of 14 times, and the ADEQ standard was met 8 out of the 14 times (57% standard attainment). Overall, levels of ammonia have greatly decreased since the treatment plant upgrade was completed and are lower than in the 2008 water year.

- **Rio Rico:** 2 of the 5 samples met the standard (40% attainment). *2008 = 0% attainment*
- **Tubac:** 4 of the 7 samples met the standard (57% attainment). *2008 = 0% attainment*
- **Amado:** 2 of the 2 samples met the standard (100% attainment). *2008 = No data*

P TOTAL PHOSPHORUS

Phosphorus is an essential nutrient for plant and animal life; however, too much phosphorus can reduce the quality of aquatic habitat. Elevated levels of phosphorus can accelerate plant growth that can ultimately decrease the amount of dissolved oxygen and kill aquatic animals. The median amount of total phosphorus monitored in the Rio Rico reach from 1992-1999 was approximately 5 mg/L. Because ADEQ does not have a standard for total phosphorus in this stretch of the Upper Santa Cruz River, this assessment uses the 1992–1999 median of 5 mg/L as the historical standard.

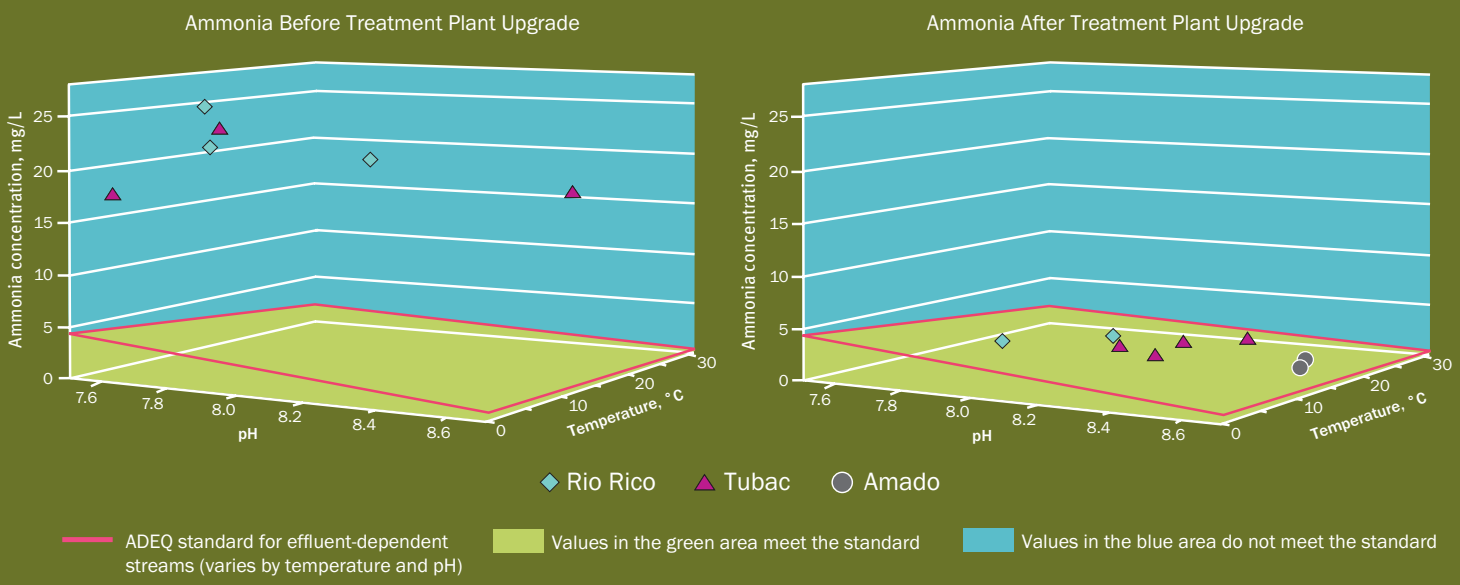


2009 Results

Phosphorus was monitored a total of 14 times. Overall, the historical standard was met 9 out of the 14 times (64% standard attainment). During the 2009 water year, 7.3 mg/L was the maximum amount of total phosphorus measured. In contrast, 2 samples during the 2008 water year had greater than 45 mg/L of total phosphorus.

- **Rio Rico:** 1 of the 5 samples met the historical standard (20% attainment). *2008 = 25% attainment*
- **Tubac:** 6 of the 7 samples met the historical standard (86% attainment). *2008 = 25% attainment*
- **Amado:** 2 of the 2 samples met the historical standard (100% attainment). *2008 = No data*

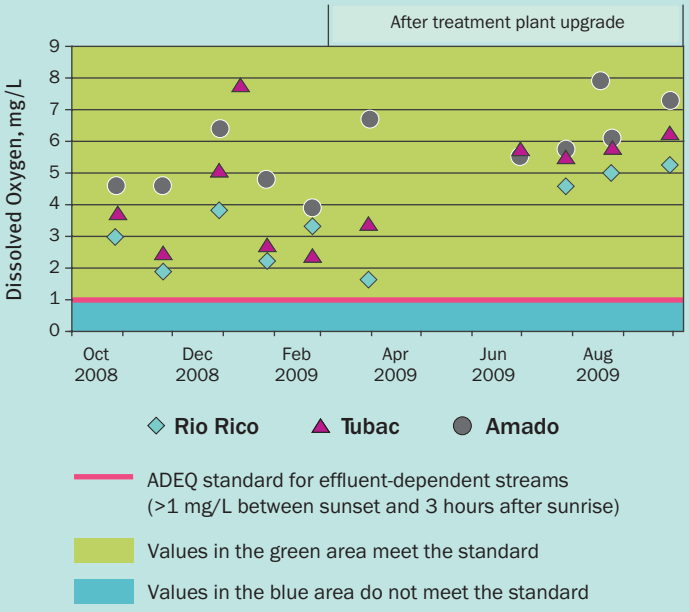
Data Source: Arizona Department of Environmental Quality, Friends of the Santa Cruz River, National Park Service Sonoran Desert Network, and Sonoran Institute



Data Source: Arizona Department of Environmental Quality, Friends of the Santa Cruz River, National Park Service Sonoran Desert Network, and Sonoran Institute

O_2 DISSOLVED OXYGEN

Fish and other aquatic animals need oxygen to survive. Rivers absorb oxygen from the atmosphere and aquatic plants produce oxygen. Natural causes of variability in dissolved oxygen levels include nutrient levels, groundwater discharge, water temperature, and time of day. ADEQ sets the minimum standard for dissolved oxygen in effluent-dependent streams at 1 milligram per liter (mg/L) measured between sunset and three hours after sunrise, and 3 mg/L at other times. All data was measured within three hours after sunrise, thus measures of dissolved oxygen that are greater than 1 mg/L meet the standard.



2009 Results

Dissolved oxygen was measured a total of 31 times. All of the 31 samples met the standard (100% standard attainment). Although there was no difference from the 2008 water year in overall percent attainment, data from all sites tended to have higher levels of dissolved oxygen in the 2009 water year, most notably after the treatment plant upgrade was completed.

- **Rio Rico:** 9 of the 9 samples met the standard (100% attainment). *2008 = 100% attainment*
- **Tubac:** 11 of the 11 samples met the standard (100% attainment). *2008 = 100% attainment*
- **Amado:** 11 of the 11 samples met the standard (100% attainment). *2008 = 100% attainment*

Data Source: Arizona Department of Environmental Water Quality, Friends of the Santa Cruz River, and Sonoran Institute

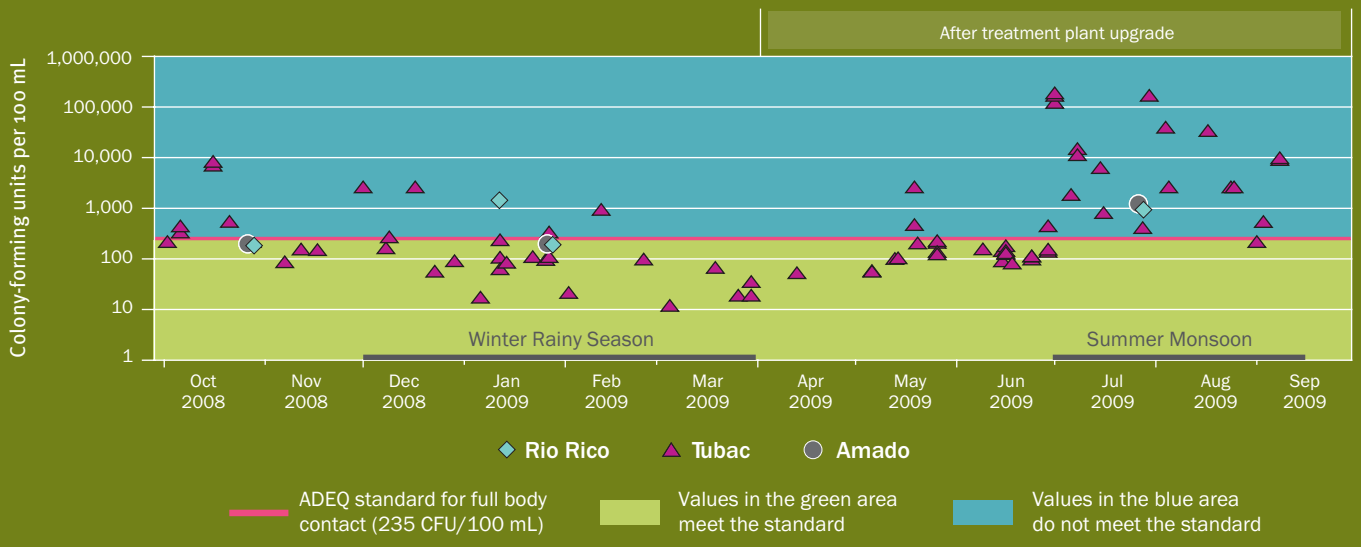
E. COLI

Escherichia coli (E. coli) is one of the main species of bacteria living in the lower intestines of mammals, and its presence in water is an indication of fecal contamination. The presence of *E. coli* indicates the potential presence of other pathogenic microorganisms such as bacteria and viruses that might be a health risk to people swimming or wading in the river. The ADEQ standard for a single sample maximum for full body contact (swimming) is 235 colony-forming units per 100 milliliters of water (CFU/100mL). For partial body contact (wading or boating) the single sample maximum is 576 CFU/100mL. The results are compared to the stricter standard, thus samples with greater than 235 CFU/100mL do not meet the standard.

2009 Results

E. coli concentrations were highly variable and consistently above full body contact standards during the summer monsoon season. *E. coli* was monitored a total of 86 times across the three reaches, with most of the monitoring in the Tubac reach done by staff at Tumacácori National Historical Park. Overall, the ADEQ standard was met 52 out of the 86 times (61% standard attainment). While a greater percentage of samples met the standard compared to the 2008 water year, *E. coli* levels continued to exceed the standard, especially during the summer monsoon season. High levels during the rainy season suggest that the *E. coli* is coming from multiple sources within the watershed.

- **Rio Rico:** 2 of the 4 samples met the standard (50% attainment). *2008 = 66% attainment*
- **Tubac:** 48 of the 79 samples met the standard (61% attainment). *2008 = 34% attainment*
- **Amado:** 2 out of 3 samples met the standard (67% attainment). *2008 = 33% attainment*



Data Source: Arizona Department of Environmental Quality, Friends of the Santa Cruz River, National Park Service at Tumacácori National Historical Park, and National Park Service Sonoran Desert Network

METALS

In high concentrations metals cause major disruption to wildlife in aquatic ecosystems by lowering reproductive success, interfering with normal growth and development, and, in extreme cases, causing death. The Upper Santa Cruz River is exposed to pollutant metals through numerous sources, including mine drainage, roadways, industrial wastewater discharge, and by the release of metals naturally occurring in near-surface rock strata and sediments. Most of these contaminants accumulate in aquatic food webs and may pose long-term threats to all organisms in the aquatic environment.

2009 Results

During the 2009 water year, several groups monitored metals, including the Friends of the Santa Cruz River volunteer group that monitors a suite of metals (arsenic, cadmium, copper, lead, selenium, and zinc) on a quarterly basis. During the 2009 water year, most of the samples met the appropriate ADEQ standards set for the protection of aquatic wildlife. However, all samples measured for cadmium were above the standard. Cadmium is lethal to aquatic wildlife at relatively low concentrations and comes from numerous human produced sources such as fertilizers, pesticides, coal combustion, mine wastes, and electroplating processes.

Rio Rico: Overall 21 of the 24 samples tested met the standard (88% attainment). *2008 = 95% attainment**	
Standards Met	Arsenic: 5 of the 5 samples
	Copper: 4 of the 4 samples
	Lead: 3 of the 3 samples
	Selenium: 4 of the 4 samples
	Zinc: 5 of the 5 samples
Standards Not Met	Cadmium: 0 of the 3 samples met the standard; exceedances ranged from 0.001 to 0.003 mg/L above the standard
Tubac: Overall, 12 of the 15 samples tested met the standard (80% attainment). *2008 = No data**	
Standards Met	Arsenic: 2 of the 2 samples
	Copper: 3 of the 3 samples
	Lead: 2 of the 2 samples
	Zinc: 3 of the 3 samples
Standards Not Met	Cadmium: 0 of the 2 samples met the standard; exceedances ranged from 0.0002 to 0.002 mg/L above the standard
	Selenium: 2 of the 3 samples met the standard; the single exceedance was 0.001 mg/L above the standard
Amado: No samples were collected. *2008 = No data**	

*See Corrections to 2008 water year report on page 23

Data source: Arizona Department of Environmental Quality, Friends of the Santa Cruz River, and National Park Service Sonoran Desert Network

riparian

DEPTH TO GROUNDWATER

The interactions between riparian vegetation, surface water, and groundwater in the Upper Santa Cruz River are important factors in overall riparian health. Cottonwoods and willows dominate native riparian forests in the Southwest and depend on surface water and groundwater to meet their annual water requirements.

Several scientific studies have investigated the maximum depth to groundwater required to sustain mature native riparian trees. Scientists have estimated that the maximum depth to groundwater required to sustain mature Fremont cottonwoods ranges from 2.5 to 5.1 meters.

Since the Upper Santa Cruz River is recognized for its cottonwood-willow riparian forest, locations with maximum groundwater depths less than 5.1 meters meet the scientific standard. It is important to note that areas with maximum depths to groundwater of greater than 5.1 meters may support other types of riparian vegetation.

2009 Results

A total of 17 wells within and near the 100-year floodplain were monitored at least once during the 2009 water year. Depth to groundwater measurements are determined relative to areas that may support cottonwoods and are displayed on the map on the page 19.

- **Rio Rico:** Maximum depth to groundwater levels in seven wells were: 0.93 m, 1.81 m, 2.21 m, 2.67 m, 2.97 m, 3.61 m, and 7.36 m (86% attainment). *2008 = 86% attainment*
- **Tubac:** Maximum depth to groundwater levels in six wells were: 0.99 m, 2.33 m, 2.63 m, 2.78 m, 3.58 m, and 3.59 m (100% attainment). *2008 = 100% attainment*
- **Amado:** Maximum depth to groundwater levels in four wells were: 3.58 m, 5.96 m, 6.87 m, and 9.40 m (25% attainment). While these depths may not support cottonwood forests, they are within the historical range of variability for the Amado reach. *2008 = 0% attainment*

GROUNDWATER VARIABILITY

The variability in groundwater levels affects the growth and survival of riparian plants. There are several natural and human causes of groundwater variability. Naturally, groundwater levels decline after the winter rainy season ends and increase once the summer monsoons begin. Studies on the San Pedro River, in Arizona, indicate that cottonwood trees can withstand declines in groundwater levels up to 0.8 meters from January to June. Wells with groundwater levels that decline no more than 0.8 m between January and June met this scientific standard.

2009 Results

Groundwater declines from January to June 2009 could be calculated for 8 wells that were monitored throughout the 2009 water year (see graph for annual variability in each well). Overall, 7 of the 8 wells met the scientific standard (88% attainment). Note that the decrease in percent attainment for the Rio Rico reach in the 2009 water year is likely the result of having additional data available from a second well rather than due to a significant change in groundwater levels in this reach. With small amounts of data, the addition of a well can

Data Source: Arizona Department of Water Resources and National Park Service Sonoran Desert Network

BIRDS

According to Tucson Audubon Society and the National Park Service, the birds of the Upper Santa Cruz Valley attract thousands of visitors each year. Birds are influenced by many factors at various locations that may or may not reflect what is happening at a site-specific level, such as a reach on the Upper Santa Cruz River. Therefore, birds are not an indicator for this assessment. However, because of their importance to the region, bird monitoring information is included.

In 1997, the National Park Service began to collect data at Tumacácori National Historical Park as a part of the Monitoring Avian Productivity and Survivorship (MAPS) program. The MAPS program has recorded a total of 169 species over the past 13 years. In addition to the MAPS program, the National Park Service monitors birds at Tumacácori National Historical Park using point-transect surveys during the resident bird breeding season. The Tucson Audubon Society uses similar methods to monitor birds at the Esperanza Ranch and Clark's Crossing in the Amado and Tubac reaches.

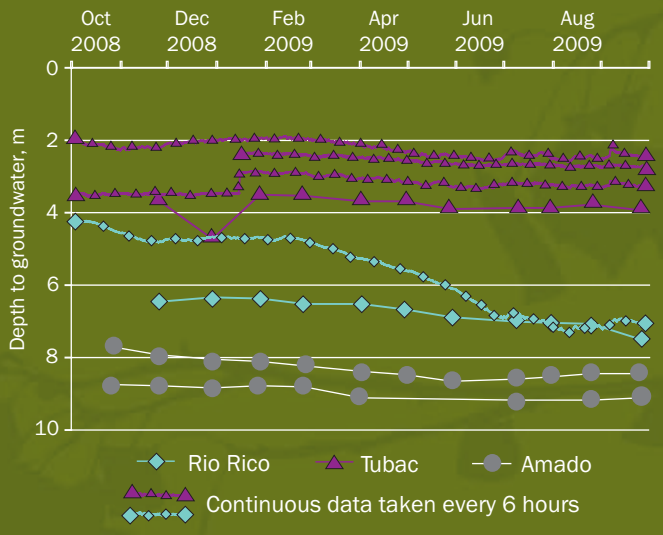
2009 Results

- **Rio Rico:** Birds were not monitored.
- **Tubac:** Surveys detected 74 native and 3 non-native species at the Tumacácori National Historical Park. The non-native species detected were European Starling, Eurasian Collared-Dove, and House Sparrow. Surveys at Clark's Crossing detected 43 native species.
- **Amado:** Surveys detected 56 native and 1 non-native species at the Esperanza Ranch. The non-native species detected was the Eurasian Collared-Dove.


Vermillion Flycatcher

cause large changes in percent attainment values. Overall, results were similar to the 2008 water year.

- **Rio Rico:** Groundwater declined 0.64 m and 2.25 m in two wells (50% attainment). *2008 = 100% attainment*
- **Tubac:** Groundwater declined 0.32 m, 0.33 m, 0.37 m, and 0.49 m in four wells (100% attainment). *2008 = 100% attainment*
- **Amado:** Groundwater declined 0.40 m and 0.49 m in two wells (100% attainment). *2008 = 100% attainment*



RIPARIAN VEGETATION

Riparian vegetation represents a small percentage of the land cover in the Upper Santa Cruz watershed, but it provides important services, functions, and benefits to the region. Riparian vegetation's many ecosystem services include filtering contaminants from effluent-dominated water before it infiltrates into groundwater drinking supplies, slowing flood waters, reducing erosion potential along stream banks, increasing groundwater recharge, and providing habitat for resident and migratory wildlife species.

In 2006, Santa Cruz County, the University of Arizona, and the Sonoran Institute mapped the riparian vegetation along the Upper Santa Cruz River. Though there is no scientific standard quantifying the amount of riparian vegetation necessary to maintain an overall healthy Upper Santa Cruz River, a simplified version of the 2006 map establishes a baseline from which to measure future changes in extent or composition of vegetation.

The types of vegetation and land cover within the river's 100-year floodplain are divided into five broad categories: cottonwood forests and woodlands; mesquite forests and woodlands; other riparian vegetation; human infrastructure; and agriculture and pasture. Forests and woodlands have greater than 10 percent cottonwood or mesquite tree cover. Other riparian vegetation includes areas not dominated by cottonwood or mesquite trees. Human infrastructure includes areas with roads, railroads, and housing. Agriculture and pasture include crop fields and pasture land. The 2006 baseline map was updated by using hundreds of aerial photos to identify large changes (>1 acre) in these five categories. Though aerial photos from 2007, 2008, and 2009 were used to update the baseline map, over 60% of the observed changes occurred during the 2009 water year. The results of the updated vegetation map are shown on the opposite page.

Overall there were no major changes in extent of riparian vegetation, with nearly 2,500 acres (36%) of the area within the 100-year floodplain dominated by cottonwoods (over 1,000 acres) and mesquites (nearly 1,400 acres); over 500 acres (8%) used for human infrastructure; and 1,700 acres (25%) used for crops or pastures. There was a small decrease in the extent of cottonwoods and mesquites due to several small fires in the riparian area in 2008 and 2009, as well as some clearing of land for pasture. Even with a few fires in the Tubac area, this reach still has the largest percentage of area dominated by cottonwoods (26%) compared to the Rio Rico (13%) and Amado (8%) reaches.

The following legend corresponds to well monitoring, displayed on the map at right. Wells that met the scientific standard are shown in light green and grey. Wells that did not meet the scientific standard are shown in yellow-green.

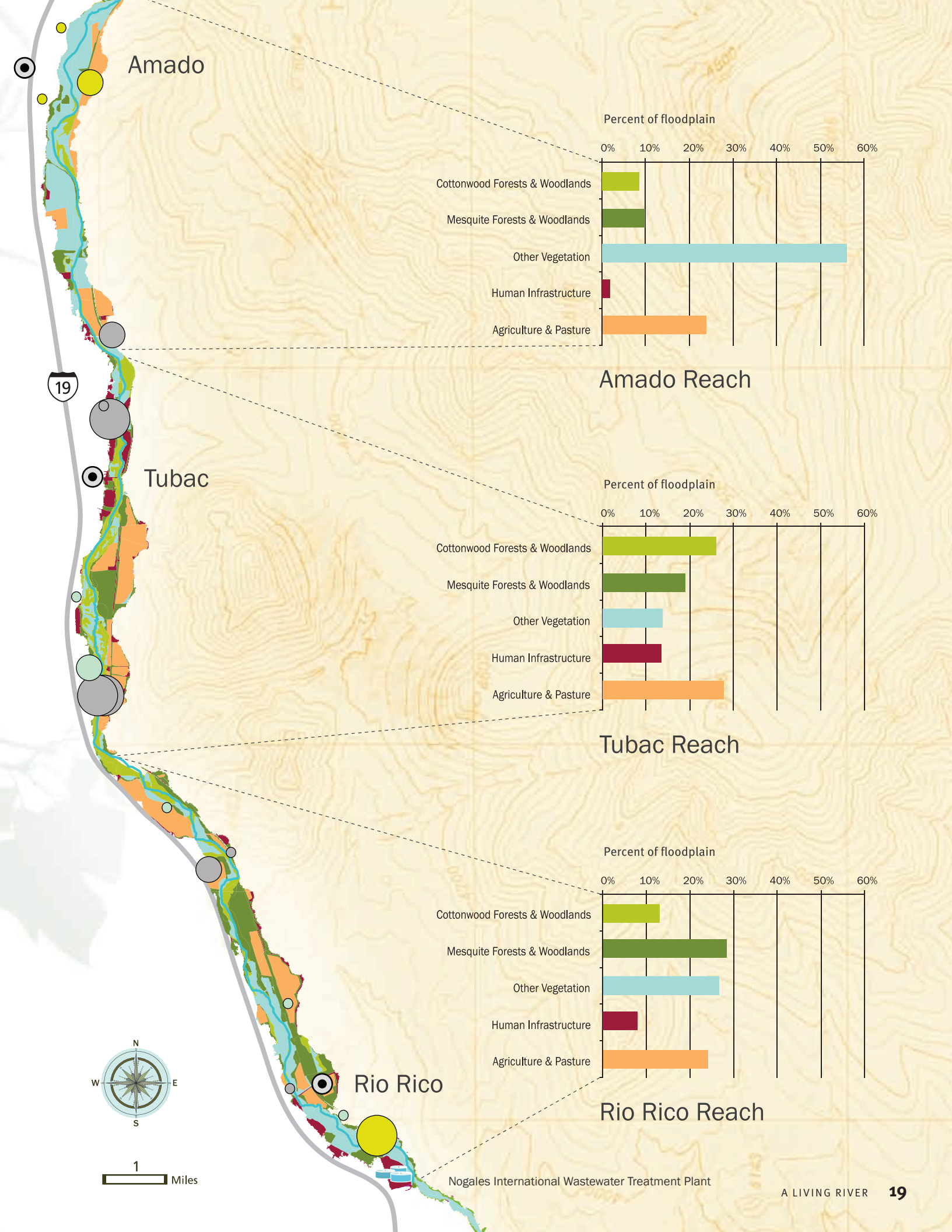
Maximum depth

- < 2.5 m
- 2.5 – 5.1 m
- > 5.1 m

Number of measurements

- 1
- 2 – 12
- Continuous

Overflight for photography of riparian vegetation generously provided by Lighthawk (www.Lighthawk.org)


Amado
Tubac
Rio Rico
19
N
W
E
S
1
Miles
Nogales International Wastewater Treatment Plant
Percent of floodplain
0%
10%
20%
30%
40%
50%
60%
Cottonwood Forests & Woodlands
Mesquite Forests & Woodlands
Other Vegetation
Human Infrastructure
Agriculture & Pasture
Amado Reach
Percent of floodplain
0%
10%
20%
30%
40%
50%
60%
Cottonwood Forests & Woodlands
Mesquite Forests & Woodlands
Other Vegetation
Human Infrastructure
Agriculture & Pasture
Tubac Reach
Percent of floodplain
0%
10%
20%
30%
40%
50%
60%
Cottonwood Forests & Woodlands
Mesquite Forests & Woodlands
Other Vegetation
Human Infrastructure
Agriculture & Pasture
Rio Rico Reach

ECOLOGICAL HEALTH SUMMARY

Data in the 2009 water year indicate several areas of improvement on the Upper Santa Cruz River since the 2008 water year (visit the Sonoran Institute website for a side-by-side comparison of the data from the two reports). Overall, health of the aquatic ecosystem showed signs of improvement, and the riparian ecosystem remained relatively stable. In the aquatic ecosystem, there was an increased presence of aquatic animals and better water quality. Much of this improvement occurred after the upgrade to the Nogales International Wastewater Treatment Plant in Rio Rico, Arizona, was completed in March 2009.

During the 2009 water year, levels of ammonia decreased following the NIWTP upgrade, and there were no instances of very high levels of phosphorus. While dissolved oxygen passed the standard in both the 2008 and 2009 water years, levels tended to increase in the months following the NIWTP upgrade.

Although there were improvements in water quality, *E. coli* levels and concentrations of metals caused some concern. During the 2009 water year, *E. coli* levels posed a risk to humans swimming in or drinking from the Upper Santa Cruz River. *E. coli* levels during the summer monsoon season

Category	Indicators and Standards	% Attainment of Standard**					
		Rio Rico		Tubac		Amado	
		2008	2009	2008	2009	2008	2009
aquatic	**Dissolved oxygen:** > 1 mg/L	100%	100%	100%	100%	100%	100%
	Ammonia: varies with temperature & pH	0%	40%	0%	57%	no data	100%
	Total phosphorus: < 5 mg/L	25%	20%	25%	86%	no data	100%
	E. coli: < 235 CFU/100mL	66%	50%	34%	61%	33%	67%
	Metals: varies by specific metal	95%*	88%	no data*	80%	no data*	no data
	Aquatic invertebrates: 2008 baseline	no data		no data		baseline	
	Fish: 2008 baseline	+		+		+	
riparian	**Depth to groundwater:** < 5.1 m	86%	86%	100%	100%	0%	25%
	Groundwater variability: < 0.8 m/yr	100%	50%	100%	100%	100%	100%
	Riparian vegetation: 2006 baseline	no change		no change		no change	

**For indicators lacking a standard whose data is compared to a baseline in order to track change, direction of change is summarized with: "+" increase, "-" decrease, or "no change" for indicators that have not significantly changed over the past year.

*See Corrections to 2008 water year report on page 23

ECOLOGICAL HEALTH SUMMARY CONTINUED

consistently exceeded the swimming (full body contact) standard, indicating that there are likely multiple sources of contamination. Levels of cadmium were above the standard for wildlife in both the Rio Rico and Tubac reaches and posed a risk to aquatic organisms. Research to identify the sources of *E. coli* and cadmium is already underway.

Fish surveys conducted during the fall of 2009 found numerous Longfin Dace in all reaches compared to only two individuals in the fall of 2008. In addition, non-native Western Mosquitofish were found in the Tubac and Amado reaches. Continued monitoring will determine if the aquatic ecosystem can support greater numbers of individuals and species of native fish. Information on the Upper Santa Cruz River's aquatic invertebrate population remains limited, as samples collected in the Tubac reach were not analyzed by press time. Though the aquatic invertebrate assemblage in Amado contained only a small percentage of pollution tolerant species, the dominance of a single family (Erpobdellidae) suggests that this reach could be under environmental stress.

Maximum depth to groundwater levels in the Rio Rico and Tubac reaches met the scientific standard for sustaining cottonwood forests. Although the maximum depths to groundwater in the Amado reach did not meet the scientific standard, depths were within the historical range of data and this reach has not historically had cottonwood forests. Groundwater variability in 2009 was similar to the results in 2008. The change in groundwater variability in the Rio Rico reach is likely the result of having additional data available from a second well rather than due to a significant change in groundwater levels in this reach. Groundwater varies with location, and additional data provides a better understanding of a reach's conditions.

There was little change in the extent of riparian vegetation, with nearly 2,500 acres (36%) of the area within the 100-year floodplain dominated by cottonwoods (over 1,000 acres) and mesquites (nearly 1,400 acres). The Tubac reach continues to have the largest percentage of area dominated by cottonwoods (26%) compared to the Rio Rico (13%) and Amado (8%) reaches. Over 2,000 acres are used by humans for infrastructure, crops, and pastures.

ONGOING EFFORTS

This report builds on numerous research and monitoring efforts that have been tracking conditions along the river. Data that contributed to this assessment of conditions along the Upper Santa Cruz River during the 2009 water year were collected by the following organizations:

- Arizona Department of Environmental Quality—water quality monitoring as part of the Monitoring and Assessment Program which ensures that water quality standards are being met.
- Arizona Department of Water Resources—monitoring of groundwater levels.
- Friends of the Santa Cruz River—monthly water quality monitoring by trained volunteers with support from ADEQ as part of RiverWatch and annual fish surveys conducted with the Arizona Game and Fish Department and the U.S. Fish and Wildlife Service.
- National Park Service—monitoring of birds, water quality, flow, and aquatic and riparian conditions within the Tumacácori National Historical Park.
- National Weather Service—continuous monitoring of precipitation and weather.
- Sonoran Institute—monitoring of aquatic and riparian conditions in the Tubac and Amado reaches and the extent of riparian vegetation along the Upper Santa Cruz River from the international border to Amado.
- Tucson Audubon Society—monitoring of birds in the Amado and Tubac reaches.
- U.S. Geological Survey—continuous monitoring of streamflow in the Upper Santa Cruz River.

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The Sonoran Institute convened a Science Advisory Committee of ecology, hydrology, and wildlife experts to bring the best available science to bear on the development of the *Living River* health assessments and a State of the Upper Santa Cruz River Report (to be published in 2011).

The Committee provided scientific guidance on: identifying indicators of riparian health, establishing standards for ecological health, aggregating indicators to quantify riparian health, 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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Gita Bodner, The Nature Conservancy
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Additional reviewers of this report provided valuable knowledge, insight, and assistance. We wish to acknowledge those reviewers who are not otherwise members of the Science Advisory Committee:

Arizona Department of Water Resources — Keith Nelson
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University of Arizona — Rosalind Bark
U.S. Environmental Protection Agency — Jared Vollmer and Matt Weber
U.S. National Park Service — Colleen Filippone, Andy Hubbard, and Larry Norris


Rufous-crowned Sparrow

SONORAN INSTITUTE MISSION AND VISION

The Sonoran Institute's mission is to inspire and enable 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.

Our passion is to help shape the future of the West with:

- **Healthy Landscapes** that support native plants and wildlife, diverse habitat, open spaces, clean energy and water, and fresh air.
- **Livable communities** where people embrace conservation to protect quality of life today and in the future.
- **Vibrant economies** that support prosperous communities, diverse opportunities for residents, productive working landscapes and stewardship of the natural world.

The Sonoran Institute is a nonprofit organization with offices in Tucson and Phoenix, Arizona; Bozeman, Montana; Glenwood Springs, Colorado; Cheyenne and Sheridan, Wyoming; and Mexicali, Baja California, Mexico. For more information, visit **www.sonoraninstitute.org**

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CORRECTIONS TO: *A Living River: Charting the Health of the Upper Santa Cruz River 2008 Water Year*

- Metals were not compared to the newly accepted standards as noted in the 2008 report on page 9. If they had been compared to the new standards, results would have included one exceedance for cadmium in the Rio Rico reach and resulted in a total of 95% attainment for all metals.
- Metals were only collected in the Rio Rico reach. The final summary table on page 20 should have read Rio Rico "95%," Tubac "no data," and Amado "no data" for percent attainment of the standard.
- One well in each of the Rio Rico and Tubac reaches was incorrectly displayed in green on the map on page 19. These should have been grey as their maximum depth was between 2.5 and 5.1 meters.

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GET INVOLVED

If you would like to contribute to research, monitoring, or conservation efforts along the Upper Santa Cruz River, here are some actions you can take:

- Join Friends of the Santa Cruz River and volunteer with RiverWatch to monitor water quality. To sign up visit: ***www.friendsofsantacruzriver.org***.
- Volunteer with the Audubon's Important Bird Areas Program in Arizona and monitor birds in the Upper Santa Cruz River Important Bird Area (Tumacácori to Amado). Contact the Tucson Audubon Society at 520-629-0510 Ext. 7004, or go to: ***www.aziba.org***.
- Visit Tumacácori National Historical Park and Sonoita Creek State Natural Area to learn more about the plant and animal life in riparian systems.
- Check Sonoran Institute's website for an electronic copy of this report, as well as the 2008 *Living River* report, and for a side-by-side comparison of the data from the 2008 and 2009 water years. Additional updates on Upper Santa Cruz River conservation projects are also available: ***www.sonoraninstitute.org***.

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