DRAFT

MEMORANDUM

Date: May 8, 2000

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

From: C.H. Huckelberry
County Administrator

Re: **Riparian Vegetation Mapping Pilot Study**

I. Background

Two studies are attached to describe the progress of riparian mapping that is being developed as part of the Sonoran Desert Conservation Plan: *Riparian Habitat and Riparian Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan*, and the *Pima County Riparian Vegetation Mapping Pilot Study*. On January 18, 2000, the Board awarded Harris Environmental Group a contract to carry out riparian vegetation mapping, which is one of several tasks related to the biological evaluation. The biological evaluation workplan defined the riparian mapping task in this way:

A. The consultant shall produce the following:

1. Vegetation maps and a map showing field verification locations as Arc/Info vector coverages or in a format pre-approved by the Pima County Department of Transportation Technical Services GIS Section.

2. A complete reproducible set of mylars registered to 7.5 minute USGS quadrangle maps. Each mylar shall contain a legend, scale, index map, and title block. Each map shall portray the locations of boundaries and the geographic extent of vegetative communities. Each polygon shall be labeled numerically with the vegetation classification. In addition, one mylar index map shall be provided.

3. A report shall be prepared describing the methods, the scale and source of base information used, assumptions made, the nature of any interim products, and a non-statistical assessment of reliability in the mapping in terms of 1) positional accuracy and 2) classification accuracy as it varies by geographic area and by classification category. To the extent thought reliable, existing sources of information shall be used. Information to be reviewed includes but is not limited to the following:

   a) PAG maps of perennial, intermittent, and ephemeral streams and shallow groundwater zones (digital)

   b) Digital USGS orthophoto quadrangles for portions of Pima County

c) Unincorporated Pima County riparian habitat maps (digital)

d) Gap Analysis Program vegetation maps (digital)

e) NDVI map for portions of Pima County (digital)

f) PAG 208 maps for non-urban Pima County (paper)

g) Wildlife Habitat Inventory maps for metropolitan Tucson (digital)

h) Organ Pipe Cactus National Monument vegetation map (digital)

i) PAG 208 vegetation and soils data cards (paper)

j) Cienega Creek Natural Preserve vegetation map (paper)

k) USGS and Pima County stream center lines (digital)

l) USFWS wetland inventory maps (mostly paper)

Emphasis shall be placed on classifying the existing riparian areas as delineated on Pima County's riparian habitat maps, delineating additional riparian areas where no data currently exists, and addressing specific mapping requirements below. Work shall emphasize areas outside existing public reserves.

B. Vegetation Mapping Requirements

1. Discriminate the location of riparian vegetation versus upland vegetation with a minimum map area of 5 acres.

2. Identify physiognomy and dominance, discriminating among leguminous tree forests, broadleaf deciduous forests, tamarisk forests, other riparian forests, emergent marsh, tobosa or sacaton grassland, and riparian scrub. Units should be mapable on a 7.5 minute scale — i.e. 5 acres minimum unit.

3. Map unit classifications should be compatible with the National Vegetation Classification System. The hierarchical classification system used by Brown, Lowe and Pase is acceptable.

C. Procedure

1. Refine and develop a mapping protocol to meet the STAT vegetation mapping requirements, budget, and schedule.

2. Design and conduct a pilot vegetation mapping exercise covering several nonadjacent USGS 7.5 minute quadrangles, including field verification. The pilot study areas need to represent the range of vegetation types present in the study area, as well as the variation in available data sources. Evaluate and refine the mapping protocol and classification scheme.

II. Reports

The attached reports provide the context for prior mapping efforts, and the pilot study by Harris Environmental Group, as described in the paragraph immediately above. In *Riparian Habitat and Riparian Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan*, a number of previous riparian mapping efforts are reviewed, including a 1976 initiative by Arizona Game and Fish, the U.S. Geological Survey's Gap Analysis map, the Pima County Wildlife Habitat Inventory Phase 2 study, the Pima Association of Governments 208 studies, and Pima County's Riparian Habitat Maps. More detailed mapping for riparian areas is required to develop the Sonoran Desert Conservation Plan since: the PAG maps are outdated; the USGS maps have classification errors; and the County's maps depict vegetation volume but do not distinguish plant species and plant structures, and such distinctions are necessary in order to understand wildlife associations to vegetation communities. To carry out the *Pima County Riparian Vegetation Mapping Pilot Study*, the Harris Group performed a qualitative riparian inventory within several sites in Eastern Pima County. Study areas included:

- the Black Wash in the Brown Mountain area;
- portions of the Canada del Oro Wash inhabited by the pygmy-owl;
- portions of the Santa Cruz river that has effluent dominated flow; and
- floodplain corridors to the southeast of Tucson.

Detailed descriptions of the vegetation within each area are found on pages 14 through 17 of the attached Harris report. Compared to previous efforts the Harris study classified vegetation communities by the dominant species at a finer level. Corrections to the GAP maps have been made. The pilot study enabled the Harris Group to determine that two existing data sets will be useful for mapping beyond the pilot areas: the Pima County Riparian Habitat Mapping project and the Arizona Game and Fish perennial riparian data base. Now existing riparian areas will delineated and vegetation communities at the biome level will be identified.

III. Conclusion

The template for multi-species conservation planning is the vegetation map of the study area. The fact that the Sonoran Desert Conservation Plan requires a detailed and comprehensive riparian vegetation map is a reflection of the importance of riparian habitats to the overall health of the plant and animal community in our region. Additional reports and studies have been completed or are underway to assess the potential for change in riparian vegetation based on the hydrologic conditions that shape these systems in Pima County. This combination of reports and maps will inform both habitat preservation and riparian restoration initiatives proposed as a result of the Sonoran Desert Conservation Plan.

Riparian Habitat and Riparian Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan

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Riparian Habitat and Riparian Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan

by Julia Fonseca, Pima County Flood Control District

May 2000

The purpose of this report is to examine the strengths and weaknesses of previous riparian vegetation mapping efforts for their use in the Sonoran Desert Conservation Plan (SDCP). Vegetation maps will be used in combination with other GIS data layers to examine habitat suitability for specific wildlife species and to define "species-rich" zones in order to develop conservation plan recommendations. In addition, vegetation maps will be utilized to determine how well specific plant communities or wildlife habitat types are represented by existing public reserves in Pima County.

Definitions

The word "riparian" originates from a Latin word meaning "along the river". Here, in the semi-arid western United States, it means along a watercourse, arroyo, seep, pond, or other location where the availability of water is increased. Riparian vegetation, then, is the vegetation that grows along streams, dry washes, seeps, ponds, and other places where the availability of water is higher than the uplands.

"Habitat" is not the same as vegetation. It refers to all of the things an organism needs to survive. So, riparian habitats could include the barren sand bars where lizards run, the little holes along the banks where swallows nest, or the pools of water where toads breed after the summer rains. It also includes the vegetation that provides food and shelter to various organisms.

Significance of Riparian Vegetation

Riparian areas have been called "streams of life" and "lifeblood" of the desert. Approximately 60 to 75% of Arizona's resident wildlife species are dependent on riparian habitats to sustain their populations, yet these riparian areas occupy less than 0.5% of the state's total land (ARC, 1994). Riparian areas are among the most productive ecosystems in the world and they may be the highest, rivaling our best agricultural lands, in the production of biomass (ARC, 1994)

In the last 100 years, most of Arizona's low-elevation riparian habitats have been altered or destroyed by human activities (ARC, 1994). Little more than a century ago, portions of the Santa Cruz River, Tanque Verde Creek, Pantano Wash, Rillito Creek, and San Pedro River flowed year round in Pima County (Hendrickson and Minckley, 1986). As previously documented in Pima County's *Water Resources and the Sonoran Desert Conservation Plan,* many plant and wildlife species that use riparian areas, and more particularly, groundwater-dependent riparian zones, are threatened with extinction or regional elimination.

Classification and Mapping Issues

As one can tell from the definition, "riparian" is a relative term; therefore, mapping just where riparian vegetation ends and upland vegetation begins is dependent upon both the definitions, the purpose, and the methodology being used.

A person might use a discernable change in the density of vegetation as the basis of her mapping, evidence of past flooding or other soil moisture conditions, or the occurrence of certain plant species which only occurs under certain soil moisture conditions. In any case, mapping involves drawing a line across what is, in fact, a natural gradient.

Scale is another factor affecting mapping. Using the scale of one inch equals one mile, riparian vegetation may seem to be a narrow, dark line along a watercourse. However, when one is standing on the land, the boundary may be hard to discern. Projects that involve extensive areas, such as the Sonoran Desert Conservation Plan, will use a coarse scale to map vegetation, rather than one might for management of a specific reserve or ranch. Narrow washes with less dense vegetation may not be apparent until more detailed studies are performed.

Previous Efforts

There have been many efforts to describe the complex arrangement of riparian vegetation on the landscape and the significance of this distribution for wildlife and people. Table 1 lists the regional efforts and their useful attributes for the Sonoran Desert Conservation Plan.

Individual, detailed vegetation maps exist for areas such as Saguaro National Park, Cienega Creek Natural Preserve, portions of the Santa Cruz River, Bingham Cienega Natural Preserve and Organ Pipe Cactus National Monument (Table 2). In addition, studies prepared under Pima County's specific plan ordinance usually include riparian vegetation maps.

Characteristics of the more regional efforts are discussed below in detail, and summarized in Table 1.

AGFD Vegetation Map:

Riparian areas along Cienega Creek, Santa Cruz River, San Pedro River, Altar Wash and tributaries, Los Robles Wash , Cañada del Oro, lower Rillito Creek, and portions of the Brawley Wash were mapped in 1976 by various wildlife managers (game wardens) of the Arizona Game and Fish Department (AGFD). The original scale of maps was 1:126,720 and the base maps used were the "County General" series provided by Arizona Department of Transportation.

The classification system used riparian deciduous forest (322.2), riparian deciduous woodland (333.1), and mesquite bosques (333.11) as map units.

University of Arizona digitized the maps during 1992 and 1993 and imported the polygons for the Altar Wash and tributaries, Los Robles Wash, and Brawley system into the GAP vegetation map. The classification for Los Robles and Brawley washes is mixed broadleaf, which I believe to be erroneous.

Arizona Gap Analysis Program (GAP):

U. S. Geological Survey's Biological Resource Division used LANDSAT thematic map images from the early 1990's in combination with other sources to map the distribution of various vegetation communities in Arizona. The work covers Pima County, except for a portion of the upper Santa Cruz valley. The vegetation classification is hierarchical similar to the Brown, Lowe and Pase system. The units are mapped to the series level, in general. There are 6 riparian plant map units defined for the Pima County. Map units are as small as 3 acres along riparian zones.

Some of the riparian polygons were based on the 1976 AGFD map. Some of these polygons may bear incorrect classifications, as discussed above.

Mapping for Sabino Creek, San Pedro River and Cienega Creek was based in part on the 1992AGFD vegetation mapping effort for selected perennial streams in Arizona conducted by the University of Arizona. This effort utilized aerial videography in combination with LANDSAT imagery to classify vegetation.AGFD (Kubly et al., 1997) published an accuracy assessment of the perennial streams riparian mapping which included Sabino Creek, San Pedro River, and Cienega Creek in Pima County. Statewide, 1671 GAP polygons were sampled in the field by AGFD staff. Of these, 87% were correctly identified as containing predominantly riparian vegetation (as opposed to upland). This level of accuracy was obtained after adjusting polygon boundaries by comparing them to topographic maps and aerial photographs. Only 35% of the polygons were correctly classified to the appropriate vegetation series. Incorrect boundary delineation was prevalent for mesquite communities at low elevations and conifer communities at high elevations. Most montane riparian areas were too narrow to be resolved using 30-meter remote sensing.

As part of the accuracy assessment, AGFD identified dominant plants and collected age-class information between October 1992 and October 1994. A relational database containing the geodetic location and all riparian measurements collected in the field for each polygon is available for this work, and would include locations on Sabino Creek, San Pedro River, and Cienega Creek (Ruth Valencia, personal communication).

The AGFD assessment contained the following recommendations:

1. Use caution in assessing the distribution of riparian vegetation classes based on these maps.

2.. Relational databases created to store, retrieve and analyze groundtruthing data for this project need to be integrated and attributed in a GIS to improve the utility of these databases. A metadata document needs to be created and provided along with any export of these data.

3. A classification system for Arizona riparian areas should be completed using groundtruthing data from the perennial and intermittent stream investigations. The riparian classification system should not be strictly taxonomically based, but should include elements of structure that have proven important to wildlife diversity. The classification system should be related to wildlife functions and values.

4. Develop a Riparian Vulnerability Index similar to the Aquifer Vulnerability Index developed by Environmental Protection Agency and Arizona Department of Environmental Quality to identify riparian areas in need of protection, restoration or remedial action.

In June 1999, staff evaluated the GAP vegetation mapping in a document entitled *An Evaluation of Previous Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan*. That evaluation found gross errors in the mapping of riparian vegetation polygons and their classification along Cienega Creek and its tributaries. In addition, we identified nearly 2000 acres of riparian in the Goldwater/ Cabeza Prieta Refuge that are misclassified as water.

Pima County Wildlife Habitat Inventory Phase 2 (WHIP2)

This study produced a land cover map for metropolitan Tucson with an associated data base of vegetation characteristics (Shaw et al., 1996). Land cover categories were derived from parcel-based land use maps, and updated based by 1995 aerial photographs for land cover changes affecting more than 20 acres. Land cover types included ponds, "major rivers" and "wash/riparian areas". The "major river" and "wash/riparian areas" land cover types do not represent vegetation per se, but the mixture of vegetated areas and bare ground that occur along a watercourse. Hence the term "habitat". The polygons were classified into two vegetation series either velvet mesquite-mixed scrub (234.713) or cottonwood-willow (243.531) on a separate GIS layer. These polygons would over-represent area of riparian vegetation if taken at face value.

Ground investigations related land cover types to the amount of 1) native vegetation, 2) escape cover, 3) structural diversity and 4) total vegetative cover. The major river and wash/riparian land cover types possessed the highest percentages of native vegetation and escape cover of the 33 land cover types measured. These land cover types average about 40% vegetative cover. Golf courses and neighborhood parks had higher total vegetation cover than major rivers and wash/riparian areas. However, golf courses and neighborhood parks had much lower percentages of native vegetation and escape cover.

PAG 208 studies

Vegetation, geology, landforms, slope, land use, water bodies and soils were mapped by Office of Arid Lands (OALS) for all of Pima County, excluding the metropolitan area, in the late 1970's, based on 1972 and 1973 aerial stereophotographs. Mylars of the final maps reside with Pima Association of Governments (PAG). The mylars have not been digitized. The mapping covers all of the county except for metropolitan Tucson. The mylars are registered to USGS 15-minute maps, however there is some distortion within each mylar. Minimum mapping unit size is about 20 acres.

Vegetation and soils were mapped based on 1000 field records, plus existing information, aerial photographs, NASA satellite imagery, and personal knowledge. The polygons on the final PAG maps are edge-adjusted composites, however, the original mylars and field records for each data layer are available from OALS. Western Pima County (Cabeza Prieta and the Goldwater Range) received no field verification, Eastern Pima County received some field verification, and the Tohono O'odham Nation received the most intensive field verification.

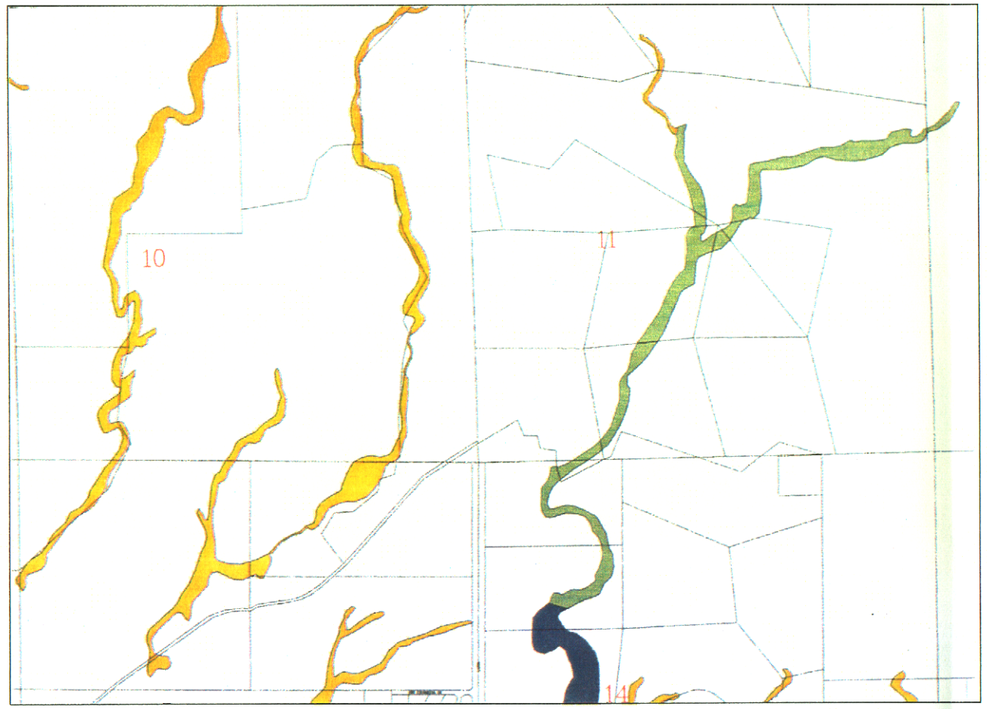
Vegetation classifications are hierarchical, with the first class referring to structure, and four successive classes relating to dominant or indicator plants. Most data cards contain point location information keyed to a reduced 15-minute orthophotograph, along with a description of the abundance and prominence of plants species at that site. The data cards are more useful for understanding upland than for riparian vegetation.

In June 1999, staff evaluated the PAG vegetation mapping in a document entitled *An Evaluation of Previous Vegetation Mapping Efforts for the Sonoran Desert Conservation Plan*. Staff found that the PAG maps do not reflect the changes in riparian areas which have occurred since the 1970's, including clearing and natural revegetation. Small streams are not mapped at all.

Pima County Riparian Habitat Maps

Pima County mapped the location of riparian vegetation in unincorporated Pima County for regulatory purposes. Incorporated areas and public reserves were excluded. The classification system used by Pima County was based on vegetation volume inferred from multi-spectral LANDSAT images from the early 1990's. The system does not refer to species composition; instead riparian vegetation is classified as hydromesoriparian, or xeroriparian class A, B, C or D. The hydromesoriparian classification is based on the assumed availability of surface or groundwater. Xeroriparian classes are related to specific ranges of total vegetation volume.

A sample map is illustrated at the top of Figure 1. The length and width of riparian vegetation polygons (enclosed in black lines) were based on 1990 1:12,000 aerial photographs. In the metropolitan area, these photographs were rectified; outside of this area, they were unrectified. A minimum map length of 420 m was chosen.



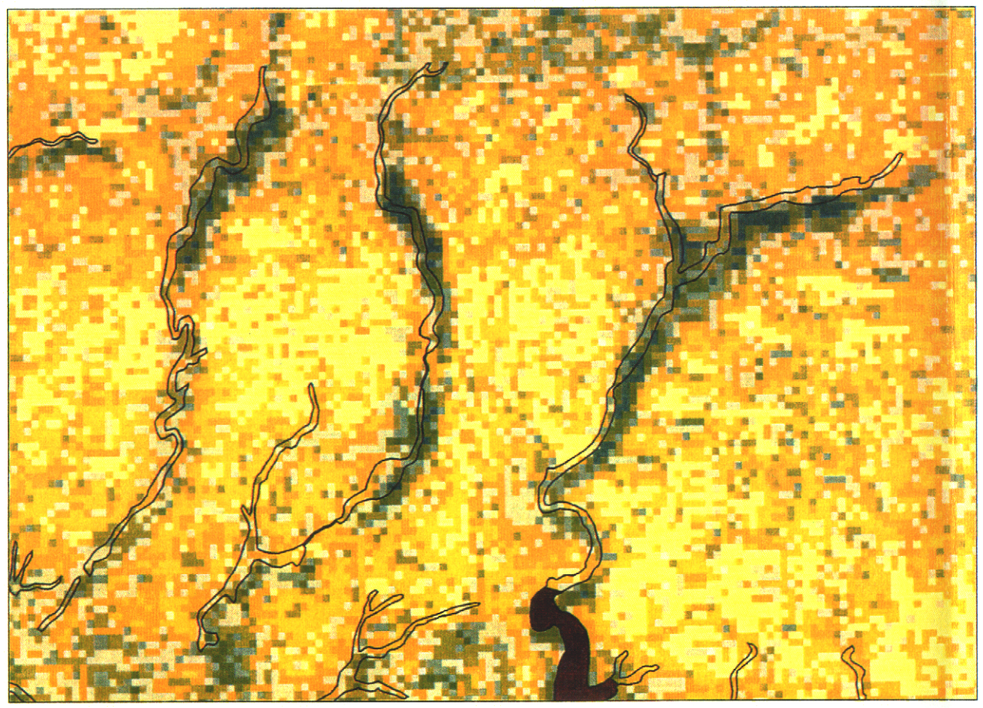


Figure 1

Classification of Riparian Habitat

- A XERO-RIPARIAN HABITAT
- B XERO-RIPARIAN HABITAT
- C XERO-RIPARIAN HABITAT
- D XERO-RIPARIAN HABITAT
- HYDRO-MESO RIPARIAN HABITAT
- 25 SECTION NUMBER
- PARCEL BASE

In this example, poor registration resulted in class B and C designations, rather than class A and B designations.

Figure 1
Classification of Riparian Habitat

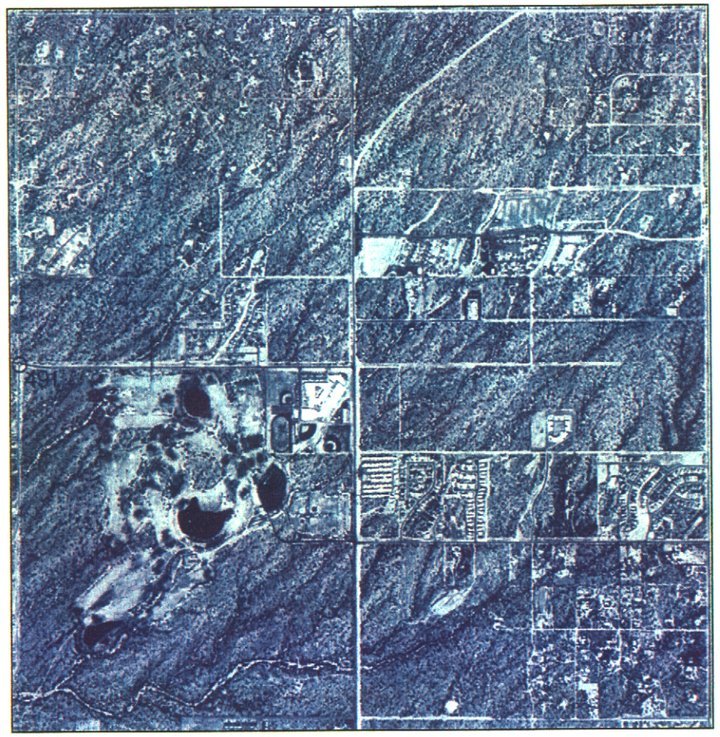
Satellite imagery was processed using the normalized vegetation difference index (NDVI) for riparian vegetation. This index is a mathematical equation that relates to the reflectance in infrared and near-infrared spectral bands of LANDSAT--it is used in image processing for vegetation characteristics. The relationship of the NDVI to total vegetation volume was tested at five locations along watercourses, two in Avra Valley, two in Altar Valley and one near Cienega Creek, and showed a high degree of correlation. A separate NDVI data layer exists for all of eastern Pima County, including the public reserves and incorporated areas, as well as unincorporated Pima County in the Ajo/Why area.

The aerial photo polygons were superimposed on the NDVI-processed LANDSAT imagery (bottom of Figure 1). The NDVI of the pixels which fell within xeroriparian areas were classified into 10 classes, and then averaged within each stream reach. The resulting average was classified into four vegetation volume categories A through D (yellow and green colors in the legend of Figure 1). In Figure 1, lower half, it can be seen that the polygons do not align exactly with the darkest pixels. This illustrates the effects of a local problem with the rectification of the LANDSAT, which resulted in lowering the classification of some stream reaches from xeroriparian A and B to B and C in this area. Reach segmentation, which was based on aerials rather than the NDVI layer, may also obscure the location of high-volume zones through including them in longer, low-volume reaches.

The methodology used by Pima County also makes it difficult to discriminate narrow, discontinuous, or lower vegetation-volume riparian areas. An example of this can be seen in the Tortolita piedmont area (Figure 2). Most of the riparian zones along small watercourses in this area were not delineated. Riparian zones protected under Pima County's ordinance are shown in yellow on Figure 2; blue represents federally-mapped floodplains. This occurs because riparian zones which lie along small, fine-textured drainage networks are not easily distinguished from the uplands in either the NDVI data layer or even the aerial photographs. Similar fine-textured drainages exist in the piedmont of the Tucson Mountains.

Xeroriparian areas with a total vegetation volume less than 0.5 m^3/m^2 were initially analyzed, but were not protected under County ordinance. The vegetation volume of 0.5 m^3/m^2 was chosen as a threshold value for protection under Pima County's riparian habitat mitigation ordinance because it represents the upper limits of the vast majority of Sonoran Desertscrub and Semidesert Grassland biomes (SWCA, 1993). As a result, very few riparian areas in western Pima County were qualified.

Figure 3 illustrates the degree to which riparian vegetation has been mapped along a broader area of the Tortolita piedmont. Where watercourses are thickened with a riparian polygon, vegetation has been mapped and protected. Elsewhere, whether due to jurisdictional boundaries, vegetation volume limits, minimum reach lengths or failure to define riparian polygons on aerials, vegetation is not mapped.



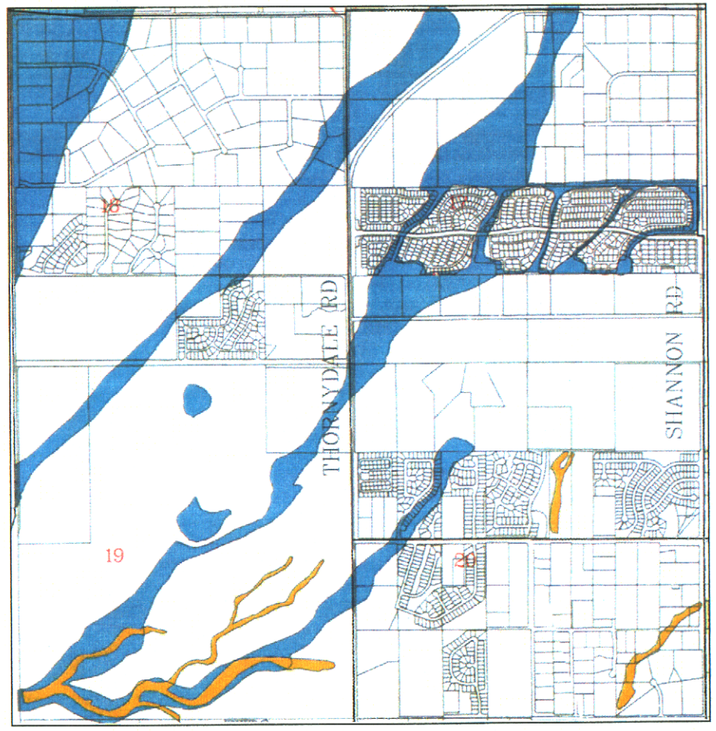


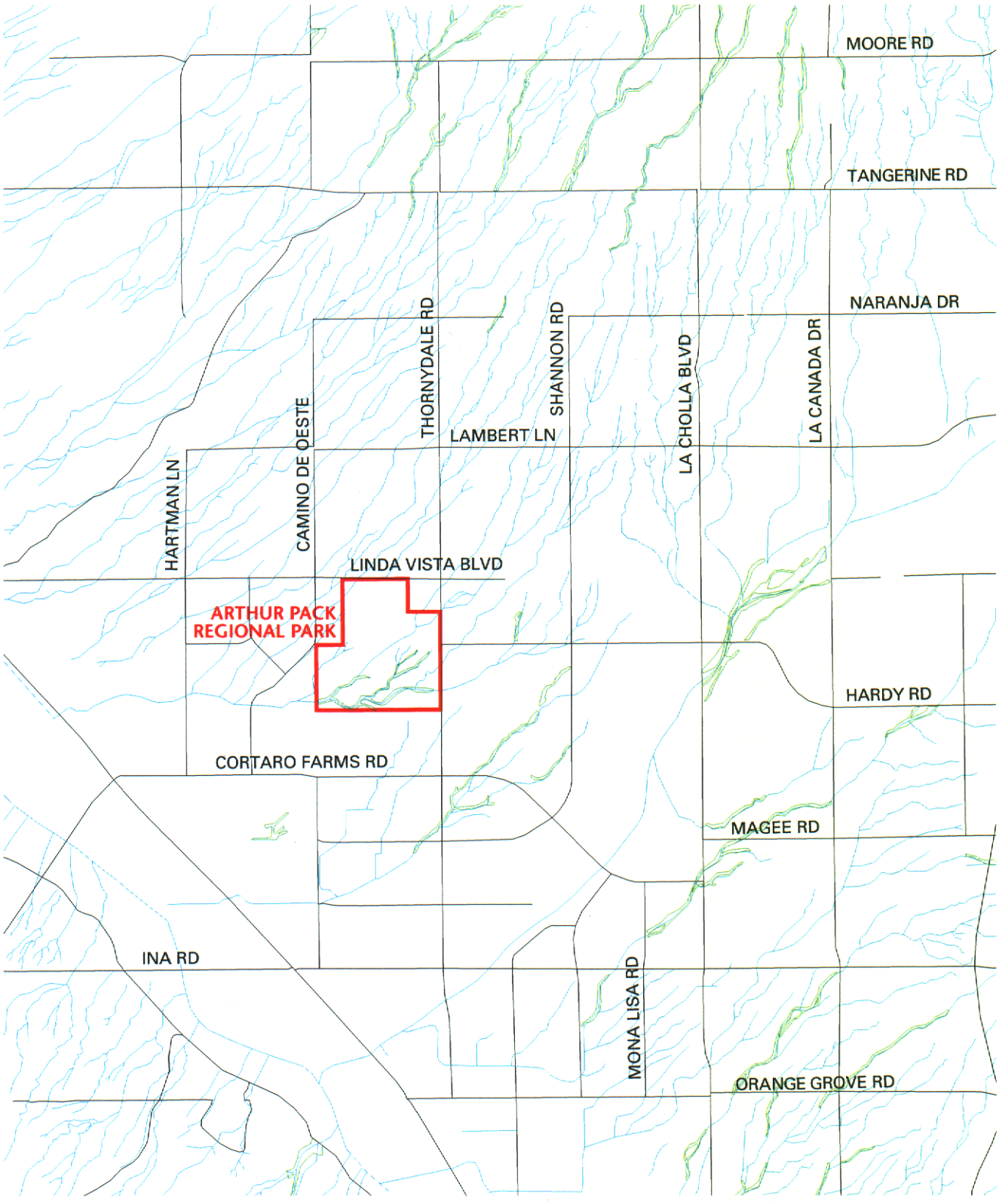
Figure 2

Aerial photograph and
final riparian habitat map,
Tortolita piedmont

A XERO-RIPARIAN HABITAT
B XERO-RIPARIAN HABITAT
C XERO-RIPARIAN HABITAT
D XERO-RIPARIAN HABITAT
HYDRO-MESO RIPARIAN HABITAT
100 YEAR FLOODPLAIN
25 SECTION NUMBER
PARCEL BASE
MAJOR ROADS

Figure 2
Aerial photograph and
final riparian habitat map,
Tortolita piedmont

Overlay of Wash Centerlines With Pima County Riparian Habitat



PIMA COUNTY DEPARTMENT OF TRANSPORTATION
TECHNICAL SERVICES

Wash Centerlines
Riparian Habitat
Arthur Pack Regional Park

THE SEAL OF PIMA COUNTY ARIZONA

/pygmyowl2/sonora/amls/wash_rip.aml / Graphic Design 5/00 sb

FIGURE 3

Plotted: 12/10/99

Figure 4 shows the effect of mapping habitat relative to the floodplains which sustain them. Only certain patches of riparian vegetation were mapped in this rapidly developing area, while other patches of vegetation (shown as dark areas near E. Los Reales Rd. for instance) were overlooked. The broad floodplains and associated structures influence the distribution of the riparian vegetation. Changes in the hydrologic regime will affect the distribution of riparian vegetation over this area.

National Wetland Inventory Maps

The National Wetlands Inventory project was established to generate information about the characteristics, extent and status of the Nation's wetland habitat. A complete set of hard copy maps were obtain from U.S. Fish and Wildlife Service (FWS) for Pima County. Most of the maps are 1:100,000 scale and some are in 1:24,000 scale. Currently none of the maps are available in a digital format.

Most of the maps available for Pima County are from the early 1980s. The analysis and classification was based on stereoscopic analysis of high altitude aerial photos taken in the early 1970s to early 1980s. Some sites were ground surveyed for verification purposes.

The grossest level of the classification hierarchy differentiates riverine, lacustrine and palustrine environments from non-wetland environments. Each of the categories has subsystems (classes); the classes are characterized based on the substrata material, hydrology and vegetation. The grossest level of classification is the best available for most of Pima County. In general, these maps show stream centerlines as perennial or non-perennial riverine streambeds. (The perennial stream definitions have been considered in the PAG streams mapping project.) The maps also show ephemeral earthen ponds (charcos) and playas as palustrine open water or palustrine flats.

More detailed classification has been conducted on the Cabeza Prieta National Wildlife Refuge.

Discussion and Recommendations

On the basis of a June 1999 review of existing information, the Science Technical Advisory Team (STAT) determined that a special effort would be needed to improve the accuracy of riparian classification and delineation. The PAG 208 riparian maps are out of date. The GAP riparian classifications should not be relied on too heavily due to mapping and classification errors. The Pima County riparian maps do not depict plant species and plant structure which are important for some wildlife species and it overlooks riparian areas that are in incorporated areas and reserves.

Harris Environmental Group was selected to improve the quality of available riparian mapping. Fortunately, many riparian versus upland delineations are already available for the unincorporated portions and existing reserves of Pima County at an accuracy which is probably sufficient for the SDCP. Harris has been working with the STAT to define and apply a classification method which serves the goals of the SDCP. The attached report (Appendix A) summarizes Harris' progress to date.

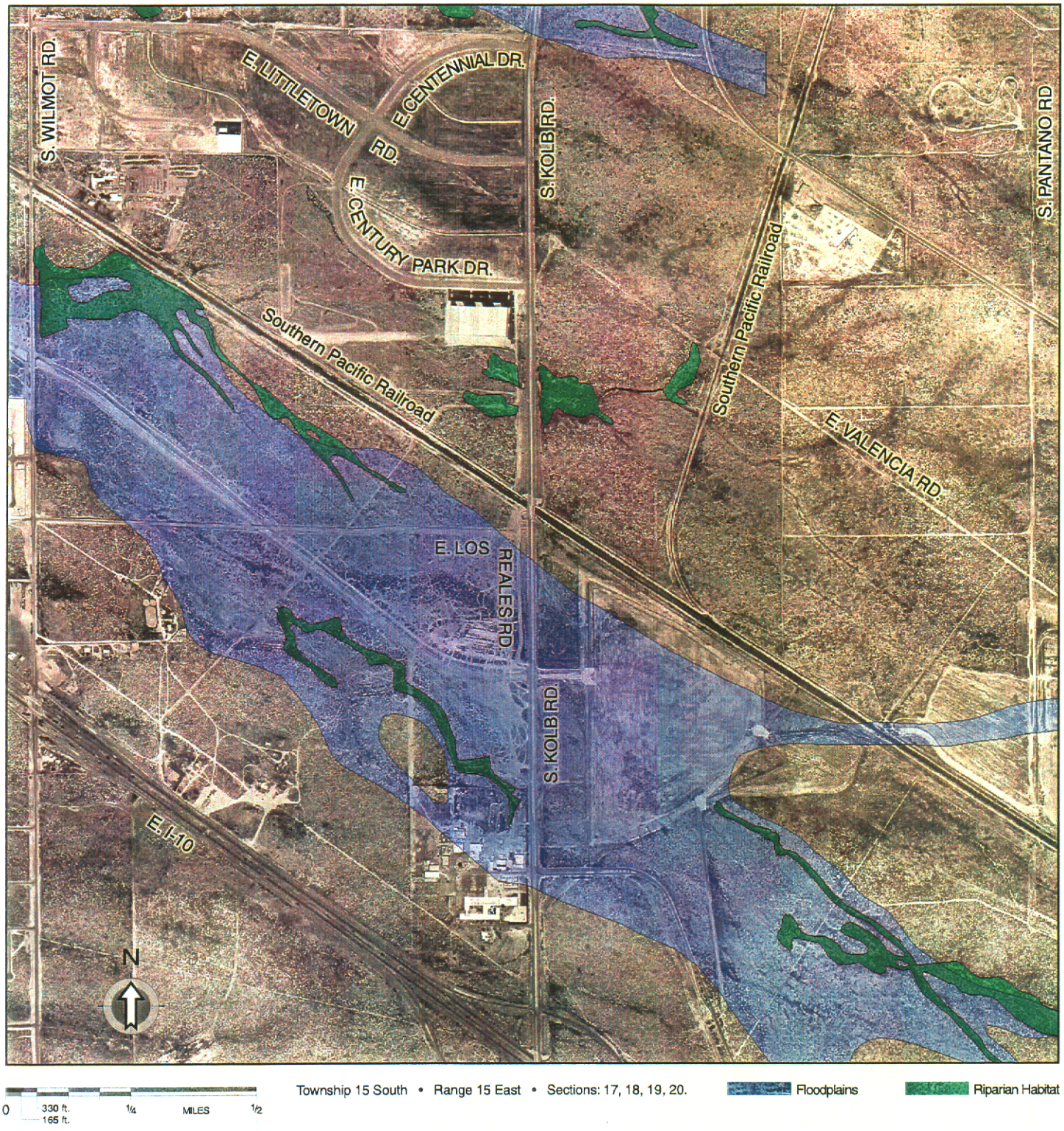


Figure 4. Pima County Riparian Habitat Maps and Floodplains, Southeast Tucson Basin

In low desert areas, ephemeral washes, charcos, barren floodplain flats, and small alluvial fans possessing low vegetation volume during most of the year become, during brief rainy seasons, areas of high productivity by virtue of the growth of annuals, and bursts of insect and amphibian life. These transient bursts of productivity are not likely to be captured in remote-sensing or aerial photography or even field measurements, but the phenomenon may be an important ecological factor to consider. If so, physiographic features, instead of vegetative features, may need to be identified. The STAT's existing workplan does not include mapping features of this sort.

Higher resolution (1-5 meter) multi-spectral imagery is available today than was available in the early 1990's, and could be used to identify narrower riparian areas than the 30-meter LANDSAT imagery. However, Pima County's experience has shown that securing and processing new imagery is both time-consuming and costly. Also, smaller pixels alone will not resolve the classification and rectification issues which challenge remote sensing techniques. Harris will rely upon recent (post 1995) U. S. Geological Survey orthophoto quadrangles at a scale of 1:24,000.

Any riparian mapping effort faces the problem of continual change over time in the distribution of vegetation. We can be sure that the structure, vegetation volume, and distribution of riparian areas will change over the term of the plan, as floods and droughts occur, vegetation matures, development proceeds, and the groundwater table fluctuates.

One way to assess the potential for change is to examine the hydrologic conditions which shape these systems throughout Pima County. In addition to mapping perennial and intermittent streams, and shallow groundwater zones, Pima County is examining factors likely to change the frequency and magnitude of floods, and the availability of groundwater, over the planning horizon through separate contracts.

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TABLE 1. REGIONAL RIPARIAN VEGETATION MAPS

Source	Coverage	Basis	Map Units	Advantages	Deficiencies
GAP vegetation	Pima County except for Upper Santa Cruz Valley	1990's 30 M Landsat & AGFD videography plus 1976 AGFD state vegetation map	6 Brown, Lowe, Pase (BLP) vegetation series	Recent (1990s) origin; defines sacaton and marsh	No small systems; few ephemeral streams; many map errors and omissions
Wildlife Habitat Inventory Project	Metropolitan Tucson	1990's 1:12,000 orthophotographs and 1995 aerial photographs and fieldwork	Mesquite-scrub vs cottonwood-willow; major rivers vs wash riparian	Washes in urban area related to cover characteristics of biologic significance	Only two riparian map units; accuracy of cottonwood-willow modest; washes don't represent vegetation
PAG 208	Pima County except for metropolitan Tucson	1970's Aerial photographs and field checking	Dominant/sub-Dominant species and gross physiognomy	Ephemeral streams and streams of intermediate size/length included	Late 1970s field work; few small systems included; not digital
Pima County Riparian Habitat	Unincorporated Pima County outside reserves for polygon delineations	1990's Landsat and 1:12,000 ortho-photography and unrectified aerials	3 Vegetation volume classes and one hydromesoriparian zone	Vegetation volume has biologic significance; recent	No species or structural info; many xeroriparian areas not included; incomplete coverage
National Wetland Inventory	Pima County excluding Goldwater/Cabeza Prieta NWR	Aerial photography 1972-73 1:120,000	Riverine vs palustrine; perennial vs "intermittent"	Covers many small streams and isolated wetlands/ephemeral ponds	No species information; almost no structural information
National Wetland Inventory	Goldwater/Cabeza Prieta NWR	Color infrared aerial photography 1980-81 1:58,000	Forested vs Scrub-shrub and mesquite vs cottonwood vs salt cedar vs mixed broadleaf	Small ephemeral streams and isolated wetlands included	Possible changes since 1980-81, not digital

Table 2. DETAILED VEGETATION MAPS

Source	Coverage	Basis	Map Units	Advantages	Disadvantages
National Park Service	Organ Pipe Cactus National Monument	Aerial photos/fieldwork	BLP associations--10 of riparian/aquatic significance	1990's, digital	None
Pima County	Bingham Cienega Natural Preserve	Fieldwork/aerial photos	7 land cover types with dominant species listed	1994	Not rectified
Pima County	Cienega Creek Natural Preserve	Fieldwork/aerial photos	BLP associations with density qualifier on mesquite	1994	None
U.S. Bureau of Reclamation	Santa Cruz River Roger Rd. to Trico Rd.	Fieldwork/aerial photos	BLP associations	2000: digital	No density information on mesquite association
U. S Bureau of Reclamation	parts of Cañada del Oro and Big Wash; and Santa Cruz River	Fieldwork/aerial photos	Vegetation volume with dominant species and structure	1995--vegetation volume allows prioritization within association	None
Lacey et. al, 1975	Cienega Creek/Pantano Wash/San Pedro	1:125,000 Color IR and fieldwork	BLP associations	Distinguishes dominant species	1972-73
U.S. Fish and Wildlife Service	Cabeza Prieta National Wildlife Refuge	Unknown--in progress	Unknown	2001? Will be digital format	Not available
U.S. Bureau of Land Management	Empire-Cienega Resource Conservation Area	Fieldwork/color IR photos--not yet reviewed		1990's	Unknown-not yet reviewed

APPENDIX A

PIMA COUNTY
RIPARIAN VEGETATION MAPPING
PILOT STUDY

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APRIL 12, 2000
REVISED

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INTRODUCTION

On 18 January 2000, Pima County Government, Arizona, contracted with the biological consulting team of Harris Environmental Group, Inc., Dames & Moore, and R. B. Duncan & Associates to conduct a riparian habitat mapping study in Pima County as part of the County's Sonoran Desert Conservation Plan. The first phase of the project was to conduct a pilot study. The purpose of the pilot study was to develop and refine mapping methodology that will be efficient and effective in terms of meeting the Sonoran Desert Conservation Plan's Scientific and Technical Advisory Team's (STAT) riparian vegetation mapping requirements for Pima County.

There have been several vegetation-mapping studies done throughout the County, including those specific to riparian habitats, but few were comprehensive in describing the vegetation communities countywide. The 2 most recent are the Pima County Riparian Habitat Mapping and the U. S. Geological Survey (USGS), Biological Resources Division's Gap Analysis Program.

The Pima County Riparian Habitat Mapping (conducted in the early 1990s) describes the riparian vegetation in unincorporated portions of Pima County and was used for regulatory purposes (Pima County Floodplain and Erosion Hazard Ordinance 1994 – FC-2). This project does not describe vegetation in terms of species; instead riparian vegetation was classified as mesoriparian, or xeroriparian class A, B, or C. These are related to specific ranges of total vegetation volume. This mapping project focused on eastern Pima County and only included washes in the unincorporated areas.

The Gap Analysis Program (GAP) is a scientific method for identifying the degree to which native animal species and natural communities are represented in our

present-day mix of conservation lands. Those species and communities not adequately represented in the existing network of conservation lands constitute conservation "gaps." A preliminary Arizona GAP map has been produced and a final report is due in 2000. The GAP vegetation layer for the State of Arizona, as is the case for all of the United States, was described in terms of species using the National Vegetation Classification System (Anderson et al. 1998, Grossman et al. 1998). However, the STAT has evaluated the GAP map (Draft report dated June 1999) and determined that it was inadequate for the purposes of the Sonoran Desert Conservation Plan's goals.

The current mapping project will be a combination of integrating existing information and conducting new fieldwork. The results of the pilot study will give direction on how this process should be undertaken for the remaining portions of Pima County. As part of the pilot study, we conducted a qualitative riparian inventory within several sites, representing diverse situations in existing mapping information, definition of riparian area, and vegetation classification.

STUDY AREA

Three sites were chosen by Pima County for the pilot study. These areas represented a range of vegetation types present in Pima County. These study areas also represented the variation in available data sources. Given the time-sensitive nature of the overall project, pilot sites were also chosen for their proximity to Tucson (to minimize travel time) and for the availability of aerial photographs processed in a GIS (Geographic Information System) format.

The 3 Pima County riparian mapping pilot study areas are listed as follows by USGS 7.5 minute topographic map quadrangle locations (See Figure 1):

1) *Brown Mountain SE ¼*

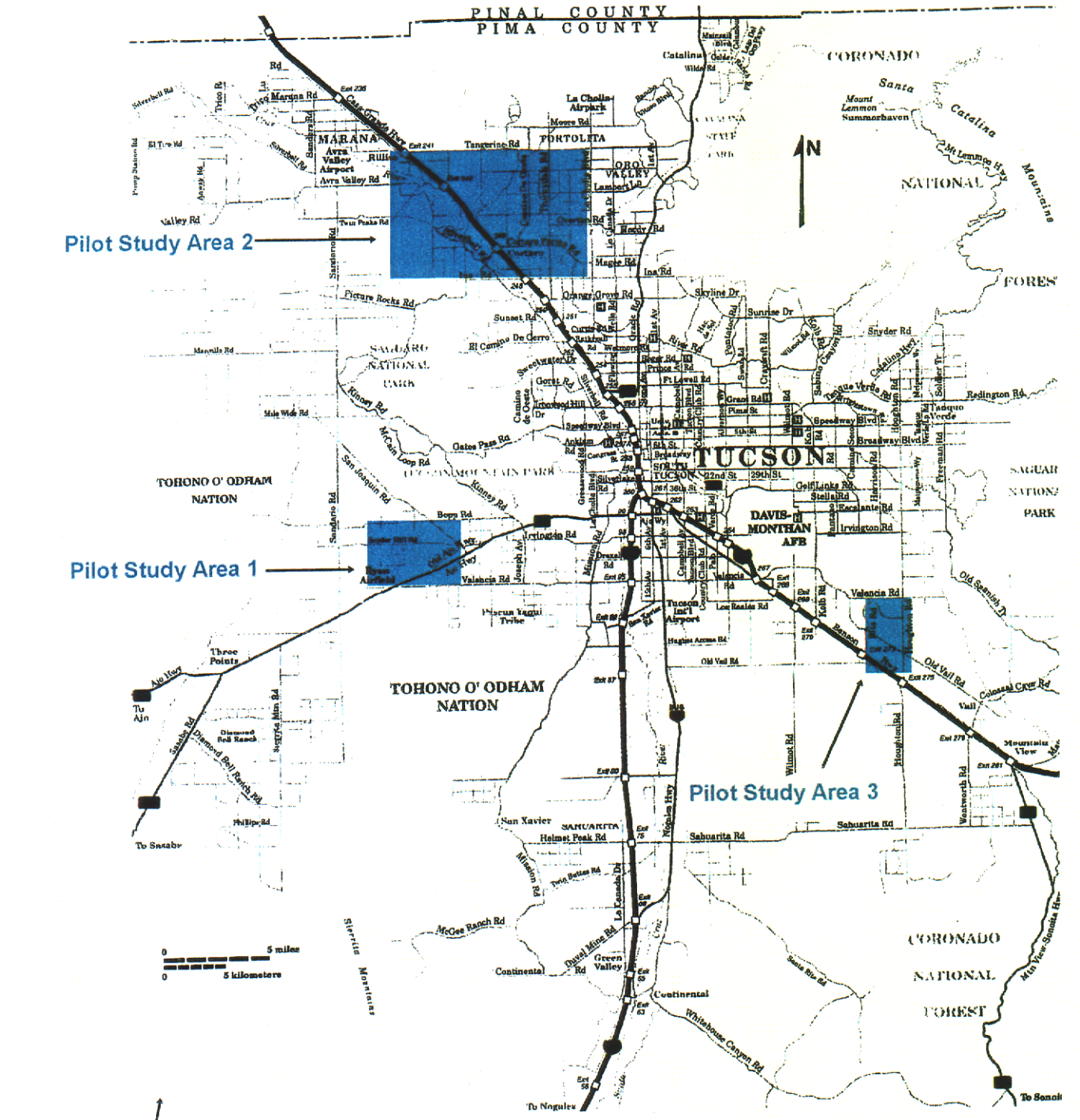
Pilot Study Area 1 includes Black Wash, a developing area thought to include a significant amount of desert riparian scrub and possibly more mesic riparian woodland, and known to have some unique drainage patterns not represented by the other areas.

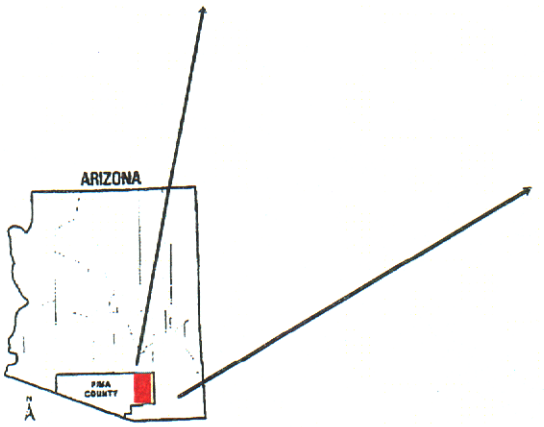
2) *Jaynes NE ¼ and NW ¼ and Ruelas SE ¼ and SW ¼*

Pilot Study Area 2 is located in an area that is inhabited by the federally listed endangered cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*). Riparian vegetation mapping is lacking or inadequate here. This area includes portions of the Cañada del Oro Wash and Santa Cruz River. The reach of the Santa Cruz River that is in this study area has been enhanced by treated effluent discharge.

3) *Tucson Southeast NE ¼*

Pilot Study Area 3 includes broad floodplain corridors containing both desert riparian scrub with shrub-like, perennial bunch grasses. Some of this area is within the jurisdiction of the City of Tucson, where there is no existing riparian vegetation information.





Sonoran Desert Conservation Plan:
Riparian Pilot Study Areas
April 2000

HARRIS ENVIRONMENTAL GROUP INC
1749 E.10th St., Tucson, AZ 85719

METHODOLOGY

We evaluated 9 existing data sets that contain riparian information for Pima County. Data sets reviewed in detail include the GAP analysis, Earth Resources Observation Systems (EROS) Data Center maps, wash centerlines, and the Pima County Riparian Habitat Mapping project. Additional data sets provided by Pima County for evaluation included Cienega Creek, Arizona Game and Fish Department's (AGFD) statewide riparian inventory, Bown, Lowe, and Pace (BLP) natural vegetative communities, The University of Arizona's Wildlife Habitat Inventory Study (WHIPS) BLP layer, and WHIPS land cover layer. The latter referenced data sets were evaluated and eliminated from further investigation based on staff knowledge, extent of the data set outside the pilot sites, and review of the information contained in the data set.

Since species information is important in wildlife conservation, we developed a vegetation classification system based on the Brown, Lowe, and Pase (1979) hierarchical biotic communities classification system (Table 1). The BLP system will be used instead of the vegetative volume classification system used in the previously funded Pima County mapping effort. The BLP system is based on the biome concept that allows development of a hierarchical evolutionarily related classification and is well suited to mapping extensive areas for assessment of animal-plant distributions. Biomes are natural communities of plants and animals characterized by a distinctive vegetation physiognomy within a formation (forest, woodland, scrubland, grassland, etc.).

Since the Pima County Riparian Habitat Mapping project was conducted for regulatory purposes, only certain size washes were included. In an effort to determine the

usefulness of this existing database, we conducted the riparian inventory within the pilot sites without their use so that we would not be biased in our data collection. We then compared our results with the previously documented mapping project.

For delineating the riparian areas and classifying the vegetation within the pilot sites, we used the most current (June 1996) USGS ortho-rectified aerial photographs (1:12,000 scale) and Pima County's non ortho-rectified (1998) aerial photographs (1:400 scale). The non ortho-rectified aerial photographs were used in the field because of their higher resolution and availability when fieldwork began. An Arc Macro Language (AML) program was developed to generate base maps for biologists to transcribe lateral boundaries and type of riparian vegetation from the 1:400 to 1:12,000 scale maps. The base maps contained 4 data layers, the USGS digital ortho-photo quarter quadrangles, the quadrangle boundary, township, range, and section boundaries (from Arizona State Land Department), and lands currently identified as inside existing public reserves, based on the land ownership layer from Arizona State Land Department. Lands identified as inside existing public reserves include Arizona Game and Fish Department, Indian lands, military reservations, National Parks, regional and state parks, U.S. Forest Service, and National Wildlife Refuges. These lands were identified on the maps with a white patch to indicate to the biologist not to inventory in these areas.

Using the non-ortho aerial photographs, we delineated all of the riparian areas based on the presence of a more-or-less linear swath of darker vegetation. Lowe (1964) defined riparian vegetation as that which occurs in and along drainage system channels, their margins and/or their floodplains, and is further characterized by different species

Table 1: Sonoran Desert Conservation Plan
Riparian Pilot Study
Vegetation Categories[1]

154 Tropical-Subtropical Desertlands
- 154.1 Sonoran Desertscrub
  - 154.11 Creosote-Bursage ("Lower Colorado Valley") Series
    - 154.118 *Cercidium spp.-Olneya tesota* riparian Association
    - 154.119 *Cercidium floridum-Prosopis spp.* riparian Association
  - 154.12 Paloverde-Mixed Cacti ("Arizona Uplands") Series
    - 154.127 Mixed shrub-*Cercidium microphyllum-Olneya tesota*-mixed scrub Association
    - 154.128 Mixed shrub-*Cercidium microphyllum-Chilopsis linearis*-mixed scrub Association
  - 154.13 Brittlebush-Ironwood ("Plains of Sonora") Series
  - 154.18 Desertbroom-Burrobush Series

224 Tropical-Subtropical Swamp, Riparian and Oasis Forests
- 224.5 Sonoran Riparian and Oasis Forests
  - 224.52 Mesquite Series
    - 224.521 *Prosopis juliflora velutina* Association
  - 224.53 Cottonwood-Willow Series

234 Tropical-Subtropical Swamp and Riparian Scrub
- 234.7 Sonoran Deciduous Swamp and Riparian Scrub
  - 234.71 Mixed Scrub Series
    - 234.712 *Prosopis juliflora velutina* (mesquite bosque) Association

[1] Brown, D., Lowe, C. H., and C. H. Pase. 1979. A digitized classification system for the biotic communities of North American and community (series) and association examples for the Southwest. J. Arizona-Nevada Academy of Science 14(Suppl.1)1-16.

and/or life forms than that of the immediately surrounding non-riparian (upland) vegetation.

The desert washes dissecting the study area that drain from the adjacent mountain ranges are easily recognizable by the presence of a linear assemblage of trees and shrubs that are denser and taller than the sparse vegetation on the adjacent uplands. Polygons were drawn around these riparian areas. The designation of riparian areas and location of polygon boundaries were internally verified by Dr. Margaret Livingston, The University of Arizona, and Mr. Russell Duncan, R. B. Duncan & Associates.

The base maps were first produced at 1:24,000 map scale. An evaluation of the imagery at this scale determined the resolution to be too small to accurately depict vegetation to the Association level of the BLP vegetation classification system, which was our initial goal for the pilot study. Maps were then enlarged to 1:12,000 map scale. These maps were used in conjunction with the 1:400 aerial imagery to identify the riparian vegetation.

Plant communities were defined, through interpretation of ortho-photo images and field verification. We described the vegetation communities to the Series or Association level. After visiting several areas for confirmation of vegetation classification, field verification eventually consisted of the qualitative assessment of riparian areas. Vegetation polygons were delineated to the minimum mapping unit of 5 acres. The polygon information was then transferred to the ortho-rectified aerial photographs (1:12,000) for digitizing.

Vegetation polygons were digitized and labeled in the *ArcEdit* module of *ARCINFO* (ESRI 1999). GIS analysts reviewed the resulting maps to ensure all polygons

were closed, labeled and that edge matching occurred between quadrangles. Maps were registered to the township/range/section data set. Check plots were generated to verify all boundaries and labels were entered correctly.

Analysts then generated a frequency of the BLP vegetation types. This frequency was a secondary quality assurance/quality control (QA/QC) verification to ensure that all vegetation types were entered correctly into the GIS database. Final maps were generated showing the completed pilot study.

RESULTS AND DISCUSSION

Riparian Area Comparison

We inventoried all existing riparian areas within our pilot sites visible on the 1998 non ortho-rectified aerial photographs (1: 400 scale). In comparison with the 2 previous mapping projects, our coverage was more comprehensive. For example, within pilot study area 2 (Jaynes NE ¼ and NW ¼ and Ruelas SE ¼ and SW ¼), we inventoried 4,312 acres of riparian area, compared to 348 acres in the Pima County's Riparian Habitat Mapping project, and 297 acres in the GAP project. The GAP project showed only 1 riparian area within this pilot site; the Santa Cruz River (See Appendices A & B).

Vegetation Summary

Upland (non-riparian) vegetation of the pilot sites is mainly representative of Sonoran Desertscrub (154.1) but also includes areas dominated by Semidesert Grassland (143.1). Associated mesic riparian communities in the pilot study area (found mainly along the Santa Cruz River and Cañada del Oro Wash) include Sonoran Riparian and

Oases Forests and Woodlands (224.5), Sonoran Deciduous Swamp and Scrub (234.7), and Sonoran Interior Strands (254.7). These riparian communities are present along stream channels and their associated terraces with perennial or near perennial water sources, and in areas where ground water is at a shallow depth. Much of the more mesic riparian habitat along the Santa Cruz River has been enhanced by discharge of treated effluent water. Such habitat would not be present today were it not for the presence of the effluent. Historically this habitat did exist along portions of the Santa Cruz River near Tucson. Much of this riparian habitat in Arizona is now lost, degraded, or highly fragmented due to various human related impacts, including ground water down-pumping.

The existing upland and riparian communities in the Tucson area are a result of a broad range of factors including elevation, topography, temperature, precipitation, geology, soil, fire, and an assortment of anthropogenic effects. A generalized but reasonably accurate vegetation map of the Tucson area was produced by Turner (1974). Detailed descriptions of the aforementioned upland and mesic riparian vegetation communities can be found in Brown 1982, Minckley and Brown 1982, and Turner and Brown 1982.

Included in the pilot study area are desert riparian scrub communities (also known as xeroriparian habitat) composed largely of species from adjacent uplands. These are found along normally dry washes. There is no permanent flow in these washes; instead, flow is intermittent based on seasonal rainfall as well as strength and duration of individual storms. Runoff from the surrounding uplands increases the available water in and adjacent to the washes. This permits growth of plant species not found in the

surrounding open desertscrub and because of the added moisture allows plants also found on upland sites to grow more luxuriantly. Desert riparian scrub species are generally considered facultative riparian species. Facultative species can be observed as dominant vegetation in uplands as often as in desert riparian scrub habitats. Vegetation within each of the pilot study areas is described below.

Pilot Site 1: Brown Mountain SE ¼

Upland habitat was scrub grassland or semidesert grassland (143.155 = Mixed scrub-mixed grass association) and Sonoran Desertscrub, Lower Colorado River Valley Subdivision (154.111) or ecotonal between the two (See Appendix C). Dominant perennial species included *Larrea tridentata*, *Ambrosia deltoidea* and locally *A. dumosa*, *Acacia constricta*, *Prosopis velutina*, *Atriplex canscens*, *Isocoma tenuisecta*, and mixed grasses (in alphabetical order: *Andropogon barbinoidis*, *Aristida* sp., *Chloris virgata*, *Eragrostis* sp. [incl. *E. lehmanniana*], *Erioneuron pulchellum*, *Muhlenbergia porteri*, *Pappophorum mucronulatum*, *Sporobolus* cf. *cryptandrus*, and *Trichachne californica*). *Aristida* sp., *Erioneuron pulchellum*, and *Muhlenbergia porteri* were the most common. Cacti present included mainly *Opuntia fulgida* and also *Ferrocatus wislizenii*, and *Opuntia phaecantha*. *Carnegiea gigantea* was occasionally encountered.

Desert riparian scrub habitat in this area was dominated by *Acacia constricta*, *Prosopis velutina*, *Atriplex canescens*, *Lycium* sp., and mixed grasses. The most common grasses were *Pappophorum mucronulatum*, *Andropogon barbinoidis*, and *Chloris virgata*. Also present was *Cercidium floridum*. *Ambrosia ambrosioides* was found along the larger wash channels.

In some areas of Pilot Study Area 1, it was very difficult to distinguish between upland and riparian habitat because of the braided nature of the washes and the fact that the area seems to be prone to sheet flooding. Where upland habitat was distinct it was clearly characterized as creosote bush dominated desertscrub. The nature of the valley bottom's soil contained a high degree of silts, and here creosote bush was dominant. The more sandy and gravelly sites (usually associated with the wash complex) included *Amborsia deltoidea* and/or *A. dumosa*. *Atriplex* was locally abundant and mostly associated with the riparian habitat.

Pilot Study Area 2: Jaynes NE ¼ and NW ¼ and Ruelas SE ¼ and SW ¼

Here desert riparian scrub was dominated by *Cercidium microphyllum* and *C. floridum*, *Olneya tesota*, *Acacia constricta* and *A. greggii*, *Ambrosia ambrosioides*, *Hymenoclea salsola*, *Celtis pallida*, *Lycium* cf. *andersonii*, and other less common species (See Appendices D & E). The upland community was a "Mixed shrub-*Cercidium microphyllum-Olneya tesota*-mixed scrub association (154.127). *Ambrosia deltoidea* was the most common subshrub and *Larrea tridentata* the most common shrub. Saguaro (*Carnegiea gigantea*) was common and locally abundant throughout. Other species of cacti that were present included *Opuntia acanthocarpa*, *O. fulgida*, *O. phaecantha*, *Ferrocactus wislizenii*, *Echinocactus engelmannii*, and *Mammillaria microcarpa*. In some places where the washes formed a braided complex it was often difficult to ascertain where the upland and desert riparian scrub habitat began and ended.

Hymenoclea salsola was prevalent and often co-dominant in these difficult to define areas of the alluvial fan.

Pilot Study Area 3: Tucson Southeast NE ¼

In this area desert riparian scrub was dominated by *Prosopis glandulosa*, *Acacia constricta*, and locally *Hilaria mutica* (See Appendix E). Other common species present along the washes included *Atriplex canescens*, *Lycium* cf. *andersonii*, and *Larrea tridentata*. In some areas *Atriplex canescens* appeared co-dominant. *Pennisetum ciliare* was present and locally abundant.

Adjacent upland vegetation was dominated by *Larrea tridentata* and *Prosopis glandulosa* (154.119) with locally abundant and sometimes co-dominant *Zinnia acerosa* and *Tiquilia canescens*. Other species identified in the uplands included *Cercidium microphyllum* (local), *Acacia constricta*, *Psilostrophe cooperi*, *Opuntia fulgida*, *O. versicolor*, *O. phaeacantha*, *Ferrocactus wislizenii*, *Fouquieria splendens*, *Muhlenbergia porteri*, *Erioneuron pulchellum*, and *Aristida* sp. Turner (1974) mapped the area as Sonoran Desert, Creosotebush series with a woody phase of desert grassland fingering into the area along the washes in the area of the fairgrounds and racetrack.

In comparison with the other existing mapping projects, we classified the vegetation community by dominant species at the Series or Association level. The Pima County's Riparian Habitat Mapping project classified vegetation by volume, regardless of species composition. The GAP project classified vegetation by species, however,

significant errors have been found. For example, in Pilot Study Area 2 (Jaynes NE ¼ and NW ¼ and Ruelas SE ¼ and SW ¼), GAP showed only 1 riparian area, the Santa Cruz River. GAP classified the vegetation as Mogollon Deciduous Swampforest (Mixed Broadleaf).

This is incorrect, as this type of vegetation does not exist in Pima County. Our fieldwork classified the area as Cottonwood-Willow Series (224.53) of Sonoran riparian deciduous forest and woodland. However, this was based on working from 1:400 scale maps, considerable fieldwork, and extensive knowledge of the area. For the Pima County inventory part of this project we will work from 1:24,000 aerial photos with minimal fieldwork. Classifying vegetation at the Series/Association level will be impractical, if not impossible, at this scale.

Comprehensive Mapping Protocol

The comprehensive riparian inventory for Pima County (excluding already protected lands and lands owned by the Tohono O'odham Nation) will be a combination of existing map data and original work resulting from this pilot study. Results of the pilot study identified 2 useful existing data sets, the Pima County Riparian Habitat Mapping project and AGFD's perennial riparian database. Both data sets identify lateral boundaries of the vegetation reasonably well and will be used in the countywide inventory. In areas where these 2 data sets overlap, the Pima riparian inventory will over ride the AGFD perennial riparian database. We will combine these maps with other existing mapping projects that were conducted for specific areas, such as the Cienega Creek map, Santa Cruz River (portions) map, and the Town of Oro Valley's Sensitive Land Ordinance

(Harris Environmental Group 2000), where vegetation communities were described using the BLP system.

Maps will then be generated at 1:24,000 map scale containing the USGS digital ortho-photo quarter quadrangles, township/range/section lines, quadrangle boundary, lands currently identified as inside existing public reserves, based on the Pima County ownership layer and polygon boundaries from the Pima County riparian and AGFD perennial streams riparian inventories.

Using overlays, we will delineate existing riparian areas that have not been previously identified in our source map database. We will describe the vegetation communities to the biome level, using the BLP (1979) system. We will field check areas where an accurate vegetative description is not possible. The riparian vegetation will be entered in a process similar to the pilot study. The only variation will be to register the maps to the quadrangle boundary instead of the township/range/section layer.

We will present the information to the Sonoran Desert Conservation Plan's Scientific and Technical Advisory Team (STAT) for review and discussion. An important biome community that is associated with many special status species is the Sonoran riparian and oasis forests (224.5), also known as Sonoran riparian deciduous forest and woodland (Brown, Lowe, and Pase 1979, Minkley and Brown 1982). To the extent possible, we will further classify these riparian areas (with input from the STAT) to the Series or Association level. As necessary, we will visit areas unfamiliar to members of the STAT and the project team to describe the vegetation community.

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APPENDICES

1. GAP Data for Jaynes Quadrangle—North Half
2. Gap Data for Ruelas Canyon Quadrangle—South Half
3. SDCP Riparian Vegetation for Brown Mountain Quadrangle—South Half
4. SDCP Riparian Vegetation for Ruelas Canyon Quadrangle—South Half
5. SDCP Riparian Vegetation for Jaynes Quadrangle—North Half
6. SDCP Riparian Vegetation for Tucson SE Quadrangle—North Half

Legend

- Magollon Deciduous Swampforest (Mixed Broadleaf)
- Magollon Deciduous Swampforest (Cottonwood—Willow)
- Sonoran Riparian and Oasis Forest (Cottonwood—Willow)
- Sonoran Deciduous Swamp and Riparian Scrub (Mixed Scrub)
- Sonoran Interior Marshland (Cattail)
- Playa
- Quadrangle Boundary
- Township/Range/Section Boundary

Coordinate Reference:
Projection System UTM, Zone 12
Units Meters, North American Datum 1927

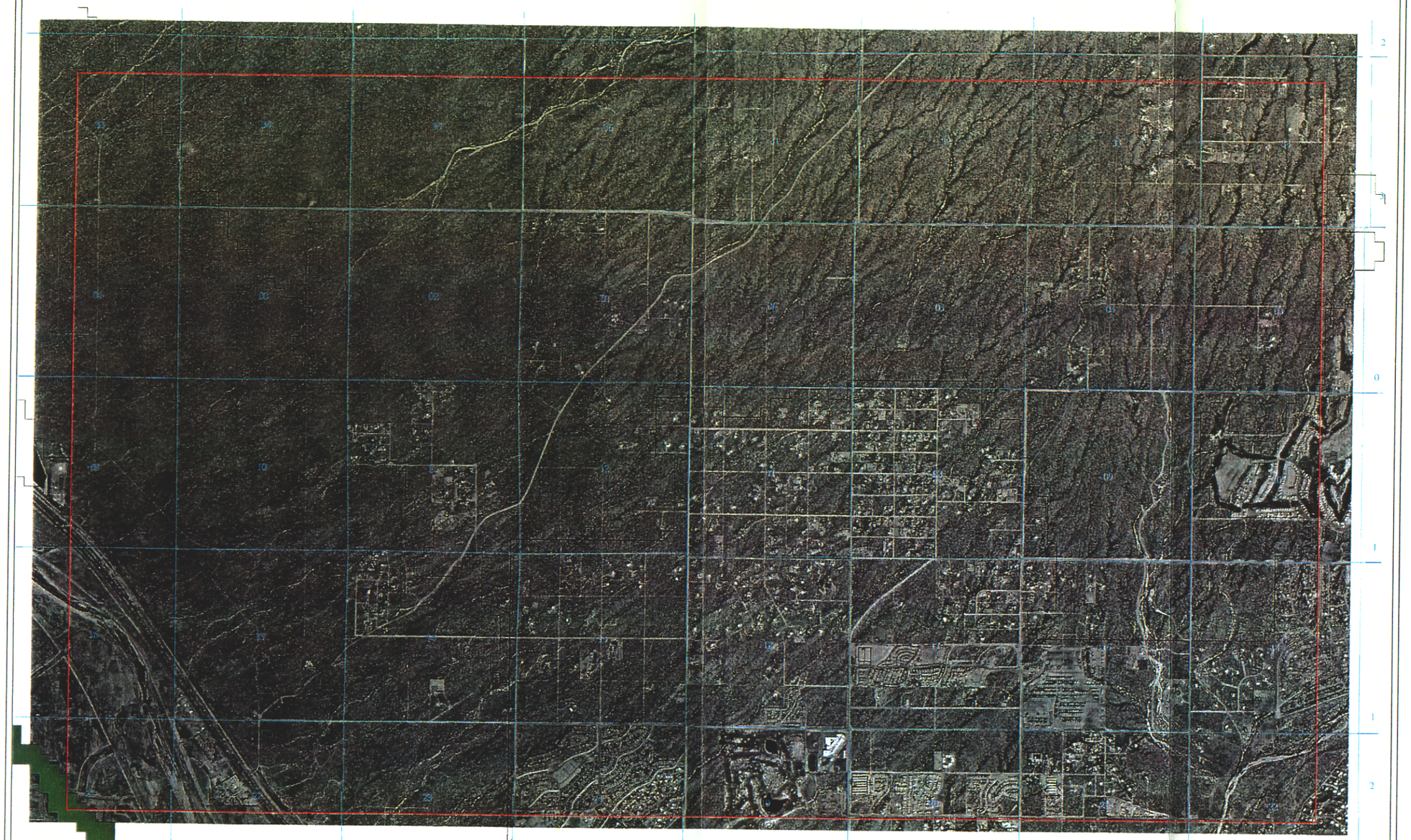
0 5000 Feet

0 .5 1 Mile

GAP Data for JAYNES QUADRANGLE –North Half
SDCP Riparian Mapping Pilot Project
April 19, 2000

DAMES & MOORE

APPENDIX 1



Legend

- Mogollon Deciduous Swampforest (Mixed Broadleaf)
- Mogollon Deciduous Swampforest (Cottonwood--Willow)
- Sonoran Riparian and Oasis Forest (Cottonwood--Willow)
- Sonoran Deciduous Swamp and Riparian Scrub (Mixed Scrub)
- Sonoran Interior Marshland (Cattail)
- Playa
- Quadrangle Boundary
- Township/Range/Section Boundary

Coordinate Reference:
Projection System: UTM, Zone 12
Units Meters, North American Datum 1927

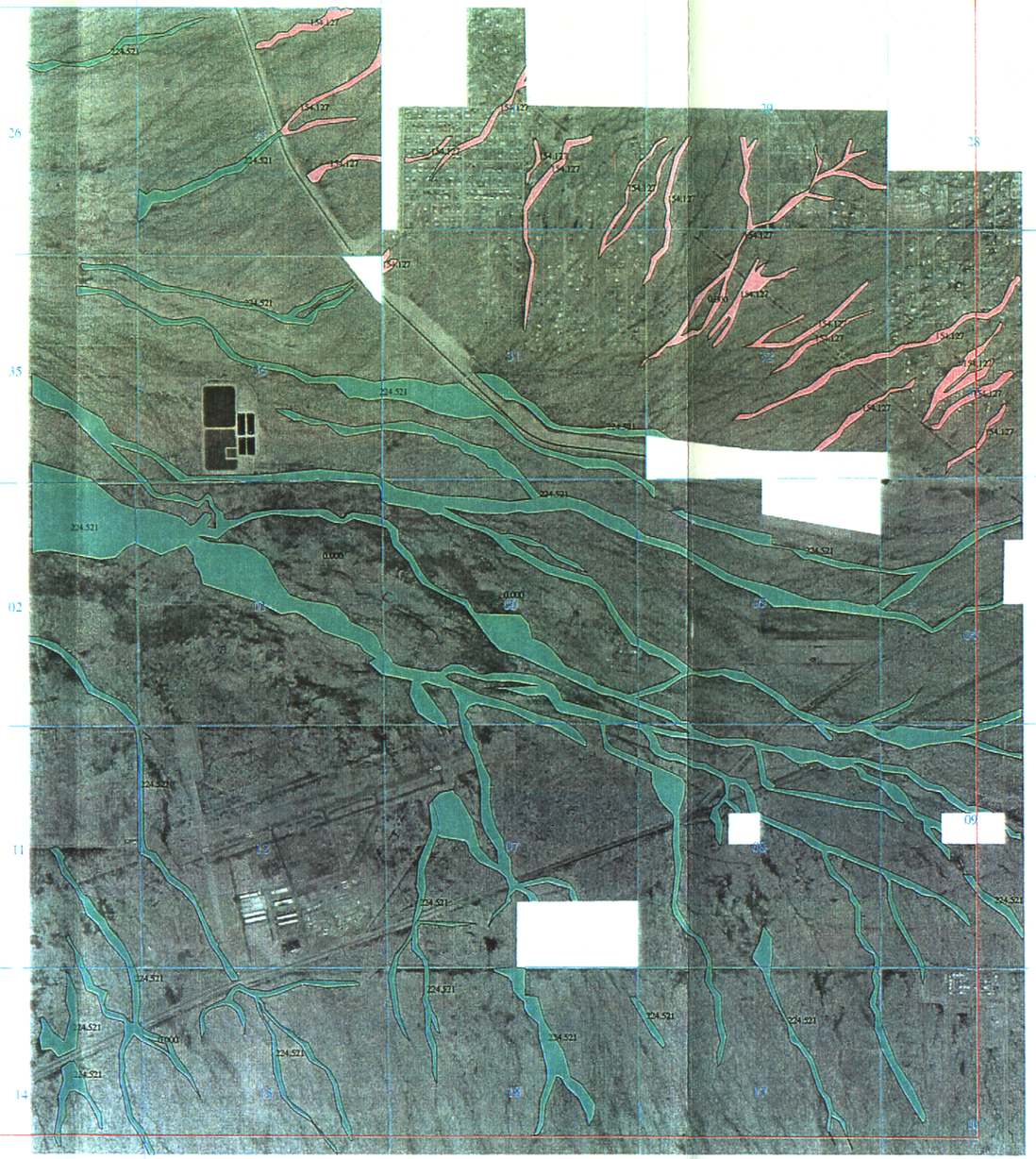
0 5000 Feet

0 .5 1 Mile

GAP Data for RUELAS CANYON QUADRANGLE –South Half
SDCP Riparian Mapping Pilot Project
April 19, 2000

DAMES & MOORE

APPENDIX 2



Legend

- 154.110 Creosote-Bursage ("Lower Colorado Valley") Series
- 154.118 Cercidium spp. -Olneya tesota riparian Association
- 154.119 Cercidium floridum -Prosopis spp. riparian Association
- 154.120 Paloverde-Mixed Cacti ("Arizona Uplands") Series
- 154.127 Mixed Shrub-Cercidium microphyllum-Olneya tesota-mixed scrub Association
- 154.128 Mixed Shrub-Cercidium microphyllum-Chilopsis linearis-mixed scrub Associ
- 224.521 Prosopis juliflora velutina Association
- 224.530 Cottonwood-Willow Series

Quadrangle Boundary
Township/Range/Section Boundary

Coordinate Reference:
Projection System UTM, Zone 12
Units Meters, North American Datum 1927

0 5000 Feet

0 .5 1 Mile

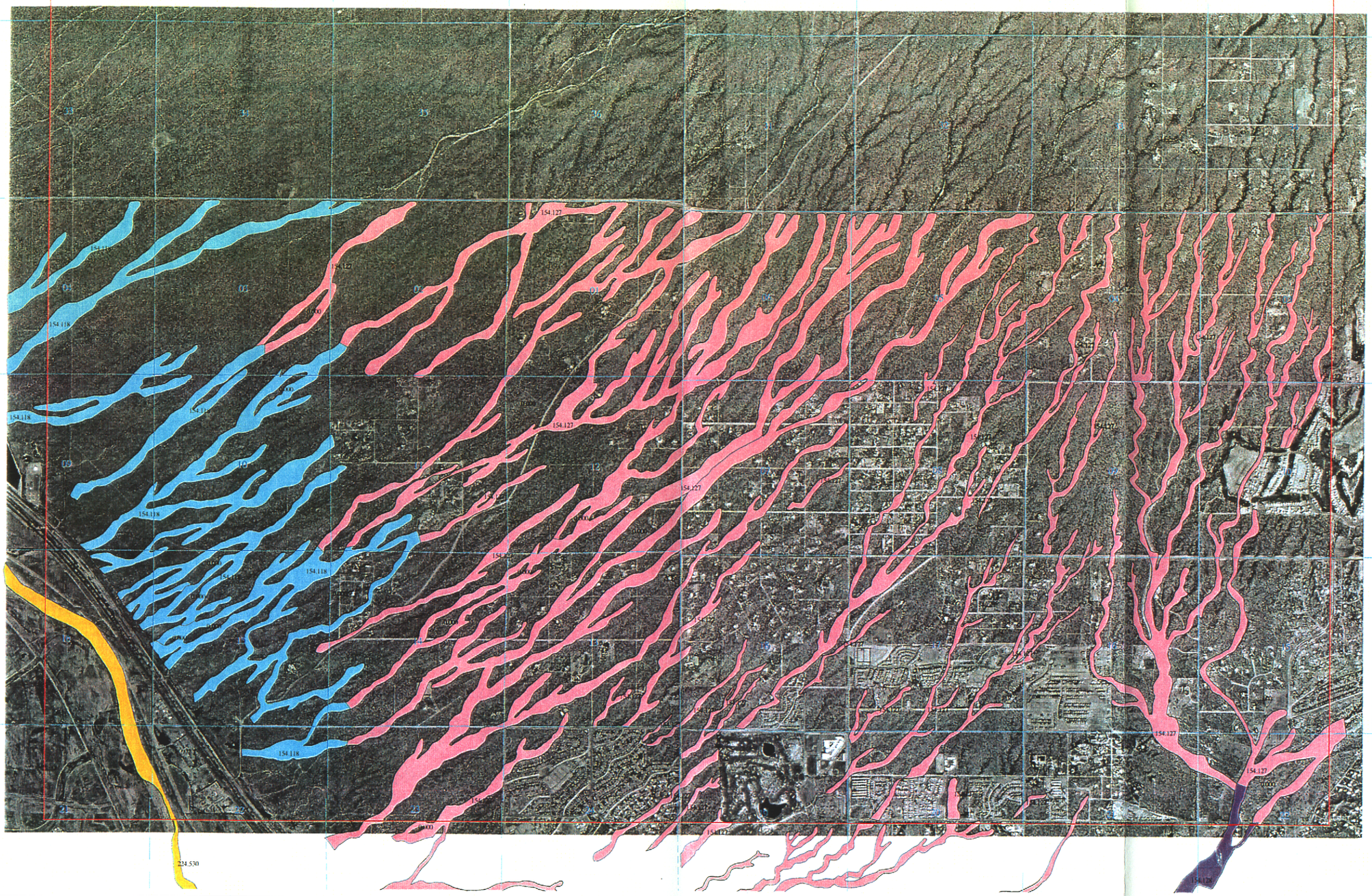
SDCP Riparian Vegetation for BROWN MOUNTAIN QUADRANGLE –South Half

SDCP Riparian Mapping Pilot Project

March 08, 2000

BARNES & MOORE

APPENDIX 3



Legend

- 154.110 Creosote-Bursage ("Lower Colorado Valley") Series
- 154.118 Cercidium spp. –Olneya tesota riparian Association
- 154.119 Cercidium floridum –Prosopis spp. riparian Association
- 154.120 Paloverde-Mixed Cacti ("Arizona Uplands") Series
- 154.127 Mixed Shrub-Cercidium microphyllum-Olneya tesota-mixed scrub Association
- 154.128 Mixed Shrub-Cercidium macrophyllum-Chilopsis linearis-mixed scrub Associ
- 224.521 Prosopis juliflora velutina Association
- 224.530 Cottonwood-Willow Series

Quadrangle Boundary
Township/Range/Section Boundary

Coordinate Reference:
Projection System UTM, Zone 12
Units Meters, North American Datum 1927

0 5000 Feet

0 .5 1 Mile

SDCP Riparian Vegetation for RUELAS CANYON QUADRANGLE –South Half
SDCP Riparian Mapping Pilot Project
March 08, 2000

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APPENDIX 4

Legend

- 154.110 Creosote-Bursage ("Lower Colorado Valley") Series
- 154.118 Cercidium spp. -Olneya tesota riparian Association
- 154.119 Cercidium floridum – Prosopis spp. riparian Association
- 154.120 Paloverde-Mixed Cacti ("Arizona Uplands") Series
- 154.127 Mixed Shrub-Cercidium microphyllum-Olneya tesota-mixed scrub Association
- 154.128 Mixed Shrub-Cercidium microphyllum-Chilopsis linearis-mixed scrub Associ
- 224.521 Prosopis juliflora velutina Association
- 224.530 Cottonwood-Willow Series

Quadrangle Boundary
Township/Range/Section Boundary

Coordinate Reference:
Projection System UTM, Zone 12
Units Meters, North American Datum 1927

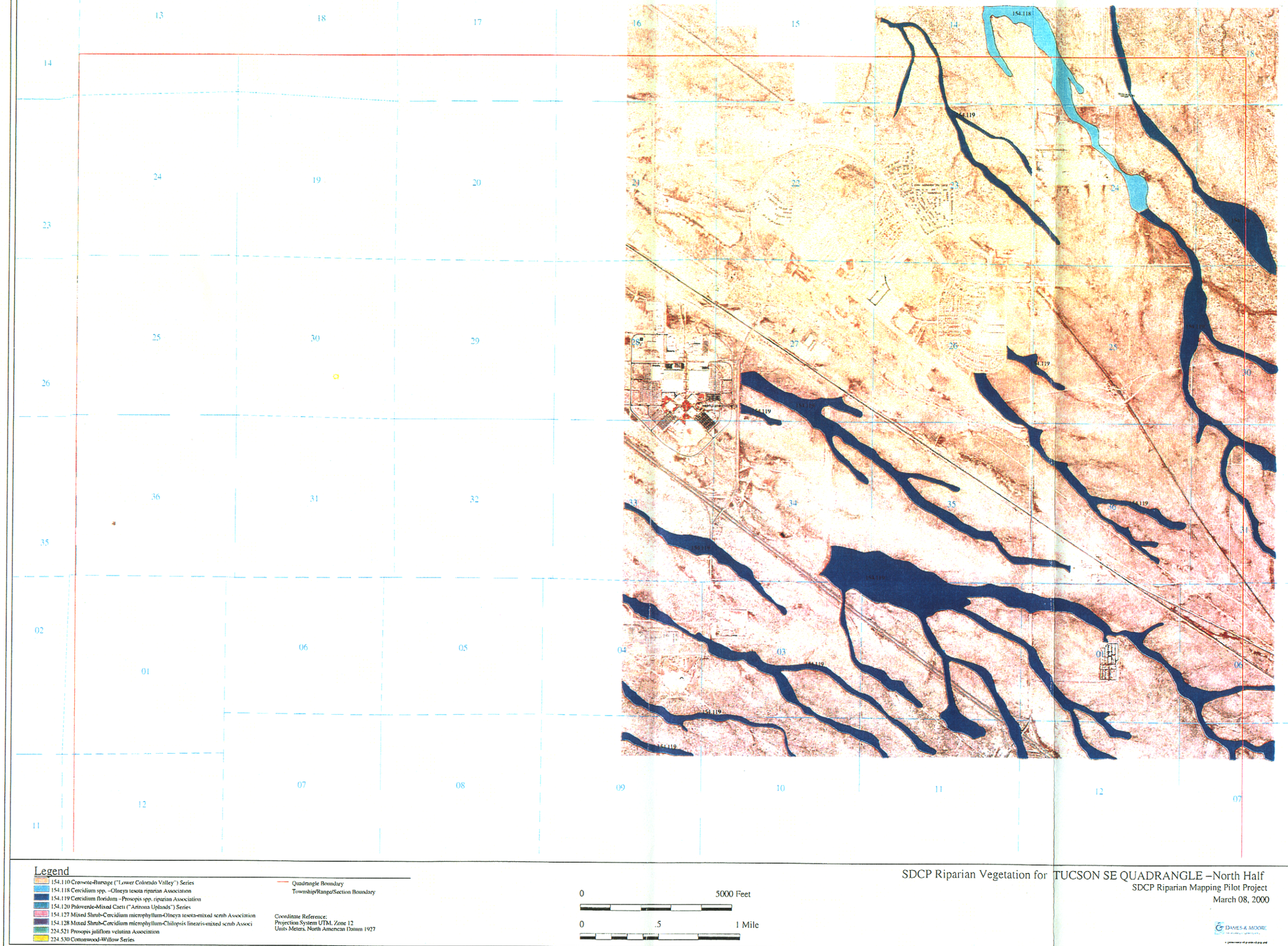
0 5000 Feet

0 .5 1 Mile

SDCP Riparian Vegetation for JAYNES QUADRANGLE –North Half
SDCP Riparian Mapping Pilot Project
March 08, 2000

DAMES & MOORE

APPENDIX 5



Legend

- 154.110 Creosote-Bursage ("Lower Colorado Valley") Series
- 154.118 Cercidium spp. –Olneya tesota riparian Association
- 154.119 Cercidium floridum – Prosopis spp. riparian Association
- 154.120 Paloverde-Mixed Cacti ("Arizona Uplands") Series
- 154.127 Mixed Shrub-Cercidium microphyllum-Olneya tesota-mixed scrub Association
- 154.128 Mixed Shrub-Cercidium microphyllum-Chilopsis linearis-mixed scrub Associ
- 224.521 Prosopis juliflora velutina Association
- 224.530 Cottonwood-Willow Series

Quadrangle Boundary
Township/Range/Section Boundary

Coordinate Reference:
Projection System UTM, Zone 12
Units Meters, North American Datum 1927

0 5000 Feet

0 .5 1 Mile

SDCP Riparian Vegetation for TUCSON SE QUADRANGLE –North Half
SDCP Riparian Mapping Pilot Project
March 08, 2000

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APPENDIX 6