DRAFT

MEMORANDUM

Date: October 19, 2000

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

From: C.H. Huckelberry
County Administrator

Re: **Draft Reserve Design Guidelines, Goals, Opportunities and Constraints**

I. Overview

In the past months we have received a number of studies drafted by the team of scientists working with Recon Consulting to develop the Multi-Species Conservation Plan, which is the biological component of the Sonoran Desert Conservation Plan. Studies by the Recon team include:

- Land Cover Data Assessment
- Biological Stress Assessment
- Review of Vulnerable Species List
- Priority Vulnerable Species: Data Compilation and Synthesis
- Priority Vulnerable Species: Habitat Data Analysis
- Identification and Evaluation of Problematic Species

In the future, we will receive studies, reports, and documents from the Recon team that cover these subject areas:

- Species Report (incorporating peer review)
- Concept Draft Environmental Impact Statement
- Habitat Suitability Modeling for Covered Species
- Adaptive Management Recommendations
- Vulnerable Species Goals
- Reserve Design Recommendations
- Adaptive Management Plan and Manual
- Drafts of the Multi-Species Conservation Plan (1-5, and final plan)
- Drafts of the Environmental Impact Statement (1-5, and final document)

The attached study entitled *Draft Reserve Design Guidelines, Goals, Opportunities, and Constraints* is presented to describe the methods that are used in order to prepare reserve design alternatives in the area of biological conservation.

In addition to summarizing the Recon report, this memorandum provides a brief history of reserve design theory, and demonstrates how the principles of biological reserve design have been extended to the other Elements of the Sonoran Desert Conservation Plan, including Cultural Resource Protection, Riparian Protection, Ranch Conservation, and Mountain Park Expansion.

II. Three Eras of Biological Reserve Design Principles

- In 1967 an influential text was published by Robert MacArthur and E.O. Wilson entitled *The Theory of Island Biogeography*. This volume was written almost as a pilot study but it launched a quarter century of discussion within the scientific community about general conservation principles.

- Dr. Reed Noss and others have developed and distilled these early ideas into a comprehensive expression of the generalizations about reserve design, and these generalizations have been adopted by the science community as a means of identifying and prioritizing land areas in need of protection.

- Most recently, the work of Dr. Michael Gilpin and others in the area of metapopulation biology shows how the field of conservation biology continues to become more sophisticated and more able to quantify the dynamic relationship of animals and their habitats as it attempts to account for complexity beyond the general principles of reserve design.

A. Island Biogeography

1. Intent to Move From Facts to Theory -- The opening lines of *The Theory of Island Biogeography* express a hope that has been nearly realized:

> "This book had it origins when, about five years ago [1962], an ecologist (MacArthur) and a taxonomist and zoogeographer (E.O. Wilson) began a dialogue about common interests in biogeography. The ideas and the language of the two specialities seemed initially so different as to cast doubt on the usefulness of the endeavor. But we had faith in the ultimate unity of population biology, and this book is the result. ... A great deal of faith in the feasibility of a general theory is still required. We do not seriously believe that the particular formulations advanced in the chapters to follow will fit for very long the exacting results of future empirical investigation. We hope instead that they will contribute to the stimulation of new forms of theoretical and empirical studies, which will lead in turn to a stronger general theory, and ... 'a tradition of mathematical work devoted to biological problems.'"

2. Islands as Laboratories for Testing Quantitative Theory -- Wilson and MacArthur tested a few theories of biogeography at the species level by studying distribution and abundance of species within the contained area of islands. Working at this reduced scale allowed them to make striking, often quantified observations about the relation of area to species richness and diversity, colonization, and dispersal.

3. Intent to Move from Narrowly Applicable Theory to Broad Theory -- The last lines of *The Theory of Island Biogeography* are dedicated to the authors' hopes that future theories will expand on their island-based work. They state: "biogeography appears to us to have developed to the extent that it can be reformulated in terms of the first principles of population ecology and genetics." This is exactly what happened as their text became a centerpiece of discussion for the next quarter century in conservation biology.

B. Protecting Islands of Habitat within Larger Landscapes

From Descriptive to Prescriptive Islands -- Based on the description of the importance of islands in *Theory of Island Biogeography*, prescriptions for core areas, refuges and reserves -- islands within larger land bases -- have been formulated by conservation biologists. Dr. Reed Noss and others have stated that: "The central component of a landscape design for conservation is the core area where human uses are greatly restricted." A number of generalizations grew out of the notion that core areas are valuable, including that: large blocks of habitat are better than small blocks; contiguous blocks are better than fragments; and interconnected blocks are better than isolated blocks. At least three approaches to reserve selection developed: (1) mapping of special elements (resources of high value); (2) protection of representative types of habitat within the conservation area; (3) protecting habitat to meet the needs of focal species. To the extent this information can be described at a fine scale and represented through geographic information system analysis, optimal reserve networks can be assembled. The combination of mathematical modeling and geographic information systems pushes conservation biology to the next level of sophistication.

C. Metapopulation Analysis

From Static Reserves to Dynamic Patches; View of the Whole Landscape -- Metapopulation theory, pioneered by Dr. Michael Gilpin, has started to displace island biogeography in conservation literature. In general, it is more dynamic than earlier versions of conservation biology, and more flexible. It promotes a tolerance for variations in local populations of an animal, if there is sufficient recolonization taking place on another patch included within the metapopulation. A text edited by Dr. Gilpin explains that what metapopulation principles could mean on the ground is a shift from traditional reserve management to "mosaic management in which reserves (patches) are combined with areas that receive varied human use." (Wiens at 60) An essay in the *Metapopulation Biology* text states that whereas the general principles of reserve design have served to justify establishing refuges and a few reserves, the realization is setting in that:

> "much of the history of refuge establishment consists simply of locating apparently healthy populations and preserving their sites. ...A more constructive approach is to use metapopulation models to rank alternative scenarios of landscape change in terms of persistence of a focal species. One may ask, for instance whether the entire removal of one large habitat patch is more detrimental to a metapopulation than reducing the areas of several patches. The theory of island biogeography inspired the rules of refuge design. The analogous contribution from metapopulation theory is predictions about the relative performance of particular species in particular fragmented landscape based on relatively simple but spatially realistic models. There are two reasons to expect the latter sorts of predictions to be more helpful than the island biogeographic rules of refuge design. First, the rules of refuge design are static. ... Second, the rules of refuge design contrast fixed general alternatives, whereas the spatially realistic metapopulation models practically force one to compare specific fragmented landscapes." (Hanski and Simberloff at p. 23)

III. Draft Reserve Design Guidelines, Goals, Opportunities and Constraints

This brief history of reserve design tells us that in the1960s E.O. Wilson and Robert MacArthur created the theoretical basis for biogeography by combining and integrating their interests in ecology and zoogeography. More recently conservation biologists have been able to extend biogeography, or move beyond its limits, through the development of geographic information system support which at its highest level incorporates dynamic, patch based approaches to reserve design and in this way captures a larger conservation potential of the landscape by not only conserving areas but making the reserve itself more viable by including habitat creating processes within the protected area. The attached report by Recon outlines the reserve design guidelines, goals, opportunities and constraints by anchoring the reserve design guidelines for the multi-species plan in the biological goals and objectives of the Sonoran Desert Conservation Plan.

A. Goals

The biological goal of the Sonoran Desert Conservation Plan, established by the Science Technical Advisory Team, is:

> To ensure 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.

Objectives that arise from this goal include:

- Promote recovery of federally listed and candidate species to the point where their continued existence is no longer at risk.
- Where feasible and appropriate, reintroduce and recover species that have been extirpated from this region.
- Maintain or improve the status of unlisted species whose existence in Pima County is vulnerable.
- Identify biological threats to the region's biodiversity posed by exotic and non-native species of plants and animals, and develop strategies to reduce these threats and avoid additional invasive exotics in the future.
- Identify compromises to ecosystem functions within target plant communities selected for their biological significance and develop strategies to mitigate them.
- Promote long-term viability for species, environments and biotic communities that have special significance to people in this region because of their aesthetic or cultural values, regional uniqueness, or economic significance.

B. Guidelines

The guidelines for biological reserve design outlined in the Recon report are inclusive of, and build upon the knowledge of, the last quarter century of conservation research. By dividing analysis into guidelines for individual species and guidelines for the reserve system as a whole, the method described captures both the traditional and progressive aspects of biological planning. Some points from the report include:

- "The reserve system guidelines that concern individual species primarily focus on metapopulation characteristics of the populations in Pima County. The ultimate goal for each of the species considered will be to provide adequate habitat under conservation management in a configuration that will ensure the long-term persistence of the population." Guidelines include:
    - comprehensive conservation of vulnerable species
    - maximum patch size containing large populations of focal vulnerable species
    - adjacency and proximity of habitat blocks
    - contiguity of habitat at the landscape level
    - connectivity of reserves with functional corridors
- Reserve guidelines for the system as a whole are achieved through protection of components that "provide the structure for conservation on a landscape scale. These guidelines are primarily concerned with diversity of species (beyond the vulnerable species list), sites with exceptional biodiversity, diversity of vegetation characteristics, and representativeness."
    - diverse representation of physical and environmental conditions
    - intact ecosystem function with few or no impacts from exotic or invasive species
    - minimum fragmentation and maximum roadlessness
- "In the context of the reserve design guidelines, we propose that Recon, the County and the STAT consider, discuss, and evaluate the following priority landscapes:
    - core reserves
    - areas of known or suspected shallow groundwater
    - stream segments with perennial flow
    - stream segments with intermittent flow
    - areas of high degree of roadlessness
    - designated critical habitat
    - high-medium potential or presence of federally endangered/threatened species
    - high-medium potential or presence of keystone, focal, target habitats
    - vacant lands in areas of low density land use designation
    - riparian habitat designations and xeroriparian extensions into preserves

- areas adjacent to existing reserve system
- land areas within proposed reserve areas
- areas identified through ecoregional planning as hotspots
- areas with high potential for successful reintroduction
- areas with relatively low levels of habitat loss and fragmentation and few roads
- areas with relatively high value habitat that are currently threatened
- areas of high species richness
- areas of high species richness outside existing reserve systems
- underrepresented priority plant communities
- gaps in conservation areas
- opportunities to maximize connectivity and minimize fragmentation
- areas needed to support minimum viable populations of each priority species
- areas providing connectivity between significant reserve areas

C. Methods of Developing the GIS-based Reserve Design

Pages 12 through 26 of the report discuss how four overlapping and complementary perspectives will be analyzed to create reserve design alternatives for the community to consider:

- vegetation associations and rare ecosystem elements
- vulnerable species
- biological diversity
- integration of values other than biological resources

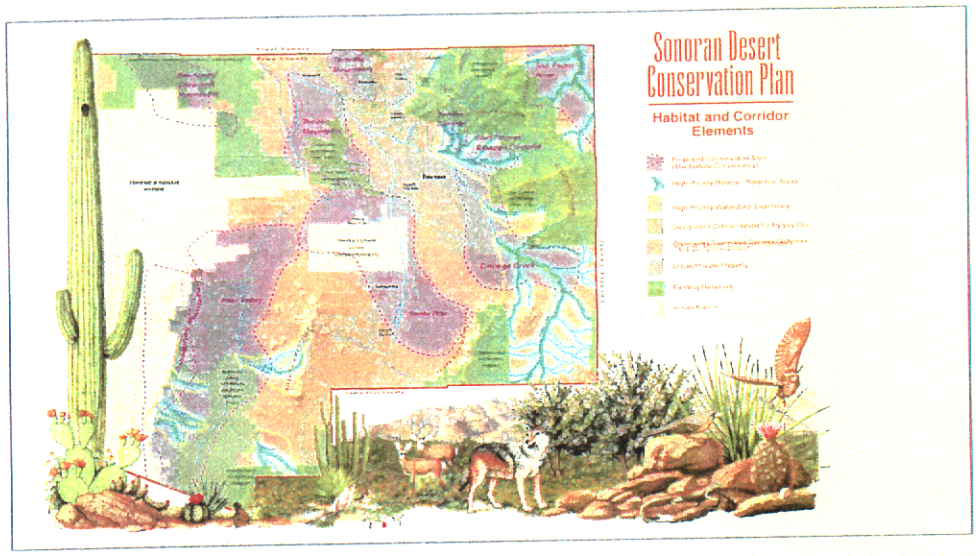
1. Vegetation associations and rare ecosystem elements – Pages 12 through 17 discuss the mechanics of assessing the conservation coverage of vegetation communities. Each vegetation type is described in terms of its total acreage, and the percent that falls within an area that is:

(1) a core reserve;
(2) a potential reserve expansion;
(3) a potential reserve connection or buffer; or
(4) outside of reserves.

The need to protect a percent of certain vegetation communities frames the discussion within the community about where best to achieve the science based goals within the landscape.

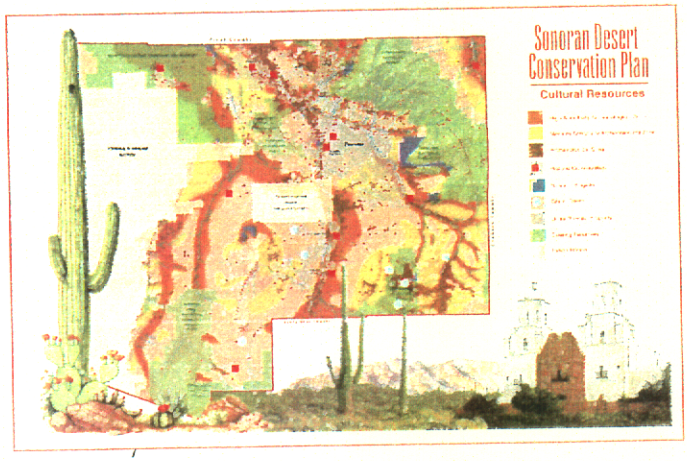
2. Vulnerable species – Pages 17 through 20 outline the method that will be used to determine the location and amount of habitat for priority vulnerable species. After each species known and potential habitat is assessed, an analysis of the conservation coverage of that habitat is performed. Again, opportunities about where to meet the habitat needs of the species will take place in the community, once the science based analysis for the priority vulnerable species of concern is completed. A peer review process is currently taking place.

3. Biological diversity – Pages 20 through 25 cover the topic of how species richness and diversity hotspots are identified and mapped. The ecoregional planning effort of The Nature Conservancy serves as a foundation for this analysis. Shown in purple on the draft map of the Habitat and Corridors Element of the draft *Preliminary Sonoran Desert Conservation Plan*, this data layer is one of several significant layers that will ultimately make up the biological element.

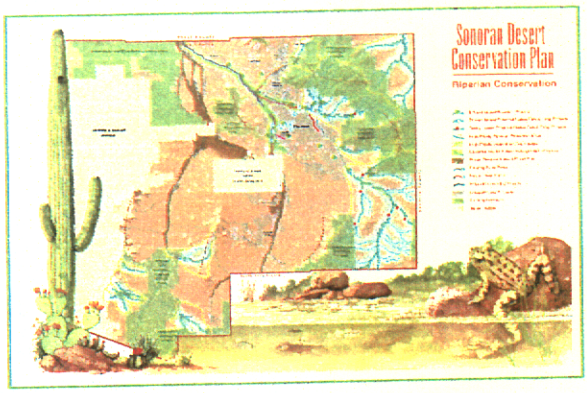


4. Integration of values other than biological resources – Reserve design alternatives are shaped by the biological resource base and constraints to conservation opportunities. The Sonoran Desert Conservation Plan expands the traditional analysis of resources to be protected by including Elements beyond habitat and corridors. Riparian protection, cultural resource protection, mountain park protection and ranch conservation all act in a complementary manner to support particular biological objectives or broad landscape goals of the Sonoran Desert Conservation Plan. The basic reserve potential of each of these Elements has been assessed and now Pima County seeks comments and review of these proposed reserve possibilities.

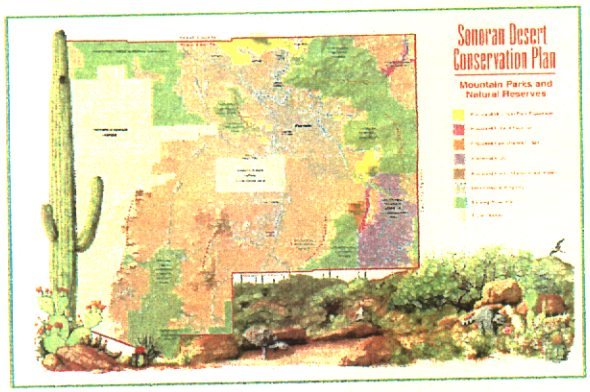
- **Cultural Resource Protection**:



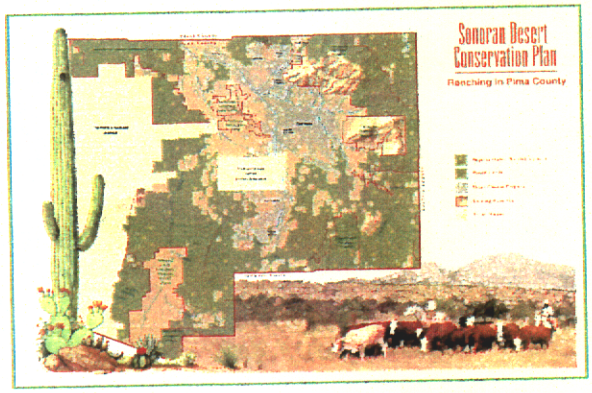
- **Riparian Protection:**



- **Mountain Park Expansion:**



- **Ranch Conservation:**



IV. Conclusion

The attached report describes a method of assessing reserve design alternatives. The Recon approach encompasses the fundamental principles of conservation biology in addition to the most progressive methods and theories in conservation biology today. The comprehensive inclusion of all six resource planning Elements of the larger Sonoran Desert Conservation Plan will strengthen the over all reserve and provide a wider range of effective options and alternatives.

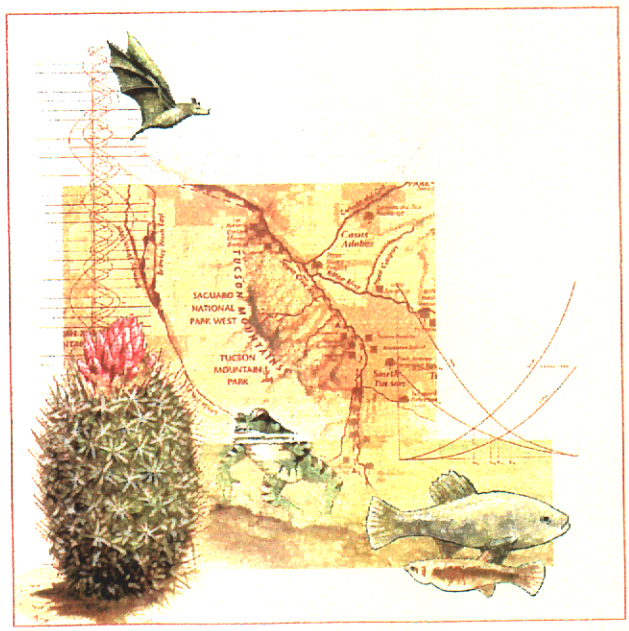
The method described in the Recon study will be reflected in future reports that map out reserve design alternatives more specifically. Preliminary conclusions of the attached report are:

- "The existing core reserves provide a strong framework for the development of a reserve system that can address the goals and objectives of the Sonoran Desert Conservation Plan and the Endangered Species Act."

- "In the Apache Highlands (primarily eastern Pima County), just under 20 percent of the land area is within core reserves.

The reserve design recommendations will be finalized and forwarded when riparian mapping is completed, peer review of species accounts is finalized, and special element mapping is improved. All of these efforts are underway and more defined, mapped-based reserve recommendations for the multi-species component of the Sonoran Desert Conservation Plan will be forthcoming in the next months.

Attachment



DRAFT
Draft Reserve Design:
Guidelines, Goals, Opportunities, and Constraints

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I. Introduction and Background

This draft document has been developed for the purpose of identifying the intentions and mechanisms for designing a reserve system for the Biological Element of the Sonoran Desert Conservation Plan (SDCP). Prepared and compiled by RECON, it is a reflection of the work effort undertaken during the last six months in working with Pima County staff, the Science Technical Advisory Team (STAT), and other community experts. It is presented to the STAT for review, as a preliminary look at the information that RECON proposes to consider for the reserve design and the mechanisms of evaluating and prioritizing that information.

The documents and work products prepared by the RECON team as part of our initial work effort serve as the basis for this document and future efforts. They are summarized as follows:

1. **Land Cover Data Assessment**. This task established the vegetation and land cover data layer from available resources, incorporated a standard classification system, developed a system for incorporating new data, and prioritized mapping needs and improvements. The land cover map serves as the basis for RECON's geographic information system (GIS) mapping analysis of biological resources.

2. **Biological Stress Assessment**. This assessment described key potential threats and stressors to biological resources, particularly the vulnerable species in Pima County. Discussed by watershed subareas, it identified species and habitats of particular concern, management and problematic species issues, and conservation opportunities. Threats and stressors were evaluated in the context of the level of protection offered by existing levels of conservation and land management strategies to facilitate use of the data in subsequent GIS analyses.

3. **Review of Vulnerable Species List**. RECON reviewed and evaluated the list of vulnerable species that was established by the STAT and, with the STAT's input and review, prioritized 56 species for further consideration and evaluation. These 56 species are those species considered most likely to meet the criteria and need for coverage by the SDCP and Habitat Conservation Plan (HCP). The distributions of these species within Pima County will be one of the primary focuses used to evaluate existing conservation coverage and to develop potential alternative reserve configurations.

4. **Priority Vulnerable Species: Data Compilation and Synthesis**. This report and associated maps, currently under review by STAT and other species-specific experts, constitute the species accounts for the 56 priority vulnerable species. The accounts provide a comprehensive compilation of the existing biological and management information known for each species. The associated range and distribution maps reflect known locations and potential habitat. As part of the review and refinement of this information, quantitative and qualitative goals for each species will be established to the extent possible, given the current scientific knowledge base.

5. **Priority Vulnerable Species: Habitat Data Analysis**. The analysis of the information and data presented in the species accounts resulted in the development of a species-environment matrix with a ranking for each of numerous habitat characteristics for each species. The matrix is being used to develop maps of the distribution of potential habitat for each species using GIS modeling techniques. This information will serve as a companion document to the species accounts and allow RECON and the STAT to refine, correct, and revise assumptions on habitat preferences and species distribution. As an interim product, a

composite map of the high, medium, or low potential habitat value for all of the 56 species has been prepared. It reflects the degree of biodiversity potential for lands within Pima County.

6. **Identification and Evaluation of Problematic Species.** The RECON team evaluated the list of problematic species that was established by the STAT and, with the STAT's input and review, identified those with the most widespread impact or level of concern. Each ecosystem represented in Pima County is evaluated in terms of the presence and impacts of problematic species, priority vulnerable species that are affected, and management concerns and considerations on a systems level. Information gathered for the Biological Stress Assessment and the species accounts is being incorporated. This study, currently in process, will provide the basis for assessing the level of intactness of existing and proposed reserves in Pima County and assist in the development of an Adaptive Management Plan for the SDCP.

In order to begin the process of designing a reserve system, these documents and analytical tools and the information and patterns they have revealed are being reviewed in the context of the goals and guidelines established for the Biological Element of the SDCP.

II. Goals

The following information has been presented to the STAT and is currently under review and discussion.

In accordance with our scope of work, RECON is working with STAT to develop detailed reserve design guidelines for use in the GIS-based reserve design. It is intended that the guidelines also address corridors for selected focal species.

The overall goals and objectives that have already been established for the SDCP provide the framework through which to develop a set of reserves for the conservation of biological resources within Pima County and are as follows:

> The biological goal of the Sonoran Desert Conservation Plan is to ensure 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.
>
> Inherent within this broad goal are several objectives:
>
> - Promote recovery of federally listed and candidate species to the point where their continued existence is no longer at risk.
> - Where feasible and appropriate, reintroduce and recover species that have been extirpated from this region.
> - Maintain or improve the status of unlisted species whose existence in Pima County is vulnerable.
> - Identify biological threats to the region's biodiversity posed by exotic and native species of plants and animals, and develop strategies to reduce these threats and avoid additional invasive exotics in the future.
> - Identify compromises to ecosystem functions within target plant communities selected for their biological significance and develop strategies to mitigate them.
> - Promote long-term viability for species, environments and biotic communities that have special significance to people in this region because of their aesthetic or cultural values, regional uniqueness, or economic significance.
>
> In the broadest sense, this conservation element of the SDCP will be the framework for integrating biological conservation into Pima County's development process. If the plan effectively addresses the objectives above, it will also lead to Section 10 Permits under the Endangered Species Act, for those species where it is justified by scientific evidence and by the implementation of a defensible habitat conservation plan.

These objectives establish a framework against which the reserve design guidelines for the SDCP must be measured and considered. In addition, the STAT has provided guidelines with respect to the conservation of riparian resources (Appendix A) and the criteria for inclusion of species in the Endangered Species Act Section 10(a) process (Appendix B).

III. Preliminary Reserve Design Guidelines

The conservation guidelines used for the *Southern California Coastal Sage Scrub Natural Community Conservation Planning* effort provide basic procedures for use in the GIS-based reserve design. These guidelines outline the general principles of conservation biology. The guidelines provided here focus on the identification of rules that fit the actual biological, social, political, and economic needs and constraints of Pima County.

These guidelines are mixed in their focus between those that concern individual species and those that concern ecosystems as a whole or more general considerations.

A. Reserve Guidelines for Individual Species

The reserve system guidelines that concern individual species primarily focus on metapopulation characteristics of the populations in Pima County. The ultimate goal for each of the species considered will be to provide adequate habitat under conservation management in a configuration that will ensure the long-term persistence of the population. Each of these guidelines is discussed below with reference to how it will be incorporated into the reserve design process used to develop the SDCP.

Comprehensive Conservation of Vulnerable Species. Conserve federally listed and other vulnerable species throughout Pima County. Species that are well distributed across their native ranges are less susceptible to extinction than are species confined to small portions of their ranges (species distributions relative to plan area and heterogeneity).

The 56 species on the vulnerable species list represent the first step in application of this guideline. This list stands on its own as species meeting the criteria used in its development, which emphasized conservation need and feasibility. Additional species may be added to this list, to improve the coverage of the full range of species diversity in the county. The ultimate intent will be to provide coverage of all species in the county either through directed analysis and conservation or as a result of the umbrella characteristics of the focal species.

Maximum "Patch" Size. Larger reserves are better than small reserves. Large blocks of habitat (patches) containing large populations of the focal vulnerable species are superior to small patches containing small populations.

Assessment of the adequacy of patch size concept, along with adjacency/proximity and contiguousness, requires some level of metapopulation analysis for each of the species considered. The role and adequacy of individual patches of habitat will depend upon how interconnected they are with other patches. The entire interconnected system must meet some specified goal in terms of numbers of individuals or acres of habitat considered to be sufficient to provide for long-term persistence. This goal should be developed for each of the species in the analysis (the vulnerable species plus additional umbrella, flagship, or keystone species as appropriate).

Adjacency/Proximity. Blocks of habitat that are adjacent to or close to one another are better than blocks of habitat far apart, especially when separated from urbanized or otherwise fragmented lands. Reserve areas are better if they are in close proximity to high quality/high functioning ecosystems.

For individual species, the concept of adjacency or proximity is particularly important where individual habitat patches are fragmented or relatively isolated. Proximity is a function of the movement capabilities of the species, dispersal distances, and the facility with which dispersal or movement can occur across the intervening landscape. "Near" for a bird is not "near" for a snail. Species-specific movement capabilities will be a key component in this evaluation.

Proximity and adjacency are also important ecosystem concepts, with respect to the long-term balance between extinction and recolonization probabilities, factors in the maintenance of individual populations as well as over biodiversity.

Contiguity. Keep habitat contiguous. Unfragmented habitat that occurs in contiguous blocks is preferable to habitat that is fragmented or isolated by urban lands. Contiguous reserve areas facilitate movement of wildlife and support greater biodiversity.

Specifically, this involves the maintenance of landscapes interconnected by continuous vegetation communities. This concept overlaps with connectivity.

Connectivity. Link reserves with corridors. Interconnected blocks of habitat serve conservation purposes better than do isolated blocks of habitat. Corridors function better when the habitat within then resembles habitat that is preferred by species potentially using them.

Functionally, connections may be through areas that are not preferred habitat for species,but which allow for movement or dispersal. For example, for some species non-native grasslands will provide connectivity between patches of scrub habitat.

B. Reserve Guidelines for the Reserve System as a Whole

Reserve design considerations for other than focal species provide the structure for conservation on a landscape scale. These guidelines are primarily concerned with diversity of species (beyond the vulnerable species list), sites with exceptional biodiversity (The Nature Conservancy's [TNC] "biodiversity hot spots"), diversity of vegetation characteristics, and representativeness.

Diversity. Reserves should be diverse. The reserve system and its various landscapes should contain a diverse representation of physical and environmental conditions, thereby addressing the needs of the diverse array of vulnerable species considered.

The TNC report *An Ecological Analysis of Conservation Priorities in the Sonoran Desert Ecoregion* (Marshall et al. 2000) provides an analysis of biodiversity that incorporates Pima County. Additional measures of biodiversity appropriate to the resources of Pima County will be developed from existing species and vegetation community and ecosystem element data.

Intactness. Conservation areas that are not under siege from invasive species have a higher level of ecosystem function. Reserve areas should have few or no impacts from exotic or invasive species.

The report being developed on problematic species in Pima County will provide data to augment the information assembled in the Biological Stress Assessment issued in March, 2000. The information from both of these sources is being assembled into a GIS data layer depicting the distribution of invasive and exotic species of management concern.

Minimum of Fragmentation/Maximum of Roadlessness. Protect reserves from encroachment. Blocks of conserved area that are roadless or otherwise inaccessible to human disturbance serve to better conserve target species than do accessible conserved area blocks. Roadless areas of lower conservation value that surround areas of higher value can fulfill the role of effective buffers by offering spatial protection.

Several versions of road density data layers have been developed by the County and will be modified to provide appropriate measures of roads and levels of fragmentation to be used in the reserve design process.

Priority. Establish priority areas that identify the most vulnerable components of the reserve system design for initial implementation and management actions. Prioritize vegetation community types that are represented by a disproportionately high number of vulnerable species (areas with high "species richness"). Consider areas identified by prior or concurrent regionwide studies as having regional significance (e.g., TNC's recently released ecoregion plan).

Opportunity. In developing reserve system alternatives, look for opportunities to build on the existing reserve system, the current interest in establishing new public reserves, and the opportunities for reclassification of State Trust lands. Identify areas with vegetation community restoration needs where conditions are conducive to supporting self-sustaining ecosystems. Identify areas with high potential for successful introduction or reintroduction of vulnerable or extirpated species. Identify areas with management practices that could be altered to increase biological value and ecosystem function.

Reality. The reserve design process should take into consideration land use constraints such as existing and proposed land uses, land values, and parcel size as well as the mandates and capabilities of the existing land managers in Pima County.

These will all be incorporated into the analysis through the development of appropriate data layers. The distribution of existing and proposed land uses is to a large extent embodied in the current conservation status data set. Parcel data as well as land cost data are available, although the appropriate means to incorporate these data in the analysis remains to be developed.

IV. Criteria for Identifying and Prioritizing Reserve Areas

Working with the STAT, the RECON team will further refine and develop the reserve guidelines in a manner that facilitates their incorporation into the GIS decision modeling process by assigning values to classes of information contained in the data layers that comprise reserve design considerations. As in Clark County, RECON will continue to emphasize ecosystem-based planning that folds in the concepts of flagship, umbrella, and keystone species to provide the broadest base for individual species coverage.

Following the review and refinement of the species data synthesis phase, the RECON team will make reserve design recommendations based on the best available scientific information for all remaining focal species, special vegetation communities, species associations, and plant communities. Reserve boundaries will maximize, where possible, areas with high species richness and rare species and vegetation communities and minimize areas that are highly disturbed, are easily accessible, and contain high concentrations of pest species.

Reserve design will take into consideration the concepts of maximizing patch size and connectivity and minimizing fragmentation. Reserve design and management recommendations will be based upon estimators of long-term population viability, focal species ecology and behavior, community ecology, and other relevant biological considerations.

Reserve alternatives will address the goals and objectives of the plan, integrating conservation of focal species, special vegetation communities, plant associations, and plant communities according to the priority ranking described above. Alternatives will clearly indicate priority areas that identify the most vulnerable components of the reserve design for quick action. Reserve design alternatives will not be developed in a planning vacuum. It is important that alternative designs be implementable as well as provide for the conservation of the species. Reserve management recommendations will take into consideration land use constraints such as existing and proposed land use, land value, and parcel size as well as the mandates and capabilities of the existing land managers. GIS coverages of reserve design alternatives will be documented and delivered to the decision support model team for incorporation into their optimization modeling for final reserve design.

As an interim step, certain priorities have already been identified that are an appropriate focus for further discussion. These priorities are embodied in different attributes that can be weighted and folded into the GIS analysis, along with the species' habitat-specific data. In the context of the final reserve design guidelines, we propose that RECON, the County, and the STAT consider, discuss, and evaluate the following priority landscapes:

Priority Landscape	Status/Method of Analysis
Core Reserves. Areas that currently exist within a public or private reserve	Categories 1, 2, and 3b from Conservation Status data set
Areas of known or suspected shallow groundwater (and a given proximity)	Existing data set
Stream segments with perennial flow (and a given proximity)	Existing data set
Stream segments with intermittent flow	Existing data set
Areas of a high degree of roadlessness	Evaluate appropriate measure of road density or occurrence

Priority Landscape	Status/Method of Analysis
Designated Critical Habitat	Digitize critical habitat boundaries
High-medium potential or presence of federally endangered or threatened species	Detailed species habitat analysis and modeling
High-medium potential or presence of keystone/focal/target habitats	Detailed species habitat analysis and modeling
Vacant lands in areas of low-density land use designation	Existing data set
Riparian habitat designations and xeroriparian extensions into preserves	In process (Harris Environmental)
Areas adjacent to existing reserve system	Conservation Status data set
Land areas within proposed reserve areas	Conservation Status data set
Areas identified by TNC as having regional significance for conservation ("hot spots")	Obtain digital file from TNC
Areas with high potential for ecological restoration to a self-sustaining system (or nearly, with only the addition of effluent or CAP water)	Detailed species habitat analysis and modeling, riparian element
Areas with high potential for successful introduction or reintroduction of endangered or other vulnerable species	Detailed species habitat analysis and modeling
Areas of relatively low levels of habitat loss and fragmentation and few roads	Problematic species analysis and road density analysis
Areas of relatively high value habitat areas that are currently threatened by existing or planned land use activities	Conservation Status data set
Areas of high species richness	Combine detailed species habitat analysis and modeling with additional species distribution information, TNC digital data
Areas of high species richness outside of existing reserve system	Combine species richness data layer with Conservation Status layer
Underrepresented priority plant communities	Overlay Conservation Status data set with vegetation community and special element data sets
Gaps in conservation areas	Overlay Conservation Status data set with all resource data sets
Opportunities to maximize connectivity and minimize fragmentation	Conservation Status data set
Areas needed to support minimum viable populations of each priority vulnerable species	Detailed species habitat analysis and modeling
Areas providing connectivity between significant reserve areas	Conservation Status data set

V. Conservation Opportunities and Constraints

A. Conservation Options

Pima County's options for a reserve design vary in scale, cost, and effort to achieve. It is anticipated that numerous strategies will be employed in a multifaceted approach in order to meet the goals and guidelines. The strategies will also be multiterm actions and management. Some examples of the varied conservation opportunities are as follows:

Maintain and Manage the Existing Reserve System. We start with an established reserve system that serves as the core upon which the SDCP reserve design will build over time.

Expand and Enhance the Existing Reserve System. Opportunities exist to expand the boundaries of existing reserves such as Tucson Mountain Park, Tortolita Park, Cienega Creek Natural Preserve, Colossal Cave Mountain Park, Empire Mountain Park, Catalina State Park, Buenos Aires National Wildlife Refuge along the Arivaca Creek, and some of the private preserves managed by The Nature Conservancy such as the Buehman-Bingham Natural Preserve. Other opportunities exist in the private lands that are within the expanded boundaries of Saguaro National Park.

Create New Reserves. We have seen the recent creation of the biologically rich Ironwood National Monument. Additional opportunities exist with the proposed Las Cienegas National Conservation Area, Santa Rita Mountain Park, Davidson Canyon Natural Preserve, and Cerro Colorado Mountain Park.

"Willing-Seller" Purchase of Sensitive Lands. It is anticipated that the reserve design process will identify a range of sensitive lands, some of which will lend themselves to outright purchase for conservation. Certain sensitive areas have already been identified for consideration by the Open Space Acquisition Master Plan report. This option is particularly appropriate in areas of vacant land with low-density zoning and affordable land values.

"Willing-Seller" Purchase of Development Rights (PDR). As an option to fee-simple acquisition, PDR keeps the land under private ownership and management but puts specific limitations on the use of the land (or "extinguishing" the development rights altogether) while protecting its agricultural and conservation values. The key to establishing a successful PDR program is securing a steady source of public funding to enable a targeted approach to protecting special lands threatened by imminent development.

"Willing-Seller" Purchase or Retirement of Water Rights. This option may provide a means to reduce groundwater pumping in certain areas where groundwater declines either are now or are expected to negatively affect riparian ecosystems. It may be especially appropriate where the full development potential under current zoning could foreseeably result in an overdraft with direct impacts to vulnerable species' habitat, such as in the Arivaca area.

Conservation Easements on Private Land. Conservation easements are also entirely voluntary and leave valuable, environmentally sensitive property in private ownership, on the local tax rolls yet under permanent protection. Development rights are transferred to qualified easement holders (such as land trusts) in a way that is individually tailored to the property and the landowner's intentions.

Extend Length of State Land Leases. Certain existing leases (Special Land Use Permits) have a five-year time limit and may be discontinued at that time. This relatively short time frame does not lend itself to the long-term land stewardship practices that support conservation values. Extending some of these leases, particularly those for grazing, will enhance the viability of ranches dependent upon them and therefore strengthen ranching as a mechanism by which natural open space and habitat values can be conserved under the SDCP.

Custom-design Appropriate Management Strategies. There will be a need to develop specific management policies and actions for both existing and future reserve areas to improve conditions for existing vulnerable species, establish conditions that will support the introduction or reintroduction of native species, and address other issues such as those associated with non-native and invasive species. Management needs to be adaptive to changing conditions of ecosystems, species viability, level of stress, and many other factors. Ongoing examples are the changing, or evolving, policies of land and wildlife management agencies with regard to their stances on invasive versus native aquatic species and wildfire management. Management strategies under the Biological Element of the SDCP will be folded into an Adaptive Management Plan.

B. Conservation Constraints

Constraints to conservation are equally as important as the opportunities and are an inherent and useful tool in identifying the various strategies for implementing the reserve design. Many of the constraints represent factors that we have no control over, yet have an influence on the reserve system. The following are examples of the many factors that we propose RECON and the STAT consider, discuss, and evaluate in the development of the reserve design and adaptive management plan.

Level of Species-specific Information. This is critical in determining the species that will be included by coverage by the HCP in order to meet approval by the U.S. Fish and Wildlife Service. Currently, the STAT is reviewing a set of draft standards that identifies the need for adequate knowledge about the status, life history, distribution, and habitat requirements in order to be confident that the issuance of a permit will contribute towards the long-term survival and recovery of species in Pima County. (See Appendix A.)

Existing and Future Actions or Landscape Elements That May Pose Impacts to Vulnerable Species. As identified in the Biological Stress Assessment report, land use, water use, transportation elements, and utility corridors all have the implications as potential threats and stressors to vulnerable species and their habitats.

Land Use Conflicts within Biological Significant Areas. There will be areas where existing or future land uses conflict with the needs of vulnerable species. In some cases, habitat may be so impacted that its value is diminished to a level beyond reasonable conservation standards. In other cases, land use considerations may be compromised and tailored to respond to biological needs.

Conflicting Needs of Different, Equally Important Species. There may be areas where two or more vulnerable species exist in the same ecosystem competing for food sources or with conflicting needs for or other habitat elements.

Costs of Land, Expertise, Improved Data, and Mapping. Cost is a significant determinant in the reserve design, implementation, and management.

Land Management Policies and Practices. How the reserve system is managed, in part and as a whole, will be critical to its success. The land management stakeholders—local, state, and federal agencies as well as private parties—will be challenged to define and refine management policies and practices to best meet both their goals and those of the SDCP. The SDCP must realistically consider limitations while identifying new sources of funding in both the short term and long term.

Current and Future Agency Staffing Levels and Budgets. Agencies' current staffing levels and budgets will need to be reviewed to determine their adequacy in light of the potential for increased management and monitoring responsibilities.

Changes Over Time. The fact that the landscape is a dynamic system that changes over time is something that needs to be considered not only in the reserve design but also, perhaps more importantly, in the development of an Adaptive Management Plan that is able to insure monitoring and appropriate adjustment of management strategies.

Because of their inherent dichotomy, the conservation opportunities and constraints can therefore be viewed as opposing and *at the same time* complementary elements of the reserve design process. Viewing the level of current conservation status of lands shows us at the same time the areas outside of protection. Conversely, identifying the ecosystems that are most threatened by current and future actions shows us the areas most in need of protective measures and conservation. This identification of the gaps in conservation and management forms the basis for the reserve design and for the identification of those species that warrant inclusion and coverage by the HCP.

VI. Methods and Mechanics of Developing the GIS-based Reserve Design

Our approach to proceeding with the reserve design process for Pima County is to view the landscape from four different but overlapping and complementary perspectives:

- Vegetation associations and rare ecosystem elements
- Vulnerable species
- Biological diversity
- Integration of values other than biological resources

Each of these perspectives is amenable to analysis using GIS data and is discussed below.

We have developed preliminary analyses for the first two perspectives based on an evaluation of conservation status of land within Pima County developed for the Biological Stress Assessment.

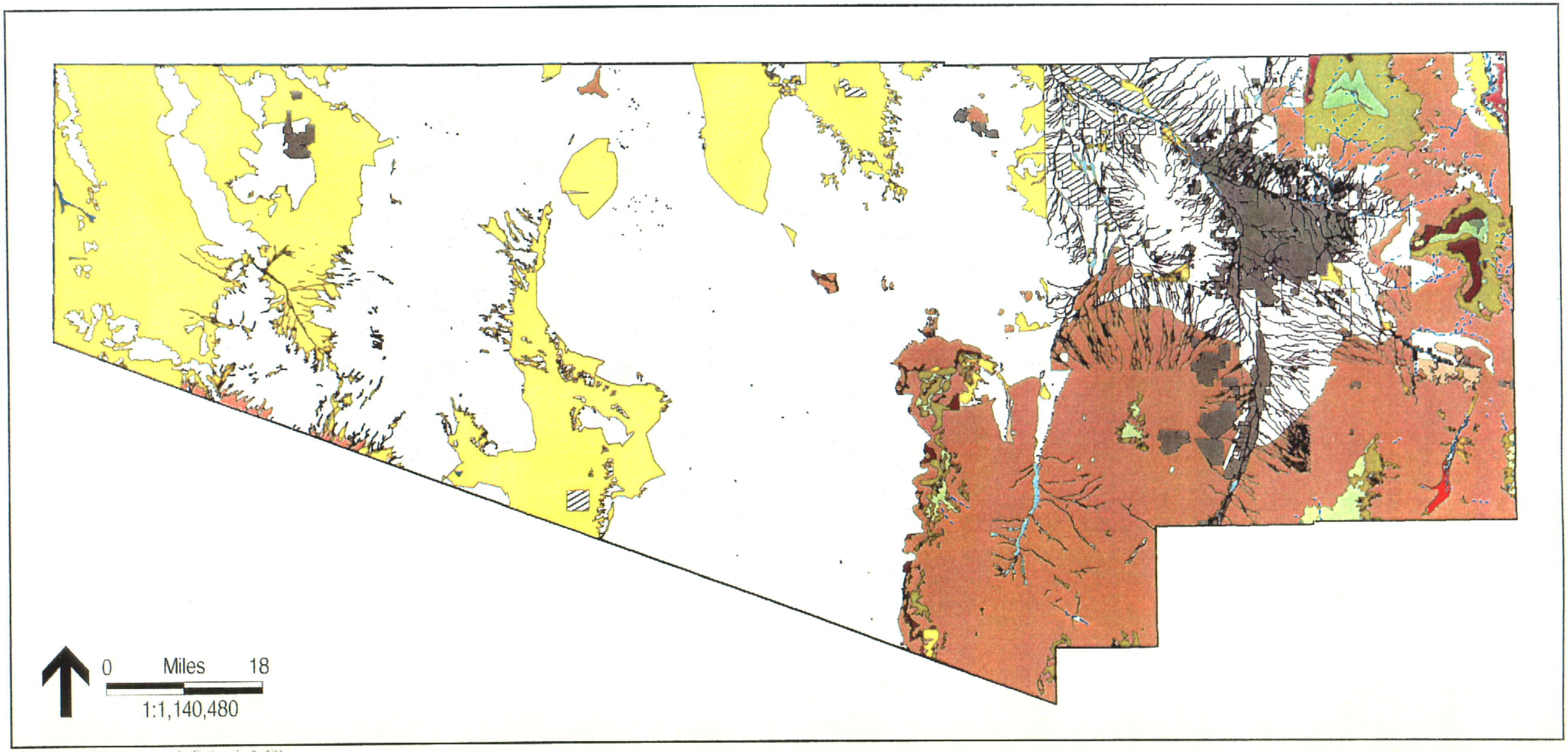
A. Vegetation Associations and Rare Ecosystem Elements

The starting point for the assessment of the conservation coverage of biological resources in Pima County is an understanding of the current conservation status of vegetation communities. The most current representation of vegetation communities is the composite land cover map produced from existing data sources for the Land Cover Data Assessment in Pima County (Figure 1). Current conservation status of lands within Pima County was assembled as part of the preparation of the Biological Stress Assessment (Figure 2).

The conservation status mapped information was simplified into four categories for a preliminary reserve assessment from the multiple categories in the GAP Analysis Program (GAP) status scheme (Figure 3).

GAP Status Categories	Reserve Planning Category
1a, 1b, 2, 3a (public lands with conservation management)	Core reserve
3b, 4a (public and private lands with no management but few if any incompatible uses)	Potential for reserve expansion, addition, connection, or buffer
4b, 4c (public and private lands with some incompatible uses and potential for conversion to more intensive uses)	Potential for reserve connection or buffer
4d, 4f (public and private lands with incompatible uses)	Outside reserves

These reserve planning categories were overlain to evaluate the conservation status of vegetation series in the composite land cover layer associated into bioregions (Table 1). Several preliminary conclusions emerge from cursory review of the results.



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Composite Land Cover

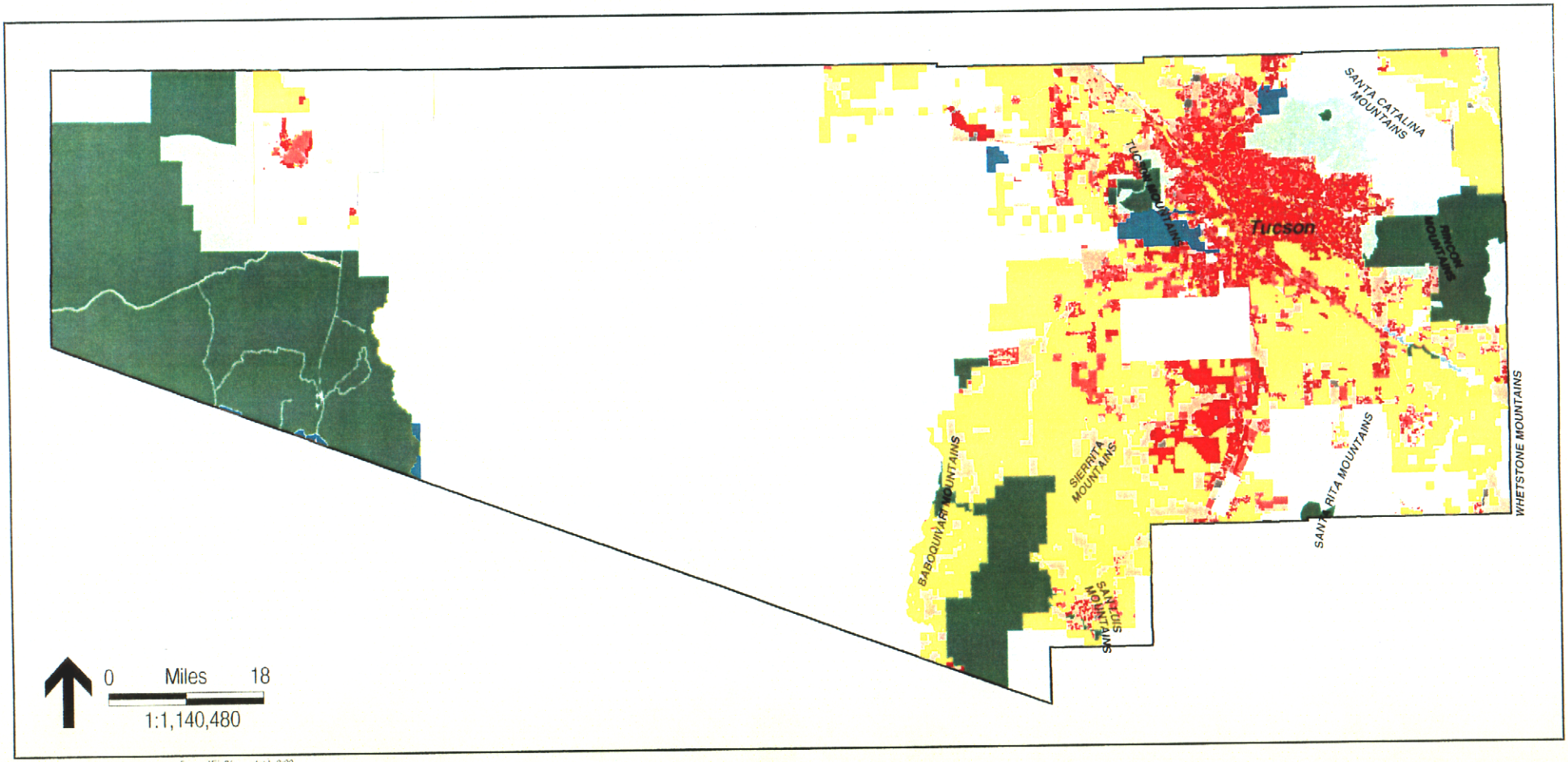
Vegetation Communities
(Composite Land Cover Map, RECON, June 2000)

- 122.41 Pinyon-Juniper
- 122.61 Douglas-Fir-Mixed Conifer
- 122.62 Pine
- 123.31 Encinal (Oak)
- 123.32 Oak-Pine
- 124.71 Mesquite
- 133.32 Manzanita
- 133.36 Mixed Evergreen Sclerophyll
- 143.14 Sacatan-Scrub
- 143.15 Mixed Grass-Scrub
- 143.16 Shrub-Scrub Disclimax
- 153.21 Creosotebush-Tarbush
- 153.26 Mixed Scrub
- 154.11 Creosote-Bursage
- 154.12 Paloverde-Mixed Cacti
- 154.17 Saltbush
- 223.21 Cottonwood-Willow
- 223.22 Mixed Broadleaf
- 224.52 Mesquite
- 224.53 Cottonwood-Willow
- 234.71 Mixed Scrub
- 244.71 Cattail
- 244.75 Saltgrass

Other Land Cover Types

- 999.0 Unclassified
- 999.1 Agriculture
- 999.2 Urban
- 999.3 Water
- 999.4 Bare Ground

Figure 1



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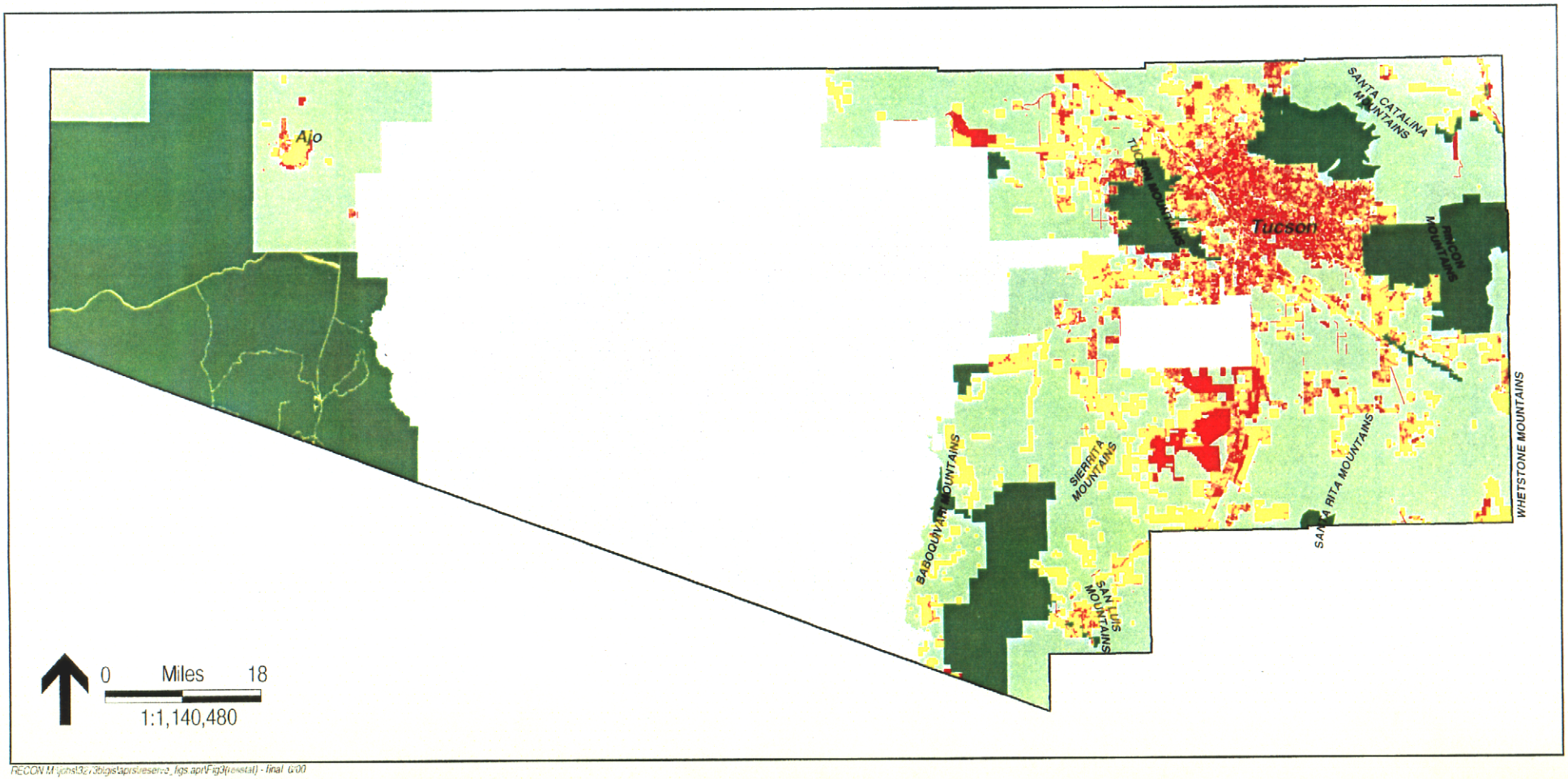
Conservation Status

Pima County Boundary

Level of Threat		Conservation Status	
Low	1a	Most Protected	(Public lands with permanent protection)
	1b		(Public lands with permanent protection, but may contain uses that detract from quality of biological resources)
	2		(Public lands with permanent protection, but includes uses that degrade quality of biological resources)
	3a		(Public lands managed to maintain biodiversity, but not subject to permanent protection)
	3b		(Public lands with permanent protection, but subject to extractive uses)
	4a		(Unprotected private or public lands without existing land uses which limit the value for conservation)
	4b		(Unprotected private or public lands with no existing development, but with existing land uses which limit the value for conservation)
	4c		(Unprotected private or public lands with existing land use designations for increased intensity of land uses)
	4e		(Unprotected private or public lands with entitlements to increased intensity of land uses)
	4f		(Native American lands)
High	4x	Least Protected	(Private or public lands with existing development)

Figure 2



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Existing Reserve Constraints and Opportunities

Pima County Boundary

Reserve Planning Status

- Core Reserves
- Potential Reserve Expansion/Addition/Connection/Buffer
- Potential Reserve Connection/Buffer
- Outside Reserve
- Tohono O'Odham Nation

Figure 3

TABLE 1
CONSERVATION STATUS OF VEGETATION SERIES

Land Cover Classification	BLP Class	Core Reserves 1	2	3a	Subtotal	Potential Reserve Expansion/ Addition/Connection/Buffer 3b	4a	Subtotal	Potential Reserve Connection/Buffer 4b	4c	Subtotal	Outside Reserves 4f	SDCP Plan Area Total	Tohono O'odham Nation 4e	Pima County Total
Sonoran Desert															
Paloverde-Mixed Cacti Series	154.12	354,686	27,005	624	382,315	191,219	271,874	463,094	74,628	82,103	156,732	69,834	1,071,975	2,001,357	3,073,331
Creosote-Bursage Series	154.11	404,732	17	382	405,131	156,388	69,484	225,872	13,512	4,195	17,706	5,324	654,033	349,008	1,003,041
Saltbush Series	154.17	8,315	762		9,076		21	21	855		855	2	.9,955		9,955
Mesquite Series	224.52	945		389	1,334		21	21	23	0	23	1	1,380		1,380
Subtotal		768,678	27,784	1,395	**797,857**	347,607	341,400	**689,008**	89,018	86,298	**175,316**	**75,162**	**1,737,343**	2,350,364	**4,087,707**
Apache Highlands															
Mixed Grass-Scrub Series	143.15	174,645	4,521	143	179,310	218,826	523,805	742,631	127,432	48,628	176,060	32,195	1,130,196	85,587	1,215,784
Encinal (Oak) Series	123.31	53,848			53,848	65,290	11,745	77,035	2,435	307	2,742	255	133,879	13,924	147,803
Mixed Scrub Series	153.26	8,187	600	414	9,201	4,961	21,435	26,396	7,478	6,114	13,593	7,359	56,548	4,536	61,084
Oak-Pine Series	123.32	5,861			5,861	12,516	3,466	15,982	582	10	593		22,435	5,239	27,674
Manzanita Series	133.32	14,736			14,736	399	24	424					15,159	9,901	25,060
Pine Series	122.62	6,873			6,873	9,774	5	9,780					16,653		16,653
Mixed Evergreen Sclerophyll Series	133.36	304		0	305	2,918	4,723	7,642	369	125	495	244	8,685	1,544	10,228
Creosotebush-Tarbush Series	153.21	178		507	685	1,439	10,035	11,474	1,719	210	1,930	132	14,221		14,221
Sacaton-Scrub Series	143.14					4,394	473	4,867	3	5	7		4,874		4,874
Douglas-fir-Mixed Conifer Series	122.61	1,000			1,000	737		737					1,737		1,737
Pinyon-Juniper Series	122.41	673			673		15	15					688	0	688
Subtotal		266,306	5,121	1,065	**272,491**	321,255	575,726	**896,982**	140,019	55,400	**195,419**	**40,185**	**1,405,077**	120,730	**1,525,807**
Riparian/Aquatic															
Mixed Broadleaf Series	223.22	313			313	572	589	1,161	233	222	455	281	2,209		2,209
Cordgrass Series	243.53			126	126	307	308	615	453	273	726	689	2,156		2,156
Cottonwood-Willow Series	223.21	76		57	133	981	290	1,271	384	34	417	91	1,912		1,912
Cattail Series	244.71	170		50	220		1	1	220	3	223	54	499		499
Shrub-Scrub Disclimax Series	143.16	86		18	104		1	1				0	106		106
Saltgrass Series	244.75	79			79		1	1	6		6		86		86
Subtotal		724		251	**975**	1,860	1,191	**3,051**	1,296	531	**1,827**	**1,115**	**6,968**		**6,968**
Urban, Agriculture, and Other															
Urban	999.20	3	153		156	1,609	28,621	30,230	9,967	20,273	30,240	126,326	186,953	5,889	192,842
Agriculture	999.10	226		111	337	1,262	25,055	26,318	20,708	4,590	25,297	4,395	56,346	3,985	60,331
Other		2,588	0	2	2,590	301	424	725	146	39	185	25	3,525	2,376	5,901
Subtotal		2,817	153	113	**3,082**	3,173	54,100	**57,273**	30,821	24,902	**55,723**	130,746	**246,824**	12,250	**259,074**
GRAND TOTAL		1,038,525	33,057	2,823	**1,074,405**	673,895	972,418	**1,646,314**	261,154	167,131	**428,285**	**247,208**	**3,396,212**	2,483,345	**5,879,556**

Within the Sonoran Desert ecoregion (primarily western Pima County), the amount of each of the major vegetation series within core reserves is not the issue. The concerns in this ecoregion are (1) providing connections to the north and south and into the Tohono O'odham Nation and (2) covering any resources of limited distribution not represented on the vegetation series mapping (such as springs, riparian areas, caves, and mines).

The Apache Highlands will require careful and detailed application of the reserve design guidelines, with respect to vegetation series. Only a few of the higher elevation forest and pinyon communities appear to be adequately represented in the core reserves, based on area. The majority of the other communities are within areas providing opportunities for addition to reserve status or connections or buffers.

The preliminary look at the riparian and aquatic communities reinforces the need to (1) conserve additional acreage; (2) conserve key localities for vulnerable species; (3) provide continuity in linear communities; and (4) provide continuity and connectivity with associated upland communities, especially to larger blocks.

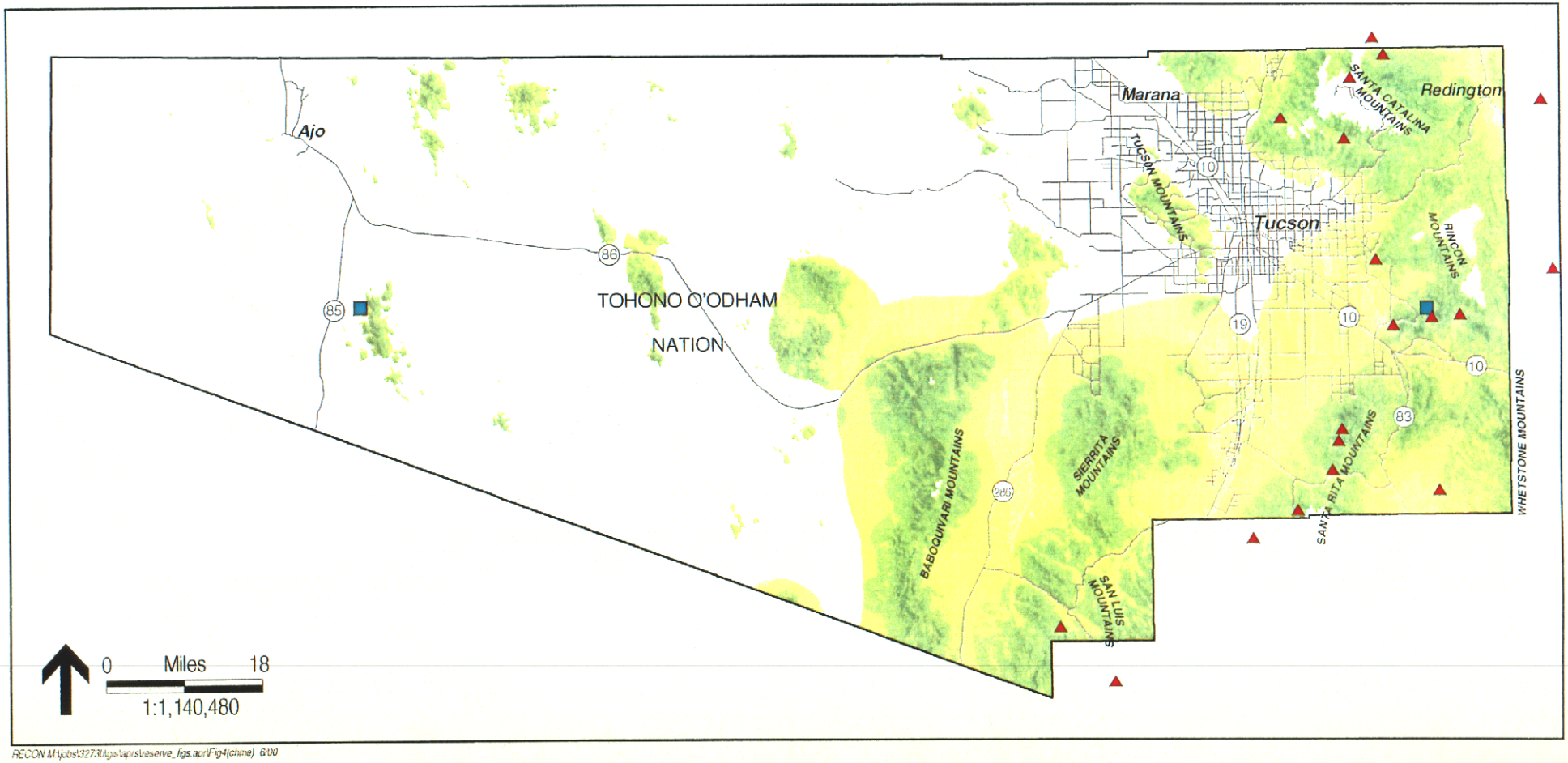
The substantial acreage of urban, agriculture, and other classification identified within the core reserves and other supposedly undeveloped lands needs clarification and modification in the base data set.

B. Vulnerable Species

Assessing and incorporating habitat for vulnerable species is another approach to reserve design. As part of the habitat analysis task, potential habitat for vulnerable species is modeled using GIS. To date, preliminary models and potential habitat maps have been constructed, which will be reviewed and revised in cooperation with STAT. When final habitat maps are produced, they will be overlaid with the reserve planning coverage to identify data gaps for individual species and assess needs for including adequate habitat in the reserve design. An example of Mexican long-tongued bat will be used to demonstrate the overlay process and the conclusions that may be drawn from this kind of analysis.

Based on habitat associations with certain environmental variables, potential habitat for the Mexican long-tongued bat was modeled using GIS. The resulting map is shown in Figure 4. High and medium potential habitat predicted by the model are selected and combined then overlaid with a reserve coverage to assess gaps in conservation and identify opportunities for incorporating habitat into a reserve design. The results are displayed in Figure 5, where potential habitat is shown as a black outline on the reserve map.

Acreages of reserve planning categories within the Mexican long-tongued bat potential habitat are summed in Table 2. Based on the model of potential habitat for this species, 18 percent of its habitat is included in core reserves and almost half is included in potential reserve expansion areas. Depending on the habitat requirements for this species, this preliminary analysis indicates that an adequate amount of habitat does not currently exist in core reserves. Adequate habitat could be reserved for Mexican long-tongued bat by adding to core reserves primarily from public lands and private lands that have no incompatible uses.



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Mexican Long-tongued Bat *(Choeronycteris mexicana)* Preliminary Modeled Potential Habitat

Pima County Boundary

Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)

No Potential

Low Potential

Medium Potential

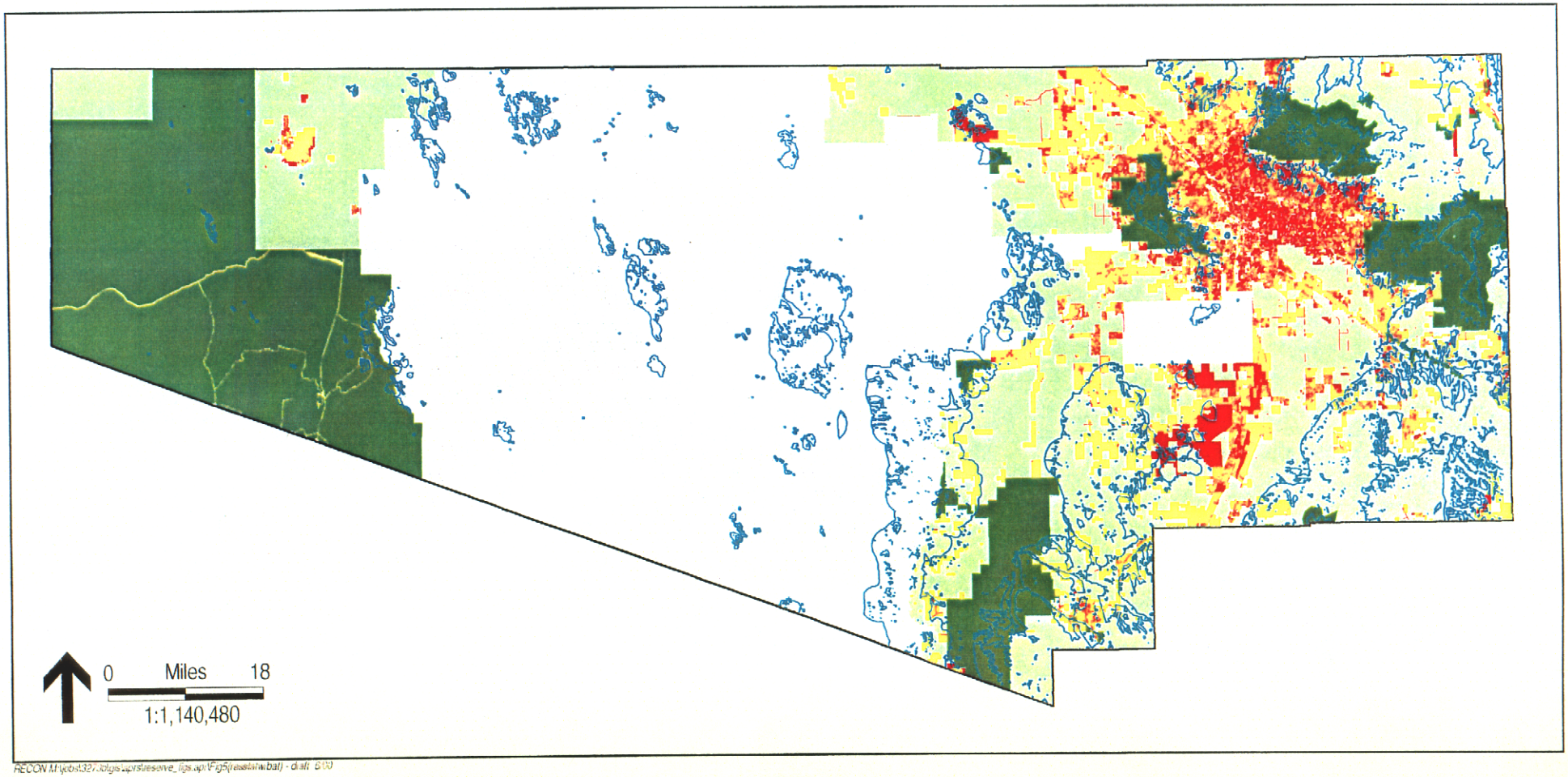
High Potential

Known Locations

(SWCA, 2000)

(HDMS, 2000)

Figure 4



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Preliminary
Reserve Planning Status for Mexican Long-Tongued Bat

Pima County Boundary

Modeled Medium and High Potential Habitat
(RECON, June 2000)

Reserve Planning Status
- Core Reserves
- Potential Reserve Expansion/Addition/Connection/Buffer
- Potential Reserve Connection/Buffer
- Outside Reserve
- Tohono O'Odham Nation

Figure 5

TABLE 2
RESERVE PLANNING STATUS FOR
MEXICAN LONG-TONGUED BAT POTENTIAL HABITAT

Reserve Planning Status	Medium/High Potential Habitat (Acres)	Percent Habitat
Core reserves (conservation status 1a, 1b, 2, 3a)	214,671	18
Potential reserve expansion/addition/connection/buffer (conservation status 3b, 4a)	601,720	49
Potential reserve connection/buffer (conservation status 4b, 4c)	126,480	10
Outside reserve (conservation status 4f)	27,810	2
Tohono O'odham Nation	252,655	21
GRAND TOTAL	1,223,338	100

This kind of reserve planning analysis can be conducted for each species to help identify priority areas for conservation and assess the feasibility of reserving adequate habitat for vulnerable species. By examining the overlap in conservation gaps for all vulnerable species, one is also able to develop priorities for reserve expansion.

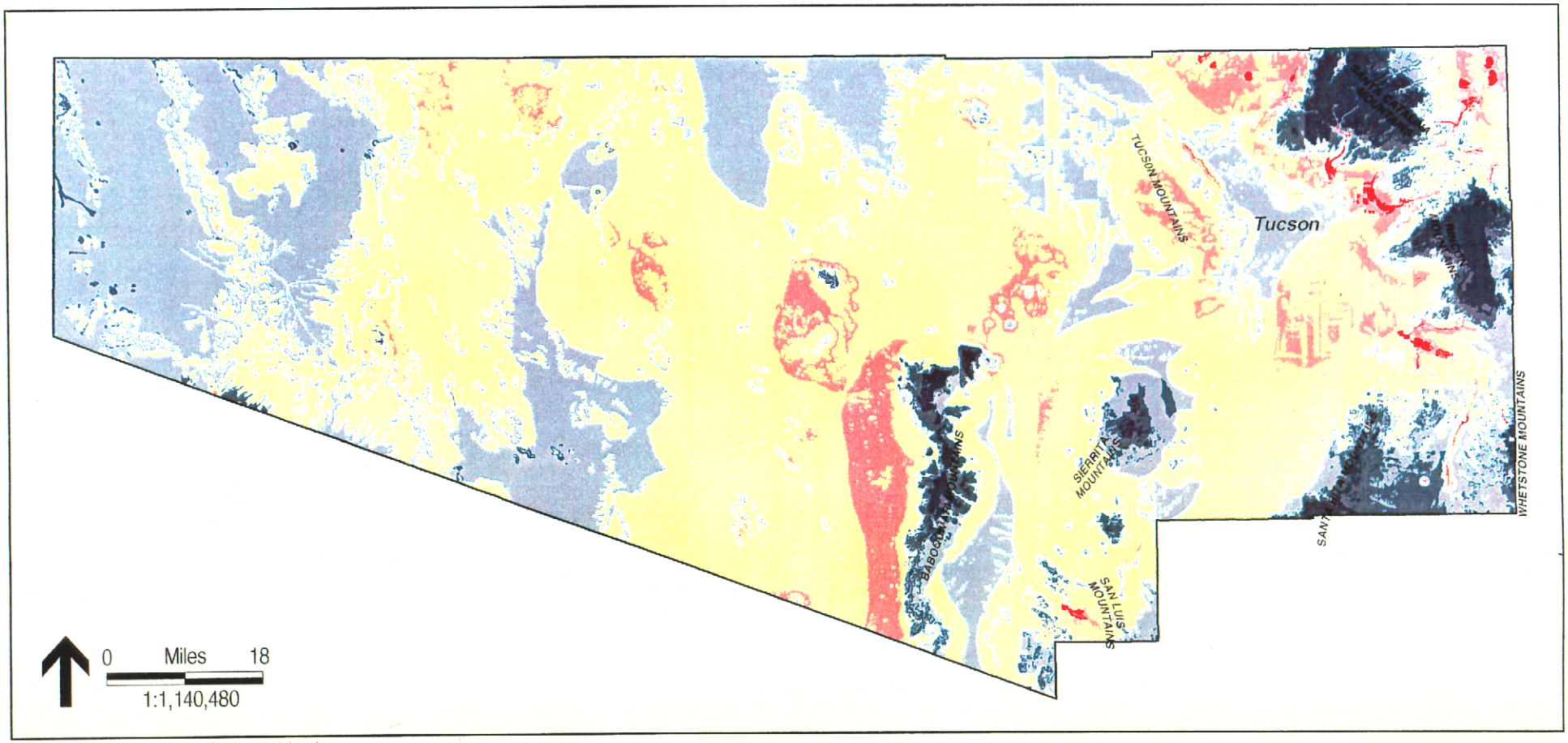
Vulnerable species richness can also be mapped by overlaying all vulnerable species habitats. Given that habitat models adequately depict species distributions, the sum of all models can be used to represent areas of high value habitat and high diversity of priority vulnerable species. Draft models are used in these analyses, so the assessment will likely change, but these analyses offer a preliminary view of patterns of species richness and illustrate the kinds of assessments that can be made using these data and methods.

Medium and high value habitat for each species were used in the overlay analysis; talus snails and pseudoscorpion have no adequate potential distribution maps at this time, so there are 39 maps representing species. When all species grids were summed, the resulting map shows areas containing potential habitat for 2 to 37 species (Figure 6). The areas containing habitat for the most species may be considered hot spots for vulnerable species richness.

Overlaying this species richness map with core reserves, we can assess species-rich areas contained within or missing from current core reserves (Figure 7).

C. Biological Diversity

The biological resources are intrinsically important characteristics of the local landscape but also are part of the larger regional landscape. The recent evaluation of the Sonoran Desert bioregion (Marshall et al. 2000) provides a preliminary assessment of the potential role of the SDCP in conservation at the ecoregional scale (Figure 8). Pima County encompasses portions of the Lower Colorado River Valley and Arizona Upland Sonoran subdivisions of the Sonoran Desert ecoregion. At the eastern end, the county supports vegetation communities of the Apache Highlands ecoregion (including semidesert grasslands and scrub and higher elevation communities).



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Preliminary
Vulnerable Species Modeled Richness

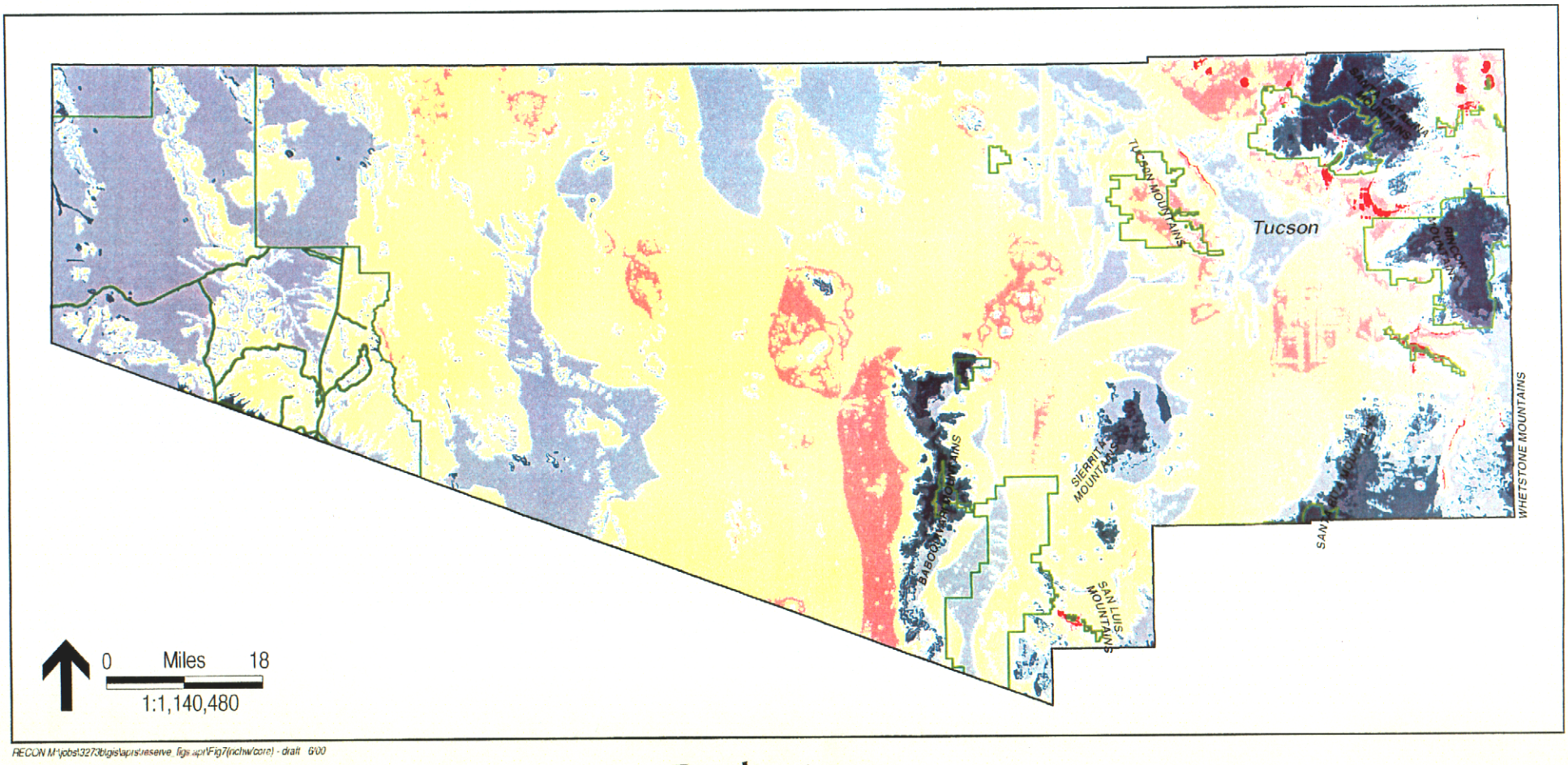
Pima County Boundary

Preliminary Vulnerable Species Modeled Richness

Lower

Higher

Figure 6



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Preliminary
Vulnerable Species Modeled Richness and Core Reserves

Preliminary Vulnerable Species Modeled Richness

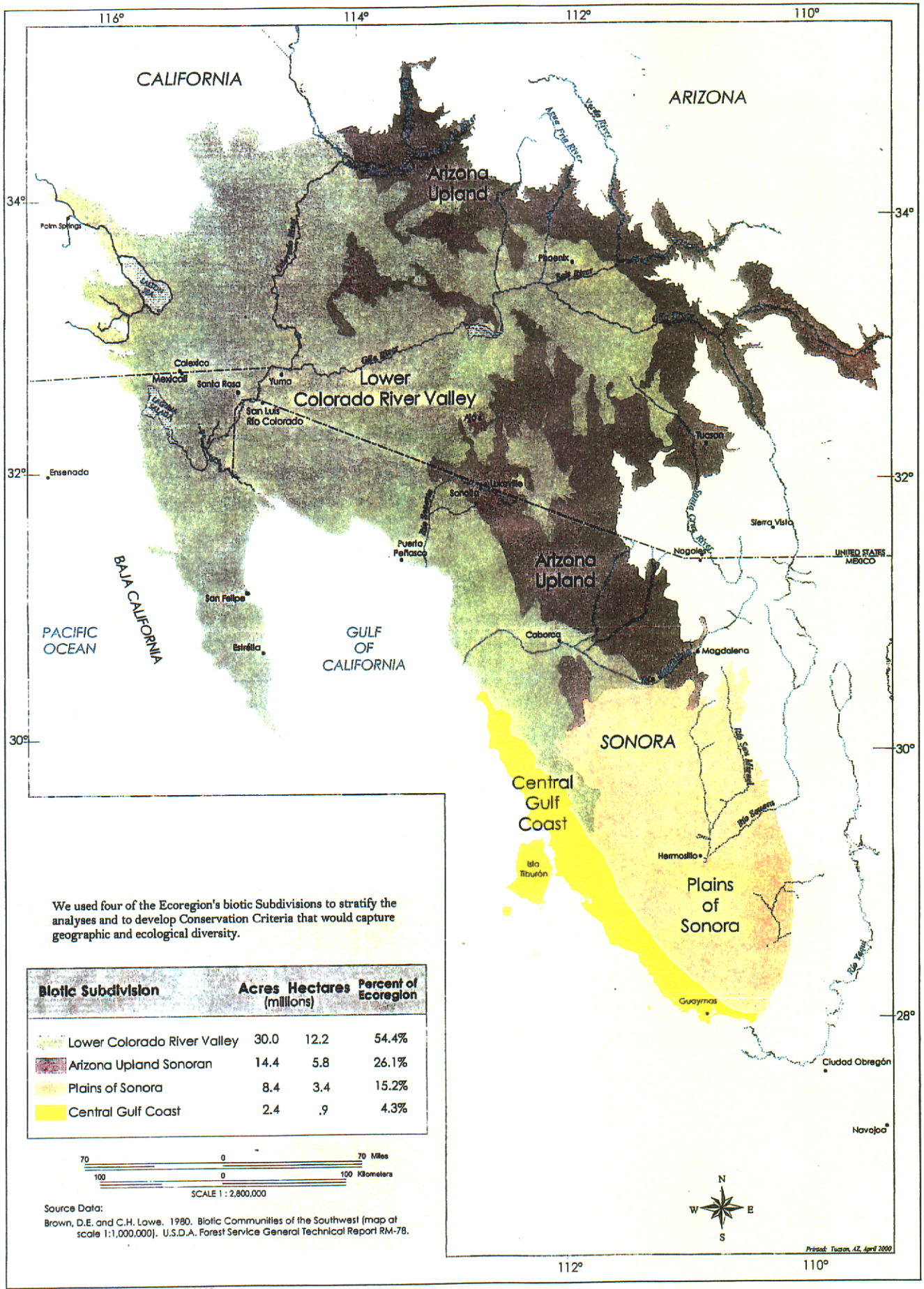
Lower

Higher

Pima County Boundary

Core Reserves

Figure 7



Source: The Nature Conservancy, April 2000

Biotic Subdivisions of the Sonoran Desert Ecoregion

Figure 8