Suitability Analysis and Representation Goals for Cottonwood-Willow Forest Habitat

DRAFT

Sonoran Desert Conservation Plan 2001

Pima County, Arizona
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MEMORANDUM

Date: October 1, 2001

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: **Suitability Analysis and Representation Goals for Cottonwood-Willow Forest Habitat**

Background

At an early meeting of the Science Technical Advisory Team in 1999, Dr. Gary Nabhan stated as part of a dialogue that if the Science Team had to choose one species to preserve and restore perhaps it should be Cottonwood. Cottonwood-willow forests, where they exist and are healthy, indicate the presence of a viable riparian area, which is in turn the key to conserving great proportions of our native species.

The attached study entitled *Suitability Analysis and Representation Goals for Cottonwood-Willow Forest Habitat in Pima County, Arizona,* is one of the most original research documents to be produced by County staff through the Science Technical Advisory Team and larger science community. Julia Fonseca and John Regan are the primary authors. Peer review was provided by Dr. Julie Stromberg and Dr. Lisa Harris. A host of agency, University and private sector biologists contributed to aspects of the study.

As a result, we have knowledge of the distribution of the existing forested areas and recommendations for areas potentially suitable for expansion. The gaps in protective status of existing areas are quantified. Preservation and restoration options are described. Innovative in its approach and use of data to model suitable habitat, this study is also encyclopedic in its description and assessment of 57 existing stands across Pima County. This memorandum provides a brief summary of highlights and a recap of the recommendations forwarded in *Suitability Analysis and Representation Goals for Cottonwood-Willow Forest Habitat in Pima County, Arizona*.

Distribution of Existing Forested Areas

A reflection of the dire status of our riparian systems is that the Sonoran cottonwood-willow and Sonoran Mesquite-Cottonwood forests are limited in aggregate size to 3116 acres. Scattered in approximately 146 areas, an average patch is 21 acres in size. Sixty-three percent of this forest is located within existing reserves. Sonoran cottonwood-willow is found in 83 patches across 2946 acres. The chart below reflects the location and general acreage by watercourse.

Sonoran Cottonwood-Willow Forest

WASH, CREEK, SPRING, TRIBUTARY	ACRES
Cienega Creek (upper)	722 acres
Santa Cruz River	342 acres
Rincon Creek System	324 acres
Fraguita Wash	221 acres
Sycamore Canyon and Tributary	149 acres
Sabino Creek (lower)	138 acres
Edgar Canyon	120 acres
Arivaca Lake	110 acres
Gardner Canyon	109 acres
Cienega Creek	98 acres
Brown Canyon	89 acres
Empire Gulch	83 acres
Arivaca Creek	62 acres
Tanque Verde Creek	60 acres
Sardina Canyon	55 acres
Honey Bee Canyon	48 acres
East Fork Apache	42 acres
Posta Quemada	33 acres
Wakefield Canyon	29 acres
Unnamed Spring	28 acres
Scholefield Canyon	17 acres
Bootlegger Spring	17 acres
Sabino Canyon	13 acres
Agua Caliente Spring	12 acres
Smitty Spring	11 acres
Yellow Jacket Wash	5 acres
Ventana Canyon	4 acres

Distribution of Potentially Suitable Habitat for Future Restoration

While the existing acreage for the cotton-willow forest is extremely restricted, suitable habitat does not open up vast landscapes for future restoration. Conservative estimates would double the amount of acreage while the most generous assumptions would expand existing habitat no more than five-fold. This limitation gives emphasis to the Science Team goal to preserve existing habitat of this type. Restoration strategies ranging from changing the way existing riparian lands are managed, to restoring impaired stream and spring flows are described in pages 17 through 27. Detailed recommendations for these potential restoration sites are included:

- Cienega Creek downstream from Vail Diversion
- San Pedro River
- Cedar and Arivaca Creek
- Tanque Verde Creek (outside the National Forest)
- Sabino Creek (outside the National Forest)
- Santa Cruz River (Santa Cruz County to Canoa)

Conclusions and Recommendations

Pages 27 through 29 include these conclusions and recommendations:

- "Cottonwood-willow forests in Pima County need improved protection and restoration to achieve the goals set forth by the Science Technical Advisory Team for the Sonoran Desert Conservation Plan. Depending on the actual reserve design, as much as 25 percent of the higher elevation forests may remain unprotected. Thirty-seven percent of the low-elevation Sonoran cottonwood-willow forest remain unprotected by the existing reserve system. Given the disproportionate importance of these plant communities and their historic loss, the Science Team recommends that all of them be incorporated into a biological reserve." (P. 27)

- "In addition, this report recommends a doubling of the acreage of existing Sonoran Cottonwood-willow forest through a combination of improved land management and restoration of diverted water resources. Preferable sites will have the fluvial processes, water availability and biotic interactions needed to maintain patches of forest at least 20 acres in size, embedded in a riparian areas of 200 acres in size." ... "Several locations where large areas could be restored include Cienega Creek, the San Pedro River, Arivaca, Sabino and Tanque Verde Creek." (Pp. 27-28)

Prioritization of effluent based restoration is discussed. In the inventory and assessment of 57 existing forests, improved land management recommendations are also offered. *Suitability Analysis and Representation Goals for Cottonwood-Willow Forest Habitat in Pima County, Arizona* is a tour-de-force, combining field knowledge with geographic information skill in a way that greatly improves the community's understanding of options and constraints in conserving this most important species.

SUITABILITY ANALYSIS AND CONSERVATION GOALS FOR COTTONWOOD-WILLOW FOREST IN PIMA COUNTY, ARIZONA

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SUITABILITY ANALYSIS AND CONSERVATION GOALS FOR COTTONWOOD-WILLOW FOREST HABITAT IN PIMA COUNTY, ARIZONA

1.0 Purpose

This document describes a GIS-based suitability analysis and proposes preservation and restoration criteria for cottonwood-willow forest, prepared under the supervision of members of the Science Technical Advisory Team (STAT). Goals for conservation and restoration are described and applied regionally. A gazetteer describes current locations and opportunities for preserving and restoring this important plant community.

1.1 Background

The biological goal of the Sonoran Desert Conservation Plan (SDCP) is to:

> *insure the long-term survival of the full spectrum of plants and animals that are indigenous to Pima County through maintaining or improving the habitat conditions and ecosystem functions necessary for their survival.*

The STAT has recommended that all existing patches of riparian deciduous forest should be regarded as constraints for reserve design. As a consequence, all mapped occurrences of forests are included in the biologically preferred alternative for the Sonoran Desert Conservation Plan. If achieved, this goal will result in a representative range of natural variation in reserve design. This is because the species diversity within the cottonwood-willow series changes with elevation (Szaro, 1989). The STAT has also advised that we identify compromises to ecosystem functions within target plant communities selected for their biological significance and develop strategies to mitigate them. More specifically, the STAT has adopted these riparian ecosystem function goals:

1. To the extent possible, maintain or restore the connection between interdependent components of river systems: channel, overbank floodplain, distributary flow zones, riparian vegetation and connected shallow groundwater.

- maintain or restore natural flooding and sediment balance;
- preserve or re-establish connection between channels and their floodplains, and channels and their distributary flow zones

- maintain or re-establish hydrologic connections between riparian and aquatic ecosystems and shallow groundwater zones

2. Manage uplands as appropriate to protect the functioning of riparian and aquatic ecosystems within the watershed;

3. Manage point-source and non-point source pollution to maintain water quality at a level needed to support SDCP biological goals;

4. Insure sufficient instream flows to achieve and protect natural functions of riparian and aquatic ecosystems.

These functional goals are consistent with the intent of the Endangered Species Act, which is to conserve the ecosystems upon which endangered species depend.

The STAT has specifically directed that Sonoran cottonwood-willow forests be augmented through restoration. The basis for this goal is that there have been greater proportion of losses at lower elevations because of disappearance of flowing streams and the greater destruction by agricultural and urban uses. Conservation of the Sonoran cottonwood-willow forest at the current level would not address the losses that have historically occurred in Pima County. These losses have been previously documented in reports prepared for the Sonoran Desert Conservation Plan, such as Water Resources and the Sonoran Desert Conservation Plan (Pima County 1999a) and, Environmental Restoration in Pima County (Pima County 1999b).

Conservation of all existing forests and restoration of additional suitable lands will be needed if Pima County is to contribute meaningfully to the persistence and recovery of species like the yellow-billed cuckoo and the southwestern willow flycatcher. The STAT has designated both of these birds as priority vulnerable species in the Sonoran Desert Conservation Plan, and Pima County may seek coverage for both species under a Section 10(a) permit. Mature cottonwood-willow forest provides habitat for breeding cuckoos (RECON, 2001). Tent caterpillars, which infest the trees from time to time, are an important food source. Southwestern willow flycatchers utilize dense, young cottonwood-willow forests, among other habitats.

2.0 Definitions and Classification

This plant community consists of an overstory of Fremont Cottonwood (*Populus fremontii*) and Goodding Willow (*Salix gooddingii*) or Bonpland Willow (*Salix bonplandiana*) trees. The understory varies greatly from grasses such as sacaton to shrubs, annuals, vines and wetland plants. In Arizona, these plant communities include several hundred species of plants. These diverse communities sustain a rich food base for wildlife (Wolden and Stromberg 1997 in USFWS, 2001b). A glossary listing scientific and common names of common species in cottonwood-willow forests can be found in Appendix A.

These forests are described as the Cottonwood-Willow Series by the Brown et al. (1979) classification system used in the Sonoran Desert Conservation Plan. This series is found within two biomes. The biomes are the Sonoran Riparian and Oasis Forest biome (224.5 in Brown et al. [1979], also known as BLP) and the Interior Southwest Riparian Deciduous Forest and Woodland (223.2 in Brown et al. [1979]). The difference between the two biomes is based on climate, with the former located within a subtropical climatic regime and the latter within a warm-temperate climatic regime (Brown, 1982).

The series is best developed along alluvial floodplains of large, low gradient perennial streams in wide valleys at elevations below 1,350 meters (4500 ft) according to Szaro (1989). At higher elevations, this series grades into the Mixed Broadleaf series (223.2 Brown et al. [1979]), wherein Fremont Cottonwood and Goodding Willow may persist at moderate densities along with Velvet Ash (*Fraxinus velutina*), Arizona Walnut (*Juglans major*), Bonpland Willow and Wright's Sycamore (*Platanus wrightii*) (Stromberg, 1994). Collectively, whether dominated by cottonwood, willow, ash, walnut or sycamore, we can call these broadleafed riparian deciduous forests. Sonoran deciduous riparian scrub (e.g., 234.7 open *Prosopis/Acacia* and *Chilopsis linearis*) and Sonoran Interior Strand (e.g., 254.7 *Baccharis* spp. and/or *Hymenoclea monogyra*) sometime occur within the same lower elevation drainages as cottonwood-willow forests (R. Duncan, pers. comm.)

Because of their dependence on dependable water sources cottonwood-willow forests are small, linear, patch features found within the desert scrub or grassland-scrub matrix.

Cottonwood-willow forests are also found outside the Pima County planning area. Significant stands are found along the Bill Williams, Hassayampa, Verde, upper Santa Cruz, Colorado and San Pedro Rivers in Arizona, and the Rio Magdalena in Mexico.

3.0 Important Ecosystem Processes

The process of forming a cottonwood-willow forest starts with a large (>25-year return interval) flood that reworks the floodplain, producing extensive low terraces on either side of the channel for cottonwood, willow, and seepwillow germination (streamside/herbaceous-strand). The stream abandons its primary channel in many places and realigns to new locations as meanders move laterally and downstream. After large floods, the patches begin or resume the successional pathways shown in Figure 1 (Gori, 1996). Cottonwood, willow, and seepwillow seedlings will become saplings in the next growing season in non-inundated portions of the streamside herbaceous/strand providing no large, erosive flows occur during this period.

For optimum development of extensive forest, the groundwater table is usually less than 3 m (10 feet) below the floodplain surface (Stromberg,1994). Wide alluvial aquifers allow the cottonwood and willow trees to grow within the floodplain at greater distances from the active channel, a feature that promotes persistence of the trees during flooding.

Ecological models suggest that tamarisk is the dominant species at sites where the water table is deeper, such as where groundwater declines have occurred (ADWR, 1994). Within multi-species patches of seedlings, livestock prefer the more palatable cottonwoods and willows over tamarisk, giving tamarisk a competitive edge in grazed situations (Stromberg, 1998).

4.0 Methods

4.1 Calculating Existing Forested Area

Realizing the importance of this plant community and the inadequacy of existing distributional information at the County level, the STAT directed staff to obtain additional information about the distribution of existing forests. As a result, a GIS coverage, which includes polygons depicting stands of cottonwood or Goodding willow forest that actually exist, was produced for the Sonoran Desert Conservation Plan. The report entitled Riparian Vegetation Mapping and Classification, Sonoran Desert Conservation Plan, Final Report (Harris et al., 2000) describes the results. The maps can be viewed at http://nteim.dot1.co.pima.az.us/eim/dcp/. The actual Arc Info coverages reside with Pima County Technical Services.

In addition, we prepared a gazetteer describing conditions at 57 sites in Pima County (Appendix B). The draft gazetteer was provided to the team that was mapping riparian areas, to help them identify areas where cottonwood-willow forest exists. The gazetteer documents field observations

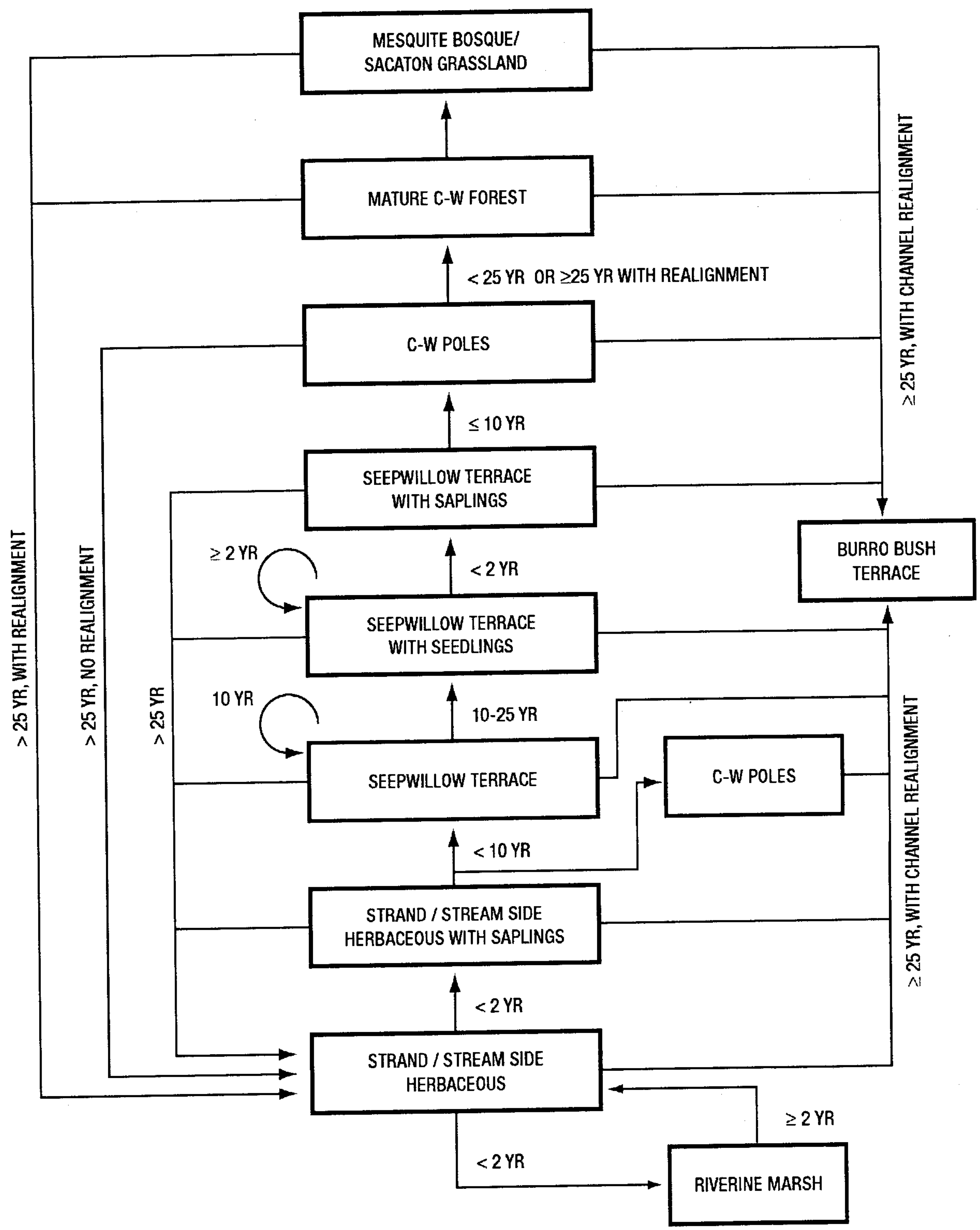


Figure 1. Riparian patch model for cottonwood-willow riparian forests (Gori, 1996). Transitions between patch types or vegitation associations occur as a result of succession and the action of floods of varying recurrence intervals. Floods can (i) maintain a particular patch type; (ii) permit it to move to another state via succession; or (iii) interrupt succession and change the patch to another type.

by biologists and hydrologists about conditions in cottonwood-willow forests that are not apparent on maps. For instance, some forests are not very diverse in tree species or age structure while other locations have extensive, diverse forests with a mixture of old, young and middle-aged trees. Some forests which are mapped as cottonwood-willow actually have more ash trees or sycamore. Where possible, land uses affecting condition are mentioned in the gazetteer.

4.2 Determining Protection Status of Existing Forested Area

To assess the degree of protection against land conversion and fragmentation offered to riparian patches, we used the Gap Analysis Program (GAP) status classification previously developed for the Sonoran Desert Conservation Plan, which follows national standards (RECON 2001b). The classification is based on detailed review of the legal status and management of individual parcels. For analysis purposes, all forest with GAP status 1 through 3 were considered protected against future land conversion, and forests in areas of GAP status 4 were considered to be unprotected. Pima County's Assessor's parcel base was used to determine ownership of all lands.

4.3 Assessing Potential for Forest Expansion

The GIS methodology used in the suitability analysis was based on the STAT's biological guidance outlining which areas of habitat for cottonwood-willow forest will be better to protect and restore over the long term. The suitability analysis identifies areas that have differing potentials for producing a forest structure that may not be evident at the current time. Forests might not be present because they are too young, eroded by floods, or suppressed by grazing, fire or previous mechanized disturbances. Forests might be overlooked for several reasons, such as being too small in area. Also, stands of these trees may not necessarily be replaced as they mature and senesce, simply for lack of suitably timed floods. The suitability analysis presents an opportunity to consider factors other than the mapped presence of mature trees.

Below, we present a GIS-based approach for the potential occurrence of cottonwood-willow forests, where:

suitability = f(riparian corridor + water availability + existing forest patches)

The riparian, water and patch GIS layers (coverages) were prepared for the modeling process by combining each with an outline of Pima County. This ensured all data would have the same point of origin, required to successfully execute the model. A cell size of 200 feet (0.92 acre) was selected to provide adequate resolution to the model. The original layers were in a vector data structure of points (springs), lines (streams) and polygons (riparian and patches). These were converted to a raster data structure where a regular array of cells is used to represent the entire county. Values for each cell were based on attributes assigned to features in the vector coverages, and the background had a value of 0. Feature values are described below.

The first layer considers whether the area is riparian or upland. Physiographically, these forests cannot be expected to occur outside the stream corridors, except at springs. The SDCP riparian polygons (Harris et al., 2000) were used to delineate where the riparian zone ends and uplands begin. Values assigned are:

Riparian	1
Upland	0

Availability of water is another important factor. The STAT ranked the various classifications of water availability as follows:

Perennial	3
Intermittent	2
Effluent-dominated perennial or intermittent	1
Ephemeral	0
Springs	2

Springs were assumed to have a minimum cell size of 200 feet.

Water resource information was based on PAG (2000a), augmented by additional work performed by Pima County staff regarding the distribution of springs and streams. The value weighting is purposely biased toward more natural, persistent flow conditions. Persistence of flow is one factor that affects the ecological integrity of the site. Areas with persistent flow will be able to absorb small perturbations or to return some given level of productivity and species composition following major disturbances.

Shallow groundwater zones were not used in this model because the depth to water in these areas, by definition, may be up to 50 feet (PAG 2000a). This is too deep to support cottonwoods or willows (ADWR, 1994). Also, shallow groundwater zones were not delineated for all streams.

The model was improved by considering locations where forest stands already exist. Based on the SDCP riparian delineations, we generated a ¼-mile buffer around each patch and added areas with existing riparian forest to the suitability analysis:

Having riparian deciduous forest patches	1
Not having riparian deciduous forest patches	0

This weighting assigns a value to those areas where flow is ephemeral, but subsurface conditions maintain a forest structure. Portions of the riparian corridor ¼ mile upstream and downstream of existing patches were also considered to have the potential for forest structure. Existing patches were ranked to make sure as much area as possible around existing patches was captured in the model. Polygons representing both Sonoran Cottonwood-Willow Series (224.5300 and 224.5230) and Interior Southwestern Riparian Deciduous Forest and Woodland (223.2000 and 223.2230) were used as indicators of existing cottonwood-willow patches.

Once all the layers were prepared, the grids were added together. Resulting cell values reflected the totals of values in each layer's cells. Values ranged from 0 to 7, with all but 60 cells having values ranging from 0 to 5. Cells with values of 6 or 7 were artifacts of the vector-to-raster process. The terminal cells of perennial streams overlap with the terminal cells of intermittent streams in places resulting in 44 cells with a value of 6 in riparian zones. There are 16 cells with values of 7. These are terminal cells of perennial and intermittent streams in riparian zones falling within existing forest patches.

Colors were assigned to cell values to represent lowest to highest values.

Another biologic factor considered was the presence of invasive species. Tamarisk, for example, may be a symptom of other ecosystem stresses, such as salinity, water stress or livestock browsing. No comprehensive GIS-based mapping is available for tamarisk along the streams in the planning area. SDCP riparian map units (Harris et al. 2000) may include tamarisk, but in many cases there is inadequate information to delineate the boundaries of tamarisk-dominated patches. For these reasons, no weighting was assigned to streams having tamarisk.

Several criteria were used to determine the locations of proposed restoration projects. First, the sites should be located primarily below 4500 feet, where historic losses have been greater. Second, the sites should include broad, alluvial floodplains that could support this vegetation type, if other ecosystem processes were restored. Third, large volumes of water should be available to sustain or restore floodplain aquifers, if social and economic conditions permitted.

To identify where restoration is feasible also requires knowing where hydrogeologic conditions are suitable for shallow floodplain aquifers. Where detailed studies are lacking, we used historic streamflow, plant and animal communities as a guide; the locations of aquatic plants and animals implies that the underlying hydrogeology is likely to be suitable for restoration. Restoration guidelines were developed using expert input from the STAT and from Dr. Juliet Stromberg, and from published literature.

5.0 Results

5.1 Distribution of Existing Forested Area

The amount of existing Interior Southwestern mixed deciduous forest is 5833 acres (Table 1). This figure is derived from adding the acreage of Harris et al. (2000) polygons with Brown Lowe and Pase code 223.2 as their primary code. The Interior Southwestern deciduous forest typically contains ash, walnut, alder, and sycamore in addition to cottonwoods and willows. The average patch size is 86 acres.

The Sonoran cottonwood-willow forest is more limited in total acreage, and more patchily distributed than is the Interior Southwestern deciduous forest. Sonoran cottonwood-willow forest area is 3116 acres. This is derived by adding the area of all polygons with BLP codes 224.53 and 224.523 as primary designations. The average patch size of Sonoran cottonwood-willow is 21 acres, and there are approximately 146 polygons.

Table 1

Acreage and Number of Polygons with Broadleaf Riparian Deciduous Forest (Harris et al. 2000)

Community Name	BLP Code (type)	Acreage	Patches
Interior Southwestern Riparian Deciduous Forest	223.2000	5826	67
Ash-dominated Forest	223.2230	7	1
Sonoran Cottonwood-willow	224.5300	2946	83
Sonoran Mesquite-Cottonwood	224.5230	169	63
Total		8948	

The mapping indicates that the largest, contiguous patches of the Interior Southwest Riparian deciduous forest are generally along mountain streams with large watershed areas in the higher elevations. Madera, Paige, Edgar, Alder and Canada del Oro Creeks have the largest patches of Interior Southwestern deciduous forest (Table 2).

Table 2. Watercourses with the Largest Areas of Riparian Deciduous Forest

BLP	WASH	ACRES
223.2	Atchley Canyon / Alder Canyon	549
	Paige / Miller / Turkey Creek Area	533
	Edgar Canyon	531
	Madera Canyon	416
	Canada Del Oro	324
223.223	Oro Blanco (only 1 polygon)	7
224.52	San Pedro River (2 polygons)	752 / 706 (1458)
	Black Wash	924
	Tanque Verde Creek	678
	Aguirre Wash / Aguirre Valley	494
224.521	Cienega Creek (4 polygons)	45 / 43 / 38 / 30 (156)
	Black Wash	130
224.523	Cienega Creek (5 polygons)	11 / 11 / 10 / 8 / 8 (48)
224.53	Cienega Creek (Upper) (2 polygons)	562 / 149 (711)
	Rincon Creek System	219
	Fraguita Wash	215
	Sycamore Canyon and Tributary	149

For comparison purposes, the largest mesquite bosque stands (224.52 and 224.521) are also listed in Table 2.

Appendix C lists the total area of riparian deciduous forest by watercourse. These numbers are derived by adding together the acreages of polygons as they occur along a watercourse.

A review of the forests described in the gazetteer relative to the Harris et al. (2000) maps shows that all but one of those listed in the gazetteer were included in riparian mapping. The small forest stand in Shaw Canyon, which was not mapped at all, is within a wilderness area. Riparian maps prepared by Harris et al. (2000) did not extend into GAP status 1 and 2 areas, such as Congressionally designated wilderness areas and national parks. However, the gazetteer would suggest that these areas possess very little to the amount of cottonwood-willow forest. This is probably due to the fact that these areas tend to be steep, rocky areas with few water resources , at least in Pima County.

Some of the stands described in the gazetteer were too small to be identified as distinct cottonwood-willow polygons, and so were combined in the more extensive mesquite woodland (224.52) association. In certain circumstances, Harris assigned a polygon with two BLP codes. For example, if an area was dominated by mesquite et al. (2000) but cottonwoods are present but not dominant then it received the BLP Code 224.52 with a secondary classification of 224.53 (Harris et al. 2000). Only the primary code was used for the purpose of this analysis.

5.2 Protective Status of Existing Forests

Seventy-five per cent of the Interior Southwest forest type is within an existing reserve. All of the streams with the largest patches (Table 2) originate inside the National Forest. These patches contain a mixture of broadleafed riparian trees such as sycamore, ash, cottonwood and willow.

Sixty-three per cent of Sonoran cottonwood-willow forest (BLP 224.53 and 224.523 is located with an existing reserve (an area of GAP status 1-3). The largest Sonoran cottonwood-willow forests stands are along Upper Cienega Creek in the National Conservation Area, and along the Rincon Creek system. Part of Rincon Creek is in Saguaro National Park, the rest is privately owned. Other large patches are along Fraguita Wash, which is a tributary of Arivaca Creek, on State and National Forest, and Sycamore Canyon, in the Coronado National Forest in the Santa Catalina Mountains.

5.3 Habitat Suitability Analysis

As a result of this analysis, there were a total of 28,772 cells having a rank of two, 3,150 with a rank of three, and 2679 cells with a rank of four or more. The distribution of modelled suitability in various riparian corridors is depicted in figures 2 through 6, and in Table 3.

Table 3

Distribution of Suitable Habitat by SDCP Sub-area

Watershed Name	Rank	Cell Count
San Pedro	2	3796
	3	547
	4-7	733
Cienega-Rincon	2	7077
	3	718
	4-7	876
Upper Santa Cruz-Sopori	2	1816

	3	42
	4	81
Middle Santa Cruz	2	4175
	3	1110
	4-7	573
CDO- Lower Santa Cruz	2	4431
	3	613
	4-7	134
Altar- Arivaca	2	1621
	3	111
	4-7	282
Avra	2	1
Tohono O'Odham	2	16
Western Pima County	2	10
	3	9

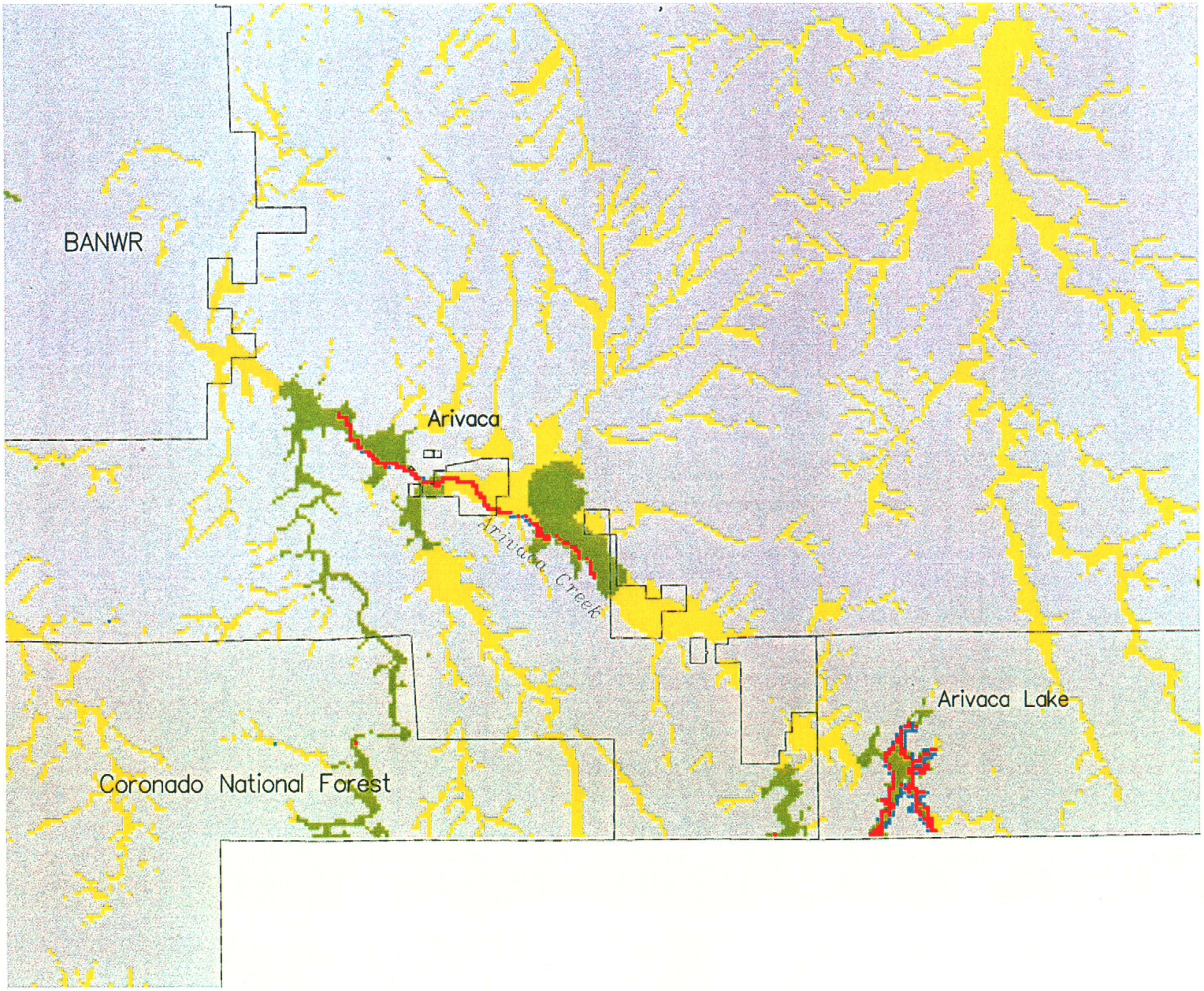
Table 3 indicates that suitable habitat for cottonwood-willow forest is preferentially distributed in eastern Pima County, with the greatest amount located in the Cienega-Rincon subarea.

Suitable habitat in Pima County is extremely limited in total acreage. Each cell is approximately 0.92 acre in size, so we estimate that 26,000 acres may be suitable using the most generous of assumptions. Comparing this to the known forests from Harris mapping, potentially suitable habitat (ranked 2 or higher) is estimated to be three times the amount of existing forested area. If we were to restrict the definition of suitability to those areas having a score of 3 or more, then the total area of suitable habitat would drop to around 5,800 acres, a value which is less than the existing acreage of these forests.

A rank of two may be achieved by a site having effluent-dominated flow, or being a spring, or having a forest already. Since spring cells are small, 0.92 acre in size, most of the cells having a rank of two result from the presence of effluent stream flow or from the presence or proximity (1/4 mile buffer) of an existing forest along an ephemeral stream.

A rank of three can result from riparian corridors having intermittent flow or springs which are located within them, but which presently lack cottonwood-willow forest. A rank of three can also include cottonwood-willow forest along effluent-dominated flows. Since the area of springs and existing forests along effluent-dominated flows is known to be small, most of the cells ranked

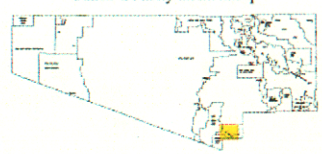
Cottonwood-Willow Suitability Model Results: Arivaca



- Value of 1
- Value of 2
- Value of 3
- Values of 4 to 7

Figure 2

Pima County Index Map



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Cottonwood-Willow Suitability Model Results: Cienega Creek

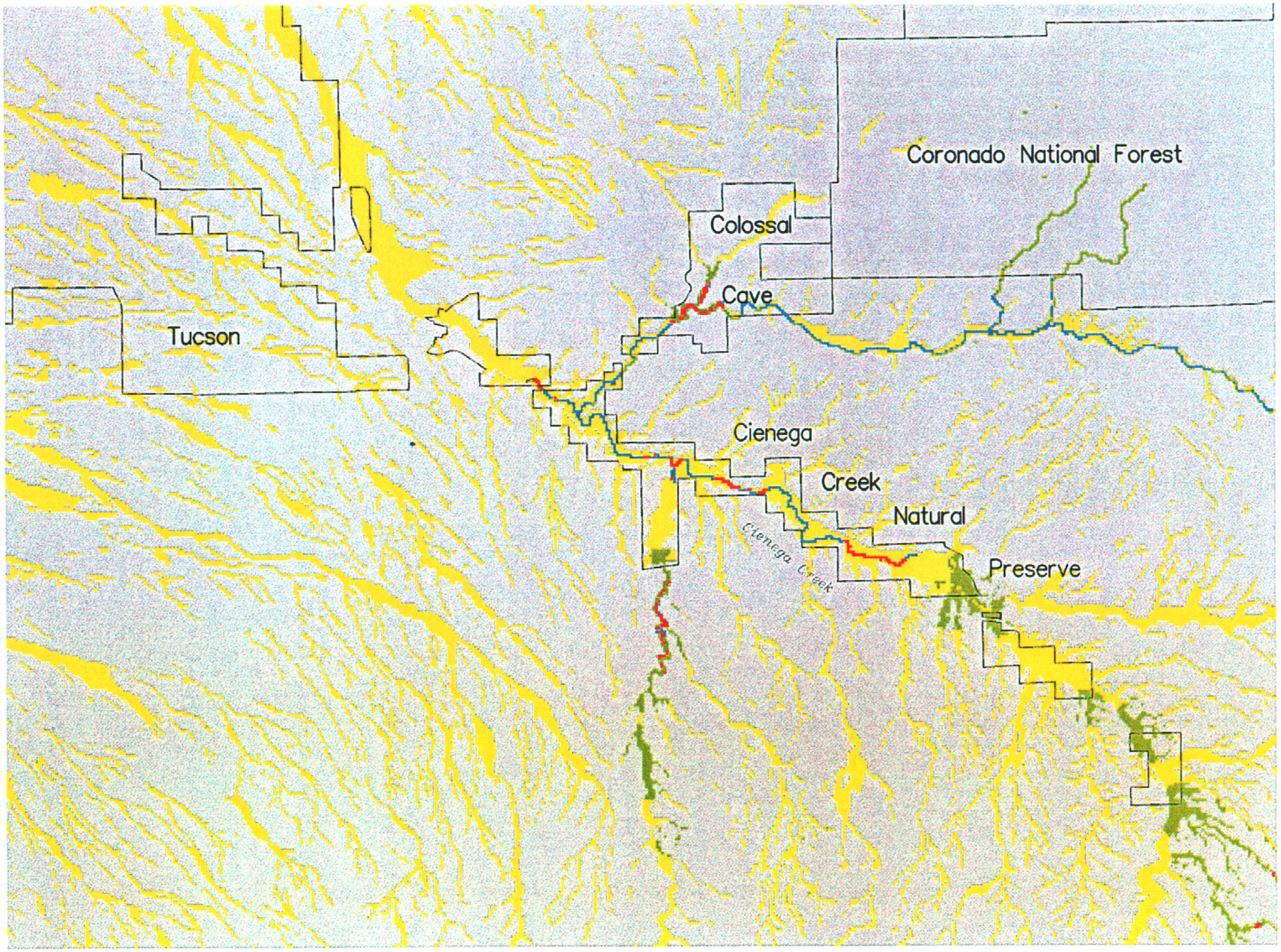

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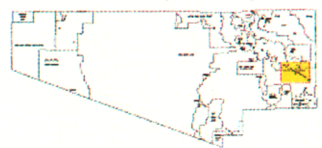
Figure 3

Pima County Index Map



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THE SEAL OF PIMA COUNTY ARIZONA

Cottonwood-Willow Suitability Model Results: San Pedro River

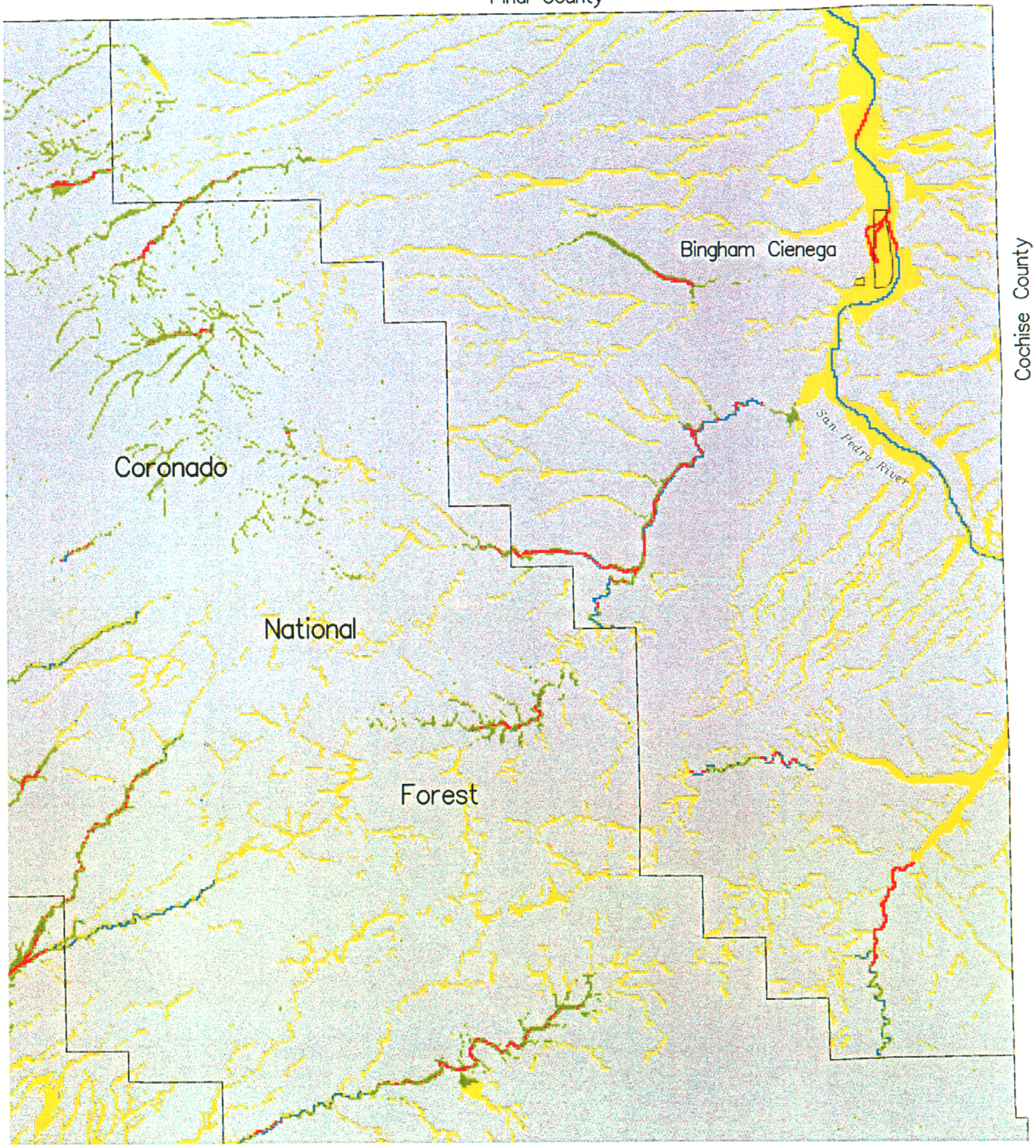
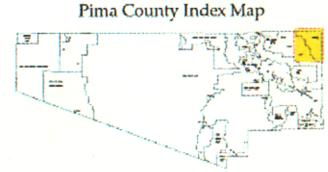
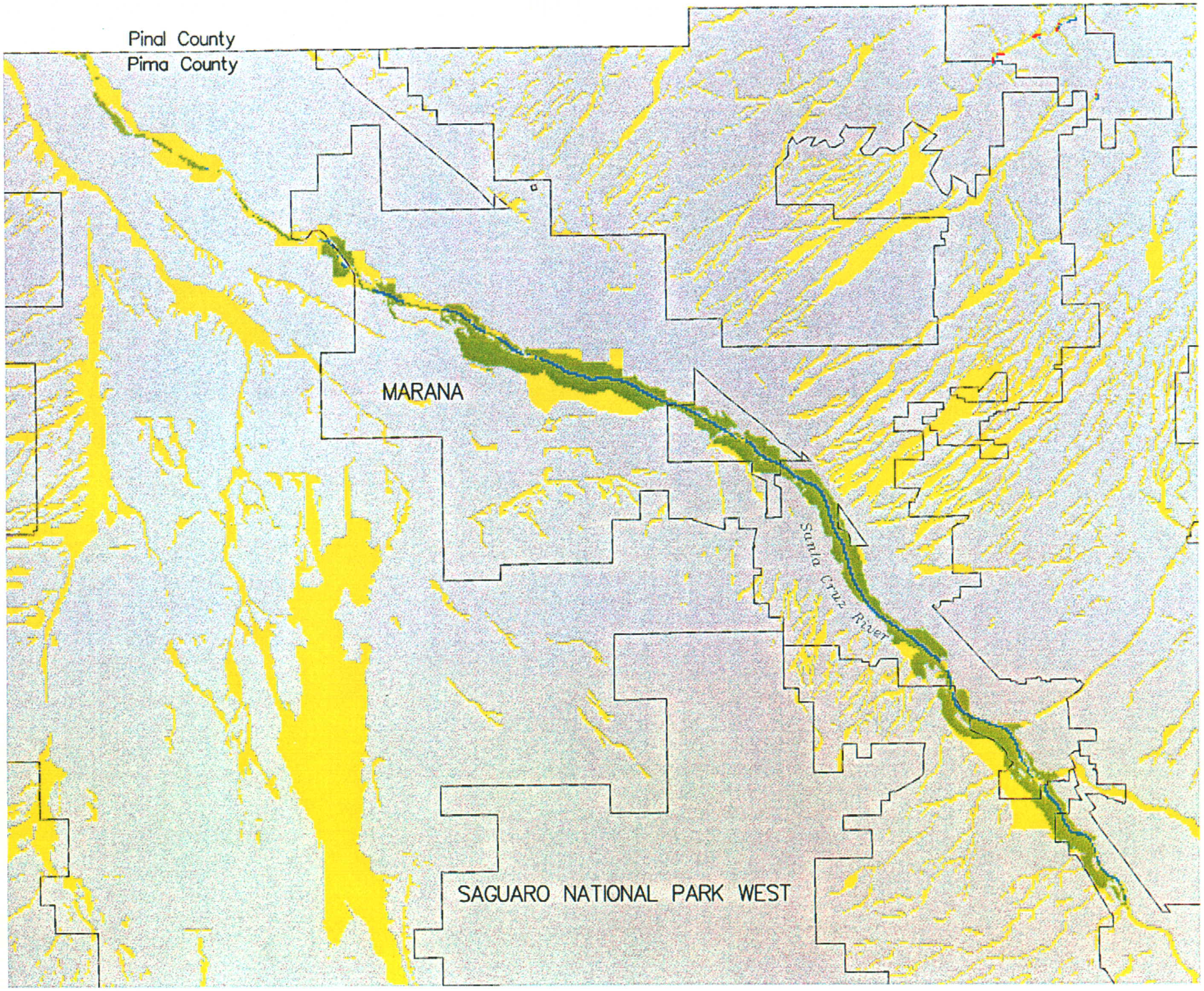


Figure 4



PIMA COUNTY DEPARTMENT OF TRANSPORTATION TECHNICAL SERVICES



Cottonwood-Willow Suitability Model Results: Santa Cruz River

Value of 1
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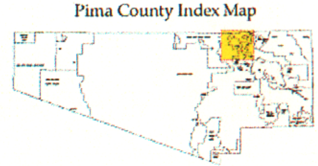
Figure 5

Pima County Index Map



Index Map Scale 1:1,500,000

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PIMA COUNTY DEPARTMENT OF TRANSPORTATION
TECHNICAL SERVICES

THE SEAL OF PIMA COUNTY ARIZONA

Cottonwood-Willow Suitability Model Results: Tanque Verde Creek

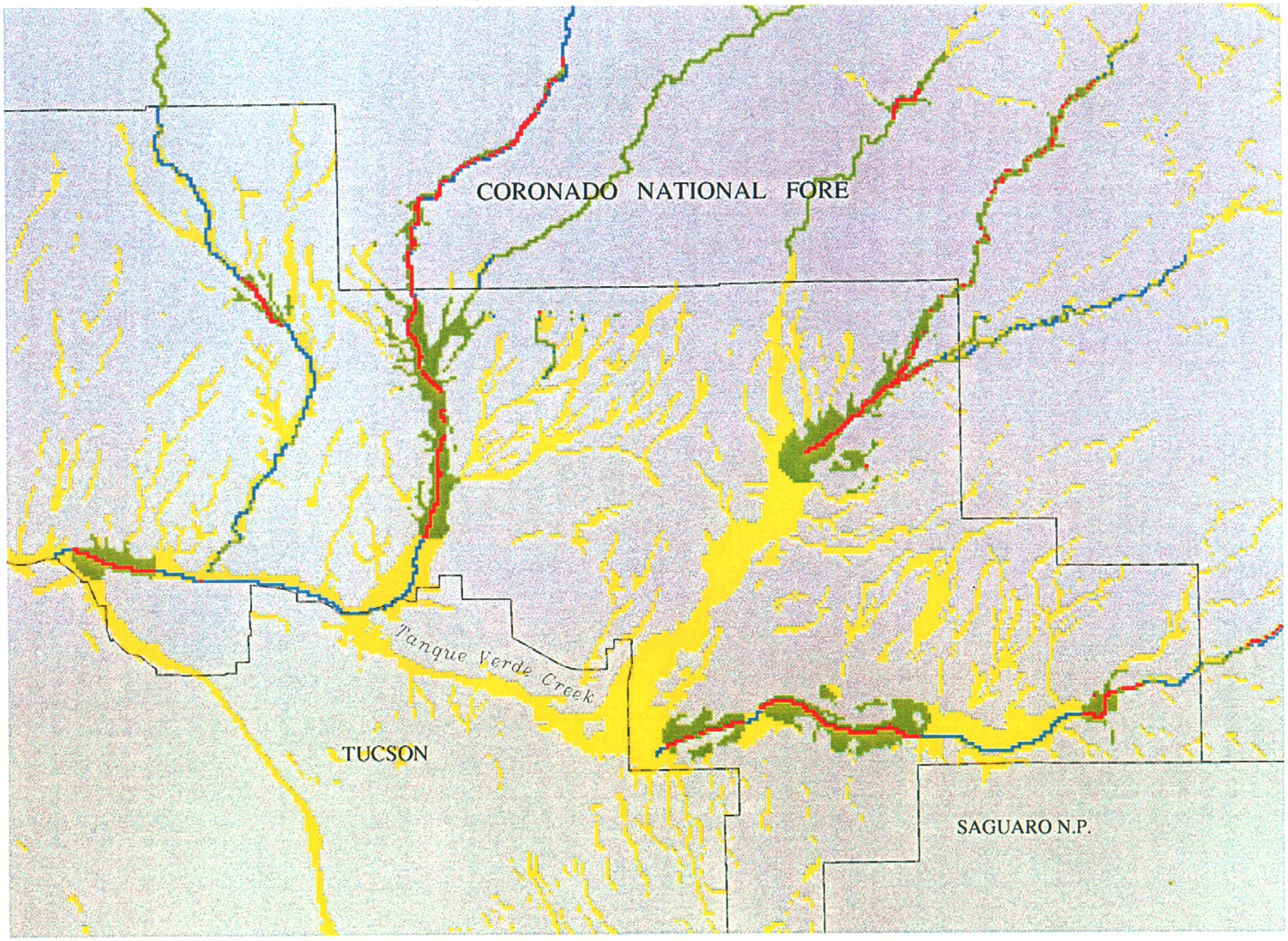

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Figure 6

Pima County Index Map

TECHNICAL SERVICES

THE SEAL OF PIMA COUNTY ARIZONA

6.0 Discussion

6.1 Preservation Goals

The STAT recommends that all occurrences of cottonwood-willow forests be maintained for the Sonoran Desert Conservation Plan. This goal is related to the importance of cottonwood-willow forest to a wide variety of species. As a result, the biologically-preferred reserve design, which has been prepared by STAT, places all of mapped occurrences into existing or proposed biological reserves.

While the biologically preferred alternative includes all of the known forest in reserves, other alternatives now under consideration would not. The one alternative, for example, would rely only on existing reserves. Under this condition, as much as 5400 acres of cottonwood-willow forest would lack protection from land conversion. The existing reserve system gives little protection to Sonoran cottonwood-willow forest (BLP 224.53 and 224.523). Only 63% of this forest type is located with an existing reserve (an area of GAP status 1-3). This is a far lower degree of protection than is available to many other, more common vegetation communities in Pima County (Connolly, 1999), and falls well short of the STAT's goals for conservation.

The situation for Interior Southwestern forests (223.2000 and 223.2230) is somewhat better, but still does not achieve the STAT's goals. Seventy-five per cent of this forest type is within an existing reserve. These forests are generally located in higher elevation mountain canyons, which are better represented in the existing reserve system.

Of the forests outside existing reserves, 1782 acres are located on private lands and 1226 acres are on state lands. The remainder would be on unreserved BLM or municipal lands. Even forests within reserves are not necessarily secure. Groundwater depletion or surface water diversions under state law and mineral extraction under the 1872 Mining Law will likely continue in existing reserves due to exercise of valid property rights. These activities may degrade the suitability of sites for cottonwood-willow forests. Also, many of the existing areas within reserves are grazed, and some have roads through them (See Appendix B). Excessive grazing, motor vehicle use, and road maintenance and repair can damage the reproduction and growth of plants associated with these forests. Channelization can increase scour during floods. The damages from these uses, however, are more easily reversed than are land-surface disruption from mining and water-table depletion from groundwater pumping.

The largest areas of existing broadleafed riparian deciduous forest (which includes ash and sycamore forests) at risk of not being included in future reserves are located along the following streams (see Appendix C for totals by watercourse):

- Buehman, Edgar, Alder and Paige Canyons, which are tributaries of the San Pedro River;
- Cienega Creek and its tributaries, Agua Verde Creek, Davidson Canyon, and Wakefield Canyon;
- Upper Rincon Creek and lower portions of its tributaries Chiminea/Madrona
- Tanque Verde Creek and its tributaries Sabino Canyon, Bear Canyon and Agua Caliente Creeks;
- Madera Canyon downstream of Coronado National Forest;
- Fraguita Creek, a tributary of Arivaca Creek, downstream of the Forest; and
- Effluent-dominated Santa Cruz River downstream of Roger Road

6.2 Restoration Goals

"Restoration" is the effort to eliminate anthropogenic sources of stress that are reducing ecosystem productivity and diversity below their potential. Restoration of ecosystems need not, however, create the same array of vegetation communities that were present in the past.

Other terms such as "replacement" or "rehabilitation" have been suggested when there is no attempt to restore ecosystem structures and functions similar to what was present prior to the activities that degraded the resources. For instance, the creation of artificially supported wetlands where none ever existed is not restoration. However, one could speak of restoring vegetation structure through artificial plantings, say, for certain riparian bird species along a watercourse, without restoring all of the other components of the riparian ecosystem (such as the aquifer and the flooding and erosion which used to create the vegetation structure).

Guidelines for Restoration

To allow for full ecological restoration, biologists working toward recovery of riparian bird species have recommended these general guidelines:

(1) Restore the diversity of fluvial processes, such as movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plains, that allow a diverse assemblage of native plants to co-exist.

(2) Restore necessary hydrogeomorphic elements, notably shallow water tables and flows of water, sediments, and nutrients, consistent with the natural flow regime.

(3) Restore biotic interactions, such as livestock herbivory, within evolved tolerance ranges of the native riparian plant species. (Appropriate levels of livestock utilization will need to be determined on a site-by-site basis; in certain cases the utilization may be zero.)

(4) Re-establish extirpated, keystone animal species, especially keystone species such as beaver, to appropriate sites within their historic range.

Biologists recognize that the potential for restoration success varies among sites with many physical, biological, and societal factors. Where possible:

(1) Fully restore these natural processes and elements by removing management stressors.

(2) Where full restoration by removal of stressors is not possible, modify the management stressors, by naturalizing flow regimes, modifying grazing regimes, removing exotic species, or removing barriers between channels and flood plains, for example, to allow for natural recovery.

(3) Take over processes such as plant establishment (e.g., nursery stock plantings) only if the above options are not available.

<u>Some additional general recommendations:</u>

(1) Focus restoration efforts at sites with the conditions necessary to support self-sustaining ecosystems, and at sites that are connected or near to existing high quality riparian sites.

(2) Develop restoration plans that encompass goals, models, performance criteria, and monitoring.

(2) If mitigation is required, call for "up-front" mitigation (mitigation achieved prior to destruction/degradation of habitat)

<u>Some specific recommendations dealing with water and channel management:</u>

(1) Conduct regional planning to identify sites most suitable for riparian restoration upon the release of reclaimed water (effluent), ground water recharge, or agricultural return flows.

(2) Conduct regional assessments to determine the merits of dam removal as a riparian ecosystem restoration strategy.

(3) Secure operating agreements for dams that incorporate environmental flows, for example to allow for tree and shrub regeneration flows during wet years and maintenance (survivorship) flows at other times.

(4) Pursue options for restoring sediment flows to below dam reaches.

(5) Secure operating agreements to manage reservoir drawdowns in such a way as to allow for regeneration of desired plant species.

(6) Develop water use management plans for river basins that will sustain or restore shallow ground water tables and perennial stream flows.

(7) At appropriate sites, remove barriers that reduce the connectivity between channels and floodplains.

Some specific recommendations dealing with land management:

(1) Within grazed watersheds, coordinate and communicate to establish goal-consensus among land managers and to achieve grazing levels compatible with riparian restoration.

(2) Establish a series of livestock enclosures that encompass riparian lands and/or watersheds, to provide benchmarks against which sites managed for livestock production can be compared.

(3) Monitor reference sites and grazed sites for a wide variety of measures of ecosystem integrity, including stream channel morphology and plant cover, composition, and structure, in addition to direct measures of plant utilization.

For the SDCP, our suggested goal is to at least double the acreage of cottonwood-willow forest, rather than to maintain only a subset of what currently exists. Since the lower-elevation forests have suffered disproportionate losses, and are less protected, restoration should emphasize augmenting Sonoran cottonwood-willow forest, which usually occurs below 4500 feet in elevation. In acres, the goal would be to augment through restoration the existing amount of Sonoran cottonwood-willow forest from approximately 3000 acres to 6000 acres, while maintaining the ecosystem processes needed for the existing forested patches. At any given time, not all of the potential habitat may have a forest structure present due to factors such as fire and flooding. Therefore, in order to do achieve this goal, the biologically preferred alternative would manage an acreage that includes more than 6000 acres of suitable habitat.

Management and restoration should focus on increasing patch size. The Nature Conservancy recommends considering size as one factor affecting the ecological integrity of a community (Groves and Valutis, 1999). One rule of thumb that can be used to guide patch development further is the concept of the minimum dynamic unit (Groves and Valutis, 1999). This is the smallest patch that also is effectively resistant or recoverable from disturbances. Natural disturbances create a mosaic of growth stages and habitat setting. Patches need to be big enough to ensure survival or re-colonization from disease, insect outbreaks, drought, flooding or fire. Fire or flood could easily remove a 5-acre patch of forest, but total removal of a 50-acre patch seems less likely. Given that the average size of mapped Sonoran cottonwood-willow forests based on the work by Harris et al. (2000) is only 21 acres, some patches may be at risk of loss.

Another consideration is that Western yellow-billed cuckoos, a priority vulnerable species which uses these forests, appear to need large blocks of riparian habitat for nesting (USFWS, 2001a).

Along the Sacramento River in California, nesting yellow-billed cuckoos occupied home ranges which included 25 acres (ac) (10 hectares (ha)) or more of riparian habitat (Gaines 1974, Laymon et al. 1993 in USFWS, 2001a). Home ranges in the South Fork of the Kern River in California averaged about 42 ac (17 ha) (Laymon et al. 1993 in USFWS, 2001a). Yellow-billed cuckoos have only 50% occupancy for riparian habitat under 100 ac (40 ha) in size. To support viable breeding populations, the riparian habitat may have to be over 200 ac (80 ha) (RHJV 2000 in USACE, 2000). Nesting west of the Continental Divide occurs almost exclusively close to water, and biologists have hypothesized that the species may be restricted to nesting in moist river bottoms in the west because of humidity requirements for successful hatching and rearing of young (Hamilton and Hamilton 1965 in USFWS, 2001; Rosenberg et al. 1991 in USFWS 2001a).

In Arizona, Southwestern willow flycatchers appear to use a wider variety of riparian habitat than do cuckoos, including high elevation willows and low elevation tamarisk, as well as cottonwood-willow forests. This bird seems to prefer a young, dense forest structure, preferably near water or moist soil. In low elevation sites, they have been observed to nest in riparian patches varying from 442 ac (177 ha) sizes as low as 2.5 ac (1 ha) (AFGD, 2001). The Southwestern Willow Flycatcher Recovery Team (USFWS, 2001) observes that metapopulations of flycatchers appear most stable and secure where there are a large number of sites of substantial size, which are highly interconnected, such as exists in the Lower San Pedro from Dudleyville to Winkelman. Sites less than 9.3 miles (15 km) apart, each with 10 to 25 territories, seem likely to enhance long-term persistence.

Based on this information, we suggest that our goal be to restore sites which would accommodate 20-acre patches of Sonoran cottonwood-willow forest embedded in larger riparian areas of 200 acres in size. Ideally, these sites would include intermittent surface water. Large riparian areas are most likely to provide a meaningful contribution to cuckoos, as well as southwestern willow flycatcher, and many other species.

6.3 Restoration Options

There appear to be two different methods by which the restoration goal of fostering an additional 3000 acres of Sonoran cottonwood-willow forest might be achieved. The first is changing the way existing riparian lands are managed, and the second is restoring impaired stream and spring flows.

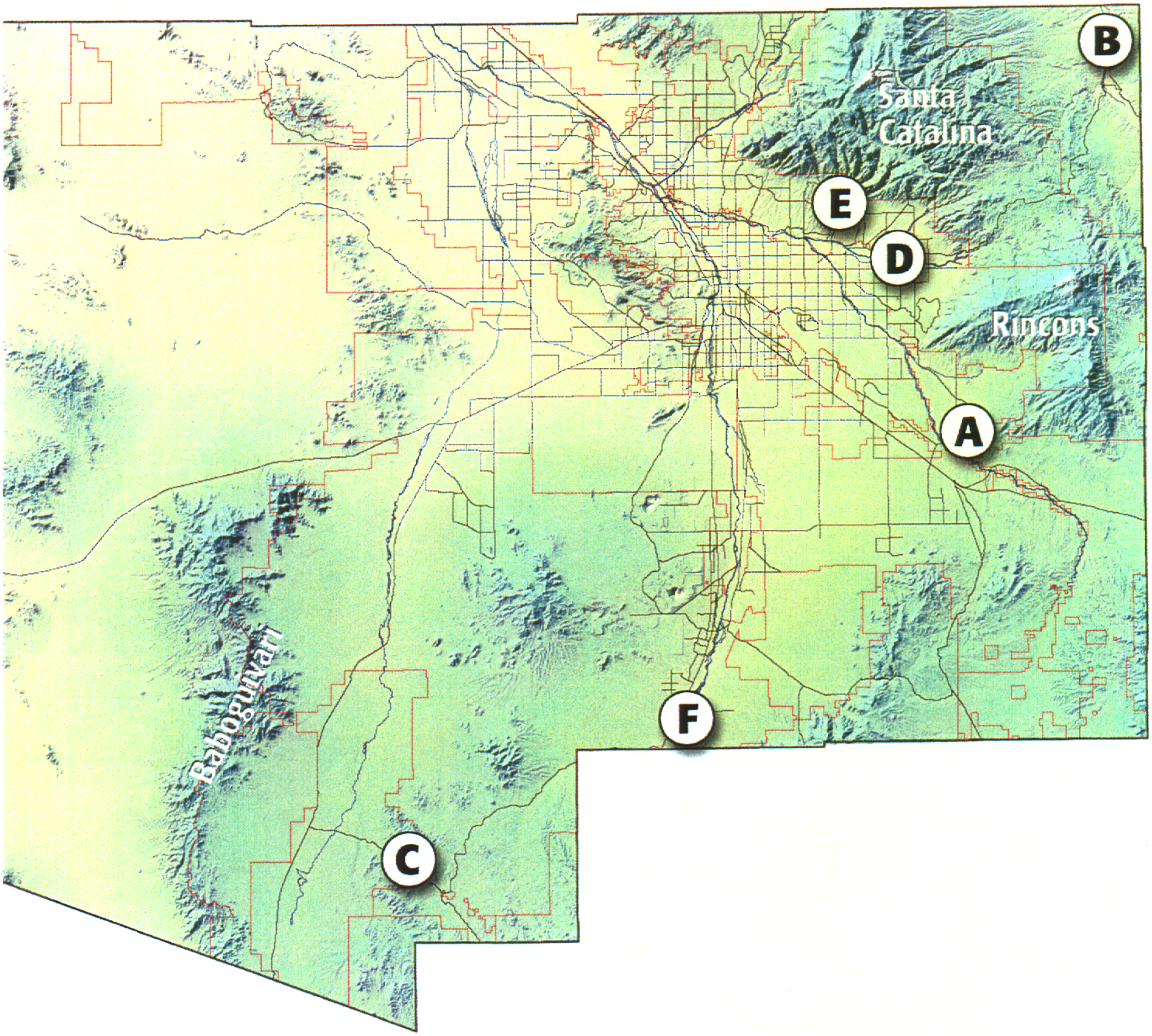
With improved land management, using the riparian restoration guidelines previously discussed, Pima County citizens would likely see an increase in the amount of habitat that actually contains cottonwood-willow forest. The advantage of this method is that gains could be achieved without any additional water being allocated for restoration. The components of an improved land management strategy for those forests are roadway, recreation, flood control, and grazing management. Many efforts to exclude livestock grazing and motor vehicle use have already been made along Cienega Creek in both the Empire-Cienega Ranch and the County Natural Preserve, Sabino Creek, Tanque Verde Creek, Agua Caliente Wash and portions of Arivaca Creek, Paige Creek, Wakefield Canyon/Nogales Spring and Buehman Canyon. The Bureau of Land Management has recently removed portions of a flow diversion channel and some levees in conjunction with a stream restoration project along Cienega Creek.

As another means of improving land management, land managers might consider re-establishing beaver. Beaver are known to have occurred in Pima County along the San Pedro River and at Fort Lowell on Tanque Verde Creek where it joins Pantano Wash. Beaver have recently re-established themselves on the San Pedro River downstream of Pima County, and have been sighted near Bingham Cienega.

Beaver can assist in the improvement of hydrologic conditions for cottonwood-willow forests, if the water is of sufficient permanence and sufficient food is available. By constructing small dams, they induce greater storage of water in the adjoining channel margins, thus broadening the riparian corridor. In addition, their dams help spread and slow the velocity of small storm flows, decreasing erosion and inducing greater infiltration. Beaver feed on willow and cottonwood, and affect forest structure in ways that may favor bird species which prefer dense, young trees, such as the Southwest willow flycatcher.

Beaver might locally improve conditions for cottonwood-willow forests along the effluent-dominated Santa Cruz River (Stromberg, 2001) where the lack of a connected groundwater table restricts the area where these forest establish and persist. However, beaver can be a nuisance for agricultural activities. They may also foster conditions which favor non-native species such as bullfrog and non-native fish. Arizona Game and Fish Department is requesting proposals to evaluate this potential.

Available information is insufficient to tell us whether improved land management can produce all of the additional 3000 acres, but the GIS habitat analysis and gazetteer certainly indicate the potential for accommodating expansion of these forests. Areas which will respond most quickly will be where there is severe grazing, extensive channelization or roads, or recreational overuse. In some areas, land managers have already relieved many riparian areas from these stresses, and have been rewarded with astounding increases in these forests, assisted by favorable



- **A** Cienega Creek downstream of Vail Diversion
- **B** San Pedro River (in Pima County)
- **C** Cedar and Arivaca Creek
- **D** Tanque Verde Creek (outside National Forest)
- **E** Sabino Creek (outside National Forest)
- **F** Santa Cruz River (Santa Cruz County to Canoa)

Figure 7. Potential Restoration Locations.

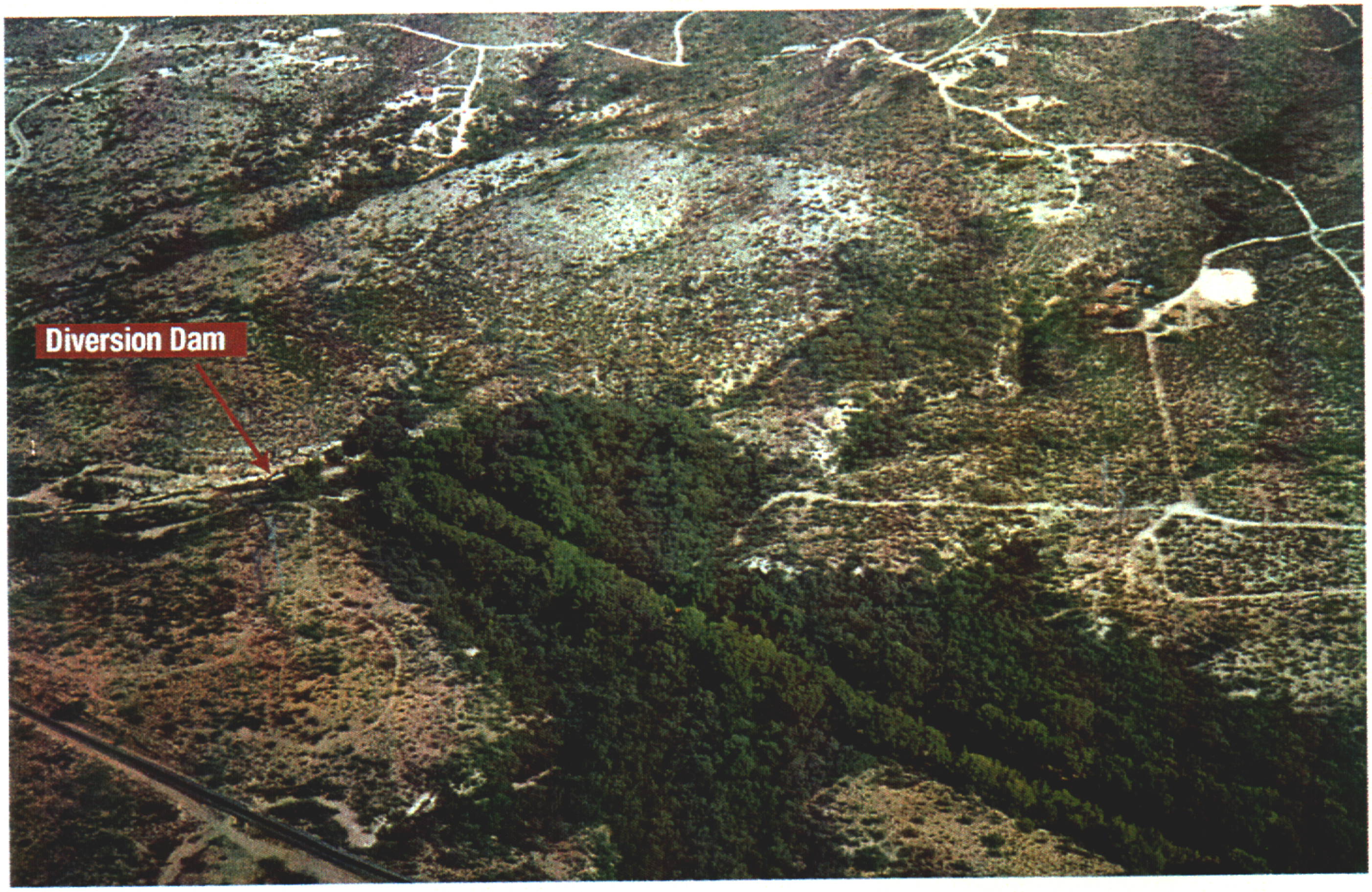
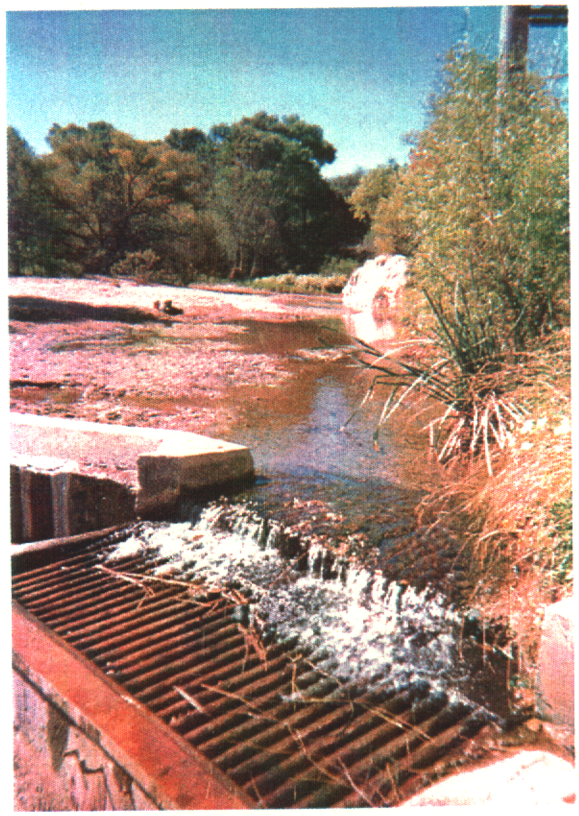


Figure 8. (Top) Cienega Creek at the diversion dam .
(September 18, 1997). Riparian vegetation decreases downstream (left) of the diversion.

(Right) This structure diverts the perennial base flows of Cienega Creek into a pipeline to irrigate landscaping downstream within the Vail Valley development. (October 16, 1998)



climatic conditions from the El Nino events of the 1980's and 1990's. Continued success will depend on reversing the impacts of poor land management on the remaining sites.

A few sites in Pima County seem capable of producing large, new cottonwood-willow forests which would augment existing riparian corridors (Figure 7). Several locations where large areas of cottonwood-willow forest could be restored are discussed below. They include Cienega Creek, the San Pedro River, Arivaca, Sabino and Tanque Verde Creek. At all of these locations, diversions of large volumes of water by existing dams or groundwater pumping are a significant limiting factor. With changes in how water is used, these areas could contribute substantially to the restoration goal. Without changes, the no-action SDCP alternative could bring declines in the ability of these areas to maintain even the existing riparian and aquatic environments.

Cienega Creek downstream of Vail diversion

Cienega Creek Natural Preserve was established by the Pima County Board of Supervisors in 1986 is located near Vail, Arizona. It contains extensive mesquite bosques, a perennial stream, and cottonwood-willow forest patches.

A one-acre inholding in the Preserve contains two key features, a diversion dam and a well, as well as a streamflow gauging station used by U. S. Geological Survey and Pima County Flood Control District. The dam serves a surface water right held by Vail Water Company, which uses up to 1300 acre-feet per year to maintain lakes and a golf course at the Vail Valley development. All of the normal base flow of the stream is diverted at the dam into a pipeline, which dries the channel below (Figure 8). The dam itself, which was constructed in 1910, improves habitat conditions upstream by locally increasing water availability to an upstream cottonwood-willow forest, and by checking channel bed erosion. The dam may also serve as a barrier to fish migration, given that exotic fish have been introduced downstream.

Drawdowns of the aquifer at an adjacent well within the inholding potentially jeopardize the largest cottonwood forest in the Preserve, which is located upstream of the diversion. The well, which is currently unused, could be pumped to serve either potable or irrigation needs. Because Arizona Department of Water Resources does not consider the well to be surface water, the amount which could be pumped is only limited by standards set forth for the Tucson Active Management Area, and the interpretations given to the recent subflow ruling of the Arizona Supreme Court.

While the District holds water rights which could protect the stream against future impacts from pumping, the District's water rights do not provide the means necessary to restore streamflow diverted into the Vail Water Company pipeline. By acquiring the inholding and the associated water right, the flows could be restored. Based on a 1908 topographic map, it appears that a 1908 surface diversion is responsible for desiccating five miles of perennial flow. One to five miles of streamflow could be restored by purchasing the water right and the associated dam diversion.

To enable this to happen, the Vail Water Company will need a replacement source of water for its development, either groundwater pumped from outside the Preserve, effluent, or CAP water. Pumping groundwater from other downgradient wells would be an alternative that would not damage the flows, because localized geologic features within the Preserve would appear to isolate the floodplain aquifer along at least the upper one mile of the restored flow segment from the deeper regional aquifer present downstream. By letting the water flow downstream to replenish the regional aquifer, a natural riparian area could be restored. Base flows might eventually extend past the Vail Valley development itself. In 1908, perennial streamflow extended past the development.

San Pedro River near Redington

The San Pedro River flows through the extreme northeastern part of Pima County, near Redington, Arizona. It contains one of the larger mesquite bosques in the SDCP planning area, but at present, there are relatively few cottonwoods and willows.

Historic accounts indicate that the San Pedro River in Pima County had perennial to intermittent flow, extensive sacaton bottomlands, cottonwoods and beaver in the late 1800's (Fonseca, 1994). Flows were diverted by means of a number of canals to irrigate adjacent farm fields. Today, in the approximately 12-mile reach of river in Pima County, there are approximately 1260 acres of terrace land that are irrigated. The Hydrographic Survey Report for the San Pedro estimated that the maximum observed irrigation for these lands was 7782 acre-feet per year (Harris, 2000). The water used is a combination of surface water diverted from the San Pedro River and groundwater. Total volume of groundwater pumping upstream of Pima County, from Fairbank to Redington, increased from 2,500 acre-feet per year in 1945 to nearly 35,000 acre-feet in 1990. Evapotranspiration declined to less than half of its early value, the result of a lower water table and losses of riparian plant communities (Harris, 2000).

Using a groundwater model, Lombard (1998 in Harris, 2000) simulated potential impacts on streamflow from retirement of agricultural pumping in selected areas upstream of Redington and downstream of Benson. Retirement of all or a portion of wells resulted in the restoration of perennial flow to most of the San Pedro River upstream of the Pima/Cochise County line. The Nature Conservancy has requested Pima County's financial support to extend the existing groundwater model throughout Pima County, and to refine and calibrate the model. The study will determine to what extent irrigation retirement will restore perennial flow, shallow water tables, sacaton and cottonwood-willow forest to the stretches of the San Pedro River in Pima County. It will also assist in identifying properties where conservation agreements and acquisition would provide the benefit to the riparian community. The study will also result in the development of a stress monitoring system for the San Pedro River between Cascabel and Mammoth, which would be used to evaluated the hydrologic effect of climate variability and to measure the success of conservation actions taken in Cochise and Pima Counties.

Cedar and Arivaca Creek, downstream of Arivaca Lake

Arivaca Creek is located in southern Pima County, near Arivaca, Arizona. Cedar Canyon is the name given to the upper portion of this watershed, where Arivaca Lake is located. The lake itself is bordered by a number of Goodding willow trees (Figure 9a). The reach below the lake has one of the largest sacaton bottomlands in the planning area, as well as a cienega (Figure 9b).

Arizona Game and Fish Department holds a perfected surface water right for 1037 acre-feet, which is approximately the lake capacity. In most years, the lake captures all runoff from Chimney and Cedar Canyon. Only during extremely wet periods will the lake, by way of an overflow, release water downstream (Laurenzi, 1993). Major flow events lasting more than three days have occurred eight times in the last 26 years, most recently in late 2000.

Since Arivaca Lake rarely releases flows, it severely impairs the natural flooding process for the stream reaches below. In addition, the reduction of recharge also may adversely affect the ability of cottonwood-willow forests to establish below the dam. On the rare occasions when the dam does spill water, downstream residents have observed water tables rise from 40 to 20 feet below the land surface (Regan 1992 in Laurenzi, 1993).

The Arivaca Water Education Task Force has recently suggested that the dam operations be examined and adjusted to enhance recharge, wildlife and recreational values downstream (AWET, 2001). This could include discharges from the lake before the monsoon season. AWET

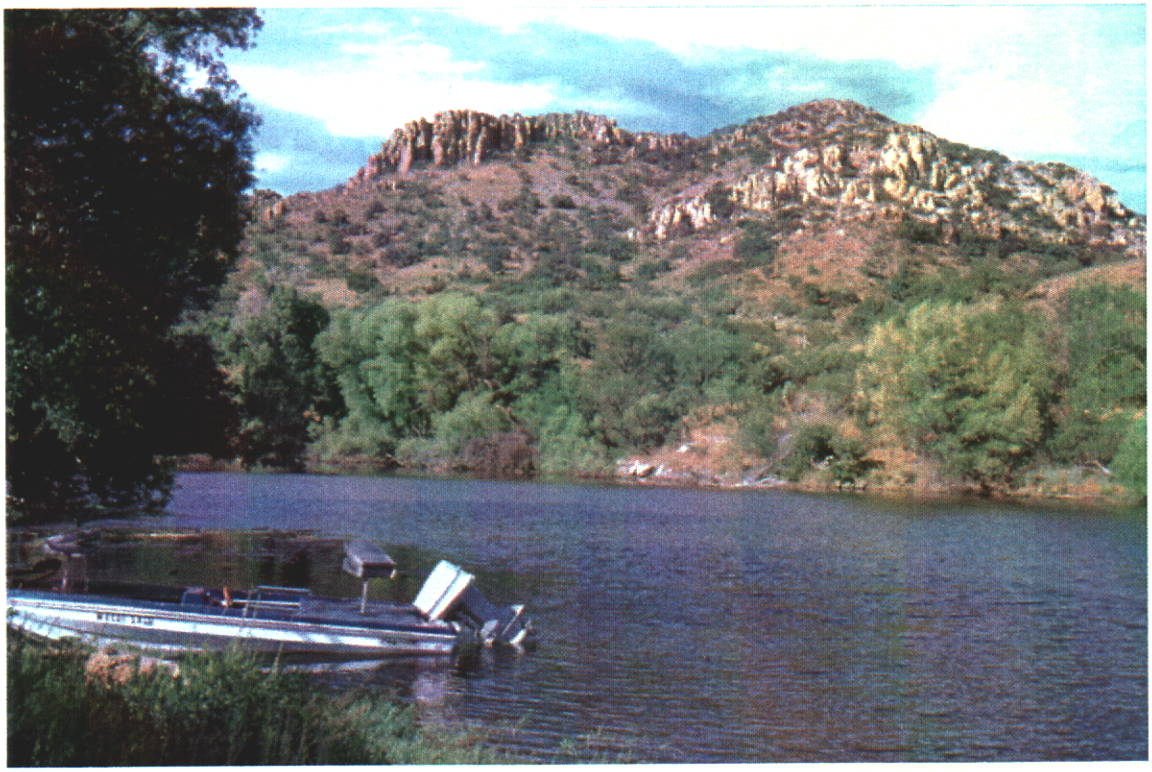


Figure 10a. Arivaca Lake

Figure 10b. Cottonwood tree in Arivaca Cienega

also has recommended utilizing and expanding existing environmental monitoring systems in cooperation with various agencies, and preparing drought mitigation plans.

Pima County Flood Control District has requested Pima Association of Governments to begin development of a groundwater model for Arivaca Creek and to prepare a website for posting hydrologic monitoring data collected by AWET and others. The model, if sufficiently calibrated, may prove useful in evaluating the impacts of changes in dam releases upstream, or the impacts of future increased groundwater pumping.

Portions of Cedar Creek and Arivaca Creek already possess conditions sufficient to maintain cottonwood trees, once established. The junior author has found that cottonwoods can survive without irrigation, on shallow ground water along Cedar Creek, after three years of periodic irrigation of pole plantings.

Tanque Verde Creek downstream of Coronado National Forest

Tanque Verde Creek originates in the Redington Pass area, and flows into the Tucson basin. Downstream of the National Forest, it has extensive mesquite bosques, with occasional groves of cottonwood trees.

Tanque Verde Creek was identified in the Riparian Element of the draft *Preliminary Sonoran Desert Conservation Plan* (Pima County, 2000) as a major opportunity for discharge or aquifer restoration since hydrogeologic conditions are favorable to restore localized aquifers. Tanque Verde Creek had Gila topminnow as late as 1943 (Scalero et al. 2000). In *Groundwater Level Changes in the Tanque Verde Valley,* Hill et al. (2001) documented the decline of the water table along the reach upstream of Sabino Canyon during the period 1947 to 1999. In 1947, the water table profile was 10 to 20 feet below the valley floor. In 1999, depths to water varied from as little as 12 feet in the upper reaches near the Tanque Verde Guest Ranch, to more than 100 feet in the lower reaches.

Hill et al. (2001) stated that decreased pumping could improve habitat conditions and recommended alternative sources of water be used to meet the drinking water and irrigation needs of the human population in the Tanque Verde Valley. Tucson's plans for utilizing CAP water would provide the opportunity for water companies in the area to retire or partially retire production wells in the Tanque Verde Valley. Extensions of the reclaimed system to the Tanque Verde Valley also would reduce demands.

Baird et al. (2001) also recommended the elimination of as many pumping wells as possible. Baird et al. (2001) further recommended discouraging expansion of the wastewater sewer system and promoting the use of septic tanks, which return some wastewater to the area. The report also advised that importing reclaimed wastewater to the upper ends of the tributaries would benefit the habitat.

<u>Sabino Creek downstream of Coronado National Forest</u>

Sabino Creek originates in the Catalina Mountains, and is an important tributary of Tanque Verde Creek. It has a broadleafed deciduous riparian forest embedded in a broader riparian zone.

Sabino Creek is impaired by surface water diversions and groundwater pumping. Some of the surface water rights are utilized by pumping from the shallow water table. There are over 200 wells located within one mile of the channel of Sabino Creek. The average reported annual withdrawal from non-exempt wells is 3603 acre-feet (af) (PAG, 2000). Most of the groundwater pumping is localized in the lower reaches. Of these, 75 are non-exempt wells, which may pump at a rate greater than 35 gallons per minute (gpm). Exempt wells are limited to 35 gpm or less, and a rate of 1 af per year is estimated for these wells. (PAG, 2000b)

Many of the existing properties are large lots. Conservation agreements and purchase of surface water rights could be used to reduce groundwater pumping. Municipal pumping could be curtailed through deliberate substitution of renewable water supplies such as CAP water and reclaimed effluent for water withdrawn from wells in the vicinity.

6.4 Effluent-based Restoration

Effluent derived from wastewater treatment plants could be an important sources of water for ecological restoration efforts. For this reason, the STAT has developed guidelines intended to assist evaluation of the biological benefits of the use of effluent and reclaimed water for the Sonoran Desert Conservation Plan. The STAT recognizes that on a site basis, decision-makers will need to weight biological benefits of a project against such constraints such as presence of landfills and lack of infrastructure, as well as a diverse range of other economic and land use issues.

Overall, the STAT prioritizes protecting existing self-sustaining riparian and aquatic ecosystems over the creation of new or enhanced areas of riparian and aquatic life which depend on continuing inputs of water, energy and materials. Reducing groundwater pumping along the remaining groundwater-dependent riparian areas is top priority. Restoring floodplain aquifers is second priority. Because they do not restore impaired ecosystem functions, revegetation projects requiring irrigation are the STAT's least preferred method for effluent-based restoration.

These principles are further amplified in the guidelines below:

1. **Protect systems that are self-sustaining over those that need continual inputs**. Based on this belief, the STAT prioritizes substitution of renewable water supplies for groundwater and surface water diversions in areas where high-quality aquatic and riparian ecosystems still exist and where diversion of water is a primary stressor of those systems. For example, previous work has identified the Tanque Verde Valley as an example of an important riparian resource that has been degraded by groundwater pumping. Substitution of reclaimed water for land uses which are diverting water from the aquatic and riparian ecosystems will help relieve this source of biologic stress.

2. **Restore or enhance native riparian and aquatic ecosystems by releasing water to restore local aquifer conditions.** Where ground water pumping is limited and favorable hydrogeologic conditions exist, reclaimed water and secondary effluent can be released to in an area in a manner that restores local aquifer conditions. The STAT believes that where hydrogeologic conditions are suitable, restoring localized shallow groundwater systems and floodplain dynamics will have a greater likelihood of success in creating a sustainable system than construction of artificial wetlands and container plantings or seedings of riparian vegetation.

3. **If plantings are to be used: a) revegetation is favored in areas where perpetual irrigation will not be needed;** Ideally, these projects will be designed to avoid disturbance of existing vegetation and minimize the need for perpetual irrigation and maintenance. Placement in areas where hydrologic conditions are suitable can provide the necessary water. **b) conflicts with other social objectives should be minimized**; Revegetation sites should be chosen to minimize future conflicts with aesthetic, recreation, or public safety considerations**.** These other social demands can reduce the value of the plantings for self-perpetuation and for wildlife use. For instance, pruning and eradication of the understory reduces the utility of areas for most forms of wildlife. **c) native species appropriate to the site must be used;** Using native species that are adapted to the specific soil, aspect and elevation of the site will assist in establishment and **d) sites which augment existing high-quality riparian habitats are favored.**

4. **Enhance the ability of secondary effluent or reclaimed water to support aquatic life.** In some cases, improvement of water quality may be necessary to support aquatic species such as fish or other aquatic organisms in the food chain.

5. **Manage riparian and aquatic ecosystems for native species.** In many cases, sites using reclaimed water or secondary effluent will require active management against non-native species and public education about why control efforts are needed. This is particularly true where open water bodies exist. Where open water bodies are proposed, the potential consequences on native species should be considered.

Guideline 1 emphasizes how effluent may be used to substitute for damaging water uses in the few places where it is most likely to make a difference . Sending effluent to the northwest Tucson Basin will not protect or restore riparian forests, but sending it to places like Vail Valley (in exchange for surface water) and Sabino or Tanque Verde Creek (in exchange for reduced groundwater pumping) will help. However, this infrastructure would be expensive. At this time extensions of infrastructure are planned only for turf and park irrigation purposes.

Guideline 2 invites us to search for locations where shallow groundwater systems might be created or restored using effluent. The major opportunities for aquifer restoration projects are where renewable water infrastructure exists and where hydrogeologic conditions are favorable. Water courses with favorable hydrogeologic conditions to restore localized aquifers are those reaches which possess an extensive low-permeability layer at a shallow depth: portions of Pantano Wash and Rillito Creek, Ventana Wash, Sabino Canyon, Tanque Verde Creek, Agua Caliente Wash, and portions of the Santa Cruz River. Of these sites, only Ventana Wash, Sabino Canyon, lower Pantano, upper Rillito and the Santa Cruz River currently have the required infrastructure. Of these, the Santa Cruz River lacks existing groundwater-dependent vegetation.

The Santa Cruz River has approximately 342 acres of willow or mixed willow-tamarisk forest. At present the distribution of forest patches along the Santa Cruz River is very scattered, and each patch is very narrow. The existing discharges of treated sewage (effluent) from Tucson have created these forests and other valuable riparian habitats for many wildlife species, particularly migratory birds. At this time, no one knows whether effluent flows in the Santa Cruz River will increase or decrease. The long-term reliability of flows depend largely on the actions of City of Tucson, which has a major share of the effluent, and the Secretary of the Interior, who holds in trust 28,300 acre-feet of effluent for the benefit of the Tohono O'Odham Nation.

Continued groundwater pumping and existing hydrogeologic conditions minimize the potential for the regional aquifer along the Santa Cruz River downstream of Roger Road to rise to levels where the roots of riparian trees could reach. Allowing recharged effluent to mound to the surface would be a concern along this part of the Santa Cruz River, where landfills occur. Localized, shallow aquifers do exist, however, and development of shallow aquifers might be encouraged for riparian restoration purposes. To meet the ecological restoration goals, such sites must be subject to flooding and embedded in larger riparian woodland units.

The County and City have created a Conservation Effluent Pool for use in riparian restoration projects. The amount of water available from the Conservation Pool is 10,000 acre-feet per year. If all of this water was used for irrigation purposes, it could sustain approximate 1500 acres of cottonwood-willow forest. If all of this water were discharged at a single location on a continuous basis, the discharge would amount to 14 cubic feet second (cfs). Presently, an amount in excess of 80 cfs is discharged to the Santa Cruz River today. If the effluent flows decrease, we can expect to see a reduction in the abundance and vegetation volume of the willow forest along the Santa Cruz River and potentially, a shift towards more tamarisk (Stromberg, 2001.).

If used for irrigated revegetation projects, the STAT's least preferred method for use of effluent-based restoration, the water could still greatly assist in achieving the overall goal of creating 3000 acres of Sonoran cottonwood-willow forest. The STAT's third guideline suggest ways to improve the likelihood of success. The sites where this can be done are limited to those where infrastructure exists to bring irrigation water is nearby and where sufficient undeveloped land is available. These areas are primarily along the Santa Cruz River and Rillito Creek, where several local entities are investigating the feasibility of such projects in conjunction with the U. S. Army Corps of Engineers. The Corps will consider the potential habitat benefits against the costs, to determine if federal funding is available for constructing these projects.

To improve the likelihood that irrigated revegetation projects will contribute to ecological restoration goals, such sites should be subject to flooding and embedded in larger riparian woodland units. These criteria would further restrict the site selection process, because increasing the amount of vegetation in the floodplain can obstruct the flow of water. Detailed studies will be needed to determine the degree to which additional vegetation can be added to the floodplain without increasing the risk of damage to public or private property. Another limitation is that if Tucson's reclaimed water system is used to deliver the water to sites along the Santa Cruz River or elsewhere, there is a transportation cost, and the supply will be subject to interruption during times of peak demand.

The effluent-dominated Santa Cruz River at Canoa Ranch and south to the Santa Cruz County line presents additional opportunities for restoration of cottonwood-willow forest. Here, the existing depth to the regional aquifer is shallow and intermittent flows occur due to effluent discharges in Santa Cruz County. Historically, flow in this part of the Santa Cruz River was perennial or nearly so. The senior author has observed that cottonwoods still establish in abundance following appropriately timed storm flows. Although the channel has been straightened, it is not constrained by soil-cement bank stabilization, nor is aggregate mining disrupting the sediment transport regime. Pima County's recent acquisitions at Canoa Ranch will help to preclude these threats, although the floodplain south of Elephant Head Road is still vulnerable to future development. The reliability of effluent flows in the Canoa area depends on the actions of Sonora and Nogales, upstream.

Pima County is considering monitoring riparian vegetation, surface flows and groundwater conditions at Canoa. In addition, livestock are no longer free to graze the young cottonwoods and other riparian plants. Future efforts will consider whether it is possible to restore the sinuosity of the channel while protecting the historic Canoa ranch houses from damage due to erosion and inundation.

6.5 CAP-based Restoration

Relatively few sites offer the combination of access to Central Arizona Project (CAP) water, suitable hydrogeologic structures, lack of landfills, sufficient channel conveyance, and sufficient open space for large-scale restoration opportunities. One suitable area is the Santa Cruz River near Martinez Hill, where the San Xavier District (District) of the Tohono O'odham Nation is reconstructing agricultural irrigation features in order to use their allocation of CAP water. The re-establishment of agriculture in the historic fields can be expected to increase incidental recharge in this area and to benefit the adjacent mesquite and saltbush scrub by locally increased soil moisture. Negotiations are nearing completion to protect groundwater levels in the area from off-reservation pumping. CAP recharge is occurring in constructed basins upstream, and the District is planning to release water to a terrace adjacent to the river so that a small mesquite-cottonwood-wetland complex can be sustained.

While none of these efforts alone is likely to restore a riparian area of sufficient size to meet the restoration objectives stated earlier, the necessary components are present to restore the underlying floodplain aquifer. Should the San Xavier District decide to utilize more of its CAP allocation for recharge, the restored floodplain aquifer could support a substantial riparian corridor that would include mesquite bosques and cottonwood-willow forest. . Large areas of land adjacent to the river and upstream of Martinez Hill have not been converted to agriculture.

7.0 Conclusions and Recommendations

Cottonwood-willow forests in Pima County need improved protection and restoration to achieve the goals set forth by the Science Technical Advisory Team for the Sonoran Desert Conservation Plan. Depending on the actual reserve design, as much as 25% of the higher-elevation forests may remain unprotected. Thirty-seven percent of the low-elevation Sonoran cottonwood-willow forest remain unprotected by the existing reserve system. Given the disportionate importance of these plant communities and their historic loss, the STAT recommends that all of them be incorporated into a biological reserve.

In addition, this report recommends a doubling of the acreage of existing Sonoran cottonwood-willow forest through a combination of improved land management and restoration of diverted water resources. Preferable sites will have the fluvial processes, water availability and biotic interactions needed to maintain patches of forest at least 20 acre in size, embedded in a riparian areas of 200 acres in size. The GIS suitability analysis and the gazetteer of existing forests together indicate the potential for restoration of forests through improved management. Areas which will respond most quickly will be where there is severe grazing, extensive channelization or roads, or recreational overuse.

A few sites in Pima County seem capable of producing large, new cottonwood-willow forests which would augment existing riparian corridors. Several locations where large areas of cottonwood-willow forest could be restored include Cienega Creek, the San Pedro River, Arivaca, Sabino and Tanque Verde Creek. At all of these locations, diversions of large volumes of water by existing dams or groundwater pumping are a significant limiting factor. With changes in how water is used, these areas could contribute substantially to the restoration goal. Without changes, the no-action SDCP alternative could bring declines in the ability of these areas to maintain even the existing riparian and aquatic environments. Additional hydrogeological investigations and negotiations with existing land owners are needed for these areas.

The STAT's highest priority for the use of treated effluent or reclaimed water is to minimize groundwater pumping in the vicinity of groundwater-dependent riparian resources. The areas where the reclaimed water supply infrastructure overlaps with groundwater-dependent forests is limited to the northeastern Tucson Basin. Additional studies and discussions with water suppliers and water users are needed to determine the potential for renewable sources of water, such as effluent or CAP, to result in lasting benefits to riparian areas.

Along the Santa Cruz River in Tucson, treated effluent supports a valuable riparian forest that has been included in the biologically-preferred alternative. Along the Santa Cruz River at Canoa, effluent from Santa Cruz County supports a vegetation community that might, with improved management, someday include cottonwood-willow forest. Discussions with water owners are needed to ensure the continuing discharge of treated effluent in these areas.

The STAT's lowest priority method for effluent-based restoration is for irrigated revegetation projects. Sites where this can be done are limited to those where infrastructure exists to bring irrigation water is nearby and where sufficient undeveloped land is available. These areas are primarily along the Santa Cruz River and Rillito Creek. To improve the likelihood that such projects will contribute to ecological restoration goals, such sites should be subject to flooding and embedded in larger riparian woodland units. Detailed studies are needed to determine the degree to which additional vegetation can be added to the floodplain without increasing the risk of damage to public or private property.

8.0 Acknowledgments

This report was prepared for the STAT by Julia Fonseca, Pima County Flood Control District (PCFCD) and John Regan, Pima County Technical Services (PCTS). David Scalero (PCFCD) and Bill Tanksley (PCTS) assisted with stream identification and GIS analysis, respectively. Many thanks go to Martha Catalan (PCFCD), who heroically persevered through many edits and a lost file.

Sherry Ruther, Doug Duncan and Russell Duncan are the STAT's riparian subcommittee. They worked with staff to develop guidelines for effluent restoration, which were later adopted by the STAT. They also served as reviewers for earlier drafts of the report.

Dr. Lisa Harris and Dr. Julie Stromberg reviewed later drafts of this report and provide many useful editorial suggestions which greatly improved the clarity of the report. Their assistance is gratefully acknowledged.

We appreciate the support of Drs. Ross Gerrard and Peter Stine, who provided the concept of a GIS-base suitability analysis to the STAT, and advised us on its execution. Thanks to Dr. Phillip Rosen for providing the idea of a gazetteer. Staff biologists of the Arizona Game and Fish Department, coordinated by Sherry Ruther, and Staffan Schorr, David Hall, Russell Duncan, Dr. Rosen, and Brian Powell provided information for the gazetteer. Robert LeFevre provided riparian assessments for the streams in Coronado National Forest. Kevin Dahl, Dale Turner and Neva Connolly provided supplementary review. Peter Corrao and Bill Singleton illustrated the report.

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Appendix A. Gazetteer of Cottonwood-Willow Forests in Pima County

Locations are grouped according to these watersheds: Canada del Oro, Rillito, Cienega, San Pedro, Santa Cruz and other. Unless otherwise noted, the descriptions were prepared by the senior author. Dates are provided for observations.

Cañada del Oro, interior of Santa Catalina Mountains. Sycamore, cottonwood and willow present (PAG 2000). Limited and isolated stands located in the lower section of the stream. The upper portion has some excellent riparian in the interior of the Forest Service unit (AGFD, 2000).

Cargodera Canyon, Santa Catalina Mountains (D. Hall, pers. comm., 2000). Intermittent section of this stream i s a mile long section beginning 1.5 miles upstream from its confluence with Sutherland Wash. The intermittent section contains a high number of ash trees. However there are three stands of sycamore trees within this area. Emory Oak are common. Cottonwood, walnut and willow are scattered and rare throughout the entire stream. Hackberry is common. The lower reaches of the stream are mesquite dominated with desert willow. Lowland Leopard frogs were last seen in this canyon in 1989 and are known to be extinct from this canyon. The canyon contains a population of Canyon Tree Frogs, Sonoran Mud Turtles and Black-neck Garter Snakes. Cattle have been allowed to graze in the riparian areas over at least the past eighteen years, and appear to impact the riparian environment adversely at times. This is particularly true during severe drought periods when cattle are allowed to concentrate in the areas of free standing water.

Romero Canyon. (D. Hall, pers. comm., 2000) Ash, cottonwood, sycamore, walnut, and willow are all common throughout the length between 3,000 - 4,000 ft elevations. Above 4,000 ft Arizona Cypress are found. Introduced Green Sunfish occur below 3,800 ft. Natural fish barriers have prevented these fish from moving above 3,800 ft elevation. Above 3,800 ft elevation Lowland Leopard Frogs are found in abundance. Green Sunfish apparently exclude Leopard Frogs via predation pressure.

The area known as Romero Pools (elevation 3,400 ft) is a popular hiking destination and receives heavy human use. Cattle have been excluded from this area for at least the past 20 years.

Montrose Canyon. (D. Hall, pers. comm., 2000) Ash, willow, and cottonwood dominate. Walnut and sycamore are rare. Hackberry and mesquite are common. This is the least disturbed riparian area on the west-side of the Santa Catalina Mountains. Leopard frogs are common throughout as are all obligate riparian herpetofauna. No introduced fish species. Cattle have been excluded from the area for at least the past 20 years.

Alamo Canyon. (D. Hall, pers. comm., 2000) Willow and cottonwood trees are dominant. Ash is absent or rare as are sycamore and walnut. Mesquite is common. Intermittent section is short and centered around 3,400 ft elevation. Leopard Frogs were last seen in 1993 and are presumed to be extinct from this canyon after many subsequent surveys have failed to find them here.

Sutherland Wash. (D. Hall, pers. comm., 2000) A long and diverse wash. Area known as The Cottonwoods (area just west of Baby Jesus ridge) has a large and healthy gallery forest of cottonwood and hackberry. Below here are isolated patches of willow and cottonwood as well as at least one seep with some sycamore trees (just above confluence of Cargodera stream). Inside Catalina State Park, the floodplain is a savanna of annual exotic grass with mesquite, and few desert willow and ancient ash trees (Fonseca, 1996). One of the largest walnut trees on this side of the Catalina Mountains can be found along this wash in Catalina State Park (at the Romero Ruins trailhead). This wash may function as a corridor for dispersion between canyons for Sonoran Mud Turtles, Canyon Tree Frogs, and Lowland Leopard Frogs (D.Hall, pers. comm., 2000).

Honey Bee Canyon, Tortolita Piedmont (1986). Goodding willow is the dominant broadleaf tree. A mesquite bosque is present at the lower end.

Pima Canyon: Cottonwoods are present (Lori Woods, pers. comm., 2000).

Ventana Canyon, Santa Catalina Mountains (2000). A young, dense forest of Goodding willow trees is present at Sunrise Road. A few young cottonwoods and tamarisk are also present, as is a mesquite bosque. Eucalyptus, acacia, and blue palo verde trees are also present. The channel bed is bouldery and the sediments are partially cemented by natural deposition. The site is not grazed or roaded, but the floodplain has been encroached by urban development and roadway construction.

Sabino Canyon: A few isolated stands of cottonwoods exist near water sources (AGFD, 2000). Lower Sabino Canyon is heavily pumped (PAG, 2000) and stabilized with soil cement.

Bear Canyon, Santa Catalina Mountains (2000). Downstream of the forest boundary, the bed is bouldery. Sycamores and hackberry are more frequent than cottonwoods or Goodding willows, but a closed-canopy forest is absent. Most large trees are located near channel margins or adjacent to mid-channel boulders. New roads and homes are under construction outside the channel, on the terrace where mesquite and hackberry grow. Acquisitions of land could reduce habitat loss and fragmentation. Grazing is minimal, recreational use is primarily hiking.

This watershed is dammed at Rose Canyon and Sycamore Reservoir. Effects of the lakes on water supply and flooding are not well known. There is a proposal to deepen the lake (Rosen, 2000).

Molino Canyon, Santa Catalina Mountains (2000). Downstream of the forest boundary there are a few isolated ash trees, but no forest structure. Bumelia is present.

Agua Caliente Canyon, Tucson. At its lower end, a few ash and walnut trees mix into the Tanque Verde bosque. There was evidence of recent recruitment in 1999, but the tiny seedlings could have been disturbed by natural forces or recreational traffic since then. Between the Forest Boundary and Soldier Trail are occasional isolated sycamore or ash trees. Ash trees become more frequent near the Forest boundary and there is evidence of recruitment. The 6 to 15-foot high saplings had brown, dry leaves or browning leaves in August 2000. Restoration of impounded flows from Agua Caliente Spring might assist in development of the forest in Agua Caliente Wash.

Rillito Creek, Tucson (1986-2001). Cottonwoods occur in many locations along the channel, but tamarisk, Goodding willow and ash are rare. Cottonwoods generally occur as isolated individuals located on channel bars and near storm sewer outfalls. There is a particularly large, healthy cottonwood located just upstream of the Interstate Highway 10 bridge, which seems to have survived the recent frontage road construction. There are several stands near Swan and Craycroft that probably rely upon a shallow aquifer, which pre-date the 1993 flood.

Tanque Verde Creek, Tucson (1986-2001). A mesquite bosque much stressed by a decline in groundwater pumping. One of the best stands of cottonwoods is near the Tanque Verde Guest Ranch. . These cottonwoods showed yellowing leaves in August 2000. Near here, spring flows have been diverted to serve a lake.

Fires in the mid-1990s have eliminated many stands of mesquite and the old cottonwoods near the Pantano confluence. Horse grazing has destroyed understory structure in many areas. Off-road vehicular use degrades it elsewhere, where the mesquites have not yet been. Elderberry is a component of the mesquite woodlands, as is soapberry and hackberry. Cottonwood recruitment occurred in the 1980s and early 1990s in portions of the channel, particularly the soil-cemented reach between Tanque

Verde Road bridge and the Sabino Canyon confluence, and the reach upstream of Wentworth Road. Channelization for urban development has reduced the floodplain, particularly downstream of Sabino Canyon Road. Upstream of Tanque Verde Road, informal levees of earth and dumped concrete are common. Acquisition of land or easements, reduction of vehicular use, removal of levees, and reductions in diversions or outright augmentation of natural water supply would be needed to reduce further losses. In National Forest, cottonwoods and Goodding willow are largely absent. Ash and sycamore are more common along with oak. Riparian condition is up (USFS, 1999)

Canyon del Salto, Tucson (2000). Isolated young cottonwood trees were showing signs of water stress in late August 2000. In National Forest, riparian includes young ash and willow: condition is stable (USFS, nd.).

Soldier Canyon (USFS, 1999) Mature willow is present, with young cottonwoods coming in. Condition is stable.

Ft. Lowell Park, Tucson (1999). A grove of cottonwoods was planted in the 1960s to recreate the historic appearance of the site. These trees used to be flood irrigated, but they are now irrigated with drip or bubblers. Many of these trees appear water-stressed, and some have died. Those that have died have been replaced with young trees. A healthy-looking group of cottonwoods exists next to a spring of reclaimed water, elsewhere in the park. These were planted in the 1970s. Mesquite, ash and elderberries have self-established in the moist soil along concrete-lined channels, where water flows out. The contrast between the two sites is a good demonstration of the differences that result from irrigation strategies and park maintenance practices.

Rincon Creek, Rincon Mountains. Agriculture and livestock grazing have degraded the Rocking K Ranch riparian area. Walnut was historically a dominant riparian tree (Briggs, pers. comm., n.d.), which today is absent. A developer will plant and irrigate 118.5 acres of the floodplain to offset damages under Section 404 of the Clean Water Act. Upstream of Rocking K is a mesquite bosque with hackberry, blue palo verde and desert willow (Briggs, pers. comm., 1999). Sycamores are the most common broadleaf deciduous tree, but the full complement of broadleaf trees is present. On a tributary located behind the fire station is a stand of mature cottonwoods and willow trees (1997). If the developers make a lake here, they may drown the trees. Groundwater pumping is also a concern (PAG 2000, Baird et al., 2001).

Posta Quemada Creek, Rincon Mountains (2000). A dense young forest of cottonwoods is found within Colossal Cave Park, where the channel is incised into alluvium. Foot traffic is directed away from the cottonwoods. The site is not grazed. The adjacent terraces host a mesquite bosque, picnic ground, trails, housing, roadways and a campground. A natural sinkhole, which has formed upstream of the cottonwoods, has directed surface flows away from the site (Bill Peachey, pers. comm.), however in early summer 2000, the trees did not appear water stressed. Groundwater pumping may be another concern.

Shaw Canyon, Rincon Mountains (2001**)**. This canyon has an intermittent stream and sufficient alluvium to support a more extensive forest than presently exists. There are a few isolated ash, cottonwoods and Goodding willow trees, with little evidence of recruitment. Livestock concentrate in the canyon bottom. Historically, this canyon had a sacaton bottom, based on remnant plants observed on a terrace, below which the stream has incised.

Agua Verde Creek, Rincon Mountains (2000). An extensive mesquite bosque with isolated cottonwoods. Grazed.

Ciénega Creek, from I-10 to Vail Water Company diversion. Over the period 1986-2000, many new stands of cottonwoods have formed inside the arroyo walls. The largest cottonwood grove is located just upstream of the diversion dam. Understory trees which established during this time period include many walnut, mesquite, hackberry and ash. Tamarisk is present, but not dominant. Goodding willow is not being recruited much. The shift in composition from Goodding willow to cottonwood may be due to water stresses. A decline in length of surface flows and discharge has occurred 1994-2000. The terraces are dominated by mesquite woodlands. Off-road vehicular use occurs near the Southwest Gas pipeline and in the vicinity of Interstate Highway 10.

Ciénega Creek, the Narrows to Gardner Canyon (1998-2000). Young, mature forest of Cottonwoods and Goodding willows, with mesquite and sacaton on adjacent bottomlands. Proportion of sacaton to other communities increases going upstream, as arroyo becomes less wide and incised. Portions of the stream have been excluded from grazing. Restoration of the natural flow path of Cienega Creek within the National Conservation Area may increase the extent of the cottonwood-willow forest over time.

Apache Spring (1998). A grove of large ash trees is used for picnics and camping. No recruitment is evident.

Davidson Canyon, from Cienega Creek to National Forest (2000). Occasional small stands of young ash, willow, cottonwood and tamarisk trees or isolated old cottonwoods, ash and willow are found within the arroyo walls, but the majority is riparian scrub (broom, burrobrush) and mesquite. Walnuts, yew-leaved willow and hackberry trees are also present. Arizona Highway 83 borders the riparian area, and a number of houses have been constructed recently at the margins of the valley. Grazing is permitted upstream of I-10.

Smitty Spring (1994, 1997). A small grove of Goodding willow trees is present. The site is grazed and a road passes through the moist soil around the spring.

Wakefield Canyon, Whetstone Mountains (1997). Sycamore and mesquite are most common, with walnuts, hackberry and *Rhus choriophylla* present. There are a few old cottonwood. The canyon is grazed.

Empire Gulch (2000), Santa Rita Mountains. A young, dense stand of cottonwoods and willows has developed in a livestock exclosure established by BLM. A large, old stand of cottonwoods with little recruitment exists near the Empire Ranch headquarters.

Mainstream San Pedro River. Where not cleared for agriculture, pasture, or homes, the floodplain contains a large mesquite bosque. The channel is mostly open riparian scrub. Much bank erosion occurred during the 1993 flood, as a result of sediment moved into the mainstem from Buehman and Edgar Canyons. Since then, many of the sand bars have become stabilized with vegetation. In places tamarisk, Goodding willows and cottonwood trees have established, many of the latter following the 1993 flood. Most of the San Pedro River is grazed. Water is diverted from the channel just upstream of the Cochise County line.

Bingham Ciénega. A grove of ash trees, cattail-bulrush ciénega, and mesquite bosques in several successional stages are present. During the period 1989 to 1992, Goodding willow established in the ciénega, however, a recent fire (January 2000) has killed some of these. Recruitment of hackberry and mesquite has also occurred, particularly along the eastern margin of the ciénega. The site is not grazed.

Gessaman Canyon, Santa Catalina Mountains. This stream has occasional stands of cottonwoods and sycamores (AGFD, 2000).

Alder Canyon, Santa Catalina Mountains (AGFD, 2000). There are spotty stands of cottonwoods in this canyon. A few small galleries are located in the upper section of the canyon. These include alder, sycamore, and soapberry. Riparian conditon is stable. (USFS, 1999)

Stratton Canyon, Santa Catalina Mountains (AGFD, 2000). A small stand of sycamores and ash are in the upper portion of the canyon between the U Circle ranch and the Forest boundary.

Edgar Canyon, Santa Catalina Mountains. The dominant tree in middle Edgar Canyon forest is sycamore, with ash and willow as common associates (J. Bill, pers. comm., 2000) There is potential for improved forest quality (TNC, 2000). Edgar has some excellent cottonwood and willow galleries in the middle and upper portions of the canyon where overgrazing has not occurred (AGFD, 2000). The upper section has perennial water present (AGFD, 2000).

Buehman Canyon, Santa Catalina Mountains (2000): An extensive mesquite forest is present along the valley floor where this stream meets the San Pedro River. Upstream, contains a mixed broadleaf forest (Harris, 2000) of ash, cottonwood, willow and sycamore (PAG, 2000). An extensive cottonwood, sycamore, and ash gallery with perennial water is located in the section of land that is for sale below the Nature Conservancy property in Buehman; this would make an excellent acquisition (AGFD, 2000). Riparian conditon is stable (USFS, 1999)

Bullock Canyon: Contains a mixed broadleaf forest (TNC, 2000). Evidence of ash and sycamore recruitment is present (Fonseca, 2000). A road follows much of the channel, destabilizing sediment and vegetation. Small cottonwood, sycamore, and ash gallery present 1-2 miles above confluence with Buehman Canyon at Bullock spring (AGFD, 2000).

Youtcy Canyon (2000), Santa Catalina Mountains. Mesquite bosque is present, with isolated cottonwood trees.

Espiritu Canyon (2000), Santa Catalina Mountains. This site hosts an ash-dominated forest, with cottonwood, Goodding willow, and a few yew-leafed willow, bordered by mesquite and hackberry. Buttonbush is a notable riparian component. This site is within the City of Tucson s A7 Ranch. Closure of the 4WD road that borders the channel would reduce erosion and compaction of fine alluvial fill. This site is grazed. It is unclear to me whether this stream will be fenced off or used in the grass bank.

Turkey Creek, Rincon Mtns, downstream of FS boundary, at the Turkey Creek trailhead (S. Schorr, 1999). There is a good size stand of mature and old sycamores at the trailhead, with an occasional mature or old ash. The area is used intensively for recreation. In previous visits, I have seen large groups of people camp there for multiple days with constant motorcycle, truck, and other OHV traffic on and off the roads. I did not see any evidence of recent grazing in the area, but there are signs of grazing in the past. Presumably due to vehicle traffic, there is no recruitment occurring at the trailhead/parking area. However, there are young sycamores and ash along and within the creek bed, next to the parking area. I did not see any cottonwood or willow in this area. The bases of the trees at the trailhead are buried by sediment, so flood events may have played a hand in wiping out the young trees in the area. Recruitment of cottonwood, ash, and sycamore was observed upstream of the trailhead, where vehicle traffic and grazing is prohibited. At the confluence of Turkey and Paige Creeks, >1 mile downstream of the trailhead next to the Clopton Ranch, there is a diverse population of sycamores, along with some cottonwood, ash, and willow trees.

Miller Creek, Rincon Mountains (S. Schorr, 1999). As of 1995, ASARCO owned 3 mining claims in Happy Valley: near the confluence of Miller and Paige Creeks, the Turkey Creek trailhead area, and near the confluence of Turkey and Paige Creeks (mostly in Cochise Co.). These parcels were included in the proposed land swap for the Rosemont Ranch area. (ASARCO 1995, The Rosemont Ranch Land Exchange.)

Paige Canyon, Little Rincon and Rincon Mountains (1996). Tremendous recruitment of ash, sycamore and cottonwood appears to have occurred following flooding and erosion during the 1993 flood. Efforts to control erosion and herbivory from grazing and compaction and erosion from off-road vehicular use associated with camping were needed to improve channel bed and bank stability. Riparian condition is considered stable (USFS, 1999).

Ash Creek, Rincon Mountains (2000). An ash-dominated riparian area is degraded by cars, campers, and livestock. Riparian condition is down (USFS, 1999)

Arivaca Creek (2000). A variety of communities including sacaton, mesquite bosque, and stand of ash, cottonwood and Goodding willow forest. Elderberries are present in small numbers. Closed canopy; good regeneration (AGFD, 2000). Riparian condition is down (USFS, 1999) Plans that might involve elimination of Arivaca Lake, which is in-drainage upstream, should be pursued with an eye toward long-term restoration of native species and relatively natural habitat conditions at Arivaca Ciénega and Creek (Rosen, 2000).

Cedar Canyon (USFS, 1999) Riparian include young ash and willow, with mature ash, willow-cottonwood mesquite, juniper and hackberry. Trend of riparian condition is down.

Oro Blanco and Tonkin Wash Confluence (2000). A floodplain of annuals and isolated hackberries, where many of the mesquites were removed at some time in the past (Nathan Sayre, pers. comm.). Along Oro Blanco Wash, there are old ash trees with young ash, hackberry and mesquite. Interestingly, hackberry occurs high above the stream bed on rocky north-facing, a pattern which is not uncommon in the Arivaca area. The site is grazed, but there is evidence of recruitment. Yew-leafed willow is present. The rancher recently closed the road along the creek bottom (S. Chilton, pers. comm.).

Fraguita Wash, near Arivaca (2001) This gravel bed stream is dominated by ash trees in the reach downstream of the National Forest, but the canopy is not closed. There is relatively little recruitment of ash, but there are a number of young hackberry. Seepwillow is abundant, along with annuals and lovegrass. Deergrass is not common. Flow is interrupted intermittent and in places, bedrock constrains the movement of the channel. This channel, along with Yellow Jacket Wash, received a large flood in summer 1992 (Francine Pierce, per. comm.).

Fresnal Canyon, SE margin of Altar Valley. These are low mountains supporting a dry tropic scrub with some oak woodland. They support a number of plant and animal species with much more southerly distribution, and are a special resource for the County, State, and Nation. Most of the range is grazed by lease agreement with the Arizona State Land Department and the USDA Forest Service ownership. Some of the land is privately held. These mountains are connected with the Tumacacori-Atascosa-Pajarito complex via a swath of undisturbed native desert open space which supports remarkably high biodiversity. Fresnal Canyon is one of the few drainages in this area that supports significant riparian resources. There is perennial water with sycamore & willow. Fresnal Canyon is currently grazed (horses and cattle). There is little evidence of regeneration (AGFD, 2000).

Brown Canyon 1997 –1999. (Brian Powell, pers, comm.) The lower canyon (from where Brown Canyon enters into the Altar Wash) is dense thickets of velvet mesquite trees (*Prosopis velutina*), netleaf hackberry (*Celtis reticulata*) and spinescent shrubs such as desert hackberry (*Celtis pallida*), mimosa (*Mimosa spp.*), and acacia (*Acacia spp.*). The riparian area in this zone contained dense thickets of shrubs including gray thorn (*Ziziphus obtusifolia*), desert olive (*Forestiera shrevei*), wolfberry (Lycium spp.), and seep willow (*Baccharis salicifolia*) Sycamore (Platanus wrightii)enters the picture about 1.5 km downshtream from the Harm house (the soon-to-be visitors center of the Refuge, but not lodge that's further upstream). Sycamore are found along the entire stream, but only in a few places do they form dense stands. For the most part they are mature trees with huge crowns. There are only 2 or 3 areas that have any recruitment (from perhaps 5-10 years ago); young, even-aged (linear) stands of trees, many of which are dying. The xeriparian stands are, in some places in the lower canyon, completely impenetrable. In a few, isolated areas, there are willows (desert or Goodings?) The upper canyon is Madrean Evergreen Woodland dominated by three species of oak: Arizona white (Quercus arizonica), Mexican blue (Q. oblongifolia), and Emory (Q.emoryi) as well as Arizona walnut (Juglans major) and sycamore. There seems to be a moderate amount of recruitment of walnut trees. Also note that Jaguar Canyon, which flows into Brown above the lodge, also has some sycamore trees. There is no longer cattle grazing in the formal anywhere in the canyon, but there are feral cattle, and the refuge has given up trying to catch these animals.

Thomas Canyon (1997-1999). This stream has a few sycamore trees lower down in the canyon (Brian Powell, pers. communication). Downstream of Reservation boundary for approximately 1 mile there are pockets of sycamore with good regeneration (AGFD, 2000) There is no evidence of exotics (AGFD, 2000)

Santa Cruz River, Tucson (1999-2001). The effluent-dominated reach has several stands dominated by Goodding willow and tamarisk. Cottonwoods are present near the ADOT gravel pit, near Roger Road outfall. These stands are generally supported by surface flows. When the location of the flows shift, the stands can die, so the more mature trees are often found near locations where the channel stability is higher. The effluent-dominated reach has a high rate of ground water pumping (PAG 2000). The water table is generally greater than 50 feet.

The ephemeral reach near Valencia Road has some young and a few old individual cottonwood trees, but no forest structure. Efforts to irrigate cottonwoods in the river parks adjacent to bank protection appear to have failed repeatedly. Many of the specimens planted have died over the 1990s, and the rest appear stunted. Depth to the regional water table is generally greater than 50 feet.

Sopori Wash (2000). Goodding willow, ash, and hackberry in association with Elias Spring #1. There is also mesquite forest. The majority of the cottonwood groves are in Santa Cruz County in association with the Batamote Wash confluence and Elias Spring #2. If agricultural areas could be restored, grazing, and groundwater pumping and surface diversion eliminated or reduced, the Santa Cruz County reach could probably contribute greatly to an increase in the cottonwood-willow forest. Sopori Ranch, which is currently for sale, has a developed spring that yields as much as 2500 af/yr (Halpenny and Halpenny 1995). Most of the cottonwoods are old, but there was some recruitment in 1983.

Santa Cruz River, Canoa (2001). I observed monkeyflower, veronica, seep willow and cottonwood growing in the low-flow channel in May–all of these species were heavily grazed. These plants show that this reach of the Santa Cruz River is capable of regenerating a valuable type of biological community that is scarce in our region. In 1993, I observed many young cottonwood seedlings establishing along the reach near Elephant Head Road, but it appears none of this generation survived. The cottonwoods I saw along the channel this year established much more recently than 1993, and appear to represent several different years. Bank erosion is a concern for this reach of the Santa Cruz River. Livestock grazing along the channel should be reduced or eliminated; greater vegetative growth in the channel will promote more stability in the bank position.

Box Canyon, Santa Rita Mountains (2000). Ash, hackberry, sycamore, mesquite trees are present, and mesquite is dominant in the portions within Santa Rita Experimental Range.

Sycamore Canyon, Santa Ritas (2001). Isolated mature ash, walnut and cottonwood trees amidst burrobrush and <u>Bebbia</u> with little evidence of tree recruitment in the lower reaches below and just above the National Forest boundary. Much channel bank widening from recent flows is removing adjoining mesquite and hackberry trees. Intermittent flows in the bedrock reaches near the National Forest boundary. An inactive limestone quarry is located in the bed of the channel, and there is a small stone dam, which has been breached, in the National Forest.

Shamrod Spring (2000). Ash with oak and <u>Rhus choriophylla</u>. At times, water from one spring is diverted. Direct livestock use is minimal due to the steep, rocky slopes.

Tohono O'odham Nation (2000). One of the largest patches of cottonwood forest is in Alambre Valley, where there are some old sediment or water retention structures. These trees are old and there is no sign of recruitment (Scott Bailey, personal comm). Small patches of deciduous riparian forest also occur in some of the canyons in the Baboquivari Range, and may occur at certain impoundments scattered throughout the Nation.

Appendix B.
Some Common Native Plants of Sonoran Cottonwood-willow Forest in Pima County, Arizona

Scientific Name	Common Name
Amaranthus palmeri	Palmer Pigweed
Baccharis glutinosa	Seepwillow
Cephalanthus occidentalis	Common Button Bush
Chloris virgata	Feather Fingergrass
Cyperus odoratus	Flat Sedge
Distichlis spicata	Desert Saltgrass
Elymus triticoides	Beardless Wild Rye
Fraxinus velutina	Velvet Ash
Helianthus annuus	Common Sunflower
Hordeum pusillum	Little Barley
Hymenoclea monogyra	Burrobrush
Ipomoea coccinea	Scarlet Creeper
Juglans major	Walnut
Leptochloa uninervia	Mexican Sprangletop
Muhlenbergia rigens	Deergrass
Panicum obtusum	Vine Mesquite Grass
Platanus wrightii	Sycamore
Populus fremontii	Cottonwood, Fremont cottonwood
Prosopis velutina	Velvet Mesquite
Salix exigua	Coyote Willow
Salix gooddinggi	Goodding Willow
Sambucus mexicana	Elderberry, Mexican Elder
Sapindus drummondii	Western Soapberry
Sarcostemma cynanchoides	Climbing Milkweed

Setaria macrostachya	Plains Bristlegrass
Sporobolus wrightii	Sacaton Grass
Typha domingensis, Typha latifolia	Cattail
Vitis arizonica	Canyon Grape

Appendix C. Acreages of Broadleafed Riparian Deciduous Forest by Watercourse

Interior Southwestern Riparian Deciduous Forest

BLP	WASH	ACRES
223.2	Madera Canyon	416
	Florida Canyon	226
	Wild Cow Spring	2
	Apache Spring	2
	Montosa Canyon	3
	Unnamed Spring	2
	Wakefield Canyon	309
	Davidson Canyon	119
	Thomas Canyon	9
	Ash Creek	290
	Miller / Turkey / Paige Creek Area	533
	Tanque Verde Creek	133
	Agua Caliente Canyon	13
	Molino Canyon	56
	Soldier Canyon	5
	Bullock Canyon	116
	Buehman Canyon	417
	Rose Canyon	24
	Geesaman Wash	133
	Sabino Canyon	46
	Cargodera Canyon	60
	Sutherland Wash	119
	Canada Del Oro	367
	Box Canyon	175
	West Sawmill Canyon	211
	East Sawmill Canyon	54
	Enzenberg Canyon	151
	Boston Gulch / Fish Canyon	455
	Little Fish Canyon	24
	Barrel Canyon	11
	Unnamed Tributary to Cienega Creek	71
	Cumero Canyon	53
	Edgar Canyon	531
	Atchley Canyon / Alder Canyon	549
	Stratton Canyon	166
	Catalina Wash	176

Ash-dominated Forest

BLP	WASH	ACRES
223.223	Oro Blanco	7

Sonoran Cottonwood-Willow Forest

BLP	WASH	ACRES
224.53	Fraguita Wash	221
	Arivaca Creek	62
	E. Fork Apache	42
	Brown Canyon	89
	Empire Gulch	83
	Gardner Canyon	109
	Cienega Creek (Upper)	722
	Unnamed Spring	28
	Smitty Spring	11
	Wakefield Canyon	29
	Bootlegger Spring	17
	Cienega Creek	98
	Posta Quemada	33
	Rincon Creek System	324
	Edgar Canyon	120
	Tanque Verde Creek	60
	Sabino Canyon	13
	Sabino Creek (Lower)	138
	Ventana Canyon	4
	Santa Cruz River	342
	Honey Bee Canyon	48
	Arivaca Lake	110
	Sardina Canyon	55
	Agua Caliente Spring	12
	Yellow Jacket Wash	5
	Scholefield Canyon	17
	Sycamore Canyon and Tributary	149