National Park Service
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Natural Resource Stewardship and Science

San Antonio Missions National Historical Park

Natural Resource Condition Assessment

Natural Resource Report NPS/SAAN/NRR—2016/1191

ON THE COVER
Mission San José at San Antonio Missions National Historical Park
Photograph courtesy of the National Park Service

San Antonio Missions National Historical Park

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Natural Resource Report NPS/SAAN/NRR—2016/1191

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help San Antonio Missions National Historical Park (SAAN) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at SAAN. The final project framework contains 15 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by SAAN resource managers, NPS Gulf Coast Network staff, and outside experts, when appropriate.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in a number of cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for 5 of the 15 components (33%) due to these data gaps.

For those components with sufficient available data, the overall condition varied. For featured components with available data and fewer data gaps, assigned conditions varied. Five components are considered of low concern: upland shrublands/woodlands, reptiles, breeding and resident birds, and hydrology. Two components (fish and water quality) were of moderate concern. Three components were of high concern: air quality, soundscape, and viewscape. Soundscape and viewscape also appeared to show a deteriorating trend due to continued urban development. The high concern levels are primarily due to the urban land uses surrounding the park and are largely beyond NPS control. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in SAAN. Those of primary concern include the presence of non-native invasive species and effects of urban development (e.g., habitat loss and fragmentation, pollution, hydrologic alterations). Climate change could also threaten many resources, as the San Antonio region is likely to become warmer and drier for at least parts of the year within the next century. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus conservation strategies to maintain the health and integrity of park ecosystems.

Acknowledgments

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Acronyms and Abbreviations

ALU - Aquatic life use

CLI - Cultural Landscape Inventory

CLR - Cultural Landscape Report

CRP - Clean Rivers Program

dB - Decibels

DEM – Digital Elevation Model

DO - Dissolved Oxygen

EPA – Environmental Protection Agency

GIS – Geographic Information System

gpm - Gallons per minute

GULN - Gulf Coast Network

I&M - Inventory and Monitoring

IMPROVE - Interagency Monitoring of Protected Visual Environments

IBI - Index of Biotic Integrity

NAAQS - National Ambient Air Quality Standards

NADP - National Atmospheric Deposition Program

NCDC - National Climatic Data Center

NFI - Noise Free Interval

NPS - National Park Service

NPS ARD – National Park Service Air Resources Division

NRCA – Natural Resource Condition Assessment

NST - Night Sky Team

NVCS – National Vegetation Classification Standard

PHDI - Palmer Hydrological Drought Index

PM – Particulate Matter

SAAN - San Antonio Missions National Historical Park

SARA - San Antonio River Authority

SARIP - San Antonio River Improvement Project

SMUMN GSS – Saint Mary’s University of Minnesota, Geospatial Services

SpC - Specific Conductance

SSF - Stinson Municipal Airport

TCEQ – Texas Commission on Environmental Quality

TDS - Total Dissolved Solids

TSS - Total Suspended Sediments

TWDB - Texas Water Development Board

USGS – United States Geological Survey

WCS - Weighted Condition Score

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…
Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[6]An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

San Antonio Missions National Historical Park (SAAN) preserves the largest concentration of Spanish colonial era cultural resources in the U.S. (NPS 2000). It was designated a National Historical Park and signed into public law 10 November 1978, by President Jimmy Carter (P.L. 95-629):

> *"In order to provide for the preservation, restoration, and interpretation of the Spanish Missions of San Antonio, Texas, for the benefit and enjoyment of present and future generations, there is hereby established the San Antonio Missions National Historical Park consisting of Concepcion, San Jose, San Juan, and Espada Missions, together with areas and features historically associated therewith."*

In addition to the four Missions, the original legislation included the Espada Dam and Aqueduct and portions of the Espada and San Juan Acequias (Amdor et al. 1994). The park boundary was expanded in 1978 to include more of the historic acequias and original Mission compounds (Amdor et al. 1994). The Rancho de las Cabras Unit, which consists of lands historically associated with Mission Espada's ranching activities, was acquired by the NPS in September 1995 (OCULUS 1998).

2.1.2 Geographic Setting

SAAN consists of two distinct units: the Missions Unit and the Rancho de las Cabras Unit. The Missions Unit (Figure 1) is located within San Antonio, Texas (Bexar County), which supports a population of over 1.4 million people (USCB 2015). The Rancho Unit lies in a more rural area of Wilson County, near the town of Floresville, approximately 51.5 kilometers (32 mi) to the southeast of the Missions Unit (Figure 2). The park encompasses 389.3 hectares (962 ac) and includes historic landscapes, structures, and natural areas (Greg Mitchell, SAAN Natural Resources Program Manager, written communication, 22 September 2015). Missions within the park include: Mission San Francisco de la Espada (Mission Espada), Mission San José y San Miguel de Aguayo (Mission San José), Mission San Juan Capistrano (Mission San Juan), and Mission Nuestra Señora de la Purísma Concepción de Acuña (Mission Concepción). Both park units are situated along the San Antonio River (NPS 2001).

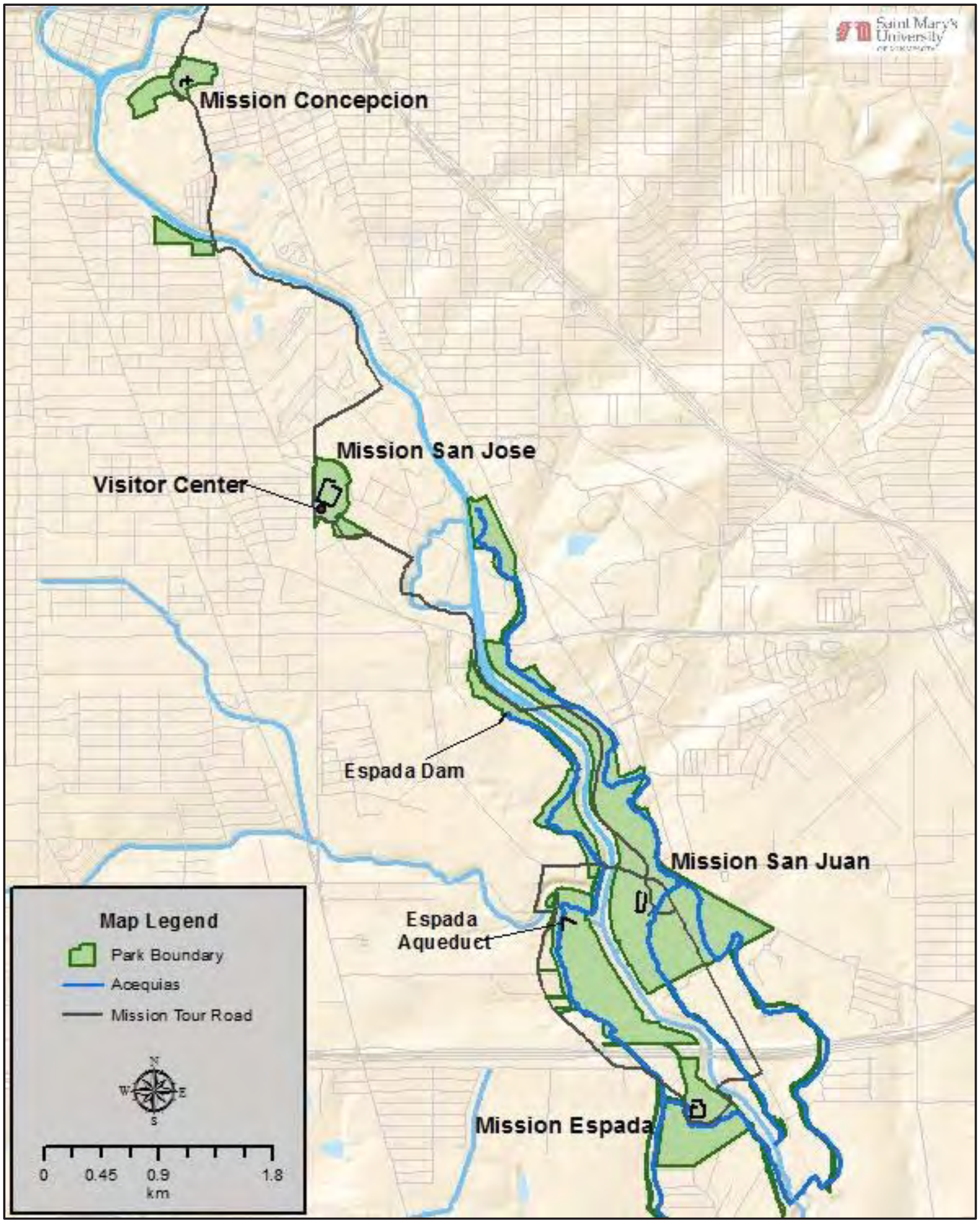

Figure 1. The Missions Unit of SAAN.

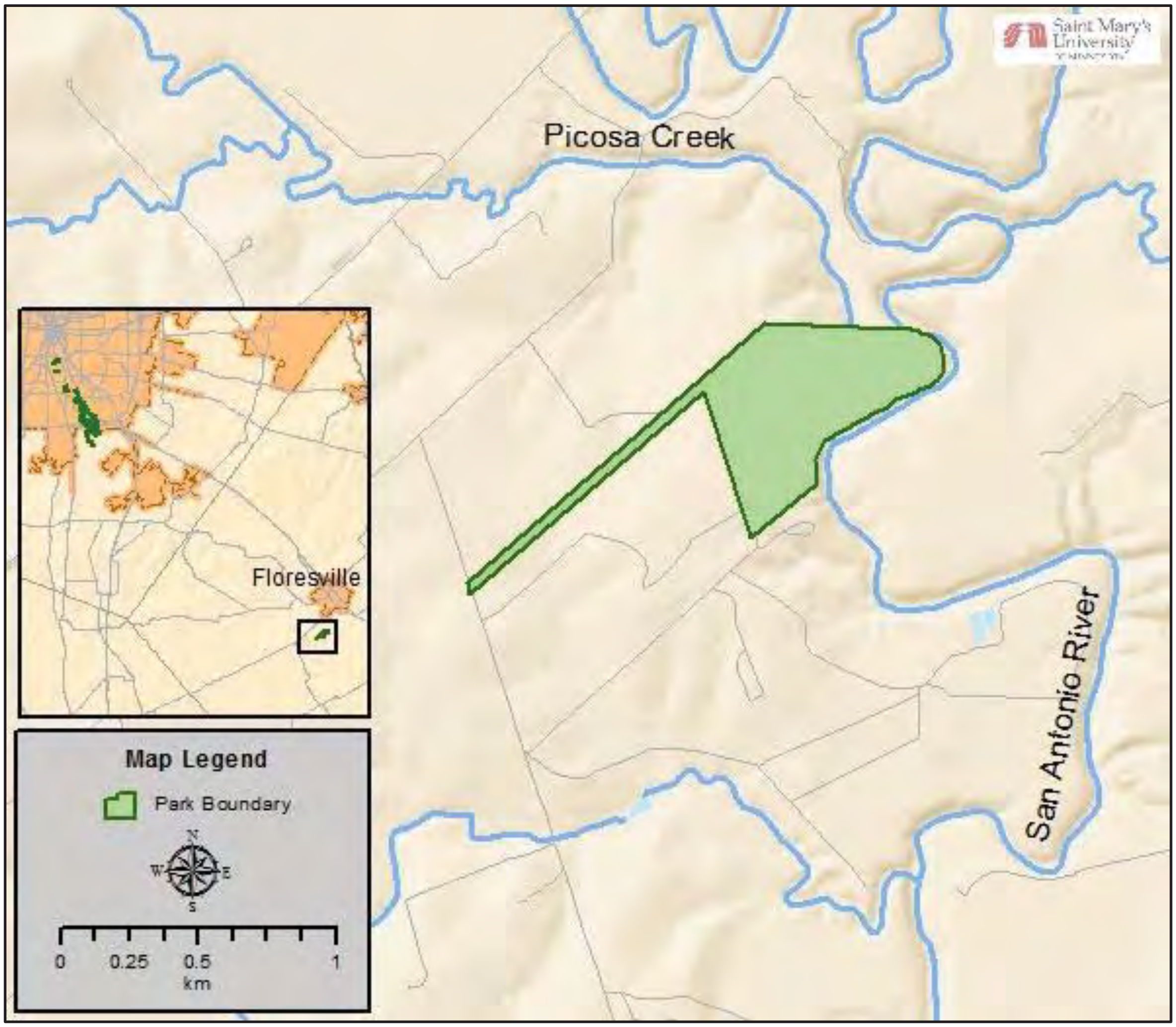

Figure 2. Location of the Rancho de las Cabras Unit of SAAN.

SAAN is located in the western climatic sub-region of the Gulf Coast and is characterized as subtropical, with mild winters and high heat and humidity in the summer (Segura et al. 2007, NPS 2015a). Mean annual temperature in the San Antonio area is 21.0° C (69.8° F). The annual mean high temperature is 27.1°C (80.8°F), with an average of 110 days above 32.2°C (90°F) (NCDC 2015, Table 1). The average low temperature is 14.9°C (58.8°F) with freezing temperatures (0° C or 32° F or below) occurring on average only 14 days per year (NCDC 2015). Mean annual high temperature around Floresville (near the Rancho Unit) is slightly higher than in San Antonio, while mean annual low temperatures are over a degree lower (Table 2). Mean annual precipitation in the San Antonio area is 77.5 cm (30.5 in) with one peak in early summer and one in fall (NCDC 2015, Table 1). Mean annual precipitation near Floresville is slightly lower at 73.8 cm (29.1 in). Thunderstorms are common during the late spring and early summer months, sometimes bringing heavy precipitation in short bursts or isolated events (NPS 2001). Precipitation in winter months arrives typically as light rain, drizzle, or even fog; snowfall is rare (NPS 2001). SAAN is located 225 km (140 mi) from the Gulf of Mexico and, as a result, is sometimes affected by tropical storms and hurricanes, producing heavy rainfall and occasional tornadoes (NPS 2001).

Table 1. 30-year climate normals (1981-2010) for the San Antonio Stinson Municipal Airport weather station near SAAN (NCDC 2015).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	17.4	19.7	23.4	27.4	30.9	33.6	35.0	36.4	32.4	28.1	22.6	17.9	27.1
Min	5.2	7.4	11.0	14.9	19.6	22.6	23.1	23.4	20.8	15.8	10.1	5.3	14.9
Average Precipitation (cm)													
Total	4.4	4.6	5.9	5.5	8.7	9.5	5.3	6.4	7.2	9.5	5.8	4.8	77.5

Table 2. 30-year climate normals (1981-2010) for the Floresville weather station near SAAN's Rancho Unit (NCDC 2015).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	18.0	20.1	23.6	27.6	31.0	33.8	35.3	36.1	33.1	28.7	23.6	18.9	27.5
Min	2.9	5.1	9.1	13.3	18.6	21.6	22.7	22.4	19.4	14.2	8.9	3.7	13.5
Average Precipitation (cm)													
Total	4.0	4.5	5.1	5.4	8.6	7.7	6.3	5.4	7.8	8.5	5.6	4.8	73.8

2.1.3 Visitation Statistics

Over the 10-year period from 2004-2013, SAAN received an average of just over 1 million visitors annually, with a peak around 1.56 million in 2009 (NPS 2015b). The park provides free tours of the missions and a museum of artifacts from the time period (NPS 2013). The Visitor Center at Mission San Jose regularly shows a film on the native people of south Texas during the 18th century. Nearly 13 km (8 mi) of paved trail stretches along the San Antonio River between Mission Concepción and Mission Espada, allowing visitors to enjoy the scenic beauty and natural resources of the park (NPS 2013).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The Missions Unit of SAAN lies within the Environmental Protection Agency's (EPA) Texas Blackland Prairies Level III Ecoregion. According to the EPA (2010, p. 7), this ecoregion is

> *"…distinguished from surrounding regions by its fine-textured, clayey soils and predominantly prairie potential natural vegetation. This region now contains a higher percentage of cropland than adjacent regions, and pasture and forage production for*

> *livestock is common. Large areas of the region are being converted to urban and industrial uses."*

Griffith et al. (2007) states that less than one percent of the region's original grassland vegetation currently remains. Within the park, these former prairies are now old agricultural fields or scrublands (Cooper et al. 2005).

The Rancho Unit lies in the East Central Texas Plains ecoregion (Figure 3) also known as the Post Oak Savanna or the Claypan Area. The EPA (2010, p. 7) states that

> *"this region of irregular plains was originally covered by post oak savanna vegetation, in contrast to the more open prairie-type regions to the north, south, and west… Many areas have a dense, underlying clay pan affecting water movement and available moisture for plant growth. The bulk of this region is now used for pasture and range."*

Honey mesquite (*Prosopis glandulosa*) is the primary tree in the East Central Texas Plains ecoregion; however, many other trees and shrubs are found including other species of mesquite, acacias (*Acacia* spp.), and dwarf oak (*Quercus margaretta*) (McMahan 1984). The East Central Texas Plains support a diversity of animal species due to the range of habitat types available. Near tropical species that are common in Mexico, grassland species that are found in the north, and even desert species can be found in this region (Diamond 2010).

Both units of SAAN fall within the San Antonio River watershed, which is further divided into "upper" and "lower" sections. The Missions Unit is in the Upper San Antonio River Watershed and the Rancho Unit is in the Lower San Antonio River Watershed.

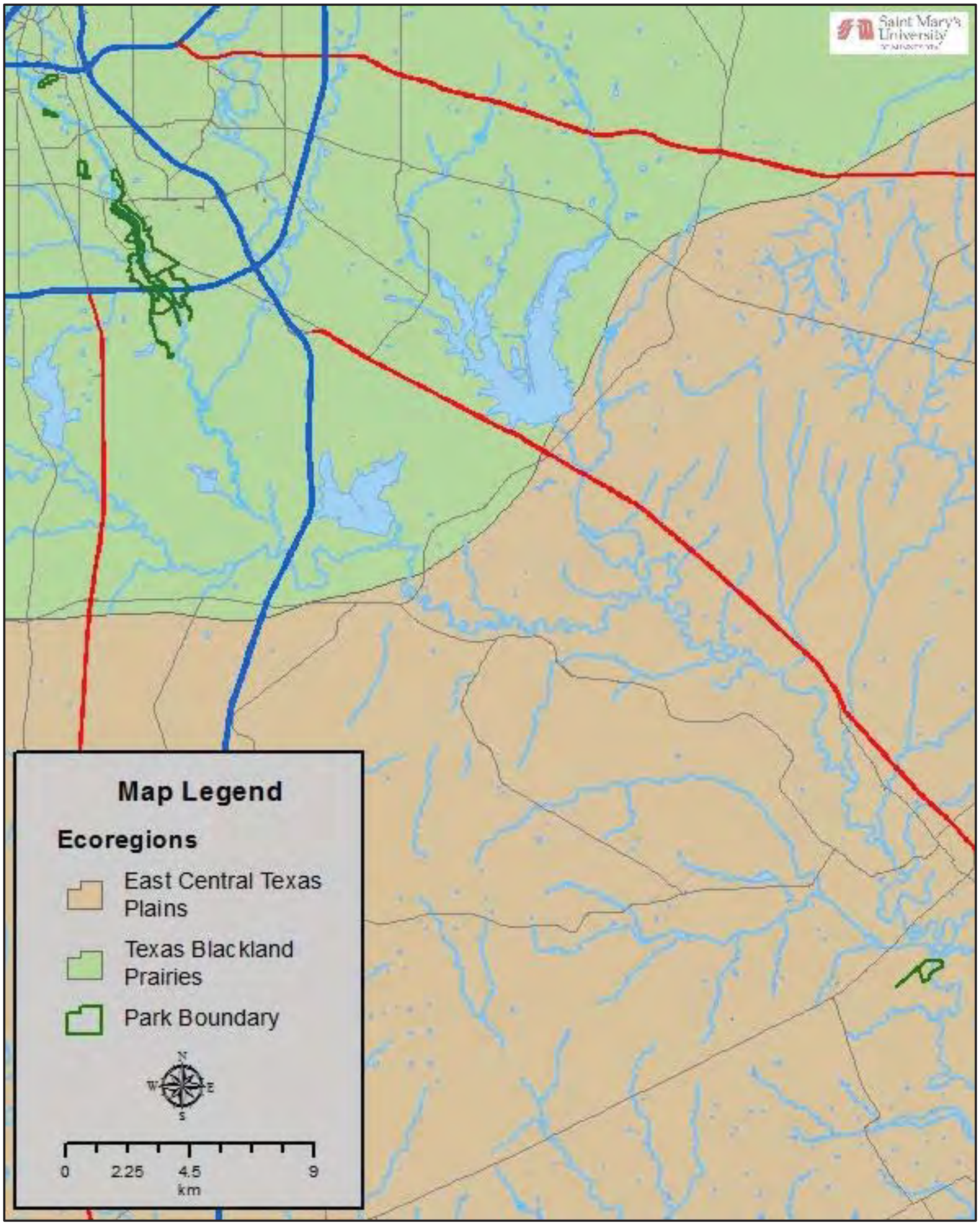

Figure 3. Ecoregions surrounding SAAN park units (EPA 2011).

2.2.2 Resource Descriptions

Cultural Resources

The Missions within SAAN were founded by Spanish missionaries during the 18th century (NPS 2001). These missions were established near water, a resource that was invaluable at the time. The San Antonio River was diverted for irrigation and other mission needs using acequias (hand-dug irrigation ditches) (NPS 2001). The acequias create oases of unique riparian habitat that are home to an assortment of wildlife, including fish, amphibians, small mammals, and many species of birds. Today, only two acequias remain: the Espada and San Juan Acequias (Photo 1a). The Espada Acequia includes a historic and still functioning aqueduct. Constructed in 1748, the Espada Aqueduct is the only continuously operating Spanish colonial aqueduct in the country (NPS 2001).

Photo 1a. The San Juan Acequia (above) and Espada Aqueduct (below) (Photos by Shannon Amberg, SMUMN GSS 2013).

Photo 1b. Espada Aqueduct (below) (Photos by Shannon Amberg, SMUMN GSS 2013).

The churches within SAAN are still active parishes, owned and operated by the Archdiocese of San Antonio (NPS 2001; Photo 1b). NPS staff oversees care for all the buildings not associated with the active parishes, as well as managing other historic structures within the park. Park staff are responsible for preserving and interpreting the landscapes of the missions and providing a historical account of the lives of missionaries and inhabitants of the original mission compounds (NPS 2001).

Biological Resources

The vegetation communities in SAAN contain a high level of diversity, with just over 570 plant species documented as present in the park (NPS 2014a). Historically, the San Antonio area was primarily grassland with few trees or woodlands and riparian forests along the San Antonio River (Van Auken and Bush 1984, Cooper et al. 2005). Brush or shrublands containing acacia species and honey mesquite were more common around the Rancho Unit (Cooper et al. 2005, Cogan 2007). No native grassland currently remains within park boundaries, although restoration efforts have been initiated in both units (Mitchell 2013). Upland shrublands are common at SAAN and support many native species such as huisache (*Acacia farnesiana*), agarito (*Berberis trifoliolata; also called algerita),* Texan hogplum *(Colubrina texensis*), and hackberries (*Celtis* spp.) (Carr 2003a, Cogan 2007). Both units also support riparian areas with tree species such as pecan (*Carya illinoinensis*), black willow (*Salix nigra*), cedar elm (*Ulmus crassifolia*), and eastern cottonwood (*Populus deltoides*) (Cogan 2007).

The varied habitats in SAAN are home to a surprising diversity of wildlife. Mammals observed in the park include the coyote (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), collared peccary or javelina (*Tayassu tajacu*), and nine-banded armadillo (*Dasypus novemcinctus*) (NPS 2014a). Also present in the park are several species of bats and many rodent species (NPS 2014a).

Photo 1c. The church at Mission Espada (Photo by Shannon Amberg, SMUMN GSS 2013)

Of the over 220 bird species observed in SAAN, approximately 70 are thought to breed within the park (NPS 2014a). The riparian woodland and brushland habitats within the park along the San Antonio River in the Missions Unit and along the river corridor in the Rancho Unit provide important habitat for a variety of birds during migration and for nesting and breeding (NPS 2010). SAAN supports several unique species whose breeding ranges only extend into the U.S. near the U.S./Mexico border, such as the crested caracara (*Caracara cheriway*; Photo 2), the painted bunting (*Passerina ciris*), and the great kiskadee (*Pitangus sulphuratus*) (NPS 2014a).

Photo 2. Crested caracara (USFWS photo).

Reptiles are common in SAAN, including snakes, turtles, and lizards (NPS 2014a). Amphibians are present but are less common (NPS 2014a). The Texas tortoise (*Gopherus berlandieri*), listed as threatened in the state of Texas, was historically present in the park; however, the species has not been seen at SAAN since 2007 (Dittmer and Fitzgerald 2011). It is likely extirpated from the Missions Unit and may also be absent from the Rancho Unit. Native fish have been documented in SAAN, both in the acequias and the San Antonio River and its tributaries (SARA 2005). Species include largemouth bass (*Micropterus salmoides*), catfish (order Siluriformes), shiners (*Notropis* and *Cyprinella* spp.), and western mosquito-fish (*Gambusia affinis*) (SARA 2005, NPS 2014a).

Although little is known about the park's invertebrate communities (Cooper et al. 2005), both terrestrial and aquatic, they perform important functions for the ecosystems. Insects in particular play critical roles in pollination, decomposition, and as a food source for other animals (Losey and Vaughan 2006).

2.2.3 Resource Issues Overview

Urban Development and Land Use

The Missions Unit of SAAN lies within San Antonio, the seventh most populated city in the United States with over 1.4 million people (USCB 2015). San Antonio has also been among the top five U.S. cities for population growth (USCB 2012). As the city of San Antonio continues to grow, so too does its need for private development of lands surrounding the Missions. Additional developments would further threaten the integrity of the park (NPS 2001).

Over the past few centuries, human development and eventual urbanization have impacted native vegetation through overgrazing, fire suppression, exotic plant species introduction, and other activities (NPS 2001). These changes contribute to habitat loss and fragmentation that impact native wildlife species. The proximity of developed areas to the Missions also impacts visitor experience, as many sights and sounds (e.g., aircraft overflights, highway traffic) that would not have been historically present are now commonplace (NPS 2001, Lynch 2009).

Water Threats

The Missions were intentionally established near water, which continues to be an essential element within the park today. The park is dependent upon and a stakeholder in water quality and quantity of the San Antonio River (Meiman 2012). The NPS staff has little to no control over the San Antonio River and its subsequent effects on the park (NPS 2001). Due to drainage into the river by a city with a population of over 1.4 million, the Upper San Antonio River has water quality issues. It is on the Texas 303(d) list for non-attainment status for bacteria (*E. coli*) and impaired fish habitat (Meiman 2012). Other problems in park waters include depressed oxygen levels and elevated nutrient concentrations (e.g., phosphorous) (Cooper et al. 2005, Meiman 2012). The San Antonio area has experienced much alteration, modification, and development of its waterways and surrounding areas. Flood hazard reduction and channel modification projects in the mid-20th century transformed the San Antonio River into a straight, largely uniform channel, which degraded aquatic and riparian habitat (Meiman 2012). The majority of the threats to the San Antonio River and other surface waters, such as urban runoff, originate outside the park boundary and are beyond NPS control.

Non-native (Exotic) and Invasive Species

Of the 889 organisms considered present in the park, 177 of these are classified as non-native (NPS 2010). Plants make up the majority of the non-native invasive species found in the park and are a threat due to their ability to outcompete native plant species (Cooper et al. 2005). Exotic grasses such as Bermudagrass (*Cynodon dactylon*), yellow (or King's ranch) bluestem (*Bothriochloa ischaemum*), and Johnson grass (*Sorghum halepense*) were introduced for agriculture and now dominate some area of the park (Carr 2003a, b). NatureServe, in cooperation with The Nature Conservancy and NPS, developed a system for ranking non-native invasive species, based on each species' ecological impact and management difficulty (NPS 2010). Table 3 lists species confirmed within SAAN that received high or medium invasiveness ranks. A full list of non-native plant species documented in SAAN (by unit) by Halvorson and Guertin (2006) in 2004 can be found in Appendix A.

Table 3. Non-native invasive plant species within SAAN receiving high or medium invasiveness rankings from NatureServe (adapted from NPS 2010).

Scientific Name	Common Name	Invasiveness Rank
Arundo donax	giant reed	high
Pennisetum ciliare	buffelgrass	high
Triadica sebifera	Chinese tallow	high
Eichhornia crassipes	common water hyacinth	high
Albizia julibrissin	silktree	high/low
Nandina domestica	sacred bamboo	high/low
Pennisetum setaceum	crimson fountaingrass	high/medium
Sorghum halepense	Johnsongrass	high/medium
Lonicera japonica	Japanese honeysuckle	high/medium
Hydrilla verticillata	water thyme	high/medium
Ligustrum sinense	Chinese privet	high/medium
Morus alba	white mulberry	high/medium
Centaurea melitensis	Maltese star-thistle	medium
Alternanthera philoxeroides	alligatorweed	medium
Lolium perenne	perennial ryegrass	medium
Vinca major	bigleaf periwinkle	medium
Lantana camara	lantana	medium
Ailanthus altissima	tree of heaven	medium
Ficus carica	edible fig	medium

An exotic plant control program has been active in the park since 2000 (Mitchell, written communication, February 2015). Early efforts focused on Chinaberry (*Melia azedarach*), privet (*Ligustrum* spp.), and giant reed (*Arundo donax*) (NPS 2001). Recent work has expanded to include many more species. Areas where exotic plant removal has occurred, along with the number of times each area has been treated, are shown in Figure 4.

The main threat from non-native mammalian species is from the feral hog (*Sus scrofa*). These hogs have been present in Texas since at least the 1930s and are now abundant in the state (Taylor 2003). The feral hog is highly adaptive and able to thrive in almost any environment, but prefers habitats with areas for wallowing; this can be anywhere mud forms, including creek banks, ponds, and drainages. Feral hogs reproduce quickly, with reproductive maturity achieved as early as 6 months in a healthy female, and litters of up to 12 piglets (Taylor 2003). As opportunistic omnivores, hogs compete for food with a variety of wildlife species; their destructive rooting behavior is particularly damaging to natural resources (Taylor 2003). Feral cats and dogs also occur in the park (NPS 2001); these have an unknown impact on native animal populations and are a potential safety concern for visitors. Feral cats are known to impact bird populations through predation (Loss et al. 2012).

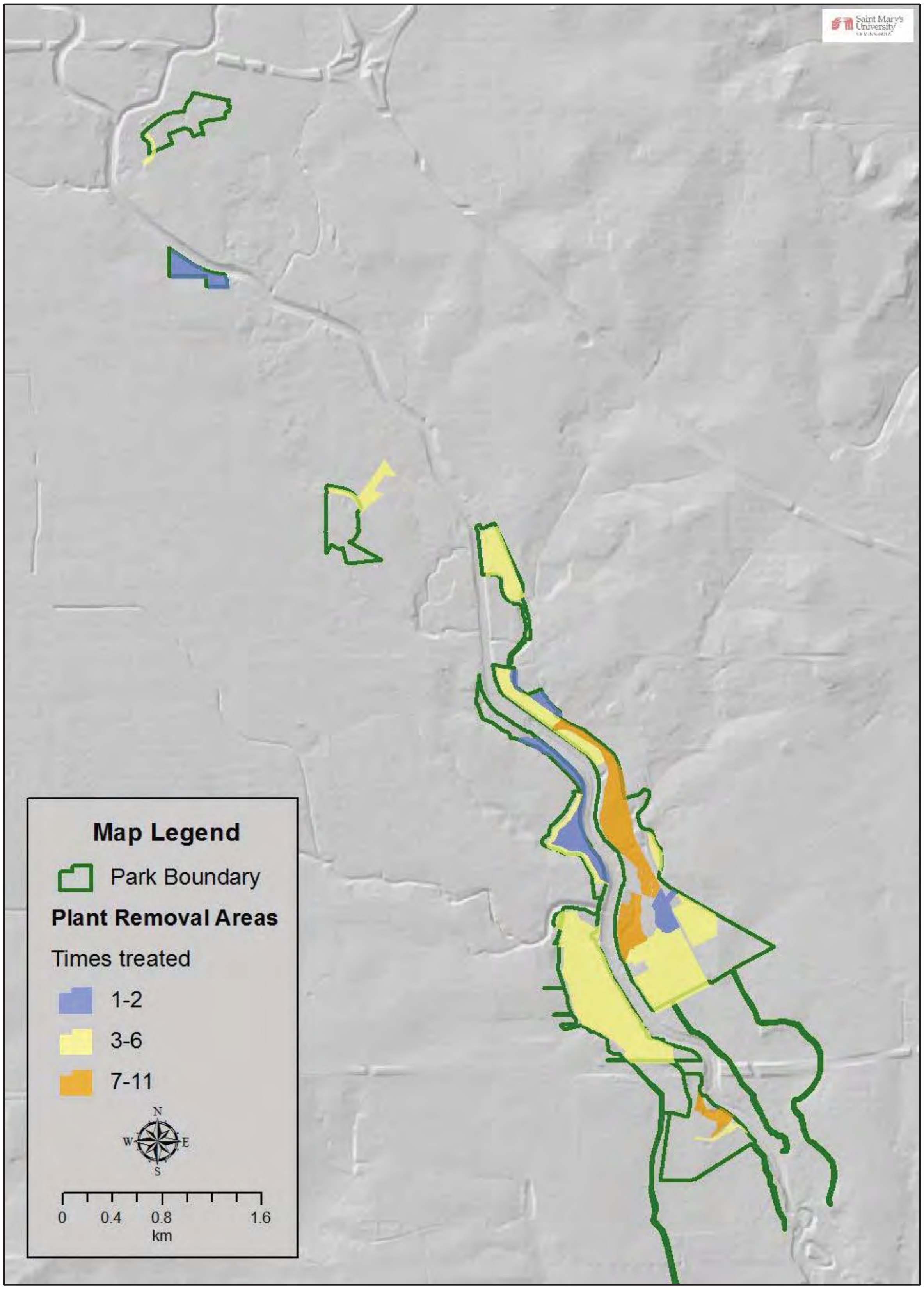

Figure 4. Exotic plant removal areas with the number of times each area has been treated since 2001 (NPS 2014b).

Climate Change

Global climate change is expected to impact the entire U.S. during this century, although the expected changes vary across the country. Since 1951, the regional climate around SAAN has shown little change. Annual mean temperatures have remained relatively stable, while annual precipitation has increased slightly, primarily due to increases in summer precipitation (Figure 5; PRISM 2014). Over the next century, mean annual precipitation around SAAN is predicted to decrease slightly (Figure 6), due primarily to significant decreases in winter and spring precipitation (Figure 7, Figure ; Maurer et al. 2007). In contrast, summer precipitation may increase slightly (Figure 8; Maurer et al. 2007). Annual mean temperature is expected to increase approximately 1.7-2.2°C (3-4°F) by 2050 and 3.3-3.9°C (6-7°F) by 2100 (Figure 9; Maurer et al. 2007). These expected temperature increases will increase evaporation rates and plant transpiration (i.e., plant moisture use); combined with seasonal precipitation declines, this will result in greater aridity, meaning overall drier conditions, particularly in the winter and spring (Figure 10; Maurer et al. 2007).

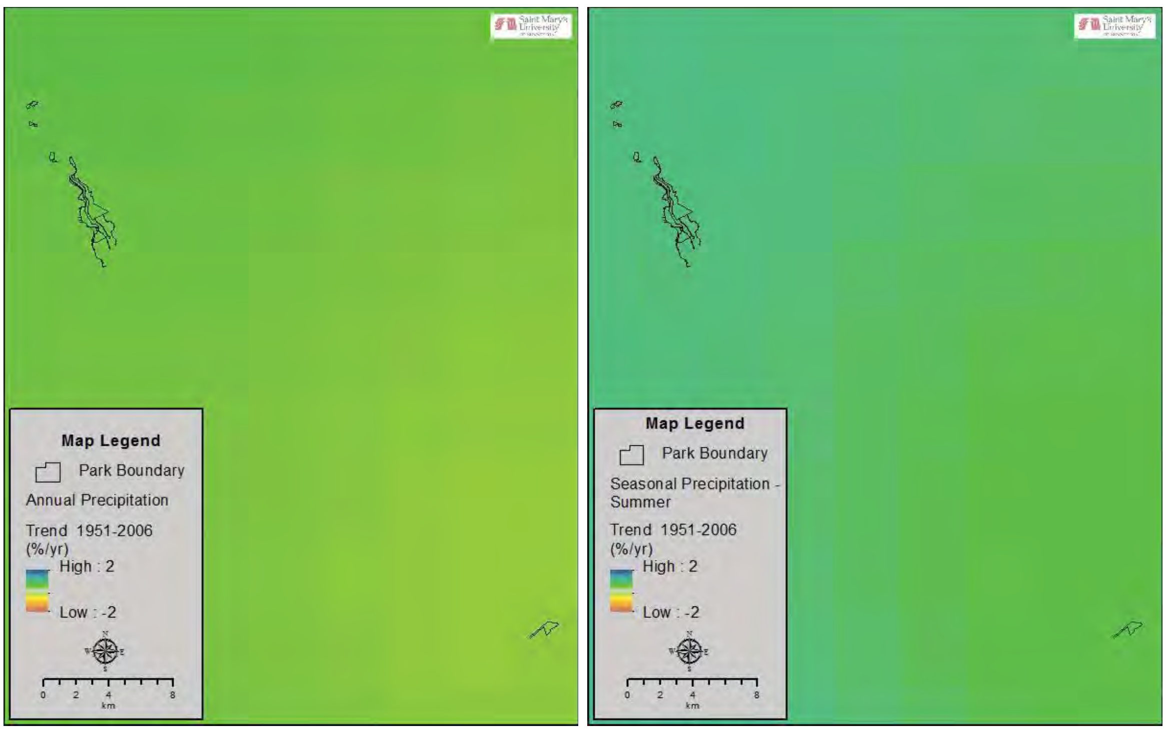

Figure 5. Change in mean **annual** precipitation (left) and mean **summer** precipitation (right) in the SAAN region between 1951 and 2006 (PRISM 2014).

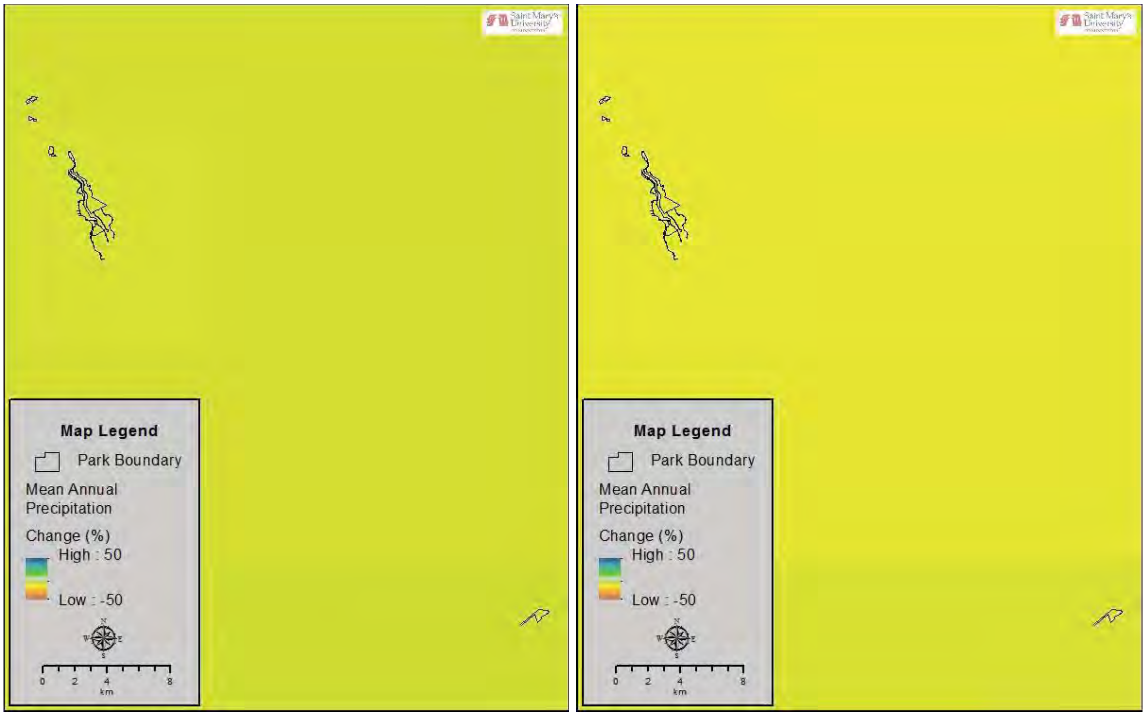

Figure 6. Projected change in mean **annual** precipitation in the SAAN region by 2050 (left) and by 2100 (right) (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

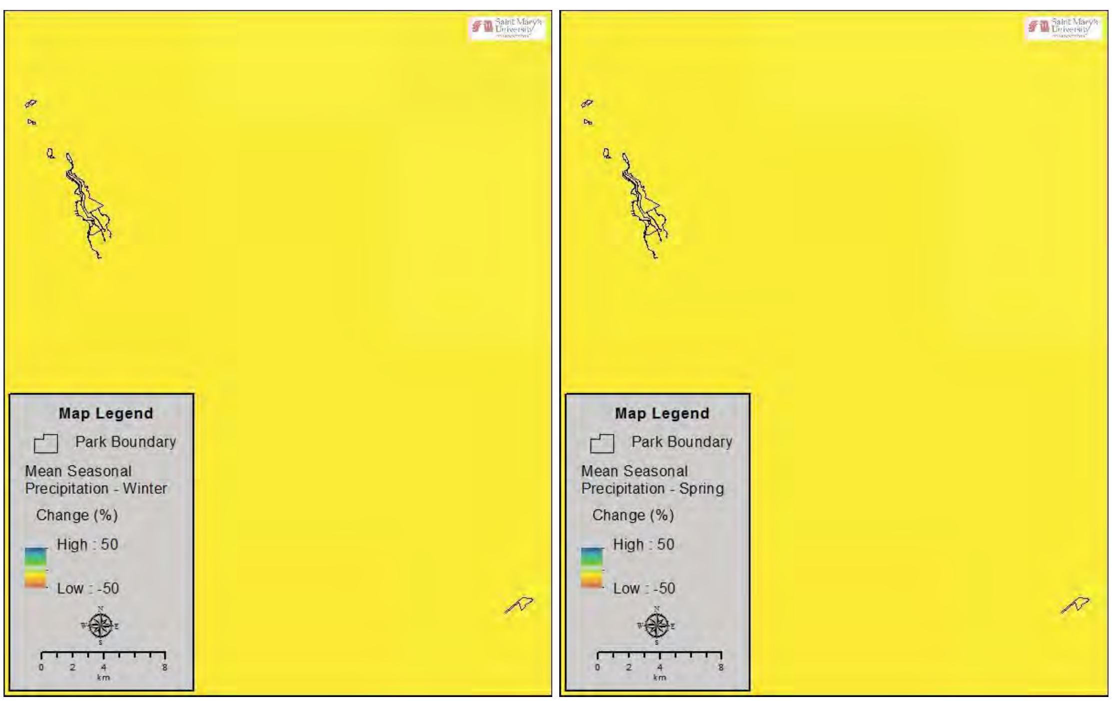

Figure 7. Projected change in mean **winter** precipitation (left) and mean **spring** precipitation (right) in the SAAN region by 2050 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

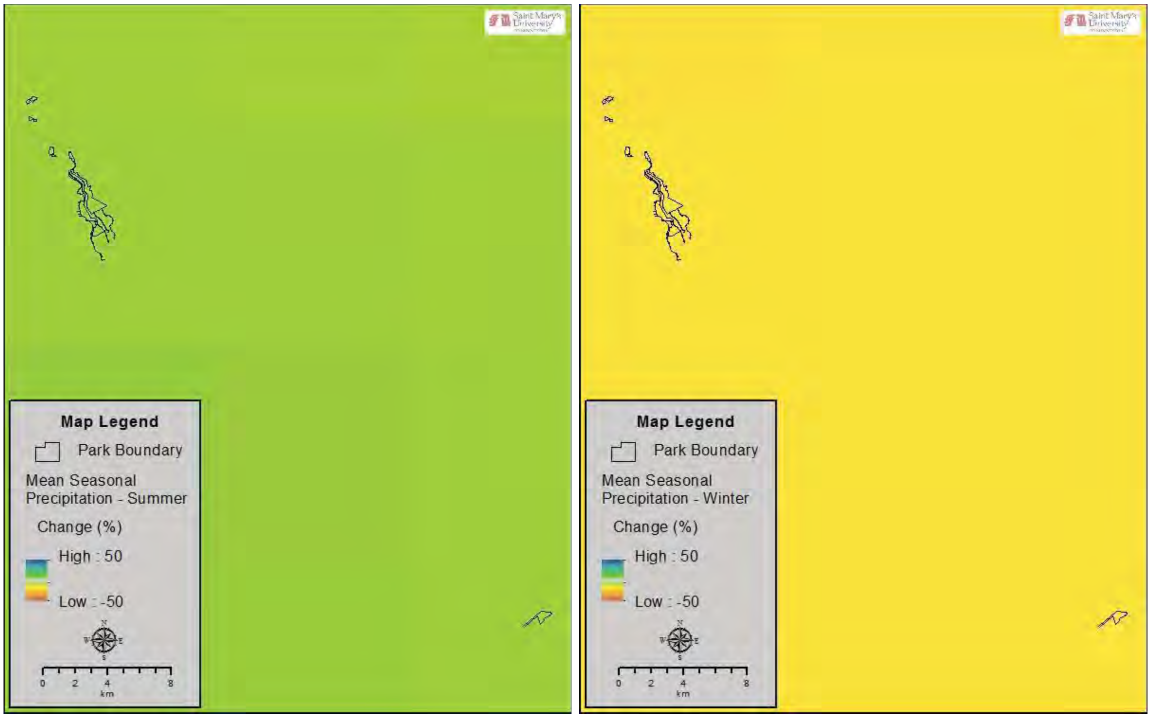

Figure 8. Projected change in mean **winter** precipitation (left) and mean **summer** precipitation (right) in the SAAN region by 2100 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

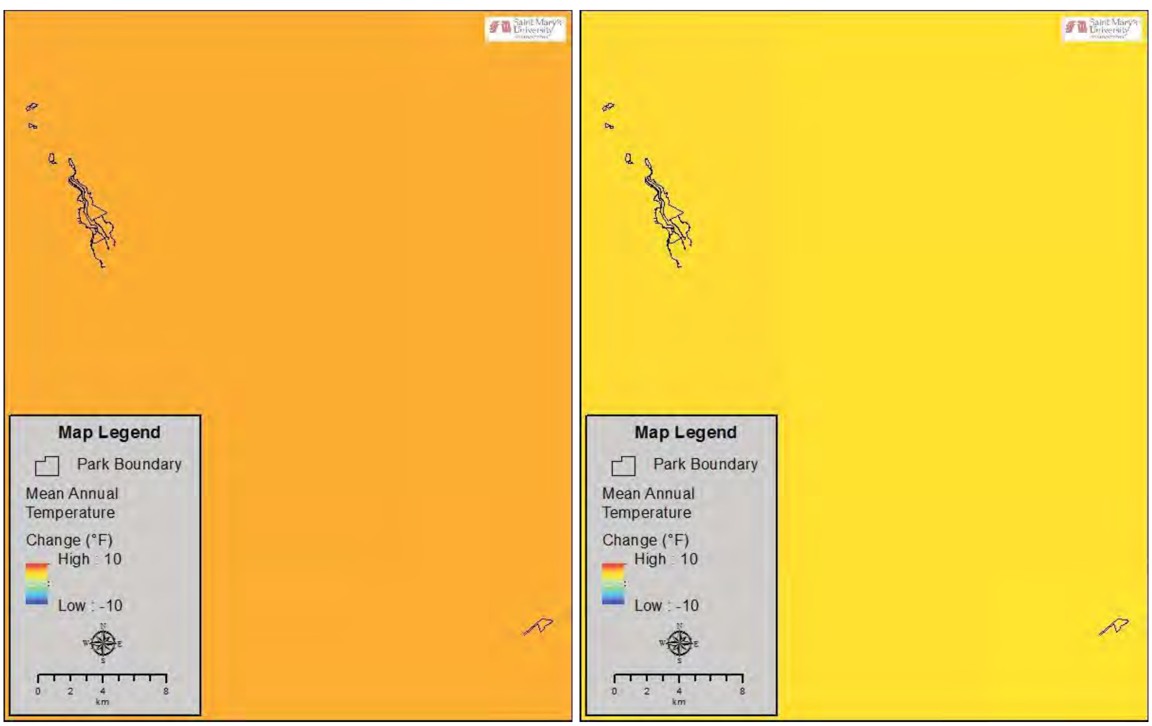

Figure 9. Projected change in mean **annual** temperature in the SAAN region by 2050 (left) and by 2100 (right) (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

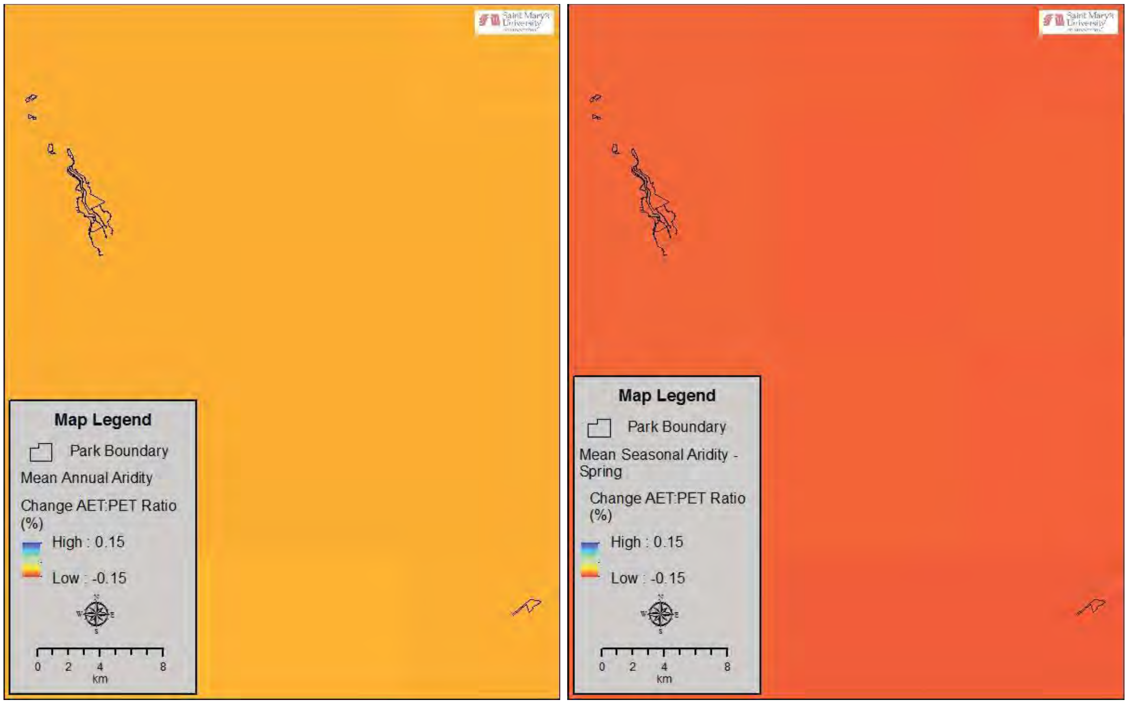

Figure 10. Projected change in mean **annual** aridity (left) and mean **spring** aridity (right) by 2050, as predicted by the change in AET:PET ratio (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

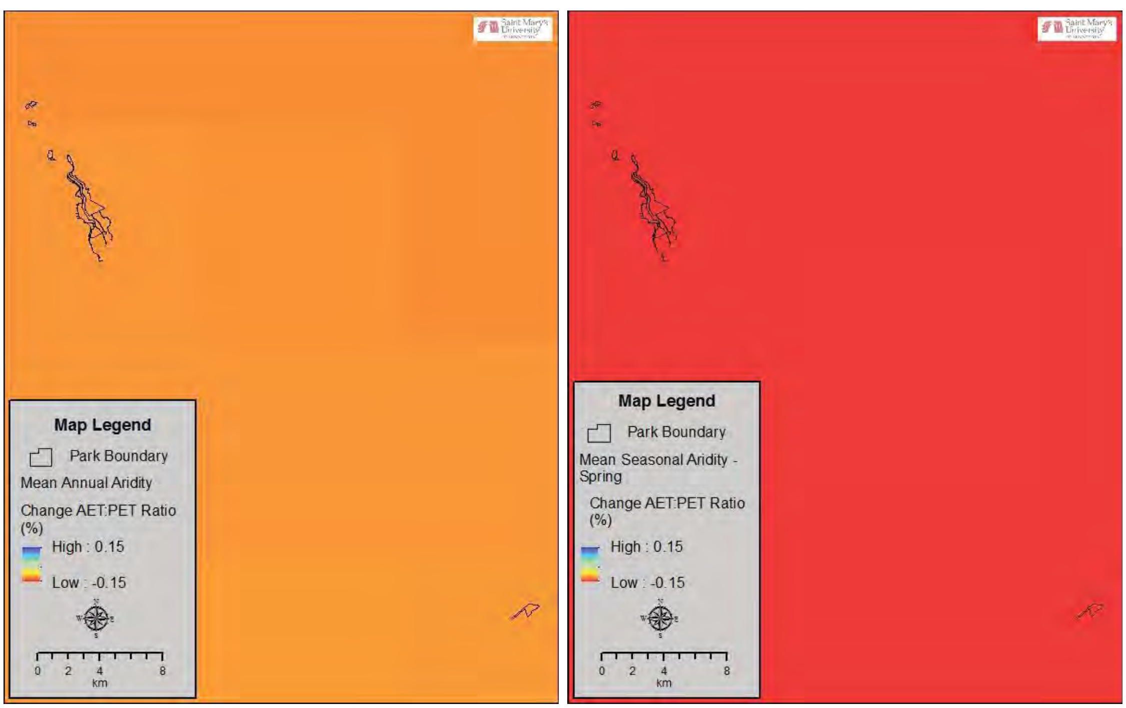

Figure 11. Projected change in mean **annual** aridity (left) and mean **spring** aridity (right) by 2100, as predicted by the change in AET:PET ratio (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

The park's resource management plan (NPS 2001, p. 7) states,

> *"Because the original natural environment of the San Antonio Missions has been extensively altered or destroyed by man's intervention during the past three centuries, the goals for natural resource management are limited to protecting and improving the condition of the existing resources and, where feasible, returning the condition and appearance of the landscape to a state which better reflects the spirit of the mission period. The latter must be undertaken only in coordination with management of the cultural resources and after sufficient research has been accomplished."*

The plan further outlines natural resources objectives to meet this goal, including (NPS 2001):

- Continue coordination between the natural and cultural resource programs to assure activities from each program are compatible with protection and management of both resources.
- Develop and maintain inventory and monitoring programs to assure that management of the park's natural resources is proactive based on a thorough knowledge and understanding of the resources.
- Cooperate with the State of Texas, other government agencies, and private entities for the purpose of protecting natural resources from adverse effects due to non-park uses and developments.
- Promote an understanding of the park's natural resources to those outside of the park.

2.3.2 Status of Supporting Science

The Gulf Coast Network (GULN) identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2007, the GULN completed and released a Vital Signs Monitoring Plan (Segura et al. 2007); Table 1 shows the GULN Vital Signs selected for monitoring in SAAN.

The San Antonio River Authority (SARA) manages the San Antonio River and its tributaries while the NPS retains water rights for the historic Acequias Espada and San Juan (Meiman 2012). In October 2007, the GULN contracted with SARA to establish four permanent long-term water quality monitoring stations in the park: Piedras Creek, Acequia de Espada, San Antonio River at San Juan Capistrano and the Acequia de San Juan. SARA samples these four sites bimonthly as part of its Clean Rivers Program monitoring effort (Meiman 2012). SARA has also collected data on fish and aquatic macroinvertebrate populations within park waters.

Table 1. GULN Vital Signs selected for monitoring in SAAN (Segura et al. 2007).

Category	GULN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]	No Monitoring Planned
Air and Climate	Ozone		X		
	Air Contaminants		X		
	Weather/Climate		X		
Geology and Soils	Stream/River Channel Dynamics and Geomorphology				X
	Erosion and Deposition				X
	Soil Biota				X
	Soil Chemistry				X
	Soil Structure and Stability				X
Water	Groundwater Hydrology				X
	Water Chemistry	X			
	Water Nutrients	X			
	Water Toxics		X		
Biological Integrity	Non-native Vegetation	X			
	Non-native Animals			X	
	Riparian Communities	X			
	Forest Health	X			
	Freshwater Invertebrates				X
	Terrestrial Invertebrates				X
	Amphibians	X			
	Non T&E Reptiles				X
	Migratory Birds	X			
	Resident Birds	X			
	Non T&E Small Mammals				X
	Terrestrial Vegetation	X			
	T&E/Rare Birds			X	

[a] **Category 1** represents Vital Signs for which the network will develop protocols and implement monitoring.

[b] **Category 2** represents Vital Signs that are monitored by SAAN, another NPS program, or by another federal or state agency using other funding.

[c] **Category 3** represents high-priority Vital Signs for which monitoring will likely be done in the future.

Table 4 (continued). GULN Vital Signs selected for monitoring in SAAN (Segura et al. 2007).

Category	GULN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]	No Monitoring Planned
Biological Integrity (continued)	T&E/Rare Freshwater Fish			X	
	T&E/Rare Plants			X	
	T&E/Rare Reptiles				X
Human Use	Visitor Usage				X
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	X			
	Land Cover/Land Use	X			
	Soundscape				X

[a] **Category 1** represents Vital Signs for which the network will develop protocols and implement monitoring.

[b] **Category 2** represents Vital Signs that are monitored by SAAN, another NPS program, or by another federal or state agency using other funding.

[c] **Category 3** represents high-priority Vital Signs for which monitoring will likely be done in the future.

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Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the SAAN resource management team and GULN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held on 19-21 November 2013. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to SAAN managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by SAAN resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid SAAN resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: SAAN resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.
- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.
- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds, plant communities), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in SAAN. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were adapted from the GULN Vital Signs Monitoring Plan (Segura et al. 2007). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in March 2014 following acceptance from NPS resource staff. It contains a total of 15 components (Figure 12a-b) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

San Antonio Missions National Historic Park
Natural Resource Condition Assessment Framework

Category	Component	Measures	Stressors	Reference Condition
Biotic Composition				
Ecological Communities				
	Forested Riparian Corridors (including acequias)	Community extent, community composition (e.g., species richness), percent coverage of native species, age class structure	Nonnative species (feral hogs, nutria, plants); adjacent land use practices (including increased paving carrying more water into acequias and ornamental introduction); disease; drought and hydrological changes	Ideally, condition during Missions period, but data from this time are not available
	Native Grassland/Prairie	Community extent, community composition, percent coverage of native species	Nonnative species (feral hogs, plants); fire suppression; atmospheric deposition of pollutants; drought	Management goal 5 years after seeding: coverage of 60-70% native grasses and 30-40% forbs and wildflowers; <15% cover by woody vegation; minimum of 80% cover by native species
	Upland Shrublands/Woodlands	Community extent, community composition, percent coverage of native species	Nonnative species (feral hogs, plants); adjacent land use practices (including ornamental introduction); drought; climate change	Ideally, condition during Missions period, but data from this time are not available
Herptiles				
	Reptiles	Species richness, relative abundance, reproductive success	Nonnative species (feral hogs, cats); habitat loss and fragmentation; drought; climate change	Undefined; Strecker (1915) provides some information on species richness in San Antonio area
	Amphibians	Species richness, relative abundance, reproductive success	Nonnative species (feral hogs, cats); habitat loss; displacement by nonnatives (Rio Grande chirping frog); disease; drought; climate change	Undefined; Strecker (1915) provides some information on species richness in San Antonio area
Birds				
	Breeding Birds	Species richness, relative abundance, distribution	Habitat loss; brood parasitic species (cowbird); nonnative species (cats, feral hogs); adjacent land use; fire ants	Coonan (1987) for species richness; undefined for abundance and distribution
	Resident/Year-round Birds	Species richness, relative abundance, distribution	Habitat loss; brood parasitic species (cowbird); nonnative species (cats, feral hogs); adjacent land use; fire ants	Coonan (1987) for species richness; undefined for abundance and distribution
Freshwater Biota				
	Aquatic Macroinvertebrates	IBI rating	Habitat loss and degradation; water quality impairments; impervious cover carrying more water and chemicals into waterways; drought; decreased flows; hydrological changes ; past contamination in soils;	TCEQ standards (2007)
	Fish	Species richness, IBI rating	Habitat loss and degradation; water quality impairments; impervious cover carrying more water and chemicals into waterways; drought; decreased flows; hydrological changes; climate change	Standards used by SARA, based on the EPA Rapid Bioassessment Protocol V (RBP, EPA 1989)
Environmental Quality				
	Water Quality	Water temperature, pH, specific conductance (TDS), dissolved oxygen, total suspended solids (turbidity), coliform bacteria, nutrients (phosphorus, nitrogen), chloride, sulfate	Impervious surface runoff; drought (introduction of reuse water); flooding; adjacent land uses; point and non-point source pollution	TCEQ standards (2014)
	Air quality	Ozone, deposition of nitrogen, deposition of sulfur, visibility, particulate matter	Urban development and land use; vehicle traffic; coal-burning powerplant; nearby oil refinery and fracking; meat packing facility	NPS ARD guidelines, based on NAAQS

Figure 12a. San Antonio Missions National Historical Park natural resource condition assessment framework.

San Antonio Missions National Historic Park
Natural Resource Condition Assessment Framework

	Component	Measures	Stressors	Reference Condition
Environmental Quality				
	Soundscape	Loudness, frequency, and percent of time audible of non-contributing human-caused sound	Urban development and land use; Stinson airport operations (overflights); vehicle traffic; railroad noise	Loudness: 52 dBA (level of speech interference for interpretive programs (EPA 1974); Percent of time audible: no increase above levels documented by Lynch (2009); Frequency: undetermined
	Dark Night Skies	NPS Night Sky Team's suite of measures	Urban lights/development; lights along Hwy 410; refinery flaring; blinking lights on cell towers	Conditions at the time the Missions were active
	Viewscape	Number of non-contributing features visible within the park, number of non-contributing features visible outside of park, appearance of San Juan labores	Urban development expanding south; powerline corridors, cell towers, encroaching vegetation, in-park development	Non-contributing features visible within the park: no increase from current; management goal of zero woody vegetation in the labores and intact shrub/tree rows between fields.
Physical Characteristics				
	Hydrology (surface and ground water)	Stream flow rates (amount and timing), width:depth ratio, depth to groundwater (Rancho only)	Drought; extreme flooding events; climate change (changes in precipitation patterns); repurposing of the reuse water	Undefined; Ideally, condition during Missions period but this is no longer feasible given the significant alterations to the San Antonio River

Figure 12b. San Antonio Missions National Historical Park natural resource condition assessment framework.

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time SAAN staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were also provided by NPS staff. Additional data and literature were acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from SAAN and the GULN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 2. This categorization allows measures that are more important for determining condition of a component (higher Significance Level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 2. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 3). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 3. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	**Of NO** concern. No net loss, degradation, negative change, or alteration.
1	**Of LOW** concern. Signs of limited and isolated degradation of the component.
2	**Of MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	**Of HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.0). Figure 13 displays the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles that a resource is in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there were currently insufficient data to make a statement about the condition of a component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a "snapshot-in-time" of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A horizontal arrow indicates an unchanging condition or trend, and an arrow pointing down indicates deterioration in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. In situations where the trend of the component's condition is currently unknown, no arrow is given.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence *(explanation is required if a trend symbol or a medium/high confidence band is shown)*				

Figure 13. Description of symbology used for individual component assessments.

Examples of how the symbols should be interpreted:

Resource is in good condition, its condition is improving, high confidence in the assessment.

Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.

Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.

Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and SAAN and GULN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by SAAN resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and outside resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures
Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component are presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining

the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices referenced in each section (component) of Chapter 4 are listed in that component's "Literature Cited" section.

3.3 Literature Cited

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. http://glei.nrri.umn.edu/default/glossary.htm (accessed 19 January 2015).

The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

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.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 15 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

- Description
- Measures
- Reference Condition
- Data and Methods
- Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
- Sources of Expertise
- Literature Cited

The order of components follows the project framework (Figure 12a-b):

4.1 Forested Riparian Corridors

4.2 Native Grasslands

4.3 Upland Shrublands/Woodlands

4.4 Reptiles

4.5 Amphibians

4.6 Breeding Birds

4.7 Resident Birds

4.8 Aquatic Macroinvertebrates

4.9 Fish

4.10 Water Quality

4.11 Air Quality

4.12 Soundscape

4.13 Dark Night Skies

4.14 Viewscape

4.15 Hydrology

4.1 Forested Riparian Corridors

4.1.1 Description

Along the San Antonio River, Piedras Creek, Picosa Creek, other tributaries, and the historic acequias, there are forested riparian areas with diverse plant communities in mid to late stages of succession (Photo 3). These are often considered critical habitat for both flora and fauna (Wagner 2003, Cogan 2007). Riparian corridors serve important ecological functions, partly by maintaining water quality. The vegetation provides shade which regulates the water temperature, the plants physically bind streambanks together which provides channel stability, and perhaps most importantly, captures excess nutrients and sediment that are transported by runoff (Wagner 2003). These structural features all improve water quality and promote diversity, supporting a wide variety of both aquatic and terrestrial species (Wagner 2003).

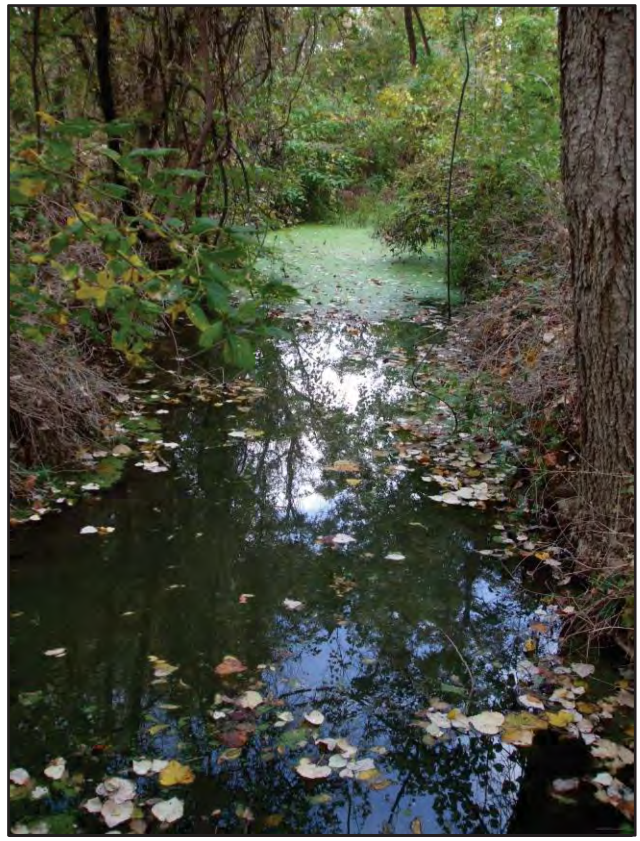

Photo 3. An example of a forested riparian corridor located along the Acequia de Espada (photo by Kathy Allen, SMUMN GSS 2013).

In SAAN, elements of Chihuahuan Desert, coastal grassland, subtropical woodland, and Tamaulipan thornscrub are intermingled within the riparian zones (Cogan 2007). Typically, riparian forest communities are layered with tall trees, shrubs, and wetland herbaceous plants. There are mixes of native and introduced species in various combinations comprising the forested riparian corridors of SAAN (Cogan 2007). The composition of plant species in these communities is influenced by the climate, soil composition, and topography (Cogan 2007). Introduced exotic species and past land management practices (e.g., fire suppression) have also had a strong effect on plant community composition in SAAN (Cogan 2007).

Tree species that are common in the riparian areas of the Missions Unit include pecan (*Carya illinoinensis*), black willow (*Salix nigra*), sugarberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), and box elder (*Acer negundo*). These trees occur in large, mixed stands along the main channel and tributaries in the unit (Cogan 2007). The Rancho de las Cabras Unit has a similar riparian community structure, with some additional tree species, including eastern cottonwood (*Populus deltoides*) (Cogan 2007). These trees create the upper layer of SAAN's forested riparian communities, and at Rancho de las Cabras there are also underlying shrub communities associated with both the riparian and upland scrublands (Cogan 2007). Common species are blackbrush acacia (*Acacia rigidula*), Texas hogplum (*Colubrina texensis*), rough leaf dogwood (*Cornus drummondii*), and Brazilian bluewood (*Condalia hookeri*) (Cogan 2007). These communities are referred to as palustrine, where roots are wetted regularly in the summer, but lack flowing water and undergo short dry periods (Cogan 2007).

4.1.2 Measures

- Community extent
- Community composition
- Percent coverage of native species
- Age class structure

4.1.3 Reference Conditions/Values

Ideally, a reference condition from the Missions period would serve as a baseline for the measures in this assessment. Unfortunately, there are not sufficient descriptions available from that reference period. There are very limited data and descriptions of the forested riparian corridors in SAAN to use in comparison with the current conditions or trends in these communities. The information presented in this report may be considered the baseline for studies of the park's forested riparian corridors in the future.

4.1.4 Data and Methods

Carr (2003a, b) conducted a botanical inventory of both the Missions and Rancho de las Cabras Units of SAAN over a two-year period. The purpose of the study was to obtain baseline inventories of flora as part of the NPS Inventory and Monitoring (I&M) Program (Carr 2003a, b). Field work was completed concurrently in the Missions and Rancho de las Cabras from July through October in 2001, and March through October in 2002 (Carr 2003a). Fieldwork consisted of transect sampling in each macrohabitat of the Missions and Rancho de las Cabras Units, including riparian woodlands (Carr 2003a, b).

Cogan (2007) completed vegetation classification and mapping in and around SAAN (Figure 14), based on field work conducted in 2005-2006. The results provide mapped vegetation communities, extent of acreage for each type, and lists of species typically found in each community. Classification methods and categories followed the National Vegetation Classification Standard (NVCS) accepted by the Federal Geographic Data Committee (FGDC 2008).

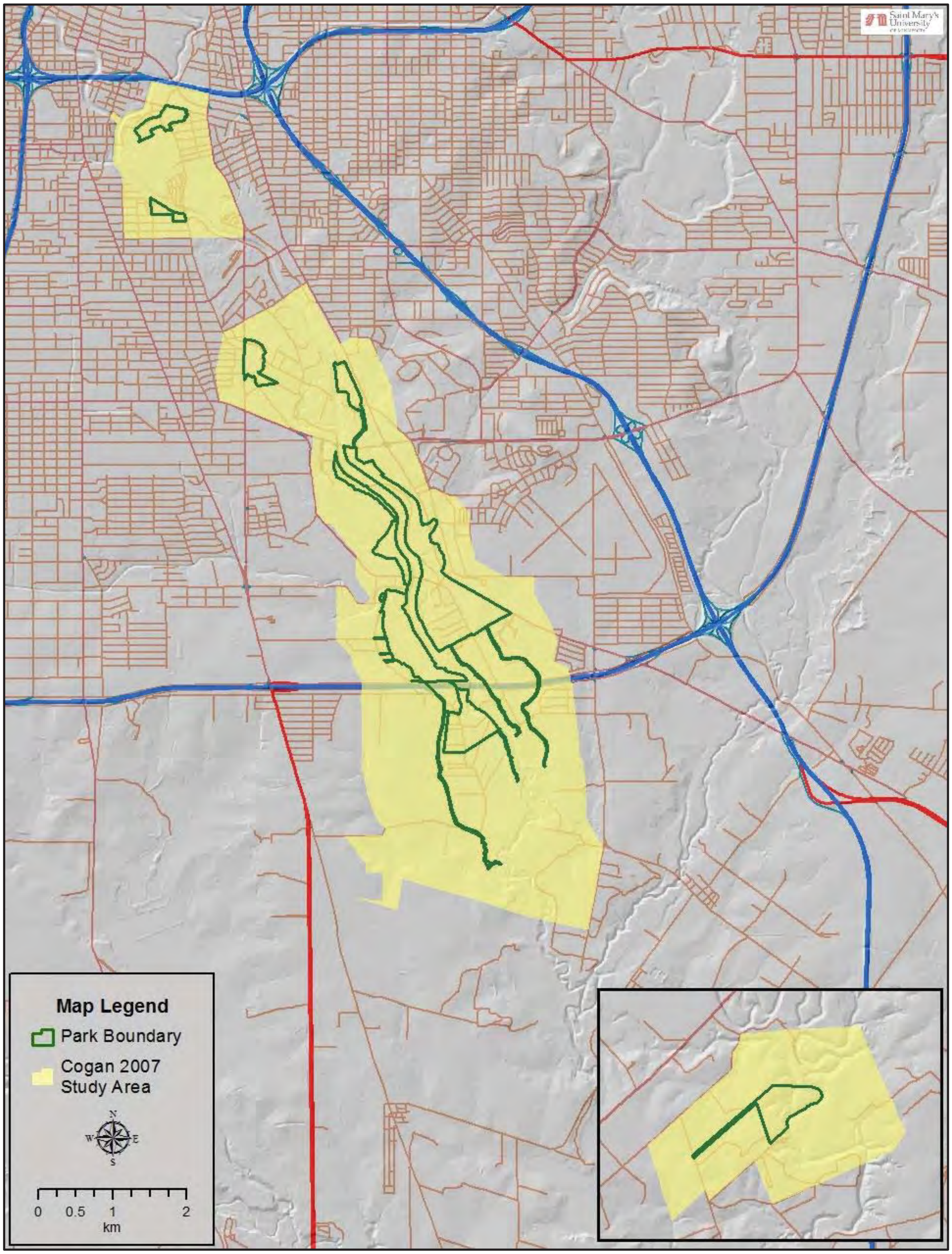

Figure 14. Cogan's (2007) study boundary (yellow) relative to the park boundaries.

4.1.5 Current Condition and Trend

<u>Community Extent</u>

Vegetation communities were mapped throughout both units of the park by Cogan (2007). The extent of forested riparian communities is provided in Table 7 and shown by location in Figure 15, Figure 16, and Figure 17.

Table 4. Extent of forested riparian communities (in hectares) within park boundaries and within Cogan's (2007) study area.

	Extent (ha)		
Forested Riparian Corridors	**Missions (303)**	**Rancho (41)**	**Cogan (2007) Study Area**
Eastern cottonwood temporarily flooded forest alliance	0.0	3.3	26.0
Live oak temporarily flooded forest alliance	0.9	0.9	37.1
Black willow temporarily flooded shrubland alliance stand	0.0	0.2	0.4
Pecan-Sugarberry Forest	71.2	0.0	198.6
Cedar Elm-Sugarberry/Possum-haw/Virginia wild rye forest	17.9	8.8	215.3
Totals	**89.8**	**13.2**	**477.4**

The eastern cottonwood and live oak (*Quercus virginiana*) temporarily flooded alliances occur in both the Missions and the Rancho de las Cabras Units of SAAN. The live oak alliance is primarily found in small patches in the northwestern Missions Unit (Figure 15) and Rancho de las Cabras..

The most abundant forested riparian community type is the pecan-sugarberry forest, which is found primarily in the southeastern Missions (Figure 16). The second most extensive community type is the cedar elm-sugarberry/possum-haw/Virginia wild rye forest, which is also the predominant riparian type in the Rancho de las Cabras Unit. The black willow temporarily flooded forest alliance is very small, with just one stand located in the Rancho de las Cabras Unit; the size of this alliance in the park is below the minimum mapping unit and is not included in the spatial file that shows the layout of other riparian vegetation types at SAAN (Figure 16).

In comparison to the entire Cogan (2007) study area, some of these forested riparian corridors are found outside of the park in larger acreages; for example, the pecan-sugarberry forest within the park comprises 71 ha (175.4 ac) while the total for the study is 198.6 ha (485.8 ac). The cedar elm-sugarberry/possum-haw/Virginia wild rye forest total is 215.3 ha (532ac), the largest of the four types, but only 26.7 ha (66ac) is inside of SAAN. In summary, out of the total hectares of riparian areas that were mapped for the project, only about 22% of them are protected by the NPS within the boundaries of SAAN. Approximately 36% of the total pecan-sugarberry forest, 13% of eastern cottonwood temporarily flooded forest alliance, 13% of cedar elm-sugarberry/possum-haw/Virginia wild rye forest, and 5% of live oak temporarily flooded forest alliance were documented inside of SAAN (Cogan 2007). Half of the black willow temporarily flooded shrubland alliance stand is within SAAN, covering slightly less than half a hectare (Cogan 2007).

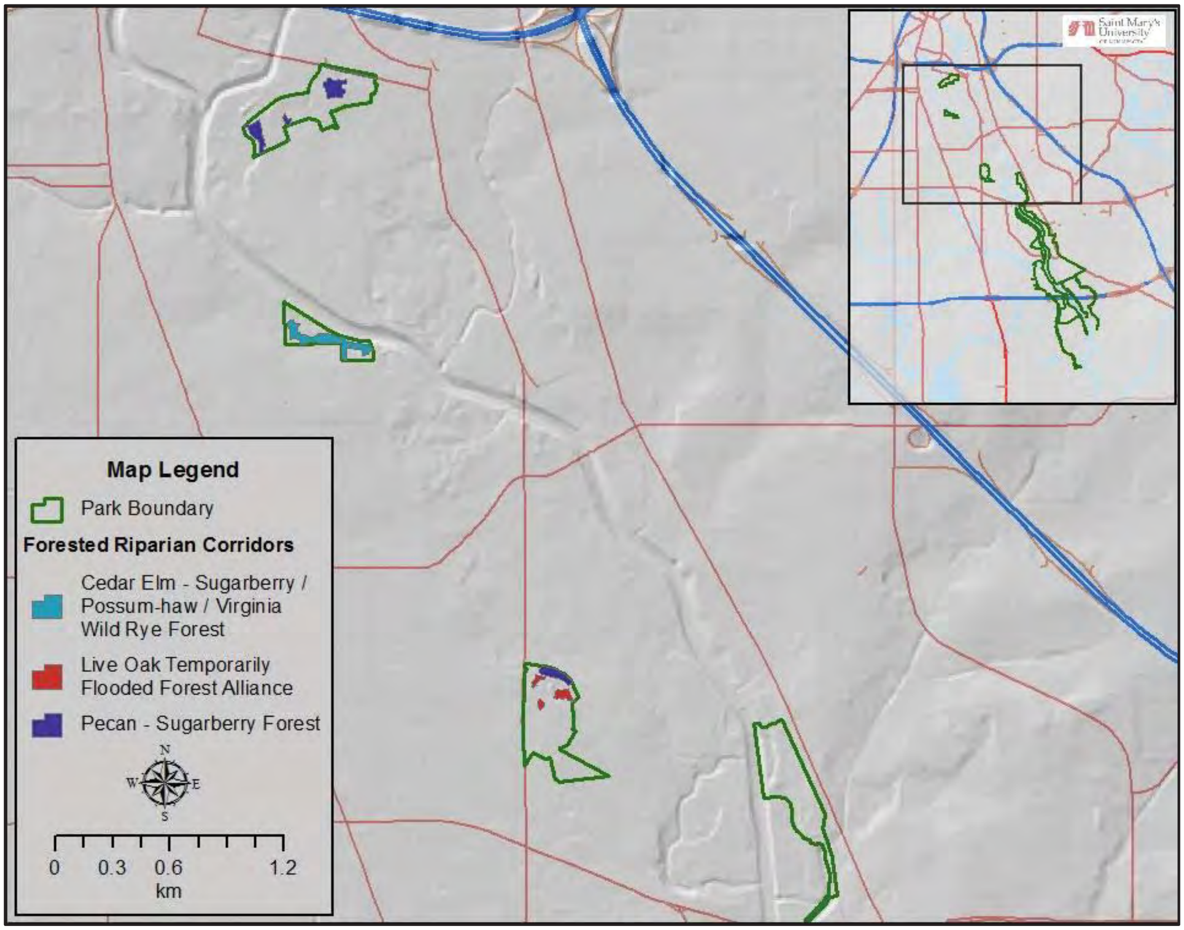

Figure 15. Forested riparian communities within the northwestern area of the Missions Unit (data from Cogan 2007).

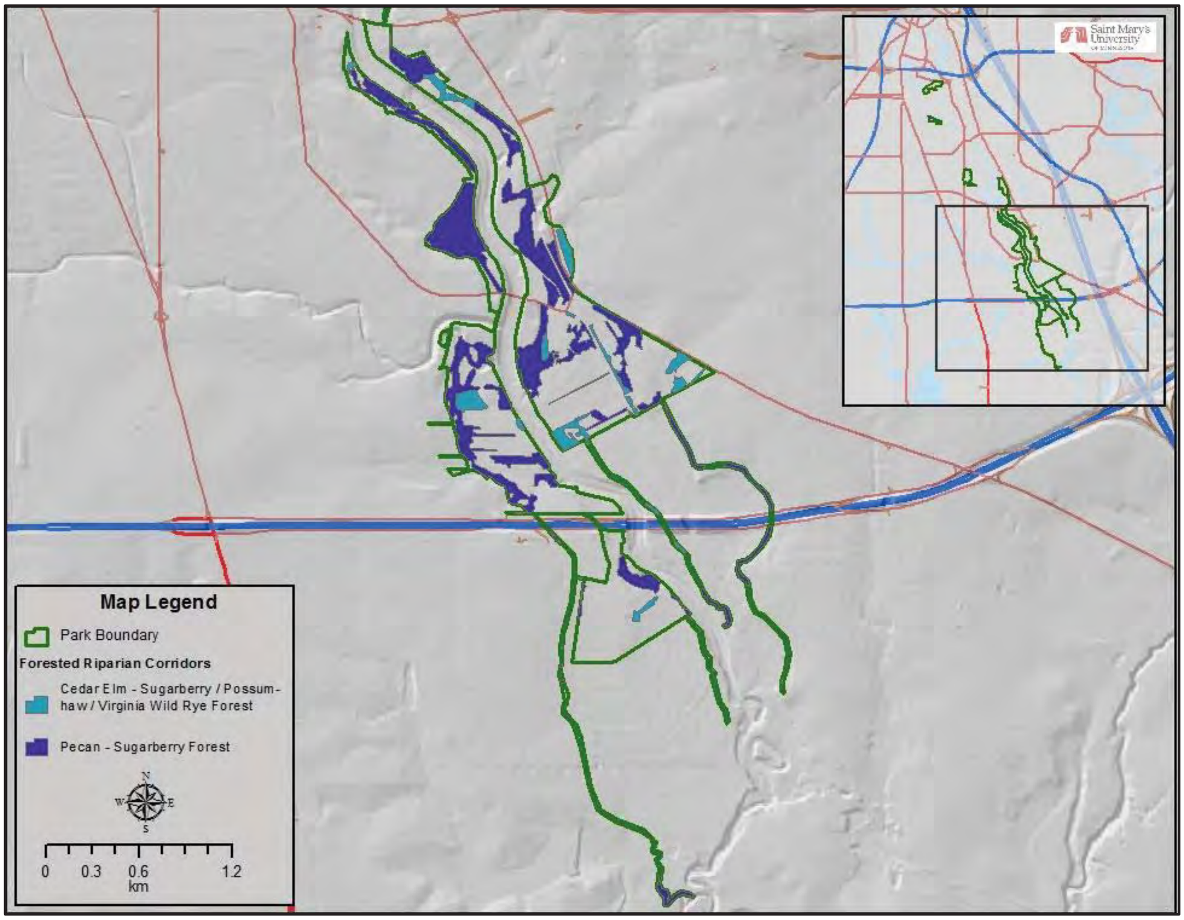

Figure 16. Forested riparian communities within the southeastern Missions Unit at SAAN (Cogan 2007).

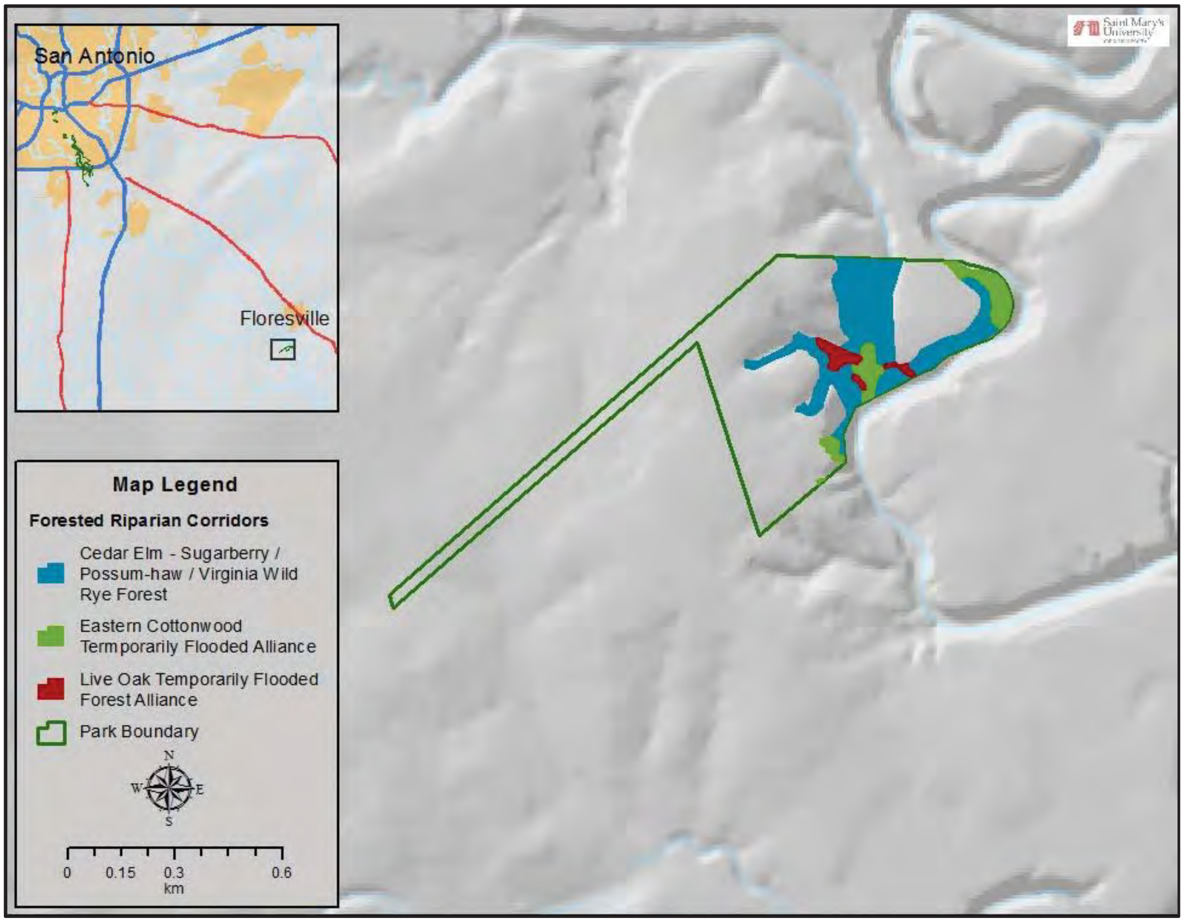

Figure 17. Forested riparian communities within the Rancho de las Cabras Unit at SAAN (Cogan 2007).

Community Composition

The inventory conducted by Carr (2003a, b) documented 188 plant species associated with riparian woodland and forest communities in SAAN. Riparian species that occur in each of the park's units are listed in Appendix B. There were 128 species documented within the Missions Unit and 117 species in the Rancho de las Cabras, including 42 total non-native species (Carr 2003a, b). Cogan (2007) listed species that were associated with the forested riparian corridors and included them with the descriptions of each type (excluding black willow).

Pecan-Sugarberry Forest

Pecan-sugarberry riparian forest canopy (15-25 m [49-82 ft] height) in the late successional phase in SAAN is dominated by pecan and boxelder (*Acer negundo*) trees, with a thick layer of sugarberry sub-canopy (Cogan 2007). The sub-canopy is mostly underlain with a sparse shrub layer of shrubs and saplings, mostly roughleaf dogwood and American black elderberry (*Sambucus nigra*) (Cogan 2007). Beneath the sub-canopy are several species of low shrubs and vines, as well as shade-tolerant forbs that make up the often sparse (<50%), ground layer (Table 5; Cogan 2007). Amongst the typical ground layer species are also seedlings of the various species in this riparian forest. Chinaberry trees (*Melia azedarch*) are common in the pecan-sugarberry forests and are an invasive exotic species (Cogan 2007).

Table 5. Species occurring in the pecan-sugarberry forest (recreated from Cogan 2007).

Type	Scientific Name	Common Name
Tree	*Carya illinoinensis*	pecan
	Celtis laevigata	sugarberry
	Acer negundo	boxelder
	*Melia azedarach**	Chinaberrytree
Shrub	*Cornus drummondii*	roughleaf dogwood
Herb	*Rubus riograndis*	Rio Grande dewberry
	Toxicodendron radicans	poison ivy
	Ambrosia trifida	great ragweed
	Calyptocarpus vialis	straggler daisy
	Galium aparine	cleavers, stickwilly
	Malvaviscus arboreus	wax mallow
	*Torilis arvensis**	spreading hedgeparsely
	Elymus virginicus	Virginia wild rye
Invasive	*Ligustrum japonicum**	Japanese privet

* Non-native

In the mid-successional phase the sugarberry dominated canopy seldom exceeds 15 m (49 ft) and usually has 75% cover (Cogan 2007). There are some sites where Chinaberry trees got an early foothold and are the dominant canopy species; the invasive exotic Japanese privet (*Ligustrum japonicum*) is often found in this forest type as well. The ground layer is thicker in the mid-successional phase (up to 70% thicker) and is dominated by cleavers (*Galium aparine*) and spreading hedgeparsley (*Torilis arvensis*) (Cogan 2007).

Eastern Cottonwood Temporarily Flooded Forest Alliance

This riparian forest type is considered the dominant association for both height and density amongst the riparian forests of SAAN; this is likely due to the tendency of cottonwood trees, which are the dominant canopy species, to reach such towering heights (Cogan 2007). On average, the canopy reaches up to 30 m (98 ft) and has a wide range of coverage (40% to 70%), with a sub-canopy coverage that is equal and at times greater than the upper canopy (Cogan 2007). Both the sub-dominant canopy and the sub-canopy species consist of boxelder, pecan, sugarberry, American elm (*Ulmus americana*), and cedar elm (Cogan 2007). This forest type tends to have a sparse shrub layer with a fairly thick ground layer with up to 40% cover (Table 6; Cogan 2007). Many of the ground layer species are vines, such as Rio Grande dewberry (*Rubus riograndis*), saw greenbriar (*Smilax bona-nox*), and poison ivy (*Toxicodendron radicans*), and shade-tolerant grasses such as Indian woodoats (*Chasmanthium latifolium*) and Virginia wild rye (*Elymus virginicus*).

Table 6. Species occurring in the eastern cottonwood temporarily flooded forest alliance (recreated from Cogan 2007).

Type	Scientific Name	Common Name
Tree	*Populus deltoides*	eastern cottonwood
	Acer negundo	boxelder
	Carya illinoinensis	pecan
	Celtis laevigata	sugarberry
	Ulmus americana	American elm
	Ulmus crassifolia	cedar elm
Herb	*Rubus riograndis*	Rio Grande dewberry
	Toxicodendron radicans	poison ivy
	Smilax bona-nox	saw greenbrier
	Ambrosia trifida	great ragweed
	Chasmanthium latifolium	Indian woodoats
	Elymus virginicus	Virginia wild rye

Cedar Elm-Sugarberry/Possum-haw/Virginia Wild Rye Forest

This riparian forest type has canopies that range from 15 to 20 m (49 –66 ft) in height and cover is generally around 70-90% in the main areas (Cogan 2007). There are areas upslope of the main body that tend to have less than 15 m (49 ft) canopy height and around 50% cover where the vegetation is growing in narrow ravines (Cogan 2007). The dominant species in this riparian forest type is cedar elm, but may include various ratios of live oak, sugarberry, white mulberry (*Morus alba*), and honey mesquite (*Prosopis glandulosa*) (Table 7; Cogan 2007). The sub-canopy cover in main areas is around 30%, but in the upslope ravines is much thicker with about 70% cover (Cogan 2007). Important species include Brazilian bluewood, Texas persimmon (*Diospyros texana*), and common hoptree (*Ptelea trifoliata*); these species are found sporadically, but are not widely associated with the cedar elm-sugarberry riparian forest alliances (Cogan 2007).

Table 7. Species occurring in the cedar elm-sugarberry/possum-haw/Virginia wild rye forest (recreated from Cogan 2007).

Type	Scientific Name	Common Name
Tree	*Ulmus crassifolia*	cedar elm
	Quercus virginiana	live oak
	Celtis laevigata	sugarberry
	Prosopis glandulosa	honey mesquite
Herb	*Elymus virginicus*	Virginia wild rye
Invasive	*Ligustrum japonicum**	Japanese privet
	*Melia azedarach**	Chinaberrytree
	*Torilis arvensis**	spreading hedge parsely
	*Morus alba**	white mulberry

* Non-native

Live Oak Temporarily Flooded Forest Alliance

The canopy height of this riparian forest type ranges from 15 to 20 m (49 –66 ft) with high closure (80%) and has a far lighter understory of around 30% cover (Cogan 2007). Live oak dominates over cedar elm, with few other species occuring in these areas (Cogan 2007). This riparian forest alliance has very little in terms of understory and ground cover, though there are some shade-tolerant grasses sparsely scattered on the forest floors (Table 8) where flooding likely prevents any substantial vegetation from establishing itself (Cogan 2007).

Table 8. Species occurring in the live oak forest alliance (recreated from Cogan 2007).

Type	Scientific Name	Common Name
Shrub	*Quercus virginiana*	live oak
Tree	*Ulmus crassifolia*	cedar elm
Herb	*Chasmanthium latifolium*	Indian woodoats
	Elymus virginicus	Virginia wild rye

Percent Coverage of Native Species

The percent cover of native species, especially in comparison to cover of exotic species, can provide an indication of how similar current riparian forests are to the historic forests present during the Missions period, prior to most exotic species invasions. However, no information is available with regard to the percent coverage of native species in the forested riparian corridors of SAAN. The park's exotic plant control program has been working to clear non-native plants from the park since

2000 (Greg Mitchell, SAAN Natural Resources Program Manager, written communication, February 2015), which has likely increased the percent coverage of native species.

Age Class Structure

Age class structure can be helpful in determining both the history and current successional status of forested areas. The age class structure of forested riparian corridors at SAAN has not been studied at this time. Currently this measure is considered a data gap.

Threats and Stressor Factors

Threats to SAAN's forested riparian corridors include non-native species, disease, hydrological changes, adjacent land use practices, and drought. Many of these threats are exacerbated by the fragmented and isolated nature of the park units (Robert Woodman, GULN Ecologist, written communication, February 2015).

The feral hog (*Sus scrofa*) is a highly destructive non-native species in most of Texas and is prolific throughout the San Antonio area despite the densely populated areas around the Missions and Rancho de las Cabras. The omnivorous nature of feral hogs and their destructive wallowing behavior cause particularly high levels of damage to riparian areas, which is a preferred habitat (Taylor 2003).

The nutria (*Myocastor coypus*) is a large, exotic invasive rodent species that originated in South America, where they are native (Carter 2014). Nutrias are large (8.2-9.1kg) semiaquatic creatures that were introduced to North America in the late 1800s for their furs (Texas Invasives 2011). In the late 1940s, a hurricane dispersed nutria along the Gulf of Mexico coastlines of Texas and Louisiana, which is likely how they became established in Texas (Texas Invasives 2011). Nutria have been confirmed in SAAN, and are a threat to the forested riparian corridors since their feeding habits cause damage to vegetation (NPS 2014, Carter 2014).

Introduction of exotic ornamental plant species can be problematic in native plant communities as they can become established and out-compete the native flora. There are several invasive ornamentals already present in SAAN that are among the 42 listed exotics confirmed within the forested riparian corridors (Carr 2003a, b). These include Chinese tallow (*Triadica sebifera*), Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), golden bamboo (*Phyllostachys aurea*), Chinaberrytree, and giant reed (*Arundo donax*; Photo 4).

There are disease risks that threaten a few of the tree species in forested riparian corridors. These include the live oaks and the two elm species (cedar and American) that occur in the riparian forests. Live oaks are susceptible to a fungal disease called oak wilt that causes defoliation and eventual death of the affected tree (TOW 2012). The other disease is a vascular pathogen called Dutch elm disease (*Ophiostoma novo-ulmi*) that affects the cedar elm and the American elm tree species (Appel 2009). The American elm is highly susceptible and the cedar elms are considered intermediately susceptible to the disease, which is contagious to neighboring trees, and some appear to have varying degrees of resistance to infection (Appel 2009).

Photo 4. The front-most vegetation is the invasive giant reed growing in the San Juan Woods (Photo by Shannon Amberg, SMUMN GSS 2013).

Over the last 100 years, the San Antonio River, which flows through both units of SAAN, has undergone drastic hydrological changes (Cawthon 2008). The basin has become heavily urbanized and as a result, impervious surface cover has increased dramatically (Cawthon 2008). This, combined with channelization of the river, has compounded the effects of runoff during and after storm events (Cawthon 2008). Runoff water from urban areas is often highly toxic, full of contaminants and high levels of nutrients that can degrade water quality and destabilize channels (Cawthon 2008). Forested riparian corridors serve as both a catchment mechanism, stabilization, and as a filtration system and therefore are very important to both human communities as well as the natural ecology of the San Antonio River basin (Wagner 2003, Cawthon 2008). Focusing conservation efforts and remediation activities on the preservation and restoration of existing and future riparian communities will not only alleviate damaging flood pulse affects, but also preserve the integrity of the SAAN aesthetic setting (Wagner 2003, Cawthon 2008). This is especially important during periods of drought, which have been major in Texas during the past 5 to 10 years (USDM 2014). The storm events following a period of drought will often carry more contaminant-loaded material into waterways because it has been allowed time to build up on the terrestrial surface. These drought periods can result in the desiccation of vegetation, which is important to soil stability. Without adequate vegetation cover, soil is washed directly into waterways, especially where there lacks a riparian corridor to filter and soak up solids and excess water. Recently, SARA and the U.S. Army Corps of Engineers have been working to improve the Missions Reach of the San Antonio River by restoring more natural flow conditions and native vegetation (SARIP 2013). This will likely benefit riparian corridors in and around the park.

Data Needs/Gaps

The lack of data to use for reference condition renders the current condition useful only as a baseline to compare with future studies and surveys. There are no studies available addressing the percent coverage of native species or age class structure so these measures are data gaps in both reference condition and current condition. However, surveys that are currently taking place or are starting soon will provide some insight in these areas.

The GULN is currently developing a vegetation monitoring protocol that will begin gathering data at both the Missions and Rancho Units by 2016 (Woodman, written communication, December 2014). This sampling will provide information on plant community composition and coverage, and will identify trends in those parameters and species richness, as well as monitoring for new non-native species (Woodman, written communication, December 2014).

In 2016, Ladybird Johnson Wildflower Center staff will be surveying and mapping exotic plant species in the park (Mitchell, written communication, 7 May 2015). This information will be useful for evaluation condition in future assessments.

Overall Condition

Community Extent

The measure for community extent was assigned a *Significance Level* of 2. While there are limited historical data for comparison, given the development and hydrological changes that have occurred in the San Antonio area, it is almost certain that forested riparian areas currently cover much less area than they did during the Missions period. As a result, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Community Composition

The measure for community composition was assigned a *Significance Level* of 3. Currently, the baseline is Carr (2003a, b), a botanical inventory report that was conducted in 2001 and 2002. Assessing a *Condition Level* for this measure is not possible at this time, as the Carr (2003a, b) survey is outdated and there are also no data for a reference condition regarding this measure.

Percent Coverage of Native Species

The *Significance Level* of percent coverage of native species was assigned a 3. Since there are no data for reference condition or current condition, a *Condition Level* cannot be assigned at this time.

Age Class Structure

Age class structure was assigned a *Significance Level* of 3. There are no data for this measure and a *Condition Level* cannot be assigned. There are, however, plans in place to begin collecting age class structure data in SAAN in the near future.

Weighted Condition Score

A *Weighted Condition Score* was not calculated for SAAN's forested riparian corridors, largely due to data gaps. Three of the four measures could not be assigned *Condition Levels*. Further monitoring and data collection will allow trends in these measures to be assessed in the future. The community extent and composition information presented here can serve as baselines for comparison in future studies.

Forested Riparian Corridors			
Measures	Significance Level	Condition Level	WCS = N/A
Community Extent	2	2	
Community Composition	3	n/a	
Percent Coverage of Native Species	3	n/a	
Age Class Structure	3	n/a	

4.1.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resources Program Manager

Robert Woodman, GULN Ecologist

4.1.7 Literature Cited

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4.2 Native Grasslands

4.2.1 Description

Prior to European settlement, much of the upland in the San Antonio area supported native grasslands, with just small patches of brush (Cooper et al. 2005). In the area just south and east of the city, travelers would have seen, "…a prairie which during the fall was covered largely with perennial grasses about 2 ft. tall. During the spring, between the sere grasses was a carpet of flowers" (Johnston 1963, p. 457, citing Santleben 1910, Sanchez 1926, Bollaert 1956). The Missions likely relied on these grasses as forage for their livestock (Fearing 1981). Native grasslands are the only Spanish colonial period landscape currently missing from SAAN (Mitchell 2013).

After the Mission period, ranching continued and intensified. Many areas were overgrazed, which resulted in vegetation trampling, soil compaction, and overall degradation of grassland communities (OCULUS 1998). The effects of overgrazing, combined with a reduction in fire occurrence, allowed honey mesquite and other shrubs to invade, and much of the region's native prairie was lost (OCULUS 1998, Cooper et al. 2005). Additional areas, particularly near the city of San Antonio, were cleared for farming and construction (Cogan 2007).

Human settlement and farming lead to the introduction of many exotic species, especially grasses planted to feed livestock (Carr 2003a, Cogan 2007). Any grasslands remaining within SAAN today are dominated by these exotic grasses, such as Bermudagrass (*Cynodon dactylon*), Kleberg's bluestem (*Dichanthium annulatum*), yellow bluestem (*Bothriochloa ischaemum*), and Johnsongrass (*Sorghum halepense*) (Cooper et al. 2005, Cogan 2007). Some native grasses remain, including Texas wintergrass (*Nassella leucotricha*), little bluestem (*Schizachyrium scoparium*), and plains lovegrass (*Eragrostis intermedia*), occasionally co-dominating with the exotics. Additional native grass species found around the Missions are Virginia wildrye, Ozarkgrass (*Limnodea arkansana*), and purple threeawn (*Aristida purpurea*) (Cogan 2007). Common native grassland species at the Rancho de las Cabras Unit include sand dropseed (*Sporobolus cryptandrus*), browntop signalgrass (*Urochloa fusca*), Texas signalgrass (*Urochloa texana*), and sideoats grama (*Bouteloua curtipendula*) (Carr 2003a, Cogan 2007).

Photo 4. Indian blanket (*Gaillardia pulchella*), a native wildflower, in a prairie planting at Mission San Juan (Photo by Kathy Allen, SMUMN GSS 2013).

4.2.2 Measures

- Community extent
- Community composition
- Percent coverage of native species

4.2.3 Reference Conditions/Values

The ideal reference condition for this component would be the condition of native grasslands during the Mission period. However, given the significant changes in land cover and land use since that time (e.g., shrub invasion, city expansion), this is no longer considered feasible. NPS staff have selected the following management goals for SAAN prairie restoration areas 5 years after their establishment (Mitchell 2013), which will be used as reference conditions for this assessment:

- Minimum of 80% cover by native species
- Coverage of 60-70% native grasses and 30-40% forbs and wildflowers
- <15% cover by woody vegetation

4.2.4 Data and Methods

Since no intact native grasslands currently exist within SAAN, little information is available regarding the community. Vegetation studies by Carr (2003a, b) and Cogan (2007) documented some native grassland plant species occurring in the park's old fields. The park has been interested in restoring native prairie to the SAAN landscape since 2003. The idea was first proposed in the 1998 Rancho de las Cabras Cultural Landscape Report (OCULUS 1998). In 2011, funding was obtained for prairie restorations in two areas of the park, totaling approximately 8.9 ha (22 ac) (Mitchell 2013). The park has prepared a restoration management plan (Mitchell 2013) that describes the project sites and methods, as well as outlining proposed maintenance and monitoring.

4.2.5 Current Condition and Trend

<u>Community Extent</u>

No intact native grassland communities currently exist at SAAN. Prairie restorations are underway at two sites, one at Rancho de las Cabras (4 ha [10 ac]) and one near San Juan Dam (4.9 ha [12 ac]) in the Missions Unit. Site preparation (i.e., removal of current woody and non-native vegetation) occurred from April 2013 through 2014. Seeding is expected to occur in late 2015 and 2016 (Mitchell, written communication, December 2014).

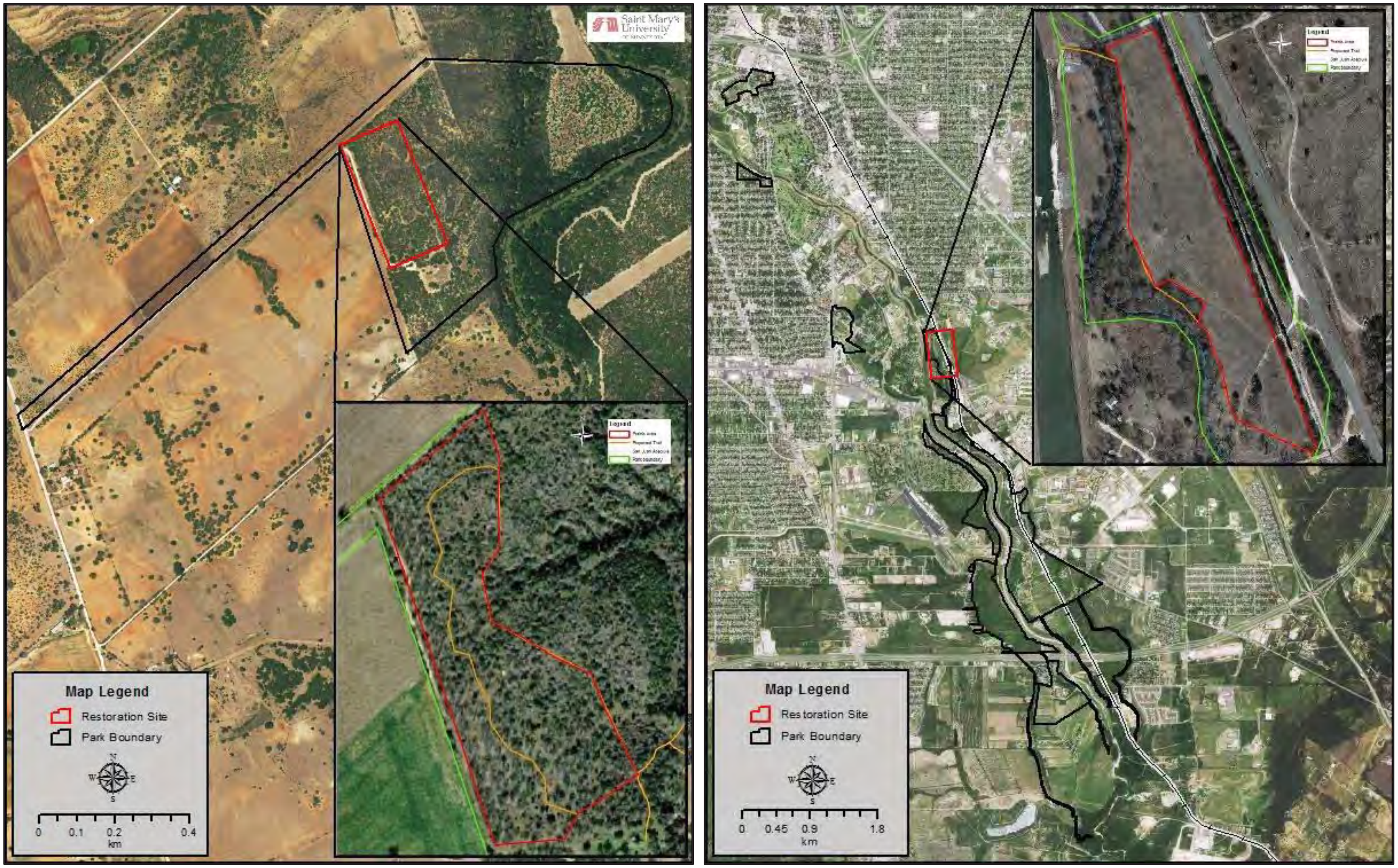

Figure 18. Native grassland restoration sites at the Rancho Unit (left) and near San Juan Dam in the Missions Unit (right) (close-up aerial photos from Mitchell 2013).

Community Composition

While native grassland communities are not currently present in SAAN, native plant species that would occur in these grasslands are still found at both the Missions and Rancho Units. Carr (2003a, b) conducted plant inventories at SAAN and documented 187 native herbaceous species in the park's old field grasslands (Appendix C). One hundred and ten species were found in the Rancho Unit (Carr 2003a) and 130 at the Missions Unit (Carr 2003b). The species proposed for inclusion in the seed mix for the park's two prairie restoration areas (and, therefore the expected composition of these restored grasslands) are listed in Table 9.

Table 9. Native species in the seed mix for SAAN's prairie restorations (Mitchell 2013).

Grasses		**Wildflowers**	
Scientific name	**Common name**	**Scientific name**	**Common name**
Schizachyrium scoparium	little bluestem	*Rudbeckia hirta*	black-eyed susan
Sorghastrum nutans	Indiangrass	*Lupinus* spp.	bluebonnets
Bouteloua curtipendula	sideoats grama	*Dracopis amplexicaulis*	clasping coneflower
Setaria sp.	Catarina bristlegrass	*Phlox drummondii*	Drummond phlox
Leptochloa dubia	green sprangletop	*Gaillardia pulchella*	Indian blanket
Bouteloua repens	slender grama	*Monarda citriodora*	lemon mint (beebalm)
Pappophorum vaginatum	whiplash pappusgrass	*Ratibida columnifera*	Mexican hat
Panicum virgatum	switchgrass	*Coreopsis* spp.	coreopsis
Chloris cucullata	hooded windmillgrass	*Oenothera* spp.	evening primrose
Bothriochloa laguroides ssp. *torreyana*	silver beardgrass	*Castilleja* spp.	Indian paintbrush

Percent Coverage of Native Species

In prairie restorations, it often takes several years for native plant species to become established. The goals selected by park staff regarding coverage of native species are for five years after seeding at the project sites. It will still be a few years before the coverage of native species can be assessed in these restoration areas. No information is available regarding the coverage of native species in the park's current old field (non-native dominated) grasslands.

Threats and Stressor Factors

Once established at SAAN, native grasslands will face many threats, such as non-native invasive species, fire suppression, atmospheric deposition of pollutants, and drought. Non-native invasive plants will likely be difficult to control in the prairie restoration areas. Over 150 non-native species have been documented in SAAN (NPS 2010), although not all of these are invasive and not all would threaten grasslands. Some non-native grasses were actually planted historically for hay to feed livestock (Carr 2003a, Cooper et al. 2005). Non-natives likely to be of high concern due to their potential to outcompete native grassland species include buffelgrass (*Pennisetum ciliare*), Johnsongrass, Bermudagrass, and yellow bluestem (also known as King Ranch bluestem) (Cooper et al. 2005, NPS 2010). All of these species were documented by Halvorson and Guertin (2006) in 2004 at both the Missions and Rancho Units (Appendix A).

Historic fire suppression likely led to the conversion of much of the area's original grasslands to shrublands (Van Auken and Bush 1984, Van Auken 2000). Fire eliminates or inhibits woody species in favor of native grassland species; in the absence of fire, shrubs such as mesquite and acacias invade and outcompete grassland species (Van Auken and Bush 1984, Van Auken 2000). It may be a challenge to maintain any prairie restorations in the Missions Unit with burning, given that opportunities for burning could be limited by concerns over smoke management within the San Antonio city limits.

The deposition of pollutants such as nitrogen and sulfur dioxides can cause acidification and nutrient enrichment of soils (Sullivan et al. 2011a, b). Native grasslands in semi-arid regions, like that around SAAN, are considered sensitive to excess nitrogen and acidic deposition (Sullivan et al. 2011c, 2011d). Nutrient enrichment may create favorable conditions for non-native grass invasion (Fenn et al. 2003). Air pollution in the region around SAAN is discussed in further detail in section 4.11 of this report.

Research has shown that drought can impact grassland species richness and above-ground biomass (Tilman and El Haddi 1992). Annual plants and rare species are especially at risk, as one dry year could cause them to be lost from a local plant community (Tilman and El Haddi 1992). Droughts may increase in frequency and duration as a result of global climate change (Twilley et al. 2001, Davey et al. 2007), which could pose a challenge for the park's grassland restoration efforts. In some grasslands, soil water availability (from precipitation) appears to limit grass seedling establishment (i.e., recruitment) (Lauenroth et al. 1994). Therefore, it may be difficult to establish native grasslands from seed if a drought occurs.

Data Needs/Gaps

Since the original native grasslands are no longer present at SAAN, very little is known about what their exact composition and extent would have been. The current restoration efforts provide an excellent opportunity to study the process and the restored grasslands. For example, park staff and researchers could learn which species thrive and which struggle at the selected sites, and which non-native species or other stressors (e.g., drought) are the greatest threat to the restoration. Insight could also be gained regarding how the restoration impacts other park resources, such as neighboring vegetation communities and wildlife. Any lessons learned could be applied to future restoration efforts at the park or in the region.

As mentioned in the previous chapter, the GULN is developing a vegetation monitoring protocol that will begin gathering data by 2016 (Woodman, written communication, December 2014). This sampling will provide information on plant community composition and coverage.

Overall Condition

Community Extent
The project team assigned this measure a *Significance Level* of 2. At this time, no intact native grassland communities exist at SAAN. Native grasslands are the only Spanish colonial period landscape currently missing from the park, although staff are in the process of restoring 8.9 ha (22 ac) at two separate sites (Mitchell 2013). Since native grasslands are not present at SAAN, the *Condition Level* for this measure is a 3, indicating high concern.

Community Composition
The community composition measure was assigned a *Significance Level* of 3. Since native grasslands do not occur at SAAN, their composition cannot be studied. Therefore, this measure is not applicable at this time and no *Condition Level* is assigned. However, a plant inventory by Carr (2003a, b) confirmed that many native grassland species still occur, intermixed with non-native species in the park's old fields.

Percent Coverage of Native Species
This measure was assigned a *Significance Level* of 3. Given that the park's prairie restoration areas are not yet established and no information is available on the coverage of native species in existing old fields, a *Condition Level* could not be assigned for this measure.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for native grasslands, since two of the three measures could not be assessed at this time. This is due to the fact that no intact native grassland communities currently exist at SAAN.

Native Grasslands			
Measures	Significance Level	Condition Level	WCS = N/A
Community Extent	2	3	
Community Composition	3	n/a	
Percent Coverage of Native Species	3	n/a	

4.2.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resources Program Manager

Robert Woodman, GULN Ecologist

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4.3 Upland Shrublands/Woodlands

4.3.1 Description

The upland shrublands and woodlands at SAAN are mid-successional communities, occurring primarily on former grasslands that will eventually transition to forests in the absence of disturbance (Carr 2003a, b, Cogan 2007). The conversion of grasslands to shrublands was aided by ranching during and after the Missions period; overgrazing and fire suppression allowed woody species to invade native grasslands throughout Texas (Van Auken and Bush 1984, OCULUS 1998). Shrublands and woodlands are now common in the abandoned labores (old fields) and on uplands bordering the San Antonio River valley (Cogan 2007). Typical species in these communities include huisache (*Acacia farnesiana*), honey mesquite, Texan hogplum, Brazilian bluewood, and hackberries (*Celtis* spp.) (Photo 6; Carr 2003a, Cogan 2007). While the ground layer can be sparse in dense stands, more open areas support herbaceous ground cover. Some stands retain the native grasses and forbs that occurred previously in the original grasslands, but others are dominated by invasive non- native species (Carr 2003a).

Photo 6. Upland woodland at SAAN's Rancho de las Cabras Unit (photo by Shannon Amberg, SMUMN GSS 2013).

4.3.2 Measures

- Community extent
- Community composition
- Percent coverage of native species

4.3.3 Reference Conditions/Values

The ideal reference condition for this component would be the condition of upland shrublands and woodlands during the Mission period. However, given the significant changes in land cover and land use since that time (e.g., city expansion and development), this may no longer be attainable. In addition, very little historical information is available regarding shrublands and woodlands in the SAAN area. The information presented in this NRCA could be used as a baseline for future assessments.

4.3.4 Data and Methods

Carr (2003a, b) conducted botanical inventories at both the Missions and Rancho Units from 2001-2002. Nine transects were sampled in upland woodland habitats within the Missions Unit, and one transect was sampled in each of the two upland habitats (upland woodland and upper-slope shrubland) at the Rancho Unit. Cogan (2007) produced a vegetation classification system and map for SAAN based on field work conducted from 2005-2006. Classification methods and categories followed the National Vegetation Classification Standard (NVCS).

4.3.5 Current Condition and Trend

Community Extent

As of 2005-06, upland shrubland and woodland communities covered 89.1 ha (220.2 ac) within park boundaries (Table 13; Cogan 2007). The majority of these communities (71.6 ha) are in the Missions Unit. The most common shrubland/woodland type is the Huisache - (Honey Mesquite) Woodland, comprising a total of 55.7 ha (137.6 ac), almost entirely within the Missions Unit (Cogan 2007). The most common woodland type at the Rancho Unit is dominated by honey mesquite (Table 13). Privet shrubland stands, characterized by the exotic species Japanese privet, were present only in the Missions Unit (Cogan 2007). The locations of shrublands and woodlands within the park are shown in Figure 19 and Figure 20 (Missions Unit), and Figure 21 (Rancho Unit). In recent years, some of these shrublands have been cleared as part of grassland and labores restoration efforts (Woodman, written communication, February 2015).

Table 13. Extent of upland shrubland and woodland communities (in hectares) within park boundaries and within Cogan's (2007) study area.

	Extent (ha)		
Woodland/Shrubland Type	**Missions**	**Rancho**	**Cogan (2007) Study Area**
Chaparro-Prieto Shrubland	1.4	5.3	144.2
Honey Mesquite - Granjeno/Prickly-pear Species - South Texas Ericameria Woodland	10.0	11.7	153.8
Huisache - (Honey Mesquite) Woodland	55.2	0.5	342.1
Privet Shrubland Stand	5.0	0	23.6
Totals	**71.6**	**17.5**	**663.7**

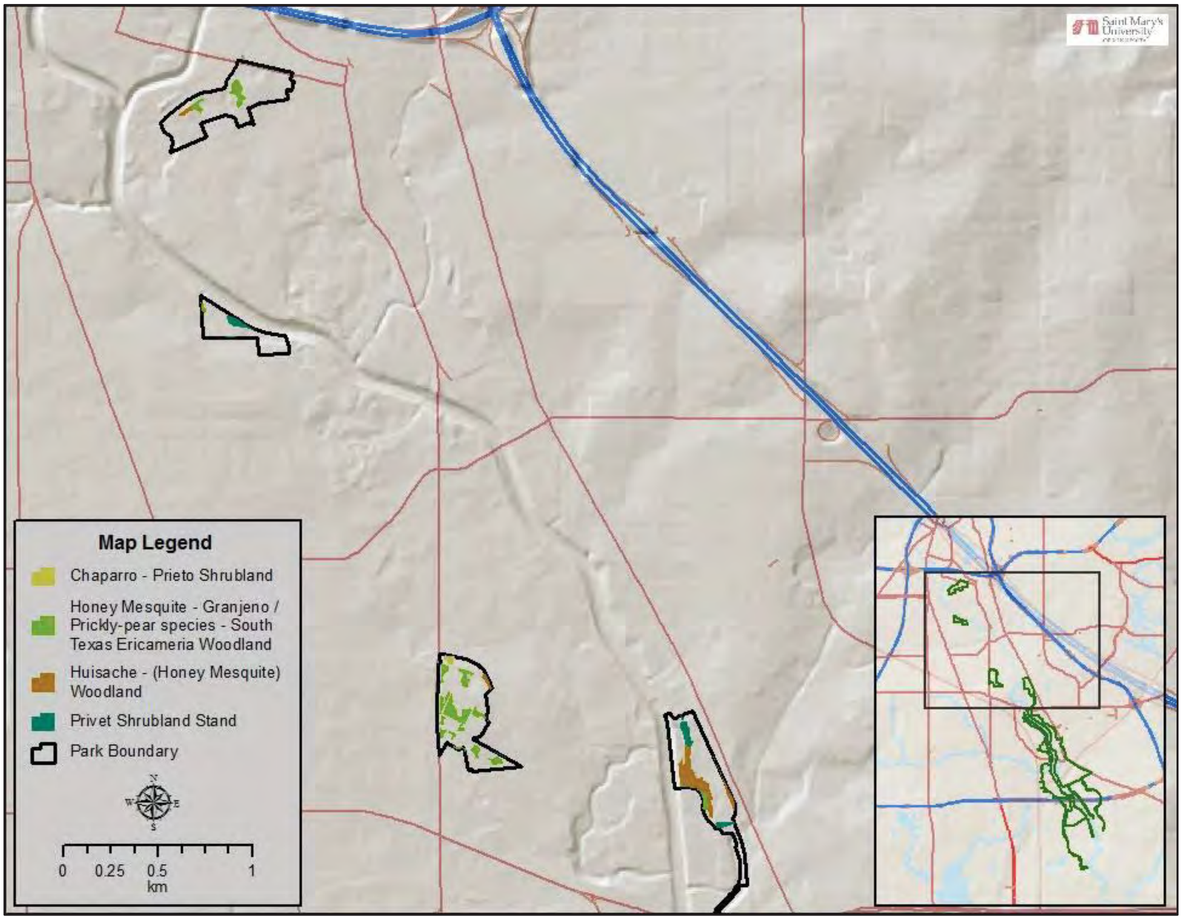


Figure 19. Extent of upland shrublands and woodlands in the northwest portion of the Missions Unit (data from Cogan 2007).

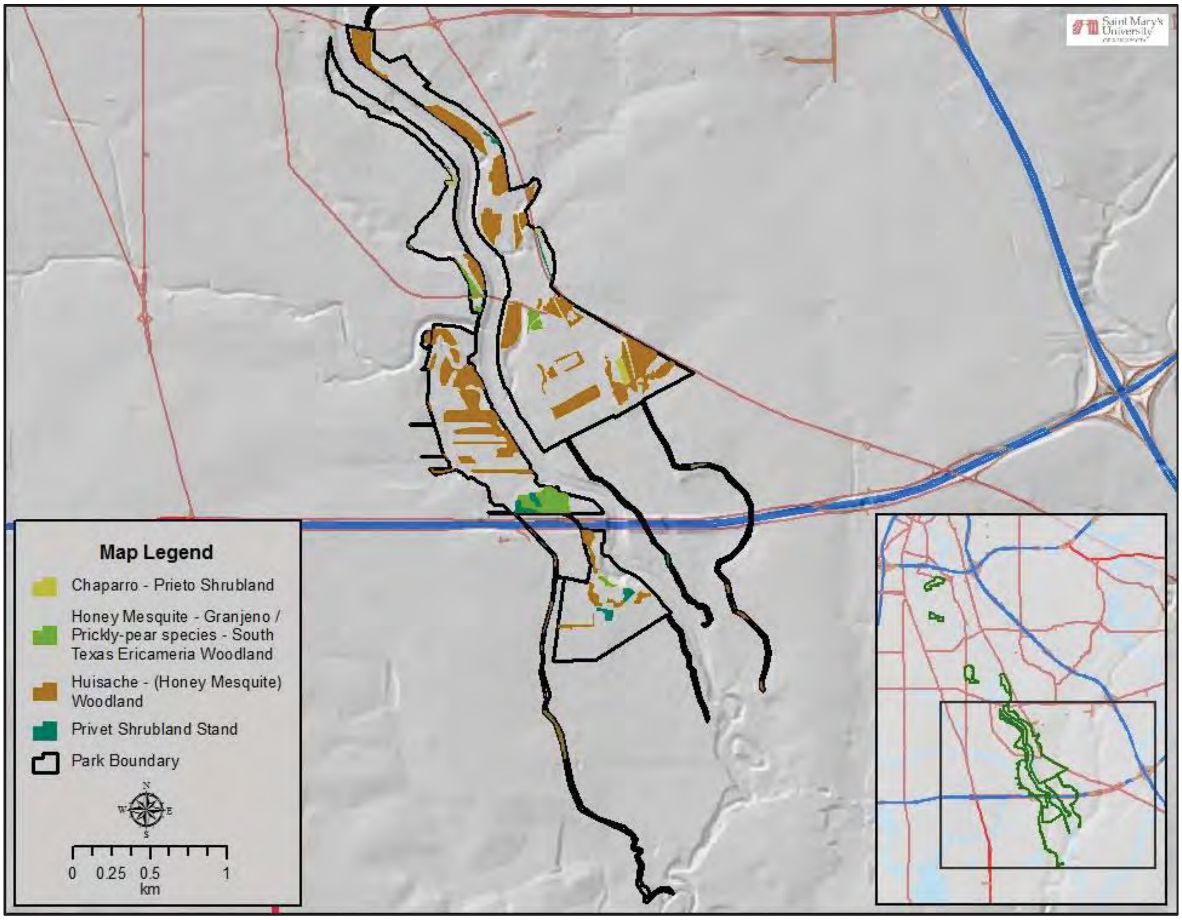


Figure 20. Extent of upland shrublands and woodlands in the southeast portion of the Missions Unit (data from Cogan 2007).

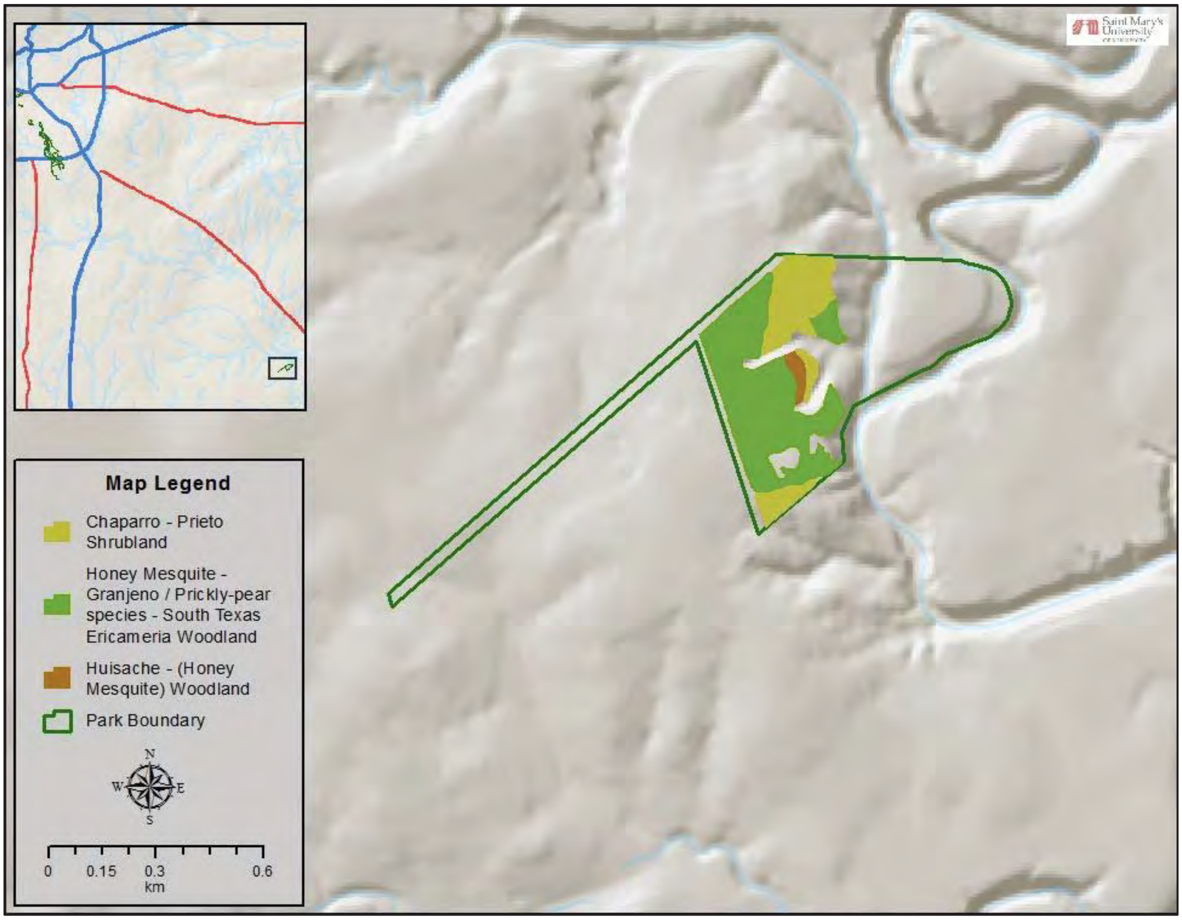


Figure 21. Extent of upland shrublands and woodlands in the Rancho Unit (data from Cogan 2007).

<u>Community Composition</u>

Carr (2003a, b) conducted botanical inventories at both SAAN units and tracked species occurrence by macrohabitat (i.e., vegetation community). Within the Missions Unit, there was just one upland woodland macrohabitat, while at Rancho there were two - upland woodlands and upper-slope shrubland. The full species list for these communities can be found in Appendix D. A total of 282 plant species were documented within the park's upland shrublands and woodlands, including 30 non-native species. The upland woodlands within the Missions Unit supported 151 plant species, 26 of which were non-native (Carr 2003b). The Rancho's upland woodlands and upper-slope shrublands contained 133 and 156 species, respectively. Twelve of the plant species in the Rancho's upper woodlands were non-native, while only six non-native species were observed in the upper-slope shrublands (Carr 2003a). Native species documented in all three macrohabitats are presented in Table 14.

Table 10. Native plant species found in all three of Carr's (2003a, b) upland woodland and shrubland macrohabitats.

Shrubs and Vines		Grasses and Forbs	
Scientific name	**Common name**	**Scientific name**	**Common name**
Gutierrezia texana	Texas snakeweed	*Amblyolepis setigera*	huisache daisy
Berberis trifoliolata	algerita; agarito	*Ambrosia psilostachya*	western ragweed
Opuntia engelmannii var. *lindheimeri*	Texas pricklypear	*Aphanostephus ramosissimus*	plains dozedaisy or lazy daisy
Diospyros texana	Texas persimmon	*Symphyotrichum ericoides*	heath aster
Eysenhardtia texana	Texas kidneywood	*Calyptocarpus vialis*	straggler daisy
Passiflora tenuiloba	birdwing passionflower	*Cirsium texanum*	Texas thistle
Clematis drummondii	Drummond's clematis	*Fleischmannia incarnata*	pink thoroughwort
Colubrina texensis	Texan hogplum	*Helianthus annuus*	common sunflower
Condalia hookeri var. *hookeri*	Brazilian bluewood	*Croton monanthogynus*	prairie tea, oneseeded croton
Celtis ehrenbergiana	spiny hackberry	*Desmanthus virgatus*	wild tantan
Celtis laevigata var. *reticulata*	netleaf hackberry	*Oxalis dillenii*	slender yellow woodsorrel
Phoradendron tomentosum	Christmas mistletoe	*Bothriochloa laguroides* ssp. *torreyana*	silver beardgrass
		Limnodea arkansana	Ozarkgrass
		Nassella leucotricha	Texas wintergrass
		Setaria leucopila	streambed or plains bristlegrass
		Sporobolus cryptandrus	sand dropseed
		Tridens texanus	Texas tridens or fluffgrass
		Castilleja indivisa	entireleaf Indian paintbrush
		Plantago rhodosperma	redseed plantain

Cogan (2007) included lists of species that were associated with each upland shrubland and woodland community type.

Honey Mesquite - Granjeno / Prickly-pear species - South Texas Ericameria Woodland
The canopy in these woodlands is dominated by honey mesquite (10-15 m [32.8-49.2 ft] high), with cover ranging from 30-50% (Cogan 2007, Table 11). A sparse shrub layer includes hackberry (*Celtis*

pallida), Texan hog plum, and sugarberry saplings. The ground layer, dominated by Texas wintergrass and weedy or shade tolerant forbs, typically provides 50-70% cover (Cogan 2007).

Table 11. Species occurring in the Honey Mesquite - Granjeno / Prickly-pear species - South Texas Ericameria Woodland (Cogan 2007).

Type	Scientific Name	Common Name
Tree	*Prosopis glandulosa*	honey mesquite
Shrub	*Celtis laevigata*	sugarberry
	Celtis pallida	desert hackberry
	Colubrina texensis	Texan hog plum
	Condalia hookeri	Brazilian bluewood
	Diospyros texana	Texas persimmon
	Opuntia leptocaulis	Christmas cactus
Herb	*Croton monanthogynus*	prairie tea
	Gutierrezia texana	Texas snakeweed
	Justicia pilosella (*Siphonoglossa pilosella*)	Gregg's tubetongue
	Verbesina virginica	white crownbeard
	Nassella leucotricha	Texas wintergrass
Invasive	*Cynodon dactylon*	bermudagrass

Chapparo-Prieto Shrubland

The canopy in this shrubland is only 2-3 m (6.6-9.8 ft) high, with 30-60% cover (Cogan 2007). The dominant vegetation is a mix of blackbrush acacia, Texas persimmon, Brazilian bluewood, and honey mesquite (Table 12). The ground layer, with 60-70% cover, consists primarily of the native grasses purple three-awn and Texas wintergrass (Cogan 2007).

Table 12. Species occurring in the Chapparo-Prieto Shrubland (Cogan 2007).

Type	Scientific Name	Common Name
Shrub	*Acacia rigidula*	blackbrush acacia
	Celtis laevigata	sugarberry
	Celtis pallida	desert hackberry
	Colubrina texensis	Texan hog plum
	Condalia hookeri	Brazilian bluewood
	Diospyros texana	Texas persimmon

Table (continued). Species occurring in the Chapparo-Prieto Shrubland (Cogan 2007).

Type	Scientific Name	Common Name
Shrub (cont.)	*Eysenhardtia texana*	Texas kidneywood
	Guaiacum angustifolium	Texas lignum-vitae
	Berberis trifoliolata	algerita, agarito
	Opuntia leptocaulis	Christmas cactus
	Prosopis glandulosa	honey mesquite
	Ptelea trifoliata	common hoptree
	Sideroxylon lanuginosum	gum bully
	Yucca constricta	Buckley's yucca
Herb	*Wedelia acapulcensis* var. *hispida*	hairy wedelia
	Aristida purpurea	purple three-awn
	Carex planostachys	cedar sedge
	Nassella leucotricha	Texas wintergrass

Huisache-(Honey Mesquite) Woodland

The canopy in these woodlands ranges from 10-60% cover and 5-15 m (16.4-49.2 ft) in height (Cogan 2007). The dominant vegetation is typically dominated by huisache, honey mesquite, or a mix of the two (Table 13). Shrub layer density is highly variable, but common species include hackberry, Brazilian bluewood, Texas persimmon, agarito (*Berberis trifoliolata*), and sugarberry saplings. Ground cover is also highly variable, ranging from 10-80%, depending on shading from the canopy. Native grasses such as purple three-awn and Texas wintergrass may dominate, but the non-native spreading hedgeparsley is common where grasses are absent (Cogan 2007).

Table 13. Species occurring in the Huisache-(Honey Mesquite) Woodland (Cogan 2007).

Type	Scientific Name	Common Name
Tree	*Acacia farnesiana*	huisache; sweet acacia
	Prosopis glandulosa	honey mesquite
	Celtis laevigata	Sugarberry
Shrub	*Celtis pallida*	desert hackberry
	Condalia hookeri	Brazilian bluewood
	Diospyros texana	Texas persimmon
	Berberis trifoliolata	agarito, algerita

Table 17 (continued). Species occurring in the Huisache-(Honey Mesquite) Woodland (Cogan 2007).

Type	Scientific Name	Common Name
Herb	*Ambrosia trifida*	great ragweed
	Calyptocarpus vialis	straggler daisy
	Clematis drummondii	Drummond's clematis
	Viguiera dentata	toothleaf goldeneye
	Aristida purpurea	purple three-awn
	Nassella leucotricha	Texas wintergrass
Invasive	*Ligustrum japonicum*	Japanese privet
	Melia azedarach	Chinaberrytree
	Torilis arvensis	spreading hedgeparsley

Percent Coverage of Native Species

The percent cover of native species, especially in comparison to cover of exotic species, can provide an indication of how similar current shrublands and woodlands are to the historic communities that were present during the Missions period, prior to most exotic species invasions. No information is available regarding the percent coverage of native species in SAAN’s upland shrublands and woodlands. However, the park’s exotic plant control program has been working to clear non-native plants from the park since 2000 (Mitchell, written communication, February 2015), which has likely increased the percent coverage of native species.

Threats and Stressor Factors

Threats to the upland woodlands and shrublands include non-native species, adjacent land use practices (particularly introduction of ornamental species), drought, and climate change. Many of these threats are exacerbated by the fragmented and isolated nature of the park units (Woodman, written communication, February 2015). More than 150 non-native plant species have been confirmed within the park (NPS 2010; Appendix A), 30 of which were documented in upland woodlands and shrublands by Carr (2003a, b). The highly invasive Japanese privet had become dominant in some of the park’s shrublands, but management efforts over the past decade have reduced its extent within the park (Mitchell, written communication, 3 February 2015). Growing development on adjacent lands can increase the risk of non-native plant introduction through the escape of ornamental species (Cogan 2007). Feral hogs, which are a non-native faunal species, are also a threat to the park’s shrublands.

Over the past several years, much of Texas has been experiencing moderate to severe drought conditions (USDM 2015). Climate change models predict warmer temperatures and likely drier conditions for Texas in the future (TWDB 2008, Foster 2011), which could increase the frequency and duration of droughts. Extreme drought can cause plant mortality and reduced seedling survival in shrublands and woodlands (Swetnam and Betancourt 1998). Less severe droughts could still influence plant community composition, favoring species that are more tolerant of dry conditions.

Data Needs/Gaps

Due partly to the fact that shrublands and woodlands are often mid-successional communities, information on these habitats in the park is limited. The most recent survey of vegetation community extent at SAAN was in 2005-2006 (Cogan 2007). An update would help determine if shrublands have expanded since this time. Community composition has also not been thoroughly studied since Carr (2003a, b), which focused only on species occurrence and did not document percent composition of the various plant species. In addition, the percent coverage of native species (as opposed to introduced species) has not been studied. The GULN is developing a vegetation monitoring protocol that will begin gathering data on plant community composition and coverage by 2016 (Woodman, written communication, December 2014).

In 2016, Ladybird Johnson Wildflower Center staff will be surveying and mapping exotic plant species in the park (Mitchell, email communication, 7 May 2015). This information will be useful in future assessments, particularly in updating the extent of privet shrubland stands within SAAN.

Overall Condition

Community Extent

The project team assigned this measure a *Significance Level* of 2. Shrublands and woodlands are almost certainly more widespread today than they were during the Missions period (Van Auken and Bush 1984). This is partly natural succession from grasslands, but the process has been aided by overgrazing and fire suppression. Since this community is currently more extensive within SAAN than it was historically, this measure is of no concern (*Condition Level* = 0).

Community Composition

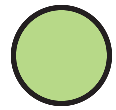
The community composition measure was assigned a *Significance Level* of 3. Carr (2003a, b) documented over 280 plant species in SAAN's upland woodlands and shrublands, with nearly 90% of these species being native. The composition of these communities is currently of low concern (*Condition Level* = 1).

Percent Coverage of Native Species

This measure was assigned a *Significance Level* of 3. No information is available regarding the percent coverage of native species within SAAN's upland shrublands and woodlands. Therefore, a *Condition Level* could not be assigned for this measure.

Weighted Condition Score

The *Weighted Condition Score* for upland shrublands and woodlands in SAAN is 0.13, indicating good condition. Since vegetation community extent has not been updated since 2006 and community composition was last studied in depth over a decade ago, a trend could not be determined.

Upland Shrublands/Woodlands			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.13**
Community Extent	3	0	
Community Composition	2	1	
Percent Coverage of Native Species	3	n/a	

4.3.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resources Program Manager

Robert Woodman, GULN Ecologist

4.3.7 Literature Cited

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4.4 Reptiles

4.4.1 Description

Reptiles are sensitive to changes in their habitats such as pollution and warmer, drier climates (EPA 2012), and are considered biological indicators of ecosystem health; because of this, reptiles have been selected as a Vital Sign by the GULN (Segura et al. 2007). Reptiles are an important part of the ecosystem's food chain because some species serve as both predators and prey. Reptiles can also help control pest populations by consuming rodents and insects (ESI 2011).

Photo 7. Texas brown snake (*Storeria dekayi texana*) in SAAN in 2003 (photo from Duran 2004).

SAAN provides habitat for a number of reptiles, including snakes, lizards, turtles, and tortoises. Snakes are the most diverse reptile group in SAAN, with 21 species documented in the park (Photo 7; NPS 2014). Twelve turtle species and 10 lizard species have also been documented in SAAN (Appendix E). Two threatened and endangered (T&E) species have been documented in SAAN: the Texas tortoise (*Gopherus berlandieri*) and the Texas horned lizard (*Phrynosoma cornutum*) are listed as threatened in the state of Texas (Appendix E). These two species are thought to be present in the park; however, the Texas tortoise has not been seen at SAAN since 2007, and there are no confirmed observations of Texas horned lizard within the park (Duran 2004, Dittmer and Fitzgerald 2011).The Cagle's map turtle (*Graptemys caglei*) is another T&E species native to SAAN, but it has likely been extirpated from the park (Duran 2004). The Cagle map turtle is also listed as threatened in the state of Texas.

4.4.2 Measures

- Species richness
- Relative abundance
- Reproductive success

4.4.3 Reference Conditions/Values

A specific reference condition for reptiles was not identified for SAAN; however, Strecker (1915) may provide a reference for the San Antonio area. Strecker catalogues herptiles in Texas during the early 20th century. Strecker (1915) documented 19 reptile species in or near San Antonio, and included nine snakes, five turtles, and five lizards. It should also be noted that this study covered a larger area than SAAN, and not all species may have occurred in the park. Appendix E displays the reptile species that were documented in the general San Antonio area.

4.4.4 Data and Methods

Duran (2004) conducted an inventory of the reptiles and amphibians in SAAN from 2002 to 2003. Duran (2004) sampled six sites in SAAN, with major sampling efforts focusing on the upland woodlands, grassland/old fields, riparian woodlands, and grassland/riparian areas, which are displayed in Figure 22. Trapping methods used in Duran (2004) included drift-fence arrays and coverboards, while observation methods included visual and auditory surveys. All observations were spatially documented using GPS units. Sampling efforts occurred over a short period of time and cannot be considered as comprehensive distributional surveys.

Dittmer and Fitzgerald (2011) surveyed the Missions and Rancho de las Cabras Units for Texas tortoise and Texas horned lizard. Surveys were conducted on the weekends (Friday – Saturday) in May, June, and October of 2010 as well as May and June of 2011. Survey methods included tortoise blitz (an area-defined visual search), coverboard arrays, and PVC pipe traps. Visual encounter surveys were also conducted.

Figure 22. Major herptile sampling sites in SAAN at the Missions Unit (left) and Rancho de las Cabras Unit (right) (Duran 2004).

Woodman (2013) summarized reptile observation data collected in the two units (Missions, Rancho de las Cabras) of SAAN for the 2012 monitoring year. Sampling occurred at monthly intervals for the study period. The two sampling methods used were terrestrial cover board and arboreal PVC-pipes. There were six coverboard arrays (10 panels each) placed in the Missions Unit; all of the arrays were placed in wooded areas along the banks of the San Antonio River. Four cover board arrays were placed in the Rancho de las Cabras Unit (Photo 8). Those arrays were placed in the upland old fields and upper wooded bank habitat.

Photo 8. Cover board used in the Rancho de las Cabras Unit of SAAN (Photo by Shannon Amberg, SMUMN GSS 2013).

4.4.5 Current Condition and Trend

Species Richness

Duran (2004) observed 24 reptile species (13 snakes, six lizards, and five turtles) during the 2003 inventory in SAAN; however, 34 total species were documented with the aid of vouchers and literature sources. The species richness was above the assigned reference condition. Appendix E displays the list of reptiles that were directly observed during the inventory as well as having historically occurred in the park according to Duran (2004).

Dittmer and Fitzgerald (2011) documented five reptile species in SAAN (Missions and Rancho Units) between May and June of 2010 and 2011. No reptiles were found using the PVC pipe traps; the reptiles found under cover boards included three lizard species and two snake species; the Mediterranean gecko (*Hemidactylus turcicus*) was the only non-native species found. The snake species observed were the mountain patch-nose snake (*Salvadora grahamiae*) and a garter snake species (*Thamnophis* sp.). It should be noted that the species richness in this survey was very low compared to the reference condition.

Woodman (2013) documented 15 reptile species in SAAN during the 2012 monitoring year. Eight and 10 species were represented at the Missions sites and the Rancho de las Cabras Unit, respectively (Appendix E). The species richness in this survey was low compared to the reference condition.

The NPS Certified Species List (NPS 2014) documented 34 reptiles in SAAN. Twenty-eight species are listed as present in the park, five species recorded as probably present, and one with historic presence but currently not in the park (Cagle's map turtle). The Mediterranean gecko was the only nonnative species recorded. Appendix E displays all reptile species recorded in SAAN as of 2014. Figure 23 displays the species richness from each study addressed in this analysis.

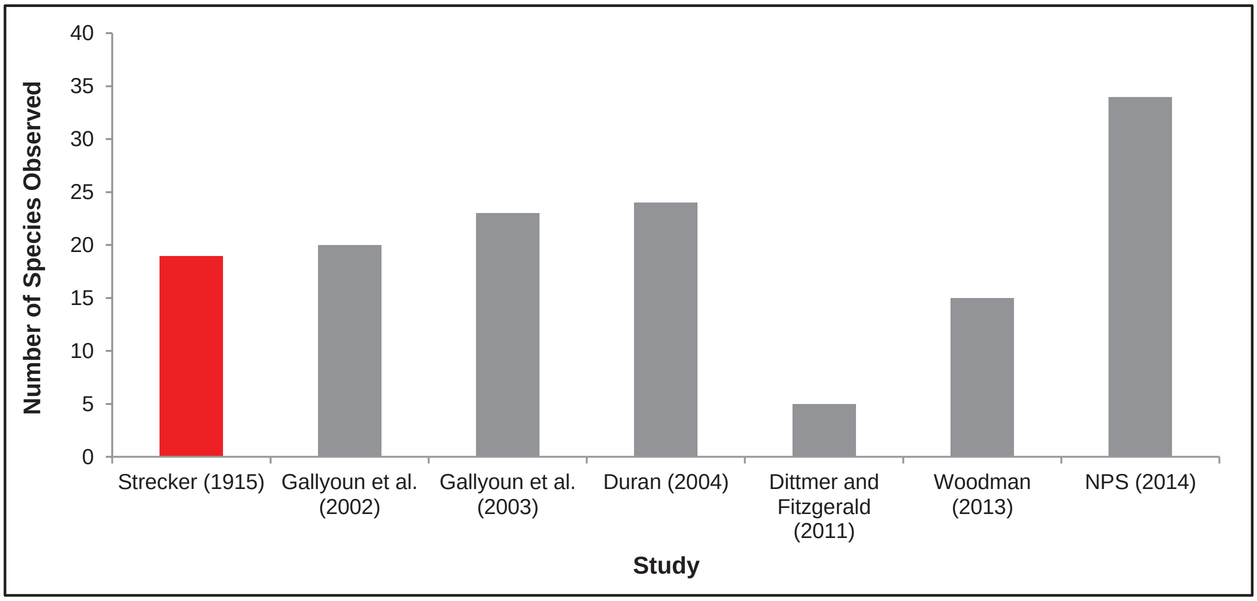

Figure 23. Species richness of reptiles in SAAN (data from Strecker 1915, Gallyoun et al. 2002, Gallyoun et al. 2003, Duran 2004, Dittmer and Fitzgerald 2010, Woodman 2013, NPS 2014). The reference condition (Strecker 1915) is the red bar on the far left.

Relative Abundance

Duran (2004) observed 24 reptile species during a 2003 inventory in SAAN. The total number of observations was recorded for each species documented, showing that some reptiles were more commonly observed than others. During Duran's (2004) inventory, the most commonly observed species in SAAN were the Texas spiny lizard (*Sceloporus olivaceus*), ground skink (*Scincella lateralis*), Guadalupe spiny softshell turtle (*Apalone spinifera guadalupensis*), western diamondback rattlesnake (*Crotalus atrox*), and Mediterranean gecko (Table 18). The Texas tortoise was observed four times, while the Texas horned lizard was not observed during the inventory. The Cagle map turtle was mentioned in the inventory as being historically present, but it is considered extirpated in the area. Some of the species rarely seen during Duran (2004) were the desert king snake (*Lampropeltis getula splendida*), rose-bellied lizard (*Sceloporus variabilis marmoratus*), Texas brown snake (*Storeria dekayi texana*), and Texas long-nosed snake (*Rhinocheilus lecontei tessellatus*). Table 18 displays the number of observations of all reptile species documented during Duran's (2004) herpetofauna inventory of SAAN. However, it is important to note that reptile survey results may be influenced by sampling methods (e.g., drift fences, coverboards, pitfall traps) and timing. Certain reptiles may be too large to fit under coverboards or may simply avoid them for unknown reasons. Some reptile species are seasonal and can only be found in the park at certain times of the year (Woodman, written communication, January 2013) while other species may be present in the park if adequate rains keep standing water in nearby streams (Duran 2004).

Table 18. Reptile species that were observed by Duran (2004) during the 2003 inventory of SAAN.

Scientific Name	Common Name	Number of Observations
Anolis carolinensis	green anole	8
Apalone spinifera guadalupensis	Guadalupe spiny softshell	10
Chelydra serpentina	common snapping turtle	6
Cnemidophorus gularis gularis	Texas spotted whiptail	3
Crotalus atrox	western diamondback rattlesnake	10
Elaphe guttata emoryi	Great Plains rat snake	6
Elaphe obsoleta	Texas rat snake	5
Gopherus berlandieri	Texas tortoise	4
Hemidactylus turcicus	Mediterranean gecko	10
Lampropeltis getula splendida	desert king snake	1
Leptotyphlops dulcis dulcis	plains blind snake	8
Masticophis flagellum testaceus	western coachwhip	5
Masticophis schotti schotti	Schott's whipsnake	5
Nerodia rhombifer	diamondback water snake	4
Pseudemys texana	Texas river cooter	4
Rhinocheilus lecontei tessellatus	Texas long-nosed snake	1
Salvadora grahamiae lineata	Texas patch-nosed snake	3
Sceloporus variabilis marmoratus	rose-bellied lizard	1
Sceloporus olivaceus	Texas spiny lizard	17
Scincella lateralis	ground skink	11
Storeria dekayi texana	Texas brown snake	1
Thamnophis marcianus marcianus	checkered garter snake	3
Trachemys scripta elegans	red-eared slider	7
Virginia striatula	rough earth snake	5

Dittmer and Fitzgerald (2011) documented relative abundance of five reptiles in SAAN (Table 19). The Texas spotted whiptail and a garter snake species were each only captured once. The mountain patch-nose snake and ground skink were captured two and five times, respectively. The Mediterranean gecko was the most common species captured during the survey with 14 recorded captures.

Table 19. Relative abundance of reptile species captured with coverboard method (Dittmer and Fitzgerald 2011).

Scientific Name	Common Name	Number of Coverboard Captures
Cnemidopherus gularis	Texas spotted whiptail	1
Hemidactylus turcicus	Mediterranean gecko	14
Salvadora grahamiae	mountain patch-nosed snake	2
Scincella lateralis	ground skink	5
Thamnophis sp.	garter snake sp.	1

Woodman (2013) recorded relative abundance for 15 reptiles in SAAN between 2011 and 2012. The ground skink had the highest relative abundance being observed 16 times in the Missions unit and 12 times in the Rancho del las Cabras unit. Mediterranean geckos were common (16 observations) in the Missions unit, but the geckos were only observed once in the Rancho de las Cabras unit. Reptiles with low relative abundance (one observation per species) included plains blind snake (*Leptotyphlops dulcis dulcis*), coachwhip (*Masticophis flagellum testaceus*), Texas coral snake (*Micrurus tener*), Texas river cooter (*Pseudemys texana*), blotched water snake (*Nerodia erythrogaster transversa*), Texas spiny lizard, and rough earth snake (*Virginia striatula*). Table 20 displays the relative abundance of reptile species observed at the Missions Unit and Rancho de las Cabras Unit in SAAN between 2011 and 2012.

Table 20. Relative abundance of reptile species observed at the Missions Unit and Rancho de las Cabras Unit in SAAN between 2011 and 2012 (Woodman 2013).

Scientific Name	Common Name	Missions Unit	Rancho de las Cabras Unit
Anolis carolinensis	green anole	4	
Cnemidophorus gularis gularis	Texas spotted whiptail		2
Elaphe guttata emoryi	great plains rat snake		4
Hemidactylus turcicus	Mediterranean Gecko	16	1
Leptotyphlops dulcis dulcis	plains blind snake		1
Masticophis flagellum	coachwhip		1
Masticophis schotti schotti	Schott's whipsnake	2	1
Micrurus tener	Texas coral snake	1	
Nerodia erythrogaster transversa	blotched water snake	1	
Pseudemys texana	Texas river cooter	1	
Salvadora grahamiae lineata	Texas patch-nose snake		5

Table 20 (continued). Relative abundance of reptile species observed at the Missions Unit and Rancho de las Cabras Unit in SAAN between 2011 and 2012 (Woodman 2013).

Scientific Name	Common Name	Missions Unit	Rancho de las Cabras Unit
Sceloporus olivaceus	Texas spiny lizard	1	
Sceloporus variabilis marmoratus	rose-bellied lizard		5
Scincella lateralis	ground skink	16	12
Virginia striatula	rough earth snake		1

NPS (2014) reported relative abundance for 27 reptile species in SAAN. The red-eared slider (*Trachemys scripta elegans*) and Texas river cooter were the two species identified as abundant in the park. Fourteen reptile species were documented as common in the park. Nine reptiles were classified as uncommon in the park, and the one nonnative species was recorded as being rare. Table 21 displays the reptile species with reported relative abundance in SAAN.

Table 21. Reptile species with relative abundance in SAAN (NPS 2014).

Scientific Name	Common Names	Relative Abundance
Anolis carolinensis	green anole	Common
Apalone spinifera	spiny softshell turtle	Common
Chelydra serpentina	common snapping turtle	Common
Cnemidophorus gularis gularis	Texas spotted whiptail	Uncommon
Crotalus atrox	western diamondback rattlesnake	Common
Gopherus berlandieri	Texas tortoise	Uncommon
Hemidactylus turcicus	Mediterranean gecko	Rare
Kinosternon flavescens	yellow mud turtle	Unknown
Leptotyphlops dulcis dulcis	plains blind snake	Common
Masticophis flagellum testaceus	western coachwhip	Common
Masticophis schotti schotti	Schott's whipsnake	Common
Micrurus tener	Texas coral snake	Uncommon
Nerodia erythrogaster transversa	blotched water snake	Uncommon
Nerodia rhombifer	diamondback water snake	Common
Opheodrys aestivus	rough green snake	Uncommon
Pseudemys texana	Texas river cooter	Abundant

Table 21 (continued). Reptile species with relative abundance in SAAN (NPS 2014).

Scientific Name	Common Names	Relative Abundance
Rhinocheilus lecontei tessellatus	Texas long-nosed snake	Uncommon
Salvadora grahamiae lineata	Texas patch-nosed snake	Common
Sceloporus olivaceus	Texas spiny lizard	Common
Sceloporus variabilis marmoratus	rose-bellied lizard	Uncommon
Scincella lateralis	ground skink	Common
Sonora semiannulata	ground snake	Uncommon
Sternotherus odoratus	common musk turtle	Common
Storeria dekayi texana	Texas brown snake	Uncommon
Thamnophis marcianus marcianus	checkered garter snake	Common
Trachemys scripta elegans	red-eared slider	Abundant
Virginia striatula	rough earth snake	Uncommon

Reproductive Success

At the time of publication, there are no data regarding reptile reproductive success in SAAN. Continuation of the GULN annual surveys and monitoring programs may allow this measure to be assessed in the future.

Threats and Stressor Factors

SAAN staff identified many threats to the reptile population of the park. Some of these threats include non-native species, habitat loss and fragmentation, and drought.

Non-native species

Non-native species are a threat to native reptile species in SAAN. Feral hogs have been known to negatively affect native wildlife through habitat loss and depredation. Feral hogs cause habitat loss by foraging on native vegetation (Jolley et al. 2010), and have been observed turning over rocks and logs and generally disturbing vegetative terrain used by reptiles (Dittmer and Fitzgerald 2011). According to Dittmer and Fitzgerald (2011), the Missions and Rancho de las Cabras Units showed signs of heavy use by feral hogs.

Red fire ants (*Solenopsis invicta*) are another non-native species that are a direct and indirect threat to reptiles in the park. Fire ants act as predators and competition for reptiles, and have been known to prey on eggs and hatchlings, as well as invertebrates that are a key staple of the Texas horned lizard’s diet (Allen et al. 1994). According to Dittmer and Fitzgerald (2011), fire ants were found in abundance under coverboards set out to trap the Texas horned lizard in the park.

Habitat Loss / Fragmentation

Habitat loss can be a major stressor to reptiles. Habitat is lost or fragmented when native vegetation is cleared for aesthetics, new housing, roadways, and farms. Increased highway traffic has also caused mortality to reptiles crossing roads (Thode 1999). Fragmentation and removal of habitat, in and around the park, have been caused by landscaping (mowing), land development and conversion. Approximately 73 ha (180 ac) of the Missions Unit is actively mowed (Dittmer and Fitzgerald 2011; Mitchell, written communication, 16 September 2014), which causes loss of habitat and a direct threat to reptiles traveling through mowed areas. During the Duran (2004) inventory, a Texas coral snake was struck and killed by a mower. Another factor influencing habitat loss is urbanization. According to Duran (2004), urbanization has probably contributed to the elimination of reptile species that were historically present in the park.

Drought/Climate Change

Texas has experienced moderate to severe drought conditions that are likely a result of global climate change (GCC) (Figure 24). GCC will likely compound the negative effects of habitat fragmentation through drought. Drought decreases wetland and other ephemeral inundations, which can further increase the distance between aquatic habitats (Walls et al. 2013). Lizards, snakes, and reptiles are all affected by climate change; however, each species has varying degrees of vulnerability (Olson and Saenz 2013). GCC induced droughts have the greatest negative affect on turtles because of their dependency on aquatic environments. Turtle reproductive success may also be of concern because they have temperature-sensitive sex determination. If temperatures continue to increase, turtles could produce nests of only female offspring (Olson and Saenz 2013). Lizards also rely on temperature for reproductive success. Lizard reproduction occurs over a narrow period of time in the spring and summer when temperatures are suitable with moist conditions. A warmer, drier climate may cause seasons with reproductive failure (Olson and Saenz 2013). Snakes are also affected by warming temperatures. As a result of warmer nightly temperatures, GCC has caused changes in snake species niches resulting in smaller ranges for some species (rattlesnake spp.) but also increased activity for others (rat snake spp.) (Olson and Saenz 2013).

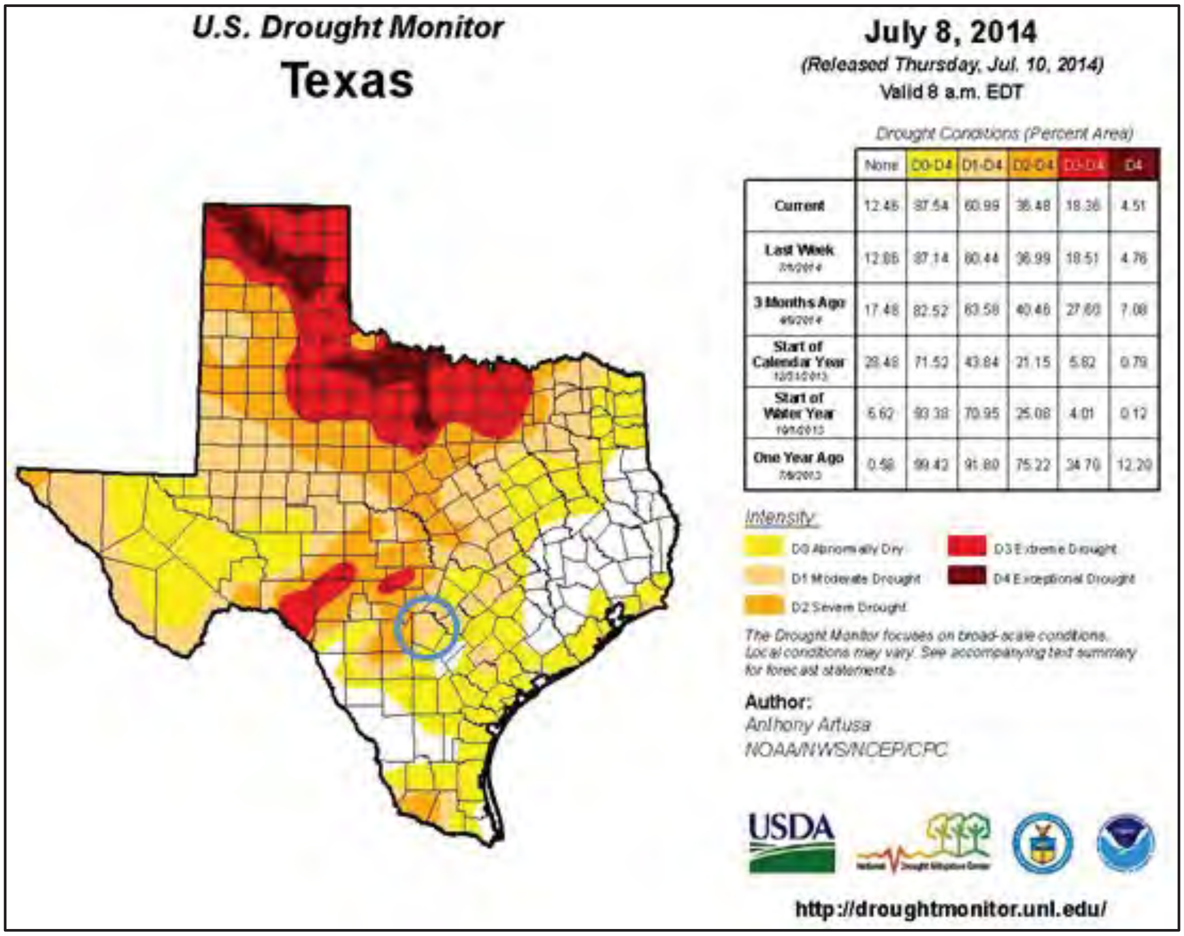

Figure 24. Texas is experiencing varying degrees of drought; Bexar county is circled in blue (USDM 2014).

<u>Data Needs/Gaps</u>

No information is available that characterizes reptile reproductive success in SAAN. Duran (2004) documented baseline information such as annotated checklists of reptiles and locations of reptiles found during the inventory. However, this inventory occurred over a short period in time and is nearly a decade old. Dittmer and Fitzgerald (2011) and Woodman (2013) documented more current data on species richness and relative abundance, but the data were also collected over a short period of time. Monitoring should continue and will be helpful to park managers in the future.

<u>Overall Condition</u>

Species Richness

The project team defined the *Significance Level* for species richness as a 3. Species richness is relatively high in SAAN, representing several different taxa. Only one nonnative species, the Mediterranean gecko, was observed in SAAN during the surveys cited in this assessment. There were two studies (Dittmer and Fitzgerald 2011, Woodman 2013) that documented species richness below the reference condition. NPS (2014), however, documented species richness above the reference condition. As a result, the *Condition Level* of species richness is a 1, representing a low level of concern.

Relative Abundance

The project team defined the *Significance Level* for relative abundance as a 3. Relative abundance is moderate in SAAN. Duran (2004) documented that some reptiles were more commonly observed than others. The most commonly observed species in SAAN were the Texas spiny lizard, ground skink, and Guadalupe spiny softshell turtle, western diamondback rattlesnake, and Mediterranean gecko; these species were observed 17, 11, 10, 10, 10 times, respectively. Woodman (2013) recorded 28 ground skinks and 17 Mediterranean geckos during the study. The other species were recorded less than or equal to five times each. The *Condition Level* of relative abundance is a 1, representing a low level of concern.

Reproductive Success

The project team defined the *Significance Level* for reproductive success as a 3. There are no current available data characterizing the reproductive success of reptiles in SAAN. Therefore, it is not possible to assign a *Condition Level* for this measure.

Weighted Condition Score (WCS)

The *Weighted Condition Score* for reptiles in SAAN is 0.22, indicating a low level of concern for this resource. After assessing the available data, there appears to be a stable trend in the park.

Reptiles			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.22**
Species Richness	3	1	
Relative Abundance	3	1	
Reproductive Success	3	n/a	

4.4.6 Sources of Expertise

Robert Woodman, GULN Ecologist

Billy Finney, GULN Field Biologist

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4.5 Amphibians

4.5.1 Description

Amphibians are considered a high priority Vital Sign within all GULN units and are important species at SAAN as they are potential indicators of subtle ecological changes (Segura et al. 2007). Amphibians are highly sensitive to human impacts such as habitat disturbances, fragmentation, and pollutants; they are also of special interest due to their current decline on a global scale (Woodman 2013).

The aquatic and riparian habitats that exist in SAAN provide suitable habitat for amphibian species assemblages that have persevered despite considerable fragmentation due to urban development around San Antonio (NPS 2010). Currently, there are nine confirmed amphibian species that occur in SAAN; this includes three toads and six frogs (NPS 2014). The Great Plains narrowmouth toad (*Gastrophryne olivacea*), the Blanchard's cricket frog (*Acris crepitans blanchardi*), and the non-native Rio Grande chirping frog (*Eleutherodactylus cystignathoides campi*) are pictured in Photo 9.

Photo 9. Three amphibian species present in SAAN are shown from left to right; Rio Grande chirping frog, Great Plains narrowmouth toad, and the Blanchard's cricket frog (photo by Duran 2004).

4.5.2 Measures

- Species richness
- Relative abundance
- Reproductive success

4.5.3 Reference Conditions/Values

The ideal reference condition for this component would be the condition of amphibian populations during the Mission period; however, there is no information on amphibians from this time. Strecker (1915) catalogued herptiles in Texas during the early 20th century, and is likely the oldest available data on the amphibian community of the San Antonio area. Species found in the vicinity of where the park units are currently located are presented in Table 22. This list, which includes species that currently inhabit SAAN as well as some that are no longer present within the park, can be used as a reference condition for species richness. Reference conditions have not been determined for relative abundance or reproductive success.

Table 22. List of amphibian species catalogued by Strecker (1915) in the San Antonio area. Locations are shown in Figure 24.

Scientific Name	Common Names	Observation Location
*Rana catesbeiana** (*Lithobates catesbeianus*)	bull frog	Bexar County
Hyla chrysoscelis/versicolor	chameleon tree frog *(Cope's grey treefrog)	San Antonio
Hyla cinerea	green tree frog	San Antonio
Gastrophryne olivacea	Great Plains narrow-mouth toad	San Antonio
Lithobates berlandieri (Rana berlandieri)*	Rio Grande leopard frog	San Antonio
Scaphiopus couchii	Couch's spadefoot	From southern Texas to north of San Antonio
Bufo punctatus (Anaxyrus punctatus)*	spotted toad	San Antonio
Chorophilus triseriatus (Pseudacris clarkii)*	striped tree frog (spotted chorus frog)	Helotes
Acris gryllus[1]	western cricket frog	State wide
Hyla squirella	southern tree frog	San Antonio
Smilisca baudinii	Mexican tree frog	Bexar County
Bufo debilis (Anaxyrus debilis debilis)*	little green toad	Bexar County
Bufo lentiginosus americanus (Anaxyrus americanus)*	American toad	San Antonio
Ambystoma texanum	Texan salamander* (small-mouthed salamander)	San Antonio

* indicates a nomenclature or naming update; current, valid names are in parentheses.

[1]This was likely *Acris crepitans blanchardi*, Blanchard's cricket frog, as the species currently known as *Acris gryllus* does not occur west of the Mississippi.

4.5.4 Data and Methods

Strecker (1915) surveyed the entire state of Texas between 1902 and 1912 for herptiles and listed the observations by county and, in some cases, by township (Figure 24).

Duran (2004) inventoried herptiles within GULN; SAAN was surveyed by trapping, visual encounter surveys (VES), coverboards, and auditory surveys (Figure 25). Trapping was conducted for two 3-day periods during the summer of 2003. VES were conducted along transects in the same area as the trapping sites and a total of 4 km (2.5 mi) was surveyed on foot (Duran 2004). The coverboards were installed and left undisturbed, starting in the summer of 2002, and after 2 months, bi-weekly checks were conducted until the spring of 2003. Auditory surveys were conducted later than originally planned due to below average rainfall conditions from April-June in 2002. The auditory surveys resumed in late June of 2003 when substantial rain occurred and were conducted anytime rain occurred from July to October of 2003 (Duran 2004). Sampling efforts occurred over a short period of time and cannot be considered as comprehensive distributional surveys.

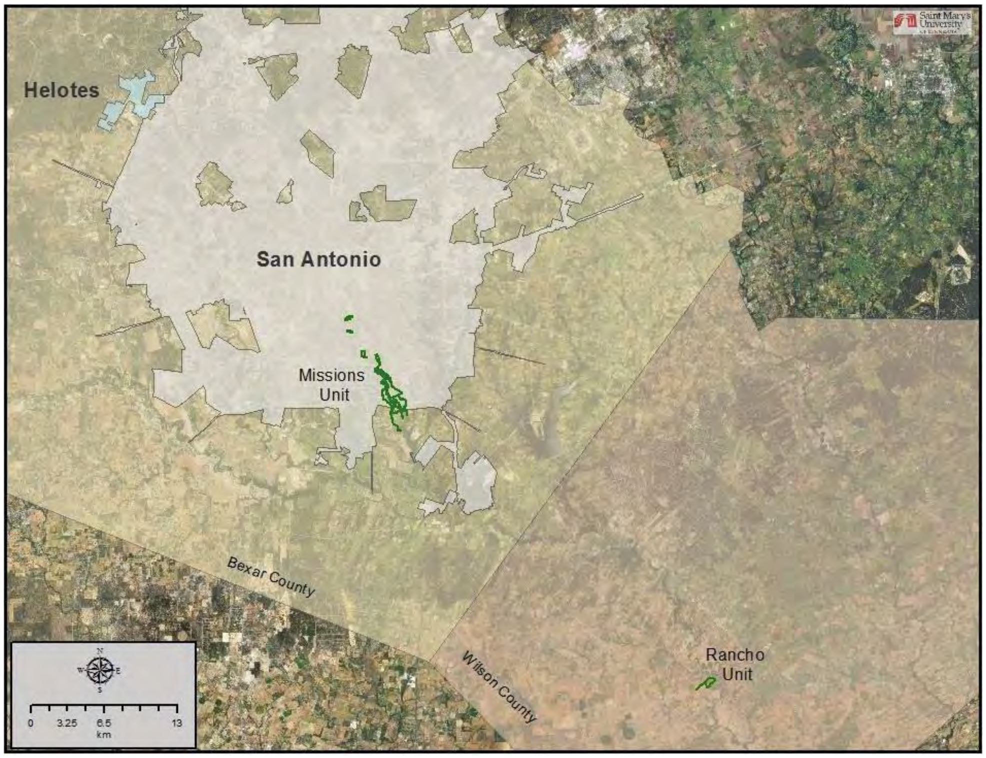

Figure 25. Areas in the vicinity of SAAN where Strecker (1915) observed amphibian species (see Table 22).

Figure 26. Major sampling sites in SAAN at the Missions Unit (left) and Rancho de las Cabras Unit (right) (Duran 2004).

Both of the SAAN units were selected for the GULN's recently developed reptile and amphibian monitoring protocol (GRAMP), which samples amphibians and reptiles simultaneously, as well as collecting auxiliary data such as temperature and relative humidity (Woodman 2013). Terrestrial cover-board and arboreal PVC-pipe fixed point sampling were conducted during 2012 on a monthly schedule (Photo 10). This monitoring is expected to continue on an annual basis. Starting in 2015, additional reports of this nature will be completed on a four to five-year cycle to assess trends in species richness, abundance, and assemblage composition and structure (Woodman 2013).

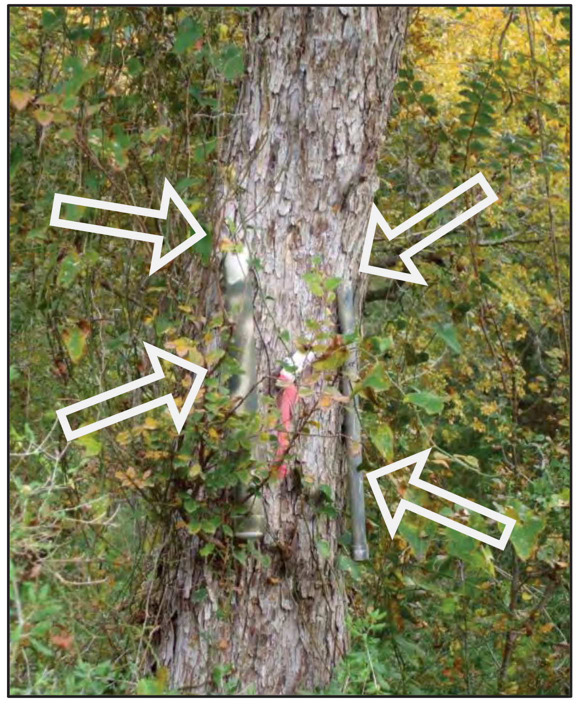

Photo 10. An arboreal PVC-pipe, shown with green arrows, mounted on a tree trunk at the Rancho Unit; these were used in amphibian sampling efforts in 2012 (Photo by Kathy Allen, SMUMN GSS 2013).

4.5.5 Current Condition and Trend

Species Richness

Duran (2004) documented seven species of amphibians during the 2002 and 2003 inventory (Table 23). Based on previous records, another five species were listed as possibly occurring in the park. Woodman (2013) lists six species that were observed during the 2012 GRAMP surveys. Table 23 includes observed species in Missions (MS) and Rancho de las Cabras (RS); the difference in amphibian community composition between the two units is likely due to the distance between them and differences in land uses. The Missions Unit lies within a predominantly urban area, while the lands surrounding Rancho de las Cabras have remained largely rural. There are nine amphibian species present within SAAN according to the most recent NPS (2014) species list.

Table 23. The amphibian species listed in Duran (2004) and Woodman (2013).

Scientific Name	Common Name	Duran* (2004)	Woodman* (2013)	NPS* (2014)
Acris crepitans blanchardi	Blanchard's cricket frog	x		x
Anaxyrus debilis debilis	little green toad (eastern green toad)	P		
Incilius nebulifer	coastal plain toad	x	RS	x
Anaxyrus speciosus	Texas toad	P		
Eleutherodactylus cystignathoides campi	Rio Grande chirping frog	x	MS	x

* Symbols key: x=observed in park, P=possibly occurring in park, RS=observed in Rancho de las Cabras unit, and MS=observed in Missions unit.

Table 23 (continued). The amphibian species listed in Duran (2004) and Woodman (2013).

Scientific Name	Common Name	Duran* (2004)	Woodman* (2013)	NPS* (2014)
Gastrophryne olivacea	Great Plains narrowmouth toad	x	MS/RS	x
Hyla chrysoscelis/versicolor	Cope's treefrog		RS	x
Hyla cinerea	green tree frog	x	MS/RS	x
Lithobates sphenocephalus	southern leopard frog		MS/RS	
Pseudacris clarkii	spotted chorus frog	P		
Pseudacris streckeri	Strecker's chorus frog	P		
Rana berlandieri	Rio Grande leopard frog	P		x
Rana catesbeiana	bull frog	x		x
Scaphiopus couchii	Couch's spadefoot toad	x		x

* Symbols key: x=observed in park, P=possibly occurring in park, RS=observed in Rancho de las Cabras unit, and MS=observed in Missions unit.

Relative Abundance

The abundance of amphibians has not been monitored regularly within the park. Duran (2004) categorized species as common, uncommon, or rare. Three species were considered common: the Blanchard's cricket frog, the coastal plain toad (*Incilius nebulifer*), and the Great Plains narrowmouth toad. There were three uncommon species: the green tree frog (*Hyla cinerea*), the bull frog (*Rana catesbeiana*), and the Rio Grande chirping frog. Only the Couch's spadefoot toad (*Scaphiopus couchii*) was considered rare (Duran 2004). The most relevant data that relates to the general abundance of each species is Woodman (2013), which is shown in Table 24. Future monitoring efforts could be compared to this as a baseline to determine if relative abundance is changing within the park.

Table 24. The relative abundance (number of individuals) of amphibians during 2012 surveys at the Missions Unit and Rancho de las Cabras Unit (Woodman 2013).

Scientific Name	Common Name	Missions Unit	Rancho Unit
Eleutherodactylus cystignathoides	Rio Grande chirping frog	68	0
Hyla cinerea	green tree frog	3	1
Gastrophryne olivacea	Great Plains narrow-mouth toad	70	18
Lithobates sphenocephalus	southern leopard frog	1	1
Hyla versicolor/chrysoceles	gray tree frog	0	1
Incilius nebulifer	coastal plain toad	0	3

The NPS (2014) species list provides relative abundances of the species of amphibians that occur in SAAN (Table 25). Only three species are considered abundant or common while five are uncommon or rare.

Table 25. Amphibian species abundance (NPS 2014).

Scientific Name	Common Name	Relative Abundance
Incilius nebulifer	coastal plain toad	Abundant
Eleutherodactylus cystignathoides campi	Rio Grande chirping frog	Uncommon
Acris crepitans blanchardi	Blanchard's cricket frog	Abundant
Hyla chrysoscelis/versicolor	Cope's tree frog	Unknown
Hyla cinerea	green tree frog	Uncommon
Gastrophryne olivacea	Great Plains narrowmouth toad	Common
Lithobates berlandieri	Rio Grande leopard frog	Uncommon
Lithobates catesbeianus	bull frog	Rare
Scaphiopus couchii	Couch's spadefoot	Uncommon

Reproductive Success

At the time of publication, there are no data regarding amphibian reproductive success in SAAN. Continuation of the GULN annual surveys and monitoring programs may allow this measure to be assessed in the future.

Threats and Stressor Factors

Habitat Loss

The city of San Antonio has an estimated population of 1.4 million within the 1,194 km^2 (461 mi^2) city area. Bexar County, where the largest portion of the park resides, has an estimated population of 1.8 million; Wilson County, where the smaller Rancho Unit of the park resides, has an estimated population of 45,418 (U.S. Census Bureau 2014). The park provides an oasis from the encroachment of urban sprawl, but also is connected and susceptible to air and water quality degradation from these heavily populated areas where land is converted from vegetation to impermeable surfaces such as parking lots and buildings. With urban sprawl comes increased emissions, effluent, and demand on water resources, which can leave areas like SAAN depleted of aquatic resources crucial to amphibian success (Kreuter et al. 2001).

Displacement by Non-natives (Rio Grande chirping frog)

The Rio Grande chirping frog is an introduced non-native species that currently resides only in the Missions unit of SAAN. These frogs do not require standing water for reproduction since their eggs hatch as froglets, completely skipping the tadpole phase (Wright and Wright 1949, Hayes-Odum 1990, as cited by Fuller 2014). This life history trait may allow this species to expand and multiply in dry periods while other, native species may decline; this may be revealed by monitoring efforts at the park.

Non-native Species (Hogs and cats)

Feral hogs are an exotic species, abundant throughout Texas. They compete for food with local wildlife as well as livestock since they are opportunistic omnivores and will eat just about anything, including amphibian species (Taylor 2003). The hogs are not new to the area, as their introduction likely occurred in the 1930s when batches were released for sport hunting and multiplied rapidly in the wild (Taylor 2003). Feral hogs reproduce quickly, with reproductive maturity achieved as early as 6 months in a healthy female, and litters of up to 12 piglets. The feral hog is highly adaptive and able to thrive in almost any environment, but prefers habitats with areas for wallowing; this can be anywhere mud forms, including creek banks, ponds, and drainages. Aside from food competition, the destructive rooting behavior of the feral hog is what causes the most damage to natural resources (Taylor 2003).

Feral cats (*Felis catus*) are an invasive species found throughout the United States, including the San Antonio area. They are considered a threat to the amphibian community at the park since they are indiscriminate predators of any small animal, including frogs and toads (Hildreth et al. 2010). Loss et al. (2013) estimates that between 95 and 299 million amphibians could be killed by feral cats in the United States each year.

Disease

The aquatic *Batrachochytrium dendrobatidis* (Bd), or chytrid fungus, causes chytridiomycosis, a lethal skin disease in amphibians that is linked to population declines in many areas of the world, including the GULN region (Weldon et al. 2004, Hossack et al. 2009). The fungus parasitizes the host's keratinized skin and mouthparts, and is afflicting hundreds of species around the world (Kriger 2006). In a few locations near Austin, Texas, including Bastrop State Park, the headwaters of the San Marcos River, Barton Springs, and Brushy Creek, the fungus has been positively identified in amphibian sampling (Olson 2014). Sampling for the chytrid fungus has not been conducted within SAAN.

Drought/Climate Change

Texas has experienced moderate to severe drought conditions that are likely a result of global climate change (GCC) (see Figure 24 in Section 4.4). A limiting factor in amphibian distribution is water availability and the local hydrological regime stability. GCC is rapidly changing the hydrologic conditions of environments. Walls et al. (2013) states that monitoring efforts should incorporate both aquatic and terrestrial components of amphibian life history stages in order to better understand and manage the effect that GCC is having on their localized ecology. GCC will likely compound the negative effects of habitat fragmentation through drought and deluge. Drought decreases wetland and other ephemeral inundations, which can further increase the distance between aquatic habitats. Deluges can temporarily connect neighboring sites, causing the introduction of predatory fish and the spread of exotic invasive species into otherwise isolated aquatic environments (Walls et al. 2013).

Data Needs/Gaps

There are no data on the reproductive success of amphibians in SAAN at this time. There is also no information on the impact of the non-native Rio Grande chirping frog and possible competition with native amphibians at the park. Future monitoring will focus primarily on species richness, relative abundance, and changes in measurable assemblage composition and structure (Woodman 2013).

Overall Condition

Species Richness

The *Significance Level* for species richness was assigned a 3. Strecker (1915) documented 14 amphibian species in the vicinity of San Antonio between 1902 and 1912. More recent studies such as Duran (2004) and Woodman (2013) have documented only seven and six amphibians, respectively. It is difficult to determine if this represents an actual decline in species richness or just differences in inventory methods and taxonomic classifications. However, species richness was assigned a *Condition Level* of 1, or of low concern.

Relative Abundance

The *Significance Level* for relative abundance was assigned a 3. Woodman (2013) has a count of individuals by species and park unit. It should be noted that Woodman (2013) did not document relative abundance throughout the entire park. There are no other data to confirm or compare the level of relative abundance historically. As a result of the lack of data, relative abundance cannot be assigned a *Condition Level* at this time.

Reproductive Success

The *Significance Level* for reproductive success was assigned a 3. There are no data for reproductive success in the park. Due to this data gap, reproductive success cannot be assigned a *Condition Level* at this time.

Weighted Condition Score

The *Weighted Condition Score* for amphibians in SAAN was not assigned due to the lack of relative abundance and reproductive success data. The condition and any trends in this resource are unknown at this time.

Amphibians			
Measures	Significance Level	Condition Level	WCS = N/A
Species Richness	3	1	
Relative Abundance	3	n/a	
Reproductive Success	3	n/a	

4.5.6 Sources of Expertise

Billy Finney, GULN Field Biologist

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4.6 Breeding Birds

4.6.1 Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are often highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Despite being a small, urban park, SAAN is home to several unique habitat types including riparian, grassland, and huisache (acacia) woodlands (Van Auken 1981). The unique ecosystems and landforms in SAAN provide bird species with a variety of habitat types and food sources. Monitoring avian population health and diversity in SAAN habitats will be important for detecting population and ecosystem changes.

Photo 11. The painted bunting, a South Texas specialty species whose breeding range extends into SAAN (Photo by Ronnie Maum, USFWS).

The small size and location of the park represents a unique situation, as birds in the park most likely indicate ecosystem changes occurring in areas outside of the park. There have been extensive restoration efforts along the San Antonio River outside of the park, particularly in regards to the riparian corridor. As these restoration efforts continue, it is likely that an increase in abundance and diversity in bird species will follow (Woodman, written communication, 19 December 2014). These increases will extend into SAAN lands, even though SAAN may harbor only a portion of these critical riparian habitats.

Many of the breeding bird species present in SAAN are common to other areas of the U.S. and Mexico (e.g., mourning dove [*Zenaida macroura*], northern mockingbird [*Mimus polyglottos*]). However, SAAN is also home to several unique species whose breeding ranges only extend into the U.S. near the U.S./Mexico border. Examples of these species include the crested caracara (*Caracara cheriway*), the painted bunting (*Passerina ciris*; Photo 11), and the great kiskadee (*Pitangus sulphuratus*).

4.6.2 Measures

- Species richness
- Relative abundance
- Distribution

4.6.3 Reference Conditions/Values

Few avian surveys or inventories have taken place in SAAN, and the establishment of a reference condition is problematic for this component. Most studies that have taken place in the park have used differing methodologies, timing, and sampling locations, which makes comparisons between studies difficult.

Coonan (1987) represents the earliest inventory in the park, and will serve as the reference condition when data sources are comparable. Coonan (1987) reports species richness for the San Juan Woods and Espada Labores, but also includes the total number of species observed during the study. For the species richness measure in this assessment, only the total number of species observed during Coonan (1987) will be used as the reference condition. This will help to eliminate some problems and biases that exist when comparing species richness values from different sampling sites. The relative abundance and distribution measures are difficult to establish a reference condition for, as the data from the three major studies that have taken place in the park are not easily compared. The three studies that have taken place in the park have occurred in mostly different locations, and have reported relative abundance uniquely. For the purpose of this assessment, a reference condition will not be established for these measures.

4.6.4 Data and Methods

This component focuses exclusively on the breeding bird species of the park, and does not discuss any migratory or vagrant bird species. A species was classified as breeding based on the NPS Certified Bird Species List (NPS 2014, Appendix F). Species in NPS (2014) that had residency designations of "Breeding" were included in this component's discussion and analysis; the designation of "Breeding" solely refers to the fact that SAAN lies within the species' breeding range, and does not signify the species actually breeds annually in the park. Species that were identified as "Resident" are discussed in Chapter 4.7 of this document. In instances where NPS (2014) did not assign residency, the Cornell University Lab of Ornithology's All About Birds online database (http://www.allaboutbirds.org) was used to approximate a species' residency as either breeding, migratory, resident, or vagrant. Migratory bird species represent a data gap in SAAN, and are not discussed separately in this NRCA.

Coonan (1987) inventoried the avian population of SAAN from 1985-1986. Surveys took place four times a year in the San Juan Woods and Espada Labores land tracts. One survey transect was set up in the San Juan woods, while three transects were set up in the Espada Labores site. Surveyors observed and recorded the number of individuals, species, and distance from observer from sunrise until about 3 hours post-sunrise. The survey results were grouped based on season: fall (October-November 1985), winter (December-February 1985-86), spring (March-May 1986), early summer (June-July 1986), and late summer (August-September 1986). SMUMN GSS made one modification to the data presented in Coonan (1987). Records for the tufted titmouse (*Baeolophus bicolor*) were reclassified as the black-crested titmouse (*Baeolophus atricristatus*), as was previously done by NPS (2014).

From 2003-2005, Scully (2006) attempted to document at least 90% of the bird species believed to occur in SAAN. Two major study units were created during these surveys: The City of San Antonio Unit (buildings and grounds associated with Missions San Jose, San Juan, Espada, and Concepcion) (Figure 27), and the Rancho de las Cabras property (40 ha [99 ac] property in Wilson County) (Figure 28). Within each study unit, a series of 25 survey points were established. Eighteen survey points were located in the San Antonio unit, and seven points were in the Rancho de las Cabras unit; no point was within 250 m (820 ft) of another point (Scully 2006). Surveys began 30 minutes before sunrise and continued up until 4 hours post-sunrise. All species observed, whether visually or aurally, during 5 minute surveys were recorded. In addition, Scully (2006) documented distance from observer, sex, and age class of birds when possible.

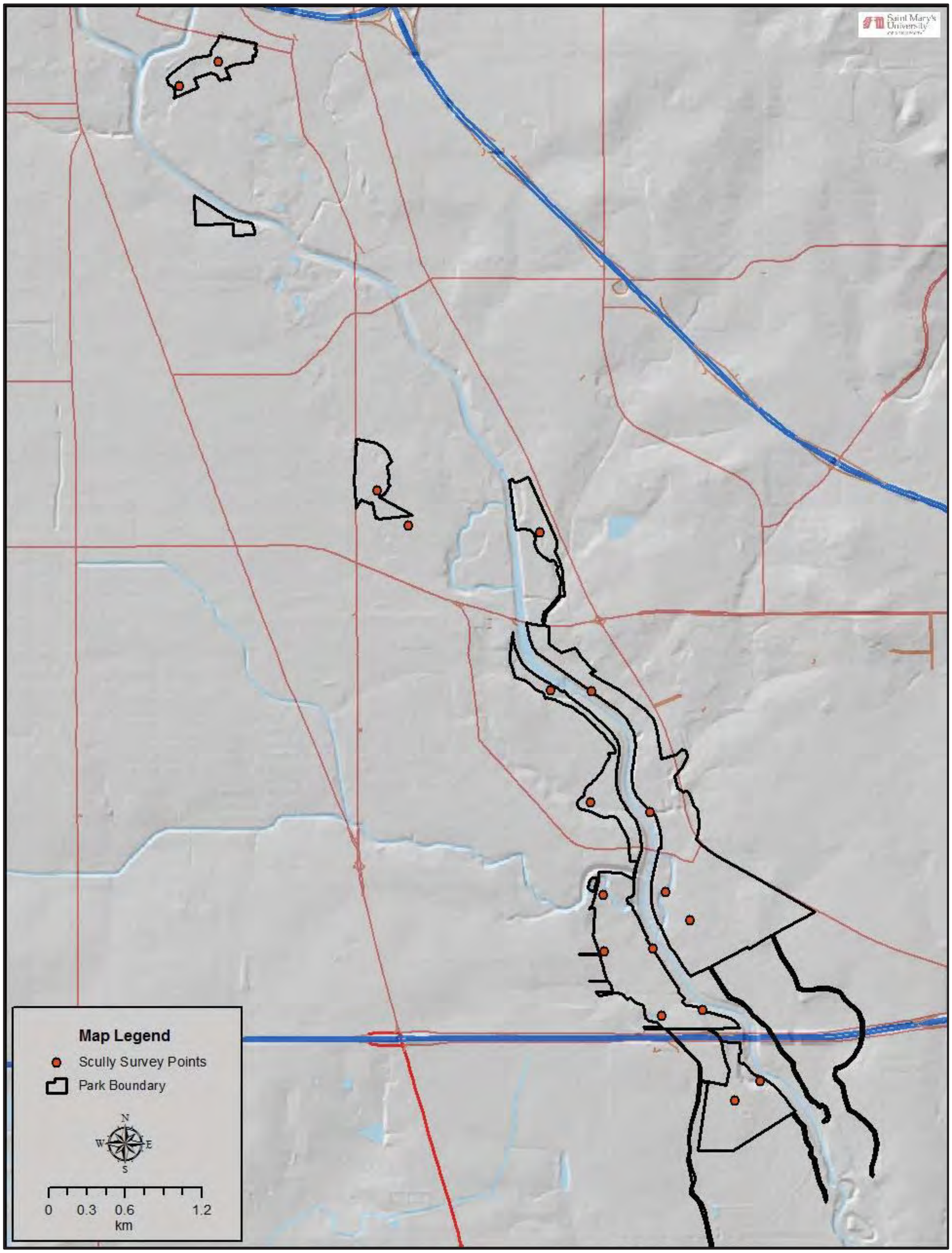

Figure 27. Scully (2006) sample sites in the City of San Antonio study unit during 2003-2005 surveys of SAAN.

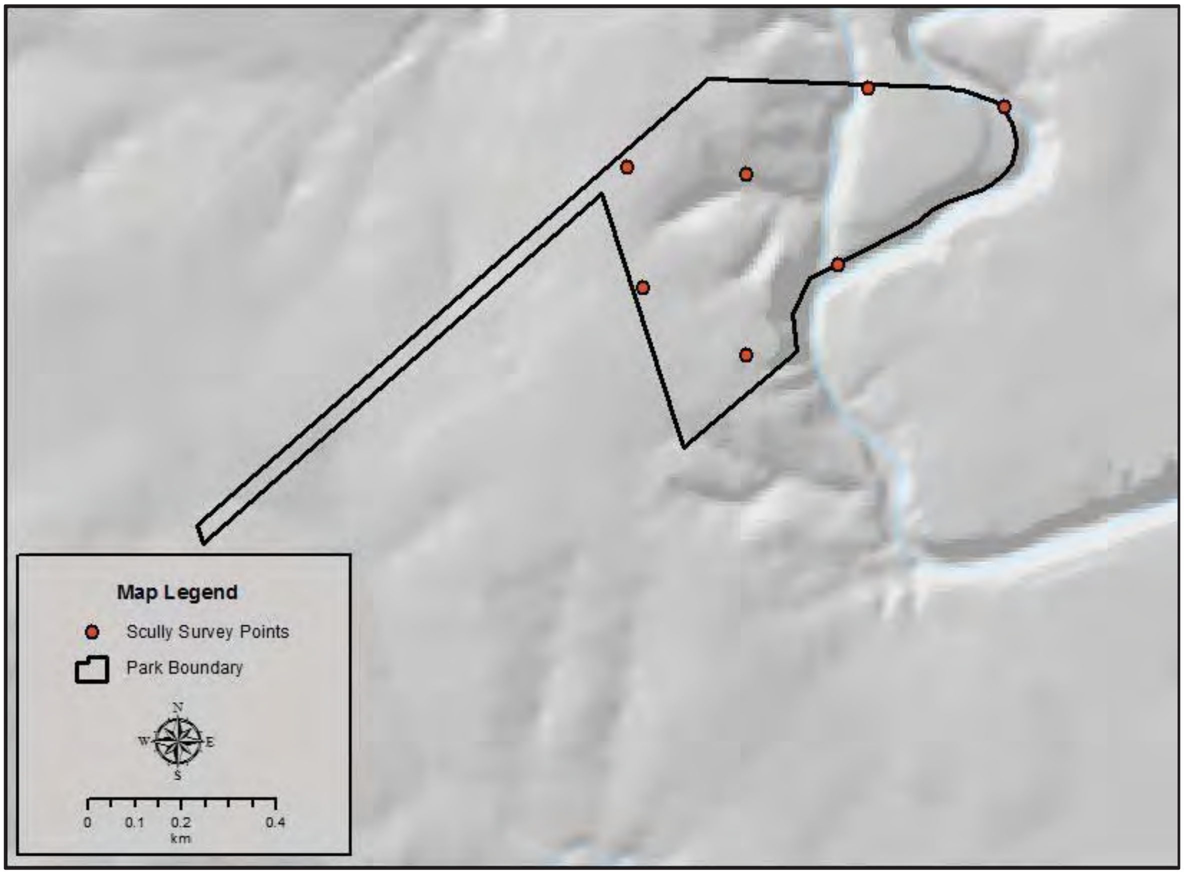

Figure 28. Scully (2006) sample sites in the Rancho de las Cabras study unit during 2003-2005 surveys of SAAN.

As part of a GULN monitoring initiative, Twedt (2013) observed the wintering and breeding bird populations of SAAN from 2010-2013. For this assessment, only the data relating to the breeding bird surveys were discussed and analyzed. Twedt (2013) monitored the breeding population of SAAN from May-June between 2010-2012. In total, 40 point count locations were established in the Missions and Rancho units of the park, and each point count was surveyed for 10 minutes. Timing of bird observation (i.e., what minute of the point count the bird was observed), species, number of individuals, and detection distance were recorded during each survey. Complete, detailed methodologies for this study are provided in Twedt (2013).Of note, however, is that Twedt (2013) randomly selected the breeding bird sample points. If any of these random sample points fell within 250 m (820 ft) of a sample point from Scully (2006), the sample point was moved to that legacy sample point from Scully (2006). By doing this, some level of continuity was added between the two survey efforts.

4.6.5 Current Condition and Trend

<u>Species Richness</u>

The species richness measure allows simultaneous assessment of abundance or presence for the entire breeding bird community. This measure can also indicate overall habitat suitability for breeding birds, and is vital to understand the effects of changing landscapes on native biodiversity.

NPS Certified Species List (NPS 2014)

The NPS Certified Bird Species List contains 229 species, 71 (31%) of which are potentially breeding bird species (Appendix F). This list, however, does not allow for a specific analysis of species richness, as no data are collected other than the presence (or historic presence) of the identified species.

Coonan (1987)

During an inventory of the avifauna of SAAN from 1985-1986, Coonan (1987) documented 101 bird species, 44 of which were breeding species (44%; Appendix F). Coonan (1987) investigated the distribution of species in the park as well (discussed in the distribution measure below), and surveyed the San Juan Woods and Espada Labores land tracts four times each season (fall, winter, spring, early summer, late summer). Table 26 displays the species richness values observed in each season for both sampled habitat types.

Table 26. Species richness values by habitat type and by season observed during Coonan (1987).The grand total value represents the reference condition for the species richness measure in this assessment.

	San Juan Woods	Espada Labores
Fall	12	24
Winter	14	19
Spring	17	24
Early Summer	16	31
Late Summer	17	27
Total Sp.	**27**	**41**
Grand Total	**44**	

Scully (2006)

Scully (2006) completed a bird inventory in SAAN from 2004-2006, and sampled park units within the City of San Antonio and the Rancho de las Cabras units. Scully (2006) documented 197 species total, 68 of which were breeding species (35%; Appendix F); the species richness value obtained by Scully (2006) exceeded the Coonan (1987) reference condition value by 24 species (Table 26, Table 27). The species richness total reported in Scully (2006) includes species detected outside of the specified sampling points. Excluding species detected outside of count locations (i.e., incidental detections), the species richness for SAAN was 146 species, 65 of which were breeding species (45%; Table 27). This value still exceeded the reference condition value of 44 species obtained by Coonan (1987) (Table 26).

Table 27. Species richness values reported by Scully (2006) for both the units of the park within City of San Antonio and the Rancho de las Cabras units of SAAN (2004-2006). Numbers in parentheses indicate the number of sample points within each study site.

	City of San Antonio (18)	Rancho de las Cabras (7)
Species Observed Total	61	52
Species Observed at Points	57	49
Grand Total (sp. observed at sample points)	**68 (65)**	

Twedt (2013)

Breeding bird surveys were completed in 2010-2012 between May-June and identified 89 species total, 60 of which were breeding species (67%; Appendix F). Species richness values were reported yearly by Twedt (2013); richness values for breeding species ranged from 42 species (2010) to 48 species (2011; Figure 29), and only 2010 had a species richness value that was below the Coonan (1987) reference condition. The number of sample points increased from 20 to 30 in 2011, and remained at 30 points for the 2012 survey. This difference in sample size may explain why the 2010 value was lower than subsequent years. The 3-year average for breeding species richness was 45.7, which is above the reference condition for this measure.

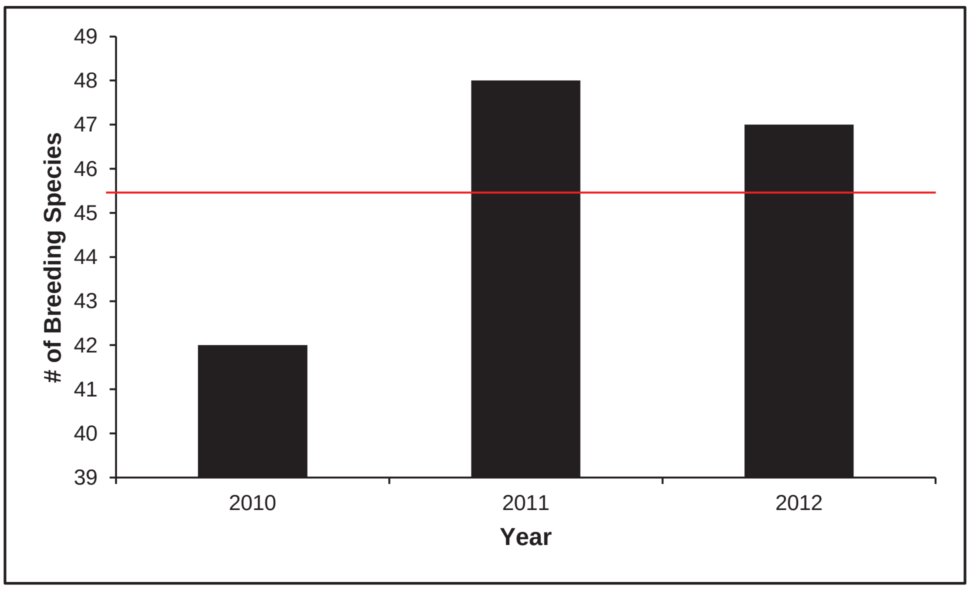

Figure 29. Breeding species richness values from 2010-2012 in SAAN. The red line indicates the 3-year species richness average value for SAAN (45.7).

<u>Relative Abundance</u>

Coonan (1987)

Coonan (1987) estimated relative abundance (A) for each species using the following formula:

$$A = \left(\frac{n}{L}\right)\left(\frac{1}{1{,}000\text{m of transect}}\right)$$

n = total number of birds of one species recorded for one season and area
L = total length of transects in that season and area.

Relative abundance was estimated for each sampling transect (i.e., San Juan Woods and Espada Labores) during each of the five sampling seasons. Relative abundance estimates for all breeding species are presented in Appendix G, and the most abundant species for each season in both sampling sites are represented in Table 28 and Table 29.

Table 28. Breeding species with the highest relative abundance values (# of birds/1000 m of transect) observed during each season for the San Juan Woods land tract in SAAN, 1985-86. Species are arranged alphabetically, and not by overall abundance (Table modified from Coonan 1987).

Species	Fall	Winter	Spring	Early Summer	Late Summer
Carolina chickadee			4.4	9.6	5.9
Carolina wren	11.8		8.8	14	16.9
chimney swift	7.4				
European starling				4.4	
golden-fronted woodpecker		6.6	7.4	9.6	8.8
great-tailed grackle	5.2	6.6	4.4	7.4	4.4
lark sparrow	3.7				
mourning dove	7.4	10.3			
northern mockingbird	3.7			5.2	
black-crested titmouse	5.9	10.3	9.6	5.2	5.9
western kingbird					2.9
white-eyed vireo			2.9	2.9	2.9
yellow-billed cuckoo				5.2	3.7

Table 29. Breeding species with the highest relative abundance values (# of birds/1000 m of transect) observed during each season for the Espada Labores land tract in SAAN, 1985-86. Species are arranged alphabetically, and not by overall abundance (Table modified from Coonan 1987).

Species	Fall	Winter	Spring	Early Summer	Late Summer
brown-headed cowbird			5.2	10.4	5.2
Carolina chickadee				3	
Carolina wren	4			4.2	7.6
chimney swift				5	14.7
European starling	11.7		3		

Table 29 (continued). Breeding species with the highest relative abundance values (# of birds/1000 m of transect) observed during each season for the Espada Labores land tract in SAAN, 1985-86. Species are arranged alphabetically, and not by overall abundance (Table modified from Coonan 1987).

Species	Fall	Winter	Spring	Early Summer	Late Summer
golden-fronted woodpecker		3.2	3.4	4.6	4.6
great-tailed grackle	7.2	3.8	5.0	21.1	5.2
house finch			3.4	3.2	
lark sparrow	6.0				
lesser goldfinch	5.0				
loggerhead shrike					2.4
mourning dove	13.5	7.8	11.0	9.0	12.9
northern mockingbird	7.8	6.2	3.6	3.8	2.6
painted bunting				3.0	
red-winged blackbird	9.2				
scissor-tailed flycatcher	6.0				
black-crested titmouse			2.0	5.8	
white-winged dove					5.0

Scully (2006)

Scully (2006) recorded relative abundance as the number of times a species was detected (i.e., observations) (Appendix H); data were collected during bimonthly surveys from 2004 -2006. In addition, Scully (2006) recorded the percentage of a species' detections that were a result of auditory cues only (Table 30). Scully (2006) only reports the number of individuals observed for the 25 most commonly observed species (22 of which were breeding species; Table 30).

Table 30. Relative abundance for the 22 most commonly observed breeding bird species during Scully (2006). Detections indicate each time a bird was observed at a point count, while # of individuals represent the actual number of birds that were counted (table modified from Scully 2006).

Species	# of times detected	% detections by sound alone	# of individuals detected
Carolina wren	356	96	359
great-tailed grackle	302	31	1476
northern mockingbird	227	71	255
white-eyed vireo	205	97	205
white-winged dove	193	16	737

Table 30 (continued). Relative abundance for the 22 most commonly observed breeding bird species during Scully (2006). Detections indicate each time a bird was observed at a point count, while # of individuals represent the actual number of birds that were counted (table modified from Scully 2006).

Species	# of times detected	% detections by sound alone	# of individuals detected
American crow	187	76	315
black-crested titmouse	123	91	133
golden-fronted woodpecker	122	82	127
mourning dove	100	32	163
red-shouldered hawk	94	74	108
European starling	85	13	407
blue jay	80	83	93
house sparrow	76	70	165
turkey vulture	74	1	335
scissor-tailed flycatcher	67	39	94
ladder-backed woodpecker	65	84	66
red-winged blackbird	60	26	1105
black vulture	54	0	192
barn swallow	52	4	90
rock pigeon	51	7	232
yellow-billed cuckoo	49	94	48
black-bellied whistling duck	48	21	274
Total	**2,670**		**6,979**

March and May were the months with the highest number of breeding bird detections (714 and 954 detections, respectively; Appendix H), while November had the lowest number of detections (313). The 2,670 breeding bird detections in Table 30 represent 56% of all bird detections during Scully (2006) (i.e., the 22 most common breeding birds were observed at 56% of all bird detections). When looking at the total number of all breeding bird detections (3,343; Appendix H), breeding birds were observed at 70% of all bird detections.

The great-tailed grackle (*Quiscalus mexicanus*; Photo 11) and the red-winged blackbird (*Agelaius phoeniceus*) were the most numerous species observed, with 1,476 and 1,105 individuals observed, respectively (Table 30). The number of individual breeding birds in Table 30 represents 54% of all individuals observed during the Scully (2004) inventory.

Twedt (2013)

Twedt (2013) surveyed both the breeding and wintering bird populations of SAAN, and reported abundance as the number of individuals observed per year for each breeding species. For this metric, only species counted during the breeding season (May-June) are summarized.

Photo 12. Great-tailed grackle, which was among the most commonly observed species during Scully (2006) (NPS Photo).

In 2010, there were 20 count locations sampled; 301 individual breeding birds were identified (Figure 30, Appendix I), which accounted for 77% of all individuals observed during the survey. In 2011, 30 count locations were sampled and 556 individual breeding birds were observed (Figure 30). This estimate accounted for 79% of all individuals observed during the survey. In 2012, 508 individual breeding birds, accounting for 78% of all individual observations, were observed at 30 count locations in SAAN (Figure 30, Appendix I). The 3-year average for breeding species abundance was 455 individuals/year (Figure 30). Appendix I displays the relative abundance for each species observed from 2010-2012, but does not include observations where detection distance of a species could not be recorded (i.e., bird flyovers).

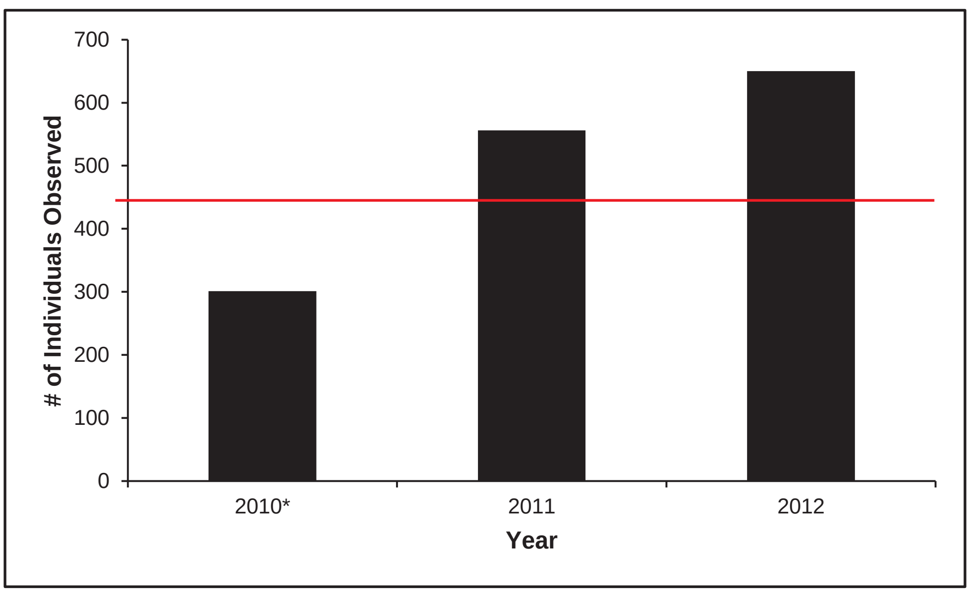

Figure 30. Number of breeding individuals observed during the Twedt (2013) surveys of SAAN from 2010-2012. The red line on the figure represents the average number of individuals observed (455), and * indicates a survey year where only 20 sample points were used (other years had 30).

Distribution

Coonan (1987)

Coonan (1987) compares species richness, density, and diversity between two sampling zones in SAAN. The data summarized by Coonan (1987) are not specific to breeding species. Due to this, several of the summary statistics discussed in this measure (i.e., diversity, density) will include species not classified as breeding species (per the procedure outlined in Section 4.6.4 above). Whenever possible, preference was given to sampling periods that took place during the breeding season, as this sampling period would be most representative of the breeding species present in the park. Regardless, care should be taken when interpreting these data, as they may not be truly representative of trends observed only in the breeding species of the park.

The San Juan Woods sampling tract comprised about 10.1 ha (25 ac) and was mainly riparian forest and huisache woodlands. The vegetation in this land tract was considered to be fairly representative of what the forest stands along the San Antonio River would have been prior to channelization (Coonan 1987). Sixty-five species (27 of which were breeding; Table 26) were observed in the San Juan Woods during survey efforts, and density estimates were highest in this habitat type during every season (Table 31); fall and winter densities were higher compared to other seasons (Table 31). Conversely, species diversity values in the San Juan Woods were lower than the Espada Labores in all seasons except for the fall (Table 32).

Table 31. Seasonal bird densities (birds/ha) for the San Juan Woods and Espada Labores land tracts at SAAN, 1985-86 [1, 2] (Table reproduced from Coonan 1987).

Season	San Juan Woods Average ± SD	Espada Labores Average ± SD
Fall	25.81 ± 5.22 [A]	21.10 ± 1.45 [CD]
Winter	28.29 ± 2.74 [A]	21.36 ± 4.59 [C]
Spring	21.38 ± 1.37 [AB]	15.58 ± 2.45 [D]
Early Summer	17.40 ± 4.80 [B]	15.59 ± 3.05 [D]
Late Summer	16.82 ± 0.49 [B]	14.10 ± 2.06 [D]

[1] n = 4 surveys per area/season

[2] Two factor ANOVA determined that both season and area affect bird density ($F = 13.69$, $p < 0.0005$; $F = 18.86$, $p < 0.0005$)

[A] Density means with the same superscript are equivalent, according to Newman-Keuls multiple range test

The Espada Labores land tract was about 48.6 ha (120 ac) and contained all of the identified habitat types from Van Auken (1981) except for marshlands and parklands (present in the land tract were: riparian, grassland, huisache woodlands, and acequia woodlands). However, the majority of the habitat in this area was huisache woodlands and grasslands (Coonan 1987). Eighty-seven species (41 of which were breeding; Table 26) were observed in the Espada Labores during survey efforts, and density estimates were consistently lower than what was observed in the San Juan Woods tract

(Table 31). Species diversity values were marginally higher in the Espada Labores tract, with the exception of the fall season (Table 32).

Table 32. Seasonal bird species diversities (Shannon-Wiener Diversity Index, H') for the San Juan Woods and Espada Labores land tracts at SAAN, 1985-86 [1 2] (Table reproduced from Coonan 1987).

Season	San Juan Woods Average ± SD	Espada Labores Average ± SD
Fall	0.957 ± 0.132 [AB]	0.944 ± 0.127 [D]
Winter	1.089 ± 0.064 [A]	1.197 ± 0.063 [C]
Spring	0.934 ± 0.1 [B]	1.209 ± 0.02 [C]
Early Summer	0.868 ± 0.015 [B]	1.19 ± 0.02 [C]
Late Summer	0.978 ± 0.089 [AB]	1.177 ± 0.059 [C]

[1] n = 4 surveys per area/season

[2] Two factor ANOVA determined that both season and area affect bird species diversity (F = 6.30, p < 0.001; F = 49.73, p < 0.0005)

[A] Density means with the same superscript are equivalent, according to Newman-Keuls multiple range test

Photo 13. Northern mockingbird, which was among the most abundant ground-dwelling insectivores observed in the Espada Labores land tract during Coonan (1987) (NPS Photo).

Coonan (1987) offers several hypotheses as to why the trends in the observed data may appear as they do. The Espada Labores land tract had nearly twice as many observed species than the San Juan land tract, and Coonan (1987) suggests that this may be because of the larger area and number of habitats that are found in the Espada Labores tract. Additionally, three transects were set up in the Espada Labores land tract, whereas only one transect was set up in the San Juan Woods. These differences and sampling biases may have contributed to some of the differences in distribution data between the two sites.

In terms of the distribution of various foraging guilds, Coonan (1987) observed higher numbers of insectivores in the San Juan Woods (28% more in the fall, and 81% more in the spring), and both areas had peak numbers of insectivores during the winter months when there is an influx of migratory and overwintering species. For each season, there were twice as many (or more) foliage insectivores observed in the San Juan Woods compared to the Espada Labores. The stands of mature forests and dead snags in the San Juan Woods likely attract and provide more habitat for insects, which in turn supports more insectivore species. The only group of insectivores that were more abundant in the Espada Labores tract were the ground-dwelling insectivores (e.g., great-tailed grackle, northern mockingbird, and European starling [*Sturnus vulgaris*]).

Granivores (seed-eating species) were more abundant in the Espada Labores tract, and were nearly 16 times more abundant in this tract in the late summer when compared to the San Juan Woods (Coonan 1987). These species were most commonly observed during the fall and winter when seed crops were at peak availability.

Scully (2006)
Scully (2006) had a primary objective of documenting 90% of the bird species that occurred in SAAN. Because of the emphasis on species identification, the number of individuals observed at each survey site was not reported. Two major study units (SAAN properties within the City of San Antonio, and the Rancho de las Cabras property) were surveyed using point counts from January 2004-May 2006. The surveys in the City of San Antonio resulted in 61 breeding species being observed, 57 of which were observed at a point count location (Appendix H). The Rancho de las Cabras property had 52 breeding species observed, 49 of which were observed at a point count location.

Twedt (2013)
Although population estimates, density estimates, and detection probabilities were calculated, Twedt (2013) did not document the distribution of breeding bird species in SAAN.

Threats and Stressor Factors
One of the major threats facing land bird populations across all habitat types is habitat loss due to land cover change (Morrison 1986). Land cover change is not restricted to breeding habitat; many species depend on specific migratory and wintering habitat types that are also changing. The encroachment of non-native plant species may be a contributor to land cover change in all habitats. Altered habitats can also compromise the reproductive success or wintering survival rates of species adapted to that habitat. They can also allow generalist, non-native avian species, such as the European starling or house sparrow (*Passer domesticus*), to move in and out-compete native bird species. Breeding species often require a specific vegetative community (e.g., dense stands of shrubs, riparian vegetation) for successful nesting to occur. A loss or alteration of these vegetative structures, or competition for resources from non-native species could compromise the nesting success of these native species in SAAN.

Avian brood parasite species (e.g., brown-headed cowbird [*Molothrus ater*]) represent a threat to several avian species in SAAN. Brood parasites are species that lay their eggs in the nests of other breeding species, which then in turn incubate and care for the young (Photo 14; Payne 1977). Brood parasitism generally reduces the reproductive success of the host species, as host species typically fledge fewer young compared to other non-parasitized parents of the same species (Payne 1977).

Photo 14. Brown-headed cowbird egg (mottled color), that has been laid in a chipping sparrow (*Spizella passerina*) nest (NPS Photo).

Brown-headed cowbirds are a native species in SAAN, and can directly contribute to the reduced nesting success of host species, as they will often puncture or remove host species eggs (Friedmann 1963). Brown-headed cowbirds often hatch earlier than host species eggs, and grow larger and faster than the host species, which often results in the death of the host chicks due to starvation, neglect, overcrowding, or direct mortality by trampling or removal from the nest (Friedmann 1963, Payne 1977). Many breeding species are targeted by brood parasites, although warblers, blackbirds, and vireos are among the most commonly parasitized species. While a natural phenomenon, brood parasitism can be actively managed against; instances of cowbird egg removal from host nests has resulted in increases in reproductive success in various parts of the species' home range (Mayfield 1960, Walkinshaw 1972, Payne 1977).

Non-native animal species also represent a threat to the bird population in the park. Domestic cats are one of the largest causes of bird mortality in the United States. According to Loss et al. (2012), annual bird mortality caused by outdoor cats is estimated to be between 1.4 and 3.7 billion individuals. The median number of birds killed by cats was estimated at 2.4 billion individuals, and almost 69% of bird mortality due to cat predation was caused by un-owned cats (i.e., strays, barn cats, and completely feral cats) (Loss et al. 2012). The urban setting of SAAN likely increases the risk for cat predation, as stray and house cats from nearby San Antonio may enter the park.

Feral hogs, a non-native species, may be a direct and indirect threat to the bird population in SAAN; they have been well documented on the Rancho unit of the park. Feral hogs have been known to negatively affect native wildlife through habitat loss and depredation. Feral hogs cause habitat loss by foraging on native vegetation (Jolley et al. 2010). Feral hog rooting and wallowing can disturb large patches of vegetation, destabilizing wetland areas and potentially exposing them to non-native plant invasion (Taylor 2003). Additionally, feral hog disturbance can disrupt the nesting of ground nesting species. Feral hogs frequently prey upon northern bobwhite (*Colinus virginianus*) and wild turkey (*Meleagris gallopavo*) eggs (Timmons et al. 2011), both of which are confirmed species in the park (NPS 2014). It appears that the Rancho unit may serve as a refuge area for local feral hogs, and there is an increased potential for hog impact on birds in that unit (Woodman, written communication, 19 December 2014).

As urban areas continue to develop and grow, modern alterations to the landscape often foster competition between native and non-native bird species. Human-made structures may fragment and reduce the continuity of a landscape, and often as these changes occur, non-native bird species are able to inhabit the areas. Marzluff (2001, pp. 26-28) states that, "The most consistent effects of increasing settlement were increases in non-native species of birds, increases in birds that use buildings as nest sites (e.g., swallows and swifts), increases in nest predators and nest parasites (brown-headed cowbirds), and decreases in interior- and ground-nesting species." Non-native bird species are frequently observed at SAAN, and include species such as rock dove (*Columba livia*), Eurasian collared-dove (*Streptopelia decaocto*), European starling, and house sparrow.

Another threat to the park's birds are fire ants (*Solenopsis geminata*, *S. invicta*) that were accidentally brought to the U.S. on a shipping vessel from South America, and have since spread rapidly across the southeastern U.S. (Wetterer and Moore 2005). These ant species are well-known predators of bird hatchlings, and ground nesting bird species are particularly vulnerable. Fire ants can completely eliminate ground nesting birds, such as the northern bobwhite, from an area (Allen et al. 2004). Additionally, fire ants can outcompete predatory birds, such as the loggerhead shrike (*Lanius ludovicianus*), when foraging for invertebrate species.

Several studies have documented fire ants having detrimental effects on breeding bird species that may be observed in SAAN: Kopachena et al. (2000) documented 25% mortality in barn swallows (*Hirundo rustica*) due to fire ants at a study site in Texas, Dickinson and Arnold (1996) observed fire ant predation on crested caracara chicks in south Texas, and Cely and Glover (2000) implicated fire ants as a major cause for the decline in common ground doves (*Columbina passerina*) in South Carolina.

Data Needs/Gaps

Continued monitoring of the breeding bird community, particularly the work of Twedt (2013), is necessary for park managers to establish baseline values for the identified measures in this component. An expansion of current survey methods to document the distribution of various breeding species would be helpful to identify priority habitats in the park. Continuation of these surveys will also allow for trend analysis after 5-10 years of data collection.

The migratory bird population of the park represents a significant data gap in SAAN, and monitoring efforts geared specifically for this group of birds are needed. Survey efforts concentrated on the peak spring and fall migratory periods would help managers better understand what species pass through the park, and if any migratory species spend extended periods of time in the park.

While not an identified measure in this assessment, monitoring of the trends in breeding species of conservation concern is needed. As climate change, habitat fragmentation, and energy development efforts threaten bird communities, it will be important to identify potential trends in these indicator species.

Overall Condition

Species Richness

The species richness measure was assigned a *Significance Level* of 3 during project scoping. NPS (2014) has identified 71 breeding species in the park. The number of species observed during the various surveys that have been completed in the park since 1985 has ranged from 44 (Coonan 1987) to 68 (Scully 2006). The most recent surveys completed by Twedt (2013) spanned 2010-2012, and the average number of species per year was 45.7. The 2010 survey by Twedt (2013) was the only survey in the park that had a value below Coonan (1987).

When investigating the biodiversity or health of an ecosystem using species richness, it is important to understand that changes in the ratio of native to non-native species may not be well represented (Lepczyk et al. 2008). While it does not appear to be an issue at this time (only four of the 72 breeding species identified in NPS [2014] are non-native), this ratio is important to keep in mind for future assessments of condition.

Recent estimates of species richness do not indicate any cause for concern for park managers, although continued monitoring is advised to determine any long-term trends or variations in this measure. The *Condition Level* for the species richness measure was assigned as a 0, indicating it is currently of no concern to park managers.

Relative Abundance
Relative abundance of breeding bird species was assigned a *Significance Level* of 3 by NPS staff during project scoping. While documented by multiple reports, each report used a different definition of relative abundance; Coonan (1987) estimated this measure as the number of birds per 1,000 m (3,281 ft) of transect, Scully (2006) reported it as the number of times a species was detected, and Twedt (2013) reported it as the number of individuals observed per year.

There do not appear to be any major concerns related to the relative abundance of breeding species in the park, and the measure was assigned a *Condition Level* of 1. While variations are evident in the data, this is not unusual as annual fluctuations in breeding species abundance are to be expected. Species arrival dates, survey dates/duration, and variation in breeding initiation may all contribute to the annual variation in abundance. Additionally, variation observed in abundance in Twedt (2013) is likely due to sample size variations; 2010 surveys were completed at 20 count locations, while 2011 and 2012 had 30 count locations.

Distribution
The *Significance Level* for distribution was determined to be 3 by NPS staff. As an urban park, the remaining stands of undisturbed habitat along the San Antonio River and the native shrub and grasslands likely serve as breeding sanctuaries for many species in the park. Only two surveys have documented the distribution of breeding species (Coonan 1987, and to a lesser extent Scully 2006). Limited data have been provided for this measure, and future monitoring of the distribution of breeding species in the park is needed. There are likely only a few habitat types in the park that can support breeding species, and a more complete understanding of how the breeding bird species of SAAN utilize these habitats would be of great importance for managers. Because of the data gaps that exist for this measure, and the lack of any recent distribution data, a *Condition Level* was not assigned to this measure.

Weighted Condition Score (WCS)
A *Weighted Condition Score* of 0.17 was calculated for the breeding bird component. A trend arrow was not assigned to this component, as data related to distribution are lacking in recent years, and it is difficult to determine if apparent trends in richness and abundance from 2010-2012 are due to varying sample size, or actual trends in the breeding population.

Breeding Birds			
Measures	Significance Level	Condition Level	WCS = 0.17
Species Richness	3	0	
Relative Abundance	3	1	
Distribution	3	n/a	

4.6.6 Sources of Expertise

Dan Twedt, USGS Research Wildlife Biologist, Patuxent Wildlife Research Center

Greg Mitchell, SAAN Natural Resources Program Manager

4.6.7 Literature Cited

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4.7 Resident Birds

4.7.1 Description

Resident bird species are birds that remain in one area throughout the year and do not migrate (Mettke-Hofmann et al. 2009). Unlike migratory birds, trends in resident bird species' populations are likely due to changes occurring in their immediate habitat or ecosystem, and (in theory) it is possible to study all of their population processes directly throughout the year (Koskimies 1989). This particular assemblage of birds serves as a valuable ecological indicator for the park, as they are year-round residents and their health and abundance are dependent upon many ecosystems found in and around SAAN ecosystems.

Photo 15. Eastern meadowlark, a common resident species in SAAN (NPS Photo).

The small area of SAAN incorporates many neighboring ecosystems, and the resident bird species of the park and their associated ecosystems are likely more extensive than the park's boundaries. Changes in resident bird populations are likely to reflect changes that are occurring outside of SAAN, perhaps moreso than changes that are occurring within the park.

Excluding breeding bird species (which are discussed in Chapter 4.6), NPS (2014) identifies 91 resident bird species in the park; these include waterfowl, raptors, and passerine species. Several of the resident species in the park, such as the gadwall (*Anas strepera*) and the black-necked stilt (*Himantopus mexicanus*), are dependent upon the river/shoreline habitat along the San Antonio River, while other species, such as the eastern meadowlark (*Sturnella magna*; Photo 15) and the Swainson's hawk (*Buteo swainsoni*), rely on the grassland and shrub habitats in and around SAAN. Monitoring of the resident bird populations in SAAN may help managers to protect the vital bird habitats present in the park.

4.7.2 Measures

- Species richness
- Relative abundance
- Distribution

4.7.3 Reference Conditions/Values

Few avian surveys or inventories have taken place in SAAN, and the establishment of a reference condition is problematic for this component. Most studies that have taken place in the park have used differing methodologies, timing, and sampling locations, which makes comparisons between studies difficult.

Coonan (1987) represents the earliest inventory in the park, and will serve as the reference condition when data sources are comparable. Coonan (1987) reports species richness for the San Juan Woods and Espada Labores, but also includes the total number of species observed during the study. For the species richness measure in this assessment, only the total number of species observed during Coonan (1987) will be used as the reference condition. This will help to eliminate some problems and biases that exist when comparing species richness values from different sampling sites. The relative abundance and distribution measures are difficult to establish a reference condition for, as the data from the three major studies that have taken place in the park are not easily compared. The three studies that have taken place in the park have occurred in mostly different locations, and have reported relative abundance uniquely. For the purpose of this assessment, a reference condition will not be established for these measures.

4.7.4 Data and Methods

This component focuses exclusively on the resident bird species of the park, and does not discuss any migratory or vagrant bird species. A species was classified as a resident based on the NPS Certified Bird Species List (NPS 2014, Appendix J). Species in NPS (2014) that had residency designations of “Resident” were included in this component’s discussion and analysis. Species that were identified as “Breeding” are discussed in Chapter 4.6 of this document. In instances where NPS (2014) did not assign residency, the Cornell University Lab of Ornithology’s All About Birds online database (http://www.allaboutbirds.org) was used to approximate a species’ residency as either breeding, migratory, resident, or vagrant. Migratory bird species represent a data gap in SAAN, and are not discussed separately in this NRCA.

Coonan (1987) inventoried the avian population of SAAN from 1985-1986. Surveys took place four times a year in the San Juan Woods and Espada Labores land tracts. One survey transect was set up in the San Juan Woods, while three transects were set up at the Espada Labores site. Surveyors observed and recorded the number of individuals, species, and distance from observer from sunrise until about 3 hours post-sunrise. The survey results were grouped based on season: fall (October-November 1985), winter (December-February 1985-86), spring (March-May 1986), early summer (June-July 1986), and late summer (August-September 1986). SMUMN GSS made one modification to the data presented in Coonan (1987). Records for the green-backed heron were changed to green heron (*Butorides virescens*) to reflect the correct taxonomy for that species.

From 2003-2005, Scully (2006) attempted to document at least 90% of the bird species believed to occur in SAAN. Two major study units were created during these surveys: The City of San Antonio Unit (buildings and grounds associated with Missions San Jose, San Juan, Espada, and Concepcion), and the Rancho de las Cabras property (40 ha [99 ac] property in Wilson County). Within each study unit, a series of 25 survey points were established. Eighteen survey points were located in the San Antonio unit, and seven points were in the Rancho de las Cabras unit; no point was within 250 m (820 ft) of another point (Scully 2006). Surveys began 30 minutes before sunrise and continued up until 4 hours post-sunrise. All species observed, whether visually or aurally, during 5 minute surveys were recorded. In addition, Scully (2006) documented distance from observer, sex, and age class of birds when possible.

As part of a GULN monitoring initiative, Twedt (2013) monitored the wintering and breeding bird populations of SAAN from 2010-2013. Twedt (2013) surveyed during the breeding season in SAAN from May-June 2010-2012. Forty point count locations were established in the park (utilizing habitat in both the Missions and Rancho de las Cabras Units), and each point was surveyed for 10 minutes. Timing of bird observation (i.e., what minute of the point count the bird was observed), species, number of individuals, and detection distance were recorded during each survey. Complete, detailed methodologies for this study are provided in Twedt (2013).

4.7.5 Current Condition and Trend

Species Richness

The species richness measure allows simultaneous assessment of abundance or presence for the entire breeding bird community. This measure can also indicate overall habitat suitability for breeding birds, and is vital to understand the effects of changing landscapes on native biodiversity.

NPS Certified Species List (NPS 2014)

The NPS Certified Bird Species List contains 229 species, 91 (40%) of which are resident bird species (Appendix J). This list, however, does not allow for a specific analysis of species richness, as no data are collected other than the presence (or historic presence) of the identified species.

Coonan (1987)

From 1985-1986, Coonan (1987) documented 101 bird species, 40 of which were resident species (Appendix J). Coonan (1987) also investigated the distribution of species in the park (discussed in the distribution measure below), and surveyed the San Juan Woods and Espada Labores land tracts four times each season (fall, winter, spring, early summer, and late summer). Table 33 displays the species richness values observed in each season for both sampled habitat types.

Table 33. Species richness values for resident species sorted by habitat type and by season observed during Coonan (1987).

Season	San Juan Woods	Espada Labores
Fall	13	20
Winter	21	24
Spring	10	18
Early Summer	3	5
Late Summer	5	9
Total Sp.	**26**	**34**
Grand Total	**40**	

Scully (2006)

From 2004-2006, Scully (2006) inventoried the bird population of SAAN and sampled park units within the City of San Antonio and the Rancho de las Cabras units. Scully (2006) documented 197 bird species in total, 81 of which were resident species (41%; Appendix J); the species richness value obtained by Scully (2006) exceeded the Coonan (1987) reference condition by 41 species (Table 33, Table 34). The species richness total reported in Scully (2006) includes species detected outside of the specified sampling points. When species detected outside of count locations (i.e., incidental observations) were excluded, the species richness for SAAN was 146 species, 61 of which were resident species (42%, Table 34). This value still exceeded the reference condition value of 40 species obtained by Coonan (1987).

Table 34. Species richness values reported by Scully (2006) for both the units of the park within the City of San Antonio and the Rancho de las Cabras units of SAAN (2004-2006). Numbers in parentheses in the table header indicate the number of sample points within each study site.

	City of San Antonio (18)	**Rancho de las Cabras (7)**
Species Observed Total	74	43
Species Observed at Points	56	32
Grand Total (sp. observed at sample points)	**81 (61)**	

Twedt (2013)

Twedt surveyed the bird population of SAAN from 2010-2013, and timed surveys to coincide with the overwintering period and the breeding season. When the breeding and winter survey results were combined, 56 resident bird species were observed in the park (Appendix J), which is above the Coonan (1987) reference condition of 40 species (Table 33). Species richness results from the winter surveys were pooled across all years, and were not reported yearly (as was done for breeding surveys). From 2010-2013, 48 resident bird species were observed during winter surveys (Appendix K); 35 of these resident bird species were observed within a 50 m (164 ft) radius from the point count location. The winter survey species richness estimate (48) exceeded the reference condition of 40 species obtained by Coonan (1987).

The Twedt (2013) surveys that took place during the breeding season (May-June) resulted in the observation of 18 resident species (Appendix L); eight of the species observed during the breeding survey were not observed during winter surveys. Species richness values were reported yearly during the breeding surveys and ranged from eight species (2010) to 13 species (2011; Figure 31); the 3-year average for resident species richness was 10.3 (Figure 31). The number of sample points increased from 20 to 30 in 2011, and remained at 30 points for the 2012 survey. All survey years were below the Coonan (1987) reference condition for species richness.

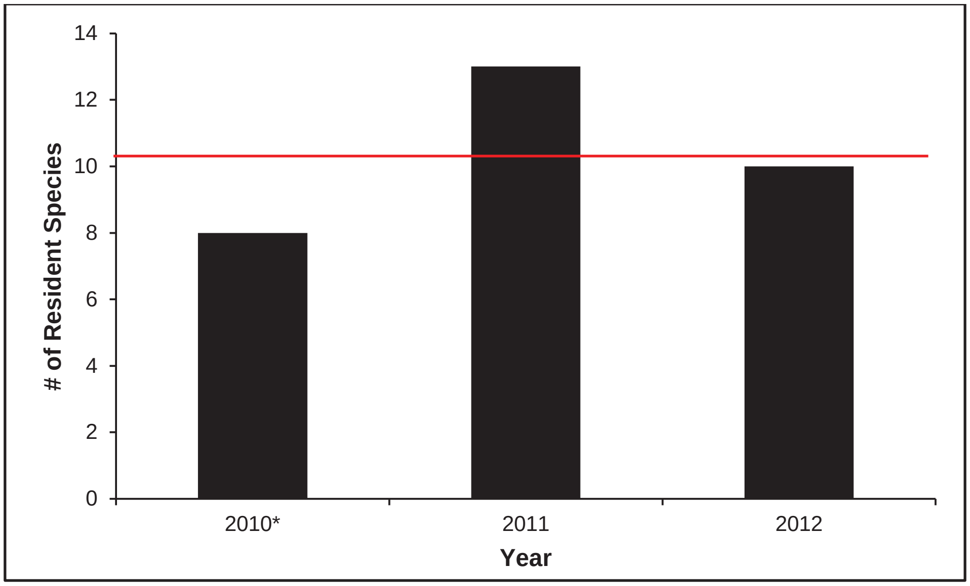

Figure 31. Resident species richness values from 2010-2012 in SAAN (Twedt 2013). The red line indicates the 3-year average for species richness in SAAN (10.3).

Relative Abundance

Coonan (1987)

Coonan (1987) estimated relative abundance (A) for each species using the following formula:

$$A = \left(\frac{n}{L}\right)\left(\frac{1}{1{,}000\text{m of transect}}\right)$$

$$n = \text{total number of birds of one species recorded for one season and area}$$
$$L = \text{total length of transects in that season and area.}$$

Relative abundance was estimated for each sampling transect (i.e., San Juan Woods and Espada Labores) during each of the five sampling seasons. Relative abundance estimates for all resident species are presented in Appendix M, and the most abundant species for each season in both sampling sites are represented in Table 35 and Table **36**.

Table 35. The most abundant resident bird species in each season for the San Juan Woods land tract in SAAN, 1985-1986 (Coonan 1987). Values are reported as number of birds per 1,000m of transect, and are arranged alphabetically.

Species	Fall	Winter	Spring	Early Summer	Late Summer
American robin		24.3			
blue-gray gnatcatcher			4.4		2.9
cedar waxwing		16.2	8.1		
eastern phoebe	3.7				

Table 35 (continued). The most abundant resident bird species in each season for the San Juan Woods land tract in SAAN, 1985-1986 (Coonan 1987). Values are reported as number of birds per 1,000m of transect, and are arranged alphabetically.

Species	Fall	Winter	Spring	Early Summer	Late Summer
golden-crowned kinglet		6.6			
Lincoln's sparrow			2.9		
northern cardinal	19.9	16.2	44.9	38.2	33.8
ruby-crowned kinglet	5.2	8.8			
yellow-rumped warbler	13.2	28.7	2.9		

Table 36. The most abundant resident bird species in each season for the Espada Labores land tract in SAAN, 1985-1986 (Coonan 1987). Values are reported as number of birds per 1,000 m of transect, and are arranged alphabetically.

Species	Fall	Winter	Spring	Early Summer	Late Summer
American goldfinch		7.2			
American robin	7.4	12.5			
cedar waxwing		12.9	6.8		
eastern bluebird		4.4			
eastern meadowlark	4.0				
field sparrow				2.4	
northern cardinal	10.7	15.7	21.5	21.1	16.9
northern oriole					4.8
ruby-crowned kinglet		3.6			
vesper sparrow		17.1			
western sandpiper					5.2
yellow-rumped warbler		6.2			

Scully (2006)

Scully (2006) recorded relative abundance as the number of times a species was detected during surveys (i.e., the number of times a species was observed; Appendix E). Data were collected during bimonthly surveys from 2004-2006, and observers recorded the number of detections for each species (1,368 total detections; Appendix N), number of individuals detected, and the percentage of a species' detections that were the result of auditory cues only. However, the number of individuals observed and the percentage of detections that were due to sound were only summarized for the 25 most commonly observed species during the study, and most of these species (22 of 25) were breeding species; the breeding species data are summarized in Chapter 4.6 of this report.

March and January were the months with the highest number of resident bird detections, with 321 and 308 detections, respectively (Appendix N). September had the lowest number of resident bird detections, with only 98 detections recorded. The 1,368 resident bird detections represent 29% of all bird detections during Scully (2006). The northern cardinal (*Cardinalis cardinalis*; Photo 16) was the most abundant species during each month of the survey, and was detected 674 times. Northern cardinal detections made up 49% of all resident species detections and 14% of all species detections (resident, migratory, and breeding). Other commonly detected species included the great egret (*Ardea alba*; 90 detections), ruby-crowned kinglet (*Regulus calendula*; 61 detections), snowy egret (*Egretta thula*; 48 detections), and the American goldfinch (*Carduelis tristis*; 44 detections) (Appendix N).

Photo 16. A northern cardinal, one of the most commonly observed resident species in SAAN (NPS Photo).

Twedt (2013)

Twedt (2013) surveyed the avifauna of SAAN during both the winter and breeding seasons from 2010-2013, and reported abundance as the number of individuals observed per year for each resident species. Each winter, Twedt (2013) selected 30 count locations at random, and area searches at each location lasted 20 minutes. From 2010-2013, a total of 90 area searches at 40 locations in the park were completed. In total, 1,932 resident bird individuals were observed during winter surveys in SAAN from 2010-2013 (Appendix K). When the results were adjusted to include only resident species that were observed within a 50 m (164 ft) radius of the point count location (i.e., excluding flyovers and distant observations), 952 individuals were observed. The most abundant resident species observed during the 2010-2013 winter surveys (including all observations) were the American goldfinch (283 individuals), northern cardinal (261 individuals), and the yellow-rumped warbler (*Setophaga coronata*; 226 individuals) (Appendix K).

Breeding season surveys occurred in May and June of 2010-2012. The same 40 locations as the winter surveys were randomly selected as point count locations for these surveys; 20 point counts were used in 2010, while 30 point counts were used in 2011 and 2012. Surveys lasted only 10 minutes during the breeding season, compared to the 20 minute area searches used during the winter. Total abundance values for resident birds during the breeding season varied by year, and ranged from 88 individuals (2010) to 136 individuals (2011; Figure 32). The 3-year average for resident species abundance was 117.7 individuals (Figure 32). The most abundant resident bird species during the breeding surveys was the northern cardinal, with several other species being observed in comparably low numbers throughout the duration of the survey (Table 37).

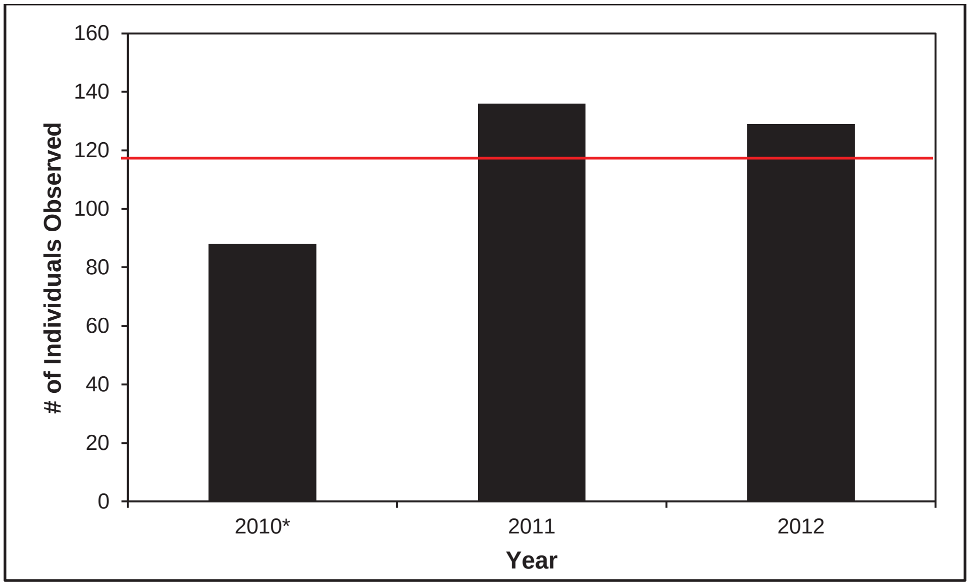

Figure 32. Number of resident individuals observed during the Twedt (2013) breeding surveys of SAAN from 2010-2012. The red line on the figure represents the average number of individuals observed (117.7), and * indicates a survey year where only 20 sample points were used (other years had 30 sample points).

Table 37. Resident bird species and number detected during 10-minute surveys of 40 randomly located point locations in SAAN during the breeding season (May-June) from 2010-2012. Birds for which no detection distance was recorded (i.e., flyovers) are not reported in this table. * indicated a species not observed during winter surveys by Twedt 2013 (Table modified from Twedt 2013).

Common Name	2010	2011	2012
black-crowned night-heron*		1	
blue-headed vireo			1
black-necked stilt*			1
cattle egret*		3	2
chipping sparrow		1	
eastern bluebird	1	2	
eastern phoebe	1		1
field sparrow*	2		
great egret	2	8	2
green heron*	1	1	
little blue heron		1	
monk parakeet*		1	
Neotropic cormorant	1	3	2

Table 37 (continued). Resident bird species and number detected during 10-minute surveys of 40 randomly located point locations in SAAN during the breeding season (May-June) from 2010-2012. Birds for which no detection distance was recorded (i.e., flyovers) are not reported in this table. * indicated a species not observed during winter surveys by Twedt 2013 (Table modified from Twedt 2013).

Common Name	2010	2011	2012
northern cardinal	79	109	115
snowy egret		3	2
spotted sandpiper		1	
Swainson's hawk*			1
yellow-crowned night-heron*	1	2	2
Individuals detected	**88**	**136**	**129**
Species detected	**8**	**13**	**10**

Distribution

Coonan (1987)

Coonan (1987) compared species richness, density, and diversity between two sampling zones in SAAN. However, the data summarized by Coonan (1987) (e.g., diversity, and density) were not specific to resident species, and it is not possible to isolate the resident species-specific data from the report. For a detailed summary of the distribution data for all bird species and groups please see Chapter 4.6 of this NRCA (Breeding Birds).

Scully (2006)

Scully (2006) had a primary objective of documenting 90% of the bird species that occurred in SAAN. Because of the emphasis on species identification, the number of individuals observed at each survey site was not reported. Two major study units (SAAN properties within the City of San Antonio, and the Rancho de las Cabras property) were surveyed using point counts from January 2004-May 2006. The surveys in the City of San Antonio resulted in 74 resident species being observed, 56 of which were observed at a point count location (Appendix N). The Rancho de las Cabras property had 43 breeding species observed, 32 of which were observed at a point count location.

Twedt (2013)

Although population estimates, density estimates, and detection probabilities were calculated for SAAN as a whole, Twedt (2013) did not document the distribution of resident bird species in SAAN.

Threats and Stressor Factors

Because resident bird species do not migrate, they are entirely dependent upon the SAAN ecosystem for their survival. As a result, stressors on the SAAN landscape become stressors to the resident bird population; a decline in the resident bird population is likely indicative of a much larger issue occurring within the park. The breeding bird chapter of this NRCA (Chapter 4.6) summarizes the stressors of the avifaunal community. Many, if not all, of the stressors summarized in that component are applicable to the resident bird community of SAAN.

Data Needs/Gaps

Continued monitoring of the resident bird community, particularly the work of Twedt (2013) during the winter, is necessary for park managers to establish baseline values for the identified measures in this component. An expansion of current survey methods to document the distribution of various resident species would be helpful to identify priority habitats in the park. Continuation of these surveys will also allow for trend analysis after 5-10 years of data collection.

While not an identified measure in this assessment, monitoring of the trends in resident species of conservation concern is needed. As climate change, habitat fragmentation, and energy development efforts threaten bird communities, it will be important to identify potential trends in these indicator species.

Overall Condition

Species Richness

The species richness measure was assigned a *Significance Level* of 3 during project scoping. NPS (2014) identifies 71 resident bird species as confirmed in the park, and the surveys that have occurred in the park have had species richness values ranging from 40 (Coonan 1987) to 68 (Scully 2006). The most recent surveys to take place in the park (Twedt 2013) identified 48 resident species during winter surveys, and 18 species during breeding season surveys. Twedt (2013) was hesitant to draw any assumptions about the trends in SAAN's bird population, as the data were collected over only 3 years, and patterns may not yet be evident. However, the breeding season surveys in the park were the only surveys to fall below the species richness reference condition from Coonan (1987) of 40 species. Through the various surveys in the park, it does not appear that the species richness in SAAN is of major concern, and a *Condition Level* of 1 was assigned to this measure.

Relative Abundance

Relative abundance of breeding bird species was assigned a *Significance Level* of 3 by NPS staff during project scoping. While documented by multiple reports, each report used a different definition of relative abundance; Coonan (1987) estimated this measure as the number of birds per 1,000 m of transect, Scully (2006) reported it as the number of times a species was detected, and Twedt (2013) reported it as the number of individuals observed per year.

There do not appear to be any major concerns related to the relative abundance of resident species in the park, and the measure was assigned a *Condition Level* of 1. While resident species abundance was lower than breeding species abundance, the annual variations were not extreme. Additionally, variation observed in abundance in Twedt (2013) was likely due to sample size variations; 2010 surveys were completed at 20 count locations, while 2011 and 2012 had 30 count locations. Winter months produced the highest relative abundance estimates in the park, and the most abundant resident species in all studies were consistent (northern cardinal, American goldfinch, and yellow-rumped warbler). Twedt (2013) was hesitant to draw any conclusions regarding trends or population estimates for the park, as the data collected for that study spanned only 3 years. As data collection continues, trend analysis and a more accurate estimate of the resident population size of SAAN may be possible.

Distribution
The *Significance Level* for distribution was determined to be 3 by NPS staff. As an urban park, the remaining stands of undisturbed habitat along the San Antonio River and the native shrub and grasslands likely serve as vital habitat for many species in the park. Only two surveys have documented the distribution of resident species in SAAN (Coonan 1987, and to a lesser extent Scully 2006). Limited data have been provided for this measure, and future monitoring of the distribution of resident species in the park is needed. A more complete understanding of how the resident bird species of SAAN utilize these habitats would be of great importance for managers. Because of the data gaps that exist for this measure, and the lack of any recent distribution data, a *Condition Level* was not assigned to this measure.

Weighted Condition Score (WCS)
A *Weighted Condition Score* of 0.33 was calculated for the resident bird component, indicating good condition. A trend was not assigned to this component, as data related to distribution are lacking in recent years, and it is difficult to determine if apparent trends in richness and abundance from 2010-2012 are due to varying sample size, or actual trends in the resident population.

Resident Birds			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Species Richness	3	1	
Relative Abundance	3	1	
Distribution	3	n/a	

4.7.6 Sources of Expertise

Dan Twedt, USGS Research Wildlife Biologist, Patuxent Wildlife Research Center

Greg Mitchell, SAAN Natural Resources Program Manager

4.7.7 Literature Cited

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4.8 Aquatic Macroinvertebrates

4.8.1 Description

Macroinvertebrates are often used as biological indicators in assessing overall aquatic ecosystem health: the absence of macroinvertebrates in an aquatic ecosystem may reflect disturbances, such as pollution, that can affect higher trophic levels (EPA 2012). Additionally, macroinvertebrates are an important food source for birds, fish, and other wildlife in SAAN (EPA 2012).

The Missions Units are located within the upper segment of the San Antonio River Basin, and the Rancho Unit is within the lower segment (Figure 33). The upper reach (segment 1911) of the San Antonio River has been heavily impacted by channelization, non-native plants, pollution, and drought. This is largely the result of urban sprawl of the city of San Antonio.

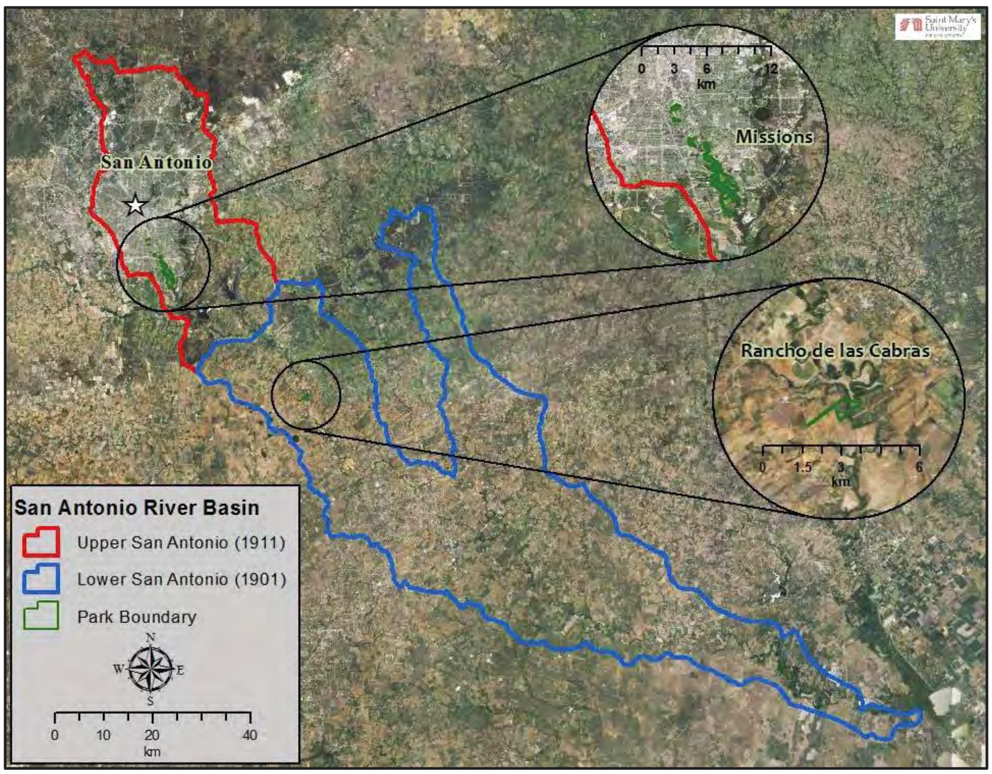

Figure 33. The location of SAAN units in the San Antonio River Basin.

Macroinvertebrate indicator species can range from sensitive species such as caddisflies (order Trichoptera) and Unionids (freshwater mussels of the family Unionidae, also known as naiads), to the much more tolerant midge (Diptera) and aquatic worm (Oligochaeta) species. Other benthic organisms that are categorized as aquatic macroinvertebrates include leeches (phylum Annelida), snails (class Gastropoda), flatworms (phylum Platyhelminthes), and various insects in their aquatic life stage (e.g. mayflies [order Ephemeroptera], dragon and damsel flies [order Odonata], and stoneflies [order Plecoptera]) (TCEQ 2007). In the upper San Antonio River segment, 15 families of benthic macroinvertebrates were identified, 11 of which are considered intolerant to degradation of the habitat (SARA 2007).

Freshwater invertebrates, or aquatic macroinvertebrates, are considered a Vital Sign by the GULN, but the network has no foreseeable plans to conduct invertebrate-specific monitoring in SAAN waterways (Segura et al. 2007). The monitoring of aquatic macroinvertebrates that has occurred in or near SAAN has been conducted by the San Antonio River Authority (SARA), the Texas Commission on Environmental Quality (TCEQ), and the Texas Clean Rivers Program (CRP) as part of a collaborative, long-term water quality monitoring effort (SARA 2013).

4.8.2 Measures

- Index of Biotic Integrity (IBI) Rating

4.8.3 Reference Conditions/Values

The reference condition for the park is based on the TCEQ (2007) metrics and scoring criteria for benthic macroinvertebrates. The scoring metrics include taxa richness, Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa abundance, biotic index (HBI), percent Chironomidae, percent dominant taxon, percent dominant functional feeding group (FFG), percent predators, ratio of intolerant : tolerant taxa, percent of total Trichoptera as Hydropsychidae, number of non-insect taxa, percent collector-gatherers, and percent of total number as Elmidae. These metrics are used to calculate IBI. An IBI is defined by TCEQ (2007, Appendix F, p. 3) as: "A composite index of the overall condition of a fish or benthic community based on the cumulative score of separate metrics." An aquatic life use point score (ALU) is determined by the IBI and has four categorical levels (Table 38). The TECQ (2007, Appendix F, p. 1) defines the ALU as:

> *A beneficial use designation (in state water quality standards) in which the water body provides suitable habitat for survival and reproduction of desirable fish, benthic macroinvertebrates, shellfish, and other aquatic organisms.*

For this assessment, the reference condition will be the high range or above (Table 38).

Table 38. Aquatic Life Use scores (ALU) are based on the points calculated with the metrics listed above to evaluate the benthic invertebrate sample to assess the condition of the aquatic habitat (TCEQ 2007).

ALU Category	IBI Ranges
Exceptional	>36
High	29-36
Intermediate	22-28
Limited	<22

IBIs have also been calculated for aquatic habitats using TCEQ (2007) methods. Characteristics considered by this method include instream channel characteristics (e.g., riffles, substrate type), stream morphology (e.g., width, depth, flow), and the riparian environment (vegetation, bank slope, etc.). These habitat evaluations are helpful in determining the potential for a stream to support aquatic life (TCEQ 2007). Habitat IBIs and ALU designations will be included in this assessment to supplement the limited macroinvertebrate IBI data. The habitat IBI ranges are different from those for macroinvertebrates, as shown in Table 39.

Table 39. The ALU and IBI values for aquatic habitat assessments (TCEQ 2007).

ALU Category	IBI Ranges
Exceptional	23-31
High	20-25
Intermediate	14-19
Limited	≤13

4.8.4 Data and Methods

SARA (2003) conducted collaborative water quality monitoring for the San Antonio River watershed which involved limited sampling of benthic macroinvertebrates and assessing aquatic habitat quality. Routine sampling involved collecting data on field and conventional parameters, nutrients, and bacteria; metals, nekton, benthic, and habitat assessments were collected annually. The bulk of data were collected by SARA, but TCEQ, U.S. Geological Survey (USGS), and the Guadalupe-Blanco River Authority (GBRA) were also partners in the effort; the CRP facilitated the collaboration of data entities (SARA 2003). The areas that pertain to SAAN park units are river segments 1911 and 1901, which are the upper and lower San Antonio River watersheds. Stations where sampling occurred included Mitchell St., Mission Road, and Loop 410 (Figure 34; SARA 2003). Data collection was conducted from January 1998 through December 2002 under the quality assurance project plan (QAPP). Trend analysis was derived from data collected, where applicable, from January 1993 through December 2002; it should be noted that data collected before 1996 had not been conducted under the QAPP, which was developed by the CRP (SARA 2003).

SARA (2008) sampled benthic macroinvertebrates in 2003 at Mission Road, and again in 2004 at Loop 410. Habitat assessments were also completed for each of these locations, as well as at the Mitchell St. location (Figure 34). Samples were also taken for two locations in 2012 (SARA 2012).

4.8.5 Current Condition and Trend

<u>IBI Rating</u>

The IBI is a measure that captures the aquatic biological community structure and is often an additional metric to standard water quality monitoring parameters (TCEQ 2007). This measure is assessed by sampling the area of interest to see which species of fish, invertebrates, or plants are most abundant. This can then indicate the conditions and detect impairment of the aquatic and riparian habitat. From the IBI score, an aquatic life use level (ALU) is determined (TCEQ 2007).

SARA (2003) calculated benthic macroinvertebrate and habitat IBIs for several locations within SAAN between 2000 and 2002 (Table 40). Benthic macroinvertebrates were sampled at two locations during the survey period while habitat was assessed at three sites (see Figure 35). While six out of seven habitat assessments resulted in *high* ALU designations, two out of three macroinvertebrate ALUs were in the *limited* range.

SARA (2005) conducted habitat assessments in 2004 at eight monitoring stations that are within or adjacent to SAAN (Table 41). Six of the seven locations received IBI scores in the *intermediate* range with only one location (Piedras Creek) scoring in the *high* range.

SARA (2008) presented benthic macroinvertebrates ALU designations for stations on the upper San Antonio River in 2003-2004. The only stations sampled within SAAN were Mission Road and Loop 410. While a high ratio of intolerant to tolerant taxa at the Mission Road location suggested favorable conditions for the macroinvertebrate community, low ratings for percent of predator, gatherer, and dominant taxa reflected an imbalance in the community structure; this was possibly due to a physiochemical imbalance and the overall degradation of the site location (SARA 2008). The Loop 410 site had an elevated number of tolerant taxa, indicative of disturbances in the physiochemical composition. A high percentage of Chironomidae and percent total Trichoptera as Hydropsychidae suggest a community structure imbalance (SARA 2008). The resulting ALU scores for both Mission Road and Loop 410 were *limited*, indicating a fair amount of degradation (Table 42). While the exact cause of degradation is not known, these scores merit the need for further investigation and monitoring of the benthic community.

SARA (2012) collected samples and calculated IBIs for two locations in SAAN in 2012: Piedras Creek at Espada Aqueduct and Ashley Road. Piedras Creek received an *intermediate* rating while Ashley Road was *limited* (Table 43).

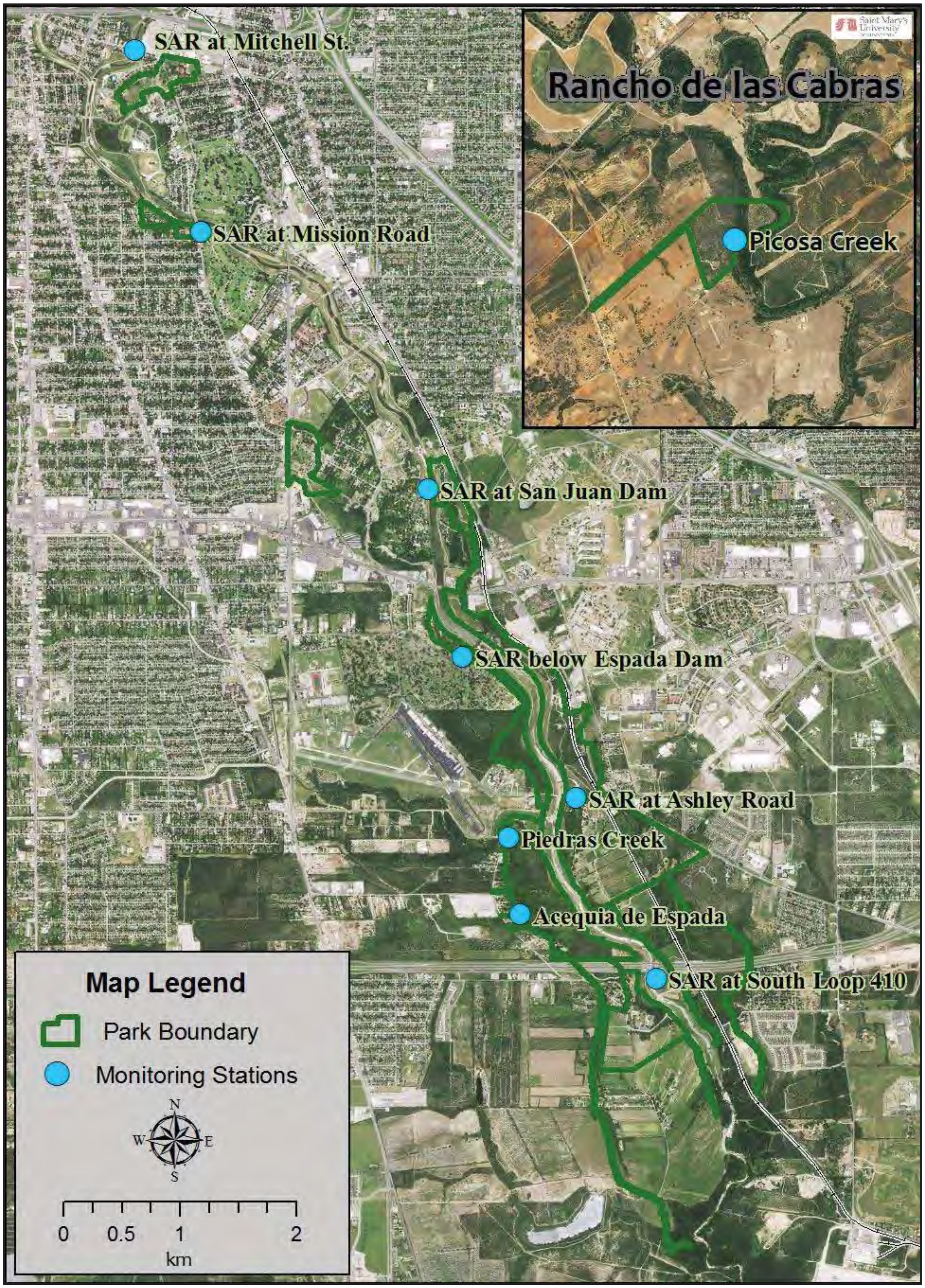

Figure 34. Locations of the water quality monitoring stations that are within, or in close proximity, to the SAAN units. SAR=San Antonio River.

Table 40. Results of San Antonio River water quality monitoring, 2000-2002 (SARA 2003).

Station	Date	Macroinvertebrate ALU (IBI)	Habitat ALU (IBI)
Mitchell Street	3/28/2000	Limited (<22)	High (26-31)
	3/20/2001	-	High (26-31)
	3/18/2002	-	High (26-31)
Mission Road	3/26/2001	-	High (26-31)
	3/25/2002	-	Intermediate (14-19)
Loop 410	4/18/2000	Limited (<22)	High (26-31)
	4/1/2002	Intermediate (22-28)	High (26-31)

Table 41. Results of SARA habitat assessments (SARA 2005).

Segment*	Station	Date	Habitat IBI	ALU
1911	San Juan Dam	6/24/2004	17.0	Intermediate
	Below Espada Dam	5/18/2004	19.0	Intermediate
	Acequia de Espada	5/6/2004	17.0	Intermediate
	Ashley Road	7/15/2004	19.0	Intermediate
	Piedras Creek	5/20/2004	21.0	High
	Loop 410	4/13/2004	19.0	Intermediate
1901	Picosa Creek	9/16/2004	17.5	Intermediate

*****Segment refers to the Upper San Antonio River (1911) and the Lower San Antonio River (1901).

Table 42. Results of San Antonio River water quality monitoring, 2003-2004 (SARA 2008).

Station	Date	Macroinvertebrate ALU (IBI)
Mission Road	2003	Limited (<22)
Loop 410	2004	Limited (<22)

Table 43. Results of San Antonio River water quality monitoring, 2012 (SARA 2012).

Station	Date	Macroinvertebrate ALU (IBI)
Piedras Creek	June 2012	Intermediate (28)
Ashley Road	June 2012	Limited (21)

Threats and Stressor Factors

Habitat loss and degradation; water quality impairments; impervious cover carrying more water and chemicals into waterways; drought; decreased flows; hydrological changes (e.g., lower water tables and water diversions); and past contamination in soils were identified as the major stressors to aquatic macroinvertebrates in SAAN. Additionally, hydraulic fracturing, persistent organic pollutants, contaminants in sediment, and potential contaminants in personal care and pharmaceutical products are currently a challenge to monitor and assess (SARA 2013a).

Habitat loss and degradation is a threat to the aquatic macroinvertebrate communities in SAAN. Habitat degradation has been at least partly caused by the expanding population of San Antonio, which continues to grow (SARA 2013a). The upper and middle segments of the upper San Antonio River have been engineered for flood control, which has reduced habitat quality for fish and benthic macroinvertebrates (SARA 2008). Water quality impairments are also a threat, as they adversely affect intolerant invertebrate species. According to SARA (2013a), the upper San Antonio River segment had impaired fish communities in 2012, meaning that it did not support the high aquatic life use designation for the segment. This impairment could be due to habitat conditions, levels of nutrients, and/or the presence of *E.coli* in the river segment. Given that conditions are impaired for fish, it is likely that they are unfavorable for intolerant macroinvertebrate assemblages as well.

Urbanization Impacts

Impervious surfaces (e.g., paved roads, parking lots, roofs) increase with urban development of land (urbanization), and divert water directly into streams and rivers as runoff. This runoff can greatly increase the river's flow, causing channel alteration by expansion laterally or by incision (Cawthon 2008). Urbanization can also cause unnatural flood peak levels, especially after storm events, and alter the overall flow regimes of streams and rivers (Cawthon 2008). In response to this phenomenon, managers will often alter the river channel via dikes, levees, and terraces to carry the excess runoff water away from the urban areas faster and stabilize the river channel so it cannot naturally meander. This inevitably increases the erosion of natural streambed materials at the channelized area and contributes to increased aggradation (channel filling in with the deposition of sediment) downstream (Cawthon 2008). These alterations can degrade aquatic habitat conditions and adversely affect the benthic community.

According to Cawthon (2008), increased flow rates in the San Antonio River are partially attributed to impervious surface increases in and around San Antonio due to urbanization. This increased runoff is accompanied by pollutants and contaminants that are carried directly into rivers and streams (SARA 2013a, b). Under natural conditions, rainfall has time to infiltrate soils, recharge underground water tables, evaporate, and be absorbed by plants with very little runoff. This process also filters out substances that would otherwise impair waterways, such as bacteria, sediment, and other dissolved materials (SARA 2013b). The San Antonio River basin is now heavily urbanized and the channel has been engineered to carry away runoff pulses after storm events to avoid disastrous flooding. This has impacted the water quality, making conditions less than ideal for the benthic community to thrive, especially those that are sensitive to changes in the water physiochemical parameters that can be severely altered by runoff contamination. Alterations to riparian habitat can be detrimental to the benthic community by reducing bank stability which increases turbidity, decreased temperature regulation of the water, and eliminating refuge from predators (SARA 2013b).

Drought
In the San Antonio River basin, another compounding factor of the urbanization issue is drought (SARA 2013a). Periods of drought can cause the remaining pervious surfaces such as lawns, farm fields, and other permeable surfaces to accumulate materials and become extremely dry. The rainfall following a prolonged period of drought not only runs off of the impervious surfaces, but will not soak in to over-dry surfaces either. The runoff moves fast, carrying accumulated bacteria, nutrients (e.g., pet waste), petroleum on parking lots and pavement, dust, topsoil, and other materials that have settled on the ground from the air, directly into the water (SARA 2013a). This can impair water quality and negatively impact aquatic organisms; excess nutrients from runoff cause algae blooms that can severely decrease dissolved oxygen which is crucial to aquatic ecological health (SARA 2013a). Drought also can drop the rivers and streams below normal flow, reducing the available habitat, and can concentrate levels of contaminants since they become less diluted as the volume of water is reduced. The 2011 drought conditions were exceptional, and the area around the park is still experiencing abnormally dry conditions with severe drought conditions to the north (Figure 35; U.S. Drought Monitor 2014).

Data Needs/Gaps
Many of the monitoring efforts in the park have not collected aquatic macroinvertebrates, or have collected only sporadically, which leaves many gaps in data (both spatially and temporally). For example, no macroinvertebrate IBIs have been calculated within the park's Rancho Unit. The data discussed above are outdated and not sufficient for an assessment of any trends in SAAN in regard to the aquatic macroinvertebrate community. However, there are plans for ongoing, long-term monitoring of the San Antonio River segment that runs through SAAN (SARA 2013a).

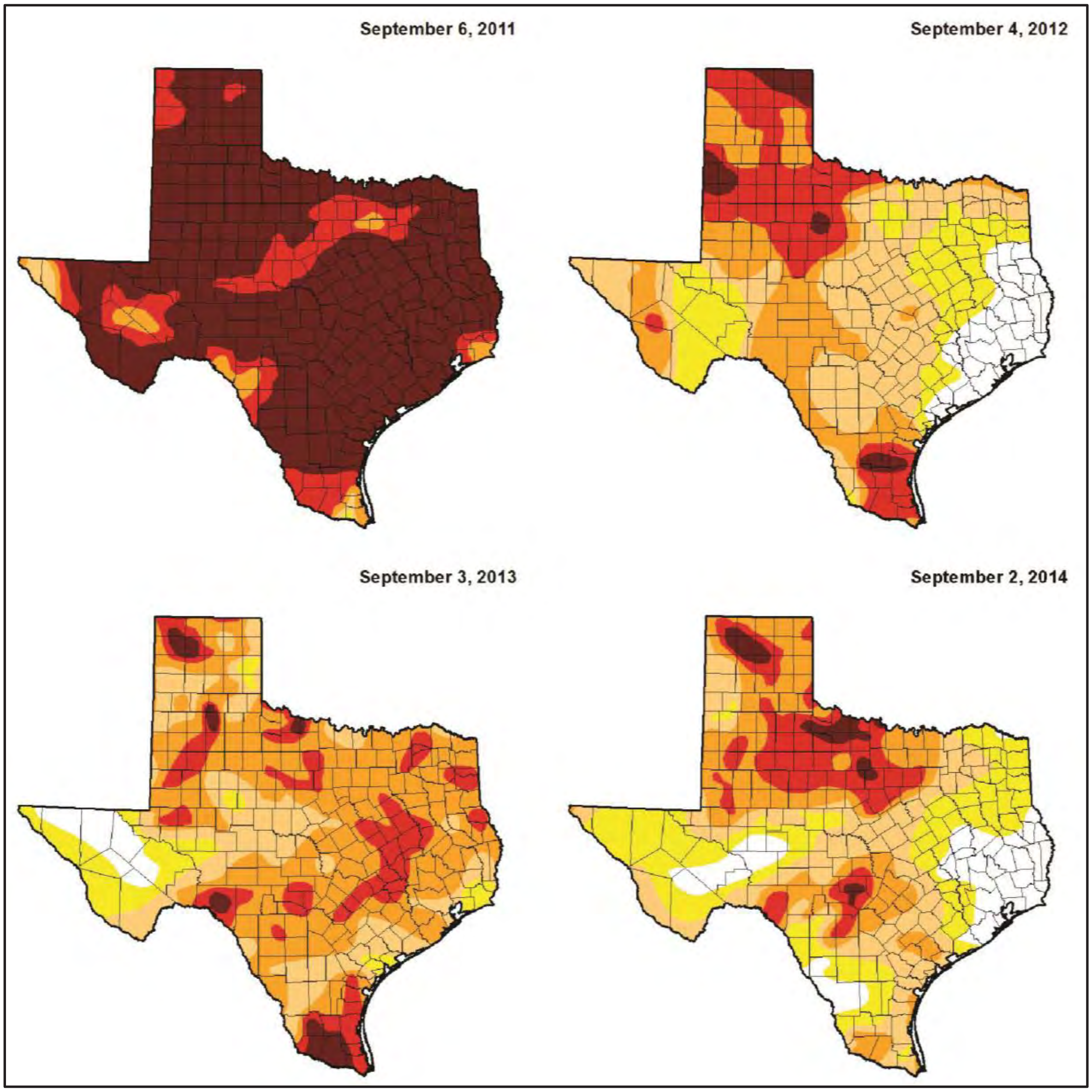

Figure 35. The severity of drought in Texas 2011-2014. Drought severity ranges from the darkest red areas, which represent “exceptional” droughts, to yellow areas, which are “abnormally dry” (reproduced from U.S. Drought Monitor 2014).

<u>Overall Condition</u>

IBI Rating

The project team assigned a *Significance Level* of 3 for the IBI rating measure. While the IBI scores that are available for macroinvertebrates suggest the community is likely degraded, there is not enough data to assess the condition of aquatic macroinvertebrates within SAAN at this time. Therefore, a *Condition Level* cannot be assigned.

Weighted Condition Score

A *Weighted Condition Score* cannot be calculated at this time, due to the lack of data for the only measure. The current condition and any trends for the aquatic macroinvertebrate community are unknown.

Aquatic Macroinvertebrates			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
IBI Score	3	n/a	

4.8.6 Sources of Expertise

San Antonio River Authority (SARA)

4.8.7 Literature Cited

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4.9 Fish

4.9.1 Description

Fish play an important part in aquatic ecosystems, as they act as predators that control macroinvertebrate populations, and as a food source for predatory aquatic and terrestrial species (SARA 2014). Fish communities are good indicators of water quality because some species are more intolerant of changes in nutrient level, turbidity, water temperature and dissolved oxygen levels (DO) than other species. For example, the USDA (2001) identifies species of darter, sunfish, and suckers that are sensitive/intolerant to stream degradation, siltation, and the presence of chemicals, respectively. Although the fish species that occur within SAAN are not known to be sensitive species, they are still a valuable and important component in assessing the overall health of the aquatic habitats in the park.

The San Antonio River runs through both units of SAAN, and there are over 70 species of fish confirmed to exist within the watershed (SARA 2005). According to NPS (2014), the fish species in the SAAN reach of the river represent six orders and eight families. Orders represented in the park include: Characiformes, Cypriniformes (such as the common carp [*Cyprinus carpio*]), Clupeiformes, Cyprinodontiformes, Perciformes (such as the largemouth bass [*Micropterus salmoides*]), and Siluriformes (such as the channel catfish [*Ictalurus punctatus*]) (Photo 17). The species pictured above are three of several fish species considered common in the park's aquatic habitats (NPS 2014). Two native species that are considered rare in SAAN are the American gizzard shad (*Dorosoma cepedianum*) and the green sunfish (*Lepomis cyanellus*) (NPS 2014). There are several non-native fish in SAAN, with four species considered abundant in the park: the Mexican tetra (*Astyanax mexicanus*), a Rio Grande cichlid (*Herichthys cyanoguttatum*), Mozambique mouth-breeder (*Oreochromis mossambicus*), and sailfin molly (*Poecilia latipinna*) (NPS 2014).

Photo 17. From top to bottom, the largemouth bass, and channel catfish (photos by SARA 2014).

4.9.2 Measures

- Species richness
- IBI rating

4.9.3 Reference Conditions/Values

The reference condition for fish in SAAN is based on the EPA Rapid Bioassessment Protocol V (RBP) (EPA 1989), which is used by SARA to assess fish communities in the watershed. The RBP includes an index of biotic integrity (IBI) based on methods developed by Karr (1981). Table 44 displays the range of total IBI scores, integrity classes, and associated attributes. IBI is a multimetric index; metrics included in the index calculation are the number of fish species and individuals, number of darters, number of species of sunfish, number of species of suckers, number of intolerant species, percentage of tolerant species, percent omnivores and piscivores, percentage of diseased fish, and percentage of species with multiple age groups (USDA 2001). For the purpose of this assessment, the reference condition for IBI will be scores in the *good* integrity class or above.

Table 44. Total IBI score, integrity class, and attributes to those respective scores (reproduced from SARA 2005).

Total IBI Score	Integrity Class	Attributes
58-60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age (size) classes; balanced trophic structure.
53-57 48-52	Very Good Good	Species richness somewhat below expectations, especially due to the loss of the most intolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress.
45-47 39-44	Good to Fair Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g., increasing frequency of omnivores and cichlids or other tolerant species); older age classes of top predators may be rare.
36-38 28-35	Fair to Poor Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
24-27 12-23	Poor to Very Poor Very Poor	Few fish are present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
	No Fish	Repeated sampling finds no fish.

4.9.4 Data and Methods

SARA (2003) compiled a summary report for monitoring activities in the San Antonio River Basin. Data were collected between 1998 and 2002, with eight water quality monitoring stations sampled from the Upper (segment 1911) and Lower San Antonio River Basin (segment 1901) (see Figure 29 in the previous section). Generally, stations were monitored for fish once per year; the Mitchell Street station was sampled twice in 2000. Three of the eight stations that were assessed for fish IBIs were located within SAAN.

SARA (2005) conducted inventories of fish species in SAAN during 2003 and 2004. Four stations were sampled during 2003, and eight during 2004. In 2003, three of the four stations were located in the San Antonio River at Mission Road, San Juan Dam, and below Espada Dam, while the fourth station was in Piedras Creek (for station locations, see Figure 35 in the previous section). In 2004, four of the eight stations sampled were located on the San Antonio River: San Juan Dam, below Espada Dam, Ashley Road, and South Loop 410. The other three stations sampled in 2004 were at Acequia de Espada, Piedras Creek, and Picosa Creek. In 2003, the stations were each sampled once in the month of October (7 October – 28 October). In 2004, the stations were sampled between March and September (SARA 2005). The inventory documented the fish species identified, distribution, and frequency of occurrence. An IBI score was calculated for each station sampled (SARA 2005). The document also contains a list of fish species occurring in the Upper San Antonio River taken from SARA (1996).

Sampling was conducted by SARA at three locations in 2011, 2012, and 2013. The Espada Aqueduct at Piedras Creek, Aquequia de Espada (Loop 410), and Ashley Road monitoring stations were sampled and IBIs for fish were calculated in June of 2011 and 2012, and May and June of 2013 (SARA 2011, 2012, 2013b).

NPS (2014) represents an annotated list of fish species for SAAN, which documents occurrence (e.g., present, probably present), nativeness, and relative abundance.

4.9.5 Current Condition and Trend

<u>Species Richness</u>

SARA (2005) documented 27 fish species in the San Antonio River and its tributaries within SAAN. The most commonly observed native species were red shiners (*Cyprinella lutrensis*) (Photo 18), central stonerollers (*Campostoma anomalum*), and western mosquitofish (*Gambusia affinis*). Commonly observed introduced species included sailfin molly, Amazon molly (*Poecilia formosa*), Rio Grande cichlid, and Mexican tetra. The inventory also included a fish species list for the Upper San Antonio River from 1996 that documented 31 fish. Table 45 displays the fish shiners that are a native species inventory in 2005.

Photo 18. Red shiners are a native species species commonly observed at SAAN (photo by shiners that (SARA 2014).

Table 45. List of fish species by source and documentation in SAAN. Note that SARA (1996) covers the Upper San Antonio River and is not exclusive to SAAN.

Scientific Name	Common Name	SARA (1996)	SARA (2005)	NPS (2014)
Ameiurus melas	black bullhead			X^
Ameiurus natalis	yellow bullhead	X	X	X
Astyanax mexicanus	Mexican tetra*	X	X	X
Atractosteus spatula	alligator gar	X		
Campostoma anomalum	central stoneroller		X	X
Chaenobryttus gulosus	Warmouth	X	X	X
Cyprinella lutrensis	red shiner	X	X	X
Cyprinella venusta	blacktail shiner	X		
Cyprinus carpio	common carp*		X	X
Dionda episcopa	roundnose minnow	X		
Dorosoma cepedianum	gizzard shad	X	X	X
Gambusia affinis	western mosquitofish	X	X	X
Herichthys cyanoguttatum	Rio Grande cichlid*	X	X	X
Hypostomus plecostomus	suckermouth catfish*		X	X
Ictalurus furcatus	blue catfish	X		X^
Ictalurus punctatus	channel catfish	X	X	X
Lepisosteus oculatus	spotted gar	X		
Lepisosteus osseus	longnose gar	X		
Lepomis auritus	redbreast sunfish	X	X	X
Lepomis cyanellus	green sunfish	X	X	X
Lepomis macrochirus	bluegill	X	X	X
Lepomis megalotis	longear sunfish	X	X	X
Lepomis microlophus	redear sunfish	X		
Lepomis punctatus	spotted sunfish	X		
Liposarcus multiradiatus	sailfin catfish		X	X
Micropterus punctulatus	spotted bass		X	X
Micropterus salmoides	largemouth bass	X	X	X
Moxostoma congestum	gray redhorse	X		

*introduced species, ^unconfirmed presence

Table 45 (continued). List of fish species by source and documentation in SAAN. Note that SARA (1996) covers the Upper San Antonio River and is not exclusive to SAAN.

Scientific Name	Common Name	SARA (1996)	SARA (2005)	NPS (2014)
Notropis amabilis	Texas shiner		X	X
Notropis buchanani	ghost shiner		X	X
Notropis texanus	weed shiner		X	X
Notropis volucellus	mimic shiner	X	X	X
Noturus gyrinus	tadpole madtom	X		
Oreochromis mossambicus	Mozambique mouth-breeder*		X	X
Pimephales promelas	fathead minnow	X		
Pimephales vigilax	bullhead minnow	X	X	X
Poecilia formosa	Amazon molly*	X	X	X
Poecilia latipinna	sailfin molly*	X	X	X
Pylodictis olivaris	flathead catfish	X		
Tilapia aurea	blue tilapia*	X		
Tilapia mossambica	Mozambique tilapia*	X		X
Tilapia zillii	redbelly tilapia*		X	X

*introduced species, ^unconfirmed presence

NPS (2014) documented 29 species of fish as "present" or "probably present" in SAAN (Table 45). Most fish species have been confirmed as present in the park; the only two species that were listed as "probably present" or "not confirmed" were black bullhead (*Ameiurus melas*) and blue catfish (*Ictalurus furcatus*). Of the 29 identified species, nine are non-native to SAAN (see Table 45). The western mosquitofish is considered abundant in the park, while other common fish species are yellow bullhead (*Ameiurus natalis*), red shiner, and weed shiner (*Notropis texanus*).

IBI Rating

SARA (2003) documented IBI integrity classes for fish that ranged from *poor* to *good* along river segment 1911, which comprises the Upper San Antonio River Basin where the Missions Unit is located. Only three of the segment 1911 stations are located within the boundaries of SAAN: Mitchell Street, Mission Road, and Loop 410 (Figure 30). The Loop 410 station was rated in the *good* integrity class, and the other 1911 stations ranged from *fair* to *poor*, though the later samples (2001, 2002) were in the *poor* integrity class (Table 46). According to SARA (2003), insectivores were the dominant taxa in comparison to omnivore taxa throughout segment 1911. The Mitchell Street and Mission Road stations had the greatest numbers of omnivores, although omnivores were still in lower ratios to insectivores at these sites. Table 46 displays the IBI integrity class summary of San Antonio River stations within the park sampled between 1998 and 2002.

Table 46. IBI and integrity class summary for stations in SAAN, 1998-2002 (SARA 2003).

River Segment	Stations	Date	IBI	Integrity Class
1911	Mitchell Street	6/10/1998	<35	Poor
		3/28/2000	39-44	Fair
		8/1/2000	<35	Poor
		3/20/2001	<35	Poor
		3/18/2002	<35	Poor
	Mission Road	3/26/2001	<35	Poor
		3/25/2002	<35	Poor
	Loop 410	4/18/2000	48-52	Good
		4/1/2002	48-52	Good

SARA (2005) contains IBI scores for fish at seven stations that are within or adjacent to SAAN's Missions Unit and one within the Rancho Unit (Picosa Creek). Sampling occurred in 2003 and 2004, with six stations sampled twice and two stations sampled once. In 2003, four stations were sampled for fish and integrity classes ranged from *poor* at the Mission Road station, to *fair* at the Piedras Creek and Espada Dam stations (Table 47). In 2004, seven stations in SAAN were sampled for fish (three stations were sampled twice). The majority of these samples showed little change in fish integrity classes. The stations sampled twice in the same year showed no change in fish IBI scores, with the exception of the Acequia de Espada station. The Acequia de Espada station had an IBI of 36 in the late-spring and increased to 42 in early summer. The San Juan Dam station showed improvement between fall of 2003 and mid-summer of 2004; IBI went from a 38 to a 44, changing the integrity class from the *fair to poor* category to *fair* (Table 47). The single IBI rating from the Rancho Unit (Picosa Creek) was in the *good* class (SARA 2005).

Table 47. IBI ratings for the SAAN fish community in river segments 1911 and 1901, 2003-2004 (SARA 2005).

River Segment	Stations	Date	IBI	Integrity Class
1911	Mission Road	10/7/2003	34	Poor
	Piedras Creek	10/7/2003	40	Fair
		5/20/2004	42	Fair
	San Juan Dam	10/21/2003	38	Fair to Poor
	San Juan Dam	6/24/2004	44	Fair
	Below Espada Dam	10/28/2003	44	Fair
		5/18/2004	42	Fair

Table 47 (continued). IBI ratings for the SAAN fish community in river segments 1911 and 1901, 2003-2004 (SARA 2005).

River Segment	Stations	Date	IBI	Integrity Class
1911 (cont.)	Ashley Road	3/23/2004	42	Fair
		7/15/2004	46	Good to Fair
	Loop 410	4/13/2004	46	Good to Fair
		6/29/2004	48	Good
	Acequia de Espada	5/6/2004	36	Fair to Poor
		6/15/2004	42	Fair
1901	Picosa Creek	9/16/2004	48	Good

In 2010, assessments were performed at three stations on the upper (1911) segment of the San Antonio River. The results reflect a decline of 8 IBI points at the Ashley Creek station, 6 at Piedras Creek, and only 4 at Acequia de Espada (SARA 2010). The decline changed the integrity classes for Ashley Creek and Piedras Creek, but Acequia de Espada remained the same (SARA 2010).

Table 48. IBI scores for fish collected in 2010 in the San Antonio River in August (SARA 2010).

River Segment	Station	Date	IBI	Integrity Class
1911	Piedras Creek	8/5/2010	36	Fair to Poor
	Ashley Road	8/16/2010	38	Fair to Poor
	Acequia de Espada	8/17/2010	38	Fair to Poor

SARA (2011) sampled fish and assessed IBIs at three stations in 2011 (Table 49). The Ashley Road station had an IBI of 38 in 2010 and a 46 in 2011, increasing the integrity class to *fair* (Table 48 and Table 49). The Piedras Creek station had an IBI of 36 in 2010 and 40 in 2011, also changing the integrity class for the better (Table 49). The Acequia de Espada station did not change in IBI score (SARA 2011).

SARA (2012) sampling results show an increase of only two IBI points at Piedras Creek, which did not affect the integrity class standing for that station. Ashley road IBI, however, declined four points which brought the integrity class down from *good to fair* to *fair* (Table 50). Additionally, Acequia de Espada couldn’t be sampled in 2012 due to no-flow conditions. This was likely due to acequia maintenance or construction activities (Mitchell, written communication, 22 September 2015).

Table 49. IBI scores for fish collected at three (segment 1911) stations in June of 2011 (SARA 2011).

River Segment	Stations	Date	IBI	Integrity Class
1911	Ashley Road	6/6/2011	46	Good to Fair
	Piedras Creek	6/27/2011	40	Fair
	Acequia de Espada	6/28/2011	38	Fair

Table 50. IBI scores for fish collected at three (segment 1911) stations in June of 2012 (SARA 2012).

River Segment	Stations	Date	IBI	Integrity Class
1911	Ashley Road	6/14/2012	42	Fair
	Piedras Creek	6/11/2012	42	Fair
	Aceqia de Espada	N/A	*No sampling due to no-flow conditions*	

SARA (2013b) sampled the same three stations in SAAN (Table 49, Table 50, and Table 51). The IBI scores overall declined from 2011 to 2013 suggesting some type of degradation was likely to have occurred in these areas, although what caused the decline is not clear. All of the scores from 2011, 2012, and 2013 are also below the selected reference condition of the *good* integrity class or higher (≥48).

Table 51. IBI scores for fish collected at three (segment 1911) stations in May and June of 2013 (SARA 2013b).

River Segment	Stations	Date	IBI	Integrity Class
1911	Ashley Road	6/12/2013	34	Poor
	Piedras Creek	5/15/2013	38	Fair
	Acequia de Espada	5/20/2013	36	Poor

Threats and Stressor Factors

Habitat loss and degradation are a threat to the fish communities in SAAN. Habitat degradation has been partly caused by the continually expanding population in San Antonio (SARA 2013a). The upper and middle segments of the upper San Antonio River have been engineered for flood control, which has reduced habitat quality for fish (SARA 2008). Water quality impairments are also a threat to the fish community in SAAN, as they adversely affect intolerant fish species. According to SARA (2013a), the Upper San Antonio River segment had impaired fish communities in 2012. River segment 1911, which runs through the park, was placed in the category of not supporting the water quality standards for fish community IBI. This assessment of poor fish conditions could be due to the concerning habitat condition, level of nutrients, and the presence of *E.coli* in the river segment. These threats and stressors are discussed in more detail in Chapter 4.8 of this document, as the aquatic macroinvertebrate communities in SAAN face many of the same threats as the fish community.

Climate change has implications for the aquatic ecosystem, with increased severity and frequency of drought and warming temperatures expected in the SAAN region. Water temperatures are affected by the ambient air temperature, and at SAAN water temperatures vary by nearly 25°C (45°F) during a typical year due to seasonal air temperature fluctuations (Meiman 2012). From 1999 to 2012, some stations had detected periodic water temperatures that exceeded the state standard, a maximum of 32.2°C (Meiman 2012). The recent water temperature spikes were attributed to the warming climate trend, and are expected to become more common in the future, although the restoration of riparian zones may offset the impacts of rising air temperatures on the water temperature (Meiman 2012). Higher water temperatures reduce capacity to carry dissolved oxygen (DO) which is essential to fish health and survival. Low DO can also be the result of nutrient overload, which is often a problem after significant rainfall events, when storm runoff washes excess nutrients and contaminants into the water (SARA 2013a). Droughts will likely become more frequent and longer in duration as the climate changes (Twilley et al. 2001, Davey et al. 2007). In 2011, the drought conditions in Texas reduced Picosa Creek in the Rancho Unit to patches of lentic, shallow ponds fit for intense algal blooms and unfavorable for fish survival (Meiman 2012; Photo 19).

Data Needs/Gaps

Limited data exist for both measures used in this assessment. The establishment of annual, routine monitoring of fish species richness and IBI would aid in the management of fish communities in the San Antonio River and its tributaries within SAAN. Furthermore, the only data for Rancho de las Cabras are from one date in 2004 at the Picosa Creek station (SARA 2005). The 2011 drought in Texas likely negatively affected the fish community.

There is no information regarding the impacts of nonnative fish on native fish species. The fish community may be shifting towards nonnative species, given that all the nonnative fish species confirmed in SAAN are considered common or abundant (NPS 2014). The number of native fish species listed in SARA (1996) was 25 with six nonnative species, which is a 19% nonnative fish community for the Upper San Antonio River at that time. SARA (2005) listed 20 native and seven nonnative species of fish, or nearly 26% nonnative. The official NPS (2014) list for SAAN shows 21 native species (two are unconfirmed) and eight nonnative species, which is over 27% nonnative. Fish inventories will be important for assessing the trends in the native and nonnative fish communities and should continue with future monitoring efforts in SAAN.

Photo 19. Picosa Creek during the 2011 drought (NPS photo by Joe Meiman).

Overall Condition

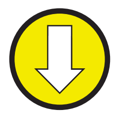
Species Richness

The project team defined the *Significance Level* for species richness as a 2. The earliest available species list for the Upper San Antonio River contains 31 species, six of which are nonnative (SARA 1996). Nearly 10 years later, SARA (2005) observed 27 species of fish within SAAN, with seven nonnative species. NPS (2014) lists 29 species of fish occurring in SAAN, with eight nonnative species that are considered common or abundant. Given that data on species richness is somewhat limited and out-of-date, the *Condition Level* for this measure cannot be assigned at this time.

IBI Rating

The project team defined the *Significance Level* for the IBI rating as a 3. SARA monitoring (2003, 2005, 2011, 2012, 2013b) has shown varied IBI ratings ranging from poor to good with at least three areas showing signs of possible degradation. The Acequia de Espada location has experienced degradation between 2004 and 2013, declining from the *fair to poor* range in 2004 to *poor* in 2013. Ashley Road has also declined, from *good to fair* in 2011 to *poor* in 2013. Since all of the most recent IBI ratings (2011, 2013) for locations within SAAN are below the selected reference condition of a *good* integrity class or higher, the *Condition Level* for this measure has been assigned a 2, indicating moderate concern.

Weighted Condition Score
Although the *Condition Level* for the species richness measure cannot be assigned at this time due to a temporal gap in data, the IBI ratings are low for SAAN and are in decline for some areas. The *Weighted Condition Score* for the fish community is a 0.67, which indicates moderate concern.

Fish			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.67**
Species Richness	2	n/a	
IBI	3	2	

4.9.6 Sources of Expertise

San Antonio River Authority (SARA)

4.9.7 Literature Cited

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4.10 Water Quality

4.10.1 Description

Water quality is a Vital Sign for parks in the GULN, including SAAN. The water quality of the San Antonio River has long been a focus of attention and its quality has been the focus of regulation since the late 1700s (Porter 2009, as cited by Meiman 2012). Situated in the semi-arid region of Texas, the river is a highly valued resource and the primary reason the original mission locations were chosen by their founders.

Photo 20. Acequia de Espada at the Espada Aqueduct (photo by Shannon Amberg, SMUMN GSS 2013).

The San Antonio River is central to the character of both SAAN park units. Extending from and running parallel to the main channel of the river is a system of Spanish-built acequias from the 18th century (Meiman 2012). These gravity fed irrigation ditches provided water to the surrounding fields and allowed agriculture to flourish in support of the missionaries and settlers. The two remaining acequias within SAAN, Acequia de San Juan (constructed in 1731) and Acequia de Espada (constructed 1731-1745; Photo 20) (TSHA 2014), are still flowing today.

In modern times, development around and upstream of San Antonio has increased water demand, decreasing the natural water supply that historically maintained flows in the San Antonio River. The San Antonio Water System (SAWS) has developed an innovative water re-use system. Presently, during the dry months of summer or during drought conditions, 95% or more of the water flowing in the urban segment of the San Antonio River is actually highly treated recycled water (Meiman 2012). This recycled water is introduced into the river in downtown San Antonio and is indistinguishable from the river's natural flow to the observer. While this water is visually indistinguishable, several components of water quality are impacted when compared to the quality of the natural source of the river, the Edwards Aquifer.

Photo 21. Aqueduct along the Espada Acequia (photo by Kathy Allen, SMUMN GSS 2013).

The areas surrounding the missions have become extremely developed and urban in nature. According to the NPS (2012), “Few other parks in the country have as much alteration, modification, or development of its watershed and surrounding areas as the San Antonio Missions National Historical Park”. With the city of San Antonio’s population now in excess of 1.4 million (USCB 2015) and the diverse array of land uses present in the area, the natural state of the park provides a sharp contrast to its urban surroundings.

The Concepción, San José, San Juan, and Espada Missions are each located within the urban footprint of San Antonio (Figure 36). SAAN’s southernmost unit, Rancho de las Cabras lies southeast of the city and is quite rural. Following the flow of the San Antonio River, the Rancho de las Cabras Unit is located approximately 80 km (50 m) downstream from Mission Espada.

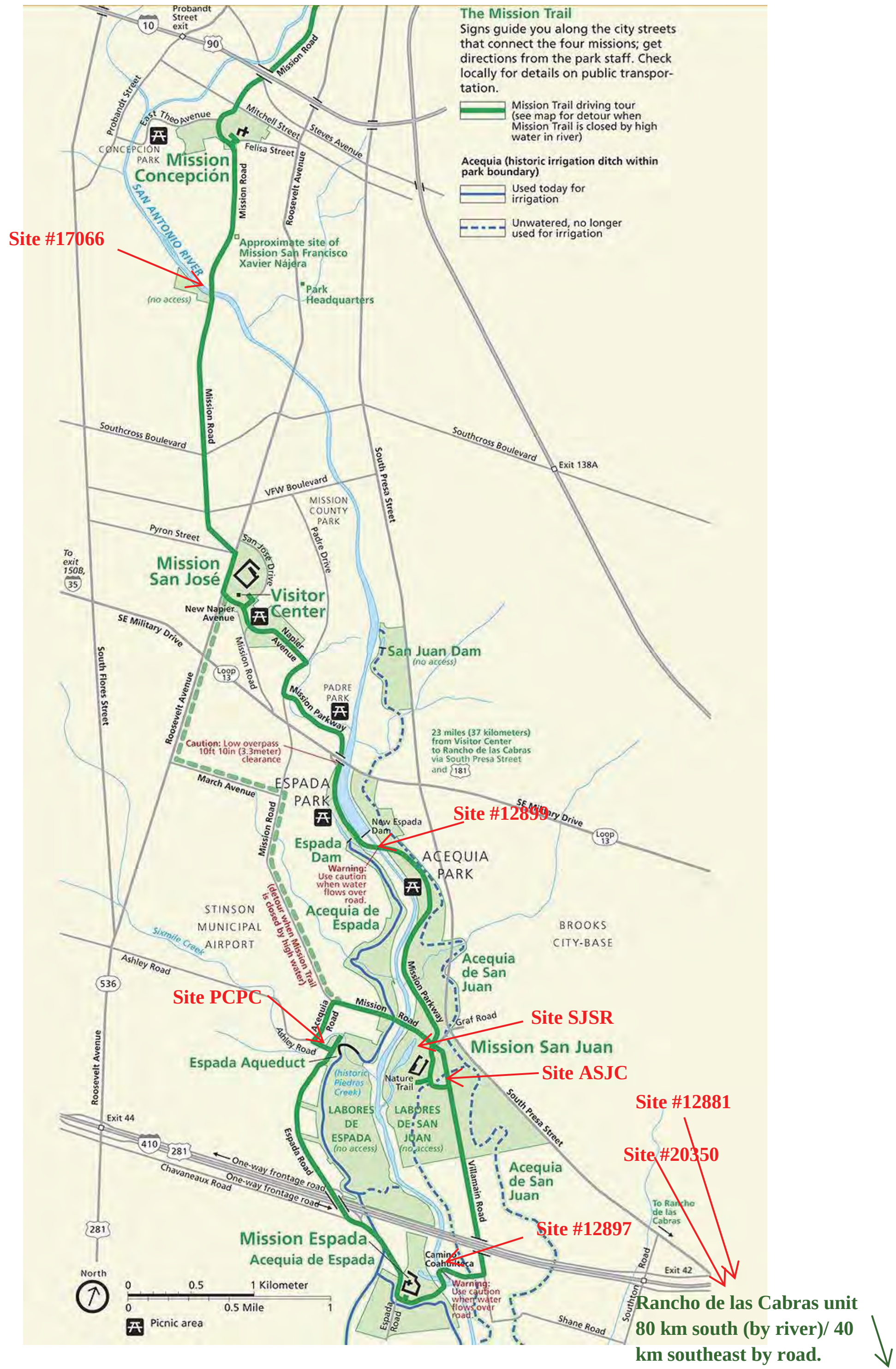


Figure 36. The San Antonio Missions Unit with water quality sampling locations (Meiman 2012). Sites with four-letter identifications are park of the GULN water quality program. Numeric identifies are part of the SARA Clean Rivers Monitoring Program. Both programs use the same protocol and schedule. SARA is contracted by the GULN to conduct sampling on the four SAAN sites; PCPC (Piedras Creek), AEAE (Acequia Espada), SJSR (San Antonio River at Mission San Juan de Capistrano, and ASJC (Acequia San Juan de Capistrano).

4.10.2 Measures

- Temperature
- Total dissolved solids (as measured by specific conductance)
- Dissolved oxygen
- pH
- Prevalence of coliform bacteria
- Prevalence of nutrients (phosphates, nitrates)
- Prevalence of sulfate
- Prevalence of chloride
- Total suspended solids (as measured by turbidity)

Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, but it also affects biological activity and growth within water systems (USGS 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). As temperature increases or decreases too far past this range, the number of species and individuals able to survive eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water, making them more toxic to aquatic life (USGS 2010).

Total Dissolved Solids

Total dissolved solids (TDS) represent the concentration of dissolved inorganic and organic compounds in the water. Most TDS are inorganic salts including calcium, magnesium, carbonates, nitrates, chlorides, and sulfates (SDWF 2012). These make their way into waterways primarily through runoff. Sources of TDS often include erodible landscapes that deposit materials into waterways, mineral springs, and agricultural or urban runoff. The concentration of TDS affects the water balance in the cells of aquatic organisms (EPA 2012); if the TDS are extremely low, an organism's cells will swell, and if the TDS are too high, an organism's cells will shrink. The TDS influences an organism's ability to remain in the water column (EPA 2012). One way of measuring the presence of dissolved solids is through specific conductance of water, which is the measure of the ionic activity and content of water, or water's ability to conduct electricity. The higher the concentration of dissolved solids (calcium, various salts, magnesium, etc.), the higher the conductivity of the water. Specific conductance is included here as a measure for understanding concentrations of dissolved solids in the San Antonio River that flows through SAAN.

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. In order to survive, fish and zooplankton filter out or "breathe" dissolved oxygen from the water (USGS 2010). Oxygen enters water from the air, when atmospheric oxygen mixes with water at turbulent, shallow riffles in a waterway, or when released by algae and other plants as a byproduct of photosynthesis. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more

DO than warm water (USGS 2010). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Indicator Bacteria (coliform spp.)

Bacteria are a common natural component of surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals, can cause illness in humans (USGS 2011). Fecal coliform bacteria are a subgroup of coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. *Escherichia coli* (*E. coli*) is a specific species of bacteria that belongs to the larger group of coliform bacteria and is characterized by its ability to break down urease (an enzyme that breaks down urea into carbon dioxide and ammonia) (USGS 2011). Thus, *E. coli* is a preferred indicator for determining if potential pathogens are present in freshwater resources. It is tested by counting colonies that grow on micron filters placed in an incubator for 22-24 hours. High concentrations of *E. coli* can cause serious illness in humans (USGS 2011).

Nutrients

Nutrients, such as nitrogen and phosphorus, are crucial in supporting healthy aquatic environments. However, elevated concentrations of these nutrients can negatively impact water quality and threaten the ability of plants and aquatic organisms to thrive (USGS 2013a). Nitrogen occurs naturally in the atmosphere and in soils and is deposited into surface waters through precipitation and runoff; nitrogen deposition is increased by human inputs such as sewage, fertilizers, and livestock waste (USGS 2013b). Nitrates can cause a host of water quality related problems when present in high concentrations including, but not limited to, excessive plant and algae growth, eutrophication, and depleted dissolved oxygen available to aquatic organisms (USGS 2013b). Nitrate in drinking water can be harmful to humans, particularly young children, and livestock (USGS 2013b). Phosphorus is commonly found in agricultural fertilizers, manure, organic wastes in sewage, and sometimes industrial effluent (USGS 2013b). In excess, phosphorus in water systems can increase the rate of eutrophication, encourage overgrowth of aquatic plants, deplete dissolved oxygen, and threaten fish and macroinvertebrate populations (USGS 2013b). Soil erosion is the primary contributor of phosphorus input into surface waters, in which enriched soils are deposited into waterways through runoff during heavy precipitation events (USGS 2013b).

Sulfate and Chloride

Chloride is an inorganic salt found naturally in water, but additional chloride can be washed into surface waters from several general sources, including road salting, agricultural runoff, and oil and gas wells (McDaniel 2012). In arid landscapes, higher rates of evaporation increase mineral accumulation (such as sodium chloride, borates, or gypsum) in soils, lakes, and rivers (USGS 1997). Large amounts of chloride in surface water are toxic to aquatic life such as fish and macroinvertebrates. Chloride becomes more toxic when combined with potassium or magnesium (NHDES 2008). Toxic metals can also be released when chloride is present in water. Dissolved oxygen levels, are reduced when these metals are released, causing added stress to the aquatic life in the area (NHDES 2008).

Sulfate, like chloride, is an inorganic salt found naturally in surface and ground water. In arid landscapes, sulfates can become concentrated in soils due to higher rates of evaporation (USGS 1997); these can then be carried into waterways by runoff. Elevated levels of sulfate in waterways can be toxic to aquatic life (Lenntech 2011). Some aquatic species are more sensitive to sulfate than others, such as intolerant macroinvertebrates. Possible sources of excess sulfate include sulfate ores, large deposits resulting from evaporation, and industrial wastes (Lenntech 2011).

Total Suspended Sediment (TSS)

Total suspended sediments (TSS) are inorganic and organic particles (e.g., sand, silt, algae) suspended within a water body. The suspended sediments are often measured by their dry weight as collected from the water column and expressed in milligrams per liter (Meiman 2012). Sample water is passed through a glass filter of known weight and pore size (Michaud 1994). This filter is then dried and re-weighed with the difference between the beginning weight and end weight being the TSS (Michaud 1994).

TSS can also be estimated indirectly from turbidity (Michaud 1994). Using a turbidity meter, Nephlelometric turbidity units (NTU), Jackson Turbidity Units (JTU), and Formazin Turbidity Units (FTU), the extent to which light penetrates the sample is estimated and used as an approximation of TSS (Robertson et al. 2006). Using turbidity as an estimation of TSS, however, has linear regression limitations as it is affected by particle size, shape and color, unlike the dry weight method of measuring TSS (Joe Meiman, NPS Hydrologist, written communication, 14 October 2014).

4.10.3 Reference Conditions/Values

The reference conditions for water quality in SAAN are the TCEQ 2014 water quality criteria considered to be protective of aquatic life and human recreation and bathing. Table 52 shows the standards for various surface water quality parameters set by the TCEQ. For some measures (e.g., nutrients), neither TCEQ nor the EPA have set applicable standards. The TCEQ has published "screening levels", or levels of concern, indicating that if these levels are exceeded a concern for water quality is warranted.

Table 52. Texas Commission on Environmental Quality surface water quality standards for surface-water quality (TCEQ 2014).

Water Quality Measure	TCEQ Standard
Temperature	Maximum 90°F (32.2°C)
Total Dissolved Solids	≤750 mg/L
Dissolved oxygen (mg/L)	≥5.0 mg/L
pH	6.5 – 9.0
Indicator bacteria (coliform)	≤126 CFU/100 mL
Chloride	≤150 mg/L
Sulfate	≤150 mg/L
Nutrients (nitrates, phosphates)	Phosphorous ≤ 0.69 mg/l, Nitrate ≤ 1.95 mg/l * State Screening Levels
Suspended Solids (TSS)	No TCEQ standard

4.10.4 Data and Methods

NPS (1999) and Meiman (2012) were primary sources for this assessment. No specific long-term water quality monitoring studies have been completed within SAAN boundaries. Meiman (2012) is intended as the beginning of such a long-term study.

NPS (1999) contains an extensive baseline of water quality data for the parks and surrounding areas. The study area for this document included areas 4.8 km (3 mi) upstream and 1.6 km (1 mi) downstream of each of the park units (NPS 1999). The EPA's database resources used in this study included; Storage and Retrieval System (STORET), Industrial Facilities Discharge (IFD), DRINKS (Drinking Water Supplies), GAGES (Water Gages), DAMS (Water Impoundments), and RF3 (River Reach File, Version 3). The report summarized the number of observations that exceeded EPA and NPS water quality criteria for a variety of water quality parameters.

Meiman (2012) provides more recent data and concentrates on only eight sampling locations either within or immediately adjacent to the park. The data were collected between 1999 and 2011. The metrics focused on by Meiman (2012) coincide well with the measures chosen by the park for this NRCA.

4.10.5 Current Condition and Trend

<u>Temperature</u>

Water temperature in SAAN is greatly influenced by the urban environment surrounding the parks. The urban population of approximately 1.4 million people and the concentration of industry and infrastructure impact the water temperature of the San Antonio River. The high demand for water supply reduces the water flow in the river and development reduces the natural ground and vegetative cover, thereby reducing infiltration and allowing warmer rain water to run off into the river. Water temperature can vary as much as 25°C throughout the year (Meiman 2012).

Water temperature does not have a federal or EPA regulated standard. As such, the NPS (1999) document did not analyze the level of compliance for this measure. More than 15,000 observations were recorded at 160 sampling locations from 1975 – 1998 (NPS 1999). These data are available for review but no summary or compliance analysis was performed on this measure. Only one temperature observation was reported from the monitoring station inside the park (SAAN 0070) a reading of 19.4°C (67°F) in January 1976.

Meiman (2012) reports that during the summer months, when flow is naturally low and air temperatures reach their highest, water temperature readings have exceeded the TCEQ standards. On several occasions since 1999, temperature readings have exceeded the TCEQ standard of 32.2°C (Figure 37) at three different sampling locations (#12987, #17006, SJSR) (Meiman 2012).

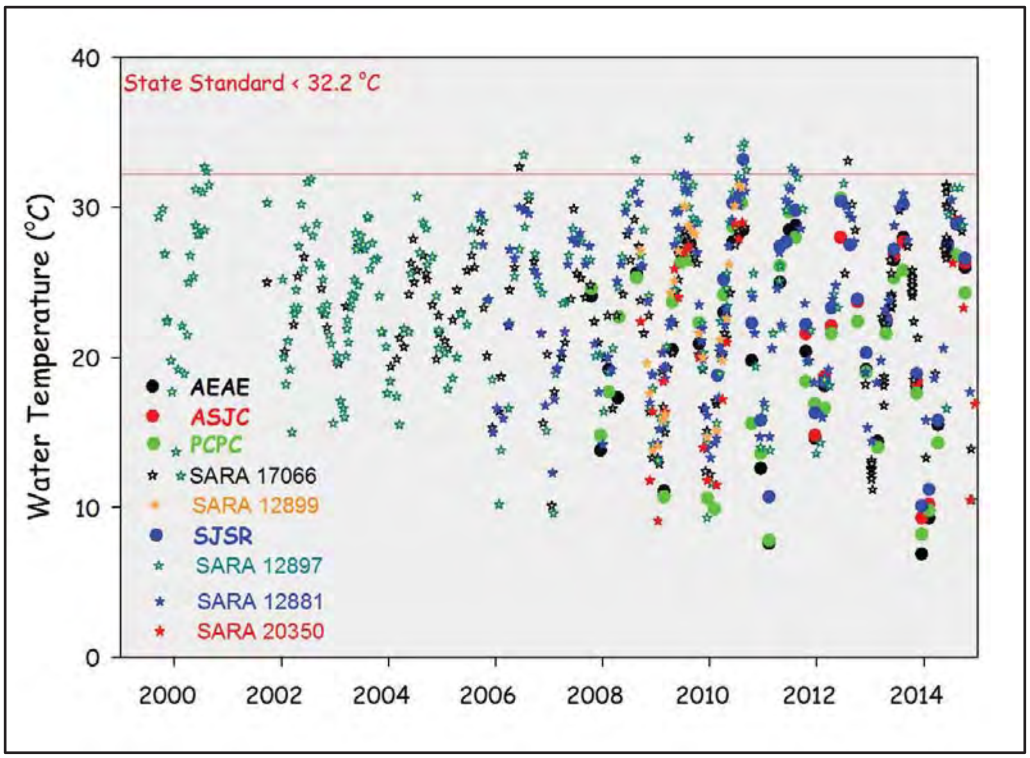


Figure 37. Water temperature readings (Received from Joe Meiman, February 2015).

Total Dissolved Solids

Total dissolved solids, as measured by specific conductance (SpC), is also a highly variable measure in the San Antonio River at SAAN (Meiman 2012). SpC has a naturally inverse relationship with stream flow. Barring anthropogenic influence, as flow increases the volume of water the in relation to the portion of dissolved solids increases thereby decreasing the overall SpC. Lower flow volumes are associated with higher SpC measurements.

The TCEQ standard for TDS is ≤750 mg/L. While no federal standard exists for SpC, it is being used to estimate TDS. As such, NPS (1999) did not analyze the level of compliance for this measure. 15,835 SpC observations were recorded at 236 sampling locations from 1975 – 1998 in the SAAN study area (NPS 1999). These data are available for review but no summary or compliance analysis was performed. Only one specific conductance observation of 1050 µS/cm in January 1976 was reported from inside the park (NPS 1999).

Meiman (2012) reports several unusually high SpC measurements at site #20350 (Figure 38). This site is located on Picosa Creek and routinely experiences low or stagnant flow. This fact, coupled with the presence of a large dairy operation nearby, may account for these unusual measurements. Picosa Creek is a seasonal tributary to the San Antonio River at the Rancho de las Cabras Unit.

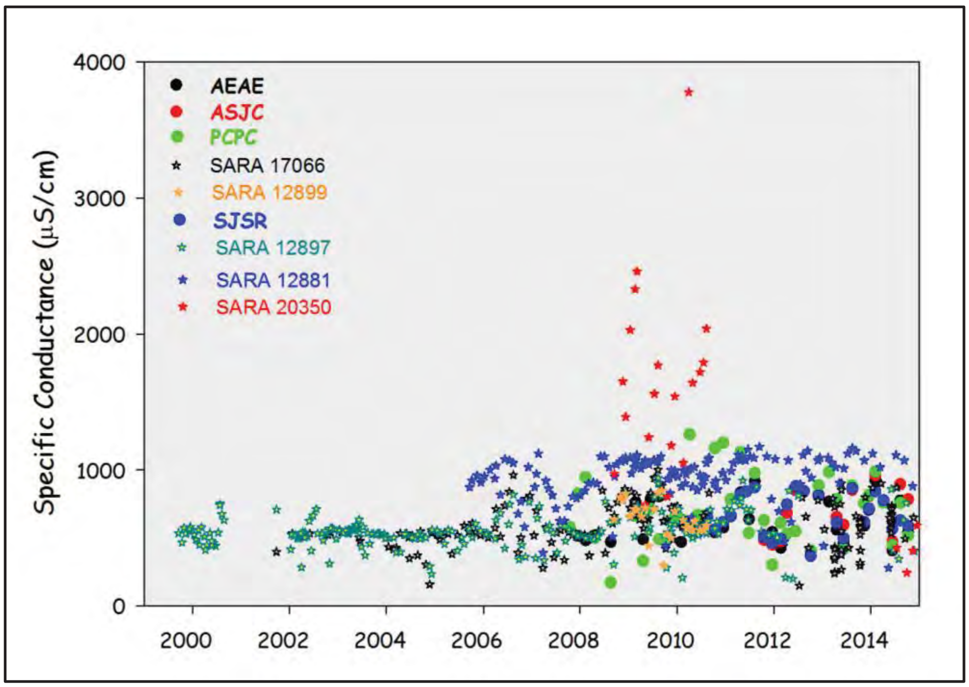


Figure 38. Specific conductance in SAAN (Received from Joe Meiman, February 2015).

Dissolved Oxygen

NPS (1999) reported 11,303 DO observations from 1975-1998 at a total of 108 stations in the SAAN study area. DO during this time period did not meet the EPA cold-water (1 day) standard value of 4 mg/L on 1,092 occasions or 10% of the time. The one DO observation within the park (January 1976) was 8.5 mg/L (NPS 1999).

As shown in Figure 39, six of the nine sampling locations have recorded readings below the state instantaneous DO standard of 5 mg/L with four of the nine sampling locations dropping below the standard with some regularity. None of these low DO sampling sites were located on the main stem of the San Antonio River. Meiman (2012) notes that two of these locations are acequias and do not undergo the aeration process of a normal stream. Another location (Piedras Creek) frequently experiences low flow during the summer months which often results in stagnant, warm water

(Meiman 2012). And the final location was on Picosa Creek, which may be unnaturally impacted by local dairy farming practices (Meiman 2012).

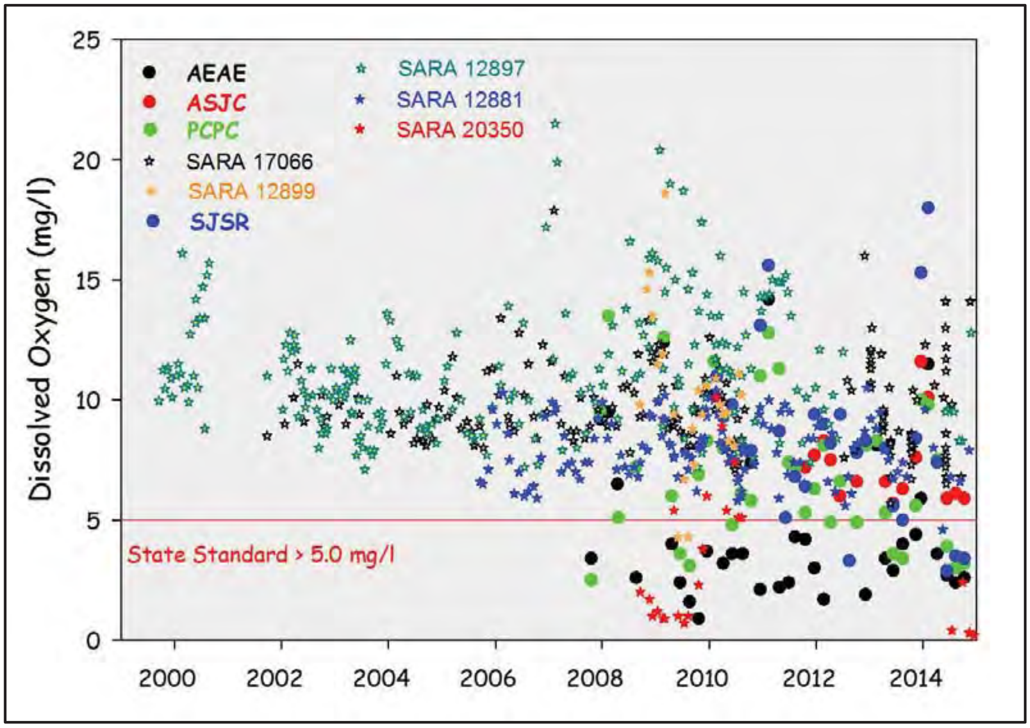


Figure 39. Dissolved oxygen data for SAAN (Received from Joe Meiman, February 2015).

pH

NPS (1999) documented 8,190 pH (field recordings) observations from 1975-1998 at a total of 141 stations and 10,844 pH (lab results) during that same time period from 188 stations in the SAAN study area. pH as recorded in this document exceeded the EPA standard value of 6.5 – 9 on 284 occasions for an exceedance probability of 1%. The single pH observation at SAAN 0070 made in January 1976 was 6.6 (NPS 1999).

According to Meiman (2012), the San Antonio River is naturally alkaline. The lowest pH values recorded were on a tributary close to the Rancho de las Cabras, which is to be expected as no limestone bedrock is exposed in that watershed (Meiman 2012). Two sampling locations (SARA 12897 and SARA 12899) recorded some pH values above 9, which exceeds the state reference conditions (Figure 40; Meiman 2012). No reason for this exceedance is known at this time (Meiman 2012).

Prevalence of Coliform Bacteria

Total coliform bacteria exceeded the state standard in 81% of the samples in the SAAN study area between 1973 and 1998 (NPS 1999). The NPS (1999) report indicates 6,785 total observations at 140 sampling locations. One total coliform measurement of 2,600 CFU/100 ml and a fecal coliform measurement of 430 CFU/100 ml were reported from the park in 1976 (NPS 1999). These values exceed water quality criteria.

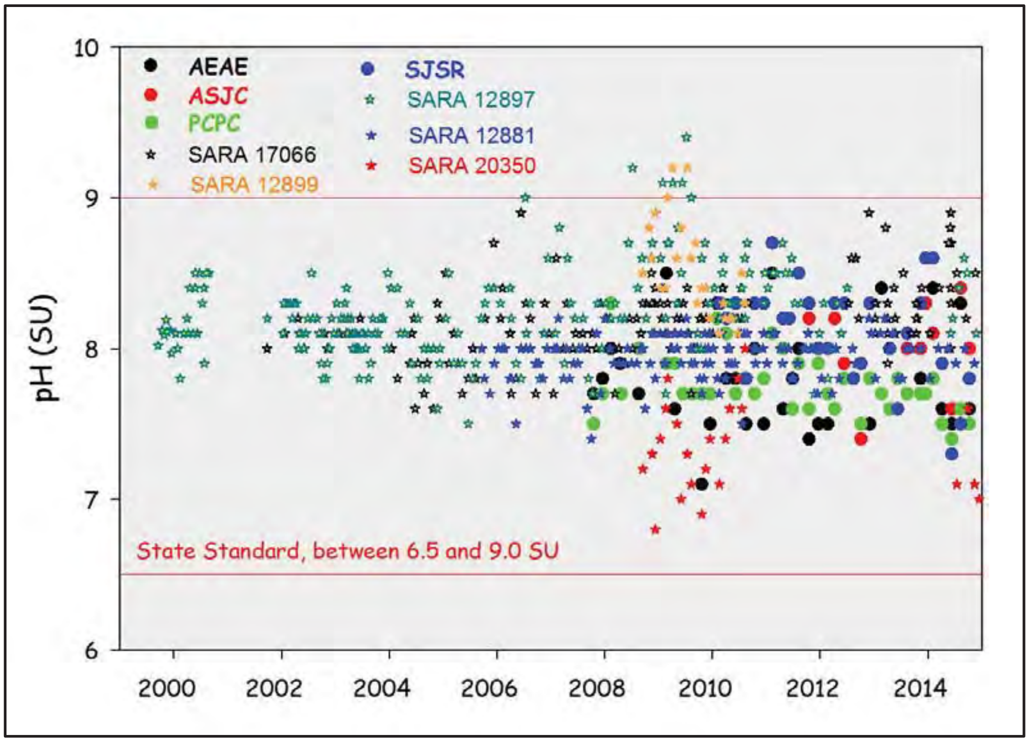


Figure 40. pH readings from SAAN, 2000-2012 (Received from Joe Meiman, February 2015).

Meiman (2012) reports that the urban stretch of the San Antonio River (from Mission Concepción to Mission Espada) is on the Texas 303(d) list for non-attainment due to bacteria (*E. coli*). While this report does not contain data on bacteria levels, he comments that "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…Without reuse water, the San Antonio River would not flow during most summer months and during drought" (Meiman 2012, p. 41).

Prevalence of Nutrients (phosphates, nitrates)

Total phosphorous was measured 3,333 times between 1975 and 1998 from 123 sampling locations (NPS 1999). No EPA or state limits have been set for this nutrient, so no summary or compliance analysis was reported in the NPS (1999) document. No phosphorous observations were reported from the park during this time.

Meiman (2012) reports that phosphorous measurements in SAAN are typically high and coincide with elevated nitrogen measurements. These elevated measures are most likely caused by the urban environment surrounding the SAAN locations. While there are no EPA or state reference conditions for phosphorous, the state has set a "screening level" of 0.69 for mg/L. While four of nine sampling locations exceed the state screening level for phosphorous, only two of the nine sampling locations exceed that in multiple sample years (Figure 41).

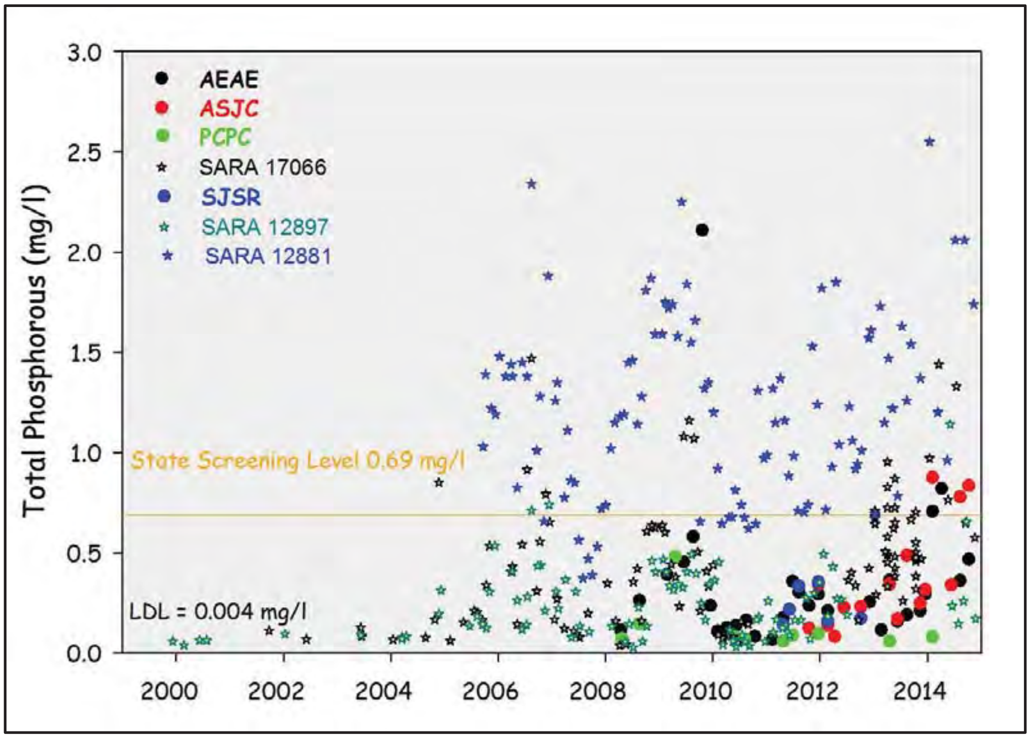


Figure 41. Total phosphorous levels in SAAN (Received from Joe Meiman, February 2015).

Total nitrogen was measured 391 times between 1975 and 1984 from 19 sampling locations (NPS 1999). No EPA or state limits have been set for this nutrient, so no summary or compliance analysis was reported in the NPS (1999) document. No nitrogen observations were reported from the park during this time.

Total nitrate nitrogen was measured 10,650 times between 1975 and 1984 from 162 sampling locations (NPS 1999). Total nitrate plus nitrite was measured 1,480 times between 1975 and 1984 from 81 sampling locations. Lastly, Total Kjeldahl nitrogen was measured 1,871 times between 1975 and 1984 from 102 sampling locations. No EPA or state limits have been set for these nutrients, so no summary or compliance analysis was reported in NPS (1999).

Meiman (2012) reports that nitrate levels in the San Antonio River are notoriously high and are attributable to the intense urban environment surrounding SAAN (Figure 42). These elevated nitrogen loads are most likely the result of the recycled wastewater introduced into the river. While there is no EPA or state reference condition for nitrate, the state has set a “screening level” of 1.95 mg/L. Nitrate levels in the San Antonio River appear to increase when the elevation of the Edwards Aquifer water table declines (NPS 2015). When the water table drops, headwater springs that feed the river dry up, and the contribution of supplemental recycled wastewater (higher in nitrates) increases (NPS 2015). This is shown in Figure 43, which relates nitrate concentrations to the water table elevation at the Edwards Aquifer Authority’s monitoring well J17.

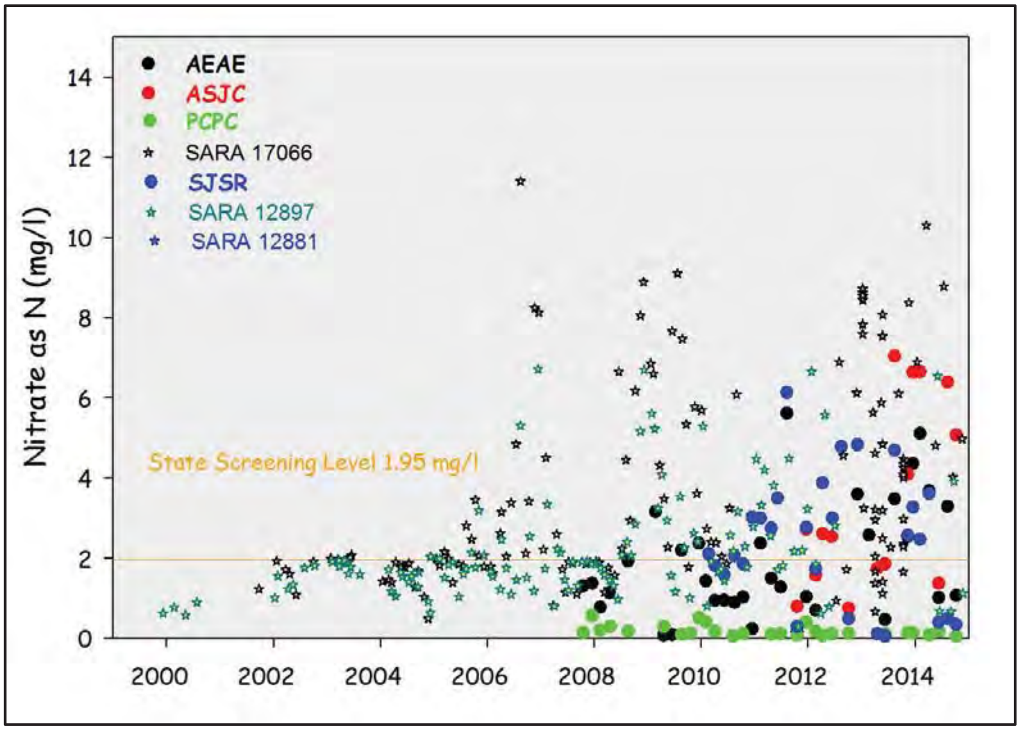


Figure 42. Nitrate concentrations (Received from Joe Meiman, February 2015).

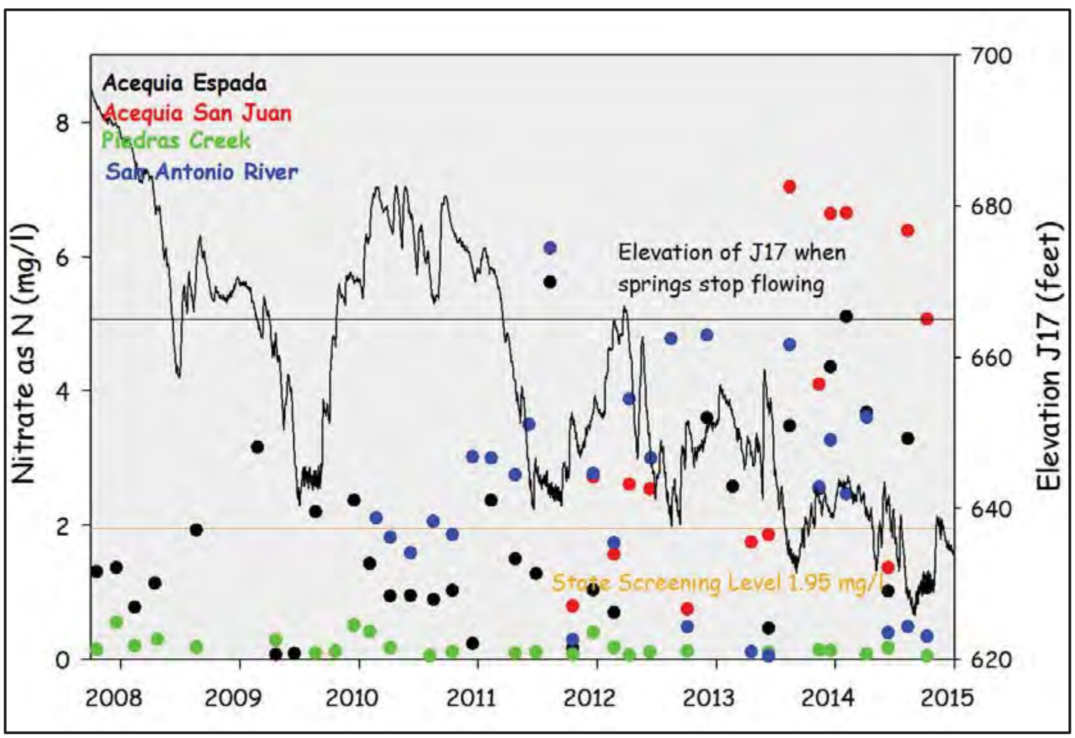


Figure 43. Nitrate concentrations and monitoring well elevation (Received from Joe Meiman, February 2015).

EPA or state reference criteria for nitrite do not exist. In Meiman (2012), only two of the nine sampling locations exhibited high nitrite levels (Figure 44). One of these sites is in an acequia, and is not representative of the main channel of the San Antonio River (Meiman 2012).

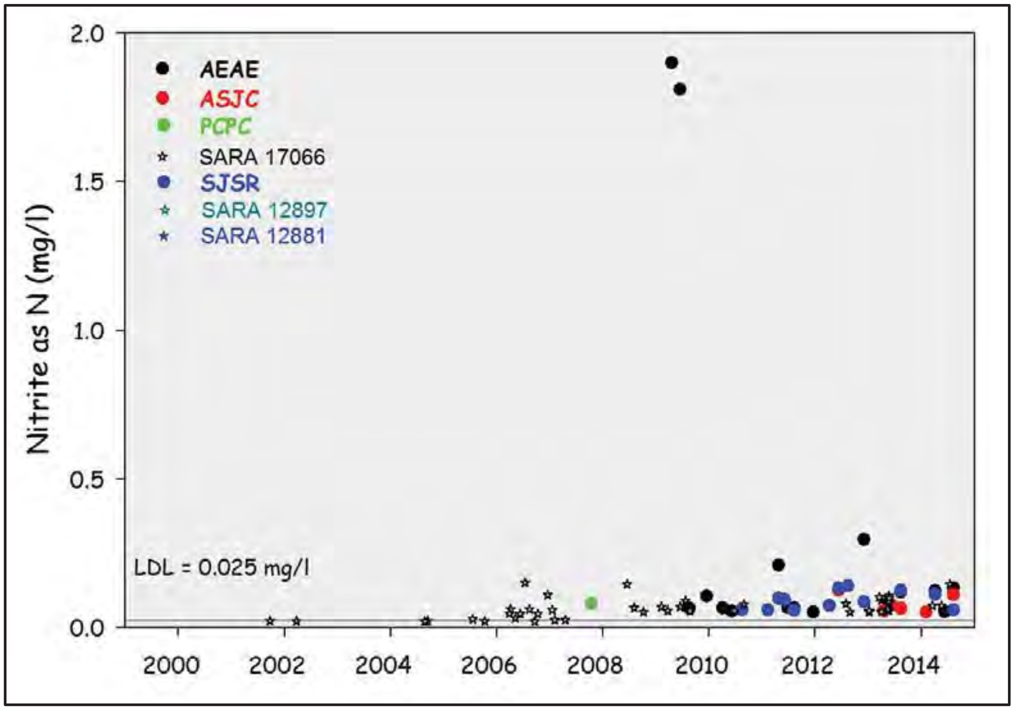


Figure 44. Nitrite levels in SAAN (Received from Joe Meiman, February 2015).

EPA or state reference criteria for total Kjeldahl nitrogen (TKN) do not exist. The only extremely high reading for TKN in Meiman (2012) was from the same acequia that was high in nitrite and is not representative of the main channel of the San Antonio River (Figure 45) (Meiman 2012).

Prevalence of Sulfate

According to NPS (1999), total sulfate was sampled a total of 13,410 times at 232 different sampling locations from 1963 to 1998. Total sulfate was found to exceed the EPA reference criteria in 6% of the samples. A single sulfate observation of 22 mg/L was reported from in the park in 1976 (NPS 1999).

Sulfate levels in the Meiman (2012) report were below the state standard of 150 mg/L in all but three of the samples (Figure 46). All three samples were from the same location in a tributary to the main channel (Piedras Creek) and were associated with times of very low flow (Meiman 2012).

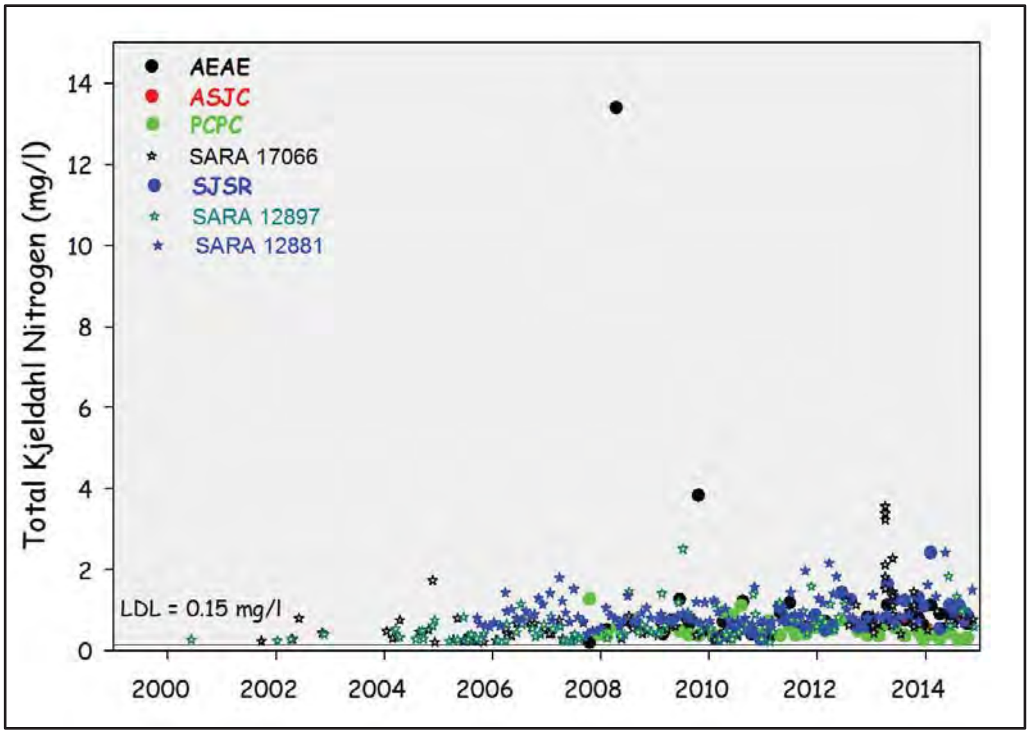


Figure 45. Total Kjeldahl nitrogen (TKN) (Received from Joe Meiman, February 2015).

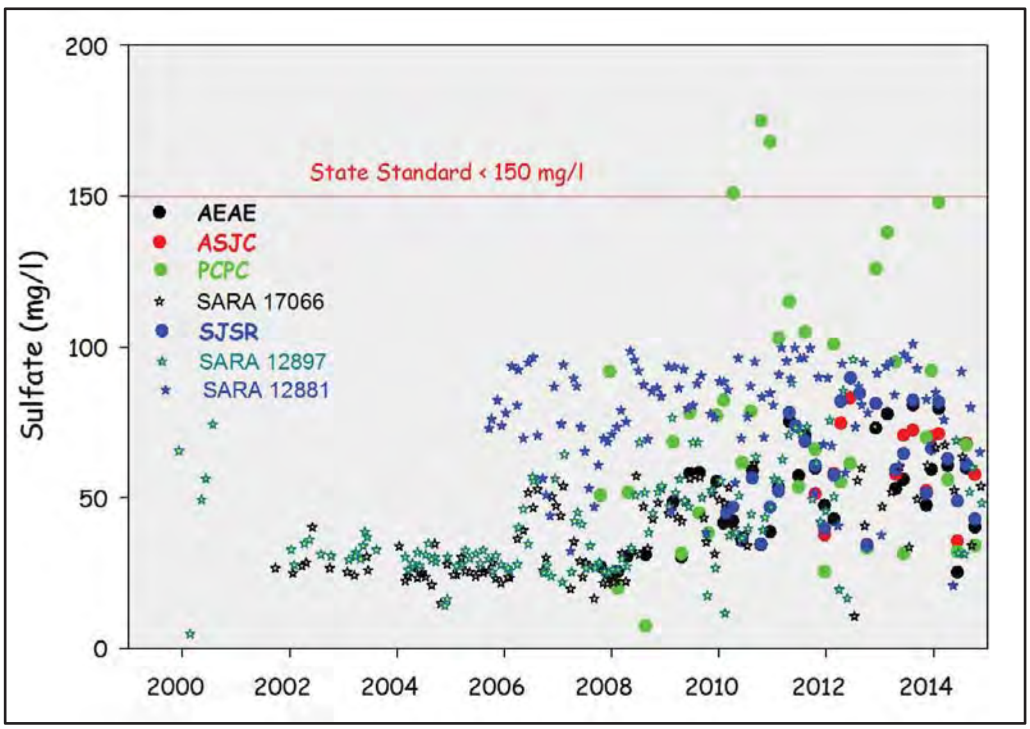


Figure 46. Total sulfate in SAAN (Received from Joe Meiman, February 2015).

Prevalence of Chloride

Total chloride was sampled 14,367 times between 1955 and 1998 (NPS 1999). Total chloride was found to exceed the EPA reference criteria in 1% of the samples. The only measurement of chloride from in the park was 28 mg/L in 1976 (NPS 1999).

According to Figure 47, chloride was below the state standard of 150 mg/L in all but eight of the samples. Four of the samples were from the same location in a tributary to the main channel (Piedras Creek) and were associated with times of very low flow.

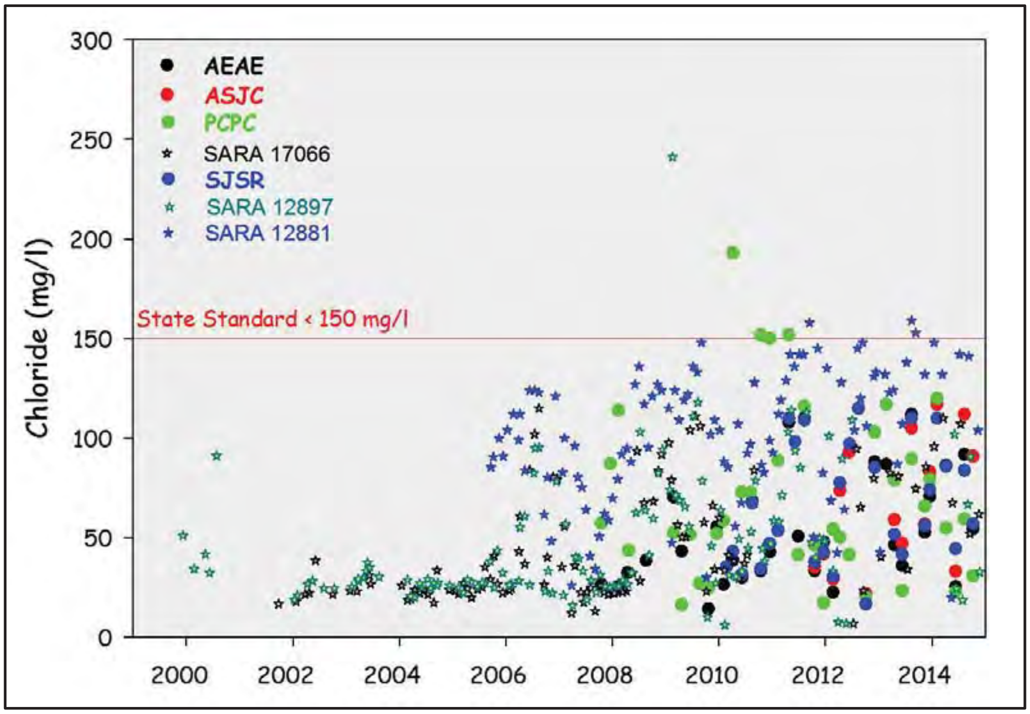


Figure 47. Chloride levels within SAAN (Received from Joe Meiman, February 2015).

Total Suspended Solids

Total suspended solids (TSS), as estimated by turbidity (measured in Jackson Candle Units), was recorded in the NPS (1999) report. Turbidity data were collected on 318 occasions from 1985 through 1998. Forty percent of these observations exceeded the EPA water quality criteria (NPS 1999). Turbidity (Hach Turbidimeter) was measured 2,291 times and was found to exceed the EPA water quality criteria 29% of the time (NPS 1999). Neither TSS nor turbidity were measured inside the park during the NPS (1999) study period.

Meiman (2012) also did not address TSS as a measured parameter. Meiman (2012) did report that as part of SARA’s monitoring program, five locations in and around SAAN have monitored TSS, along with several other parameters, since 1999. Likely due to the lack of state or federal criteria for TSS, this water quality parameter was not included in the Meiman (2012) report.

Threats and Stressor Factors

The densely urban character of the land surrounding SAAN is the primary source of threats to the water quality in the parks. With an ever increasing population currently at 1.4 million (USCB 2015) and a growing business economy, the threat to water quality will likely only increase. Continued urbanization of the surrounding landscape could lead to more impervious surface areas in the watersheds, which could in turn lead to increased runoff at increased temperatures. The rapid changes in land use are a concern and could contribute to both point and non-point sources of contaminants.

Recycled wastewater is also considered a stressor to water quality in SAAN. During the dry months of summer nearly 100% of water flowing within the San Antonio River (in the area of the Missions Unit) consists of recycled wastewater. The quality of this water is obviously a significant concern to SAAN. While the river is in non-attainment status for bacteria (*E. coli*) and listed as impaired for fish habitat due to this recycled water, it must rely on this source of water or go dry (Meiman 2012). The quality of the recycled water is known and tested routinely in order to minimize the risk of severely degrading the water quality.

At certain times of year and during drought, up to 100% of the water flow in the San Antonio River's urban reach is composed of recycled waste water; it is important to understand the water quality characteristics associated with this water. High levels of conductivity, nitrates, ammonia, and phosphate are indicative of recycled waste water (Meiman 2012). Table 53 is a comparison of the natural source water for the San Antonio River, the Edwards Aquifer, and the recycled wastewater.

Table 53. Typical water quality from the Edwards Aquifer and San Antonio recycled water. Values that routinely exceeded state screening levels are in bold (Meiman 2012).

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**

Table 53 (continued). Typical water quality from the Edwards Aquifer and San Antonio recycled water. Values that routinely exceeded state screening levels are in bold (Meiman 2012).

Component	Units	Edwards Aquifer	Recycled Water
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

In the rural area of the Rancho Unit, it is not urbanization that is a potential threat as much as the agricultural nature of the area. Common threats in this area include grazing of livestock, conversion of riparian areas to pasture or crop land, as well as the application of fertilizers, pesticides, and disposal of animal wastes and byproducts.

Flooding is an ongoing concern for SAAN. Flooding can drastically alter the course of the water channel as well as bring in potentially harmful quantities of nutrients and pollutants into the stream. The arid climate in Texas is often deluged with excessive rainfall at different times of the year. Storms are common in the spring and fall as patterns of air movement change with the seasons. The city of San Antonio and SAAN are situated directly south of a geologic feature known as the Balcones Escarpment (Figure 48). The Balcones Escarpment is a geologic uplift across central Texas with an elevation increase varying from 30 m – 150 m (100 ft – 500 ft) (Caran and Baker 1986). As the warm, moist air from the Gulf of Mexico moves northward and inland, heavy rainfalls often occur along the Balcones Escarpment (Caran and Baker 1986). The increase in elevation at the escarpment causes the moisture laden air to rise abruptly and then drop its cargo of moisture on the region as precipitation.

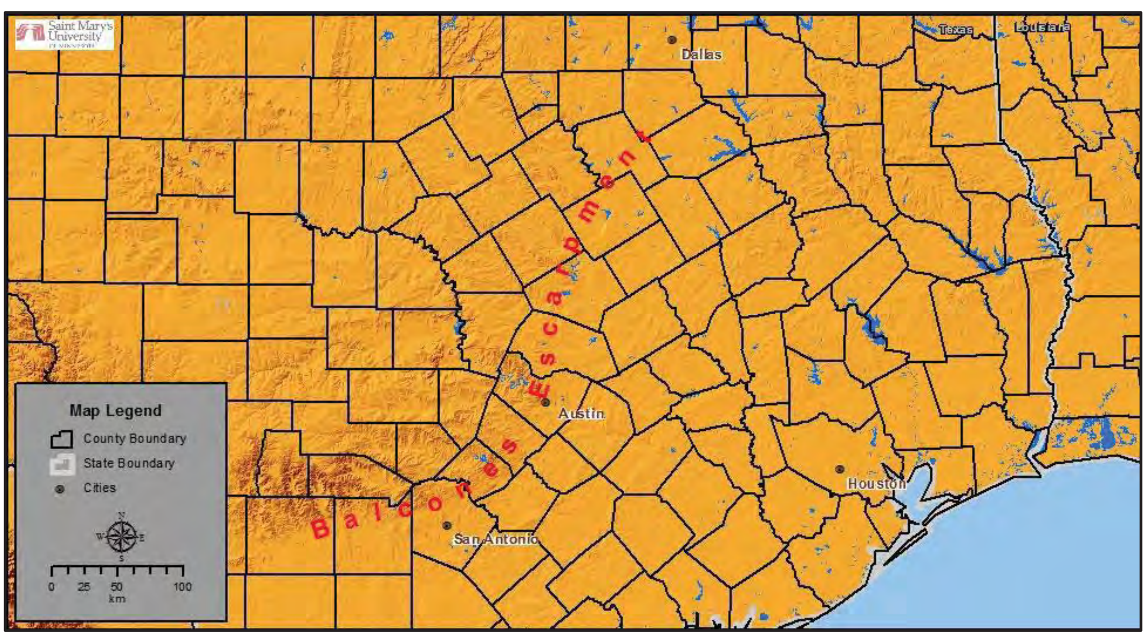


Figure 48. Balcones Escarpment geologic uplift indicated in red letters.

Just as rainfall events around SAAN are often unpredictable and intense, the other extreme of drought is present as well. Drought has a long history in Texas and at present, the state is in one of its worst droughts in history (Figure 49). Threats from drought associated with water quality include decreased surface flow; increased concentration of contaminants, sediments and salts; decreased water resources available from aquifers; and increased wildfire potential.

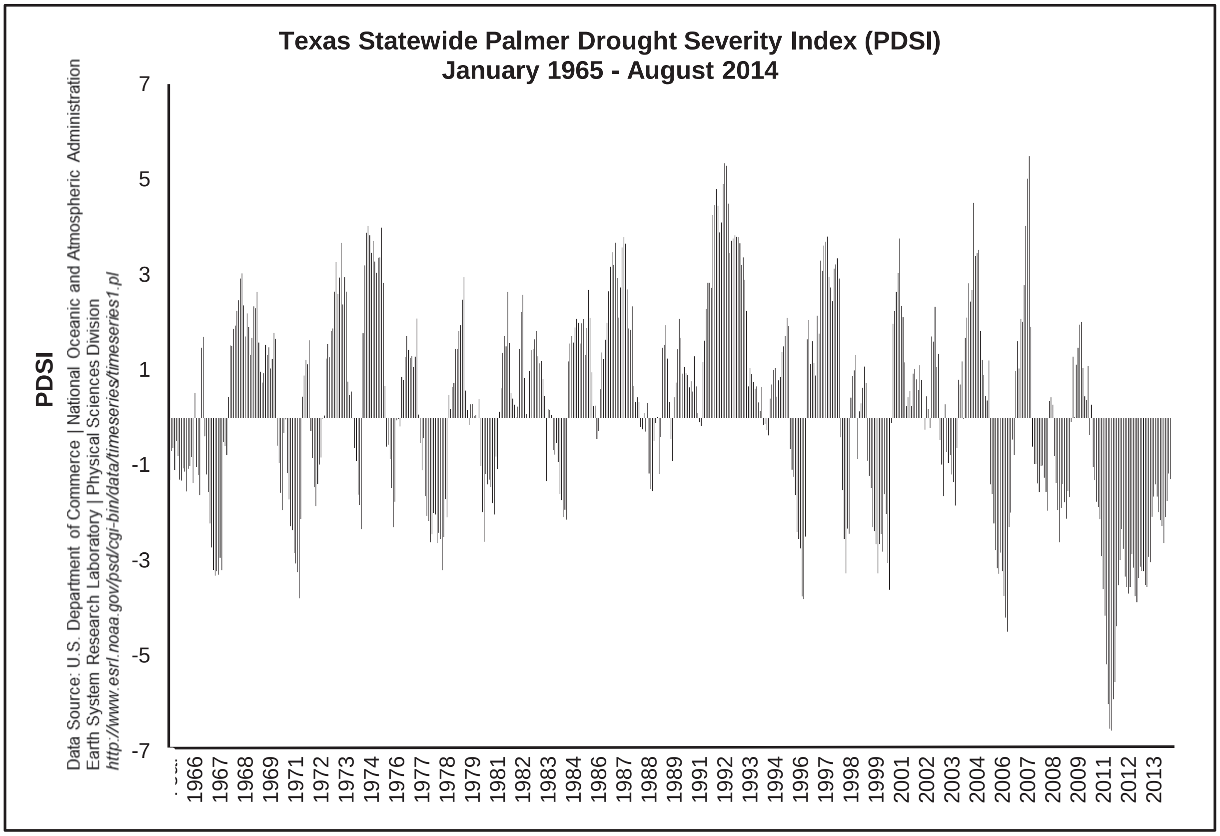


Figure 49. Palmer Drought Severity Index for Texas (USDOC 2014).

<u>Data Needs/Gaps</u>

No long term water quality studies have been completed within SAAN. Meiman (2012) acknowledges the GULN's intention to implement long term monitoring and indicates the report itself is part of that endeavor.

Large amounts of data exist and have been assembled in the NPS (1999) report. However, analysis including the TCEQ standards is lacking. The data are perhaps too broad, as a 4.8 km (3 mi) up river area and a 1.6 km (1 mi) down river area were included in the study. Considering that much of the year the primary source of water in the river is recycled waste water, a smaller study area may more accurately reflect conditions within SAAN. A recompilation of the data from the NPS (1999) report, with a more limited geographic area, as well as any new data, and focusing on EPA as well as TCEQ standards might yield a better picture of the water quality in SAAN.

Overall Condition

Water Temperature

The project team defined the *Significance Level* for water temperature as a 2. Meiman (2012) evaluated water temperature over the last 12 years and concluded that, due to the nature of the recycled water and the lack of flow from the source aquifer during summer months, temperatures were as expected. Only seven measurements exceeded the state standard during the reported time period and these were identified as exceptions due to drought conditions (Meiman 2012). Therefore, water temperature is of low concern (*Condition Level* = 1).

Total Dissolved Solids (as estimated by specific conductance)

The *Significance Level* for specific conductance was also defined as a 2. Total dissolved solids (TDS) were not measured directly but were estimated by the measurement of specific conductance (SpC). The value of TDS is estimated by multiplying SpC x 0.65 (Joe Meiman, NPS Hydrologist, written communication, 14 October 2014). Using this formula to convert the Texas TDS standard to SpC measurements, yields approximately ≤1,154 mg/l (SpC) to be the equivalent of the TCEQ standard of ≤ 750 mg/l for TDS. Based on this estimate, Figure 49 illustrates that while exceptions did occur, the vast majority of SpC measurements were below the TCEQ standard. Using this estimation method, TDS is currently of low concern (*Condition Level* = 1).

Dissolved Oxygen

The project team defined the *Significance Level* for dissolved oxygen as a 3. The TCEQ standard is a DO value ≥5.0 mg/l. The only exceedances recorded within SAAN from 2007 to 2011 occurred at sampling locations AEAE and PCPC (Meiman 2012). AEAE is the Acequia de Espada, which is not a natural stream channel and as such does not experience normal aeration activity. PCPC is a site on a tributary where low flow is common. Having satisfactory explanations for these low DO readings allows the DO data as a whole to be viewed as meeting the TCEQ standard. As a result, dissolved oxygen is currently of no concern (*Condition Level* = 0).

pH

The *Significance Level* for pH was defined as a 2. Meiman (2012) reports that the TCEQ pH standard has only been exceeded four times in a period of 12 years. Meiman (2012) does caution, however, that many of the sites have less than 25 samples and must be interpreted with discretion. pH, therefore, is of no concern (*Condition Level* = 0).

Coliform Bacteria

The project team defined the *Significance Level* for coliform bacteria as a 3. The NPS (1999) baseline inventory reported that bacteria (*E. coli*) exceeded the state standard in 81% of the 6,735 measured observations. The presence of *E. coli*, most likely via the recycled wastewater, is extensive but expected. Coliform bacteria are currently of high concern (*Condition Level* = 3).

Total Suspended Solids (sediment)

The project team defined the *Significance Level* for total suspended sediment (TSS) as a 3. While TSS was not measured directly, turbidity measurements were recorded in the NPS (1999) study. Turbidity and TSS do not have a direct correlation but turbidity has been used to approximate TSS.

Cautiously using the NPS (1999) results, turbidity (as measured by Jackson Candle Units) exceeded the EPA water quality criteria in 40% of the tests (NPS 1999). Turbidity (as measured by Hach Turbidimeter) was found to exceed the EPA water quality criteria in 29% of the tests. However, these data are over a decade old and no more recent data are available from NPS or SARA sampling. Since total suspended solids do not seem to be recognized as a major issue by park or river managers, this measure is considered of low concern (*Condition Level* = 1).

Nutrients

The project team defined the *Significance Level* for nutrients as a 3. Nutrient levels are notoriously high (Meiman 2012) due to the intense urban environment and the input of recycled wastewater into the river. Many of the phosphorous and nitrate observations reported in Meiman (2012) exceeded the TCEQ “screening level”. Therefore, nutrients are of high concern (*Condition Level* = 3).

Sulfate

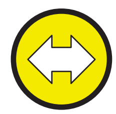
The project team defined the *Significance Level* for sulfate as a 2. Sulfate exceeded EPA standards in only 6% of the observations in the NPS (1999) document. Meiman (2012) also identified sulfates as exceeding standards only rarely. As a result, sulfates are of low concern (*Condition Level* = 1).

Chloride

The project team defined the *Significance Level* for chloride as a 2. Chloride exceeded EPA standards in only 1% of the observations in the NPS (1999) document. Meiman (2012) also identified chloride as exceeding standards only rarely. Therefore, chloride is of low concern (*Condition Level* = 1).

Weighted Condition Score

The *Weighted Condition Score* for water quality in SAAN is 0.44. This score indicates that water quality, while stable in recent years, still warrants moderate concern.

Water Quality			
Measures	Significance Level	Condition Level	WCS = 0.44
Water Temperature	2	1	
TDS (SpC)	2	1	
Dissolved Oxygen	3	0	
pH	2	0	
Coliform Bacteria	3	3	
TSS (Turbidity)	3	1	
Nutrients	3	3	
Sulfate	2	1	
Chloride	2	1	

4.10.6 Sources of Expertise

Joe Meiman, NPS Hydrologist, Gulf Coast Region

4.10.7 Literature Cited

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4.11 Air Quality

4.11.1 Description

Air pollution can significantly affect natural resources and their associated ecological processes. Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act, the Clean Air Act of 1977 (CAA) and the CAA's subsequent amendments. The CAA defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels (EPA 2013a). For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allow for moderate development (EPA 2013a). SAAN is designated as a Class II airshed.

Photo 22. Gas flaring at the Calumet Refinery next to Acequia Park, south of Espada Dam (Photo by Shannon Amberg, SMUMN GSS, 2013)

Parks designated as Class I and II airsheds typically use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. The EPA believes these standards, if not exceeded, protect human health and the health of natural resources (EPA 2013a). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2013a). However, the EPA acknowledges that the current NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone, nitrogen, and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010, EPA 2011a). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008).

4.11.2 Measures

- Nitrogen deposition
- Sulfate deposition
- Ozone concentration
- Particulate matter ($PM_{2.5}$)
- Visibility

<u>Atmospheric Deposition of Nitrogen and Sulfur</u>

Nitrogen and sulfur oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012a). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2012a, NPS 2008). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012a). Deposition of sulfur and nitrogen can have significant effects on ecosystems, including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water, and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b). The native vegetation in the semi-arid plant communities in SAAN is considered sensitive to excess nitrogen and acidic deposition (Sullivan et al. 2011c, 2011d).

Ozone

Ozone occurs naturally in the earth's atmosphere where, in the upper atmosphere, it protects the earth's surface against ultraviolet radiation (EPA 2012a). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone is also one of the most widespread pollutants affecting vegetation and human health in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth effects for sensitive plants in natural ecosystems (EPA 2012c, NPS 2008). Specific effects include reduced photosynthesis, premature leaf loss, and reduced biomass, and prolonged exposure can increase vulnerability to insects and diseases or other environmental stressors (NPS 2008). At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans, reduce lung function, cause acute respiratory problems, and increase susceptibility to respiratory infections (EPA 2012a, EPA 2012d, EPA 2013b); this could be a concern for visitors and staff engaging in aerobic activities in the park, such as walking the trails.

Particulate Matter (PM) and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets suspended in the atmosphere. Fine particles ($PM_{2.5}$) are those smaller than 2.5 micrometers in diameter (EPA 2009). Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2009, EPA 2013c). Fine particles are a major cause of reduced visibility (haze) in many national parks and wildernesses (EPA 2012a). $PM_{2.5}$ can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries, and/or vehicles react with air (EPA 2009, EPA 2012a). Particulate matter either absorbs or scatters light. As a result, the clarity, color, and distance that humans can see decreases. Water in the atmosphere causes particles like nitrates and sulfates to expand, increasing their light-scattering efficiency (EPA 2012a). $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2009, EPA 2012a, EPA 2013c). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation (EPA 2009, EPA 2012a, EPA 2013c).

4.11.3 Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 54) (NPS 2011). Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb) (an annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years). Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2011). Finally, NPS ARD recommends the following values for determining air quality condition (Table 54). The "good condition" metrics may be considered the reference condition for SAAN.

Table 54. National Park Service Air Resources Division air quality index values (NPS 2011).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Visibility (dv*)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

*a unit of visibility proportional to the logarithm of the atmospheric extinction (TCEQ 2012); one deciview represents the minimal perceptible change in visibility to the human eye.

4.11.4 Data and Methods

<u>Monitoring in the Park</u>

There is no active on-site monitoring of air quality parameters at SAAN (Segura et al. 2007).

<u>NPS Data Resources</u>

Although data on air quality parameters are not actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in SAAN. NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on data interpolations from all air quality monitoring stations operated by the NPS, the EPA, various states and other entities, averaged over the most recent five years (e.g., 2008-2012). These estimates are available from the Explore Air website (NPS 2014) and are used to evaluate air quality conditions. On-site or nearby data are needed for a statistically valid trends analysis, while a 5-year average interpolated estimate is preferred for the condition assessment.

<u>Other Air Quality Data Resources</u>

The National Atmospheric Deposition Program–National Trends Network (NADP) database provides annual average summary data for nitrogen and sulfur concentration and deposition across Texas. The nearest NADP monitoring site (TX16) is located in Edwards County, Texas, approximately 130 km (80 mi) northwest of SAAN. The site has actively collected data from 1984 through 2012. However, this distance from SAAN makes it difficult to extrapolate conditions accurately; thus, data from this monitoring station were not considered in this assessment.

The EPA Air Trends Database provides annual average summary data for ozone concentrations near SAAN. Ozone concentrations are collected at the Pecan Valley monitoring site (ID 48-029-0055), approximately 8 km (5 mi) northeast of the northern portion of the park (Figure 50). Data are gathered by Dios Dado Environmental Ltd and reported to the TCEQ. Data are available from 1999 through August 2014 (TCEQ 2014a). Another monitoring location with long-term data is Calaveras Lake (ID 48-029-0059), located approximately 16 km (10 mi) east of the SAAN complex of properties and 23 km (14 mi) northwest of the town of Floresville (near the Rancho Unit; Figure 50). The site is operated by the TCEQ and has collected data from May 1998 through March 2014 (EPA 2014a). The Pecan Valley and Calaveras Lake monitoring sites also collect data on particulate matter concentrations ($PM_{2.5}$). Data collection began in 2007 at Pecan Valley and in 2008 at Calaveras Lake (TCEQ 2014b). Results from monitors located within 16 km (10 mi) from parks are generally considered to be representative of park conditions (Ellen Porter, NPS Air Resources Division Air Quality Specialist, phone communication, 25 October 2012). Data recorded at monitors beyond this distance from parks may represent regional conditions, but may not be representative of actual park conditions.

The Clean Air Status and Trends Network (CASTNet) provides summaries of the composition of nitrogen and sulfur deposition in various regions around the U.S. Similarly, the Interagency Monitoring of Protected Visual Environments Program (IMPROVE) actively monitors visibility conditions in Class I airsheds across the U.S. However, the nearest IMPROVE monitoring sites are located in Big Bend National Park, approximately 482 km (300 mi) west of SAAN, and in Houston, Texas, approximately 322 km (200 mi) east of SAAN. This distance and the variations in terrain make it difficult to extrapolate data accurately; thus, data from these monitoring stations were not considered in this assessment.

Special Air Quality Studies

Sullivan et al. (2011a) assessed the relative sensitivity of national parks to the potential effects of acidification caused by acidic atmospheric deposition from nitrogen and sulfur compounds. The relative risk for each park was assessed by examining three variables: the level of exposure to emissions and deposition of nitrogen and sulfur; inherent sensitivity of park ecosystems to acidifying compounds (N and/or S) from deposition; and level of mandated park protection against air pollution degradation (i.e., wilderness and Class I). The outcome was an overall risk assessment that estimates the relative risk of acidification impacts to park resources from atmospheric deposition of nitrogen and sulfur (Sullivan et al. 2011a). Using the same approach, Sullivan et al. (2011b) assessed the sensitivity of national parks to the effects of nutrient enrichment by atmospheric deposition of nitrogen. The outcome was an overall risk assessment that estimates the relative risk to park resources of nutrient enrichment from increased nitrogen deposition.

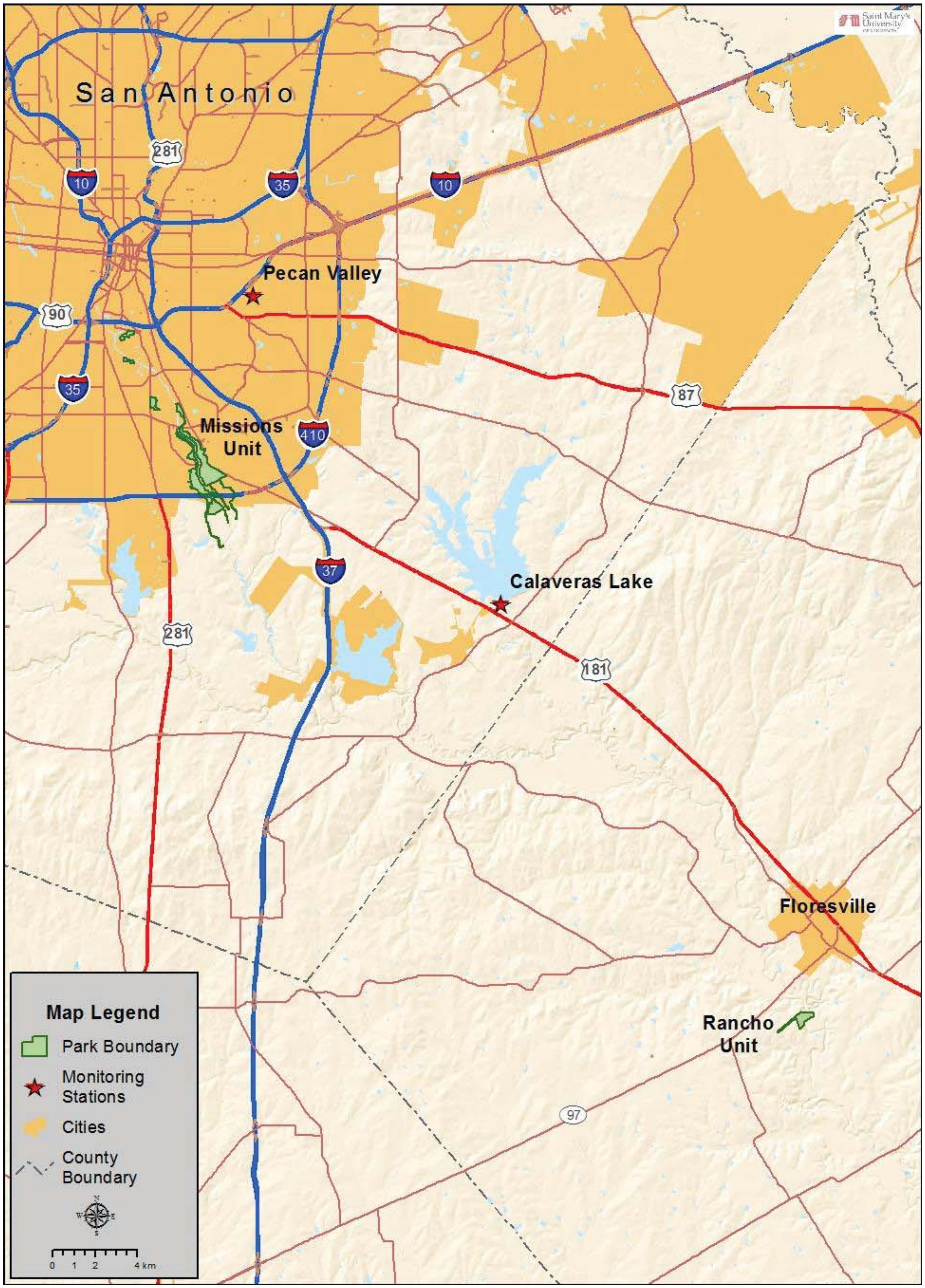

Figure 50. Locations of ozone and PM monitoring stations relative to the two SAAN park units.

4.11.5 Current Condition and Trend

Atmospheric Deposition of Nitrogen and Sulfur

Five-year interpolated averages of total nitrogen (from nitrate and ammonium) wet deposition and total sulfur (from sulfate) wet deposition are used to estimate condition for deposition; using a 5-year average smoothes out annual variations in precipitation, such as heavy precipitation one year versus drought conditions in another. The current 5-year average (2008-2012) estimates total wet deposition of nitrogen in SAAN at 3.3 kg/ha/yr, while total wet deposition of sulfur is 2.7 kg/ha/yr (NPS 2014). Relative to the NPS ratings for air quality conditions (see Table 54 for ratings values), atmospheric deposition of nitrogen falls under the *Significant Concern category* while sulfur is in the *Moderate Condition category*.

Relative risk of acidification and nutrient enrichment of ecosystems was assessed by examining exposure to nitrogen deposition and acidification, inherent sensitivity of park ecosystems, and mandates for park protection. Sullivan et al. (2011c) ranked SAAN as having moderate exposure to acidifying (nitrogen and sulfur) pollutants, low ecosystem sensitivity to acidification, and moderate park protection due to its Class II airshed status. The ranking of overall risk from acidification due to acid deposition was moderate relative to other parks (Sullivan et al. 2011c). In a separate examination, Sullivan et al. (2011d) used the same approach to assess the sensitivity of national parks to nutrient enrichment effects from atmospheric nitrogen deposition relative to other parks. SAAN was ranked as having moderate risk for nitrogen pollutant exposure, high ecosystem sensitivity, and moderate park protection mandates (Class II airshed). The ranking of overall risk of effects from nutrient enrichment from atmospheric nitrogen deposition was high relative to other parks (Sullivan et al. 2011d).

Ozone Concentration

The NAAQS standard for ground-level ozone is the benchmark for assessing current ozone conditions within park units. In 2008, the standard was strengthened from 80 ppb to 75 ppb, based on the annual fourth highest daily maximum 8-hour concentration, averaged over 3 years (EPA 2012b). The condition of ozone in NPS units is determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2011). The current 5-year average (from 2008-2012) for SAAN indicates an average ground-level ozone concentration of 72.3 ppb (NPS 2014), which falls under the *Moderate Condition* category based on NPS guidelines (NPS 2013).

Long-term data that characterize ozone concentrations within the park do not exist. However, ozone concentrations are monitored daily at the Pecan Valley and Calaveras Lake monitoring sites, approximately 8 km (5 mi) northeast and 16 km (10 mi) east of SAAN, respectively. Conditions in the northern, more urban sections of the park are likely closer to those at the Pecan Valley site, while conditions in the southern, suburban units may be similar to those at Calaveras Lake. The Rancho Unit is even further away from the city than the Calaveras Lake station, and therefore, ozone levels may be even lower at Rancho. Figure 51 illustrates the trend in annual fourth-highest daily maximum 8-hour values from 1999 to 2014 at Pecan Valley; these are presented with both the old and revised national standards to provide perspective on acceptable versus potentially harmful ozone conditions in the region. Since 2008, the fourth-highest daily maximum 8-hour value has approached or exceeded the new standard of 75 ppb three times.

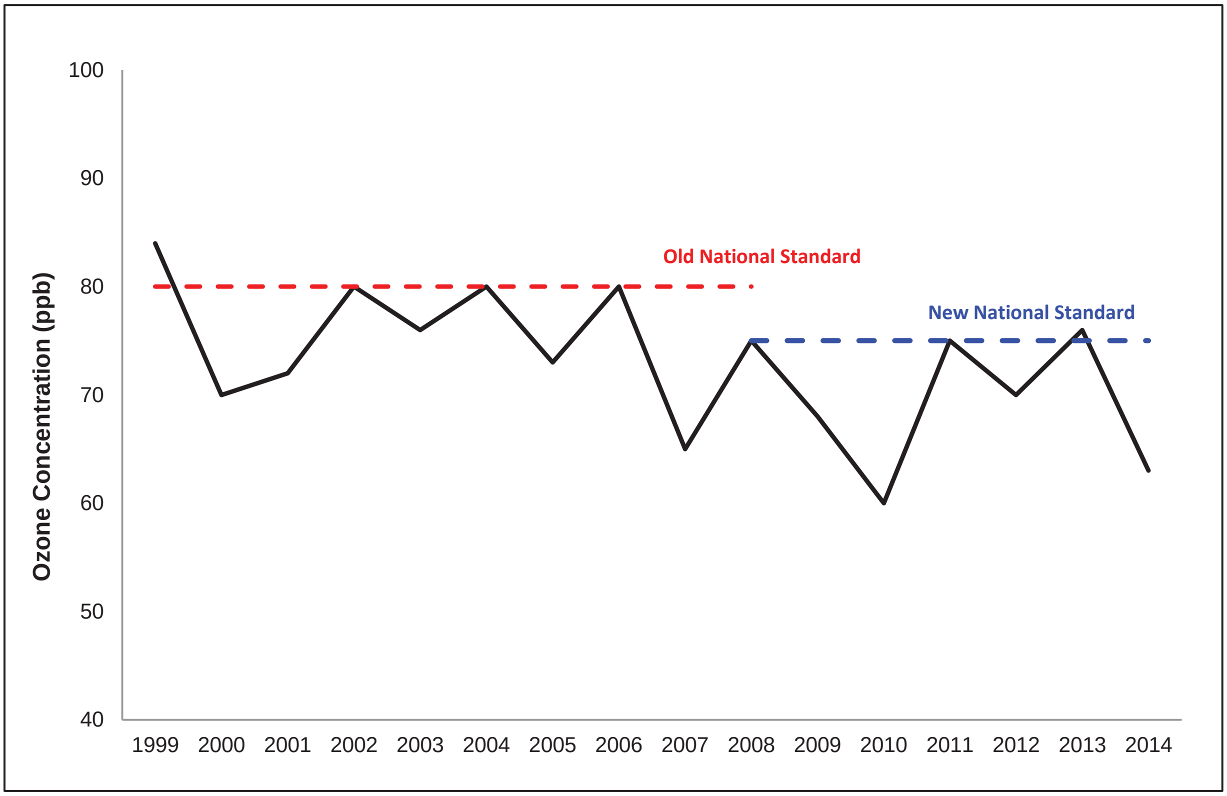

Figure 51. Annual 4th highest 8-hour maximum ozone (O_3) concentrations (ppb) at the Pecan Valley monitoring station (site 48-029-0055), 1999-2014 (TCEQ 2014a). Note: this site is located in San Antonio, Texas, approximately 8 km (5 mi) northeast of SAAN. Prior to 2008, the NAAQS ozone standard was 0.08 ppm (80 ppb) (shown in red); in March 2008, the standard was amended to 0.075 ppm (75 ppb) (shown in blue).

Figure 52 shows the trend in annual fourth-highest daily maximum 8-hour values from 1998 to 2013 at Pecan Valley. Measurements within the last 7 years appear to be well within the updated NAAQS standard considered to be protective of human health.

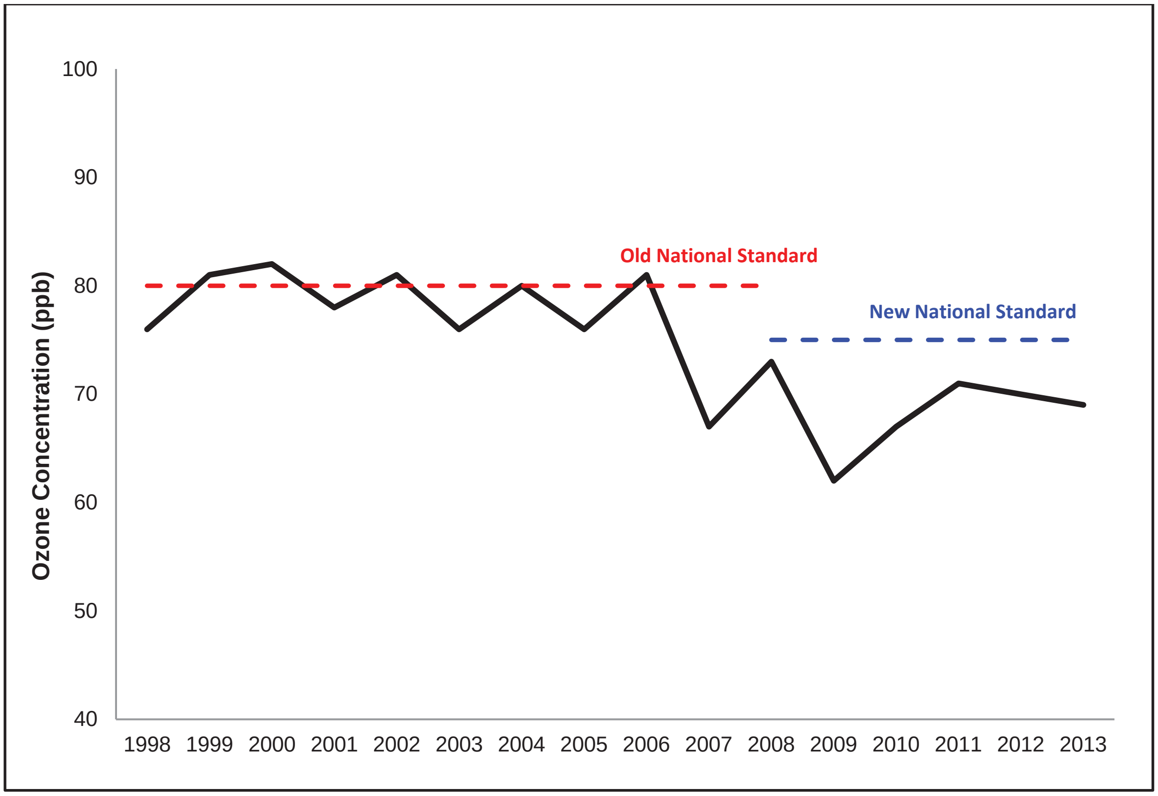

Figure 52. Annual 4th highest 8-hour maximum ozone (O_3) concentrations (ppb) at the Calaveras Lake monitoring station (site 48-029-0059), 1998-2013 (EPA 2014a). Note: this site is located southeast of San Antonio, Texas, approximately 16 km (10 mi) east of SAAN and northwest of Floresville (near the Rancho Unit). Prior to 2008, the NAAQS ozone standard was 0.08 ppm (80 ppb) (shown in red); in March 2008, the standard was amended to 0.075 ppm (75 ppb) (shown in blue).

Kohut (2004) assessed ozone concentrations in GULN and the risk of injury to plant species that are sensitive to sustained ozone exposure. Estimations by interpolation indicate that, from 1995-1999, ambient ozone concentrations around SAAN frequently exceeded 60 ppb each year and occasionally exceeded 80 ppb. Concentrations exceeded 100 ppb intermittently, although one year catalogued 30 hours above this threshold; at these levels, it is possible for vegetation to sustain injury. Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more); however, the levels of exposure experienced in SAAN are not likely to cause foliar damage (Kohut 2004). Overall, the risk of foliar injury from ozone is moderate due to frequent exposures to ozone greater than 80 ppb and occasional exposure to concentrations of 100 ppb (Kohut 2004). American elder (*Sambucus canadensis*), American sycamore (*Platanus occidentalis*), and redbud (*Cercis canadensis*) are identified as plant species in SAAN that are sensitive to elevated ozone levels, and which may be used as bioindicators for extended periods of elevated ozone concentrations (Kohut 2004).

Particulate Matter ($PM_{2.5}$)

The NAAQS standard for $PM_{2.5}$ is a weighted annual mean of 15.0 $\mu g/m^3$ or 35 $\mu g/m^3$ in a 24-hour period over an average of 3 years (EPA 2012b). Particulate matter concentrations collected at the Pecan Valley and Calaveras Lake monitoring sites are presented in Figure 53 and Figure 54, respectively. Weighted annual average $PM_{2.5}$ concentrations in the SAAN region have been relatively stable since monitoring began at the sites, fluctuating between 7.75 and 9.5 $\mu g/m^3$ at Calaveras Lake, and 9.0 and 10.5 $\mu g/m^3$ at Pecan Valley. All measurements are well within the EPA standards for levels that are protective of human health; concentrations on the haziest days contribute to occasional impaired visibility in the park.

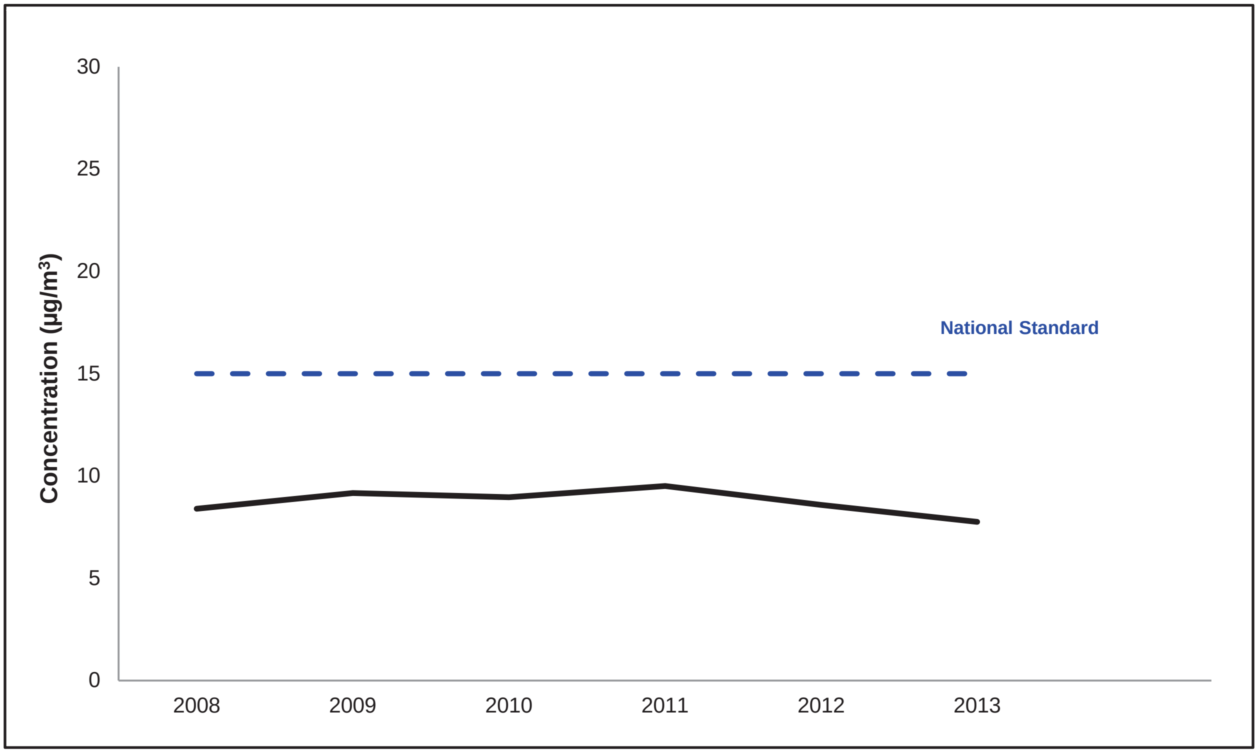

Figure 53. Annual particulate matter ($PM_{2.5}$) concentrations (weighted annual mean) at Pecan Valley (site 48-029-0055), 2007 - August 2014 (TCEQ 2014b). Note: this site is located in San Antonio, Texas, approximately 8 km (5 mi) northeast of SAAN.

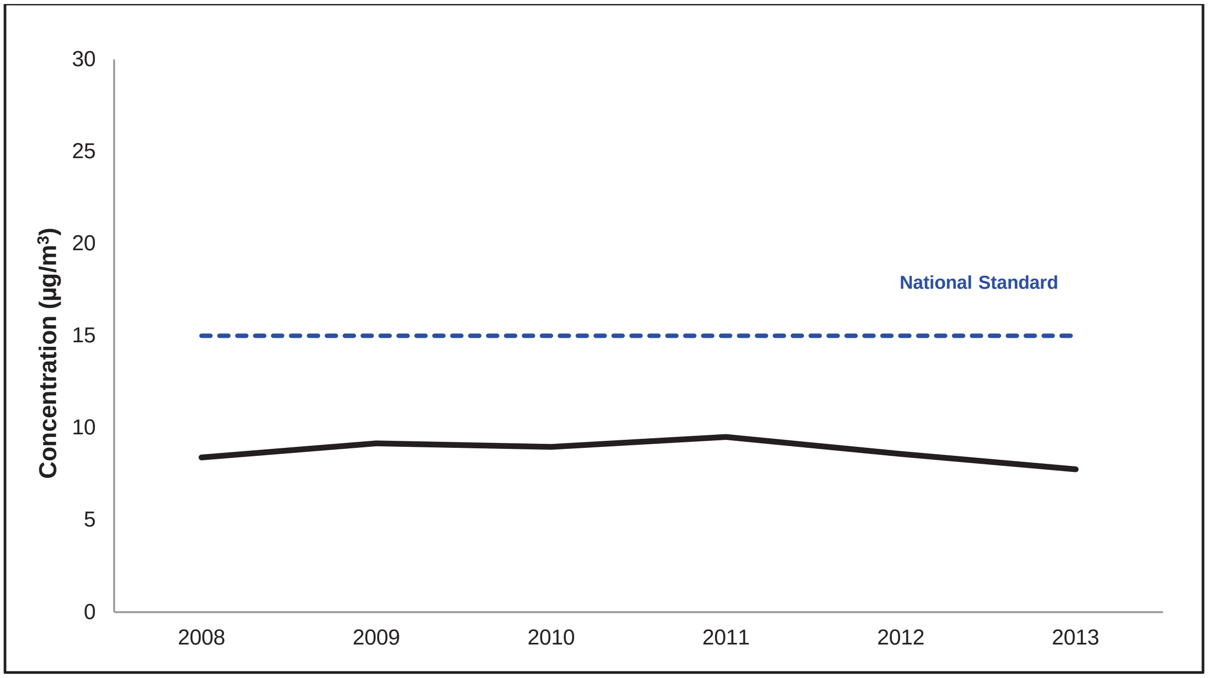

Figure 54. Annual particulate matter ($PM_{2.5}$) concentrations (weighted annual mean) near SAAN, 2008-2013 (EPA 2014a). Note: Calaveras Lake monitoring site (ID 48-029-0059) is located approximately 16 km (10 mi) east of SAAN.

Visibility

Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called "light extinction," which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the CAA of 1977, federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I airsheds. The goals of the program are to 1) establish current visibility conditions in Class I airsheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2010, NPS 2013).

The most current 5-year average (2008-2012) estimates average visibility in SAAN to be 8.8 dv above average natural visibility conditions (NPS 2013, NPS 2014). This falls into the *Significant Concern* category for NPS air quality condition assessment (NPS 2013).

The clearest and haziest 20% of days each year are also examined for parks (NPS 2014), as these are the measures used by states and EPA to assess progress towards meeting the national visibility goal. Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier. The most current 5-year average (2008-2012) estimates visibility at SAAN at 8.6 dv on the 20% clearest days and 19.8 dv on the 20% haziest days (NPS 2014). Even on the 20% clearest days, visibility still falls into the significant concern category.

Threats and Stressor Factors

Park managers have identified a number of threats and stressors to air quality in SAAN, including land use activities within and adjacent to the park (particularly emissions from development and gas flaring from nearby refineries), vehicle emissions from nearby highway/roads (SAAN is an urban park), and smoke from grassland fires in and around the park.

Nitrogen deposition results from nitrogen oxides in vehicle emissions, power plants, and other combustion sources, and ammonia from agricultural activities and fires. In ecosystems adapted to naturally low amounts of nitrogen (such as semi-arid systems and grasslands), increased nitrogen deposition can alter plant communities and reduce diversity (Sullivan 2011b). Higher nitrogen levels favor certain plant species, like fast-growing invasive species, at the expense of native forbs and shrubs (Sullivan 2011b). Sulfur emissions and particulate matter often originate from such sources as coal-fired power plants, petroleum refining, and chemical processing operations, many of which are located in central, southern and coastal Texas, as well as northern Mexico. Prevailing seasonal winds may carry these emissions into SAAN.

Oil and gas development in the Eagle Ford Shale, which includes the southern portion of Wilson County (where the Rancho Unit is located), is a potential threat to the area's air quality. Production and exploration produce nitrogen oxides and VOCs, which are precursors to ozone (AACOG 2013). A trend analysis conducted by the Alamo Area Council of Governments (AACOG) predicts that VOC emissions from the Eagle Ford Shale will double between 2012 and 2023 (AACOG 2013).

According to the EPA and IPCC, global climate change is expected to negatively affect air quality (EPA 2011b). Both ozone and particulate pollution are heavily influenced by weather shifts. The EPA projects that climate change could increase summertime average ground-level ozone concentrations in many areas by 2-8 ppb. It could also cause particulate pollution to increase in some regions and decrease in others (EPA 2011b).

Data Needs/Gaps

Monitors located at Pecan Valley and Calaveras Lake provide data on particulate matter and ozone concentration as both daily and annual average summaries for the region; these monitors are near enough to SAAN to be considered representative of the conditions in the Missions Unit of the park. However, Calaveras Lake (23 km northwest of Floresville) may not be close enough to the Rancho Unit, which is south of Floresville, to accurately represent conditions there (see Figure 52). The nearest active NADP monitor that provides annual averages for nitrogen and sulfur deposition is located in Edwards County, Texas, approximately 130 km (80 mi) northwest of SAAN. Finally, the nearest CASTNet and IMPROVE sites, which monitor acid deposition and visibility respectively, are located in Big Bend National Park, approximately 482 km (300 mi) west of SAAN and in Houston, Texas, approximately 322 km (200 mi) east of SAAN. Monitoring of nitrogen and sulfur deposition and visibility in or near both units of the park would help managers better understand the local air quality conditions in and around SAAN.

Overall Condition

Nitrogen Deposition

The *Significance Level* for atmospheric deposition of nitrogen was defined as a 2. Current NPS interpolated averages for nitrogen deposition are considered to be of significant concern (NPS 2014) based on NPS criteria for rating air quality when factoring in the sensitivity of the ecosystem.

Likewise, Sullivan et al. (2011b, 2011d) rate SAAN as having moderate risk for pollutant exposure and high ecosystem sensitivity, with an overall high risk of nutrient enrichment relative to other parks. Deposition of nitrogen is of high concern in SAAN (*Condition Level* = 3).

Sulfate Deposition

The *Significance Level* for atmospheric deposition of sulfate was defined as a 2. Current NPS interpolated averages for sulfate deposition are considered to be of moderate condition (NPS 2014) based on NPS criteria for rating air quality when factoring in the sensitivity of the ecosystem. Sullivan et al. (2011a, 2011c) rate SAAN as having moderate exposure to acidifying pollutants, low ecosystem sensitivity to acidification, and moderate park protection against pollution. The overall risk due to acid deposition was categorized as moderate relative to other parks. Deposition of sulfate is of moderate concern in SAAN (*Condition Level* = 2).

Ozone Concentration

The *Significance Level* for ozone concentration was defined as a 3. Current average ground-level ozone concentrations fall into the moderate condition category based on NPS criteria for rating air quality condition. Annual 4^{th} highest 8-hour maximum concentrations (1998 through 2014) suggest a declining trend since the mid-2000s, but with fluctuations between 60 and 76 ppb at Pecan Valley and 65 and 72 ppb at Calaveras Lake in the last six years. All measurements at Calaveras Lake are within EPA standards protective of human health, while this standard has been matched or exceeded three times at Pecan Valley since 2008. Kohut (2004) suggests the risk of foliar injury from ozone is moderate for the park. However, it should be noted that the EPA is currently reviewing the NAAQS ground-level ozone standard and may suggest a stricter standard between 60-70 ppb (EPA 2014b). If a stricter standard is enacted, much of the SAAN region would be in “nonattainment” (i.e., not meeting the federal air quality standard). Therefore, the *Condition Level* for ozone concentration is a 3, of high concern.

Particulate Matter Concentration ($PM_{2.5}$)

The *Significance Level* for concentration of fine particulate matter ($PM_{2.5}$) was defined as a 3. Average $PM_{2.5}$ concentrations near SAAN have been relatively stable over the last 5 years and are well within the EPA standards for levels that are protective of human health. The *Condition Level* for $PM_{2.5}$ is a 1, of low concern.

Visibility

The *Significance Level* for visibility was defined as a 2. Current interpolated average visibility estimates for SAAN fall into the significant concern category based on NPS criteria. However, no data are collected at the park, and the nearest visibility monitor is over 482 km (300 miles) west of the park; this makes it difficult to determine average conditions or trends in visibility conditions in SAAN. The *Condition Level* for visibility could not be determined.

Weighted Condition Score

The *Weighted Condition Score* (WCS) for the air quality component is 0.73, indicating the condition warrants high concern; this condition is assigned with a moderate level of confidence. Air quality is considered a vital sign for SAAN and, although it is not monitored directly in the park, air quality information is interpolated from regional air monitors and parameters are estimated for SAAN on a yearly basis. No trend was determined based on limited long-term data for air quality in the region and at the park specifically. This condition designation is more representative of the Missions Unit of the park and may not fully reflect conditions at the Rancho Unit, which is further from air quality monitoring stations and from the urban area of San Antonio, where air quality is possibly less degraded.

Air Quality			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.73**
Nitrogen Deposition	2	3	
Sulfate Deposition	2	2	
Ozone Concentration	3	3	
Particulate Matter	3	1	
Visibility	2	n/a	

4.11.6 Sources of Expertise

Ellen Porter, Biologist, NPS Air Resources Division

Greg Mitchell, SAAN Natural Resources Program Manager

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4.12 Soundscape

4.12.1 Description

The definition of soundscape in a national park is the total ambient sound level of the park, comprised of both natural ambient sound and human-made sounds (NPS 2000). The NPS's mission is to preserve natural resources, including natural soundscapes, associated with the national park units. Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (NPS 2000). In addition, traffic or other human-caused noise sources can interrupt interpretive programs being held within a park. According to a survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery (NPS 2000).

Photo 23. Church at Mission San Juan (NPS photo).

Noise not only affects visitor experience, it can also alter the behavior of wildlife. Repeated noise can cause chronic stress to animals, possibly affecting their energy use, reproductive success, and long-term survival (Radle 2007). Many factors affect how visitors and wildlife perceive and respond to noise. Primary acoustical factors include the loudness, frequency (i.e., pitch), and duration of the noise. Non-acoustical factors, such as climate, vegetation, topography, and individual hearing sensitivity also play a role in how visitors and wildlife respond to noise (NPS 2014).

SAAN has a very unique soundscape due to the urban location of most of the park and the rapid expansion of San Antonio. Because SAAN is a historical park representing the Missions Period, some anthropogenic sounds are expected (e.g., conversations, tolling bells, and other noises associated with mission life). However, the Missions Unit has become surrounded by sounds from the city that would not have occurred during the Missions Period. These are considered "non-contributing" sounds, as they do not contribute to the historical experience at the park. The non-contributing sounds of traffic, airplanes, and trains can be heard almost constantly at the Missions Unit and have become a large part of the park's unique soundscape. These sounds are less prevalent but still heard occasionally at the more rural Rancho Unit southeast of San Antonio.

4.12.2 Measures

- Loudness of non-contributing human-caused sound
- Frequency of non-contributing human-caused sound

- Percent of time non-contributing human-caused sound is audible

4.12.3 Reference Conditions/Values

The ideal reference condition for soundscape at SAAN would be a sound environment similar to at the time of the active Missions period (might be helpful to provide a range of years that this period spanned). However, given the urban development that has occurred around SAAN since that time, this goal is no longer feasible. For the purpose of this assessment, the reference condition for loudness will be that non-contributing human-caused sounds do not exceed 52 dBA, which is the level that interferes with speech and would interrupt interpretive programs (EPA 1974; Table 14). For the percent of time non-contributing sound is audible, the reference condition will be no further increase over baseline levels documented in Lynch (2009) for the Missions Unit; since no baseline data has been gathered at the Rancho Unit, baseline levels are currently unknown. No reference condition has been established for frequency.

Table 14. Explanation of sound level values, for reference (Lynch 2009).

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008) Also, ANSI standard for sound level in classrooms without people (ASA 2008)
45	World Health Organization’s recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (EPA 1974)
60	Speech interruption for normal conversation (EPA 1974)

4.12.4 Data and Methods

Lynch (2009) conducted a noise and vibration study at the Tufa House at Mission San Juan in SAAN in 2008 (Photo 24, Figure 55). Lynch (2009) collected sound level data for 27 days using a Larson Davis 831 sound level meter (SLM). The Larson Davis 831 SLM is a real-time data analyzer that records sound pressure levels and exports the data to external storage devices; the SLM station at SAAN included a microphone with environmental shroud, a preamplifier, 10 12-volt lantern cell batteries, an anemometer, an MP3 recorder, and a meteorological data logger (Lynch 2009). Data collected by the SLM included sound pressure level (SPL) data in the form of A-weighted decibel readings (dBA), continuous digital audio recordings, and one-third octave band

Photo 24. Sound monitoring equipment at Tufa House (NPS photo).

data ranging from 12.5 Hz to 20,000 Hz. In addition to the SLM station, researchers also listened to a subset of recordings to identify the sources of sounds and their durations (Lynch 2009).

Kimley-Horn and Associates (2013) updated the Stinson Municipal Airport's master plan. The Stinson Municipal Airport is located to the west of SAAN (Figure 55). The master plan update included an inventory of facilities and services, aviation activity forecast, demand/capacity analysis and facility requirements, alternatives development, environmental review, financial plan, and a set of drawings for the airport layout plan. The activity forecast extends to 2031.

No information is available regarding soundscape at the Rancho Unit. Therefore, the following condition sections will apply only to the Missions Unit.

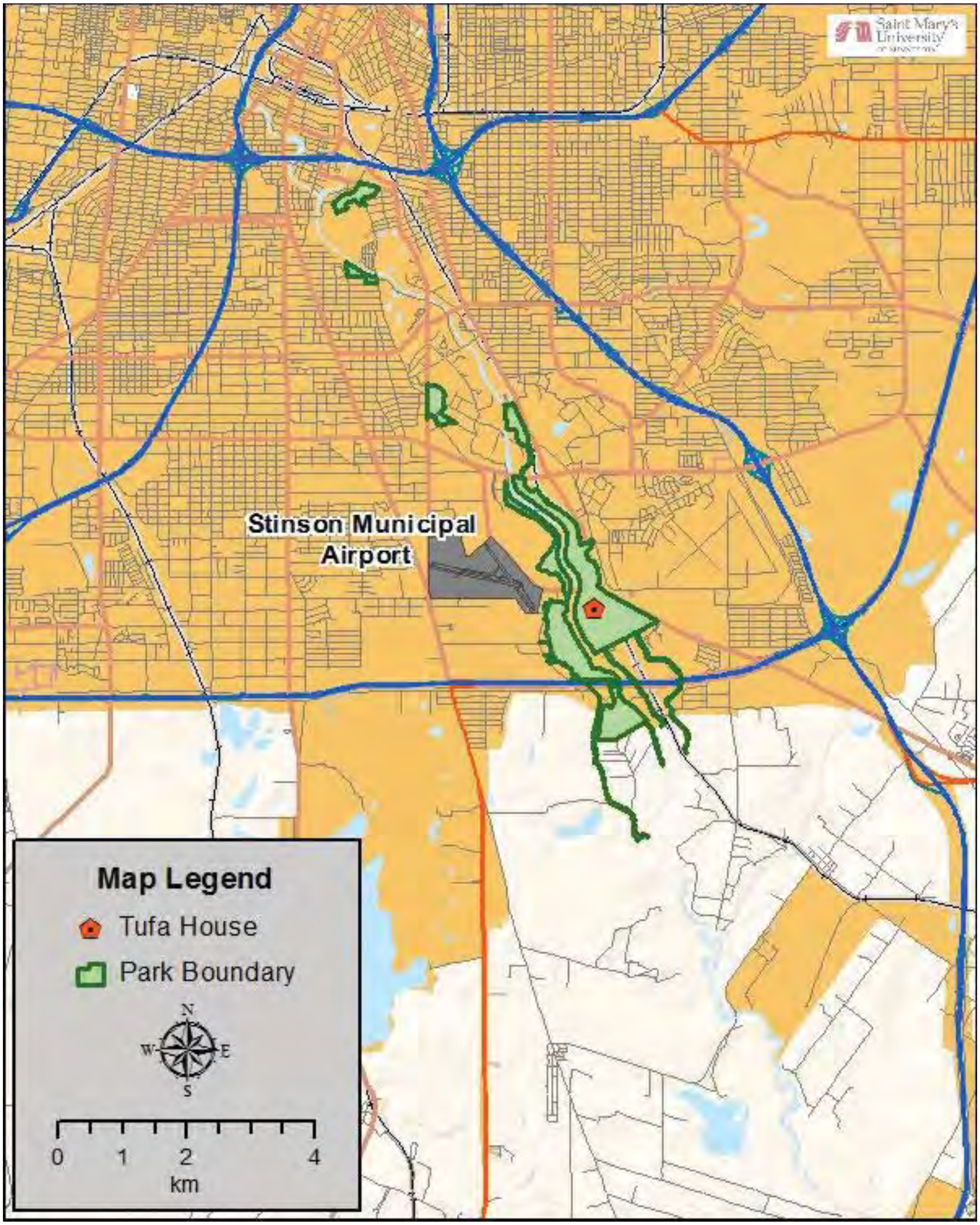


Figure 55. The location of Tufa House (Mission San Juan) within SAAN, and the Stinson Municipal Airport.

4.12.5 Current Condition and Trend

Loudness of Non-contributing Human-caused Sound

Lynch (2009) documented the percent exceedances for four sound levels (35 dBA, 45 dBA, 52 dBA, and 60 dBA) at the Tufa House site in SAAN. Sound levels at this site exceeded 35 dBA 100% of the time during both the daytime and the nighttime (7:00 PM to 6:59 AM) periods. Sound levels exceeded 52 dBA 25.7% of the time during the daytime, and 8.2% during the night time (Table 56).

Table 56. Percent time sound exceeds the given dBA level (Lynch 2009).

	% Exceedence nighttime (7pm - 6:59 am)				**% Exceedence daytime (7am - 6:59 pm)**			
Site Name	**35 dBA**	**45 dBA**	**52 dBA**	**60 dBA**	**35 dBA**	**45 dBA**	**52 dBA**	**60 dBA**
Tufa House	100.0	60.1	8.2	1.0	100.0	93.4	25.7	2.8

Frequency of Non-contributing Human-caused Sound

The frequency of sounds, typically measured in hertz (Hz), can influence the perceived loudness of a sound; some frequencies that occur are inaudible to humans. Most unnatural human-caused sounds range in frequencies from 100 Hz to 1,000 Hz, as seen in Figure 56. At SAAN, lower frequency noises are typically louder (i.e., higher sound levels in dB). Not enough data have been collected to establish a mean frequency of non-contributing human-caused sounds.

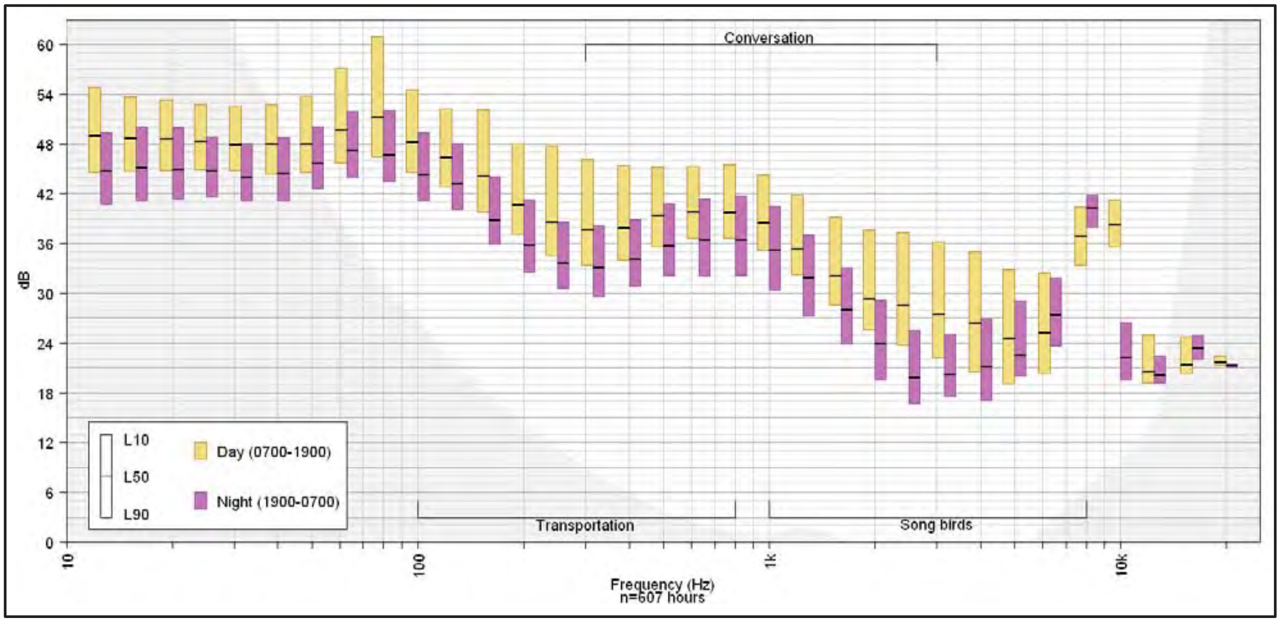


Figure 56. Day and night dBA measurements by frequency for 27 days at SAAN's Tufa House sampling site. Gray shaded areas represent sound levels typically outside the range of human hearing (Lynch 2009).

Percent of Time Non-contributing Human-caused Sound is Audible

Lynch (2009) documented the number of times a sound source was heard and the percent of time that source was audible at SAAN over 27 days. The most frequent sources of sound were aircrafts, people, vehicles, and grounds care (Table 57). The sounds from people and aircraft activity occurred most often, with 103 counts over the study period. Vehicle noise was counted 75 times and grounds care noise counted 55 times. Vehicle noise occurred approximately 86% of the time, aircraft propellers were heard 30% of the time, grounds care 18%, and people 10% of the time. Non- natural sound sources, as a whole, were audible 99.4% of the time. Table 57 displays the summary of sound sources and the frequency count during an audible survey in SAAN.

Table 57. Summary of sound sources identified during on site audible surveys in SAAN (Lynch 2009). SD = standard deviation.

Sound Source	Percent Time Audible	Max Event Length (seconds)	Mean Event Length (seconds)	Min Event Length (seconds)	SD Event Length (seconds)	Count
Aircraft	0	26	26	26	1	
Jet	1	45	27	6	14	7
Aircraft, Propeller	30	230	53	4	47	103
Helicopter	3	176	60	2	55	8
Vehicle	86	1,372	207	3	294	75
Alarm, Horn	1	14	3	0	3	45
Brakes	0	4	1	0	1	27
Siren	2	110	72	32	30	5
Motorcycle	2	93	36	3	38	9
Bus (capacity > 9 people)	1	57	23	3	25	5
Truck (6+ tires)	3	64	15	2	13	31
Train	1	102	102	102	1	
Train Horn	0	10	9	6	2	3
Grounds Care	18	794	59	2	135	55
People	10	153	18	0	26	103
Interpretive Talk	0	38	38	38	1	
Non-natural Other	2	85	11	1	16	36
All Aircraft	33.4					
All Road Vehicles	87.9					
All Non-natural Sources	99.4					

Lynch (2009) recorded 17 human-caused sound sources from five on-site audible survey sessions in SAAN. The three human sources that had the longest duration were vehicles, grounds care, and aircraft propellers. The noise from vehicles had the longest maximum length of 1,372 seconds (nearly 23 minutes); however, vehicle sounds could also be as short in duration as 3 seconds. Grounds care could last anywhere from 794 seconds (13.2 minutes) to only 2 seconds. Aircraft propellers were similar in duration, ranging from 4 seconds to 230 seconds (3.4 minutes). There were sources that had a constant duration length throughout the survey. Trains, interpretive talk, and aircrafts occurred for 26 seconds, 38 seconds, and 102 seconds, respectively. Table 57 displays the minimum, average, and maximum duration lengths of human-caused sound sources.

Kimley-Horn and Associates (2013) documented an activity forecast for Stinson Municipal Airport for a 20-year planning period that included peak monthly operations. Aircraft operations are estimated to increase in frequency from 14,900 operations per month in 2011 to 28,500 operations a month by the end of the 20-year planning period.

Threats and Stressor Factors

Due to the location of SAAN, there are many threats and stressors to the park's soundscape. The Stinson Municipal Airport (SSF) is a major threat to SAAN soundscape and is a concern to park managers seeking to preserve the natural atmosphere of SAAN. Aircraft noise also impacts visitor activities, as noise frequently interrupts interpretive programs at the Missions Unit in SAAN. The airport is located less than 3.2 km (2 mi) from the western border of SAAN. According to AirNav (2014), there was an average of 250 aircraft operations a day in 2013. Local general aviation was the most common operation, occurring 54% of the time; approximately 35%, 11%, and 1% were transient general aviation, military, and air taxi operations, respectively. The average maximum sound levels for all types of aircraft overflights exceed the reference condition of 52 dBA selected for this assessment (Table 58). The SSF plans on expanding the number of based aircrafts as well as the number of annual operations within the next 20 years. As of 2011, there were a total of 140,700 operations that occurred, and by 2031 the total annual operations are estimated to be 268,800 (Kimley-Horn and Associates 2013). This is nearly a doubling in activity over 20 years. In 2007, SSF applied to lengthen their runway by 1524 m. (5,000 ft.), a proposal which was later approved by the Texas Department of Transportation.

Table 58. Average maximum dB levels for aircraft overflights during Lynch's (2009) 27 day monitoring period.

Aircraft Type	Count	Average Max dB
Helicopter	18	69.3
Jet	89	59.2
Military Propeller	59	75.1
Propeller	1,294	60.8

There are three other airports in the city of San Antonio. The San Antonio International Airport (SAT) is the most utilized and could pose a threat, even though it is located approximately 15 km (9.32 mi) north of SAAN. Marrow et al. (2009) produced a Noise Compatibility Planning Study for SAT in 2009. Operations with sound levels at or higher than 65 dBA have been documented at the airport since 1990. According to Marrow et al. (2009), the number of yearly operations peaked in 1998 with over 270,000 operations. After 1998, the number of operations decreased to 223,501 operations a year, with an average of 612 operations a day. However, a 3% increase to 229,651 operations was predicted by 2014 (Marrow et al. 2009).

Due to the park's proximity to Route 122 and Interstate 410, vehicles are the most common human-caused sound (audible 86% of the time; Lynch 2009). Trains are also heard occasionally. Between the highway traffic and the almost non-stop air traffic, the typical noise free interval (NFI) at SAAN is very short. The mean NFI was 12 seconds, while the maximum was 46 seconds (Lynch 2009). These short NFIs suggest that SAAN is highly affected by human-caused noise; on average a visitor can go about 12 seconds without hearing unnatural human-caused sound (Lynch 2009).

<u>Data Needs/Gaps</u>

The acoustical monitoring study (Lynch 2009) was performed prior to the expansion of SSF; the National Sounds Program recommends that another monitoring system be deployed within 2 to 3 years of completion of the construction at SSF. Although the study was thorough, it was only conducted for 27 days at one location during April and May. There are no long-term sound data for SAAN, making it impossible to determine how much the soundscape has deteriorated over time. In addition there are no soundscape data at all for the Rancho Unit of the park. Given its more rural setting, soundscape conditions at this location are likely very different from those within the Missions Unit. A baseline survey should be conducted at the Rancho Unit as soon as possible to document conditions before they are further impacted by surrounding activities.

<u>Overall Condition</u>

Loudness of Non-contributing Human-caused Sound

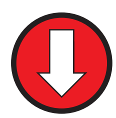
The project team assigned this measure a *Significance Level* of 3. Lynch (2009) suggested that the loudness of non-contributing human sounds is a concern at SAAN. Since there were no soundscape studies at SAAN prior to Lynch (2009), there is no baseline sound level to compare recent data to. For this assessment, a reference level of 52 dBA was selected, because noise at that level interferes with interpretive programs (EPA 1974). During Lynch's (2009) monitoring, sound level reached or exceeded 52 dBA 25.7% of the time, possibly causing functional effects on visitors. This gives reason for moderate concern (*Condition Level* = 2).

Frequency of Non-contributing Human-caused Sound

This measure was also assigned a *Significance Level* of 3. Due to the lack of data on frequency and any analysis of its influence on overall sound conditions at SAAN, a *Condition Level* could not be assigned. Further studies regarding frequency in hertz should be performed in order to get a proper condition level.

Percent of Time Non-contributing Human-caused Sound is Audible
The project team assigned this measure a *Significance Level* of 3. Lynch (2009) shows that human-caused noises could be heard in SAAN approximately 98.4% of the day. Although some human-caused sounds are culturally acceptable within SAAN's soundscape, the majority of these sounds are non-contributing. Noise from vehicles was heard 86% of the time and had a mean duration of 1,372 seconds. Aircraft were heard 30% of the time with duration ranging from 4 to 230 seconds. With non-contributing sounds being heard so often, there is high concern (*Condition Level* = 3) about their impact on the park's soundscape.

Weighted Condition Score (WCS)
The *Weighted Condition Score* for SAAN soundscape is 0.83. The overall condition for the Missions Unit is of significant concern and is likely deteriorating. This is due to the park's location within the city limits of San Antonio, which severely impacts the soundscape. Unfortunately, park staff have little control over the soundscape and its condition due to the park's geographic locale. The condition of soundscape at the Rancho Unit is unknown due to a lack of data.

Soundscape			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.83**
Loudness	3	2	
Frequency	3	n/a	
Percent of Time	3	3	

4.12.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resources Program Manager

4.12.7 Literature Cited

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4.13 Dark Night Skies

4.13.1 Description

A “lightscape” is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2007). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural processes such as plant phenology (NPS 2006, 2014a). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2014a). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

4.13.2 Measures

During site visits, the NPS Night Sky Team (NST) collects data for a suite of measures in order to define the current condition of dark night skies in a park unit. While the NST has not visited SAAN, the suite of measures that they would use on a visit includes:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second or milli-candela per square meter) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a “Johnson-Cousins V” filter. It is similar to the “CIE photopic” broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);
- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;
- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;
- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;
- Visual observations by a human observer, such as Bortle Class and Zenithal limiting magnitude;
- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter, in V magnitudes per square arc second;

4.13.3 Reference Conditions/Values

The reference condition for dark night skies in SAAN is defined as the night sky visibility as observed when the Missions were active.

The NST defines reference condition in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> *No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated the naturally dark zone (Dan Duriscoe, NPS Night Sky Team, pers. comm., 2011).*

Achieving this reference condition for preserving natural night skies is well summarized in the NPS Management Policies (2006, p. 57) as follows in section 4.10:

> *The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.*

Implementing this directive in SAAN requires that facilities within the park and local communities around the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;
- be of an intensity that meets the minimum requirement for the task but does not excessively exceed that requirement;
- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;
- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

4.13.4 Data and Methods

SAAN is a unique NPS unit because it is separated into two units (Missions, Rancho de las Cabras) located in two different geographical settings. The Missions Unit is located in the city of San Antonio. Since the Missions Unit is located within the San Antonio city limits, it is greatly affected by light pollution. The Missions closer to downtown (further north, e.g., Concepción) are more heavily impacted than those in more of a neighborhood setting (e.g., Espada). The Rancho de las Cabras Unit, which is comprised of historic ranch land for the Missions, is approximately 51.5 km (32 mi) south of the city of San Antonio and is less affected by light pollution than the Missions Unit. Unfortunately, no data have been collected by the NPS in SAAN related to dark night skies.

4.13.5 Current Condition and Trend

<u>Background for NPS Night Sky Team's Suite of Measures</u>

While no data have been collected in SAAN, it is important to recognize that anthropogenic light in the night environment can be significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a "detector" or a measuring device, or entering the observer's pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English). It is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen / m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith are much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified.

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as "sky glow". This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional. When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a "full cutoff" design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 57 and Figure 58, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NST.

Figure 57. Grayscale representation of sky luminance from a location in Joshua Tree National Park, California (Figure provided by Dan Duriscoe, NPS Night Sky Team).

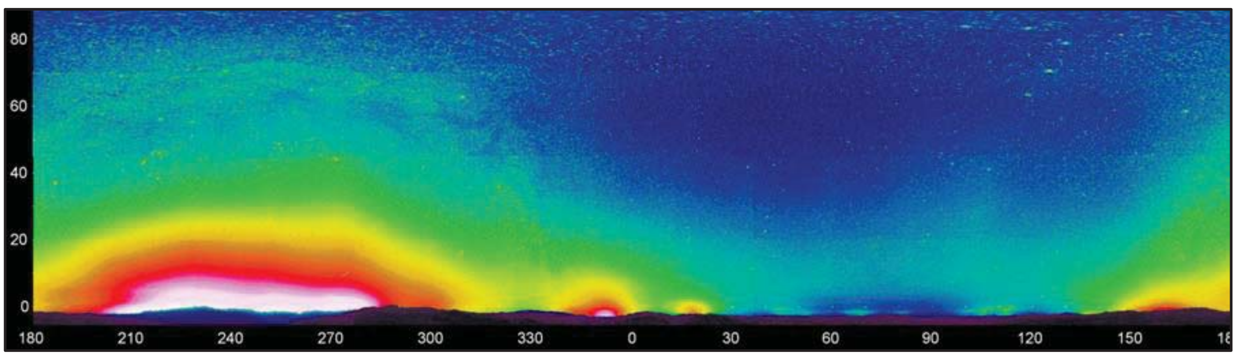

Figure 58. False color representation of Figure 56 after a logarithmic stretch of pixel values (Figure provided by Dan Duriscoe, NPS Night Sky Team).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NST utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 57 and Figure 58 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called “permanent aurora” which varies in intensity over time) (Roach and Gordon 1973). The NST has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 59). Figure 58 represents “total sky brightness” while Figure 59 displays “anthropogenic sky glow” or “net light pollution.” This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

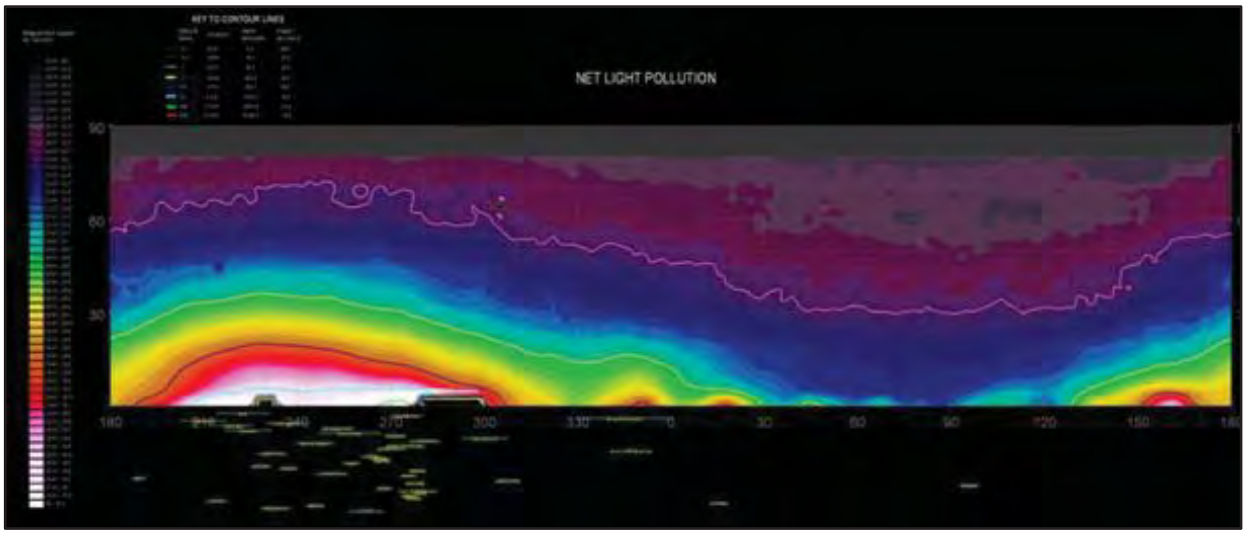

Figure 59. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 58 with natural sources of light subtracted (Figure provided by Dan Duriscoe, NPS Night Sky Team).

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric of the resource condition - a ratio of anthropogenic to natural light. Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2008). This so-called “light pollution ratio” is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NST data, the atmospheric conditions determined from each individual data set.

The reference conditions for anthropogenic sky luminance were identified as no more than 200 percent brighter than natural conditions in *any* area of the sky and no more than 10 percent brighter at the Zenith. These values correspond to light pollution ratios of 2.0 and 0.1, respectively. The NST has obtained values of 50-100 for this measure at the core of city light domes seen from several areas administered by the NPS, including Lake Mead National Recreation Area, Saguaro National Park, and Colorado National Monument (NPS Night Sky Team, unpublished data). This is because these NPS areas are very close to the cities of Las Vegas, Nevada; Tucson, Arizona; and Grand Junction, Colorado, respectively.

A quick and accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron Sky Quality Meter. The Unihedron Sky Quality Meter is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Because the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NST produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron Sky Quality Meter. The performance of the Sky Quality Meter has been tested and reviewed by Cinzano (2005). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered "pristine", providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken.

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a "pristine sky" filled with easily observable features and class 9 represents an "inner city sky" where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

Another visual method for assessing sky quality is Zenithal Limiting Magnitude (ZLM), which is the apparent brightness or magnitude of the faintest star observable to the unaided human eye, which usually occurs near the Zenith. This method involves many factors, the most important of which is variability from observer to observer. A ZLM of 7.0-7.2 is usually considered "pristine" or representing what should be observed under natural conditions; observation of ZLM is one of the factors included in the Bortle Dark Sky Scale. Zenith Limiting Magnitude is often referenced in literature on the quality of the night sky, and is the basis for the international "Globe at Night" citizen-scientist program (see http://www.globeatnight.org/index.html). The NST has experimented with the use of this observation in predicting sky quality, and has found that it is a much coarser measure and prone to much greater error than accurate photometric measures over the entire sky. For these reasons, it is not included in the reference conditions section.

Threats and Stressor Factors

Situated in close proximity to a major urban area (San Antonio, Texas), the Missions Unit of SAAN is subjected to high levels of anthropogenic light pollution. This light pollution comes from human developments on the land surrounding the park, and areas further away from the park (downtown San Antonio, Texas) also contribute light pollution. Many businesses have unobstructed lights that are orientated upwards, and these lights remain on even when the business's operating hours have passed. The Rancho de las Cabras Unit is located in a rural area and is subjected to lower levels of light pollution. Lorenz (2006) and Danko (2014) recreated a light pollution map that displays the level of light pollution occurring in San Antonio and surrounding areas (Figure 60). The Missions Unit is located in several levels of light pollution ranging from five to eight on the Bortle Scale, which means the dark night sky is moderately to heavily impaired. The Rancho de las Cabras Unit is located in an area of moderate light pollution.

The park's urban location also results in high levels of traffic passing by the site, and at night the lights from passing vehicles contribute to light pollution. Transportation infrastructure (i.e., street lights) has increased in size in the past decade, most notably the lights along Texas State Highway 410, which runs through the southern portion of the Missions Unit.

Refinery flaring is another source of light pollution and threat to dark night skies in SAAN, especially at the Missions Unit as two refineries are located within a mile of park boundaries. Figure 61 displays the location of the nearest refineries in relation to SAAN. Blinking lights on cell towers are also a source of light pollution affecting dark night skies.

Air pollution from the city of San Antonio may adversely affect the dark night skies in SAAN. According to NPS (2014b), light pollution is scattered more when air quality is poor, which results in brighter skies near sources of light.

Data Needs/Gaps

There has been no collection of dark night skies baseline data at SAAN. Without these data, an assessment of the condition of the night skies cannot be completed. A visit from the NST would allow for measurements of the entire sky brightness condition. Measurements should occur on a periodic basis, about once every 5 years, with the highest point in the park serving as the preferred observing site, in order to track external threats.

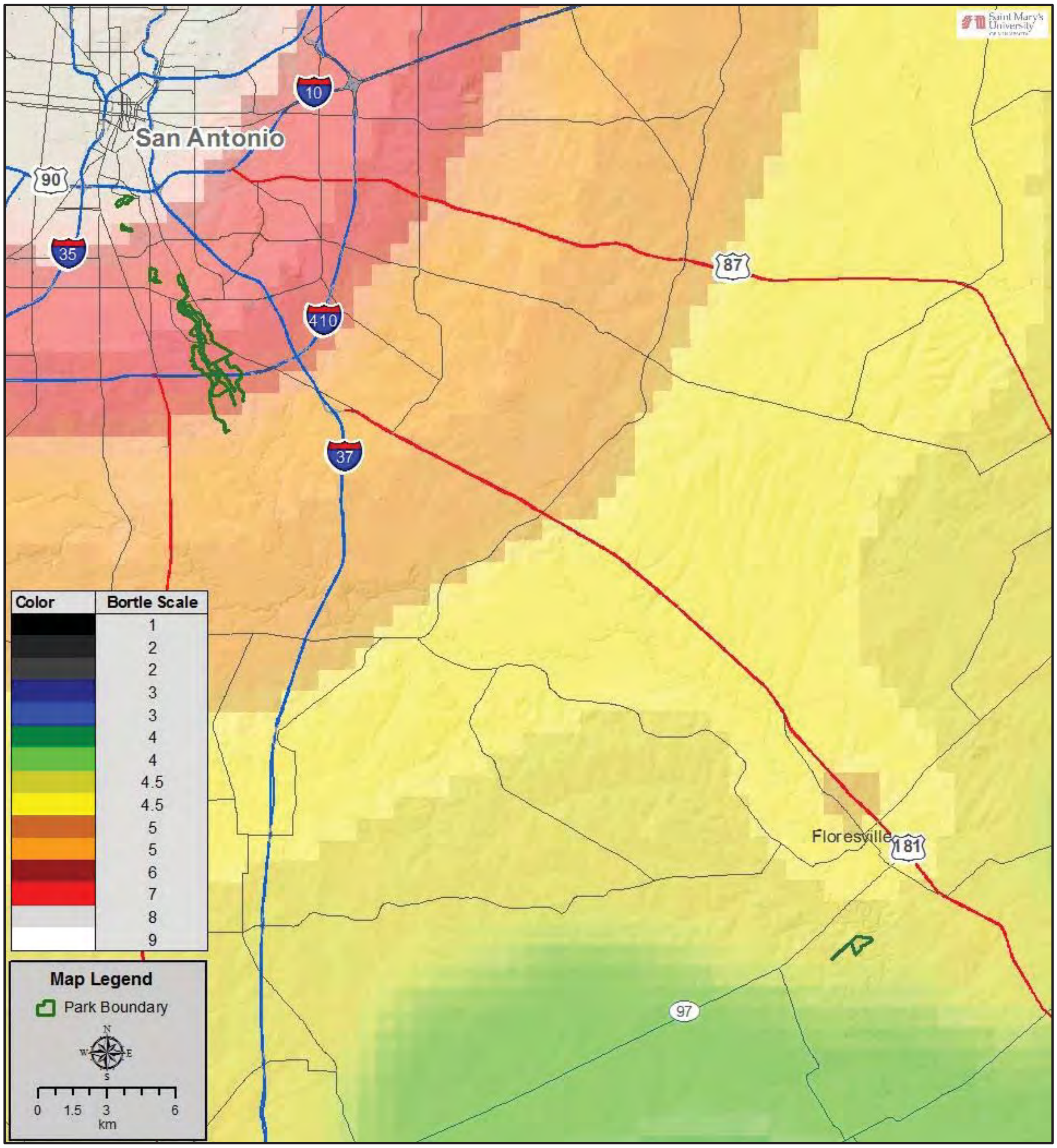

Figure 60. Levels of light pollution occurring in San Antonio and surrounding areas (Lorenz 2006; Danko 2014).

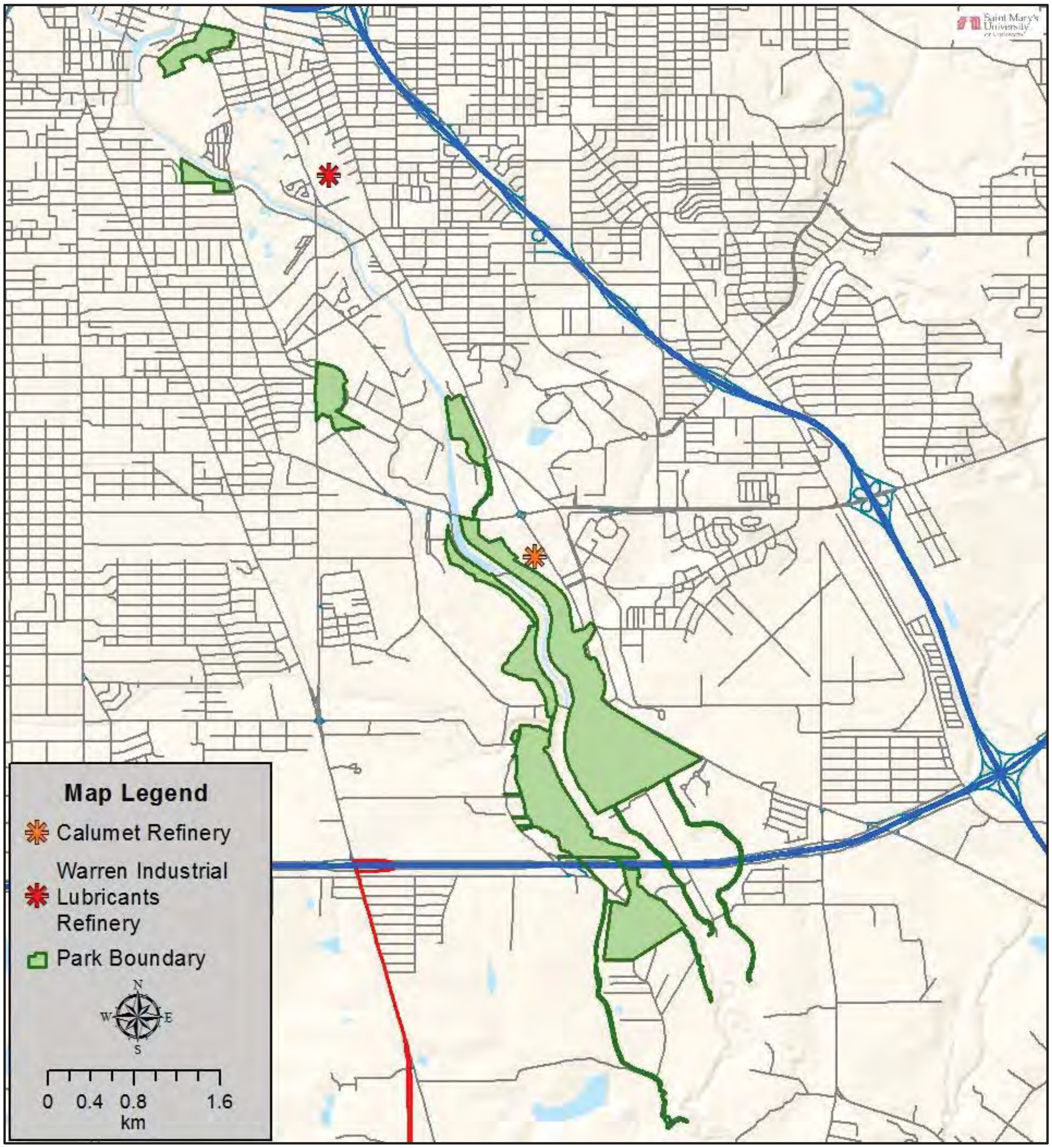

Figure 61. Location of refineries near the SAAN Missions Unit.

Overall Condition

NPS Night Sky Team's Suite of Measures

During scoping meetings, the SAAN NRCA team assigned the NPS Night Sky Team's suite of measures a *Significance Level* of 3. Despite the lack of available data, it is clear that the current condition of dark night skies is negatively impacted by the urbanization of the areas surrounding SAAN. It should be noted that conditions likely vary between the two park units, considering the Missions Unit is in San Antonio and the Rancho de las Cabras Unit is in a rural area. While a *Condition Level* cannot be assigned to this resource due to the lack of recent data, the level of concern for this resource is believed to be high. A visit from the NPS NST would provide baseline dark night sky measurements and would allow for a more accurate depiction of current condition and trend for SAAN.

Weighted Condition Score
Because SMUMN GSS could not assign a *Condition Level* for the selected measure, no *Weighted Condition Score* was assigned. The current condition of dark night skies at SAAN is unknown.

Dark Night Skies			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.83**
NPS Night Sky Team Suite of Measures	3	n/a	

4.13.6 Sources of Expertise

National Park Service Night Sky Team members Dan Duriscoe, Chad Moore, Teresa Jiles, Jeremy White, and Robert Meadows

4.13. 7 Literature Cited

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4.14 Viewscape

4.14.1 Description

For this assessment, viewscape refers to the visible natural and cultural features on the landscape in SAAN. A viewshed is the area that is visible from a particular location or set of locations, often developed using GIS analysis tools. Two datasets are required to calculate a viewshed using GIS: a digital elevation model (DEM) and point or polyline data defining points from which a person would be viewing a landscape. With the defined data, GIS software determines visibility to and from a particular cell or set of cells in a DEM, resulting in a viewshed layer. This viewshed layer is a raster that defines the visible area on the landscape from the point or set of points contained within an outline of a polygon. Analyzing layers that identify areas of undesirable impacts on the landscape within viewsheds creates a quantitative description of visual stress on a viewshed; repeating this process for multiple viewshed layers in a pre-defined landscape, such as a national park, provides a quantitative description of stress across the viewscape in the area.

Photo 25. View of Mission Espada (NPS Photo).

Multiple studies indicate that people prefer natural compared to developed landscapes (Sheppard 2001, Kearney et al. 2008, Han 2010). The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewscapes of national parks, monuments, and reservations. At SAAN, cultural landscape viewing is a primary visitor activity. SAAN cultural vistas include the four Missions (San Jose, Concepcion, San Juan, and Espada), the San Juan labores, and ranch land at the Rancho de las Cabras site.

4.14.2 Measures

- Number of non-contributing features visible within the park
- Number of non-contributing features visible outside of park
- Appearance of San Juan labores

4.14.3 Reference Conditions/Values

The ideal reference condition would be the SAAN viewscape at the time when Missions were active. However, given the development of the surrounding city of San Antonio, this is no longer feasible. In addition, park management has little to no influence over the number of non-contributing features outside the park. The reference condition for number of non-contributing features visible within the park, which park management has some control over, would be no more than a 10% increase from the current condition. This "allowable" percentage of increase would be for future needed park development (e.g., signs, and bollards) (James Oliver, SAAN Landscape Architect, written communication, 9 March 2015). The reference condition for the labores, located near the southern boundary of the Missions Unit, is to maintain zero woody vegetation in the labores and to preserve the shrub and tree rows between fields.

4.14.4 Data and Methods

Park staff identified 24 observation points and one trail of interest within or near the park units for analysis in this NRCA: eight points from San Juan, seven points from Espada, four points from San Jose, three points from Concepcion, two points from Rancho de las Cabras, and one line feature following the panhandle entrance to the Rancho Unit (Figure 62). For each of these points or lines, a viewshed was calculated using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.2, which requires point or polyline GIS data (representing the viewing location) and a DEM. For each of the observation points, a point shapefile was created for use with the Viewshed Tool (Figure 63). For line features, a polyline was created; the Viewshed Tool uses each vertex in the line to determine the viewshed of the feature as a whole.

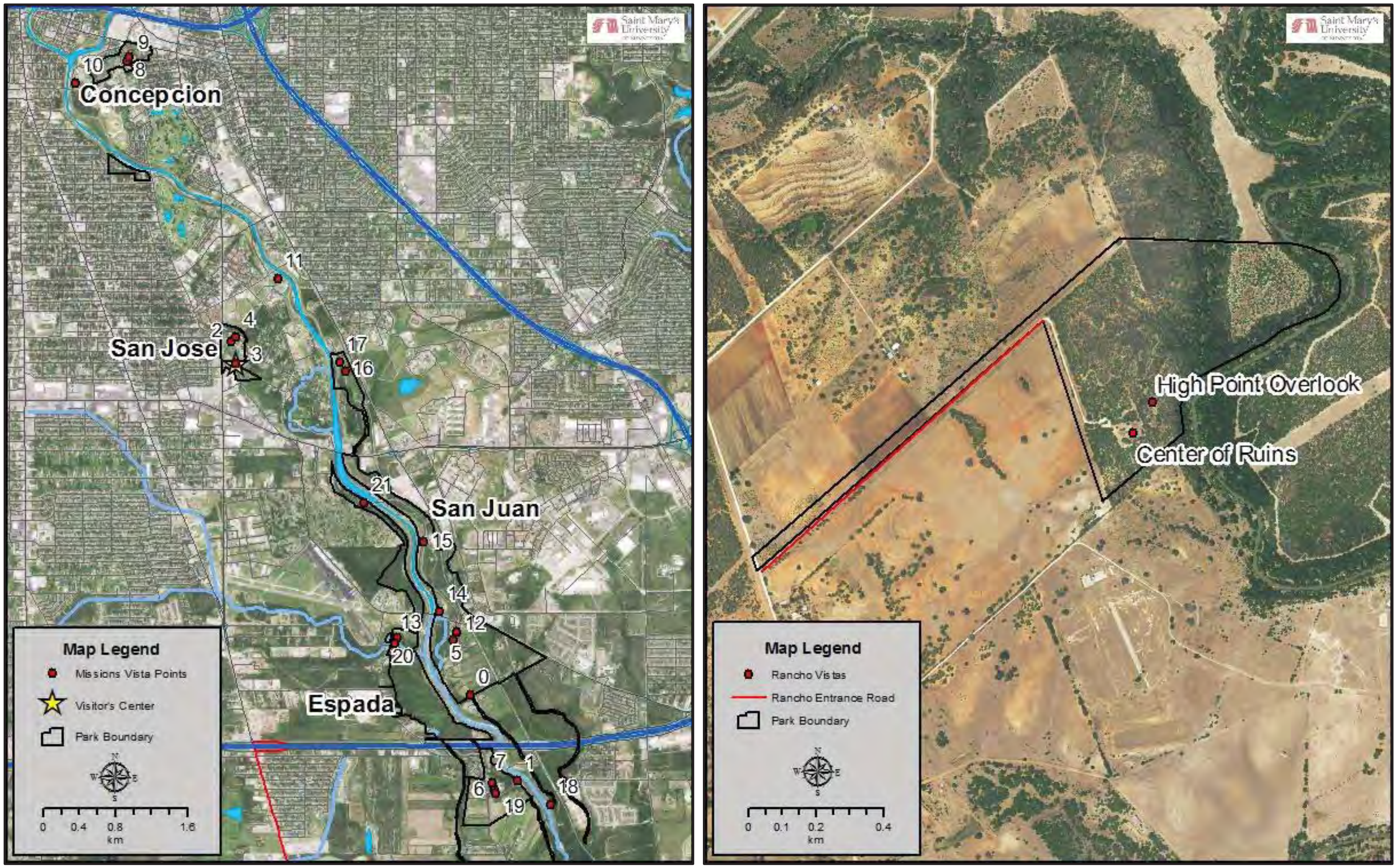

Figure 62. Locations of vistas in the Missions (left) and Rancho de las Cabras Units (right).

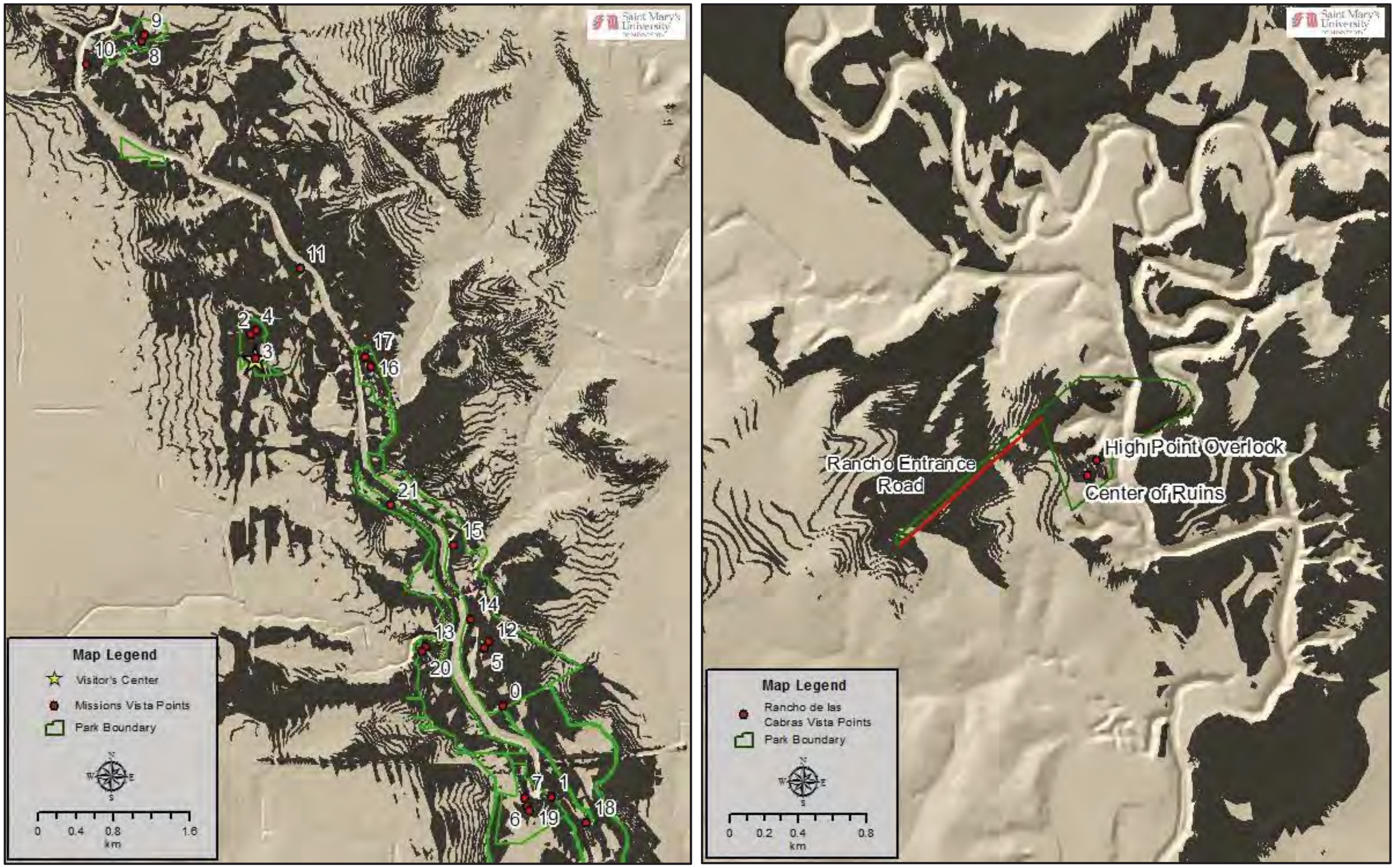

Figure 63. Composite viewshed analysis for the 22 vistas in the Missions Unit (left) and three vistas in the Rancho de las Cabras Unit (right). The darker shaded areas are visible from the park vistas.

The DEM used was the 1/3-arc second National Elevation Dataset (NED) DEM. A 1.7-m (5.5-ft) offset was applied to each observation point shapefile to account for average human height. The result of the operation is a theoretical viewshed layer that represents the visible area from a point without correcting for visibility factors (e.g., vegetation, smoke, humidity, heat shimmer, or curvature of the earth). Figure 63 displays the viewshed analysis for the Missions Units (left) and the Rancho de las Cabras Unit (right).

Current photos were provided by SAAN, to display the non-contributing features visible from within and outside of SAAN. These photos from late 2014 and early 2015 were taken by park staff to aid in this assessment.

The City of San Antonio has been actively involved in viewscape conservation for SAAN since 2008. SAAN has since been nominated for inclusion on the World Heritage Site list (Bailey 2014).

Cultural Landscape Inventories (CLIs) were completed for each Mission and the Rancho de las Cabras Unit during different years. The NPS conducted a CLI for Mission San Jose (NPS 1998a) and for Rancho de las Cabras (NPS 1998c) in 1998. NPS (2002) conducted a cultural landscape inventory for Mission Concepcion in 2002. In 2011, NPS conducted CLIs for Mission Espada (NPS 2011a) and Mission San Juan (NPS 2011b). The CLIs document the contributing and non-contributing features within the units and when they were established or built. The CLI also evaluates the integrity of the historic identity (location, setting, design, community organization, material/species, workmanship, and management techniques) of the park.

Cultural Landscape Reports (CLRs) were also completed for Missions Concepcion and San Jose as well as the Rancho de las Cabras Unit. NPS (1995, 1998b) conducted the CLRs for San Jose and Concepcion in 1995 and 1998, respectively. OCULUS (1998) conducted the CLR for the Rancho de las Cabras Unit in 1998. The CLRs are similar to the CLIs; however, the CLRs also offer recommendations on preserving, restoring, and rehabilitating historically significant features. CLRs also evaluate the integrity of the historic identity (location, setting, design, community organization, material/species, workmanship, and management techniques) of the park.

4.14.5 Current Condition and Trend

<u>Number of Non-Contributing Features Visible within the Park</u>

Concepcion

NPS (1998b) documented several non-contributing features within or outside of the unit. Non-contributing features were listed under four areas of the compound: core area, foreground, seminary, and visitor service areas. Those features included splash blocks, wells, sidewalks (concrete, wood, and brick), benches, fencing, steel stairs, grotto/pond, power poles and light fixtures, trash receptacles, bike racks, parking lot, signs and panels, basketball court, urban development, admissions/visitor contact buildings, and stone seating. NPS (2002) recorded five non-contributing landscape features within or outside of the unit. Those non-contributing features include the visitor center, utility features, urban development around the unit, mortared stone and pre-cast concrete splash blocks, and altered hydrological cycle. The visitor center was not visible in the current NPS photos, as it is located southeast of the selected points. It should be noted that there were no non-contributing features inside the park visible from vista 10.

There were six non-contributing features inside SAAN that were visible from vista 8. The non-contributing features identified from a northern view were sidewalks and park signs (Photo 26). Light fixtures and the paved parking lot could be seen to the south of the vista. The paved roads could be seen to the west of the vista, and there was chain-link fencing in the park visible from the eastern view.

Photo 26. Views of Vista 8 (State archaeological monument on site sign) from all four cardinal directions (NPS Photos by Greg Mitchell).

There were 10 non-contributing features inside SAAN that were visible from vista 9. The non-contributing features identified to the north were a sidewalk, a utility pole, stone benches, and imported vegetation (Photo 27). A sidewalk was the only non-contributing feature seen to the east of the vista. Sidewalks, a parking lot, park signs, a brick splash wall, and light fixtures were visible to the south of this vista. A utility marker, paved road, and associated light fixtures were visible in the park to the west of Vista 9.

Photo 27. Views of Vista 9 (Mission Concepcion Church) from all four cardinal directions (NPS Photos by Greg Mitchell).

San Jose

NPS (1998a) recorded one non-contributing landscape feature within the unit: the convent garden. Other possible non-contributing features may include utility features, and urban development. NPS (1995) documented twelve non-contributing features within the San Jose compound. Those features include brick walks, flagstone walks and paving, southwest portico, metal grates, metal and wood slat bench, Wilson Harris plaque, portable signage on concrete bases, trash receptacles, wooden benches, the wooden cross in the convent garden, metal ash cans, and a water fountain. All of these features, with the exception of the convent garden, are considered non-contributing because they were added after the 1911 – 1941 period of significance. Vistas 2, 3, and 4 were located in the San Jose Missions. Vista 11 was a portal associated with the unit, but it was located less than a kilometer northwest of this unit. It should be noted that there were no non-contributing features inside the park visible from vista 11.

There were six non-contributing features inside SAAN that were visible from Vista 2. A metal grate, sidewalks, trash receptacle, and benches can be seen from the northern view (Photo 28). The non-contributing features from the eastern view were imported vegetation, an ash can, and sidewalks. A sidewalk was the only non-contributing feature from the southern view, and a metal bench under a tree and the sidewalk were the only non-contributing features in the western view.

Photo 28. Views of Vista 2 (Mission San Jose Church) from all four cardinal directions (NPS Photos by Greg Mitchell).

There were 10 non-contributing features in the park at Vista 3 (Visitor Center). According to the CLR, the visitor center building is a non-contributing feature to SAAN. Imported or disturbed vegetation and sidewalks were visible from all directions (Photo 29). A park sign was visible to the north of this vista. Blue barricades and the parking lot were the non-contributing features to the east. Roads, associated signs, and light fixtures are visible from the southern view of this vista. A trash receptacle, park signs, and metal benches are visible from the western view of this vista.

Photo 29. Views of Vista 3 (Visitor Center) from all four cardinal directions (NPS Photos by Greg Mitchell).

There were eight non-contributing features in the park at Vista 4. It should be noted that construction was occurring at Vista 4 while this assessment was being completed. That being said, some non-contributing features may not have been included due to lack of visibility. Imported or disturbed vegetation, sidewalks, a road, guard rails, and a marker were visible to the north (Photo 30). A fence and shed were the non-contributing features to the east. A brick wall and fence were visible to the south of this vista. A trash receptacle, sidewalk, and fence were visible to the west of this vista.

Photo 30. Views of Vista 4 (GPS mark washer north of Grist Mill) from all four cardinal directions (NPS Photos by Greg Mitchell). Tarps and webbed fencing were part of the construction activities occurring at this vista.

San Juan

NPS (2011a) documented seven non-contributing features located within or outside of Mission San Juan. Those features include: Slattery Hall; a new pump house north of the old dam; a gazebo associated with San Antonio State hospital; private, post-colonial houses built on historic labores; privately owned houses and outbuildings near former Graf Road; masonry stone walls along the new San Juan dam access road; and a well structure associated with San Antonio State Hospital west of the old dam. Other non-contributing features may include power lines, light fixtures, paved roads, sidewalks, metal benches, and disturbed or imported vegetation. Vistas 0, 5, 12, 14, 15, 16, 17, and 18 were all located in the San Juan Missions Unit.

Vista 0 is located on the southwest border of the San Juan labores in the San Juan Missions Unit. None of the non-contributing features listed in the CLR for Mission San Juan were visible from this vista. The only non-contributing features visible in the park from Vista 0 were power lines (west) and disturbed vegetation. Disturbed vegetation was visible from all four cardinal directions (Photo 31).

Photo 31. Views of Vista 0 (Carsonite marker at acequia mile 3.3) from all four cardinal directions (NPS Photos by Greg Mitchell).

There were six non-contributing features in the park at Vista 5. The visible non-contributing features included disturbed and imported vegetation, street signs, park signs, paved roads, a utility box, and power lines. Disturbed or imported vegetation could be seen from all directions (Photo 32). Disturbed and imported vegetation, roads and associated signs, a utility box, and power lines were visible to the north of this vista. A park sign was the only non-contributing feature that was visible to the east. A power line was the only non-contributing feature to the west. None of the non-contributing features mentioned in the CLR were visible from this location.

Photo 32. Views of Vista 5 (Mission San Juan) from all four cardinal directions (NPS Photos by Greg Mitchell).

There were 11 non-contributing features in the park at Vista 12. The major non-contributing feature was Slattery Hall; it was located directly east of the vista (Photo 33). Slattery Hall was the only non-contributing feature mentioned in the CLR for this unit. Sidewalks and disturbed or imported vegetation could be seen from all directions. The non-contributing features visible to the north of this vista include the parking lot, roads, street lamps, and power lines (Photo 33). To the east, a road, street signs, and a parking lot were visible. A metal bench and park sign were visible to the south, and a bike rack and another metal bench were visible to the west.

Photo 33. Views of Vista 12 from all four cardinal directions (NPS Photos by Greg Mitchell).

There were three non-contributing features in the park at Vista 14. Disturbed vegetation was a non-contributing feature that could be seen from all directions. To the north, a park sign is visible, along with some kind of structure in the distance. A bridged road was seen to the west of this vista (Photo 34). The only non-contributing feature to the east was disturbed vegetation. The road was also visible to the south as well as a brick splash wall. None of the non-contributing features mentioned in the CLR were visible from this location.

Photo 34. Views of Vista 14 (Mill Ruins) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 15 was located at the Acequia Park security building. There were seven non-contributing features in the park at this vista. Disturbed or imported vegetation was visible in all four directions (Photo 35). The rest area, signs, road and guard rail were all non-contributing features to the north. A parking lot, associated sign, roads, and building beyond the tree line were visible to the east. The road and guard rail were the only non-contributing features to the south of this vista. None of the non-contributing features mentioned in the CLR were visible from this location.

Photo 35. Views of Vista 15 (Acequia Park Security Building) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 16 is located in the grassy area near the dam. There were only two non-contributing features visible in the park at this vista (Photo 36). Disturbed or imported vegetation was visible from all four directions. A road could be seen to the north, south, and west of this vista.

Photo 36. Views of Vista 16 (in prairie near the dam) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 17 was the dam overlook. There were six non-contributing features inside the park that were visible from this vista. Brick block retaining walls, a gravel walk, and disturbed and imported vegetation were visible to the north (Photo 37). Concrete stairs, metal railing, a brick block retaining wall, and disturbed or imported vegetation are visible to the east. Disturbed vegetation may be the only non-contributing feature visible to the south, although a road can be seen through the trees when they are not in leaf. The dam, chain link fencing, the dam access road, and disturbed vegetation were visible to the west of the overlook. None of the non-contributing features mentioned in the CLR were visible from this location.

Photo 37. Views of Vista 17 (the dam overlook) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 18 was located at the end of the Acequia Trail. There was one non-contributing feature inside the park that was visible from this vista. A fence surrounding the unit boundary was the only feature visible; it was visible to the east of this vista (Photo 38). None of the non-contributing features mentioned in the CLR were visible from this location.

Photo 38. Views of Vista 18 (End of Acequia Trail) from all four cardinal directions (NPS Photos by Greg Mitchell).

Espada

NPS (2011b) documented six major non-contributing features located within or outside of Mission San Francisco de la Espada. Those features include: the River Rest Pavilion and auxiliary structures; Army Corps of Engineers river channel alterations (weir, concrete-lined channels, new dam); former Head Start headquarters and playground; Parish Hall; Espada Convent; and mobile homes in the labores. Camino Coahuilteca, hiking and biking trail, Interstate Loop 410, low water crossing bridges, sidewalks and paths, driveways, park and street signs are minor non-contributing features listed for Mission Espada. Other non-contributing features may include power lines, light fixtures, metal benches, and disturbed or imported vegetation. Vistas 1, 6, 7, 13, 19, 20, and 21 were located in or near the Espada Mission.

Vista 1 was located near the River Rest Pavilion. There were 11 non-contributing features visible inside the park from this vista. The two major non-contributing features visible were Camino Coahuilteca, and the River Rest pavilion and auxiliary structures (Photo 39). Camino Coahuilteca, a sidewalk, and park sign were visible to the north; a wood fence and sidewalk were visible to the east; the pavilion and associated structures (e.g., metal picnic tables, trash receptacles, flag pole), and a wooden bench were visible to the south; Camino Coahuilteca, utility building, utility pole, light and a fixture were visible to the west. Disturbed or imported vegetation may also be considered a non-contributing feature visible in every direction at this vista.

Photo 39. Views of Vista 1 (River Rest Pavilion) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 6 was located near the Mission Espada sign. There were 14 non-contributing features visible inside the park from this vista. The three major non-contributing features visible were Camino Coahuilteca, Parish Hall, and the former Head Start headquarters building, which were both visible to the south and east of this vista (Photo 40). There were no non-contributing features visible to the north. An unidentified road and wooden guardrail were also visible to the east. A parking lot, trash receptacle, park sign, road sign, and fire hydrant were visible to the south. Espada Road, wooden guardrail, light fixtures with banners; short brick walls, and residences were visible to the west.

Photo 40. Views of Vista 6 from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 7 is located near the San Francisco de la Espada Mission. There were 12 non-contributing features visible inside the park from this vista. The two major non-contributing features visible were the former Head Start headquarters building and playground, which were both visible to the east of this vista (Photo 41). A wooden guardrail and gravel parking lot were the only non-contributing features to the north. A short brick wall was also visible to the east. A park sign, stop sign, and light fixture were visible to the south. A short brick wall, benches, sidewalk, park sign, imported vegetation, trash receptacle, and wooden guardrail were visible to the west.

Photo 41. Views of Vista 7 (San Francisco de la Espada Mission) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 13 is located near the Espada Aqueduct. There were 10 non-contributing features visible inside the park from this vista. There were no major non-contributing features visible at this vista (Photo 42). A metal bench, sidewalk, and drainage pipe were the non-contributing features visible to the north. A sidewalk, paving stones, and a wooden guardrail were visible to the south. A park sign, powerlines, light fixture, and a trash receptacle were visible to the west.

Photo 42. Views of Vista 13 (Espada Aqueduct) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista19 is located in the parking lot near the San Francisco de la Espada Mission. There were 15 non-contributing features visible inside the park from this vista. The two major non-contributing features visible were Parish Hall and Camino Coahuilteca, which were visible to the north and south, respectively (Photo 43). Camino Coahuilteca was also visible to the east and west of this vista. Other non-contributing features to the north include a parking lot, parking signs, park signs, and light fixtures. The parking lot was also visible to the east and west. A utility box, light fixtures with banners, power lines, a metal gate, and street signs were also visible to the east. Only a fire hydrant was visible to the south. A large shed, guardrail, street signs, and more light fixtures with banners were visible to the west.

Photo 43. Views of Vista 19 (parking lot near the San Francisco de la Espada Mission) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 20 is located in a grassy area near the aqueduct. There were four non-contributing features visible inside the park from this vista. There were no major non-contributing features visible at this vista. There were no non-contributing features to the east, south, or west (Photo 44). The parking lot, utility box, power lines, and park signs were visible to the north.

Photo 44. Views of Vista 20 (grassy area near the aqueduct) from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 21 is located east of the original Espada Dam. There were nine non-contributing features visible inside the park from this vista. River-channel alterations of the dam were the major non-contributing features visible at this vista (Photo 45). There were no non-contributing features to the south. A wooden guardrail, metal fence, brick marker, sidewalk, and brick retaining were the non-contributing features to the north. A park road, a wooden guardrail, sidewalk, road signs, and a bike rack were visible to the east. A retaining wall, park sign, and concrete marker were visible to the west.

Photo 45. Views of Vista 21 (east of the original dam) from all four cardinal directions (NPS Photos by Greg Mitchell).

Rancho de las Cabras

NPS (1998b) and OCULUS (1998) documented several non-contributing features within or outside of the Rancho Unit. Features were considered non-contributing if creation or presence in the unit occurred after the period of significance. The period of significance for the Rancho Unit is described as Spanish colonial. Non-contributing features in the Rancho Unit include the quarry (caliche excavation), an earthen dam, electric transmission lines, buried gas line easements, archeological investigations, the entrance road and gate, vehicle tracks (along northern and western property, upland margin, and surrounding ruins and quarry), early succession from improved pasture vegetation community, improved pasture vegetation community, recently disturbed imported and quarry vegetation community, gate at the end of the panhandle, fencing (along panhandle, along northern southern and western property boundary, along the upland margin, along eastern field margin), historical markers and signs at the compound, and views of neighboring residences and discarded waste.

Vista 22 is located in the center of the ruins in the Rancho Unit. The non-contributing features visible from this vista included the quarry, disturbed and imported vegetation, archeological investigations, the historical marker, gravel road, and fencing. Other non-contributing features (vehicle tracks) may be present but are not visible from the photos. Disturbed and imported vegetation could be seen in every direction in the ruins area. Some archaeological investigations and the quarry are located in the northern section of the ruins. More archeological investigation activity was visible south of the vista point. A small section of fencing was visible at the eastern edge of the ruins. Photo 46 displays the vista 22 which is located at the center of the ruins in the Rancho Unit.

Photo 46. Views of Vista 22, located at the center of the ruins, from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 23 is located at the high point overlook in the Rancho Unit. The non-contributing features inside the park and visible from this vista included disturbed and imported vegetation. A road can also be seen to the west of this point. Other non-contributing features (vehicle tracks) may be present but are not visible from the photos (Photo 47).

Photo 47. Views of Vista 23, located at the high point overlook, from all four cardinal directions (NPS Photos by Greg Mitchell).

Vista 24 is the entrance road to the Rancho Unit. Three photo points (24, 25, and 26) were used to determine the non-contributing features visible inside and outside the park along the entrance road. The photos points were located along the entrance road from the eastern most culvert along the entrance road to the entrance gate (Photo 48– 50, Figure 64). There were a few non-contributing features visible from photo point 24. A water tower can be seen in the distance from the north. Grazed (disturbed) vegetation can be seen just past the northern park boundary. Electric transmission and power towers could be seen to the south and west of this point. A neighboring residence can also be seen to the west.

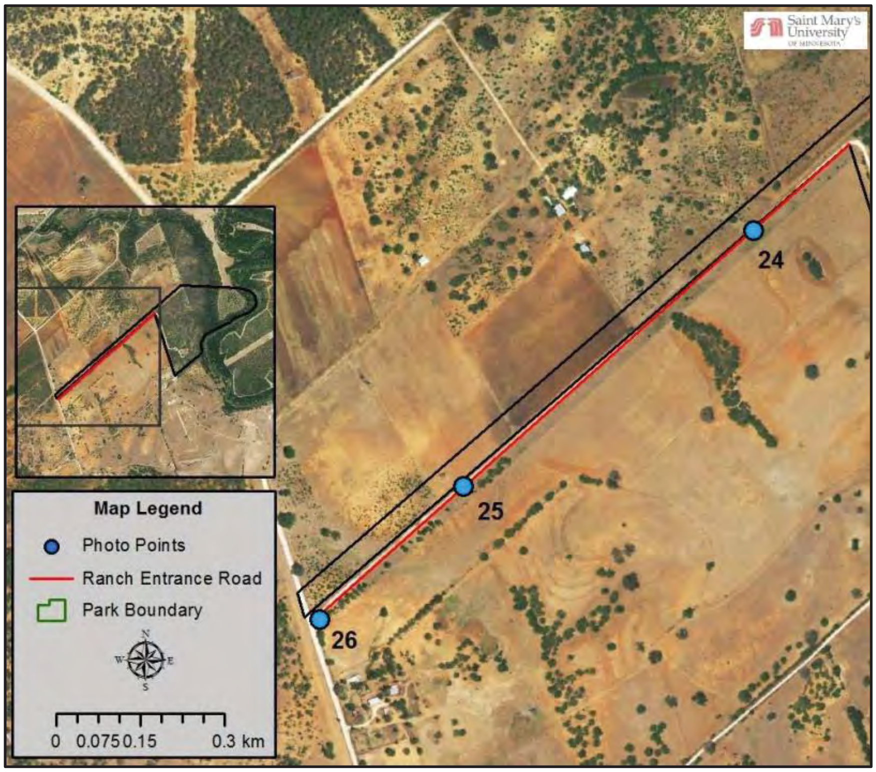

Figure 64. Locations of photo points used to display non-contributing features along the entrance road (Vista 24).

Photo point 24 was located at the eastern most culvert along the entrance road in the Rancho Unit. The non-contributing features inside the park and visible from this vista included disturbed and imported vegetation and fencing. Fencing and disturbed vegetation could be seen in every direction at this vista. Photo 48 displays the views from the eastern point on the entrance road in the Rancho Unit.

Photo 48. Views of photo point 24, located at the eastern most culvert along the entrance road, from all four cardinal directions (NPS Photos by Greg Mitchell).

Photo point 25 is located at the middle of the entrance road in the Rancho Unit. The non-contributing features inside the park and visible from this vista included disturbed and imported vegetation, fencing, signs, and the entrance road. Fencing and disturbed vegetation could be seen in every direction at this vista. A power line corridor can be seen to the north and south. A warning sign is seen to the north of the road (Photo 49).

Photo 49. Views of photo point 25, located near the middle point on the entrance road, from all four cardinal directions (NPS Photos by Greg Mitchell).

Photo point 26 is located at the entrance gate along the entrance road in the Rancho Unit. The non-contributing features inside the park and visible from this vista included disturbed and imported vegetation, fencing, and the entrance road. Fencing and disturbed vegetation could be seen in every location at this vista (Photo 50).

Photo 50. Views of photo point 26, located at the entrance gate of the Rancho Unit, looking northeast and east into the park (NPS Photos by Greg Mitchell).

Number of Non-Contributing Features Visible Outside of the Park

Concepcion

Non-contributing features located outside of the park were visible from all three vistas associated with Mission Concepcion (8, 9, 10). Urban development (residential/commercial buildings) was the main type of non-contributing feature located outside of the park visible from Mission Concepcion Vistas. Saint Peter – Saint Joseph Children's Home is visible to the south and west of Vista 8; more residential buildings and a convenience store were north and west of this vista. Saint Peter – Saint Joseph Children's Home is just visible from Vista 9 (see Photo 25 and Photo 26).

Vista 10, a portal location, was located outside SAAN west of Concepcion. The top of the Mission can just be seen over the trees to the east. Vista 10 is located at a park pavilion (sidewalks, brick mosaic walls, fencing, light fixtures, utility box) which is a non-contributing feature. Imported vegetation could have also been placed at this location to add to its aesthetics. To the west of Vista 10, urban development (residential housing, light fixtures, sidewalks) and a human-altered river corridor are the non-contributing features that are visible (Photo 51).

Photo 51. Views of Vista 10, portal located to the west of the Mission Concepcion Unit, from all four cardinal directions (NPS Photos by Greg Mitchell).

San Jose

Non-contributing features located outside of the park were visible from two vistas (3, 11). Vistas 2 and 4 were surrounded by the mission walls or vegetation tall enough to limit the viewshed to within the park. Vista 3 was located at the visitor center. Urban development (buildings) and power lines were non-contributing features visible outside the park at this vista; they were visible to the south above the tree line (Photo 28).

Vista 11 is another portal located in Mission County Park, which is outside of SAAN. Although not seen in the selected photos below, Mission San Jose is visible to the southwest from this location. Imported or disturbed vegetation, sidewalks, and power lines could be seen in all directions. Residential buildings, roads, a light fixture, and trash receptacles are visible to the north. The altered river channel, commercial buildings, a bridge, and a playground were visible to the east. The park facility building, parking lot, and more residential buildings are visible to the south, and roads and residential buildings were visible to the west (Photo 52).

Photo 52. Views of Vista 11, portal located to the northeast of the Mission San Jose Unit, from all four cardinal directions (NPS Photos by Greg Mitchell).

San Juan

Non-contributing features located outside of the park were visible from five vistas associated with Mission San Juan (0, 14, 15, 16, and 18). Vistas 5, 12, and 17 were surrounded by vegetation tall enough to limit the viewshed to within the park. Power lines were visible to the east and south, and a dumpster was visible past the tree line to the east of Vista 0 (Photo 31). Mission Road, its associated road signs, and power lines could be seen to the west of Vista 14 (Photo 34). The refinery smoke stacks were the only non-contributing features visible to the north of Vista 15 (Photo 35). North of Vista 16, a billboard was visible through a tree line (Photo 36). Vista 18 was located just outside the SAAN boundary in Mission San Juan (Photo 38). A sidewalk, bench, and trash receptacle were visible to the north of Vista 18. The San Antonio River runs just southeast of Vista 18; human influence on San Antonio River corridor may be considered a non-contributing feature occurring to the west and south of this vista.

Espada

Non-contributing features located outside of the park were visible from three vistas (1, 20, and 21). Vistas 6, 7, 13, and 19 were surrounded by vegetation tall enough to limit the viewshed to within the park. At Vista 1, paved sidewalks could be seen to the north and east; an overpass and paved road were also visible to the north of this vista (Photo 39). Ashley Road, associated road signs, and urban development could be seen to the west of Vista 20 (Photo 44). Vista 21 seemed most effected by non-contributing features outside of the park. The Mission Park Cemetery plots are visible to the west, and the tall refinery smoke stacks were visible to the east (Photo 45).

Rancho de las Cabras
The Rancho Unit may be in a more rural location than the Missions Unit, but tall non-contributing features can be seen from all five vistas and photo points in the park. Vistas 22 and 23 were located in the main portion of the ranch, surrounded by vegetation. Vista 22 was located in the center of the ruins in the Rancho Unit (Photo 46). Tall vegetation prevented visibility of most features outside the park from this location. As a result, only one non-contributing feature was visible at this vista. A water tower could be seen to the north of the ruins. Vista 23 was located at the high point overlook in the Rancho Unit (Photo 47). Tall vegetation prevented visibility of features outside the park to the south and west of this location. The non-contributing features visible from this vista included a water tower and electric transmission towers and lines. The water tower can be seen to the north and the transmission lines comprise the eastern view.

Photo points 24 through 26 (entrance road vista) occur along the entrance road from the eastern most culvert along the entrance road to the entrance gate (Figure 65).

Photo point 24 was near the panhandle of the Rancho Unit (Photo 48, Figure 65). The non-contributing features outside the park and visible from this point included disturbed and imported vegetation, neighboring residences, and electric transmission towers and lines. Disturbed and imported vegetation can be seen in all directions. Power lines, a water tower, and a neighboring residential building were visible to the north of this point. Electric transmission lines and towers as well as a neighboring residence can be seen to the west of this point, and an indiscernible feature can be seen to the left of the tree line to the south of this point.

Photo point 25 was near the middle of the entrance road vista (near the electric transmission towers) in the Rancho Unit (Photo 49, Figure 65). The non-contributing features outside the park and visible from this point included disturbed and imported vegetation, neighboring residences, electric transmission towers and lines, and fencing. Disturbed and imported vegetation can be seen in all directions. Power lines, a water tower, and a neighboring residential building were visible to the north of this point. Fencing can be seen in the distance to the east. Electric transmission lines and towers, fencing and neighboring residence can be seen to the south of this point. A transmission tower is located very close (several meters) to the park and west of this point.

Photo point 26 was located at the entrance gate to the Rancho Unit (Photo 50, Figure 65). This photo point only displays non-contributing features to the east and northeast. The non-contributing features outside the park and visible from this point include disturbed and imported vegetation, neighboring residences, electric transmission towers and lines, a water tower, and fencing. Disturbed and imported vegetation and transmission lines, and fencing can be seen in both directions. An electric transmission tower and a water tower can be seen to the northeast, and neighboring residential property was visible to the east of this point.

Appearance of San Juan Labores

The San Juan labores, or historic Mission farmland, are a cultural resource in the park. These labores were used to grow several crops, including corn, beans, chilies, melons, cotton, sugar cane, and squash (NPS 2007). They are located near the southern border of the Missions Unit near the San Antonio River, and were historically irrigated by irrigation ditches called acequias (NPS 2007, Figure 62). Park staff provided current photos of the San Juan labores from several vantage points.

The reference condition for the San Juan labores is to maintain zero woody vegetation in the labores and to preserve the shrub and tree rows between fields. From the aerial view alone, it can be said that there is some woody vegetation (shrubs and trees) in the labores north of gate 9155, but most of the labores have remained clear of woody vegetation. Photo 53 displays the views of the San Juan labores from gates 9155 (left) and 9107 (right).

Photo 53. Views of the San Juan labores from gates 9155 (left) and 9107 (right) (NPS Photos by Greg Mitchell).

Threats and Stressor Factors

SAAN park staff have identified several threats that impact the park's cultural and natural viewscape. Those threats include urban development expanding south, power line corridors, cell towers, encroaching vegetation, and in-park development.

Urban development that is expanding south of the park poses a threat to the SAAN viewscape. According to Cooper et al. (2005), adjacent land use and outside development are high priority management issues because they may significantly impact several natural resources in the park, including viewscape. Figure 66 and Figure 67 display the landcover changes in SAAN and surrounding areas from 2001 to 2011.

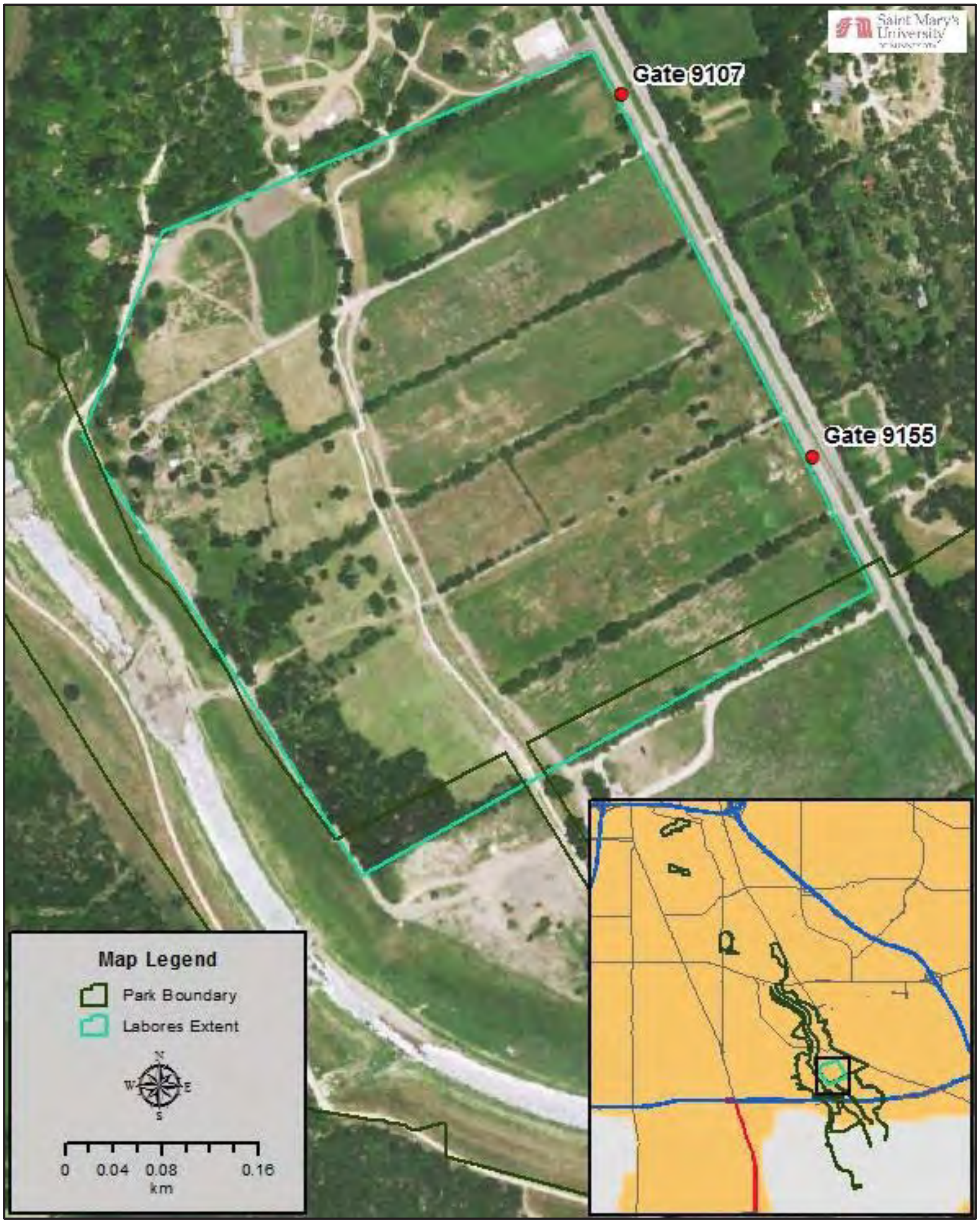

Figure 65. Extent of the San Juan labores in SAAN.

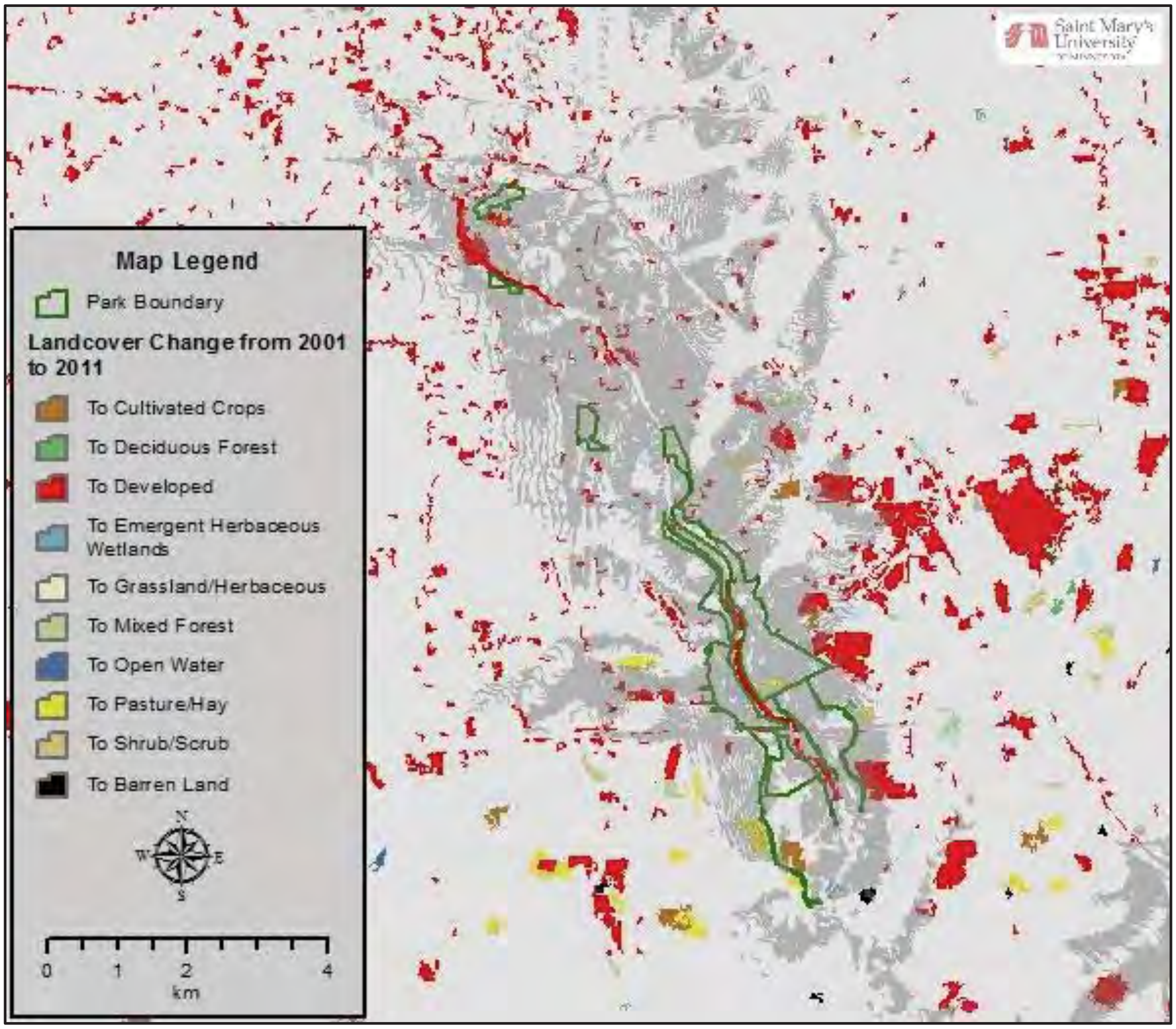

Figure 66. Landcover change from 2001 to 2011 in SAAN and surrounding areas (MRLC 2014). Areas shaded in darker gray are the areas visible from the park vistas.

The electric transmission towers and cell towers are also a threat to the viewscape of SAAN. Due to the location of the Missions Unit in San Antonio, the power lines and cell towers can be seen from most of the unit. The Rancho Unit may be in a more rural location, but a transmission tower is located in close proximity to its northern boundary. Power lines or transmission towers can be seen at all vistas in the Rancho Unit (Photo 46-Photo 50).

Encroaching vegetation is a potential threat to the SAAN viewscape. The Espada and San Juan labores may be at risk of encroachment of exotic species due to the open landscape of native plant communities if not consistently managed; however, the labores are mowed annually and therefore are currently not at risk (Mitchell, written communication, 9 March 2015). There were two exotics, in particular, that may negatively impact unmanaged labores. Those species are Chinaberry and glossy privet (*Ligustrum lucidum*) (Saperstein 2002). According to Saperstein (2002) these exotics occur throughout the park, but seem to thrive more in areas of human disturbance. Control actions have been put in place to remove these two exotic species, so they do not spread further within the park.

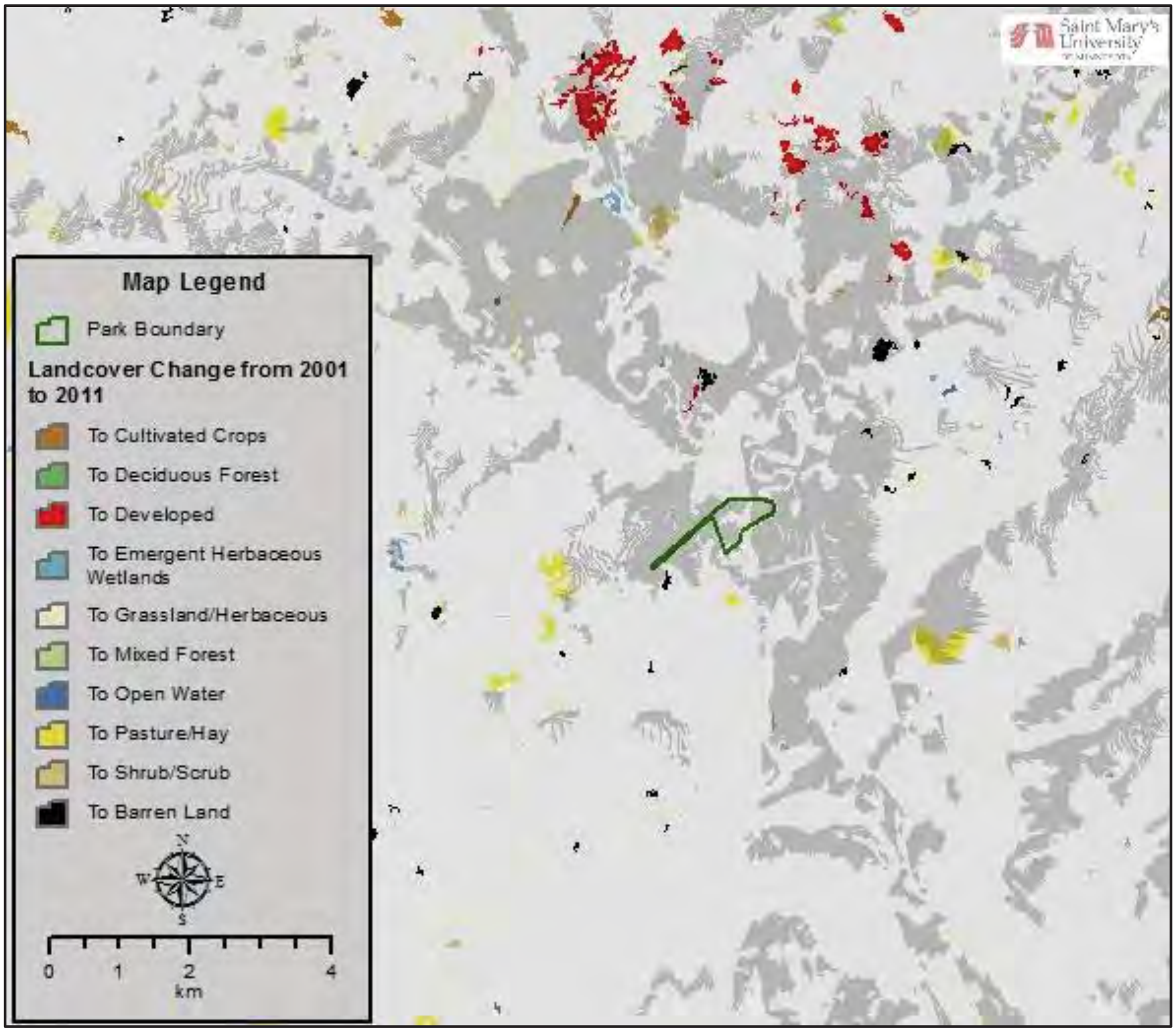

Figure 67. Landcover change from 2001 to 2011 in SAAN's Rancho Unit and surrounding areas (MRLC 2014). Areas shaded in darker gray are the areas visible from the park vistas.

In-park development is another threat to viewscape in SAAN. A new parking facility and the development of the Spanish Colonial demonstration farm are examples of the most current developments (Oliver, written communication, 9 March 2015). The demonstration farm will display another side to the Missions' culture. According to Los Compadres de San Antonio Missions (2015), Mission San Juan was known for its rich farmlands and pastures. The objectives of the farm will be to utilize historic farmlands and create an emphasis on SAAN's living history. While the farm itself will be a contributing feature to the cultural landscape, the parking area and any interpretive signage or modern structures to support farm operations will be non-contributing features.

<u>Data Needs/Gaps</u>

Continued development of spatial data that explain landscape change will enable accurate and up-to-date viewshed assessments of the metrics examined in this analysis. These data could help park staff work with city planners to minimize the impact of surrounding development on the park's viewshed.

Overall Condition

Number of Non-Contributing Features Visible Within the Park

The *Significance Level* for number of non-contributing features visible within the park boundary was defined as a 3. There were several non-contributing features visible inside the park at all of the vistas in Missions Concepcion, San Jose, and Espada. A few vistas in San Juan were in less developed areas; those vistas had fewer than three non-contributing features each. The number of non-contributing features at both Mission Concepcion and Mission San Jose vistas ranged from six to 10 features. At Mission Espada vistas, the number of non-contributing features ranged from 4 to 15. The number of non-contributing features at Mission San Juan vistas ranged from one to 11 features, while the number of non-contributing features at the Rancho de las Cabras Unit vistas ranged from two to six features. As a result, the *Condition Level* for this measure is a 3, indicating high concern.

Number of Non-Contributing Features Visible Outside of the Park

The *Significance Level* for number of non-contributing features visible outside the park boundaries was defined as a 2. There were several non-contributing features visible outside the park at all of the vistas. The number of non-contributing features at both Mission Concepcion and Mission San Juan vistas was 10 features each. The number of non-contributing features at Mission Espada and Rancho Unit vistas totaled five and seven features, respectively. The number of non-contributing features at Mission San Jose vistas totaled 12 features. Missions Concepcion and San Jose may be at a higher risk of non-contributing features outside of the park than Missions San Juan and Espada because the first two units are small and lack tall vegetation bordering the unit boundary. San Juan and Espada are also further from the city center, where urban development has not been as intense. The *Condition Level* for this measure is also a 3, or high concern.

Appearance of San Juan Labores

The *Significance Level* for appearance of the San Juan labores was defined as a 3. The aerial photo and NPS photos were helpful in showcasing the appearance of the labores as of 2014. From the aerial view alone, it can be said that there are some shrubs and trees in the labores north of gate 9155, but most of the labores have remained clear of woody vegetation. The reference condition for the San Juan labores is to maintain zero woody vegetation in the labores and to preserve the shrub and tree rows between fields. As a result, the *Condition Level* for this measure is currently a 1, or low concern.

Weighted Condition Score

The *Weighted Condition Score* (WCS) for the component is 0.75, indicating viewscape is of significant concern overall. The change in landcover from 2001 to 2011 illustrates a growing city of San Antonio. This increase in development surrounding SAAN suggests a declining trend for viewscape.

Viewscape			
Measures	Significance Level	Condition Level	WCS = 0.75
Number of Non-Contributing Features Visible inside of the Park	3	3	
Number of Non-Contributing Features Visible outside of the Park	2	3	
Appearance of San Juan Labores	3	1	

4.14.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resource Specialist

James Oliver, SAAN Landscape Architect

4.14.7 Literature Cited

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4.15 Hydrology (Surface and Groundwater)

4.15.1 Description

Availability of a reliable water source is of great importance in semi-arid regions such as south-central Texas (Meiman 2012). This importance can be seen throughout the park. The Missions that make up SAAN would not have been built if not for the San Antonio River, as it was the reliable source the native peoples and missionaries used to irrigate their fields and grazing areas (Meiman 2012). Irrigation was accomplished through a series of acequias (gravity-fed ditches) that carried water to the fields and grazing areas (Meiman 2012).

As shown in Figure 68, the San Antonio River has its headwaters at the San Antonio Springs within the San Antonio city limits (USACE 1965). The river flows in a southeasterly direction for approximately 386 km (240 mi) (USACE 1965, Phillips 2011). The river drains an area of approximately 10,859 km² (4,193 mi²) before it joins the Guadalupe River (Phillips 2011, USDA-NRCS 2014). This confluence is in a tidally-influenced delta area, just upstream of Tivoli, Texas, approximately 11 km (6.5 mi) upstream of Guadalupe/San Antonio Bay (Phillips 2011).

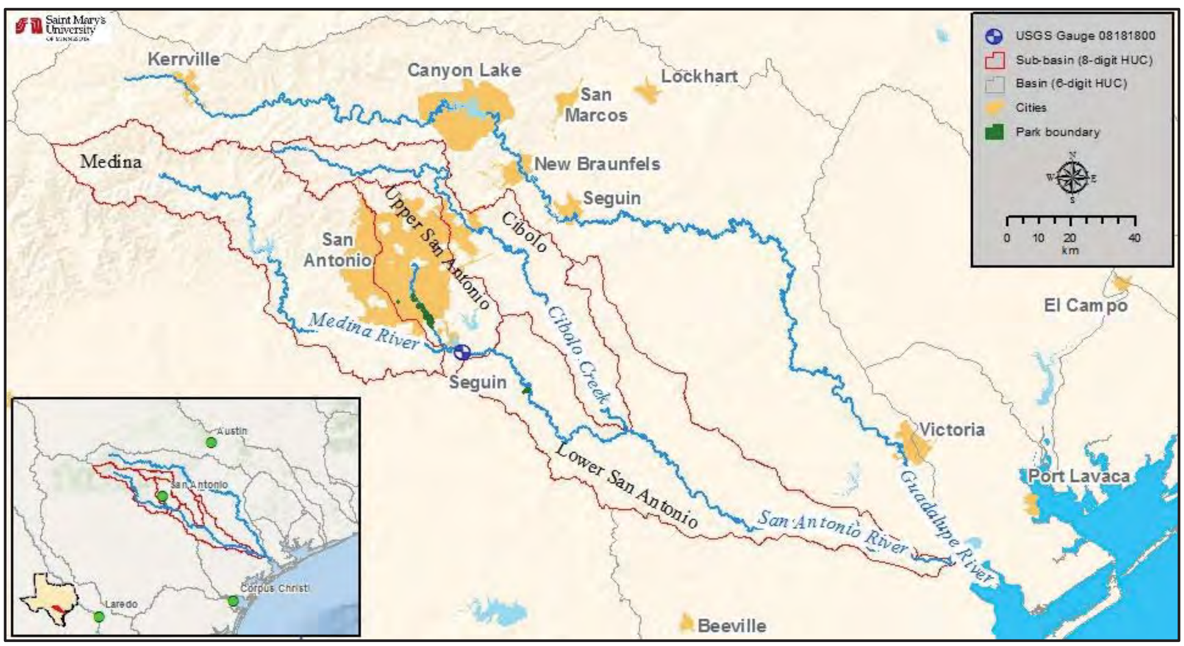

Figure 68. General location of SAAN and the San Antonio River in southeast Texas.

Historically, the main source of base flow in the San Antonio River was from the headwater springs and other area springs (TIFP 2009, TIFP 2012). Over the past several decades, the river has evolved from a system driven by spring flow to a system that is highly influenced by year-round wastewater treatment plant discharges, intermittent diversions, and a mix of various urban and rural land uses (TIFP 2009, TIFP 2012). While this is especially the case for the upper reaches of the San Antonio River, the hydrology of the lower portion (below USGS gauge 08181800 near Elmendorf [Figure 67]) continues to be variable with the seasons (TIFP 2009, TIFP 2012). Flow in this reach is dependent on precipitation patterns and is supported by spring flow (TIFP 2009, 2012). However, recently the flow in the river has been augmented by treated municipal effluent, primarily through return flows from groundwater pumped from the Edwards Aquifer (TIFP 2009, 2012).

SAAN is comprised of a series of small disconnected parcels located along the San Antonio River within the greater San Antonio River basin. Mission Concepción, Mission San José, Mission San Juan and Mission Espada (Missions Unit) are within the San Antonio urban boundary and the Rancho de las Cabras (Rancho) is located to the southeast of San Antonio, near Floresville, Texas (Figure 68). The San Antonio River basin is comprised of four sub-basins, the Medina, Cibola, Upper San Antonio and Lower San Antonio (USDA-NRCS 2014). The Missions Unit is located in the Upper San Antonio sub-basin and the Rancho is located within the Lower San Antonio sub-basin (Figure 68). The Upper San Antonio and Lower San Antonio sub-basins differ in land use, channel characteristics and flow regime (TIFP 2009, 2012, Meiman 2012, NPS 2014).

The Upper San Antonio sub-basin drains approximately 131,274 ha (324,384 ac) of mostly the metropolitan San Antonio area. This sub-basin has undergone a great deal of alteration and modification over the past several decades due to urban development (TIFP 2009, 2012, NPS 2014). The land-use within this sub-basin is primarily developed urban, with a relatively level topography, except in the vicinity of the old river channels (Carr 2003a). The channel remnants have become riparian habitat for many wildlife species (Cooper et al. 2005). The current active channel of the San Antonio River has been highly modified for flood control purposes and is administered and maintained by the San Antonio River Authority (SARA) (Carr 2003a). Elevation within the sub-basin ranges from about 152 m (500 ft) above mean sea level near Mission Espada to 183 m (600 ft) at Mission Concepción (Carr 2003a).

The Lower San Antonio sub-basin drains approximately 384,216 ha (949,418 ac) of primarily rural sparsely populated land (SARA 2003). In this basin the San Antonio River becomes a free-flowing undeveloped stream (Meiman 2012). The river also becomes more entrenched with steep, muddy banks, and is generally deeper than the upper sub-basins (SARA 2003). Elevation within the Rancho ranges from about 122 m (420 ft) above mean sea level at the gate along the county road to about 101 m (330 ft) along the San Antonio River (Carr 2003b).

While SAAN does not own any portion of the San Antonio River, it does have ownership of some areas that are within the high-water mark (Meiman 2012). The park also retains water rights to supply the two remaining acequias which are owned and maintained by the park (Meiman 2012). The Acequia de Espada is located along the west side of the river and the Acequia de San Juan on the east side (Meiman 2012). In addition, the park also manages a segment of Piedras Creek, running from approximately 60-90 m (200-300 ft) upstream of where it is crossed by the Acequia de Espada aqueduct to its confluence with the San Antonio River (Greg Mitchell, SAAN Natural Resources Program Manager, written communication, 9 March 2015, Meiman 2012). Surface water resources within SAAN are shown in Figure 69. In the Missions Unit area, these resources consist of three segments of the San Antonio along with the acequias and Piedras Creek (Cooper et al. 2005). The inset of Figure 69 shows the surface water resources at Rancho de las Cabras. They are comprised of features including the San Antonio River and Picosa Creek, among others (Cooper et al. 2005).

4.15.2 Measures

- Stream flow rates
- Width:depth ratio
- Depth to groundwater (Rancho only)

4.15.3 Reference Conditions/Values

The ideal reference condition for this component would be the hydrological conditions during the Mission period. However, given the significant alterations to the San Antonio River basin since that time, this is no longer feasible. A specific reference condition for hydrology at SAAN was not defined. Given the long period of record, historic flows could be used as a reference condition.

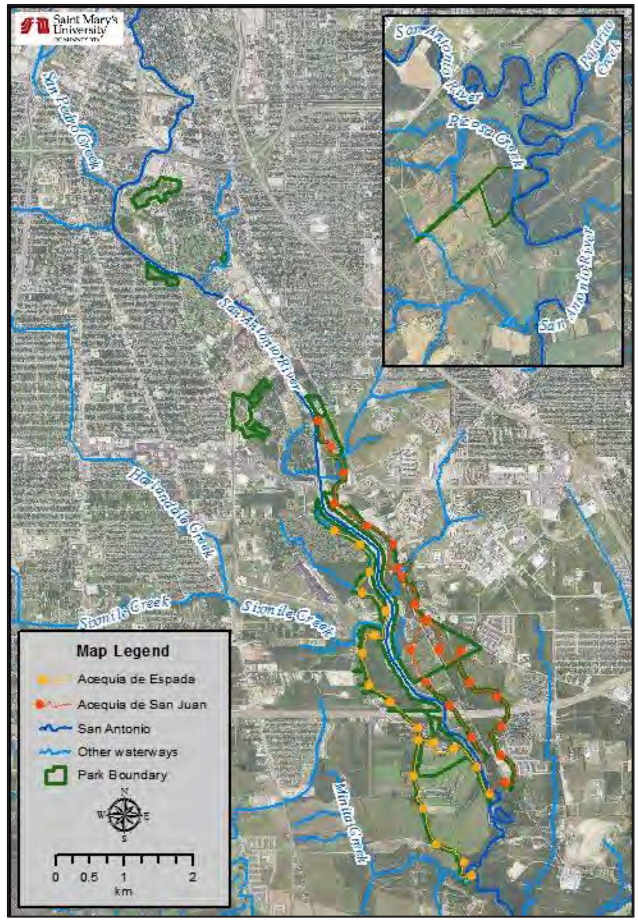

Figure 69 Surface hydrology features at SAAN.

4.15.4 Data and Methods

The information for this assessment was gathered primarily from hydrologic information included in several existing studies on the water quality, hydrology and geomorphology of the San Antonio River (e.g., USACE [1965], SARA [2003, 2009, 2012], TIFP [2009 and 2012], Meiman [2012]). Stream discharge and groundwater flow rates were obtained from the United States Geological Survey (USGS) Water Information System website. Data for the stream gauges located along the San Antonio River, from upstream of Mission Concepción to downstream of Rancho (gauges 08178000, 08178050, 08178565, 08181800, 08183200 and 08183500], were downloaded for use in the discharge analysis (http://waterdata.usgs.gov/nwis/inventory/). Two groundwater wells are located to the west of Rancho de las Cabras near the Ray Farm Airport (TWDB 2014c). One well is administrated by the Texas Water Development Board (TWDB) and the other is administered by the USGS. Data for USGS groundwater monitoring well (290802098232901) were downloaded from the USGS Water Information website (http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=290802098232901) and data for the TWDB well (6862104) were downloaded from the TWDB website (http://www.waterdatafortexas.org/groundwater/well/6862104). Additional groundwater data for well J-17 were also obtained from the Edwards Aquifer Authority (EAA) website. The J-17 index well is located near the national cemetery at Fort Sam Houston (Eckhardt 2015). It has a lengthy period of record and can be used to identify the effects of groundwater use within San Antonio on the depth to groundwater in the Rancho. Data for J-17 were downloaded from the EAA website (http://www.edwardsaquifer.org/aquifer-data-and-maps/historical-data/historic-data-downloads).

4.15.5 Current Condition and Trend

Stream Flow Rates

The USGS has monitored streamflow in the San Antonio River through a network of gauges since the 1920s (TIFP 2009, 2012). Six of these stations, with varying periods of record, are located in proximity to SAAN property and can be used to analyze stream discharge for the park (Figure 70). A summary of the data from the period of record for these gauges is listed in Table 59 and Figure 71 is a hydrograph of daily mean discharge for USGS Station 081178565.

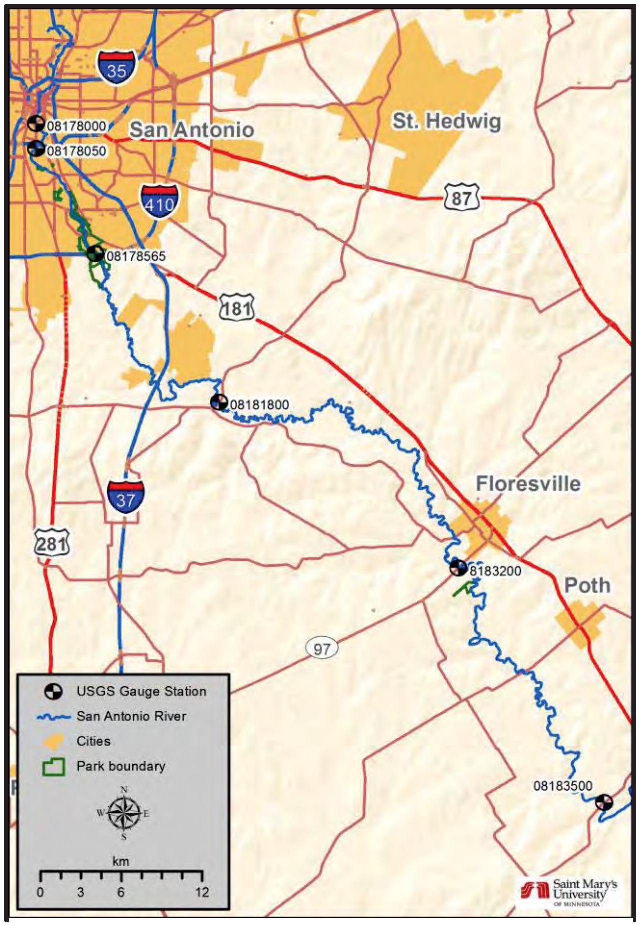

Figure 70. USGS stream gauges in the vicinity of SAAN.

Analysis of streamflow in the San Antonio River basin shows that beginning with the earliest flow records, an increase in base flow is evident at all gauges in the basin (TIFP 2011). Several factors have contributed to this increase. Since the flow in the river is so dependent on reuse water, urban growth, groundwater pumping and return flows from the San Antonio metropolitan area have contributed to the increase in flow (TIFP 2009, 2011, 2012). Also changes in precipitation have also contributed to increase in flow (TIFP 2009, 2011, 2012). Average annual precipitation has increased from 70.6 cm (27.8 in) per year for the period 1940 through 1969 to 83.4 cm (33 in) per year during the period from 1970 to 2007 (TIFP 2009, 2012). The city of San Antonio and surrounding areas receive most of their municipal water supply from groundwater pumped from the Edwards Aquifer (TIFP 2009, 2012). According to U.S. Census Bureau (2014) data, the population of the city has increased from about 250,000 in 1940 to more than 650,000 in 1970 to more than 1.4 million in 2013. The San Antonio metropolitan area is projected to grow an additional 8.65% through 2018 (SAEDF 2014). This growth and expansion has, and will continue to result in changes in water withdrawals and return flows and to the patterns of surface runoff (TIFP 2009, 2012). Discharge from wells in the Edwards Aquifer in 2012 was estimated at 47,450 hectare-meters (384,685 acre-feet), which was above the 40,434 hectare-meter (327,800 acre-feet) median for the period of record (1934-2012) (EEA 2013). The maximum annual well discharge rate over the period of record was 64,684 hectare-meter (524,400 acre-feet), occurring in 1989 (EEA 2013). The minimum annual discharge rate over the period of record was 12,569 hectare-meter (101,900 acre-feet), which occurred in 1934 (EEA 2013). Table 60 summarizes the median and mean estimated annual discharge from the Edwards Aquifer for both wells and springs for the period or record and the last 10 years.

Table 59. Discharge observations based on mean daily discharge for USGS streamflow gauges near SAAN (TIFP 2012, USGS 2014). The top row for each gauge shows observations for the entire period of record, while the second row shows these measurements just over the past decade (2004-2014).

Gauge	Earliest Record	Latest Record	Minimum Flow cms (cfs)	Maximum Flow cms (cfs)	Median Flow cms (cfs)	Drainage Area km^2 (mi^2)
08178000	1915	Present	0.002 (0.1)	90.3 (3190)	0.74 (26)	108.3 (41.8)
		2004 - 2014	0.04 (1.4)	4.4 (154)	0.71 (25)	
08178050	1992	Present	0.004 (0.1)	77.9 (2750)	0.8 (30)	109.3 (42.2)
		2004 - 2014	0.004 (0.1)	76.747 (2710)	0.68 (24)	
08178565	1986	Present	0.01 (0.5)	478.6 (16,900)	1.3 (47)	323.7 (125)
		2004 - 2014	0.01 (0.5)	396.48 (14000)	1.25 (44)	
08181800	1962	Present	0.7 (25)	1,767.2 (62,400)	8.8 (312)	4,514.3 (1,743)
		2004 - 2014	1.05 (37)	945.888 (33400)	7.62 (269)	
08183200	2006	Present	0.9 (33)	736.3 (26,000)	6.5 (229)	5,086.7 (1,964)
08183500	1925	Present	0.5 (19)	1,523.6 (53,800)	7.3 (258)	5,472.6 (2,113)
		2004 - 2014	1.1 (39)	722.2 (25,500)	7.7 (273)	

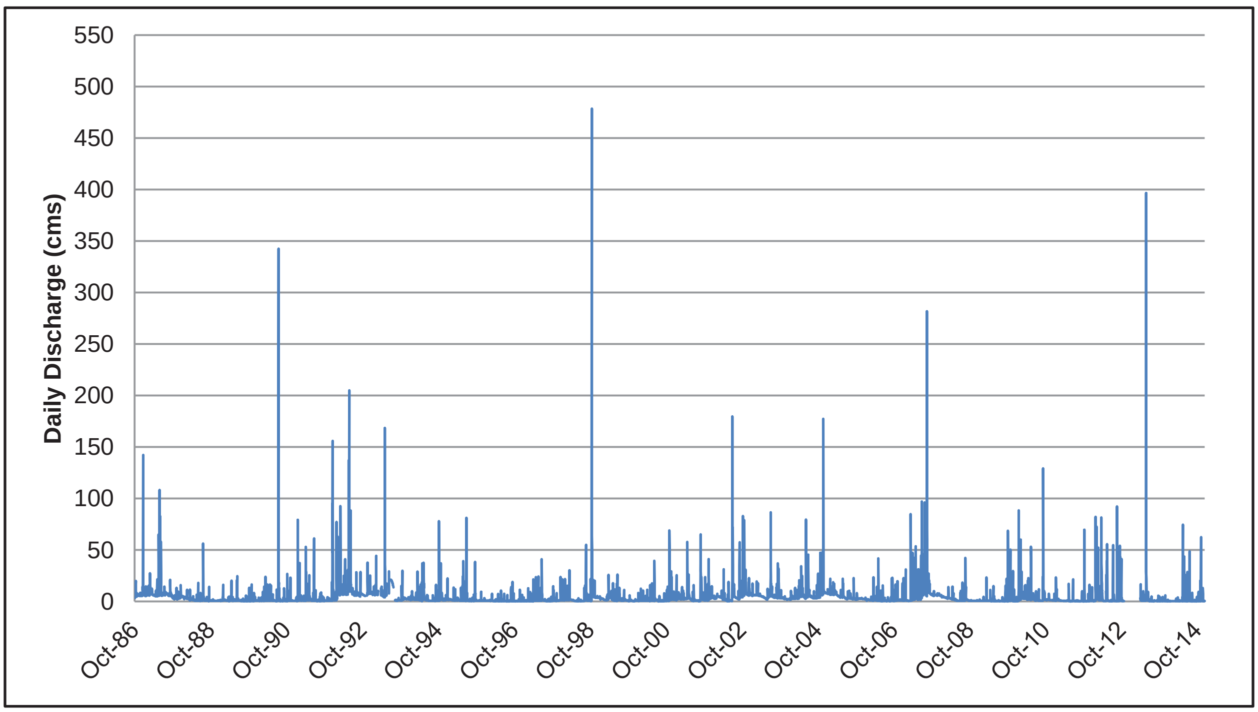

Figure 71. Period of record hydrography for daily mean discharge for USGS 08178565 (USGS 2014).

Table 60. Annual estimated groundwater discharge data for Edwards Aquifer, 1934–2012 (measured in thousands hectare-meters) (EAA 2013).

	For period of record 1934–2012		For period of record 2003–2012	
	Total for wells ha-m (ac-ft)	Total for springs ha-m (ac-ft)	Total for wells ha-m (ac-ft)	Total for springs ha-m (ac-ft)
Median discharge	40.4 (327.8)	47.4 (383.9)	47.7 (386.6)	55.9 (453.6)
Mean discharge	38.8 (314.6)	47.3 (383.2)	47.5 (385.2)	56.6 (458.7)

During the last 50 years, water use in the San Antonio River basin has undergone a rapid transformation (TIFP 2009). This use has had an impact on streamflow in the San Antonio River. River flow has been increasingly augmented by return flows from municipal use within the San Antonio metropolitan area (TIFP 2009). In fact, the river has changed from a groundwater driven system to one highly influenced by year-round treated wastewater discharges, intermittent discharges and withdrawals, and a variety of urban and rural land uses (TIFP 2009, Lizarraga and Wehmeyer 2012). It is so dependent on these augmented flows that without the reuse water, the San Antonio River would not flow during most summer months and during periods of drought (Meiman 2012). For example, flow at USGS Streamflow Gauge 08178565 (which drains the area from the headwaters to Interstate Highway 410 [I-410, or Loop 410] crossing) consists of 70 to 95% reuse water (Meiman 2012). Other studies have shown that, on average, the annual streamflow in the Lower San Antonio sub-basin at USGS Streamflow Gauge 08181800 consisted of 33% stormwater runoff, 22% inflow from the Medina River, 20% wastewater discharge, and 18% groundwater inflow (Ockerman and McNamara 2002).

Some data are also available for flow rates in Piedras Creek (PCPC) and the Acequia de Espada (AEAE) within SAAN for a period between October 2007 and December 2011 (Meiman 2012). Flows for PCPC ranged from >0.001 to 1 cms (0.01 to 37 cfs), while flows in AEAE ranged from no flow to 0.02 cms (0.7 cfs) (Meiman 2012).

Width:Depth Ratio

Stream channel hydraulic geometry analysis was first developed by Leopold and Maddock (1953). They related a number of dependent variables including steam width, depth, velocity and total sediment load as a function of discharge. These relationships provide a method of quantitatively describing channel form and the way in which the underlying variables vary with discharge (Gordon et al. 2004). Olson-Rutz and Marlow (1992) described four metrics derived from these variables that could be useful for quantifying change in channel form over time through the use of cross-sectional data from permanent transects. These matrices were: net percent change in area, absolute percent change in area, width/depth ratio, and the Gini coefficient. Net percent change quantifies the net change in cross-sectional area of a transect, the absolute percent change in area quantifies cumulative channel change, the width/depth ratio is an index of the shape of the stream, and the Gini coefficient is calculated as the arithmetic average of the differences between all pairs of depths along the transect (Olson-Rutz and Marlow 1992, Gordon et al. 2004).

The width/depth ratio (W/D) is calculated by dividing the bankfull width by the bankfull depth (Gordon et al. 2004). It is a very sensitive metric, in that it can reflect even small changes in streamflow or channel-forming processes (Rosgen 2001). Because of this sensitivity it can be diagnostic of channel instability, making it a key variable in determining whether a stream is departing from a stable reference condition (Rosgen 2001, EPA 2012). In general, W/D increases in the downstream direction, however it is strongly dependent on the composition (soil type, slope and vegetative cover) of the stream bank (Gordon et al. 2004).

As W/D changes over time, it is important to distinguish the differences between increases versus decreases in the ratio (EPA 2012). Increases in W/D are often associated with accelerated stream bank erosion, excessive sediment deposition, streamflow changes, channel widening and direct alteration of stream shape from channelization projects (Rosgen 2001). A decrease in W/D is only rated as a high risk when accompanied by a low bank height ratio (lowest bank height/maximum bankfull depth), which indicates along with the decrease in W/D, there is an associated increase in shear stress and unit stream power (EPA 2012).

The W/D can also be used as an indicator of aquatic habitat (Foster et al. 2001). Shade from the riparian vegetation, cover from undercut banks, and thermoregulation are all affected by W/D (Foster et al. 2001). A high W/D could increase the stream's exposure to solar radiation, potentially resulting in higher temperatures and undercut banks are often reduced (Foster et al. 2001). In general, relatively deep and narrow streams (low W/D value) tend to provide better fish habitat than shallow wide streams (high W/D value), especially for salmonids (Foster et al. 2001).

During the 1900s, flood hazard reduction and channel modification projects were implemented on the San Antonio River (USACE 2004). Prior to these changes, the San Antonio River was an equilibric, less altered system with a natural sediment supply (USACE 2004). The river had a much wider flood plain, a higher W/D, along with a low gradient and greater sinuosity (USACE 2004). The construction efforts straightened the river, increased the gradient, and narrowed its flood plain (USACE 2004). While these efforts did convey flood flows more rapidly, they also resulted in increased channel instability and an overall degraded aquatic and riparian habitat (USACE 2004). Improved engineering techniques emerged in the 1990s, allowing the river to be converted from essentially a drainage ditch to a more natural setting, all the while maintaining its flood water control and capacity functions (USACE 2004). The San Antonio River Improvement Project (SARIP) was initiated to restore the river to a more natural state (SARA 2001). SAAN is located within the "Mission Reach" portion of SARIP. The approach SARIP designed for the Mission Reach was to apply fluvial geomorphology metrics to restore the river to a more natural and stable condition (SARA 2001). Historic photographs, field surveys of natural channel reaches upstream and downstream of the flood control channel, and existing gradient measurements of the San Antonio River were used to classify the natural condition (SARA 2001). It was determined that the river should be restored to a "C" type stream according to the Rosgen Stream Classification System (SARA 2001). In terms of W/D, type "C" streams have a moderate to high W/D (USACE 2004). The construction of the Mission Reach restoration project was completed in October 2013 (SARIP 2014).

Depth to Groundwater (Rancho Only)

The growth in the population and urban boundary of San Antonia has impacted the availability of river flow and groundwater in the areas to the south, such as where the Rancho is located (TFIP 2009, 2012). The growth has led to an increased water demand, much of which has been met through increased pumping of groundwater (TFIP 2009). Pumping of groundwater increased from about 15,000 ha-m/year (120,000 ac-ft/year) in 1940 to a maximum of nearly 67,000 ha-m/year (542,000 ac-ft/year) in 1989 (TFIP 2009). Since that high point, pumping averaged approximately 49,500 ha-m/year (401,300 ac-ft/year) over the period 199-2007, with a median well production rate of 46,900 ha-m/year (379,900 ac-ft/year) over the same period (TFIP 2009). This pumping has led to a decline in depth to groundwater in the Edwards Aquifer which can be shown using data from the J-17 index well located near the national cemetery at Fort Sam Houston (EAA 2013, Eckhardt 2015). Depth to groundwater in the Edwards Aquifer has decreased from 16.8 m (55.2 ft) in 1932 to 26.4 m (86.5 ft) in April 2015 (EAA 2015). Depth to groundwater for the period of record for J-17 is shown in Figure 72.

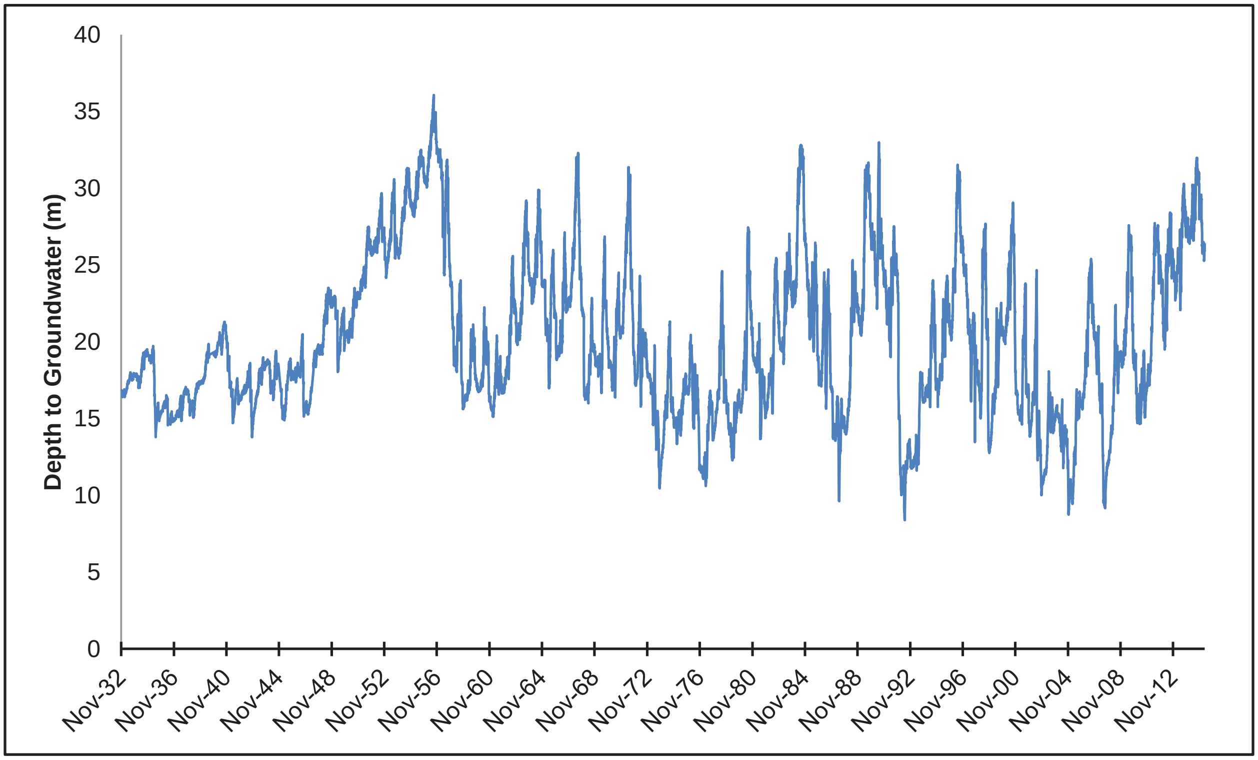

Figure 72. Depth to groundwater for J-17 index well for period November 1932 to April 2015 (EAA 2015).

The Rancho is located within the Carrizo-Wilcox Aquifer (TWDB 2014b). The rest of the SAAN properties are located within the Edwards Aquifer (Cooper et al. 2005). The Carrizo-Wilcox is a confined aquifer and is primarily composed of sand, interbedded with gravel, silt, clay and lignite (TWDB 2014a, 2014c). Two wells with depth to groundwater data are located in the vicinity of the Rancho, as shown in Figure 73. Groundwater levels for the period of record for each well are shown in Figure 74 and Figure 75. Depth to groundwater has been increasing over the period of record for both of these wells. This is consistent with conditions found in the Carrizo-Wilcox aquifer (George et al. 2011).

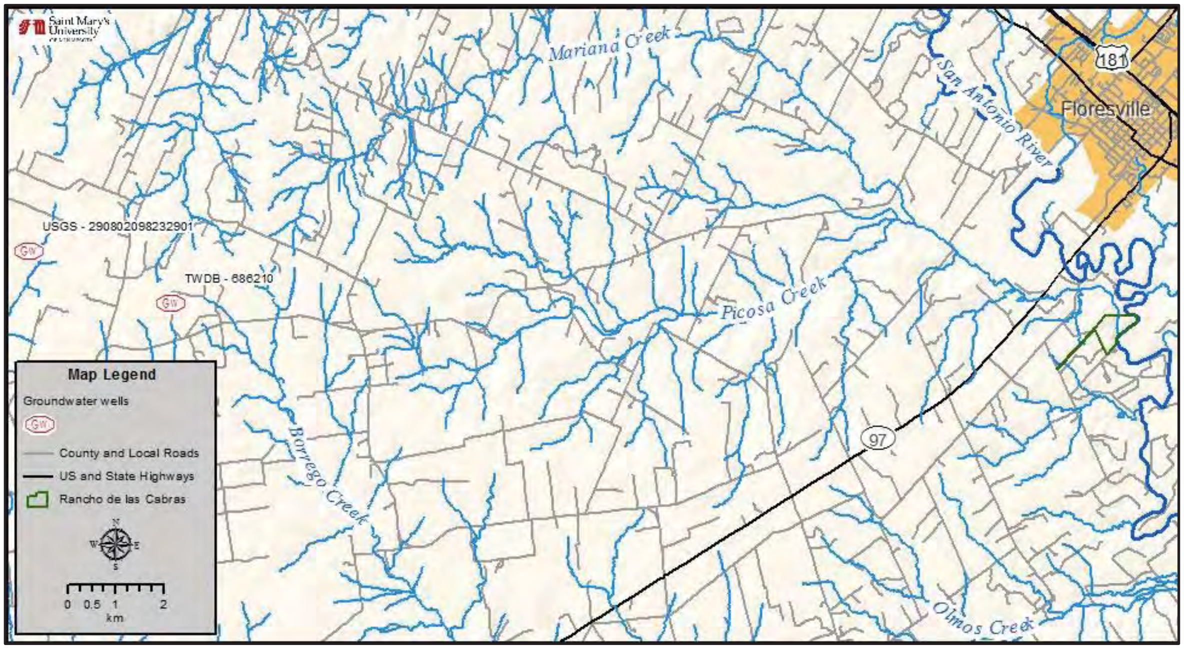

Figure 73. Location of groundwater monitoring wells in relation to the Rancho Unit.

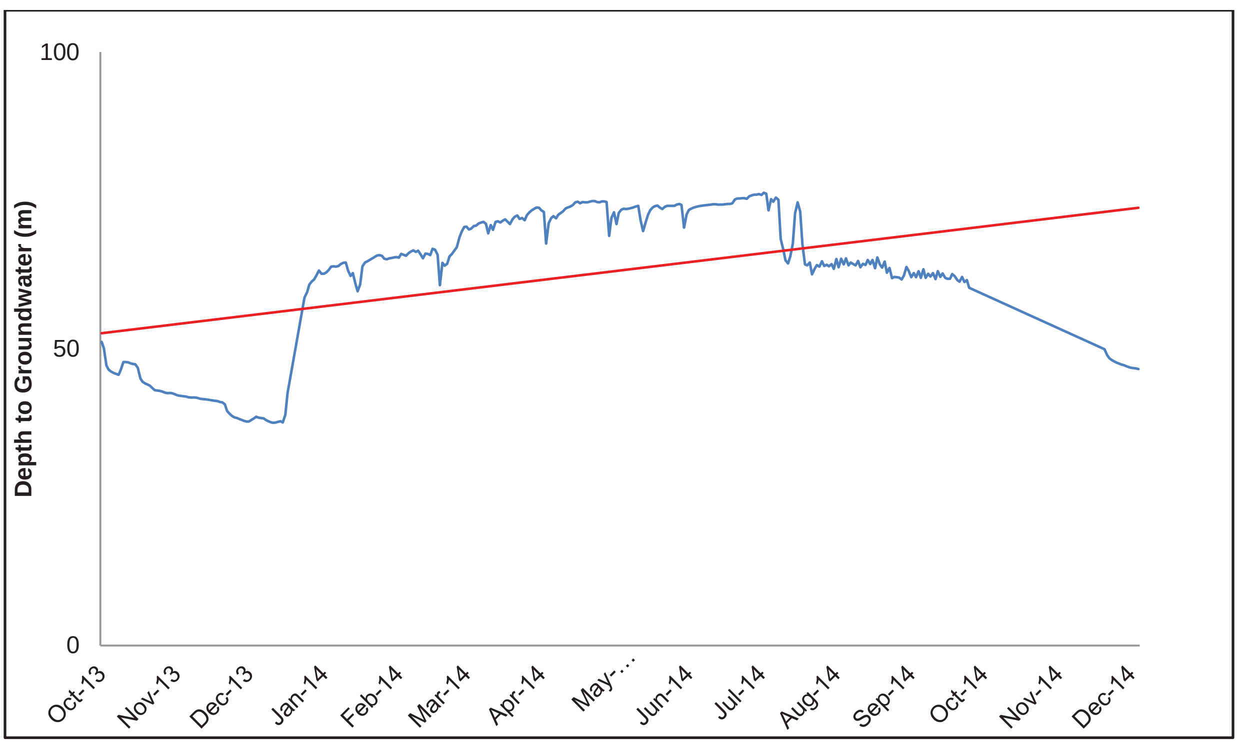

Figure 74. Depth to groundwater levels for groundwater monitoring well USGS 290802098232901 (USGS 2014).

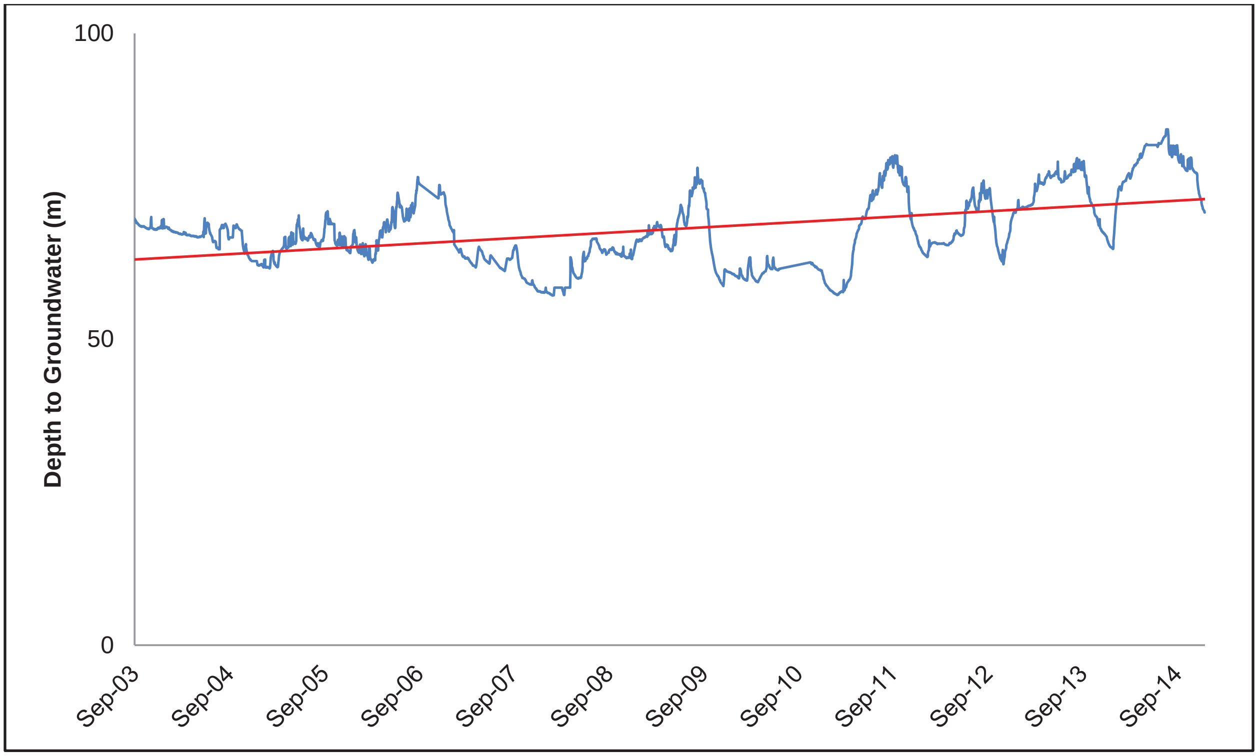

Figure 75. Depth to groundwater levels for groundwater monitoring well TWDB 6862104 (TWDB 2014c).

Threats and Stressor Factors

SAAN staff identified several potential threats and stressors to the surface water and groundwater resources in the park. These are both anthropogenic threats (repurposing of the reuse water) and naturally occurring threats that have been exacerbated by human activity (drought, extreme flooding events and climate change).

The climate for the San Antonio River Basin is dry to sub-humid with milder winters and hotter summers (Twidwell and Davis 1987). During the winter, minimum temperatures are rarely below freezing, but summertime maximum temperatures usually exceed 32.2° C (90° F) and sometimes exceed 37.7° C (100° F) (Twidwell and Davis 1987). Average annual rainfall varies over the basin, but average monthly rainfall is fairly consistent. Precipitation generally occurs as thunderstorms, so the total monthly accumulation may occur in only a handful of days (Twidwell and Davis 1987). Precipitation peaks in late spring and again in mid fall, with May being the wettest month (Twidwell and Davis 1987, Cawthon and Curran 2008). Since the 1970s, there has been a slight increase in the average annual precipitation for each decade (Cawthon and Curran 2008). Climate change models do not agree on the long term precipitation projections for Texas (TWDB 2008). Of the 23 models widely used for climate change projections, the results are split roughly in half between predicting drier or wetter conditions for East Texas (TWDB 2008). However, the majority of them do predict drier conditions for West Texas (TWDB 2008). Climate change models predict an increase in temperature for Texas, with average temperature increasing by 2-5° C (3.6-9° F) by the end of the 21st century (Foster 2011). Depending on the emission scenario used, daily maximum temperature could shift from the current range of 10-20 days above 37.7° C (100° F) to more than 100 days per year exceeding that mark (Foster 2011).

Climate change is a growing concern and threat to surface hydrology at SAAN, as well as across Texas (Foster 2011). A conference on climate change in Far West Texas concluded that all surface waters in Texas are subject to some level of risk from the potential impacts of climate change (TWDB 2008). In a study for the San Antonio Water System, hydraulic modeling was conducted using two climate change models under two emission scenarios (CH2M Hill 2008). Results from the study projected that streamflow would decrease under all climate change scenarios by 2050, despite a projected increase in precipitation. Groundwater at SAAN is also at risk from the impacts of climate change (Mace and Wade 2008). Karst aquifers, like the Edwards aquifer, have the potential to be more affected than others by climate change. The Edwards aquifer is probably the most vulnerable aquifer to climate change impacts in Texas (Mace and Wade 2008). The Carrizo-Wilcox aquifer may be less impacted by climate change. Due to its geology and the location of most pumping wells in the confined part of the aquifer, the Carrizo-Wilcox aquifer is unlikely to be directly impacted by climate change (Mace and Wade 2008). Any impact would likely be an indirect effect, as the Carrizo-Wilcox could become an alternative water source for San Antonio and other surrounding communities (Mace and Wade 2008).

Periods of drought have had a significant impact on surface water and groundwater supplies in the San Antonio area (Meiman 2012). Over time, extended periods of drought have led to the point where natural recharge of the San Antonio River is becoming uncommon (Meiman 2012). In fact, during the latter portion of the 20th century, the San Antonio River would not have had flow without augmentation from water pumped from wells in the Edwards aquifer (Meiman 2012).

The Palmer Hydrological Drought Index (PHDI) can be used to show hydrological (long-term cumulative) drought and wet conditions, as it more accurately reflects groundwater conditions and surface water conditions (NCDC 2013). The PHDI uses 0 as normal condition, and drought conditions are shown as negative numbers (Palmer 1965). An index of -4 indicates extreme drought conditions, -3 indicates severe drought conditions, -2 indicates moderate drought conditions, and -1 indicates mild drought conditions (Palmer 1965). Wet conditions are the positive counterpart of these designations (Palmer 1965). Figure 76 shows the PHDI for the state of Texas since 1900. Over the last 10 years, the extended drought has compounded the existing water quality impairments and concerns in the San Antonio River basin (SARA 2013). Climatologists have indicated that the drought of 2011 was the worst single-year drought in the period of record. Estimates are that approximately 97% of the state experienced either extreme (PDHI = -4) or severe (PDHI = -3) drought conditions, including Bexar County where SAAN is located (SARA 2013). In general, drought conditions have an adverse effect on many water quality parameters, including concentrating pollutants, and low dissolved oxygen (DO) levels in waterbodies (SARA 2013). These are mainly due to reduced flow levels. Reduced flow also has an adverse impact on the aesthetics of a waterbody and the biological communities they support (SARA 2013).

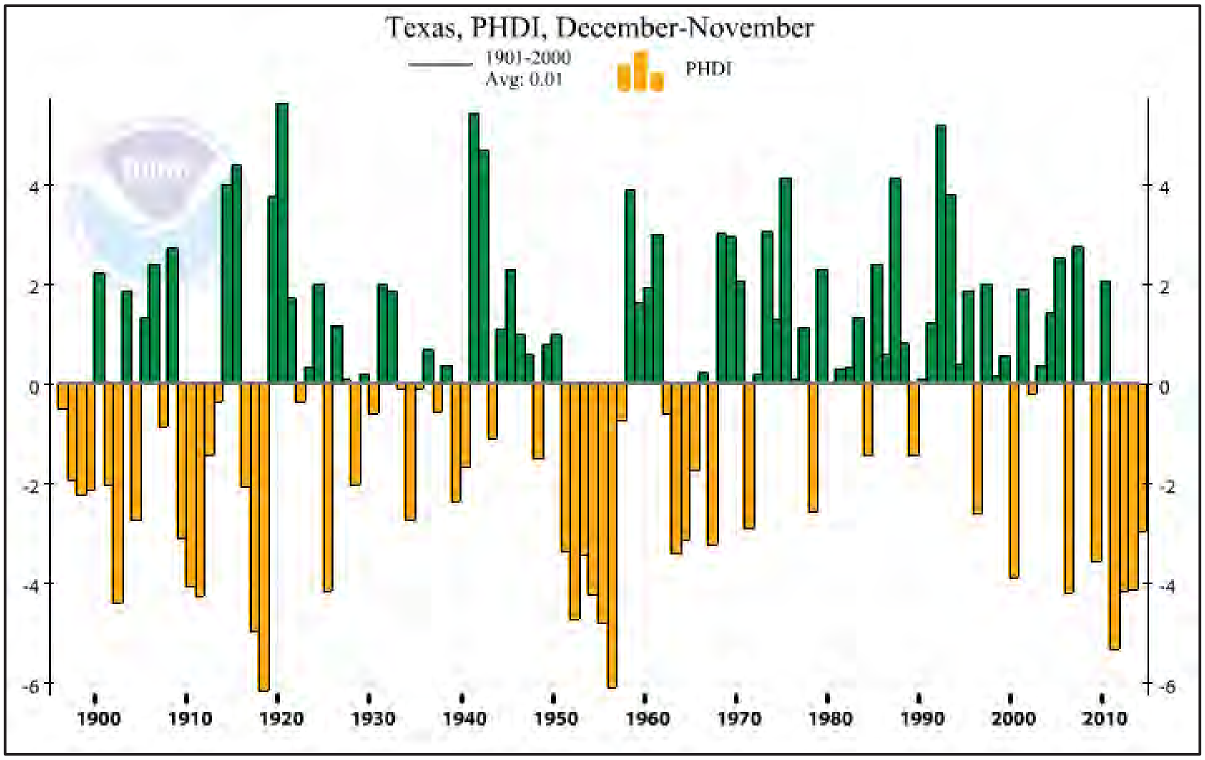

Figure 76. Palmer Hydrologic Drought Index (PHDI) for Texas. Graph was created and downloaded from time series data from the National Climatic Data Center (NCDC 2014).

SAAN is located in a region commonly referred to as "flash flood alley" (SARA 2008). The natural geography of the area tends to allow the collision of tropical storms from the Gulf of Mexico and large air masses from the north, resulting in very heavy rain events in Central Texas and the Hill Country (SARA 2008). The steep slopes, sparse vegetation, thin soils and increasing development of central Texas and the Hill Country create a condition where stormwater runoff is both rapid and destructive (SARA 2008). The rapid runoff causes scouring of river channels, disruption or destruction of aquatic and riparian habitats, mass wasting and bank failure (USACE 2004, SARA 2008). The resultant flooding also endangers lives and property (SARA 2008).

As discussed previously, flood hazard reduction and channel modification projects were implemented on the San Antonio River during the 1900s (USACE 2004). These projects were designed to effectively and efficiently control flood events (SARA 2001). The SARIP restored the river to a more natural state while maintaining its flood control capacity (SARA 2001).

Over the last 50 years, the San Antonio River basin has undergone a transformation due to the rapid development in the basin, especially in Bexar County (TIFP 2009, Lizarraga and Wehmeyer 2012). Flow in the river has been increasingly augmented by return flows from municipal uses within the City of San Antonio and the surrounding areas (TIFP 2009, Lizarraga and Wehmeyer 2012). Over this period the river has gone from a system driven primarily by groundwater discharge to a system that is highly influenced by year-round treated wastewater discharges, intermittent discharges and withdrawals, and a variety of urban and rural land uses (TIFP 2009, Lizarraga and Wehmeyer 2012).

In more recent years, the increased use of groundwater to sustain this rapid development has resulted in increasing base flows in the San Antonio River as the groundwater is returned to the river at reuse water discharge points (TIFP 2009). This trend may continue if population growth in the basin is supported by additional groundwater usage or surface water transfers from outside the basin (TIFP 2009). Lower river base flows may also result from employing management strategies such as water reuse (TIFP 2009). Without the reuse water, the river would not flow during most summer months and especially during drought periods (Meiman 2012). Augmenting the river flow with reuse water fulfills an essential economic need and plays a vital ecologic role (Meiman 2012). SAAN is dependent upon, and a stakeholder in, water quality and quantity of the San Antonio River (Meiman 2012). The park lies downstream of reuse water recharge points and the Rancho is downstream of even larger reuse discharge points (Meiman 2012). Additionally the two acequia headgates, located at the Espada Dam (Acequia de Espada) and the Archimedes Screw (Acequia de San Juan), directly draw water from the San Antonio River (Meiman 2012).

Data Needs/Gaps

In reviewing the background literature and data, no major data gaps were found that would have affected this assessment. However, establishment of stream transects in the San Antonio River to collect stream geomorphology data would allow the assessment of the width:depth ratio over time. Since the streambed is managed by SARA, this research could be a collaborative effort. The restoration project on the Missions Reach of the San Antonio River was recently completed and a period of time is needed for the new channel to establish its equilibrium state in this new design. Over time, stream flow in this equilibrium state may cause changes to the as-built conditions.

Overall Condition

Stream Flow Rates

The measure of stream discharge was assigned a *Significance Level* of 3. Stream flow is only being assessed in terms of flow in the San Antonio River. Flows in the acequias are regulated through the headgates. The increased use of groundwater as a water supply for the growing population and returning it to the river to augment flow has resulted in increased base flows (TIFP 2009, 2012). This trend may continue if population growth in the basin is supported by additional groundwater usage or surface water transfers from outside the basin (TIFP 2009). The San Antonio River is dependent on the input of reuse water to augment its flow (Meiman 2012). However, lower river base flows may also result, depending on how reuse management strategies are employed (TIFP 2009). Due to these factors and SAAN's location downstream from water reuse discharge points the *Condition Level* for this measure is 1, indicating low concern.

Width:Depth Ratio

The *Significance Level* for width:depth ratio was a 3. The width:depth ratio is only assessed for the San Antonio River channel. The SARIP recently completed stream restoration projects in the San Antonio River basin to return the river to a more natural geomorphological condition, yet still maintaining its effectiveness for flood control and flood protection (SARA 2001, SARIP 2014). This included altering the width:depth ratio to match the historic conditions. While the restoration efforts have restored the San Antonio River to reflect a more natural condition, it is still an engineered channel. How well the channel maintains its more natural condition will need to be monitored. Since the restoration was just recently completed and though more natural in nature, the width:depth ratio currently is not the result of a natural flow regime. Due to this, the *Condition Level* for this measure is given a 1, indicating low concern.

Depth to Groundwater (Rancho Only)

The *Significance Level* for depth to groundwater was a 1. Limited data are available on the depth to groundwater at SAAN's Rancho Unit. Groundwater levels in the area have been declining, but not as rapidly as other areas of the Carrizo-Wilcox aquifer (George et al. 2011). Increased dependence on groundwater as a water supply could increase this rate of decline (George et al. 2011). Due to this potential impact, a *Condition Level* of 1 is assigned, indicating low concern.

Weighted Condition Score

The *Weighted Condition Score* for hydrology at SAAN is 0.33, meaning the component is at the upper limit of good condition, bordering on moderate concern. Since the concern levels given for the measures are based on uncertainty of how the river will respond to the restoration efforts, the level of concern may be reduced in future assessments. A trend arrow was not assigned to this component at this time. Restoration projects on the San Antonio River were recently completed and, coupled with a lack of data on width and depth measurements, it is difficult to make a trend assessment for this component. In addition, the flow rates could either increase or decrease in the future dependent on factors such as population growth and water repurposing management strategies.

Hydrology			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Stream flow rates	3	1	
Width:depth ratio	3	1	
Depth to groundwater	1	1	

4.15.6 Sources of Expertise

Greg Mitchell, SAAN Natural Resources Program Manager

Joe Meiman, NPS Hydrologist, Gulf Coast Region

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Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 61 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 61. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Forested Riparian Corridors (including acequias)	➢ No data regarding coverage of native species or age class structure.
Native Grassland/Prairie	➢ Little is known about exact composition and extent of historic native grasslands. ➢ Current restoration efforts provide an opportunity to study the process and the restored grasslands.
Upland Shrublands/Woodlands	➢ Update vegetation mapping to determine if shrublands/woodlands have expanded. ➢ Percent coverage of native species has not been studied.
Reptiles	➢ No information on reproductive success. ➢ Continue monitoring of species richness and abundance to identify any changes over time.
Amphibians	➢ No information on reproductive success. ➢ Continue monitoring of species richness and abundance to identify any changes over time. ➢ Identify any impacts from non-native species (e.g., competition, predation).
Breeding Birds	➢ Continued monitoring to establish baseline values for the identified measures.

Table 61 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Breeding Birds (continued)	➢ Monitoring/studies of the migratory bird population are needed. ➢ Monitoring of the trends in breeding species of conservation concern is also needed.
Resident Birds	➢ Continued monitoring, especially during winter, to establish baseline values for the identified measures. ➢ Monitoring of the trends in resident species of conservation concern is needed.
Aquatic Macroinvertebrates	➢ Sampling has been sporadic, leaving many gaps in data, both spatially and temporally. No IBIs have been calculated for the Rancho Unit.
Fish	➢ Establishment of annual, routine monitoring of fish species richness and IBI would aid in management. ➢ No information regarding the impacts of nonnative fish on native fish species.
Water Quality	➢ Continuation of GULN monitoring efforts ➢ A recompilation of data from the NPS (1999) report within a more limited geographic area, as well as any new data, and focusing on EPA as well as TCEQ standards might yield a better picture of long-term trends in the park's water quality.
Air Quality	➢ Current monitoring stations may not be close enough to the Rancho Unit, which is south of Floresville, to accurately represent conditions there. ➢ Monitoring of nitrogen and sulfur deposition and visibility in or near both units would help managers better understand the local air quality conditions.
Soundscape	➢ Current available data are for a short period during one season and from one location in the park. Additional monitoring should be conducted as soon as possible to help document any changes due to surrounding development. ➢ No data for the Rancho Unit; conditions at this rural location are likely very different from the more urban Missions Unit. A baseline survey should be conducted as soon as possible to document conditions before they are further impacted by surrounding activities.
Dark Night Skies	➢ No baseline data has been collected from either park unit.
Viewscape	➢ Continued development of spatial data to explain landscape change, enabling accurate and up-to-date viewshed assessments. These data could help minimize the impact of surrounding development on the park's viewshed.

Table 61 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Hydrology (Surface and Groundwater)	➢ Establishment of stream transects to collect stream geomorphology data would allow the assessment of the width:depth ratio over time (collaborative effort with SARA).

Some of the park's data needs involve continuing recently established monitoring programs, to accumulate enough data for identifying any trends over time (e.g., reptiles, amphibians, birds). Many of the vegetation community data gaps will be addressed through soon-to-be implemented GULN monitoring efforts.

5.2 Component Condition Designations

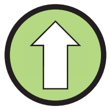
Table 62 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 77 following Table 62). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 62) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historical data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information. Condition could not be determined for five of the 15 selected components: forested riparian corridors, native grasslands, amphibians, aquatic macroinvertebrates, and dark night skies.

For featured components with available data and fewer data gaps, assigned conditions varied. Five components are considered to be of low concern: upland shrublands/woodlands, reptiles, breeding and resident birds, and hydrology. Two components (fish and water quality) were of moderate concern. Three components were of high concern: air quality, soundscape, and viewscape. The high concern levels are primarily due to the urban land uses surrounding the park and are largely beyond NPS control.

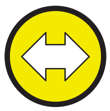
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence *(explanation is required if a trend symbol or a medium/high confidence band is shown)*				

Figure 77. Description of symbology used for individual component assessments.

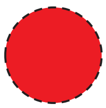
<u>Examples of how the symbols should be interpreted:</u>



Resource is in good condition, its condition is improving, high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.

Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Table 62. Summary of current condition and condition trend for featured NRCA components.

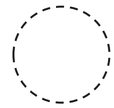
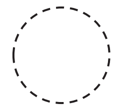
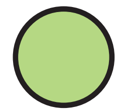
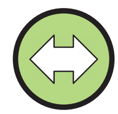
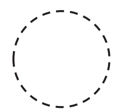
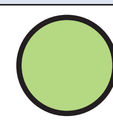
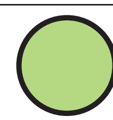
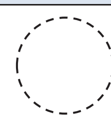
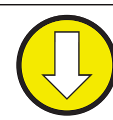
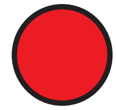
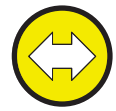
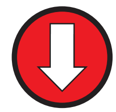
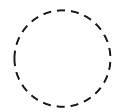
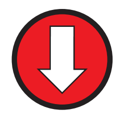
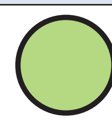
Component	WCS	Condition
Biological Composition		
Ecological communities		
Forested Riparian Corridors	N/A	
Native Grasslands	N/A	
Upland Shrublands/Woodlands	0.13	
Herptiles		
Reptiles	0.22	
Amphibians	N/A	
Birds		
Breeding Birds	0.17	
Resident Birds	0.33	
Freshwater Biota		
Aquatic Macroinvertebrates	N/A	
Fish	0.67	

Table 62 (continued). Summary of current condition and condition trend for featured NRCA components.

Component	WCS	Condition
Environmental Quality		
Air quality	0.79	
Water quality	0.53	
Soundscape	0.83	
Dark Night Skies	N/A	
Viewscape	0.75	
Physical Characteristics		
Geologic & Hydrologic		
Hydrology (Surface and Groundwater Dynamics)	0.33	

5.3 Park-wide Condition Observations

Despite the disjunct nature of SAAN's units, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park).

Vegetation Communities

The vegetation communities of SAAN have been influenced by centuries of human impacts, from agricultural use during the Missions period to more recent urban development. However, the plant communities still provide habitat for wildlife and perform critical ecological functions. Given a lack of data for several key measures, a condition could not be determined for forested riparian corridors. Many of these information gaps will be addressed by a GULN vegetation monitoring program starting soon and by an exotic plant survey and mapping effort scheduled for 2016. A condition was not determined for native grasslands because this community is currently absent from the park, although some plant species historically found in grasslands can still be found. Efforts are underway to restore this habitat to the park at two sites: one in the Missions Unit and one at Rancho de las Cabras. Upland shrublands and woodlands are in good condition, as this community is thought to have a wider distribution now than it did historically (Van Auken and Bush 1984).

Other Biotics

Animals featured as NRCA components were reptiles, amphibians, breeding and resident birds, fish, and aquatic macroinvertebrates. Because of limited data sources, overall condition could not be determined for amphibians and aquatic macroinvertebrates. With the continuation of sampling and surveys currently underway (by the GULN for amphibians and SARA for macroinvertebrates), enough information should be available within a few years to better assess the condition of these resources. Reptiles, breeding birds, and resident birds are currently in good condition. Fish are considered of moderate concern due to low and/or decreasing IBI ratings over the past decade (SARA 2005, 2013a). Habitat loss and degradation, water quality impairments, and droughts (which may be exacerbated by climate change) have all likely contributed to degradation of the fish community in the SAAN region (SARA 2013b).

Environmental Quality

Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be affected substantially by the condition of air and water quality. Air quality is of high concern at SAAN, particularly due to high ozone concentrations and nitrogen deposition levels around the city of San Antonio (TCEQ 2014, NPS 2014). Although ozone concentrations have only occasionally exceeded standards at monitoring stations near the park in recent years, the EPA is currently reviewing the NAAQS ground-level ozone standard and may suggest a stricter standard between 60-70 ppb (EPA 2014). If a stricter standard is enacted, much of the SAAN region would be in "nonattainment" (i.e., not meeting the federal air quality standard). It is also likely that increased oil and gas development southeast of the park and climate change will negatively influence air quality in the coming decades (EPA 2011, AACOG 2013)

Water quality is of moderate concern, with nutrients and coliform bacteria as the individual parameters of highest concern. Many of the area's water quality impairments are related to its location near an urban environment and the use of recycled wastewater ("reuse water") to maintain flows in the San Antonio River (Meiman 2012). Water quality could also be threatened by climate change, as extreme weather events (e.g., droughts, heavy rains, heat waves) are predicted to increase (Davey et al. 2007).

The park's viewscape and soundscape are of high concern, due to continued urban development around the Missions Unit of the park. Anthropogenic sounds such as road and air traffic are audible almost constantly around the Missions (Lynch 2009). While view- and soundscape are in better condition at the Rancho Unit due to its more rural location, conditions are likely deteriorating here as well due to human activities. As mentioned previously, the majority of negative impacts on these resources come from outside park boundaries and are largely beyond the control of park managers. A condition could not be determined for dark night skies because no data have been gathered at either park unit. Given that most of the Missions Unit lies within the city of San Antonio, dark night skies are almost certainly impaired there.

Physical Characteristics

The San Antonio River has been greatly manipulated in the San Antonio area, largely due to flood control activities. These alterations have influenced hydrology and aquatic habitats. In recent years, efforts have been made to restore the river to more natural conditions (SARA 2001). However, the increasing use of recycled wastewater ("reuse water") to maintain San Antonio River flows is a concern. Without reuse water, portions of the river could dry up in the summer months, especially during droughts (Meiman 2012).

Park-wide Threats and Stressors

Several threats and stressors influence the condition of multiple resources throughout SAAN. These include the presence of non-native invasive species and effects of urban development (e.g., habitat loss and fragmentation, pollution, hydrologic alterations). Drought is also a looming threat which may be exacerbated by climate change. Invasive plant species such as Chinaberry and exotic grasses are a threat to all of the park's vegetation communities, due to their ability to out-compete native plants (Cooper et al. 2005, NPS 2010). Among non-native animals, feral hogs are perhaps the greatest threat. Their destructive rooting and wallowing behavior could impact all of the park vegetation communities as well as native wildlife (herptiles, birds, invertebrates, etc.) (Taylor 2003).

Development and human activity prior to park establishment drastically altered the historic Missions landscape, causing widespread habitat loss and fragmentation. Continued development in more recent decades, particularly around the Missions Unit, has impacted the environmental quality (particularly viewscape and soundscape) of the park. Many of the park's air and water quality concerns are due to the Missions Unit's urban location. As mentioned previously, these threats and stressors are largely beyond the control of park management.

Much of Texas has been experiencing drought conditions for several years now (U.S. Drought Monitor 2014). Droughts negatively impact many park resources, from riparian vegetation, amphibians, and fish, to water quality and hydrology. Unfortunately, droughts are likely to increase in the future as a result of climate change (Twilley et al. 2001, Davey et al. 2007). Winter and spring precipitation are projected to decrease in the San Antonio region over the next century; combined with warmer temperatures, this will lead to overall drier conditions in the region (Maurer et al. 2007; see Chapter 2).

Overall Conclusions

Despite its largely urban location, SAAN supports a variety of valuable natural resources. These resources are key components of the park's cultural landscape. Although SAAN is impacted by adjacent human activities, the natural setting still provides an oasis from the surrounding developed areas for both wildlife and human visitors. Maintaining and/or improving these resources will contribute to the environmental health of the surrounding area and provide important opportunities for urban residents to connect with the natural world.

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Appendices

Appendix A. Non-native plant species documented in SAAN (ornamentals excluded) (Halvorson and Guertin 2006).

Scientific name	Common Name	Missions	Rancho	>20 ha infested?	TX noxious weed
Ailanthus altissima	tree of heaven	x		x	
Albizia julibrissin	silktree	x			
Alternanthera Philoxeroides	alligatorweed	x			x
Ammi majus	large bullwort	x		x	
Anagallis arvensis	scarlet pimpernel	x	x	x	
Antigonon leptopus	coral vine	x		x	
Arundo donax	giant reed	x		x	x
Asparagus officinalis	garden asparagus	x			
Avena sativa	common oat	x	x	x	
Bignonia capreolata	crossvine	x			
Bothriochloa ischaemum var. *songarica*	yellow bluestem (formerly King's Ranch blustem)	x	x	x	
Bromus catharticus	rescuegrass	x	x	x	
Bromus arvensis (formerly *japonicus*)	field brome	x	x	x	
Broussonetia papyrifera	paper mulberry	x		x	
Buglossoides arvensis	corn gromwell	x		x	
Capsella bursa-pastoris	shepherd's purse	x	x		
Centaurea melitensis	Maltese star-thistle	x	x		
Chenopodium sp.	goosefoot	x	x	x	
Clematis terniflora	sweet autumn virginsbower	x			
Colocasia esculenta	coco yam	x		x	
Convolvulus arvensis	field bindweed	x	x	x	x
Cynodon dactylon	Bermudagrass	x	x	x	
Cyperus rotundus	nutgrass	x		x	
Dichanthium annulatum var. *annulatum*	Diaz bluestem	x	x		

Appendix A (continued). Non-native plant species documented in SAAN (ornamentals excluded) (Halvorson and Guertin 2006).

Scientific name	Common Name	Missions	Rancho	>20 ha infested?	TX noxious weed
Dichanthium aristatum	Angleton bluestem	x			
Echinochloa colona	jungle rice	x	x		
Eichhornia crassipes	common water hyacinth	x			x
Eleusine indica	Indian goosegrass	x			
Eragrostis barrelieri	Mediterranean lovegrass	x	x		
Eragrostis cilianensis	stinkgrass	x			
Eriobotrya sp.	loquat	x			
Erodium cicutarium	redstem stork's bill	x			
Ficus carica	edible fig	x			
Fumaria officinalis	drug fumitory	x			
Hedera sp.	ivy	x			
Hedypnois cretica	Cretanweed	x			
Heliotropium indicum	Indian heliotrope		x		
Hordeum murinum ssp. *leporinum*	hare barley	x			
Hydrilla verticillata	water thyme	x			X
Lactuca serriola	prickly lettuce	x	x	x	
Lagerstroemia indica	crapemyrtle	x			
Lamium amplexicaule	henbit deadnettle	x			
Leucaena leucocephala	white leadtree	x			
Ligustrum japonicum	Japanese privet	x		x	
Lolium perenne	perennial ryegrass	x	x		
Lonicera japonica	Japanese honeysuckle	x			
Malva parviflora	cheeseweed mallow	x			
Medicago lupulina	black medick	x	x		
Medicago polymorpha	burclover	x	x	x	
Medicago sativa	alfalfa	x			
Melia azedarach	Chinaberrytree	x	x	x	
Melilotus officinalis	sweetclover	x			

Appendix A (continued). Non-native plant species documented in SAAN (ornamentals excluded) (Halvorson and Guertin 2006).

Scientific name	Common Name	Missions	Rancho	>20 ha infested?	TX noxious weed
Melilotus indicus	annual yellow sweetclover	x	x		
Mirabilis jalapa	marvel of Peru	x			
Morus alba	white mulberry	x	x		
Nandina domestica	sacred bamboo	x			
Paspalum dilatatum	dallisgrass	x	x		
Pennisetum ciliare	buffelgrass	x	x		
Phyllostachys aurea	golden bamboo	x			
Pilea microphylla	rockweed	x			
Plantago major	common plantain	x			
Poa annua	annual bluegrass	x	x		
Polycarpon tetraphyllum	fourleaf manyseed		x		
Polypogon monspeliensis	annual rabbitsfoot grass	x			
Punica granatum	pomegranate	x			
Ranunculus muricatus	spinyfruit buttercup	x			
Rapistrum rugosum	annual bastardcabbage	x			
Rhynchosia minima	least snoutbean	x		x	
Ricinus communis	castorbean	x			
Nasturtium officinale	watercress	x			
Rumex crispus	curly dock	x	x		
Rumex pulcher	fiddle dock	x	x		
Scandix pecten-veneris	shepherdsneedle	x			
Sisymbrium irio	London rocket	x	x		
Sonchus asper	spiny sowthistle	x	x	x	
Sonchus oleraceus	common sowthistle	x	x		
Sorghum halepense	Johnsongrass	x	x	x	
Stellaria media	common chickweed	x	x		
Stenotaphrum secundatum	St. Augustine grass	x			

Appendix A (continued). Non-native plant species documented in SAAN (ornamentals excluded) (Halvorson and Guertin 2006).

Scientific name	Common Name	Missions	Rancho	>20 ha infested?	TX noxious weed
Taraxacum officinale	common dandelion	x			
Torilis arvensis	spreading hedgeparsley	x	x	x	
Torilis nodosa	knotted hedgeparsley	x	x		
Triadica sebifera	small Chinese tallow	x			
Tribulus terrestris	puncturevine	x			
Urochloa maxima	guineagrass	x	x		
Verbena brasiliensis	Brazilian vervain	x			
Veronica agrestis	green field speedwell	x			
Veronica anagallis-aquatica	water speedwell	x			
Veronica arvensis	corn speedwell	x			
Veronica persica	birdeye speedwell	x			
Vitex agnus-castus	lilac chastetree	x			
	Totals	**89**	**35**	**24**	**5**

Appendix B. Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Acacia farnesiana (formerly *minuta*)	sweet acacia; huisache	x	x
Acer negundo	boxelder		x
Acer negundo var. *texanum*	boxelder	x	
Adiantum capillus-veneris	common maidenhair	x	
Allium canadense var. *canadense*	meadow garlic	x	x
*Alternanthera philoxeroides**	alligatorweed		x
Ambrosia trifida	giant ragweed	x	x
Ampelopsis arborea	peppervine	x	x
Anemone berlandieri	tenpetal thimbleweed	x	
*Antigonon leptopus**	coral vine	x	
Apocynum cannabinum	Indianhemp		x
*Arundo donax**	giant reed	x	
Bignonia capreolata	crossvine	x	
Bowlesia incana	hoary bowlesia	x	x
*Bromus catharticus**	rescuegrass		x
*Broussonetia papyrifera**	paper mulberry	x	
Calyptocarpus vialis	straggler daisy	x	x
Campsis radicans	trumpet creeper	x	x
*Capsella bursa-pastoris**	shepherd's purse		x
*Cardiospermum halicacabum**	balloon vine		x
Carex bulbostylis	false hair sedge	x	x
Carex tetrastachya	Britton's sedge	x	x
Carya illinoinensis	pecan		x
Celosia nitida	West Indian cock's comb	x	x
Celtis ehrenbergiana	spiny hackberry	x	x
Celtis laevigata var. *laevigata*	sugarberry	x	x
Cephalanthus occidentalis	common buttonbush		x
Cephalanthus occidentalis var. *californicus*	common buttonbush	x	
Chaerophyllum tainturieri var. *dasycarpum*	hairyfruit chervil	x	

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
Chamaesyce nutans	eyebane		x
Chamaesyce prostrata	prostrate sandmat		x
Chasmanthium latifolium	Indian woodoats	x	x
Cheilanthes alabamensis	Alabama lipfern		x
Chloracantha spinosa	spiny chloracantha		x
Cirsium texanum	Texas thistle		x
Cissus trifoliata	sorrelvine	x	x
Clematis drummondii	Drummond's clematis	x	x
Clematis pitcheri	bluebill	x	x
*Clematis terniflora**	sweet autumn virginsbower	x	
Cocculus carolinus	Carolina coralbead	x	
Colubrina texensis	Texan hogplum		x
Commelina erecta var. *erecta*	whitemouth dayflower	x	x
Condalia hookeri var. *hookeri*	Brazilian bluewood		x
Cooperia pedunculata	prairie lily		x
Cornus drummondii	roughleaf dogwood	x	x
Corydalis sp.	fumewort; scrambled eggs		x
Crataegus sp.	hawthorn		x
*Cynodon dactylon**	Bermudagrass	x	x
Cyperus erythrorhizos	redroot flatsedge	x	
Cyperus ochraceus	pond flatsedge	x	x
Dichanthelium oligosanthes var. *oligosanthes*	Heller's rosette grass		x
Dichondra carolinensis	Carolina ponysfoot	x	
Dicliptera brachiata	branched foldwing	x	x
Diospyros texana	Texas persimmon		x
*Echinochloa colona**	jungle rice	x	
Ehretia anacua	knockaway; anacua	x	
*Elaeagnus macrophylla**	silverberry	x	

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
Elymus virginicus var. *virginicus*	Virginia wildrye		x
Erigeron philadelphicus	Philadelphia fleabane	x	x
Eupatorium serotinum	lateflowering thoroughwort		x
Euphorbia spathulata	warty spurge		x
*Ficus carica**	edible fig	x	
Fleischmannia incarnata	pink thoroughwort		x
Fraxinus berlandieriana	Mexican ash	x	x
Galium aparine	cleavers, stickwilly	x	x
Gamochaeta pensylvanica	Pennsylvania everlasting		x
Geranium texanum	Texas geranium		x
Guaiacum angustifolium	Texas lignum-vitae		x
Helenium microcephalum	smallhead sneezeweed		x
Heliotropium indicum	Indian heliotrope		x
Hordeum pusillum	little barley		x
Hydrocotyle verticillata	whorled marshpennywort	x	
Ilex decidua	possumhaw	x	
Iva annua	annual marsh elder	x	
Juglans nigra	black walnut	x	
Lactuca sp.	wild lettuce		x
Lactuca floridana	woodland lettuce	x	
Lactuca ludoviciana	biannual lettuce	x	
*Lactuca serriola**	prickly lettuce	x	
*Lamium amplexicaule**	henbit deadnettle	x	x
Lemna aequinoctialis	lesser duckweed		x
*Ligustrum japonicum**	Japanese privet	x	
*Ligustrum sinense**	Chinese privet	x	
Limnodea arkansana	Ozarkgrass	x	
*Lolium perenne**	perennial ryegrass	x	

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
*Lonicera japonica**	Japanese honeysuckle	x	
Lycium berlandieri	Berlandier's wolfberry		x
Malvaviscus arboreus var. *drummondii*	wax mallow	x	x
Marsilea macropoda	bigfoot waterclover		x
Matelea reticulata	netted milkvine	x	x
*Medicago lupulina**	black medick		x
*Medicago polymorpha**	Burclover		x
*Melia azedarach**	Chinaberrytree	x	x
Melothria pendula	Guadeloupe cucumber	x	x
Mikania scandens	climbing hempvine	x	
*Mirabilis jalapa**	marvel of Peru	x	
*Morus alba**	white mulberry		x
Morus rubra	red mulberry		x
Nama jamaicense	Jamaicanweed		x
*Nandina domestica**	sacred bamboo	x	
Nassella leucotricha	Texas wintergrass	x	x
Nemophila phacelioides	largeflower baby blue eyes		x
Nothoscordum bivalve	crowpoison	x	
Oenothera rosea	rose evening primrose	x	
Onosmodium bejariense var. *bejariense*	soft-hair marbleseed	x	
Oxalis dillenii	slender yellow woodsorrel		x
Panicum capillare	witchgrass	x	
Panicum dichotomiflorum	fall panicgrass	x	
Parietaria pensylvanica	Pennsylvania pellitory		x
Parthenocissus quinquefolia	Virginia creeper	x	x
Paspalum denticulatum	longtom	x	
*Paspalum dilatatum**	dallisgrass	x	
Paspalum langei	rustyseed paspalum	x	x

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
Paspalum pubiflorum	hairyseed paspalum		x
*Paspalum urvillei**	Vasey's grass		x
Phalaris caroliniana	Carolina canarygrass		x
Phoradendron tomentosum	Christmas mistletoe	x	
Phyla nodiflora	turkey tangle fogfruit	x	x
*Phyllostachys aurea**	golden bamboo	x	
Physalis angulata	cutleaf groundcherry		x
*Plantago major**	common plantain	x	
Plantago rhodosperma	redseed plantain	x	
*Poa annua**	annual bluegrass	x	
Polygonum punctatum	dotted smartweed		x
Polygonum ramosissimum	bushy knotweed		x
Populus deltoides	eastern cottonwood	x	x
Prosopis glandulosa var. *glandulosa*	honey mesquite		x
Ptelea trifoliata	common hoptree		x
Quercus virginiana	live oak	x	x
Ranunculus muricatus	spinyfruit buttercup	x	
*Rapistrum rugosum**	annual bastardcabbage	x	
Rivina humilis	rougeplant	x	x
Rubus riograndis	Rio Grande dewberry	x	x
Rudbeckia hirta var. *angustifolia*	Perdue blackeyed susan	x	
Ruellia drummondiana	Drummond's wild petunia	x	
Ruellia nudiflora var. *nudiflora*	violet wild petunia		x
Rumex chrysocarpus	amamastla	x	
Rumex pulcher	fiddle dock	x	x
Sabal mexicana	Rio Grande palmetto	x	
Salix nigra	black willow	x	x
Salvia coccinea	blood sage	x	x

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
Sambucus nigra ssp. *canadensis*	American black elderberry	x	x
Samolus valerandi ssp. *parviflorus*	seaside brookweed	x	
Sanicula canadensis	Canadian blacksnakeroot	x	
Sapindus saponaria var. *drummondii*	western soapberry	x	x
*Scandix pecten-veneris**	shepherdsneedle	x	
Scutellaria ovata	heartleaf skullcap		x
Sesbania sp.	riverhemp		x
Sideroxylon lanuginosum	gum bully	x	x
Smilax bona-nox	saw greenbriar	x	x
Solidago canadensis	Canada goldenrod	x	
*Sonchus asper**	spiny sowthistle	x	x
*Sonchus oleraceus**	common sowthistle	x	
*Sorghum halepense**	Johnsongrass	x	
Stachys crenata	mousesear		x
*Stellaria media**	common chickweed	x	x
Stellaria prostrata	prostrate starwort		x
*Stenotaphrum secundatum**	St. Augustine grass	x	
Strophostyles helvula	amberique-bean; wild bean	x	
Symphyotrichum ericoides	heath aster	x	
Symphyotrichum lanceolatum ssp. *lanceolatum*	white panicle aster	x	x
Taxodium distichum	bald cypress	x	
Teucrium canadense	Canada germander	x	
Thelypteris ovata var. *lindheimeri*	Lindheimer's marsh fern	x	
Tillandsia recurvata	small ballmoss	x	x
Tinantia anomala	widowstears	x	x
*Torilis arvensis**	spreading hedgeparsley	x	x
Toxicodendron radicans	poison ivy	x	x
Tradescantia sp.	spiderwort	x	

Appendix B (continued). Plant species documented in SAAN's riparian woodlands/forests (Carr 2003a, b). Asterisks (*) indicate non-native species.

Scientific Name	Common Name	Missions	Rancho
Chaerophyllum tainturieri var. *tainturieri*	hairyfruit chervil	x	x
*Triadica sebifera**	Chinese tallow	x	
Triodanis biflora	small Venus' looking-glass		x
Ulmus americana	American elm	x	x
Ulmus crassifolia	cedar elm	x	x
*Urochloa maxima**	guineagrass	x	
Urtica chamaedryoides	heartleaf nettle		x
Valerianella radiata	beaked cornsalad	x	
*Verbena brasiliensis**	Brazilian vervain	x	
Verbesina virginica	white crownbeard	x	x
Veronica peregrina	neckweed	x	x
Vicia ludoviciana ssp. *ludoviciana*	Lousiana vetch		x
Viguiera dentata	toothleaf goldeneye	x	
*Vinca major**	bigleaf periwinkle	x	
Viola sp.	violet		x
*Vitex agnus-castus**	lilac chastetree	x	
Vitis cinerea var. *helleri*	Heller's grape	x	
Vitis mustangensis	mustang grape	x	x
Xanthium strumarium	rough cocklebur		x
	Totals	**128**	**117**

Appendix C. Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Carlowrightia texana	Texas wrightwort	x	
Justicia pilosella	Gregg's tube tongue	x	
Ruellia metziae	Metz's wild petunia	x	
Ruellia nudiflora var. *runyonii*	Runyon's wild petunia	x	
Yucca constricta	narrowleaf or Buckley's yucca	x	
Amaranthus palmeri	carelessweed	x	
Amaranthus polygonoides	Berlandier or tropical amaranth	x	
Spermolepis inermis	Red River scaleseed	x	
Daucus pusillus	American wild carrot		x
Aristolochia erecta	swanflower		x
Asclepias oenotheroides	zizotes milkweed	x	x
Ambrosia confertiflora	weakleaf bur ragweed	x	
Ambrosia psilostachya	western ragweed	x	x
Ambrosia trifida	giant ragweed	x	x
Aphanostephus ramosissimus	plains dozedaisy or lazy daisy	x	x
Aphanostephus skirrhobasis	Arkansas dozedaisy		x
Symphyotrichum divaricatum	southern annual saltmarsh aster		x
Symphyotrichum ericoides	heath aster	x	
Astranthium integrifolium	entireleaf western daisy		x
Baccharis neglecta	Rooseveltweed	x	x
Baccharis texana	prairie false willow		x
Calyptocarpus vialis	straggler daisy	x	x
Cirsium texanum	Texas thistle	x	
Conyza canadensis	horseweed	x	x
Coreopsis nuecensis	crown tickseed		x
Coreopsis tinctoria	golden tickseed or plains coreopsis	x	
Thymophylla tenuiloba var. tenuiloba	bristleleaf pricklyleaf	x	
Engelmannia peristenia	Engelmann's daisy	x	
Gaillardia pulchella	Indian blanket		X

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Evax verna	spring pygmycudweed	x	
Florestina tripteris	sticky florestina	x	
Gaillardia pulchella	Indian blanket	x	
Grindelia squarrosa	curlycup gumweed	x	
Gutierrezia texana	Texas snakeweed	x	
Helianthus annuus	common sunflower	x	X
Helianthus debilis ssp. *cucumerifolius*	cucumberleaf sunflower	x	
Helianthus maximiliani	Maximilian sunflower	x	
Heterotheca subaxillaris	camphorweed	x	X
Hymenopappus scabiosaeus var. *corymbosus*	Carolina woolywhite	x	
Krigia caespitosa	weedy dwarfdandelion		X
Lindheimera texana	Texas yellowstar	x	
Lygodesmia texana	Texas skeletonplant	x	
Pyrrhopappus pauciflorus	smallflower desert chicory		X
Ratibida columnifera	upright prairie coneflower; Mexican hat	x	
Rudbeckia hirta var. *angustifolia*	Perdue blackeyed susan		X
Solidago canadensis	Canada goldenrod	x	
Thelesperma filifolium	stiff greenthread	x	
Verbesina encelioides	golden crownbeard		x
Viguiera dentata	toothleaf goldeneye	x	
Xanthisma texanum	Texas sleepydaisy		x
Arabis petiolaris	Brazos rockcress		x
Descurainia pinnata	western tansymustard		x
Draba platycarpa	broadpod draba	x	
Lepidium austrinum	southern pepperweed or pepperwort	x	x
Polypremum procumbens	juniper leaf		x
Opuntia engelmannii var. *lindheimeri*	Texas pricklypear	x	x

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Opuntia macrorhiza	twistspine pricklypear		x
Cylindropuntia leptocaulis	Christmas cactus; tasajillo	x	
Triodanis biflora	small Venus' looking-glass	x	x
Triodanis perfoliata	clasping Venus' looking-glass	x	
Polanisia dodecandra ssp. *trachysperma*	sandyseed clammyweed	x	
Chenopodium berlandieri	pitseed goosefoot		x
Commelina erecta var. *angustifolia*	whitemouth dayflower	x	
Commelina erecta var. *erecta*	whitemouth dayflower	x	x
Tinantia anomala	widowstears		x
Tradescantia sp.	spiderwort	x	x
Convolvulus equitans	Texas bindweed	x	
Dichondra recurvate	oakwoods ponysfoot		x
Ipomoea cordatotriloba	tievine	x	x
Ipomaea hederacea	ivyleaf morning-glory	x	
Merremia dissecta	noyau vine	x	
Cucurbita foetidissima	Missouri gourd	x	
Ibervillea lindheimeri	Lindheimer's globeberry		x
Carex tetrastachya	Britton's sedge	x	
Cyperus retroflexus	oneflower flatsedge		x
Acalypha lindheimeri	shrubby copperleaf	x	
Acalypha ostryifolia	pineland threeseed mercury	x	
Argythamnia humilis var. *humilis*	low silverbush	x	
Croton capitatus	hogwort		x
Croton glandulosus	tooth-leaved croton; vente conmigo		x
Croton monanthogynus	prairie tea, oneseeded croton	x	x
Euphorbia dentata	toothed spurge	x	x
Euphorbia nutans	small eyebane	x	
Euphorbia peplidion	low spurge		x
Euphorbia prostrata	prostrate sandmat	x	

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Euphorbia serpens	matted sandmat	x	x
Chamaesyce glyptosperma	small ribseed sandmat		x
Phyllanthus polygonoides	smartweed leaf-flower		x
Tragia brevispica	shortspike noseburn	x	x
Tragia ramosa	branched noseburn	x	
Astragalus nuttallianus var. *trichocarpus*	turkeypeas	x	x
Dalea emarginata	wedgeleaf prairie clover		x
Desmanthus virgatus	wild tantan	x	X
Mimosa latidens	Kairn's sensitive-briar	x	
Rhynchosia minima	least snoutbean	x	
Rhynchosia senna var. *texana*	Texas snoutbean	x	
Vicia ludoviciana ssp. *leavenworthii*	Leavenworth's vetch		x
Vicia ludoviciana ssp. *ludoviciana*	Louisiana vetch		x
Sabatia campestris	Texas star; prairie rose gentian		x
Geranium texanum	Texas geranium		x
Nama hispidum	bristly nama		x
Nama jamaicense	Jamaicanweed		x
Sisyrinchium langloisii	roadside blue-eyed grass	x	x
Hedeoma drummondii	Drummond's false pennyroyal	x	
Hedeoma hispida	rough false pennyroyal	x	
Monarda citriodora ssp. *citriodora*	lemon beebalm	x	
Monarda punctata	spotted beebalm		x
Scutellaria drummondii	Drummond's skullcap	x	
Cooperia drummondii	evening rainlily	x	x
Nothoscordum bivalve	crowpoison	x	x
Linum imbricatum	tufted flax		x
Rhynchosida physocalyx	buffpetal	x	x
Sida abutifolia	spreading fanpetals	x	x
Sida spinosa	prickly fanpetals	x	x

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Cocculus carolinus	Carolina coralbead or snailseed	x	
Boerhavia diffusa	red spiderling	x	
Boerhavia erecta	erect spiderling	x	
Mollugo verticillata	green carpetweed		x
Mirabilis linearis	narrowleaf four o'clock	x	x
Nyctaginia capitata	devil's bouquet; scarlet muskflower	x	
Menodora heterophylla	low menodora	x	
Gaura brachycarpa	plains beeblossom		x
Gaura coccinea	scarlet gaura or beeblossom	x	
Gaura parviflora	velvetweed	x	x
Gaura sinuata	wavyleaf beeblossom	x	
Oenothera laciniata	cutleaf evening primrose		x
Oenothera speciosa	pinkladies	x	x
Oxalis dillenii	slender yellow woodsorrel	x	x
Argemone aurantiaca	Texas pricklypoppy	x	
Passiflora foetida var. *gossypiifolia*	cottonleaf passionflower	x	
Plantago hookeriana	California or Hooker plantain		x
Plantago rhodosperma	redseed plantain	x	x
Plantago wrightiana	Wright's plantain		x
Aristida purpurea var. *purpurea*	purple threeawn	x	x
Aristida purpurea var. *longiseta*	Fendler threeawn	x	x
Bothriochloa laguroides ssp. *torreyana*	silver beardgrass	x	x
Bouteloua dactyloides	buffalograss	x	
Cenchrus spinifex	coastal sandbur	x	x
Chloris ciliata	fringed windmill grass	x	x
Chloris cucullata	hooded windmill grass	x	x
Chloris verticillata	tumble windmill grass	x	
Digitaria ciliaris	southern crabgrass		X
Digitaria cognata	fall witchgrass	x	x

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Eragrostis curtipedicellata	gummy lovegrass	x	x
Eragrostis intermedia	plains lovegrass	x	x
Eragrostis secundiflora ssp. *oxylepis*	red lovegrass		x
Hordeum pusillum	little barley		x
Leptochloa panicea ssp. *mucronata*	mucronate sprangletop	x	
Limnodea arkansana	Ozarkgrass	x	x
Nassella leucotricha	Texas wintergrass	x	x
Panicum hallii	Hall's panicgrass	x	x
Phalaris caroliniana	Carolina canarygrass		x
Setaria leucopila	streambed or plains bristlegrass	x	
Sporobolus cryptandrus	sand dropseed		x
Tridens albescens	white tridens	x	
Tridens muticus var. *elongatus*	slim tridens	x	
Tridens texanus	Texas tridens or fluffgrass	x	
Urochloa ciliatissima	fringed signalgrass		x
Urochloa fusca	browntop signalgrass	x	x
Urochloa texana	Texas signallgrass		x
Vulpia octoflora	sixweeks fescue		x
Phlox drummondii	annual phlox		x
Portulaca pilosa	kiss me quick		x
Portulaca umbraticola	wingpod purslane		x
Anemone berlandieri	tenpetal thimbleweed	x	x
Clematis drummondii	Drummond's clematis	x	
Galium virgatum	southwestern bedstraw		x
Houstonia parviflora	Greenman's bluet	x	
Richardia tricocca	prairie Mexican clover		x
Cardiospermum halicacabum	balloon vine	x	
Agalinis strictifolia	stiffleaf false foxglove	x	x
Nuttallanthus texanus	Texas toadflax		x

Appendix C (continued). Native herbaceous species documented in SAAN's old fields (Carr 2003a, b).

Scientific Name	Common Name	Missions	Rancho
Physalis cinerascens var. *cinerascens*	smallflower groundcherry	x	x
Solanum dimidiatum	western horsenettle	x	
Solanum elaeagnifolium	silverleaf nightshade	x	x
Solanum rostratum	buffalobur nightshade	x	
Melochia pyramidata	pyramidflower	x	
Corchorus hirtus	Orinoco jute	x	
Glandularia bipinnatifida	Dakota mock vervain	x	x
Glandularia pumila	pink mock vervain	x	x
Glandularia quandrangulata	beaked mock vervain		x
Phyla nodiflora	turkey tangle fogfruit	x	
Verbena canescens	gray vervain	x	
Verbena halei	Texas vervain	x	x
Verbena plicata	fanleaf vervain		x
Hybanthus verticillatus	babyslippers	x	x
Vitis mustangensis	mustang grape	x	
	Number of species	130	110

Appendix D. Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Carlowrightia texana	Texas wrightwort			x
Dyschoriste linearis	polkadots			x
Justicia pilosella	Gregg's tube tongue		x	x
Ruellia nudiflora var. *nudiflora*	violet wild petunia		x	x
Agave sp.*	agave	x		
Manfreda maculosa	spice lily			x
Yucca constricta	narrowleaf or Buckley's yucca	x		x
Yucca treculeana	Don Quixote's lace	x		x
Amaranthus palmeri	carelessweed	x		
Amaranthus polygonoides	Berlandier or tropical amaranth		x	
Froelichia gracilis	slender snakecotton		x	
Toxicodendron radicans	poison ivy	x		x
Daucus pusillus	American wild carrot		x	x
*Torilis arvensis**	spreading hedgeparsley	x	x	x
Aristolochia erecta	swanflower			x
Cynanchum barbigerum	bearded swallow-wort	x		x
Matelea reticulata	netted milkvine	x		
Asclepias oenotheroides	zizotes milkweed		x	
Funastrum cynanchoides ssp. *cynanchoides*	fringed twinevine		x	
Amblyolepis setigera	huisache daisy	x	x	x
Ambrosia confertiflora	weakleaf bur ragweed	x	x	
Ambrosia psilostachya	western ragweed	x	x	x
Ambrosia trifida	great ragweed	x		
Aphanostephus ramosissimus	plains dozedaisy or lazy daisy	x	x	x
Aphanostephus riddellii	Riddell's dozedaisy			x
Symphyotrichum ericoides	heath aster	x	x	x
Astranthium integrifolium	entireleaf western daisy	x		x

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Baccharis neglecta	Rooseveltweed	x		
Baccharis texana	prairie false willow		x	
Calyptocarpus vialis	straggler daisy	x	x	x
*Centaurea melitensis**	Maltese star-thistle	x	x	
Chaptalia texana	silverpuff	x		x
Cirsium texanum	Texas thistle	x	x	x
Conyza canadensis	horseweed	x		
Coreopsis tinctoria	golden tickseed or plains coreopsis	x		
Coreopsis wrightii	rock tickseed		x	x
Thymophylla pentachaeta var. *pentachaeta*	fiveneedle pricklyleaf			x
Engelmannia peristenia	Engelmann's daisy	x		
Evax verna	spring pygmycudweed		x	
Fleischmannia incarnata	pink thoroughwort	x	x	x
Florestina tripteris	sticky florestina		x	
Gaillardia pulchella	Indian blanket	x	x	
Grindelia squarrosa	curlycup gumweed	x		
Gutierrezia texana	Texas snakeweed	x	x	x
Helianthus annuus	common sunflower	x	x	x
Helianthus debilis ssp. *cucumerifolius*	cucumberleaf sunflower	x		
Heterotheca subaxillaris	camphorweed	x	x	
Lactuca ludoviciana	biannual lettuce	x		
*Lactuca serriola**	prickly lettuce	x		
Liatris punctata var. *mucronata*	blazing star			X
Lygodesmia texana	Texas skeletonplant			X
Lindheimera texana	Texas yellowstar	x		
Parthenium confertum	Gray's feverfew			X

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
*Parthenium hysterophorus**	Santa Maria feverfew		x	X
Pinaropappus roseus	white rocklettuce			X
Pyrrhopappus pauciflorus	smallflower desert chicory		x	
Ratibida columnifera	upright prairie coneflower; Mexican hat	x	x	
Rudbeckia hirta var. *angustifolia*	Perdue blackeyed susan		x	
Senecio ampullaceus	Texas ragwort		x	
Simsia calva	awnless bushsunflower	x		X
Solidago canadensis	Canada goldenrod	x		
Solidago gigantea	giant goldenrod	x		
*Sonchus asper**	spiny sowthistle	x	x	
*Sonchus oleraceus**	common sowthistle	x		
Tetraneuris scaposa	stemmy four-nerve daisy			X
Thelesperma ambiguum	Colorado greenthread			X
Viguiera dentata	toothleaf goldeneye	x		
Wedelia acapulcensis var. *hispida*	orange zexmenia		x	X
Berberis trifoliolata	algerita; agarito	x	x	X
Ehretia anacua	knockaway; anacua	x		
Cryptantha texana	pick me nots		x	
Lithospermum mirabile	San Antonio stoneseed		x	X
Arabis petiolaris	Brazos rockcress			X
Lepidium austrinum	southern pepperweed or pepperwort		x	X
Lesquerella argyraea	silver bladderpod			X
*Rapistrum rugosum**	annual bastardcabbage	x		
Tillandsia recurvata	small ballmoss	x		X
Thelocactus setispinus	miniature barrel cactus	x		X
Opuntia engelmannii var. *lindheimeri*	Texas pricklypear	x	x	X
Cylindropuntia leptocaulis	Christmas cactus; tasajillo	x		X

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Triodanis biflora	small Venus' looking-glass		x	X
*Lonicera japonica**	Japanese honeysuckle	x		
Silene antirrhina	sleepy sirene; sticky catchfly		x	
*Stellaria media**	common chickweed	x		
Schaefferia cuneifolia	desert yaupon	x		X
Chenopodium berlandieri	pitseed goosefoot		x	
Commelina erecta var. *angustifolia*	whitemouth dayflower	x		
Commelina erecta var. *erecta*	whitemouth dayflower	x		X
Tradescantia sp.	spiderwort	x	x	
Convolvulus equitans	Texas bindweed	x	x	
Evolvulus sericeus var. *sericeus*	silver dwarf morning-glory		x	X
Ipomoea cordatotriloba	tievine	x		x
Merremia dissecta	noyau vine	x		
Ibervillea lindheimeri	Lindheimer's globeberry	x		
Cuscuta sp.	dodder		x	
Carex sp.	sedge	x		x
Carex planostachys	cedar sedge			x
Diospyros texana	Texas persimmon	x	x	x
Acalypha ostryifolia	pineland threeseed mercury		x	
Argythamnia humilis var. *humilis*	low silverbush		x	
Cnidoscolus texanus	Texas bullnettle		x	
Croton monanthogynus	prairie tea, oneseeded croton	x	x	x
Euphorbia spathulata	warty spurge	x		
Jatropha dioica	leatherstem			x
Phyllanthus polygonoides	smartweed leaf-flower	x		
Tragia brevispica	shortspike noseburn	x		
Tragia ramosa	branched noseburn	x		
Acacia farnesiana (formerly minuta)	sweet acacia; huisache	x		

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Acacia greggii var. *greggii*	catclaw acacia			x
Acacia rigidula	blackbrush acacia			x
Astragalus nuttallianus	smallflowered milkvetch			x
Dalea pogonathera	bearded prairie clover		x	x
Desmanthus velutinus	velvet bundleflower		x	
Desmanthus virgatus	wild tantan	x	x	x
Eysenhardtia texana	Texas kidneywood	x	x	x
*Melilotus indicus**	annual yellow sweetclover		x	
*Melilotus officinalis**	sweetclover	x		
Mimosa borealis	fragrant mimosa			x
Mimosa latidens	Kairn's sensitive-briar			x
Neptunia lutea	yellow puff	x		
Parkinsonia aculeata	Jerusalem thorn	x		
Prosopis glandulosa var. *glandulosa*	honey mesquite		x	x
Rhynchosia minima	least snoutbean	x		
Rhynchosia senna var. *texana*	Texas snoutbean	x	x	
Senna pumilio	dwarf senna			x
Styphnolobium affine	Eve's necklacepod	x		
Vicia ludoviciana ssp. *leavenworthii*	Leavenworth's vetch		x	x
Corydalis sp.	fumewort; scrambled eggs		x	
Geranium texanum	Texas geranium		x	x
Nama hispidum	bristly nama			x
Nama jamaicense	Jamaicanweed		x	x
Phacelia congesta	caterpillars; blue curls			x
Krameria lanceolata	trailing krameria			x
Hedeoma drummondii	Drummond's false pennyroyal		x	x
Hedeoma hispida	rough false pennyroyal	x		x
*Lamium amplexicaule**	henbit deadnettle	x		

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Monarda citriodora ssp. *citriodora*	lemon beebalm	x		
Monarda punctata	spotted beebalm		x	x
Salvia ballotiflora	shrubby blue sage			X
Scutellaria drummondii	Drummond's skullcap		x	x
Stachys crenata	mousesear	x		
Teucrium cubense	small coastal germander	x		
Allium canadense var. *canadense*	meadow garlic	x		
Allium drummondii	Drummond's onion	x		x
Cooperia drummondii	evening rainlily		x	x
Cooperia pedunculata	prairie lily		x	x
Habranthus tubispathus	Rio Grande copperlily		x	
Schoenocaulon drummondii	green feathershank			x
Linum imbricatum	tufted flax		x	x
Abutilon fruticosum	Texas Indian mallow			x
Abutilon wrightii	Wright's Indian mallow			
Callirhoe leiocarpa	tall poppymallow		x	x
*Malvastrum coromandelianum**	threelobe false mallow	x	x	
Malvaviscus arboreus var. *drummondii*	wax mallow	x		
Rhynchosida physocalyx	buffpetal	x		
*Melia azedarach**	Chinaberrytree	x		
Cocculus carolinus	Carolina coralbead	x		
*Broussonetia papyrifera**	paper mulberry	x		
Boerhavia diffusa	red spiderling	x		
Acleisanthes obtusa	Berlandier's trumpets		x	x
Acleisanthes longiflora	angel's trumpets		x	x
Mirabilis albida	white four o'clock	x		
*Mirabilis jalapa**	marvel of Peru	x		

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Nyctaginia capitata	devil's bouquet; scarlet muskflower		x	
Menodora heterophylla	low menodora		x	
Forestiera angustifolia	Texas swampprivet	x		x
*Ligustrum japonicum**	Japanese privet	x		
Gaura brachycarpa	plains beeblossom		x	x
Gaura coccinea	scarlet gaura or beeblossom	x		
Gaura parviflora	velvetweed	x	x	x
Gaura sinuata	wavyleaf beeblossom	x		
Oenothera speciosa	pinkladies	x		
Oxalis dichondrifolia	peonyleaf woodsorrel			x
Oxalis dillenii	slender yellow woodsorrel	x	x	x
Oxalis drummondii	Drummond's woodsorrel		x	x
Argemone aurantiaca	Texas pricklypoppy	x		
Argemone sanguinea	red pricklypoppy		x	
Passiflora tenuiloba	birdwing passionflower	x	x	x
Rivina humilis	rougeplant		x	
Plantago hookeriana	California or Hooker plantain		x	
Plantago rhodosperma	redseed plantain	x	x	x
Aristida purpurea var. *purpurea*	purple threeawn		x	x
*Arundo donax**	giant reed	x		
Bothriochloa ischaemum var. *songarica**	yellow bluestem	x	x	X
Bothriochloa laguroides ssp. *torreyana*	silver beardgrass	x	x	x
Bouteloua curtipendula	sideoats grama		x	
Bouteloua dactyloides	buffalograss		x	
Bouteloua rigidiseta	Texas grama		x	x
Bouteloua trifida	red grama			x

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
*Bromus arvensis** (formerly *japonicus*)	field brome	x		
*Bromus catharticus**	rescuegrass		x	x
Cenchrus spinifex	coastal sandbur		x	
Chloris ciliata	fringed windmill grass		x	
Chloris cucullata	hooded windmill grass	x	x	
Chloris verticillata	tumble windmill grass		x	
*Cynodon dactylon**	Bermudagrass	x	x	x
*Dichanthium annulatum**	Kleberg's bluestem	x	x	x
Digitaria ciliaris	southern crabgrass		x	
Digitaria cognata	fall witchgrass		x	
Eragrostis intermedia	plains lovegrass		x	x
Eragrostis sessilispica	tumble lovegrass			x
Eriochloa sericea	Texas cupgrass			x
Hilaria belangeri	curly-mesquite		x	x
Hordeum pusillum	little barley		x	x
Leptochloa dubia	green sprangletop	x		x
Limnodea arkansana	Ozarkgrass	x	x	x
Nassella leucotricha	Texas wintergrass	x	x	x
Panicum capillarioides	slender panicgrass		x	
Panicum hallii	Hall's panicgrass	x		
*Urochloa maxima**	Guineagrass	x		
*Paspalum dilatatum**	Dallisgrass	x		
Paspalum pubiflorum	hairyseed paspalum	x		
*Poa annua**	annual bluegrass	x		
Schizachyrium scoparium	little bluestem	x		
Setaria leucopila	streambed or plains bristlegrass	x	x	x
Setaria reverchonii ssp. *ramiseta*	Rio Grande bristlegrass		x	x
Setaria scheelei	southwestern bristlegrass		x	x

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
*Sorghum halepense**	Johnsongrass	x	x	
Sporobolus compositus var. *compositus*	composite dropseed			x
Sporobolus cryptandrus	sand dropseed	x	x	x
Trichloris pluriflora	multiflower false Rhodes grass			x
Tridens albescens	white tridens			x
Tridens eragrostoides	lovegrass tridens	x		x
Tridens muticus var. *muticus*	slim tridens			x
Tridens texanus	Texas tridens or fluffgrass	x	x	x
Urochloa fusca	browntop signalgrass	x		
Giliastrum incisum	splitleaf gilia	x		x
Polygala alba	white milkwort			X
Polygala lindheimeri	shrubby milkwort			X
Phemeranthus aurantiacus	orange fameflower	x	x	
Talinum paniculatum	jewels of Opar	x		
Cheilanthes alabamensis	Alabama lipfern	x		X
Pellaea atropurpurea	purple cliffbrake			X
Anemone berlandieri	tenpetal thimbleweed	x	x	X
Clematis drummondii	Drummond's clematis	x	x	X
Delphinium carolinianum	Carolina larkspur			X
Colubrina texensis	Texan hogplum	x	x	X
Condalia hookeri var. *hookeri*	Brazilian bluewood	x	x	X
Ziziphus obtusifolia	lotebush	x		X
Rubus riograndis	Rio Grande dewberry	x		
Galium aparine	cleavers, stickwilly	x		
Galium virgatum	southwestern bedstraw		x	X
Stenaria nigricans var. *nigricans*	diamondflowers			X
Houstonia parviflora	Greenman's bluet			X
Ptelea trifoliata	common hoptree			X

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Thamnosma texana	rue of the mountains	x		X
Sapindus saponaria var. *drummondii*	western soapberry	x		
Sideroxylon lanuginosum	gum bully	x		X
Agalinis strictifolia	stiffleaf false foxglove		x	X
Castilleja indivisa	entireleaf Indian paintbrush	x	x	X
Maurandella antirrhiniflora	roving sailor	x		X
*Ailanthus altissima**	tree of heaven	x		
Smilax bona-nox	saw greenbriar	x		X
Bouchetia erecta	paintedtongue			X
Capsicum annuum	cayenne pepper	x		X
Chamaesaracha coronopus	greenleaf five eyes		x	
Lycium berlandieri	Berlandier's wolfberry	x		X
Physalis cinerascens var. *cinerascens*	smallflower groundcherry		x	X
Solanum elaeagnifolium	silverleaf nightshade		x	X
Solanum triquetrum	Texas nightshade		x	
Hermannia texana	Texas burstwort	x		X
Celtis laevigata var. *laevigata*	sugarberry	x		
Celtis laevigata var. reticulata	netleaf hackberry	x	x	X
Celtis ehrenbergiana	spiny hackberry	x	x	X
Ulmus crassifolia	cedar elm	x		X
Parietaria pensylvanica	Pennsylvania pellitory			X
Aloysia gratissima	whitebrush	x		X
Glandularia bipinnatifida	Dakota mock vervain		x	
Glandularia pumila	pink mock vervain		x	
Glandularia quandrangulata	beaked mock vervain		x	
Lantana urticoides	West Indian shrubverbena	x		X
Tetraclea coulteri	Coulter's wrinklefruit		x	
Verbena canescens	gray vervain		x	

Appendix D (continued). Plant species documented in SAAN's upland shrublands/woodlands (Carr 2003a, b). UW = upland woodland, US = upper-slope shrubland. Asterisks (*) indicate non-native species.

			Rancho	
Scientific Name	**Common Name**	**Missions**	**UW**	**US**
Verbena halei	Texas vervain		x	
Verbena plicata	fanleaf vervain		x	x
Phoradendron tomentosum	Christmas mistletoe	x	x	x
Cissus trifoliata	sorrelvine			x
Vitis cinerea var. *helleri*	Heller's grape	x		
Vitis mustangensis	mustang grape	x		x
Guaiacum angustifolium	Texas lignum-vitae			x
Kallstroemia parviflora	warty caltrop		x	
*Tribulus terrestris**	puncturevine		x	
	Totals	**151**	**133**	**156**

Appendix E. Reptiles identified in or near SAAN (data compiled from museum vouchers, Strecker 1915, Gallyoun et al. 2002, Gallyoun et al. 2003, Duran 2004, Woodman 2013, and NPS 2014). Strecker (1915) is highlighted in gray because it serves as the reference condition for this NRCA. It should also be noted that Strecker's (1915) study covered a larger area than SAAN, and not all species occurred in the park.

Scientific Name	Common Name	Strecker (1915)	Literature/ Museum Vouchers	Duran (2004)	Woodman (2013)	NPS (2014)
Agkistrodon contortrix	copperhead	X	X			
Agkistrodon piscivorus	cottonmouth		X	R		X
Anolis carolinensis	green anole		X	X	X	X
Apalone spinifera guadalupensis	Guadalupe spiny softshell	X	X	X		X
Arizona elegans	glossy snake	X				
Chelydra serpentine	common snapping turtle	X	X	X		X
Cnemidophorus grahamii	bold checkered whiptail	X				
Cnemidophorus gularis gularis	Texas spotted whiptail		X	X	X	
Coleonyx brevis	Texas banded gecko	X				
Crotalus atrox	western diamondback rattlesnake		X	X		X
Crotalus molossus	black-tailed rattlesnake	X				
Crotalus viridis	prairie rattlesnake	X				
Elaphe guttata emoryi	Great Plains rat snake		X	X	X	
Elaphe obsolete	Texas rat snake	X	X	X		
Eumeces tetragrammus brevilineatus	short-lined skink		X			PP

X - Direct observation

R - Rare

PP - Probably Present

* - Historically present in park, extirpated from area

Appendix E (continued). Reptiles identified in or near SAAN (data compiled from museum vouchers, Strecker 1915, Gallyoun et al. 2002, Gallyoun et al. 2003, Duran 2004, Woodman 2013, and NPS 2014). Strecker (1915) is highlighted in gray because it serves as the reference condition for this NRCA. It should also be noted that Strecker's (1915) study covered a larger area than SAAN, and not all species occurred in the park.

Scientific Name	Common Name	Strecker (1915)	Literature/ Museum Vouchers	Duran (2004)	Woodman (2013)	NPS (2014)
Gopherus berlandieri	Texas tortoise	X	X	X		X
Graptemys caglei	Cagle's map turtle		X			X*
Hemidactylus turcicus	Mediterranean gecko		X	X	X	X
Heterodon platirhinos	eastern hognose snake		X			
Holbrookia maculata	lesser earless lizard	X				
Holbrookia propinqua	keeled earless lizard	X				
Kinosternon flavescens	yellow mud turtle		X			X
Lampropeltis getula splendida	desert kingsnake		X	X		X
Lampropeltis Triangulum	milk snake	X				
Leptotyphlops dulcis dulcis	plains blind snake		X	X	X	X
Macrochelys temminckii	alligator snapping turtle	X				
Masticophis flagellum testaceus	western coachwhip		X	X	X	X
Masticophis schotti	Schott's whipsnake		X	X	X	X
Micrurus tener	Texas coral snake	x	X	R	X	X
Nerodia erythrogaster transversa	blotched water snake		X		X	X

X - Direct observation

R - Rare

PP - Probably Present

* - Historically present in park, extirpated from area

Appendix E (continued). Reptiles identified in or near SAAN (data compiled from museum vouchers, Strecker 1915, Gallyoun et al. 2002, Gallyoun et al. 2003, Duran 2004, Woodman 2013, and NPS 2014). Strecker (1915) is highlighted in gray because it serves as the reference condition for this NRCA. It should also be noted that Strecker's (1915) study covered a larger area than SAAN, and not all species occurred in the park.

Scientific Name	Common Name	Strecker (1915)	Literature/ Museum Vouchers	Duran (2004)	Woodman (2013)	NPS (2014)
Nerodia rhombifer	diamondback water snake		X	X		X
Opheodrys aestivus	rough green snake		X	R		X
Phrynosoma cornutum	Texas horned lizard		X	R		PP
Pseudemys texana	Texas river cooter		X	X	X	X
Regina grahamii	Graham's crayfish snake	X	X			PP
Rhinocheilus lecontei tessellatus	Texas long-nosed snake		X	X		X
Salvadora grahamiae lineata	Texas patch-nosed snake		X	X	X	X
Sceloporus consobrinus	prairie lizard		X	X		PP
Sceloporus olivaceus	Texas spiny lizard		X	X	X	X
Sceloporus variabilis marmoratus	rose-bellied lizard	X	X	X	X	X
Scincella lateralis	ground skink		X	X	X	X
Sonora semiannulata	ground snake					X
Sternotherus odoratus	common musk turtle		X			X
Storeria dekayi texana	Texas brown snake		X	X		X
Tantilla gracilis	flat-headed snake		X			

X - Direct observation

R - Rare

PP - Probably Present

* - Historically present in park, extirpated from area

Appendix E (continued). Reptiles identified in or near SAAN (data compiled from museum vouchers, Strecker 1915, Gallyoun et al. 2002, Gallyoun et al. 2003, Duran 2004, Woodman 2013, and NPS 2014). Strecker (1915) is highlighted in gray because it serves as the reference condition for this NRCA. It should also be noted that Strecker's (1915) study covered a larger area than SAAN, and not all species occurred in the park.

Scientific Name	Common Name	Strecker (1915)	Literature/ Museum Vouchers	Duran (2004)	Woodman (2013)	NPS (2014)
Tantilla nigriceps	plains black-headed snake	X				
Terrapene carolina	common box turtle	X				
Terrapene ornata	ornate box turtle		X			
Thamnophis marcianus marcianus	checkered garter snake		X	X		X
Thamnophis proximus rubrilineatus	redstripe ribbon snake		X	R		PP
Trachemys scripta elegans	red-eared slider		X	X		X
Tropidoclonion lineatum	lined snake		X			
Virginia striatula	rough earth snake		X	X	X	X

X - Direct observation

R - Rare

PP - Probably Present

* - Historically present in park, extirpated from area

Appendix F. Breeding bird species observed in SAAN from 1985-2012.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
red-tailed hawk	*Buteo jamaicensis*	X	X	X	X
red-shouldered hawk	*Buteo lineatus*	X	X	X	X
turkey vulture	*Cathartes aura*	X	X	X	X
black vulture	*Coragyps atratus*	X	X	X	X
Egyptian goose	*Alopochen aegyptiaca*	X			
mallard	*Anas platyrhynchos*	X		X	X
black-bellied whistling duck, black-bellied whistling-duck	*Dendrocygna autumnalis*	X	X	X	X
chimney swift	*Chaetura pelagica*	X	X	X	X
black-chinned hummingbird	*Archilochus alexandri*	X	X	X	X
lesser nighthawk	*Chordeiles acutipennis*	X		X	X
common nighthawk	*Chordeiles minor*	X	X	X	X
killdeer	*Charadrius vociferus*	X	X	X	X
common pigeon, rock dove, rock pigeon	*Columba livia*	X		X	X
Inca dove	*Columbina inca*	X	X	X	X
common ground dove, common ground-dove	*Columbina passerina*	X		X	
white-tipped dove	*Leptotila verreauxi*	X			X
Eurasian collared dove, Eurasian collared-dove	*Streptopelia decaocto*	X		X	X
white-winged dove	*Zenaida asiatica*	X	X	X	X
mourning dove	*Zenaida macroura*	X	X	X	X
yellow-billed cuckoo	*Coccyzus americanus*	X	X	X	X
greater roadrunner	*Geococcyx californianus*	X		X	X
crested caracara, northern crested caracara	*Caracara cheriway*	X		X	X

Appendix F (continued). Breeding bird species observed in SAAN from 1985-2012.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
northern bobwhite	*Colinus virginianus*	X	X	X	
wild turkey	*Meleagris gallopavo*	X		X	X
pyrrhuloxia	*Cardinalis sinuatus*	X	X	X	X
blue grosbeak	*Passerina caerulea*	X		X	X
painted bunting	*Passerina ciris*	X		X	X
indigo bunting	*Passerina cyanea*	X	X	X	X
dickcissel	*Spiza americana*	X		X	X
American crow	*Corvus brachyrhynchos*	X		X	X
blue jay	*Cyanocitta cristata*	X		X	X
olive sparrow	*Arremonops rufivirgatus*	X		X	X
lark sparrow	*Chondestes grammacus*	X	X	X	
lesser goldfinch	*Carduelis psaltria*	X	X	X	X
house finch	*Carpodacus mexicanus*	X	X	X	X
barn swallow	*Hirundo rustica*	X	X	X	X
cave swallow	*Petrochelidon fulva*	X		X	X
American cliff swallow, cliff swallow	*Petrochelidon pyrrhonota*	X		X	X
purple martin	*Progne subis*	X	X	X	X
red-winged blackbird	*Agelaius phoeniceus*	X	X	X	X
Bullock's oriole	*Icterus bullockii*	X		X	X
orchard oriole	*Icterus spurius*	X	X	X	X
bronzed cowbird	*Molothrus aeneus*	X		X	
brown-headed cowbird	*Molothrus ater*	X	X	X	X

Appendix F (continued). Breeding bird species observed in SAAN from 1985-2012.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
great-tailed grackle	*Quiscalus mexicanus*	X	X	X	X
cedar waxwing	*Bombycilla cedrorum*		X		
loggerhead shrike	*Lanius ludovicianus*	X	X	X	X
northern mockingbird	*Mimus polyglottos*	X	X	X	X
curve-billed thrasher	*Toxostoma curvirostre*	X	X	X	
long-billed thrasher	*Toxostoma longirostre*	X		X	X
black-crested titmouse	*Baeolophus atricristatus*	X	X	X	X
Carolina chickadee	*Poecile carolinensis*	X	X	X	X
yellow-breasted chat	*Icteria virens*	X		X	X
house sparrow	*Passer domesticus*	X	X	X	X
verdin	*Auriparus flaviceps*	X		X	X
European starling	*Sturnus vulgaris*	X	X	X	X
Bewick's wren	*Thryomanes bewickii*	X	X	X	X
Carolina wren	*Thryothorus ludovicianus*	X	X	X	X
ash-throated flycatcher	*Myiarchus cinerascens*	X		X	X
great crested flycatcher	*Myiarchus crinitus*	X	X	X	X
brown-crested flycatcher	*Myiarchus tyrannulus*	X		X	X
great kiskadee	*Pitangus sulphuratus*	X		X	
scissor-tailed flycatcher	*Tyrannus forficatus*	X	X	X	X
western kingbird	*Tyrannus verticalis*	X	X	X	X
Bell's vireo	*Vireo bellii*	X	X	X	
yellow-throated vireo	*Vireo flavifrons*	X			

Appendix F (continued). Breeding bird species observed in SAAN from 1985-2012.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
white-eyed vireo	*Vireo griseus*	X	X	X	X
golden-fronted woodpecker	*Melanerpes aurifrons*	X	X	X	X
downy woodpecker	*Picoides pubescens*	X	X	X	
ladder-backed woodpecker	*Picoides scalaris*	X	X	X	X
great horned owl	*Bubo virginianus*	X	X	X	
barred owl	*Strix varia*	X		X	X
Total Number of Breeding Species Observed		**71**	**44**	**68**	**60**

Appendix G. Breeding bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-86 (Appendix reproduced from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
black-bellied whistling duck	SAJU					
	ESPA			1.2		
black vulture	SAJU			2.9		
	ESPA		0.2			
turkey vulture	SAJU			0.7		
	ESPA	1	0.2	1.4	1	1
red-shouldered hawk	SAJU		0.7			
	ESPA		0.2	0.4	0.4	1
red-tailed hawk	SAJU	1.5	0.7			
	ESPA	0.4	1.2	1	0.8	0.8
northern bobwhite	SAJU					
	ESPA		0.2		0.2	
killdeer	SAJU			1.5		2.2
	ESPA	1	1.2	1.6	0.2	1.8
white-winged dove	SAJU					
	ESPA	0.2				5
mourning dove	SAJU	7.4	10.3	2.2	1.5	0.7
	ESPA	13.5	7.8	11	9	12.9
Inca dove	SAJU		1.5	1.5		1
	ESPA	0.4			0.8	1.6
yellow-billed cuckoo	SAJU			0.7	5.2	3.7
	ESPA			0.6	1.8	0.2
great horned owl	SAJU		0.7	1.5	0.7	1.5
	ESPA					
common nighthawk	SAJU					
	ESPA				0.2	
chimney swift	SAJU	7.4		1.5	2.2	1.5
	ESPA	1.2			5	14.7
black-chinned hummingbird	SAJU			1.5	2.2	
	ESPA					
golden-fronted woodpecker	SAJU	2.2	6.6	7.4	9.6	8.8
	ESPA	2.4	3.2	3.4	4.6	4.6

Appendix G (continued). Breeding bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-86 (Appendix reproduced from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
ladder-backed woodpecker	SAJU					
	ESPA			1	0.4	
downy woodpecker	SAJU					
	ESPA	0.4				
great crested flycatcher	SAJU					
	ESPA			0.8		0.6
western kingbird	SAJU					2.9
	ESPA				1.6	0.2
scissor-tailed flycatcher	SAJU					
	ESPA	6		0.4	0.8	1.2
purple martin	SAJU				0.7	
	ESPA				0.2	
barn swallow	SAJU				0.7	2.2
	ESPA	0.6			1.8	2.8
Carolina chickadee	SAJU	2.2	1.5	4.4	9.6	5.9
	ESPA	0.8	2	2	3	2
black-crested titmouse	SAJU	5.9	10.3	9.6	5.2	5.9
	ESPA	1.8	3	2.8	5.8	2
Carolina wren	SAJU	11.8	2.2	8.8	14	16.9
	ESPA	4	2.4	2.4	4.2	7.6
Bewick's wren	SAJU					
	ESPA				0.4	
northern mockingbird	SAJU	3.7	2.9		5.2	1.5
	ESPA	7.8	6.2	3.6	3.8	2.6
curve-billed thrasher	SAJU		1.5			
	ESPA					0.2
cedar waxwing	SAJU	0.7	16.2	8.1		
	ESPA		12.9	6.9		
loggerhead shrike	SAJU					
	ESPA	2.6	2	0.2	0.2	2.4
European starling	SAJU	2.9	0.7	2.2	4.4	
	ESPA	11.7	6	3	0.2	0.2

Appendix G (continued). Breeding bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-86 (Appendix reproduced from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
white-eyed vireo	SAJU			2.9	2.9	2.9
	ESPA			0.2	1.6	1.8
Bell's vireo	SAJU					
	ESPA					0.6
pyrrhuloxia	SAJU					
	ESPA	0.2	0.2		0.2	
indigo bunting	SAJU					
	ESPA				0.2	
lark sparrow	SAJU	3.7				
	ESPA	6	1.4	2.6	0.2	
red-winged blackbird	SAJU					
	ESPA	9.2		1.4	0.4	1
great-tailed grackle	SAJU	5.2	6.6	4.4	7.4	4.4
	ESPA	7.2	3.8	5	21.1	5.2
brown-headed cowbird	SAJU				2.9	??
	ESPA			5.2	10.4	5.2
orchard oriole	SAJU					0.7
	ESPA					
house finch	SAJU					
	ESPA	4	1	3.4	3.2	1
lesser goldfinch	SAJU					
	ESPA	5				
house sparrow	SAJU					
	ESPA	0.2				
Number of Breeding Species	**SAJU**	**31**	**31**	**32**	**33**	**35**
	ESPA	**39**	**35**	**36**	**41**	**38**

Appendix H. Relative abundance and distribution of breeding bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	City of San Antonio (18)	Rancho de las Cabras (7)	Jan	Mar	May	Jul	Sep	Nov	Total
black-bellied whistling duck	**X**	**X**	2	20	12	6	1	7	48
mallard	**X**			5	8	1	1	2	17
wild turkey		**X**	1	7	5		2	2	17
northern bobwhite		X							0
turkey vulture	**X**	**X**	11	19	10	11	18	5	74
black vulture	**X**	**X**	15	15	3	9	9	3	54
red-shouldered hawk	**X**	**X**	20	23	15	5	9	22	94
red-tailed hawk	**X**	**X**	2	1	7		4	1	15
crested caracara	**X**	**X**	8	6	1	2	2	2	21
killdeer	**X**	**X**	7	5	4	2	6	5	29
rock pigeon	**X**		7	12	10	9	3	10	51
Eurasian collared-dove		**X**			1				1
white-winged dove	**X**		18	39	53	43	16	24	193
mourning dove	**X**	**X**	13	24	27	16	14	6	100
Inca dove	**X**	**X**		1	8	3	3	1	16
common ground dove	**X**	**X**	1		8	5	6		20
yellow-billed cuckoo	**X**	**X**			36	13			49
greater roadrunner		**X**			2	1	2	1	6
great horned owl	**X**	X				1			1
barred owl	X	**X**		1	1			2	4

Appendix H (continued). Relative abundance and distribution of breeding bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
lesser nighthawk	**X**				1				1
common nighthawk	**X**	X			1				1
chimney swift	**X**	**X**			10	11	14		35
black-chinned hummingbird	**X**	**X**			6	1			7
golden-fronted woodpecker	**X**	**X**	25	42	21	9	9	16	122
ladder-backed woodpecker	**X**	**X**	12	6	15	8	15	9	65
downy woodpecker	X								0
ash-throated flycatcher	**X**	**X**			2	1			3
great-crested flycatcher	**X**	**X**		2	12	1			15
brown-crested flycatcher		**X**			1				1
great kiskadee		**X**		1					1
western kingbird	**X**	**X**			8	7			15
scissor-tailed flycatcher	**X**	**X**		8	24	12	23		67
loggerhead shrike	**X**	**X**	6	5	6	5	4	1	27
white-eyed vireo	**X**	**X**	6	63	65	37	33	1	205
Bell's vireo	**X**			1					1
blue jay	**X**		24	12	5	9	13	17	80
American crow	**X**	**X**	47	39	32	13	29	27	187
purple martin	**X**	**X**		7	15	24			46
cliff swallow	**X**	**X**		3	25	14			42

Appendix H (continued). Relative abundance and distribution of breeding bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
cave swallow	X	X		4	17	14	11	1	47
barn swallow	X	X		12	22	13	5		52
Carolina chickadee	X	X	8	8	12	2	3	2	35
black-crested titmouse	X	X	9	40	53	11	5	5	123
verdin	X	X	2	3	6	1	1	1	14
Carolina wren	X	X	53	78	93	57	46	29	356
Bewick's wren	X	X	4	4	5	2	7	3	25
northern mockingbird	X	X	30	42	53	31	35	36	227
long-billed thrasher	X			1	1				2
curve-billed thrasher	X	X	2	3	1		3	2	11
European starling	X	X	9	18	22	12	12	12	85
yellow-breasted chat	X				1				1
olive sparrow		X			11				11
lark sparrow	X	X		2	1		1		4
pyrrhuloxia	X	X	1	2			1		4
blue grosbeak	X	X			7				7
indigo bunting	X						2		2
painted bunting	X	X			23	10			33
dicksissel	X	X			25	4	6		35
red-winged blackbird	X	X	14	30	7	5	1	3	60

Appendix H (continued). Relative abundance and distribution of breeding bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
great-tailed grackle	**X**		50	68	71	51	28	34	302
bronzed cowbird	**X**			1					1
brown-headed cowbird	**X**	**X**	6	11	17	7		3	44
orchard oriole	**X**				4				4
Bullock's oriole	X								0
house finch	**X**	**X**	5	6	13	7	8	8	47
lesser goldfinch	**X**				2	1		1	4
house sparrow	**X**		6	14	27	15	5	9	76
Total Number of Detections	**n/a**	**n/a**	**424**	**714**	**954**	**522**	**416**	**313**	**3343**
Species Observed Total	**61**	**52**							
Species Observed at Points	**57**	**49**							
Grand Total	**68**								

Appendix I. Breeding bird species and the number of detections during 10-minute surveys of 40 randomly located point locations on San Antonio Missions National Historical Park (Table modified from Twedt 2013).

Common Name	2010	2011	2012
American Crow	5	12	17
ash-throated flycatcher			1
barred owl	1		1
barn swallow	1	18	5
black-bellied whistling duck		2	3
brown-crested flycatcher	1		
black-chinned hummingbird	1	3	1
black-crested titmouse	34	19	23
Bewick's wren	3	3	
brown-headed cowbird	11	26	11
blue grosbeak		2	3
blue jay	2	5	3
black vulture		2	3
Bullock's oriole		2	2
Carolina chickadee	6	3	7
Carolina wren	38	64	76
cave swallow	3	11	11
chimney swift		6	4
cliff swallow	35	9	18
common nighthawk	1		
crested caracara	1		
dickcissel		1	
Eurasian collared-dove			1
European starling	22	14	12
great crested flycatcher	5	7	11
golden-fronted woodpecker	7	22	17
greater roadrunner	2		1
great-tailed grackle	21	37	27
house finch	1	10	12
house sparrow	3	20	18
indigo bunting		1	
Inca dove		7	4

Appendix I (continued). Breeding bird species and the number of detections during 10-minute surveys of 40 randomly located point locations on San Antonio Missions National Historical Park (Table modified from Twedt 2013).

Common Name	2010	2011	2012
killdeer		3	1
long-billed thrasher		2	
ladder-backed woodpecker	4	15	12
lesser goldfinch	1	4	5
lesser nighthawk	1		
loggerhead shrike		1	1
mallard	5	2	
mourning dove	6	15	10
northern mockingbird	19	65	63
olive sparrow	3	4	2
orchard oriole		2	
painted bunting	9	20	20
purple martin	1	10	10
pyrrhuloxia	1		
rock pigeon		6	7
red-shouldered hawk	7	11	1
red-tailed hawk	1	1	2
red-winged blackbird	3	6	1
scissor-tailed flycatcher	2	20	11
turkey vulture		6	1
verdin	1		1
western kingbird	2	7	5
white-eyed vireo	24	34	27
wild turkey	1		
white-tipped dove		1	
white-winged dove	3	12	22
yellow-breasted chat			3
yellow-billed cuckoo	3	3	11
Individuals detected	**301**	**556**	**508**
Species detected	**42**	**48**	**47**
Total Species detected		**60**	

Appendix J. Resident bird species observed in SAAN from 1985-2013.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
Cooper's hawk	*Accipiter cooperii*	X	X	X	X
sharp-shinned hawk	*Accipiter striatus*	X	X	X	X
Swainson's hawk	*Buteo swainsoni*	X	X	X	X
northern harrier	*Circus cyaneus*	X		X	X
osprey, western osprey	*Pandion haliaetus*	X	X	X	X
wood duck	*Aix sponsa*	X		X	
northern pintail	*Anas acuta*	X		X	
American wigeon	*Anas americana*	X			
northern shoveler	*Anas clypeata*	X		X	X
Eurasian teal, green-winged teal	*Anas crecca*	X		X	
gadwall	*Anas strepera*	X		X	X
lesser scaup	*Aythya affinis*	X		X	
ring-necked duck	*Aythya collaris*	X		X	
hooded merganser	*Lophodytes cucullatus*	X		X	
ruddy duck	*Oxyura jamaicensis*	X			
rufous hummingbird	*Selasphorus rufus*	X	X		
common poorwill	*Phalaenoptilus nuttallii*	X		X	
European herring gull, herring gull	*Larus argentatus*	X			
ring-billed gull	*Larus delawarensis*	X		X	
Bonaparte's gull	*Larus philadelphia*	X		X	
forster's tern	*Sterna forsteri*	X		X	
ae'o, black-necked stilt, hawaiian stilt	*Himantopus mexicanus*	X			X

Appendix J (continued). Resident bird species observed in SAAN from 1985-2013.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
American avocet	*Recurvirostra americana*	X		X	
spotted sandpiper	*Actitis macularia*	X		X	X
least sandpiper	*Calidris minutilla*	X		X	X
Wilson's snipe	*Gallinago delicata*	X		X	
long-billed dowitcher	*Limnodromus scolopaceus*	X		X	X
	Scolopax minor	X		X	
lesser yellowlegs	*Tringa flavipes*	X	X	X	X
greater yellowlegs	*Tringa melanoleuca*	X		X	X
belted kingfisher	*Ceryle alcyon*	X	X	X	
green kingfisher	*Chloroceryle americana*	X		X	X
ringed kingfisher	*Ceryle torquata*			X	
peregrine falcon	*Falco peregrinus*	X	X		
American kestrel	*Falco sparverius*	X	X	X	X
American coot	*Fulica americana*	X		X	X
cedar waxwing	*Bombycilla cedrorum*	X	X	X	X
northern cardinal	*Cardinalis cardinalis*	X	X	X	X
brown creeper	*Certhia americana*	X	X		
grasshopper sparrow	*Ammodramus savannarum*	X		X	
dark-eyed junco	*Junco hyemalis*	X		X	X
Lincoln's sparrow	*Melospiza lincolnii*	X	X	X	X
savannah sparrow	*Passerculus sandwichensis*	X		X	X
spotted towhee	*Pipilo maculatus*	X		X	X

Appendix J (continued). Resident bird species observed in SAAN from 1985-2013.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
vesper sparrow	*Pooecetes gramineus*	X	X	X	X
chipping sparrow	*Spizella passerina*	X	X	X	X
field sparrow	*Spizella pusilla*	X	X	X	X
white-throated sparrow	*Zonotrichia albicollis*	X	X	X	X
white-crowned sparrow	*Zonotrichia leucophrys*	X	X	X	X
American goldfinch	*Carduelis tristis*	X	X	X	X
northern rough-winged swallow	*Stelgidopteryx serripennis*	X		X	
Brewer's blackbird	*Euphagus cyanocephalus*	X		X	
common grackle	*Quiscalus quiscula*	X	X	X	X
eastern meadowlark	*Sturnella magna*	X	X	X	X
western meadowlark	*Sturnella neglecta*	X		X	X
gray catbird, grey catbird	*Dumetella carolinensis*	X	X	X	
brown thrasher	*Toxostoma rufum*	X	X		
American pipit, buff-bellied pipit	*Anthus rubescens*	X		X	X
yellow-rumped warbler	*Dendroica coronata*	X	X	X	X
common yellowthroat	*Geothlypis trichas*	X		X	
black-and-white warbler	*Mniotilta varia*	X	X	X	
orange-crowned warbler	*Vermivora celata*	X	X	X	X
blue-gray gnatcatcher	*Polioptila caerulea*	X	X	X	X
ruby-crowned kinglet	*Regulus calendula*	X	X	X	X
golden-crowned kinglet	*Regulus satrapa*	X	X	X	
cactus wren	*Campylorhynchus brunneicapillus*	X			

Appendix J (continued). Resident bird species observed in SAAN from 1985-2013.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
winter wren	*Troglodytes troglodytes*	X		X	X
hermit thrush	*Catharus guttatus*	X	X	X	X
eastern bluebird	*Sialia sialis*	X	X	X	X
American robin	*Turdus migratorius*	X	X	X	X
vermilion flycatcher	*Pyrocephalus rubinus*	X		X	X
eastern phoebe	*Sayornis phoebe*	X	X	X	X
Say's phoebe	*Sayornis saya*	X		X	
Couch's kingbird	*Tyrannus couchii*	X		X	
solitary vireo, blue-headed vireo	*Vireo solitarius*	X	X	X	X
great egret	*Ardea alba*	X	X	X	X
great blue heron	*Ardea herodias*	X	X	X	X
cattle egret, western cattle egret	*Bubulcus ibis*	X		X	X
green heron	*Butorides virescens*	X	X	X	X
little blue heron	*Egretta caerulea*	X		X	X
snowy egret	*Egretta thula*	X		X	X
tricolored heron	*Egretta tricolor*	X		X	
yellow-crowned night heron, yellow-crowned night-heron	*Nyctanassa violacea*	X	X	X	X
black-crowned night heron, black-crowned night-heron	*Nycticorax nycticorax*	X		X	X
American white pelican	*Pelecanus erythrorhynchos*	X		X	
northern flicker	*Colaptes auratus*	X	X	X	X
yellow-bellied sapsucker	*Sphyrapicus varius*	X	X		X
black-necked grebe, eared grebe	*Podiceps nigricollis*	X			

Appendix J (continued). Resident bird species observed in SAAN from 1985-2013.

Common Names	Scientific Name	NPS (2014)	Coonan (1987)	Scully (2006)	Twedt (2013)
pied-billed grebe	*Podilymbus podiceps*	X		X	X
least grebe	*Tachybaptus dominicus*	X		X	
monk parakeet	*Myiopsitta monachus*	X		X	X
Neotropic cormorant	*Phalacrocorax brasilianus*	X		X	X
		91	**40**	**81**	**56**

Appendix K. Bird species and number detected during 90 area search survey visits to 40 randomly located survey locations in SAAN during winters of 2010-2011 (n=30 visits), 2011-12 (n=30 visits), and 2012-2013 (n=30 visits). "All" detections includes birds detected at any distance from plot center (including flyovers), whereas "50-m Radius" includes only birds $\leq$ 50m from plot center when first detected (Appendix modified from Twedt 2013).

	All		50-m Radius	
Common Name	**Number Points**	**Number Individuals**	**Number Points**	**Number Individuals**
American coot	1	1		
American goldfinch	37	283	18	182
American kestrel	4	4	1	1
American pipit	7	64		
American robin	2	2		
blue-gray gnatcatcher	6	9	5	8
blue-headed vireo	3	3	2	2
cedar waxwing	4	74		
chipping sparrow	2	42	2	42
common grackle	1	12	1	12
Cooper's hawk	2	2		
eastern bluebird	12	29	4	13
eastern meadowlark	7	78	4	29
eastern phoebe	37	49	25	35
gadwall	9	47	1	2
great blue heron	9	9	4	4
green kingfisher	1	1		
great egret	14	24	1	1
greater yellowlegs	4	4		
hermit thrush	34	64	29	48
long-billed dowitcher	2	4	1	1
little blue heron	2	2	1	1
least sandpiper	6	101		
lesser yellowlegs	1	2		
Lincoln's sparrow	15	24	13	21
neotropic cormorant	13	22		
northern cardinal	72	261	59	136
northern flicker	23	32	8	9

Appendix K (continued). Bird species and number detected during 90 area search survey visits to 40 randomly located survey locations in SAAN during winters of 2010-2011 (n=30 visits), 2011-12 (n=30 visits), and 2012-2013 (n=30 visits). "All" detections includes birds detected at any distance from plot center (including flyovers), whereas "50-m Radius" includes only birds $\leq$ 50m from plot center when first detected (Appendix modified from Twedt 2013).

	All		50-m Radius	
Common Name	**Number Points**	**Number Individuals**	**Number Points**	**Number Individuals**
northern harrier	2	2	1	1
northern shoveler	1	4		
orange-crowned warbler	21	31	20	28
osprey	2	2		
pied-billed grebe	3	6	1	1
ruby-crowned kinglet	41	74	32	53
savannah sparrow	9	121	8	58
dark-eyed junco	1	15	1	15
snowy egret	7	12	1	1
spotted sandpiper	5	6	2	2
spotted towhee	11	16	9	11
sharp-shinned hawk	4	4	3	3
vermillion flycatcher	1	1		
vesper sparrow	5	17	3	10
white-crowned sparrow	4	80	1	5
western meadowlark	3	42	1	1
winter wren	2	2	1	1
white-throated sparrow	3	21	3	21
yellow-bellied sapsucker	1	1	1	1
yellow-rumped warbler	40	226	34	193
Totals	**496**	**1932**	**301**	**952**

Appendix L. Resident bird species and number detected during 10-minute surveys of 40 randomly located point locations in SAAN during the breeding season May-June 2010 (n = 20 counts), 2011 (n = 30 counts), and 2012 (n = 30 counts). Birds for which no detection distance was recorded (i.e., FLYOVERS) are not reported in table. * indicates a resident species that was observed in the breeding season but not in the winter surveys (appendix modified from Twedt 2013).

Common Name	2010	2011	2012
black-crowned night-heron*		1	
blue-headed vireo			1
black-necked stilt*			1
cattle egret*		3	2
chipping sparrow		1	
eastern bluebird	1	2	
eastern phoebe	1		1
field sparrow*	2		
great egret	2	8	2
green heron*	1	1	
little blue heron		1	
monk parakeet*		1	
Neotropic cormorant	1	3	2
northern cardinal	79	109	115
snowy egret		3	2
spotted sandpiper		1	
Swainson's hawk*			1
yellow-crowned night-heron*	1	2	2
Individuals detected	**88**	**136**	**129**
Species detected	**8**	**13**	**10**

Appendix M. Resident bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-1986 (Appendix modified from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
great blue heron	SAJU		0.7			
	ESPA	1.6	1	0.2	0.2	
great egret	SAJU					
	ESPA		1			
green heron	SAJU		0.7	1.5	0.7	1.5
	ESPA			0.2	0.2	0.8
yellow-crowned night heron	SAJU					
	ESPA			0.2		
osprey	SAJU					
	ESPA		0.2			
sharp-shinned hawk	SAJU					
	ESPA		0.2			
Cooper's hawk	SAJU					
	ESPA	0.2				
Swainson's hawk	SAJU					
	ESPA					0.4
American kestrel	SAJU	2.2	2.9			
	ESPA	1.2	1			
peregrine falcon	SAJU					0.7
	ESPA					0.3
lesser yellowlegs	SAJU					
	ESPA		0.2	0.2		
rufous hummingbird	SAJU				0.7	
	ESPA	1				
belted kingfisher	SAJU		0.7			
	ESPA	0.4	0.4			1
yellow-bellied sapsucker	SAJU		0.7			
	ESPA					

Appendix M (continued). Resident bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-1986 (Appendix modified from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
northern flicker	SAJU	1.5	0.7			
	ESPA	0.4				
eastern phoebe	SAJU	3.7	1.5			1.5
	ESPA	0.6	2.4	0.2		0.2
brown creeper	SAJU	0.7	0.7			
	ESPA					
golden-crowned kinglet	SAJU	1.5	6.6	0.7		
	ESPA	1	2	1.4		
ruby-crowned kinglet	SAJU	5.2	8.8	1		
	ESPA	1	3.6	0.4		
blue-gray gnatcatcher	SAJU			4.4		2.9
	ESPA	0.4	1.2			1.8
eastern bluebird	SAJU					
	ESPA	1.2	4.4	0.2		
hermit thrush	SAJU	0.7	3			
	ESPA					
American robin	SAJU	1.5	24.3			
	ESPA	7.4	12.5	1.6		
gray catbird	SAJU			0.7		
	ESPA					
brown thrasher	SAJU					
	ESPA	0.2	0.4			
cedar waxwing	SAJU	0.7	16.2	8.1		
	ESPA		12.9	6.9		
solitary vireo	SAJU	2.2				
	ESPA					0.2
orange-crowned warbler	SAJU		2.2			
	ESPA		0.2			

Appendix M (continued). Resident bird species abundance by season for the San Juan Woods (SAJU) and Espada Labores (ESPA) land tracts, SAAN, 1985-1986 (Appendix modified from Coonan 1987).

Species	Area	Fall	Winter	Spring	Early Summer	Late Summer
yellow-rumped warbler	SAJU	13.2	28.7	2.9		
	ESPA	0.8	6.2	2		
black-and-white warbler	SAJU					
	ESPA					
northern cardinal	SAJU	19.9	16.2	44.9	38.2	33.8
	ESPA	10.7	15.7	21.5	21.1	16.9
chipping sparrow	SAJU					
	ESPA	0.4				
field sparrow	SAJU					
	ESPA		2.4	0.4	2.4	
vesper sparrow	SAJU		1.5			
	ESPA	2.8	17.1	2.2		
Lincoln's sparrow	SAJU		0.7	2.9		
	ESPA	0.2	1.8	2		
white-throated sparrow	SAJU		0.7			
	ESPA					
white-crowned sparrow	SAJU	1.5	1.5	1.5		
	ESPA		0.4			
eastern meadowlark	SAJU		1.5			
	ESPA	4	1.4	1.2		
common grackle	SAJU					
	ESPA			1.4	0.4	0.6
American goldfinch	SAJU					
	ESPA	0.4	7.2	0.4		
Number of Sp. (Resident)	**SAJU**	**13**	**21**	**10**	**3**	**5**
	ESPA	**20**	**24**	**18**	**5**	**9**

Appendix N. Relative abundance and distribution of resident bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
wood duck		**X**	1						1
Gadwall	**X**	X	6	2					8
northern shoveller	X								0
northern pintail	X								0
green-winged teal	**X**		3						3
ring-necked duck	X								0
lesser scaup	X								0
hooded merganser	**X**		1						1
least grebe		X							0
pied-billed grebe	**X**			2				1	3
American white pelican		**X**		1					1
Neotropical cormorant	**X**		1	2	3			2	8
great blue heron	**X**	X	8	4	1	5	4	4	26
great egret	**X**	**X**	12	12	26	21	10	9	90
snowy egret	**X**	X	6	7	8	8	10	9	48
little blue heron	**X**	X	1	3	6	8	4	3	25
tri-colored heron	X								0
cattle egret	**X**	**X**		1	9	12	6		28
green heron	**X**	X			2	5	3		10
black-crowned night heron	**X**		1		1				2
yellow-crowned night heron	**X**				7	3			10
Osprey	**X**		5	1				4	10
northern harrier		**X**	3						3
sharp-shinned hawk	**X**	X	2					1	3
Cooper's hawk	**X**	X						1	1
Swainson's hawk	X	**X**				1			1
American kestrel	**X**	**X**		1				1	2

Appendix N (continued). Relative abundance and distribution of resident bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
American coot	X								0
American avocet	**X**						1		1
greater yellowlegs	**X**		2	2				3	7
lesser yellowlegs		**X**			1				1
spotted sandpiper	**X**		5	3	6	2	3	4	23
least sandpiper	**X**			1	1			3	5
long-billed dowitcher	**X**		1						1
Wilson's snipe	**X**								0
American woodcock	X								0
Bonaparte's gull	X								0
ring-billed gull	**X**		7					1	8
Forster's tern	X								0
monk parakeet	**X**				1				1
common poorwill	X								0
ringed kingfisher	X								0
belted kingfisher	**X**		3	3		1	5	7	19
green kingfisher	**X**	**X**	1	2	2				5
northern flicker	X	**X**						1	1
eastern phoebe	**X**	**X**	12	5			1	10	28
Say's phoebe	**X**		1						1
Vermillion flycatcher	**X**		2						2
Couch's kingbird	**X**			1			2		3
blue-headed vireo	X								0
northern rough-winged swallow	X								0
winter wren	X								0
golden-crowned kinglet	**X**	**X**	1						1
ruby-crowned kinglet	**X**	**X**	24	22				15	61

Appendix N (continued). Relative abundance and distribution of resident bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	**City of San Antonio (18)**	**Rancho de las Cabras (7)**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Total**
blue-gray gnatcatcher	**X**	**X**	1	10	1		2	1	15
eastern bluebird	**X**	**X**				1	1	2	4
hermit thrush	**X**	**X**	3					3	6
American robin	**X**	**X**	7	1				9	17
gray catbird	**X**				1				1
American pipit	**X**		13					8	21
cedar waxwing	**X**	**X**	7	1				4	12
orange-crowned warbler	**X**	**X**	6					5	11
yellow-rumped warbler	**X**	**X**	19	4				14	37
black-and-white warbler	**X**	X		1					1
common yellowthroat	**X**	**X**		2	1				3
spotted towhee	**X**	**X**	1	1				2	4
chipping sparrow	**X**			1					1
field sparrow	**X**								0
vesper sparrow	**X**	**X**	2	1					3
savannah sparrow	**X**	**X**	6	6				2	14
grasshopper sparrow		X							0
Lincoln's sparrow	**X**	**X**	4	7	1			3	15
white-throated sparrow	**X**	**X**	4	4				2	10
white-crowned sparrow	**X**	**X**	3	1					4
dark-eyed junco	X								0
northern cardinal	**X**	**X**	104	192	182	124	46	26	674
eastern meadowlark	X	X							0
western meadowlark	**X**	**X**	4					1	5
Brewer's blackbird		**X**	2						2
common grackle	**X**	**X**	3	6				3	12
American goldfinch	**X**	**X**	10	8				26	44

Appendix N (continued). Relative abundance and distribution of resident bird species observed during Scully (2006). Bold species indicate a species that was observed at one of the point count locations.

	Species Observed		Number of Times Detected						
Species	City of San Antonio (18)	Rancho de las Cabras (7)	Jan	Mar	May	Jul	Sep	Nov	Total
Total Number of Detections	**n/a**	**n/a**	**308**	**321**	**260**	**191**	**98**	**190**	**1368**
Species Observed Total	**74**	**43**							
Species Observed at Points	**56**	**32**							
Grand Total	**81**								

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.

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