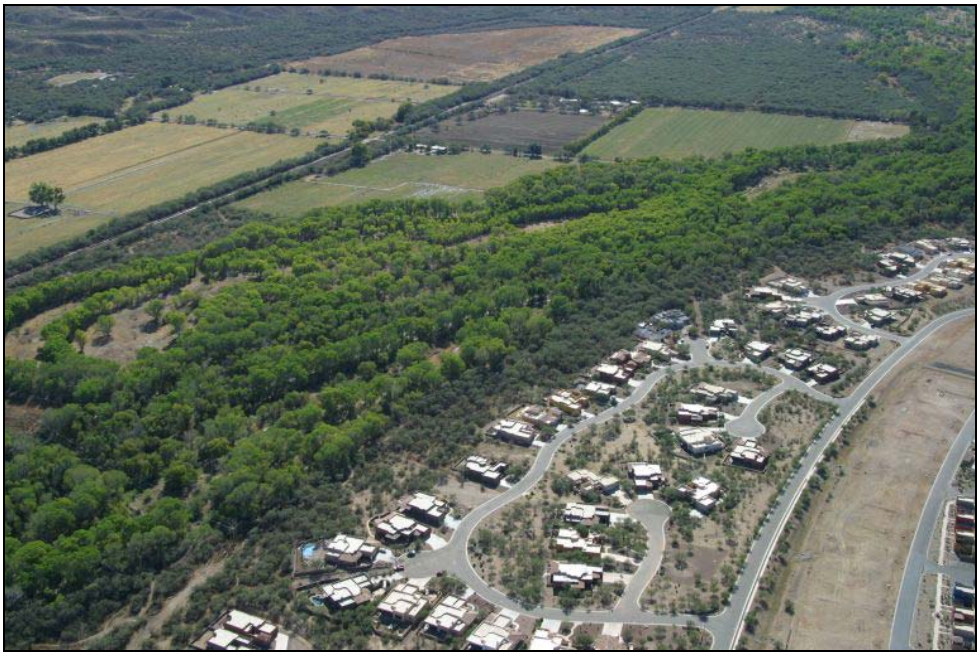
Santa Cruz River Riparian Vegetation Mapping Project
Santa Cruz County, Arizona



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Prepared for Santa Cruz County

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Prepared by:

Sonoran Institute

7650 E. Broadway Blvd. Suite 203

Tucson, Arizona 85710

University of Arizona Remote Sensing Center

Office of Arid Lands Studies

University of Arizona

1955 E. 6th Street

Tucson, Arizona 85719

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This project resulted from the efforts of many people and organizations. Funding for the project was provided by generous grants from the Environmental Protection Agency Wetlands Division and the Mead Foundation. Friends of the Santa Cruz River contributed significant time and expertise throughout the project. Aerial photographs were used to identify seasonal changes in vegetation and were taken during aerial flights provided by the volunteer-based aviation organizations Lighthawk and EcoFlight. Santa Cruz County staff provided historic aerial photographs and field assistance. Friends of the Santa Cruz River and Tucson Audubon Society provided valuable review of the final report.

EXECUTIVE SUMMARY

Riparian vegetation communities represent a small percentage of the land cover in Santa Cruz County but provide invaluable services, functions, and benefits to the region. Working in tandem, riparian vegetation and floodplain lands enhance livelihoods in Santa Cruz County by:

- Filtering effluent-dominated water prior to assimilation with ground water drinking supplies;
- Slowing flood waters;
- Reducing erosion potential along stream banks;
- Facilitating groundwater recharge;
- Sustaining resident and migratory wildlife species;
- Providing recreational opportunities for the local community (i.e. hiking, birding, picnicking);
- Increasing property values of properties adjacent to riparian lands;
- Attracting tourist dollars and new residents to the area.

This report summarizes the creation of the first riparian vegetation map for the Upper Santa Cruz River from the US-Mexico border to the Pima County-Santa Cruz County line. Knowledge of the distribution, extent, and species composition of the riparian community along the Santa Cruz River provided in this map establishes a vital foundation from which to develop a comprehensive riparian conservation and floodplain protection program.

To create the map, we used high-resolution satellite imagery and extensive field surveys to identify riparian vegetation along the Upper Santa Cruz River. A total of 4,545.3 hectares (ha) (11,231.6 acres) of riparian vegetation were mapped along the main stem of the river and a portion of the Nogales Wash (Table 1.). Using information on the dominant plant species observed in the field, we described 40 vegetation alliances (groupings of different species) within 8 dominant vegetation formations: forest, woodland, wooded shrubland, shrubland, tree savanna, shrub savannah, herbaceous, and strand. Riparian vegetation patterns varied along the length of the river from sparsely vegetated shrub savannahs to dense forests. These vegetation patterns largely reflect the diverse hydrologic conditions of the river basin, and in particular are a visual indication of the depth to groundwater in underlying water tables.

While riparian systems operate holistically and each component of the system is important, a total of 1,017.1 ha (2,513.6 acres) or 22% of the total area mapped was determined to be of particularly high conservation priority (Table 1). These areas include 8 vegetation alliances from forest and woodland formations that have complex structure, species diversity, and high ecological value. Most of the area considered a conservation priority is currently located within unbuildable parts of the floodway and is thus provided some protection from building modifications. The remaining conservation priority areas, representing only 9% of the total area mapped, are found in and

beyond the 100-year floodplain and are vulnerable to modifications from development and floodplain alterations (Table 1).

Table 1. Summary of the total area and conservation priorities mapped within the floodway, beyond the floodway but in the 100-year floodplain, and beyond the 100-year floodplain along the Santa Cruz River from the US-Mexico border to the Pima County-Santa Cruz County line.

	Total Area Mapped		**Conservation Priorities**		
	hectares	*acres*	*hectares*	*acres*	*% Grand total*
In Floodway	1,815	4,485.1	618.2	1,527.6	13%
Beyond Floodway/In 100-year Floodplain	2,159.1	5,335.2	312.6	772.7	7%
Beyond 100-year Floodplain	571.2	1,411.3	86.3	213.3	2%
Grand Total	4,545.3	11,231.6	1,017.1	2,513.6	22%

This report provides important baseline data for helping establish a comprehensive riparian conservation and floodplain protection program. Included in this report are:

- detailed descriptions of methodology used to complete this map,
- detailed summaries indicating the location and extent of riparian vegetation mapped at both formation and alliance levels,
- maps highlighting the location of vegetation formations, alliances, and priority conservation areas,
- descriptions of vegetation alliances located along the Santa Cruz River,
- a list of plant species observed during field surveys,
- and concluding recommendations.

In addition, GIS files and imagery for the final map are available at Santa Cruz County to reference in future conservation and planning efforts.

INTRODUCTION

PROJECT PURPOSE

The primary purpose of this project was two-fold:

i. Map vegetation in the riparian corridor along the Upper Santa Cruz River from the U.S./Mexico border to the Santa Cruz-Pima County line (Figure 1),
ii. Generate a list of native riparian plants observed during field surveys.

The overarching goal of the project was to provide critical information to ongoing community-based conservation planning and implementation of the Santa Cruz County Comprehensive Plan, specifically Goal #8 of the Plan which states: "The Santa Cruz River and its watershed are conserved and managed as "living river" ecosystems."

BACKGROUND AND NEED

The Santa Cruz River Basin is a bi-national watershed that includes one of the few rivers that begins as a southerly flow, then reverses direction and flows north. After originating in eastern Santa Cruz County, the Santa Cruz River flows into Mexico and makes a 35-mile U-turn before returning to the U.S., east of the sister cities of Nogales, Sonora and Nogales, Arizona, and heading north. Historically, the river has flowed, mostly perennially, from its headwaters through Santa Cruz County.

Perennial surface flow in the river results from a combination of shallow groundwater, run-off during storm events, and treated wastewater, referred to commonly as effluent, from the Nogales International Wastewater Treatment Plant (NIWTP). The river and shallow groundwater tables support significant riparian vegetation, which in turn provides habitat to several threatened bird species and a federally endangered fish species, the Gila topminnow (*Poeciliopsis occidentalis*). The shallow groundwater also provides most of the water supply for agriculture, residential, commercial, and industrial use. Due primarily to groundwater pumping in the floodplain aquifer (also referred to as the Younger Alluvium), the river now flows only ephemerally as it heads north from the U.S./Mexico border to the NIWTP in Rio Rico. From the NIWTP to approximately the Santa Cruz-Pima County line (Amado area), the river flows perennially due in large part to the approximately 15 million gallons of effluent discharged per day from the bi-national NIWTP. This effluent discharge also augments groundwater recharge.

Riparian vegetation ecosystems provide important services and functions that directly benefit surrounding human populations. Working in tandem, riparian vegetation and floodplain lands help to filter and purify effluent-dominated surface water as it infiltrates and recharges groundwater and drinking water supplies. The roots of riparian plants stabilize soil and reduce erosion from floods and significant rainfall events. Riparian shrubs and trees moderate flood flows and help prevent loss of land due to erosive floods. From an economic perspective, a 2002 study identifies a property value premium of 3-6% for homes located within half a mile of riparian areas (Colby and

Wishart, 2002). In addition, riparian forests are major aesthetic and recreational assets by providing habitat for wildlife and attracting tourism dollars.

Current uses for riparian lands include recreation, agriculture, commercial building, and residential development. The rate of residential development is rapidly increasing as out-of-state residents discover the convenience, natural beauty, and relatively inexpensive cost-of-living that Santa Cruz County has to offer. Although building in the 100-year floodplain is currently difficult under County ordinances, the practice is not prohibited. Therefore, the floodplain may experience increased modification and development.

Riparian protection efforts have recently accelerated in Santa Cruz County with the acquisition of additional lands to extend boundaries of the Tumacácori National Historical Park and Sonoita Creek Natural Area, and Tucson Audubon Society's establishment of a conservation easement on riparian lands just north of Tubac. Despite interest the above initiatives have generated, there is a need for a comprehensive riparian and floodplain conservation program that extends along the length of the Santa Cruz River and ensures habitat continuity and effective floodplain protection. Knowledge of the distribution, extent, and species composition of the riparian community along the Santa Cruz River is vital to establishing and managing a comprehensive riparian and floodplain conservation program. The four objectives accomplished with this project have laid a foundation for future riparian conservation work. These objectives were to:

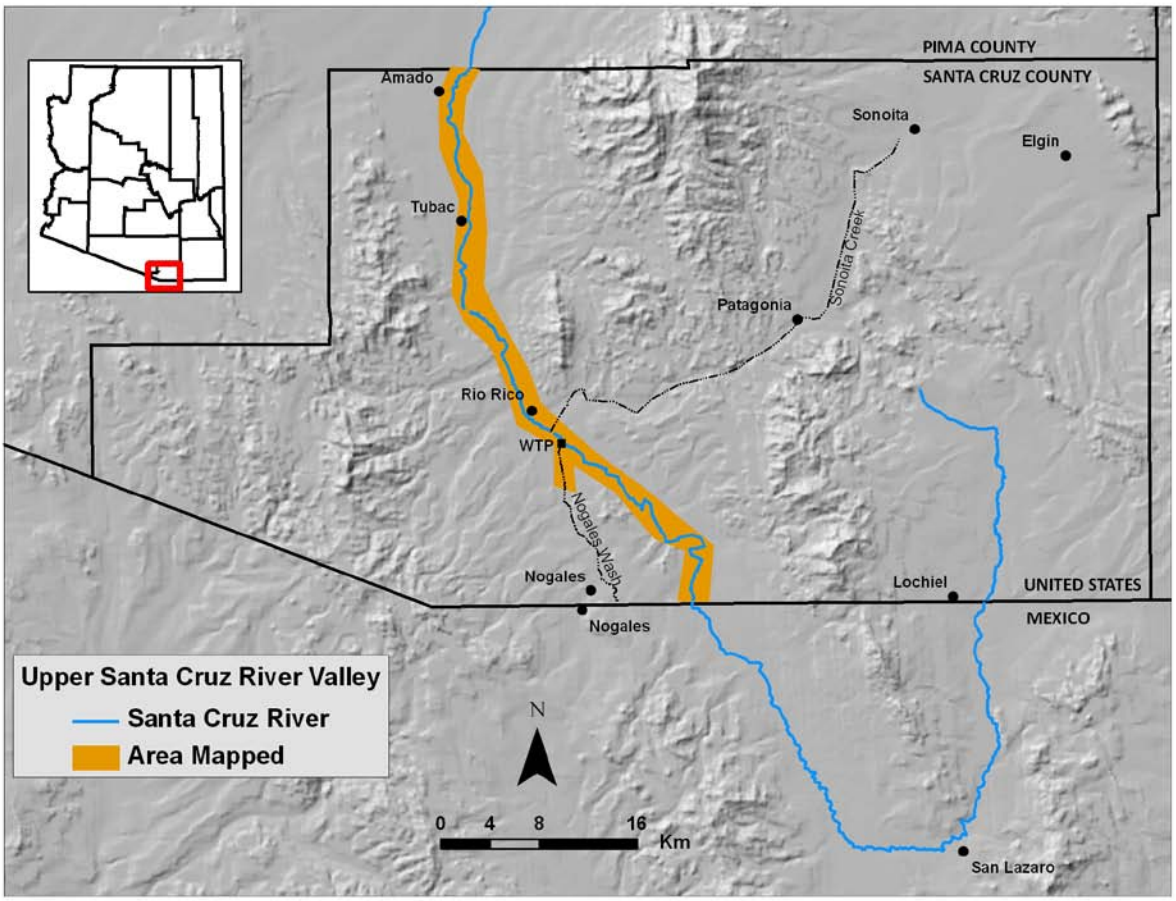
1) Identify the extent, alliance type, and status of riparian habitat along the river between the US-Mexico border and the Pima County-Santa Cruz County line (Figures 4 and 5).

2) Identify and prioritize areas for conservation planning purposes (Figures 6, 7, and 8).

3) Describe the vegetation alliances located in the riparian zone along the river.

4) Generate a partial riparian plant list from species observed in the field.

FIGURE 1. MAP OF THE SANTA CRUZ RIVER FLOWING THROUGH SANTA CRUZ COUNTY, ARIZONA AND THE PORTIONS OF THE RIVER AND NOGALES WASH WHERE RIPARIAN VEGETATION WAS MAPPED.



METHODS

DEFINITIONS

The following is a list of terms and definitions used in this report or in the map database.

- Formation: a vegetation type defined by the structural appearance of the dominant species present, such as forest, shrubland or savanna.
- Alliance: a vegetation classification unit defined by a characteristic species or group of species, one of which is typically in the dominant stratum of vegetation (eg. Cottonwood-Willow Forest). Order of species names reflect the order of dominance; names in brackets [Cottonwood-Willow] indicate co-dominance.
- Stratum: term referring to one of three vegetation height classes, which generally coincide with plant life forms – trees, shrubs or grasses/forbs.
- Branch-die back: a condition related to drought or stress where trees lose leaves at the ends of their branches leaving exposed branches.
- Shapefile: a group of 6 files that contain the digital version of the map which can be viewed using geographic information system (GIS) software.
- Attribute table: a table associated with the map shapefile that includes information pertaining to each vegetation polygon, such as species observed during field work.
- Polygon: a shape drawn about a particular area and used to delineate the location of an area of relatively uniform vegetation; a mapping unit.
- Developed woodland: a formation defined as an area with several buildings and roads, driveways, and/or parking lots that appeared to be maintained.

SURVEY/MAPPING

We approached the task of riparian vegetation mapping through visual interpretation of high resolution satellite imagery and aerial photography to produce a draft formation map, followed by extensive field data collection to verify and refine the draft and create a polygon map of vegetation alliances.

QUICKBIRD IMAGERY

We acquired high-resolution imagery from DigitalGlobe Inc.'s Quickbird (QB) satellite on August 27, 2006. We purchased the "Ortho-ready Standard" bundle of 4 spectral bands (blue, green, red and near-infrared) at 2.4m spatial resolution, plus the broadband panchromatic data at 0.6m resolution. This imagery is intended to be orthorectified by the user and is only coarsely geo-registered with a nominal spatial accuracy of 23m CE90. This means that 90% of features in the imagery must be within 23 meters of their true location on the ground.

ORTHORECTIFICATION AND PANSHARPENING

Orthorectification is an imagery pre-processing step required to remove terrain distortion in images. Multispectral and panchromatic images were orthorectified using a 10m National Elevation Dataset Digital Elevation Model (DEM) and registered to 1996 Digital Orthophoto Quarter Quadrangle (DOQQ) reference imagery. Spatial accuracy of the orthorectified images in relation to the DOQQ reference was 2.3m for the multispectral data and 1.9m for the panchromatic.

Following orthorectification, we pan-sharpened the multispectral imagery to aid visual interpretation. Pan-sharpening merges the high resolution 0.6m panchromatic image with the 2.4m multispectral image to produce a multispectral image with 0.6 m resolution.

FORMATION MAP

We mapped formations through visual interpretation of the pan-sharpened QB imagery. We delineated formations based on visual estimation of percent cover of life-form as defined by the "Key to Vegetation Formations" based on the National Vegetation Classification System (Figure 2, The Nature Conservancy 1994). Photo-interpretation of discrete vegetation communities requires the interpreter to: 1) have some knowledge of local vegetation types and life-forms and 2) understand how "visual signatures" (visual cues which include texture, color, and shape) of these types are manifested in the imagery. Using ArcGIS Editor (Environmental Systems Research Institute, Redlands, California) we sketched polygons around distinct vegetated areas (minimum mapping unit > 0.5 ha) and assigned formation type according to estimated percent cover of plants present. We mapped polygons in 8 formations of natural or semi-natural vegetation and areas dominated by agriculture and developed woodland, for a total of 10 formations (Table 2).

To verify the formation map and obtain more detailed species composition information to determine alliances, we collected extensive field data for a subset of polygons from April 2007 – April 2008. Field crews used this initial formation map and Global Positioning System (GPS) units to locate, verify, and delineate as needed vegetation polygons *in situ*. Field crews noted the top three dominant species and other common associates for each stratum and made note of other observations such as active grazing and presence of stressed or dead trees (Appendix B, Mapping data sheet). We used notes and information obtained by the field crews to correct and refine the draft formation map in ArcGIS. All dominant and common plant species and other notes were included in the attribute table. Plants species and codes used in the attribute table can be found in the plant list (Table 4). We verified areas with limited accessibility with photos taken during three

low-altitude over flights (October 2006, November 2007, and May 2008). We noted polygons verified in this manner as 'classified by aerial photo'; species composition information for these polygons is not as complete as for polygons visited on the ground due to our inability to see or identify some species in the photos.

TABLE 2. FORMATIONS (AND CODES) THAT WERE MAPPED ALONG THE RIPARIAN CORRIDOR ALONG THE SANTA CRUZ RIVER FROM THE US-MEXICO BORDER TO THE PIMA COUNTY-SANTA CRUZ COUNTY LINE.

Formation	Formation Code
Forest	F
Woodland	W
Wooded Shrubland	WS
Shrubland	S
Tree Savanna	TS
Shrub Savanna	SS
Herbaceous	H
Strand	St
Agriculture	Ag
Developed Woodland	DW

FIGURE 2. KEY USED IN DETERMINING FORMATION.

KEY TO VEGETATION FORMATIONS:

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 question B.

B. Tree cover > Shrub cover?

YES = "Tree savanna", NO = "Shrub savanna"

5. Rock/Bare Soil:

A. Is the site predominantly bedrock or surface rock?

YES = "Rock outcrop", NO = "Barren"

PLANT LIST

We generated a list of riparian plant species by including all species observed during extensive field work. We confirmed observed species with lists available in the PLANTS Database (USDA and NRCS 2008) and the inventory completed for Tumacácori National Historic Park (Powell et al. 2005). Plants could not always be defined to species level and occasionally were grouped under the genus. For example, plants in the genus *Tamarix* were grouped as *Tamarix* species due to uncertainty of exact species. Plants listed as introduced were listed as non-native in the PLANTS Database. Since we only recorded dominant species and other common associates, the plant list generated for this report is not an exhaustive flora. For a more complete flora of plants that can potentially be found in the riparian zone in Santa Cruz County, refer to previously listed references or contact the University of Arizona Herbarium (http://ag.arizona.edu/herbarium/index.php).

ALLIANCE ASSIGNMENT

We used the National Vegetation Classification System (The Nature Conservancy 1994) to define vegetation alliances found in the mapped formation polygons. Alliances are often defined by one dominant species, but can include up to three co-dominant species (The Nature Conservancy 1994). Formation polygons visited in the field were evaluated for species composition and relative cover of dominant species to identify the vegetation alliance(s) present in each. Often the formation polygons were homogeneous and contained only one alliance, so were clearly assignable, for example, from "Forest" to "Mesquite forest". For polygons containing more than one alliance, the field crew annotated the draft map prints to delineate alliance boundaries and indicate their identity. In the GIS lab, the annotations were transferred to the digital master map. A similar approach was used for mapping alliances from photos taken during low-altitude over flights, but confidence in interpretation was less than with field data available. After final map corrections were made, each polygon was given a unique id that consisted of a numerical alliance code followed by a three-digit number to identify the particular polygon (e.g. 1.005, the fifth polygon of alliance type 1). Although we did not conduct field surveys of agriculture or developed woodland, we generated a similar unique id for polygons in these two formations. Thus leading codes of 50 or 60 refer to agriculture and developed woodland formations respectively, and not to alliances (e.g. 50.001 = the first polygon of agriculture).

ALLIANCE VERIFICATION

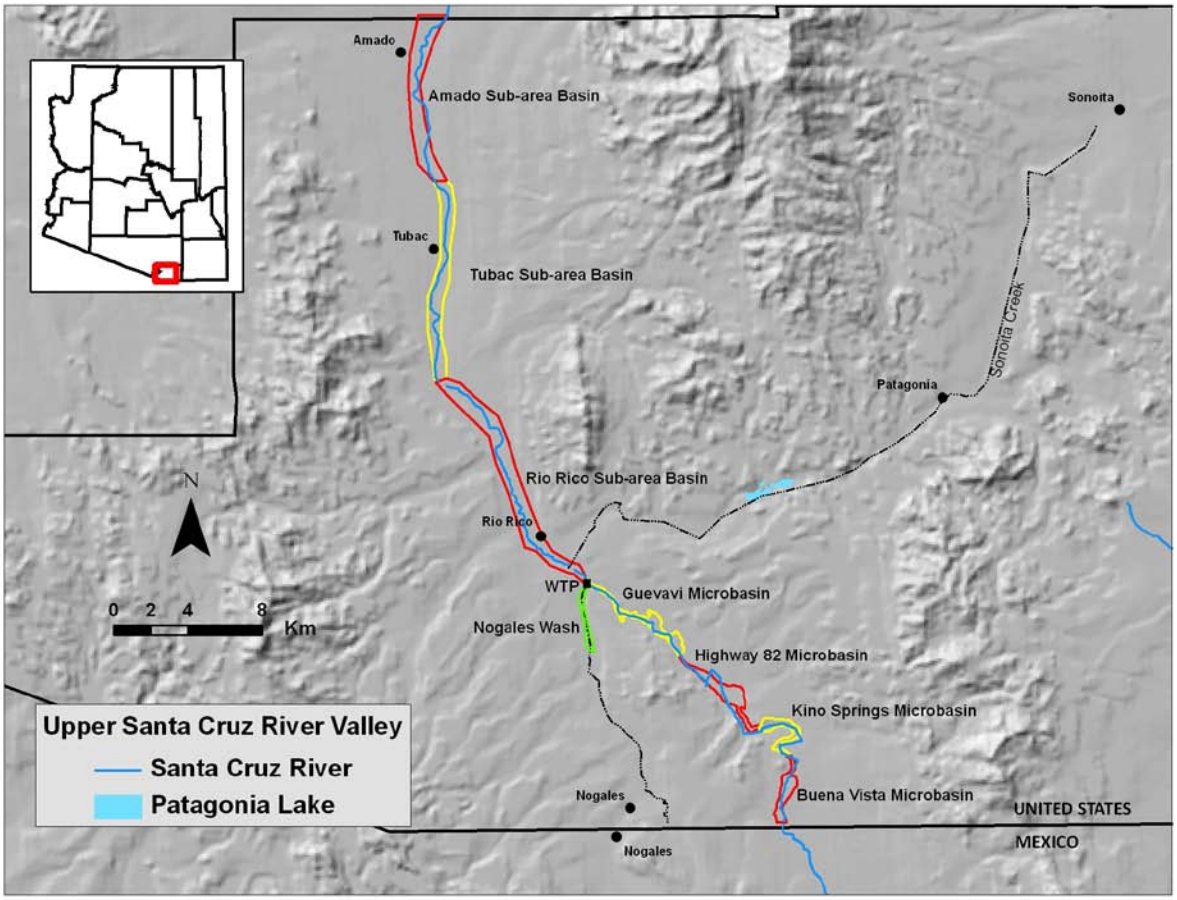
An accuracy assessment of forests and woodlands, formations considered of conservation priority (see below), was conducted in May 2008. We assessed the accuracy of alliances to the first dominant species, with the exception of velvet mesquite – elderberry – netleaf hackberry forest. Therefore, forest and woodland alliances were aggregated into six classes based on the single dominant species. We randomly selected a minimum of 7 polygons of each aggregated class for assessment. The accuracy assessment field crew used a GPS and hardcopy maps to navigate to selected polygons, assessed polygon formation type and dominant vegetation, and assigned it one of the six accuracy classes (Appendix C, Accuracy Assessment data sheet). We compared results of

this field assessment to the original alliance assignments to verify that polygons had been correctly classified. Map accuracy was determined using the Kappa coefficient, a statistical measure of agreement between classified map polygons and field verified polygons. Kappa values range from 0-1.0 and a value of 0.8-1.0 represents excellent agreement between map data and field data. Because most of the classified map polygons were initially mapped in the field, a high Kappa value and high map accuracy were anticipated.

GROUNDWATER BASIN ASSIGNMENT

The Santa Cruz River relies upon three contributing water sources: surface run-off, effluent from the Nogales International Wastewater Treatment Plant (NIWTP), and groundwater discharge. Groundwater can be found in three relatively distinct aquifers. The first aquifer, the Younger Alluvium, fills a series of independent micro- and sub-area basins immediately bordering and underlying the stream channel. These micro- and sub-area basins have low storage capacity and range in depth from 40-150 feet (Arizona Department of Water Resources 1999). Due to the basin-fill material within the Younger Alluvium, water easily moves through basins. During flood events, micro and sub-area basins rapidly re-fill causing water to cascade into adjacent downstream basins. In addition, basins are very responsive to prolonged drought events when water levels can steadily drop. Riparian vegetation is uniquely adapted to draw water from both surface flow and groundwater and is thus fundamentally dependent on the stream and on shallow water tables. Given this essential relationship between groundwater basins and riparian vegetation, we examined spatial patterns of vegetation according to micro-basin and sub-area basin locations along the Upper Santa Cruz River. Micro-basins have been clearly defined (Figure 3, Erwin 2007) and sub-area basins are roughly defined according to well-logs and geophysical data (Nelson 2007); therefore, we mapped approximate locations of sub-area basins to look at spatial patterns of riparian vegetation (Figure 3). We mapped a small segment of Nogales Wash just south of the NIWTP (Figure 3). Nogales Wash is located in a different sub-area basin and was therefore treated as a separate area. We assigned each polygon to a basin. Polygons crossing basin boundaries were assigned to both basins. For these polygons, the basin containing greater polygon area was selected for the final summary. We occasionally mapped areas just outside of the younger alluvium formation; polygons not contained within a basin boundary were assigned to the nearest basin.

FIGURE 3 MAP OF THE SUB-AREA BASINS, MICRO-BASINS, AND SEGMENT OF NOGALES WASH WHERE RIPARIAN VEGETATION WAS MAPPED ALONG THE SANTA CRUZ RIVER FROM THE US-MEXICO BORDER TO THE PIMA COUNTY-SANTA CRUZ COUNTY LINE.



CONSERVATION PRIORITIZATION

Functioning riparian ecosystems in the southwestern United States are vital indicators of the health of river basins and play a pivotal role in maintaining streamflow conditions, facilitating groundwater recharge, providing natural water quality enhancement, and mitigating flood flows (Ohmart and Anderson 1986, Tabbachi et al. 2000, Webb and Leake 2006). The importance of riparian ecosystems is especially notable considering that in the arid southwest, riparian systems constitute 0.5% of the landscape or less (Webb and Leake 2006). Given the important ecological goods and services that riparian areas provide to growing human populations and the small percentage of land area that they occupy, riparian areas are increasingly the focus of conservation and management efforts (Webb and Leake 2006).

While riparian systems operate holistically and each component of the system is important, this vegetation map can be used as a foundation to guide focused conservation and management efforts by prioritizing certain vegetation alliances. We prioritized the most complex, diverse, and mature vegetation alliances as determined by the riparian vegetation map. "Mature" is defined by Naiman et al. 2005 as a riparian forest that includes "three-dimensional structural characteristics such as large, living old trees; …relatively open canopies with foliage in many layers; and a diverse understory." The forest and woodland alliances that we selected for the highest level of conservation priority reflect this definition of mature in the numbers of trees, shrubs, and herbaceous species represented, as well as the structural complexity and diversity of the mid- and understory layers.

After selecting the most mature vegetation alliances, we delineated polygons located within and outside of the Regulatory Floodway. The Regulatory Floodway is defined by the Santa Cruz County Flood Control District as: "the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without increasing the water surface elevation more than one foot" (Santa Cruz County 2008). Furthermore, the current Santa Cruz County Floodplain and Erosion Hazard Management Ordinance No 2001-03 states that the "since the floodway is an extremely hazardous area due to the velocity of floodwaters which carry debris, potential projectiles, and erosion potential, no structures or fill of any type will be allowed to be constructed or placed." Due to the variable and hazardous flood conditions that can potentially occur within the floodway, alliances that fall within the floodway may not be as immediately vulnerable to anthropogenic modification and development as alliances that fall outside of the floodway, but within the 100-year floodplain. Therefore, we determined that complex, diverse, and mature forest and woodland alliances outside of the floodway should be given the most immediate level of conservation priority since they may be more susceptible to impacts from anthropogenic floodplain modifications. The second tier of priority is given to those mature forests and woodlands that fall within the floodway, though it is worth noting that the floodway does shift and these geographical delineations are not ironclad.

We used ArcGIS to assign locations of polygons to one of three categories: polygons within the floodway, polygons beyond the floodway but within the 100-year floodplain, and polygons beyond the 100-year floodplain. Polygons were often found overlapping the boundaries between these waterways. To avoid reducing polygons to smaller areas, we used centroid location (geometric center) to determine category assignment. For example, a polygon with a centroid in the floodway, but containing some overlap in the 100-year floodplain, would be assigned to the floodway.

RESULTS

FORMATION AND ALLIANCE MAPPING

A total of 698 polygons or 4,545.3 hectares (ha) (11,231.6 acres) were mapped in the riparian corridor along the Santa Cruz River from the US-Mexico border to the Pima County-Santa Cruz County line (Table 3, Figure 4). After excluding areas mapped as agriculture or developed woodland, a total of 598 polygons or 3,406.5 ha (8,417.7 acres) of riparian vegetation remained. Of these, 450 polygons were visited on the ground during extensive field surveys. Due to inaccessible areas and high number of polygons, the remaining 148 vegetation polygons were 'visited' with aerial photos. To confirm classification determined from aerial photos, we visited 28 on the ground; we found no discrepancies.

We documented a total of 108 species (25 tree, 21 shrub, and 62 herbaceous species) in the riparian area (Table 4). The majority of these species have been previously documented in the inventory conducted at Tumacácori National Historic Park (Powell et al. 2005). Herbaceous plants were difficult to identify and were often documented in 6 general categories: mixed forbs, mixed grass, native grass, non-native grass, mixed vines, and unknown herb. We observed 17 species that were non-native or introduced to the riparian area. Of these, only a few species had extensive distribution and abundance. For a more comprehensive list of plants found along the Santa Cruz River, see references cited in the methods section.

Examination of all polygons of riparian vegetation resulted in 40 vegetation alliances (Table 5, Figure 5). Descriptions of each vegetation alliance can be found in Appendix A. Alliances were often spatially distributed among hydrologic sub-area basins and micro-basins (Table 6). The forest formation was primarily located north of the treatment plant. The few polygons of forest south of the treatment plant were dominated by mesquite with one polygon dominated by cottonwood that was located along irrigated pastures. Although scattered throughout, tamarisk was only found among the top three dominant plant species in alliances found in the Tubac and Amado sub-area basins.

TABLE 3. SUMMARY OF THE NUMBER OF POLYGONS AND AREA MAPPED IN EACH OF THE 11 FORMATIONS ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

Formation	Polygons	Area (ha)	Area (acres)
Forest	185	971.7	2,401.1
Woodland	138	907.6	2,242.5
Wooded Shrubland	17	65.1	160.8
Shrubland	46	191.3	472.7
Tree Savanna	86	430.7	1,064.2
Shrub Savanna	41	336.9	832.4
Herbaceous	61	332.3	821.2
Strand	24	170.9	422.5
Developed Woodland	48	165.2	408.1
Agriculture	52	973.6	2,405.9
Grand Total	*698*	*4,545.3*	*11,231.6*

ALLIANCE VERIFICATION

A total of 44 forest and woodland polygons representing 11 alliances were randomly selected and field-checked for accuracy (Table 7). All aggregated map classes had a minimum of 7 polygons with the exception of Tamarisk forest; a recent fire prevented access to selected polygons of tamarisk forest. Overall, the map was 88.1% accurate (correctly classified polygons/total polygons x 100) with a Kappa score of 0.86 (Table 8). Specific class accuracies were high with the exception of the "Other Mesquite-dominated Forest" (Table 8). Unlike the majority of polygons mapped, the four misclassified polygons in this class were not initially classified on the ground but classified using aerial photography, explaining the low accuracy. Polygons classified by aerial imagery typically resulted in lower categorical fidelity because of the difficulty of identifying and ranking multiple species from photographs. One mapped "Cottonwood-dominated Woodland" polygon was misclassified as "Mesquite-dominated Woodland" in the field. In this instance the error is not a mapping error, but is attributed to the field team, who could not safely access the entire polygon and obtained a mesquite-biased assessment from the portion observed.

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FIGURE 4. MAP OF 8 RIPARIAN VEGETATION FORMATIONS, AGRICULTURE, AND DEVELOPED WOODLAND FOUND ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

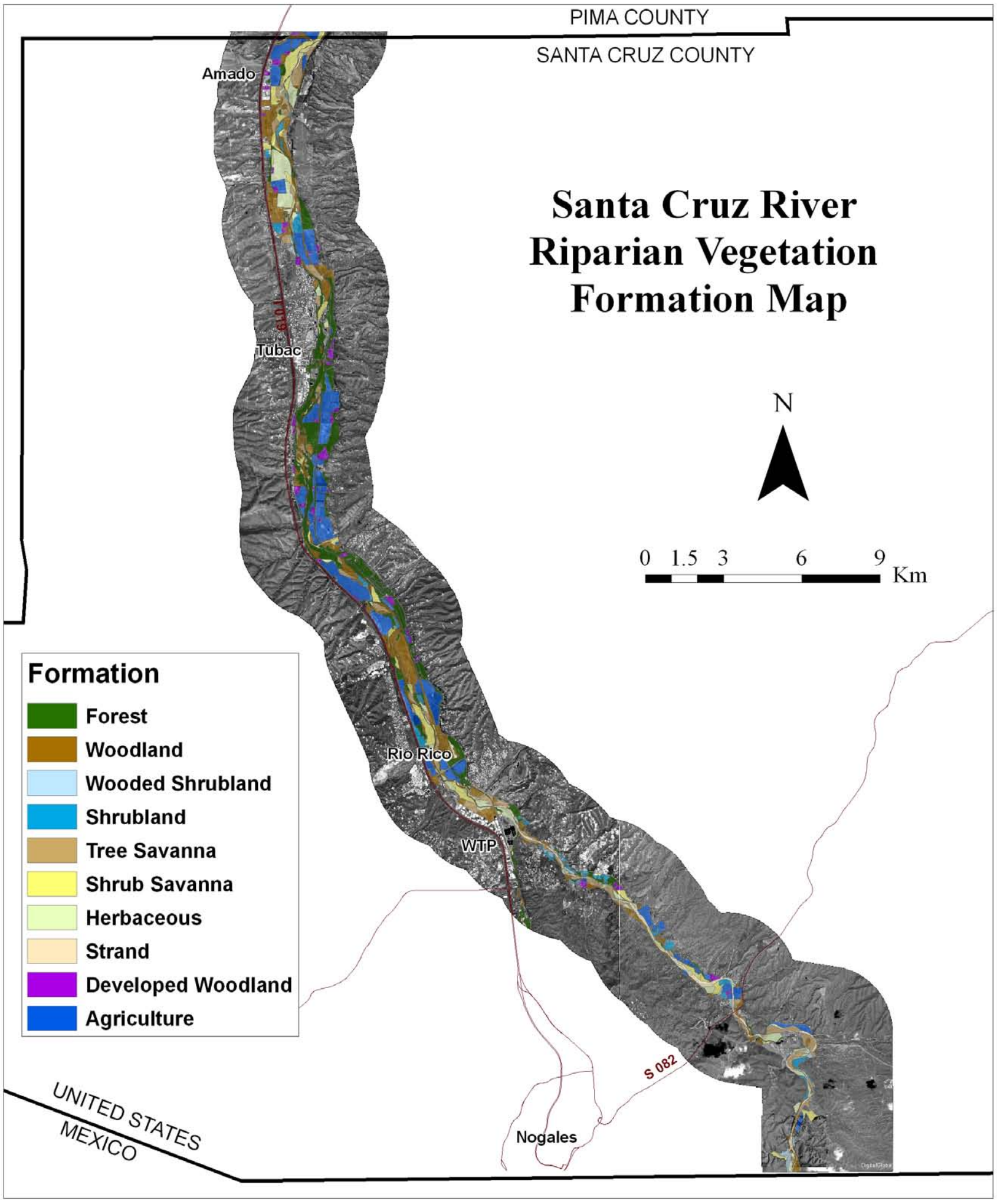

TABLE 4. TREES, SHRUBS, AND HERBACEOUS PLANTS OBSERVED DURING VEGETATION SURVEYS ALONG THE SANTA CRUZ RIVER IN 2007 AND 2008 FROM THE US-MEXICO BORDER TO THE PIMA COUNTY-SANTA CRUZ COUNTY LINE. CODES WERE USED IN THE ATTRIBUTE TABLE OF THE GIS SHAPEFILE TO DOCUMENT SPECIES PRESENCE IN A GIVEN POLYGON. A "Y" INDICATES A SPECIES WAS OBSERVED IN TUMACÁCORI NATIONAL HISTORICAL PARK INVENTORY (TUMA), IS INTRODUCED TO THE AREA (INTRO), AND MAY OCCUR IN AREAS WHERE NATIVE GRASSES (NAGR) AND FORBS (FORB) ARE NOTED IN THE ATTRIBUTE TABLE OF THE MAP.

Code	Common Name	Scientific Name	TUMA	INTRO	NAGR	FORB
Trees						
ACCO	whitethorn acacia	*Acacia constricta*	*y*			
ACGR	catclaw acacia	*Acacia greggii*	*y*			
ALOB	Arizona alder	*Alnus oblongifolia*				
CELE	netleaf hackberry	*Celtis laevigata var. reticulata*	*y*			
CEPA	desert/spiny hackberry	*Celtis ehrenbergiana*	*y*			
CHLI	desert willow	*Chilopsis linearis*	*y*			
FRVE	velvet ash	*Fraxinus velutina*	*y*			
JUCO	redberry juniper	*Juniperus coahuilensis*	*y*			
JUMA	Arizona walnut	*Juglans major*	*y*			
MEAZ	Chinaberrytree	MELIA AZEDARACH	*y*	*y*		
MOMI	Texas mulberry	*Morus microphylla*	*y*			
PAAC	Mexican paloverde	*Parkinsonia aculeata*				
PAFL	blue paloverde	*Parkinsonia florida*				
POFR	Fremont cottonwood	*Populus fremontii*	*y*			
PRVE	velvet mesquite	*Prosopis velutina*	*y*			
SANI	common/blue elderberry	*Sambucus nigra*	*y*			
SAGO	Goodding's willow	*Salix gooddingii*	*y*			
SASA	western soapberry	*Sapindus saponaria* var. *drummondii*				
SATA	yewleaf willow	*Salix taxifolia*	*y*			
QUEM	Emory oak	*Quercus emoryi*				
ULPU	Siberian elm	*Ulmus pumila*		*y*		
Shrubs						
ANTH	Thurber's desert honeysuckle	*Anisacanthus thurberi*	*y*			
ATCA	fourwing saltbush	*Atriplex canescens*	*y*			
BASL	seepwillow	*Baccharis salicifolia*	*y*			
BASA	desertbroom	*Baccharis sarothroides*	*y*			
CEGR	desert ceanothus	*Ceanothus greggii*	*y*			
COSP	snakewood	*Condalia* species	*y*			
COWA	Warnock's snakewood	*Condalia warnockii*				
CYSP	cholla species	*Cylindropuntia*				
FEWI	candy barrelcactus	*Ferocactus wislizeni*	*y*			
HYMO	hymenoclea	*Hymenoclea monogyra*	*y*			

Code	Common Name	Scientific Name	TUMA	INTRO	NAGR	FORB
ITSE	burroweed	*Isocoma tenuisecta*	y			y
LYAN	wolfberry	*Lycium andersonii*	y			
LYSP	wolfberry	*Lycium* species				
MIBI	catclaw mimosa	*Mimosa aculeaticarpa var. biuncifera*	y			
MOAL	white mulberry	*Morus alba*		y		
NIGL	tree tobacco	*Nicotiana glauca*	y	y		
TARA	saltcedar	*Tamarix ramosissima*	y	y		
TASP	tamarisk	*Tamarix* species				
UNKS	unknown shrub					
YUEL	soaptree yucca	*Yucca elata*	y			
ZIOB	graythorn	*Ziziphus obtusifolia*	y			
Herbaceous						
AMCO	weakleaf bur ragweed	*Ambrosia confertiflora*	y			y
AMPA	Amaranth	*Amaranthus palmeri*	y			
ARDO	giant reed	*Arundo donax*	y	y		
ARPL	southwestern pricklypoppy	*Argemone pleiacantha*	y			y
ARSP	threeawn species	*Aristida* species	y		y	
BILE	fewflower beggarticks	*Bidens leptocephala*	y			
BOAR	needle grama	*Bouteloua aristidoides*	y		y	
BOBA	cane bluestem	*Bothriochloa barbinodis*	y		y	
BOCU	sideoats grama	*Bouteloua curtipendula*	y		y	
BORA	purple grama	*Bouteloua radicosa*	y		y	
BORO	Rothrock's grama	*Bouteloua rothrockii*	y		y	
BOSP	spiderling	*Boerhavia* species	y			y
BOUS	grama	*Bouteloua* species	y		y	
BRSP	mustard	*Brassica* species				y
BRTO	Asian mustard	*Brassica tournefortii*		y		y
CHSP	goosefoot	*Chenopodium* species	y			y
CHVI	feather fingergrass	*Chloris virgata*	y		y	
CLLI	western white clematis	*Clematis ligusticifolia*	y			
COMA	poison hemlock	*Conium maculatum*	y	y		y
COPA	cotta grass	*Cottea pappophoroides*	y		y	
CUSP	gourd	*Cucurbita* species	y			
CYDA	Bermudagrass	*Cynodon dactylon*	y	y		
DAIN	sacred datura	*Datura inoxia*		y		
DASP	jimsonweed	*Datura* species				
DICA	Arizona cottontop	*Digitaria californica*	y		y	
ERAS	unknown lovegrass	*Eragrostis* species	y	y		
ERCI	stinkgrass	*Eragrostis cilianensis*	y	y		
ERLE	Lehmann lovegrass	*Eragrostis lehmanniana*	y	y		
ERSP	buckwheat	*Eriogonum* species	y			y
FORB	mixed forbs					y
GASP	beeblossom	*Gaura* species	y			y

Code	Common Name	Scientific Name	TUMA	INTRO	NAGR	FORB
GOSO	Sonoran globe amaranth	*Gomphrena sonorae*	*y*			*y*
GUSP	snakeweed	*Gutierrezia* species	*y*			*y*
GRAS	mixed grasses					
HEAN	common sunflower	*Helianthus annus*	*y*			
HYSP	pennywort	*Hydrocotyle*	*y*			*y*
IPSP	morning glory	*Ipomoea species*	*y*			
LEDU	green sprangletop	*Leptochloa dubia*	*y*		*y*	
LESP	bladderpod	*Lesquerella spp.*				*y*
LOHU	foothill deervetch	*Lotus humistratus*	*y*			*y*
LPSP	pepperweed	*Lepidium* species	*y*			*y*
MAVU	horehound	*Marrubium vulgare*	*y*	*y*		*y*
MESP	blazingstar	*Mentzelia* species	*y*			*y*
MUSP	muhly	*Muhlenbergia* species	*y*		*y*	
NAGR	native grasses					
NNGR	non-native grasses					
OESP	primrose	*Oenothera* species	*y*			*y*
OPSP	prickly pear	*Opuntia* species				
PAME	Mexican passionflower	*Passiflora mexicana*	*y*			
PODO	red-whisker clammyweed	*Polanisia dodecandra*	*y*			*y*
PRSP	devil's claw	*Proboscidea* species	*y*			*y*
RIHU	rougeplant	*Rivina humilis*	*y*			*y*
RONA	watercress	*Nasturtium officinale*	*y*	*y*		*y*
SASP	sage	*Salvia* species	*y*			*y*
SATR	tumbleweed	*Salsola tragus*	*y*	*y*		
SEFL	threadleaf ragwort	*Senecio flaccidus*	*y*			*y*
SESP	bristlegrass	*Setaria* species	*y*	*y*	*y*	
SOHA	Johnsongrass	*Sorghum halepense*	*y*	*y*		
SPCO	spike dropseed	*Sporobolus contractus*	*y*		*y*	
SPSP	globe mallow	*Sphaeralcea* species	*y*			*y*
SPWR	big sacaton	*Sporobolus wrightii*	*y*			
SOEL	silverleaf nightshade	*Solanum elaeagnifolium*	*y*			*y*
TENE	hairy fournwort	*Tetramerium nervosum*	*y*			*y*
TISP	tithonia	*Tithonia* species	*y*			*y*
UNKH	unknown herb					
VIAR	canyon grape	*Vitis arizonica*	*y*			
VINE	mixed vines					
XAST	rough cocklebur	*Xanthium strumarium*	*y*			

TABLE 5. ALLIANCE CODES AND NAMES, NUMBER OF POLYGONS, AND TOTAL AREA FOR EACH OF THE 40 VEGETATION ALLIANCES FOUND ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

Alliance Code	Alliance	Polygons	Area (ha)	Area (acres)
1	Cottonwood-Goodding's Willow Forest	25	199.1	492.0
2	Cottonwood-[Velvet Mesquite-Elderberry] Forest	8	10.7	26.3
3	Tamarisk Forest	7	5.7	14.1
4	VelvetMesquite-[Elderberry-Netleaf Hackberry] Forest	64	267.8	661.7
5	VelvetMesquite-CatclawAcacia Forest	43	230.8	570.4
6	VelvetMesquite Forest	38	257.6	636.5
7	Cottonwood-Goodding's Willow-Tamarisk Woodland	12	36.9	91.1
8	Cottonwood-Goodding's Willow Woodland	36	236.7	584.8
9	Cottonwood-Velvet Mesquite Woodland	5	14.5	35.8
10	Cottonwood Woodland	2	5.5	13.6
11	VelvetMesquite-Catclaw Acacia Woodland	12	66.3	163.8
12	VelvetMesquite-Elderberry Woodland	13	69.1	170.8
13	VelvetMesquite-NetleafHackberry Woodland	21	182.5	450.9
14	VelvetMesquite Woodland	37	296.1	731.7
15	VelvetMesquite/CatclawAcacia Wooded Shrubland	5	15.7	38.8
16	VelvetMesquite/VelvetMesquite Wooded Shrubland	12	49.4	122
17	CatclawAcacia - Whitethorn Acacia- CatclawMimosa Shrubland	6	12.5	30.8
18	Hymenoclea Shrubland	5	16.3	40.3
19	Seepwillow Shrubland	3	13	32.1
20	Tamarisk Shrubland	1	0.7	1.8
21	VelvetMesquite - CatclawAcacia Shrubland	15	46.9	115.8
22	VelvetMesquite Shrubland	16	101.9	251.9

Alliance Code	Alliance	Polygons	Area (ha)	Area (acres)
23	Cottonwood/Amaranth Tree Savanna	30	127.3	314.6
24	Cottonwood/NativeGrass Tree Savanna	4	47.1	116.4
25	Elderberry/Amaranth Tree Savanna	6	55.4	136.8
26	Tamarisk/Amaranth Tree Savanna	4	15.5	38.4
27	VelvetMesquite/Amaranth Tree Savanna	34	157.9	390.2
28	VelvetMesquite/NativeGrass Tree Savanna	5	19.5	48.1
29	VelvetMesquite/Tumbleweed Tree Savanna	3	8	19.7
30	Baccharis species/Amaranth Shrub Savanna	6	7.7	19
31	Baccharis species/Grass Shrub Savanna	7	76.2	188.3
32	Hymenoclea/Mixed Herb Shrub Savanna	14	106.1	262.1
33	VelvetMesquite/Mixed Herb Shrub Savanna	14	146.9	363
34	Amaranth Herbaceous	25	127.3	314.6
35	Forbs Herbaceous	12	32.3	79.8
36	Grass Herbaceous	9	86.2	213.1
37	Unknown Herbaceous	15	86.5	213.7
38	Cottonwood-Goodding's Willow Strand	11	116.2	287.2
39	Herbaceous Strand	4	31.9	78.9
40	Shrub Strand	9	22.8	56.4

FIGURE 5. MAP OF 40 RIPARIAN VEGETATION ALLIANCES, AGRICULTURE, AND DEVELOPED WOODLAND FOUND ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

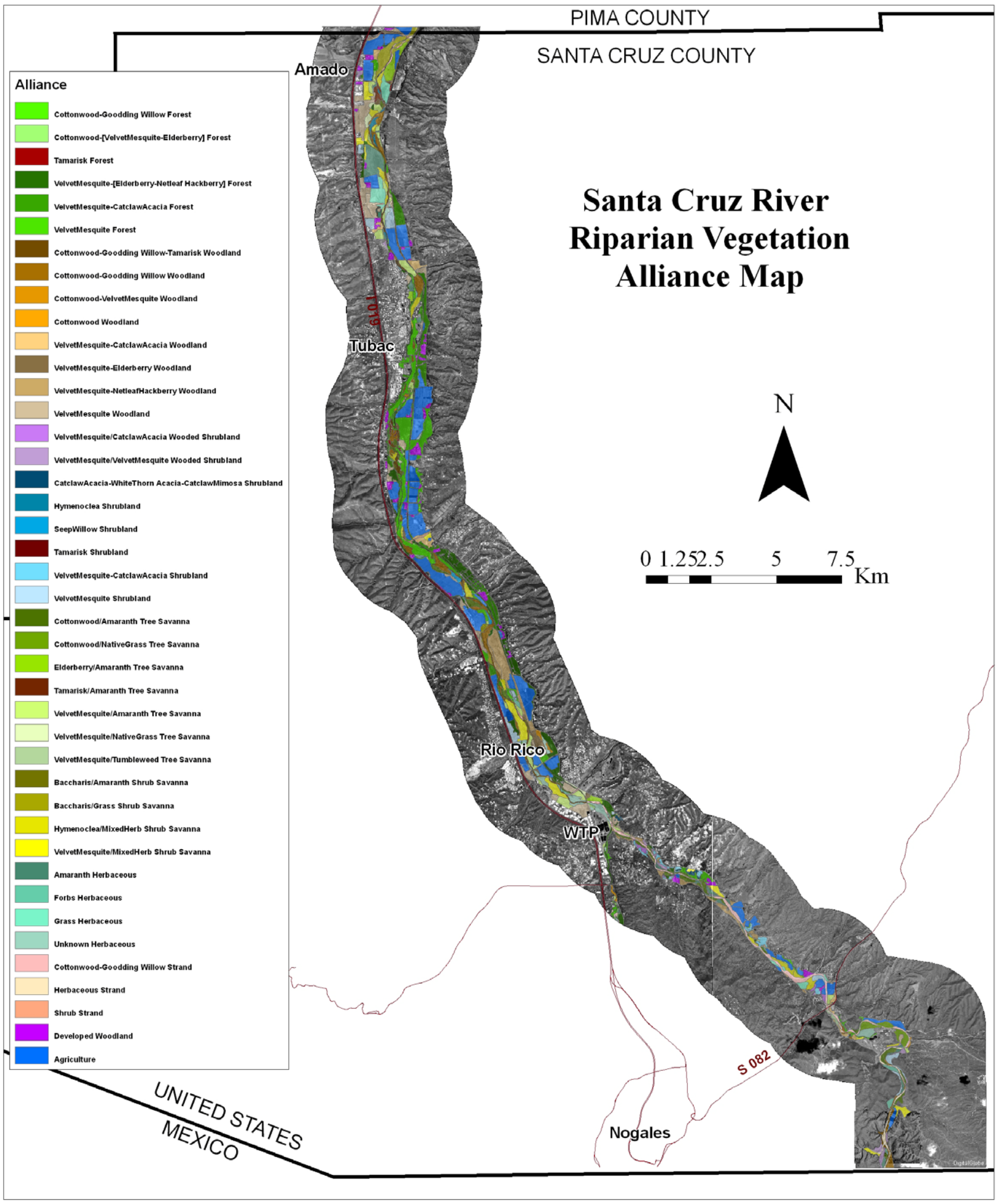

TABLE 6. PERCENT TOTAL ALLIANCE AREA AND NUMBER OF POLYGONS [% (NUMBER)] OF EACH ALLIANCE FOUND WITHIN MICROBASINS, SUB-AREA BASINS, AND A PORTION OF NOGALES WASH ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE. FROM SOUTH TO NORTH, MICROBASINS: BUENA VISTA (BV), KINO SPRINGS (KS), HIGHWAY 82 (H82), GUEVAVI (G); NOGALES WASH (NW); SUB-AREA BASINS: RIO RICO (RR), TUBAC (T), AND AMADO (A).

Alliance	BV	KS	H82	G	NW	RR	T	A
1 Cottonwood-Goodding's Willow Forest	-	-	-	-	-	22.4 (2)	75.9 (20)	1.7 (3)
2 Cottonwood-[Velvet Mesquite-Elderberry] Forest	-	-	15.8 (1)	-	27.7 (3)	24.3 (1)	24.5 (2)	7.7 (1)
3 Tamarisk Forest	-	-	-	-	-	-	53.6 (4)	46.4 (3)
4 VelvetMesquite-[Elderberry-Netleaf Hackberry] Forest	-	-	0.2 (1)	3.4 (5)	6.2 (3)	71.4 (35)	13.4 (17)	5.4 (3)
5 VelvetMesquite-CatclawAcacia Forest	-	-	-	-	-	28.6 (24)	53.4 (15)	18.0 (4)
6 VelvetMesquite Forest	-	1.9 (2)	4.8 (3)	8.3 (3)	5.2 (3)	20.3 (12)	54.4 (12)	5.2 (3)
7 Cottonwood-Goodding's Willow-Tamarisk Woodland	-	-	-	-	-	-	60.7 (7)	39.3 (5)
8 Cottonwood-Goodding's Willow Woodland	13.6 (6)	0.7 (1)	2.2 (3)	-	-	47.5 (11)	19 (8)	17.0 (7)
9 Cottonwood-Velvet Mesquite Woodland	-	16.8 (1)	-	-	-	64.7 (2)	18.5 (2)	-
10 Cottonwood Woodland	-	-	-	-	83.9 (1)	-	16.1 (1)	-
11 VelvetMesquite-Catclaw Acacia Woodland	-	-	24.7 (4)	-	-	21.3 (1)	28.9 (3)	25.2 (4)
12 VelvetMesquite-Elderberry Woodland	-	-	-	-	-	60.0 (5)	8.3 (3)	31.8 (5)
13 VelvetMesquite-NetleafHackberry Woodland	-	-	8.6 (7)	27.8 (11)	-	63.6 (3)	-	-
14 VelvetMesquite Woodland	-	1.4 (1)	2.1 (5)	3.5 (2)	0.3 (1)	27.9 (11)	11.7 (6)	53.1 (11)
15 VelvetMesquite/CatclawAcacia Wooded Shrubland	-	-	48.7 (2)	51.3 (3)	-	-	-	-
16 VelvetMesquite/VelvetMesquite Wooded Shrubland	46.7 (4)	15.3 (2)	-	22.4 (4)	-	-	-	15.6 (2)
17 CatclawAcacia-Whitethorn Acacia-CatclawMimosa Shrubland	-	-	-	100 (6)	-	-	-	-
18 Hymenoclea Shrubland	-	-	-	-	-	-	-	100 (5)
19 Seepwillow Shrubland	-	-	-	-	-	100 (3)	-	-
20 Tamarisk Shrubland	-	-	-	-	-	-	-	100 (1)
21 VelvetMesquite - CatclawAcacia Shrubland	-	-	45.2 (6)	53.0 (8)	-	-	1.8 (1)	-

Alliance	BV	KS	H82	G	NW	RR	T	A
22 VelvetMesquite Shrubland	5.9 (2)	14.3 (1)	8.7 (2)	-	-	30.5 (7)	2.2 (1)	38.4 (3)
23 Cottonwood/Amaranth Tree Savanna	10.9 (4)	10.9 (1)	4.6 (4)	36.6 (12)	-	27.5 (5)	7.3 (3)	2.2 (1)
24 Cottonwood/NativeGrass Tree Savanna	-	96.6 (3)	-	-	-	-	3.4 (1)	-
25 Elderberry/Amaranth Tree Savanna	-	-	2.0 (1)	-	-	18.6 (1)	13.4 (2)	66.0 (2)
26 Tamarisk/Amaranth Tree Savanna	-	-	-	-	-	-	24.0 (2)	76.0 (2)
27 VelvetMesquite/Amaranth Tree Savanna	-	1.6 (1)	4.5 (2)	3.5 (3)	2.1 (2)	39.8 (10)	16.6 (5)	31.9 (11)
28 VelvetMesquite/NativeGrass Tree Savanna	-	-	-	-	-	27.8 (2)	11.3 (1)	60.9 (2)
29 VelvetMesquite/Tumbleweed Tree Savanna	-	-	100 (3)	-	-	-	-	-
30 Baccharis species/Amaranth Shrub Savanna	-	-	-	-	-	31.7 (1)	68.3 (5)	-
31 Baccharis species/Grass Shrub Savanna	-	-	-	-	-	15.5 (2)	-	84.5 (5)
32 Hymenoclea/Mixed Herb Shrub Savanna	-	-	27.1 (3)	-	-	10.8 (1)	21.4 (3)	40.7 (7)
33 VelvetMesquite/Mixed Herb Shrub Savanna	13.5 (2)	3.9 (2)	3.0 (1)	8.9 (2)	-	51.6 (4)	-	19.1 (3)
34 Amaranth Herbaceous	8.9 (3)	4.6 (2)	-	16.9 (8)	0.6 (1)	4.2 (3)	8.0 (3)	56.9 (5)
35 Forbs Herbaceous	19.5 (1)	23.1 (1)	9.4 (4)	-	1.9 (1)	28.1 (2)	3.5 (1)	14.5 (2)
36 Grass Herbaceous	-	-	19.4 (6)	-	-	-	1.7 (1)	78.9 (2)
37 Unknown Herbaceous	-	20.3 (1)	-	-	2.4 (2)	70.5 (10)	-	6.8 (2)
38 Cottonwood-Goodding's Willow Strand	-	19.2 (1)	53.3 (2)	22.3 (1)	2.1 (3)	2.2 (3)	0.9 (1)	-
39 Herbaceous Strand	95.1 (2)	-	-	-	-	-	-	4.9 (2)
40 Shrub Strand	-	-	-	-	-	35.2 (3)	10.8 (3)	54.0 (3)

TABLE 7. SUMMARY OF ALLIANCES REPRESENTED IN THE RANDOM SELECTION OF 44 FOREST AND WOODLAND POLYGONS FOR ACCURACY ASSESSMENT OF THE VEGETATION MAP ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE. ALLIANCES WERE AGGREGATED FOR ASSESSMENT PURPOSES INTO SINGLE SPECIES CLASSES, WITH THE EXCEPTION OF MESQUITE - [ELDERBERRY – HACKBERRY] FOREST.

Alliance	Polygons	Aggregated Classes	Polygons
Cottonwood-Goodding Willow Forest	5	Cottonwood-dominated Forest (CDF)	7
Cottonwood-[Velvet Mesquite-Elderberry] Forest	2		
Tamarisk Forest	5	Tamarisk-dominated Forest (TDF)	5
Velvet Mesquite-[Elderberry-Netleaf Hackberry] Forest	7	Mesquite - [Elderberry - Hackberry] Forest (MF)	7
Velvet Mesquite-Catclaw Acacia Forest	5	Other Mesquite-dominated Forest (OMF)	9
Velvet Mesquite Forest	4		
Cottonwood-Goodding Willow-Tamarisk Woodland	3	Cottonwood-dominated Woodland (CDW)	7
Cottonwood-Goodding Willow Woodland	4		
Velvet Mesquite-Catclaw Acacia Woodland	3	Mesquite-dominated Woodland (MDW)	9
Velvet Mesquite-Netleaf Hackberry Woodland	4		
Velvet Mesquite Woodland	2		
Total	44		44

TABLE 8. TOTAL NUMBER OF POLYGONS VISITED, PERCENT ACCURACY, AND KAPPA SCORE FOR FIELD ACCURACY ASSESSMENT OF THE VEGETATION MAP ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE. FOREST AND WOODLAND POLYGONS WERE ASSESSED FOR ACCURACY BY CONFIRMING THE DOMINANT TREE SPECIES IN THE AGGREGATED VEGETATION CLASS. GREY HIGHLIGHT INDICATES THE NUMBER OF POLYGONS CORRECTLY CLASSIFIED.

	Field Assessed Aggregated Class							
Actual Aggregated Class	CDF	TDF	MF	OMF	CDW	MDW	Total	User Accuracy (%)
Cottonwood-dominated Forest (CDF)	7						7	100
Tamarisk-dominated Forest (TDF)		5					5	100
Mesquite - [Elderberry - Hackberry] Forest (MF)			7				7	100
Other Mesquite-dominated Forest (OMF)			4	5			9	55.6
Cottonwood-dominated Woodland (CDW)					6	1	7	85.7
Mesquite-dominated Woodland (MDW)						9	9	100
Total	7	5	11	5	6	10	44	
Producer's Accuracy (%)	100	100	63.6	100	100	90		
Kappa	0.86							
Overall Accuracy (%)	88.64							

CONSERVATION PRIORITIZATION

We have identified the following 8 forest and woodland alliances for conservation that have complex structure, great species diversity, and high ecological value. These areas are located throughout the micro- and sub-area basins (Table 9), as well as within the floodway (Figure 6), beyond the floodway but within the 100-year floodplain (Figure 7), and beyond the 100-year floodplain (Figure 8).

Cottonwood - Willow (*Populus fremontii – Salix gooddingii*) Forest Alliance *(Alliance Code 1)*

Cottonwood - Velvet Mesquite - Elderberry (*Populus fremontii – Prosopis velutina – Sambucus nigra*) Forest Alliance *(Alliance Code 2)*

Velvet Mesquite – [Elderberry – Net-leaf Hackberry] (*Prosopis velutina – Sambucus nigra – Celtis laevigata var. reticulata*) Forest Alliance *(Alliance Code 4)*

Cottonwood – Willow – Tamarix species (*Populus fremontii – Salix gooddingii – Tamarix* species) Woodland Alliance *(Alliance Code 7)*

Cottonwood – Willow (*Populus fremontii – Salix gooddingii*) Woodland Alliance *(Alliance Code 8)*

Cottonwood – Velvet Mesquite (*Populus fremontii – Prosopis velutina*) Woodland Alliance *(Alliance Code 9)*

Velvet Mesquite – Elderberry (*Prosopis velutina – Sambucus nigra*) Woodland Alliance *(Alliance Code 12)*

Velvet Mesquite – Net-leaf Hackberry (*Prosopis velutina – Celtis laevigata var. reticulata*) Woodland Alliance *(Alliance Code 13)*

A total area of priority alliances is 1,017.2 ha (2,513.6 acre), comprising approximately 22% of the total riparian vegetation that was mapped (Table 10). Of this, 312.6 ha (772.7 acre) are located outside of the floodway but within the 100-year floodplain and 86.3 ha (213.3 acre) are located beyond the 100-year floodplain (Table 10). These areas are considered a primary priority for conservation and make up only 9% of the total area mapped. The remaining area is located within the current floodway and while still considered a priority for conservation, is less likely to be impacted by development.

TABLE 9. AREA AND PERCENT OF TOTAL AREA OF CONSERVATION PRIORITY ALLIANCES FOUND WITHIN MICROBASINS, SUB-AREA BASINS, AND A PORTION OF NOGALES WASH ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE. FROM SOUTH TO NORTH, MICROBASINS: BUENA VISTA (BV), KINO SPRINGS (KS), HIGHWAY 82 (H82), GUEVAVI (G); NOGALES WASH (NW); SUB-AREA BASINS: RIO RICO (RR), TUBAC (T), AND AMADO (A).

Area	BV	KS	H82	G	NW	RR	T	A	Total
Hectares (ha)	32.3	4.2	23	60	19.5	517.6	265.3	95.4	1,017.2
Acres	79.8	10.3	56.8	148.2	48.2	1,279	655.5	235.8	2,513.6
% Total	3.2	0.4	2.3	5.9	1.9	50.9	26.1	9.4	100

FIGURE 6. PRIORITY FOREST AND WOODLAND AREAS FOR CONSERVATION WITHIN THE FLOODWAY ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

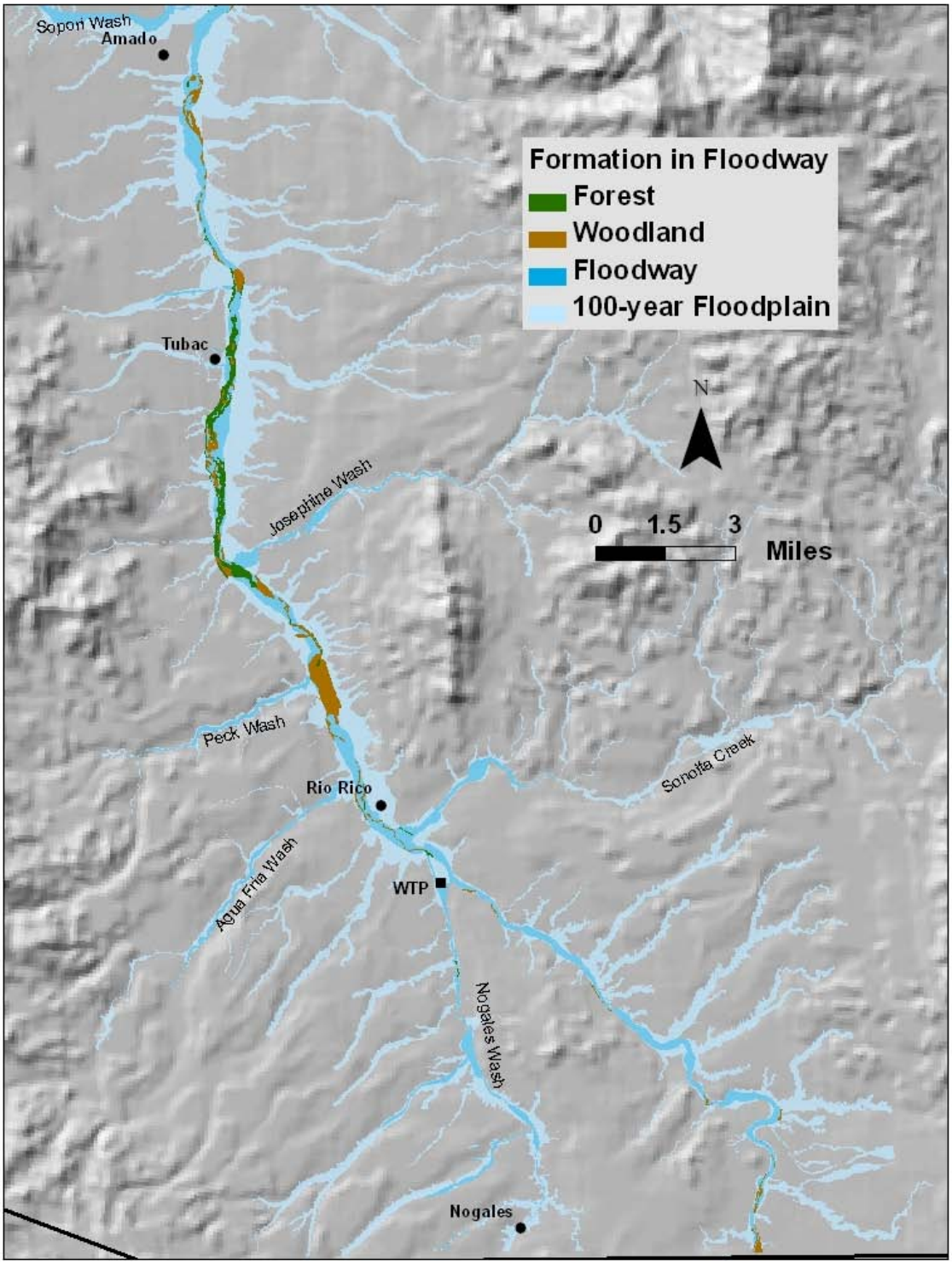

Figure 7. Priority forest and woodland areas for conservation beyond the floodway but within the 100-year floodplain along the Santa Cruz River riparian corridor spanning from the US-Mexico border to the Santa Cruz-Pima County line.

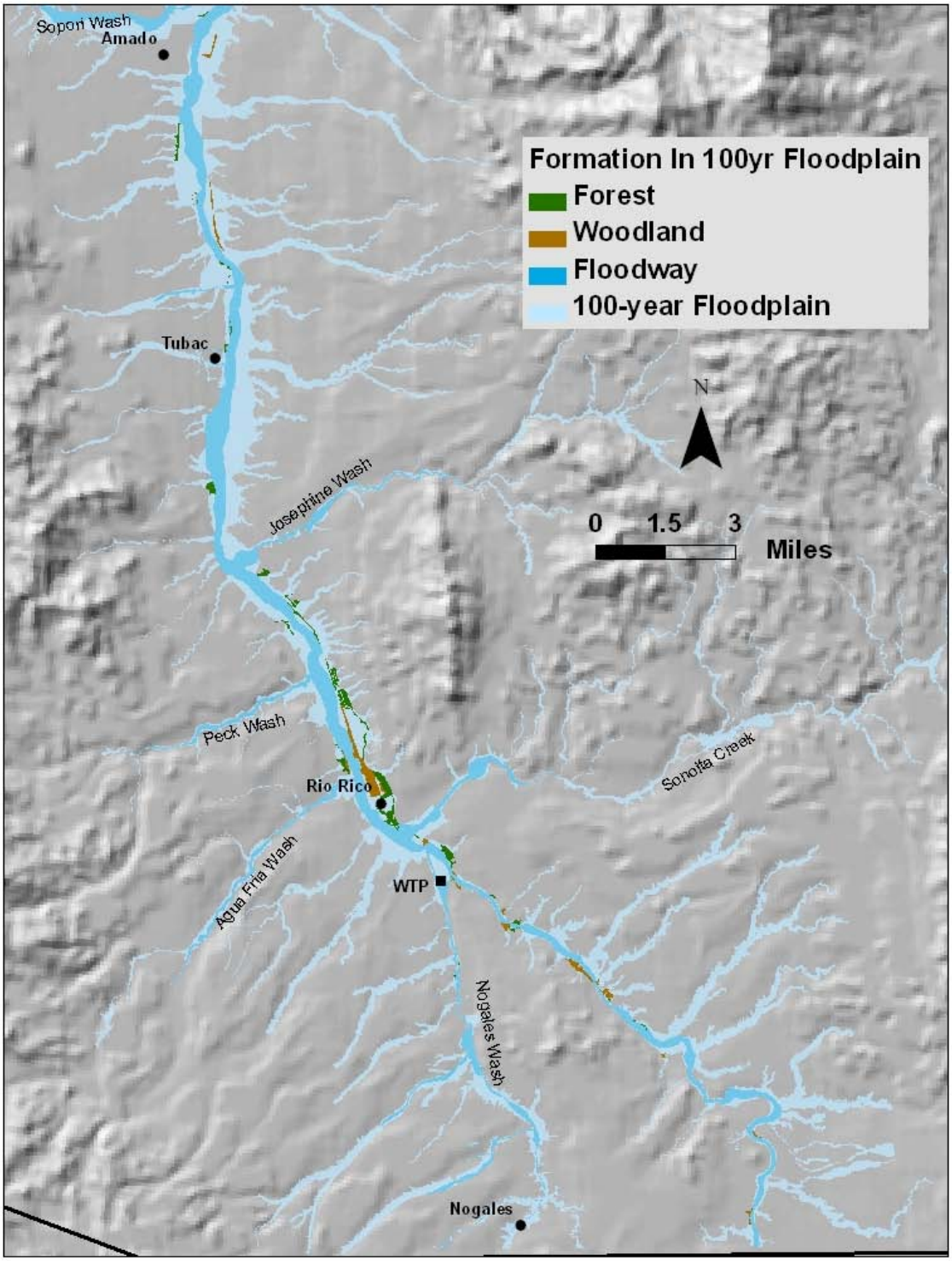

Figure 8. Priority forest and woodland areas for conservation beyond the 100-year floodplain along the Santa Cruz River riparian corridor spanning from the US-Mexico border to the Santa Cruz-Pima County line.

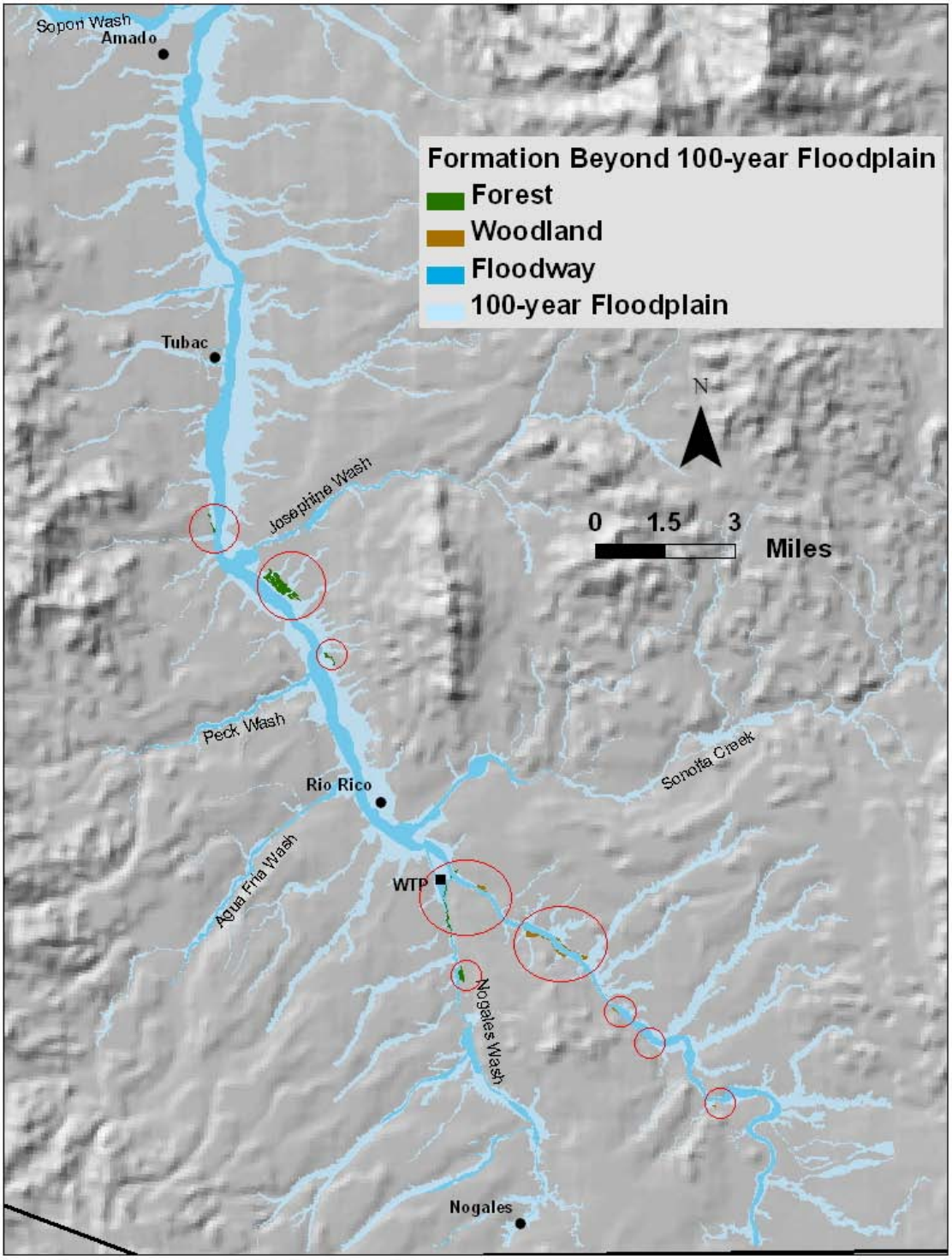

TABLE 10. SUMMARY OF AREA OF MAPPED IN THE FLOODWAY, BEYOND THE FLOODWAY BUT WITHIN THE 100-YEAR FLOODPLAIN, AND BEYOND THE 100-YEAR FLOODPLAIN ALONG THE SANTA CRUZ RIVER RIPARIAN CORRIDOR SPANNING FROM THE US-MEXICO BORDER TO THE SANTA CRUZ-PIMA COUNTY LINE.

	Floodway (FW)		**Beyond FW/In 100yr Floodplain**		**Beyond 100yr Floodplain**		**Total**		**%Total Mapped**
	ha	*acres*	*ha*	*acres*	*ha*	*acres*	*ha*	*acres*	
Riparian Vegetation*	985.9	2436.2	1057.8	2613.8	345.7	854.1	2389.4	5904.1	53%
Priority Vegetation	618.2	1527.6	312.6	772.7	86.3	213.3	1017.1	2513.6	22%[1]
Agriculture	206.7	510.9	680	1680.1	87	214.9	973.7	2405.9	21%
Developed Woodland	4.2	10.4	108.7	268.6	52.2	129	165.1	408	4%
Total Mapped	**1815**	**4485.1**	**2159.1**	**5335.2**	**571.2**	**1411.3**	**4545.3**	**11231.6**	**100%**

*does not include priority riparian vegetation

[1]%Total Mapped Beyond FW/In 100yr Floodplain = 7%; %Total Mapped Beyond 100yr Floodplain = 2%

CONCLUSIONS AND RECOMMENDATIONS

This report includes detailed baseline information about species composition, extent, and spatial distribution of riparian vegetation along the Santa Cruz River between the U.S.-Mexico border and the Santa Cruz-Pima County line. The accompanying GIS-based map illustrates the mosaic pattern of riparian vegetation along the main stem of the Upper Santa Cruz River and a portion of the Nogales Wash. Riparian vegetation patterns vary along the length of the river from sparsely vegetated shrub savannahs to dense forests. This vegetation pattern largely reflects the diverse hydrologic conditions of the river basin, and in particular is a visual indication of the depth to groundwater in underlying water tables. Riparian vegetation is uniquely adapted to utilize both surface and groundwater resources and relies upon both sources of water for optimal growth and health. Regular floods are also an important component of riparian health, as floodwaters scour the bottom of the stream channel to allow for rapid infiltration of surface water into groundwater tables. Floods also distribute seeds and support a diverse assemblage of riparian species along the length of the corridor.

Riparian systems are dynamic and are dependent upon seasonal flooding, precipitation, and groundwater tables. Changes in riparian vegetation can result from changes to any of these supporting elements and as a result, we recommend periodically updating the vegetation map using aerial photography, on-the-ground surveys, and/or satellite imagery. These updates can be used to record modifications in the vegetation that result from changing climate conditions, drought, and land-use patterns. Additionally, we would recommend surveying tributaries and streams throughout the county in a similar fashion to expand the content and scope of this map.

Ultimately, ensuring the continued health and function of the riparian area and the services it provides to the surrounding communities will require integrated floodplain, groundwater, and surface water management plans. This map, by illustrating the location and type of riparian vegetation in relation to groundwater tables and floodplain lands, will hopefully inform such integrated efforts in the future.

REFERENCES

Arizona Department of Water Resources 1999. Third management plan for the Santa Cruz Active Management Area. Management Plan available at: www.azwater.gov/dwr/WaterManagement/Content/AMAs/SantaCruzAMA/default.htm

Baird, K. J., J. C. Stromberg, and T. Maddock. 2005. Linking riparian dynamics and groundwater: An ecohydrologic approach to modeling groundwater and riparian vegetation. Environmental Management **36**:551-564.

Colby, B. and Wishart, S. 2002. Riparian Areas Generate Property Value Premium for Landowners. University of Arizona, Agricultural and Resource Economics Report.

Erwin, G. 2007. Groundwater flow model of the Santa Cruz Active Management Area Microbasins, International Boundary to Nogales International Wastewater Treatment Plant, Santa Cruz County, Arizona. Arizona Department of Water Resources, Modeling Report No.15.

Naiman, R. J., and H. Decamps. 1997. The ecology of interfaces: Riparian zones. Annual Review of Ecology and Systematics **28**:621-658.

Naiman, R. J., H. Decamps, and M. E. McClain. 2005. Riparia - Ecology, Conservation, and Management of Streamside Communities. Elsevier Academic Press, Burlington, MA.

Nelson, K. 2007. Groundwater flow model of the Santa Cruz Active Management Area along the effluent-dominated Santa Cruz River, Santa Cruz and Pima Counties, Arizona. Arizona Department of Water Resources, Modeling Report No.14.

Ohmart, R. D., and B. W. Anderson. 1986. Riparian Habitat. Pages 169-200 *in* A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart, editors. Inventory and Monitoring of Wildlife Habitat. United States Bureau of Land Management Service Center, Denver, Colorado.

Powell, B.F., E.W. Albrecht, W.L. Halvorson, C.A. Schmidt, P. Anning, K. Docherty. 2005. Vascular Plant and Vertebrate Inventory 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.

Stromberg, J. C. 1993. Fremont cottonwood-goodding willow riparian forests: a review of their ecology, threats, and recovery potential. Journal of the Arizona-Nevada Academy of Science **26**:97-110.

Swift, B. L. 1984. Status of Riparian Ecosystems in the United-States. Water Resources Bulletin **20**:223-228.

Tabacchi, E. , L. Luc, H.A. Guilloy, A, Planty-Tabacchi, E. Muller, H. DeAcamps, 2000. Impacts of riparian vegetation on hydrological process. *Hydrological Process* 14:2959-2976.

The Nature Conservancy and Environmental Systems Research Institution. 1994. Final Draft Standardized National Vegetation Classification System. Document available at: http://biology.usgs.gov/npsveg/classification/index.html.

USDA, NRCS. 2008. The PLANTS Database (http://plants.usda.gov, 8 May 2008). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Webb, R. H., and S. A. Leake. 2006. Ground-water surface-water interactions and long-term change in riverine riparian vegetation in the southwestern United States. Journal of Hydrology **320**:302-323.

APPENDIX A: ALLIANCE DESCRIPTIONS

FOREST ALLIANCES

COTTONWOOD-GOODDING'S WILLOW FOREST ALLIANCE

Scientific Name: *Populus fremontii – Salix gooddingii* Forest Alliance

Location: Tubac Sub-area basin to upper Rio Rico Sub-area basin (Chavez Siding Road Crossing to Palo Parado Road)

Alliance Code: 1

General Description: This mature forest alliance is found lining both sides of the main river channel, in an area where effluent is the primary component in the surface flow. This alliance is dominated by mature cottonwood and Goodding's willow, with Goodding's willow occasionally the more dominant. Other common trees associated with this alliance may include elderberry (*Sambucus nigra*), tamarisk (*Tamarix* species), velvet ash (*Fraxinus velutina*), and velvet mesquite (*Prosopis velutina*). Shrubs in this alliance are primarily dominated by seepwillow (*Baccharis salicifolia*), but may occasionally be dominated by elderberry (*Sambucus nigra*) or tamarisk. Other shrub species associated with this alliance may include desertbroom (*Baccharis sarothroides*), netleaf hackberry (*Celtis laevigata* var. *reticulata*), and velvet mesquite. The herbaceous cover may be dominated by Bermudagrass (*Cynodon dactylon*), native grasses, mixed forbs, or occasionally amaranth (*Amaranthus palmeri*). Other herbaceous species may include cocklebur (*Xanthium strumarium*) and mixed vines. In addition to tamarisk and Bermudagrass, invasive species include Johnson grass (*Sorghum halepense*) and giant reed (*Arundo donax*).

COTTONWOOD-[VELVET MESQUITE-ELDERBERRY] FOREST ALLIANCE

Scientific Name: *Populus fremontii* – [*Prosopis velutina – Sambucus nigra*] Forest Alliance

Location: localized areas in Tubac (Tumacácori National Historic Park), Amado (near Pima county line), and Rio Rico sub-area basins (near Nogales International Wastewater Treatment Plant), and along Nogales Wash

Alliance Code: 2

General Description: This forest alliance is comprised of 'stringers' of riparian trees located in the floodplain along former river channels that now lack regular surface water flow. Included in this alliance are patches of forest with sources of surface water other than the main channel, including the Nogales Wash tributary and the outlet of the Nogales International Wastewater Treatment Plant. This alliance is dominated by mature cottonwood. The second and third dominant tree species alternate between velvet mesquite (*Prosopis velutina*) and elderberry (*Sambucus nigra*).

Goodding's willow (*Salix gooddingii*) and netleaf hackberry (*Celtis laevigata* var*. reticulata*) are also commonly associated with this alliance. This alliance may include stands of cottonwood with other tree species absent or nearly absent. The dominant shrub in this alliance is desertbroom (*Baccharis sarothroides*), but other shrubs include velvet mesquite and elderberry. The herbaceous cover is not clearly defined due to restricted access and poor visibility, but may include mixed forbs, sunflowers (*Helianthus annus*), fewflower beggarticks (*Bidens leptocephala*), and occasional amaranth (*Amaranthus palmeri*). Invasive species include giant reed (*Arundo donax*) and Bermudagrass (*Cynodon dactylon*).

TAMARISK FOREST ALLIANCE

Scientific Name: *Tamarix* species Forest Alliance

Location: localized patches in Amado and Tubac Sub-area basins

Alliance Code: 3

General Description: This forest alliance is located in the floodplain and on the terrace above the floodplain. Though patches of this forest are generally small and localized, this alliance is distinguished from others by the dominance and high density of tamarisk trees. Cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*) were occasionally associated with this alliance. The shrubs are uncommon but may include seepwillow (*Baccharis salicifolia*), desertbroom (*Baccharis sarothroides*), hymenoclea (*Hymenoclea monogyra*). The herbaceous cover when present is dominated by amaranth (*Amaranthus palmeri*) and Bermudagrass (*Cynodon dactylon*). Invasive species include Bermudagrass and tamarisk. Two of the polygons associated with this alliance are located along agricultural fields. Tamarisk in these locations have been planted and are a different species from the tamarisk found in other parts of the riparian zone.

VELVET MESQUITE – [ELDERBERRY – NETLEAF HACKBERRY] FOREST ALLIANCE

Scientific Name: *Prosopis velutina* – [*Sambucus nigra – Celtis laevigata var. reticulata*] Forest Alliance

Location: primarily Tubac and Rio Rico Sub-area basins (Tubac Golf Course to Rio Rico Road), but includes a few polygons in Amado Sub-area basin, Nogales Wash, and Guevavi microbasin

Alliance Code: 4

General Description: This forest alliance is located on the terrace above the active floodplain, typically on the edge of the riparian corridor. Polygons of this forest alliance are generally small, or long and narrow, and adjacent to more open areas, such as active or old agricultural fields. This alliance is dominated by mature velvet mesquite (8-9m), with occasional polygons dominated by elderberry and netleaf hackberry. The second and third dominate tree species alternate between mature elderberry (4.5-6m) and netleaf hackberry (4.5-9m). Other trees associated with this

alliance include, catclaw acacia (*Acacia greggii*) and Goodding's willow (*Salix gooddingii*). Common shrubs in this alliance include graythorn (*Ziziphus obtusifolia*), catclaw acacia, mesquite, and wolfberry (*Lycium* species). The herbaceous cover may include mixed vine species, amaranth (*Amaranthus palmeri*), big sacaton (*Sporobolus wrightii*), and mixed native grasses and forbs. Invasive species include Bermudagrass (*Cynodon dactylon*). Active grazing was observed.

VELVET MESQUITE – CATCLAW ACACIA FOREST ALLIANCE

Scientific Name: *Prosopis velutina – Acacia greggii* Forest Alliance

Location: primarily Tubac and Rio Rico Sub-area basins (Chavez Siding Road crossing to Peck Canyon Drive exit) and three polygons in Amado Sub-area basin

Alliance Code: 5

General Description: This forest alliance is located on the terrace above the active floodplain, typically on the edge of the riparian corridor. Polygons of this forest alliance are generally long and narrow and adjacent to more open areas, such as agricultural fields and development. Many of the polygons in this alliance are in areas with plans for future development. This alliance is dominated by mature velvet mesquite (4.5-9m) and catclaw acacia (2.5-6m). Netleaf hackberry (*Celtis laevigata var. reticulata*) is commonly the third dominant tree species. Other trees associated with this alliance include graythorn (*Ziziphus obtusifolia*), velvet ash (*Fraxinus velutina*), and elderberry (*Sambucus nigra*). Dominant shrubs in this alliance may include catclaw acacia, graythorn, and occasionally wolfberry (*Lycium* species). Other associated shrubs may include desert hackberry (*Celtis ehrenbergiana*) and desertbroom (*Baccharis sarothroides*). The herbaceous cover is primarily dominated by mixed vine species or amaranth (*Amaranthus palmeri*). Native grasses and forbs are other common herbaceous cover. Invasive species include Johnson grass (*Sorghum halepense*) and non-native grass in two polygons. Active grazing was observed.

VELVET MESQUITE FOREST ALLIANCE

Scientific Name: *Prosopis velutina* Forest Alliance

Location: primarily Tubac, and Rio Rico Sub-area basins, scattered polygons in Amado Sub-area basin, Nogales Wash, and Guevavi, Highway 82, and Kino Springs microbasins

Alliance Code: 6

General Description: This forest alliance is located on the terrace above the active floodplain, typically on the edge of the riparian corridor. Patches of this forest alliance are generally remnant forest fragments adjacent to more open areas, such as agricultural fields and development. The vegetation community in this alliance is not clearly defined as many areas had limited access or were surveyed with photos obtained during aerial fly-over. Many polygons likely mature with structural and species diversity, but are fragments surrounded by future development. Several patches are younger forests located on recovering agricultural fields. This alliance is dominated by

velvet mesquite trees. Other trees may include catclaw acacia (*Acacia greggii*) and cottonwood (*Populus fremontii*). The shrubs in this alliance may include velvet mesquite, catclaw acacia, and fourwing saltbush (*Atriplex canescens*). The herbaceous cover is primarily unknown herbaceous cover, but may include mixed vine species, native grasses, desert honeysuckle (*Anisacanthus thurberi*), amaranth (*Amaranthus palmeri*), and big sacaton (*Sporobolus wrightii*). Invasive species include Bermudagrass (*Cynodon dactylon*).

WOODLAND ALLIANCES

COTTONWOOD – GOODDING'S WILLOW – TAMARISK WOODLAND ALLIANCE

Scientific Name: *Populus fremontii* **–** *Salix gooddingii* **–** *Tamarix* species Woodland Alliance

Location: Amado Sub-area basin (Amado-Montosa Road to Chavez Siding Road crossing) and Tubac Sub-area basin (north end of Tumacácori National Historic Park)

Alliance Code: 7

General Description: This woodland alliance is primarily located along both sides of the active channel. The main difference with this alliance and the Cottonwood-Goodding's willow alliance is presence of tamarisk among the top three dominant species. Cottonwood is the dominant species, though in some patches tamarisk is dominant. The second and third dominant species alternate between Goodding's willow and tamarisk. Other trees associated with this alliance include velvet mesquite (*Prosopis velutina*), elderberry (*Sambucus nigra*), and velvet ash (*Fraxinus velutina*). Shrubs in this alliance may be dominated by seepwillow (*Baccharis salicifolia*), hymenoclea (*Hymenoclea monogyra*), or desertbroom (*Baccharis sarothroides*). The herbaceous cover is primarily dominated by amaranth (*Amaranthus palmeri*), but occasionally may be dominated by native grass, giant reed (*Arundo donax*), or tumbleweed (*Salsola tragus*). Other herbaceous species may include forbs and Bermudagrass (*Cynodon dactylon*). Invasive species may include Bermudagrass, tamarisk, and giant reed. Evidence of die-back on cottonwoods and dead mesquites occurs in two polygons.

COTTONWOOD – GOODDING'S WILLOW WOODLAND ALLIANCE

Scientific Name: *Populus fremontii* **–** *Salix gooddingii* Woodland Alliance

Location: primarily in Amado, Tubac, and Rio Rico Sub-area basins (Amado-Montosa Road to Nogales International Wasterwater Treatment Plant), small patches in Highway 82 and Kino Springs microbasins, and all along Buena Vista microbasin

Alliance Code: 8

General Description: This woodland alliance is primarily located along both sides of the main channel and in the active floodplain. This alliance is dominated by mature cottonwood (6-15m) and Goodding's willow (3-10m). Goodding's willow occasionally is the dominant tree species. Other trees associated with this alliance may include velvet mesquite (*Prosopis velutina*), netleaf hackberry (*Celtis laevigata var. reticulata*), desert willow (*Chilopsis linearis*), and occasionally yew-leaf willow (*Salix taxifolia*), elderberry (*Sambucus nigra*), and velvet ash (*Fraxinus velutina*). The shrubs in this alliance are often dominated by seepwillow (*Baccharis salicifolia*), but may be dominated by hymenoclea (*Hymenoclea monogyra*), velvet mesquite, or desertbroom (*Baccharis*

sarothroides). The herbaceous cover is often dominated by amaranth (*Amaranthus palmeri*), but may be dominated by native grasses, forbs, rough cocklebur (*Xanthium strumarium*), or Bermudagrass (*Cynodon dactylon*). Other herbaceous species may include sunflowers (*Helianthus annus*) and mixed vines. Bermudagrass (*Cynodon dactylon*) is the most common invasive species, others include occasional Johnson grass (*Sorghum halepense*), giant reed (*Arundo donax*), and tamarisk (*Tamarix* species). A few polygons contain a notable quantity of dead or dying trees and evidence of drought stress with branch die-back. Areas closer to the border, particularly in Buena Vista microbasin, have lots of regeneration of both cottonwood and willow. Active grazing observed.

COTTONWOOD – VELVET MESQUITE WOODLAND ALLIANCE

Scientific Name: *Populus fremontii* **–** *Prosopis velutina* Woodland Alliance

Location: three localized areas: Tubac Sub-area basin (Tubac golf course to Clark Crossing Road), Rio Rico Sub-area basin (Rio Rico Road), and Kino Springs microbasin

Alliance Code: 9

General Description: This woodland alliance is located in three small areas along both sides of the active channel and in the floodplain. This alliance is dominated by cottonwood (6-15m) and mesquite (4-6m), but may include hackberry (*Celtis laevigata var. reticulata*) and desert willow (*Chilopsis linearis*). The shrubs associated with this alliance may include velvet mesquite. The herbaceous cover is dominated by amaranth (*Amaranthus palmeri*) or big sacaton (*Sporobolus wrightii*). Other herbaceous species may include native grasses and occasional tumbleweed (*Salsola tragus*). One polygon notes unhealthy mesquite and hackberry trees.

COTTONWOOD WOODLAND ALLIANCE

Scientific Name: *Populus fremontii* Woodland Alliance

Location: three localized areas: Tubac Sub-area basin (Clark Crossing Road), Nogales Wash, and Kino Springs microbasin

Alliance Code: 10

General Description: This mature woodland alliance is primarily located in three small areas along both sides of the active channel and along the Nogales Wash tributary. This alliance is dominated by cottonwood, and may include elderberry (*Sambucus nigra*) and netleaf hackberry (*Celtis laevigata var. reticulata*). The shrubs associated with this alliance may include yewleaf willow (*Salix taxifolia*), velvet mesquite (*Prosopis velutina*), netleaf hackberry, and desertbroom (*Baccharis sarothroides*). The herbaceous cover is dominated by amaranth (*Amaranthus palmeri*) or Bermudagrass (*Cynodon dactylon*), and may include forbs and unknown herbaceous cover. Invasive species include Bermudagrass and giant reed (*Arundo donax*).

VELVET MESQUITE – CATCLAW ACACIA WOODLAND ALLIANCE

Scientific Name: *Prosopis velutina – Acacia greggii* Woodland Alliance

Location: Amado and Tubac Sub-area basins (Arivaca Road to Chavez Siding Road crossing), Rio Rico Sub-area basin (north of Palo Parado crossing), and Highway 82 and Kino Springs microbasins

Alliance Code: 11

General Description: This woodland alliance is primarily located on the terrace above the active floodplain, though in a few cases along the main channel and side washes. This alliance is dominated by velvet mesquite (3-6m) and catclaw acacia (3-4.5m). Other trees associated with this alliance may include netleaf hackberry (*Celtis laevigata var. reticulata*), elderberry (*Sambucus nigra*), desert willow (*Chilopsis linearis*), and occasional velvet ash (*Fraxinus velutina*) and blue palo verde (*Parkinsonia florida*). Shrubs are primarily dominated by catclaw acacia or greythorn (*Ziziphus obtusifolia*), but may include velvet mesquite. The herbaceous cover is often dominated by amaranth (*Amaranthus palmeri*) and may include mixed vine species, forbs, and native grasses. Invasive species include Johnson grass (*Sorghum halepense*) and tamarisk (*Tamarix* species). One polygon has dying mesquite trees and another is adjacent to a grove of dying netleaf hackberry trees.

VELVET MESQUITE – ELDERBERRY WOODLAND ALLIANCE

Scientific Name: *Prosopis velutina – Sambucus nigra* Woodland Alliance

Location: Amado, Tubac, and Rio Rico Sub-area basins (localized patches from Arivaca Road to Nogales International Wastewater Treatment Plant)

Alliance Code: 12

General Description: This woodland alliance is primarily located on the terrace above the active floodplain, though in a few cases in the floodplain and along the main channel. This alliance is dominated by velvet mesquite (4-7m) and elderberry trees (4.5-6m). Occasionally elderberry may be more dominant than velvet mesquite. In one polygon, tamarisk (*Tamarix* species) is more dominant than elderberry. Other trees associated with this alliance may include netleaf hackberry (*Celtis laevigata var. reticulata*) and cottonwood (*Populus fremontii*), with occasional catclaw acacia (*Acacia greggii*) and desert hackberry (*Chilopsis linearis*). The shrubs in this alliance are primarily dominated by velvet mesquite, but may be dominated by hymenoclea (*Hymenoclea monogyra*) or greythorn (*Ziziphus obtusifolia*). Other shrub species may include desertbroom (*Baccharis sarothroides*) and catclaw acacia. The herbaceous cover is dominated by mixed forbs, native grasses, amaranth (*Amaranthus palmeri*), or occasionally sunflowers (*Helianthus annus*). Some dead cottonwood trees and branch die-back on elderberry and hackberry trees were noted. Active grazing was observed. Invasive species associated with this alliance include tamarisk, which was observed in one polygon.

VELVET MESQUITE – NETLEAF HACKBERRY WOODLAND ALLIANCE

Scientific Name: *Prosopis velutina – Celtis laevigata var. reticulata* Woodland Alliance

Location: Rio Rico Sub-area basins (Peck Canyon Drive road to Rio Rico Road), Guevavi and Highway 82 microbasins

Alliance Code: 13

General Description: This woodland alliance is primarily located on the terrace above the active floodplain. This mature alliance is diverse with multi-layered strata. The trees in this alliance are dominated by velvet mesquite (3-7.5m) and netleaf hackberry (3-7.5m). Occasionally netleaf hackberry may be more dominant than velvet mesquite. Other trees associated with this alliance include elderberry (*Sambucus nigra*), with occasional cottonwood (*Populus fremontii*), velvet ash (*Fraxinus velutina*), Goodding's willow (*Salix gooddingii*), and western soapberry (*Sapindus saponaria var. drummondii*). The shrubs in this alliance are mainly dominated by catclaw acacia (*Acacia greggii*) or velvet mesquite. Other shrubs may include netleaf hackberry, elderberry, graythorn (*Ziziphus obtusifolia*), hymenoclea (*Hymenoclea monogyra*) and desert honeysuckle (*Anisacanthus thurberi*). The herbaceous cover is primarily dominated by amaranth (*Amaranthus palmeri*), and may include native grasses, big sacaton (*Sporobolus wrightii*), and Bermudagrass (*Cynodon dactylon*). Invasive species include Bermudagrass, stinkgrass (*Eragrostis cilianenesis*), and Lehmann lovegrass (*Eragrostis lehmanniana*). One area in the Highway 82 microbasin appears to be water-stressed with considerable mortality.

VELVET MESQUITE WOODLAND ALLIANCE

Scientific Name: *Prosopis velutina* Woodland Alliance

Location: primarily in Amado and Rio Rico Sub-area basins, smaller localized areas in Tubac Sub-area basin, and Highway 82 and Kino Springs microbasins

Alliance Code: 14

General Description: This woodland alliance is primarily located on the terrace above the active floodplain, typically on the edge of the riparian corridor. This alliance includes areas where the vegetation community is less clearly defined due to limited access and/or surveys conducted with photos obtained during aerial fly-over. This alliance is dominated by velvet mesquite trees (4-7m). Other trees associated with this alliance include cottonwood (*Populus fremontii*), elderberry (*Sambucus nigra*), and netleaf hackberry (*Celtis laevigata var. reticulata*). Velvet mesquite shrubs are the primary dominant shrub in this alliance. Desertbroom (*Baccharis sarothroides*) and catclaw acacia (*Acacia greggii*) shrubs are commonly found in this alliance and occasionally may be most dominant shrub. Other associated shrubs include white-thorn acacia (*Acacia constricta*) and

hymenoclea (*Hymenoclea monogyra*). The herbaceous cover is not clearly defined and may be dominated by native grasses or amaranth (*Amaranthus palmeri*) and includes occasional big sacaton (*Sporobolus wrightii*). Invasive species include Lehmann lovegrass (*Eragrostis lehmanniana*).

WOODED SHRUBLAND ALLIANCES

VELVET MESQUITE / CATCLAW ACACIA WOODED SHRUBLAND ALLIANCE

Scientific Name: *Prosopis velutina / Acacia greggii* Wooded Shrubland Alliance

Location: localized polygons in Guevavi and Highway 82 microbasins

Alliance Code: 15

General Description: This wooded shrubland alliance is primarily located on the terrace above and occasionally adjacent to the active channel. This alliance is dominated by velvet mesquite trees (6-8m). Other trees associated with this alliance include catclaw acacia and netleaf hackberry (*Celtis laevigata var. reticulata*). Catclaw acacia is the dominant shrubs species. Other common shrubs include velvet mesquite and catclaw mimosa (*Mimosa aculeaticarpa var. biuncifera*), with occasional desert honeysuckle (*Anisacanthus thurberi*). The dominant herbaceous cover is amaranth (*Amaranthus palmeri*). Other herbaceous cover may include native grasses and forbs. Invasive species include Lehmann lovegrass (*Eragrostis lehmanniana*). Occasional water stress observed in trees and shrubs of this alliance.

VELVET MESQUITE / VELVET MESQUITE WOODED SHRUBLAND ALLIANCE

Scientific Name: *Prosopis velutina / Prosopis velutina* Wooded Shrubland Alliance

Location: primarily in Guevavi and Buena Vista microbasins, two small polygons in Amado Sub-area basin

Alliance Code: 16

General Description: This wooded shrubland alliance is located on the terrace above the active channel. This alliance is a well developed shrubland with scattered trees. The trees are dominated by velvet mesquite (6-7m). Netleaf hackberry (*Celtis laevigata var. reticulata,* 6-9m) is another common tree associated with this alliance and is occasionally found to be most dominant. Velvet mesquite is the dominant shrubs species, though whitethorn acacia (*Acacia constricta*) may occasionally be most dominant. Other common shrubs include catclaw acacia (*Acacia greggii*) and netleaf hackberry, with occasional catclaw mimosa (*Mimosa aculeaticarpa var. biuncifera*) and desert honeysuckle (*Anisacanthus thurberi*). The dominant herbaceous cover is amaranth (*Amaranthus palmeri*) with native grasses occasionally dominant but typically second dominant. Invasive species include Bermudagrass (*Cynodon dactylon*) and Lehmann lovegrass (*Eragrostis lehmanniana*). Two polygons have observed stress in mesquite trees.

SHRUBLAND ALLIANCES

CATCLAW ACACIA – WHITETHORN ACACIA – CATCLAW MIMOSA SHRUBLAND ALLIANCE

Scientific Name: *Acacia greggii – Acacia constricta – Mimosa aculeaticarpa var. biuncifera* Shrubland Alliance

Location: 2 localized areas in Guevavi microbasin

Alliance Code: 17

General Description: This shrubland alliance is located on the west-facing rocky slopes above the floodplain. This alliance is comprised of a thick shrub layer dominated by catclaw acacia, whitethorn acacia, and catclaw mimosa shrubs. Other associated shrub species include velvet mesquite (*Prosopis velutina*) and mixed cacti species. Trees occasionally associated with this alliance are velvet mesquite and redberry juniper (*Juniperus coahuilensis*). The dominant herbaceous cover is native grass. Amaranth (*Amaranthus palmeri*) is also commonly found, and occasionally is more dominant than grass. Other herbaceous species occasionally found include big sacaton (*Sporobolus wrightii*) and forbs.

HYMENOCLEA SHRUBLAND ALLIANCE

Scientific Name: *Hymenoclea monogyra* Shrubland Alliance

Location: Amado Sub-area basin

Alliance Code: 18

General Description: This shrubland alliance is located in the floodplain adjacent to the main channel. This alliance is dominated by hymenoclea, but includes desertbroom (*Baccharis sarothroides*) and seepwillow (*Baccharis salicifolia*). Trees occasionally associated with this alliance are tamarisk (*Tamarix* species) and velvet mesquite (*Prosopis velutina*). The dominant herbaceous cover is comprised of native grasses and forbs. All invasive species observed in this type are associated with one polygon and include tamarisk, Johnson grass (*Sorghum halepense*), giant reed (*Arundo donax*), and Bermudagrass (*Cynodon dactylon*). Areas where this alliance occurs have active grazing and are interspersed with patches of dirt and herbaceous cover.

SEEPWILLOW SHRUBLAND ALLIANCE

Scientific Name: *Baccharis salicifolia* Shrubland Alliance

Location: Rio Rico Sub-area basin (near Palo Parado Crossing).

Alliance Code: 19

General Description: This localized shrubland alliance is found in the floodplain adjacent to the main channel. This alliance is dominated by seepwillow shrubs and may include hymenoclea (*Hymenoclea monogyra*). Associated trees include cottonwood (*Populus fremontii*), Goodding's willow (*Salix goodingii*), and velvet mesquite (*Prosopis velutina*). The herbaceous cover is not clearly defined due to limited access and surveys by aerial fly-over. Herbaceous species may include rough cocklebur (*Xanthium strumarium*), amaranth (*Amaranthus palmeri*), and native grasses.

TAMARISK SHRUBLAND ALLIANCE

Scientific Name: *Tamarix* species Shrubland Alliance

Location: isolated polygon in Amado Sub-area basin (near Chavez Siding Crossing).

Alliance Code: 20

General Description: This shrubland alliance is found in the floodplain adjacent to the main channel. This alliance is dominated by tamarisk shrubs and may include seepwillow (*Baccharis salicifolia*) and hymenoclea (*Hymenoclea monogyra*). Associated trees include cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*). Herbaceous cover is dominated by tumbleweed (Salsola tragus) and includes giant reed (Arundo donax). Invasive species include tamarisk and giant reed.

VELVET MESQUITE – CATCLAW ACACIA SHRUBLAND ALLIANCE

Scientific Name: *Prosopis velutina – Acacia greggii* Shrubland Alliance

Location: throughout Guevavi and Highway 82 microbasins, one small polygon in Tubac Sub-area basin (near Chavez Siding Road)

Alliance Code: 21

General Description: This well-developed shrubland alliance, comprised of open areas and low shrubs, is located on the terrace above the active floodplain, typically on the edge of the riparian corridor. This alliance is dominated by velvet mesquite and catclaw acacia shrubs. Whitethorn acacia (*Acacia constricta*) is also common and occasionally is the second dominant shrub species. Other associated shrubs include catclaw mimosa (*Mimosa aculeaticarpa var. biuncifera*) and mixed cacti species. Trees occasionally associated with this alliance are velvet mesquite and redberry juniper (*Juniperus coahuilensis*). The dominant herbaceous cover is amaranth (*Amaranthus palmeri*), though mixed native grasses are also common and occasionally the most dominant herbaceous cover. Lehmann lovegrass (*Eragrostis lehmanniana*) was the only invasive species observed and was listed in two polygons as the most dominant herbaceous species.

VELVET MESQUITE SHRUBLAND ALLIANCE

Scientific Name: *Prosopis velutina* Shrubland Alliance

Location: Amado, Tubac, and Rio Rico Sub-area basins and Highway 82, Kino Springs, and Buena Vista microbasins

Alliance Code: 22

General Description: This shrubland alliance is located on the terrace above the floodplain often along the edge of the riparian corridor. The vegetation community in this alliance is not clearly defined as many areas had limited access or were surveyed with aerial fly-over. This alliance is dominated by velvet mesquite shrubs, though occasionally dominated by desert willow (*Chilopsis linearis*). Other shrub species may include hymenoclea (*Hymenoclea monogyra*) and catclaw acacia (*Acacia greggii*). Trees occasionally associated with the alliance include velvet mesquite (*Prosopis velutina*), cottonwood (*Populus fremontii*), and Goodding's willow (*Salix gooddingii*). The herbaceous cover is not well defined but may be dominated by amaranth (*Amaranthus palmeri*) or native grasses. Invasive species include Lehmann lovegrass (*Eragrostis lehmanniana*) and Bermudagrass (*Cynodon dactylon*). Active grazing observed.

TREE SAVANNA ALLIANCES

COTTONWOOD/AMARANTH TREE SAVANNA ALLIANCE

Scientific Name: *Populus fremontii/Amaranthus palmeri* Tree Savanna Alliance

Location: several patches in Tubac and Rio Rico Sub-area basins, but primarily in Guevavi, Highway 82, Kino Springs, and Buena Vista microbasins

Alliance Code: 23

General Description: This tree savanna alliance is located in the floodplain along the main channel. The tree component of this alliance is dominated by cottonwood trees (5-20m), but may include Goodding's willow (*Salix gooddingii*) and velvet mesquite (*Prosopis velutina*). The dominant shrub associated with this alliance is often elderberry (*Sambucus nigra*), though occasionally velvet mesquite, seepwillow (*Baccharis salicifolia*), and hymenoclea (*Hymenoclea monogyra*) are most dominant. Netleaf hackberry (*Celtis laevigata var. reticulata*) shrubs are also commonly associated with this alliance. The herbaceous component of this alliance is not always clearly defined because some areas had limited access or were surveyed with aerial fly-over. Herbaceous cover is commonly dominated by amaranth (*Amaranthus palmeri*). Bermudagrass (*Cynodon dactylon*) and mixed native grasses and forbs are also common species in the herbaceous cover. Bermudagrass is the most common invasive species, with occasional tamarisk (*Tamarix* species). Mixed dead and live cottonwoods were noted only for one polygon. Young cottonwood trees were observed in several polygons when viewing the aerial fly-over photos, suggesting regeneration is occurring.

COTTONWOOD/NATIVE GRASS TREE SAVANNA ALLIANCE

Scientific Name: *Populus fremontii/*Native grass Tree Savanna Alliance

Location: primarily in Kino Springs microbasin with one polygon in Tubac Sub-area basin

Alliance Code: 24

General Description: This tree savanna alliance is located in the floodplain along the main channel. The tree component of this alliance is dominated by cottonwood trees (5-20m) and may include yewleaf willow (*Salix taxifolia*), netleaf hackberry (*Celtis laevigata var. reticulata*), and velvet mesquite (*Prosopis velutina*). Shrubs associated with this alliance include yewleaf willow, catclaw acacia, velvet mesquite, and hymenoclea (*Hymenoclea monogyra*). The herbaceous component of this alliance dominated by native grasses, but occasionally may be dominated by sunflowers (*Helianthus annus*). Other associated herbaceous species include amaranth (*Amaranthus palmeri*).

ELDERBERRY/AMARANTH TREE SAVANNA ALLIANCE

Scientific Name: *Sambucus nigra/Amaranthus palmeri* Tree Savanna Alliance

Location: small localized polygons in Amado, Tubac, and Rio Rico Sub-area basins, and Kino Springs microbasins

Alliance Code: 25

General Description: This tree savanna alliance is located in the floodplain adjacent to the main channel. The tree component of this alliance is dominated by elderberry trees, but may include velvet mesquite (*Prosopis velutina*) and netleaf hackberry (*Celtis laevigata var. reticulata*). Shrubs are uncommon and may include velvet mesquite and hymenoclea (*Hymenoclea monogyra*). The herbaceous cover is occasionally not clearly defined due to surveys with aerial fly-over. Herbaceous cover may be dominated by amaranth (*Amaranthus palmeri*) or native grasses and may include forbs, sunflowers (*Helianthus annus*), tumbleweed (*Salsola tragus*), and rough cocklebur (*Xanthium strumarium*).

TAMARISK/AMARANTH TREE SAVANNA ALLIANCE

Scientific Name: *Tamarix* species*/Amaranthus palmeri* Tree Savanna Alliance

Location: localized polygons in Amado and Tubac Sub-area basins (near Amado-Montosa Road and Clark Crossing)

Alliance Code: 26

General Description: This tree savanna alliance is located in the floodplain adjacent to the main channel. The tree component of this alliance is dominated by tamarisk, commonly includes cottonwood (*Populus fremontii*), and occasionally may include Goodding's willow (*Salix gooddingii*), and elderberry (*Sambucus nigra*). Shrubs associated with this alliance may include hymenoclea (*Hymenoclea monogyra*), seepwillow (*Baccharis salicifolia*), and desertbroom (*Baccharis sarothroides*). The herbaceous cover is dominated by amaranth (*Amaranthus palmeri*), although occasionally dominated by native grasses. Other herbaceous species may include forbs and tumbleweed (*Salsola tragus*). Aside from tamarisk trees, other invasive species include Bermudagrass (*Cynodon dactylon*).

VELVET MESQUITE/AMARANTH TREE SAVANNA ALLIANCE

Scientific Name: *Prosopis velutina/Amaranthus palmeri* Tree Savanna Alliance

Location: primarily in Amado and Rio Rico Sub-area basins, with a few scattered areas in Tubac Sub-area basin, and Highway 82 and Kino Springs microbasins

Alliance Code: 27

General Description: This tree savanna alliance is located on the terrace and in the floodplain adjacent to the main channel. The tree component of this alliance is dominated by velvet mesquite (4-9m), and may include elderberry (Sambucus nigra), cottonwood (*Populus fremontii*), netleaf hackberry (*Celtis laevigata var. reticulata*), and Goodding's willow (*Salix gooddingii*). Shrubs found in this alliance may include velvet mesquite, hymenoclea (*Hymenoclea monogyra*), seepwillow (*Baccharis salicifolia*), desertbroom (*Baccharis sarothroides*), and catclaw acacia (*Acacia greggii*). The herbaceous cover is not always well defined due to limited access and surveys from aerial fly-over. The herbaceous cover is primarily dominated by amaranth (*Amaranthus palmeri*), but may include native grasses, tumbleweed (*Salsola tragus*), and rough cocklebur (*Xanthium strumarium*). Invasive species include occasional Bermudagrass (*Cynodon dactylon*) and tamarisk (*Tamarix* species). Active grazing observed. Occasional branch die-back on velvet mesquite and dead cottonwood trees are associated with this alliance.

VELVET MESQUITE/NATIVE GRASS TREE SAVANNA ALLIANCE

Scientific Name: *Prosopis velutina/*Native Grass Tree Savanna Alliance

Location: a few scattered areas in Amado, Tubac, and Rio Rico Sub-area basins

Alliance Code: 28

General Description: This tree savanna alliance is located on the terrace and in the floodplain adjacent to the main channel. The tree component of this alliance is dominated by velvet mesquite (4-5m), and may include elderberry (*Sambucus nigra*) and Goodding's willow (*Salix gooddingii*). Shrubs in this alliance are dominated by velvet mesquite and may include desertbroom (*Baccharis sarothroides*) and hymenoclea (*Hymenoclea monogyra*). The herbaceous cover is dominated by native grasses but may include amaranth (*Amaranthus palmeri*), tumbleweed (*Salsola tragus*), forbs, and big sacaton (*Sporobolus wrightii*).

VELVET MESQUITE/TUMBLEWEED TREE SAVANNA ALLIANCE

Scientific Name: *Prosopis velutina/Salsola tragus* Tree Savanna Alliance

Location: localized in Highway 82 microbasin

Alliance Code: 29

General Description: This tree savanna alliance is located in the floodplain adjacent to the main channel. The tree component of this alliance is dominated by velvet mesquite (4-6m), and includes netleaf hackberry (*Celtis laevigata var. reticulata*), Arizona walnut (*Juglans major*), and occasional catclaw acacia (*Acacia greggii*) and elderberry (*Sambucus nigra*). Shrubs are dominated by hymenoclea (*Hymenoclea monogyra*) and include desertbroom (*Baccharis sarothroides*). The herbaceous cover is dominated by tumbleweed (*Salsola tragus*), and may include sunflowers (*Helianthus annus*), native grasses, and amaranth (*Amaranthus palmeri*).

SHRUB SAVANNA ALLIANCES

BACCHARIS/AMARANTH SHRUB SAVANNA ALLIANCE

Scientific Name: *Baccharis* species/*Amaranthus palmeri* Shrub Savanna Alliance

Location: localized in Tubac Sub-area basin (Tumacácori National Historic Park)

Alliance Code: 30

General Description: This shrub savanna alliance is located in the floodplain adjacent to the main channel. The shrub component of this alliance is dominated by one of two Baccharis species, seepwillow (*Baccharis salicifolia*) or desertbroom (*Baccharis sarothroides*). Other shrubs include velvet mesquite (*Prosopis velutina*) and hymenoclea (*Hymenoclea monogyra*). Trees associated with this alliance include occasional cottonwood (*Populus fremontii*). The herbaceous cover is primarily dominated by amaranth (*Amaranthus palmeri*), though occasionally dominated by Bermudagrass (*Cynodon dactylon*) or rough cocklebur (*Xanthium strumarium*). Herbaceous cover may include forbs and native grass. Invasive species include occasional Bermudagrass.

BACCHARIS/GRASS SHRUB SAVANNA ALLIANCE

Scientific Name: *Baccharis* species/Grass Shrub Savanna Alliance

Location: two localized areas in Amado and Rio Rico Sub-area basins (Amado: near county line; Rio Rico: near Peck Canyon)

Alliance Code: 31

General Description: This shrub savanna alliance is located in the floodplain adjacent to the main channel. The shrub component of this alliance is dominated by seepwillow (*Baccharis salicifolia*) with desertbroom (*Baccharis sarothroides*) commonly the second dominant. Other shrubs include velvet mesquite (*Prosopis velutina*) and occasional prickly pear (*Opuntia* species). Trees associated with this alliance include cottonwood (*Populus fremontii*) and velvet mesquite. The herbaceous cover is dominated by grasses and may include amaranth (*Amaranthus palmeri*), forbs, and occasional sunflowers (*Helianthus annus*). Presence of young cottonwood and mesquite suggest good areas of regeneration.

HYMENOCLEA/MIXED HERBS SHRUB SAVANNA ALLIANCE

Scientific Name: *Hymenoclea monogyra*/Mixed Herbs Shrub Savanna Alliance

Location: primarily in Amado and Tubac Sub-area basins, one area in Rio Rico Sub-area basin (Palo Parado crossing), several patches in Highway 82 microbasin

Alliance Code: 32

General Description: This shrub savanna alliance is located in the floodplain adjacent to the main channel. While the shrub component of this alliance is primarily dominated by Hymenoclea; there are occasional sizeable patches where desert willow (*Chilopsis linearis*) and yewleaf willow (*Salix taxifolia*) are the dominate shrub. Other shrubs may include seepwillow (*Baccharis salicifolia*), velvet mesquite (*Prosopis velutina*), and desertbroom (*Baccharis sarothroides*). Trees commonly associated with this alliance include velvet mesquite (Prosopis velutina), cottonwood (*Populus fremontii*), desert willow, and Goodding's willow (*Salix gooddingii*). The herbaceous cover is dominated by mixed herbs that may include native grasses, amaranth (*Amaranthus palmeri*), tumbleweed (*Salsola tragus*), forbs, and Bermudagrass (*Cynodon dactylon*). Invasive species include Bermudagrass and tamarisk (*Tamarix* species). Active grazing observed. Occasional hymenoclea found growing from larger dead forms and die-back among other species.

VELVET MESQUITE/MIXED HERB SHRUB SAVANNA ALLIANCE

Scientific Name: *Prosopis velutina/*Mixed Herb Shrub Savanna Alliance

Location: primarily in Rio Rico Sub-area basin and Kino Springs and Buena Vista microbasins, three polygons in Amado Sub-area basin

Alliance Code: 33

General Description: This shrub savanna alliance is located in the floodplain adjacent to the main channel and on the terrace above the main floodplain. The shrub component of this alliance is dominated by velvet mesquite, but may include catclaw acacia (*Acacia greggii*), desertbroom (*Baccharis sarothroides*), netleaf hackberry (*Celtis laevigata var. reticulata*), hymenoclea (*Hymenoclea monogyra*), and mixed cacti species. Trees associated with this alliance may include velvet mesquite (Prosopis velutina), netleaf hackberry, and elderberry (*Sambucus nigra*). The herbaceous cover is dominated by mixed herbs that may include amaranth (*Amaranthus palmeri*), native grasses, forbs, and rough cocklebur (*Xanthium strumarium*). Invasive species include occasional Bermudagrass (*Cynodon dactylon*). Active grazing observed. Several polygons have dead/downed cottonwood trees. Several polygons have young cottonwood and mesquite, indicating regeneration is occurring.

HERBACEOUS ALLIANCES

AMARANTH HERBACEOUS ALLIANCE

Scientific Name: *Amaranthus palmeri* Herbaceous Alliance

Location: primarily in Amado and Tubac Sub-area basins, and Guevavi, Kino Springs, and Buena Vista microbasins, two polygons found in Rio Rico Sub-area basin

Alliance Code: 34

General Description: This herbaceous alliance is located in the floodplain adjacent to the main channel. The herbaceous cover is dominated by amaranth (*Amaranthus palmeri*) and commonly includes native grasses and forbs. Herbaceous species occasionally associated with this alliance include tumbleweed (*Salsola tragus*), Bermudagrass (*Cynondon dactylon*), and rough cocklebur (*Xanthium strumarium*). Trees occasionally associated with this alliance include velvet mesquite (*Prosopis velutina*), elderberry (*Sambucus nigra*), cottonwood trees (*Populus fremontii*), and Goodding's willow (*Salix gooddingii*). The shrubs occasionally associated with this alliance include velvet mesquite, hymenoclea (*Hymenoclea monogyra*), and elderberry. Bermudagrass is the most common invasive species associated with this alliance; others include stinkgrass (*Eragrostis cilianensis*). Active grazing observed. A couple polygons of this alliance have many dead cottonwoods while a few others have regeneration along the edges.

FORBS HERBACEOUS ALLIANCE

Scientific Name: Forbs Herbaceous Alliance

Location: localized polygons is Amado, Tubac, and Rio Rico Sub-area basins, and Highway 82, Kino Springs, and Buena Vista microbasins, one polygon in Nogales wash

Alliance Code: 35

General Description: This herbaceous alliance is located in the floodplain adjacent to the main channel. The herbaceous cover is dominated by mixed forbs that may include rough cocklebur (*Xanthium strumarium*), tumbleweed (*Salsola tragus*), and sunflowers (*Helianthus annus*). Other herbaceous species may include amaranth (*Amaranthus palmeri*) and native grasses. Trees occasionally associated with this alliance include cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*). The shrubs occasionally associated with this alliance include velvet mesquite (*Prosopis velutina*), seepwillow (*Baccharis salicifolia*), and hymenoclea (*Hymenoclea monogyra*). Invasive species may include Bermudagrass (*Cynodon dactylon*), Johnson grass (*Sorghum halepense*), and tamarisk (*Tamarix* species). Active grazing observed. A couple polygons in this alliance have cottonwood regeneration.

GRASS HERBACEOUS ALLIANCE

Scientific Name: Grass Herbaceous Alliance

Location: localized patches found in Amado and Tubac Sub-area basins, and Highway 82 microbasin

Alliance Code: 36

General Description: This herbaceous alliance is located in the floodplain adjacent to the main channel, and in one case about a man-made pond. Although primarily dominated by native grasses, Johnson grass (*Sorghum halepense*) occasionally dominates the herbaceous cover. Other common herbaceous species may include amaranth, Bermudagrass (*Cynodon dactylon*), Lehmann lovegrass (*Eragrostis lehmanniana*), and mixed forb species. Trees occasionally associated with this alliance include cottonwood (*Populus fremontii*), elderberry (*Sambucus nigra*), and velvet mesquite (*Prosopis velutina*). The shrubs occasionally associated with this alliance include hymenoclea (*Hymenoclea monogyra*) and seepwillow (*Baccharis salicifolia*). Other invasive species include occasional tamarisk (*Tamarix* species).

UNKNOWN HERBACEOUS ALLIANCE

Scientific Name: Unknown Herbaceous Alliance

Location: primarily in Rio Rico Sub-area basin (Rio Rico Drive to Nogales International Wastewater Treatment plant) and localized patches found in Amado Sub-area basin, Nogales wash, and Kino Springs microbasins

Alliance Code: 37

General Description: This herbaceous alliance is located on the floodplain adjacent to the main channel. The vegetation community in this alliance is not clearly defined because all areas had limited access and/or were surveyed with aerial fly-over. As a result, the herbaceous cover is primarily dominated by unknown herbaceous species, but likely includes amaranth (*Amaranthus palmeri*), rough cocklebur (*Xanthium strumarium*), and mixed native grasses. Trees occasionally associated with this alliance include cottonwood (*Populus fremontii*), velvet mesquite (*Prosopis velutina*), and elderberry (*Celtis laevigata var. reticulata*). The shrubs occasionally associated with this alliance include velvet mesquite and seepwillow (*Baccharis salicifolia*).

STRAND ALLIANCES

COTTONWOOD-GOODDING'S WILLOW STRAND ALLIANCE

Scientific Name: *Populus fremontii – Salix gooddingii* Strand Alliance

Location: primarily in Guevavi, Highway 82, and Kino Springs microbasins with isolated patches in Rio Rico and Tubac Sub-area basins and Nogales wash

Alliance Code: 38

General Description: This strand alliance, characterized by sand with scattered vegetation, is located in the main channel, primarily in the stretch of the river south of the Nogales International Wastewater Treatment Plant where there is little to no surface water. The plants associated with this alliance are not clearly defined because most areas had limited access and/or were surveyed with aerial fly-over. The dominant visible vegetation in this alliance is cottonwood and Goodding's willow. The shrubs associated with this alliance are primarily unknown, but may include occasional seepwillow (*Baccharis salicifolia*), desertbroom (*Baccharis sarothroides*), hymenoclea (*Hymenoclea monogyra*), and velvet mesquite (*Prosopis velutina*). The occasional herbaceous cover is primarily unknown herbaceous species, but likely includes amaranth (*Amaranthus palmeri*), native grasses, and Bermudagrass (*Cynodon dactylon*). Invasive species in these areas remain unknown, but Bermudagrass was observed in one polygon surveyed on the ground.

HERBACEOUS STRAND ALLIANCE

Scientific Name: Herbaceous Strand Alliance

Location: primarily Buena Vista microbasin, with two small polygons in Amado Sub-area basin

Alliance Code: 39

General Description: This strand alliance, dominated by sand and scattered herbaceous cover, is located in the main channel. The plants associated with this alliance are not clearly defined because most areas had limited access and/or were surveyed with aerial fly-over. Trees are uncommon with occasional young cottonwood (*Populus fremontii*). The shrubs, if any, are of unknown species. The herbaceous cover when present is dominated by unknown species but likely includes native grasses and amaranth (*Amaranthus palmeri*). Invasive species in these areas are unknown.

SHRUB STRAND ALLIANCE

Scientific Name: Shrub Strand Alliance

Location: localized polygons in Amado, Tubac, and Rio Rico Sub-area basins

Alliance Code: 40

General Description: This strand alliance is located in the main channel along a major tributary (Sopori Wash) and the stretch of the river dependent on effluent from the Nogales International Wastewater Treatment Plant. The plants associated with this alliance are not clearly defined because most areas had limited access and/or were surveyed with aerial fly-over. Trees are uncommon, and may include occasional cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), and velvet mesquite (*Prosopis velutina*). The shrubs associated with this alliance commonly include desertbroom (*Baccharis sarothroides*), seepwillow (*Baccharis salicifolia*), and hymenoclea (*Hymenoclea monogyra*). The occasional herbaceous cover may include native grasses, amaranth (*Amaranthus palmeri*), rough cocklebur (*Xanthium strumarium*), and Bermudagrass (*Cynodon dactylon*). Invasive species in these areas are primarily unknown, but Bermudagrass was observed in one polygon surveyed on the ground.

APPENDIX B. DATASHEET USED DURING FIELD MAPPING SURVEYS

Santa Cruz Vegetation Mapping
Field Data Sheet

Proofread by: _____ Copied by: _____
Entered by: _____ Verified by: _____

Date:

Location and Event Information

Map #:	Polygon centroid:
Polygon ID:	New poly ID (if applicable):
Recorder Name:	Observer Name(s):

Formation T ype

Tentative Formation:	Keyed Formation:

List top three dominant species in each stratum
Rank in second column 1=dominant or co -dominant, 2= second dominant, 3=least dominant

TREE >2m	1,2,3	SHRUB <2m	1,2,3	HERBACEOUS (incl. grasses)	1,2,3

Other common associates

TREE >2m	SHRUB <2m	HERBACEOUS (incl. grasses)

Association name **Use ŅŠŅ within strata, ŅÓ between strata and Ņ( )Ó to denote minor species.**

APPENDIX C. DATASHEET USED FOR ALLIANCE VERIFICATION

Santa Cruz River Vegetation Mapping
Field Data Sheet: **Thematic Accuracy Assessment**

Date (mm/dd/yyyy):	Time (00:00):	Observer(s):	Recorder:
Polygon ID:	Map Sheet:		
Approximate polygon center (UTM NAD83):			

Dominant tree species by canopy cover in polygon is:		
Total (all species) tree canopy cover in polygon is:	Greater than 60 % (Forest)	Less than 60% (Woodland)

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

Cottonwood-dominated Forest
Mesquite – [Elderberry – Hackberry] Forest
Other Mesquite-dominated Forest
Cottonwood-dominated Woodland
Mesquite-dominated Woodland
Tamarisk-dominated Forest

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. Record any other notes pertinent to your assessment of this polygon. Use back of sheet as needed.

AA_Datasheet.ppt

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

APPENDIX D. ACCOMPANYING GIS FILES/INSTRUCTIONS

ArcGIS /Imagery files

Accompanying this report are the following ArcGIS and image files:

- SCR_VegMap.(dbf, prj, sbn, sbx, shp, shx) – map of vegetation polygons with species composition and other observations
    - SCR_VegMap_PriorityInFW. (dbf, prj, sbn, sbx, shp, shx) – map of vegetation polygons located in the floodway, pulled from SCR_Vegmap.
    - SCR_VegMap_PriorityInFP. (dbf, prj, sbn, sbx, shp, shx) – map of vegetation polygons located in the 100-year floodplain, pulled from SCR_Vegmap.
    - SCR_VegMap_PriorityOut100FP. (dbf, prj, sbn, sbx, shp, shx) – map of vegetation polygons located in the beyond the 100-year floodplain, pulled from SCR_Vegmap.
- PhotoPoints.(dbf, prj, sbn, sbx, shp, shx) – map of points/areas that have photos available from the aerial fly-over
- Quickbird imagery
- Folder of photos from aerial flights (VegMapPhotos)
- Microbasin.(dbf, prj, sbn, sbx, shp, shx) - (file from ADWR)
- Sub-area basin.(dbf, prj, sbn, sbx, shp, shx) - (Sonoran Institute estimated sub-area basin based on ADWR report)

A portion of the polygons were verified using photos taken during two aerial fly-overs provided by EcoFlight (2006) and LightHawk (2007). Photos from October 2006 were taken by Miguel Villarreal and those from November 2007 were taken by Amy McCoy. These photos have been included in this report and can be easily viewed. We have linked all the photos to the PhotoPoints shapefile and they can be viewed while working with the map in ArcGIS by using the hyperlink tool. To activate the hyperlink, two simple steps are required.

1) You must tell the ArcGIS project the location of your hyperlinked files. Click on File > Document properties > and in Hyperlink base, type the exact location of the folder with the photos (ex. E:\VegMapPhotos) > click ok.

2) You must tell the PhotoPoints layer which field to use for the hyperlink. Complete file names have been included in the field Photo_ID. Open Layer Properties > click Display tab > select the box to 'Support Hyperlink using field' and choose the Photo_ID field from the drop down list > click ok.

Now the lightning bolt (hyperlink) tool will be activated. When using this tool, click on any of the photo points and a photo of that area will be opened. For this photo viewing feature to work, all photos must be located in the same folder. If the folder is moved to a different location, repeat step one and enter the new location.