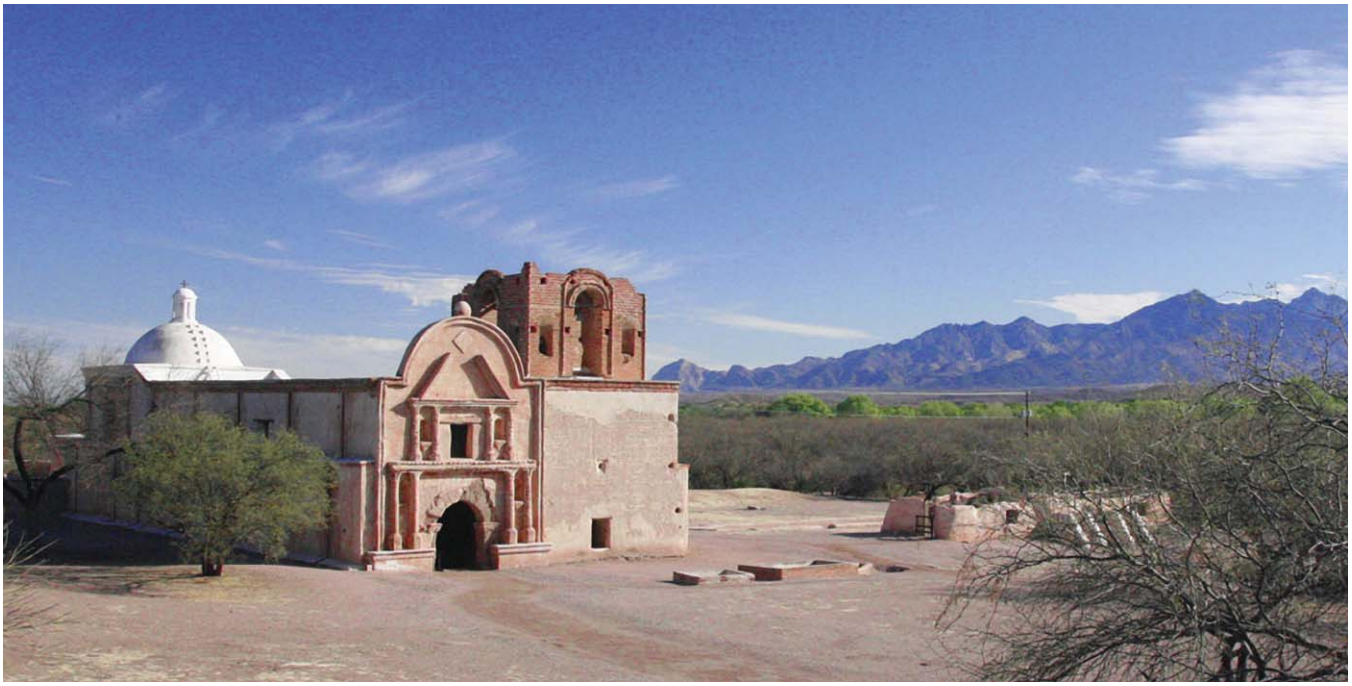
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

# Vegetation Classification, Distribution, and Mapping Report

*Tumacácori National Historical Park*

Natural Resource Report NPS/SODN/NRR—2009/148



ON THE COVER

Church and Santa Rita Mountains, Tumacácori National Historical Park. NPS photo by Jeff Axel.

# Vegetation Classification, Distribution, and Mapping Report

*Tumacácori National Historical Park*

Natural Resource Report NPS/SODN/NRR—2009/148

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# Acronyms and Abbreviations

| | |
|---|---|
| AA | accuracy assessment |
| ac | acres |
| CEGL | Community Element Code–Global |
| CIR | color infrared |
| cm | centimeter |
| DOQQ | digital orthophoto quarter quadrangle |
| DVD | digital compact disk |
| ERDAS | Earth Resources Data Analysis System |
| ESRI | Environmental Systems Research Institute |
| FGDC | Federal Geographic Data Committee |
| ft | foot/Feet |
| GB | gigabytes |
| GCP | ground control point |
| GIS | geographic information system |
| GPS | global positioning system |
| ha | hectares |
| I&M | Inventory and Monitoring Program |
| ITIS | Integrated Taxonomic Information System |
| km | kilometers |
| m | meters |
| mi | miles |
| .mdb | Microsoft Access file format |
| MMU | minimum mapping unit |
| MS | Microsoft |
| NA | not applicable |
| NAD83 | North American Datum of 1983 |
| NBII | National Biological Information Infrastructure |
| NED | National Elevation Dataset |
| NHP | National Historical Park |
| NMAS | National Map Accuracy Standards |
| NP | national park |
| NPS | National Park Service |
| NVCS | National Vegetation Classification Standard (or System) |
| NVC | National Vegetation Classification |
| OALS | Office of Arid Lands Studies (University of Arizona) |
| RMSE | root mean square error |
| RRQRR | Reversed Randomized Quadrant Recursive Raster |
| SODN | Sonoran Desert Network (National Park Service) |
| spp | species (plural) |
| .tif | tagged image file format |
| TNC | The Nature Conservancy |
| TUMA | Tumacácori National Historical Park |
| UNESCO | United Nations Education, Science, and Cultural Organization |
| USDA | U.S. Department of Agriculture |
| USGS | U.S. Geological Survey |
| UTM | Universal Transverse Mercator |
| .xls | Microsoft Excel file format |

**Map class abbreviations**

| | |
|---|---|
| ACACON | *Acacia constricta* |
| ACAGRE | *Acacia greggii* |
| AMAPAL | *Amaranthus palmeri* |
| CELLAE | *Celtis laevigata* var. *reticulata* |
| HYMMON | *Hymenoclea monogyra* |
| POPFRE | *Populus fremontii* |
| PROVEL | *Prosopis velutina* |
| PROVEL-ACAGRE | *Prosopis velutina - Acacia greggii* |
| TAMRAM | *Tamarix ramosissima* |

# Executive Summary

In 2007–2008, the National Park Service, Sonoran Desert Network Inventory and Monitoring Program, in cooperation with the Arizona Remote Sensing Center (University of Arizona, Office of Arid Lands Studies), carried out classification and mapping of vegetation at Tumacácori National Historical Park (NHP), as part of the national U.S. Geological Survey–National Park Service Vegetation Characterization Program. The primary objective of the program is to produce high-quality, standardized maps and associated data sets of vegetation and other land cover occurring within the parks (http://science.nature.nps.gov/im/inventory/veg/index.cfm). In particular, the aim of this project was to create a vegetation map at the National Vegetation Classification alliance level or finer, with a minimum mapping unit of 0.5 hectares, thematic accuracy of 80% or better per map class, and spatial accuracy meeting U.S. National Map Accuracy Standards.

Project scoping, initiated in October 2007, involved the project team and Tumacácori NHP staff. Quickbird satellite imagery, acquired in August 2006, was used for this project, which covered the three subunits of the park plus a 100-m buffer around each one, for a total area of 238 hectares. Image preprocessing and initial interpretation to the vegetation formation level were done at the Arizona Remote Sensing Center. The draft formation-level map was produced through limited field reconnaissance and visual interpretation of the pan-sharpened imagery and heads-up digitizing in ArcGIS to delineate polygons based on vegetation physiognomy.

Vegetation classification and mapping to the alliance level were done simultaneously, through intensive field work from November 2007 to April 2008. The field team, including the image interpreters, took the formation map as a starting point and verified or modified formation boundaries; split formation polygons into alliance- or finer-level, floristically based polygons; and characterized each alliance type with quantitative (plot- and polygon-based) data on species composition, relative cover, and other factors. Because Tumacácori is a small park, a census of the entire park was done in this way. Nineteen vegetation types were identified and mapped.

Thematic accuracy was assessed by the park's resources manager/archeologist after a thorough briefing on the methods used for classification and mapping, as well as on the map classes. The assessor was provided with tools similar to those used by the mappers, including a GPS-linked handheld computer loaded with draft map polygon boundaries, and printed map sections with each polygon labeled with a simple identification number. The assessor completed a census of every mapped polygon, walking through each one to evaluate the lifeform and canopy cover of the dominant species, and choosing the best-fitting map class name for the polygon. Initial accuracy was 90.2%, with four classes below 80%. Because of the small area of the park and the small number of polygons, each discrepancy between the accuracy assessment data and the map data was investigated and resolved, resulting in 100% thematic accuracy. Spatial accuracy was assessed against 2006 digital orthophoto quarter quadrangle imagery, using 20 test points for each of the park's three units. The maximum absolute error measured was less than 2 m ground distance, and maximum root mean square error was 1.03 m, well within the limits of the National Map Accuracy Standards.

While the main products of this project are the vegetation classification and the vegetation map database, a number of ancillary digital geographic information system and database products were also produced that can be used independently or to augment the main products.

# Acknowledgements

This project was a cooperative effort between the USGS-NPS Vegetation Characterization Program national office, with support from Karl Brown, Tammy Hamer, and Chris Lea; the National Park Service, Sonoran Desert Network; and the University of Arizona, Office of Arid Lands Studies.

Field work was carried out primarily by Steve Buckley and Jon Green. We would like to thank the staff of Tumacácori National Historical Park for their support and assistance during this project—particularly Jeremy Moss, who was responsible for the accuracy assessment performed on the maps. Data management support and database development were provided by the Sonoran Desert Network data management staff.

The project also benefited from the critical review of the report and digital products by: Kathryn Thomas, of the U.S. Geological Survey, and Tomye Folts, of the Southern Plains Network. The project team is extremely grateful for the help, advice, and assistance provided by all of these people and their respective institutions.

# Chapter 1
# Introduction

## 1.1 Background

Vegetation is a primary resource of natural areas, and description of vegetation composition, structure, and distribution is fundamental to effective land management. The term "vegetation" encompasses plants at multiple scales, from the most refined floristic levels (referred to as "plant communities" in this report) to the broadest physiognomic or lifeform levels. This report describes the methods and results of a two-year project (2007–2008) to classify, describe, and develop a vegetation map database for Tumacácori National Historical Park (NHP), located in Santa Cruz County, south of Tucson, Arizona.

The National Park Service's (NPS) Sonoran Desert Network (SODN), part of the servicewide Inventory and Monitoring (I&M) Program, organized and coordinated vegetation classification, description, and mapping at Tumacácori National Historical Park (TUMA). For TUMA, as well as the other network parks, the SODN needed baseline vegetation data upon which to develop and implement specific monitoring programs, and park managers needed baseline data and information on park resources for management purposes.

The current effort to create a new vegetation map for Tumacácori NHP is part of the USGS-NPS Vegetation Characterization Program (http://biology.usgs.gov/npsveg/), in cooperation with the SODN and the University of Arizona's Office of Arid Lands Studies. The map should meet the standards of the USGS-NPS Vegetation Characterization Program, including a minimum mapping unit of 0.5 hectares, 80% thematic accuracy per class, and spatial accuracy meeting the U.S. National Map Accuracy Standards.

## 1.2 Scope and Products

The aim of this project was to create a vegetation map at the National Vegetation Classification (NVC) alliance level or finer for a study area of 238 hectares (588 acres), made up of the three disjunct units of Tumacácori NHP: Mission (195 ha), Calabazas (24 ha) and Guevavi (19 ha), plus a 100-meter buffer surrounding each unit (Figures 1.2-1 and 1.2-2). Lands within park boundaries comprised 147 ha (363 ac) or 61.5% of the project area.

Products developed for Tumacácori NHP as part of this project included:

- A final report, including a vegetation key and full vegetation community-type descriptions;
- Digital photos of each vegetation type (four per polygon mapped);
- A spatial database containing vegetation data, plot data and location, accuracy assessment routes, and satellite imagery;
- Hard-copy and digital graphics of final map coverages; and
- Federal Geographic Data Committee-compliant metadata for all spatial database files and field data.

## 1.3 The USGS-NPS Vegetation Characterization Program

The USGS-NPS Vegetation Characterization Program is a cooperative project between the U.S. Geological Survey (USGS) and the NPS to classify, describe, and map vegetation in more than 270 national park units within the United States.* The USGS Center for Biological Informatics administers the program, in cooperation with the NPS I&M Program.

The Vegetation Characterization Program supports consistent vegetation classification, mapping, and accuracy-assessment protocols and standards across all park-mapping projects. The program has established guidance for all vegetation-mapping projects in four documents:

*Language for the sections on the USGS-NPS Vegetation Characterization Program, National Vegetation Classification Standard, and Federal Geographic Data Committee is from Thomas et al. (2007), modified from Van Loh et al. (2006).

- Standardized National Vegetation System (TNC and ESRI 1994a)
- Methodology for Assessing the Utility of Existing Data for Vegetation Mapping (TNC and ESRI 1996)
- Field Methods for Vegetation Mapping (TNC and ESRI 1994b)
- Accuracy Assessment Procedures (ESRI et al. 1994)

In addition, the program has defined national standards for all park vegetation classification and mapping projects:

- Vegetation classification follows the Federal Geographic Data Committee (FGDC) standard for vegetation classification, the National Vegetation Classification Standard.
- Spatial data formatting follows the FGDC standards for spatial data transfer.
- Metadata for each spatial dataset uses the FGDC metadata standard.
- Spatial data is provided with a horizontal positional accuracy that meets National Map Accuracy Standards at the 1:24,000 scale; each well-defined object within the spatial database is within 1/50 of an inch display scale or 12.2 m (40 ft) of its actual location.
- All plant names used in the classification are consistent with the Integrated Taxonomic Information System (ITIS).
- Each vegetated map class will meet or exceed 80% accuracy at the 90% confidence level.
- The minimum mapping unit (MMU) is 0.5 ha (1.24 ac).

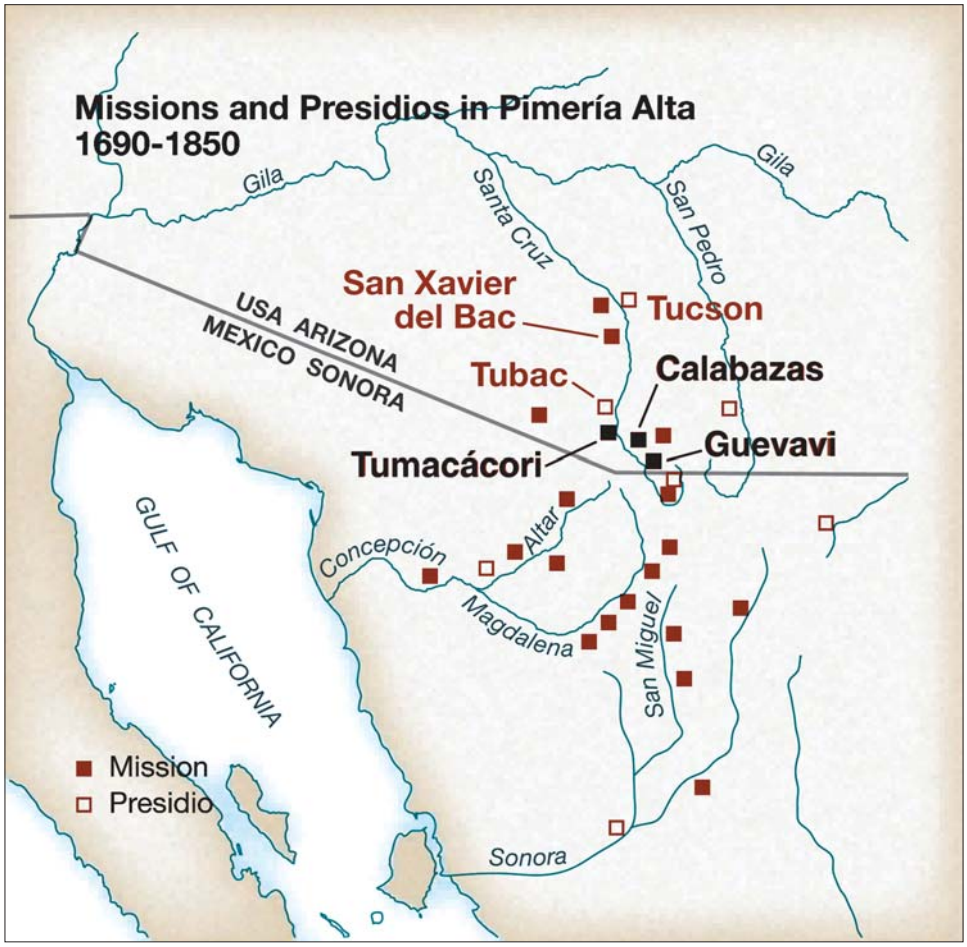


Figure 1.2-1. Location of Tumacácori National Historical Park (including the Calabazas and Guevavi units), along the Santa Cruz River in southern Arizona.

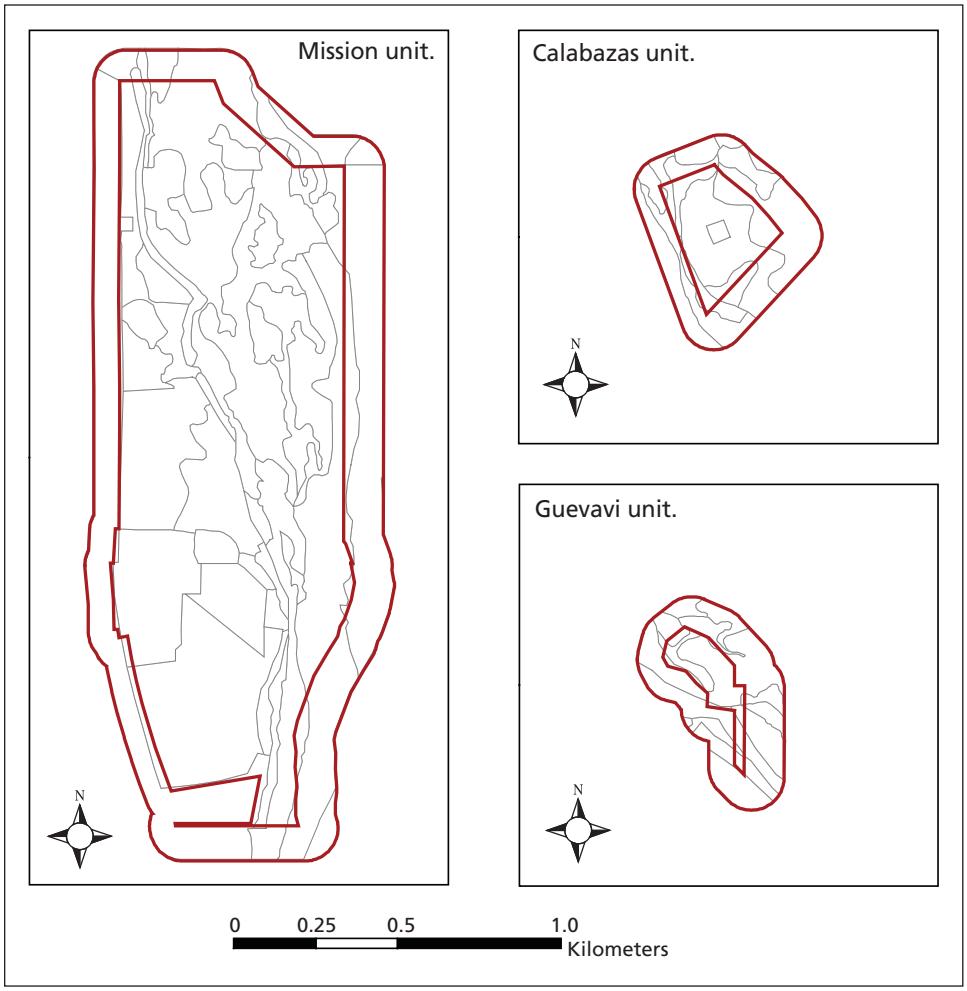


Figure 1.2-2. Tumacácori National Historical Park vegetation mapping project area. Project area includes a 100-m buffer around each unit (area between red lines).

## 1.4 The National Vegetation Classification Standard

Patterns of vegetation vary continuously over landscapes. Classification systems attempt to categorize those patterns by identifying and describing assemblages of plants that repeat in similar habitats. The National Vegetation Classification Standard (NVCS) provides a classification framework that is the standard for all NPS vegetation mapping projects (Comer et al. 2003, TNC and ESRI 1994a). In 1997, the FGDC formally adopted the NVCS version 1 (FGDC 1997). During the course of this project, version 2 of the NVCS (FGDC 2008), also known as the National Vegetation Standard, was approved, but not yet implemented.

The NVCS is a hierarchical system that allows vegetation classification to occur at multiple scales. In version 1, used for this project, there are seven levels. The upper five are based on the physiognomic characteristics of vegetation, and the lower two are based on the floristic characteristics of the plant community—relative abundance of dominant species. Table 1.4 identifies the seven levels of the NVCS used in this report and depicts their placement in the hierarchical relationship (Maybury 1999).

The NVCS evolved from vegetation classification primarily conducted over more than two decades by The Nature Conservancy (TNC), NatureServe, and the Natural Heritage Program network (Grossman et al. 1998). It derives in part from earlier vegetation classification frameworks produced by the United Nations Educational, Cultural, and Scientific Organization (UNESCO 1973, Driscoll et al. 1984). Use of this standardized classification system helps ensure data compatibility throughout the National Park Service and other agencies.

**Table 1.4. Summary of the National Vegetation Classification Standard hierarchical approach.**

| Level | Primary basis for classification | Example |
|---|---|---|
| Class | Structure of vegetation | Forest |
| Subclass | Leaf phenology | Deciduous forest |
| Group | Leaf types, corresponding to climate | Cold-deciduous forest |
| Subgroup | Relative human impact (natural/semi-natural, or cultural) | Natural/Semi-natural cold-deciduous forest |
| Formation | Additional physiognomic and environmental factors, including hydrology | Temporarily flooded cold-deciduous forest |
| Alliance | Dominant/diagnostic species of the uppermost or dominant stratum | *Populus fremontii* Temporarily Flooded Forest Alliance |
| Association | Additional dominant/diagnostic species from any strata | *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest |

## 1.5 The National Vegetation Classification

The NVCS provides a framework for levels of classification but does not provide descriptions of all existing vegetation types at all levels. Those descriptions comprise the National Vegetation Classification (NVC), which is being filled out by individual vegetation characterization projects, such as the present one, and other sources. The NVC, which is maintained by NatureServe and used by many federal agencies, including the NPS, includes the plant communities (associations and alliances) defined for the United States.

Work on the NVC, conducted primarily by TNC through 1999, provided initial definitions of some plant communities at each level. NatureServe inherited that documentation when it branched from TNC. NatureServe manages a database of NVC plant community entities. Their online database, NatureServe Explorer (http://www.natureserve.org/explorer/), provides public access to regularly updated versions of the NVC plant community listings and descriptions. NatureServe's documentation of alliances and associations is the most accessible listing currently available. However, the plant community listings within the NVC are not yet complete.

In addition to the NVC, NatureServe has created a standardized Ecological Systems Classification for describing sites, based on both vegetation and the ecological processes that drive it. Ecological systems are mid-scale biological communities that occur in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are not conceptually a unit within the NVCS but are rather a vegetation mapping concept. However, NVC associations occur within ecological systems. An association may occur in any number of ecological systems, limited only by the range of ecological settings in which that association occurs. Ecological systems are broad-scale, and can embody any number of highly specific associations that might be found in a particular setting.

For more information on the NVC, see the USGS-NPS Vegetation Characterization Program standards (http://biology.usgs.gov/npsveg/standards.html) or Grossman et al. (1998).

## 1.6 Terminology and Naming Conventions

Alliances and associations are based on both the dominant (greatest-canopy-cover) species in the upper strata of a stand and on diagnostic species (those consistently found in some land-cover types but not others). Associations are the most specific classification, and are hierarchically subsumed in alliances. Typically, each association is included in only one alliance, while each alliance may include many associations.

Alliance names are generally based on the dominant/diagnostic species in the uppermost stratum of the vegetation, though up to four species may be used, if necessary, to define the type. Associations define distinct plant compositions that repeat across the landscape, and are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in lower strata (or a diagnostic species in any stratum).

Naming conventions and syntax for all NVC names are as follows:

- A hyphen with a space on either side ( - ) separates names of species occurring in the same stratum.
- A slash with a space on either side ( / ) separates names of species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around a species name indicates the species is less consistently found either in all associations of an alliance, or in all occurrences of an association.
- Association names include the dominant species of the significant strata, followed by the class in which they are classified (e.g., Forest, Woodland, or Herbaceous).
- Alliance names also include the class in which they are classified (e.g., Forest, Woodland, or Herbaceous), but are followed by the word "Alliance" to distinguish them from associations.

The species nomenclature for all alliances and associations follows Kartesz (1999). Examples of association names from TUMA:

- *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest
- Inland Freshwater Strand Beach Sparse Vegetation

Examples of alliance names from TUMA:

- *Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance
- *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance

## 1.7 Park Environment

### *1.7.1 Park establishment*

Tumacácori National Historical Park was originally designated Tumacácori National Monument on September 15, 1908, by proclamation of President Theodore Roosevelt. The original, four-hectare monument was designated to protect Misión San Jose de Tumacácori, a Jesuit-established and Franciscan-constructed mission that was relocated to the present site in 1751, although construction of the building now protected was not completed until the mid-1820s. San Jose de Tumacácori was one of a line of Franciscan, although originally Jesuit, missions built in far northern Sonora beginning in 1691, with the arrival of the Jesuit Padre Eusebio Kino. Kino first visited the *Pimería Alta*, or the "place of the upper Pimas" as this area of southern Arizona was known at the time, and established a mission on the east side of the Santa Cruz River. A more favorable site was later selected on the west side of the river for permanent construction of the mission church and other facilities. The area was chosen because of its habitation, at the time, by O'odham people, also known as the Papago or Pima, along that stretch of the river. The word tumacácori is thought to be taken from two O'odham words, *chu-uma* and *kakul*, making reference to Saint Joseph of the flat, rocky place (http://www.nps.gov/tuma). Other sources suggest the name means caliche, or pepperbush (Lamb and Scott 1993).

Two other early churches are also part of the park's holdings, Los Santos Ángeles de Guevavi and San Cayetano de Calabazas. Guevavi is the southernmost of these units, consisting of a 3.9-hectare parcel adjacent to the Santa Cruz River 23 km SSE of the main (Mission) unit of Tumacácori NHP. Calabazas comprises an 8.9-hectare parcel situated to the south of the confluence of the Santa Cruz River and Sonoita Creek, a major tributary, 15 km SSE of the main unit. Guevavi was the earliest of all these missions, designated as a mission after Padre Kino visited the O'odham settlement in 1691. The word guevavi is derived from the O'odham *gi-vavhia*, meaning big well or big spring (http://www.nps.gov/tuma). The mission church whose ruins this unit protects was not built until the early 1750s, and was abandoned by 1775, because of continuing Apache raids.

San Cayetano de Calabazas was a mission at the site of a relocated O'odham village and, according to records, was founded in 1756, but not functional until 1773. It suffered at the hands of Apaches, just as Guevavi did. By 1853, the church was functioning as a ranch house for the Governor of Sonora, who ran 6,000 head of cattle in the area. Although it went through many other incarnations, the site was totally abandoned by 1878 (http://www.nps.gov/tuma). Both of these units were added to the park in 1990, and in 2002, Congress authorized the acquisition of an addi-

tional 125 hectares surrounding the main unit.

Today, Tumacácori National Historical Park comprises the three units for a total area of 145 hectares. All land abutting these park units is private, providing a challenge to resource managers.

### *1.7.2 Environmental history*

Tumacácori NHP is located in southern Arizona, along the Santa Cruz River valley, which is part of the southern Basin and Range physiographic province. This physiographic province, which encompasses southeastern Arizona and northern Sonora, is a "terrain of alternating fault-bounded linear mountain ranges and sediment-filled basins which began to form in southeastern Arizona as the result of dominantly east-northeast/west-southwest directed crustal extension" (Powell et al. 2005). The result is a landscape of many rugged mountain ranges: to the west, the Tumacácori and Atascosa mountains; to the east, the Santa Rita, Patagonia, and San Cayetano mountains.

The climate of the area is marked by a bimodal precipitation regime, with a monsoonal flow from the Gulf of Mexico in summer, and Pacific frontal storms in winter. The area's hot season occurs from April through October; maximum temperatures in July often exceed 40°C. Intense surface heating during the day and active radiant cooling at night can result in daily temperature ranges of 17–22° C. Winter temperatures are mild. Prevailing winds tend to follow the Santa Cruz Valley, blowing downslope (from the south) during the night and early morning, and upslope (from the north) during the day (Powell et al. 2005).

The Santa Cruz Valley has a long history of anthropogenically driven ecological change. Prior to Spanish colonization, marked by the arrival of Kino in 1691, O'odham communities are thought to have inhabited these areas for hundreds, if not thousands, of years (Spicer 1962). These small, subsistence-based agricultural communities were semi-nomadic and relied on the existence of permanent surface water for their survival (Robinett 1990). Although indications are that their impact was limited, opinions as to their overall impact vary, given the uncertainty surrounding specific practices, such as firing the landscape. With the arrival of the Spanish and their livestock, conditions changed drastically. In the 1804 Spanish census, 5,000 sheep were reported at Tubac, the presidio immediately downstream of the Tumacácori Mission unit. These numbers were replicated at Tumacácori, with 4,000 of the mission's cattle being sold in 1821, to pay for the construction of the church (http://www.nps.gov/tuma).

With the 1853 Gadsden Purchase, all land south of the Gila River, formerly owned by the Spanish, was transferred to the United States. Following the Gadsden Purchase and the end of the Apache wars, Euro-American settlement began throughout the region in earnest, further amplifying ecological change. Along the Santa Cruz River, changes in land use included the clearing of mesquite bosque and cottonwood–willow forests along the river for agricultural purposes. Evidence also indicates that cottonwoods more than six meters in diameter were girdled and killed in the 1920s, in the mistaken understanding that such actions would free up more water for agriculture (Logan 2002). Tumacácori National Monument, as designated in 1908, originally included only four hectares. The area around the mission began to be converted to more extensive agricultural operations sometime in the 1940s, replacing what appears to have been mesquite bosque (as documented in aerial photography dating to 1936). More agricultural fields appear in aerial photographs from 1956, and expand further to the north in 1959, when they appear to have totally surrounded the mission and run to the edge of the riparian zone. From the 1930s onward, there has been a general increase in the obligate riparian vegetation in this reach of the river, attributed to agricultural abandonment immediately adjacent to the river, periodic flooding that helped in the germination of cottonwood, specifically, and later, the existence of effluent water flow since the development of the Nogales International Wastewater Treatment Plant (Webb et al. 2007, Powell et al. 2005).

Beginning in the late 1970s, the agricultural fields surrounding Tumacácori began to be abandoned (J. Moss, pers. comm.). In aerial photographs from 1975, fields and historic acequias (irrigation canals) are still clearly visible. However, in aerial photographs from 1980 and 1983, these fields are clearly beginning to undergo type conversion to sparse shrubland, indicating their abandonment sometime previous to these photographs. In aerial photographs taken in 1992, 1996, 2003, and 2004, the growth of trees and shrubs in these former fields is clearly evident. Cattle ranching in the area has probably had an uninterrupted history since Spanish colonization, and continues today. Despite the park's efforts to maintain boundary

fencing, trespass cattle are a recurring problem in the park.

Cattle ranching also continues around both the Guevavi and Calabazas units. Guevavi was, in fact, part of a ranch until 1990, when the rancher donated the land to the Archaeological Conservancy. Guevavi had small, subsistence agricultural fields during the period of mission occupation, but had none of the extensive fields in the twentieth century that surrounded the main unit. Calabazas was similar in this respect, although there are indications that it was used as a farm for the mission at Tumacácori during the early 1800s (http://www.nps.gov/tuma). Neither Guevavi nor Calabazas has the same density of riparian-obligate species as is found at the main unit, although the existence of many deceased large cottonwoods is believed to be partly a consequence of local groundwater development for Nogales, in the case of Guevavi, and Rio Rico, in the case of Calabazas (Webb et al. 2007).

### *1.7.3 Vegetation*

The area of Tumacácori National Historical Park lies in the Arizona Upland division of the Sonoran Desert, as designated by Brown et al. (1979) and previously by Shreve and Wiggins (1964). Alternatively, this area is known as part of the Apache Highlands Ecoregion developed by The Nature Conservancy (Marshall et al. 2004). The vegetation is composed primarily of cottonwood–willow (*Populus fremontii–Salix gooddingii*) riparian forest and woodland along the Santa Cruz River channel, and mesquite (*Prosopis velutina)* forest (bosque) and woodland on low terraces flanking the river, with a gradation to savanna, semi-desert grassland, and desertscrub on the uplands away from the river. Within the dominant forest and woodland communities, hackberry (*Celtis laevigata* var. *reticulata*), and elderberry (*Sambucus nigra* ssp. *caerulea*) are common constituents and are, in some places, the dominant woody species along the upland edges where woodlands give way to savannas. Other associated species include acacias (*Acacia greggii, Acacia constricta*), wolfberry (*Lycium* spp.), greythorn (*Ziziphus obtusifolia*), and desert broom (*Baccharis sarothroides*). Different communities across the three park units exhibit different densities and species composition, depending not only on their site characteristics relative to the river, but also on their specific land-use histories. Although there are significant grass communities scattered throughout the park, ranging from mixed grama grass communities (*Bouteloua* spp.) to limited dominance by big sacaton (*Sporobolus wrightii*), there is a notable dominance by disturbance-tolerant species, such as amaranth (*Amaranthus palmeri*) and Bermuda grass (*Cynodon dactylon*). Bermuda grass, in particular, defines the contemporary strand vegetation community throughout the three units. There is also a notably large amount of Russian thistle (*Salsola kali*) throughout the park, possibly a lingering consequence of agricultural development around the park units.

# Chapter 2
# Classification and Mapping of Plant Communities

## 2.1 Methods

In general, we followed the classification and mapping methodology elaborated in the USGS-NPS Vegetation Characterization Program documentation, including the NVC standards. However, our approach to classification and mapping was more integrated than the traditional practice of having ecologists collect plot data for classification and photointerpreters delineate polygons with particular signatures, then combining the two efforts. Instead, we used an integrated team of observers who collected plot- and polygon-based data for classification while creating map polygons in the field.

An initial polygon map at the formation level (actually more like the class level) was drafted from interpretation of high-spatial-resolution satellite imagery and field reconnaissance (see following two sections). The field team, including the image interpreters, took this formation map as a starting point and verified or modified formation boundaries; split formation polygons into alliance or finer-level, floristically based polygons; and characterized each alliance type with quantitative data on species composition, relative cover, and other factors. Because Tumacácori is a small park, we were able to census the entire park in this way.

### *2.1.1 Satellite imagery*

The imagery we used was acquired by DigitalGlobe Inc.'s Quickbird satellite on August 27, 2006, as a new, tasked acquisition for this project. Image preprocessing and initial interpretation to the formation level were done at the Arizona Remote Sensing Center, University of Arizona. The imagery product purchased was the "Ortho-ready Standard" bundle of four spectral bands (blue, green, red and near-infrared) at 2.4-m spatial resolution, plus the broadband panchromatic data at 0.6-m resolution. This imagery is intended to be orthorectified by the user and is only coarsely geo-registered, with a nominal spatial accuracy of 23 m CE90—meaning that 90% of features in the imagery must be within 23 meters of their true location on the ground. More information about the general specifications of this imagery can be found at www.digitalglobe.com/ or, more specifically, at www.digitalglobe.com/product/standard_imagery.shtml.

### *2.1.2 Image processing*

The imagery was orthorectified with ERDAS (Leica) software, using a USGS National Elevation Dataset digital elevation model, ground control points (GCPs) from ca. 2006 digital orthophoto quarter quadrangles (DOQQs), and the Quickbird rational polynomial coefficient model. During the rectification process, the coordinates of GCP locations collected from the reference DOQQs were entered into a table and compared to image coordinates for the same GCP locations. An optimal set of GCPs was selected and the images were rectified using a polynomial model with cubic convolution resampling. The multispectral image had a root mean square error (RMSE) of 1.19 m, calculated from six GCPs. The panchromatic image had an RMSE of 0.65 m, calculated from nine GCPs. These errors are in relation to the 2006 DOQQ reference, the highest-accuracy reference source available.

Following orthorectification, the multispectral imagery was pan-sharpened for visual interpretation, using the resolution merge tool in ERDAS Imagine. Principal components and cubic convolution were selected as merge parameters. Pan-sharpening is the process of merging the high-resolution, 0.6-m panchromatic image with the 2.4-m multispectral image to produce a multispectral image with 0.6-m resolution. The draft formation-level map was produced through visual interpretation of the pan-sharpened imagery and heads-up digitizing in ArcGIS to delineate polygons. Seven formations were identified, based on the percentages of tree, shrub, and herbaceous cover present, following the formation key we had previously developed (Appendix A). These were: Forest, Woodland, Wooded Shrubland, Shrubland, Shrub Herbaceous, Wooded Herbaceous, and Herbaceous.

Each polygon in the draft formation map was assigned a unique alphanumeric identifier (ID) for reference throughout the project. When formation polygons were split, new, daughter polygons were given appropriate IDs, but still traceable to the parent. We prepared 11 × 17-inch hard-copy prints of the tentative formation polygons overlaid on the background imagery, at 1:4000 scale with a 100-m UTM grid, for use in the field-based vegetation alliance mapping. The field team also had the digital formation map and the imagery available on handheld and laptop computers, with the useful ability to zoom for viewing at multiple scales.

### *2.1.3 Field-based classification and mapping*

Field-based mapping and data collection for classification were conducted from November 1, 2007, through early April 2008. Working in teams of two or three for a multiple-observer, consensus-based approach, the field crew visited each of the formation polygons on the draft map of the study area. Assisted by the hard-copy prints and the spatial data loaded on GPS-linked handheld computers (RECONs), the field crew generally walked the boundary and much of the interior of each polygon to make a careful visual assessment of it. They determined whether the image interpreters had labeled it correctly (shrubland vs. woodland, for example) and whether its boundary needed any modifications. Then they looked at species composition and determined whether the polygon was sufficiently homogeneous to consider it a single alliance, or if it needed to be split into more than one alliance. Boundary modifications and splits were sketched on the hard-copy prints and explained in words on field data sheets.

From this point forward, work focused on the alliance-level polygons created. Next, the crews collected semi-quantitative data on canopy cover of dominant species by stratum, plant heights, associated species present, disturbance, and a range of soil/landscape characteristics. A sequence of four representative photographs was taken in the four cardinal directions from near the center of the polygon (at a specific point stored in the GPS), and a tentative alliance-type description of the polygon was written.

This was all done for each alliance-level polygon. In addition, a set of 20 × 50-m plot data was collected for each alliance type (not necessarily each polygon). Plot locations had been preselected with the spatially balanced RRQRR (Reversed Randomized Quadrant-Recursive Raster) algorithm to provide an objective, park-wide sampling basis for vegetation classification (Theobald et al. 2007). Essentially the same information was recorded in the plots as in the whole polygons, with the notable addition of measured basal diameters of trees present. The plots provided a uniform, delimited scale of observation to supplement and corroborate the extensive observations of whole polygons. To the extent that the plots are representative of the polygon or alliance type as a whole, collecting plot data can address the difficulty associated with making accurate visual estimates of the canopy cover of several species in large polygons. As such, evaluating both polygons and plots provides the most robust and useful dataset for characterizing alliances.

The RRQRR points were numbered and sampled in sequential order to maintain the spatial balance and the probabilistic nature of sampling. Each point was understood to serve as any corner of a plot, giving the field crew some flexibility to avoid major changes in vegetation type or distinct, nonrepresentative inclusions. Also, plots were oriented in any direction that most closely corresponded to the formation type in which the RRQRR point fell. Plots that crossed different types were still sampled but were placed to encompass the least amount of variation. If a plot crossed three or more community types, it was not sampled; rather, it was noted as being dropped and the crew moved to the next point. After the plot was established, the bearings of the 20-m and 50-m edges from the RRQRR origin point were recorded on the data sheet, the polygon in which the point was located was noted, and a photograph representative of the plot was taken from the origin point, the coordinates of which were marked in a GPS file in the RECON unit.

Vegetation-cover data were collected across the entire plot, with species ranked by relative dominance and assigned to absolute cover classes. Basal diameters of all individual trees of more than 2 m tall and larger than 10 cm in diameter were recorded, all woody stems of less than 10 cm in diameter were tallied, and all disturbance types were noted with the constrained vocabulary found in the NVC system. A battery of soil and landscape characterization data were taken (the same as those for polygon assessment), including topographic position, landform, surface cover, parent material, slope, aspect, and erosion features. Finally, narrative descriptions of both

vegetation and the landscape/soils were written to best characterize the community found in the plot.

At Tumacácori, we completed 60 plots associated with RRQRR points (29 at the Mission unit, 19 at Calabazas, and 12 at Guevavi), but these left some tentative alliance types undersampled, so we sampled an additional 11 plots (5 Mission, 4 Calabazas, 2 Guevavi), subjectively placed, to represent these types. This provided a dataset with at least two plots per tentative alliance type.

After each day of field work, two copies were made of completed data sheets, and safely stored. Periodically during the course of field-data collection, completed field data sheets and the annotated hard-copy prints were analyzed by the whole project team at the Arizona Remote Sensing Center. The digital (shapefile) draft formation map was extensively edited in ArcMap to incorporate all of the changes indicated on the annotated prints, and the polygon attribute database was built.

After data collection, all plot and polygon data were assembled for classification analysis. In general, data were collected at a finer thematic resolution than the alliance level, or even the association level, and a process of aggregation was needed to define desired map classes and attribute each polygon with a final map class. The aggregation condensed 29 tentative vegetation types into 19. The text descriptions of the tentative map classes were aggregated and adjusted to accommodate the range of variability in each of the 19 final map classes.

## 2.2 Results

### *2.2.1 Map classes*

Table 2.2.1 (table and figures are shown at end of this chapter) shows a summary of mapping results: map class names, number of polygons of each map class present in the study area, and area of each map class in hectares. Formation-level data are also indicated in bold font. Most of the classes are considered alliances, but where the word "alliance" is absent, the class is an NVC association or one of the three special classes identified by this project: Developed Woodland, Cropland and Pasture, and Park Facilities. Alliances marked with (P) are provisional, not yet accepted into the NVC system.

One-page text and spatial summaries of each class are presented at the end of this chapter; full descriptions of all map classes can be found in Appendix D. The completed maps of the three TUMA units are presented in Figures 2.2-1 and 2.2-2. Readers may refer to the digital maps and databases accompanying this report for more detail.

### *2.2.2 Additional areas of interest*

In a scoping meeting held prior to mapping, Tumacácori NHP personnel identified three specific areas of interest to the park: (1) the location of the invasive *Nicotiana glauca*, or tree tobacco; (2) an assessment of the amount of trash found in the park; and (3) an assessment of trespass cattle found in the park.

In the course of field work from November 2007 to April 2008, tree tobacco was found to be growing only along the riparian corridor through the Mission unit. Every specimen of tree tobacco located by the field crew was recorded as a GPS point on the RECON unit, and then eradicated. The field crew noted that the presence of tree tobacco was correlated with debris piles found in close proximity to the strand. The suggestion for future management of this plant is that periodic survey in the fall, after the monsoon, may prove necessary for preventing widespread establishment.

Trash is common at Tumacácori NHP. There are three specific types of trash: river-borne trash, trash left by migrants in camps and along trails, and incidental trash. The first type of trash is significant in every woody debris pile found along the river, where it gets concentrated. The profusion of plastic in river-borne debris is most widely evident in the stretch of river through the Mission unit. There is considerable debris at Calabazas, but it is highly localized, and there is very little at Guevavi. Exploration of Nogales Wash near the International Wastewater Treatment Plant revealed that tributary to be the most likely source of debris and trash to the river system. The relative scarcity of trash in the river and among the debris at Guevavi, upstream of Nogales Wash, supports this contention.

The second type of trash found at Tumacácori is clearly correlated with the movement of undocumented immigrants through the area. At all three park units, there are numerous sites where abandoned backpacks, bedding, clothing, empty water bottles, and empty food cans and wrappers can be found. These sites are often obvious

because of their size. They may be grouped in areas of significant cover, hidden from both aerial surveillance and from roads, but can also be in close proximity to roads, apparently where entrants have been picked up by vehicles. Although frequent throughout the three park units, such camps are often localized accumulations of trash. The third type of trash is incidental. This includes trash blowing in from adjacent urban areas, and from visitors dropping food wrappers and drink containers along trails. It also includes a few large dump piles near the southern boundary of the Mission unit. These were clearly established prior to 2002 and the subsequent expansion of the park.

Cattle were present in the main unit of the park the entire time field work was conducted. At the Mission unit, a fence along the western boundary was discovered to be damaged and cattle were common along the riparian corridor throughout the course of fieldwork. Initial discussions with park resource managers had settled on a presence-absence method to determine the extent of cattle in the park. It soon became clear, however, that the determination of presence-absence was essentially meaningless because of the ubiquity of cattle in the park. Cattle were not damaging resources per se, as there was no evidence that they were present in sufficient numbers to overgraze the park. However, there was localized damage being done in the form of a network of trails being repeatedly used by enough cattle to pulverize the soil and destroy plants, making the trails easily discernible. In marked contrast to the main unit, neither Guevavi nor Calabazas had indications of any cattle inside the park boundaries, while there was evidence of grazing right up to the boundary fence at both units.

**Table 2.2. Summary of vegetation classification and mapping results.**

| Map class | Abbreviation | # polygons | Area (ha) |
|---|---|---|---|
| **Forest** | | | |
| *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest | POPFRE Forest | 6 | 41.99 |
| *Prosopis velutina* Forest Alliance (P) | PROVEL Forest | 7 | 17.43 |
| *Celtis laevigata* var. *reticulata* Forest Alliance | CELLAE Forest | 4 | 3.73 |
| | ***Forest total*** | ***17*** | ***63.16*** |
| **Woodland** | | | |
| *Populus fremontii - Salix gooddingii* Woodland | POPFRE Woodland | 3 | 16.46 |
| *Prosopis velutina* Woodland Alliance | PROVEL Woodland | 8 | 17.56 |
| *Acacia greggii* Woodland Alliance (P) | ACAGRE Woodland | 1 | 2.08 |
| | ***Woodland total*** | ***12*** | ***36.11*** |
| **Wooded Shrubland** | | | |
| *Prosopis velutina* / [*Prosopis velutina - Acacia greggii*] Wooded Shrubland Alliance (P) | PROVEL Wooded Shrubland | ***2*** | ***7.09*** |
| **Shrubland** | | | |
| *Prosopis velutina - Acacia greggii* Shrubland | PROVEL-ACAGRE Shrubland | 3 | 8.96 |
| *Acacia constricta* Shrubland Alliance (P) | ACACON Shrubland | 1 | 6.12 |
| *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance | TAMRAM Shrubland | 1 | 1.13 |
| | ***Shrubland total*** | ***5*** | ***16.22*** |
| **Wooded Herbaceous** | | | |
| *Populus fremontii* / Mixed Annual Wooded Herbaceous Alliance (P) | POPFRE Wooded Herbaceous | 3 | 14.17 |
| *Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance (P) | PROVEL Wooded Herbaceous | 4 | 9.17 |
| | ***Wooded Herbaceous total*** | ***6*** | ***21.34*** |
| **Shrub Herbaceous** | | | |
| *Prosopis velutina / Amaranthus palmeri* Shrub Herbaceous Alliance (P) | PROVEL Shrub Herbaceous | 3 | 7.09 |
| *Hymenoclea monogyra* / [*Amaranthus palmeri - Chloris virgata*] Shrub Herbaceous Alliance (P) | HYMMON Shrub Herbaceous | 1 | 10.19 |
| | ***Shrub Herbaceous total*** | ***4*** | ***17.28*** |
| **Herbaceous** | | | |
| [*Amaranthus palmeri - Salsola kali - Chenopodium* spp.] Annual Herbaceous Alliance (P) | AMAPAL Herbaceous | ***5*** | ***3.52*** |
| **Sparsely Vegetated** | | | |
| Inland Freshwater Strand Beach Sparse Vegetation | | ***2*** | ***5.12*** |
| **Developed Woodland** | | ***1*** | ***26.46*** |
| **Cropland and Pasture** | | ***2*** | ***32.24*** |
| **Park Facilities** | | ***2*** | ***9.11*** |
| | | | |
| **Grand total** | | **58** | **237.65** |

Map classes marked with (P) are proposed, not yet accepted in the NVC system.

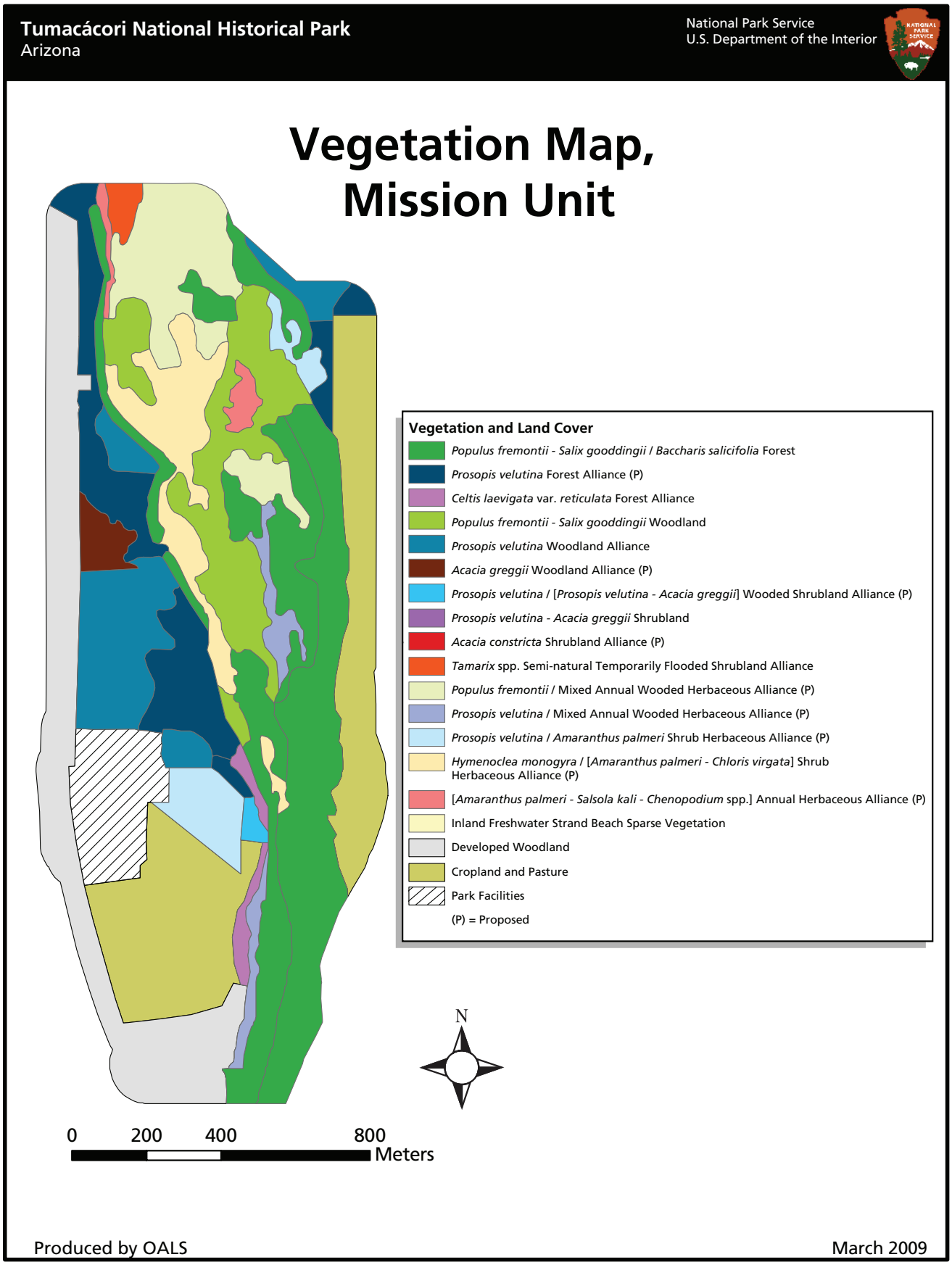


Figure 2.2-1. Vegetation map of the Mission unit of Tumacácori National Historical Park.

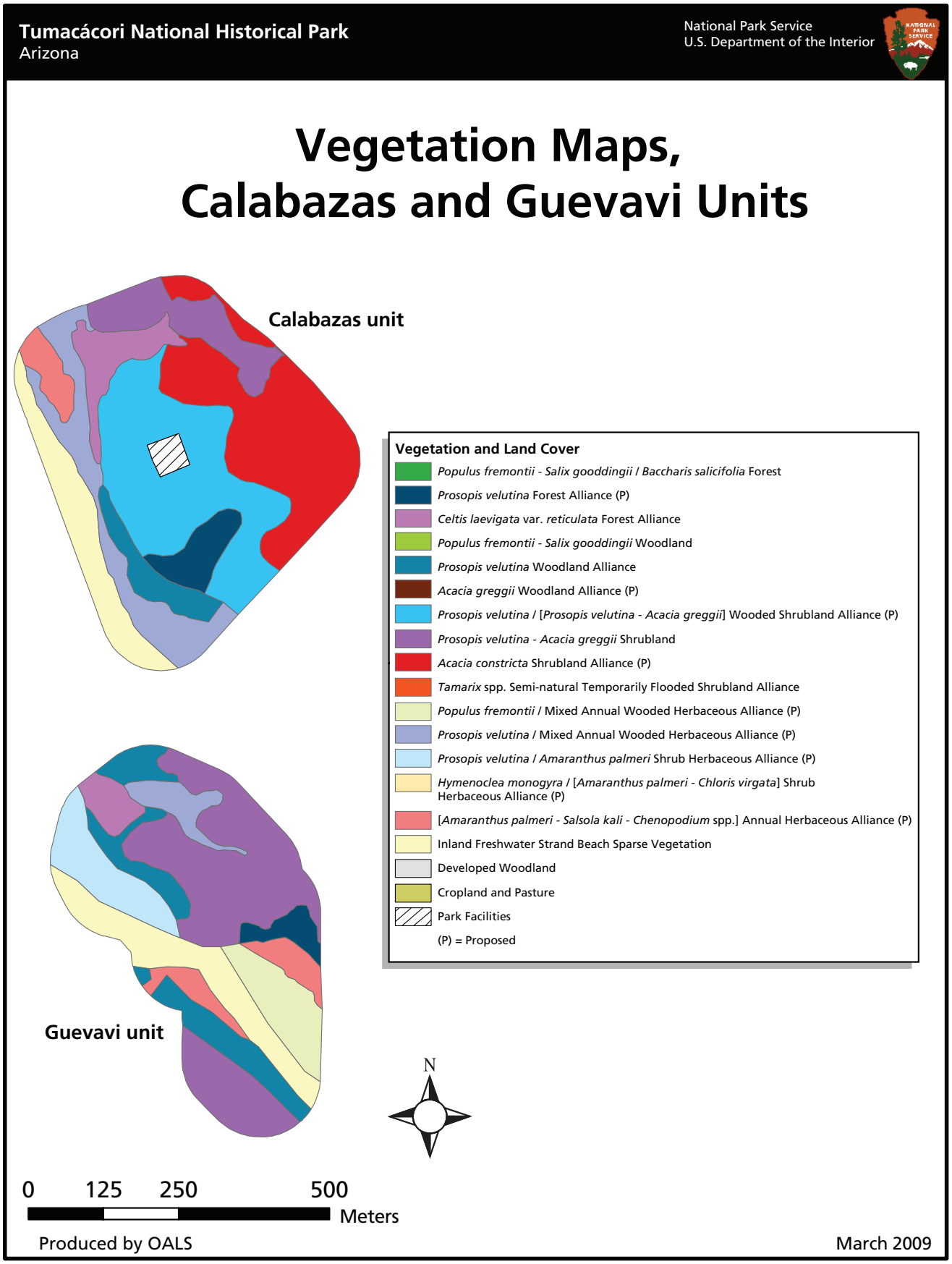


Figure 2.2-2. Vegetation map of the Calabazas and Guevavi units of Tumacácori National Historical Park.

## ***Populus fremontii - Salix gooddingii*** **Forest**
Fremont cottonwood - Goodding's willow Forest

The dominant *Populus fremontii* is diagnostic of the type, while *Salix gooddingii* is a subdominant, characteristic species found in clumps and often as a secondary canopy of 6–8 m in height. The canopy of *Populus fremontii* averages 10–20 m high throughout the type and is generally open beneath, except for areas of thick *Tamarix ramosissima* along the river channel. *Baccharis salicifolia* is widely dispersed and is not consistent in its distribution. Overall, woody species distribution in this community is a very patchy mosaic apart from the consistent *Populus fremontii* and *Salix gooddingii*, with a mixture of *Prosopis velutina*, *Celtis laevigata* var. *reticulata*, and *Sambucus nigra* ssp. *caerulea* trees and shrubs. Other associates are *Baccharis sarothroides*, *Baccharis salicifolia*, and *Anisacanthus thurberi*. The herbaceous layer is a mosaic as well, but with *Cynodon dactylon* present consistently along the river channel throughout the park, especially in areas that are flooded regularly. *Conium maculatum*, *Amaranthus palmeri*, and *Chloris virgata* are common elements of the herbaceous layer.

**Common species**
*Populus fremontii*
*Salix gooddingii*
*Baccharis salicifolia*
*Prosopis velutina*
*Celtis laevigata* var. *reticulata*
*Sambucus nigra* ssp. *caerulea*
*Anisacanthus thurberi*
*Cynodon dactylon*
*Amaranthus palmeri*

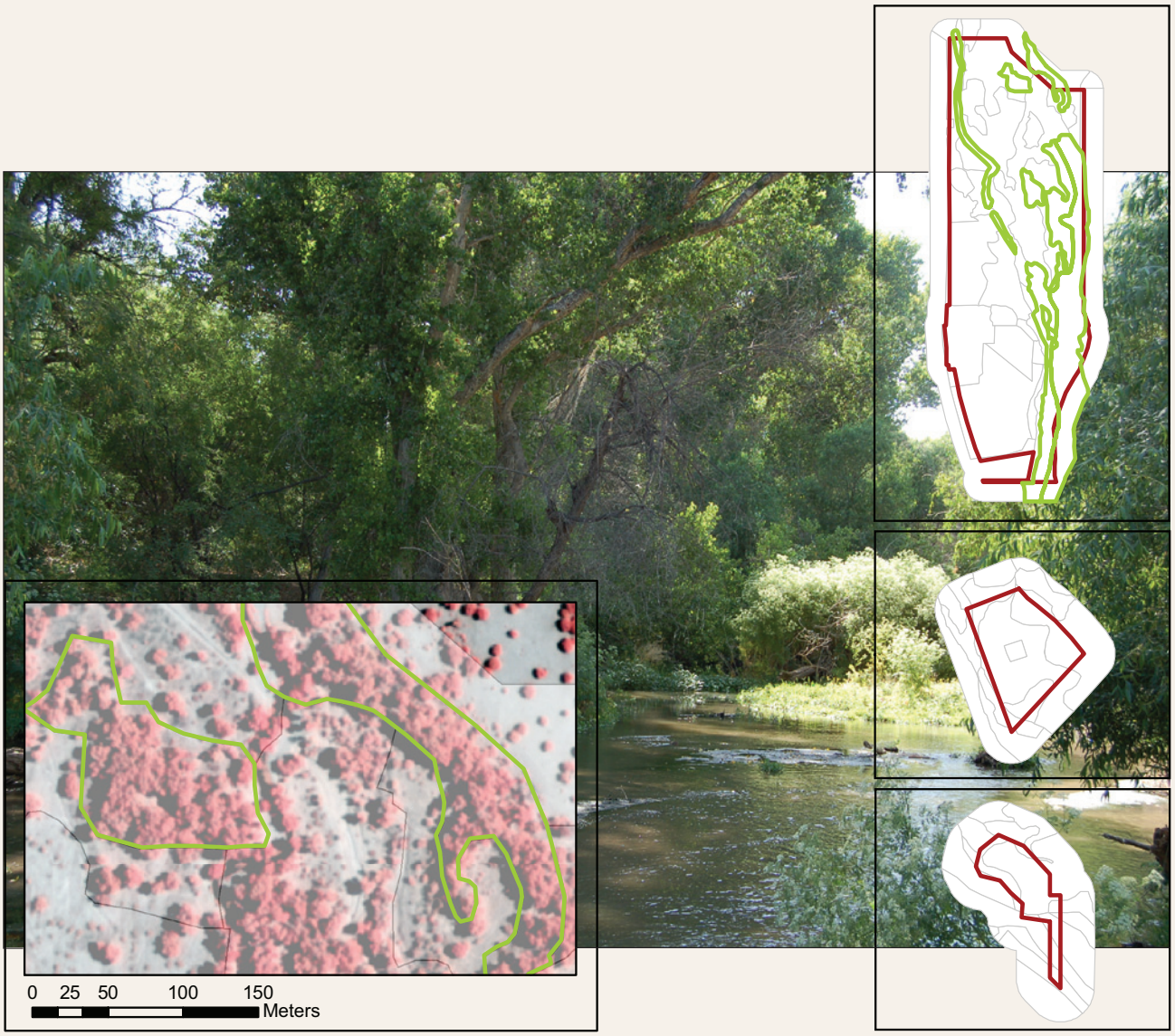


Figure 2.2-3. *Populus fremontii - Salix gooddingii* Forest.

## ***Prosopis velutina* Forest Alliance (P)**
Velvet mesquite Forest Alliance

**Common species**
*Prosopis velutina*
*Celtis laevigata* var. *reticulata*
*Sambucus nigra* ssp. *caerulea*
*Baccharis salicifolia*
*Anisacanthus thurberi*
*Cynodon dactylon*
*Amaranthus palmeri*
*Acacia greggii*
*Ziziphus obtusifolia*
*Lycium andersonii*

This alliance usually occupies alluvial terraces along the outermost edges of the Santa Cruz River floodplain, outside the band of *Populus fremontii - Salix gooddingii* forest along the channel, in areas that are relatively moist but rarely inundated, sometimes existing in narrow bands along the base of cliffs and embankments bordering the floodplain, as well as at the mouths of tributary drainages as they enter the floodplain. The alliance contains several recognizable associations with different subdominant species as well as different structure and cover, and with *Prosopis* stands of apparently different ages. Older, larger *Prosopis* stands may have *Celtis laevigata* var. *reticulata*, *Sambucus nigra* ssp. *caerulea*, and occasional *Salix gooddingii* interspersed, with a significant shrub understory of sapling trees, *Acacia greggii*, *Baccharis salicifolia*, *Ziziphus obtusifolia*, *Lycium andersonii*, and *Anisacanthus thurberi*. In addition, there may be a diverse herbaceous layer of annual and perennial grasses and forbs, and ground-to-crown vines, such as *Phaseolus ritensis*, *Clematis drummondii*, and *Ipomoea* spp.

Figure 2.2-4. *Prosopis velutina* Forest Alliance.

## *Celtis laevigata* var. *reticulata* Forest Alliance
Netleaf hackberry Forest Alliance

This alliance is found on shallow slopes that run along old agricultural fencelines. This dense forest is comprised of *Celtis laevigata* var. *reticulata* and *Prosopis velutina* that range in height from 9 to 13 m in the uppermost canopy, with considerable numbers of *Sambucus nigra* ssp. *caerulea* growing up underneath to a height of 4–8 m. The largest *Celtis* specimens are found immediately along the fencelines, which, in isolated instances, still receive runoff from actively cultivated agricultural land. This type is notable because of the multi-layered density of the entire forest, from the interlocking top canopy to the dense sub-canopy. In the sub-canopy, there is significant recruitment of *Celtis*, *Prosopis*, and *Sambucus*, and occasional *Ziziphus obtusifolia*, *Acacia greggii*, and *Lycium andersonii* shrubs. The herbaceous layer is notably sparse in areas beneath the denser canopies, where there is also considerable downed woody debris, but in openings, there is a higher diversity of both forbs and occasional grasses. In isolated sections of this type, there are *Cynodon dactylon* patches, often along foot trails.

**Common species**
*Celtis laevigata* var. *reticulata*
*Prosopis velutina*
*Sambucus nigra* ssp. *caerulea*
*Ziziphus obtusifolia*
*Acacia greggii*
*Lycium andersonii*

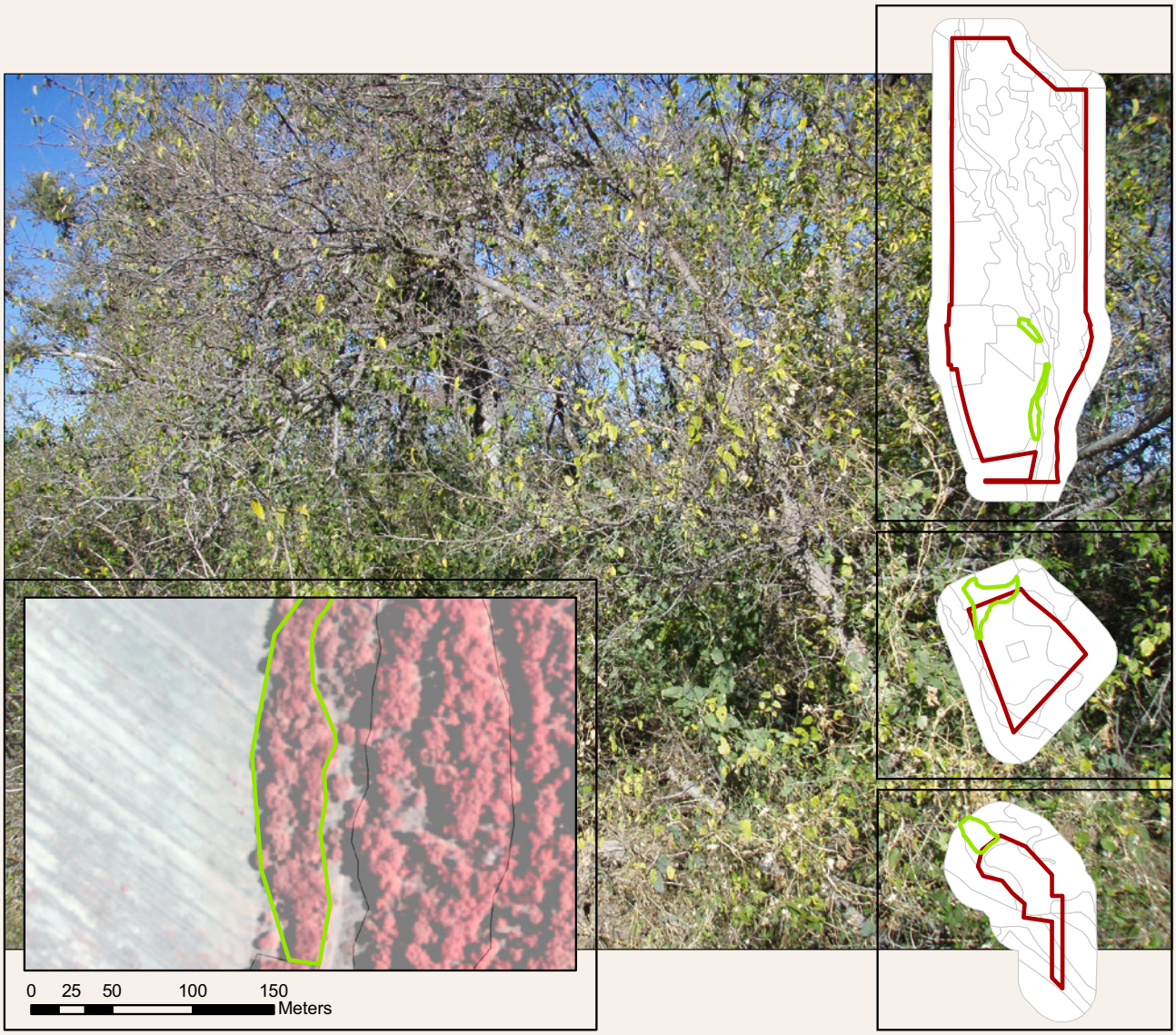


Figure 2.2-5. *Celtis laevigata* var. *reticulata* Forest Alliance.

## ***Populus fremontii - Salix gooddingii* Woodland**
Fremont cottonwood - Goodding's willow Woodland

**Common species**
*Populus fremontii*
*Salix gooddingii*
*Baccharis salicifolia*
*Hymenoclea monogyra*
*Hilaria belangeri*
*Cynodon dactylon*

This type is similar in composition to the *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest type that spans the park, but has lower plant density and cover. The type is located in the 100-year floodplain. It is dominated by *Populus fremontii*, with a patchy canopy and the inclusion of *Salix gooddingii* in specific areas. *Baccharis salicifolia* is generally the dominant shrub. The entire type is on a slightly elevated sandy-silty island, with considerable amounts of downed, woody debris piled up throughout. Beneath the *Populus fremontii* canopy, the understory is relatively open and includes more herbaceous plants, dominated by *Hilaria belangeri*, *Cynodon dactylon*, and the annual grass, *Chloris virgata*. The annual forb, *Bidens leptocephala,* is characteristically found in dense concentrations in the shade. Shrubs are often distinctly clumped and diverse, ranging from *Hymenoclea monogyra, Baccharis salicifolia,* and *Senecio flaccidus* to specimens of *Opuntia spinosior* and young *Alnus arizonica*. *Amaranthus palmeri* and *Salsola kali* are present throughout the type, but not in the same density as in neighboring wooded- or shrub-herbaceous types.

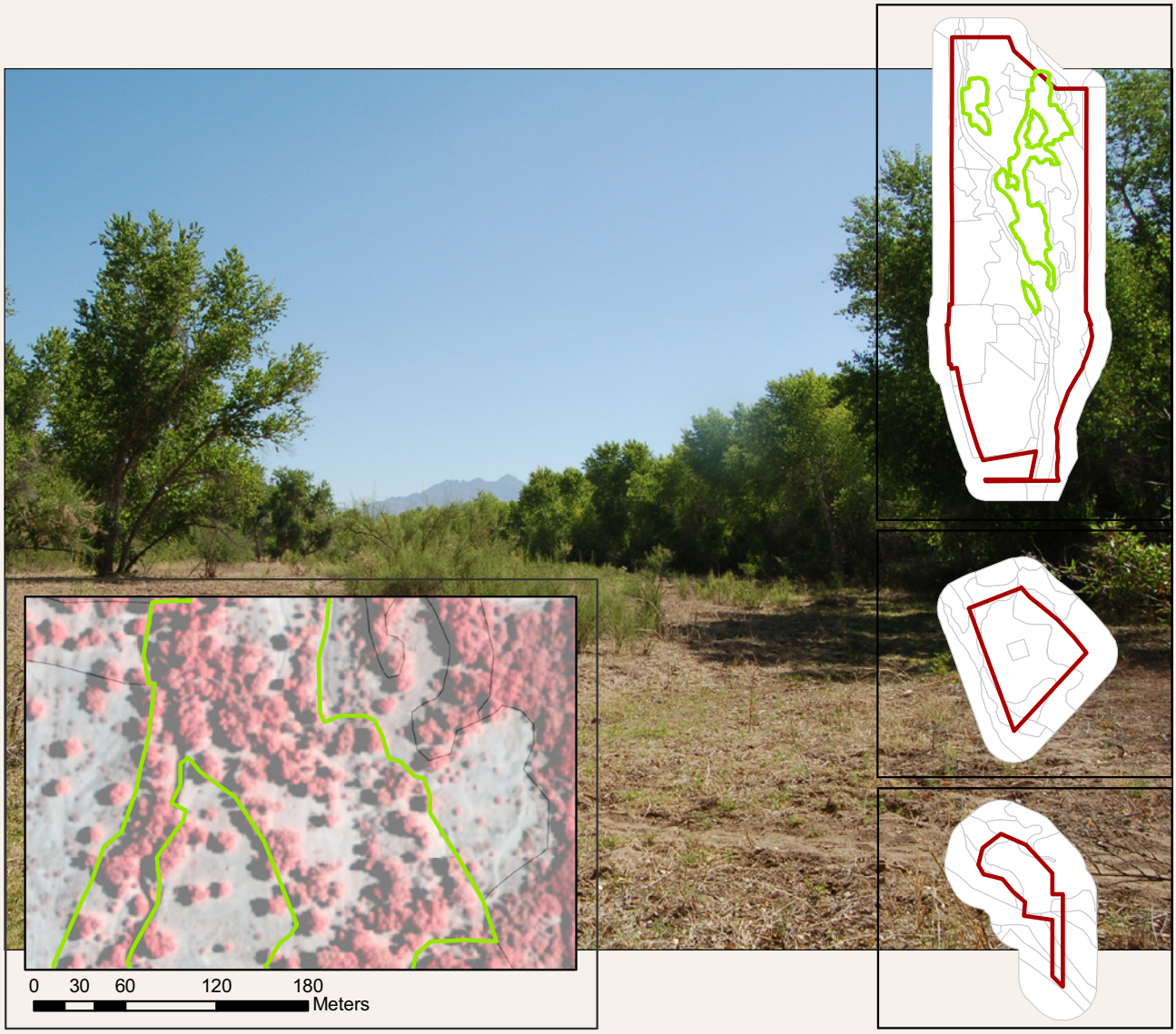


Figure 2.2-6. *Populus fremontii - Salix gooddingii* Woodland.

## *Prosopis velutina* Woodland Alliance
Velvet mesquite Woodland Alliance

This woodland alliance occurs further away from the river channel than the forest alliances, in more xeric sites. Plant canopy cover varies, with significant open or nearly-open patches possibly present. *Prosopis velutina* is usually clearly dominant in both height and canopy cover, but in places, *Acacia greggii*, commonly the second-dominant species, is a close rival. Within this type, *A. greggii* (and, to a lesser extent, *P. velutina*) can be found as a tree lifeform, a shrub lifeform, or anything in between. The *Prosopis*-dominated upper canopy averages 6–8 m in height, ranging to 10 m. *A. greggii* and occasional *Sambucus nigra* ssp. *caerulea* and *Celtis laevigata* var. *reticulata* individuals may reach this height, also. In the sub-canopy, *Prosopis* and *Acacia* still dominate (as caespitose shrubs to sapling trees), with common associates being *Celtis* and *Sambucus* saplings, *Ziziphus obtusifolia* shrubs, *Mimosa aculeaticarpa* var. *biuncifera*, *Baccharis sarothroides*, *B. salicifolia*, *Anisacanthus thurberi*, and *Hymenoclea monogyra*. The herbaceous layer is almost everywhere dominated by *Amaranthus palmeri*, occasionally by *Cynodon dactylon*.

**Common species**
*Prosopis velutina*
*Acacia greggii*
*Celtis laevigata* var. *reticulata*
*Sambucus nigra* ssp. *caerulea*
*Ziziphus obtusifolia*
*Mimosa aculeaticarpa*
*Baccharis sarothroides*
*Anisacanthus thurberi*
*Amaranthus palmeri*

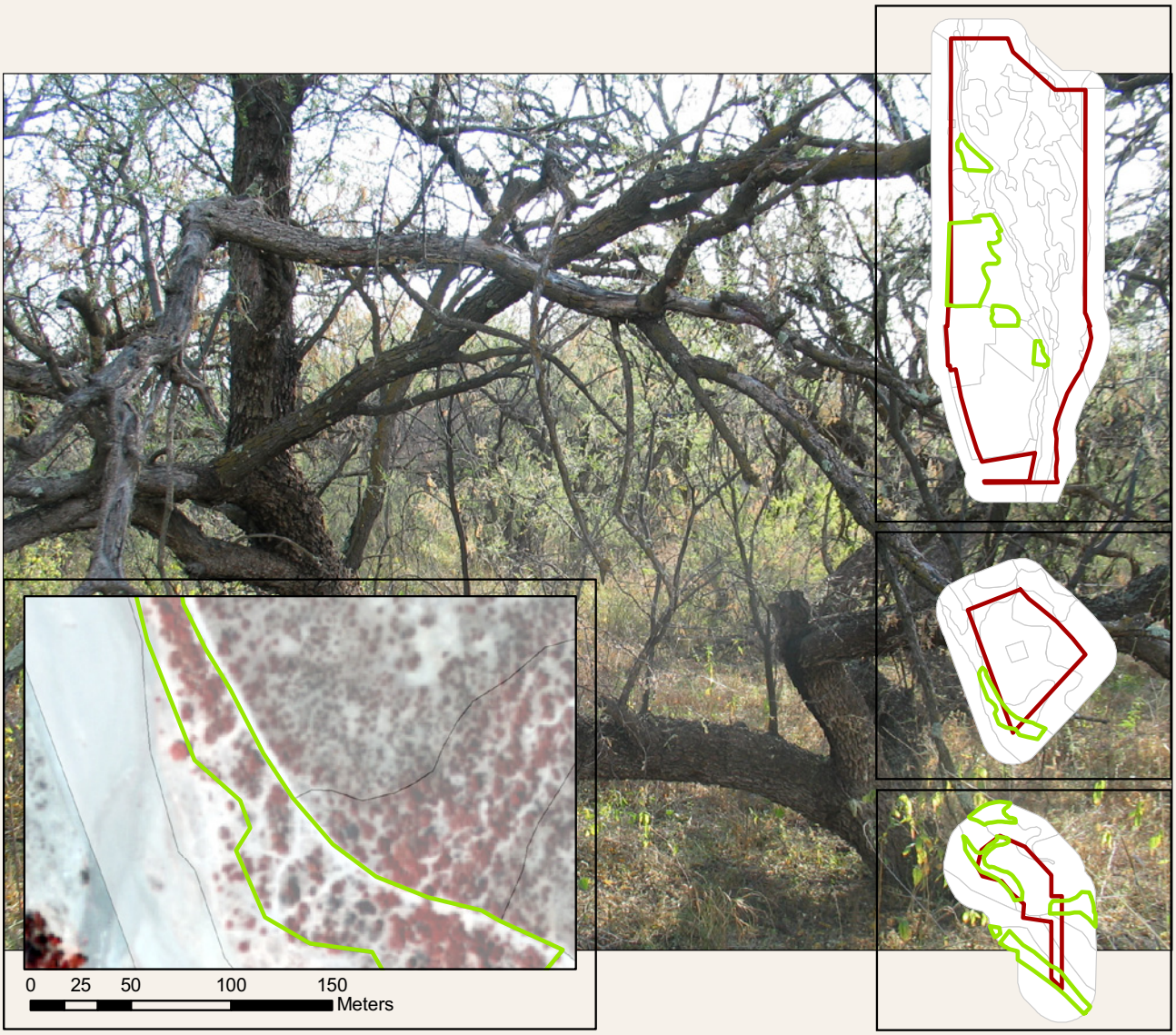


Figure 2.2-7. *Prosopis velutina* Woodland Alliance.

## *Acacia greggii* Woodland Alliance (P)
Catclaw acacia Woodland Alliance

**Common species**
*Acacia greggii*
*Prosopis velutina*
*Ziziphus obtusifolia*
*Condalia warnockii*
*Baccharis sarothroides*
*Lycium andersonii*
*Hymenoclea monogyra*
*Anisacanthus thurberi*
*Amaranthus palmeri*

This type is dominated by *Acacia greggii* and *Prosopis velutina* trees 6–8 m tall, and shorter *Acacia greggii* and *Ziziphus obtusifolia* shrubs. Associated shrub species, such as *Condalia warnockii*, *Baccharis sarothroides*, *Lycium andersonii*, *Hymenoclea monogyra*, and *Anisacanthus thurberi*, are scattered across the type. Most of the trees and shrubs in this alliance have such thick, dense canopies that herbaceous plants are largely confined to the interspaces between overstory canopies. The herbaceous layer is dominated by the annual forbs, *Amaranthus palmeri* and *Bidens leptocephala*, with a variety of other forbs and grasses interspersed widely.

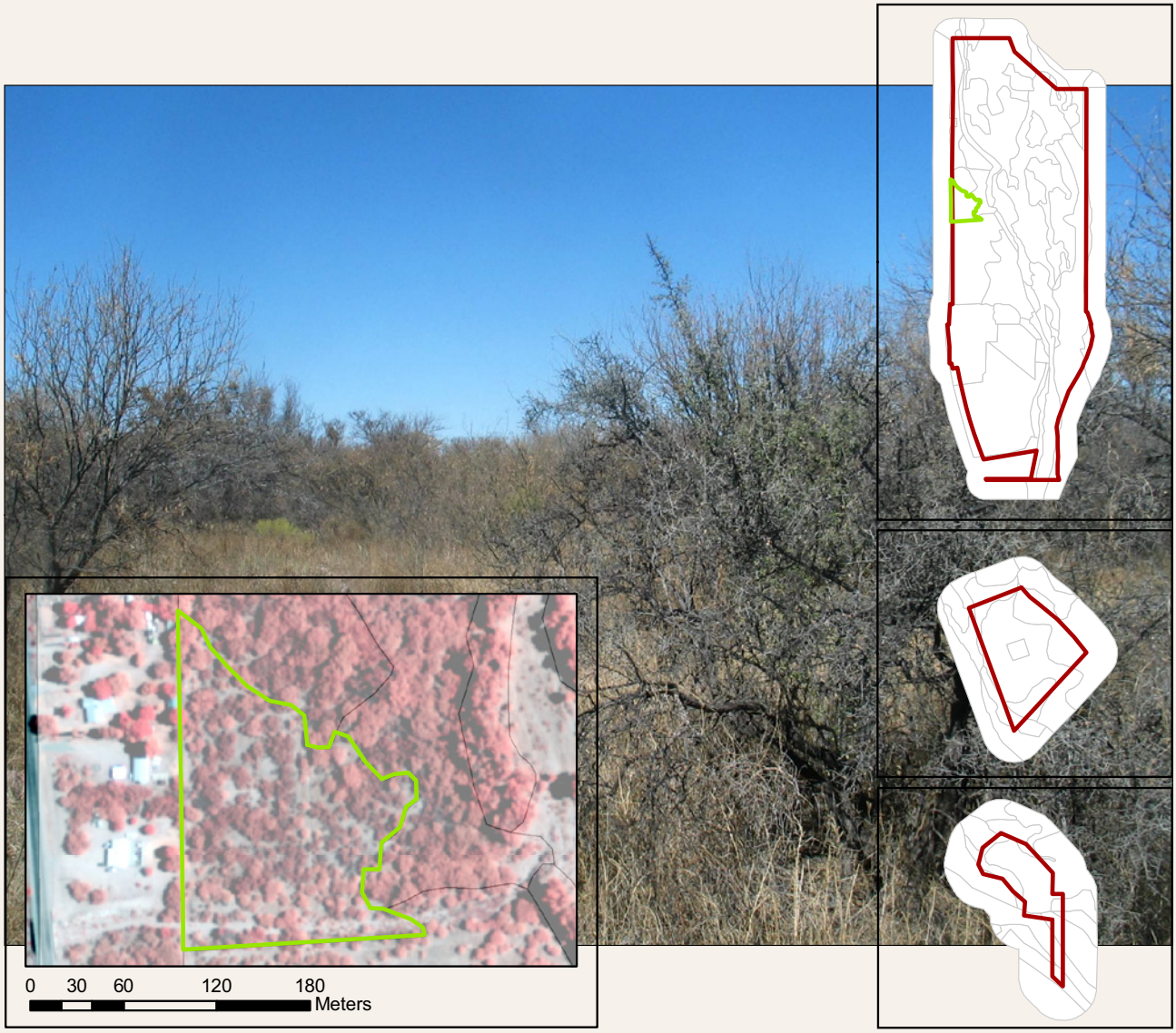


Figure 2.2-8. *Acacia greggii* Woodland Alliance.

## ***Prosopis velutina* / [*Prosopis velutina - Acacia greggii*] Wooded Shrubland Alliance (P)**

Velvet mesquite / [Velvet mesquite - Catclaw acacia] Wooded Shrubland Alliance

Although primarily found on gently sloped upland, this type also extends down steeper, relatively xeric slopes. It is characterized by an open canopy of *Prosopis velutina* shrubs, mostly 2–4 m tall but with many larger, tree-lifeform individuals up to 7.5 m. These *Prosopis* and the other trees present make up >10% cover. *Acacia greggii* is common in the shrub layer; it is usually, but not always, less abundant than *Prosopis*, and also averages 2–4 m tall. Density of the shrub layer is variable. In more xeric areas, *Baccharis sarothroides* may have significant cover and *A. greggii* may be absent or nearly so. *Acacia constricta* and *Mimosa aculeaticarpa* var. *biuncifera* are generally present. A few individuals of *Juniperus coahuilensis*, *Condalia warnockii*, and *Opuntia spinosior* may be present on hilltop flats and adjacent upper slopes, while *Ziziphus obtusifolia*, *Celtis laevigata* var. *reticulata*, and *Anisacanthus thurberi* may be found on more mesic lower slopes. *Amaranthus palmeri* and *Bidens leptocephala* are the only abundant forbs in an otherwise grass-dominated (*Bouteloua curtipendula*, *Sporobolus wrightii*, *Chloris virgata*, *Muhlenbergia porteri*) herbaceous layer.

**Common species**
*Prosopis velutina*
*Acacia greggii*
*Baccharis sarothroides*
*Acacia constricta*
*Mimosa aculeaticarpa*
*Ziziphus obtusifolia*
*Celtis laevigata* var. *reticulata*
*Anisacanthus thurberi*
*Amaranthus palmeri*

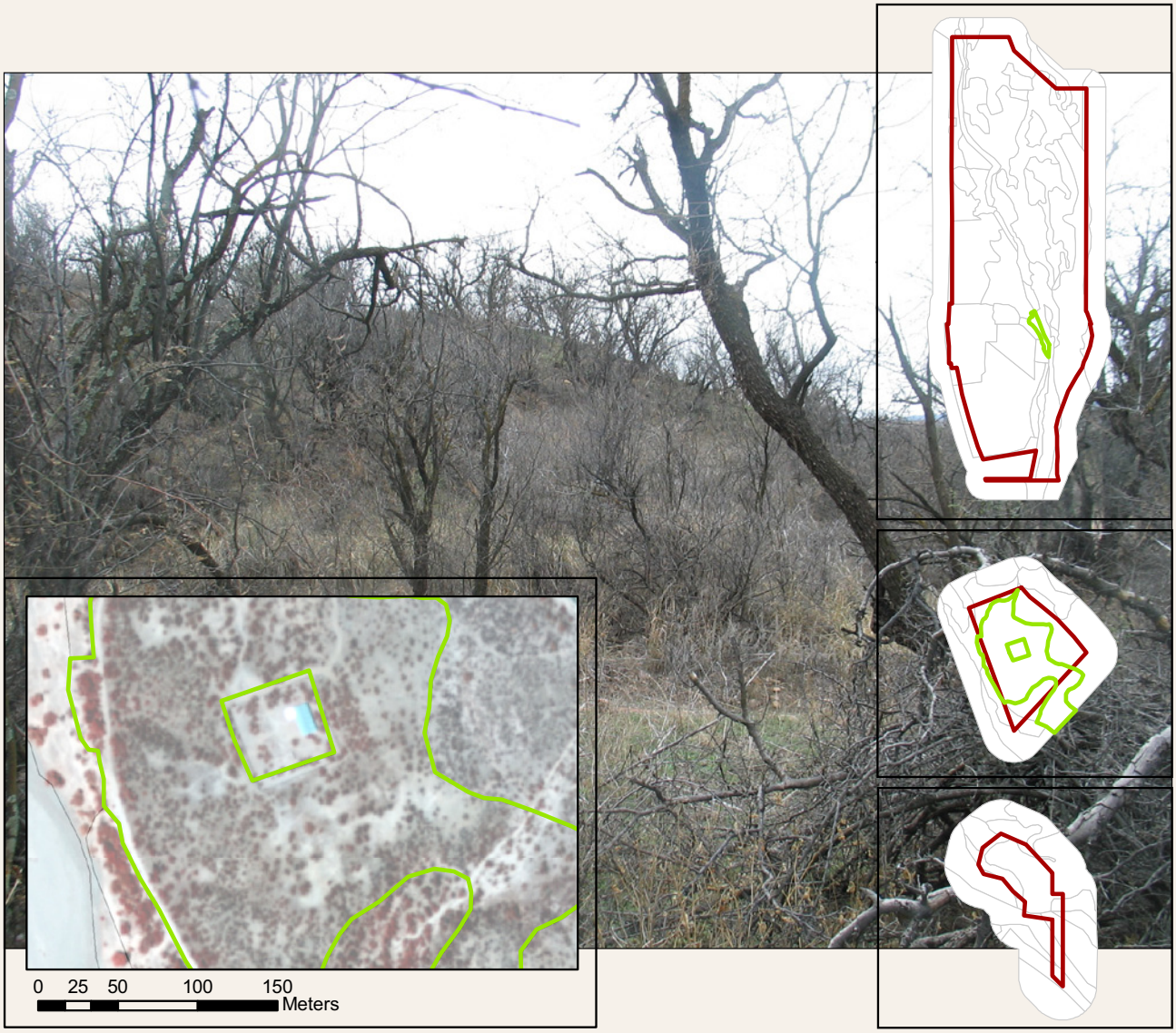


Figure 2.2-9. *Prosopis velutina* / [*Prosopis velutina - Acacia greggii*] Wooded Shrubland Alliance.

## ***Prosopis velutina - Acacia greggii*** **Shrubland**
Velvet mesquite - Catclaw acacia Shrubland

**Common species**
*Prosopis velutina*
*Acacia greggii*
*Acacia constricta*
*Opuntia spinosior*
*O. englemanii*
*Baccharis sarothroides*
*Ferocactus wislizenii*
*Amaranthus palmeri*
*Bouteloua aristidoides*

This alliance is dominated by moderate-sized *Prosopis velutina* shrubs 1–3.5 m tall, with *Acacia greggii* shrubs common on the hillslopes. In areas with greater than 5% slope, the species commingle. The slopes have a higher percentage of *Bouteloua curtipendula* in the herbaceous layer compared with the flats of the mesa-tops, where there is far more of the annual forb, *Amaranthus palmeri*, and *Bouteloua aristidoides*, in addition to other mixed *Bouteloua* spp. (likely including *B. rothrockii* and *B. barbata*) that were not reliably identifiable due to seasonal dormancy. Other woody species associated with this type include *Acacia constricta*, *Opuntia spinosior*, *O. engelmannii*, *Baccharis sarothroides*, and *Ferocactus wislizenii*, although there are rarely more than a few individuals of these species present. At Guevavi, this type includes the adobe ruins, a historically disturbed area. This may account for distributional differences among some species in the areas immediately adjacent to the ruins, including the presence of *Sporobolus wrightii*. *Eragrostis lehmanniana* and *Aristida* spp. may also be significant in the understory.

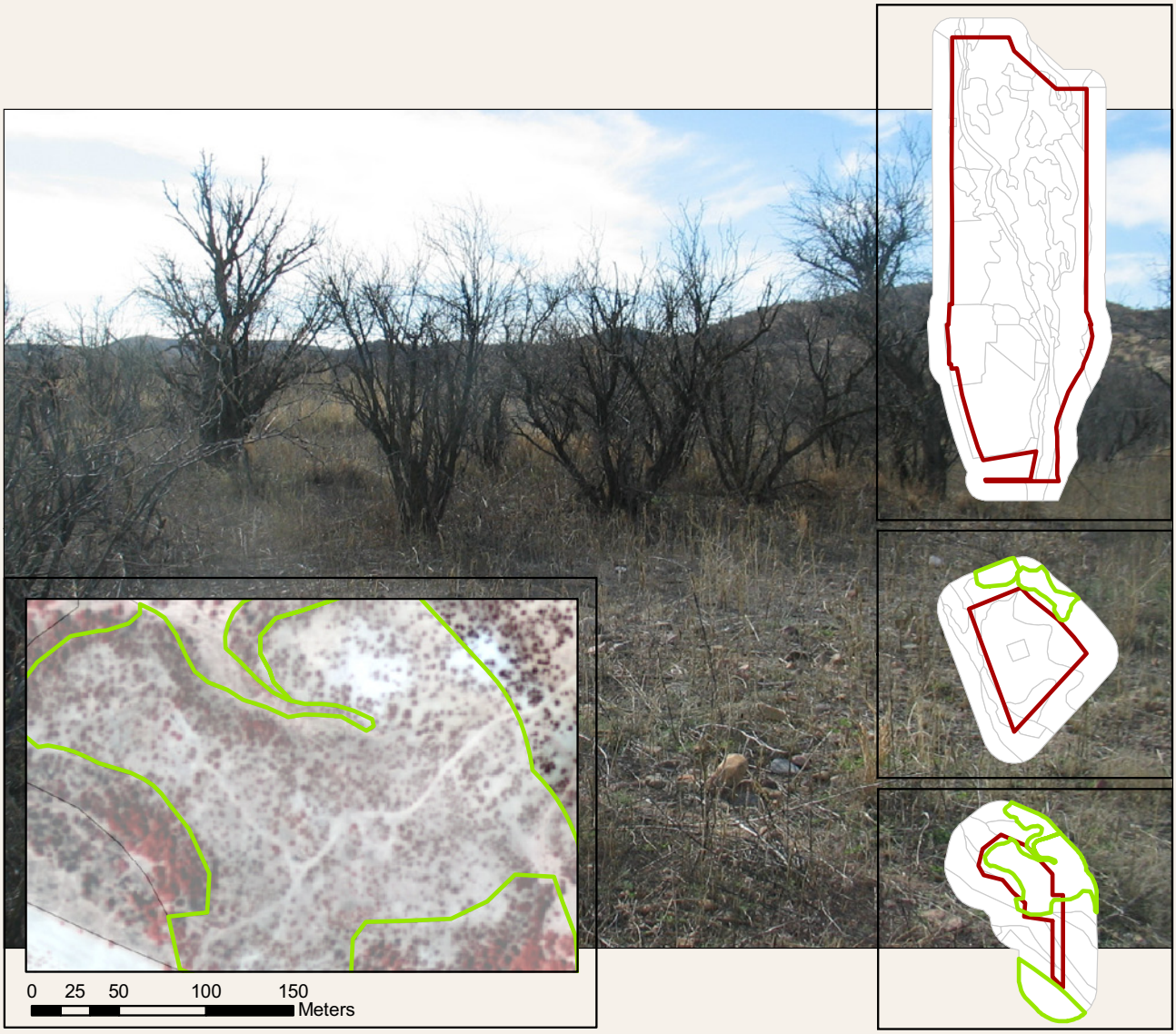


Figure 2.2-10. *Prosopis velutina - Acacia greggii* Shrubland.

## *Acacia constricta* Shrubland Alliance (P)
Whitethorn acacia Shrubland Alliance

This association is found on steeper, well-drained slopes that have thin, gravelly soils, often with exposed bedrock. *Acacia constricta*, *Acacia greggii*, and *Prosopis velutina* shrubs usually average 1.5–2.5 m tall and form dense thickets. Some *P. velutina* may attain tree size, especially where slopes are not as steep. *Acacia constricta* is dominant overall, but in patches, either *A. greggii* or *Prosopis velutina* may be the dominant species. The understory is notable for its diversity, usually composed of a mixture of native bunchgrasses, such as *Bouteloua curtipendula*, *Muhlenbergia porteri*, *Aristida purpurea*, and *Setaria* spp. Several other species, rare in the Calabazas site, are found in limited numbers in this type, including *Ceanothus greggii*, *Mimosa aculeaticarpa* var. *biuncifera*, *Ferocactus wislizenii*, *Yucca elata*, *Echinocereus* spp., *and Opuntia spinosior*. This type maintains a high percentage of native species and relatively low levels of human and livestock disturbance due to its rugged topographic position, thorny shrub cover, and protection within NPS fencelines.

**Common species**
*Acacia constricta*
*Acacia greggii*
*Prosopis velutina*
*Bouteloua curtipendula*
*Muhlenbergia porteri*
*Aristida purpurea*
*Setaria* spp.

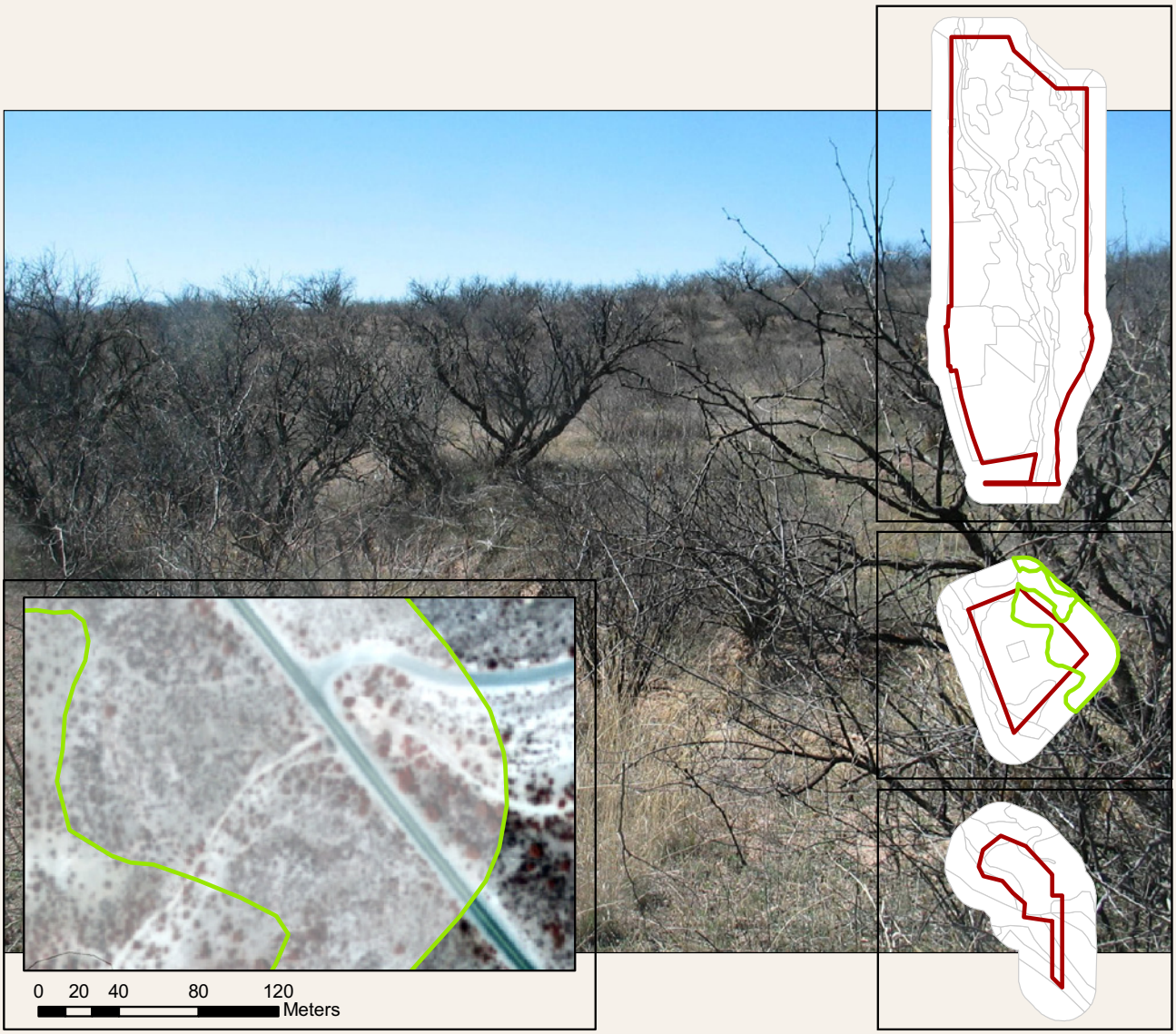


Figure 2.2-11. *Acacia constricta* Shrubland Alliance.

## *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance

Saltcedar Shrubland Alliance

**Common species**
*Tamarix ramosissima*
*Populus fremontii*

This association is found along the northern boundary of the Mission unit, with the bulk of the association found in the buffer outside the park boundary. The topography of the area is notable because of two elevated sand bars with north-south channels running between them. On top of the sand bars are dense stands of 2–3-m tall tamarisk shrubs (*Tamarix ramosissima*), with annual forbs scattered in openings where there is less litter cover. Along the margins of the dense tamarisk patches are found occasional *Populus fremontii*, infrequent *Baccharis sarothroides* recruits, and rare *Cynodon dactylon* and *Sporobolus cryptandrus* patches. In the near future, this association is expected to radically change inside the park boundary because of a tamarisk-eradication project being conducted by NPS at the time of mapping. Without the tamarisk, the portion inside the park boundary would become herbaceous-dominated.

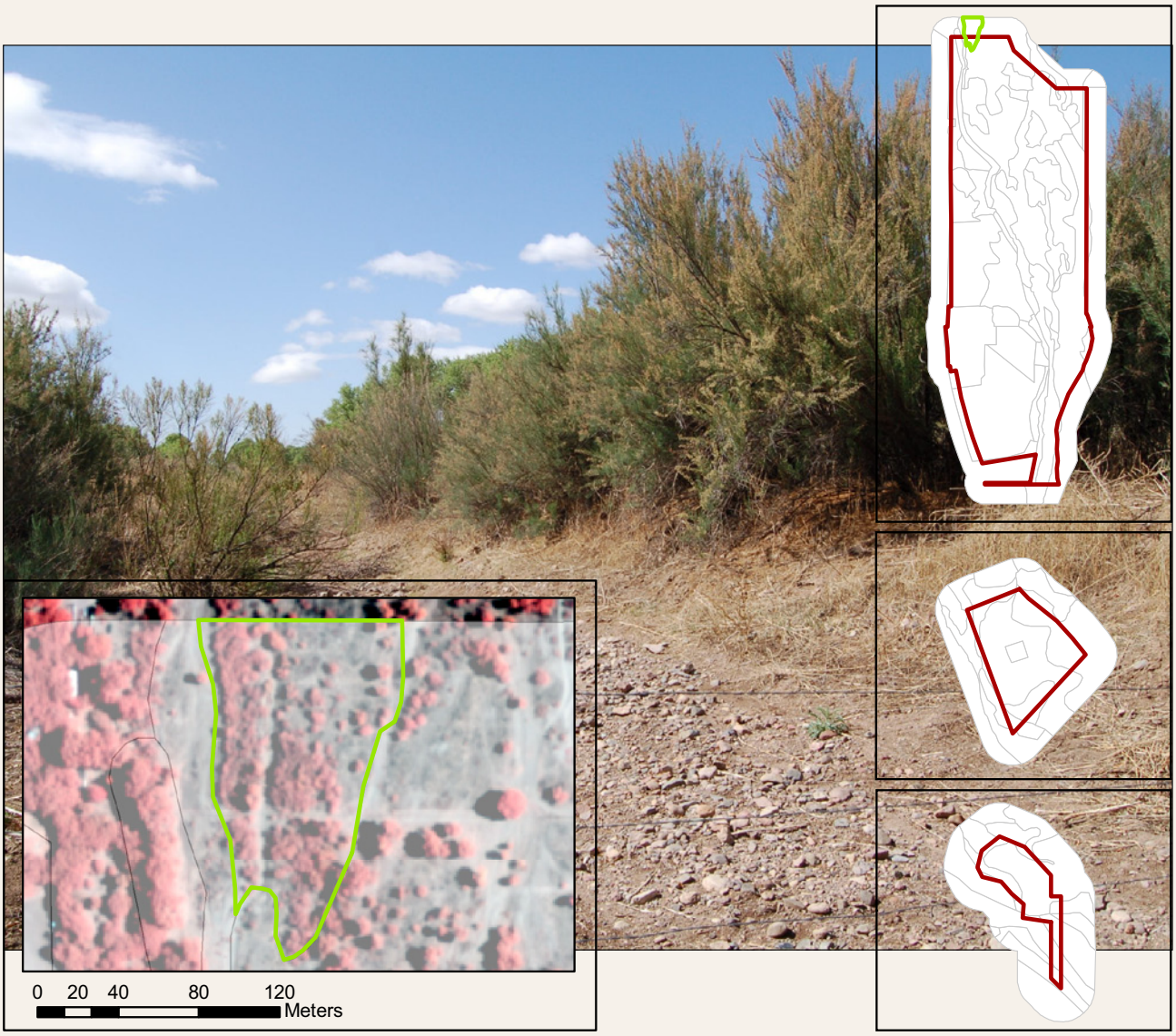


Figure 2.2-12. *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance.

## *Populus fremontii* / Mixed Annual Wooded Herbaceous Alliance (P)

Fremont cottonwood / Mixed Annual Wooded Herbaceous Alliance

*Populus fremontii* is found in small-to-large patches throughout the type, often with *Salix gooddingii* and/or *Prosopis velutina*, and clumps of *Tamarix ramosissima* in some places. Large *Populus fremontii* may reach 16–18 m, *Salix* somewhat less, and *Prosopis* usually 3–6 m. A few *Sambucus nigra* ssp. *caerulea* may be found in this type. Shrubs are generally sparse, and include *Hymenoclea monogyra*, *Prosopis velutina*, *Baccharis salicifolia*, *Acacia greggii*, *Baccharis sarothroides*, *and Senecio flaccidus*. The herbaceous layer is dominated by *Amaranthus palmeri*, with significant patches of *Aristida purpurea* widely dispersed throughout the type. Annual grasses are also commonly present, including *Chloris virgata* and *Bouteloua aristidoides*, frequently in conjunction with sandier, sloped areas, dictating slightly more xeric condtions. Associated herbaceous species include *Boerhavia coccinea*, *Boerhavia spicata*, *Cynodon dactylon*, *Ipomoea* spp., *Tithonia thurberi*, *Sporobolus cryptandrus*, *Bouteloua curtipendula*, and *Eragrostis lehmanniana*.

**Common species**
*Populus fremontii*
*Salix gooddingii*
*Prosopis velutina*
*Amaranthus palmeri*
*Aristida purpurea*
*Chloris virgata*
*Bouteloua aristidoides*

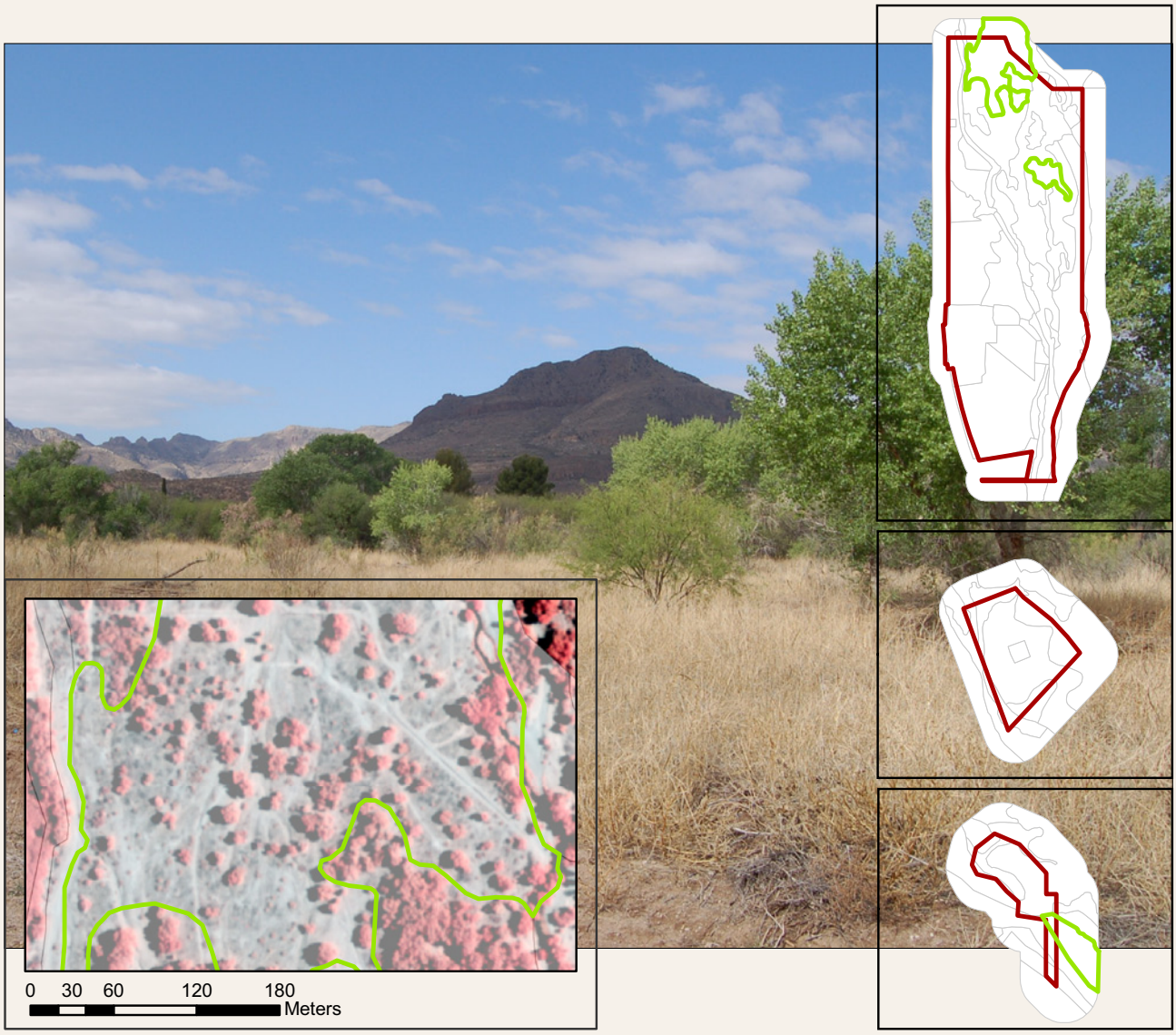


Figure 2.2-13. *Populus fremontii* / Mixed Annual Wooded Herbaceous Alliance.

## *Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance (P)

Velvet mesquite / Mixed Annual Wooded Herbaceous Alliance

**Common species**
*Prosopis velutina*
*Sambucus nigra* ssp. *caerulea*
*Celtis laevigata* var. *reticulata*
*Acacia greggii*
*Populus fremontii*
*Amaranthus palmeri*
*Sporobolus wrightii*

Where a single herbaceous species dominates, it is usually *Amaranthus palmeri*, though there are areas dominated by *Cynodon dactylon* (found in most of the open areas of the type) or *Sporobolus wrightii*. There are significant areas without a single dominant species, with the herbaceous layer comprising a diverse mosaic of annuals and perennials, including some combination of the aforementioned species and *Aristida purpurea, Chloris virgata*, *Hilaria belangeri, Sporobolus cryptandrus, Sporobolus contractus, Bothriochloa barbinodis*, *Aristida ternipes, Chloris virgata*, and the forbs, *Amaranthus palmeri, Salsola kali, Chenopodium* spp., and *Helianthus annuus*. The overstory usually has 5–25% cover of *Prosopis velutina* trees, sometimes clumped, usually interspersed with *Sambucus nigra* ssp. *caerulea*, *Celtis laevigata* var. *reticulata*, *Acacia greggii*, and *Populus fremontii*. *P. velutina* and *A. greggii* can appear as both trees and shrubs. Other associated shrubs include *Ziziphus obtusifolia* and *Hymenoclea monogyra*. Average height of the overstory is commonly 3–6 m; some *Populus fremontii* specimens can reach 14 m.

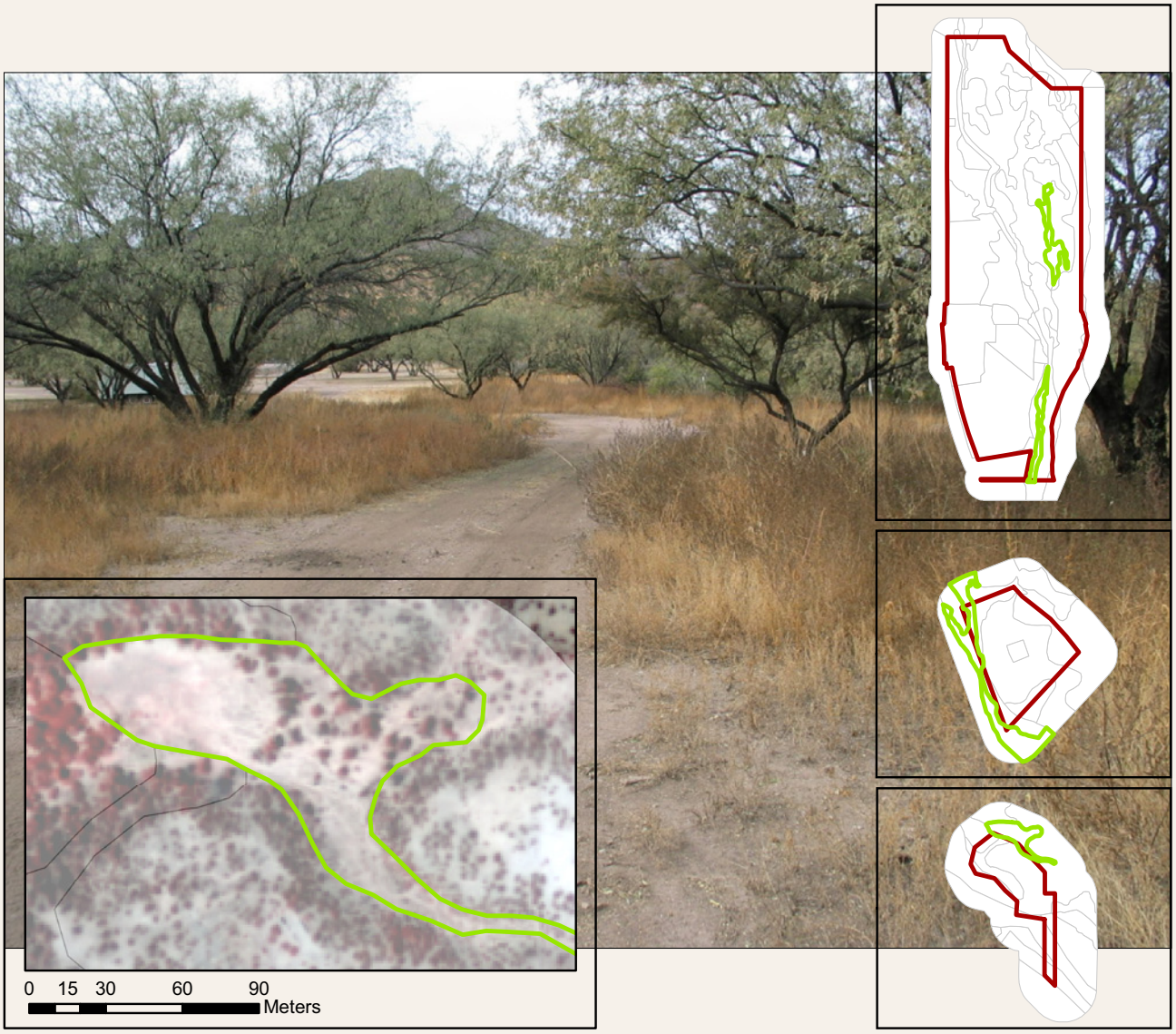


Figure 2.2-14. *Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance.

## ***Prosopis velutina / Amaranthus palmeri*** **Shrub Herbaceous Alliance (P)**
Velvet mesquite / Palmer amaranth Shrub Herbaceous Alliance

Overall, this type is dominated by *Amaranthus palmeri*, with other tall annuals and *Sporobolus wrightii* interspersed throughout. In addition to the *Prosopis velutina* shrubs, there may be a number of trees in this type, including *P. velutina, Celtis laevigata* var. *reticulata*, *Sambucus nigra* ssp. *caerulea*, and *Populus fremontii*, but they are often solitary individuals, perhaps with seedlings of these species interspersed between. In areas not mowed or cultivated in the last 3–4 years, the dominance of *A. palmeri* is apparently giving way to a mixture of annual and perennial grasses: *Cynodon dactylon, Bouteloua aristidoides, Sporobolus cryptandrus, Bouteloua curtipendula, Hilaria belangeri, Aristida purpurea,* and *Aristida ternipes*. Scattered throughout are numerous small *P. velutina* and *Baccharis sarothroides* shrubs, ranging from 0.5–1.5 m tall. The absence of disturbance and grazing has apparently allowed the widespread growth of woody species, still small and shrubby. *A. palmeri*, present throughout the area, constituted a plurality of roughly 30% of the total cover.

**Common species**
*Prosopis velutina*
*Baccharis sarothroides*
*Amaranthus palmeri*
*Sporobolus wrightii*
*Celtis laevigata* var. *reticulata*
*Sambucus nigra* ssp. *caerulea*
*Populus fremontii*

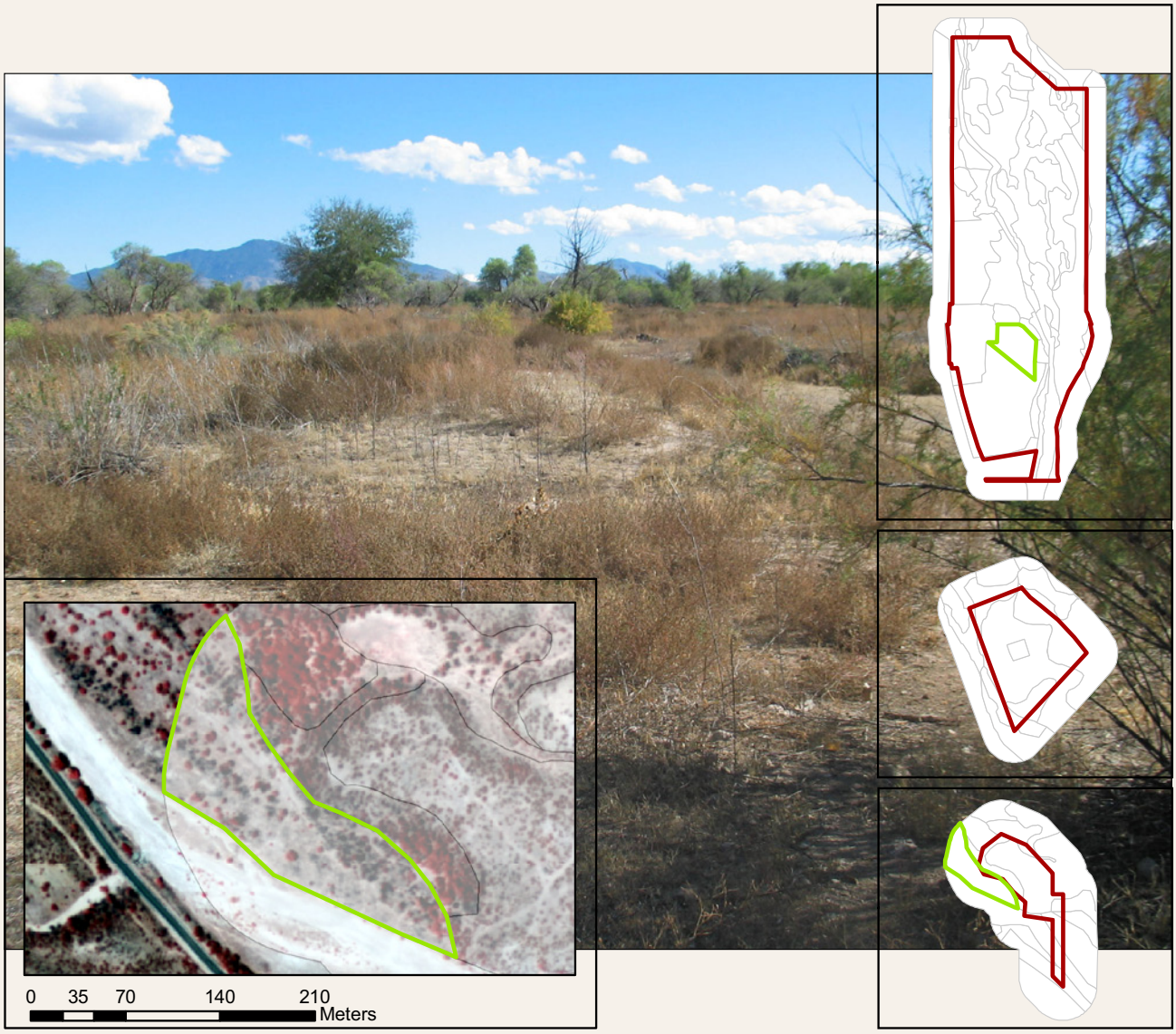


Figure 2.2-15. *Prosopis velutina / Amaranthus palmeri* Shrub Herbaceous Alliance.

## *Hymenoclea monogyra* / [*Amaranthus palmeri - Chloris virgata*] Shrub Herbaceous Alliance (P)

Singlewhorl burrobush / [Palmer amaranth - Feather windmill grass] Shrub Herbaceous Alliance

**Common species**
*Hymenoclea monogyra*
*Amaranthus palmeri*
*Chloris virgata*
*Baccharis salicifolia*
*Baccharis sarothroides*
*Prosopis velutina*
*Senecio flaccidus*
*Populus fremontii*
*Sambucus nigra* ssp. *caerulea*

This alliance is generally found in the 100-year floodplain adjacent to the west side of the Santa Cruz River at the Mission unit. It consists of sandy-to-silty soils with a diversity of annual and perennial herbaceous species, though these are widely dispersed across a large area and do not account for much cover. The herbaceous layer is dominated by *Amaranthus palmeri* and *Chloris virgata*. *Hymenoclea monogyra* is the dominant shrub throughout the type, appearing to have grown up within the last five years, as indicated by repeat photographs from an earlier inventory. *Hymenoclea monogyra* shrubs range from 2 to 4 m in height, and are generally clumped together, leaving large areas more open between them. Associated shrubs interspersed throughout the type include *Baccharis salicifolia, Baccharis sarothroides, Prosopis velutina,* and *Senecio flaccidus*. A few trees may be present, commonly *Populus fremontii* or *Sambucus nigra* ssp. *caerulea*, but these make up less than 10% cover.

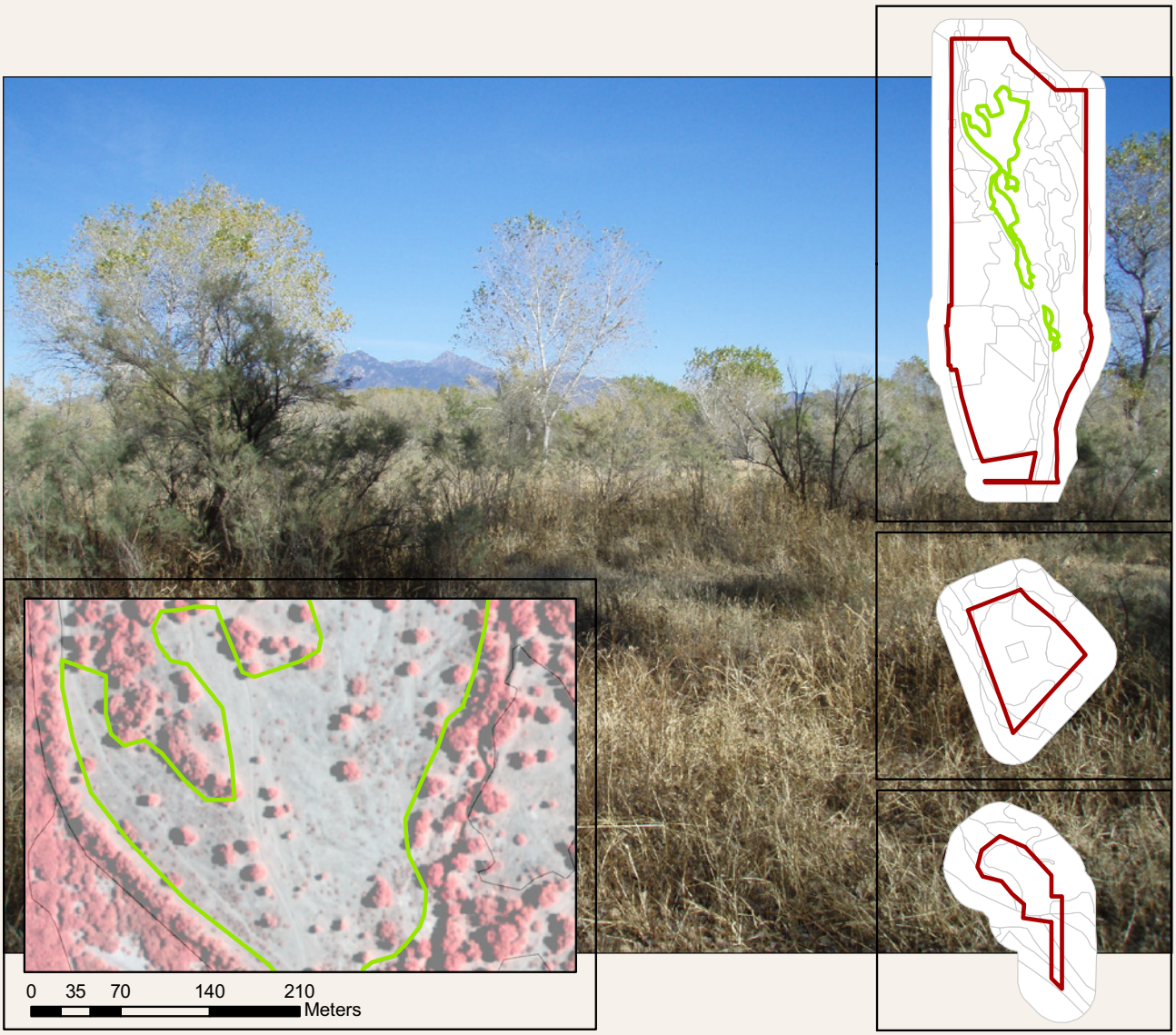


Figure 2.2-16. *Hymenoclea monogyra* / [*Amaranthus palmeri - Chloris virgata*] Shrub Herbaceous Alliance.

## [*Amaranthus palmeri - Salsola kali - Chenopodium* spp.] Herbaceous Alliance (P)

[Palmer amaranth - Tumbleweed - Goosefoot spp.] Herbaceous Alliance

This annual forb-dominated community is found on sandy soils adjacent to the Santa Cruz River. Use of brackets in the type name indicates that these species should be considered co-dominant overall, and their relative abundance may differ spatially within the type. There are areas of fairly homogeneous distribution of both *A. palmeri* and *S. kali* as co-dominants (with or without some *Chenopodium* spp.), and areas where one of the three species is clearly the single dominant, with more or less of the others possibly present. Local abundance and composition of this type may vary significantly from year to year. Grasses, both annual and perennial, grow sparsely in patches in this community: *Chloris virgata*, *Bouteloua aristidoides*, *Sporobolus cryptandrus*, *Sporobolus wrightii*, *Aristida ternipes* and *Hilaria belangeri*. The forb, *Bidens leptocephala,* may be prominent in patches. Along the edges of the herbaceous type, sparse low shrubs are often found, including *Baccharis salicifolia, Hymenoclea monogyra*, and *Prosopis velutina*, and occasionally trees, such as *Populus fremontii, Sambucus nigra* ssp. *caerulea,* or *Salix gooddingii*.

**Common species**
*Amaranthus palmeri*
*Salsola kali*
*Chenopodium* spp.
*Chloris virgata*
*Bouteloua aristidoides*
*Sporobolus cryptandrus*
*Bidens leptocephala*

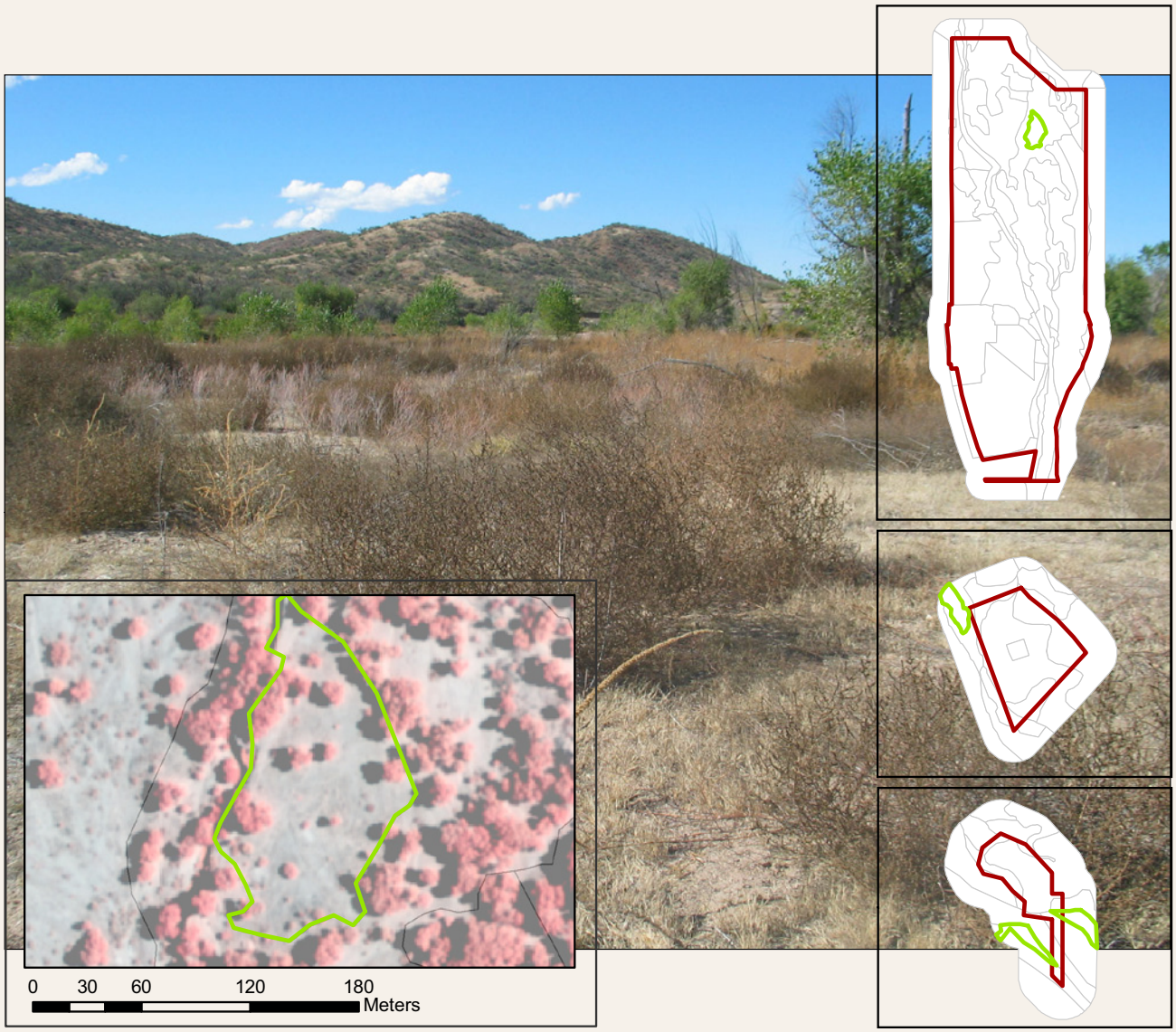


Figure 2.2-17. [*Amaranthus palmeri - Salsola kali - Chenopodium* spp.] Herbaceous Alliance.

## Inland Freshwater Strand Beach Sparse Vegetation

**Common species**
*Xanthium strumarium*
annual forbs
*Cynodon dactylon*
*Populus fremontii*
*Salix gooddingii*

This type is composed of mostly-bare sand in the Santa Cruz River's active channel. Some forbs may be present in areas colonized since the last flood event. Seedlings or saplings of *Populus fremontii* and *Salix gooddingii* may also be present. The position of strand beaches tends to shift with flood events in the fluvial system.

Figure 2.2-18. Inland Freshwater Strand Beach Sparse Vegetation.

## Developed Woodland

This type, in the Mission-unit area, comprises homes, commercial buildings, and roads built in former mesquite forest or woodland, with minimal-to-extensive clearing of trees. Occurs primarily outside park boundary, in study-area buffer.

**Common species**
*Prosopis velutina*
*Acacia greggii*
*Celtis laevigata* var. *reticulata*
*Tamarix ramosissima*
*Ziziphus obtusifolia*
*Mimosa aculeaticarpa*
*Baccharis sarothroides*
*Anisacanthus thurberi*
*Amaranthus palmeri*

Figure 2.2-19. Developed Woodland.

## Cropland and Pasture

**Common species**
*Cynodon dactylon*
*Sorghum halepense*
*Amaranthus palmeri*
*Salsola kali*
*Ambrosia* spp.

Anderson Level 2 class, applied to active irrigated pasture (in buffer), and historic cultivated area adjacent to the Mission unit.

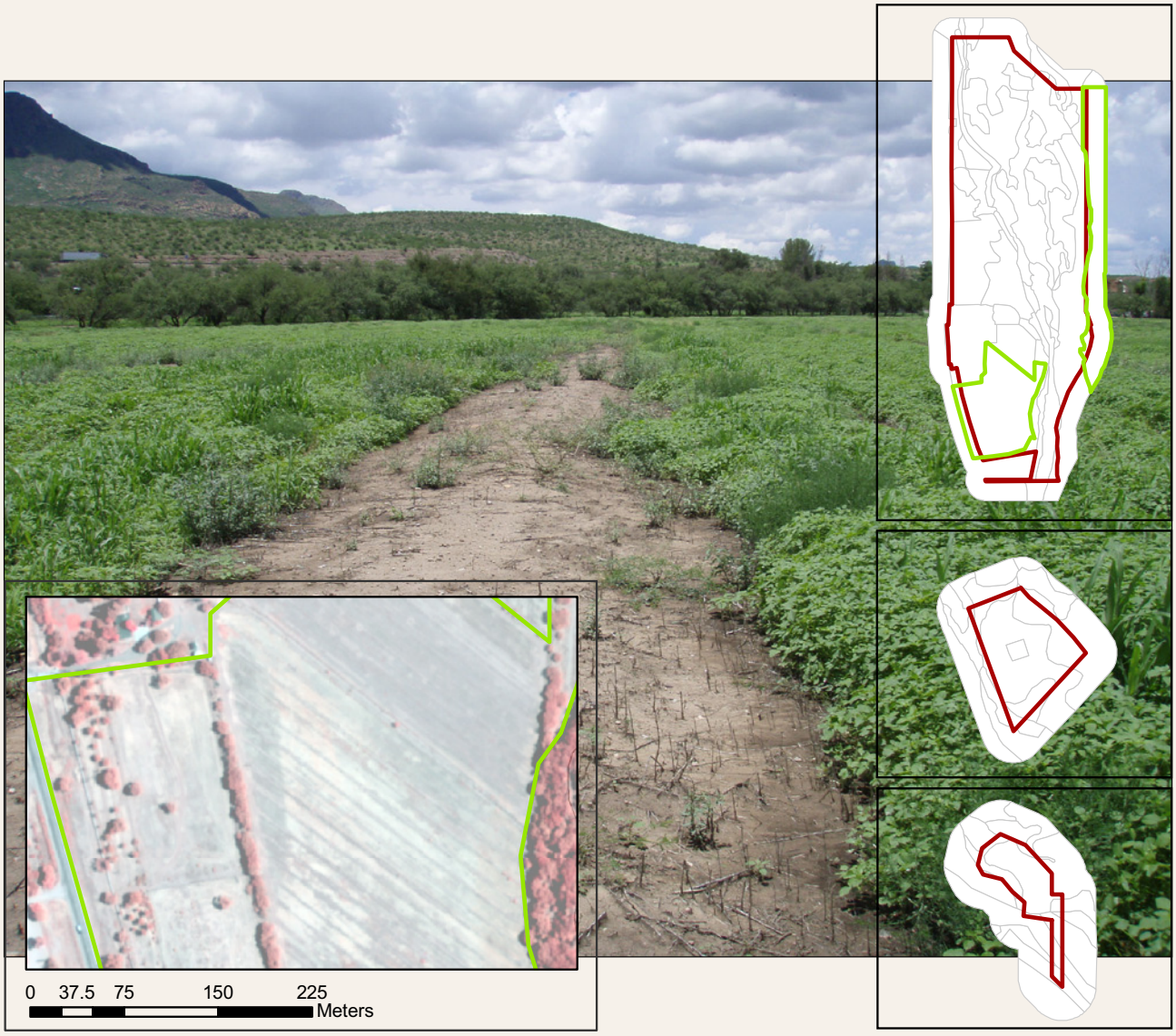


Figure 2.2-20. Cropland and Pasture.

# Chapter 3
# Accuracy Assessment

## 3.1 Methods

Following program guidelines for small parks under 300 ha, a census-based accuracy assessment was done at TUMA, rather than a sample-based one. Tumacácori NHP Resources Manager/Archeologist Jeremy Moss (hereafter "the assessor") carried out the accuracy assessment after a thorough briefing on the methods used for classification and mapping, and on the map classes. This was to ensure that the methods and thinking used to evaluate each polygon for accuracy assessment were essentially the same as those used for classification and mapping, and that the assessment would be done by an objective, knowledgeable observer who was not part of the mapping team. The briefing included discussion of plant lifeforms; familiarization with the NVC hierarchy and criteria for identifying formations, alliances, and associations; techniques for estimating species cover classes by stratum; subtleties of visual interpretation of satellite imagery for evaluation of vegetation; use of the RECON GPS-linked handheld computer; and other necessary methods.

The assessor was provided with tools similar to those used by the mappers, including a RECON unit loaded with draft map polygon boundaries, and printed map sections showing each polygon labeled with a simple ID number. Also provided were a vegetation formation key (Appendix A), a set of map class descriptions (similar to the Tumacácori NHP Summaries in Appendix D), and a stack of datasheets (Appendix F) for recording accuracy assessment (AA) data. These datasheets contained a checklist of the map classes at TUMA, and requested some redundant data to guard against erroneously checking the wrong box.

The task of the assessor was to visit each polygon, walking through it to evaluate the lifeform and canopy cover of the dominant species in each stratum, consider the text descriptions of relevant vegetation types, and check the best-fitting map-class name for the polygon on the datasheet. A rating of goodness-of-fit was also requested, as well as any notes or observations that might help future interpretation of the accuracy assessment, including notes on the polygon boundary. The assessor was asked to choose a class name for the polygon as mapped, considering the whole area of the polygon. The accuracy assessment was completed in about four full field days in January 2009.

## 3.2 Results

Table 3.2-1 (see tables at end of chapter) is an error matrix showing the results of the accuracy assessment, including user's and producer's accuracy per class, overall accuracy for all classes (90.2%) and Khat, or Kappa (89.4%), which is a measure of overall accuracy minus chance agreement.* Of the 19 map classes, only four had user's or producer's accuracy of less than 80%. However, this matrix reflects data that are somewhat misleading due to the small sample size (actually, census size; i.e., the small number of polygons of most types that were present). The small sample size resulted in too many classes with measured accuracy of 100%, inflating the overall accuracy, and too many classes dropping below 80% accuracy if just one of the 2–4 polygons was misclassified.

Also, the data as reported in the matrix somewhat overstate some class accuracies because of the way ambiguity in the reference data was handled. For nine polygons of six vegetation types, the assessor recorded two possible types, such as "mesquite forest OR mesquite woodland" in cases of uncertainty about whether mesquite cover was more or less than the 60% minimum for forest.

*User's accuracy: The probability that a sample from the mapped data actually represents that category on the ground, also known as error of commission. This quantity is computed by dividing the number of correctly classified samples by the total number of samples that were classified as belonging to that category (Story and Congalton 1986).

**Producer's accuracy:** The probability that a reference sample (the ground data) has been classified correctly, also known as error of omission. This quantity is computed by dividing the number of samples that have been classified correctly by the total number of reference samples in that class (Story and Congalton 1986).

In all nine of these cases, the mapped class was scored as correct in the error matrix if the map class matched one of the assessor's recorded classes, which they all did. Each of these cases is shown in Table 3.2-2. All resulted from the assessor's acknowledged difficulty in estimating species cover or lifeform (tree vs. shrub), rather than from errors of species identification or dominance.

Six polygons were scored as true errors in the matrix (Table 3.2-3) due to unambiguous mismatches between the mapped class and the assessed class. Because the mapping and accuracy assessment at TUMA were both census-based, we decided the best course of action would be to examine and resolve all of the true errors and the ambiguities, and correct the map to achieve 100% accuracy for each class. The adjustments are described in the next section.

## 3.3 Resolution of Discrepancies

The discrepancies and ambiguities between map data and accuracy assessment reference data shown in Tables 3.2-2 and 3.2-3 were all investigated and resolved. In eight cases, the AA data were proven to be correct and the map was changed to reflect that. In seven cases, the map data were found to be correct and the AA data were overruled, with no change in the map. Table 3.3 explains each case in turn, with reference to polygons by their ID numbers in Tables 3.2-2 and 3.2-3.

## 3.4 Spatial Accuracy Assessment

The U.S. National Map Accuracy Standards (NMAS) for spatial or positional accuracy, in use since 1947, stipulate that no more than 10% of tested points on a 1:24,000-scale map can be in error by more than 0.02 inch (0.51 mm), or 40 feet (12.2 m) ground distance. The revised National Cartographic Standards for Spatial Accuracy state accuracy as a standard error (RMSE) in the x- and y-coordinate directions, rather than as a circular error with a 90% confidence level (as is indirectly implied by the NMAS of 1947). For a Class 1 product of 1:24,000 scale, the maximum allowable RMSE is 6.0 meters (20 ft) ground distance; for a Class 2 product, the RMSE must be no more than 12.0 meters (39 ft). For digital products with no set scale, the reference to a 1:24,000 standard scale loses some relevance, but the implied ground distances can still be used as benchmarks.

The positional accuracy being measured is that of "well-defined points" on the map; that is, discrete features that can be clearly identified and located in the map product as well as the source of higher accuracy used for comparison (the reference data). Boundaries subject to interpretive judgement or certain natural boundaries subject to environmental fluctuations (e.g., river banks) generally do not qualify as well-defined points, even if they form intersections. Because vegetation boundaries are nearly always interpretive, positional accuracy statements for the TUMA vegetation map do not directly apply to the primary mapped features in the product, but instead should be understood to indicate how well the map product is registered (geocoded) to its control, and not to indicate how well the vegetation polygon boundaries reflect their true positions on the ground (ESRI et al. 1994).

For this project, the highest-accuracy spatial reference data available were a set of DOQQs from 2006; our spatial accuracy measurements were done in comparison with these. At each of the three units at TUMA, 20 test points were selected that were small, discrete, and could be definitively located in both the base satellite imagery used for mapping and in the DOQQs. Most of these were individual shrub canopies against a contrasting background. The georeferencing tool in ArcGIS was used to visually select point pairs (one in the imagery and a corresponding one in the DOQQ), record coordinates, and calculate an overall RMSE (Appendix G). MS Excel was used to calculate additional error values (Table 3.4) from the point coordinates.

As shown in Table 3.4, the TUMA vegetation map easily met the spatial accuracy standards. Features were estimated to lie within two meters, generally much less, of their "true" position on the DOQQ reference imagery. None of the test points approached the 12-m error allowable (for 10% of tested points) under the NMAS, and the maximum measured RMSE of 1.03 meters was well below the 6.0-m limit imposed by the National Cartographic Standards for a Class 1 product.

**Table 3.2-1. Accuracy assessment error matrix.**

| | Accuracy assessment field reference data | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | POPFRE Forest | PROVEL Forest | CELLAE Forest | POPFRE Woodland | PROVEL Woodland | ACAGRE Woodland | PROVEL Wooded Shrubland | PROVEL-ACAGRE Shrubland | ACACON Shrubland | TAMRAM Shrubland | POPFRE Wooded Herbaceous | PROVEL Wooded Herbaceous | PROVEL Shrub Herbaceous | HYMMON Shrub Herbaceous | AMAPAL Herbaceous | Strand | Developed Woodland | Cropland & Pasture | Park Facilities | User's accuracy |
| **Map class #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | |
| **1** | 5 | | | 1 | | | | | | | | | | | | | | | | 0.83 |
| **2** | | 6 | | | | | | | | | | | | | | | | | | 1.00 |
| **3** | | | 4 | | | | | | | | | | | | | | | | | 1.00 |
| **4** | | | | 3 | | | | | | | | | | | | | | | | 1.00 |
| **5** | | | | | 9 | | | | | | | | | | | | | | | 1.00 |
| **6** | | | | | | 1 | | | | | | | | | | | | | | 1.00 |
| **7** | | | | | | | 2 | | | | | | | | | | | | | 1.00 |
| **8** | | | | | | | | 4 | | | | | 1 | | | | | | | 0.80 |
| **9** | | | | | | | | | 1 | | | | | | | | | | | 1.00 |
| **10** | | | | | | | | | | 1 | | | | | | | | | | 1.00 |
| **11** | | | | | | | | | | | 2 | | 1 | | | | | | | 0.67 |
| **12** | | | | | | | | | | | 1 | 4 | | | | | | | | 0.80 |
| **13** | | | | | | | | | | | | 1 | 1 | | | | | | | 0.50 |
| **14** | | | | | | | | | | | | | | 1 | | | | | | 1.00 |
| **15** | | | | | | | | | | | | | | | 4 | | | | | 1.00 |
| **16** | | | | | | | | | | | | | | | 1 | 2 | | | | 0.67 |
| **17** | | | | | | | | | | | | | | | | | 1 | | | 1.00 |
| **18** | | | | | | | | | | | | | | | | | | 2 | | 1.00 |
| **19** | | | | | | | | | | | | | | | | | | | 2 | 1.00 |
| **Producer's accuracy** | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.67 | 0.80 | 0.33 | 1.00 | 0.80 | 1.00 | 1.00 | 1.00 | 1.00 | |
| | | | | | | | | | | | | | | | | | | | **Overall accuracy** | **0.902** |
| | | | | | | | | | | | | | | | | | | | **Khat** | **0.894** |

See Table 2.2 for abbreviations.

**Table 3.2-2. Cases of ambiguity in accuracy-assessment field data.**

| ID | AA field class | Map class |
|---|---|---|
| 34 | POPFRE Woodland or Forest | POPFRE Forest |
| 75 | PROVEL Wooded Herbaceous or PROVEL Woodland | PROVEL Woodland |
| 21 | PROVEL Forest or Woodland | PROVEL Woodland |
| 27 | PROVEL Forest or PROVEL Woodland | PROVEL Woodland |
| 77 | PROVEL/[PROVEL-ACAGRE] WS or PROVEL Woodland | PROVEL Woodland |
| 73 | PROVEL/[PROVEL-ACAGRE] WS or PROVEL Woodland | PROVEL/[PROVEL-ACAGRE] WS |
| 70 | PROVEL Wooded Herbaceous or PROVEL Woodland | PROVEL Wooded Herbaceous |
| 43 | HYMMON Shrub Herbaceous or POPFRE Wooded Herbaceous | HYMMON Shrub Herbaceous |
| 13 | AMAPAL Herbaceous or POPFRE Wooded Herbaceous | AMAPAL Herbaceous |

In all cases, the map class matched one of the two alternative AA-assigned classes. Polygon ID numbers are arbitrary, used for reference during accuracy assessment. WS = Wooded Shrubland. See Table 2.2 for class abbreviations.

**Table 3.2-3. Cases of true error or discrepancy between map data and accuracy-assessment field data.**

| ID | AA field class | Map class |
|---|---|---|
| 32 | POPFRE Woodland | POPFRE Forest |
| 71 | POPFRE/Mixed Annual Wooded Herbaceous | PROVEL Wooded Herbaceous |
| 65 | PROVEL/AMAPAL Shrub Herbaceous | POPFRE/Mixed Annual Wooded Herbaceous |
| 52 | PROVEL/AMAPAL Shrub Herbaceous | PROVEL-ACAGRE Shrubland |
| 45 | PROVEL Wooded Herbaceous | PROVEL/AMAPAL Shrub Herbaceous |
| 56 | AMAPAL Herbaceous | Strand |

Polygon ID numbers are arbitrary, used for reference during accuracy assessment. See Table 2.2 for class abbreviations.

**Table 3.3. Resolution of discrepancies.**

| Polygon | Changed | | Explanation |
|---|---|---|---|
| | Yes | No | |
| 13 | X | | The boundary of this polygon (H-AP01-M) was adjusted to exclude some tree cover at its margins, resulting in <10% total tree cover and a less-ambiguous map class of AMAPAL Herbaceous. |
| 21 | X | | This polygon (F-PV06-M) was changed from woodland to forest. In the GIS lab, the polygon was overlaid with 50 randomly located dots, which were scored as hitting tree canopy or interspace. This analysis produced an estimate of 71% tree cover, ample for the Forest label. |
| 27 | X | | After a slight adjustment of the boundary of this polygon (F-PV08-G), its tree cover was estimated at 84%, and it was also changed from woodland to forest. |
| 43 | X | | The boundary of this polygon (SH-HM01-M) was changed to exclude some POPFRE trees at its margins that were confounding its identification. With less tree cover included, the map class HYMMON Shrub Herbaceous fit well. |
| 56 | X | | This polygon (H-AP02-M) was changed from Strand to AMAPAL Herbaceous. It may once have been a strand, but its isolation and distance from the current active channel, plus its well-established cover of AMAPAL, led to the decision that AMAPAL Herbaceous was the best label. |
| 65 | X | | This polygon (WH-PF01-M) was actually a disjunct, two-part polygon comprising one large and one small stand. The assessor was not cognizant of this and evaluated each part separately. The AA data for the larger stand matched the map data, so there was no error there. For the smaller stand, the AA data were judged to be a better fit than the map data. The smaller stand was re-attributed as PROVEL/AMAPAL Shrub Herbaceous. |
| 70 | X | | This polygon (WPV04-M) was changed from PROVEL Wooded Herbaceous to PROVEL Woodland based on analysis of the satellite imagery, which indicated about 40% tree cover, but more tree cover than herbaceous cover due to a significant amount of bare ground. |
| 71 | X | | This polygon was large and heterogeneous, with the map class fitting one part best and the assessed class fitting another. The polygon was split, and the north part was re-labeled as POPFRE Wooded Herbaceous (WH-PF03-M), while the south part remained PROVEL Wooded Herbaceous (WH-PV01-M) as mapped. |
| 32 | | X | This polygon (F-PF05-M) was not changed. The apparent error (woodland vs. forest) resulted from different estimates of the tree canopy cover. GIS analysis produced an estimate of 74% tree cover, confirming the Forest label. |
| 34 | | X | Ambiguity between woodland and forest for this polygon (F-PF03-M) was resolved by using the GIS random-point method as for polygon 32 above, which provided an estimate of 70% tree cover. The map class of POPFRE-SALGOO forest was not changed. |
| 45 | | X | This polygon (SH-PV02-G) was not changed. The apparent error was due to different interpretations of the lifeform of the PROVEL plants in the polygon. After discussion with the mapping field crew, the *Prosopis* were judged to be large shrubs, rather than trees, so the PROVEL/AMAPAL Shrub Herbaceous label fit best. |
| 52 | | X | This polygon (S-PV02-G) was not changed. Review of the polygon and classification plot datasheets showed that PROVEL-ACAGRE Shrubland was a better fit than PROVEL/AMAPAL Shrub Herbaceous, because ACAGRE was common and shrub cover exceeded herbaceous cover. |
| 73 | | X | This polygon (WS-PV01-M) was confirmed to be a wooded shrubland by review of classification/mapping data. It was not changed. |
| 75 | | X | This polygon (W-PV02-M) was confirmed to be a woodland, as mapped, based on review of imagery and mapping/classification datasheets to re-estimate tree cover vs. herbaceous cover. |
| 77 | | X | This polygon (W-PV03-M) was judged to be a woodland rather than a wooded shrubland, based on the classification/mapping data on mesquite lifeform. It was not changed. |

See Table 2.2 for class abbreviations.

**Table 3.4. Spatial accuracy assessment summary for each of the three units at TUMA.**

| Unit | Absolute error | | RMS error | | |
|---|---|---|---|---|---|
| | Max-X | Max-Y | RMS-X | RMS-Y | RMS-All |
| Mission | 1.93 | 1.13 | 0.61 | 0.61 | 0.77 |
| Calabazas | -0.88 | 1.15 | 0.44 | 0.43 | 0.40 |
| Guevavi | -1.92 | 0.71 | 1.03 | 0.29 | 0.85 |

Values are meters, ground distance. Twenty test points were used for each unit. RMS = root mean square

# Chapter 4
# Discussion

## 4.1 Strata and Growth Form

One note on the adoption of NVC methodology at Tumacácori NHP concerns the difficulty encountered in arid southwestern ecosystems in determining the nature of both strata and growth form among certain species. Within the NVC hierarchy, the tree stratum is defined as plants taller than 5 m, the shrub stratum is from 0.5 to 5 m, and the field stratum is from 0 to 0.5 m (Jennings et al. 2006). Also, the NVC makes allowance for breaking up these categories into subcategories, which at Tumacácori we defined as a top-canopy over 5 m, a canopy from 2.5 to 5 m, a sub-canopy from 0.5 to 2.5 m, and field stratum from 0 to 0.5 m. Within these categories, it was often difficult to assess growth form according to a strict interpretation of the NVC hierarchy, although the NVC states, "not all plant species will fit clearly into the recognized strata or growth form categories" (Jennings et al. 2006).

Examples at TUMA are mesquite and catclaw acacia, in which growth form varies considerably. At Tumacácori, these species grow as shrubs, trees, and forms in between. It is often difficult to assign individuals or stands to a distinct growth form. Often, individuals over 5 m tall with multiple stems are encountered. In the course of field work, it was decided first that plants larger than 5 m were trees, regardless of the number of stems. Second, plants with multiple stems that were of a more brushy habit, meaning they had multiple similarly sized stems and no discernible upward-trending central leader, were considered shrubs if they were under 5 m. Finally, in instances where a single trunk dominated, the growth form was always considered a tree, but noted in the proper stratum depending on the size of the specimen.

## 4.2 Notable Vegetation Patterns

In the course of field work for classification and mapping, patterns of apparent vegetation community succession were observed that are seemingly related to long-term aspects of land-use history at particular sites. The observation was made that the vegetation on abandoned agricultural fields at the Tumacácori Mission unit is apparently undergoing a succession to mesquite bosque, and there are different stages of this in different locations around the park. While it is difficult to discern the specific mechanisms driving this succession, including what role water and exotic herbaceous vegetation may play, the patterns observable today suggest that a series of developmental stages have occurred since a particular site was cultivated.

The first stage of the succession is represented by a polygon labeled as agriculture that had been abandoned only within the last few years. This field is immediately to the east of the mission's historical orchard. This abandoned field has not been mowed since about 2002 (J. Moss, pers. comm.), unlike a similar field to the southwest that continues to be mowed regularly. The lack of mowing apparently has allowed the establishment and growth of woody species such as mesquite and desert broom. While the field is still dominated, in large part, by amaranth and a wide diversity of both annual and perennial grasses, the development of the woody shrubs is the first notable compositional change in the successional pattern.

The second stage is the growth of mesquite and desert broom into much larger shrubs, with mesquite becoming treelike. This stage is represented along the western boundary of the park, running from north of the Fiesta Grounds to an east-west trending arroyo and an old, relict stand of trees that was never cut—essentially, all the agricultural land abandoned in the late 1970s. This shrubland is dominated by mesquite shrubs, ranging in height from 2 to 4 m, and desert broom specimens averaging around 2.5 m tall. Another example of this stage was found immediately to the north of the agricultural field thought to be in the first stage. In this polygon, *Prosopis* and *Baccharis* were much more dense than along the western boundary, which may be explained by their proximity to a consistent water table.

In the third stage, the development of the bosque becomes more clearly discernible. Commonly, the mesquites are mid-size (5–7 m) and even-aged, and there is very little density or diversity

of herbaceous growth beneath them. This stage is found in places immediately adjacent to the second stage, often with a distinct boundary between them. The tree canopy becomes interlocked, and the community type changes from woodland to forest. In apparently longer-established patches of this type, one encounters the addition of elderberry to the community, as well as vines that grow into the canopy, appearing diagnostic of the maturing bosque. The canopy in this stage appears to push upward, allowing for a distinct layering of vegetation, first from the ground to about 2 m, where the understory is open and allows the growth of diverse herbaceous and sub-shrub species, including Thurber's honeysuckle (*Anisacanthus thurberi*).

The final stage of bosque maturity seems to be marked by dense and tall mesquites, the inclusion of hackberry, many as large trees, and the highest diversity of sub-canopy shrub and herbaceous species. The growth of morning glory vine (*Ipomoea*) and leather flower (*Clematis*) vines is notable, and recruits of mesquite and hackberry are present. Soil development is critical to moving from the first stage, where the shrubland is actually more of a shrub savanna, to this final stage. In the first two stages, the soils are sandy-gravelly-loam and support little in the way of herbaceous forbs. However, as the mesquite matures into larger trees, there is a noticeable increase in the soil being formed beneath the canopies. As the canopies continue to thicken, the soil appears to deepen and become loamier and darker with organic matter.

This assessment of the development of the bosque is only observational, and is not based on quantitative data. However, the field crew found the developmental stages to be sufficiently distinct and intriguingly correlated with possible dates of abandonment of cultivation to warrant future studies on the course and precise ecological mechanisms of bosque development.

## 4.3 Implications for Management

Tumacácori NHP presents a unique opportunity for ecological restoration in the Santa Cruz River valley. Situated along the central axis of the river basin, the main unit of Tumacácori NHP is a significant parcel of rare cottonwood-willow gallery forest and mesquite bosque riparian ecosystems. While these ecosystems are currently protected, they have been heavily impacted for centuries, through a long history of livestock grazing, agricultural conversion, and fluctuations in surface and groundwater profiles. Due to the highly disturbed nature of the ecosystems found in the park and the increasing prevalence of a variety of invasive and exotic species, Tumacácori NHP is uniquely situated to investigate and implement ecological restoration strategies with potentially basin-wide implications.

Referred to as the "lessening stream" for its once-consistent flow that diminished to a trickle and eventually disappeared under the pressures of human development (Logan 2002), agricultural abandonment immediately upstream of and along the Santa Cruz River in the vicinity of Tumacácori NHP, beginning first in the 1930s, has allowed for a resurgence of riparian vegetation (Webb et al. 2007). This resurgence, coupled with an increasing flow of effluent released by the International Wastewater Treatment plant (beginning in the 1970s), has resulted in a well-developed riparian forest through Tumacácori NHP. Additionally, the abandonment of agricultural land around the park, beginning in the 1970s, has resulted in the apparent development of conditions necessary for the successional development of mesquite bosques once present in the area (see discussion above.)

The central challenge to ecological restoration of the riparian corridor may be the composition of the park's herbaceous communities. While the overstory conditions appear to be on an ecological trajectory toward sustainability of native-species forest and woodland (with a caveat due to the currently limited presence of tamarisk), the monocultural presence of Bermuda grass and poison hemlock (*Conium maculatum*) along the river and the widespread distribution and high density of amaranth and Russian thistle throughout the park indicate that the herbaceous community remains highly disturbed. Whether this is a consequence of persistent cattle grazing or the near-total dominance of Bermuda grass upstream and downstream from Tumacácori along the river, this level of disturbance presents an opportunity to explore alternative management strategies.

Considered within a regional context, it is notable that the more-common obligate riparian herbaceous plant species, such as rushes (*Juncus* spp.) and horsetail (*Equisetum* spp.), were not found in any significant abundance along the river through the park. Also notable is the only occasional presence of big sacaton in scattered patches through all three units. Historically, it is thought that saca-

ton was a central component of these intermittently flooded riparian ecosystems throughout southern Arizona and northern Sonora (Richter and Stutz 2002). The presence of these species in reduced abundance is an indication of the impoverishment of the overall riparian ecosystem, but is also an indicator that the opportunity exists to alter management practices to support and enhance the restoration of herbaceous plant communities.

# Chapter 5
# Literature Cited


Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the southwest. Journal of Arizona-Nevada Academy of Science **14**:1–16.

Comer, P., D. Faber-Langendoen, R. Evens, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. Arlington, Va.: NatureServe.

Driscoll, R. S., D. L. Merkel, D. L. Radloff, D. E. Synder, and J. S. Hagihara. 1984. An ecological land classification framework for the United States. U.S. Forest Service Miscellaneous Publication 1439. Washington, D.C.: U.S. Forest Service.

Environmental Systems Research Institute, National Center for Geographic Information and Analysis, and The Nature Conservancy (ESRI et al.). 1994. Accuracy assessment procedures. NBS/NPS Vegetation Mapping Program. Report to U.S. Department of Interior National Biological Survey and National Park Service. http://biology.usgs.gov/npsveg/aa/index.html.

Federal Geographic Data Committee (FGDC). 1997. Vegetation classification standard. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/vegclass.pdf.

——. 2008. National Vegetation Classification Standard, Version 2. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: Terrestrial vegetation of the United States. Volume I: The National Vegetation Classification Standard. Arlington, Va.: The Nature Conservancy.

Jennings M., D. Faber-Langendoen, R. Peet, O. Loucks, D. Glenn-Lewin, A. Damman, M. Barbour, R. Pfister, D. Grossman, D. Roberts, D. Tart, M. Walker, S. Talbot, J. Walker, G. Hartshorn, G. Waggoner, M. Abrams, A. Hill, and M. Rejmanek. 2006. Description, documentation, and evaluation of associations and alliances of the U.S. National Vegetation Classification, version 4.5. The Ecological Society of America, Vegetation Classification Panel. http://www.esa.org/vegweb/docFiles/NVC_Guidelines_v45.pdf.

Kartesz, J. T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. First edition. *In* Kartesz, J. T., and C. A. Meacham. Synthesis of the North American flora [computer program]. Version 1.0. Chapel Hill, N.C.: North Carolina Botanical Garden.

Lamb, S., and S. Scott. 1993. Tumacácori National Historical Park. Tucson, Az.: Southwest Parks and Monuments Association.

Logan, M. 2002. The lessening stream. Tucson: University of Arizona Press.

Marshall, R. M., D. Turner, A. Gondon, D. Gori, C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, and P. Comer. 2004. An ecological analysis of conservation priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora, agency and institutional partners. 152pp.

Maybury, K. P., ed. 1999. Seeing the forest and the trees: Ecological classification for conservation. Arlington, Va.: The Nature Conservancy.

Powell, B. F., E. W. Albrecht, W. L. Halvorson, C. A. Schmidt, P. Anning, and K. Docherty. 2005. Vascular plant and vertebrate inven-

tory of Tumacácori National Historic Park. USGS Open-File Report 2005-1142. U.S. Geological Survey, Southwest Biological Science Center, Sonoran Desert Research Station, University of Arizona, Tucson, Az.

Richter, B. S., and J. C. Stutz. 2002. Mycorrhizal inoculation of big sacaton: Implications for grassland restoration of abandoned agricultural fields. Restoration Ecology **10**(4):607–616.

Robinett, D. 1990. Tohono O'odham range history. Rangelands **12**(6):296–300.

Shreve, F., and I. L. Wiggins. 1964. Vegetation and flora of the Sonoran Desert. 2 volumes. Stanford, Ca.: Stanford University Press.

Spicer, E. 1962. Cycles of conquest. Tucson: University of Arizona Press.

Story, M., and R. G. Congalton. 1986. Accuracy assessment: A user's perspective. Photogrammetric Engineering and Remote Sensing **52**(3):397–399.

The Nature Conservancy and Environmental Systems Research Institute (TNC and ESRI). 1994a. Standardized national vegetation classification system. Report to U.S. Department of Interior National Biological Survey and National Park Service. http://biology.usgs.gov/npsveg/classification/index.html.

——. 1994b. Field methods for vegetation mapping: NBS/NPS Vegetation Mapping Program (Final Draft). Report to U.S. Department of Interior National Biological Survey and National Park Service. http://biology.usgs.gov/npsveg/existdata/index.html.

——. 1996. Methodology for assessing the utility of existing data for vegetation mapping. Report to U.S. Department of Interior national Biological Survey and National Park Service. http://biology.usgs.gov/npsveg/existdata/index.html

Theobald, D. M., D. L. Stevens Jr., D. White, N. S. Urquart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced designs for natural resource applications. Environmental Management **40**:134–146.

Thomas, K. A., M. L. McTeague, A. Cully, K. Schulz, and J. M. S. Hutchinson. In press. Vegetation classification and distribution mapping report: Petrified Forest National Park. Natural Resource Technical Report NPS/SCPN/NRTR—2009. National Park Service, Fort Collins, Colorado.

UNESCO. 1973. International classification and mapping of vegetation. Paris: UNESCO.

Van Loh, J. et al., 2006. Draft Colorado National Monument vegetation mapping project report, Northern Colorado Plateau Network, National Park Service. Moab, Ut.

Webb, R. H., S. A. Leake, and R. M. Turner. 2007. The ribbon of green. Tucson: University of Arizona Press.

# Appendix A
# Vegetation Formation Key

**1. What is the dominant surface cover?**

Trees .....go to .....**2**
Shrubs.....go to .....**3**
Herbaceous .....go to .....**4**
Rock/Bare Soil .....go to .....**5**

**2. Trees**

A. Tree Cover >60%?
YES = Forest
NO = Woodland

**3. Shrubs**

A. Tree Cover >10%?
YES = Wooded Shrubland
NO = Shrubland

**4. Herbaceous**

A. Tree cover <10% **AND** Shrub cover <10%?
YES = Herbaceous
NO = go to B.

B. Tree cover > Shrub cover?
YES = Wooded Herbaceous
NO = Shrub Herbaceous

**5. Rock/Bare Soil**

A. Is the total vegetation cover <1%?
YES = Non-Vegetated
NO = go to B.

B. Is the total vegetation cover <10%?
YES = Sparse Vegetation
NO = go to C.

C. Determine dominant vegetation lifeform and go to **2**, **3** or **4**.

# Appendix B
# Polygon Data Sheets

**Sonoran Desert Network**
**Inventory and Monitoring Program**

National Park Service
U.S. Department of the Interior

USGS-NPS Vegetation Mapping Program  Field Data Sheet: **Polygon Vegetation**  Version: 0.04  Page ____ of ____

Proofread by: _____ Copied by: _____ Entered by: _____ Verified by: _____ GIS Edits done by: _____ New Poly ID: _____

**Location and Event Information**

| | | | |
|---|---|---|---|
| Park: | Sub-Map #: | Date (mm/dd/yyyy): | Time (00:00): |
| Poly ID(s): | | Field Poly ID: | |
| Observer(s): | Recorder: | Tentative Formation: | Keyed Formation: |
| Protocol Name: VegMap | | Protocol Version: 0.05 | |

**List top three dominant species by stratum. Rank (R) 1=dominant or co-dominant, 2=second dominant, 3=least dominant.**
**Record species cover class (C) and average height (H, in meters to nearest tenth) by stratum. Record LF, lifeform (T or S).**

**1 = < 1%  2 = 1-5%  3 = 6-10%  4 = 11-25%  5 = 26-33%  6 = 34-50%  7 = 51-75%  8 = 76-95%  9 = 96-100%**

| Canopy >5m | LF | R | C | H | Canopy 2 – 5m | LF | R | C | H | Sub-canopy 0.5 – 2m | LF | R | C | Field 0 – 0.5m | R | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Total cover all species | | | | | Total cover all sp | | | | | Total cover all sp | | | | Total cover all sp | | |

**List other common associates**

| Canopy >5m | LF | C | H | Canopy 2 – 5m | LF | C | H | Sub-canopy 0.5 – 2m | LF | C | Field 0 – 0.5m | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |

**Association name:** Use "—" within strata, "/" between strata and "( )" to denote minor species

Polygon_Veg_Datasheet_v004.ppt  If you find this datasheet completed, please call (520) 731-3420 ext. 5.

**Sonoran Desert Network**
**Inventory and Monitoring Program**

National Park Service
U.S. Department of the Interior

Page ____ of ____

**Disturbance Types:**

| (X) | Poly Homogeneity |
|---|---|
| | Homogeneous |
| | Compositional trend |
| | Conspicuous inclusions |
| | Irregular |
| | Pattern mosaic |

| (X) | Stand Maturity |
|---|---|
| | Young/ regenerating |
| | Even age/ aggrading |
| | Mature/ even-age |
| | Transition/ break up |
| | Old growth/ senescent |
| | Uneven age |
| | Other: |

**PHOTOS: From approximate center of polygon take 4 photos, one in each cardinal direction, in order (N E S W). Write photo number (last four digits from upper right corner) in table and record camera used.**
**** Please note the numbers of any additional photos taken and a description of what they depict.**

| Camera Name: |
|---|
| North |
| East |
| South |
| West |

**NOTES: Describe the overall vegetative community, especially noting differences from other similar communities.**
**Explain or diagram any polygon splits/additions/subtractions/boundary changes.**

Polygon_Veg_Datasheet_v004.ppt

If you find this datasheet completed, please call (520) 731-3420 ext. 5.

Page ____ of ____

USGS-NPS Vegetation Mapping Program Field Data Sheet: **Polygon Soil/Landscape** Version: 0.04

Proofread by: _____ Copied by: _____ Entered by: _____ Verified by: _____ New Poly ID: _____

## Location and Event Information

| | | | |
|---|---|---|---|
| Park: | Sub-Map #: | Date (mm/dd/yyyy): | Time (00:00): |
| Poly ID(s): | | Field Poly ID: | |
| Observer(s): | Recorder: | Tentative Formation: | Keyed Formation: |
| Protocol Name: VegMap | | Protocol Version: 0.04 | |

## Soil/Landscape Parameters

| (X) | Topographic Position (X all that apply) |
|---|---|
| | Crest/summit |
| | Upper slope |
| | Midslope |
| | Footslope |
| | Toeslope |
| | High flat |
| | Low flat |
| | Basin floor |
| | Channel bed/ gully |
| | Other: |

| (X) | Landform (X all that apply) |
|---|---|
| | Upper Alluvial Fan |
| | Lower Alluvial Fan |
| | Floodplain |
| | Alluvial Terrace |
| | Wash |
| | Arroyo |
| | Mountain |
| | Hill |
| | Colluvial Talus |
| | Outcrop |
| | Drainage (IFW/IFF) |

**Area Surface Cover** (circle one class per feature)

| Feature | Class | | | | | |
|---|---|---|---|---|---|---|
| Bare Soil | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Gravel: 2-75 mm | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Rock: 75 + mm | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Bedrock Outcrops | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Physical Crust | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Biological Crust | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Down Wood | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Litter | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | Horizonated |

| (X) | Parent Material (X all that apply) |
|---|---|
| | Intrusive Igneous Bedrock |
| | Extrusive Igneous Bedrock |
| | Volcanic Ash Bedrock |
| | Metamorphic Bedrock |
| | Non-calcareous sedimentary rock |
| | Calcareous sedimentary rock |
| | Colluvium |
| | Old Alluvium |
| | New Alluvium |
| | Aeolian - Windblown |

| (X) | Slope Class (X all that apply) |
|---|---|
| | 0-1% |
| | 1-6% |
| | 6-15% |
| | 15-35% |
| | 35-50% |
| | 50+% |

**Erosion Features** (circle one class per feature)

| | | | | |
|---|---|---|---|---|
| Tunneling | None | Rare | Common | Prolific |
| Sheet | None | Rare | Common | Prolific |
| Rill | None | Rare | Common | Prolific |
| Gully | None | Rare | Common | Prolific |
| Pedestals | None | Rare | Common | Prolific |
| Terracettes | None | Rare | Common | Prolific |
| Burrowing | None | Rare | Common | Prolific |

**Aspect** (circle all that apply)

N NW W SW S SE E NE



If you find this datasheet completed, please call (520) 731-3420 ext. 5.

Page ____ of ____

**NOTES: 1) Write a short descriptive paragraph on the major soil type, slope position, and geomorphic features.**
**2) Sketch any soil or geologic features within the polygon; *e.g.*, arroyos, changes in soils, rock outcrops.**

# Appendix C
# Plot Data Sheets

**Sonoran Desert Network**
**Inventory and Monitoring Program**

National Park Service
U.S. Department of the Interior

Page ____ of ____

USGS-NPS Vegetation Mapping Program  Field Data Sheet: **Intermediate Plot Vegetation**  Version: 0.00

**Location and Event Information**  Proofread by: _____ Copied by: _____ Entered by: _____ Verified by: _____ New Poly ID: _____

| | | | | | |
|---|---|---|---|---|---|
| Park: | Sub-Map #: | | Date (mm/dd/yyyy): | Time (00:00): | |
| Poly ID(s): | | | Field Poly ID: | Plot ID: | |
| Observer(s): | Recorder: | Tentative Formation: | | Keyed Formation: | |
| UTM NAD83: | | 20m Bearing: | 50m Bearing: | Protocol Name: VegMap | Protocol Version: 0.04 |

**List top three dominant species by stratum. Rank (R) 1=dominant or co-dominant, 2=second dominant, 3=least dominant.**
**Record species cover class (C) and average height (H, in meters to nearest tenth) by stratum. Record LF, lifeform (T or S).**

**1 = < 1%  2 = 1-5%  3 = 6-10%  4 = 11-25%  5 = 26-33%  6 = 34-50%  7 = 51-75%  8 = 76-95%  9 = 96-100%**

| Canopy >5m | LF | R | C | H | Canopy 2 – 5m | LF | R | C | H | Sub-canopy 0.5 – 2m | LF | R | C | Field 0 – 0.5m | R | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Total Cover All Species | | | | | Total Cover All Spp | | | | | Total Cover All Spp | | | | Total Cover All Spp | | |

**List other common associates**

| Canopy >5m | LF | C | H | Canopy 2 – 5m | LF | C | H | Sub-canopy 0.5 – 2m | LF | C | Field 0 – 0.5m | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
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**Association name:** Use "—" within strata, "/" between strata and "( )" to denote minor species

Intermediate_Plot_Veg_Datasheet_v000.ppt  If you find this datasheet completed, please call (520) 731-3420 ext. 5.

**Disturbance Types**

**Camera Name & Photo Number(s):**

| (X) | Plot Homogeneity |
|---|---|
| | Homogeneous |
| | Compositional trend |
| | Conspicuous inclusions |
| | Irregular |
| | Pattern mosaic |

| (X) | Stand Maturity |
|---|---|
| | Young/ regenerating |
| | Even age/ aggrading |
| | Mature/ even-age |
| | Transition/ break up |
| | Old growth/ senescent |
| | Uneven age |
| | Other: |

**Basal Diameter and Pole Count for Tree Species**

| Species | Basal Diameter(s) over 10 cm | Pole/Stem Count |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**NOTES: Describe the overall vegetative community, especially noting differences from other similar communities.**

Intermediate_Plot_Veg_Datasheet_v000.ppt

If you find this datasheet completed, please call (520) 731-3420 ext. 5.

**Sonoran Desert Network**
**Inventory and Monitoring Program**

National Park Service
U.S. Department of the Interior

Page ____ of ____

USGS-NPS Vegetation Mapping Program  Field Data Sheet: **Intermediate Plot Soil/Landscape**  Version: 0.00

Proofread by: _____ Copied by: _____ Entered by: _____ Verified by: _____ New Poly ID: _____

**Location and Event Information**

| | | | |
|---|---|---|---|
| Park: | Sub-Map #: | Date (mm/dd/yyyy): | Time (00:00): |
| Poly ID(s): | | Field Poly ID: | Plot ID: |
| Observer(s): | Recorder: | Tentative Formation: | Keyed Formation: |
| UTM NAD83: | | Protocol Name: VegMap | Protocol Version: 0.04 |

**Soil/Landscape Parameters**

| (X) | Topographic Position (X all that apply) |
|---|---|
| | Crest/summit |
| | Sholder |
| | Backslope |
| | Footslope |
| | Toeslope |
| | No Slope (N/A) |
| | Other: |

| (X) | Landform (X all that apply) |
|---|---|
| | Upper Alluvial Fan |
| | Lower Alluvial Fan |
| | Floodplain |
| | Alluvial Terrace |
| | Wash |
| | Arroyo |
| | Mountain |
| | Hill |
| | Colluvial Talus |
| | Outcrop |
| | Drainage (IFW/IFF) |

**Area Surface Cover** (circle one class per feature)

| Feature | Class | | | | | |
|---|---|---|---|---|---|---|
| Bare Soil | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Gravel: 2-75 mm | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Rock: 75 + mm | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Bedrock Outcrops | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Physical Crust | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Biological Crust | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Down Wood | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | |
| Litter | None | Sparse (1-15%) | Medium (15-35%) | Common (35-60%) | Dominant (>60%) | Horizonated |

| (X) | Parent Material (X all that apply) |
|---|---|
| | Intrusive Igneous Bedrock |
| | Extrusive Igneous Bedrock |
| | Volcanic Ash Bedrock |
| | Metamorphic Bedrock |
| | Non-calcareous sedimentary rock |
| | Calcareous sedimentary rock |
| | Colluvium |
| | Old Alluvium |
| | New Alluvium |
| | Aeolian - Windblown |

| (X) | Slope Class (X all that apply) |
|---|---|
| | 0-1% |
| | 1-6% |
| | 6-15% |
| | 15-35% |
| | 35-50% |
| | 50+% |

**Erosion Features** (circle one class per feature)

| | | | | |
|---|---|---|---|---|
| Tunneling | None | Rare | Common | Prolific |
| Sheet | None | Rare | Common | Prolific |
| Rill | None | Rare | Common | Prolific |
| Gully | None | Rare | Common | Prolific |
| Pedestals | None | Rare | Common | Prolific |
| Terracettes | None | Rare | Common | Prolific |
| Burrowing | None | Rare | Common | Prolific |

**Aspect** (circle all that apply)

N NW W SW S SE E NE

Intermediate_Plot_Soil_Landscape_Datasheet_v000.ppt

If you find this datasheet completed, please call (520) 731-3420 ext. 5.

Page ____ of ____

**NOTES: 1) Write a short descriptive paragraph on the major soil type, slope position, and geomorphic features.**
**2) Sketch any soil or geologic features within the plot; *e.g.*, arroyos, changes in soils, rock outcrops.**

# Appendix D
# Vegetation Type Descriptions

This appendix includes information on the vegetation type descriptions identified for Tumacácori National Historical Park. All information not identified as specific to Tumacácori NHP was collected from NatureServe Explorer (http://www.natureserve.org/explorer/), including the NatureServe codes, global descriptions, vegetation hierarchy, ecological systems placement, and references. Distinctions between types are based on the vegetation formation key (see Appendix A).

**Forest**

- *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest
- *Prosopis velutina* Forest Alliance
- *Celtis laevigata* var. *reticulata* Forest Alliance

**Woodland**

- *Populus fremontii - Salix gooddingii* Woodland
- *Prosopis velutina* Woodland Alliance
- *Acacia greggii* Woodland Alliance

**Wooded Shrubland**

- *Prosopis velutina* / [*Prosopis velutina - Acacia greggii*] Wooded Shrubland Alliance

**Shrubland**

- *Prosopis velutina - Acacia greggii* Shrubland
- *Acacia constricta* Shrubland Alliance
- *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance

**Wooded Herbaceous**

- *Populus fremontii* / Mixed Annual Wooded Herbaceous Alliance
- *Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance

**Shrub Herbaceous**

- *Prosopis velutina* / *Amaranthus palmeri* Shrub Herbaceous Alliance
- *Hymenoclea monogyra* / [*Amaranthus palmeri - Chloris virgata*] Shrub Herbaceous Alliance

**Herbaceous**

- [*Amaranthus palmeri - Salsola kali - Chenopodium* sp.] Annual Herbaceous Alliance

**Sparsely Vegetated**

- Inland Freshwater Strand Beach Sparse Vegetation

**Developed Woodland**

**Cropland and Pasture**

**Park Facilities**

# D.1 Forest

## *D.1.1 Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest

***Translated name:*** Fremont cottonwood - Goodding's willow / Mule's-fat Forest
***NatureServe code:*** A.313 / CEGL002683

### Summary

***Globally—***This is a lowland forested riparian association known from the Gila River watershed in New Mexico, and potentially occurring elsewhere in southwestern New Mexico and southern Arizona. It occurs in lowland river valleys at elevations ranging from 1,220 to 1,410 m (4,000–4,625 ft). Stream gradients are moderate (0.3–0.9%), and channel substrates gravelly or finer. Occurring on low- to mid-elevation bars within and along channels, flood-recurrence intervals vary widely, but typically range between two and five years. Some sites are considerably higher in the floodplain and are rarely flooded (25–100 years). Soils are young, weakly developed Entisols that are commonly sandy with a cobbly matrix. Others, particularly those of higher terraces, are sandy or loamy throughout. The soils are generally dry on the surface most of the year, but they may be periodically moist within the rooting zone (40–150 cm). The vegetation of this association is characterized by young to middle-aged stands of *Populus fremontii* and *Salix gooddingii* with moderate to closed canopies (usually greater than 60% cover). *Celtis laevigata* var. *reticulata, Fraxinus velutina, Juglans major, Juniperus monosperma*, and *Platanus wrightii* can occur as subcanopy associates, but are never dominant. *Baccharis salicifolia* is well-represented to abundant in the shrub layer and is diagnostic. Other shrubs are scattered and may include *Amorpha fruticosa, Ericameria nauseosa (= Chrysothamnus nauseosus), Rhus trilobata*, and *Salix exigua*. The herbaceous layer can range from sparse and species-poor to well-represented and species-rich, but variable. A total of 54 grasses and forbs have been recorded for the type, 7 of which were wetland indicators. The most common were *Hydrocotyle verticillata, Schoenoplectus pungens (= Scirpus pungens), Phyla lanceolata, Juncus balticus*, and *Muhlenbergia asperifolia*.

***Tumacácori National Historical Park—***This is the most prevalent type at Tumacácori, following both sides of the Santa Cruz River for its length through the Mission unit of the park. *Populus fremontii* is the dominant tree species in both cover and height, forming a canopy averaging 10–20 m high. Beneath this, the subdominant *Salix gooddingii* occurs at variable density and generally 6–8 m in height, though some individuals are larger. Below the cottonwood–willow canopy, the ground is relatively open except for areas of thick *Tamarix ramosissima* along the river channel that are interspersed throughout the park. At the time of mapping, the NPS was conducting a tamarisk eradication program; therefore, tamarisk cover is indeterminate, as the efficacy of the treatment is not yet known. *Baccharis salicifolia* is a widely dispersed associate, and is not consistent in its distribution, but is generally present. Overall, woody species distribution in this community is a patchy mosaic, apart from the consistent *Populus fremontii* and *Salix gooddingii*, with a mixture of *Prosopis velutina, Celtis laevigata* var. *reticulata*, and *Sambucus nigra* ssp. *caerulea* trees and shrubs. Other associates include the shrubs *Baccharis sarothroides* and *Anisacanthus thurberi*. The herbaceous layer is a mosaic as well, but with the non-native grass, *Cynodon dactylon*, frequently present along the river channel, especially in areas that are flooded regularly. In areas where river debris is significant there is little herbaceous growth, except for stands of the non-native tall forb, *Conium maculatum*, in and around debris piles where soil has been exposed. In other areas, especially those away from persistent river flows, *Amaranthus palmeri* and *Chloris virgata* are generally dominant. Throughout the association, there is a diversity (25–30 species) of annual and perennial herbaceous plants, but they are sparse and widely dispersed.

### Classification

***Classification confidence:*** 1 - Strong
***Classification comments: Globally—***This is a mid-successional community that forms

between the herbaceous/shrub types established on lower bars following floods and mature forests of upper terraces. The moist, sandy soils are suitable for the development of a rich herbaceous understory. This type is closely related to both *Populus fremontii / Baccharis salicifolia* Woodland (CEGL000941) and *Populus fremontii - Salix gooddingii / Salix exigua* Forest (CEGL002684) (Muldavin et al. 2000). All three types, in turn, are probably refinements of the Fremont cottonwood - willow type of Laurenzi et al. (1983) and Brown et al. (1979), and the *Populus fremontii / Salix gooddingii* community type of Reichenbacher (1984) and Szaro (1989) documented for Arizona, and by Campbell and Dick-Peddie (1964) and Dick-Peddie (1993) in New Mexico.

***Tumacácori National Historical Park***—This description is based on 2007–2008 field data (10 classification plots and 6 censused polygons). The global summary and classification comments apply fairly well, but at TUMA the association generally has less abundant *B. salicifolia*, and *Prosopis velutina* is a common associate. At TUMA, this forest is supported by perennial flow in the Santa Cruz River channel derived from a municipal wastewater treatment plant.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | I | Forest |
| Formation subclass | I.B | Deciduous forest |
| Formation group | I.B.2 | Cold-deciduous forest |
| Formation subgroup | I.B.2.N | Natural/Semi-natural cold-deciduous forest |
| Formation name | I.B.2.N.d | Temporarily flooded cold-deciduous forest |
| Alliance name | *Populus fremontii* Temporarily Flooded Forest Alliance | |
| Association name | *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| CES302.748 | North American Warm Desert Lower Montane Riparian Woodland and Shrubland |
| CES302.753 | North American Warm Desert Riparian Woodland and Shrubland |

## NatureServe conservation status

***Global status:*** G2 (01Dec2000)
***Rounded global status:*** G2 - Imperiled

## Distribution

***Globally***—This association is restricted to the Gila River watershed (Grant County) and probably elsewhere in southwestern New Mexico and southern Arizona.

***Tumacácori National Historical Park***—This type is found in 6 polygons, all in the Mission unit: F-PF01-M (20.6 ha), F-PF02-M (8.2 ha), F-PF03-M (7.0 ha), F-PF04-M (3.0 ha), F-PF05-M (2.0 ha), F-PF06-M (1.1 ha).

## Environmental setting

***USFWS wetland system:*** Yes

***Environmental summary: Globally***—This community type occurs in lowland river valleys at elevations ranging from 1,220 to 1,410 m (4,000–4,625 ft). Stream gradients are moderate (0.3–0.9%), and channel substrates are gravelly or finer. Occurring on low- to mid-elevation bars within and along channels, flood recurrence intervals vary widely but typically range between two and five years. Some sites are considerably higher in the floodplain and are

rarely flooded (25–100 years). Soils are young, weakly developed Entisols that are commonly sandy with a cobbly matrix. Others, particularly those of higher terraces, are sandy or loamy throughout. The soils are generally dry on the surface most of the year, but they may be periodically moist within the rooting zone (40–150 cm).

***Tumacácori National Historical Park—***The global environmental summary generally applies at TUMA, but with the association occurring at elevations down to about 900 m. A municipal wastewater treatment facility upstream of the Mission unit provides a perennial base flow in the Santa Cruz River channel supporting this association. It is not found at Calabazas or Guevavi, upstream of the facility, due to insufficient natural flow. All reaches of the river are subject to short-duration seasonal flooding.

## Vegetation

***Globally—***This type is characterized by young to middle-aged stands of *Populus fremontii* and *Salix gooddingii* with moderate to closed canopies (usually greater than 60% cover). *Celtis laevigata* var. *reticulata, Fraxinus velutina, Juglans major, Juniperus monosperma*, and *Platanus wrightii* can occur as subcanopy associates but are never dominant. *Baccharis salicifolia* is well-represented to abundant in the shrub layer and is diagnostic. Other shrubs are scattered and may include *Amorpha fruticosa, Ericameria nauseosa (= Chrysothamnus nauseosus), Rhus trilobata* var. *trilobata*, and *Salix exigua*. The herbaceous layer can range from sparse and species-poor to well-represented and species-rich but variable. A total of 54 grasses and forbs have been recorded for the type, 7 of which were wetland indicators. The most common were *Hydrocotyle verticillata, Schoenoplectus pungens (= Scirpus pungens), Phyla lanceolata, Juncus balticus*, and *Muhlenbergia asperifolia*.

***Tumacácori National Historical Park—****Populus fremontii* is the dominant tree species of the type, while *Salix gooddingii* is a subdominant, characteristic species and is found in clumps and often as a secondary canopy of 6–8 m in height. The canopy of *Populus fremontii* averages 10–20 m high throughout the type and is generally open beneath, except for areas of thick *Tamarix ramosissima* along the river channel that are interspersed throughout the park. At the time of mapping, the NPS was conducting a tamarisk eradication program; therefore, tamarisk cover is indeterminate, as the efficacy of the treatment is yet to be determined. *Baccharis salicifolia* is widely dispersed and is not consistent in its distribution. Overall, woody species distribution in this community is a patchy mosaic, apart from the consistent *Populus fremontii* and *Salix gooddingii*, with a mixture of *Prosopis velutina, Celtis laevigata* var. *reticulata,* and *Sambucus nigra* ssp. *caerulea* trees and shrubs. Other associates are *Baccharis sarothroides* and *Anisacanthus thurberi*. The herbaceous layer is a mosaic as well, but with *Cynodon dactylon* present consistently along the river channel, especially in areas that are flooded regularly. In areas where river debris is significant there is little herbaceous growth, outside of a dominance of *Conium maculatum* in and around debris piles where soil has been exposed. In other areas, especially those away from persistent river flows, *Amaranthus palmeri* and *Chloris virgata* are generally dominant. Throughout the type there is a diversity of annual and perennial herbaceous plants, but they are sparse and widely dispersed.

***Most abundant species: Globally—***Data are not available.
***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Populus fremontii, Salix gooddingii* |
| Canopy (2–5m) | *Baccharis salicifolia, Prosopis velutina* |
| Sub-canopy (0.5–2m) | *Baccharis salicifolia, B. sarothroides, P. velutina* |
| Field (0–0.5m) | *Cynodon dactylon, Conium maculatum, Bidens leptocephala* |

***Other noteworthy species: Globally—***Data are not available.

***Tumacácori National Historical Park—****Celtis laevigata* var. *reticulata, Sambucus nigra* ssp. *caerulea, Fraxinus velutina, Hymenoclea monogyra, Anisacanthus thurberi, Amaranthus palmeri, Chloris virgata, Xanthium strumarium*

## Element sources

***Global description authors:*** E. Muldavin et al.

***Local description authors:*** S. Buckley and S. Drake

***References:*** NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: January 7, 2009 ).

- Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America with community (series) and association examples for the Southwest. Journal of the Arizona-Nevada Academy of Science 14:1-16.
- Campbell, C. J. and W. A. Dick-Peddie. 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico. Ecology 45:492-501.
- Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.
- Laurenzi, A. W., R. D. Ohmart, and N. C. Hink. 1983. Classification of mixed broadleaf riparian forests in Tonto National Forest. Pages 72-81 in: Proceedings of the workshop on Southwestern habitat types. USDA Forest Service, Southwestern Region.
- Muldavin, E., P. Durkin, M. Bradley, M. Stuever, and P. Mehlhop. 2000. Handbook of wetland vegetation communities of New Mexico: Classification and community descriptions (volume 1). Final report to the New Mexico Environment Department and the Environmental Protection Agency prepared by the New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, NM.
- Reichenbacher, F. W. 1984. Ecology and evolution of southwestern riparian plant communities. Desert Plants 6(1):15-23.
- Szaro, R. C. 1989. Riparian forest and scrubland community types of Arizona and New Mexico. Desert Plants Special Issue 9(3-4):70-139.

## *D.1.2 Prosopis velutina* Forest Alliance

***Translated name:*** Velvet mesquite Forest Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is very prevalent at TUMA, usually occupying alluvial terraces along the outermost edges of the Santa Cruz River floodplain, outside the band of *Populus fremontii - Salix gooddingii* forest along the channel, in areas that are relatively moist but rarely inundated. It sometimes occurs in narrow bands along the base of cliffs and embankments bordering the floodplain as well as at the mouths of tributary drainages as they enter the floodplain. These areas receive concentrated rainfall runoff and a steady supply of fresh alluvium from adjacent uplands, resulting in relatively deep soils and higher moisture availability without the disturbance associated with frequent flood events. Soils are sandy or sandy loam, often contain significant gravel, and have at least a thin but nearly continuous litter layer. The alliance contains several recognizable associations with different subdominant species, different structure and cover, and with *Prosopis* stands of apparently different ages. It may occur on former agricultural fields, appearing as even-aged stands of nearly uniform *Prosopis velutina* averaging 3–6 m in height, with individuals closely spaced and forming an interlocking canopy, with relatively little understory. Or it may be composed of older, larger *Prosopis* with *Celtis laevigata* var. *reticulata*, *Sambucus nigra* ssp. *caerulea*, and occasional *Salix gooddingii* interspersed, with a significant shrub understory of sapling trees, *Acacia greggii*, *Baccharis salicifolia*, *Ziziphus obtusifolia*, *Lycium andersonii* and *Anisacanthus thurberi*. In addition, there may be a diverse herbaceous layer of annual and perennial grasses and forbs, and ground-to-crown vines such as *Phaseolus ritensis*, *Clematis drummondii* and *Ipomoea* species. *Sporobolus wrightii* or *Cynodon dactylon* may dominate the herbaceous layer in places.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (6 classification plots and 7 censused polygons).

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | I | Forest |
| Formation subclass | I.B | Deciduous forest |
| Formation group | I.B.2 | Cold-deciduous forest |
| Formation subgroup | I.B.2.N | Natural/Semi-natural cold-deciduous forest |
| Formation name | I.B.2.N.a | Lowland or submontane cold-deciduous forest |
| Alliance name | *Prosopis velutina* Forest Alliance | |
| Association name | Data are not available. | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This type is found in 7 polygons: 5 at the Mission unit, 1 at Calabazas and 1 at Guevavi: F-PV01-M (7.4 ha), F-PV02-M (6.1 ha), F-PV03-M (1.2 ha), F-PV04-M (0.7 ha), F-PV05-M (0.5 ha), F-PV06-C (1.0 ha), F-PV07-G (0.6 ha).

## Environmental setting

***USFWS wetland system:*** Data are not available.

***Environmental summary: Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This proposed alliance is very prevalent at TUMA, usually occupying alluvial terraces along the outermost edges of the Santa Cruz River floodplain, outside the band of *Populus fremontii - Salix gooddingii* forest along the channel, in areas that are relatively moist but rarely inundated. It sometimes occurs in narrow bands along the base of cliffs and embankments bordering the floodplain as well as at the mouths of tributary drainages as they enter the floodplain. These areas receive concentrated rainfall runoff and a steady supply of fresh alluvium from adjacent uplands, resulting in relatively deep soils and higher moisture availability without the disturbance associated with frequent flood events. Soils are sandy or sandy loam, often contain significant gravel, and have at least a thin but nearly continuous litter layer. Other surface cover types that may be present at 1–15% include bare soil, gravel or rock, and downed wood.

## Vegetation

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**The alliance contains several recognizable associations with different subdominant species, different structure and cover, and with *Prosopis* stands of apparently different ages. It may occur on former agricultural fields, appearing as even-aged stands of nearly uniform *Prosopis velutina* averaging 3–6 m in height, with individuals closely spaced and forming an interlocking canopy, with relatively little understory. Or it may be composed of older, larger *Prosopis* with *Celtis laevigata* var. *reticulata*, *Sambucus nigra* ssp. *caerulea*, and occasional *Salix gooddingii* interspersed, with a significant shrub understory of sapling trees, *Acacia greggii*, *Baccharis salicifolia*, *Ziziphus obtusifolia*, *Lycium andersonii* and *Anisacanthus thurberi*. In addition, there may be a diverse herbaceous layer (often dominated by *Amaranthus palmeri*) of annual and perennial grasses and forbs, and ground-to-crown vines such as *Phaseolus ritensis*, *Clematis drummondii* and *Ipomoea* species. *Sporobolus wrightii* or *Cynodon dactylon* may dominate the herbaceous layer in places.

***Most abundant species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—**

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina, Sambucus nigra* ssp. *caerulea, Celtis laevigata* var. *reticulata* |
| Canopy (2–5m) | *Prosopis velutina, Acacia greggii, Celtis laevigata* var. *reticulata, Sambucus nigra* ssp. *caerulea* |
| Sub-canopy (0.5–2m) | *Prosopis velutina, Ziziphus obtusifolia, Celtis laevigata* var. *reticulata, Anisacanthus thurberi* |
| Field (0–0.5m) | *Amaranthus palmeri, Sporobolus wrightii, Bidens leptocephala, Cynodon dactylon* |

***Other noteworthy species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—***Acacia greggii* (rarely in top canopy), *Ziziphus obtusifolia* (rarely in canopy), *Baccharis salicifolia*, *Opuntia spinosior*, *Yucca elata*, *Lycium* spp., *Helianthus annuus*.

### Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## *D.1.3 Celtis laevigata* var. *reticulata* Forest Alliance

***Translated name:*** Netleaf hackberry Forest Alliance
***NatureServe code:*** A.226

### Summary

***Globally—***Dune thickets, to 6 m tall, salt-pruned, with variable admixture of other species of shrubs and dwarfed trees. These forests resemble dwarf forests or shrublands in some cases. Associations in this alliance are dominated by *Celtis laevigata*, sometimes codominated by *Zanthoxylum clava-herculis*, with *Vitis mustangensis* and *Acacia farnesiana (= Acacia smallii)* often abundant. Grazing has affected the structure and species composition of many examples. Soils are dune sands with no profile development.

***Tumacácori National Historical Park—***The above global description does not apply well to the appearance of this alliance at TUMA. Only a single association within the alliance is described (from coastal Texas and Louisiana), and it does not resemble the community at TUMA. At TUMA, this alliance is found primarily on shallow slopes that run along old agricultural fencelines. This dense forest is comprised of *Celtis laevigata* var. *reticulata* and *Prosopis velutina* that range in height from 8 to 12 m in the uppermost canopy, with considerable numbers of *Sambucus nigra* ssp. *caerulea* or *Acacia greggii* growing up underneath to a height of 4–8 m. The largest *Celtis* specimens are found immediately along the fencelines, which in isolated instances still receive runoff from actively cultivated agricultural land. This type is notable because of the multi-layered structure and density of the forest, from the interlocking top canopy to the dense sub-canopy. In the sub-canopy there is significant recruitment of *Celtis, Prosopis,* and *Sambucus*, with some *Acacia greggii* and occasional *Ziziphus obtusifolia* and *Lycium andersonii* shrubs. The herbaceous layer is notably sparse in areas beneath the denser canopies, where there is also considerable downed woody debris, but in openings there is a higher diversity of both forbs and occasional grasses. In isolated sections of this type there are *Cynodon dactylon* patches, often along foot trails.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (3 classification plots and 4 censused polygons).

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | I | Forest |
| Formation subclass | I.B | Deciduous forest |
| Formation group | I.B.2 | Cold-deciduous forest |
| Formation subgroup | I.B.2.N | Natural/Semi-natural cold-deciduous forest |
| Formation name | I.B.2.N.a | Lowland or submontane cold-deciduous forest |
| Alliance name | *Celtis laevigata* var. *reticulata* Forest Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—United States

***Tumacácori National Historical Park***—This type is found in 4 polygons: 2 at the Mission unit, 1 at Calabazas and 1 at Guevavi: F-CL01-M (1.1 ha), F-CL02-M (0.7 ha), F-CL03-C (1.3 ha), F-CL04-G (0.7 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally***—Grazing has affected the structure and species composition of many examples. Soils are dune sands with no profile development.

***Tumacácori National Historical Park***—This alliance is found primarily on shallow slopes that run along old agricultural fencelines.

## Vegetation

***Globally***—Associations in this alliance are dominated by *Celtis laevigata*, sometimes codominated by *Zanthoxylum clava-herculis*, with *Vitis mustangensis* often abundant.

***Tumacácori National Historical Park***—This dense forest is comprised of *Celtis laevigata* var. *reticulata* and *Prosopis velutina* that range in height from 8 to 12 m in the uppermost canopy, with considerable numbers of *Sambucus nigra* ssp. *caerulea* or *Acacia greggii* growing up underneath to a height of 4–8 m. The largest *Celtis* specimens are found immediately along old fencelines, which in isolated instances still receive runoff from actively cultivated agricultural land. This type is notable because of the multi-layered structure and density of the forest, from the interlocking top canopy to the dense sub-canopy. In the sub-canopy there is significant recruitment of *Celtis*, *Prosopis*, and *Sambucus*, with some *Acacia greggii* and occasional *Ziziphus obtusifolia* and *Lycium andersonii* shrubs. The herbaceous layer is notably sparse in areas beneath the denser canopies, where there is also considerable downed woody debris, but in openings there is a higher diversity of both forbs and occasional grasses. In isolated sections of this type there are *Cynodon dactylon* patches, often along foot trails.

***Most abundant species: Globally***—Data are not available.
***Tumacácori National Historical Park***—

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Celtis laevigata* var. *reticulata, Prosopis velutina* |
| Canopy (2–5m) | *Celtis, Prosopis, Sambucus nigra* ssp. *caerulea, Acacia greggii* |
| Sub-canopy (0.5–2m) | *Celtis, Prosopis, Sambucus, Acacia greggii, Ziziphus obtusifolia* |
| Field (0–0.5m) | *Sporobolus wrightii, Amaranthus palmeri* |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Salix gooddingii*, *Anisacanthus thurberi*, *Bouteloua curtipendula*, *Cynodon dactylon*, *Rivina humilis*, *Bidens leptocephala*, *Helianthus annuus*, *Chenopodium* spp.

## Element sources

***Global description authors:*** A. S. Weakley/L. M. Smith. Ecological data developed by NatureServe and its network of natural heritage programs and other contributors and cooperators.

***Local description authors:*** S. Buckley and S. Drake

***References:*** Data are not available.

# D.2 Woodland

## *D.2.1 Populus fremontii - Salix gooddingii* Woodland

***Translated name:*** Fremont cottonwood - Goodding's willow Woodland
***NatureServe code:*** A.644, CEGL000944

### Summary

***Globally—***This community occurs as small isolated stands or as linear bands that parallel stream channels in the Trans-Pecos region of western Texas, in southwestern New Mexico, southeastern Arizona, and south into northern Mexico. It has also been reported from isolated tributary drainages in southern Utah. The vegetation is dependent upon a subsurface water supply and varies considerably with the height of the water table. Major flood events and consequent flood scour, overbank deposition of water and sediments, and stream meandering are important factors that shape this community. Soils are typically stratified sands, loams, and gravels. This deciduous woodland typically towers above the surrounding vegetation. *Populus fremontii* and *Salix gooddingii* may be nearly equal in abundance, or either may dominate. Individuals of *Populus fremontii* are scattered or occur in groves and may reach 30 m in height and 2 m in diameter. Other species that may occur in the canopy/subcanopy include *Populus deltoides* ssp. *wislizeni, Salix lasiolepis, Salix amygdaloides, Fraxinus berlandieriana, Celtis laevigata* var. *reticulata, Juglans microcarpa, Prosopis pubescens, Prosopis glandulosa*, and *Prosopis velutina*. The understories of most examples have been considerably altered by grazing and other factors, thus the composition and cover of the native understory is difficult to ascertain but frequently consists of shrubs and small trees (1–5 m tall). The herbaceous stratum varies in composition and coverage but is characterized by mixed annuals and short-lived perennials.

***Tumacácori National Historical Park—***This woodland association is similar in composition to the *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest that occurs throughout the park, but has lower plant density and cover. In particular, it has less than 60% tree cover, and Forest has more than 60% tree cover, following the NVC definitions. The type is located in the river floodplain, between an ephemeral channel on the west and savanna types surrounding it on the south, north, and east. It is dominated by *Populus fremontii*, with a patchy canopy and the inclusion of *Salix gooddingii* in specific areas. *Baccharis salicifolia* is generally the dominant shrub. The entire type is on a slightly elevated sandy-silty island and has considerable downed woody debris piled up throughout. Beneath the *Populus fremontii* canopy, the understory is relatively open and has more herbaceous plants than shrubs, dominated by *Hilaria belangeri*, *Cynodon dactylon*, and the annual grass *Chloris virgata*. The annual forb *Bidens leptocephala* is characteristically found in dense concentrations in the shade. Shrubs are often distinctly clumped and diverse, ranging from *Hymenoclea monogyra, Baccharis salicifolia* and *Senecio flaccidus* to specimens of *Opuntia spinosior*. Throughout the type, *Amaranthus palmeri* and *Salsola kali* are present but not in the same density as they are found in neighboring wooded-herbaceous or shrub-herbaceous types.

### Classification

***Classification confidence:*** 2 - Moderate
***Classification comments: Globally—***In Trans-Pecos Texas, this woodland is dependent on a subsurface water supply and varies considerably with the water table levels. Major flood events and consequent flood scour, overbank deposition of water and sediments, and stream meandering are important factors that shape this community. These woodlands once occupied the floodplains and riverbanks of most perennial waterways within its range, but have mostly been replaced by disturbance types dominated by exotic species.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (6 classification plots and 3 censused polygons). At TUMA, this woodland is supported by perennial flow in the Santa Cruz river channel derived from a municipal wastewater treatment plant.

*Vegetation hierarchy*

| | | |
|---|---|---|
| Formation class | II | Woodland |
| Formation subclass | II.B | Deciduous woodland |
| Formation group | II.B.2 | Cold-deciduous woodland |
| Formation subgroup | II.B.2.N | Natural/Semi-natural cold-deciduous woodland |
| Formation name | II.B.2.N.b | Temporarily flooded cold-deciduous woodland |
| Alliance name | *Populus fremontii* Temporarily Flooded Woodland Alliance | |
| Association name | *Populus fremontii - Salix gooddingii* Woodland | |

*Ecological systems placement*

| Ecological system unique ID | Ecological system name |
|---|---|
| CES302.748 | North American Warm Desert Lower Montane Riparian Woodland and Shrubland |
| CES302.753 | North American Warm Desert Riparian Woodland and Shrubland |
| CES306.821 | Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland |

## NatureServe conservation status

***Global status:*** G2 (23Feb1994)
***Rounded global status:*** G2 - Imperiled

## Distribution

***Globally***—AZ, CA, CO, NM, TX, UT

***Tumacácori National Historical Park***—This type is found in 3 polygons, all at the Mission unit: W-PF01-M (0.6 ha), W-PF02-M (13.4 ha), W-PF03-M (2.5 ha).

## Environmental setting

***USFWS wetland system:*** Yes

***Environmental summary: Globally***—This deciduous woodland is best developed along alluvial floodplains of large, low-gradient, perennial streams that flow through wide, unconstrained valleys. It has also been recorded surrounding perennially wet potholes within intermittent canyon drainages, as well as in the floodplains of intermittent streams. The vegetation is dependent upon a subsurface water supply and varies considerably with the height of the water table. Major flood events and consequent flood scour, overbank deposition of water and sediments, and stream meandering are important factors that shape this community. Soils are typically stratified sands, loams, and gravels classified as Torrifluvents or Ustifluvents, with Haplustolls on more stable sites. These coarse-textured, alluvial sediments have a low water-holding capacity and low nutrient availability.

***Tumacácori National Historical Park***—The global environmental summary applies to this association at TUMA. At TUMA, the association is located in the river floodplain, between an ephemeral channel on the west and savanna types surrounding it on the south, north, and east.

## Vegetation

***Globally***—This community occurs as small isolated stands or as narrow bands that parallel the stream channel or border a pothole. This deciduous woodland typically towers above the surrounding vegetation, with *Populus fremontii* and *Salix gooddingii* as the dominant species. These species may be nearly equal in abundance, or either may dominate. Individuals of

*Populus fremontii* are scattered or occur in groves and may reach 30 m in height and 2 m in diameter. Other species that may occur in the canopy/subcanopy include *Populus deltoides* ssp. *wislizeni, Salix lasiolepis, Salix amygdaloides, Fraxinus berlandieriana, Celtis laevigata* var. *reticulata, Fraxinus velutina, Juglans microcarpa, Prosopis pubescens, Prosopis glandulosa*, and *Prosopis velutina*. The understory of most examples has been considerably altered by grazing and other factors, thus the composition and cover of the native understory is difficult to ascertain. The understory can be dense to open and frequently consists of shrubs and small trees 1–5 m tall, including *Prosopis* spp., *Baccharis salicifolia, Salix exigua, Sambucus mexicana, Rhamnus* spp., *Morus microphylla*, and *Amorpha fruticosa*. The woody exotics *Elaeagnus angustifolia* and various species of *Tamarix* now dominate the understory of most examples. The herbaceous stratum varies in composition and coverage but is characterized by mixed annuals and short-lived perennials. While most examples now have a herbaceous flora dominated by exotic species, in particular *Cynodon dactylon*, native species reported from this community include *Amaranthus palmeri, Amsinckia* spp., *Anemopsis californica, Boerhavia coccinea, Bowlesia incana, Carex* spp., *Chloracantha spinosa, Conyza canadensis* var. *canadensis, Cucurbita* spp., *Datura wrightii, Distichlis spicata, Euthamia occidentalis, Gutierrezia sarothrae, Juncus balticus, Lemna* spp., *Oenothera* spp., *Sorghum halepense, Sporobolus wrightii*, and *Trifolium longipes* ssp. *shastense*.

***Tumacácori National Historical Park***—This type is similar in composition to the *Populus fremontii - Salix gooddingii / Baccharis salicifolia* Forest found throughout the park, but has lower plant density and cover. It is dominated by *Populus fremontii*, with a patchy canopy and the inclusion of *Salix gooddingii* in specific areas. *Baccharis salicifolia* is generally the dominant shrub. The association is confined to a slightly elevated sandy-silty island and has considerable downed woody debris piled up throughout. Beneath the *Populus fremontii* canopy the understory is relatively open and has more herbaceous plants than shrubs, dominated by *Hilaria belangeri*, *Cynodon dactylon*, and the annual grass *Chloris virgata*. The annual forb *Bidens leptocephala* is characteristically found in dense concentrations in the shade. Shrubs are often distinctly clumped and diverse, ranging from *Hymenoclea monogyra, Baccharis salicifolia* and *Senecio flaccidus* to specimens of *Opuntia spinosior*. Throughout the type, *Amaranthus palmeri* and *Salsola kali* are present but at lower density than is found in neighboring wooded-herbaceous or shrub-herbaceous types.

***Most abundant species: Globally—***

| Stratum | Species |
|---|---|
| Tree canopy | *Populus fremontii, Salix gooddingii* |
| Tree sub-canopy | *Fraxinus velutina* |

***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Populus fremontii, Salix gooddingii* |
| Canopy (2–5m) | *Baccharis salicifolia, Prosopis velutina, Hymenoclea monogyra, Sambucus nigra* ssp. *caerulea, Tamarix ramosissima* |
| Sub-canopy (0.5–2m) | *Baccharis salicifolia, Hymenoclea monogyra* |
| Field (0–0.5m) | *Cynodon dactylon, Amaranthus palmeri, Chloris virgata* |

***Other noteworthy species: Globally—***
***Tumacácori National Historical Park—****Celtis laevigata* var. *reticulata, Baccharis sarothroides, Ziziphus obtusifolia, Bidens leptocephala*

## Element sources

***Global description authors:*** E. Milford and E. Muldavin
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## *D.2.2 Prosopis velutina* Woodland Alliance

***Translated name:*** Velvet mesquite Woodland Alliance
***Alternative name:*** *Prosopis (glandulosa, velutina)* Woodland Alliance; Honey mesquite, Velvet mesquite Woodland Alliance
***NatureServe code:*** A.661

### Summary

***Globally—***This alliance occurs in southern California, Arizona, and possibly southwestern New Mexico and adjacent Mexico on a variety of sites. Sites include mesic areas such as floodplains, streambanks, intermittently flooded arroyo terraces, alkali sinks and washes, and extends into the upland on dry terraces above streams and arroyos. Substrates are generally coarse-textured, gravelly alluvium. *Prosopis* spp. trees extract groundwater with extensive root systems, but grow best where water tables are shallow such as along drainages. Woodlands included in this alliance are characterized by a moderate to dense tall woody canopy dominated by *Prosopis glandulosa* and/or *Prosopis velutina*. The diversity of other species can vary greatly with geography and substrate. The dominant understory shrubs are often species of *Atriplex*, but may include many other species. Succulents may include several species of *Opuntia* and *Yucca*. The herbaceous layer is variable from moderately dense to nearly absent. Characteristic perennial grasses may include *Aristida* spp., *Bouteloua* spp., *Buchloe dactyloides, Pleuraphis mutica (= Hilaria mutica), Muhlenbergia porteri*, and *Sporobolus* spp. Sparse annual grasses may also be present. Forb cover is also sparse, but it can be relatively diverse. Common forbs may include species of *Amaranthus, Chenopodium, Croton, Eriogonum, Euphorbia, Solanum*, and *Zinnia*. Diagnostic of this woodland alliance is the dominance of tree-sized *Prosopis glandulosa* or *Prosopis velutina* in the upper canopy.

***Tumacácori National Historical Park—***This woodland alliance generally occurs further away from the river channel than the forest alliances, in more xeric sites. Plant canopy cover varies, up to about 50%, with significant open or nearly-open patches possibly present. *Prosopis velutina* is usually clearly dominant in both height and canopy cover, but in places, *Acacia greggii*, commonly the second-dominant species, is a close rival. Within this type, *A. greggii* (and to a lesser extent *P. velutina*) can be found as a tree lifeform, a shrub lifeform, or something intermediate. The *Prosopis*-dominated upper canopy averages 6–8 m in height, ranging to 10 m. In addition to *A. greggii*, occasional *Sambucus nigra* ssp. *caerulea* and *Celtis laevigata* var. *reticulata* individuals may also reach this height and, in one patch of this alliance, a few *Populus fremontii* and *Salix gooddingii* exceed it. In the sub-canopy, *Prosopis* and *Acacia* still dominate (as caespitose shrubs to sapling trees), with common associates being *Celtis* and *Sambucus* saplings, *Ziziphus obtusifolia*, *Mimosa aculeaticarpa* var. *biuncifera*, *Baccharis sarothroides*, *B. salicifolia*, *Anisacanthus thurberi*, *Hymenoclea monogyra*, *Lycium andersonii* and *Condalia warnockii*. The herbaceous layer is almost everywhere dominated by *Amaranthus palmeri*, occasionally by *Cynodon dactylon*. Important associates are *Bouteloua curtipendula*, *Salsola kali*, *Chenopodium* sp., *Bidens leptocephala* and *Chloris virgata*, but a variety of other grasses and forbs may occur.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Classification of *Prosopis glandulosa*- and *Prosopis velutina*-dominated stands needs clarification. Because *Prosopis glandulosa* and *Prosopis velutina* can have both shrub and tree growth forms, there may be confusion classifying a given stand. For example, what characteristic separates a *Prosopis glandulosa* or *Prosopis velutina* arroyo riparian shrubland from a *Prosopis glandulosa* and/or *Prosopis velutina* 'bosque' or riparian woodland. Riparian shrublands can mature into woodlands if given time and adequate water resources.

Currently, this alliance has only one provisional association from California and Arizona with possible occurrences in New Mexico and Baja California and Sonora, Mexico. There are

several references to *Prosopis (glandulosa, velutina)* riparian woodland/forests from sub-Mogollon Arizona such as Minckley and Clark (1981, 1984) and Szaro (1989). Warren et al. (1981) describe *Prosopis glandulosa* riparian woodlands from southwestern Arizona that could be included in the provisional association within *Prosopis (glandulosa, velutina)* Woodland Alliance (A.661). Another provisional association may need to be created for the *Prosopis glandulosa* woodlands occurring in the San Joaquin Valley in California.

No associations outside of Texas have been described in the *Prosopis glandulosa* woodland or *Prosopis glandulosa* intermittently flooded woodland alliances. These woodlands appear significantly different, but more study is needed to clarify the boundaries between the Texas and California/Arizona alliances. Some arroyo riparian stands in Arizona are similar to stands in the *Parkinsonia florida - Olneya tesota* Woodland Alliance (A.588) as far as species composition and must be separated mainly by dominance.

The taxonomy of *Prosopis* may further complicate the classification. There are three varieties of *Prosopis glandulosa, Prosopis glandulosa* var. *glandulosa* which occurs in New Mexico, Texas, Colorado, Kansas, Oklahoma and Louisiana, *Prosopis glandulosa* var. *torreyana* which occurs in California, Nevada, Utah, Arizona, New Mexico and Texas, and *Prosopis glandulosa* var. *prostrata* which occurs only in Texas. *Prosopis velutina* is restricted to California, Arizona and New Mexico. Szaro (1989) describes a *Prosopis velutina* riparian community type (shrublands and woodlands) from southwestern New Mexico to western Arizona. In addition, *Prosopis glandulosa* var. *torreyana* and *Prosopis velutina* are known to intergrade where ranges overlap in southern Arizona (Kearney and Peebles 1969). See Benson and Darrow (1981) for more discussion.

***Tumacácori National Historical Park***—This description is based on 2007–2008 field data (11 classification plots and 8 censused polygons). At TUMA, velvet mesquite, *Prosopis velutina*, is the dominant; no *P. glandulosa* was observed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | II | Woodland |
| Formation subclass | II.B | Deciduous woodland |
| Formation group | II.B.3 | Extremely xeromorphic deciduous woodland |
| Formation subgroup | II.B.3.N | Natural/Semi-natural extremely xeromorphic deciduous woodland |
| Formation name | II.B.3.N.a | Thorn extremely xeromorphic deciduous woodland |
| Alliance name | *Prosopis (glandulosa, velutina)* Woodland Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

## NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—Mexico, United States. Woodlands included in this alliance occur along drainages in southern California, Arizona and possibly in southwestern New Mexico, and the Mexican states of Baja California, Sonora, and Chihuahua.

***Tumacácori National Historical Park*—**This type is found in 8 polygons: 4 at the Mission unit, 3 at Guevavi and 1 at Calabazas: W-PV01-M (9.6 ha), W-PV02-M (1.4 ha), W-PV03-M (1.2 ha), W-PV04-M (1.7 ha), W-PV05-G (1.3 ha), W-PV06-G (0.8 ha), W-PV07-G (0.5 ha), W-PV08-C (1.0 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally*—**Woodlands included in this alliance occur in southern California, Arizona, and possibly southwestern New Mexico and adjacent Mexico. Elevations range from sea level to 1,200 m. Climate is arid to semi-arid. Amount and season of precipitation is varies with geography. Mean annual precipitation ranges from 23 cm distributed bimodally with about half occurring during the late summer monsoons and half in the winter in southwestern New Mexico, to approximately 15 cm of mostly winter precipitation in southeastern California. This vegetation occurs on a variety of sites. Mesic sites include floodplains, streambanks, intermittently flooded arroyo terraces, alkali sinks and washes. Upland sites such as the rarely flooded and dry terraces above streams and arroyos. Sites are generally flat or gently sloping on any aspect. Parent material is usually sandy or gravelly alluvium. Substrates are generally coarse-textured, but may include gravelly silty loams. Some soils are moderately saline. *Prosopis* spp. trees extract ground water with extensive root systems, but grow best where water tables are shallow such as along drainages. These woodlands may grade into upland grasslands dominated by species of *Bouteloua, Sporobolus* or *Hilaria*, or be surrounded by a matrix of desertscrub that is dominated by *Larrea tridentata* or *Ambrosia* spp. In the San Joaquin Valley, Holland (1986) describes sites occurring on sandy loams with high water tables, hot-dry summers and foggy winters. The water table is fed from Sierran snowmelt.

***Dynamics:*** *Prosopis* and other shrubs have extensive root systems that allow them to exploit deep soil water that is unavailable to shallower rooted grasses and cacti (Burgess 1995). This strategy works well except on sites that have well-developed argillic or calcic soil horizons that limit infiltration and storage of winter moisture in the deeper soil layers (McAuliffe 1995). McAuliffe (1995) found *Prosopis* spp. invasion on these sites limited to a few, small individuals. This has implications in plant geography and grassland revegetation work in the southwestern U.S.

***Tumacácori National Historical Park*—**This woodland alliance generally occurs further away from the river channel than the forest alliances, in more xeric sites on terraces above the active channel. Surface cover is generally mesquite litter and bare soil, but may be gravelly or rocky. Stands vary in density, layered structure (complexity) and height, probably as a function of their age and grazing history.

## Vegetation

***Globally*—**Woodlands included in this alliance occur primarily along drainages in southern California and possibly southwestern New Mexico, Arizona, and adjacent Mexico. Stands have moderate to dense cover dominated by the xeromorphic deciduous shrubs *Prosopis glandulosa* and/or *Prosopis velutina*. The diversity of other species can vary greatly with geography and substrate. The dominant understory shrubs are often species of *Atriplex*, but may include *Acacia greggii, Acacia constricta, Ambrosia* spp., *Artemisia filifolia, Baccharis* spp., *Chilopsis linearis, Ericameria laricifolia, Gutierrezia sarothrae, Larrea tridentata, Lycium* spp., *Parkinsonia* spp., *Olneya tesota*, and *Ziziphus obtusifolia*. Succulents may include *Opuntia acanthocarpa, Opuntia leptocaulis, Opuntia imbricata, Opuntia phaeacantha, Yucca baccata*, and *Yucca elata*. The herbaceous layer can be moderately dense to insignificant depending on geography, substrate, land use history and annual precipitation the herbaceous layer can be moderately dense to insignificant. Characteristic perennial grasses may include *Aristida* spp., *Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Buchloe dactyloides, Pleuraphis mutica (= Hilaria mutica), Muhlenbergia porteri, Sporobolus flexuosus*, and *Sporobolus wrightii*. Sparse annual grasses may include *Aristida adscensionis, Bouteloua barbata*, and *Dasyochloa pulchella*

*(= Erioneuron pulchellum)*. Forb cover is also sparse, but it can be relatively diverse. Common forbs may include species of *Amaranthus, Chenopodium, Croton, Eriogonum, Euphorbia, Solanum*, and *Zinnia*. In more saline areas, shrubs are more sparse and grasses and forbs are more common, including *Sporobolus airoides, Distichlis spicata*, and *Sesuvium verrucosum*. Holland (1986) described open *Prosopis glandulosa* woodlands in the San Joaquin Valley in southern California, that have a shrub layer dominated by *Atriplex polycarpa* with *Isocoma acradenia* var. *bracteosa*. The herbaceous layer is sparse except during wet years when annual cover, dominated by the exotic grass *Bromus rubens*, is abundant. Perennial plant cover is sparse.

***Tumacácori National Historical Park***—In this woodland alliance, plant canopy cover varies, up to about 50%, with significant open or nearly-open patches possibly present. *Prosopis velutina* is usually clearly dominant in both height and canopy cover, but in places *Acacia greggii*, commonly the second-dominant species, is a close rival. Within this type, *A. greggii* (and, to a lesser extent, *P. velutina*) can be found as a tree lifeform, a shrub lifeform, or something intermediate. The *Prosopis*-dominated upper canopy averages 6–8 m in height, ranging to 10 m. In addition to *A. greggii*, occasional *Sambucus nigra* ssp. *caerulea* and *Celtis laevigata* var. *reticulata* individuals may reach this height also, and in one patch of this type a few *Populus fremontii* and *Salix gooddingii* exceed it. In the sub-canopy *Prosopis* and *Acacia* still dominate (as caespitose shrubs to sapling trees), with common associates being *Celtis* and *Sambucus* saplings, *Ziziphus obtusifolia* shrubs, *Mimosa aculeaticarpa* var. *biuncifera*, *Baccharis sarothroides*, *B. salicifolia*, *Anisacanthus thurberi*, *Hymenoclea monogyra*, *Lycium andersonii* and *Condalia warnockii*. The herbaceous layer is almost everywhere dominated by *Amaranthus palmeri*, occasionally by *Cynodon dactylon*. Important associates are *Bouteloua curtipendula*, *Salsola kali*, *Chenopodium* sp., *Bidens leptocephala* and *Chloris virgata*, but a variety of other grasses and forbs may occur.

***Most abundant species: Globally—***

| Stratum | Species |
|---|---|
| Tree canopy | *Prosopis glandulosa or P. velutina* |
| Tall shrub/sapling | *Acacia greggii* |
| Short shrub/sapling | *Atriplex canescens* |

***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina, Acacia greggii* |
| Canopy (2–5m) | *Prosopis velutina, Acacia greggii, Celtis laevigata* var. *reticulata* |
| Sub-canopy (0.5–2m) | *Prosopis velutina, Acacia greggii,Baccharis sarothroides, Ziziphus obtusifolia, Mimosa aculeaticarpa* var. *biuncifera* |
| Field (0–0.5m) | *Amaranthus palmeri, Salsola kali,Bidens leptocephala, Bouteloua* spp. |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Celtis laevigata* var. *reticulata* and *Sambucus nigra* ssp. *caerulea* (in top canopy), *Lycium andersonii, Hymenoclea monogyra, Anisacanthus thurberi, Cynodon dactylon, Chloris virgata*.

## Element sources

***Global description authors:*** K. Schulz. Ecological data developed by NatureServe and its network of natural heritage programs and other contributors and cooperators

***Local description authors:*** S. Buckley and S. Drake

*References:*


- Benson and Darrow 1981: Data are not available.
- Burgess, T. L. 1995. Desert grassland, mixed shrub savanna, shrub steppe, or semi-desert scrub. Pages 31-67 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.
- Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. Unpublished report prepared for the California Department of Fish and Game, Nongame-Heritage Program and Natural Diversity Database, Sacramento. 156 pp.
- Kearney, T. H., and R. H. Peebles, and collaborators. 1969. Arizona flora. University of California, Berkeley, CA. 1085 pp.
- McAuliffe, J. R. 1995. Landscape evolution, soil formation, and Arizona's desert grasslands. Pages 100-129 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.
- Minckley, W. L., and T. O. Clark. 1981. Vegetation of the Gila River resource area, eastern Arizona. Desert Plants 3:124-140.
- Minckley, W. L., and T. O. Clark. 1984. Formation and destruction of a Gila River mesquite bosque community. Desert Plants 6(1):23-30.
- Szaro, R. C. 1989. Riparian forest and scrubland community types of Arizona and New Mexico. Desert Plants Special Issue 9(3-4):70-139.
- Warren et al. 1995: Data are not available.

## *D.2.3 Acacia greggii* Woodland Alliance

***Translated name:*** Catclaw acacia Woodland Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is dominated by *Acacia greggii* and *Prosopis velutina* trees 6–8 m tall, and shorter *Acacia greggii* and *Ziziphus obtusifolia* shrubs. Associated shrub species, such as *Condalia warnockii*, *Baccharis sarothroides*, *Lycium andersonii*, *Hymenoclea monogyra,* and *Anisacanthus thurberi,* are scattered across the type. Most of the trees and shrubs in this alliance have such thick, dense canopies that herbaceous plants are largely confined to the interspaces between overstory canopies. The herbaceous layer is dominated by the annual forbs, *Amaranthus palmeri* and *Bidens leptocephala*, with a variety of other forbs and grasses possibly present and generally sparsely distributed.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (2 classification plots and 1 censused polygon). Lifeform of the *A. greggii* (and many *Prosopis*) in this type is somewhat ambiguous, as individuals are generally multi-stemmed at or near the ground surface, but are about 6.5 m tall and have an elevated canopy, so they were considered trees for classification. This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | II | Woodland |
| Formation subclass | II.B | Deciduous woodland |
| Formation group | II.B.3 | Extremely xeromorphic deciduous woodland |
| Formation subgroup | II.B.3.N | Natural/Semi-natural extremely xeromorphic deciduous woodland |
| Formation name | II.B.3.N.a | Thorn extremely xeromorphic deciduous woodland |
| Alliance name | *Acacia greggii* Woodland Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

### Distribution

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This type is found in 1 polygon at the Mission unit: W-AG01-M (2.1 ha).

### Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally*—**Data are not available.

***Tumacácori National Historical Park*—**The single stand of this type lies on the west boundary of the Mission unit, on a terrace relatively distant from the present river channel and adjacent to upland shrub-dominated vegetation. Surface cover is primarily litter, bare soil and rock (smooth river cobbles).

## Vegetation

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This type is dominated by *Acacia greggii* and *Prosopis velutina* trees 6–8 m tall, and shorter *Acacia greggii* and *Ziziphus obtusifolia* shrubs. Associated shrub species, such as *Condalia warnockii, Mimosa aculeaticarpa* var. *biuncifera, Baccharis sarothroides, Lycium andersonii, Hymenoclea monogyra,* and *Anisacanthus thurberi,* are scattered across the type. Most of the trees and shrubs in this alliance have such thick, dense canopies that herbaceous plants are largely confined to the interspaces between overstory canopies. The herbaceous layer is dominated by the annual forbs *Amaranthus palmeri* and *Bidens leptocephala*, with a variety of other forbs and grasses possibly present and generally sparsely distributed.

***Most abundant species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—**

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Acacia greggii, Prosopis velutina* |
| Canopy (2–5m) | *Acacia greggii, Prosopis velutina* |
| Sub-canopy (0.5–2m) | *Ziziphus obtusifolia, Acacia greggii, Lycium andersonii* |
| Field (0–0.5m) | *Amaranthus palmeri, Salsola kali, Bidens leptocephala* |

***Other noteworthy species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—***Celtis laevigata* var. *reticulata*, *Mimosa aculeaticarpa* var. *biuncifera*, *Baccharis sarothroides*, *Prospois velutina*, *Chenopodium sp.*, *Bouteloua radicosa*, *Eragrostis cilianensis*.

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

# D.3 Wooded Shrubland

## *D.3.1 Prosopis velutina / [Prosopis velutina - Acacia greggii]* Wooded Shrubland Alliance

***Translated name:*** *Velvet mesquite / [Velvet mesquite - Catclaw acacia]* Wooded Shrubland Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance covers the largest area at the Calabazas unit, including the portion surrounding the ruins. Although primarily found on gently sloped upland, this type also extends down steeper, relatively xeric slopes south and west of the ruins. These areas have very thin, sandy, or gravelly soils, with minimal litter except on toe slopes. Larger rocks or bedrock outcrops are usually visible. There is one stand of this type at the Mission unit adjacent to abandoned agricultural land, on deeper, loamier soil. This alliance is characterized by an open canopy of *Prosopis velutina* shrubs, mostly 2–4 m tall but with many larger, tree-lifeform individuals up to 7.5 m. These *Prosopis* and the other trees present make up >10% cover. *Acacia greggii* is common in the shrub layer; it is usually, but not always, less abundant than *Prosopis,* and also averages 2–4 m tall. Density of the shrub layer is variable. In more xeric areas, *Baccharis sarothroides* may have significant cover and *A. greggii* may be absent or nearly so. *Acacia constricta* and *Mimosa aculeaticarpa* var. *biuncifera* are generally present. Other woody associates vary by topographic position: a few individuals of *Juniperus coahuilensis, Condalia warnockii,* and *Opuntia spinosior* are present on the hilltop flats and adjacent upper slopes, while *Ziziphus obtusifolia, Celtis laevigata* var. *reticulata, Anisacanthus thurberi,* and *Lycium andersonii* may be found on more mesic middle- and toe-slopes. Most of the larger *P. velutina* are also found in these more mesic areas. *Amaranthus palmeri* and *Bidens leptocephala*, which may be dense in localized patches, are the only abundant forbs in an otherwise grass-dominated (*Bouteloua curtipendula, Sporobolus wrightii, Chloris virgata, Muhlenbergia porteri*) herbaceous layer.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (8 classification plots and 2 censused polygons).

***Vegetation hierarchy***

| | |
|---|---|
| Formation class | Data are not available |
| Formation subclass | Data are not available |
| Formation group | Data are not available |
| Formation subgroup | Data are not available |
| Formation name | Wooded Shrubland |
| Alliance name | *Prosopis velutina / [Prosopis velutina – Acacia greggii]* Wooded Shrubland Alliance |
| Association name | Data are not available |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—Data are not available.

***Tumacácori National Historical Park***—This type is found in 2 polygons: 1 at the Mission unit and 1 at Calabazas: WS-PV01-M (0.6 ha), WS-PV02-C (6.5 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally***—Data are not available.

***Tumacácori National Historical Park***—This alliance covers the largest area at the Calabazas unit, including the portion surrounding the ruins. Although primarily found on gently sloped upland, this type also extends down steeper, relatively xeric hillslopes. These areas have very thin, sandy or gravelly soils with minimal litter except on toe slopes. Larger rocks or bedrock outcrops are usually visible. There is one stand of this type at the Mission unit adjacent to abandoned agricultural land, on deeper, loamier soil.

## Vegetation

***Globally***—Data are not available.

***Tumacácori National Historical Park***—This alliance is characterized by an open canopy of *Prosopis velutina* shrubs, mostly 2–4 m tall but with many larger, tree-lifeform individuals up to 7.5 m. These *Prosopis* and the other trees present make up >10% cover. *Acacia greggii* is common in the shrub layer; it is usually, but not always, less abundant, and also averages 2–4 m tall. Density of the shrub layer is variable. In more xeric areas, *Baccharis sarothroides* may have significant cover and *A. greggii* may be absent or nearly so. *Acacia constricta* and *Mimosa aculeaticarpa* var. *biuncifera* are generally present. Other woody associates vary by topographic position: a few individuals of *Juniperus coahuilensis, Condalia warnockii* and *Opuntia spinosior* are present on the hilltop flats and adjacent upper slopes, while *Lycium andersonii, Ziziphus obtusifolia, Anisacanthus thurberi,* and *Celtis laevigata* var. *reticulata,* may be found on more mesic middle- and toe-slopes. Most of the larger *P. velutina* are also found in these more mesic areas. *Amaranthus palmeri* and *Bidens leptocephala*, which may be dense in localized patches, are the only abundant forbs in an otherwise grass-dominated (*Bouteloua curtipendula, Sporobolus wrightii, Chloris virgata, Muhlenbergia porteri*) herbaceous layer.

***Most abundant species: Globally***—Data are not available.
***Tumacácori National Historical Park***—

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina, Acacia greggii* |
| Canopy (2–5m) | *Acacia greggii, Prosopis velutina, Lycium andersonii* |
| Sub-canopy (0.5–2m) | *Acacia greggii, Lycium andersonii* |
| Field (0–0.5m) | *Chloris virgata, Bouteloua curtipendula, Amaranthus palmeri, Bidens leptocephala* |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Ziziphus obtusifolia*, *Baccharis sarothroides*, *Acacia constricta*, *Mimosa aculeaticarpa* var. *biuncifera, Anisacanthus thurberi, Sporobolus wrightii, Sporobolus cryptandrus*

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

# D.4 Shrubland

## *D.4.1 Prosopis velutina - Acacia greggii* Shrubland

***Translated name:*** Velvet mesquite - Catclaw acacia Shrubland
***NatureServe code:*** A.1043 / CEGL001388

### Summary

***Globally (Alliance)***—This shrubland alliance occurs in the Chihuahuan and Sonoran deserts. Sites include sandy plains, mesas, bajadas, drainage terraces and channels, floodplains, and rocky slopes. Although *Prosopis velutina* is deep-rooted, it typically occurs on sites with shallow water tables, especially along arroyos. Sites are generally flat or on gentle to moderate south-facing slopes. Substrates are generally coarse-textured, but may include gravelly clay loams. Some sites are moderately saline. Shrublands included in this alliance are dominated by the shrub/small tree *Prosopis velutina*. *Acacia greggii* and *Celtis laevigata* var. *reticulata* are frequent riparian scrub co-dominants. These shrublands often have high shrub diversity and may include *Acacia constricta, Chilopsis linearis, Ericameria laricifolia, Gutierrezia sarothrae, Hymenoclea salsola, Isocoma tenuisecta, Juniperus monosperma, Larrea tridentata, Mimosa aculeaticarpa* var. *biuncifera (= Mimosa biuncifera)*, and *Rhus* spp. The herbaceous layer has sparse to moderate cover of medium-tall and short perennial grasses. Characteristic perennial grasses include *Aristida* spp., *Bouteloua curtipendula, Bouteloua eriopoda, Dasyochloa pulchella (= Erioneuron pulchellum), Elymus elymoides, Hilaria belangeri, Muhlenbergia porteri*, and *Sporobolus* spp. Annual grasses are present, but have sparse cover. Forbs are also sparse, but may include species of *Datura, Mentzelia, Polanisia*, and *Rumex*. Succulents are often present and may include *Agave* spp., *Ferocactus wislizeni, Opuntia* spp., *Yucca baccata*, or *Yucca elata* depending on geography. Diagnostic of this alliance is the dominance of *Prosopis velutina* in the shrub layer.

***Tumacácori National Historical Park (Association)***—*Note: NatureServe Explorer describes this type as an alliance (A.1043), as in the paragraph above, and lists this type as an association (CEGL 001388), but does not describe it. The following description is for a proposed association as it occurs at TUMA.*

This association is found primarily on mesa-tops and along the crest of hillslopes at the Guevavi unit. It is dominated by moderate-sized *Prosopis velutina* shrubs 1–3.5 m tall, with *Acacia greggii* shrubs common on the hillslopes. In areas with greater than 5% slope, the species commingle. The slopes have a higher percentage of *Bouteloua curtipendula* in the herbaceous layer compared with the flats of the mesa-tops, where there is far more of the annual forbs, *Amaranthus palmeri* and *Bouteloua aristidoides,* in addition to other mixed *Bouteloua* spp. (likely including *B. rothrockii* and *B. barbata*), which were not reliably identifiable due to seasonal dormancy. Other woody species associated with this type include *Acacia constricta, Opuntia spinosior, O. englemanii, Baccharis sarothroides,* and *Ferocactus wislizenii*, although there are rarely more than a few individuals of these species present. This type includes the adobe ruins at the center of the Guevavi unit, which accounts for some disturbance, with the presence of the entrance trail, an interpretive ramada, and the church ruins themselves. There also appear to be other subsurface modifications that may account for distributional differences among some species in the areas immediately adjacent to the ruins, including the presence of *Sporobolus wrightii*. *Eragrostis lehmanniana* and *Aristida* spp. may also be significant in the understory. The indication is that the mesa-top is more mesic than the slopes, as well as having more sandy soils in areas, while the slopes are rockier.

### Classification

***Classification confidence:*** 3 - weak
***Classification comments: Globally (Alliance)***—Classification of *Prosopis velutina*-dominated stands needs clarification. Because *Prosopis velutina* can have both shrub and tree growth

forms, there may be confusion classifying a given stand. For example, what characteristic separates a *Prosopis velutina* arroyo riparian shrubland from a *Prosopis velutina* "bosque" or riparian woodland. Some arroyo riparian stands in Arizona are similar to stands in the *Baccharis sarothroides*-, *Acacia greggii*- and *Parkinsonia* spp.-dominated alliances as far a species composition and separated mainly by dominance. Also, the formation that this alliance is classified in does not allow succulents. However, many stands in this alliance have a fairly consistent presence of succulents, usually species of *Opuntia* and *Yucca*.

***Tumacácori National Historical Park (Association)***—The *Prosopis velutina - Acacia greggii* Shrubland is the only association within the *Prosopis velutina* Shrubland Alliance that occurs at TUMA. Note that the local Tumacácori elements of this description apply to the association, while the global elements apply to the alliance, and are included for additional context. Global information is from NatureServe (http://www.natureserve.org/explorer). Field data to support the association description at TUMA were collected in 2007–2008 from 7 classification plots and 3 censused polygons.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | III | Shrubland |
| Formation subclass | III.B | Deciduous shrubland |
| Formation group | III.B.3 | Extremely xeromorphic deciduous shrubland |
| Formation subgroup | III.B.3.N | Natural/Semi-natural extremely xeromorphic deciduous shrubland |
| Formation name | III.B.3.N.a | Extremely xeromorphic deciduous subdesert shrubland without succulents |
| Alliance name | *Prosopis velutina* Shrubland Alliance | |
| Association name | *Prosopis velutina - Acacia greggii* Shrubland | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| CES302.733 | Apacherian-Chihuahuan Mesquite Upland Scrub |
| CES302.752 | North American Warm Desert Riparian Mesquite Bosque |
| CES302.755 | North American Warm Desert Wash |

## NatureServe conservation status

***Global status:*** GUQ (23Feb1994)
***Rounded global status:*** GU - Unrankable

## Distribution

***Globally (Alliance)***—Data are not available.

***Tumacácori National Historical Park (Association)***—This association is found in 3 polygons: 2 at Guevavi and 1 at Calabazas: S-PV01-G (5.2 ha), S-PV02-G (1.7 ha), S-PV03-C (2.0 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally (Alliance)***—Shrublands included in this alliance occur in the Chihuahuan and Sonoran deserts. Elevation ranges from 400 to 1,520 m. Climate is arid to semi-arid. Summers are hot. Winter temperature are generally mild with freezing temperature more common in the higher elevation Chihuahuan Desert. Precipitation varies with geography. Mean annual precipitation ranges from about 22 cm in southeastern New Mexico at

the Jornada Experimental Range to 28 cm at Tucson, Arizona, but can vary greatly from year to year. At the Jornada Experimental Range, annual precipitation ranged from 7 to 45 cm, with drought not uncommon (Herbel et al. 1972). Annual precipitation has bimodal distribution with the proportion of summer precipitation decreasing westward (Barbour and Major 1977). At the Jornada Experimental Range, about two-thirds of the annual precipitation occurs in July through October and a third during the winter months. At Tucson, Arizona, about half of the annual rain falls in July to October, with the balance during the winter months. The most arid season is late spring and early summer. The summer rain often occurs as high-intensity convective storms. Sites include sandy plains, mesas, bajadas, drainage terraces and channels, floodplains and rocky slopes. Although *Prosopis velutina* is deep-rooted, tapping water tables as deep as 50 m (Burgess 1995), it typically occurs on shallow water tables, especially along arroyos. Sites are generally flat or on gentle to moderate south-facing slopes. Parent material is usually sandy or gravelly alluvium, or eolian sand derived from limestone and metamorphic rocks. Substrates are generally coarse-textured, but may include gravelly clay loams. Some sites are moderately saline. These shrublands may grade into grasslands dominated by *Bouteloua gracilis, Sporobolus airoides, Pleuraphis mutica*, or be surrounded by a matrix of desert shrublands dominated by *Larrea tridentata* or *Ambrosia* spp.

***Dynamics:*** Shrublands dominated by *Prosopis* spp. have replaced large areas of desert grasslands, especially those formerly dominated by *Bouteloua eriopoda* in Trans-Pecos Texas, southern New Mexico, and southeastern Arizona (Hennessy et al. 1983, York and Dick-Peddie 1969). Studies on the Jornada Experimental Range suggest that combinations of drought, overgrazing by livestock, wind and water erosion, seed dispersal by livestock, fire suppression, shifting dunes, and changes in the seasonal distribution of precipitation have caused this recent, dramatic shift in vegetation physiognomy (Buffington and Herbel 1965, Gibbens et al. 1983, Herbel et al. 1972, Hennessy et al. 1983, Humphrey 1974, McLaughlin and Bowers 1982, McPherson 1995, Schlesinger et al. 1990). *Prosopis* and other shrubs have extensive root systems that allow them to exploit deep soil water that is unavailable to shallower-rooted grasses and cacti (Burgess 1995). This strategy works well, except on sites that have well-developed argillic or calcic soil horizons that limit infiltration and storage of winter moisture in the deeper soil layers (McAuliffe 1995). McAuliffe found *Prosopis velutina* invasion on these sites limited to a few, small individuals. This has implications in plant geography and grassland revegetation work in the southwestern U.S.

***Tumacácori National Historical Park (Association)***—This association occurs on toe-slopes or low flats, on sandy loam soils, sometimes rocky. Predominant surface cover is gravel, generally 35–60%, with less cover of bare soil or rock.

## Vegetation

***Globally (Alliance)***—Shrublands included in this alliance cover extensive areas of sandy plains, bajadas, and mesas across southwestern New Mexico and southeastern Arizona, invading open grasslands and often forming thickets. It also occurs as arroyo riparian vegetation, where it forms a tall, often dense shrub canopy. Stands have a moderate to dense (30–80%) woody canopy cover dominated by the xeromorphic deciduous shrub/small tree *Prosopis velutina*. Frequent riparian scrub co-dominants are *Acacia greggii, Celtis laevigata* var. *reticulata*. These shrublands often have a diverse shrub layer. Other common woody species include *Acacia constricta, Chilopsis linearis, Ericameria laricifolia, Gutierrezia sarothrae, Hymenoclea salsola, Isocoma tenuisecta, Juniperus monosperma, Larrea tridentata, Mimosa aculeaticarpa* var. *biuncifera (= Mimosa biuncifera)*, and *Rhus* spp. The herbaceous layer has sparse to moderate (to 60%) cover of perennial medium-tall and short perennial grasses. Characteristic perennial grasses include *Aristida* spp., *Bouteloua curtipendula, Bouteloua eriopoda, Dasyochloa pulchella (= Erioneuron pulchellum), Elymus elymoides, Hilaria belangeri, Muhlenbergia porteri*, and *Sporobolus* spp. Annual grasses are present, but have sparse cover. Forbs are also sparse, but may include species of *Datura, Mentzelia, Polanisia*, and *Rumex*. Succulents are often present and may include *Agave* spp., *Ferocactus wislizeni, Opuntia acanthocarpa, Opuntia engelmannii, Opuntia leptocaulis, Opuntia imbricata, Opuntia phaeacantha,*

*Opuntia spinosior, Yucca baccata*, or *Yucca elata,* depending on geography.

***Tumacácori National Historical Park (Association)***—This association is found primarily on mesa-tops and along the crest of hillslopes at the Guevavi unit, with limited distribution at Calabazas. It is dominated by moderate-sized *Prosopis velutina* shrubs 1–3.5 m tall, with *Acacia greggii* shrubs common on the hillslopes. In areas with greater than 5% slope, the species commingle. The slopes have a higher percentage of *Bouteloua curtipendula* in the herbaceous layer compared with the flats of the mesa-tops, where there is far more of the annual forb *Amaranthus palmeri* and *Bouteloua aristidoides* in addition to other mixed *Bouteloua* spp. (likely including *B. rothrockii* and *B. barbata*), which were not reliably identifiable due to seasonal dormancy. Other woody species associated with this type include *Acacia constricta, Opuntia spinosior, O. engelmannii, Baccharis sarothroides,* and *Ferocactus wislizenii*, although there are rarely more than a few individuals of these species present. This type includes the adobe ruins at the center of the Guevavi unit, which accounts for some disturbance, with the presence of the entrance trail, an interpretive ramada, and the church ruins themselves. There also appear to be other subsurface modifications that may account for distributional differences among some species in the areas immediately adjacent to the ruins, including the presence of *Sporobolus wrightii. Eragrostis lehmanniana* and *Aristida* spp. may also be significant in the understory. The indication is that the mesa-top is more mesic than the slopes, as well as having more sandy soils in areas, while the slopes are rockier.

***Most abundant species: Globally (Alliance)***—Data are not available.
***Tumacácori National Historical Park (Association)***—

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina* (rare) |
| Canopy (2–5m) | *Prosopis velutina, Acacia greggii* |
| Sub-canopy (0.5–2m) | *Prosopis velutina, Acacia greggii* |
| Field (0–0.5m) | *Amaranthus palmeri,* mixed *Bouteloua* spp. |

***Other noteworthy species: Globally (Alliance)***—Data are not available.
***Tumacácori National Historical Park (Association)***—*Mimosa biuncifera, Baccharis sarothroides, Ferocactus wislizenii, Ziziphus obtusifolia, Opuntia spinosior, Sporobolus wrightii, Eragrostis lehmanniana, Aristida* spp.

## Element sources

***Global description authors (Alliance):*** K. Schulz.

***Local description authors (Association):*** S. Buckley and S. Drake

***References:*** K. Schulz. NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: September 15, 2008)


- Barbour, M. G., and J. Major, editors. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York. 1002 pp.
- Buffington, L. C., and C. H. Herbel. 1965. Vegetational changes on a semidesert grassland range from 1858 to 1963. Ecological Monographs 35(2):139-164.
- Burgess, T. L. 1995. Desert grassland, mixed shrub savanna, shrub steppe, or semidesert scrub. Pages 31-67 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.
- Gibbens, R. P., J. M. Tromble, J. T. Hennessy, and M. Cardenas. 1983. Soil movement

in mesquite dunelands and former grasslands of southern New Mexico. Journal of Range Management 36(2):145-148.

- Hennessy, J. T., R. P. Gibbens, J. M. Tromble, and M. Cardenas. 1983. Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico. Journal of Range Management 36(3):370-374.
- Herbel, C. H., F. N. Ares, and R. Wright. 1972. Drought effects on a semidesert grassland range. Ecology 53:1084-1093.
- Humphrey, R. R. 1974. Fire in the deserts and desert grassland of North America. Pages 365-400 in: T. T. Kozlowski and C. E. Ahlgren, editors. Fire and Ecosystems. Academic Press, New York.
- McAuliffe, J. R. 1995. Landscape evolution, soil formation, and Arizona's desert grasslands. Pages 100-129 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.
- McLaughlin, S. P., and J. E. Bowers. 1982. Effects of wildfire on a Sonoran Desert plant community. Ecology 63(1):246-248.
- McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 130-151 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.
- Schlesinger, W. H., J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, R. A. Virginia, and W. G. Whitford. 1990. Biological feedbacks in global desertification. Science 247:1043-1048.
- York, J. C., and W. A. Dick-Peddie. 1969. Vegetation changes in southern New Mexico during the past hundred years. Pages 157-166 in: W. O. McGinnies and B. J. Goldman, editors. Arid lands in perspective. University of Arizona Press, Tucson.

## *D.4.2 Acacia constricta* Shrubland Alliance

***Translated name:*** Whitethorn acacia Shrubland Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is found on steeper, well-drained slopes in the eastern portion of the Calabazas unit. These sites have thin, gravelly soils, often with exposed bedrock. Prevailing winds appear to seriously reduce retention of moisture, topsoil and litter. *Acacia constricta*, *Acacia greggii*, and *Prosopis velutina* shrubs are all usually present, average 1.5–2.5 m tall and compose a moderately open shrubland, but may form dense thickets. Some *P. velutina* may attain tree size, especially where slopes are not as steep. *Acacia constricta* is dominant overall, but in patches, either *A. greggii* or *Prosopis velutina* may be the dominant species. The understory is notable for its diversity, usually composed of a mixture of native bunchgrasses, such as *Bouteloua curtipendula*, *Muhlenbergia porteri*, *Aristida purpurea*, and *Setaria* spp. Several other species rare in the Calabazas unit are found in limited numbers in this type, including *Ceanothus greggii, Mimosa aculeaticarpa* var. *biuncifera, Ferocactus wislizenii, Yucca elata*, *Echinocereus* spp., *and Opuntia spinosior*. This type maintains a high percentage of native species and relatively low levels of human and livestock disturbance due to its rugged topographic position, thorny shrub cover and protection within NPS fencelines.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (6 classification plots and 1 censused polygon). This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | III | Shrubland |
| Formation subclass | III.B | Deciduous shrubland |
| Formation group | III.B.3 | Extremely xeromorphic deciduous shrubland |
| Formation subgroup | III.B.3.N | Natural/Semi-natural extremely xeromorphic deciduous shrubland |
| Formation name | III.B.3.N.a | Extremely xeromorphic deciduous subdesert shrubland without succulents |
| Alliance name | *Acacia constricta* Shrubland Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

### Distribution

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This type is found in 1 polygon at Calabazas: S-AC01-C (6.1 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally—***Data are not available.

***Tumacácori National Historical Park—***This alliance is found on steeper, well-drained slopes in the eastern portion of the Calabazas unit. These sites have thin, gravelly soils, often with exposed bedrock. Prevailing winds appear to seriously reduce retention of moisture, topsoil and litter. This type maintains a high percentage of native species and relatively low levels of human and livestock disturbance due to its rugged topographic position, thorny shrub cover and protection within NPS fencelines.

## Vegetation

***Globally—***Data are not available.

***Tumacácori National Historical Park—****Acacia constricta, Acacia greggii,* and *Prosopis velutina* shrubs are all usually present, average 1.5–2.5 m tall and compose a moderately open shrubland, but may form dense thickets. Some *P. velutina* may attain tree size, especially where slopes are not steep. *Acacia constricta* is dominant overall, but in patches, either *A. greggii* or *Prosopis velutina* may be the dominant species. The understory is notable for its diversity, usually composed of a mixture of native bunchgrasses, such as *Bouteloua curtipendula, Aristida purpurea, Muhlenbergia porteri,* and *Setaria* spp. Several other species rare in the Calabazas site are found in limited numbers in this type, including *Ceanothus greggii, Mimosa aculeaticarpa* var. *biuncifera, Ferocactus wislizenii, Yucca elata, Echinocereus* spp., *and Opuntia spinosior.*

***Most abundant species: Globally—***Data are not available.
***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina* |
| Canopy (2–5m) | *Prosopis velutina* |
| Sub-canopy (0.5–2m) | *Acacia constricta, Acacia greggii, Mimosa aculeaticarpa* var. *biuncifera* |
| Field (0–0.5m) | *Bouteloua curtipendula, Aristida purpurea, Amaranthus palmeri* |

***Other noteworthy species: Globally—***Data are not available.
***Tumacácori National Historical Park—****Juniperus coahuilensis, Ceanothus greggii, Ferocactus wislizenii, Yucca elata, Echinocereus* spp., and *Opuntia spinosior* (all occasional).

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## *D.4.3 Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance

***Translated name:*** Tamarisk (or saltcedar) species Semi-natural Temporarily Flooded Shrubland Alliance
***NatureServe code:*** A.842 / CEGL003114

### Summary

***Globally—***This alliance is composed of shrublands that form moderately dense to dense thickets on banks of larger streams, rivers, and playas across the western Great Plains, interior and southwestern U.S., and northern Mexico. Stands are dominated by introduced species of *Tamarix*, including *Tamarix ramosissima*, *Tamarix chinensis*, *Tamarix gallica*, and *Tamarix parviflora*. Introduced from the Mediterranean, *Tamarix* spp. have become naturalized in various sites, including salt flats, springs, and especially along streams and regulated rivers, often replacing *Salix* or *Prosopis* spp. shrublands or other native vegetation. A remnant herbaceous layer may be present, depending on the age and density of the shrub layer. These species have become a critical nuisance along most large rivers in the semi-arid western U.S. Because of the difficulty to remove it, *Tamarix* spp. may have irreversibly changed the vegetation along many rivers.

***Tumacácori National Historical Park—***This alliance is found along the northern boundary of the Mission unit, with the bulk of the stand found in the study area buffer, outside the park boundary. The topography of the area is notable because of two elevated sand bars with north-south channels running between them. On top of the sand bars are dense stands of 2–3-m tall tamarisk shrubs (*Tamarix ramosissima*) with small annual forbs scattered in openings where there is less litter cover. Along the margins of the dense tamarisk patches, occasional *Populus fremontii*, infrequent *Baccharis salicifolia* and *Baccharis sarothroides* recruits, moderate growth of *Amaranthus palmeri*, and often *Chloris virgata* are found, with less common *Cynodon dactylon* and *Sporobolus cryptandrus* patches. This type may radically change inside the park boundary because of a tamarisk eradication project being conducted by NPS at the time of mapping. The portion inside the park boundary would be herbaceous-dominated without the tamarisk.

### Classification

***Classification confidence:*** Confident or certain.
***Classification comments: Globally—***This broadly defined alliance is composed of many diverse *Tamarix* spp.-dominated vegetation communities from a wide variety of environments. Common species of *Tamarix* include *Tamarix ramosissima*, *Tamarix chinensis*, and *Tamarix parviflora*, but other species are reported from the western U.S., such as *Tamarix africana*, *Tamarix aphylla*, *Tamarix aralensis*, *Tamarix canariensis*, *Tamarix gallica*, and *Tamarix tetragyna* (Kartesz 1999). Powell (1988) reports that *Tamarix* spp. are a critical nuisance, most notably along the Rio Grande and Pecos River. Muldavin et al. (2000a) described 8 community types that will be reviewed as possible USNVC associations. Currently the sole USNVC tamarix association, *Tamarix* spp. Temporarily Flooded Semi-natural Shrubland (CEGL003114), is equally broadly defined.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (1 classification plot and 1 censused polygon). The tamarisk eradication program being carried out by the NPS may eliminate the presence of this alliance within the TUMA boundary, but without management it will probably continue to exist north of the Mission unit and elsewhere outside the park.

*Vegetation hierarchy*

| | | |
|---|---|---|
| Formation class | III | Shrubland |
| Formation subclass | III.A | Evergreen shrubland |
| Formation group | III.A.4 | Microphyllous evergreen shrubland |
| Formation subgroup | III.A.4.N | Natural/Semi-natural microphyllous evergreen shrubland |
| Formation name | III.A.4.N.c | Temporarily flooded microphyllous shrubland |
| Alliance name | *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance | |
| Association name | *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland | |

*Ecological systems placement*

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

## NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—Mexico, United States. This semi-natural shrubland alliance is found along drainages in the semi-arid western Great Plains, interior western and southwestern U.S., and northern Mexico, from central and eastern Montana south to Colorado, western Oklahoma and Texas west to California.

***Tumacácori National Historical Park***—This type is found in 1 polygon at the Mission unit: S-TM01-M (1.1 ha). It also exists to the north (downstream) of the Mission unit, outside the park boundary.

## Environmental setting

***USFWS wetland system:*** Yes

***Environmental summary: Globally***—The riparian shrublands included in this alliance occur across the western Great Plains, interior western and southwestern U.S., and northern Mexico. These widespread shrublands are common along larger streams, rivers, and around playas. Elevation ranges from 75 m below sea level to 1,860 m. *Tamarix* spp. have become naturalized in various sites, including riverbanks, floodplains, basins, sandbars, side channels, springs, salt flats, and other saline habitats. Stands grow especially well along regulated rivers where flood-regenerated native species of *Populus* are declining. Substrates are commonly thin sandy loam soil over alluvial deposits of sand, gravel or cobbles.

***Dynamics:*** *Tamarix* spp. are highly competitive shrubs that have invaded many riparian and wetland environments in the western U.S. Hansen et al. (1995) report that these shrubs are extremely drought- and salt-tolerant, produce prolific wind-dispersed seeds over much of the growing season, can resprout after burning or cutting, and, if kept moist, buried or broken branches will develop adventitious roots and grow. Stands seem to favor disturbed and flow-regulated rivers, but establish well in pristine areas, too. Under optimum conditions riparian areas can be converted to a dense thicket in less than 10 years (Hansen et al. 1995). Once established, stands are extremely difficult to eradicate, requiring cutting and herbicide application on stumps to prevent resprouting (Smith 1989).

***Tumacácori National Historical Park***—This alliance is found along the northern boundary of the Mission unit, with the bulk of the stand found in the study area buffer, outside the park boundary.

## Vegetation

***Globally***—This semi-natural shrubland alliance occurs along streams, rivers, and playas, where it forms a moderate to dense tall-shrub layer that is solely or strongly dominated by species of *Tamarix*, including *Tamarix ramosissima*, *Tamarix chinensis*, *Tamarix gallica*, and *Tamarix parviflora*. Other shrubs may include species of *Salix* (especially *Salix exigua*) and *Prosopis*, *Rhus trilobata*, and *Sarcobatus vermiculatus*, but with low cover (if shrub species are co-dominant, then stand is classified as a natural shrubland). Scattered *Acer negundo*, *Salix amygdaloides*, *Populus* spp., or *Elaeagnus angustifolia* trees may also be present. Depending on stand age and density of the shrub layer, an herbaceous layer may be present. Associated species include *Distichlis spicata*, *Sporobolus airoides*, and introduced forage species such as *Agrostis gigantea*, *Agrostis stolonifera*, and *Poa pratensis*. Introduced herbaceous species such as *Polypogon monspeliensis*, *Conyza canadensis*, *Lepidium latifolium*, and others have been reported from shrublands in this association. *Tamarix* spp. have become a critical nuisance along most large rivers in the semi-arid western U.S. and, because of the difficulty to remove, may have irreversibly changed the vegetation along many rivers.

***Tumacácori National Historical Park***—This alliance is dominated by dense stands of 2–4-m tall tamarisk shrubs (*Tamarix ramosissima*), with small annual forbs scattered in openings where there is less litter cover. Along the margins of the dense tamarisk patches, occasional *Populus fremontii*, infrequent *Baccharis salicifolia* and *Baccharis sarothroides* recruits, moderate growth of *Amaranthus palmeri*, and often *Chloris virgata* are found, with less-common *Cynodon dactylon* and *Sporobolus cryptandrus* patches. This type may radically change inside the park boundary because of a tamarisk eradication project being conducted by the NPS at the time of mapping. The portion inside the park boundary would be herbaceous-dominated without the tamarisk.

***Most abundant species: Globally***—Data are not available.
***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Populus fremontii* (rare) |
| Canopy (2–5m) | *Tamarix ramosissima* |
| Sub-canopy (0.5–2m) | none |
| Field (0–0.5m) | *Amaranthus palmeri, Chloris virgata* |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Baccharis sarothroides, Baccharis salicifolia, Cynodon dactylon, Sporobolus cryptandrus*

## Element sources

***Global description authors:*** M.S. Reid, mod. K.A. Schulz

***Local description authors:*** S. Buckley and S. Drake

***References:*** Ecological data developed by NatureServe and its network of natural heritage programs and other contributors and cooperators.


- Hansen, P. L., R. D. Pfister, K. Boggs, B. J. Cook, J. Joy, and D. K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Miscellaneous Publication No. 54. 646 pp. + posters.
- Kartesz 1999. Data are not available.
- Muldavin, E., P. Durkin, M. Bradley, M. Stuever, and P. Mehlhop. 2000a. Handbook

of wetland vegetation communities of New Mexico: Classification and community descriptions (volume 1). Final report to the New Mexico Environment Department and the Environmental Protection Agency prepared by the New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, NM.

- Powell, A. M. 1988b. Trees and shrubs of Trans-Pecos Texas including Big Bend and Guadalupe Mountains national parks. Big Bend Natural History Assoc., Inc. 536 pp.
- Smith, T. L. 1989. An overview of old-growth forests in Pennsylvania. Natural Areas Journal 9:40-44.

# D.5 Wooded Herbaceous

## *D.5.1 Populus fremontii* / Mixed Annual Wooded Herbaceous Alliance

***Translated name:*** Fremont cottonwood / Mixed Annual Wooded Herbaceous Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance occupies portions of the floodplain at the Mission unit and at Guevavi. *Populus fremontii* is found singly or in small to large patches throughout the type, often with *Salix gooddingii,* and clumps of *Tamarix ramosissima* in some places. *Sambucus nigra* ssp. *caerulea* and/or *Prosopis velutina* may be found in this type. Large *Populus fremontii* may reach 16–18 m, *Salix* somewhat less, and *Prosopis* usually 3–6 m. At the time of mapping, the NPS was conducting a tamarisk eradication program, so this species may be insignificant in the future. Shrubs are generally sparse, and associated species include *Hymenoclea monogyra, Prosopis velutina, Baccharis salicifolia, Acacia greggii, Baccharis sarothroides, and Senecio flaccidus*. The herbaceous layer is dominated by *Amaranthus palmeri*, with significant patches of *Salsola kali* and *Chenopodium* spp. widely dispersed throughout the type. Annual grasses are also commonly present, including *Chloris virgata, Aristida purpurea,* and *Bouteloua aristidoides*, frequently in conjunction with sandier, sloped areas, indicating slightly more xeric conditions. The topography of this type is undulating, having 1–3-m relief, with braided flood channels or swales dominated by herbaceous vegetation and occasional shrubs (*Baccharis salicifolia*, *B. sarothroides*, *Hymenoclea monogyra*), and sandbars dominated by trees. Associated herbaceous species include *Boerhavia coccinea, Boerhavia spicata, Cynodon dactylon, Ipomoea* spp., *Tithonia thurberi, Sporobolus cryptandrus, Bouteloua curtipendula,* and *Eragrostis lehmanniana*.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (6 classification plots and 3 censused polygons). This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | V | Herbaceous vegetation |
| Formation subclass | V.D ? | Annual graminoid or forb vegetation (with a sparse tree layer) |
| Formation group | | Data are not available |
| Formation subgroup | | Data are not available |
| Formation name | | Data are not available |
| Alliance name | *Populus fremontii* / mixed annual Wooded Herbaceous Alliance | |
| Association name | Data are not available. | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available. | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This type is found in 3 polygons: 2 at the Mission unit and 1 at Guevavi: WH-PF01-M (10.6 ha), WH-PF03-M (2.0 ha), WH-PF02-G (1.6 ha).

## Environmental setting

***USFWS wetland system:*** Yes

***Environmental summary: Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This type occupies portions of the floodplain at the Mission unit and at Guevavi, on characteristic undulating terrain having 1–3-m relief, with braided flood channels or swales dominated by herbaceous vegetation and occasional shrubs, and sandbars dominated by trees.

## Vegetation

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**While herbaceous species dominate this type by cover, *Populus fremontii* is found singly or in small to large patches throughout, often with *Salix gooddingii* and clumps of *Tamarix ramosissima* in some places. *Sambucus nigra* ssp. *caerulea* and/or *Prosopis velutina* may be found in this type. Large *Populus fremontii* may reach 16–18 m, *Salix* somewhat less, and *Prosopis* usually 3–6 m. At the time of mapping, NPS was conducting a tamarisk eradication program, so this species may be insignificant in the future. Shrubs are generally sparse, and associated species include *Hymenoclea monogyra, Prosopis velutina, Baccharis salicifolia, Acacia greggii, Baccharis sarothroides, and Senecio flaccidus*. The herbaceous layer is dominated by *Amaranthus palmeri*, with significant patches of *Salsola kali* and *Chenopodium* spp. widely dispersed throughout the type. Annual grasses are also commonly present, including *Chloris virgata, Aristida purpurea,* and *Bouteloua aristidoides*, frequently in conjunction with sandier, sloped areas, indicating slightly more xeric conditions. The topography of this type is undulating, having 1–3-m relief, with braided flood channels or swales dominated by herbaceous vegetation and occasional shrubs (*Baccharis salicifolia*, *B. sarothroides*, *Hymenoclea monogyra*), and sandbars dominated by trees. Associated herbaceous species include *Boerhavia coccinea, Boerhavia spicata, Cynodon dactylon, Ipomoea* spp., *Tithonia thurberi, Sporobolus cryptandrus, Bouteloua curtipendula* and *Eragrostis lehmanniana*.

***Most abundant species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—**

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Populus fremontii, Salix gooddingii* |
| Canopy (2–5m) | *Tamarix ramosissima, Sambucus nigra* ssp. *caerulea* |
| Sub-canopy (0.5–2m) | *Hymenoclea monogyra, Baccharis salicifolia* |
| Field (0–0.5m) | *Amaranthus palmeri, Chloris virgata, Salsola kali, Chenopodium* sp. |

***Other noteworthy species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—***Aristida purpurea, Eriogonum* sp., *Helianthus annuus, Boerhavia coccinea*

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## *D.5.2 Prosopis velutina* / Mixed Annual Wooded Herbaceous Alliance

***Translated name:*** Velvet mesquite / Mixed Annual Wooded Herbaceous Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is often found in wide, shallow drainages between mesa-top shrublands or on long, narrow alluvial terraces above the river's floodplain. Where a single herbaceous species dominates, it is usually *Amaranthus palmeri*, though there are areas dominated by *Cynodon dactylon* (found in most of the open areas of the type) or *Sporobolus wrightii*. In addition, there are significant areas without a single dominant species, with the herbaceous layer comprising a diverse mosaic of annual and perennial plants, including some combination of the aforementioned species and *Aristida purpurea, Chloris virgata*, *Hilaria belangeri, Sporobolus cryptandrus, Sporobolus contractus*, *Bothriochloa barbinodis,* and *Aristida ternipes*. The overstory usually has 5–25% cover of *Prosopis velutina* trees, sometimes clumped, usually interspersed with *Sambucus nigra* ssp. *caerulea*, *Celtis laevigata* var. *reticulata*, *Acacia greggii*, and *Populus fremontii*. *P. velutina* and *A. greggii* can appear as both trees and shrubs. Other associated shrubs include *Ziziphus obtusifolia* and *Hymenoclea monogyra*. Average height of the overstory is commonly 3–6 m, with some larger individuals possibly present. *Populus fremontii* specimens can reach 14 m. In areas within this type, *Sambucus nigra* ssp. *caerulea* may be the dominant tree, or nearly so. This variant of the type is likely to be dominated in absolute terms by weedy (often non-native) annual forbs, such as *Amaranthus palmeri, Salsola kali, Chenopodium* spp., *Helianthus annuus*, and the grass *Chloris virgata*. Closer to the active channel, *Cynodon dactylon* and *Xanthium strumarium* may also be abundant. Shrub and tree cover are sparse. There is often abundant evidence of cattle grazing and trampling, which combines with flood events to chronically disturb the topsoil and maintain the dominance of the invasive forbs.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (9 classification plots and 4 censused polygons). This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | V | Herbaceous vegetation |
| Formation subclass | V.D ? | Annual graminoid or forb vegetation (with a sparse tree layer) |
| Formation group | | Data are not available |
| Formation subgroup | | Data are not available |
| Formation name | | Data are not available |
| Alliance name | *Prosopis velutina* / mixed annual Wooded Herbaceous Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—Data are not available.

***Tumacácori National Historical Park***—This type is found in 4 polygons: 2 at the Mission unit, 1 at Calabazas and 1 at Guevavi: WH-PV01-M (2.0 ha), WH-PV02-M (1.5 ha), WH-PV03-G (0.8 ha), WH-PV04-C (2.8 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally***—Data are not available.

***Tumacácori National Historical Park***—This type is often found in wide, shallow drainages between mesa-top shrublands, or on long, narrow alluvial terraces above the river's floodplain. Shrub and tree cover are sparse. There is often abundant evidence of cattle grazing and trampling, which combines with flood events to chronically disturb the topsoil and maintain the dominance of the invasive forbs.

## Vegetation

***Globally***—Data are not available.

***Tumacácori National Historical Park***—Where a single herbaceous species dominates this alliance, it is usually *Amaranthus palmeri*, though there are areas dominated by *Cynodon dactylon* (found in most of the open areas of the type) or *Sporobolus wrightii*. In addition, there are significant areas without a single dominant species, with the herbaceous layer comprised of a diverse mosaic of annual and perennial plants, including some combination of the aforementioned species and *Aristida purpurea, Chloris virgata*, *Hilaria belangeri, Sporobolus cryptandrus, Sporobolus contractus, Bothriochloa barbinodis,* and *Aristida ternipes*. The overstory usually has 5–25% cover of *Prosopis velutina* trees, sometimes clumped, usually interspersed with *Sambucus nigra* ssp. *caerulea*, *Celtis laevigata* var. *reticulata*, *Acacia greggii*, and *Populus fremontii*. *P. velutina* and *A. greggii* can appear as both trees and shrubs. Other associated shrubs include *Ziziphus obtusifolia*, *Hymenoclea monogyra*, *Baccharis sarothroides*, and *Mimosa aculeaticarpa* var. *biuncifera*. Average height of the overstory is commonly 3–6 m, with some larger individuals possibly present. *Populus fremontii* specimens can reach 14 m. In areas within this type, *Sambucus nigra* ssp. *caerulea* may be the dominant tree, or nearly so. This variant of the type is likely to be dominated in absolute terms by weedy (often non-native) annual forbs, such as *Amaranthus palmeri, Salsola kali, Chenopodium* spp., *Helianthus annuus*, and the grass *Chloris virgata*. Closer to the active channel, *Cynodon dactylon* and *Xanthium strumarium* may also be abundant.

***Most abundant species: Globally***—Data are not available.
***Tumacácori National Historical Park***—

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina* |
| Canopy (2–5m) | *Prospois, Sambucus nigra* ssp. *caerulea, Acacia greggii* |
| Sub-canopy (0.5–2m) | *Ziziphus obtusifolia, Mimosa aculeaticarpa* var. *biuncifera, Hymenoclea monogyra* |
| Field (0–0.5m) | *Amaranthus palmeri, Chloris virgata, Cynodon dactylon* |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Celtis laevigata* var. *reticulata, Populus fremontii, Baccharis sarothroides, Salsola kali, Bouteloua curtipendula, Sporobolus wrightii, Aristida purpurea, Bidens leptocephala, Helianthus annuus, Ambrosia confertiflora*

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

# D.6 Shrub Herbaceous

## *D.6.1 Prosopis velutina / Amaranthus palmeri* Shrub Herbaceous Alliance

***Translated name:*** Velvet mesquite / Palmer amaranth Shrub Herbaceous Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is found at both the Mission unit and at Guevavi. At Guevavi, the area is an alluvial terrace in the floodplain beside the Santa Cruz River, where it is notable because of the significant amount of dead and downed wood that litters this portion of the river channel, as well as the numerous large *Populus fremontii* snags, some as tall as 14 m. In addition to the *Prosopis velutina* shrubs, there are a number of trees in this area, including *P. velutina, Celtis laevigata* var. *reticulata, Sambucus nigra* ssp. *caerulea*, and *Populus fremontii*, but they are often solitary individuals with numerous shrubs of these species interspersed between, predominantly found in small clumps along the upper ridges of the sandbars. *Celtis* appears to be using the dead and down cottonwood as a nurse/mulch. The type overall is dominated by *Amaranthus palmeri,* with other tall annuals and *Sporobolus wrightii* interspersed throughout. One location at the Mission unit supporting this type is an abandoned agricultural field. According to information provided by the NPS, this field has not been mowed or cultivated in the last 3–4 years. As a result, the dominance of *Amaranthus palmeri* is apparently giving way to a mixture of annual and perennial grasses: *Cynodon dactylon, Bouteloua aristidoides, Sporobolus cryptandrus, Bouteloua curtipendula, Hilaria belangeri, Aristida purpurea,* and *Aristida ternipes*. Scattered throughout are numerous small *Prosopis velutina* and *Baccharis sarothroides* shrubs, ranging from 0.5–1.5 m tall. The absence of disturbance and grazing has apparently allowed the widespread growth of woody species, still small and shrubby. *Amaranthus palmeri,* present throughout the area, constitutes a plurality of roughly 30% of the total cover here.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (3 classification plots and 3 censused polygons). This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | V | Herbaceous Vegetation |
| Formation subclass | V.D ? | Annual graminoid or forb vegetation (with a sparse shrub layer) |
| Formation group | | Data are not available |
| Formation subgroup | | Data are not available |
| Formation name | | Data are not available |
| Alliance name | *Prosopis velutina / Amaranthus palmeri* Shrub Herbaceous Alliance | |
| Association name | Data are not available. | |

***Ecological systems placement***

| ***Ecological system unique ID*** | ***Ecological system name*** |
|---|---|
| Data are not available. | Data are not available. |

***NatureServe conservation status***

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally***—Data are not available.

***Tumacácori National Historical Park***—This type is found in 3 polygons: 2 at the Mission unit and 1 at Guevavi: SH-PV01-M (1.5 ha), SH-PV02-M (3.9 ha), SH-PV03-G (1.7 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally***—Data are not available.

***Tumacácori National Historical Park***—This type is found at both the Mission unit and at Guevavi. At Guevavi, the area is an alluvial terrace in the floodplain beside the Santa Cruz River, where it is notable because of the significant amount of dead and downed wood that litters this portion of the river channel, as well as the numerous large *Populus fremontii* snags, some as tall as 14 m. One stand of this type at the Mission unit is notable for being an abandoned agricultural field, which has not been mowed or cultivated in the last 3–4 years. As a result, the dominance of *Amaranthus palmeri* is apparently giving way to a mixture of annual and perennial grasses, and the growth of shrubby *Prosopis velutina* is apparent.

## Vegetation

***Globally***—Data are not available.

***Tumacácori National Historical Park***—In addition to the *Prosopis velutina* shrubs, there may be a number of trees in this alliance, including *P. velutina, Celtis laevigata* var. *reticulata, Sambucus nigra* ssp. *caerulea*, and *Populus fremontii*, but they are often solitary individuals with numerous shrubs of these species interspersed between, predominantly found in small clumps along the upper ridges of the sandbars. The type overall is dominated by *Amaranthus palmeri*, with other tall annuals and *Sporobolus wrightii* interspersed throughout. One location at the Mission unit supporting this type is an abandoned agricultural field. According to information provided by NPS, this field has not been mowed or cultivated in the last 3–4 years. As a result, the dominance of *Amaranthus palmeri* is apparently giving way to a mixture of annual and perennial grasses: *Cynodon dactylon, Bouteloua aristidoides, Sporobolus cryptandrus, Bouteloua curtipendula, Hilaria belangeri, Aristida purpurea*, and *Aristida ternipes*. Scattered throughout are numerous small *Prosopis velutina* and *Baccharis sarothroides* shrubs, ranging from 0.5–1.5 m tall. The absence of disturbance and grazing has apparently allowed the widespread growth of woody species, still small and shrubby. *Amaranthus palmeri*, present throughout the area, constituted a plurality of roughly 30% of the total cover here.

***Most abundant species: Globally***—Data are not available.
***Tumacácori National Historical Park***—

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Prosopis velutina, Celtis laevigata* var. *reticulata* (both rare) |
| Canopy (2–5m) | *Prosopis velutina, Sambucus nigra* ssp. *caerulea* |
| Sub-canopy (0.5–2m) | *Prosopis velutina, Baccharis sarothroides* |
| Field (0–0.5m) | *Amaranthus palmeri, Cynodon dactylon* |

***Other noteworthy species: Globally***—Data are not available.
***Tumacácori National Historical Park***—*Populus fremontii, Baccharis salicifolia, Bouteloua aristidoides, Bouteloua curtipendula*

### Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## *D.6.2 Hymenoclea monogyra / [Amaranthus palmeri - Chloris virgata] Shrub Herbaceous Alliance*

***Translated name:*** Singlewhorl burrobrush / [Palmer amaranth - Feather windmill grass] Shrub Herbaceous Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This proposed alliance is generally found in the 100-year floodplain adjacent to the west side of the Santa Cruz River at Tumacácori. It consists of sandy to silty soils with a diversity of annual and perennial herbaceous species, though these are widely dispersed across a large area and account for only moderate cover. The herbaceous layer is dominated by *Amaranthus palmeri* and *Chloris virgata*. *Hymenoclea monogyra* is the dominant shrub throughout the type, appearing to have grown up within the last five years, as indicated by repeat photographs from an earlier inventory. *Hymenoclea monogyra* shrubs range from 2 to 4 m in height, and are generally clumped together, leaving large areas in between more open. Associated shrubs interspersed throughout the type include *Baccharis salicifolia*, *Baccharis sarothroides*, *Prosopis velutina*, and *Senecio flaccidus*. Some trees may be present, commonly *Populus fremontii* or *Sambucus nigra* ssp. *caerulea*, but making up less than 10% cover.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***Data are not available.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (5 classification plots and 1 censused polygon). This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | V | Herbaceous Vegetation |
| Formation subclass | V.D ? | Annual graminoid or forb vegetation (with a sparse shrub layer) |
| Formation group | | Data are not available |
| Formation subgroup | | Data are not available |
| Formation name | | Data are not available |
| Alliance name | *Hymenoclea monogyra* / [*Amaranthus palmeri – Chloris virgata*] Shrub Herbaceous Alliance | |
| Association name | Data are not available | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

### Distribution

***Globally—***Data are not available.

***Tumacácori National Historical Park*—**This type is found in one nominal polygon (in two parts), at the Mission unit: SH-HM01-M (10.2 ha). It lies along the central (river) axis of the Mission unit, with most of its area toward the north.

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally*—**Data are not available.

***Tumacácori National Historical Park*—**This alliance is found in the 100-year floodplain adjacent to the west side of the Santa Cruz River at the Tumacácori Mission unit. Soils are sandy to silty, with a diversity of annual and perennial herbaceous species, though these are widely dispersed across a large area and do not account for much cover. Surface cover is diverse, including bare soil, gravel, river rock, down wood, and plant litter.

## Vegetation

***Globally*—**Data are not available.

***Tumacácori National Historical Park*—**The herbaceous layer is dominated by *Amaranthus palmeri* and *Chloris virgata*. *Hymenoclea monogyra* is the dominant shrub throughout the type, appearing to have grown up within the last five years, as indicated by repeat photographs from an earlier inventory. *Hymenoclea monogyra* shrubs range from 2 to 4 m in height, and are generally clumped together, leaving large areas in between more open. Associated shrubs interspersed throughout the type include *Baccharis salicifolia*, *Baccharis sarothroides*, *Prosopis velutina*, and *Senecio flaccidus*. Some trees may be present, commonly *Populus fremontii* or *Sambucus nigra* ssp. *caerulea*, but making up less than 10% cover.

***Most abundant species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—**

| Stratum | Species |
|---|---|
| Top canopy (>5m) | *Populus fremontii, Sambucus nigra* ssp. *caerulea* (both rare) |
| Canopy (2–5m) | *Hymenoclea monogyra* |
| Sub-canopy (0.5–2m) | *Opuntia spinosior, O. engelmannii* (both rare) |
| Field (0–0.5m) | *Amaranthus palmeri, Chloris virgata* |

***Other noteworthy species: Globally*—**Data are not available.
***Tumacácori National Historical Park*—***Baccharis salicifolia*, *B. sarothroides*, *Prosopis velutina*, *Cynodon dactylon*

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

# D.7 Herbaceous

## D.7.1 [*Amaranthus palmeri - Salsola kali - Chenopodium* spp.] Annual Herbaceous Alliance

***Translated name:*** [Palmer amaranth - Tumbleweed - Goosefoot species] Annual Herbaceous Alliance
***NatureServe code:*** Data are not available (proposed).

### Summary

***Globally***—Data are not available.

***Tumacácori National Historical Park***—This annual forb-dominated community is found on sandy soils adjacent to the Santa Cruz River at all three units. Use of brackets in the type name indicates that these species should be considered co-dominant overall, and their relative abundance may differ spatially within the type. There are areas of fairly homogeneous distribution of both *Amaranthus palmeri* and *Salsola kali* as co-dominants (with or without some *Chenopodium* spp.), and areas where one of the three species is clearly the single dominant, with more or less of the others possibly present. This alliance is apparently highly dependent on seasonal precipitation for its local abundance and perhaps composition, which may vary significantly from year to year. The type is made up almost entirely of non-native vegetation. The bulk of associated species grow beneath the upper layer of tall forbs. Grasses, both annual and perennial, grow sparsely in patches in this community: *Chloris virgata*, *Bouteloua aristidoides*, *Sporobolus cryptandrus*, *Sporobolus wrightii*, *Aristida ternipes,* and *Hilaria belangeri*. The forb, *Bidens leptocephala,* may be prominent in patches. Along the edges of the herbaceous type, sparse low shrubs are often found, including *Baccharis salicifolia, Hymenoclea monogyra,* and *Prosopis velutina*, and occasionally trees such as *Populus fremontii, Sambucus nigra* ssp. *caerulea,* or *Salix gooddingii.* Climbing vines, such as *Ipomoea* spp., may be found in this type growing up from the ground around the taller annual forb vegetation.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally***—Data are not available.

***Tumacácori National Historical Park***—This description is based on 2007–2008 field data (2 classification plots and 5 censused polygons). Because the species composition of this vegetation type can vary over short time and spatial scales, it is best thought of as a complex. This alliance and its position in the hierarchy below are proposed.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | V | Herbaceous Vegetation |
| Formation subclass | V.D | Annual graminoid or forb vegetation |
| Formation group | V.D.2 | Temperate or subpolar annual grasslands or forb vegetation |
| Formation subgroup | V.D.2.N | Natural/Semi-natural temperate or subpolar annual grasslands or forb vegetation |
| Formation name | V.D.2.N.c | Low desert or subdesert ephemeral or episodic annual forb vegetation |
| Alliance name | [*Amaranthus palmeri – Salsola kali – Chenopodium* spp.] Annual Herbaceous Alliance | |
| Association name | Data are not available | |

*Ecological systems placement*

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available | Data are not available |

## NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

## Distribution

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This type is found in 5 polygons: 2 at the Mission unit, 2 at Guevavi, and 1 at Calabazas: H-AP01-M (1.1 ha), H-AP02-M (0.6 ha), H-AP03-G (0.5 ha), H-AP04-G (0.6 ha), H-AP05-C (0.7 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally—***Data are not available.

***Tumacácori National Historical Park—***This annual forb-dominated community is found on sandy soils adjacent to the Santa Cruz River at all three units. All sites are in the basin floor topographic position and are generally flat. Sites are disturbed by grazing and/or flooding. Predominant ground cover, other than plant bases, is bare soil (10–35%), litter (1–35%) and gravel (1–35%).

## Vegetation

***Globally—***Data are not available.

***Tumacácori National Historical Park—****Amaranthus palmeri, Salsola kali,* and *Chenopodium* spp. should be considered co-dominant overall, and their relative abundance may differ spatially within the type. There are areas of fairly homogeneous distribution of both *Amaranthus palmeri* and *Salsola kali* as co-dominants (with or without some *Chenopodium* spp.), and areas where one of the three species is clearly the single dominant, with more or less of the others possibly present. This alliance is apparently highly dependent on seasonal precipitation for its local abundance and perhaps composition, which may vary significantly from year to year. The type is made up almost entirely of non-native vegetation. Trees and shrubs make up less than 10% cover. The bulk of associated species grow beneath the upper layer of tall forbs. Grasses, both annual and perennial, grow sparsely in patches in this community: *Chloris virgata*, *Bouteloua aristidoides*, *Sporobolus cryptandrus*, *Sporobolus wrightii*, *Aristida ternipes,* and *Hilaria belangeri*. The forb, *Bidens leptocephala,* may be prominent in patches. Along the edges of the herbaceous type, sparse, low shrubs are often found, including *Baccharis salicifolia, Hymenoclea monogyra,* and *Prosopis velutina*, and occasionally trees such as *Populus fremontii, Sambucus nigra* ssp. *caerulea,* or *Salix gooddingii.* Climbing vines, such as *Ipomoea* spp., may be found in this type growing up from the ground around the taller annual forb vegetation.

***Most abundant species: Globally—***Data are not available.
***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | Not applicable, none |
| Canopy (2–5m) | Not applicable, none |
| Sub-canopy (0.5–2m) | Not applicable, none |
| Field (0–0.5m) | *Amaranthus palmeri, Salsola kali, Chenopodium* sp. |

***Other noteworthy species: Globally—***Data are not available.
***Tumacácori National Historical Park—****Chloris virgata*, *Bouteloua aristidoides*, *Sporobolus cryptandrus*, *Sporobolus wrightii*, *Aristida ternipes, Hilaria belangeri,* and *Bidens leptocephala*.

## Element sources

***Global description authors:*** Data are not available.
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

# D.8 Sparsely Vegetated

## *D.8.1 Inland Freshwater Strand Beach Sparse Vegetation*

***Translated name:*** Inland Strand Beach Sparsely Vegetated Alliance
Inland Freshwater Strand Beach Sparse Vegetation
***NatureServe code:*** A.1862 / CEGL002310

### Summary

***Globally—***This is technically not an alliance. It is a placeholder for a group of sparsely vegetated associations that do not have adequate vegetation descriptions but do share certain substrate characteristics.

***Tumacácori National Historical Park—***This type is composed of mostly-bare sand in the Santa Cruz River's active channel. Some forbs may be present in areas colonized since the last flood event. Seedlings or saplings of *Populus fremontii* and *Salix gooddingii* may also be present. The position of strand beaches tends to shift with flood events in the fluvial system.

### Classification

***Classification confidence:*** Data are not available.
***Classification comments: Globally—***This is technically not an alliance. It is a placeholder for a group of sparsely vegetated associations that do not have adequate vegetation descriptions but do share certain substrate characteristics.

***Tumacácori National Historical Park—***This description is based on 2007–2008 field data (2 censused polygons). At TUMA, this is a riverine, flood-scoured strand rather than a lacustrine beach strand, as described by NatureServefor the Great Lakes region.

***Vegetation hierarchy***

| | | |
|---|---|---|
| Formation class | VII | Sparse Vegetation |
| Formation subclass | VII.C | Unconsolidated material sparse vegetation |
| Formation group | VII.C.2 | Sparsely vegetated sand flats |
| Formation subgroup | VII.C.2.N | Natural/Semi-natural sparsely vegetated sand flats |
| Formation name | VII.C.2.N.a | Sand flats |
| Alliance name | Inland Strand Beach Sparsely Vegetated Alliance | |
| Association name | Inland Freshwater Strand Beach Sparse Vegetation | |

***Ecological systems placement***

| Ecological system unique ID | Ecological system name |
|---|---|
| Data are not available. | Data are not available. |

### NatureServe conservation status

***Global status:*** Data are not available.
***Rounded global status:*** Data are not available.

### Distribution

***Globally—***United States: IN, ME, MI, MN, NY, VT, WI. Canada: MB, ON, SK

***Tumacácori National Historical Park—***This type is found in 2 polygons: 1 at Guevavi and 1 at Calabazas: St01-G (2.7 ha), St02-C (2.4 ha).

## Environmental setting

***USFWS wetland system:*** No

***Environmental summary: Globally—***Data are not available.

***Tumacácori National Historical Park—***This type is composed of mostly-bare sand in the Santa Cruz river's active channel. Some forbs may be present in areas colonized since the last flood event. Seedlings or saplings of *Populus fremontii* and *Salix gooddingii* may also be present. The position of strand beaches tends to shift with flood events in the fluvial system.

## Vegetation

***Globally—***Data are not available.

***Tumacácori National Historical Park—***This type is composed of mostly-bare sand in the Santa Cruz river's active channel. Some forbs may be present in areas colonized since the last flood event. Seedlings or saplings of *Populus fremontii* and *Salix gooddingii* may also be present. The position of strand beaches tends to shift with flood events in the fluvial system.

***Most abundant species: Globally—***Data are not available.
***Tumacácori National Historical Park—***

| Stratum | Species |
|---|---|
| Top canopy (>5m) | none |
| Canopy (2–5m) | none |
| Sub-canopy (0.5–2m) | *Populus fremontii*, *Salix gooddingii* (seedlings) |
| Field (0–0.5m) | annual forbs |

***Other noteworthy species: Globally—***Data are not available.
***Tumacácori National Historical Park—***None.

## Element sources

***Global description authors:*** Midwestern Ecology Group
***Local description authors:*** S. Buckley and S. Drake
***References:*** Data are not available.

## D.9 Developed Woodland

DW-01-M

This is a park-special map class. This type in the TUMA area is comprised of homes, commercial buildings, and roads built in former mesquite forest or woodland, with minimal to extensive clearing of trees. Occurs primarily outside park boundary, in study-area buffer.

## D.10 Cropland and Pasture

CP-01-M, CP-02-M

IPMOW01, IPMOW02, IPMOW03, IPMOW04, IPMOW05, IPMOW06

This is an Anderson Level 2 class, applied to active irrigated pasture (in study area buffer), and historic cultivated area adjacent to Mission.

## D.11 Park Facilities

PF-01-M, PF-02-C

This is a park-special map class, as no Anderson class is applicable. Includes park ruins, historic orchard area, Fiesta Grounds, maintenance facilities, access roads, and visitor center area.

# Appendix E
# Species List

**Table E-1. Plant species observed at Tumacácori National Historical Park, organized by family.**

| Family | Scientific name | Common name | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| Acanthaceae | *Anisacanthus thurberi* | Thurber's desert honeysuckle | X | X | X |
| Acanthaceae | *Dicliptera resupinata* | Arizona foldwing | X | | |
| Acanthaceae | *Ruellia nudiflora* | violet wild petunia | X | | |
| Acanthaceae | *Tetramerium nervosum* | hairy fournwort | X | X | X |
| Agavaceae | *Yucca elata* | soaptree yucca | | X | |
| Amaranthaceae | *Amaranthus palmeri* | carelessweed | X | X | X |
| Anacardiaceae | *Rhus trilobata* | skunkbush sumac | X | | |
| Apiaceae | *Bowlesia incana* | hoary bowlesia | X | | |
| Apiaceae | *Conium maculatum* | poison hemlock | X | X | |
| Asteraceae | *Acourtia nana* | dwarf desertpeony | | X | |
| Asteraceae | *Ambrosia* | ragweed | X | X | X |
| Asteraceae | *Ambrosia confertiflora* | weakleaf burr ragweed | X | X | X |
| Asteraceae | *Aster* | aster | X | | |
| Asteraceae | *Baccharis salicifolia* | mule's fat | X | | X |
| Asteraceae | *Baccharis sarothroides* | desertbroom | X | X | X |
| Asteraceae | *Bidens lemmonii* | Lemmon's beggarticks | X | X | |
| Asteraceae | *Bidens leptocephala* | fewflower beggarticks | X | X | X |
| Asteraceae | *Chaenactis douglasii* | Douglas' dustymaiden | | | X |
| Asteraceae | *Cirsium neomexicanum* | New Mexico thistle | X | | |
| Asteraceae | *Conyza canadensis* | Canadian horseweed | X | | |
| Asteraceae | *Erigeron* | fleabane | X | | |
| Asteraceae | *Erigeron divergens* | spreading fleabane | X | | |
| Asteraceae | *Gnaphalium* | cudweed | X | | |
| Asteraceae | *Gnaphalium palustre* | western marsh cudweed | X | | |
| Asteraceae | *Gutierrezia microcephala* | threadleaf snakeweed | | X | X |
| Asteraceae | *Helianthus annuus* | common sunflower | X | X | X |
| Asteraceae | *Hymenoclea monogyra* | singlewhorl burrobrush | X | X | X |
| Asteraceae | *Isocoma tenuisecta* | burroweed | X | | |
| Asteraceae | *Senecio flaccidus* | threadleaf groundsel | X | | |
| Asteraceae | *Sonchus asper* | spiny sowthistle | X | X | |
| Asteraceae | *Tagetes micrantha* | licorice marigold | | | |
| Asteraceae | *Tithonia thurberi* | Arizona sunflowerweed | X | X | X |
| Asteraceae | *Xanthium strumarium* | rough cockleburr | X | X | X |
| Asteraceae | *Zinnia acerosa* | desert zinnia | | X | |
| Betulaceae | *Alnus oblongifolia* | Arizona alder | X | | |
| Boraginaceae | *Cryptantha* | cryptantha | | X | |
| Brassicaceae | *Brassicaceae* | mustards | X | | |
| Brassicaceae | *Descurainia pinnata* | western tansymustard | X | X | X |
| Brassicaceae | *Lepidium* | pepperweed | X | | |
| Brassicaceae | *Lesquerella gordonii* | gordon bladderpod | X | X | |
| Brassicaceae | *Sisymbrium irio* | London rocket | X | X | X |

***Plant species observed at Tumacácori National Historical Park, organized by family, cont.***

| Family | Scientific name | Common name | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| Cactaceae | *Echinocereus* | hedgehog cactus | | X | |
| Cactaceae | *Ferocactus wislizeni* | candy barrelcactus | | X | X |
| Cactaceae | *Opuntia engelmannii* | cactus apple | X | X | |
| Cactaceae | *Opuntia leptocaulis* | Christmas cactus | | X | |
| Cactaceae | *Opuntia spinosior* | walkingstick cactus | X | X | X |
| Caprifoliaceae | *Sambucus nigra* | European black elderberry | X | X | |
| Caprifoliaceae | *Sambucus nigra* ssp. *canadensis* | common elderberry | X | | X |
| Caprifoliaceae | *Sambucus nigra* ssp. *cerulea* | blue elderberry | X | X | X |
| Chenopodiaceae | *Atriplex canescens* | fourwing saltbush | X | | |
| Chenopodiaceae | *Atriplex elegans* | wheelscale saltbush | X | | |
| Chenopodiaceae | *Chenopodium* | goosefoot | X | X | X |
| Chenopodiaceae | *Chenopodium album* | lambsquarters | X | | |
| Chenopodiaceae | *Chenopodium berlandieri* | pitseed goosefoot | X | X | |
| Chenopodiaceae | *Chenopodium rubrum* | red goosefoot | X | | |
| Chenopodiaceae | *Salsola kali* | Russian thistle | X | X | X |
| Convolvulaceae | *Convolvulus arvensis* | field bindweed | X | | |
| Convolvulaceae | *Ipomoea* | morning-glory vine | X | X | X |
| Convolvulaceae | *Ipomoea coccinea* | redstar | | | X |
| Convolvulaceae | *Ipomoea hederacea* | ivyleaf morning-glory | | | X |
| Cucurbitaceae | *Cucurbita foetidissima* | Missouri gourd | X | | |
| Cupressaceae | *Juniperus coahuilensis* | redberry juniper | | X | X |
| Cyperaceae | *Cyperus* | flatsedge | X | | |
| Cyperaceae | *Cyperus odoratus* | fragrant flatsedge | X | | |
| Equisetaceae | *Equisetum arvense* | field horsetail | X | | |
| Ericaceae | *Arctostaphylos pungens* | pointleaf manzanita | X | | |
| Euphorbiaceae | *Acalypha ostryifolia* | pineland threeseed mercury | X | | |
| Euphorbiaceae | *Chamaesyce* | sandmat | X | | |
| Euphorbiaceae | *Chamaesyce albomarginata* | whitemargin sandmat | X | | |
| Euphorbiaceae | *Euphorbia heterophylla* | Mexican fireplant | X | | |
| Fabaceae | *Acacia constricta* | whitethorn acacia | | X | |
| Fabaceae | *Acacia greggii* | catclaw acacia | X | X | X |
| Fabaceae | *Astragalus* | astragalus | | X | |
| Fabaceae | *Calliandra eriophylla* | fairyduster | | X | |
| Fabaceae | *Lotus humistratus* | foothill deervetch | X | | |
| Fabaceae | *Lupinus* | lupine | X | | |
| Fabaceae | *Mimosa aculeaticarpa* | catclaw mimosa | | X | X |
| Fabaceae | *Mimosa aculeaticarpa* var. *biuncifera* | catclaw mimosa | X | X | X |
| Fabaceae | *Parkinsonia aculeata* | Jerusalem thorn | X | | |
| Fabaceae | *Phaseolus ritensis* | Santa Rita Mountain bean | X | | |
| Fabaceae | *Prosopis velutina* | velvet mesquite | X | X | X |
| Fabaceae | *Senna bauhinioides* | twinleaf senna | X | | |
| Geraniaceae | *Erodium texanum* | Texas stork's bill | | X | |
| Hydrophyllaceae | *Phacelia* | phacelia | X | X | X |
| Juncaceae | *Juncus cooperi* | Cooper's rush | | X | |
| Lamiaceae | *Marrubium vulgare* | horehound | X | | |
| Lamiaceae | *Salazaria mexicana* | Mexican bladdersage | X | X | X |
| Loasaceae | *Mentzelia* | blazingstar | X | | X |
| Loasaceae | *Mentzelia albicaulis* | whitestem blazingstar | X | X | X |

***Plant species observed at Tumacácori National Historical Park, organized by family, cont.***

| Family | Scientific name | Common name | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| Malvaceae | *Anoda cristata* | crested anoda | X | | |
| Malvaceae | *Sida* | fanpetals | X | | |
| Malvaceae | *Sida abutifolia* | spreading fanpetals | X | | |
| Malvaceae | *Sphaeralcea* | globemallow | | X | X |
| Malvaceae | *Sphaeralcea coccinea* | scarlet globemallow | X | | |
| Malvaceae | *Sphaeralcea laxa* | caliche globemallow | X | | |
| Malvaceae | *Sphaeralcea wrightii* | Wright's globemallow | X | X | X |
| Moraceae | *Morus microphylla* | Texas mulberry | X | | X |
| Nyctaginaceae | *Allionia incarnata* | trailing windmills | | X | |
| Nyctaginaceae | *Boerhavia* | boerhavia | X | | |
| Nyctaginaceae | *Boerhavia coccinea* | scarlet spiderling | X | X | X |
| Nyctaginaceae | *Boerhavia intermedia* | fivewing spiderling | X | | |
| Nyctaginaceae | *Boerhavia spicata* | creeping spiderling | X | X | X |
| Nyctaginaceae | *Mirabilis tenuiloba* | longlobe four o'clock | X | | |
| Oleaceae | *Fraxinus velutina* | velvet ash | X | | X |
| Onagraceae | *Camissonia* | suncup | | | X |
| Onagraceae | *Gaura coccinea* | scarlet beeblossom | X | | |
| Onagraceae | *Gaura mollis* | velvetweed | X | | |
| Onagraceae | *Oenothera* | evening-primrose | X | X | X |
| Onagraceae | *Oenothera primiveris* | desert evening-primrose | | X | |
| Papaveraceae | *Argemone* | pricklypoppy | X | | |
| Papaveraceae | *Argemone pleiacantha* | southwestern pricklypoppy | X | | |
| Papaveraceae | *Eschscholzia californica* | California poppy | | | X |
| Papaveraceae | *Eschscholzia californica* ssp. *mexicana* | California poppy | | X | |
| Passifloraceae | *Passiflora mexicana* | Mexican passionflower | X | | X |
| Pedaliaceae | *Proboscidea parviflora* | doubleclaw | X | X | |
| Phytolaccaceae | *Rivina humilis* | rougeplant | X | | X |
| Platanaceae | *Platanus wrightii* | Arizona sycamore | X | | |
| Poaceae | *Aristida* | threeawn | | X | X |
| Poaceae | *Aristida purpurea* | purple threeawn | X | X | X |
| Poaceae | *Aristida ternipes* | spidergrass | X | X | X |
| Poaceae | *Bothriochloa barbinodis* | cane bluestem | X | X | X |
| Poaceae | *Bouteloua* | grama | | X | X |
| Poaceae | *Bouteloua aristidoides* | needle grama | X | X | X |
| Poaceae | *Bouteloua aristidoides* var. *arizonica* | Arizona needle grama | X | | |
| Poaceae | *Bouteloua barbata* | sixweeks grama | X | | |
| Poaceae | *Bouteloua curtipendula* | sideoats grama | X | X | X |
| Poaceae | *Bouteloua radicosa* | purple grama | X | | X |
| Poaceae | *Bouteloua rothrockii* | Rothrock's grama | X | X | X |
| Poaceae | *Bromus carinatus* | California brome | X | | |
| Poaceae | *Bromus catharticus* | rescuegrass | X | | |
| Poaceae | *Chloris virgata* | feather fingergrass | X | X | X |
| Poaceae | *Cottea pappophoroides* | cotta grass | X | X | |
| Poaceae | *Cynodon dactylon* | Bermudagrass | X | X | X |
| Poaceae | *Digitaria californica* | Arizona cottontop | | X | |
| Poaceae | *Eragrostis* | lovegrass | X | X | |
| Poaceae | *Eragrostis cilianensis* | stinkgrass | X | X | X |

***Plant species observed at Tumacácori National Historical Park, organized by family, cont.***

| Family | Scientific name | Common name | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| Poaceae | *Eragrostis curvula* | weeping lovegrass | X | | |
| Poaceae | *Eragrostis lehmanniana* | Lehmann lovegrass | X | X | X |
| Poaceae | *Erioneuron avenaceum* | shortleaf woollygrass | | X | |
| Poaceae | *Hilaria belangeri* | curly-mesquite | X | | |
| Poaceae | *Leptochloa dubia* | green sprangletop | X | X | X |
| Poaceae | *Leptochloa panicea* | green sprangletop | X | | |
| Poaceae | *Muhlenbergia fragilis* | delicate muhly | X | X | X |
| Poaceae | *Muhlenbergia polycaulis* | cliff muhly | | X | |
| Poaceae | *Muhlenbergia porteri* | bush muhly | | X | X |
| Poaceae | *Panicum* | panicgrass | X | | |
| Poaceae | *Panicum miliaceum* | broomcorn millet | | X | |
| Poaceae | *Panicum obtusum* | vine mesquite | | X | |
| Poaceae | *Phragmites australis* | common reed | X | | |
| Poaceae | *Setaria* | bristlegrass | X | X | X |
| Poaceae | *Setaria leucopila* | streambed bristlegrass | | X | |
| Poaceae | *Sorghum halepense* | Johnsongrass | X | X | X |
| Poaceae | *Sporobolus contractus* | spike dropseed | X | | |
| Poaceae | *Sporobolus cryptandrus* | sand dropseed | X | X | X |
| Poaceae | *Sporobolus wrightii* | big sacaton | X | X | X |
| Polygonaceae | *Eriogonum* | buckwheat | X | | X |
| Polygonaceae | *Eriogonum inflatum* | desert trumpet | | X | |
| Polygonaceae | *Rumex hymenosepalus* | canaigre dock | X | | |
| Pteridaceae | *Cheilanthes villosa* | villous lipfern | X | X | X |
| Ranunculaceae | *Clematis* | leather flower | X | | |
| Ranunculaceae | *Clematis drummondii* | Drummond's clematis | X | | |
| Rhamnaceae | *Ceanothus greggii* | desert ceanothus | X | X | |
| Rhamnaceae | *Condalia warnockii* | Warnock's snakewood | X | X | X |
| Rhamnaceae | *Ziziphus obtusifolia* | lotebush | X | X | X |
| Rhamnaceae | *Ziziphus obtusifolia* var. *obtusifolia* | lotebush | X | | |
| Rosaceae | *Fragaria vesca* | woodland strawberry | X | | |
| Rosaceae | *Pyracantha fortuneana* | Chinese firethorn | X | | |
| Salicaceae | *Populus fremontii* | Fremont cottonwood | X | X | X |
| Salicaceae | *Salix gooddingii* | Goodding's willow | X | | X |
| Salicaceae | *Salix taxifolia* | yewleaf willow | | | X |
| Sapindaceae | *Sapindus saponaria* | wingleaf soapberry | X | | X |
| Scrophulariaceae | *Mimulus cardinalis* | scarlet monkeyflower | | | X |
| Scrophulariaceae | *Penstemon parryi* | Parry's beardtongue | | X | |
| Solanaceae | *Datura* | jimsonweed | X | | X |
| Solanaceae | *Datura stramonium* | jimsonweed | X | | |
| Solanaceae | *Lycium* | desert-thorn | X | X | X |
| Solanaceae | *Lycium andersonii* | water jacket | X | X | |
| Solanaceae | *Nicotiana glauca* | tree tobacco | X | | |
| Solanaceae | *Solanum elaeagnifolium* | silverleaf nightshade | X | | |
| Tamaricaceae | *Tamarix ramosissima* | saltcedar | X | | X |
| Ulmaceae | *Celtis laevigata* | sugarberry | X | X | X |
| Ulmaceae | *Celtis laevigata* var. *reticulata* | netleaf hackberry | X | | X |
| Ulmaceae | *Celtis pallida* | spiny hackberry | X | | |
| Urticaceae | *Parkinsonia florida* | blue paloverde | X | | |

***Plant species observed at Tumacácori National Historical Park, organized by family, cont.***

| Family | Scientific name | Common name | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| Violaceae | *Hybanthus* | greenviolet | X | | |
| Vitaceae | *Vitis arizonica* | canyon grape | | X | |
| Zygophyllaceae | *Tribulus terrestris* | puncturevine | X | | |

Nomenclature follows the Integrated Taxonomic Information System (http://www.itis.gov/)
Highlighted species are non-native (introduced).

**Table E-2. Plant species observed at Tumacácori National Historical Park, by scientific name.**

| Scientific name | Common name | Family | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| *Acacia constricta* | whitethorn acacia | Fabaceae | | X | |
| *Acacia greggii* | catclaw acacia | Fabaceae | X | X | X |
| *Acalypha ostryifolia* | pineland threeseed mercury | Euphorbiaceae | X | | |
| *Acourtia nana* | dwarf desertpeony | Asteraceae | | X | |
| *Allionia incarnata* | trailing windmills | Nyctaginaceae | | X | |
| *Alnus oblongifolia* | Arizona alder | Betulaceae | X | | |
| *Amaranthus palmeri* | carelessweed | Amaranthaceae | X | X | X |
| *Ambrosia* | ragweed | Asteraceae | X | X | X |
| *Ambrosia confertiflora* | weakleaf burr ragweed | Asteraceae | X | X | X |
| *Anisacanthus thurberi* | Thurber's desert honeysuckle | Acanthaceae | X | X | X |
| *Anoda cristata* | crested anoda | Malvaceae | X | | |
| *Arctostaphylos pungens* | pointleaf manzanita | Ericaceae | X | | |
| *Argemone* | pricklypoppy | Papaveraceae | X | | |
| *Argemone pleiacantha* | southwestern pricklypoppy | Papaveraceae | X | | |
| *Aristida* | threeawn | Poaceae | | X | X |
| *Aristida purpurea* | purple threeawn | Poaceae | X | X | X |
| *Aristida ternipes* | spidergrass | Poaceae | X | X | X |
| *Aster* | aster | Asteraceae | X | | |
| *Astragalus* | astragalus | Fabaceae | | X | |
| *Atriplex canescens* | fourwing saltbush | Chenopodiaceae | X | | |
| *Atriplex elegans* | wheelscale saltbush | Chenopodiaceae | X | | |
| *Baccharis salicifolia* | mule's fat | Asteraceae | X | | X |
| *Baccharis sarothroides* | desertbroom | Asteraceae | X | X | X |
| *Bidens lemmonii* | Lemmon's beggarticks | Asteraceae | X | X | |
| *Bidens leptocephala* | fewflower beggarticks | Asteraceae | X | X | X |
| *Boerhavia* | boerhavia | Nyctaginaceae | X | | |
| *Boerhavia coccinea* | scarlet spiderling | Nyctaginaceae | X | X | X |
| *Boerhavia intermedia* | fivewing spiderling | Nyctaginaceae | X | | |
| *Boerhavia spicata* | creeping spiderling | Nyctaginaceae | X | X | X |
| *Bothriochloa barbinodis* | cane bluestem | Poaceae | X | X | X |
| *Bouteloua* | grama | Poaceae | | X | X |
| *Bouteloua aristidoides* | needle grama | Poaceae | X | X | X |
| *Bouteloua aristidoides* var. *arizonica* | Arizona needle grama | Poaceae | X | | |
| *Bouteloua barbata* | sixweeks grama | Poaceae | X | | |
| *Bouteloua curtipendula* | sideoats grama | Poaceae | X | X | X |
| *Bouteloua radicosa* | purple grama | Poaceae | X | | X |
| *Bouteloua rothrockii* | Rothrock's grama | Poaceae | X | X | X |
| *Bowlesia incana* | hoary bowlesia | Apiaceae | X | | |
| *Brassicaceae* | mustards | Brassicaceae | X | | |
| *Bromus carinatus* | California brome | Poaceae | X | | |
| *Bromus catharticus* | rescuegrass | Poaceae | X | | |
| *Calliandra eriophylla* | fairyduster | Fabaceae | | X | |

***Plant species observed at Tumacácori National Historical Park, organized by scientific name, cont.***

| Scientific name | Common name | Family | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| *Camissonia* | suncup | Onagraceae | | | X |
| *Ceanothus greggii* | desert ceanothus | Rhamnaceae | X | X | |
| *Celtis laevigata* | sugarberry | Ulmaceae | X | X | X |
| *Celtis laevigata* var. *reticulata* | netleaf hackberry | Ulmaceae | X | | X |
| *Celtis pallida* | spiny hackberry | Ulmaceae | X | | |
| *Chaenactis douglasii* | Douglas' dustymaiden | Asteraceae | | | X |
| *Chamaesyce* | sandmat | Euphorbiaceae | X | | |
| *Chamaesyce albomarginata* | whitemargin sandmat | Euphorbiaceae | X | | |
| *Cheilanthes villosa* | villous lipfern | Pteridaceae | X | X | X |
| *Chenopodium* | goosefoot | Chenopodiaceae | X | X | X |
| *Chenopodium album* | lambsquarters | Chenopodiaceae | X | | |
| *Chenopodium berlandieri* | pitseed goosefoot | Chenopodiaceae | X | X | |
| *Chenopodium rubrum* | red goosefoot | Chenopodiaceae | X | | |
| *Chloris virgata* | feather fingergrass | Poaceae | X | X | X |
| *Cirsium neomexicanum* | New Mexico thistle | Asteraceae | X | | |
| *Clematis* | leather flower | Ranunculaceae | X | | |
| *Clematis drummondii* | Drummond's clematis | Ranunculaceae | X | | |
| *Condalia warnockii* | Warnock's snakewood | Rhamnaceae | X | X | X |
| *Conium maculatum* | poison hemlock | Apiaceae | X | X | |
| *Convolvulus arvensis* | field bindweed | Convolvulaceae | X | | |
| *Conyza canadensis* | Canadian horseweed | Asteraceae | X | | |
| *Cottea pappophoroides* | cotta grass | Poaceae | X | X | |
| *Cryptantha* | cryptantha | Boraginaceae | | X | |
| *Cucurbita foetidissima* | Missouri gourd | Cucurbitaceae | X | | |
| *Cynodon dactylon* | Bermudagrass | Poaceae | X | X | X |
| *Cyperus* | flatsedge | Cyperaceae | X | | |
| *Cyperus odoratus* | fragrant flatsedge | Cyperaceae | X | | |
| *Datura* | jimsonweed | Solanaceae | X | | X |
| *Datura stramonium* | jimsonweed | Solanaceae | X | | |
| *Descurainia pinnata* | western tansymustard | Brassicaceae | X | X | X |
| *Dicliptera resupinata* | Arizona foldwing | Acanthaceae | X | | |
| *Digitaria californica* | Arizona cottontop | Poaceae | | X | |
| *Echinocereus* | hedgehog cactus | Cactaceae | | X | |
| *Equisetum arvense* | field horsetail | Equisetaceae | X | | |
| *Eragrostis* | lovegrass | Poaceae | X | X | |
| *Eragrostis cilianensis* | stinkgrass | Poaceae | X | X | X |
| *Eragrostis curvula* | weeping lovegrass | Poaceae | X | | |
| *Eragrostis lehmanniana* | Lehmann lovegrass | Poaceae | X | X | X |
| *Erigeron* | fleabane | Asteraceae | X | | |
| *Erigeron divergens* | spreading fleabane | Asteraceae | X | | |
| *Eriogonum* | buckwheat | Polygonaceae | X | | X |
| *Eriogonum inflatum* | desert trumpet | Polygonaceae | | X | |
| *Erioneuron avenaceum* | shortleaf woollygrass | Poaceae | | X | |

***Plant species observed at Tumacácori National Historical Park, organized by scientific name, cont.***

| Scientific name | Common name | Family | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| *Erodium texanum* | Texas stork's bill | Geraniaceae | | X | |
| *Eschscholzia californica* | California poppy | Papaveraceae | | | X |
| *Eschscholzia californica* ssp. *mexicana* | California poppy | Papaveraceae | | X | |
| *Euphorbia heterophylla* | Mexican fireplant | Euphorbiaceae | X | | |
| *Ferocactus wislizeni* | candy barrelcactus | Cactaceae | | X | X |
| *Fragaria vesca* | woodland strawberry | Rosaceae | X | | |
| *Fraxinus velutina* | velvet ash | Oleaceae | X | | X |
| *Gaura coccinea* | scarlet beeblossom | Onagraceae | X | | |
| *Gaura mollis* | velvetweed | Onagraceae | X | | |
| *Gnaphalium* | cudweed | Asteraceae | X | | |
| *Gnaphalium palustre* | western marsh cudweed | Asteraceae | X | | |
| *Gutierrezia microcephala* | threadleaf snakeweed | Asteraceae | | X | X |
| *Helianthus annuus* | common sunflower | Asteraceae | X | X | X |
| *Hilaria belangeri* | curly-mesquite | Poaceae | X | | |
| *Hybanthus* | greenviolet | Violaceae | X | | |
| *Hymenoclea monogyra* | singlewhorl burrobrush | Asteraceae | X | X | X |
| *Ipomoea* | morning-glory vine | Convolvulaceae | X | X | X |
| *Ipomoea coccinea* | redstar | Convolvulaceae | | | X |
| *Ipomoea hederacea* | ivyleaf morning-glory | Convolvulaceae | | | X |
| *Isocoma tenuisecta* | burroweed | Asteraceae | X | | |
| *Juncus cooperi* | Cooper's rush | Juncaceae | | X | |
| *Juniperus coahuilensis* | redberry juniper | Cupressaceae | | X | X |
| *Lepidium* | pepperweed | Brassicaceae | X | | |
| *Leptochloa dubia* | green sprangletop | Poaceae | X | X | X |
| *Leptochloa panicea* | green sprangletop | Poaceae | X | | |
| *Lesquerella gordonii* | gordon bladderpod | Brassicaceae | X | X | |
| *Lotus humistratus* | foothill deervetch | Fabaceae | X | | |
| *Lupinus* | lupine | Fabaceae | X | | |
| *Lycium* | desert-thorn | Solanaceae | X | X | X |
| *Lycium andersonii* | water jacket | Solanaceae | X | X | |
| *Marrubium vulgare* | horehound | Lamiaceae | X | | |
| *Mentzelia* | blazingstar | Loasaceae | X | | X |
| *Mentzelia albicaulis* | whitestem blazingstar | Loasaceae | X | X | X |
| *Mimosa aculeaticarpa* | catclaw mimosa | Fabaceae | | X | X |
| *Mimosa aculeaticarpa* var. *biuncifera* | catclaw mimosa | Fabaceae | X | X | X |
| *Mimulus cardinalis* | scarlet monkeyflower | Scrophulariaceae | | | X |
| *Mirabilis tenuiloba* | longlobe four o'clock | Nyctaginaceae | X | | |
| *Morus microphylla* | Texas mulberry | Moraceae | X | | X |
| *Muhlenbergia fragilis* | delicate muhly | Poaceae | X | X | X |
| *Muhlenbergia polycaulis* | cliff muhly | Poaceae | | X | |
| *Muhlenbergia porteri* | bush muhly | Poaceae | | X | X |

***Plant species observed at Tumacácori National Historical Park, organized by scientific name, cont.***

| Scientific name | Common name | Family | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| *Nicotiana glauca* | tree tobacco | Solanaceae | X | | |
| *Oenothera* | evening-primrose | Onagraceae | X | X | X |
| *Oenothera primiveris* | desert evening-primrose | Onagraceae | | X | |
| *Opuntia engelmannii* | cactus apple | Cactaceae | X | X | |
| *Opuntia leptocaulis* | Christmas cactus | Cactaceae | | X | |
| *Opuntia spinosior* | walkingstick cactus | Cactaceae | X | X | X |
| *Panicum* | panicgrass | Poaceae | X | | |
| *Panicum miliaceum* | broomcorn millet | Poaceae | | X | |
| *Panicum obtusum* | vine mesquite | Poaceae | | X | |
| *Parkinsonia florida* | blue paloverde | Urticaceae | X | | |
| *Parkinsonia aculeata* | Jerusalem thorn | Fabaceae | X | | |
| *Passiflora mexicana* | Mexican passionflower | Passifloraceae | X | | X |
| *Penstemon parryi* | Parry's beardtongue | Scrophulariaceae | | X | |
| *Phacelia* | phacelia | Hydrophyllaceae | X | X | X |
| *Phaseolus ritensis* | Santa Rita Mountain bean | Fabaceae | X | | |
| *Phragmites australis* | common reed | Poaceae | X | | |
| *Platanus wrightii* | Arizona sycamore | Platanaceae | X | | |
| *Populus fremontii* | Fremont cottonwood | Salicaceae | X | X | X |
| *Proboscidea parviflora* | doubleclaw | Pedaliaceae | X | X | |
| *Prosopis velutina* | velvet mesquite | Fabaceae | X | X | X |
| *Pyracantha fortuneana* | Chinese firethorn | Rosaceae | X | | |
| *Rhus trilobata* | skunkbush sumac | Anacardiaceae | X | | |
| *Rivina humilis* | rougeplant | Phytolaccaceae | X | | X |
| *Ruellia nudiflora* | violet wild petunia | Acanthaceae | X | | |
| *Rumex hymenosepalus* | canaigre dock | Polygonaceae | X | | |
| *Salazaria mexicana* | Mexican bladdersage | Lamiaceae | X | X | X |
| *Salix gooddingii* | Goodding's willow | Salicaceae | X | | X |
| *Salix taxifolia* | yewleaf willow | Salicaceae | | | X |
| *Salsola kali* | Russian thistle | Chenopodiaceae | X | X | X |
| *Sambucus nigra* | European black elderberry | Caprifoliaceae | X | X | |
| *Sambucus nigra* ssp. *canadensis* | common elderberry | Caprifoliaceae | X | | X |
| *Sambucus nigra* ssp. *cerulea* | blue elderberry | Caprifoliaceae | X | X | X |
| *Sapindus saponaria* | wingleaf soapberry | Sapindaceae | X | | X |
| *Senecio flaccidus* | threadleaf groundsel | Asteraceae | X | | |
| *Senna bauhinioides* | twinleaf senna | Fabaceae | X | | |
| *Setaria* | bristlegrass | Poaceae | X | X | X |
| *Setaria leucopila* | streambed bristlegrass | Poaceae | | X | |
| *Sida* | fanpetals | Malvaceae | X | | |
| *Sida abutifolia* | spreading fanpetals | Malvaceae | X | | |
| *Sisymbrium irio* | London rocket | Brassicaceae | X | X | X |
| *Solanum elaeagnifolium* | silverleaf nightshade | Solanaceae | X | | |
| *Sonchus asper* | spiny sowthistle | Asteraceae | X | X | |
| *Sorghum halepense* | Johnsongrass | Poaceae | X | X | X |

***Plant species observed at Tumacácori National Historical Park, organized by scientific name, cont.***

| Scientific name | Common name | Family | Mission | Calabazas | Guevavi |
|---|---|---|---|---|---|
| *Sphaeralcea* | globemallow | Malvaceae | | X | X |
| *Sphaeralcea coccinea* | scarlet globemallow | Malvaceae | X | | |
| *Sphaeralcea laxa* | caliche globemallow | Malvaceae | X | | |
| *Sphaeralcea wrightii* | Wright's globemallow | Malvaceae | X | X | X |
| *Sporobolus contractus* | spike dropseed | Poaceae | X | | |
| *Sporobolus cryptandrus* | sand dropseed | Poaceae | X | X | X |
| *Sporobolus wrightii* | big sacaton | Poaceae | X | X | X |
| *Tagetes micrantha* | licorice marigold | Asteraceae | | | |
| *Tamarix ramosissima* | saltcedar | Tamaricaceae | X | | X |
| *Tetramerium nervosum* | hairy fournwort | Acanthaceae | X | X | X |
| *Tithonia thurberi* | Arizona sunflowerweed | Asteraceae | X | X | X |
| *Tribulus terrestris* | puncturevine | Zygophyllaceae | X | | |
| *Vitis arizonica* | canyon grape | Vitaceae | | X | |
| *Xanthium strumarium* | rough cockleburr | Asteraceae | X | X | X |
| *Yucca elata* | soaptree yucca | Agavaceae | | X | |
| *Zinnia acerosa* | desert zinnia | Asteraceae | | X | |
| *Ziziphus obtusifolia* | lotebush | Rhamnaceae | X | X | X |
| *Ziziphus obtusifolia* var. *obtusifolia* | lotebush | Rhamnaceae | X | | |

Nomenclature follows the Integrated Taxonomic Information System (http://www.itis.gov/)
Highlighted species are non-native (introduced).

# Appendix F
# Accuracy Assessment Data Sheet

**Tumacácori NHP Vegetation Mapping**

Field Data Sheet: **Thematic Accuracy Assessment**

| | | | |
|---|---|---|---|
| Date (mm/dd/yyyy): | Time (00:00): | Observer(s): | Recorder: |
| Polygon ID: | | Sub-map: | Unit Code: |
| Approximate polygon center (UTM NAD83): | | | |

Keyed Formation:

Dominant Formation-defining **SPECIES**:

Trees Shrubs Herbaceous Other/None

Based on your observation of this polygon and the vegetation type descriptions provided to you, check the label that best fits this polygon:

| | |
|---|---|
| | Populus fremontii – Salix gooddingii Forest |
| | Prosopis velutina Forest |
| | Celtis laevigata var. reticulata Forest |
| | Populus fremontii – Salix gooddingii Woodland |
| | Prosopis velutina Woodland |
| | Acacia greggii Woodland |
| | Prosopis velutina / [Prosopis velutina – Acacia greggii] Wooded Shrubland |
| | Prosopis velutina – Acacia greggii Shrubland |
| | Acacia constricta Shrubland |
| | Tamarix ramosissima Shrubland |
| | Populus fremontii / mixed annual Wooded Herbaceous |
| | Prosopis velutina / mixed annual Wooded Herbaceous |
| | Prosopis velutina / Amaranthus palmeri Shrub Herbaceous |
| | Hymenoclea monogyra / [Amaranthus palmeri – Chloris virgata] Shrub Herbaceous |
| | Amaranthus palmeri – Salsola kali – Chenopodium spp. Herbaceous |
| | Strand |
| | Developed Woodland |
| | Cropland and Pasture |
| | Park Facilities |

The fit of the vegetation type description to this polygon is (circle one) :

Excellent Good Fair Poor

If poor or fair, write in name of alternate vegetation type (does not need to be from above list)

Record any notes pertinent to your assessment of this polygon. Describe any recent (within the past year) disturbance that may have changed the vegetation type in this polygon, such as flooding, fire, tree cutting, etc. Use back of sheet as needed.

TUMA_AA_Datasheet.ppt

If you find this datasheet completed, please call (520) 621-4501.

# Appendix G
# Root Mean Square Error

**Table G-1. RMSE, Mission Unit**

| Pt. | X source | Y source | X map | Y map |
|---|---|---|---|---|
| 1 | 494840.7 | 3494464.6 | 494840.7 | 3494464.9 |
| 2 | 496166.1 | 3493860.6 | 496166.0 | 3493861.0 |
| 3 | 494964.5 | 3491597.8 | 494964.9 | 3491597.5 |
| 4 | 496276.1 | 3491651.7 | 496275.4 | 3491652.4 |
| 5 | 494672.2 | 3492994.5 | 494672.1 | 3492994.1 |
| 6 | 496246.2 | 3493254.4 | 496244.3 | 3493253.7 |
| 7 | 495145.1 | 3492572.4 | 495145.0 | 3492571.8 |
| 8 | 495493.6 | 3492649.9 | 495493.9 | 3492649.1 |
| 9 | 495737.1 | 3493990.7 | 495737.3 | 3493990.7 |
| 10 | 495390.5 | 3494200.5 | 495390.0 | 3494200.1 |
| 11 | 495077.7 | 3494011.8 | 495077.0 | 3494011.6 |
| 12 | 495408.0 | 3491993.0 | 495407.5 | 3491992.5 |
| 13 | 495236.3 | 3492166.0 | 495236.6 | 3492164.9 |
| 14 | 495959.7 | 3491770.1 | 495960.3 | 3491771.3 |
| 15 | 494957.1 | 3493271.1 | 494956.5 | 3493270.7 |
| 16 | 495469.8 | 3493284.5 | 495469.7 | 3493284.7 |
| 17 | 495577.1 | 3493680.6 | 495576.6 | 3493680.0 |
| 18 | 495156.2 | 3492948.8 | 495156.1 | 3492949.0 |
| 19 | 495837.8 | 3492633.1 | 495838.7 | 3492633.2 |
| 20 | 495558.7 | 3491933.4 | 495559.2 | 3491932.4 |
| | | | **MISSION RMS ERROR** | **0.7697** |

**Table G-2. RMSE, Calabazas Unit**

| Pt. | X source | Y source | X map | Y map |
|---|---|---|---|---|
| 1 | 504588.7 | 3479151.3 | 504589.3 | 3479151.6 |
| 2 | 503230.7 | 3480191.4 | 503230.8 | 3480191.1 |
| 3 | 504477.8 | 3479948.5 | 504478.7 | 3479948.8 |
| 4 | 503075.0 | 3479768.8 | 503074.6 | 3479768.3 |
| 5 | 503793.0 | 3480426.4 | 503793.4 | 3480426.2 |
| 6 | 503893.4 | 3479077.1 | 503893.9 | 3479077.0 |
| 7 | 503833.3 | 3479720.7 | 503833.4 | 3479720.3 |
| 8 | 503700.2 | 3479827.2 | 503699.8 | 3479826.8 |
| 9 | 503943.6 | 3479803.0 | 503943.1 | 3479802.9 |
| 10 | 503911.8 | 3479444.8 | 503912.2 | 3479444.3 |
| 11 | 504100.2 | 3479664.4 | 504100.9 | 3479664.3 |
| 12 | 504050.7 | 3479874.8 | 504050.7 | 3479874.5 |
| 13 | 503778.7 | 3480023.1 | 503779.1 | 3480023.4 |
| 14 | 503257.1 | 3479185.4 | 503257.5 | 3479184.3 |
| 15 | 503761.6 | 3479520.0 | 503762.0 | 3479519.4 |
| 16 | 503988.7 | 3479576.3 | 503989.1 | 3479575.6 |
| 17 | 503801.9 | 3479879.1 | 503802.0 | 3479878.9 |
| 18 | 504121.4 | 3479775.9 | 504121.5 | 3479775.7 |
| 19 | 503574.1 | 3479728.4 | 503573.9 | 3479728.3 |
| 20 | 504217.2 | 3480217.8 | 504217.6 | 3480217.6 |
| | | | **CALABAZAS RMS ERROR** | **0.3991** |

**Table G-3. RMSE, Guevavi Unit**

| Pt. | X source | Y source | X map | Y map |
|---|---|---|---|---|
| 1 | 508820.7 | 3475507.6 | 508822.0 | 3475507.5 |
| 2 | 510093.7 | 3474193.3 | 510094.3 | 3474193.0 |
| 3 | 510178.3 | 3475531.1 | 510179.6 | 3475531.0 |
| 4 | 508580.1 | 3474168.0 | 508580.9 | 3474167.9 |
| 5 | 509262.2 | 3474917.3 | 509263.9 | 3474917.0 |
| 6 | 509518.3 | 3475034.0 | 509517.5 | 3475034.1 |
| 7 | 509477.2 | 3475028.4 | 509476.8 | 3475028.0 |
| 8 | 509146.1 | 3475094.6 | 509147.1 | 3475093.9 |
| 9 | 509502.6 | 3474819.6 | 509503.3 | 3474819.9 |
| 10 | 509501.3 | 3474603.6 | 509503.3 | 3474603.4 |
| 11 | 509345.7 | 3474714.8 | 509346.2 | 3474715.1 |
| 12 | 509342.6 | 3474861.8 | 509344.0 | 3474861.4 |
| 13 | 509393.1 | 3474961.5 | 509393.5 | 3474961.1 |
| 14 | 509272.8 | 3475067.0 | 509274.0 | 3475067.1 |
| 15 | 509475.3 | 3475114.8 | 509475.0 | 3475115.1 |
| 16 | 509331.3 | 3475206.4 | 509331.4 | 3475206.3 |
| 17 | 509080.9 | 3475281.6 | 509079.9 | 3475281.2 |
| 18 | 509012.2 | 3474704.0 | 509014.0 | 3474703.9 |
| 19 | 509901.1 | 3475229.2 | 509901.3 | 3475229.4 |
| 20 | 510070.8 | 3474878.8 | 510070.6 | 3474878.6 |
| | | | **GUEVAVI RMS ERROR** | **0.8538** |

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NPS NPS 311/100300, September 2009

**National Park Service**
**U.S. Department of the Interior**

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