



Gulf Coast Network Water Quality Report

Status of Water Quality of San Antonio Missions National Historical Park

Natural Resource Technical Report NPS/GULN/NRTR—2012/588



ON THE COVER

Acequia de Espada aqueduct crossing Peidras Creek.
Photo by Joe Meiman, August 29, 2011.

Gulf Coast Network Water Quality Report

Status of Water Quality of San Antonio Missions National Historical Park

Natural Resource Technical Report NPS/GULN/NRTR—2012/588

Joe Meiman

National Park Service, Gulf Coast Network
646 Cajundome Boulevard, Room 175
Lafayette, LA 70506

June 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available from the Gulf Coast Inventory & Monitoring (I&M) Network website (<http://www.nature.nps.gov/im/units/guln/>), and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

Please cite this publication as:

Meiman, Joe. 2012. Gulf Coast Network water quality report: Status of water quality of San Antonio Missions National Historical Park. Natural Resource Technical Report NPS/GULN/NRTR—2012/588. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Acronyms and Abbreviations	ix
Gulf Coast Network Long-Term Water Quality Monitoring.....	1
Measureable Objectives.....	2
Brief Hydrologic Introduction of San Antonio Missions National Historical Park.....	3
Threats to Water Quality	4
Recreational Use and Aquatic Life.....	7
Existing Water Quality Information	7
Sampling Sites	9
Stream Designated Uses and Water Quality Standards	19
Parameters for Water Quality Inventory.....	21
Field Measures.....	21
Laboratory Measures	22
Water Quality Status	25
Bimonthly Sample Results	25
Summary	41
References.....	43

Figures

	Page
Figure 1. The San Antonio River Mission Reach restoration at Espada Park, facing downstream.	5
Figure 2. Map of water quality sampling sites at SAAN.	9
Figure 3. Piedras Creek, facing downstream.	10
Figure 4. Acequia de Espada, facing upstream.	11
Figure 5. San Antonio River at San Juan Capistrano Mission, facing downstream.	12
Figure 6. Acequia de San Juan, facing downstream.	13
Figure 7. SARA site 17066 on the San Antonio River, facing upstream.	14
Figure 8. SARA site 12897 on the San Antonio River, facing upstream.	15
Figure 9. SARA site 12881 on the San Antonio River, facing upstream from the State Highway 97 bridge.	16
Figure 10. Picoso Creek from the SH 97 bridge, facing downstream.	17
Figure 11. Ammonia levels at SAAN (n = 118).	27
Figure 12. Chloride at SAAN (n = 290).	28
Figure 13. Dissolved oxygen at SAAN (n = 426).	29
Figure 14. Nitrate and precipitation at SAAN (n = 292).	30
Figure 15. Nitrite at SAAN (n = 106).	31
Figure 16. Total Kjeldahl nitrogen at SAAN (n = 248).	32
Figure 17. pH at SAAN (n = 427).	33
Figure 18. Specific conductance at SAAN (n = 457).	34
Figure 19. Sulfate at SAAN (n = 201).	35
Figure 20. Total organic carbon for SAAN (n = 219).	36
Figure 21. Total discharge (flow) at SAAN (n = 270).	37
Figure 22. Total phosphorous at SAAN (n = 214).	38
Figure 23. Water temperature at SAAN (n = 430).	39

Tables

	Page
Table 1. Typical water quality of the Edwards Aquifer and recycled water used to recharge the San Antonio River.....	6
Table 2. 2010 303d listing for water bodies upstream of SAAN.....	6
Table 3. Stream Designated Uses.	19
Table 4. Water quality standards for parameters measured at SAAN.	20
Table 5. Brief statistical summary of SAAN (October 2007–December 2011) and SARA CRP (November 1999–December 2010) bimonthly sample results.	26
Table 6. Exceedances of state water quality standards at SAAN, 2007–2011.	26

Acronyms and Abbreviations

AEAE	Acequia de Espada
ASJC	Acequia de San Juan
°C	degrees Celsius
CaCO ₃	calcium carbonate
cfs	cubic feet per second
cl	chloride
cm	centimeter
CRP	Clean Rivers Program
DO	dissolved oxygen
Fe	iron
FM	Farm to Market Road
GULN	Gulf Coast Network
ha	hectare
km	kilometer
LDL	lower detection limit
m	meter
mg/l	milligrams per liter
n	number of a population (or measurements)
NH ₃	ammonia
NH ₃ -N	ammonia-nitrogen
NO ₂	nitrite
NO ₂ -N	nitrite-nitrogen
NO ₃	nitrate
NO ₃ -N	nitrate-nitrogen
NPS	National Park Service
PCPC	Piedras Creek
SAAN	San Antonio Missions National Historical Park
SARA	San Antonio River Authority
SAWS	San Antonio Water System
SH	State Highway
SiO ₂	silicon dioxide
SM	standard methods for the examination of water and wastewater
SO ₄	sulfate (sulfur and oxygen)
SOP	standard operating procedure
SpC	specific conductance

Acronyms and Abbreviations, cont'd

SRSJ	San Antonio River at Mission San Juan Capistrano
SU	standard unit (pH)
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TOC	total organic carbon
TP	total phosphorous
TPWD	Texas Parks and Wildlife Department
TSS	total suspended solids
µS/cm	microSiemens per centimeter
U.S.C.	United States Code
UDL	upper detection limit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Gulf Coast Network Long-Term Water Quality Monitoring

Water quality ranked among the top vital signs and was chosen to be monitored long term in the eight parks composing the National Park Service's (NPS) Gulf Coast Network (GULN). Water quality monitoring program protocols and standard operating procedures (SOPs) are located in the GULN Vital Signs Monitoring Plan (Segura et al. 2007). The report that follows is a park-specific document that describes the status of water quality knowledge, including a description of the monitoring program, sampling sites, parameters tested, results in graphic form (when available), a brief interpretation of the results, and recommendations of parameters to be measured along with long-term sampling locations and frequency.

Sampling sites were chosen following site visits by GULN hydrologist Joe Meiman in consultation with park staff. Some sites were chosen to coincide with past inventories and monitoring efforts. In most cases, sites were chosen at the downstream end of a watershed (or where a stream enters or leaves a park) to serve as an integrator of the basin, and should yield characteristics of, and contributions from, the entire watershed. Other near-shore and estuarine sites were chosen with respect to other key park resources, such as seagrass beds.

The NPS's Water Resources Division requires each network water quality program to monitor four core field parameters: water temperature, pH, specific conductance, and dissolved oxygen. While these key parameters are essential, additional parameters that are tailored to specific parks were chosen to reflect particular water quality issues.

Non-conditional synoptic sampling, where samples are taken regardless of flow and weather conditions on fixed calendar dates, is central to this effort. Basic fixed sampling locations are at integrator sites (locations commonly at tributary confluences or springs, which are representative of water quality issues of individual sub-basins) and indicator sites (locations downstream from either suspected or documented water quality threats, or pristine conditions). It is recognized that in order to best fit with other GULN monitoring activities, some flexibility in site selection is required. This strategy, over the long term, has proven to yield statistically valid data used to track long-term trends in water quality.

Specific management objectives, past water quality history, biological significance, recreational use, enabling legislation, and field logistics were considered separately for each GULN park in the design of a long-term program. While parameter lists may vary from park to park, and sampling frequency is dictated by extant programs or resource importance, there are several fundamental constants to the GULN program. Namely, all measurements are done in accordance with SOPs that are adapted from agencies such as the U.S. Geological Survey (USGS) or the Texas Commission on Environmental Quality (TCEQ). All contract laboratories are accredited with the National Environmental Laboratory Council. All in-house analyses are conducted according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association 2005).

Measurable Objectives

This is a long-term monitoring program. It is not designed to respond to catastrophic or singular water quality events. It is designed to form a comparative database to detect changes in a variety of water quality parameters over time within an individual park or stream. Parks within a particular ranking category may be cross-comparable, but charting changes in water quality within a particular park is the primary statistical objective for the long-term data. Through a series of Vital Signs Workshops and other meetings with park managers, the water quality monitoring program was devised to meet the management objectives of the GULN parks. These measurable objectives are as follows:

- Provide a backdrop to compare changes in the aquatic biologic community.
- Compare water quality to Texas water quality standards.
- Identify stressors such as land uses and land use change within the watershed.
- Determine potential pollutant sources (non-point source contaminants versus point sources).
- Ascertain impacts to water quality by in-park activities within selected watersheds.
- Determine regional effects of atmospheric contaminants (e.g., acid precipitation).

Brief Hydrologic Introduction of San Antonio Missions National Historical Park

The availability of a constant, reliable water supply has greatly affected human cultural geography. In the latter part of the seventeenth century, the Spanish Crown supported Franciscans to build missions to establish a presence in northern Mexico (present-day Texas) and spread the Catholic faith among the native peoples. Water was an essential feature in the location of any mission or presidio and a major factor in establishing Mission San Antonio de Valero, the first mission of five along the San Antonio River, in 1718.

In a semiarid land like south-central Texas, the spring-fed San Antonio River has been a cultural oasis for centuries. The importance of this water is evident throughout the 331 hectares (ha) of San Antonio Missions National Historical Park (SAAN). Indeed, the Missions would not have been built if not for the river as missionaries and native peoples (the Coahuiltecans) irrigated their fields via an intricate system of acequias. Acequias are gravity-driven ditches tapped into the river above low-head dams. Missions also held large grazing areas, also heavily reliant on surface water. SAAN includes Mission Espada's Rancho de las Cabras, located about 80 kilometers (km) downstream at the confluence of Picoso Creek and the San Antonio River.

By the first half of the nineteenth century, over 50 miles of acequias existed and the importance of routine maintenance and water quality were evident as they and the river were the primary sources of drinking water. Porter in his 2009 book, *Spanish Water, Anglo Water: Early Development in San Antonio*, describes an 1829 City Ordinance "Regarding Public Health" that contains two provisions relative to water quality. The first stated that "individuals responsible for acequia maintenance must perform a perfect job, less be fined, and that no new water could flow into an acequia without examination by the Chief of Police." The second declared that "no dead animals, pelts or other type of corruptible refuse be cast into the acequia." The city attorney was responsible to enforce this provision and had the authority to levy fines for violations. Porter (2009) further states that fines could be imposed for those "spoiling, obstructing, or polluting the water in the acequia, even when caused by domestic animals." He further notes that water quality issues were addressed as early as 1775 when Amador Delgado, alcalde (mayor) of Villa de San Fernando de Bejar (the early settlement of which grew into San Antonio) outlawed the washing of clothes in the acequia to protect the water quality of those living "down-ditch."

In spite of attempts to maintain water quality, the acequias were overwhelmed by the mid-nineteenth century (Porter 2009). Cholera epidemics broke out in San Antonio in 1845, 1849, and 1866. The final epidemic stirred public opinion to seek options for delivering safe, reliable drinking water. Eventually drinking water was delivered to San Antonio households, small farms tied to gravity irrigation faded, and acequias were abandoned. Today, the river has been supplanted by its source, the Edwards Aquifer, in supplying the ever-growing demand of drinking water for the San Antonio area.

Extended droughts and the huge demand for water have taxed the river to the point where natural recharge from its headwater spring is becoming an uncommon event. During the latter portion of the twentieth century, the San Antonio River, including its famous "River Walk," would not flow without augmentation from Edwards Aquifer wells. However the use of the drinking water supply to recharge a river proved costly and San Antonio looked to reuse waters to sustain

economic and environmental flows. Treated wastewater, or also known as reuse water, or recycled water, is a responsibility of the San Antonio Water System (SAWS), a public authority created by the State of Texas in 1992. Its reuse water system was completed in 2000 and consists of massive pumps and over 130 km of pipe connecting the Leon Creek, Salado Creek, and Dos Rios Water Recycling Centers to customers for golf course irrigation and industrial cooling as well as recharging the San Antonio River. Reuse water consisting of tertiary and advanced-secondary treated wastewaters (an annual system-wide capacity of 35,000 acre-feet, or nearly 11.5 billion gallons) is discharged into the San Antonio River and streams adjacent to the facility, pumped upstream to customers, or recharges the river at the Witte Museum and Convention Center. To highlight how dependent the San Antonio River is on reuse water, consider that the flow in the Urban Reach (the river from its headwaters down to the Interstate Highway 410 [I-410, or Loop 410] crossing) consists of 70 to 95 percent reuse water (San Antonio River Authority [SARA], personal communication 2011).

While the park does not own any portion of the San Antonio River, it does own land down to the high-water mark in some areas. The quality and quantity of water plays not only an important aesthetic interpretative backdrop, but also directly supplies flow to the acequias, which are owned and maintained by the park within park boundaries. SARA is title holder of the riverbed and banks of the river and tributaries. The park retains water rights to the two remaining mission acequias, the Acequia de Espada, flowing along the west side of the river, and the Acequia de San Juan on the east side. In September 2011, the park opened flow into the Acequia de San Juan, inactive since 1978, after the remediation of a hazardous spill site along its course. The park also manages a short segment (approximately 100 meters [m]) of Piedras Creek, from the Acequia de Espada aqueduct to its confluence with the San Antonio River.

The San Antonio River leaves the greater urban area and becomes a free-flowing, undeveloped stream to the south. Approximately 75 km downstream, the river flows along the Rancho de las Cabras unit, which was used during mission times to graze livestock. The Rancho de las Cabras also includes the seasonal Picos Creek, which joins the San Antonio River in the park. Approximately 80 km upstream of the Rancho is the confluence of the Medina River and Dos Rios Wastewater Treatment Facility. The Dos Rios facility is permitted to add an annual average flow of 125 million gallons (190 cubic feet per second [cfs]) to the San Antonio River each day (SARA 2008). During low-flow conditions, the San Antonio River downstream from the Medina is nearly 100 percent reuse water.

Threats to Water Quality

No other park in the GULN has as much alteration, modification, or development of its watershed and surrounding area as the San Antonio Missions National Historical Park. It is beyond the scope of this report to list all threats to the water quality to the San Antonio River. The park is surrounded and drained from a metropolitan area with nearly every conceivable land use present: the 2010 U.S. Census reports populations of 1.3 million in San Antonio and 1.7 million in Bexar County. In 1999, 17 permitted industrial dischargers above the Missions unit were identified along with an additional 11 dischargers above the Rancho unit (NPS 1999). This is in addition to urban and highway runoff and countless other non-point sources.



Figure 1. The San Antonio River Mission Reach restoration at Espada Park, facing downstream. The river is temporarily contained in a ditch visible on the left descending bank. Photo by Joe Meiman, August 30, 2011.

It is important to address the quality and quantity of water provided by SAWS. As discussed above, without the addition of reuse water, the San Antonio River would either be supplemented by valuable drinking water supplies of the Edwards Aquifer or go dry. SAWS provides a valuable service to the economy and ecology of the river. Although the reuse water has elevated nutrients that may alter the natural aquatic community, it can easily be argued that it is better than no water at all. Water quality typical of the Edwards Aquifer (used as a drinking water supply and, prior to 2000, used to supplement flow of the San Antonio River) and recycled or reuse water is provided by SAWS (Table 1). Note that several parameters for reuse water exceed state TCEQ screening levels: ammonia 0.33 milligrams per liter (mg/l); nitrate 1.95 mg/l; and total phosphate 0.69 mg/l. Chloride is typically just below the state water quality standard of 150 mg/l.

Under Section 303(d) of the Federal Pollution Control Act (33 U.S.C. 1251 et seq., commonly known as the Clean Water Act) states, territories, and authorized tribes are required to develop lists of impaired waters. Impairment is defined as failing to meet water quality standards as per a water body's state-defined designated use. The law requires that these jurisdictions establish priority rankings for waters on the 303(d) list (non-attainment list) and develop Total Maximum Daily Loads (TMDL) for these waters. A TMDL describes the maximum amount of a pollutant that a body of water can receive and still meet its water quality standards. Much of the Upper San Antonio River, including the entire reach through the Missions unit, is on the Texas 303(d) list for non-attainment because bacteria standards for contact recreation are routinely exceeded. The Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) lists the streams upstream of SAAN shown in Table 2 as non-attainment (TCEQ 2010).

Table 1. Typical water quality of the Edwards Aquifer and recycled water used to recharge the San Antonio River.

Values that routinely exceed state screening levels are highlighted in bold.

Component	Units	Edwards Aquifer	Recycled Water
pH	pH	7.2	7.4
Calcium as CaCO ₃	mg/l	205	225
Magnesium as CaCO ₃	mg/l	58	75
M-Alkalinity as CaCO ₃	mg/l	228	215
Conductivity	μS/cm	460	1,000
Silica as SiO ₂	mg/l	12	14
Chlorides as Cl	mg/l	25	117
Sulfates as SO ₄	mg/l	26	53
Iron as Fe	mg/l	<0.2	0.05
Nitrate as NO ₃	mg/l	<1.0	31–71
Nitrite as NO ₂	mg/l	0.0	0.0–1.2
Ammonia as NH ₃	mg/l	0.0	1.1–4.2
Total Phosphate as PO ₄	mg/l	0.2	4–11
Organics as BOD	mg/l	0.0	2
Total Suspended Solids	mg/l	<5	0.5–1.0
Total Chlorine as Cl ₂	mg/l	<1.0	1.0–1.5

Table 2. 2010 303d listing for water bodies upstream of SAAN.

Stream	Segment	Problem	Category	First Listed
Upper San Antonio River	660 m downstream of FM 791 to 100 m upstream of Hildebrand	Impaired fish community Bacteria	5c	2006
San Pedro Creek	Entire water body	Bacteria	5a	2010
Apache Creek	From confluence of San Pedro Creek to Spur 421	Bacteria	5a	2010
Alazan Creek	From confluence of Apache Creek to upstream of St. Cloud Road	Bacteria	5a	2010

Category denotes administrative status:

5a – A TMDL is underway, scheduled, or will be scheduled.

5b – A review of water quality standards will be conducted before a TMDL is scheduled.

5c – Additional data will be collected before a TMDL is scheduled.

Recreational Use and Aquatic Life

The San Antonio River through the Missions unit is classified by the state of Texas as contact recreation with a high diversity of aquatic life. The park does not promote or provide direct access to the river. There is no prevalent recreational use of the acequias or Piedras Creek managed by the park.

There are no federally listed threatened or endangered aquatic species for San Antonio Missions National Historical Park. The most recent fish inventory was completed for SARA by Gonzalez and Moran (2005) and includes an overview of the fishes found in the river, Piedras Creek, Acequia de Espada, and Picos Creek. In addition to the fish survey, water quality samples were collected and results provided. Gonzalez and Moran (2005) collected 4,912 individuals, representing 27 species. Non-native fishes made up 37 percent of all species and 36 percent of all individuals collected. Species diversity was largely a reflection of habitat. They conclude that the water quality parameters indicated conditions that can support a high aquatic life use (a condition reflective with the designated stream use).

Existing Water Quality Information

Water quality and quantity have been important issues to the San Antonio region for decades, and as growth continues, they will remain so well into the future. In order to monitor the river's (and its tributaries) quality, several efforts have been underway over the past decade. SARA was originally created by the Texas Legislature in 1937 to seek development of a barge canal linking San Antonio to the Gulf of Mexico and is now charged with preservation and management of resources of the river and its tributaries. SARA works in conjunction with the TCEQ's Clean Rivers Program (CRP) and the USGS in regional water quality monitoring planning. Through this combined effort, 41 water quality sampling locations are routinely (six times per year) sampled throughout the Upper San Antonio River.

Five of these SARA permanent water quality stations have direct monitoring benefits to the park; the river immediately upstream and immediately downstream of the Missions, and immediately upstream of the Rancho de las Cabras unit. These stations have been typically sampled six times per year since 1999. Parameters sampled at the five stations include water temperature, pH, specific conductance, dissolved oxygen, flow, total suspended solids, *Escherichia coli*, nitrogen, phosphorous, total organic carbon, chloride, and sulfate.

As stated previously, the park does not own or manage the river, but it does retain water rights for the acequias. Very little water quality monitoring has been done in the acequias, as it was generally assumed that because the river was the sole source of acequia water, its quality must be similar, if not identical. However, in an NPS-funded inventory, SARA found low dissolved oxygen and elevated phosphorous in the Acequia de Espada at the Piedras Creek aqueduct (Gonzalez and Moran 2005). This study also sampled Piedras Creek as it entered the park at the aqueduct. The heavily urbanized watershed also displayed low dissolved oxygen and elevated phosphorous, indicative of non-point source contamination.

Sampling Sites

The SARA routine monitoring sampling sites, core parameters, sample frequency, sampling protocols and analysis were considered when designing the SAAN sampling plan to allow comparison of SAAN samples with the upper watershed at large. Through a fee-for-services contract, SARA now includes an additional four sites within the SAAN in their bimonthly sampling schedule as part of the TCEQ CRP. Sampling at the four park-specific sites began in October 2007 and SARA's sampling of related sites in the Upper San Antonio River dates back to 1999 (Figure 2). The 5-digit numeric codes are the TCEQ CRP sites monitored by SARA that have direct monitoring benefits to the park. Four-character alpha codes represent the additional four sampling sites added within GULN. SARA site 12881 is on the San Antonio River just upstream of the Rancho de las Cabras unit and site 20350 is on the intermittent Picos Creek.



Figure 2. Map of water quality sampling sites at SAAN.

Piedras Creek (PCPC): Piedras Creek is monitored as it enters park lands at the crossing of Acequia de Espada aqueduct. Also known as Six Mile Creek, PCPC drains a highly urbanized watershed west of the river.



Figure 3. Piedras Creek, facing downstream.
The Acequia de Espada aqueduct is visible crossing the creek as it enters the park.
Photo by Joe Meiman, September 26, 2006.

Acequia de Espada (AEAE): This acequia is sampled immediately downstream of its Piedras Creek crossing. The acequia headgate, the Espada Dam, draws water directly from the Urban Reach (the portion of the San Antonio River upstream of Loop 410).



Figure 4. Acequia de Espada, facing upstream.
Note heavy growth of duckweed compared with the same scene in August 2011 (on cover).
Also, much of the thick vegetation overhanging the acequia has been removed as compared
with the latter scene.
Photo by Joe Meiman, September 26, 2006.

San Antonio River at Mission San Juan Capistrano (SJSR): The San Antonio River emerges from three concrete culverts as it enters the only natural reach of the Urban Reach. The river flows through this stretch, complete with heavy riparian vegetation, passing through the Mission grounds, and reentering the modified channel after approximately 1 km.



Figure 5. San Antonio River at San Juan Capistrano Mission, facing downstream. Photo was taken from the culvert outlet that empties into this only remaining natural section of the Urban Reach. Photo by Joe Meiman, August 29, 2011.

Acequia de San Juan at Mission San Juan Capistrano (ASJC): Flow was returned to the Acequia de San Juan in September 2011 for the first time since 1978. Water sampling began in October 2011. The acequia headgate, the Archimedes Screw, draws water directly from the Urban Reach (the portion of the San Antonio River upstream of Loop 410).



Figure 6. Acequia de San Juan, facing downstream.
Photo by SAAN staff, September 27, 2011.

The following sites, while not within the park, are hydraulically related and are routinely sampled by SARA (identical protocols, frequency and parameters as SAAN sites).

San Antonio River (SARA site 17066): This site is at Mission Road downstream of the confluence of San Pedro Creek. The river flows within a flood control channel over this reach, typical of the San Antonio River within city limits. This site is within the Mission Reach Restoration Project and has since undergone major changes to stream channel and riparian habitat.



Figure 7. SARA site 17066 on the San Antonio River, facing upstream.
Red shopping carts in right mid-ground provide scale.
Photo by Joe Meiman, October 26, 2006.

San Antonio River (SARA site 12897): This site is located immediately downstream of the Missions unit, adjacent to Mission Espada. The river still flows within a flood control channel, but is soon to be restored as part of the Mission Reach. Shortly downstream of this site the river returns to its natural channel.



Figure 8. SARA site 12897 on the San Antonio River, facing upstream.
Photo by Joe Meiman, October 26, 2006.

San Antonio River (SARA site 12881): This site is directly upstream of the Rancho de las Cabras unit. Unlike river sites upstream, the San Antonio River channel retains a relatively unaltered condition by the time it reaches the Rancho de las Cabras. At this point the river is free flowing in a natural channel.



Figure 9. SARA site 12881 on the San Antonio River, facing upstream from the State Highway 97 bridge. Photo by Greg Mitchell, November 9, 2006.

Picoso Creek (SARA site 20350): This stream is sampled upstream of the Rancho de las Cabras at State Highway 97 (SH 97). Picoso Creek is a seasonal stream and was reduced to isolated pools during the drought of 2011.



Figure 10. Picoso Creek from the SH 97 bridge, facing downstream. Texas was experiencing a severe drought when this photo was taken. Picoso Creek was reduced to a series of isolated, stagnant pools. Photo by Joe Meiman, August 29, 2011.

Stream Designated Uses and Water Quality Standards

Each water body sampled within the GULN has either been assigned a designated use by the state or, by using the same ranking criteria, by this author (in red) (Table 3). The Upper San Antonio River (river segment 1911) is designated as “Contact Recreation” and “High Aquatic Life” (however, the city of San Antonio prohibits swimming in the river). Nearly every water body in Texas with the exception of shipping channels is listed as “Contact Recreation.”

Although it is reasonable to assume that no one uses the Acequia de Espada or the Acequia de San Juan Capistrano in such a manner, they flow directly out of and into the San Antonio River and should adhere to the same standard.

Table 3. Stream Designated Uses.

Park	Code	Site	State	Designated Use
SAAN	PCPC	Piedras Creek	TX	CR H
SAAN	AEAE	Acequia de Espada	TX	CR H PS
SAAN	SJSR	San Antonio River at Mission San Juan Capistrano	TX	CR H PS
SAAN	ASJC	Acequia de San Juan Capistrano	TX	CR H PS
*	17066	San Antonio River at Mission Road	TX	CR H PS
*	12899	San Antonio River at Padre Road	TX	CR H PS
*	12897	San Antonio River at Camino Coahuilatechan	TX	CR H PS
*	12881	San Antonio River at SH 97	TX	CR H PS
*	20350	Picosa Creek at SH 97	TX	CR H

CR – Contact Recreation; H – High Aquatic Life Use; PS – Public Water Supply.
Designated uses in red are not specifically classified by the state.

* SARA sampled sites outside of contracted GULN sites.

Water quality standards can be used to track water quality trends in GULN parks (Table 4). By adapting the state standards, we can also track park water quality trends within the states, regions, or watersheds. These standards apply to any water quality sample taken from the Upper San Antonio River basin. For more information on Texas water quality standards, please see Chapter 307: Texas Surface Water Quality Standards §§ 307.1–307.10

([http://info.sos.state.tx.us/pls/pub/readtac\\$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y](http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y)).

Table 4. Water quality standards for parameters measured at SAAN.

Parameter	Water Quality Standard
Ammonia as N	No state standard, screening level >0.33 mg/l
Chloride	<150 mg/l
Dissolved Oxygen	>5.0 mg/l; instantaneous value
Nitrate as N	No state standard, screening level >1.95 mg/l
Nitrite as N	No state standard
Total Kjeldahl Nitrogen	No state standard
pH	Between 6.5 and 9.0 SU
Specific Conductance	No state standard
Sulfate	<150 mg/l
Total Organic Carbon	No state standard
Total Discharge/Flow	No state standard
Phosphorous, Total	No state standard, screening level >0.69 mg/l
Water Temperature	<32.2 °C

Parameters for Water Quality Inventory

SARA and GULN use TCEQ protocols for all field measures, including sample collection and transport. These protocols can be found in TCEQ (2003) “Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue”. Parameters sampled at the four sites within SAAN include water temperature, pH, specific conductance, dissolved oxygen, flow, total suspended solids, nutrients (nitrate, nitrite, ammonia, total Kjeldahl nitrogen and total phosphorous), total organic carbon, chloride, and sulfate.

Field Measures

Water Temperature

Measurements of water and air temperature at the field site are essential. Determinations of dissolved oxygen concentrations, specific conductance, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water and air temperature data are essential to document thermal alterations to the environment caused by natural phenomena and human activities. Water temperature was measured in degrees Celsius (°C) using a thermistor thermometer, which is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units.

pH

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and is therefore an important indicator of the health of a water system. pH is measured using the electrometric measurement method via a hydrogen ion electrode and reported in standard units (SU).

Specific Conductance

Electrical conductance (SpC) is a measure of the capacity of water (or other media) to conduct an electrical current (the inverse of resistance). SpC is a quick and reliable estimation of the dissolved solids in the water, but there is no universal linear relation between total dissolved substances and specific conductance. A dip-cell electrode sensor was used and SpC is measured in microSiemens per centimeter (µS/cm).

Dissolved Oxygen (DO)

Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions depend directly or indirectly on the amount of oxygen present. DO is necessary in aquatic systems for the survival and growth of many aquatic organisms. The GULN uses an amperometric method in which DO concentration is determined with a temperature-compensating, galvanic, membrane-type sensor and measured in milligrams per liter.

Total Discharge/Flow

Total discharge, or flow, is either directly measured using a flow meter or estimated when flows are too high to permit a safe or accurate measurement. If measured near a USGS gauging station, flow is adjusted according to a USGS rating curve. Flow is measured in cubic feet per second (cfs).

Laboratory Measures

As required for any data generated through the TCEQ CRP, the GULN uses only laboratories that are certified by the National Laboratory Accreditation Conference for the following parameters:

Total Suspended Solids

Total suspended solids (TSS) is a direct gravimetric measurement of particles normally suspended in water and expressed as milligrams per liter. In general terms, TSS contributes to turbidity, with higher TSS values sometimes representing higher turbidity values. TSS was measured using Standard Method (SM) 2540D.

Nutrients

Together and separately these measures of various forms of nitrogen and phosphorous describe nutrient levels. Surplus nutrients may cause excessive growth of aquatic vegetation. When nutrients are consumed, plants die and their decay depresses DO. Wastewater and agricultural runoff are typical sources of these nutrients.

Nitrate-nitrogen ($\text{NO}_3\text{-N}$), nitrite-nitrogen ($\text{NO}_2\text{-N}$), total Kjeldahl nitrogen (TKN), ammonia-nitrogen ($\text{NH}_3\text{-N}$), and total phosphorous (TP) make up the routine nutrient suite. Nitrogen exists primarily in either nitrate (NO_3), nitrite (NO_2), or ammonia (NH_3) in freshwaters, in large part depending on the amount of dissolved oxygen. While nitrate alone is not particularly toxic to aquatic life (unless is extremely high concentrations), moderate levels of nitrate can lead to eutrophication, habitat loss, and depressed dissolved oxygen. TKN is the total reactive or organic nitrogen, including ammonium and ammonia. Nitrate-nitrogen was analyzed using SM 300(A); nitrite-nitrogen using SM 300(A); and total Kjeldahl nitrogen using U.S. Environmental Protection Agency (USEPA) 351.2.

Ammonia-nitrogen (nitrogen in its reduced form) can be toxic to fish (USEPA 1988). Ammonia (NH_3) may exist as un-ionized ammonia or ionized ammonia, largely dependent on pH. At higher pH (8 SU and above), the proportion of ammonia as un-ionized ammonia increases. Elevated levels of un-ionized ammonia may be toxic to aquatic life. At lower (acidic) pH levels, the proportion of ammonia as un-ionized NH_3 is lower. Ammonia was measured using SM 4500- $\text{NH}_3\text{(D)}$.

Phosphorous in the form of orthophosphates is found in natural waters and, in low concentrations, is essential for aquatic life. While not toxic to humans except in extremely high concentrations, excess phosphates can cause eutrophication, leading to excessive aquatic plant growth. Excessive aquatic plants can cause low DO via respiration or through decomposition after the plants die. Excessive DO depletion may cause fish kills. Phosphate was reported as total phosphorous-P using USEPA Method 365.3.

Total Organic Carbon

Total organic carbon (TOC) is a measure of natural decay, including humic and fulvic acids, as well as synthetic sources, such as detergents, pesticides, fertilizers, and industrial chemicals. As with any water quality parameter with natural occurrences, many samples are needed covering all seasons and flow conditions to document backgrounds. There is no state standard for TOC. Total organic carbon is determined by USEPA method 5310-C.

Chloride

Chloride is a conservative ion, readily passing through aquatic systems with little biological interference or chemical alteration. Long-term exposures of concentrations greater than 400 mg/l may affect freshwater aquatic life. Chloride is analyzed by SM 300(A).

Sulfate

Sulfate is also found in most natural waters. Results can be coupled with chloride analysis to suggest the type of pollution. Sulfate is analyzed using SM 300(A).

Water Quality Status

Water quality has been sampled through a bimonthly sampling schedule beginning in October 2007 in the SAAN. While these data have not spanned the entire flow continuum (sampling has not been conducted during flood flow), a general picture of water quality status is beginning to emerge. It should be noted that in addition to basic field observations, weather condition, flow condition, air temperature, and precipitation during the week prior to sampling are also recorded. These data are important in interpreting water quality results.

The dataset for the Upper San Antonio River is rich with a number of short-term investigations spread through the system as well as populated with long-term records at a few key locations. This section focuses on data collected through the GULN Water Quality Monitoring Program at four sites within SAAN and SARA data from five key locations.

Bimonthly Sample Results

Bimonthly sample results presented include the four SAAN sites and the five related SARA sites. A brief statistical summary of the combined results of the two sampling programs is presented in Table 5. Waters within the park have periodically exceeded state water quality standards at SAAN from 2007 to 2011 (Table 6). The SAAN dataset consists of less than 25 sample populations (n). With a small dataset, gaining good representation of overall water quality is hampered. Timing of sampling can greatly distort interpretation of results. It is very possible that over a period of a dozen or so site visits that in nearly every visit a stream was at a base-flow state, and thus reflective of base-flow quality. Other sites may include a few higher flow visits. It will take several more years to collect data to gain a better assessment of water quality, especially in determining trends. However, the SARA CRP monitoring dataset is much larger, including sampling from November 1999 to December 2010. The SARA data provide valuable insight into the water quality within the park, aid in interpreting SAAN results, and help to compensate for the small sample size.

Not all SARA sites are represented for all sample dates or all parameters. Sites are occasionally added to the network and some sites are not sampled for the entire suite of parameters. Likewise, not all SAAN sites are displayed for all parameters as all data at a particular site may be below a quantification limit.

Table 5. Brief statistical summary of SAAN (October 2007–December 2011) and SARA CRP (November 1999–December 2010) bimonthly sample results.

Censored results are typically values that are below a quantification limit but may occasionally be above.

Parameter	Units	Total Samples	Censored Results	Net Samples	Min	Max	Mean	Median	Std Dev
Ammonia	mg/l as N	280	162	118	0.02	1.34	0.109	0.05	0.153
Chloride	mg/l	471	181	290	2.5	241	55.2	40.5	36.7
DO	mg/l	524	98	426	0.7	21.5	9.2	9.2	3
NO ₃	mg/l as N	472	180	292	0.025	16.5	3.86	1.99	3.82
NO ₂	mg/l as N	444	338	106	0.02	1.9	0.108	0.047	0.287
TKN	mg/l	479	231	248	0.1	13.4	0.69	0.059	0.92
pH	SU	525	98	427	6.8	9.2	8.1	8.1	0.4
SpC	μS/cm	551	94	457	158	3780	725	625	340
Sulfate	mg/l	379	178	201	2.5	175	47.6	39.9	25.3
TOC	mg/l	480	261	219	1.06	16.2	3.73	3.52	1.91
Discharge	cfs	284	14	270	0	3,850	178	96	375
Phos.	mg/l	456	242	214	0.03	2.34	0.55	0.36	0.54
Temp	°C	524	94	430	34.3	9.1	22.9	23.1	5.6

Table 6. Exceedances of state water quality standards at SAAN, 2007–2011.

Parameter	Standard	Site	# exceedances	# sample	% exceedances
Ammonia	0.33 mg/l*	AEAE	2	22	9
Chloride	150 mg/l	PCPC	3	21	14
DO	5 mg/l	AEAE	15	22	68
		PCPC	4	22	18
Nitrate	1.95 mg/l*	AEAE	5	22	23
		SJSR	7	11	64
Sulfate	150 mg/l	PCPC	3	21	14
Phosphorous	0.69 mg/l*	AEAE	1	18	6
Temperature	32.2 °C	SRSJ	1	11	9

* Represents a state screening level

Ammonia

As SAAN waters are typically alkaline, ammonia likely exists in its toxic ionized NH₃-N form, which may be toxic to fish and invertebrates. Currently there are no state standards for ammonia. However, Texas has established a “screening level” for ammonia (expressed as nitrogen) at 0.33 mg/l. Ammonia levels in AEAE equaled or exceeded the screening level twice (Figure 11). The USEPA is currently revising ammonia standards. It is focusing the criteria on freshwaters with mussels and early life stages of fish with pH 8 SU and above to target the toxic NH₃-N form (<http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/pollutants/ammonia/factsheet2.cfm>). Under these standards, if mussels are present, acute ammonia limits will be 2.9 mg/l and a chronic exposure limit of 0.26 mg/l. A survey of mussels has not been attempted, but mussels are known to exist in the Upper San Antonio River. While not reaching the acute limit, there were several times that SAAN and related waters exceeded the chronic exposure recommendation.

Elevated nutrients are directly linked to the highly modified state of the San Antonio River. The river is the ultimate recipient of runoff of a dense urban adjacent watershed during rainfall events and reuse water dominates recharge during periods of low flow.

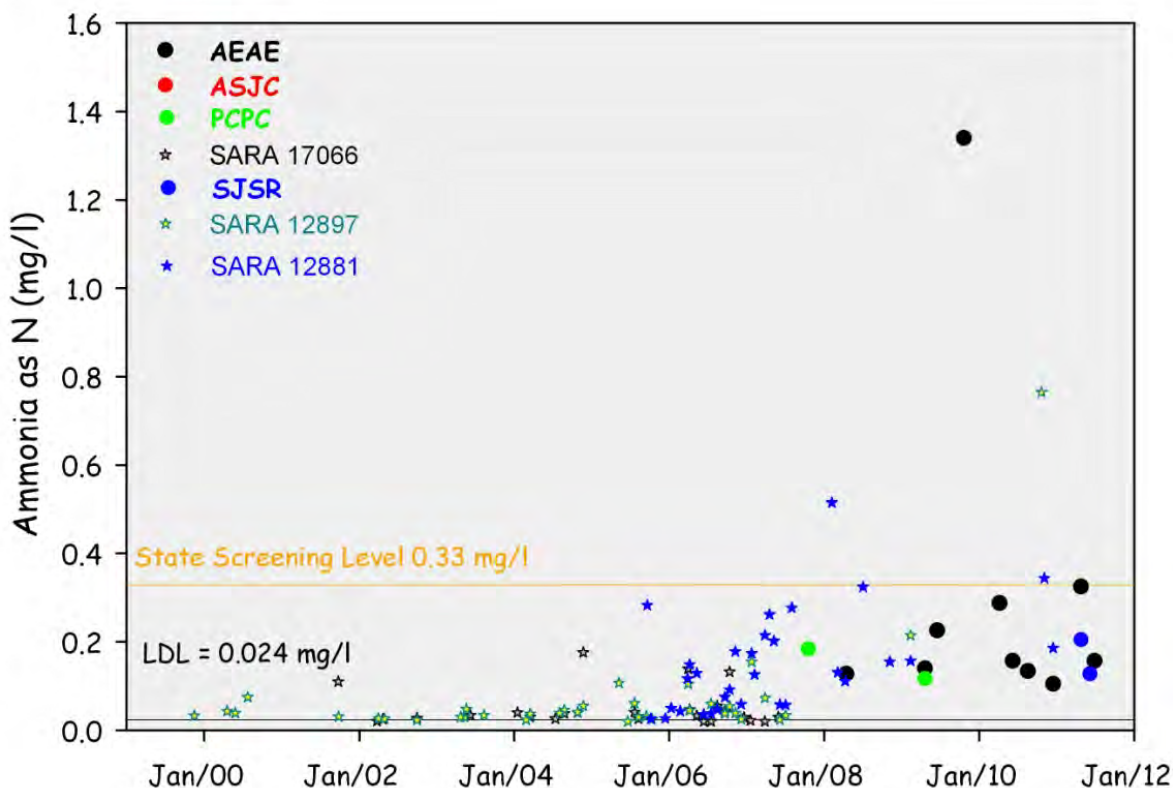


Figure 11. Ammonia levels at SAAN (n = 118). AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Chloride

Chloride is a fairly conservative ion in that it is not readily complexed or up taken through biological processes while in solution. Elevated chloride levels in the river are most likely due to SAWS reuse water. Reuse water chloride levels are typically about 117 mg/l, which are still below the state standard of 150 mg/l. An inverse relationship is evident between chloride levels and rainfall level (Figure 12). As precipitation decreases, thus diminishing natural recharge, SAWS proportion of reuse water increases.

This relationship applies to the San Antonio River but not tributaries that are not supplemented by SAWS reuse water such as PCPC. PCPC has met or exceeded the state standard of 150 mg/l four of 20 times sampled (Figure 12). The high chloride values in PCPC correspond to three very low-flow samples. As the creek nearly dries to a trickle, simple evaporation may result in elevated chloride and sulfate ions (Figure 19).

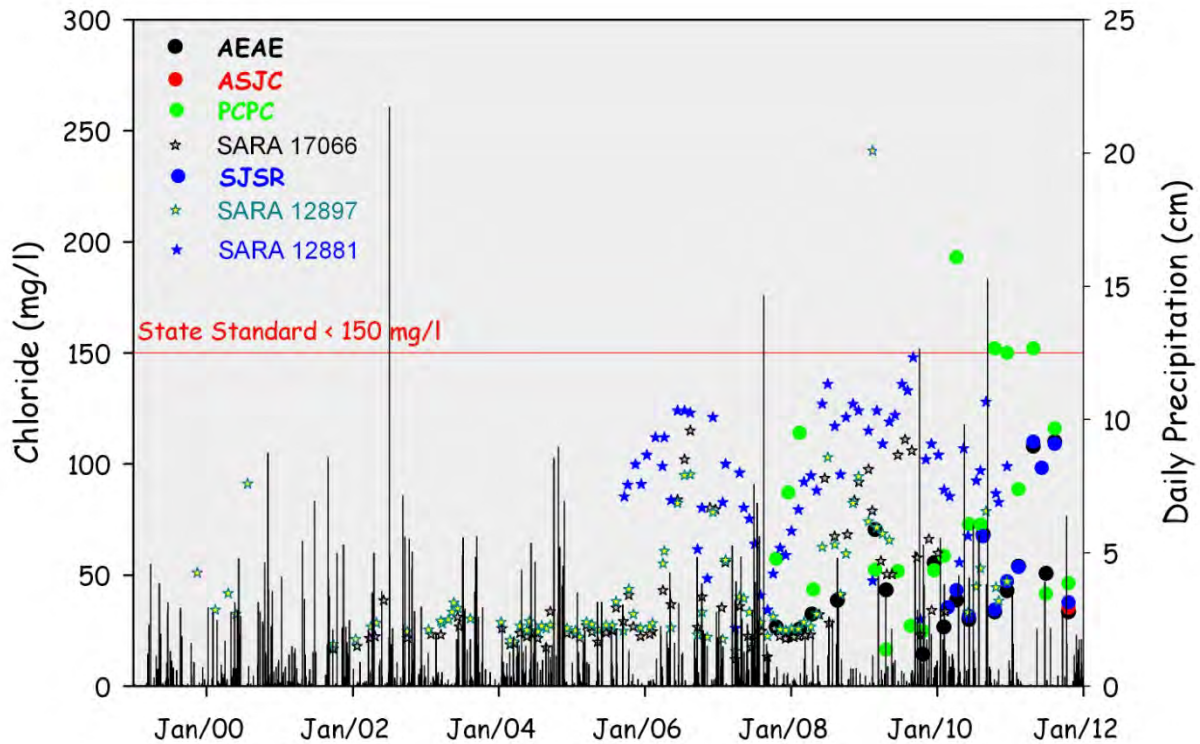


Figure 12. Chloride at SAAN (n = 290).
Precipitation data are from the San Antonio International Airport.
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Dissolved Oxygen

These data represent “instantaneous” dissolved oxygen values; that is, a single in situ reading taken during a single visit rather than a 24-hour average. AEAE experiences very low velocity (to at times, stagnant) water. An acequia is not a natural stream channel and does not undergo the aeration process of a normal stream. DO levels routinely are below the state instantaneous dissolved oxygen level of 5.0 mg/l (Figure 13). On occasion, PCPC also has reported low oxygen, occurring in summer months when flow is low, aeration is limited, warm water is inhibiting the dissolution of oxygen, and biological demand for oxygen is increased. SARA 20350 on the intermittent Picoso Creek immediately upstream of the park’s Rancho de las Cabras unit also drops below the state limit due to low-flow condition and/or water quality degradation (Figure 13). The land owner of Picoso Creek between SH 97 and the Rancho was interviewed during a field visit in August 2011. He pointed out a large dairy operation upslope and west of Picoso Creek and claims that the dairy occasionally dumps wash water and milk by-products from a holding tank into the creek. Such an addition of nutrients would increase the biological oxygen demand of the stream, causing DO to drop. NPS alerted SARA to the situation and SARA will work with the landowner to sample such events in the future.

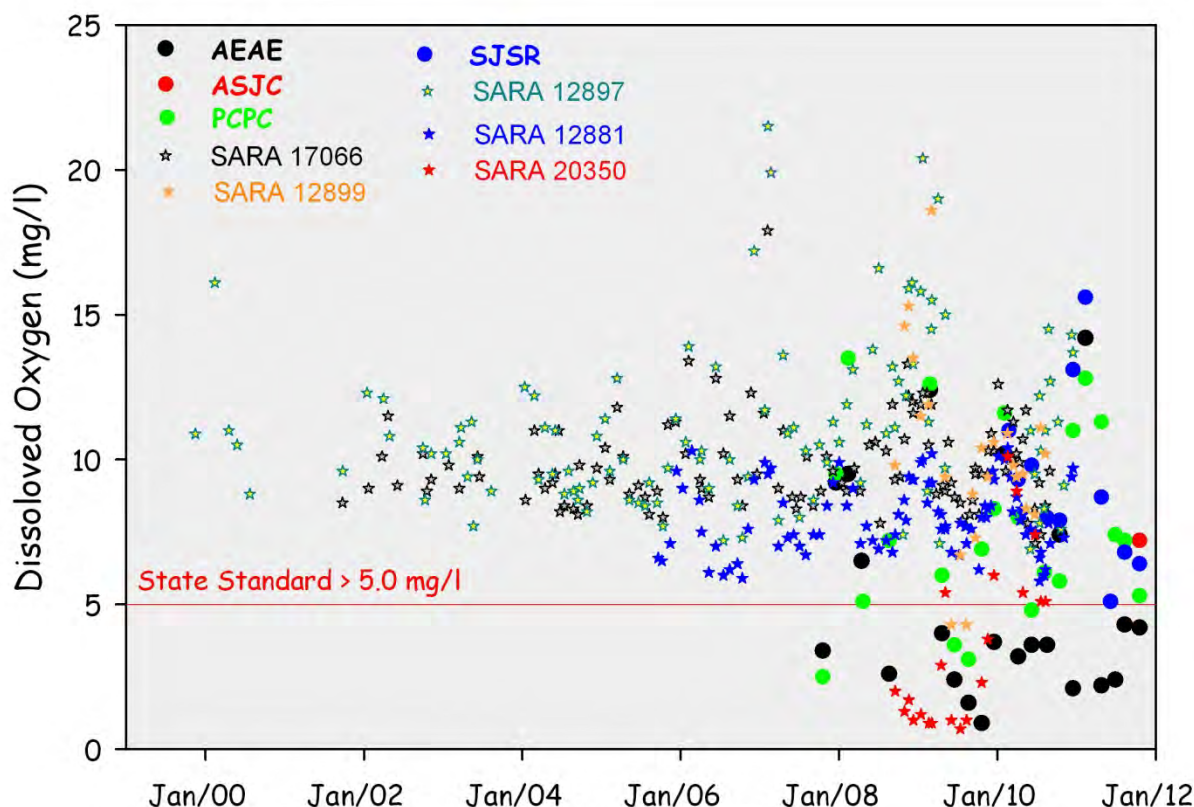


Figure 13. Dissolved oxygen at SAAN (n = 426). AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Nitrate

A river draining a metropolitan-area population of 1.25 million would be expected to have elevated nitrate. During low-flow conditions, the San Antonio River is supplemented with as much as 95 percent reuse water that is high in nitrate. Even the natural recharge of the river, the headwater springs of the Edwards Aquifer, have nitrate levels ranging from below detection limits to 2.5 mg/l (Schindel 2010).

There is no current state standard for nitrate. However, the state uses a screening level of 1.95 mg/l. Clearly the San Antonio River has nitrate problems (Figure 14). Park waters are well below the state screening level at PCPC and near or slightly exceeding this level at AEAE and SJSR.

SARA 17066 and 12897 (the San Antonio River at Mission Road and Camino Coahuilatchan, respectively) nearly always exceed the screening level of 1.95 mg/l. SJSR lies between the two SARA sites and nitrate levels are usually lower, averaging about 2 mg/l. The lower levels are likely a result of nitrate consumption by aquatic plants.

Nitrate levels routinely exceed the state screening level at the SARA 12881 site, the San Antonio River immediately upstream from Rancho de las Cabras. Levels as high as 16.9 mg/l have been

reported. This site (sampling began in late 2005) is downstream from all contributions from greater San Antonio as well as agricultural inputs from the Upper San Antonio and Medina Rivers, and the Dos Rios Water Recycling Facility, with its average daily flow capacity of 125 million gallons. As discussed earlier, SAWS supplements flow to the Urban Reach of the river. During summer months and drought, upwards of 95 percent of the river is derived from SAWS reuse water. This water typically has nitrate levels of 31 to 71 mg/l (see Table 1) and results in the high nitrates seen in the river. As natural flows diminish, nitrate levels rise. This relationship is clearly seen in Figure 14.

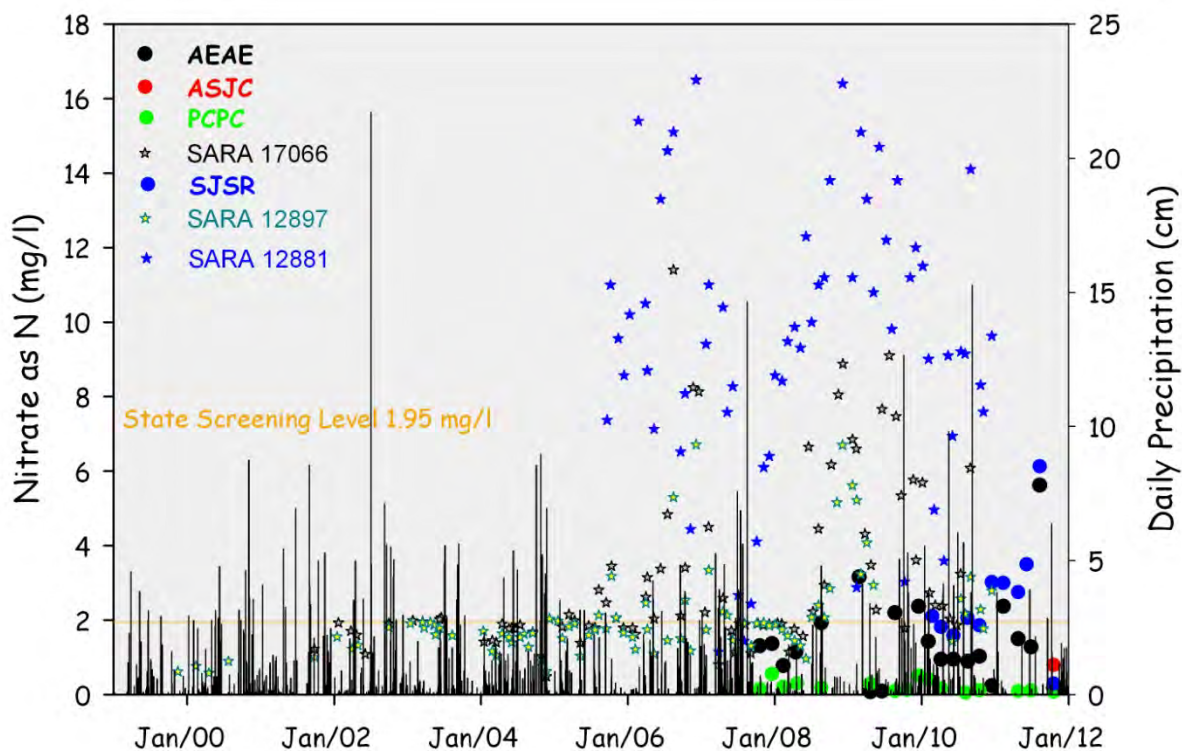


Figure 14. Nitrate and precipitation at SAAN (n = 292). Precipitation data are from the San Antonio International Airport. AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Nitrite

Nitrite is a relatively short-lived state of inorganic nitrogen as it is rapidly converted into nitrate, especially in the presence of ample dissolved oxygen. Besides what may be an outlier or entry error (SARA 12897), there are only two highly elevated nitrite values, both in AEAE (Figure 15). AEAE also experiences low DO levels (Figure 13). Although not in the range of the two AEAE values, elevated nitrite concentrations are also found at SARA 12881, and at times SARA 17066. These are the same sites that show high nitrate. It is obvious that the Upper San Antonio River has elevated nitrogen levels as a result of high volumes of reuse water.

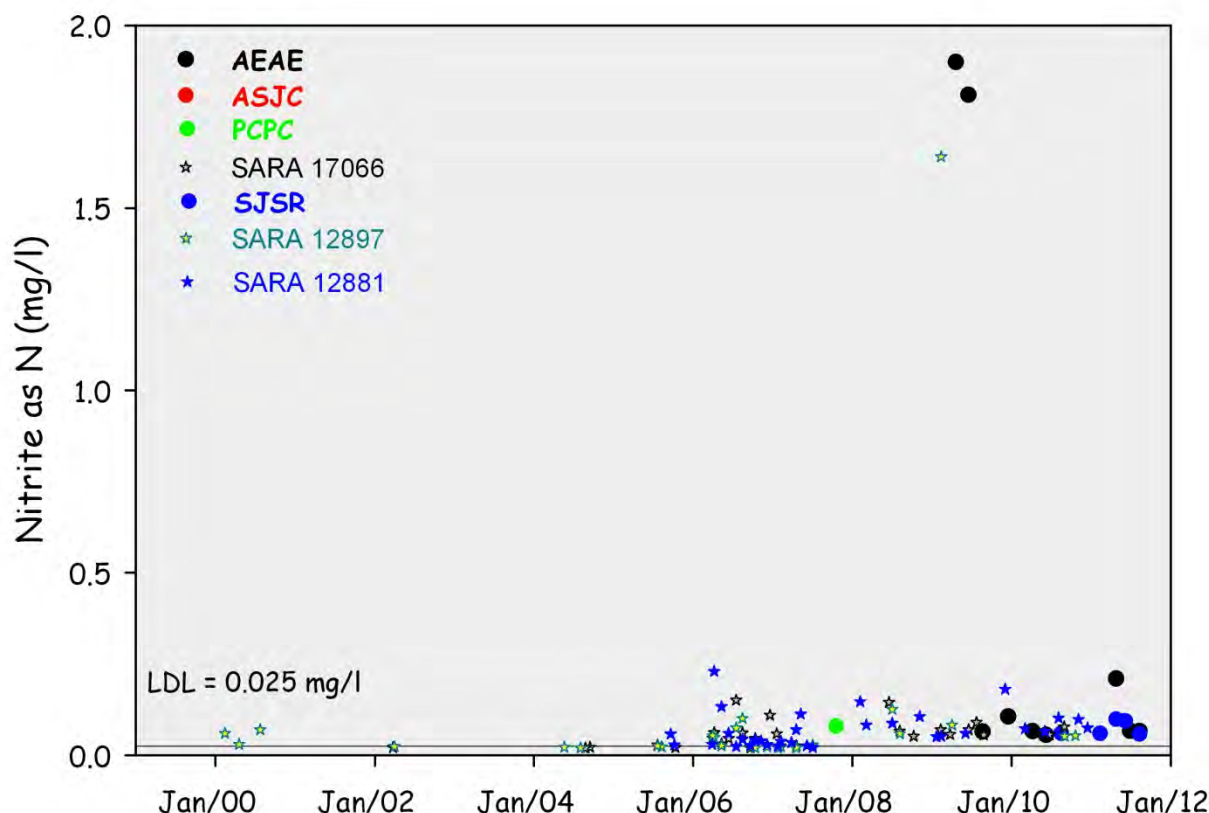


Figure 15. Nitrite at SAAN (n = 106).
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is the total of reactive (organic) nitrogen, including ammonium and ammonia. Figure 16 is dominated by the very high TKN levels occasionally found in AEAE, which also experiences occasional high ammonia (Figure 11). An acequia is not a natural stream and the flow along its slow-moving course does not permit natural processes like aeration and transport of decaying vegetation to readily occur. At times the acequia becomes a stagnant ditch partially clogged with aquatic vegetation, both living and decaying. Under such conditions, elevated nutrients can be expected. TKN at ASJC and river sites are below 2 mg/l. While there was an increase in nitrate at river sites (Figure 14), especially downstream at SARA 12881, a corresponding increase in reactive nitrogen was not evident.

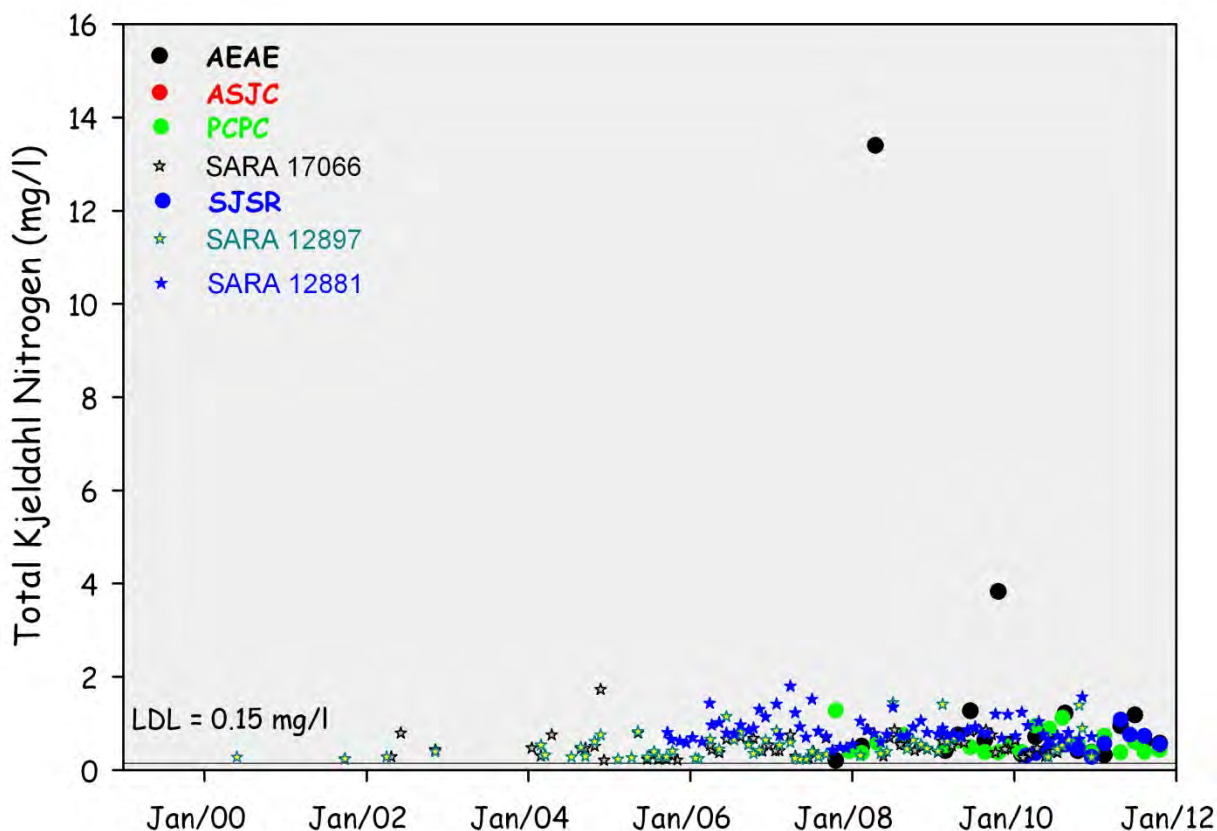


Figure 16. Total Kjeldahl nitrogen at SAAN (n = 248). AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

pH

pH of SAAN and Upper San Antonio River waters are naturally alkaline (Figure 17). Dissolution of the abundant limestone produces bicarbonate ions, which not only elevates pH but also acts as a buffer against acids entering the stream. The lowest pH values are found in SARA 20350, which has no exposed limestone in its watershed. It is underlain by the Queen City Sand (USGS 2011). On occasion, the upper pH limit of 9.0 SU has been exceeded at the SARA 12897 and 12899 sites. The reason for the gradual increase in pH at 12897 and 12899 is presently unknown.

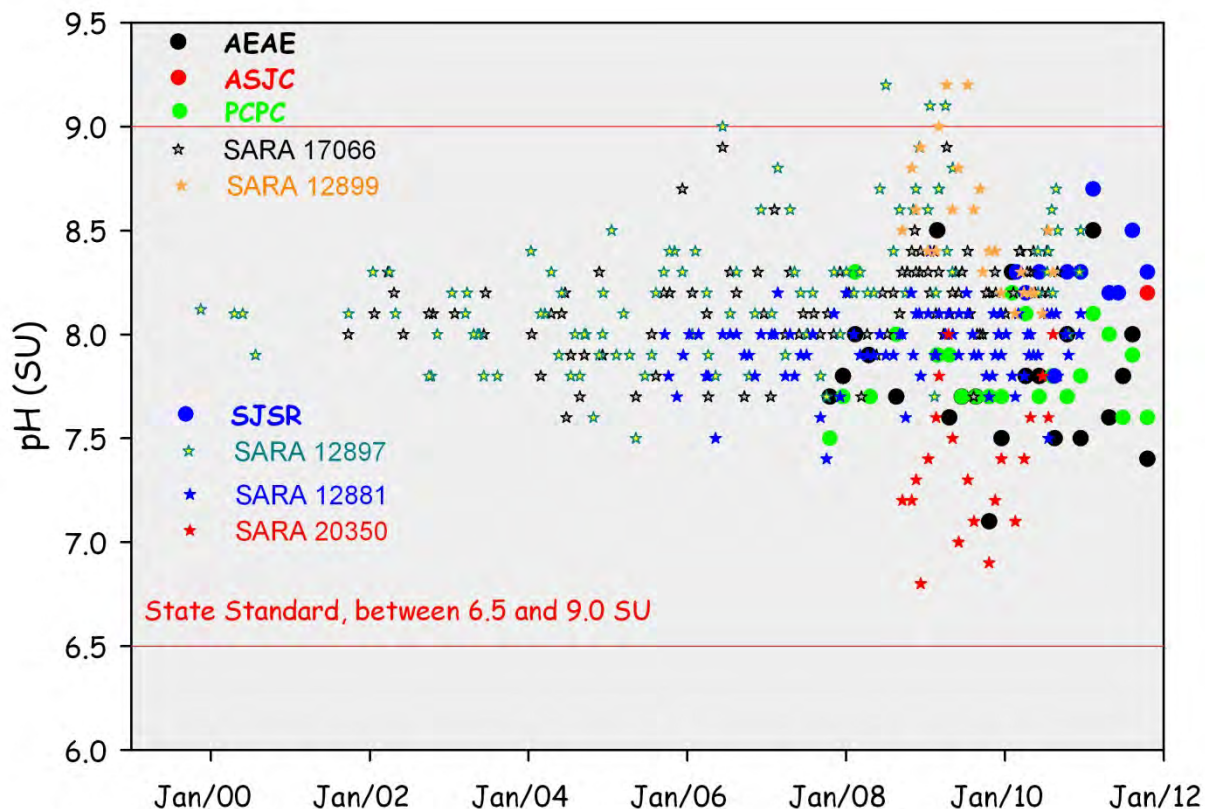


Figure 17. pH at SAAN (n = 427).
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Specific Conductance

A reliable estimation of dissolved ions, specific conductance (SpC) is highly variable (Figure 18). Without anthropogenic influence, SpC is higher in times of low flow, as dissolved ionic load increases with increased interaction between rock and water. There appears to be a similar trend between SpC levels, chloride (Figure 12) and sulfate (Figure 19) at PCPC and SARA 12881. If we consider dissolution products of limestone to remain general ionic constant, there should be additional ions contributing to the SpC signal. It is likely that chloride and sulfate ions are contributing to the higher SpC levels.

The SpC signal at SARA 20350 suggests an outside source with very high concentrations of dissolved ions. Picoso Creek is underlain by the Queen City Sand and should have a lower SpC than the Upper San Antonio River, which is recharged in large part by limestone springs. Recall that there is a large dairy operation upstream and adjacent to the Picoso Creek sampling site. It is likely that runoff or improper wastewater disposal from the dairy is causing the high SpC.

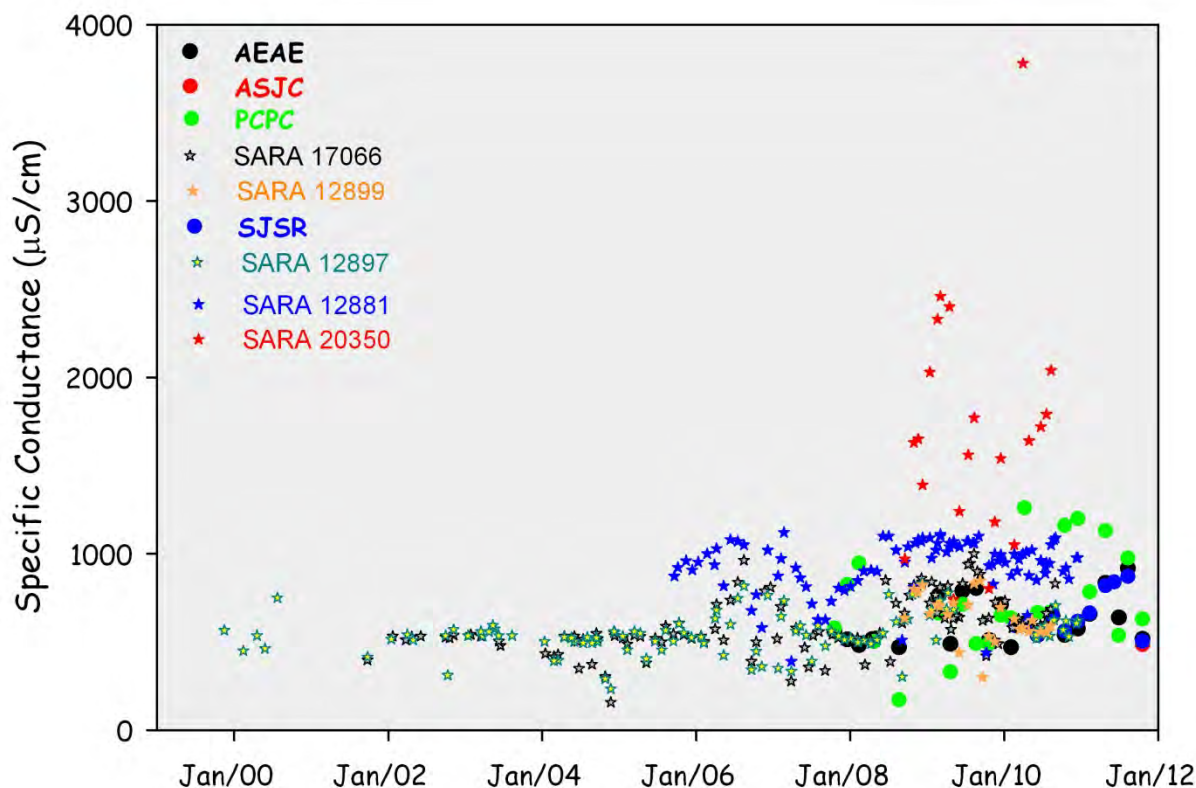


Figure 18. Specific conductance at SAAN (n = 457). AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Sulfate

Similar to the chloride and SpC signal (Figures 12 and 18), sulfate concentrations suggest a similar source and mechanism of transport (Figure 19). Sulfate data are not available for SARA 20350. The highest sulfate levels detected are from PCPC, with three samples exceeding the state limit of 150 mg/l. The highest concentrations were associated with very low flow and the lowest values during high flow. This is the same pattern as seen in chloride (Figure 12). As the creek nearly dries to a trickle, simple evaporation may result in elevated chloride and sulfate ions

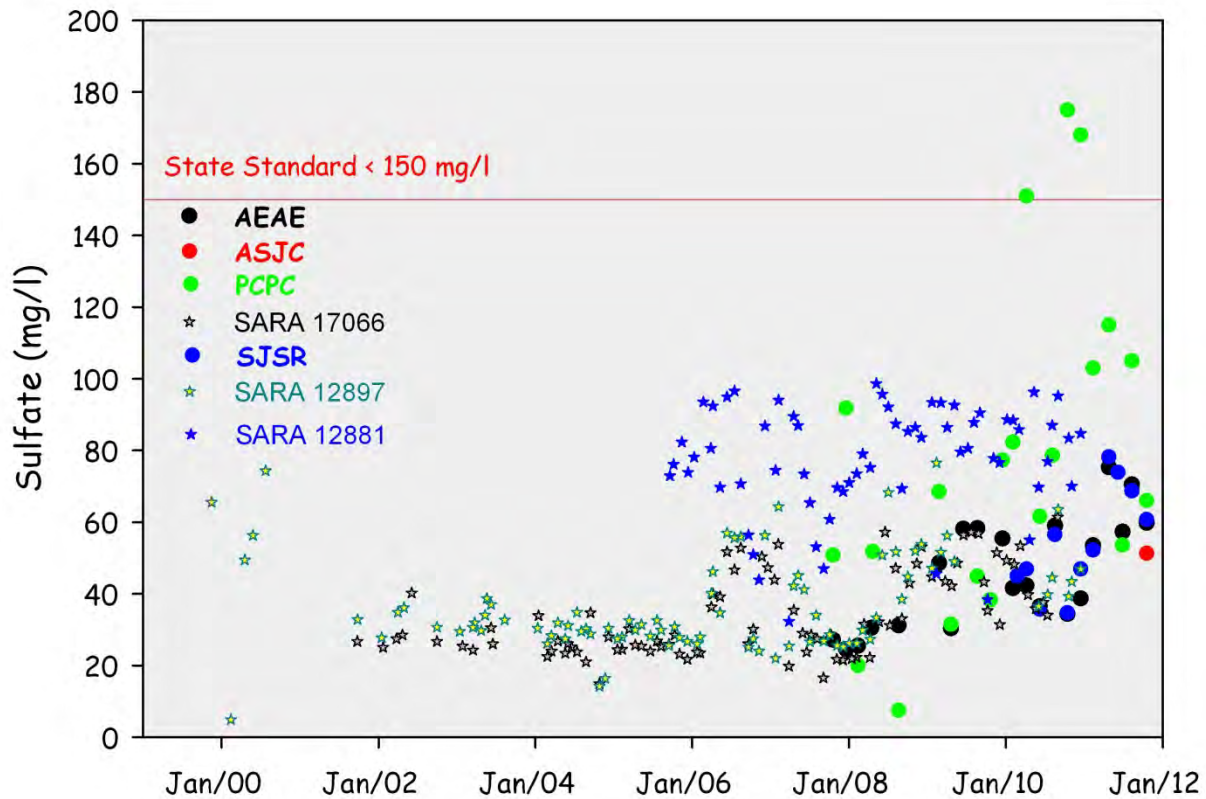


Figure 19. Sulfate at SAAN (n = 201).
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Total Organic Carbon

Total organic carbon monitoring did not begin in the Upper San Antonio River until 2004, at AEAE and PCPC until 2007, and at SRSJ until 2010 (Figure 20). Primary sources of TOC include decaying natural organic matter and synthetic sources such as detergents and fertilizers. AEAE is typically laden with decaying vegetation (see Figure 4), which is most likely the cause of elevated TOC. The higher TOC found in PCPC may be from anthropogenic sources as the stream drains a heavily developed watershed.

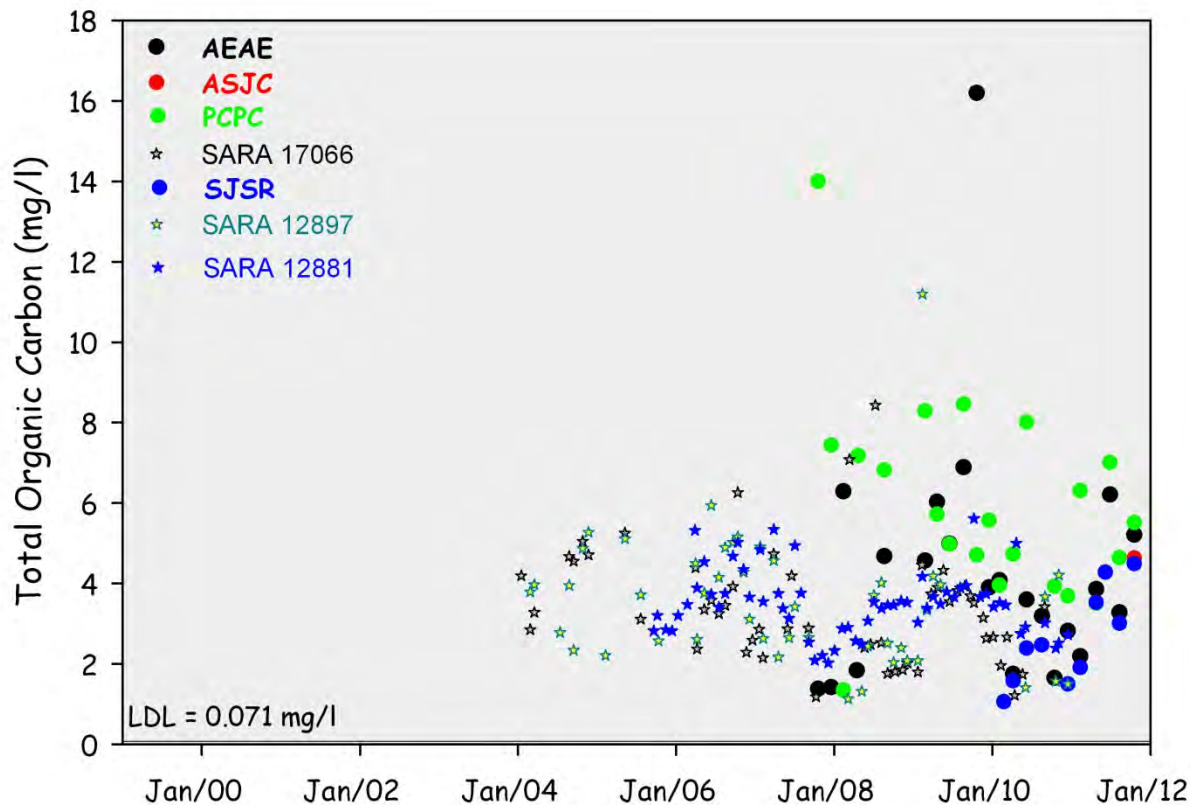


Figure 20. Total organic carbon for SAAN (n = 219). AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Total Discharge

Total discharge, or flow, aids in interpreting water quality results through associating contaminant presence and concentration with flow condition. Some contaminants are linked to high-flow events (suggesting a non-point source) while others may be more prevalent at low flow (suggesting a point-source or evaporation). The log plot of discharge allows the values of the smaller PCPC and AEAE to be compared to the larger flows of SRSJ and SARA sites on the San Antonio River (Figure 21). As expected, flows along the river are quite similar, with the exception of SARA 12881. SARA 12881 is downstream of the SAAN and past the confluence of the Medina River and Salado Creek with the river. Flows measured in PCPC ranged from 0.01 to 37 cfs, while flows in AEAE varied from no flow to 0.7 cfs. However, water has been present in the AEAE at every sampling event. Like AEAE, flow in ASJC, an acequia, and SJSR, a diversion tapping into the modified San Antonio River channel, is controlled, thus greatly limiting the upper range of discharge. While the 37 cfs event at PCPC on August 19, 2008, was high, a flood flow has not been sampled since the SAAN program began in October 2007. It should be noted that upstream of the sampling site on Piedras creek is a diversion channel taking flood waters directly to the San Antonio River, thus attenuating flood peaks at the site (Greg Mitchell, personal communication 2012). SARA discontinued discharge measurements at their sites after 2008.

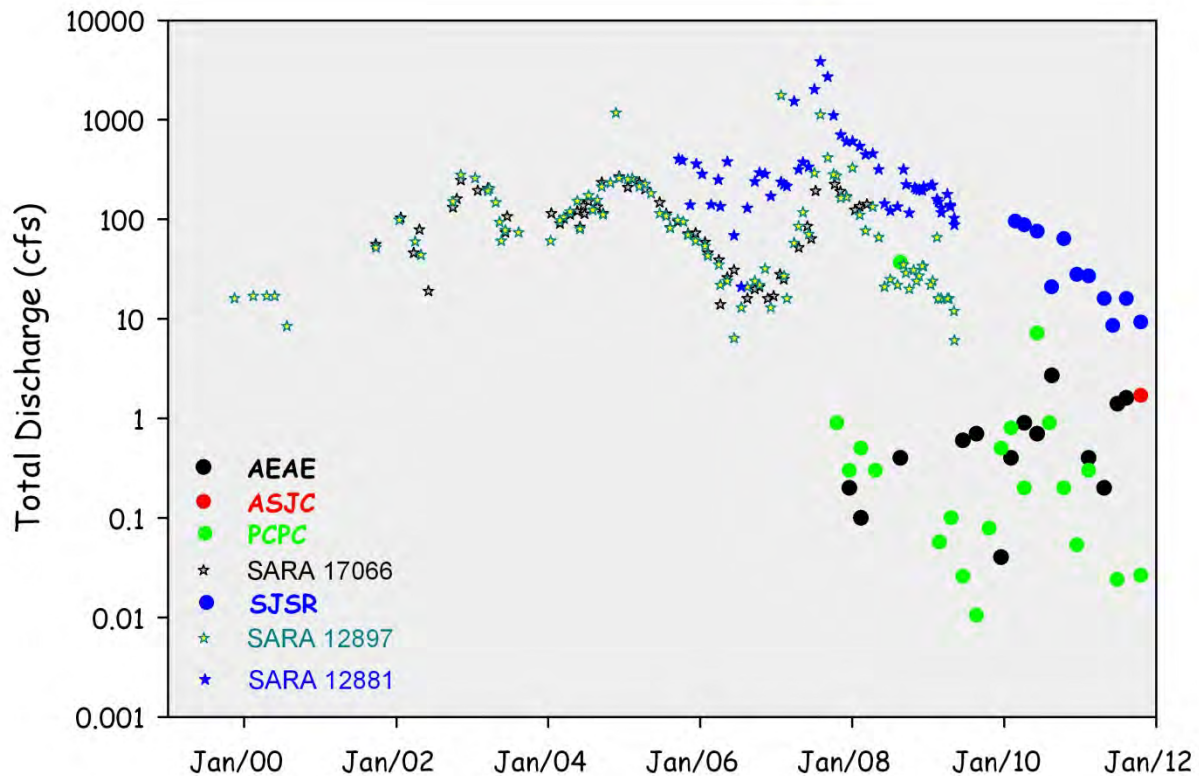


Figure 21. Total discharge (flow) at SAAN (n = 270).
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Total Phosphorous

Phosphorous levels (Figure 22) closely mimic that of nitrate (Figure 14). SARA sites 17060 and 12881 also exhibited elevated levels of nitrate. These same sites show proportionally high phosphate, typically above the state screening level of 0.69 mg/l. Reuse water is the likely source. The river nearly entirely comprises SAWS reuse waters during times of low natural flows such as the drought in recent years. SAWS reuse water typically has total phosphate levels between 4 and 11 mg/l.

AEAE on October 20, 2009, had the highest phosphate levels to date. The acequia was not flowing (reported as “tannic, pooled”) and also had elevated TOC (16 mg/l) and ammonia (1.34 mg/l). Two months later, the acequia was still pooled with abundant algae. Without flow, the acequia can quickly eutrophy as nutrients from the surrounding urban environment accumulate.

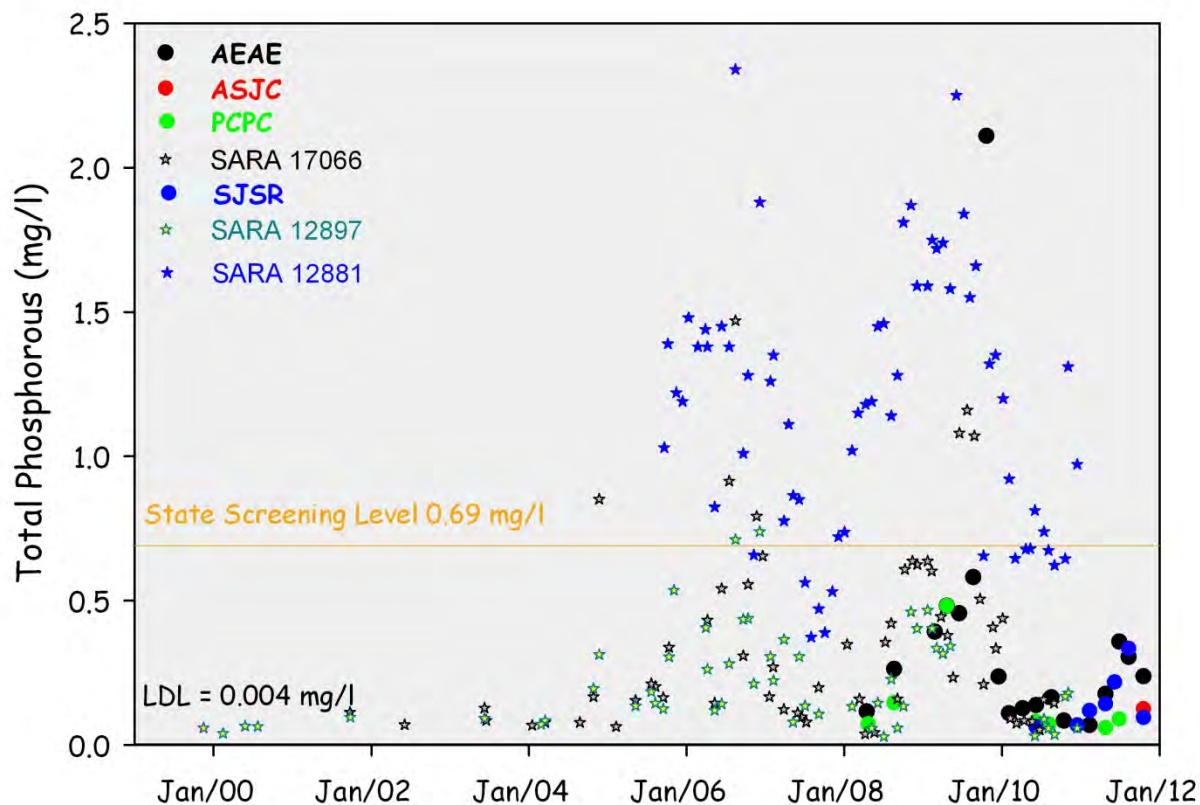


Figure 22. Total phosphorous at SAAN (n = 214).
AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Water Temperature

Water temperature responds to the seasonal pattern of air temperature, typically spanning nearly 25 °C over the course of the year (Figure 23). On seven occasions since 1999, routine sampling exceeded the standard of 32.2 °C at SARA 12897 (5 times), SARA 17006 (one time), and SJSR (one time). As the cool springs of the Edwards Aquifer do not typically flow during hot, dry summer months, little attenuation can be expected.

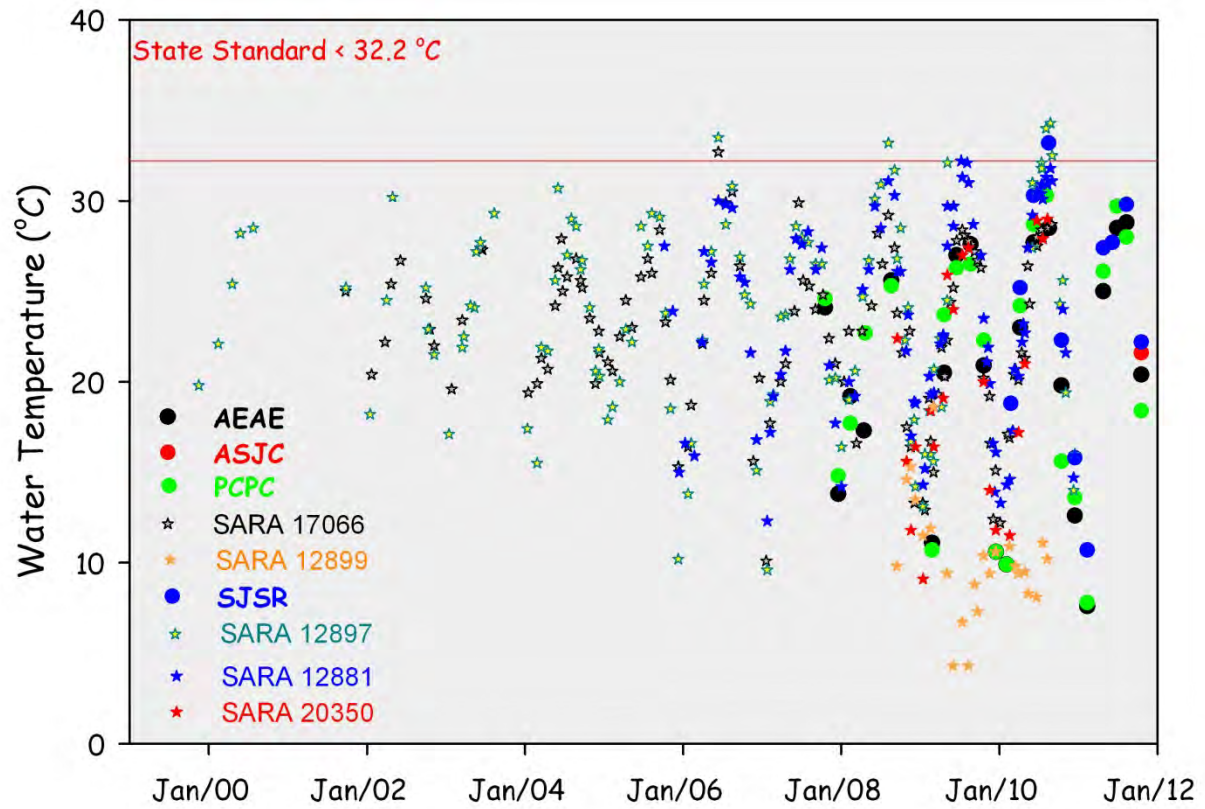


Figure 23. Water temperature at SAAN (n = 430).
 AEAE, ASJC, PCPC, and SJSR are represented by the larger symbols.

Summary

Water was the defining element in the establishment of the Missions and continues as the essential element in today's San Antonio, from its celebrated River Walk to its drinking water supply and wastewater reuse. The San Antonio Missions National Historical Park is anchored in San Antonio's past and present. While the river and tributaries are managed exclusively by the San Antonio River Authority (SARA), the National Park Service retains a water right for two historic acequias: Espada and San Juan. The reactivation of Acequia de San Juan gives the park the opportunity to divert flow to the labores, returning water to its historic role in the establishment of the Missions and San Antonio.

In October 2007, the Gulf Coast Network established four permanent long-term water quality stations in the park (Piedras Creek, Acequia de Espada, San Antonio River at San Juan Capistrano and the Acequia de San Juan) through a contract with the SARA. SARA routinely samples (bimonthly) these sites as part of its Clean Rivers Program monitoring effort. Since inception, park waters have exceeded state water quality standards or screening levels several times (Table 5). Common exceedances are the result of high volumes of reuse water in the San Antonio River elevating nutrient levels, extreme low flow in tributaries, and periodic lack of flow in the acequias.

A river that is draining a city's population of 1.3 million, and which is nearly 100 percent recharged by reuse water during the summer months, obviously has water quality issues. The Upper San Antonio River is in non-attainment status for bacteria (*Escherichia coli*) and impaired fish habitat. The river has been highly modified and the only intact natural channel and associated riparian plants in the Urban Reach is within the park at Mission San Juan.

Without reuse water, the San Antonio River would not flow during most summer months and during drought. Reuse water fulfills essential economic needs and plays a vital ecologic role. The park is dependent upon, and a stakeholder in, water quality and quantity of the San Antonio River. Sharing a boundary with SARA's channel, the park lies downstream of reuse water recharge points (the Rancho de las Cabras is downstream of even larger reuse discharge points). The two acequia headgates, the Espada Dam (Acequia de Espada) and the Archimedes Screw (Acequia de San Juan), draw water directly from the Urban Reach (portion of the San Antonio River upstream of Loop 410).

In the 1950s, the Urban Reach of the San Antonio River was straightened into a trapezoidal flood channel. As it is presently being returned to a more-natural morphology with riparian vegetation, water quality and aquatic habitat should improve. With these changes, a higher recreational role is expected and the impetus to reduce bacterial input should amplify. San Antonio Missions National Historical Park will be a direct beneficiary of these improvements. As the climate warms, violations of temperature standards are likely to be more common; however, this may be partially offset if the restoration project succeeds in restoring riparian vegetation.

The Gulf Coast Network will continue bimonthly water quality sampling at the park through the San Antonio River Authority as part of the Texas Commission on Environmental Quality's Clean Rivers Program routine schedule for the Upper San Antonio River. All aspects of the sampling, transportation, analysis, and data management will continue under the protocols of the

Gulf Coast Network and Texas Commission on Environmental Quality. Combined with the five associated routine San Antonio River Authority sites, the four locations within the park provide very good coverage. If any questions regarding the hydrology or water quality of the park arise, do not hesitate to contact the Gulf Coast Network hydrologist.

References

- American Public Health Association. 2005. Standard Methods for the Examination of Water and Wastewater, 21st ed., Port City Press, Baltimore, MD.
- Gonzales, M., and E. Moran. 2005. An Inventory of Fish Species within the San Antonio Missions National Historical Park. San Antonio River Authority. 68 p.
- Porter, C.R. 2009. Spanish Water, Anglo Water: Early Development in San Antonio. Texas A&M University Press, College Station. 181 p.
- San Antonio River Authority (SARA). 2008. Texas Clean Rivers Program, San Antonio River Basin Summary Report. 230 p.
- Schindel, G. 2010. Hydrologic Data Report for 2009, Report No. 10-02. Edwards Aquifer Authority, San Antonio, Texas. 247 p.
- Segura, M., R., Woodman, J. Meiman, W. Granger, and J. Bracewell. 2007. Gulf Coast Network Vital Signs Monitoring Plan. Natural Resource Report NPS/GULN/NRR-2007/015. National Park Service, Fort Collins, Colorado.
- Texas Commission on Environmental Quality (TCEQ). 2003. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue, RG-415, 198 pp.
- . 2010. Draft 2010 Texas 303(d) List. Available at <http://www.tceq.texas.gov/water/quality/assessment/10twqi/10twqi>.
- U.S. Environmental Protection Agency (USEPA). 1988. Quality Criteria for Water 1988, EPA 440/5-86-001, 447 p.
- U.S. Geologic Survey, 2011, Texas Geologic Map. Available at: <http://tin.er.usgs.gov/geology/state/state.php?state=TX>
- U.S. National Park Service (NPS). 1999. Baseline Water Quality Data Inventory and Analysis San Antonio National Historical Park. Technical Report NPS/NRWRD/NRTR-99/222, 1,860 p.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 472/114652, June 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov