ARIZONA MISSING LINKAGES

Ironwood–Picacho Linkage Design

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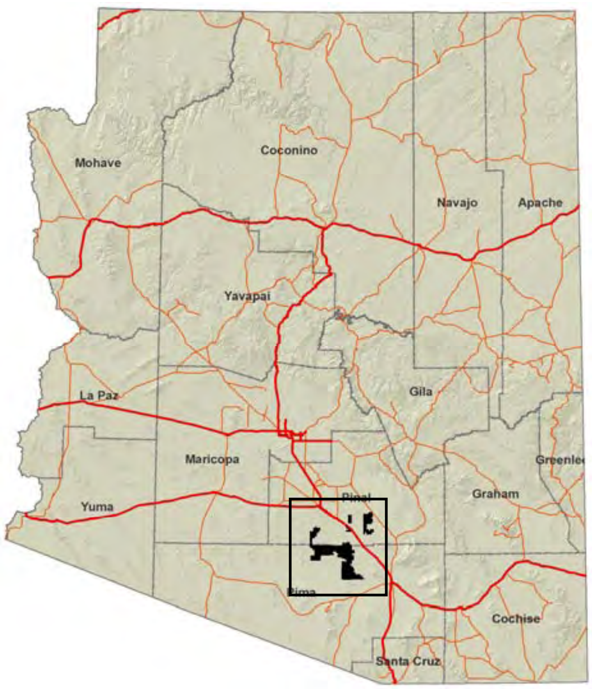
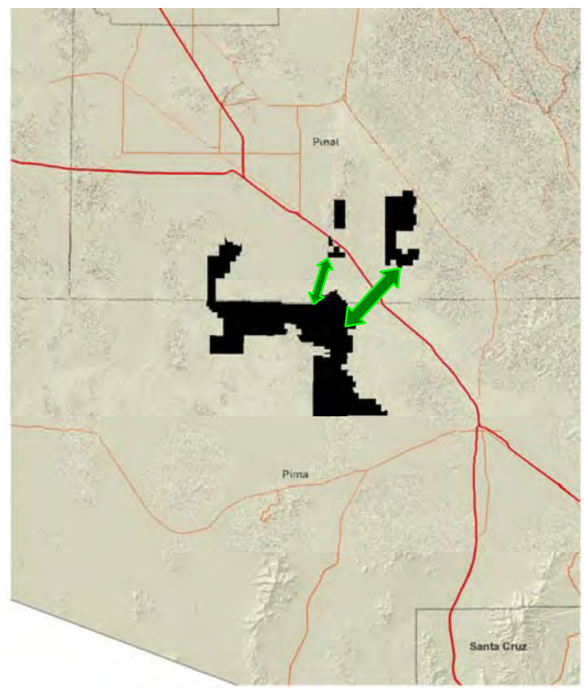
IRONWOOD – PICACHO LINKAGE DESIGN





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Terminology

Key terminology used throughout the report includes:

Biologically Best Corridor: A continuous swath of land expected to be the best route for one focal species to travel from a potential population core in one protected habitat block to a potential population core in the other protected habitat block. In some cases, the biologically best corridor consists of 2 or 3 *strands*.

Focal Species: Species chosen to represent the needs of all wildlife species in the linkage planning area.

Linkage Design: A continuous corridor of land which encompasses the biologically best corridors of all focal species and thus should – if conserved – maintain or restore the ability of wildlife to move between the *wildland blocks*.

Linkage Planning Area: Includes the wildland blocks and the potential linkage area. If the linkage design in this report is implemented, the biological diversity of the entire linkage planning area will be enhanced.

Permeability: The opposite of travel cost, such that a perfectly permeable landscape would have a travel cost near zero.

Pixel: The smallest unit of area in a GIS map – 30x30 m in our analyses. Each pixel is associated with a vegetation class, topographic position, elevation, and distance from paved road.

Potential Linkage Area: The area of private and ASLD land between the wildland blocks, where current and future urbanization, roads, and other human activities threaten to prevent wildlife movement between the wildland blocks. The *Linkage Design* would conserve a fraction of this area.

Travel Cost: Effect of habitat on a species' ability to move through an area, reflecting quality of food resources, suitable cover, and other resources. Our model assumes that habitat suitability is the best indicator of the cost of movement through the pixel.

Wildland Blocks: Large areas of publicly owned or tribal land expected to remain in a relatively natural condition for at least 50 years. These are the "rooms" that the Linkage Design is intended to connect. The value of these conservation investments will be eroded if we lose connectivity between them. Wildland blocks include private lands managed for conservation but generally exclude other private lands and lands owned by Arizona State Land Department (ASLD, which has no conservation mandate under current law). Although wildland blocks may contain non-natural elements like barracks or reservoirs, they have a long-term prospect of serving as wildlife habitat. Tribal sovereignty includes the right to develop tribal lands within a wildland block. In map legends in this report, the wildland blocks are labeled "Protected Habitat Blocks."

Executive Summary

Habitat loss and fragmentation are the leading threats to biodiversity, both globally and in Arizona. These threats can be mitigated by conserving well-connected networks of large wildland areas where natural ecological and evolutionary processes operate over large spatial and temporal scales. Large wildland blocks connected by corridors can maintain top-down regulation by large predators, natural patterns of gene flow, pollination, dispersal, energy flow, nutrient cycling, inter-specific competition, and mutualism. Corridors allow ecosystems to recover from natural disturbances such as fire, flood, and to respond to human-caused disturbance such as climate change and invasions by exotic species.

Arizona is fortunate to have vast conserved wildlands that are fundamentally one interconnected ecological system. In this report, we use a scientific approach to design a corridor (Linkage Design) that will conserve and enhance wildlife movement between three large areas of BLM-administered wildlands in the Picacho Pass-Red Rock area of southern Arizona. Running roughly east and west through this region, Interstate 10, the Tucson Canal, the Southern Pacific rail line, and potential urban and agricultural development provide an impediment to animal movement between the Ironwood Forest National Monument to the south, and the Picacho Mountains and Durham-Coronado Plain[1] to the north. These areas represent a large public investment in biological diversity, and this Linkage Design is a reasonable science-based approach to maintain the value of that investment.

To begin the process of designing this linkage, we asked academic scientists, agency biologists, and conservation organizations to identify 20 focal species that are sensitive to habitat loss and fragmentation, including 1 amphibian, 8 reptiles, 2 birds, 2 plants, 2 insects, and 5 mammals (Table 1). These focal species cover a broad range of habitat and movement requirements. Some require huge tracts of land to support viable populations (e.g. badger, bighorn sheep). Some species are habitat specialists (e.g. bighorn sheep, Tucson Shovel-nosed snake), and others are reluctant or unable to cross barriers such as freeways (e.g. mule deer, rattlesnakes, desert tortoise). Some species are rare and/or endangered (desert tortoise, cactus ferruginous pygmy-owl, Tucson shovel-nosed snake), while others like javelina are common but still need gene flow among populations. All the focal species are part of the natural heritage of this mosaic of Sonoran Desert. Together, these 20 species cover a wide array of habitats and movement needs in the region, so that the linkage design should cover connectivity needs for other species as well.

To identify potential routes between existing protected areas we used GIS methods to identify a biologically best corridor for each focal species to move between these wildland blocks. We also analyzed the size and configuration of suitable habitat patches to verify that the final Linkage Design (Figure 1) provides live-in or move-through habitat for each focal species. Finally, we visited priority areas in the field to identify and evaluate barriers to wildlife movement. We used these observations to suggest strategies to mitigate those barriers, with special emphasis on opportunities to reduce the adverse effects of Interstate-10, canals, and other human development.

The Linkage Design (Figure 1, Figure 4, Figure 5) is composed of two strands which together provide habitat for movement and reproduction of wildlife between the Ironwood, Picacho, and the Durham-Coronado Plain. We provide detailed mitigations for barriers to animal movement in the section titled *Linkage Design and Recommendations*.

[1] The **Durham-Coronado Plain** is not labeled as such on existing maps. We coined this name for this BLM-administered desert area because Durham Wash and Coronado Wash are the 2 main drainages in the area.

The Ironwood-Picacho region provides significant ecological, educational, recreational, and spiritual values of protected wildlands. Our Linkage Design represents an opportunity to protect a functional landscape-level connection. The cost of implementing this vision will be substantial—but reasonable in relation to the benefits and the existing public investments in protected wild habitat. If implemented, our plan would not only permit movement of individuals and genes between the Ironwood National Monument, Picacho Mountains, and desert BLM wildland blocks, but should also conserve large-scale ecosystem processes that are essential to the continued integrity of existing conservation investments by the US Forest Service, Arizona State Parks, Bureau of Land Management, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and other conservancy lands.

Next Steps: This Linkage Design Plan is a science-based starting point for conservation actions. The plan can be used as a resource for regional land managers to understand their critical role in sustaining biodiversity and ecosystem processes. Relevant aspects of this plan can be folded into management plans of agencies managing public lands. Transportation agencies can use the plan to design new projects and find opportunities to upgrade existing structures. Regulatory agencies can use this information to help inform decisions regarding impacts on streams and other habitats. This report can also help motivate and inform construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, and land acquisition. Implementing this plan will take decades, and collaboration among county planners, land management agencies, resource management agencies, land conservancies, and private landowners.

Public education and outreach is vital to the success of this effort – both to change land use activities that threaten wildlife movement and to generate appreciation for the importance of the corridor. Public education can encourage residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function. The biological information, maps, figures, tables, and photographs in this plan are ready materials for interpretive programs.

Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. We hope this linkage conservation plan will be used to protect an interconnected system of natural space where our native biodiversity can thrive, at minimal cost to other human endeavors.

Table 1: Focal species selected for the Ironwood-Picacho Linkage.

MAMMALS	AMPHIBIANS & REPTILES	BIRDS
*Badger *Bighorn Sheep *Black-tailed Jackrabbit *Javelina[1] *Mule Deer	*Sonoran Desert Toad *Black-tailed Rattlesnake Chuckwalla Desert Iguana *Desert Tortoise Lyre Snake *Sonoran Whipsnake Tiger Rattlesnake *Tucson Shovel-nosed Snake	Cactus Ferruginous Pygmy-Owl Roadrunner **PLANTS** Ironwood Tree Palo Verde **INSECTS** Bee species Hawkmoth

* Species modeled in this report. The other species were not modeled because there were insufficient data to quantify habitat use in terms of available GIS data (e.g., some snakes that select small rocks), or because the species probably can travel (e.g., by flying) across unsuitable habitat.

[1] During field work, we found a dead javelina (apparently road-killed) near the entrance to a culvert under I-10 in the potential linkage area.

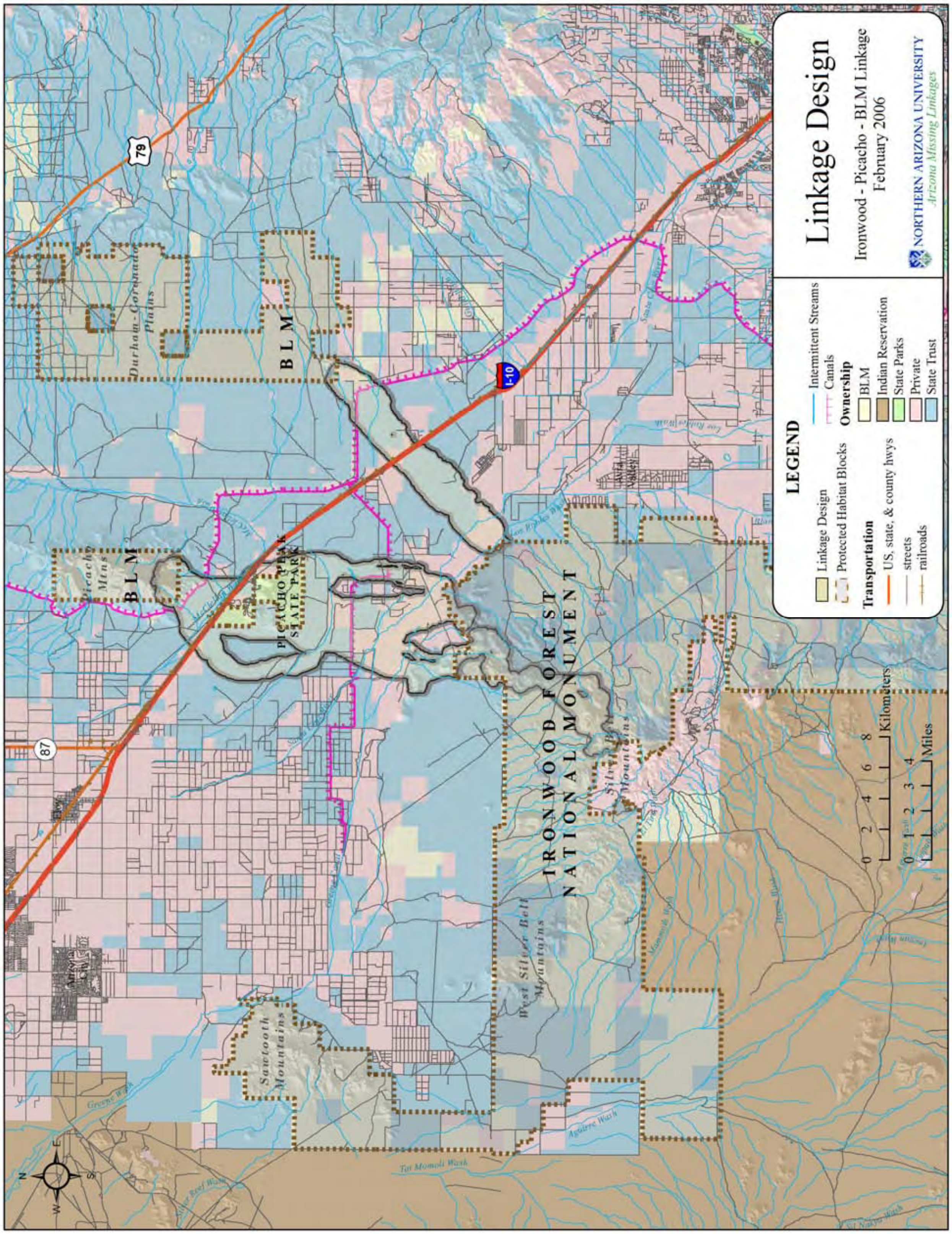

Figure 1: The Linkage Design has 2 strands: one connecting the Ironwood National Monument to the Picacho Mountains, and one connecting Ironwood National Monument to the BLM land labeled Durham-Coronado Plains.

Introduction

Nature Needs Room to Move

Movement is essential to wildlife survival, whether it be the day-to-day movements of individuals seeking food, shelter, or mates, dispersal of offspring (e.g., seeds, fledglings) to new home areas, gene flow, migration to avoid seasonally unfavorable conditions, recolonization of unoccupied habitat after environmental disturbances, or shifting of a species' geographic range in response to global climate change.

In environments fragmented by human development, disruption of movement patterns can alter essential ecosystem functions, such as top-down regulation by large predators, gene flow, natural patterns and mechanisms of pollination and seed-dispersal, natural competitive or mutualistic relationships among species, resistance to invasion by alien species, and prehistoric patterns of energy flow and nutrient cycling. Without the ability to move among and within natural habitats, species become more susceptible to fire, flood, disease, and other environmental disturbances and show greater rates of local extinction (Soulé and Terborgh 1999). The principles of island biogeography (MacArthur and Wilson 1967), models of demographic stochasticity (Shaffer 1981, Soulé 1987), inbreeding depression (Schonewald-Cox et al. 1983; Mills and Smouse 1994), and metapopulation theory (Levins 1970, Taylor 1990, Hanski and Gilpin 1991) all predict that isolated populations are more susceptible to extinction than connected populations. Establishing connections among natural lands has long been recognized as important for sustaining natural ecological processes and biological diversity (Noss 1987, Harris and Gallagher 1989, Noss 1991, Beier and Loe 1992, Noss 1992, Beier 1993, Forman 1995, Beier and Noss 1998, Crooks and Soulé 1999, Soulé and Terborgh 1999, Penrod et al. 2001, Crooks 2001, Tewksbury et al. 2002, Forman et al. 2003).

Habitat fragmentation is a major reason for regional declines in native species. Species that once moved freely through a mosaic of natural vegetation types are now being confronted with a human-made labyrinth of barriers such as roads, homes, and agricultural fields. Movement patterns crucial to species survival are being permanently altered at unprecedented rates. Countering this threat requires a systematic approach for identifying, protecting, and restoring functional connections across the landscape to allow essential ecological processes to continue operating as they have for millennia.

A Statewide Vision

In April 2004, a statewide workshop called *Arizona Missing Linkages: Biodiversity at the Crossroads* brought together over 100 land managers and biologists from federal, state, and local agencies, academic institutions, and non-governmental organizations to delineate habitat linkages critical for preserving the State's biodiversity. Meeting for 2 days at the Phoenix Zoo, the participants identified over 100 Potential Linkage Areas throughout Arizona (Arizona Wildlife Linkage Workgroup 2006).

The workshop was convened by the Arizona Wildlife Linkage Workgroup, a collaborative effort led by Arizona Game and Fish Department, Arizona Department of Transportation, Federal Highways Administration, US Forest Service, Bureau of Land Management, US Fish and Wildlife Service, Sky Island Alliance, Wildlands Project, and Northern Arizona University. The Workgroup prioritized the potential linkages based on biological importance and the conservation threats and opportunities in each area (AWLW 2006).Eight potential linkages emerged as priorities for more detailed planning. The Ironwood-Picacho Linkage is one of these first 8 linkages.

Ecological Significance of the Ironwood-Picacho Linkage

The Ironwood-Picacho-BLM Linkage Planning area lies within the 55-million acre Sonoran Desert Ecoregion of southern Arizona, southeastern California, and northwestern Sonora, Mexico. This ecoregion is the most tropical of North America's warm deserts (Marshall et al. 2000). Bajadas sloping down from the mountains support forests of ancient saguaro cacti, paloverde, and ironwood; creosotebush and bursage desert shrub dominate the lower desert (The Nature Conservancy 2006). The Sonoran Desert Ecoregion is home to more than 200 threatened species, and its uniqueness lends to a high proportion of endemic plants, fish, and reptiles (Marshall et al. 2000; The Nature Conservancy 2006). More than 500 species of birds migrate through, breed, or permanently reside in the ecoregion, which are nearly two-thirds of all species that occur from northern Mexico to Canada (Marshall et al. 2000). The Sonoran Desert Ecoregion's rich biological diversity prompted Olson and Dinerstein (1998) to designate it as one of 233 of the earth's most biologically valuable ecoregions, whose conservation is critical for maintaining the earth's biodiversity.

Within the Sonoran Desert Ecoregion, the Linkage Planning Area includes three wildland blocks: Ironwood National Monument, the Picacho Mountains, and a block of Sonoran desert we call Durham-Coronado Plains[2]. All 3 areas are administered by the Bureau of Land Management (Figure 2).

The Ironwood Forest National Monument, the southern habitat block, encompasses several desert mountain ranges including the Silver Bell, Waterman and Sawtooth Mountains, which extend for 42 km (26 mi) (Bureau of Land Management 2005). These mountains support drainage systems such as Los Robles Wash, Blanco Wash, Cocio Wash, and the Santa Cruz River. Elevation ranges from 1,800 to 4,261 feet, providing a geologic and topographic variability that contributes to high biological diversity (Bureau of Land Management 2005).

The BLM land in the Picacho Mountains is one of the northern wildland blocks in the Ironwood-Picacho Linkage Planning Area. The Picacho Mountains extend for 20 km (12.5 mi) and range in elevation from 1,725 ft to 4,508 ft at Newman Peak. This mountain range supports the Brady and McClellan Washes, and provides important wildlife habitat. Mountain lions have been documented traveling between the Picacho Mountains and the Catalina Mountains (K. Nicholson & P. Krausman, University of Arizona, personal communication).

The Durham-Coronado Plain[2] is a 20 km (12.5 mi) stretch of protected Paloverde-mixed cacti desert communities. The Durham and Coronado Washes run through this habitat block, which ranges from 2000-2500 ft elevation. This area provides protected Sonoran desert for wildlife and plant species in the region.

The Linkage Planning Area ranges from 1700 feet elevation at the Santa Cruz River valley to 4,508 feet at Newman Peak in the Picacho Mountains. Paloverde-mixed cacti desert scrub, semi-desert grassland and steppe, and creosotebush-white bursage desert scrub communities dominate the landscape, with large areas of agricultural lands along the I-10 transportation corridor (Figure 3). Riparian areas in the Linkage Planning Area include the Santa Cruz River, and McClellan, Blanco, and Cocio Washes.

The varied habitat types in the Linkage Planning Area support many animal species. Species listed as threatened or endangered by the U.S. Fish and Wildlife Service include the desert tortoise, bighorn sheep, and the cactus ferruginous pygmy-owl (USFWS 2005). The Corridor Design incorporates and connects critical habitat needed for these species to achieve viable populations. The Ironwood-Picacho Linkage Planning Area is also home to far-ranging mammals such as mule deer, mountain lion, and badger. These

[2] This block of BLM land has no formal designation on most maps. We named it after Durham Wash and Coronado Wash, which are the 2 main drainages in the area

animals move long distances to gain access to suitable foraging or breeding sites, and would benefit significantly from corridors that link large areas of habitat (Turner et al. 1995). Less-mobile species and habitat specialists such as black-tailed jackrabbits, tiger rattlesnakes, and Sonoran desert toads also need corridors to maintain genetic diversity, allow populations to shift their range in response to climate change, and promote recolonization after fire or epidemics.

Existing Conservation Investments

The three wildland blocks are comprised of land federally protected by the Bureau of Land Management. The **southern habitat block** consists of Ironwood Forest National Monument, 129,000 protected acres of ancient legume and cactus forests (Bureau of Land Management 2005). This monument provides an outstanding example of the plant and animal diversity of the Sonoran desert (Bureau of Land Management 2005). The monument's Silver Bell Mountains alone claims more than 674 species, including 64 mammals and 57 birds (Bureau of Land Management 2005). The Ironwood Forest National Monument hosts one of the richest stands of ironwood trees in the Sonoran desert, and is home to many federally listed species, including the Nichols turk's head cactus, the lesser long-nosed bat, and the desert bighorn sheep (Bureau of Land Management 2005; Sierra Club 2006).

Adjacent to the southern habitat block's Ironwood Forest National Monument is a proposed conservation reserve that would protect 6,485 acres of State Trust land in the Sonoran desert (Sonoran Institute 2005). This reserve would help to link the Ironwood Forest National Monument with the Sawtooth Mountains to the north. Another proposed conservation reserve known as Sawtooth would add 3,395 acres of protected land in the southern habitat block's vicinity and encompass a stand of mature ironwood trees not protected within the monument's borders (Sonoran Institute 2005). Both of these proposed reserves would buffer the habitat block from urban development in the Marana and Tucson areas (Sonoran Institute 2005). The Tohono O'odham Nation also abuts the Monument. Although tribal sovereignty includes the right to develop reservation land, conserving this linkage gives the tribe the opportunity to maintain a wildlife corridor to the northeast of the reservation, which is now largely in a natural condition.

The **northwestern habitat block** consists of the Picacho Mountains, 6,400 protected acres owned by the Bureau of Land Management. This habitat block would be expanded by 18,705 acres through a proposed conservation reserve protecting surrounding State Trust Lands in the Picachos (Figure 2; Sonoran Institute 2005).

The Durham-Coronado Plain is 33,200 acres of BLM-protected Sonoran desert that comprise the **northeastern habitat block** in the Linkage Planning Area. This undeveloped tract of Sonoran desert provides desert species refuge from encroaching development in the area.

Picacho Peak State Park, a protected area in the Linkage Planning Area separate from the three wildland blocks, would both contribute to and benefit from a wildlife corridor in this area. This Arizona state park consists of 3,500 acres of Sonoran desert, including the iconic landmark of Picacho Peak, rising to 3,382 feet (Arizona State Parks 2005). The park attracts 60,000 visitors per year, bringing money into the local economy (Arizona Office of Tourism 2003). Adjacent to this state park is the proposed Picacho Peak State Park conservation reserve, which would protect 3,995 acres of additional lands. This conservation reserve would convert State Trust lands for conservation and connectivity between protected lands and buffer Picacho Peak State Park from urban development (Figure 2; Sonoran Institute 2005).

Connectivity between these three valuable and wildland blocks would help to provide the contiguous habitat necessary to sustain viable populations of sensitive and far ranging species in the Sonoran Desert of southern Arizona.

Threats to Connectivity

Major potential barriers in the Potential Linkage Area include Interstate 10, the Southern Pacific Railroad, the Central Arizona Project's Tucson Canal and irrigation canals, and urban and agricultural development along the I-10 corridor, all of which inhibit wildlife movement between the three wildland blocks. Although the linkage area is not directly affected by border security fencing, steel walls, or stadium lighting, it may increasingly be affected by low level overflights and 24-hour patrols on an expanding network of new roads (Vacariu 2005).

Connectivity for resident and migratory species is essential for maintaining this unique area's diverse natural heritage. However, recent intensive and unsustainable human activities threaten to create barriers that sever natural connections and alter the functional integrity of this natural system. Conserving linkages that overcome barriers to movement will ensure that wildlife in all three wildland blocks and the potential linkage area will thrive for generations to come.

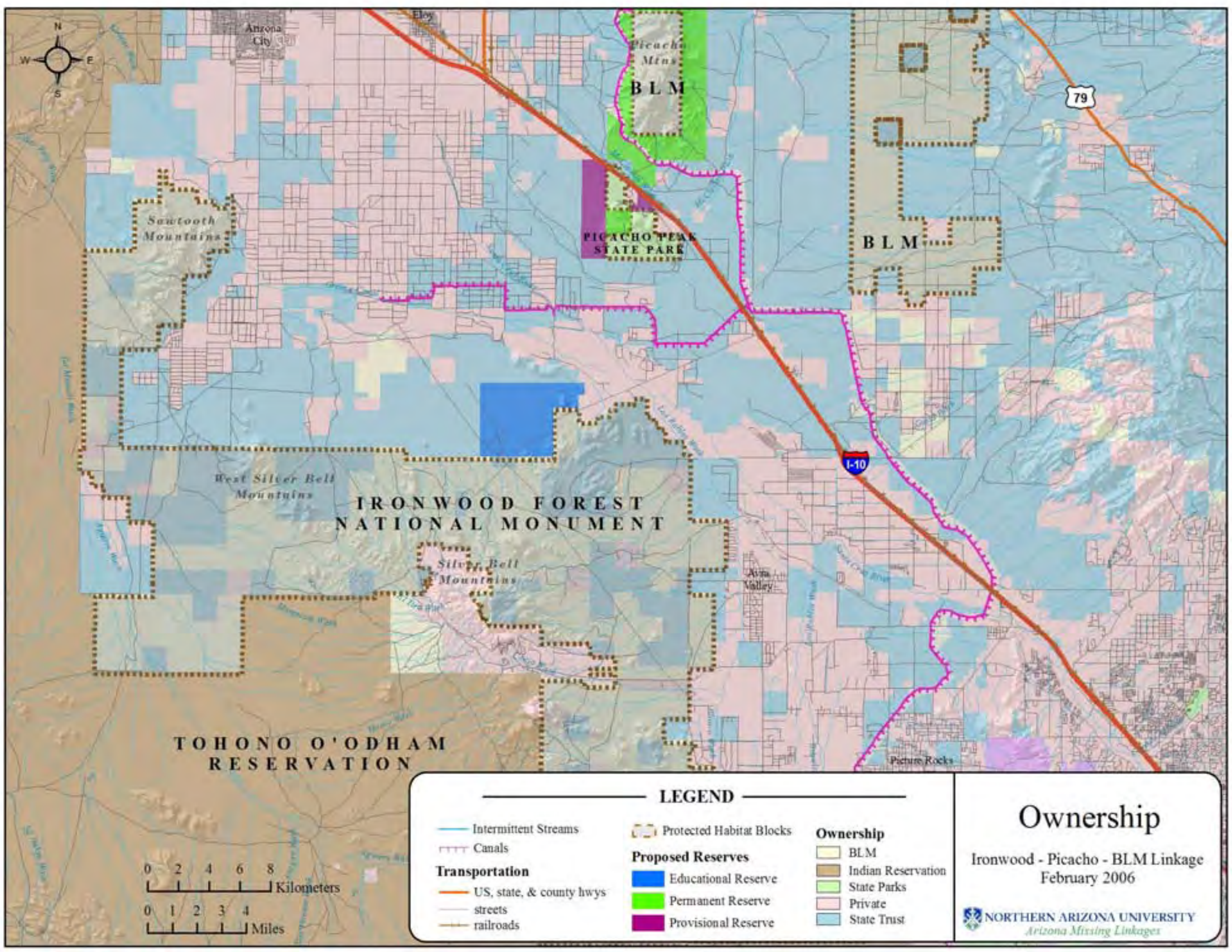

Figure 2: Land ownership within the Linkage Planning Area.

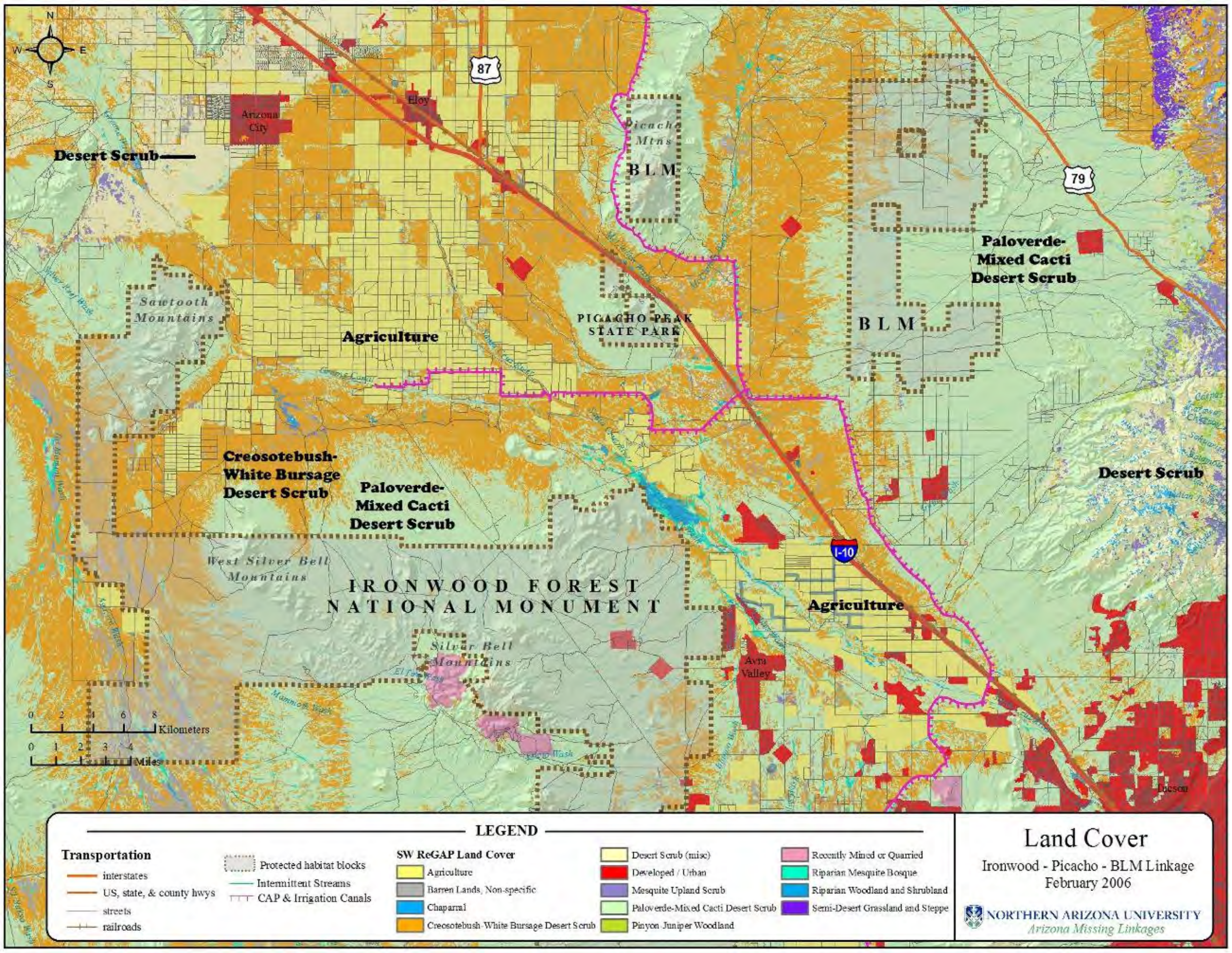

Figure 3: Land cover within the Linkage Planning Area.

Linkage Design & Recommendations

The Linkage Design (Figure 4 & Figure 5) is composed of two strands which together provide habitat for movement and reproduction of wildlife between the Ironwood, Picacho, and desert BLM protected wildland blocks. In this section, we describe the land cover and ownership patterns in the linkage design, and recommend mitigations for barriers to animal movement. The methods used to develop the linkage design are detailed in Appendixes A through E.

Two Routes Provide Connectivity Across a Diverse Landscape

LINKAGE DESIGN GOALS
• Provide move-through habitat for diverse group of species • Provide live-in habitat for species with dispersal distances too short to traverse linkage in one lifetime • Provide adequate area for a metapopulation of corridor-dwelling species to move through the landscape over multiple generations • Provide a buffer protecting aquatic habitats from pollutants • Buffer against edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species • Allow animals and plants to move in response to climate change

The linkage design consists of two distinct strands which connect Ironwood Forest National Monument to the Picacho Mountains and the Durham-Coronado Plain.

The western strand connects Ironwood Forest National Monument and the Picacho Mountain wildland blocks. It is approximately 18 km (11 miles) long, and varies in width from approximately 1.5 to 8 km (0.9 – 5 miles). This strand is primarily composed of paloverde-mixed cacti desert scrub and creosotebush-white bursage desert scrub, but also includes riparian woodland, shrubland, and agriculture. This linkage provides live-in and pass-through habitat for species dependent on desert vegetation and/or rugged topography, such as desert tortoise, black-tailed rattlesnake, desert bighorn sheep, javelina, black-tailed jackrabbit, mule deer, and Sonoran whipsnake. Important riparian areas encompassed by this linkage include portions of the Santa Cruz River and Los Robles Wash north of Ironwood Forest National Monument, and McClellan Wash north of Picacho Peak State Park. The Central Arizona Project canal and a smaller irrigation canal both pass through this linkage.

The eastern strand between Ironwood Forest National Monument and the BLM-administered Durham-Coronado Plain is approximately 15 km (9 miles) long and 2 km (1¼ miles) wide. This corridor crosses the Santa Cruz River and Los Robles Wash northeast or Ironwood, passes north of Pinal Air Park and Saguaro Power plant, and joins the BLM desert block near Desert Peak. This route is primarily composed of creosotebush-white bursage desert scrub and paloverde-mixed cacti desert scrub, but also includes riparian woodland and shrubland. This linkage provides live-in and pass-through habitat for species dependent on desert vegetation and/or flatter topography, such as Tucson shovel-nosed, badger, black-tailed jackrabbit, javelina, and Sonoran desert toad. The entire corridor is also within proposed critical habitat for the Cactus-Ferruginous Pygmy-Owl.

Land Ownership, Land Cover, and Topographic Patterns within the Linkage Design

The Linkage Design encompasses 43,400 acres (17,570 ha) of land, and is composed of 57% state trust land, 22% private land, 12% BLM land, 8% state parks land, and 1% Bureau of Reclamation land (Figure 4). Seven natural vegetation communities account for 95% of the land cover, barren lands account for 0.6%, and developed land accounts for approximately 4% of the land in the Linkage Design (Figure 5, Table 2). Natural vegetation is dominated by desert scrub-shrub associations, and has a similar composition to land cover found in each of the wildland blocks. Riparian vegetation such as mesquite bosque accounts for 3% of the linkage design.

The Linkage Design captured a range of topographic diversity, providing for the present ecological needs of species, as well as creating a buffer against a potential shift in ecological communities due to future climate change. Within the Linkage Design, 82% of the land is classified as gentle slopes, while approximately 18% of the land is classified as either canyon bottom or ridgetop, or steep slopes (Figure 6). While the majority of the land in the linkage area is flat, the widest possible range of slopes was captured, with Picacho Peak State Park acting as an important steppingstone of habitat for species dependent on rugged topography between the Ironwood and Picacho Mountains wildland blocks. Nearly 32% of the land within the linkage design was flat (no aspect). Southwest, west, northwest, and north aspects each accounted for 9%-14% of the linkage design, while northeast, east, southeast, and south each accounted for 4%-7% of the linkage design (Figure 6).

Table 2: Approximate land cover found within Linkage Design.

LAND COVER CATEGORY	ACRES	HECTARES	% OF TOTAL AREA
Evergreen Forest (< 0.1%)			
Pinyon-Juniper Woodland	13	5	< 0.1%
Scrub-Shrub (92%)			
Creosotebush-White Bursage Desert Scrub	13344	5400	30.7%
Desert Scrub (misc)	158	64	0.4%
Mesquite Upland Scrub	75	31	0.2%
Paloverde-Mixed Cacti Desert Scrub	26341	10660	60.7%
Woody Wetland (2.9%)			
Riparian Mesquite Bosque	715	289	1.6%
Riparian Woodland and Shrubland	547	221	1.3%
Barren Lands (0.6%)			
Barren Lands, Non-specific	278	113	0.6%
Volcanic Rock Land and Cinder Land	19	8	<0.1%
Developed and Agriculture (4.4%)			
Agriculture	1656	670	3.8%
Medium-High Intensity Developed	264	107	0.6%

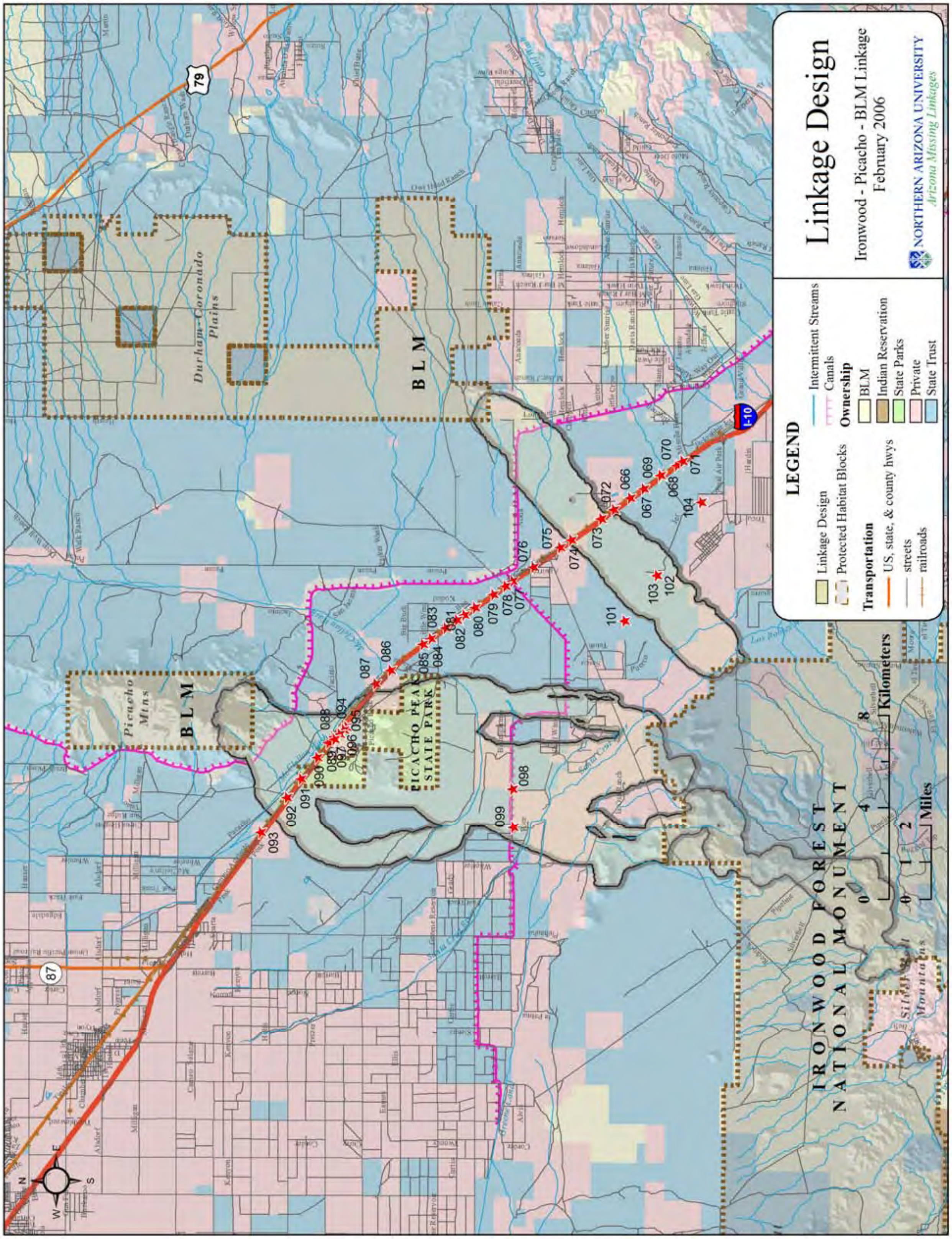

Figure 4: Property ownership and field investigation waypoints within Linkage Design. The accompanying CD-ROM includes photographs taken at most waypoints (indicated by stars).

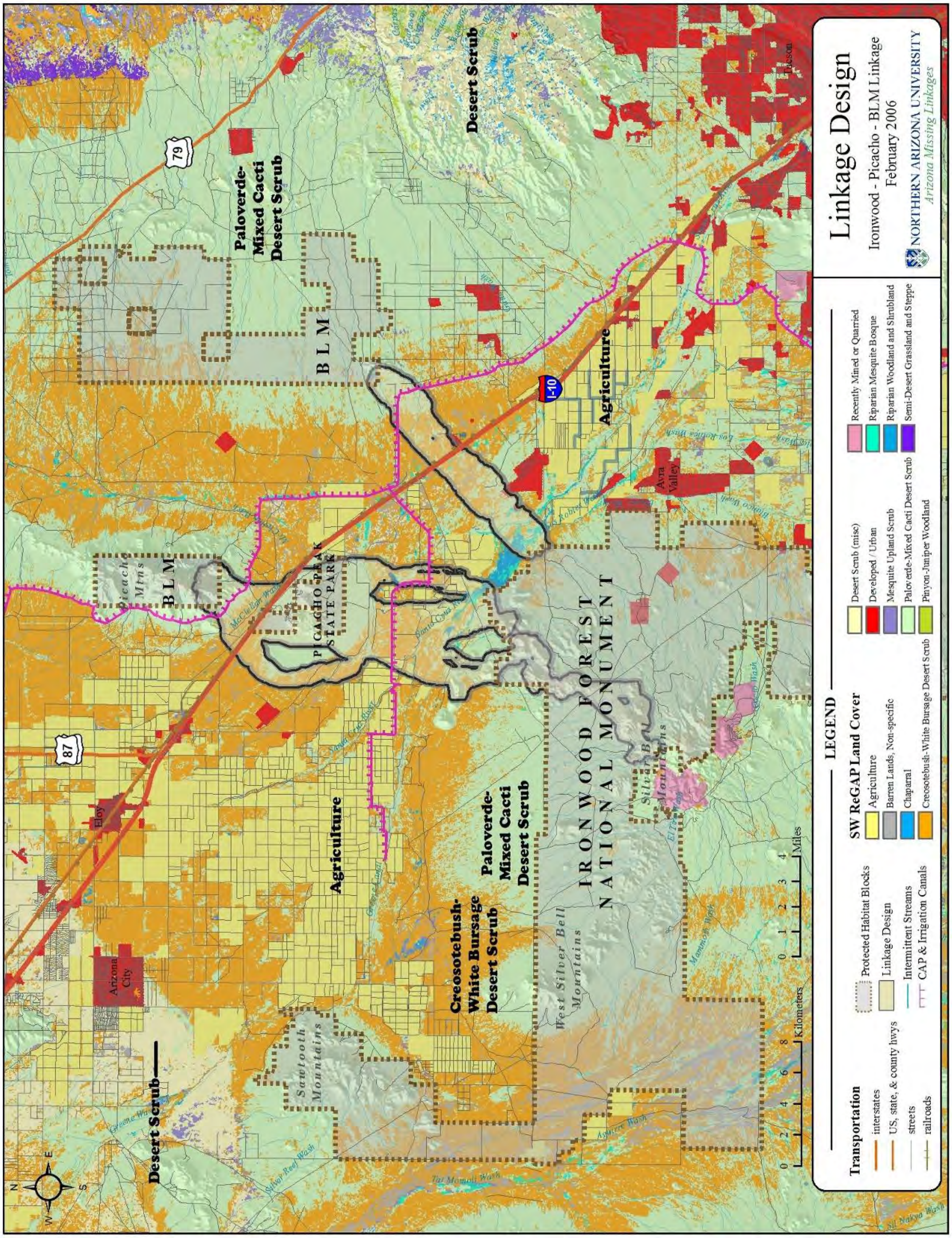

Figure 5: Land cover within Linkage Design.

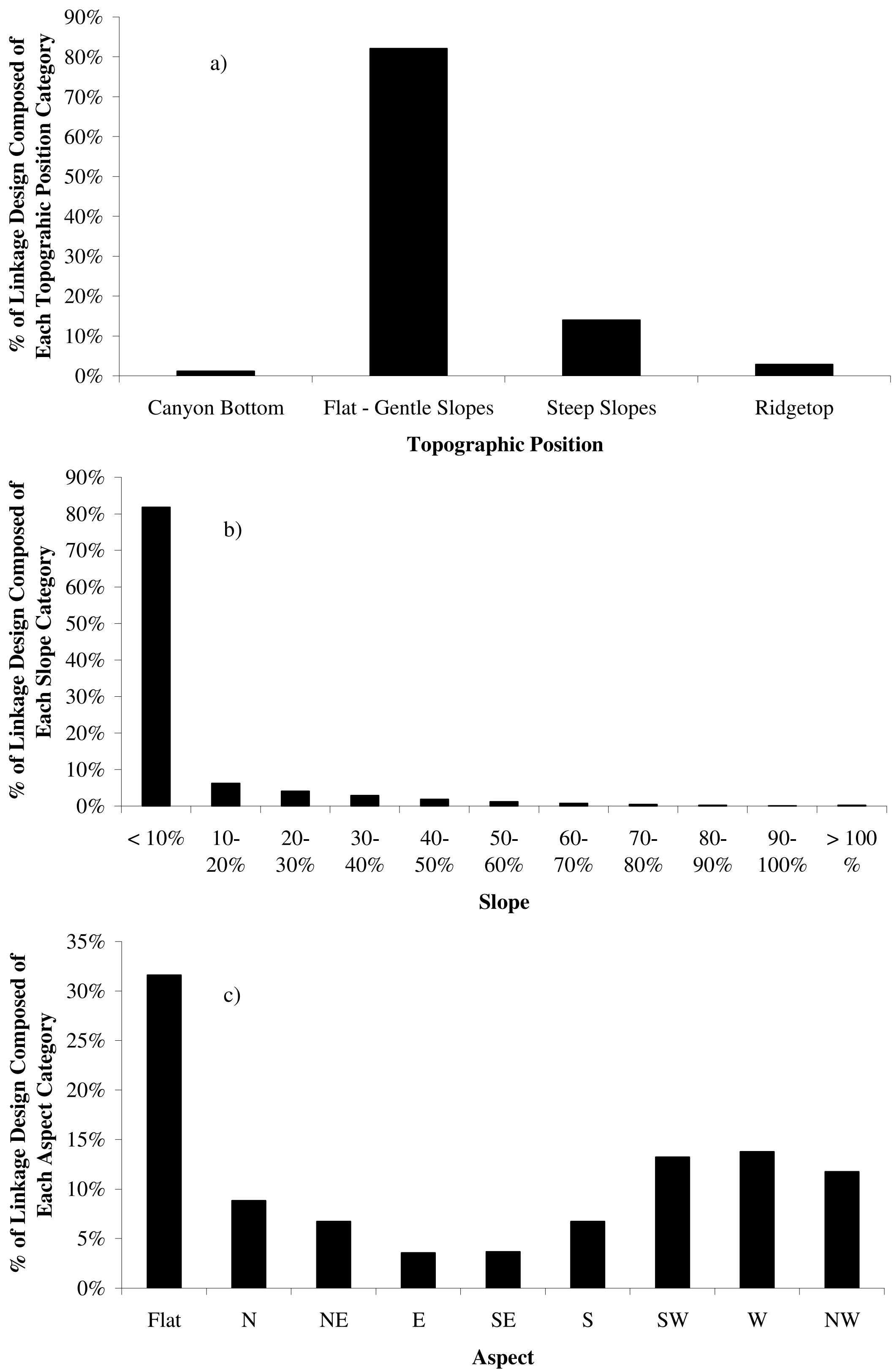

Figure 6: Topographic diversity encompassed by Linkage Design: a) Topographic position, b) Slope, c) Aspect.

Removing and Mitigating Barriers to Movement

Although roads, rail lines, canals, and agriculture occupy only a small fraction of the Linkage Design, their impacts threaten to block animal movement between the wildland blocks. In this section, we review the potential impacts of these features on ecological processes, identify specific barriers in the Linkage Design, and suggest mitigation methods for these barriers. The complete database of our field investigations, including UTM coordinates and photographs, is provided in Appendix G and the Microsoft Access database on the CD-ROM accompanying this report.

Although roads, canals, and fences impede animal movement, and the crossing structures we recommend are important, we remind the reader that crossing structures are only part of the overall linkage design. To restore and maintain connectivity between the Ironwood, Picacho Mountains, and desert BLM blocks, it is essential to consider the *entire* linkage design, including conserving the land in the linkage. Indeed, investment in a crossing structure would be futile if habitat between the crossing structure and either protected block is lost.

Impacts of Roads on Wildlife

While the physical footprint of the nearly 4 million miles of roads in the United States is relatively small, the *ecological* footprint of the road network extends much farther. Direct effects of roads include road mortality, habitat fragmentation and loss, and reduced connectivity. The severity of these effects depends on the ecological characteristics of a given species (Figure 7). Direct **roadkill** affects most species, with severe documented impacts on wide-ranging predators such as the cougar in southern California, the Florida panther, the ocelot, the wolf, and the Iberian lynx (Forman et al. 2003). In a 4-year study of 15,000 km of road observations in Organ Pipe Cactus National Monument, Rosen and Lowe (1994) found an average of at least 22.5 snakes per km per year killed due to vehicle collisions. Although we may not often think of roads as causing **habitat loss**, a single freeway (typical width = 50 m, including median and shoulder) crossing diagonally across a 1-mile section of land results in the loss of 4.4% of habitat area for any species that cannot live in the right-of-way. Roads cause **habitat fragmentation** because they break large habitat areas into small, isolated habit patches which support few individuals; these small populations lose genetic diversity and are at risk of local extinction.

In addition to these obvious effects, roads create noise and vibration that interfere with ability of reptiles, birds, and mammals to communicate, detect prey, or avoid predators. Roads also increase the spread of exotic plants, promote erosion, create barriers to fish, and pollute water sources with roadway chemicals (Forman et al. 2003). Highway lighting also has important impacts on animals (Rich and Longcore 2006).

Mitigation for Roads

Wildlife crossing structures that have been used in North America and Europe to facilitate movement through landscapes fragmented by roads include wildlife overpasses & green bridges, bridges, culverts, and pipes (Figure 8). While many of these structures were not originally constructed with ecological connectivity in mind, many species benefit from them (Clevenger et al. 2001; Forman et al. 2003). No single crossing structure will allow all species to cross a road. For example rodents prefer to use pipes and small culverts, while bighorn prefer vegetated overpasses or open terrain below high bridges. A concrete box culvert may be readily accepted by a mountain lion or bear, but not by a deer or bighorn sheep. Small mammals, such as deer mice and voles, prefer small culverts to wildlife overpasses (McDonald & St Clair 2004).

Wildlife overpasses are most often designed to improve opportunities for large mammals to cross busy highways. Approximately 50 overpasses have been built in the world, with only 6 of these occurring in North America (Forman et al. 2003). Overpasses are typically 30 to 50 m wide, but can be as large as 200 m wide. In Banff National Park, Alberta, grizzly bears, wolves, and all ungulates (bighorn sheep, deer, elk, and moose) prefer overpasses to underpasses, while species such as mountain lions prefer underpasses (Clevenger & Waltho 2005).

Wildlife underpasses include viaducts, bridges, culverts, and pipes, and are often designed to ensure adequate drainage beneath highways. For ungulates such as deer, tall, wide bridges are best. Mule deer in southern California only used underpasses below large spanning bridges (Ng et al. 2004) and the average size of underpasses used by white-tailed deer in Pennsylvania was 15 ft wide by 8 ft high (Brudin 2003). Because most small mammals, amphibians, reptiles, and insects need vegetative cover for security, bridged undercrossings should extend to uplands beyond the scour zone of the stream, and should be high enough to allow enough light for vegetation to grow underneath. In the Netherlands, rows of stumps or branches under crossing structures have increased connectivity for smaller species crossing bridges on floodplains (Forman et al. 2003).

Drainage culverts can mitigate the effects of busy roads for small and medium sized mammals (Clevenger et al. 2001; McDonald & St Clair 2004). Culverts and concrete box structures are used by many species, including mice, shrews, foxes, rabbits, armadillos, river otters, opossums, raccoons, ground squirrels, skunks, coyotes, bobcats, mountain lions, black bear, great blue heron, long-tailed weasel, amphibians, lizards, snakes, and southern leopard frogs (Yanes et al. 1995; Brudin III 2003; Dodd et al. 2004; Ng et al. 2004). Black bear and mountain lion prefer less-open structures (Clevenger & Waltho 2005). In south Texas, bobcats most often used 1.85 m x 1.85 m box culverts to cross highways, preferred structures near suitable scrub habitat, and sometimes used culverts to rest and avoid high temperatures (Cain et al. 2003). Culvert usage can be enhanced by providing a natural substrate bottom, and in locations where the floor of a culvert is persistently covered with water, a concrete ledge established above water level can provide terrestrial species with a dry path through the structure (Cain et al. 2003). It is important for the lower end of the culvert to be flush with the surrounding terrain. Many culverts are built with a concrete pour-off of 8-12 inches, and others develop a pour-off lip due to scouring action of water. A sheer pour-off of several inches makes it unlikely that many small mammals, snakes, and amphibians will find or use the culvert.

Figure 7: Characteristics which make species vulnerable to the three major direct effects of roads (from Forman et al. 2003).

	EFFECT OF ROADS		
CHARACTERISTICS MAKING A SPECIES VULNERABLE TO ROAD EFFECTS	Road mortality	Habitat loss	Reduced connectivity
Attraction to road habitat	★		
High intrinsic mobility	★		
Habitat generalist	★		
Multiple-resource needs	★		★
Large area requirement/low density	★	★	★
Low reproductive rate	★	★	★
Behavioral avoidance of roads			★

Figure 8: Potential road mitigations (from top to bottom) include: highway overpasses, bridges, culverts, and drainage pipes. Fencing (lower right) should be used to guide animals into crossing structures.

Based on the small but increasing number of scientific studies on wildlife use of highway crossing structures, we offer these standards and guidelines for all existing and future crossing structures intended to facilitate wildlife passage. These recommendations are consistent with AGFD Guidelines for constructing culverts and passage (http://www.azgfd.gov/hgis/guidelines.aspx). In selecting focal species for this report, we solicited experts to identify threatened, endangered, and other species of concern as defined by state or federal agencies, paying attention to those with special needs for culverts or road-crossing structures. At the time of mitigation, we urge planners to determine if additional species need to be considered, and to monitor fish and wildlife movements in the area in order to determine major crossing areas, behaviors, and crossing frequencies. Such data can improve designs in particular locations and provide baseline data for monitoring the effectiveness of mitigations.

1) **Multiple crossing structures should be constructed at a crossing point to provide connectivity for all species likely to use a given area** (Little 2003). Different species prefer different types of structures (Clevenger et al. 2001; McDonald & St Clair 2004; Clevenger & Waltho 2005; Mata et al. 2005). For deer or other ungulates, an open structure such as a bridge is crucial. For medium-sized mammals, black bear, and mountain lions, large box culverts with a natural earthen substrate flooring are optimal (Evink 2002). For small mammals, pipe culverts from 0.3m – 1 m in diameter are preferable (Clevenger et al. 2001; McDonald & St Clair 2004).

2) **At least one crossing structure should be located within an individual's home range**. Because most reptiles, small mammals, and amphibians have small home ranges, metal or cement box culverts should be installed at intervals of 150-300 m (Clevenger et al. 2001). For ungulates (deer, pronghorn, bighorn) and large carnivores, larger crossing structures such as bridges, viaducts, or overpasses should be located no more than 1.5 km (0.94 miles) apart (Mata et al. 2005; Clevenger and Wierzchowski 2006). Inadequate size and insufficient number of crossings are two primary causes of poor use by wildlife (Ruediger 2001).

3) **Suitable habitat for species should occur on both sides of the crossing structure** (Ruediger 2001; Barnum 2003; Cain et al. 2003; Ng et al. 2004). This applies to both *local* and *landscape* scales. On a local scale, vegetative cover should be present near entrances to give animals security, and reduce negative effects such as lighting and noise associated with the road (Clevenger et al. 2001; McDonald & St Clair 2004). A lack of suitable habitat adjacent to culverts originally built for hydrologic function may prevent their use as potential wildlife crossing structures (Cain et al. 2003). On the landscape scale, "Crossing structures will only be as effective as the land and resource management strategies around them" (Clevenger et al. 2005). Suitable habitat must be present throughout the linkage for animals to use a crossing structure.

4) **Whenever possible, suitable habitat should occur *within* the crossing structure.** This can best be achieved by having a bridge high enough to allow enough light for vegetation to grow under the bridge, and by making sure that the bridge spans upland habitat that is not regularly scoured by floods. Where this is not possible, rows of stumps or branches under large span bridges can provide cover for smaller animals such as reptiles, amphibians, rodents, and invertebrates; regular visits are needed to replace artificial cover removed by flood. Within culverts, earthen floors are preferred by mammals and reptiles.

5) **Structures should be monitored for, and cleared of, obstructions such as detritus or silt blockages that impede movement.** Small mammals, carnivores, and reptiles avoid crossing structures with significant detritus blockages (Yanes et al. 1995; Cain et al. 2003; Dodd et al. 2004). In the southwest, over half of box culverts less than 8 x 8 ft have large accumulations of branches, Russian thistle, sand, or garbage that impede animal movement (Beier, personal observation). Bridged undercrossings rarely have similar problems.

6) **Fencing should never block entrances to crossing structures, and instead should direct animals towards crossing structures** (Yanes et al. 1995). In Florida, construction of a barrier wall to guide animals into a culvert system resulted in 93.5% reduction in roadkill, and also increased the total number of species using the culvert from 28 to 42 (Dodd et al. 2004). Fences, guard rails, and embankments at least 2 m high discourage animals from crossing roads (Barnum 2003; Cain et al. 2003; Malo et al. 2004). One-way ramps on roadside fencing can allow an animal to escape if it is trapped on a road (Forman et al. 2003).

7) **Raised sections of road discourage animals from crossing roads, and should be used when possible to encourage animals to use crossing structures**. Clevenger et al. (2003) found that vertebrates were 93% less susceptible to road-kills on sections of road raised on embankments, compared to road segments at the natural grade of the surrounding terrain.

8) **Manage human activity near each crossing structure**. Clevenger & Waltho (2000) suggest that human use of crossing structures should be restricted and foot trails relocated away from structures intended for wildlife movement. However, a large crossing structure (viaduct or long, high bridge) should be able to accommodate both recreational and wildlife use. Furthermore, if recreational users are educated to maintain utility of the structure for wildlife, they can be allies in conserving wildlife corridors. At a minimum, nighttime human use of crossing structures should be restricted.

9) **Design culverts specifically to provide for animal movement**. Most culverts are designed to carry water under a road and minimize erosion hazard to the road. Culvert designs adequate for transporting water often have pour-offs at the downstream ends that prevent wildlife usage. At least 1 culvert every 150-300m of road should have openings flush with the surrounding terrain, and with native land cover up to both culvert openings, as noted above.

Existing Roads and Rail Lines in the Linkage Design Area

There are approximately 148 km (93 mi) of roads in the Linkage Design. Interstate 10 runs northwest-southeast through every strand of the linkage, and is the single most important transportation threat to connecting Ironwood Forest National Monument with the Picacho Mountains and with the Durham-Coronado Plain. Except for I-10 and its frontage roads, the other roads in the linkage are local roads with relatively low traffic and traffic speed. Parallel to I-10, about 8.3 km (523 mi) of the Union Pacific Railroad runs through the linkage area. We conducted field investigations of many of these roads to document existing crossing structures that could be modified to enhance species movements through the area.

Table 3: Major transportation routes in the Linkage Design.

ROAD NAME	KILOMETERS	MILES
I-10	8.9	5.5
Union Pacific Railroad	8.3	5.2
Peak Ln.	6.8	4.2
Camino Adelante Rd.	6.6	4.1
Sasco Rd.	5.6	3.5
Baumgartner Rd.	5.1	3.2
Jacinto Rd.	4.5	2.8
La Osa Ranch Rd.	2.9	2.7
Nona Rd.	3.5	2.2
Cripple Creek Rd.	3.0	1.8
Rice Rd.	2.6	1.6
Picacho Dr.	2.3	1.5

Pipeline Rd,	2.0	1.3
Silverbell Rd.	2.0	1.2
Picacho Peak Rd.	1.7	1.1
Grandfather Pl.	1.4	0.9
Coachway Rd.	0.9	0.6
Longhoen Trl.	0.8	0.5
Jet Dr.	0.7	0.5
Whirl Wind Way	0.6	0.4
Eisenhour	0.4	0.2
Unnamed Roads (mostly dirt roads)	77	48.1
Total length of transportation routes	148	93

Existing Crossing Structures on I-10

Interstate 10 is the most significant road barrier to connectivity within the Linkage Design. NAFTA and the proposed CANAMEX effort to promote commerce among Canada, the United States, and Mexico, will cause large increases in traffic on I-10. Because every animal moving between the Ironwood, Picacho, and Durham-Coronado Plain wildland blocks must traverse this highway, crossing structures along I-10 are crucial to success of the corridor. Within the linkage design, crossing structures have been built to accommodate intermittent stream flow in several washes. Most structures are small concrete box culverts. Because I-10 parallels the Union Pacific Railroad, most crossing structures under I-10 have an adjacent crossing under the railroad.

Within the eastern strand of the linkage design (between Ironwood National Monument and the Durham-Coronado Plain), we observed only three crossing structures. We may have failed to detect a few pipe culverts. We list them from south to north:

- At the southern end of this strand, there is a multiple span box culvert under I-10. This structure was composed of four 3 x 10 ft box culverts, and the entrance was blocked with a barbed-wire fence. Adjacent to this structure is a wooden crossing structure under the Union Pacific Railroad (Figure 9).

- Approximately 700 meters north of the southernmost crossing in this linkage area, a small twin-span cement culvert has been filled with sand and sediment. A barbed-wire wire fence blocks access to the entrance of this crossing structure. Adjacent to this structure is a wooden crossing structure under the Union Pacific Railroad (Figure 10).

- Approximately 1600 meters north of the previous crossing structure, and 150 meters south of the northern border of the Ironwood-BLM strand, is another small cement box culvert. This structure consists of three structures, each approximately 4 x 10 ft. A barbed-wire wire fence blocks access to the entrance of this crossing structure. Adjacent to this structure is a wooden crossing structure under the Union Pacific Railroad (Figure 11).

Figure 9: Four 3 x 10 ft box culverts under I-10 (photo azimuth 280) and a wooden railroad crossing (photo azimuth 174) at waypoint 72.

Figure 10: A small twin-span cement culvert (azimuth: 280) and a wooden railroad crossing (azimuth: 174) occur at waypoint 73.

Figure 11: Three small cement culverts (azimuth: 268) and a wooden railroad crossing (azimuth: 54) occur at waypoint 74, near mile post 227.

Within the western strand of the linkage design (Ironwood-Picacho Mountains), we observed nine existing crossing structures. We list them from south to north:

- Approximately 500 meters east of the linkage border is a small cement box culvert under I-10 (waypoint 87, not photographed).
- There are crossing structures consisting of two 4 x 6 ft box culverts at waypoints 94, 95, 96, 88, 89. An example of these culverts is found in Figure 12.
- Just north of Picacho Peak State Park is a small culvert that has been choked with vegetation, making it inaccessible to most species (Figure 13).
- A small crossing structure found north of Picacho Peak State Park consists of two 4 x 4 ft box culverts (Figure 14).
- A small 4 x 4 foot box culvert 700 meters northwest of Picacho Peak State Park (Figure 15).

Figure 12: Two examples of twin-span 4 x 6 ft culverts found in the Ironwood – Picacho strand of the linkage design (Left: waypoint 88, Right: waypoint 89. Azimuth on both photos: 220).

Figure 13: The entrance of this small box culvert north of Picacho Peak State Park has been blocked with vegetation (waypoint 90, azimuth 24).

Figure 14: A small twin-span cement culvert (azimuth: 220) and a wooden railroad crossing (azimuth: 22) occur at waypoint 91.

Figure 15: A small 4 x 6 ft cement culvert filled with tumbleweeds (azimuth: 228) occurs at waypoint 92.

Recommendations for Interstate 10

The existing crossing structures are not adequate to serve the movement needs of the full suite of wildlife species that need to move between Ironwood Forest National Monument, the Picacho mountains, and the block of BLM-administered Sonoran desert land. We recommend upgrading the crossing structures described above as follows:

- Replace at least one of the three cement culverts within the eastern strand of the linkage with a larger, open bridge that will allow desert mule deer to pass under I-10. As documented above, ungulates such as deer prefer open crossing structures, and avoid closed structures such as the existing box culverts. Due to the proximity of the southernmost crossing structures (Figure 9 and Figure 10) to the Saguaro Power plant, the best location for the installation of a bridge is likely the northernmost crossing structure in this strand, at waypoint 74.

- Upgrade the other two culverts within the eastern strand with larger, more open culverts. Remove barbed-wire fences from the entrance of these structures, and ensure that access is not blocked with vegetation. Use fencing to guide animals toward the crossing structures. Manage these crossing structures to ensure they do become filled with sediments, tumbleweeds, and other impediments.

Instead of periodically removing obstacles lodged in the culverts, it may be more efficient to construct a debris dam or catchment 50-100m upstream from the culvert.

- Replace at least two of the cement culverts in the western linkage strand with large open bridges or overpasses that will allow desert bighorn sheep and desert mule deer to cross I-10. None of the existing crossing structures in the linkage design are sufficient for use by ungulates, and are currently useless in maintaining connectivity across I-10 for these species. Because bighorn sheep are dependent on steep topography and likely to move through flat areas only to reach other patches of rugged topography (e.g. between the Silver Bell Mountains, Picacho Peak, and the Picacho Mountains), the best locations of bridges for ungulates are at waypoints 88, 89, and 90 (Figure 4).

- While the small crossing cement culverts in the western strand may work for some small animals, the entrances of many structures are blocked with vegetation or debris, and are filled in with sediment. We recommend that at a minimum, these culverts should be designed and maintained to encourage usage by small mammals, amphibians, and reptiles. Instead of periodically removing obstacles lodged in the culverts, it may be more efficient to construct a debris dam or catchment 50-100m upstream from the culvert.

Impacts of Canals on Wildlife

Canals can have both positive and negative impacts on desert wildlife. Some species may use canals as a water source, but the steep banks make it impossible or dangerous for most animals to do so. Desert mule deer, bighorn sheep, and Sonoran pronghorn have drowned in canals (Rautenstrauch & Krausman 1989). Canals serve as significant barriers to movement by preventing species from moving to viable habitat on the other side of the canal, drowning species, and rerouting natural movement patterns.

Canals in the Linkage Design Area

Two main canals act as barriers to connectivity in the linkage zone (Figure 16). The Central Arizona Project's (CAP) Tucson Canal crosses through both strands of the linkage design. The CAP canal is approximately 12 meters (39 ft) wide, and is lined with eight-foot fences on both sides to keep large animals out. A smaller irrigation canal connects to the CAP canal, extending westward through the strand of the linkage design connecting Ironwood Forest National Monument to the Picacho Mountains (Figure 17). This canal parallels Baumgartner Rd. for 9 km (5.6 mi), and is approximately 5 meters (16 ft) wide.

There is only one location where wildlife can safely cross the CAP canal in the linkage design. About 1.4 km of a buried stretch of the CAP canal (out of the total 2.5 km length of the buried section) lies in the eastern strand of the linkage design (Figure 16). There are no crossing structures for animals in the western strand of the linkage design.

The only opportunities to cross the smaller irrigation canal are where the canal crosses under dirt roads (Figure 18).

Mitigation for Canals

To conserve connectivity, we have the following recommendations for all existing and future canals in this linkage zone:

1) **Ensure opportunities for wildlife to cross every canal in the linkage area**. This can be accomplished by several methods. The most permeable, yet most expensive method is to bury any canal within the linkage design below ground. The eastern strand contains a buried section of canal that effectively mitigates the effect of the canal in this strand. In the western strand, a significant section of the CAP canal should be buried, or crossing structures should be installed. For *wide canals*, such as the CAP, vegetated overpasses should be installed. While no studies have examined optimal crossing structures for canals, information can be gleaned from the literature on the determinants of success for road mitigation structures. For example, Van Wieren & Worm (2001) recommend wildlife overpasses over roads be at least 40-50 m wide for optimal wildlife usage. For *narrow canals*, such as the irrigation canal in the western strand of the linkage design, an affordable solution would be to cover the canal with metal plates, and cover these plates with an earthen substrate. The existing crossings at dirt roads (Figure 18) are helpful, but lack vegetation needed for some wildlife species to find them attractive. To ensure usability by an array of species, the grade of the entrance and exit to these crossing structures should provide a gentle approach to the canal.

2) **Install fencing on all areas of the canal which do not have crossing structures.** This fencing must completely seal the canal in order for it to effectively restrict wildlife use (Rautenstrauch & Krausman 1989), and be sufficiently high to prevent deer from jumping the fence (Peris & Morales 2004).

3) **Provide alternative water sources adjacent to crossing structures** (Rautenstrauch & Krausman 1989). To discourage use of the canals as a water supply by deer and other species, a small amount of water should be diverted to water catchments to allow wildlife to drink without risk of drowning.

4) **Provide escape structures for deer and other species along any area of the canal which does not have a crossing structure or fencing.** Cable-and-float directors in conjunction with stairs or ramps should be installed in the canal to provide deer and other species means of escaping the canal. In a study of Desert mule deer use of the Mohawk Canal, Rautenstrauch and Krausman (1989) found that deer swam an average of 947 meters before escaping via escape structures. They recommend escape structures should be spaced 2 km apart or less. Every canal section with a dam, siphon, or other hazard should have at least 2 escape structures, at least 1 of them upstream from the hazard.

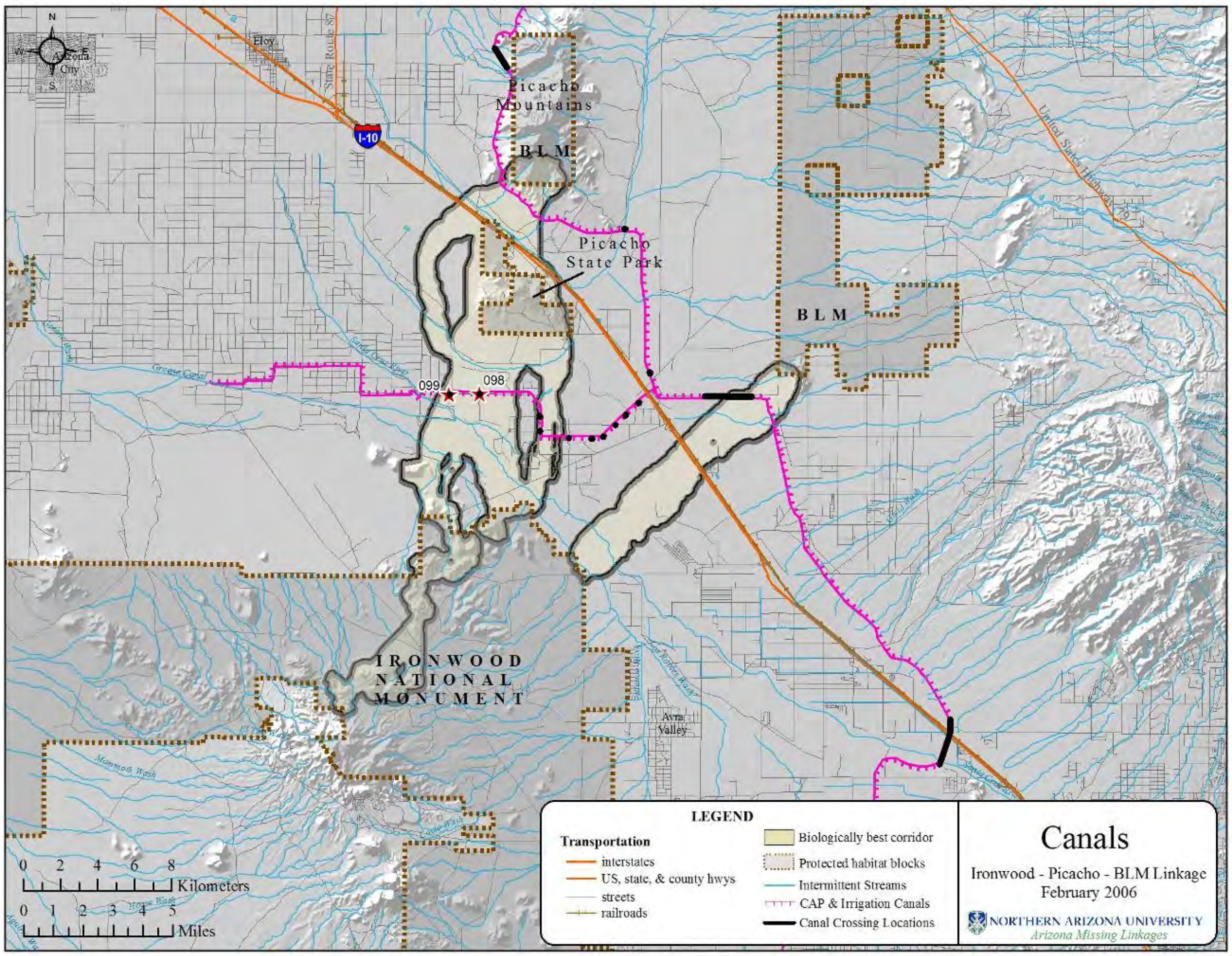

Figure 16: Canals in the Linkage Design area. The 4 black lines indicate buried sections of the Central Arizona Project canal: a 1.3-km stretch on the northwest side of the Picacho Mountains, a 70-m stretch at McClellan Wash, a 2.5-km stretch in the eastern strand of the linkage design, and a 2.5 km stretch under Interstate 10.

Figure 17: An irrigation canal connected to the CAP canal intersects all portions of the Ironwood - Picacho Mtns linkage (waypoint 98, azimuth: 96).

Figure 18: The only locations where an animal can safely cross the irrigation canal are where roads pass over the canal (waypoint 99, azimuth: 286).

Recreational Off-Highway Vehicle Use as a Barrier to Movement

Recreational off-highway vehicle (OHV) use within the linkage design area threatens connectivity. OHV use disrupts natural vegetation associations and topography, compacts soil, increases erosion, and creates a considerable noise disturbance likely to affect wildlife (Brooks & Lair 2005). Studies have found that OHV use contributes to declines of herbaceous and perennial plants, arthropods, lizards, and mammals (Luckenbach & Bury 1983). OHV users often use hills and washes, which may negatively affect desert tortoise habitat (Jennings 1997). A major location for OHV use is on State Trust Land adjacent to Pinal Air Park, within the western strand of the linkage design (Figure 19 & Figure 20). This site is accessed from Pinal Air Park Rd., and users are permitted to use the area with a $15 State Land Recreational Permit from Arizona State Trust Lands. The site is approximately 1 km^2 and extends halfway into the linkage design.

Mitigation for OHV Use

To conserve connectivity, we recommend limiting or prohibiting OHV use within the linkage design. We also recommend restoration of native vegetation and natural topography for areas degraded by OHV use. Where an ORV use area abuts the linkage design, we recommend fencing, signs, and public education to encourage responsible behavior and prevent encroachment into the linkage.

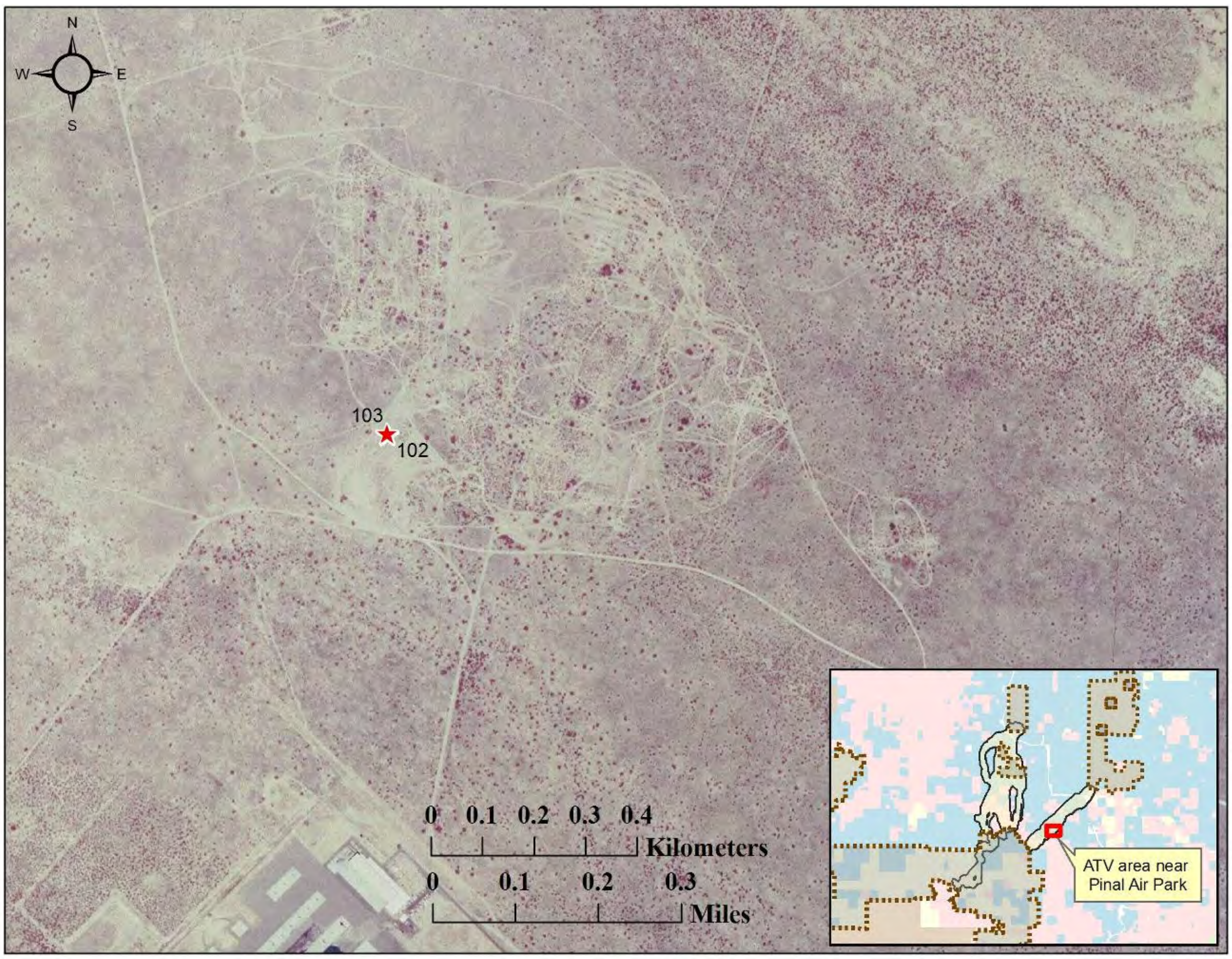

Figure 19: An OHV area on State Trust Land near Pinal Air Park affects connectivity between Ironwood Forest National Monument and the desert BLM block to thte northwest.

Figure 20: OHV use has altered vegetation and threatens connectivity (waypoint 102, azimuth: 122). See Figure 19 to locate this scene within the Linkage Design.

Urban Development as Barriers to Movement

While not a current major threat in the linkage area, urban and industrial development may become a greater threat in the future. Urban and industrial development, unlike roads, creates barriers to movement which cannot easily be removed, restored, or otherwise mitigated. Most large carnivores, small mammals, and reptiles cannot occupy these areas for a significant period of time, although several species of lizards or small mammals may occasionally occupy residential areas. While mapped urban areas only accounted for a marginal amount of the land cover in the linkage design, residential development may increase rapidly in the linkage area in the future.

Urban Barriers in the Linkage Design Area

While there are no current residential developments within the Linkage Design, there are several industrial developments. South of the Ironwood – desert BLM strand of the linkage, adjacent to I-10, is the Saguaro Power Plant (Figure 21). Several large tanks from the power plant are 200 m inside the border of this linkage.

Figure 21: The Saguaro Power Plant borders the southern end of the Ironwood - Picacho linkage adjacent to I-10 (waypoint 72; azimuth: 38).

The Pinal Air Park borders the southern end of the Ironwood – desert BLM linkage, approximately 4 km northwest of the Ironwood Forest National Monument boundary (Figure 22). In addition to storing aircraft, there is also a 1.2 mile racecourse for sports cars at the Air Park.

Figure 22: The Pinal Air Park borders the southern end of the Ironwood - Picacho linkage 4 km northwest of Ironwood Forest National Monument. ATV use in foreground (waypoint 103; azimuth: 178).

Mitigation for Urban Barriers

To conserve connectivity, we have the following recommendations for all future urban, residential, and industrial developments in this linkage zone:

1) Encourage conservation easements and land acquisition with willing land owners in the Linkage Design to protect important habitat.
2) Develop a public education campaign to inform those living and working within the linkage area about the local wildlife and the importance of maintaining ecological connectivity.
3) Encourage homeowners to focus outside lighting on their houses only, and never out into the linkage area.
4) Ensure that all domestic pets are kept indoors or in fenced areas outdoors.
5) Reduce vehicle traffic speeds in sensitive locations.
6) Discourage the conversion of natural areas within the Linkage Design into residential areas. Where development is permitted, encourage small building footprints on large (> 10-acre) parcels.
7) Encourage the use of wildlife-friendly fencing.
8) Discourage the killing of ‘threat’ species such as rattlesnakes.

Appendix A: Linkage Design Methods

Our goal was to identify a continuous corridor of land which – if conserved and integrated with underpasses or overpasses across potential barriers – will best maintain or restore the ability of wildlife to move between large *protected wildland blocks*. We call this proposed corridor the *Linkage Design*.

To create the Linkage Design, we used GIS approaches to identify optimal travel routes for focal species representing the ecological community in the area[3]. By carefully selecting a diverse group of focal species and capturing a range of topography to accommodate climate change, the Linkage Design should ensure the long-term viability of all species in the protected areas. Our approach included six steps:

1) Select focal species.
2) Create a habitat suitability model for each focal species.
3) Join pixels of suitable habitat to identify potential breeding patches & potential population cores (areas that could support a population for at least a decade).
4) Identify the biologically best corridor (BBC) through which each species could move between protected core areas. Join the BBCs for all focal species.
5) Ensure that the union of BBCs includes enough population patches and cores to ensure connectivity.
6) Carry out field visits to identify barriers to movement and the best locations for underpasses or overpasses within Linkage Design area.

Focal Species Selection

To represent the needs of the ecological community within the potential linkage area, we used a focal species approach (Lambeck 1997). Regional biologists familiar with the region identified 20 species (Table 1) that had one or more of the following characteristics:

- habitat specialists, especially habitats that may be relatively rare in the potential linkage area.
- species sensitive to highways, canals, urbanization, or other potential barriers in the potential linkage area, especially species with limited movement ability.
- area-sensitive species that require large or well-connected landscapes to maintain a viable population and genetic diversity.
- ecologically important species such as keystone predators, important seed dispersers, herbivores that affect vegetation, or species that are closely associated with nutrient cycling, energy flow, or other ecosystem processes.
- species listed as threatened or endangered under the Endangered Species Act, or species of special concern to Arizona Game and Fish Department, US Forest Service, or other management agencies.

Information on each focal species is presented in Appendix B. As indicated in Table 1, we constructed models for some, but not all, focal species. We did not model species for which there were insufficient data to quantify habitat use in terms of available GIS data (e.g., some snakes that select small rocks), or if the species probably can travel (e.g., by flying) across unsuitable habitat.

Habitat Suitability Models

[3] Like every scientific model, our models involve uncertainty and simplifying assumptions, and therefore do not produce absolute “truth” but rather an estimate or prediction of the optimal wildlife corridor. Despite this limitation, there are several reasons to use models instead of maps hand-drawn by species experts or other intuitive approaches. (1) Developing the model forces important assumptions into the open. (2) Using the model makes us explicitly deal with interactions (e.g., between species movement mobility and corridor length) that might otherwise be ignored. (3) The model is transparent, with every algorithm and model parameter available for anyone to inspect and challenge. (4) The model is easy to revise when better information is available.

We created habitat suitability models (Appendix B) for each species by estimating how the species responded to four habitat factors that were mapped at a 30x30 m level of resolution (Figure 23):

- *Vegetation and land cover.* We used the Southwest Regional GAP Analysis (ReGAP) data, merging some classes to create 46 vegetation & land cover classes as described in Appendix E.
- *Elevation.* We used the USGS National Elevation Dataset digital elevation model.
- *Topographic position.* We characterized each pixel as ridge, canyon bottom, flat to gentle slope, or steep slope.
- *Straight-line distance from the nearest paved road or railroad.* Distance from roads reflects risk of being struck by vehicles as well as noise, light, pets, pollution, and other human-caused disturbances.

To create a habitat suitability map, we assigned each of the 46 vegetation classes (and each of 4 topographic positions, and each of several elevation classes and distance-to-road classes) a score from 1 (best) to 10 (worst), where 1-3 is optimal habitat, 4-5 is suboptimal but usable habitat, 6-7 may be occasionally used but cannot sustain a breeding population, and 8-10 is strongly avoided. Whenever possible we recruited biologists with the greatest expertise in each species to assign these scores (see *Acknowledgements*). When no expert was available for a species, three biologists independently assigned scores and, after discussing differences among their individual scores, were allowed to adjust their scores before the three scores were averaged. Regardless of whether the scores were generated by a species expert or our biologists, the scorer first reviewed the literature on habitat selection by the focal species[4].

This scoring produced 4 scores (land cover, elevation, topographic position, distance from roads) for each pixel, each score being a number between 1 and 10. We then weighted each of the by 4 factors by a weight between 0% and 100%, subject to the constraint that the 4 weights must sum to 100%, and added the 4 weighted scores to produce an overall habitat suitability score that was also scaled 1-10. We used these habitat suitability scores to create a habitat suitability map that formed the foundation for the later steps.

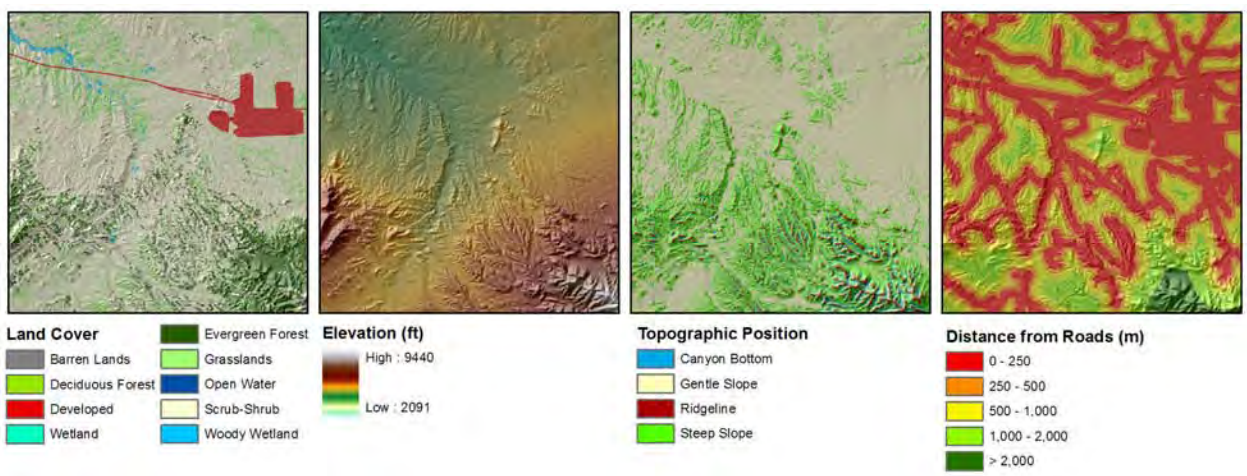

Figure 23: Four habitat factors used to create habitat suitability models. Inputs included vegetation, elevation, topographic position, and distance from roads.

[4] Clevenger et al. (2002) found that literature review significantly improved the fit between expert scores and later empirical observations of animal movement.

If necessary, we also used additional factors critical for a particular species, such as a minimum slope needed as escape terrain for bighorn sheep, or proximity to water for frogs. To create a habitat suitability model using critical features, we reclassified any pixel beyond a specified threshold distance from the critical feature as unsuitable for breeding (score > 5). This was accomplished using the equation:

New habitat score for pixel beyond threshold distance = (½ of original habitat score) + 5

Therefore, if a pixel of habitat located *beyond* the threshold distance from a critical feature had an original habitat score of 1 (optimal habitat), it received a reclassified score of 5.5 (usable, but not breeding habitat). Likewise, unsuitable habitat located outside of the threshold distance remained unsuitable: an original score of 9 would be reclassified as 9.5. All pixels of habitat *within* the threshold distance of a critical feature maintained their original habitat score.

Identifying Potential Breeding Patches & Potential Population Cores

The habitat suitability map provides scores for each 30x30-m pixel. For our analyses, we also needed to identify – both in the Wildland blocksand in the Potential linkage area – areas of good habitat large enough to support reproduction. Specifically, we wanted to identify

- *potential breeding patches*: areas large enough to support a breeding unit (individual female with young, or a breeding pair) for one breeding season. Such patches could be important stepping-stones for species that are unlikely to cross a potential linkage area within a single lifetime.
- *potential population cores*: areas large enough to support a breeding population of the focal species for about 10 years.

To do so, we first calculated the suitability of any pixel as the average habitat suitability in a neighborhood of pixels surrounding it (Figure 24). We averaged habitat suitability within a 3x3-pixel neighborhood (0.81 ha) for less-mobile species, and within a 200-m radius (12.6 ha) for more-mobile species[5]. Thus each pixel had both a *pixel score* and a *neighborhood score*. Then we joined adjacent pixels of suitable habitat (pixels with neighborhood score < 5) into polygons that represented potential breeding patches or potential population cores. The minimum sizes for each patch type were specified by the biologists who provided scores for the habitat suitability model.

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[5] An animal that moves over large areas for daily foraging perceives the landscape as composed of relatively large patches, because the animal readily moves through small swaths of unsuitable habitat in an otherwise favorable landscape (Vos et al. 2001). In contrast, a less-mobile mobile has a more patchy perception of its surroundings. Similarly, a small island of suitable habitat in an ocean of poor habitat will be of little use to an animal with large daily spatial requirements, but may be sufficient for the animal that requires little area.

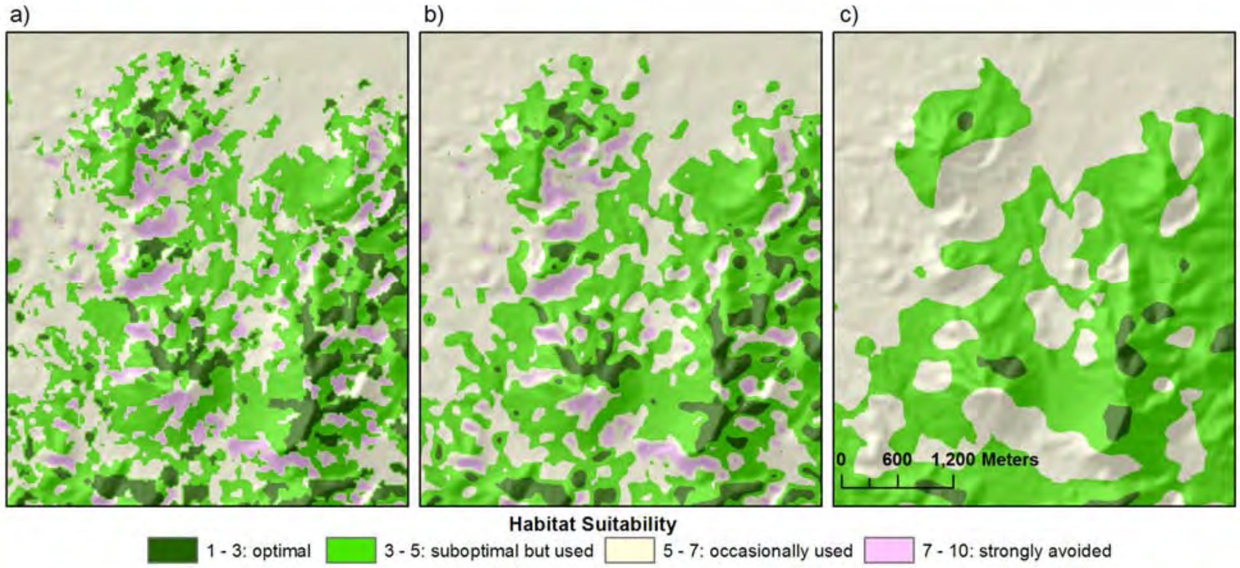

Figure 24: Example moving window analysis which calculates the average habitat suitability surrounding a pixel. a) original habitat suitability model, b) 3x3-pixel moving window, c) 200m radius moving window.

Identifying Biologically Best Corridors

The *biologically best corridor*[6] (BBC) is a continuous swath of land that is predicted to be the best (highest permeability, lowest cost of travel) route for a species to travel from a potential population core in one protected habitat block to a potential population core in the other protected habitat block. *Travel cost* increases in areas where the focal species experiences poor nutrition or lack of suitable cover. *Permeability* is simply the opposite of travel cost, such that a perfectly permeable landscape would have a travel cost at or near zero.

We developed BBCs only for some focal species, namely species that (a) exist in both protected wildland blocks, or have historically existed in both and could be restored to them, (b) can move between wildland blocks in less time than disturbances such as fire or climate change will make the current vegetation map obsolete, and (c) move near the ground through the vegetation layer (rather than flying, swimming, or being carried by the wind), and (d) have habitat preferences that can reasonably be represented using GIS variables. For focal species that did not meet these criteria, we conducted patch configuration analysis (next section).

To define the start and end points for a corridor, we identified potential population cores and habitat patches that fell completely within each protected habitat block. If potential population cores existed within each block, we used these potential cores as the starting & ending points for the corridor analysis. Otherwise, the start-end points were potential habitat patches within the protected habitat block or (for a wide-ranging species with no potential habitat patch entirely within a habitat block) any suitable habitat within the protected block.

To create each biologically best corridor, we used the habitat suitability score as an estimate of the cost of movement through the pixel[7]. We used three rules to transform habitat suitability scores into travel costs,

[6] Our approach has often been called Least Cost Corridor Analysis (Beier et al. 2006) because it identifies areas that require the least cost of travel (energetic cost, risk of mortality) to the animal. However, we avoid the words "least cost" because it is easily misunderstood as referring to the dollar cost of conserving land or building an underpass.
[7] Levey et al. (2005) provide evidence that animals make movement decisions based on habitat suitability.

depending on ecological characteristics of the species:

- For a *locally widespread species* (habitat suitability score < 5 in nearly all of the potential linkage zone, suggesting that breeding populations could occur throughout), we used the raw pixel habitat suitability score as the travel cost score.

Species that were not widespread throughout the potential linkage area were divided into 2 groups:

- For *corridor-dwelling species* (species needing weeks to generations to traverse the potential linkage area – including most reptiles, amphibians, and small mammals)[8], we reassigned a score of 1 to each pixel in a potential habitat patch or potential population core. Our rationale was that these areas provide steppingstones for multi-generational movement. We did not rescore single pixels, or polygons smaller than a potential breeding area, because these are too small to provide meaningful stopover habitat.
- For *passage species* (mobile species that can make the journey between wildland blocksin a single movement event of a few hours or days), we assigned each pixel with a pixel habitat suitability score of 1 through 5 a travel cost score of 1. In preliminary models that lacked this rescoring, the biologically best corridor tended to follow an unrealistic straight line rather than best habitat.

For each pixel, we calculated the lowest cumulative cost to that pixel from a starting point in one protected habitat block. We similarly calculated the lowest cumulative travel cost from the 2nd protected habitat block, and added these 2 travel costs to calculate the *total travel cost* for each pixel. The total travel cost thus reflects the lowest possible cost associated with a path between wildland blocks that passes through the pixel. Finally, we defined the biologically best corridor as the swath of pixels with the lowest total travel cost and a minimum width of 500 m (Figure 25). If a species had two or more distinct strands in its biologically best corridor, we eliminated any strand markedly worse than the best strand, but we retained multiple strands if they had roughly equal travel cost and spacing among habitat patches.

After developing a biologically best corridor for each species, we combined biologically best corridors to form a union of biologically best corridors (UBBC).

Patch Configuration Analysis

Although the UBBC identifies an optimum corridor between the protected wildland blocks, this optimum might be poor for a species with little suitable habitat in the potential linkage area. Furthermore, corridor analyses were not conducted for some focal species (see 2nd paragraph of previous section). To address these issues, we examined the maps of potential population cores and potential habitat patches for each focal species (including species for which a BBC was estimated) in relation to the UBBC. For each species, we examined whether the UBBC encompasses adequate potential habitat patches and potential habitat cores, and we compared the distance between neighboring habitat patches to the dispersal[9] distance of the species. For those species (*corridor-dwellers*, above) that require multiple generations to move between protected wildland blocks, a patch of habitat beyond dispersal distance will not promote movement. For such species, we looked for potential habitat patches within the potential linkage area but outside of the UBBC. When such patches were within the species' dispersal distance from patches within the UBBC or a habitat block, we added these polygons to the UBBC to create a *preliminary linkage design*.

[8] Beier & Loe (1992) introduced this distinction between *passage species* and *corridor-dwelling* species.
[9] Dispersal distance is how far an animal moves from its birthplace to its adult home range. We used dispersal distances reported by the species expert, or in published literature. In some cases, we used dispersal distance for a closely-related species.

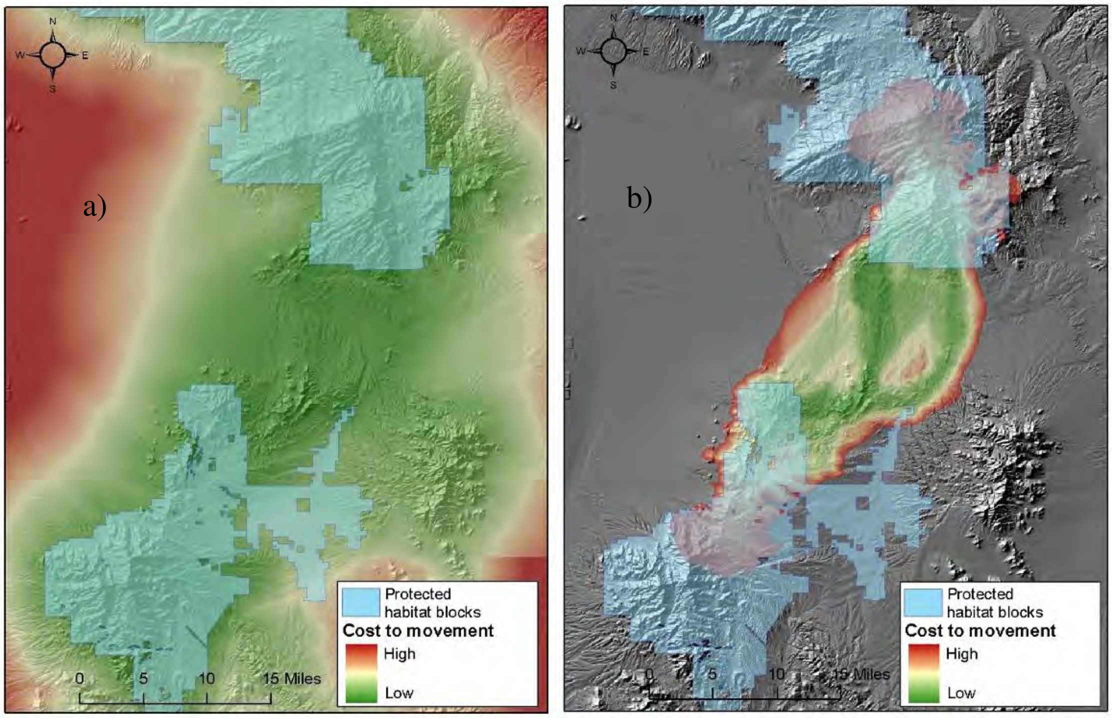

Figure 25: a) Landscape permeability layer for entire landscape, b) biologically best corridor composed of most permeable 10% of landscape.

Minimum Linkage Width

Wide linkages are beneficial for several reasons. They (1) provide adequate area for development of metapopulation structures necessary to allow corridor-dwelling species (individuals or genes) to move through the landscape; (2) reduce pollution into aquatic habitats; (3) reduce edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species; (4) provide an opportunity to conserve natural fire regimes and other ecological processes; and (5) improve the opportunity of biota to respond to climate change.

To address these concerns, we established a minimum width of 1.5 km (0.94 mi) along the length of each terrestrial branch of the preliminary linkage design, except where existing urbanization precluded such widening. We widened bottlenecks first by adding natural habitats, and then by adding agricultural lands if no natural areas were available.

It is especially important that the linkage will be useful in the face of climate change. Climate change scientists unanimously agree that average temperatures will rise 2 to 6.4 C over pre-industrial levels by 2100, and that extreme climate events (droughts and storms) will become more common (Millennium Ecosystem Assessment 2005). Although it is less clear whether rainfall will increase or decrease in any location, there can be no doubt that the vegetation map in 2050 and 2100 will be significantly different than the map of current vegetation used in our analyses. Implementing a corridor design narrowly conforming to current distribution of vegetation types would be risky. Therefore, in widening terrestrial linkage strands, we attempted to maximize local diversity of aspect, slope, and elevation to provide a better chance that the linkage will have most vegetation types well-distributed along its length during the coming decades of climate change. Because of the diversity of focal species used to develop the UBBC, our preliminary linkage design had a lot of topographic diversity, and minimal widening was needed to encompass this diversity.

Expanding the linkage to this minimum width produced the final linkage design.

Field Investigations

Although our analyses consider human land use and distance from roads, our GIS layers only crudely reflect important barriers that are only a pixel or two in width, such as freeways, canals, and major fences. Therefore we visited each linkage design area to assess such barriers and identify restoration opportunities. We documented areas of interest using GPS, photography, and field notes. We evaluated existing bridges, underpasses, overpasses, and culverts along highways as potential structures for animals to cross the highway, or as locations where improved crossing structures could be built. We noted recent (unmapped) housing & residential developments, major fences, and artificial night lighting that could impede animal movement, and opportunities to restore native vegetation degraded by human disturbance or exotic plant species. A database of field notes, GPS coordinates, and photos of our field investigations can be found in Appendix G, as well as in a MS Access database on the CD-ROM accompanying this report.

Appendix B: Individual Species Analyses

Table 4: Habitat suitability scores and factor weights for each species. Scores range from 1 (best) to 10 (worst), with 1-3 indicating optimal habitat, 4-5 suboptimal but usable habitat, 6-7 occasionally used but not breeding habitat, and 8-10 avoided.

	Badger	Bighorn Sheep	Black-tailed Jackrabbit	Javelina	Mountain Lion
Factor Weights					
Land Cover	65	30	70	50	70
Elevation	7	10	10	30	0
Topography	15	50	10	20	10
Distance from Roads	13	10	10	0	20
Land Cover					
Encinal	6	9	6	4	1
Pinyon-Juniper Woodland	4	9	4	5	1
Semi-Desert Grassland and Steppe	1	5	4	2	5
Chaparral	5	9	6	3	3
Creosotebush, Mixed Desert and Thorn Scrub	2	6	2	3	6
Creosotebush-White Bursage Desert Scrub	2	6	2	4	6
Desert Scrub (misc)	3	2	1	2	6
Mesquite Upland Scrub	3	7	4	2	4
Paloverde-Mixed Cacti Desert Scrub	4	3	1	1	7
Stabilized Coppice Dune and Sand Flat Scrub	4	8	3	7	5
Riparian Mesquite Bosque	6	9	5	1	4
Riparian Woodland and Shrubland	6	9	4	2	2
Barren Lands, Non-specific	7	8	8	9	8
Bedrock Cliff and Outcrop	9	2	8	8	6
Volcanic Rock Land and Cinder Land	10	7	9	9	9
Invasive Riparian Woodland and Shrubland	8	9	5	5	5
Recently Mined or Quarried	9	10	10	10	8
Agriculture	6	10	6	7	10
Developed, Medium - High Intensity	10	10	9	7	10
Developed, Open Space - Low Intensity	7	10	6	4	8
Open Water	9	10	9	10	9
Elevation (ft)					
Elevation range: cost	0-5500: 1 5500-8000: 3 8000-11000: 6	0-2950: 2 2950-3300: 1 3300-7000: 3 7000-11000: 7	0-6000: 1 6000-8000: 4 8000-11000: 8	0-5000: 1 5000-7000: 3 7000-11000: 10	
Topographic Position					
Canyon Bottom	5	8	3	1	1
Flat - Gentle Slopes	1	7	1	1	3
Steep Slope	8	5	4	7	3
Ridgetop	7	1	4	4	4
Distance from Roads (m)					
Distance from Roads range: cost	0-250: 6 250-1500: 1	0-1000: 6 1000-15000: 2	0-250: 9 250-500: 6 500-1000: 3 1000-15000: 1		0-200: 8 200-500: 6 600-1000: 5 1000-1500: 2 1500-15000: 1

	Mule Deer	Black-tailed Rattlesnake	Desert Tortoise	Sonoran Desert Toad	Sonoran Whipsnake
Factor Weights					
Land Cover	80	0	30	5	30
Elevation	0	0	25	50	10
Topography	15	90	40	25	45
Distance from Roads	5	10	5	20	15
Land Cover					
Encinal	3		7	7	1
Pinyon-Juniper Woodland	5		10	10	1
Semi-Desert Grassland and Steppe	2		8	2	2
Chaparral	4		10	4	1
Creosotebush, Mixed Desert and Thorn Scrub	6		6	2	2
Creosotebush-White Bursage Desert Scrub	6		5	4	7
Desert Scrub (misc)	6		4	2	3
Mesquite Upland Scrub	3		7	1	2
Paloverde-Mixed Cacti Desert Scrub	3		1	1	1
Stabilized Coppice Dune and Sand Flat Scrub	6		10	2	10
Riparian Mesquite Bosque	3		5	1	2
Riparian Woodland and Shrubland	3		10	2	2
Barren Lands, Non-specific	10		10	7	10
Bedrock Cliff and Outcrop	8		10	5	3
Volcanic Rock Land and Cinder Land	8		10	10	4
Invasive Riparian Woodland and Shrubland	3		10	3	10
Recently Mined or Quarried	6		10	4	10
Agriculture	6		10	4	10
Developed, Medium - High Intensity	9		10	6	10
Developed, Open Space - Low Intensity	5		7	4	5
Open Water	10		10	4	10
Elevation (ft)					
Elevation range: cost			0-2000: 3 2000-3000: 1 3000-5000: 3 5000-7000: 7 7000-11000: 10	0-4600: 1 4600-5250: 4 5250-5800: 5 5800-11000: 7	0-1400: 5 1400-2000: 3 2000-5600: 1 5600-7500: 5 7500-11000: 10
Topographic Position					
Canyon Bottom	2	1	8	1	1
Flat - Gentle Slopes	2	9	5	5	7
Steep Slope	4	1	1	1	1
Ridgetop	6	1	7	1	1
Distance from Roads (m)					
Distance from Roads range: cost	0-250: 7 250-1000: 3 1000-15000: 1	0-35: 10 35-500: 5 500-15000: 1	0-250: 5 250-500: 4 500-1000: 3 1000-15000: 1	0-200: 5 200-1000: 4 1000-3000: 2 3000-15000: 1	0-500: 5 500-1000: 4 1000-2000: 3 2000-15000: 1

	Tiger Rattlesnake	Tucson Shovel-nosed Snake
Factor Weights		
Land Cover	20	20
Elevation	30	20
Topography	40	45
Distance from Roads	10	15
Land Cover		
Encinal	5	10
Pinyon-Juniper Woodland	6	10
Semi-Desert Grassland and Steppe	5	10
Chaparral	6	10
Creosotebush, Mixed Desert and Thorn Scrub	3	10
Creosotebush-White Bursage Desert Scrub	7	2
Desert Scrub (misc)	3	10
Mesquite Upland Scrub	4	10
Paloverde-Mixed Cacti Desert Scrub	1	6
Stabilized Coppice Dune and Sand Flat Scrub	10	10
Riparian Mesquite Bosque	5	10
Riparian Woodland and Shrubland	5	10
Barren Lands, Non-specific	10	5
Bedrock Cliff and Outcrop	2	10
Volcanic Rock Land and Cinder Land	1	10
Invasive Riparian Woodland and Shrubland	4	10
Recently Mined or Quarried	10	10
Agriculture	10	10
Developed, Medium - High Intensity	9	10
Developed, Open Space - Low Intensity	1	8
Open Water	10	10
Elevation (ft)		
Elevation range: cost	0-4000: 1 4000-5100: 5 5100-11000: 10	0-2000: 1 2000-2400: 3 2400-2600: 6 2600-3000: 9 3000-11000: 10
Topographic Position		
Canyon Bottom	1	10
Flat - Gentle Slopes	6	1
Steep Slope	1	10
Ridgetop	3	10
Distance from Roads (m)		
Distance from Roads range: cost	0-35: 10 35-1000: 5 1000-15000: 1	0-250: 5 250-1000: 4 1000-2000: 2 2000-15000: 1

Badger (*Taxidea taxus*)

Justification for Selection

Because of their large home ranges, many parks and protected lands are not large enough to ensure protection of a badger population, or even an individual (NatureServe 2005). Consequently, badgers have suffered declines in recent decades in areas where grasslands have been converted to intensive agricultural areas, and where prey animals such as prairie dogs and ground squirrels have been reduced or eliminated (NatureServe 2005). Badgers are also threatened by collisions with vehicles while attempting to cross highways intersecting their habitat (New Mexico Department of Game and Fish 2004, NatureServe 2005).

Distribution

Badgers are found throughout the western United States, extending as far east as Illinois, Wisconsin, and Indiana (Long 1973). They are found in open habitats throughout Arizona.

Habitat Associations

Badgers are primarily associated with open habitats such as grasslands, prairies, and shrublands, and avoid densely wooded areas (NMGF 2004). They may also inhabit mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper and sagebrush habitats (Long & Killingley 1983). They prefer flat to gentle slopes at lower elevations, and avoid rugged terrain (Apps et al. 2002).

Spatial Patterns

Overall yearly home range of badgers has been estimated as 8.5 km^2 (Long 1973). Goodrich and Buskirk (1998) found an average home range of 12.3 km^2 for males and 3.4 km^2 for females, found male home ranges to overlap more than female ranges (male overlap = 0.20, female = 0.08), and estimated density as 0.8 effective breeders per km^2. Messick and Hornocker (1981) found an average home range of 2.4 km^2 for adult males and 1.6 km^2 for adult females, and found a 20% overlap between a male and female home range. Nearly all badger young disperse from their natal area, and natal dispersal distances have been recorded up to 110 km (Messick & Hornocker 1981).

Conceptual Basis for Model Development

Habitat suitability model – Badgers prefer grasslands and other open habitats on flat terrain at lower elevations. They do not show an aversion to roads (Apps et al. 2002), which makes them sensitive to high road mortality. Vegetation received an importance weight of 65%, while elevation, topography, and distance from roads received weights of 7%, 15%, and 13%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 2 km^2, which is an average of the home range found for both sexes by Messick and Hornocker (1981), and equal to the female home range estimated by Goodrich and Buskirk (1998), minus 1 standard deviation. Minimum potential habitat core size was defined as 10 km^2, approximately enough area to support 10 effective breeders, allowing for a slightly larger male home range size and 20% overlap of home ranges (Messick

& Hornocker 1981). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost <5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate significant amounts of suitable habitat for this species within the potential linkage area (Figure 26). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.7 to 7.5, with an average suitability cost of 2.4 (S.D: 0.9). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 2.4, ranging from 1.7 to 7.5 (S.D.: 1.0). Within both corridors, potential suitable habitat appears to be abundant, and the entirety of both corridors is a potential habitat core (Figure 27).

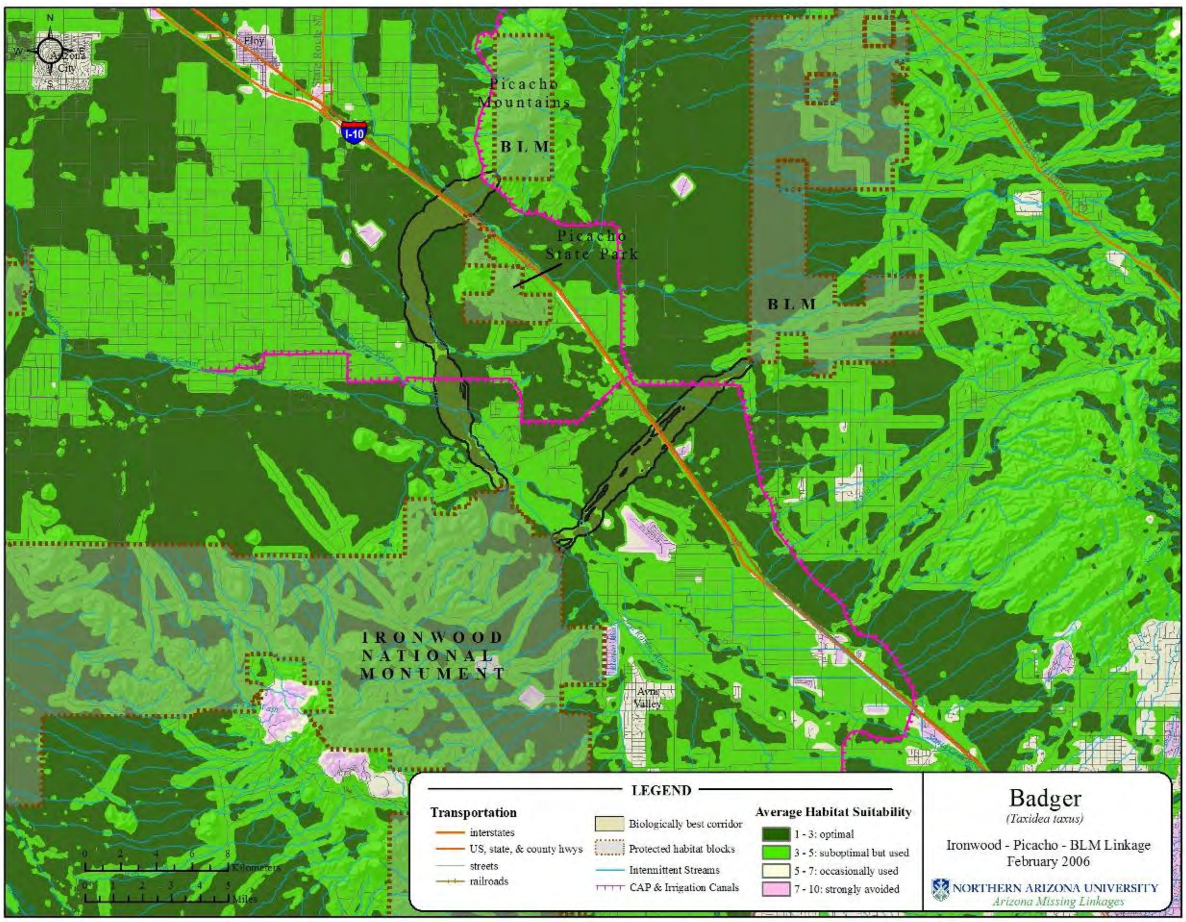

Figure 26: Modeled habitat suitability of badger.

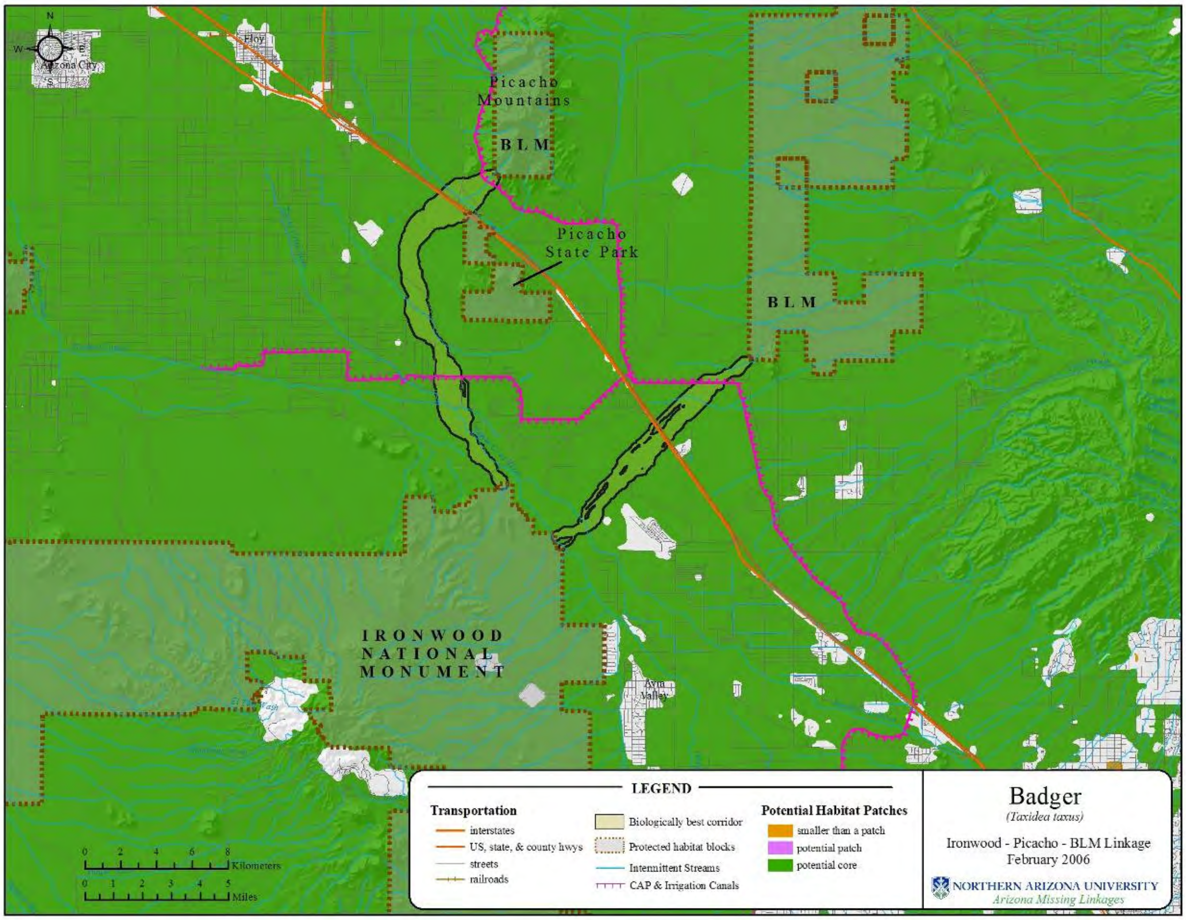

Figure 27: Potential habitat patches and cores for badger.

Union of biologically best corridors – The UBBC increases potential habitat on both sides of each strand of the biologically best corridor for badger, including expanded portions of creosotebush-white bursage desert scrub. Because there is ample habitat for this species, and nearly all portions of the UBBC could be a potential habitat core, the greatest threat to its connectivity and persistence is most likely high-traffic roads such as I-10 and habitat fragmentation.

Black-tailed Jackrabbit (*Lepus californicus*)

Justification for Selection

Black-tailed jackrabbits are important seed dispersers (Best 1996) and are frequently killed by roads (Adams & Adams 1959). They also serve as prey for predators such as hawks, eagles, owls, coyotes, badgers, foxes, and bobcats (Hoffmeister 1986; Best 1996).

Distribution

Black-tailed jackrabbits are common through western North America. They range from western Arkansas and Missouri to the Pacific Coast, and from Mexico northward to Washington and Idaho (Best 1996). They are found throughout the lower elevations of Arizona (Lowe 1978).

Habitat Associations

This species primarily prefers open country, and will typically avoid areas of tall grass or forest where visibility is low (Best 1996). In Arizona, black-tailed jackrabbits prefer mesquite, sagebrush, pinyon juniper, and desert scrub (Hoffmeister 1986). They are also found in sycamore, cottonwood, and rabbitbrush habitats (New Mexico Department of Fish and Game 2004). Dense grass and/or shrub cover is necessary for resting (New Mexico Department of Fish and Game 2004). Black-tailed jackrabbits are known to avoid standing water, making large canals and rivers possible population barriers (Best 1996).

Spatial Patterns

Home range size varies considerably for black-tailed jackrabbits depending upon distances between feeding and resting areas. Home ranges have been reported from less than 1 sq km to 3 sq km in northern Utah (NatureServe 2005); however, daily movements of several miles to find suitable forage may be common in southern Arizona, with round trips of up to 10 miles each day possible (Hoffmeister 1986). Best (1993) estimated home range size to be approximately 100 ha.

Conceptual Basis for Model Development

Habitat suitability model – Due to this species' strong vegetation preferences, vegetation received an importance weight of 70%, while elevation, topography, and distance from roads each received weights of 10%. For specific costs of classes within each of these factors used for the modeling process, see Table 4.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 100 hectares (Best 1993), and minimum potential habitat core size was defined as 500 ha, or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – While no information was available on dispersal distance for this species, black-tailed jackrabbits were considered potential corridor dwellers in this analysis because of their spatial requirements and the high habitat suitability within the linkage area. Nearly all habitat within the linkage zone was calculated as suitable, so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate significant amounts of suitable habitat for this species within the potential linkage area (Figure 28). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.0 to 7.4, with an average suitability cost of 1.6 (S.D: 0.9). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 1.6, ranging from 1.0 to 7.4 (S.D.: 1.6). Within both corridors, potential suitable habitat appears to be abundant, and the entirety of both corridors is a potential habitat core (Figure 29).

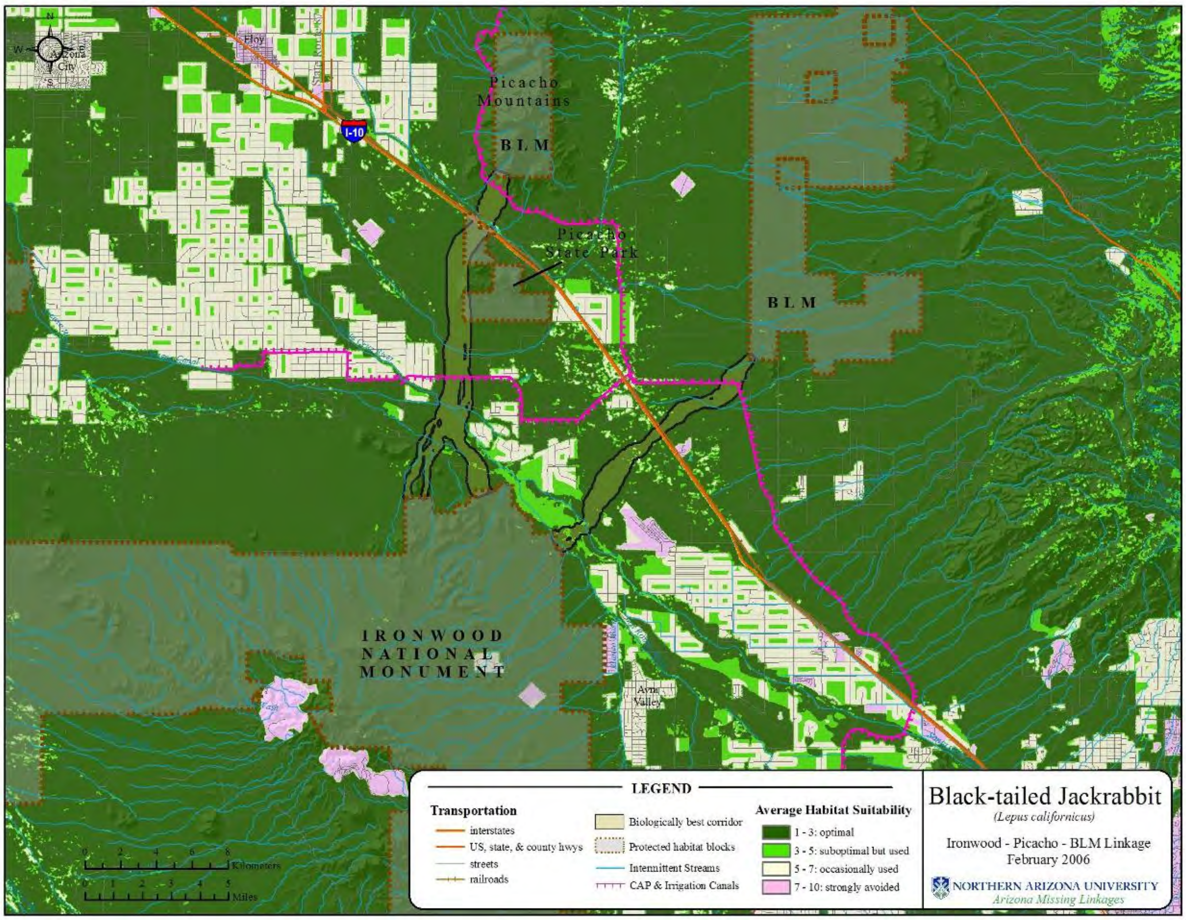

Figure 28: Modeled habitat suitability of black-tailed jackrabbit.

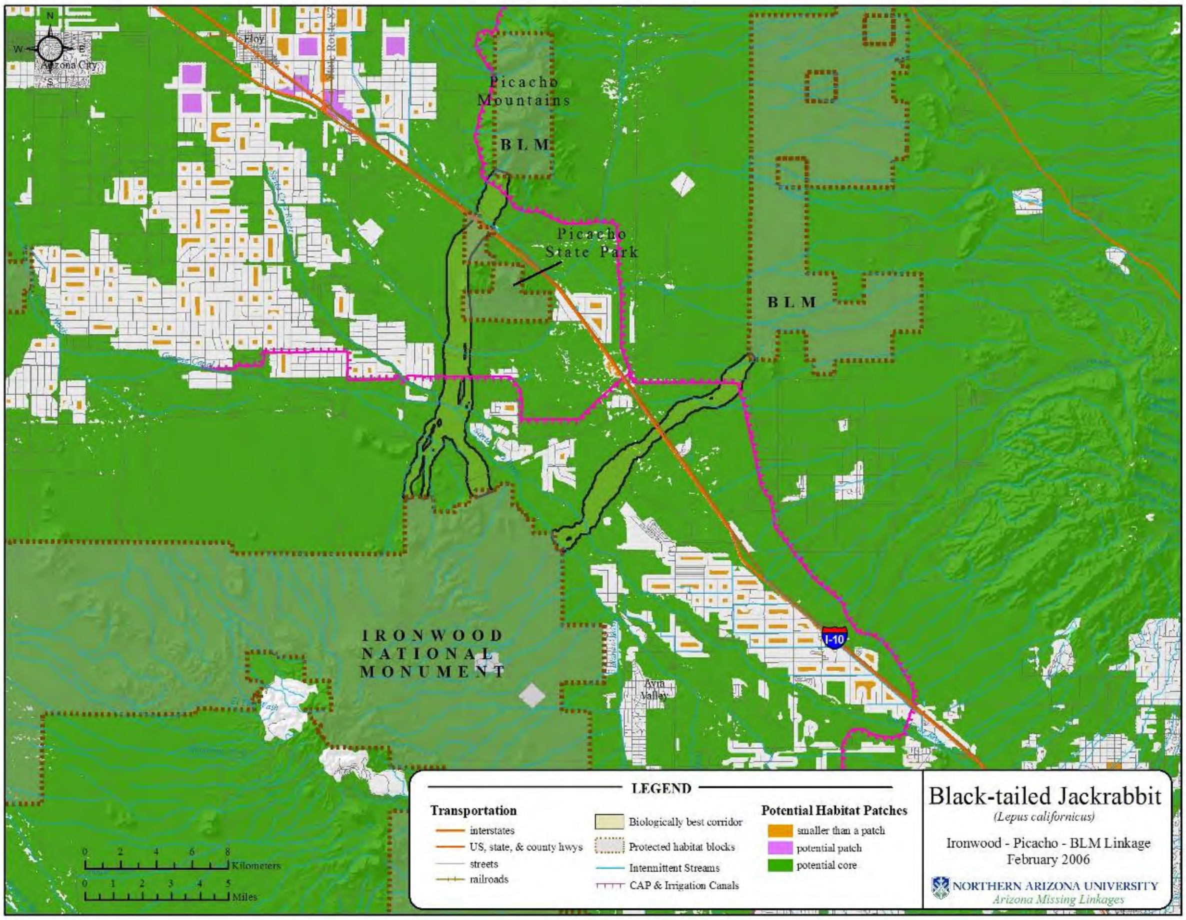

Figure 29: Potential habitat patches and cores for black-tailed jackrabbit.

Union of biologically best corridors – The UBBC increases potential habitat on both sides of each strand of the biologically best corridor for black-tailed jackrabbit, including expanded portions of paloverde-mixed cacti scrub and creosotebush-white bursage desert scrub, which are strongly preferred by this species. Because there is ample habitat for this species, and nearly all portions of the UBBC could be a potential habitat core, the greatest threat to its connectivity and persistence is most likely high-traffic roads such as I-10 and habitat fragmentation.

Desert Bighorn Sheep (*Ovis canadensis nelsoni*)

Justification for Selection

Bighorn sheep populations have suffered massive declines in the last century, including local extinctions. Human activities such as alteration of bighorn sheep habitat, urbanization, and grazing by domestic sheep have been largely responsible for population declines (Johnson and Swift 2000; Krausman 2000). These declines, along with barriers to movement such as roads and range fences, have created small, isolated groups of bighorn sheep with a highly fragmented distribution (Singer et al. 2000; Bleich et al. 1990). Isolated bighorn populations are more susceptible to extirpation than large, contiguous populations due to climate change, fire, or disease, especially introduced diseases from domestic sheep (Gross et al. 2000; Singer et al. 2000; Epps et al. 2004). Bighorn sheep are listed as USFS Sensitive in New Mexico and Arizona (New Mexico Department of Game and Fish 2004).

Distribution

Bighorn sheep are found throughout western North America from the high elevation alpine meadows of the Rocky Mountains to low elevation desert mountain ranges of the southwestern United States and northern Mexico (Shackleton 1985). Specifically, their range extends from the mountains and river breaks of southwestern Canada south through the Rocky Mountains and Sierra Nevada, and into the desert mountains of the southwest United States and the northwestern mainland of Mexico (NatureServe 2005). In Arizona, bighorns can be found from Kanab Creek and the Grand Canyon west to Grand Wash, as well as in westernmost Arizona eastward to the Santa Catalina Mountains (Hoffmeister 1986).

Habitat Associations

Bighorn sheep habitat includes mesic to xeric grasslands found within mountains, foothills, and major river canyons (Shackleton 1985). These grasslands must also include precipitous, rocky slopes with rugged cliffs and crags for use as escape terrain (Shackleton 1985; Alvarez-Cardenas et al. 2001; Rubin et al. 2002; New Mexico Department of Game and Fish 2004). Slopes >80% are preferred by bighorn sheep, and slopes <40% are avoided (Alvarez-Cardenas et al. 2001). Dense forests and chaparral that restrict vision are also avoided (NatureServe 2005). In Arizona, the desert bighorn subspecies (*O. canadensis nelsoni*) is associated with feeding grounds that include mesquite, ironwood, palo verde, catclaw coffeeberry, bush muhly, jojoba, brittlebrush, calliandra, and galleta (Hoffmeister 1986). Water is an important and limiting resource for desert bighorn sheep (Rubin et al. 2002). Where possible, desert bighorn will seek both water and food from such plants as cholla, prickly pear, agave, and especially saguaro fruits (Hoffmeister 1986). Bighorn sheep will also occasionally graze on shrubs such as sagebrush, mountain mahogany, cliffrose, and blackbrush (New Mexico Department of Game and Fish 2004). Elevation range for bighorn sheep varies across their range from 0 – 3660 m (New Mexico Department of Game and Fish 2004), but in Arizona the desert bighorn subspecies is found from 100 – 1000m elevation, with the best habitat found from 900 – 1000 m in the jojoba communities (Hoffmeister 1986; Alvarez-Cardenas et al. 2001).

Spatial Patterns

Home ranges for bighorn sheep vary depending upon population size, availability and connectivity of suitable habitat, and availability of water resources (Singer et al. 2001). Home ranges have been reported to range from 6.1 km^2 to 54.7 km^2 (Singer et al. 2001). One desert bighorn sheep study in Arizona reports an average home range of 16.9 ± 3.38 km^2 for ewes, and home ranges for males that increased with age from 11.7 km^2 for a one year old to 37.3 km^2 for a 6 year old (Shackleton 1985). Bighorn sheep that live in higher elevations are known to migrate between an alpine summer range to a lower elevation winter range in response to seasonal vegetation availability and snow accumulation in the higher elevations (Shackleton 1985; NatureServe 2005). Maximum distances for these seasonal movements are about 48 km (Shackleton 1985). Desert bighorns on low desert ranges do not have separate seasonal ranges (Shackleton 1985). Bighorns live in groups, but for most of the year males over 3 years of age live separate from maternal groups consisting of females and young (Shackleton 1985).

Conceptual Basis for Model Development

Habitat suitability model – Due to this species' strong topographic preferences, topographic position received an importance weight of 50%, while vegetation, elevation, and distance from roads received weights of 30%, 10%, and 10%. For specific costs of classes within each of these factors used for the modeling process, see Table 4. Because bighorn sheep actively select slopes greater than 40% for escape terrain, any pixel located further than 300 meters from a slope greater than 40% was reclassified to a suitability score between 5 and 10.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 16.9 km^2 (Shackleton 1985), and minimum potential habitat core size was defined as 84.5 km^2, or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Because potential habitat was patchily distributed, we re-assigned all 'suitable' habitat (score < 5) a cost of 1 to increase the likelihood of the biologically best corridor capturing the little-available habitat.

Results & Discussion

Initial biologically best corridor – Modeling results indicate little available suitable habitat for this species within the potential linkage area (Figure 30). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, the average habitat suitability cost ranged from 1.4 to 8.7, with an average suitability cost of 5.7 (S.D: 2.5). The largest gap between potentially suitable habitat patches is approximately 8.5 kilometers, between the hills northwest of Samaniego Hills, and the rugged topography found within Picacho State Park. Between Picacho State Park and the Picacho Mountains is another 3-4 kilometers of unsuitable habitat which the desert bighorn sheep must traverse to maintain connectivity (Figure 31).

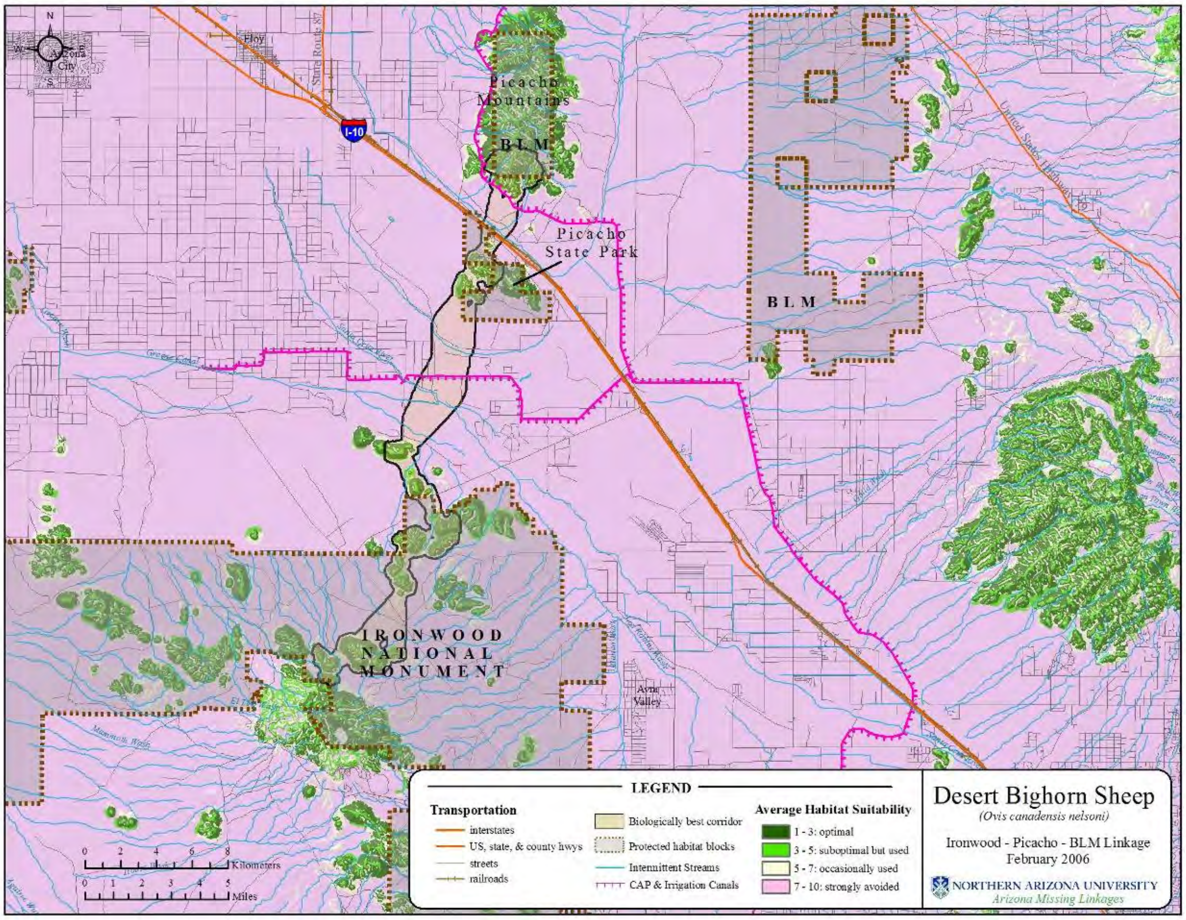

Figure 30: Modeled habitat suitability of desert bighorn sheep.

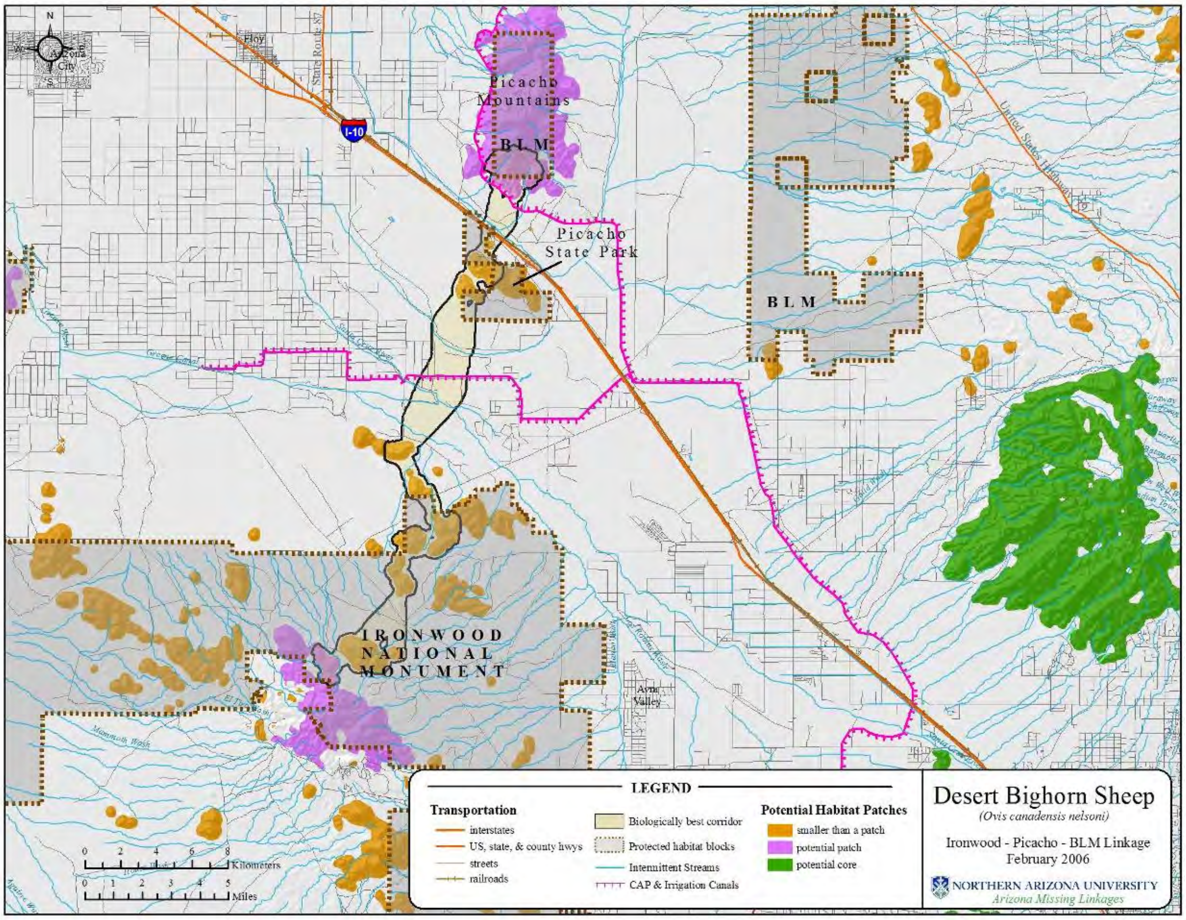

Figure 31: Potential habitat patches and cores for desert bighorn sheep.

Union of biologically best corridors – The UBBC provides little additional habitat for the desert bighorn sheep. The only additional habitat added is a segment of rugged topography approximately 2.5 km wide within Picacho Peak State Park. The largest gap between potentially suitable habitat patches continues to be the 8.5 kilometers between the hills northwest of Samaniego Hills and the rugged topography found within Picacho State Park. While bighorn sheep have been found to make seasonal movements up to 48 km (Shackleton 1985), and disperse up to 70 km (Witham & Smith 1979), and therefore could be expected to move between the Silverbell Mountains, Picacho Peak, and the Picacho Mountains. However, Interstate highways, canals, and developed areas have been found to completely eliminate gene flow in bighorn sheep populations (Epps et al. 2005), so connectivity between these blocks is dependent on effective crossing structures and maintenance of existing habitat.

Javelina (*Tayassu tajacu*)

Justification for Selection

Young javelina are probably prey items for predators such as coyotes, bobcats, foxes (Hoffmeister 1986), and jaguars (Seymour 1989). Although they habituate well to human development, their herds require contiguous patches of dense vegetation for foraging and bed sites (Hoffmeister 1986; Ticer et al. 2001; NatureServe 2005). Roads are dangerous for urban dwelling javelina (Ticer et al. 1998). Javelina are an economically important game species (Ticer et al. 2001).

Distribution

Javelina are found from Northern Argentina and northwestern Peru to north-central Texas, northwestern New Mexico, and into central Arizona (NatureServe 2005). Specifically in Arizona, they occur mostly south of the Mogollon Rim and west to Organ Pipe National Monument (Hoffmeister 1986).

Habitat Associations

Javelina have adapted to a variety of plant communities, varied topography, and diverse climatic conditions (Ticer et al. 2001). However, javelina confine themselves to habitats with dense vegetation (Ticer et al. 2001; Hoffmeister 1986; NatureServe 2005), and rarely are found above the oak forests on mountain ranges (Hoffmeister 1986). Javelina prefer habitat types such as areas of open woodland overstory with shrubland understory, desert scrub, and thickets along creeks and old stream beds (Ticer et al. 1998; Hoffmeister 1986). They also will forage in chaparral (Neal 1959; Johnson and Johnson 1964). Prickly pear cactus provides shelter, food, and water (Ticer et al. 2001, Hoffmeister 1986). Other plants in javelina habitat include palo verde, jojob, ocotillo, catclaw, and mesquite (Hoffmeister 1986). Javelina habituate well to human development, as long as dense vegetation is available (Ticer et al. 2001). Their elevation range is from 2000 to 6500 feet (New Mexico Department of Fish and Game 2004).

Spatial Patterns

Javelinas live in stable herds, though occasionally some individuals may move out of the herd to join another or establish their own (Hoffmeister 1986). Home ranges for herds have been reported as 4.7 km² in the Tortolita Mountains (Bigler 1974), 4.93 km² near Prescott (Ticer et al. 1998), and between 1.9 and 5.5 ha in the Tonto Basin (Ockenfels and Day 1990). Dispersal of javelinas has not been adequately studied, but they are known to be capable of extensive movements of up to several kilometers (NatureServe 2005).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation as it relates to both forage and cover requirements is very important for javelina. Sowls (1997) lists climate, vegetation, and topography as important factors in javelina habitat use. For this species', vegetation received an importance weight of 50%, while elevation and topography received weights of 30% and 20%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum habitat patch size for javelina was defined as 44 ha, based on an estimate for a single breeding season for one "herd" of one breeding pair. The estimate for minimum habitat core size is 222 ha, based on an estimate of 10 breeding seasons for 1 herd of mean size 9 to 12 animals (Chasa O'Brien, personal comm.). The calculation of area is based upon 3 different estimates of density of animals/ha in south-central and southern Arizona. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate significant suitable habitat for this species within the potential linkage area (Figure 32). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.0 to 5.0, with an average suitability cost of 1.6 (S.D: 0.8). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 1.6, ranging from 1.0 to 5.0 (S.D.: 0.9). Within both corridors, potential suitable habitat appears to be abundant, and the entirety of both corridors is a potential habitat core (Figure 33).

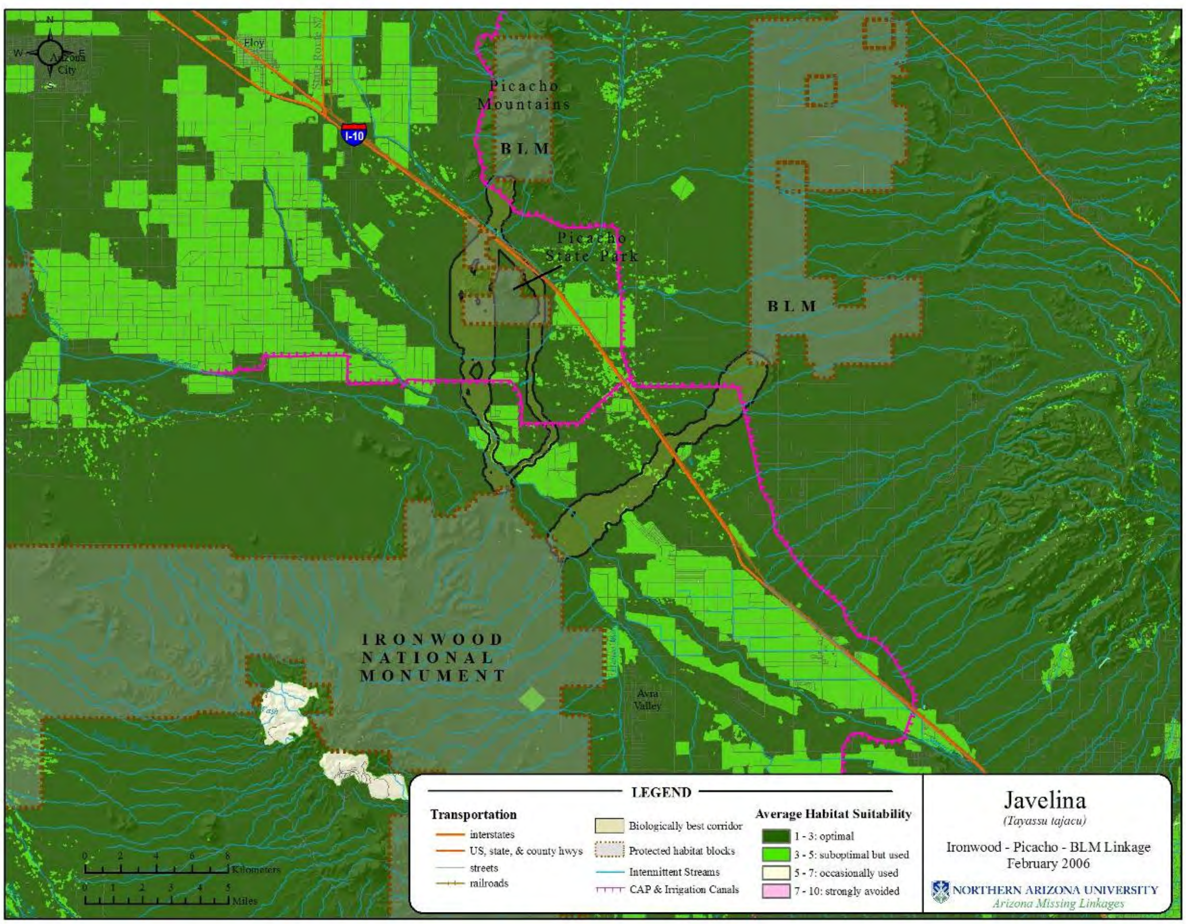

Figure 32: Modeled habitat suitability of javelina.

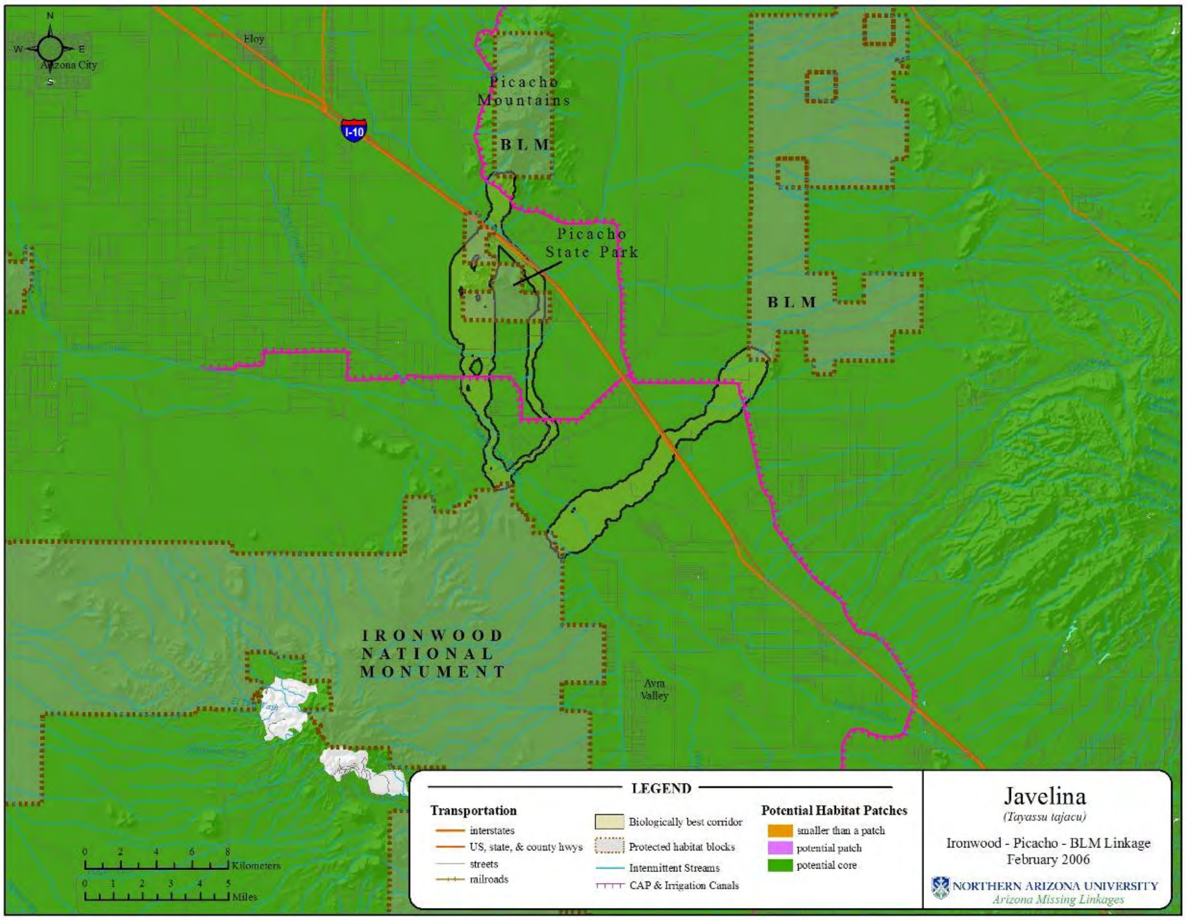

Figure 33: Potential habitat patches and cores for javelina.

Union of biologically best corridors – The UBBC increases potential habitat in both strands of the biologically best corridor for javelina, including expanded portions of paloverde-mixed cacti scrub and creosotebush-white bursage desert scrub.

Justification for Selection

Mule deer are widespread throughout Arizona, and are an important prey species for carnivores such as mountain lion, jaguar, bobcat, and black bear (Anderson & Wallmo 1984). Road systems may affect the distribution and welfare of mule deer (Sullivan and Messmer 2003).

Distribution

Mule deer are found throughout most of western North America, extending as far east as Nebraska, Kansas, and western Texas. In Arizona, mule deer are found throughout the state, except for the Sonoran desert in the southwestern part of the state (Anderson & Wallmo 1984).

Habitat Associations

Mule deer in Arizona are categorized into two groups based on the habitat they occupy. In northern Arizona mule deer inhabit yellow pine, spruce-fir, buckbrush, snowberry, and aspen habitats (Hoffmeister 1986). The mule deer found in the yellow pine and spruce-fir live there from April to the beginning of winter, when they move down to the pinyon-juniper zone (Hoffmeister 1986). Elsewhere in the state, mule deer live in desert shrub, chaparral or even more xeric habitats, which include scrub oak, mountain mahogany, sumac, skunk bush, buckthorn and manzanita (Wallmo 1981; Hoffmeister 1986).

Spatial Patterns

The home ranges of mule deer vary depending upon the availability of food and cover (Hoffmeister 1986). Swank (1958) reports that home ranges of mule deer vary from 2.6 to 5.8 km^2, with bucks' home ranges averaging 5.2 km^2 and does slightly smaller (Hoffmeister 1986). Average home ranges for desert mule deer are larger. Deer that require seasonal migration movements use approximately the same winter and summer home ranges in consecutive years (Anderson & Wallmo 1984). Dispersal distances for male mule deer have been recorded from 97 to 217 km, and females have moved 180 km (Anderson & Wallmo 1984). Two desert mule deer yearlings were found to disperse 18.8 and 44.4 km (Scarbrough & Krausman 1988).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation has the greatest role in determining deer distributions in desert systems, followed by topography (Jason Marshal, personal comm.). For this reason, vegetation received an importance weight of 80%, while topography and distance from roads received weights of 15% and 5%, respectively. For specific scores of classes within each of these factors, Table 4.

Patch size & configuration analysis – Minimum patch size for mule deer was defined as 9 km^2 and minimum core size as 45 km^2. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a significant amount of suitable habitat for this species within the potential linkage area, fragmented by less-suitable habitat. (Figure 34). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 2.8 to 9.7, with an average suitability cost of 3.7 (S.D: 1.2). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 3.8, ranging from 2.8 to 8.7 (S.D.: 1.4). The largest gap between potentially suitable habitat patches is approximately 500 meters (Figure 35).

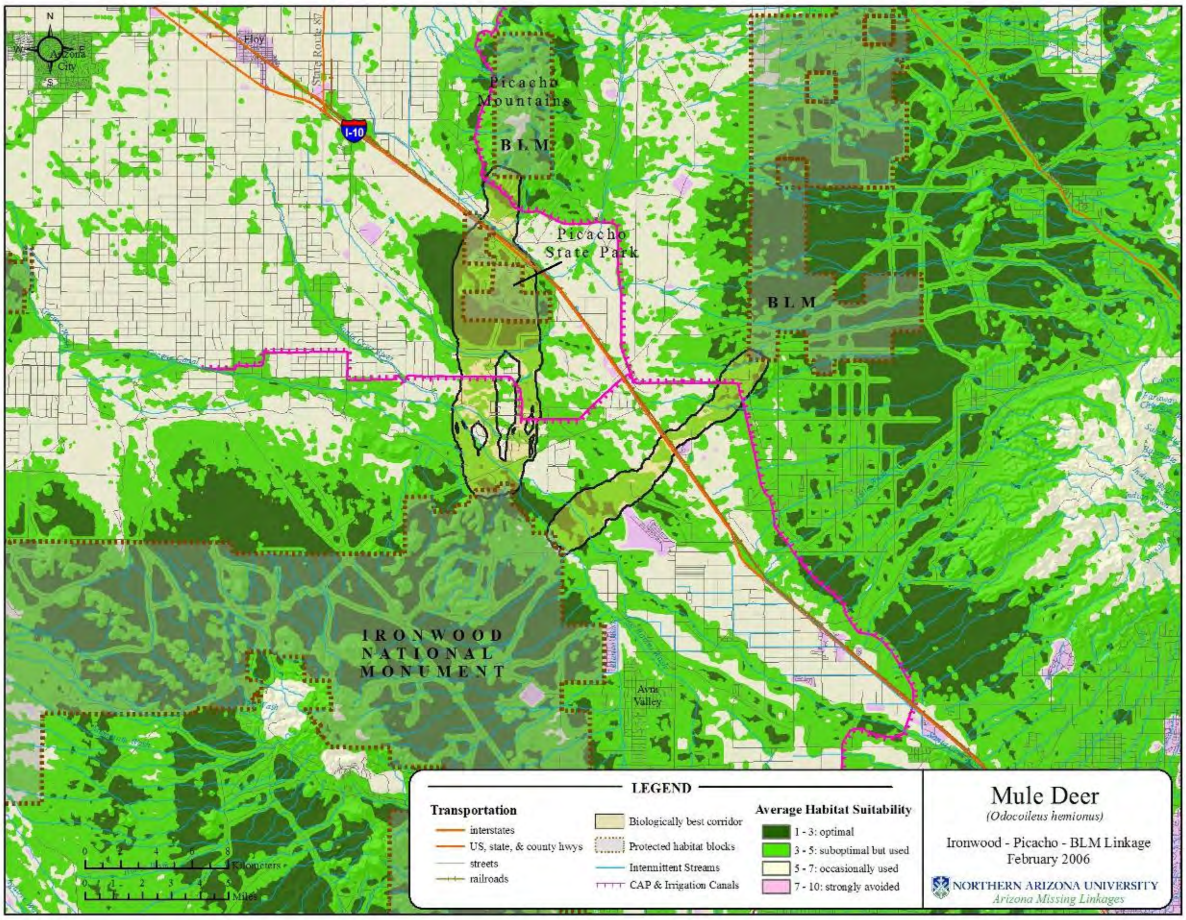

Figure 34: Modeled habitat suitability of mule deer.

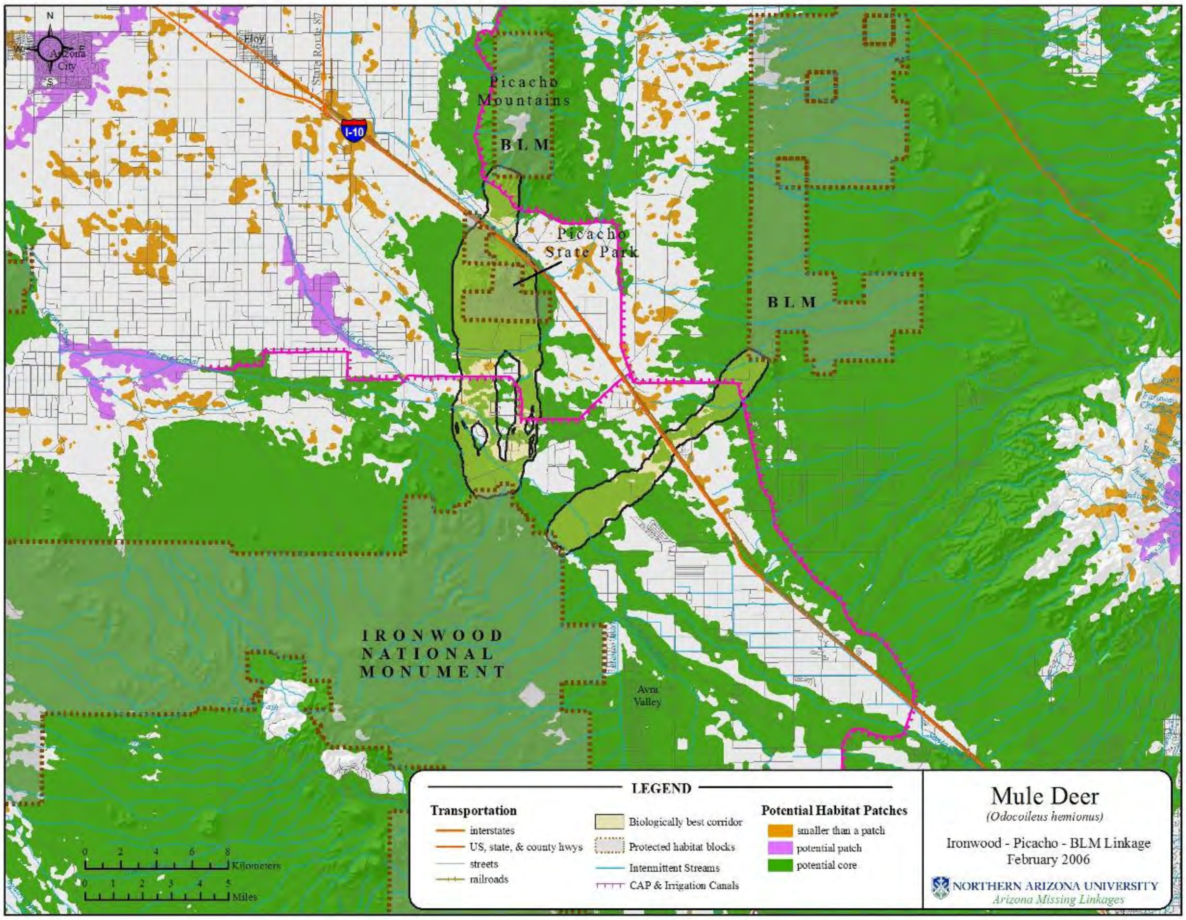

Figure 35: Potential habitat patches and cores for mule deer.

Union of biologically best corridors – While the UBBC does not reduce the minimum distance between potential habitat patches for the mule deer, it does provide a significant increase of optimal habitat adjacent to Ironwood Forest National Monument and Picacho Peak State Park.

Black-tailed Rattlesnake (*Crotalus molossus*)

Justification for Selection

The black-tailed rattlesnake is a vegetation generalist, able to live in a variety of habitats, making this species an important part of many ecosystems throughout Arizona. This rattlesnake requires various habitat types during different times of the year (Beck 1995), and relies on connectivity of these habitat types during its life cycle.

Distribution

This rattlesnake is found from central and west-central Texas northwest through the southern two-thirds of New Mexico to northern and extreme western Arizona, and southward to the southern edge of the Mexican Plateau and Mesa del Sur, Oaxaca (Degenhardt et. al 1996).

Habitat Associations

Black-tailed rattlesnakes are known as ecological generalists, occurring in a wide variety of habitats ,including montane coniferous forests, talus slopes, rocky stream beds in riparian areas, and lava flows on flat deserts (Degenhardt et. al 1996). In a radiotelemetry study conducted by Beck (1995), these snakes frequented rocky areas, but used arroyos and creosotebush flats during late summer and fall. Pine-oak forests, boreal forests, mesquite-grasslands, chaparral, tropical deciduous forests, and thorn forests are also included as habitats for this species (New Mexico Department of Game and Fish 2004). In New Mexico, black-tailed rattlesnakes occur between 1000 and 3150 meters in elevation (New Mexico Department of Game and Fish 2004).

Spatial Patterns

The home range size for black-tailed rattlesnakes has been reported as 3.5 hectares, in a study within the Sonoran desert of Arizona (Beck 1995). These snakes traveled a mean distance of 15 km throughout the year, and moved an average of 42.9 meters per day (Beck 1995). No data is available on dispersal distance for this species, but a similar species, Tiger rattlesnake (*Crotalus tigris*), has been found to disperse up to 2 km (Matt Goode & Phil Rosen, personal comm.).

Conceptual Basis for Model Development

Habitat suitability model – While this species is a vegetation generalist, it is strongly associated with rocks and outcrops on mountain slopes, and rarely seen at any distance from these environments (Matt Goode & Phil Rosen, personal comm.). Because of this strong topographic association, topography received an importance weight of 90%, while distance from roads received a weight of 10%. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Beck (1995) found home ranges from 3-4 ha in size; however, it is thought that home ranges for most black-tailed rattlesnakes are slightly larger (Phil Rosen, personal comm.), so minimum patch size was defined as 10 ha. Minimum core size was defined as 100 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – While habitat was patchily distributed for this species, the standard habitat suitability model was used in the corridor analysis because potential habitat in the Ironwood, Picacho State Park, and Picacho Mountain blocks were arranged linearly, assuring the biologically best corridor analysis would capture available habitat patches within each of these blocks.

Results & Discussion

Initial biologically best corridor – Because this species is only generally associated with mountainous areas, suitable habitat is only found within the wildland blocks (Figure 36). Within the biologically best corridor for this species, the average habitat suitability cost ranged from 1.0 to 9.1, with an average suitability cost of 6.1 (S.D: 3.5). The farthest distance between a potential patch and another patch or core within the corridor was approximately 10.5 km (Figure 37), which is significantly longer than previously observed dispersal events.

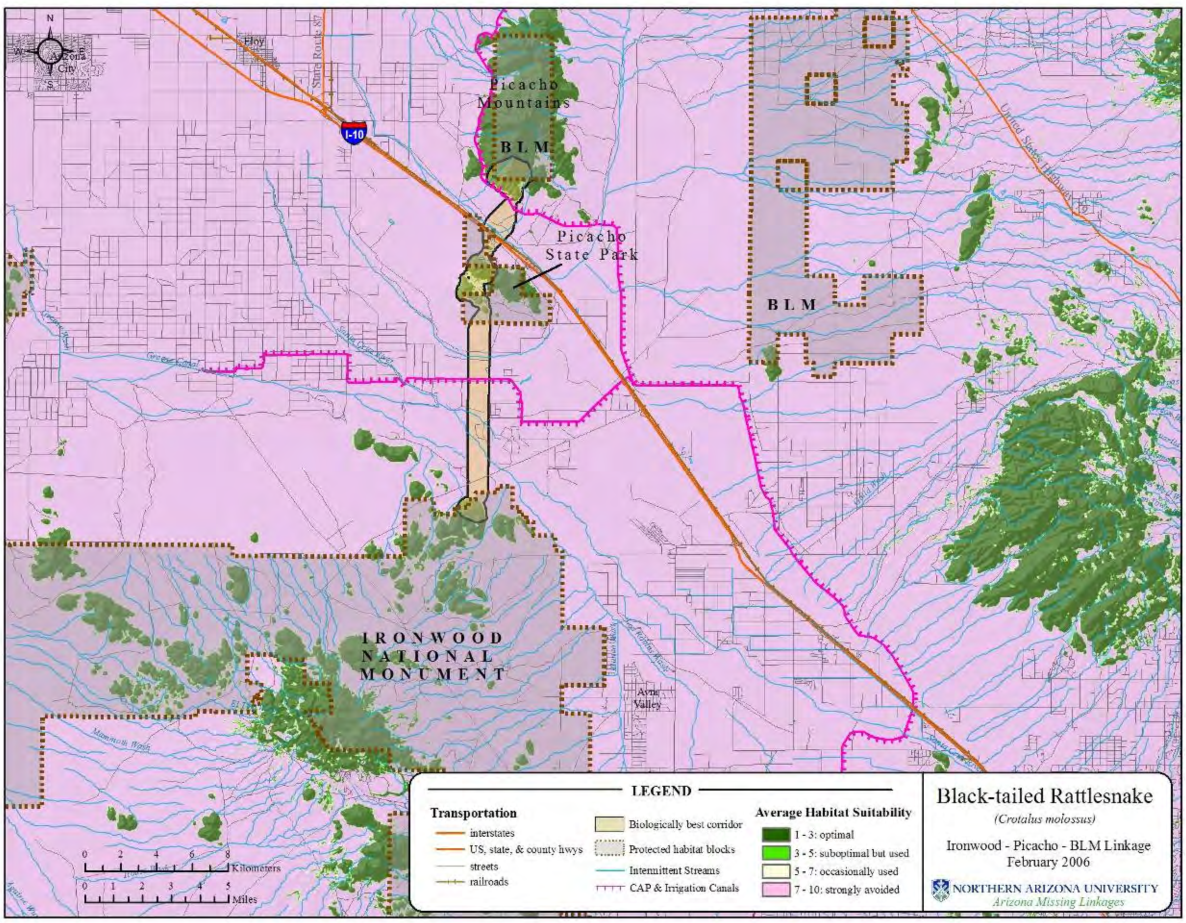

Figure 36: Modeled habitat suitability of black-tailed rattlesnake.

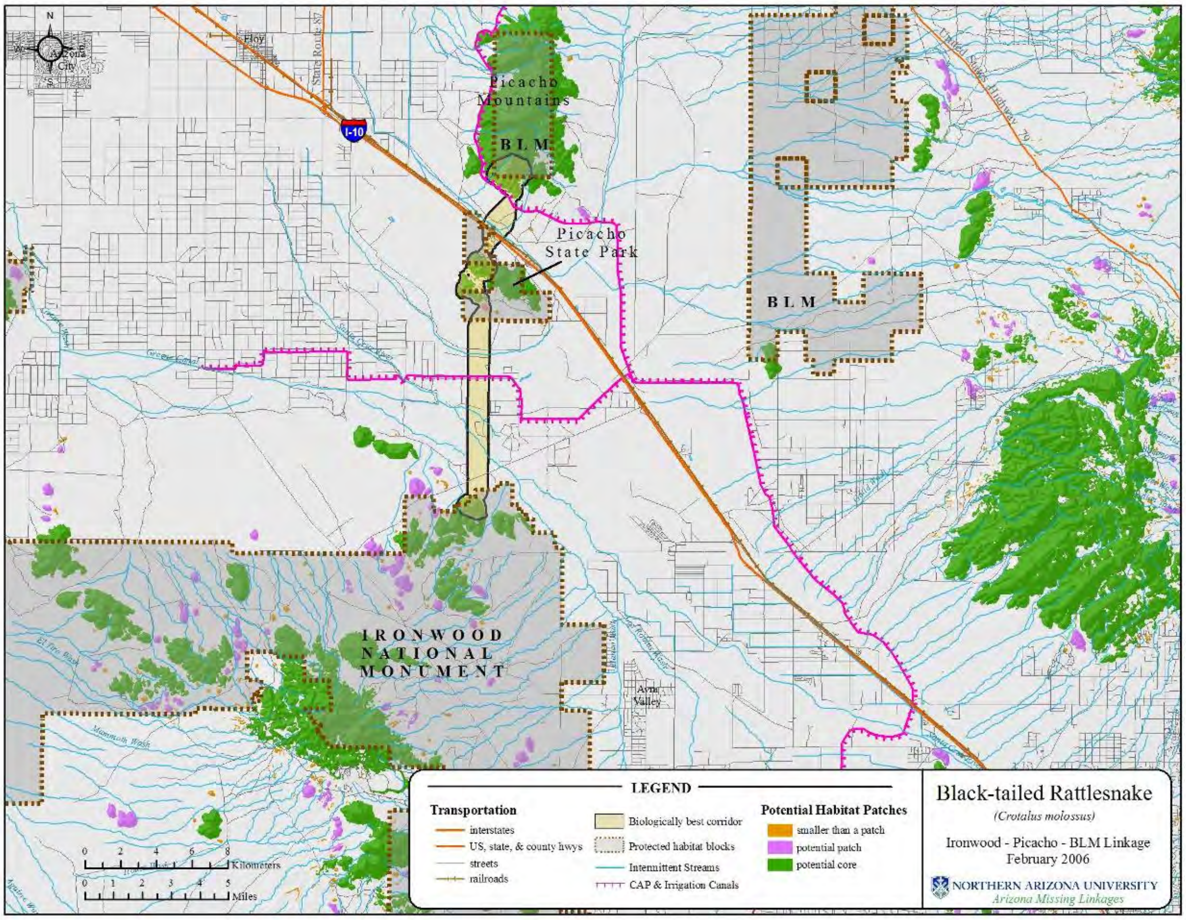

Figure 37: Potential habitat patches and cores for black-tailed rattlesnake.

Union of biologically best corridors – Like the desert bighorn sheep, the UBBC provides little additional habitat for the black-tailed rattlesnake, since it is dependent on the rugged topography found mainly within the wildland blocks. The UBBC adds additional habitat to the east of the initial corridor model for the black-tailed rattlesnake in Picacho Peak State Park, and also adds potential habitat patches and cores in the hills northwest of Samaniego Hills. This could potentially reduce the maximum dispersal distance necessary to maintain connectivity from 10.5 km to 8.5 km.

Desert Tortoise (*Gopherus agassizii*)

Justification for Selection
While the Mojave population of desert tortoise is listed as Threatened by the Fish & Wildlife Service, the Sonoran population is not currently listed. However, all desert tortoise populations are susceptible to habitat fragmentation, and need connectivity to maintain genetic diversity. Their ability to survive as an individual or population near roads is limited because of the potential for roadkill (Edwards et al. 2003).

Distribution
Desert tortoises are found deserts throughout California, southeastern Nevada, southwestern Utah, and Arizona. Desert tortoises are divided into two populations: the Mojave Desert population occurs north and west of the Colorado River, while the Sonoran Desert population occurs south and east of the Colorado River. Desert tortoises are found within Ironwood Forest National Monument with greatest frequency in the Sawtooth, West Silverbell, and Silverbell Mountains.

Habitat Associations
Tortoises are dependent on soil type and rock formations for shelter. Typical tortoise habitat in the Sonoran Desert is rocky outcrops (Bailey et al. 1995) where they make their burrows on south facing slopes. Exceptions to this rule usually involve some other topographical feature (such as caliche caves) that act similarly as shelter (Taylor Edwards, personal comm.). Desert Tortoises are obligate herbivores (Oftedal 2002) so vegetation is an important part of their habitat. However, desert tortoises also occur over a wide range of vegetation (Sinaloan thornscrub - Mojave Desert), so vegetation is therefore a variable resource. Desert tortoises eat both annuals and perennials, but not generally the desert plants that characterize a vegetation type (saguaro cactus, palo verde, etc.). Optimal habitat usually lies in Arizona Upland, between 2,200 and 3000 ft, although some low desert populations occur at ~1500 ft (Eagletail Mtns) and others breed at elevations up to ~4500ft (Chiminea Canyon) (Aslan et al. 2003; T. Edwards, personal comm.).

Spatial Patterns
Mean home range estimates (minimum convex polygon) from 5 different studies at 6 different sites accross the Sonoran Desert are between 7 and 23 ha (Averill-Murray et al. 2002). The Sonoran desert tortoise: natural history, biology, and conservation. Density of tortoise populations range from 20 - upwards of 150 individuals per square mile (from 23 Sonoran Desert populations; Averill-Murray et al. 2002). Tortoises have overlapping home ranges, so the estimated space needed for roughly 20 adults is approximately 50 hectares, which is the size of the Tumamoc Hill population near Tucson (Edwards et al. 2003). Desert tortoises are a long-lived species (well exceeding 40 years; Germano 1992) with a long generation time (estimated at 25 years; USFWS 1994). A 5-10 year time frame for a desert tortoise population is relatively insignificant, such that 20 adult individuals might maintain for 30+ years without ever successfully producing viable offspring. Also, tortoises have likely maintained long-term, small effective population sizes throughout their evolutionary history (see Edwards et al. 2004 for more insight into genetic diversity; Germano 1992; USFWS 1994). While long-distance movements of desert tortoises appear uncommon, they do occur and are likely *very* important for the long-term maintenance of

populations (Edwards et al. 2004). Desert tortoises may move more than 30 km during long-distance movements (T. Edwards, personal comm.).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 30%, while elevation, topography, and distance from roads received weights of 25%, 40%, and 5%, respectively. For specific scores of classes within each of these factors, see Table 4. Because desert tortoise are dependent on steep slopes for hibernacula and shelter (Bailey et al. 1995; T. Edwards, personal comm.), any pixel located further than 500 meters from a slope greater than 40% was reclassified to a suitability score between 5 and 10.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 15 ha, and minimum potential core size was defined as 50 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Because potential habitat was patchily distributed, we re-assigned all 'suitable' habitat (score < 5) a cost of 1 to increase the likelihood of the biologically best corridor capturing the little-available habitat.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a fair amount of suitable habitat for this species within the potential linkage area (Figure 38). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, the average habitat suitability cost ranged from 1.0 to 8.0, with an average suitability cost of 4.6 (S.D: 2.3). The largest gap between potentially suitable habitat patches is approximately 8 kilometers, between the hills northwest of Samaniego Hills, and the rugged topography found within Picacho State Park. Between Picacho State Park and the Picacho Mountains is another 2 kilometers of unsuitable habitat which the desert bighorn sheep must traverse to maintain connectivity (Figure 39).

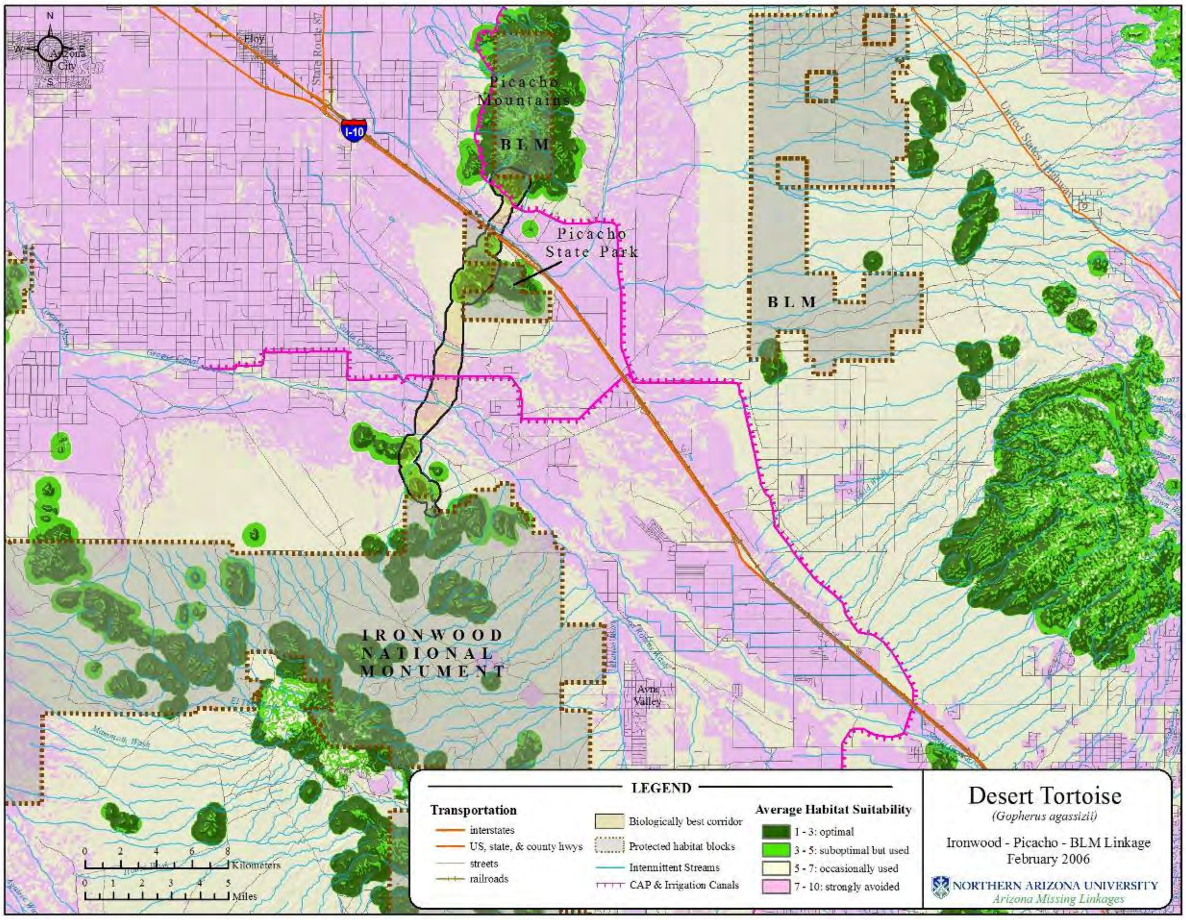

Figure 38: Modeled habitat suitability of desert tortoise.

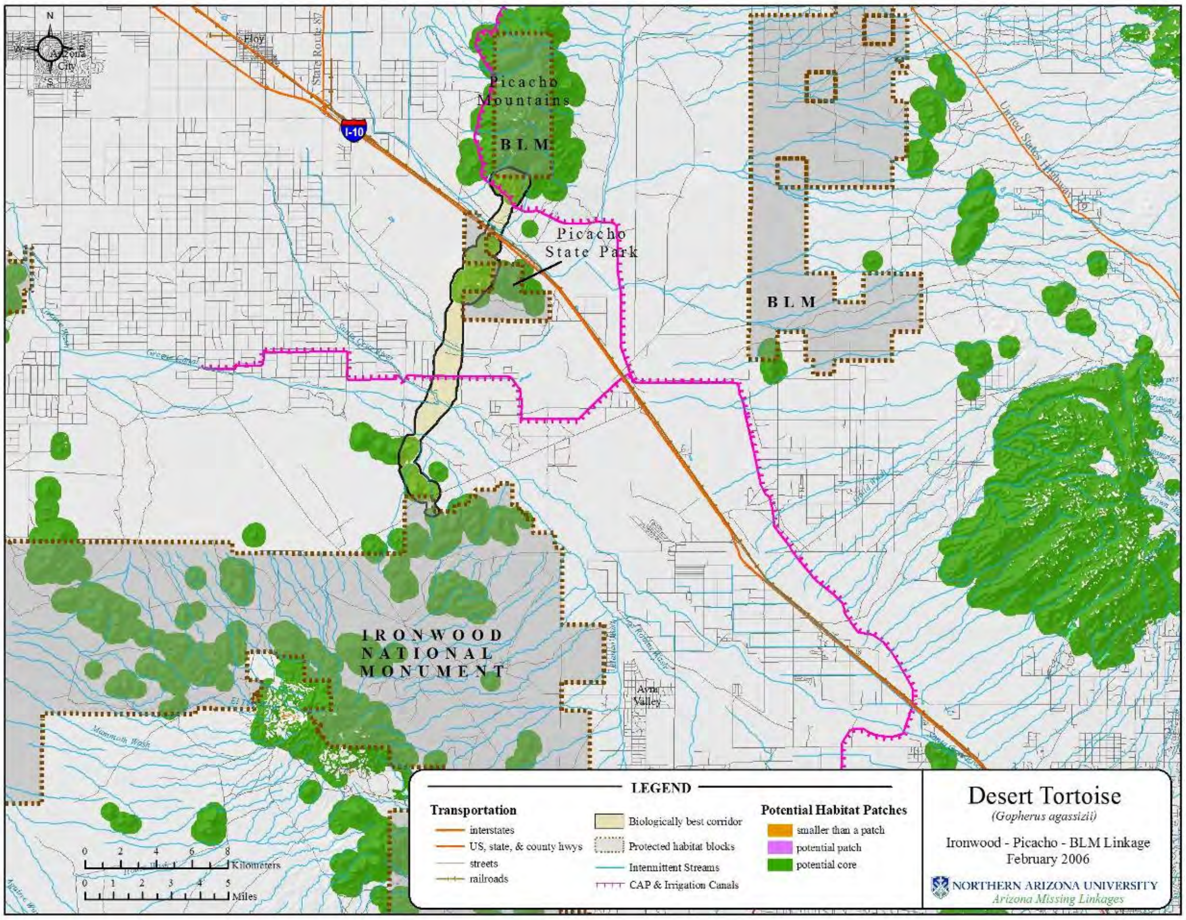

Figure 39: Potential habitat patches and cores for desert tortoise.

Union of biologically best corridors – Although, the UBBC adds additional habitat to the east of the initial corridor model for the desert tortoise within Picacho Peak State Park, it provides little additional habitat for the species outside of the wildland blocks, the rugged topography it is dependent on is found mostly within the wildland blocks.

Sonoran Desert Toad (*Bufo alvarius*)

Justification for Selection
This species is thought to be potentially susceptible to extirpation or demographic impact from road mortality due to its large size, conspicuous activity, numerous observations of road-killed adults, presumed long natural lifespan, and apparent declines in road-rich urban zones (Phil Rosen, personal comm.).

Distribution
Sonoran desert toads range from southeastern California to southwestern New Mexico (New Mexico Department of Game & Fish 2002).

Habitat Associations
Sonoran desert toads appear capable of occupying any vegetation type, from urbanized park to their maximum elevation. Roads can have a massive mortality impact and presumed population impact, but some populations live near roads that may be peripheral or marginal to the core habitat (P. Rosen, personal comm.). Breeding is naturally concentrated in canyons and upper bajada intermittent streams, and on valley floors in major pools, but not naturally frequent on intervening bajadas. With stock ponds, breeding can occur anywhere on the landscape, but valley centers and canyons likely remain as the core areas (P. Rosen, personal comm.).

Spatial Patterns
Little is know about spatial patterns for this species. Rosen (personal comm.) estimates the smallest area of suitable habitat necessary to support a breeding group for 1 breeding season to be 25 ha, based on limited knowledge of movements and smallest occupied patches in Tucson. Based on unpublished data by Cornejo, adults appear to be highly mobile, and long distance movements (5 km to be conservative) seem likely (P. Rosen, personal comm).

Conceptual Basis for Model Development
Habitat suitability model –Vegetation received an importance weight of 5%, while elevation, topography, and distance from roads received weights of 50%, 25%, and 20%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 100 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion
Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the potential linkage area (Figure 40). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.0 to 2.5, with an average suitability

cost of 1.6 (S.D: 0.3). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 1.5, ranging from 1.2 to 2.1 (S.D.: 0.2). Within both corridors, potential suitable habitat appears to be abundant, and the entirety of both corridors is a potential habitat core (Figure 41).

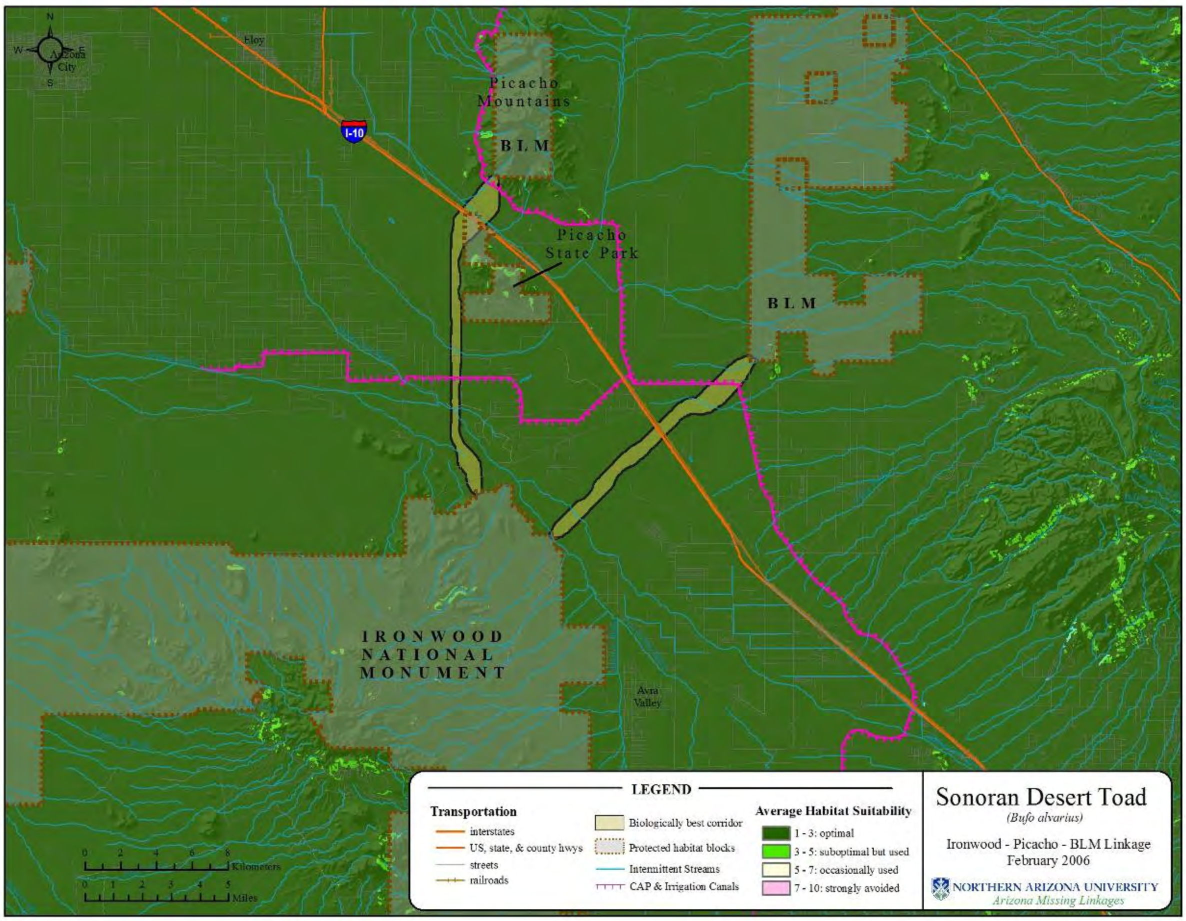

Figure 40: Modeled habitat suitability of Sonoran desert toad.

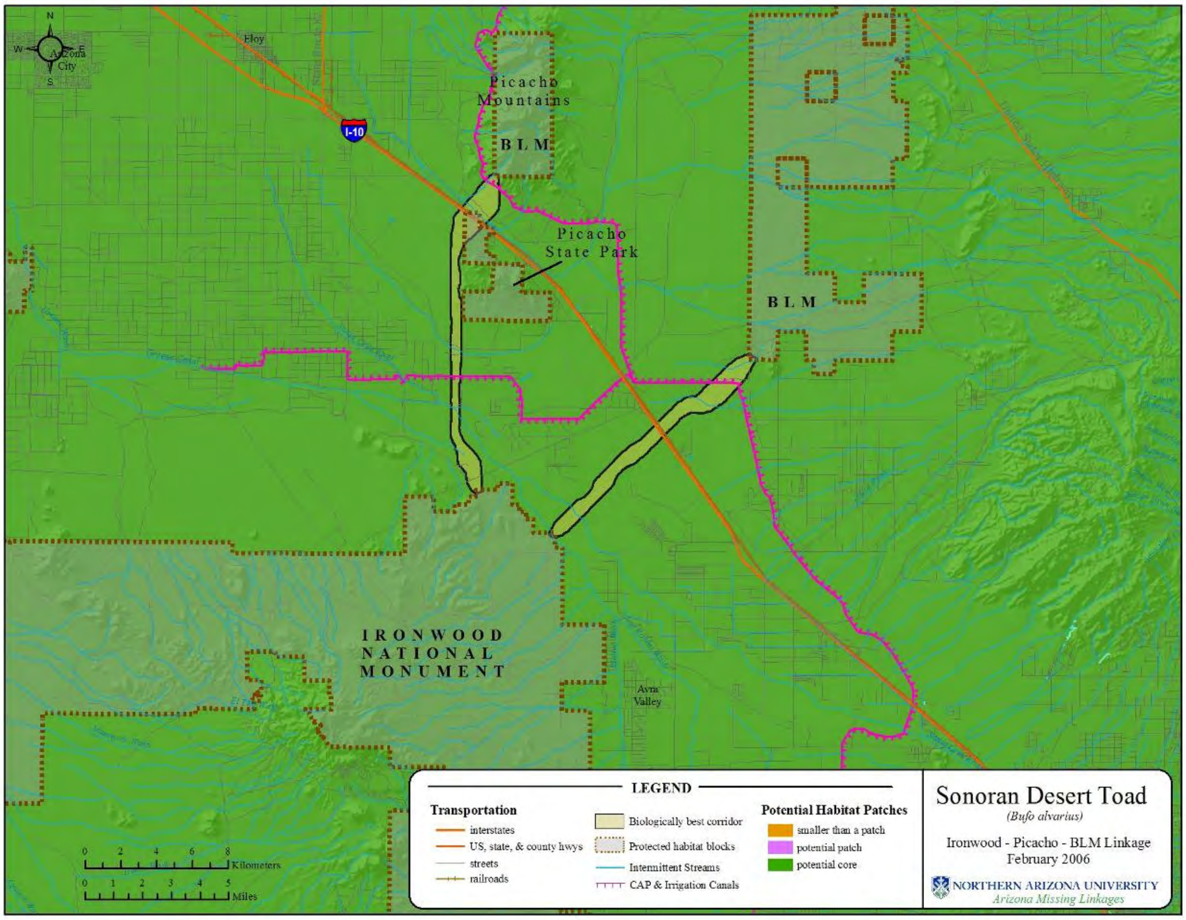

Figure 41: Potential habitat patches and cores for Sonoran desert toad.

Union of biologically best corridors – The UBBC adds additional optimal habitat to the biologically best corridor for the Sonoran desert toad. While the entire linkage area was modeled as a potential habitat core, it is important to note that because breeding is naturally concentrated in canyons and upper bajada intermittent streams and on valley floors in major pools, but not naturally frequent on intervening bajadas, these areas are particularly important for this species. Within the Linkage Design, the Santa Cruz River and Los Robles Wash may serve as breeding grounds for this species.

Sonoran Whipsnake (*Masticophis bilineatus*)

Justification for Selection
Wide-ranging, active, diurnal snakes including whipsnakes and racers are usually observed to disappear when urban road networks become dense, and the assumption is that road mortality plays a large roll (Phil Rosen, personal comm.).

Distribution
The Sonoran whipsnake is mainly found in the Sonoran desert of Mexico, but also occurs within southern Arizona and New Mexico.

Habitat Associations
This species tends to prefer areas with rugged topography, and will also use mid-to-high elevation riparian flats. This species is mobile, may occur along or move along desert and grassland washes, and thus might occasionally traverse areas of flat non-habitat between mountains, like some other larger reptiles. Preferred land cover types include Encinal, Pine-Oak Forest, Pinyon-Juniper Woodland, Chaparral, Creosotebush - Mixed Desert and Thorn Scrub, and Paloverde-Mixed-Cacti Desert Scrub.

Spatial Patterns
Home range has been estimated as 50 ha for this species (Parizek et al. 1995). Little is know about dispersal distance, but a telemetry study found one large male to move up to 1 km per day (Parizek et al. 1995). Based on observations of other whipsnakes, movement events of up to 4.5 km may be feasible (Phil Rosen, personal comm.).

Conceptual Basis for Model Development
Habitat suitability model – Vegetation received an importance weight of 30%, while elevation, topography, and distance from roads received weights of 10%, 45%, and 15%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 50 ha, and minimum potential core size was defined as 250 ha (Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – While habitat was patchily distributed for this species, the standard habitat suitability model was used in the corridor analysis because potential habitat in the Ironwood, Picacho State Park, and Picacho Mountain blocks were arranged linearly, assuring the biologically best corridor analysis would capture available habitat patches within each of these blocks.

Results & Discussion
Initial biologically best corridor – Modeling results significant suitable habitat for this species within the wildland blocks, fragmented by less-suitable habitat (Figure 42). Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.3 to 7.2, with an average suitability cost of 4.3 (S.D: 1.8). The largest gap between potentially suitable habitat patches or cores is approximately 3.5 kilometers, between Ironwood and a patch of potentially-suitable

palo verde. Between habitat surrounding Picacho State Park and the Picacho Mountains is another 1.5 km kilometers of unsuitable habitat which the Sonoran whipsnake must traverse to maintain connectivity (Figure 43).

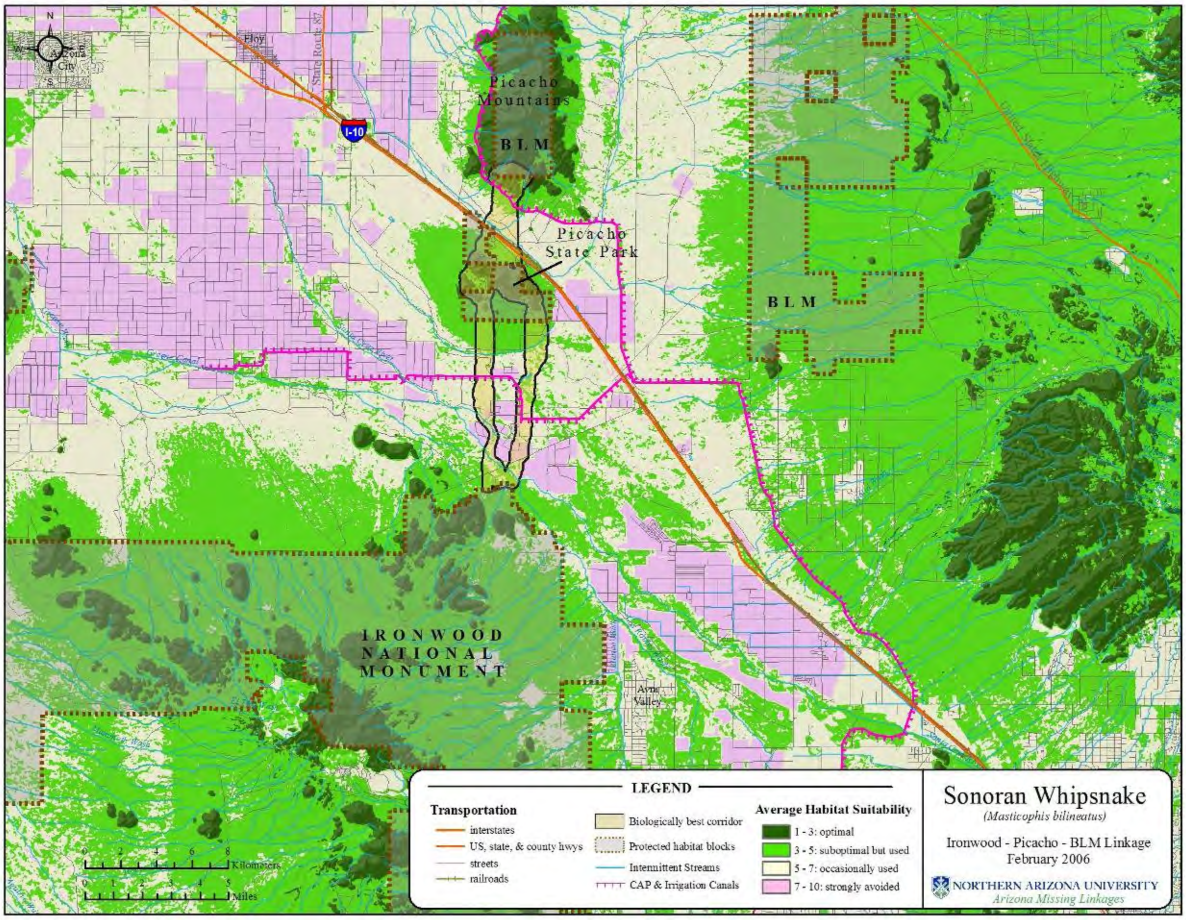

Figure 42: Modeled habitat suitability of Sonoran whipsnake.

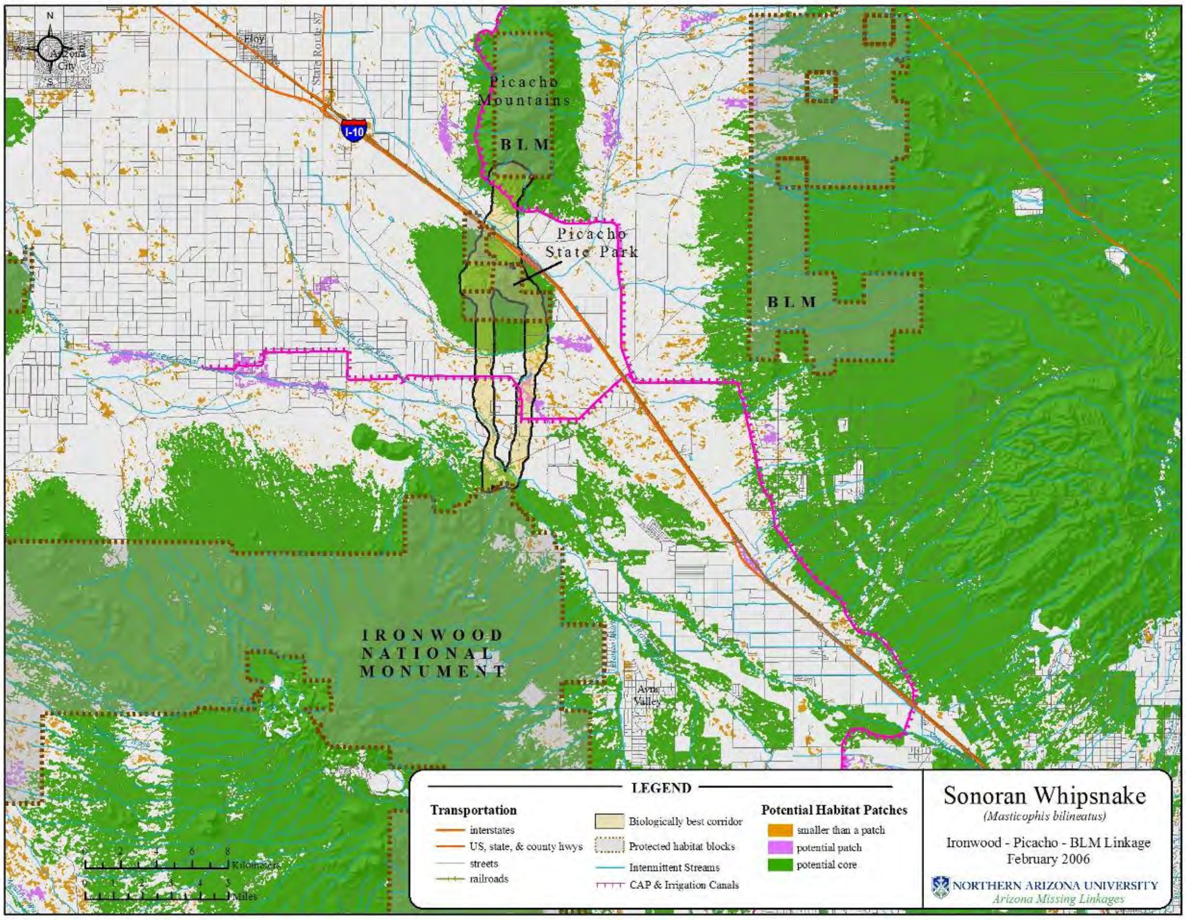

Figure 43: Potential habitat patches and cores for Sonoran whipsnake.

Union of biologically best corridors – The UBBC provides little additional habitat for the Sonoran Whipsnake, and the largest gap between potentially suitable habitat patches or cores remains approximately 3.5 kilometers.

Tucson Shovel-nosed Snake (*Chionactis occipitalis klauberi*)

Justification for Selection

Tucson shovel-nosed snakes have a very limited distribution, and are only known to exist in two counties of Arizona. They are susceptible to habitat loss, and are dependent on flat valley floors which are rapidly being converted to agriculture and residential development. A petition has recently been filed to protect the species under the Endangered Species Act.

Distribution

Tucson shovel-nosed snakes are a subspecies of the western shovel-nosed snake, which ranges from southern Arizona to southern California. This subspecies is found only within the deserts of Pima and Pinal county within Arizona, and has apparently disappeared from a large part of its range in Avra Valley, possibly due to habitat fragmentation. Populations are known to exist near Picacho Peak State Park, and probably also within Ironwood Forest National Monument (Phil Rosen, personal comm.).

Habitat Associations

This species is dependent on flat (< 1%), sandy valley floors, and may use also use washes. They occur mainly in vegetation associations consisting of creosotebush and desert grasses.

Spatial Patterns

Estimation of home range based on tracks in sandy places indicate this species may move less than many other snake species, needing only 25 ha to sustain a home range. While nothing is known about juvenile dispersal, most snakes are not known to have a dispersal phase. This species is likely to settle into a home range within 1-2 home ranges of their natal area, giving an estimated dispersal distance ranging from 0.25 – 2 km (P. Rosen, personal comm.).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 20%, while elevation, topography, and distance from roads received weights of 20%, 45%, and 15%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 250 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the potential linkage area (Figure 44); however, the actual amount of suitable habitat may be significantly less. This species is dependent on sandy flat areas, which were not mapped in the ReGAP land cover layer. Additionally, this species is found most often in Creosotebush associations, and not the Paloverde-mixed desert scrub that is found in the BLM block of Sonoran desert habitat.

Within the biologically best corridor linking the Ironwood and Picacho Mountains wildland blocks, habitat suitability ranged from 1.4 to 7.1, with an average suitability cost of 2.3 (S.D: 0.8). The biologically best corridor linking the Ironwood and desert BLM wildland blocks had an average habitat suitability cost of 2.0, ranging from 1.4 to 3.7 (S.D: 0.6). Within both corridors, potential suitable habitat appears to be abundant, and nearly the entirety of both corridors is a potential habitat core (Figure 45).

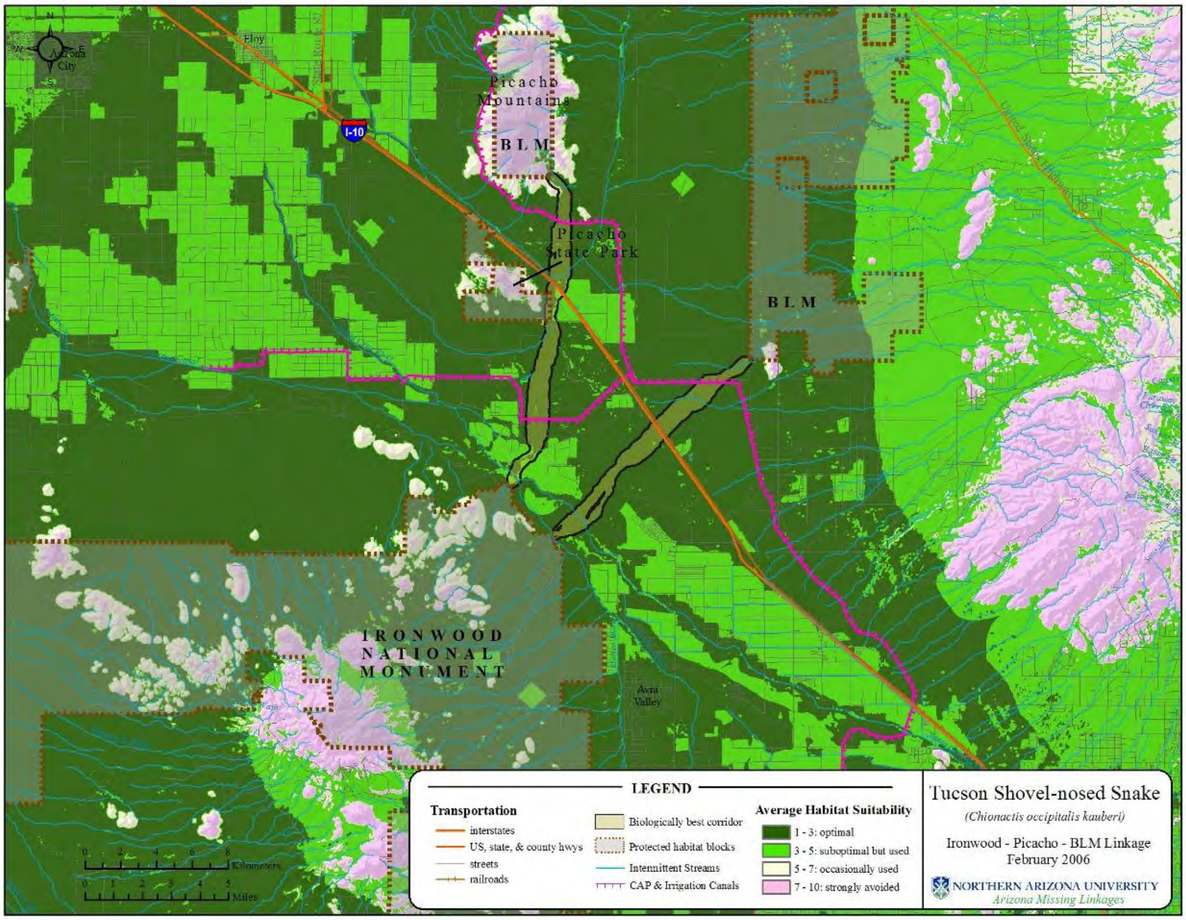

Figure 44: Modeled habitat suitability of Tucson shovel-nosed snake.

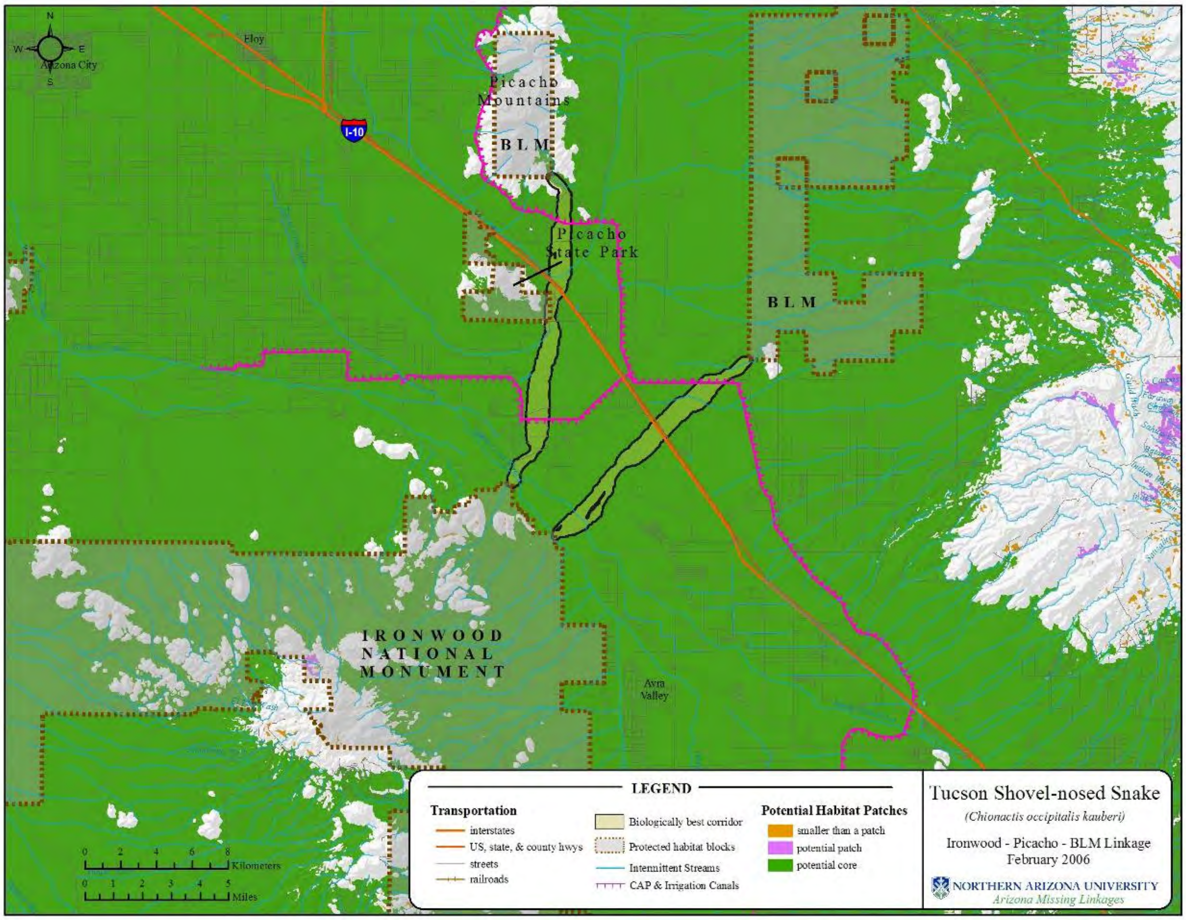

Figure 45: Potential habitat patches and cores for Tucsson shovel-nosed snake.

Union of biologically best corridors – The UBBC nearly doubles the potential habitat for this species between Ironwood Forest National Monument and the block of protected Sonoran desert administered by the BLM. While the species would not be expected to inhabit the Picacho Mountains, the linkage between the Ironwood and Picacho wildland blocks provides large amounts of potential live-in habitat.

Cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*)


Photograph: Glenn Proudfoot/USFWS

Justification for Selection
The cactus ferruginous pygmy-owl has experienced drastic declines in both range and abundance within the last 50 years (Arizona Game and Fish Department 2001). Major threats to this species includes degradation and loss of habitat due to urban development within saguaro-ironwood forests, and potential inbreeding due to small isolated and fragmented populations within its range (Arizona Game and Fish Department 2001, U.S. Fish and Wildlife Service 2003). The cactus ferruginous pygmy-owl was listed as endangered by the U.S. Fish and Wildlife Service in 1997, with proposed critical habitat in 2002 (U.S. Fish and Wildlife Service 2003). This subspecies is also listed as Forest Service Sensitive, and is a Species of Special Concern in Arizona (Arizona Game and Fish Department 2001, U.S. Fish and Wildlife Service 2003).

Distribution
The historic range of the cactus ferruginous pygmy-owl was southern Arizona and southern Texas south through the states of Tamaulipas and Nuevo Leon, Mexico (Arizona Game and Fish Department 2001). Currently in Arizona, documented distribution of this owl is limited to Pima and Pinal counties (U.S. Fish and Wildlife Service 2003).

Habitat Associations
The pygmy-owl lives in river bottom woodlands, and Palo verde cacti-mixed desertscrub areas of the Sonoran desert. This owl will also use areas of riparian drainages and semi-desert grasslands. They are cavity nesters, primarily choosing cavities in saguaro cacti. Elevation range for this species is below 4000 ft. (1,220 m) (Arizona Game and Fish Department 2001, U.S. Fish and Wildlife Service 2003).

Spatial Patterns
Very little information is known of home range requirements for this species. Estimations of territory sizes by Flesch (in prep) were 9.9, 11.7, 18.5, and 47.3 ha (Pima Co., Arizona 2005). Home ranges are believed to vary with weather conditions (Pima Co., Arizona 2005).

Conceptual Basis for Model Development
We did not perform a biologically best corridor analysis for this species. Instead, we mapped proposed critical habitat for the Cactus Ferruginous Pygmy-Owl to evaluate how well the Linkage Design encompasses potential habitat.

Results & Discussion
The strand of the Linkage Design connecting Ironwood Forest National Monument with the protected block of Sonoran desert administered by the BLM is entirely composed of proposed Critical Habitat for this species (Figure 46), indicating the Linkage Design adequately accounts for potential habitat for this species in the linkage zone.

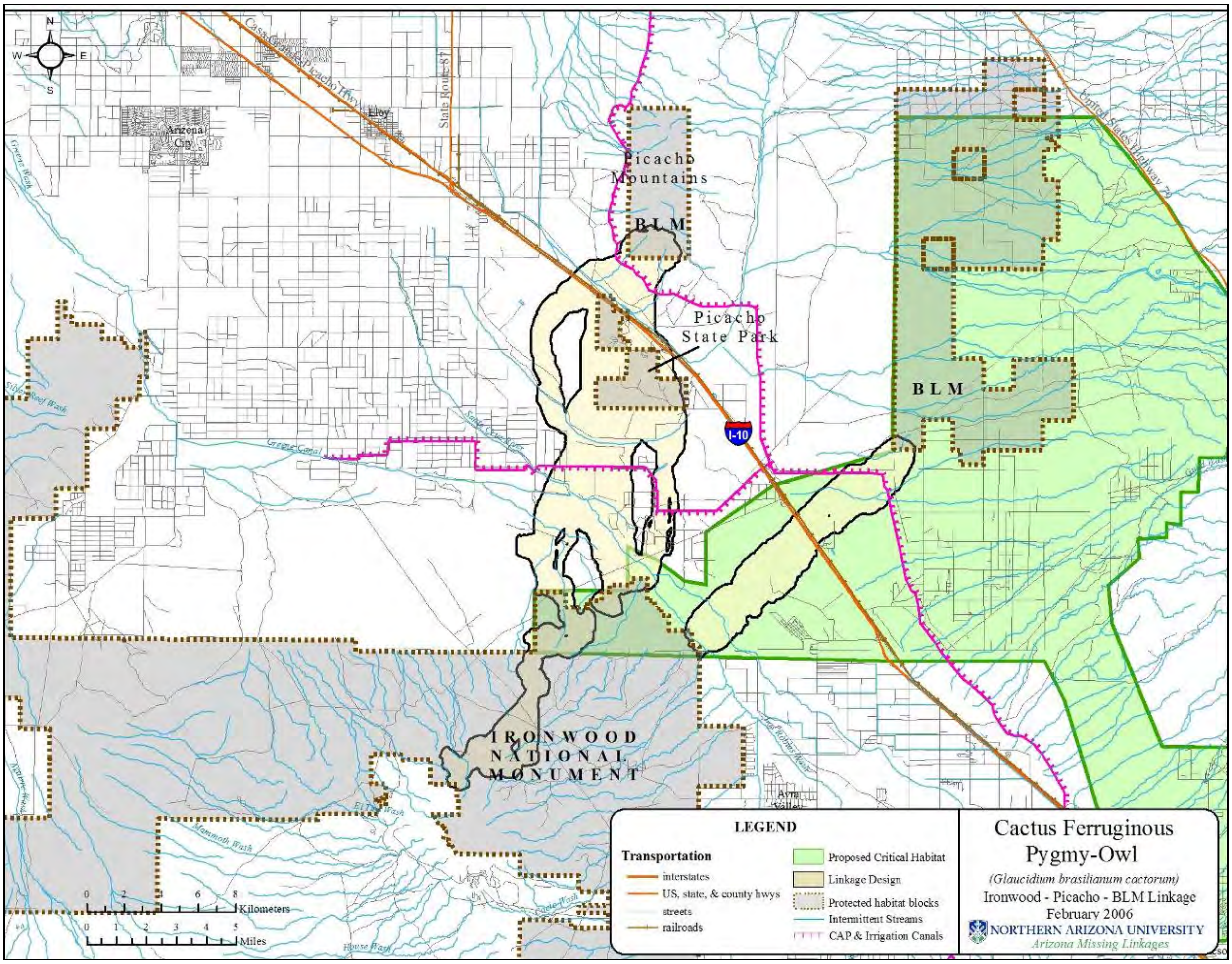

Figure 46: Proposed Critical Habitat for Cactus Ferruginous Pygmy-Owl.

Appendix C: Focal Species not Modeled

The habitat requirements and connectivity needs of several other suggested focal species were not modeled in this study. A list of these species follows:

Herpetofauna

- **Chuckwalla** (*Sauromalus ater*) – Chuckwallas prefer large rock outcrops and crevices within desert scrub vegetation associations (NMDGF 2005). The ReGAP land cover layer does not capture small rocky outcrops which are likely to be habitat for this species (often smaller than one 30 x 30 m pixel); consequently, the habitat requirements of this species could not be adequately represented by our habitat suitability modeling process.
- **Desert Iguana** (*Dipsosaurus dorsalis*) – Desert iguanas prefer sandy washes in creosote flats (Norris 1953). While we have a data layer of intermittent streams, we could not separate sandy washes from other washes, and felt we could not accurately represent the habitat requirements of this species. The linkage design encompasses washes within creosotebush-white bursage desert scrub which may be suitable habitat for this species.
- **Lyre Snake** (*Trimophodon biscutatus*) – Lyre snakes live on mountain slopes in virtually all vegetation types up to 7400 ft in Arizona, and is strongly associated with rocks and outcrops (Phil Rosen & Matt Goode, personal comm.). The habitat requirements of this species were redundant to the linkage design analysis, since this species shares similar habitat requirements with the black-tailed rattlesnake.
- **Tiger Rattlesnake** (*Crotalus tigris*) – Tiger rattlesnakes are saxicolous, prefer large rock outcrops and crevices within desert scrub vegetation associations (M. Goode & P. Rosen, personal comm.). The ReGAP land cover layer does not capture small rocky outcrops which are likely to be habitat for this species (often smaller than one 30 x 30 m pixel); consequently, the habitat requirements of this species could not be adequately represented by our habitat suitability modeling process.

Birds

- **Road Runner** (*Geococcyx californianus*) – Road runners occur in a range of desert habitat dominated by shrubs, including paloverde and creosotebush vegetation associations (NMDGF 2005). We reasoned they would be well-covered by the remaining suite of focal species.

Plants

- **Ironwood Tree** (*Olneya tesota*) – Ironwood is one of the most ecologically and economically important species in the Sonoran desert (Sonoran Desert Museum 2005). The ironwood tree occurs within the Sonoran paloverde-mixed cacti desert scrub vegetation association which dominates the Ironwood, Picacho, and Durham-Coronado wildland blocks. We did not model this species because other species which preferpaloverde, such as desert bighorn sheep, javelina, Sonoran desert toad, and desert tortoise were modeled.
- **Palo Verde** (*Parkinsonia microphylla*) – Palo verde occurs within the Sonoran paloverde-mixed cacti desert scrub vegetation association which dominates the Ironwood, Picacho, and Durham-Coronado wildland blocks. We did not model this species because other species which prefer paloverde, such as desert bighorn sheep, javelina, Sonoran desert toad, and desert tortoise were modeled.

Insects

- **Bees** – Bees are important pollinators for species such as the ironwood tree and paloverde, which need seed dispersal and pollinators to ensure population connectivity. However, bees are very mobile, and habitat preferences are difficult to model using the available GIS layers.
- **Hawk Moth** – Long-tongued hawk moths are also important pollinators for at least 20 species of night-blooming desert plants (Raguso et al. 2003); however, their mobility over highways and barren areas is good (Rob Raguso, personal comm.). Because we could not isolate the plant species they pollinate (such as *Peniocereus* cacti and *Datura* plants) from the general land cover map, we could not perform modeling for this species.

Appendix D: Creation of Linkage Design

To create the final Linkage Design, we combined biologically best corridors for all focal species modeled, with two exceptions:

- We removed the biologically best corridor model from Ironwood to the Picacho Mountains for the Tucson shovel-nosed snake, because the species is unlikely to occur within the Picacho Mountains. The remaining corridors adequately serve this species.
- We removed the eastern strand of the biologically best corridor model from Ironwood to the Picacho Mountains for javelina, because the species was adequately served by its remaining western strand of the linkage. The eastern strand added little habitat that was not represented by the remaining Linkage Design.

Appendix E: Description of Land Cover Classes

Vegetation classes have been derived from the Southwest Regional GAP analysis (ReGAP) land cover layer. To simplify the layer from 77 to 46 classes, we grouped similar vegetation classes into slightly broader classes by removing geographic and environmental modifiers (e.g. Chihuahuan Mixed Salt Desert Scrub and Inter-Mountain Basins Mixed Salt Desert Scrub got lumped into "Desert Scrub"; Subalpine Dry-Mesic Spruce-Fir Forest and Woodland was simplified to Spruce-Fir Forest and Woodland). What follows is a description of each class found in the linkage area, taken largely from the document, Landcover Descriptions for the Southwest Regional GAP Analysis Project (Available from http://earth.gis.usu.edu/swgap)

EVERGREEN FOREST (2 CLASSES) – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Encinal (Oak Woodland) – Madrean Encinal occurs on foothills, canyons, bajadas and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north intoTrans-Pecos Texas, southern New Mexico and sub-Mogollon Arizona. These woodlands are dominated by Madrean evergreen oaks along a low-slope transition below Madrean Pine-Oak Forest and Woodland and Madrean Pinyon-Juniper Woodland. Lower elevation stands are typically open woodlands or savannas where they transition into desert grasslands, chaparral or is some case desert scrub.

Pinyon-Juniper Woodland – These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus, and ridges. Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. In the southern portion of the Colorado Plateau in northern Arizona and northwestern New Mexico, *Juniperus monosperma* and hybrids of *Juniperus* spp may dominate or codominate tree canopy. *Juniperus scopulorum* may codominate or replace *Juniperus osteosperma* at higher elevations. In transitional areas along the Mogollon Rim and in northern New Mexico, *Juniperus deppeana* becomes common. In the Great Basin, Woodlands dominated by a mix of *Pinus monophylla* and *Juniperus osteosperma*, pure or nearly pure occurrences of *Pinus monophylla*, or woodlands dominated solely by *Juniperus osteosperma* comprise this system..

GRASSLANDS-HERBACEOUS (1 CLASS) – Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Semi-Desert Grassland and Shrub Steppe – Comprised of *Semi-Desert Shrub Steppe* and *Piedmont Semi-Desert Grassland and Steppe*. Semi-Desert Shrub is typically dominated by graminoids (>25% cover) with an open shrub layer, but includes sparse mixed shrublands without a strong graminoid layer. Steppe Piedmont Semi-Desert Grassland and Steppe is a broadly defined desert grassland, mixed shrub-succulent or xeromorphic tree savanna that is typical of the Borderlands of Arizona, New Mexico and northern Mexico [Apacherian region], but extends west to the Sonoran Desert, north into the Mogollon Rim and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that supported frequent fire throughout the Sky Islands and on mesas and steeper piedmont and foothill slopes in the Chihuahuan Desert. It is characterized by a typically diverse perennial grasses. Common grass species include *Bouteloua eriopoda, B. hirsuta,B. rothrockii, B. curtipendula, B. gracilis, Eragrostis intermedia, Muhlenbergia porteri, Muhlenbergia setifolia, Pleuraphis jamesii, Pleuraphis mutica*, and *Sporobolus airoides*, succulent species of *Agave, Dasylirion*, and *Yucca*, and tall shrub/short tree species of *Prosopis* and various oaks (e.g., *Quercus grisea, Quercus emoryi, Quercus arizonica*).

SCRUB-SHRUB (7 CLASSES) – Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Chaparral – This ecological system occurs across central Arizona (Mogollon Rim), western New Mexico and southwestern Utah and southeast Nevada. It often dominants along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into mountains (1000-2200 m). It occurs on foothills, mountain slopes and canyons in dryer habitats below the encinal and *Pinus ponderosa* woodlands. Stands are often associated with more xeric and coarse-textured substrates such as limestone, basalt or alluvium, especially in transition areas with more mesic woodlands.

Creosotebush, Mixed Desert and Thorn Scrub – This widespread Chihuahuan Desert land cover type is composed of two ecological systems: the Chihuahuan Creosotebush Xeric Basin Desert Scrub and the Chihuahuan Mixed Desert and Thorn Scrub. This cover type includes xeric creosotebush basins and plains and the mixed desert scrub in the foothill transition zone above, sometimes extending up to the lower montane woodlands. Vegetation is characterized by *Larrea tridentata* alone or mixed with thornscrub and other desert scrub such as *Agave lechuguilla, Aloysia wrightii, Fouquieria splendens, Dasylirion leiophyllum, Flourensia cernua, Leucophyllum minus, Mimosa aculeaticarpa var. biuncifera, Mortonia scabrella (= Mortonia sempervirens ssp. scabrella), Opuntia engelmannii, Parthenium incanum, Prosopis glandulosa*, and *Tiquilia greggii*.

Creosotebush-White Bursage Desert Scrub – This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains and low hills in the Mojave and lower Sonoran deserts. This desert scrub is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories.

Desert Scrub (misc) – Comprised of Succulent Desert Scrub, Mixed Salt Desert Scrub, and Mid-Elevation Desert Scrub. Vegetation is characterized by a typically open to moderately dense shrubland.

Mesquite Upland Scrub – This ecological system occurs as upland shrublands that are concentrated in the extensive grassland-shrubland transition in foothills and piedmont in the Chihuahuan Desert. Vegetation is typically dominated by *Prosopis glandulosa* or *Prosopis velutina* and succulents. Other desert scrub that may codominate or dominate includes *Acacia neovernicosa, Acacia constricta, Juniperus monosperma*, or *Juniperus coahuilensis*. Grass cover is typically low.

Paloverde-Mixed Cacti Desert Scrub - This ecological system occurs on hillsides, mesas and upper bajadas in southern Arizona. The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegia gigantea* (3-16 m tall) and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* less prominent. The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat is present.

Stabilized Coppice Dune and Sand Flat Scrub – This ecological system includes the open shrublands of vegetated coppice dunes and sandsheets found in the Chihuahuan Desert. Usually dominated by *Prosopis glandulosa* but includes *Atriplex canescens, Ephedra torreyana, Ephedra trifurca, Poliomintha incana*, and *Rhus microphylla* coppice sand scrub with 10-30% total vegetation cover. *Yucca elata, Gutierrezia sarothrae*, and *Sporobolus flexuosus* are commonly present.

WOODY WETLAND (2 CLASSES) – Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Riparian Mesquite Bosque – This ecological system consists of low-elevation (<1100 m) riparian corridors along intermittent streams in valleys of southern Arizona and New Mexico, and adjacent Mexico. Dominant trees include *Prosopis glandulosa* and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia, Pluchea sericea*, and *Salix exigua*.

Riparian Woodland and Shrubland – This system is dependent on a natural hydrologic regime, especially annual to episodic flooding. Occurrences are found within the flood zone of rivers, on islands, sand or cobble bars, and immediate streambanks. In mountain canyons and valleys of southern Arizona, this system consists of mid- to low-elevation (1100-1800 m) riparian corridors along perennial and seasonally intermittent streams. The vegetation is a mix of riparian woodlands and shrublands. Throughout the Rocky Mountain and Colorado Plateau regions, this system occurs within a broad elevation range from approximately 900 to 2800 m., as a mosaic of multiple communities that are tree-dominated with a diverse shrub component.

BARREN LANDS (3 CLASSES) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Barren Lands, Non-specific – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Bedrock Cliff and Outcrop – This ecological system is found from subalpine to foothill elevations and includes barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock types. Also included are unstable scree and talus slopes that typically occur bellow cliff faces. Species present are diverse and may include *Bursera microphylla, Fouquieria splendens, Nolina bigelovii, Opuntia bigelovii*, and other desert species, especially succulents. Lichens are predominant lifeforms in some areas. May include a variety of desert shrublands less than 2 ha (5 acres) in size from adjacent areas.

Volcanic Rock Land and Cinder Land – This ecological system occurs in the Intermountain western U.S. and is limited to barren and sparsely vegetated volcanic substrates (generally <10% plant cover) such as basalt lava (malpais), basalt dikes with associated colluvium, basalt cliff faces and uplifted "backbones," tuff, cinder cones or cinder fields. It may occur as large-patch, small-patch and linear (dikes) spatial patterns. Vegetation is variable and includes a variety of species depending on local environmental conditions, e.g., elevation, age and type of substrate. At montane and foothill elevations scattered *Pinus ponderosa, Pinus flexilis*, or *Juniperus* spp. trees may be present.

ALTERED OR DISTURBED (2 CLASSES) –

Invasive Southwest Riparian Woodland and Shrubland – Tamarix spp. Semi-Natural Temporarily Flooded Shrubland Alliance, or Elaegnus angustifolus Semi-Natural Woodland Alliance.

Recently Mined or Quarried – 2 hectare or greater, open pit mining or quarries visible on imagery.

DEVELOPED AND AGRICULTURE (3 CLASSES) –

Agriculture

Developed, Medium - High Intensity – *Developed, Medium Intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surface accoutns for 50-79 percent of the total cover. These areas most commonly include single-family housing units. *Developed, High Intensity*: Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

Developed, Open Space - Low Intensity – *Open Space:* Includes areas with a mixture of some construction materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed sesttings for recreation, erosion control, or aesthetic purposes. *Developed, Low intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

OPEN WATER (1 CLASS) – All areas of open water, generally with less than 25% cover of vegetation or soil.

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Appendix G: Database of Field Investigations

Attached is a database of field notes, GPS coordinates, and photos collected as part of our field investigations of this linkage zone. The database is found as an MS Access database on the CD-ROM accompanying this report. This database is also an ArcGIS 9.1 Geodatabase which contains all waypoints within it as a feature class. Additionally, all waypoints can be found as a shapefile in the /gis directory, and all photographs within the database are available in high resolution in the /FieldDatabase/high-res_photos/ directory.

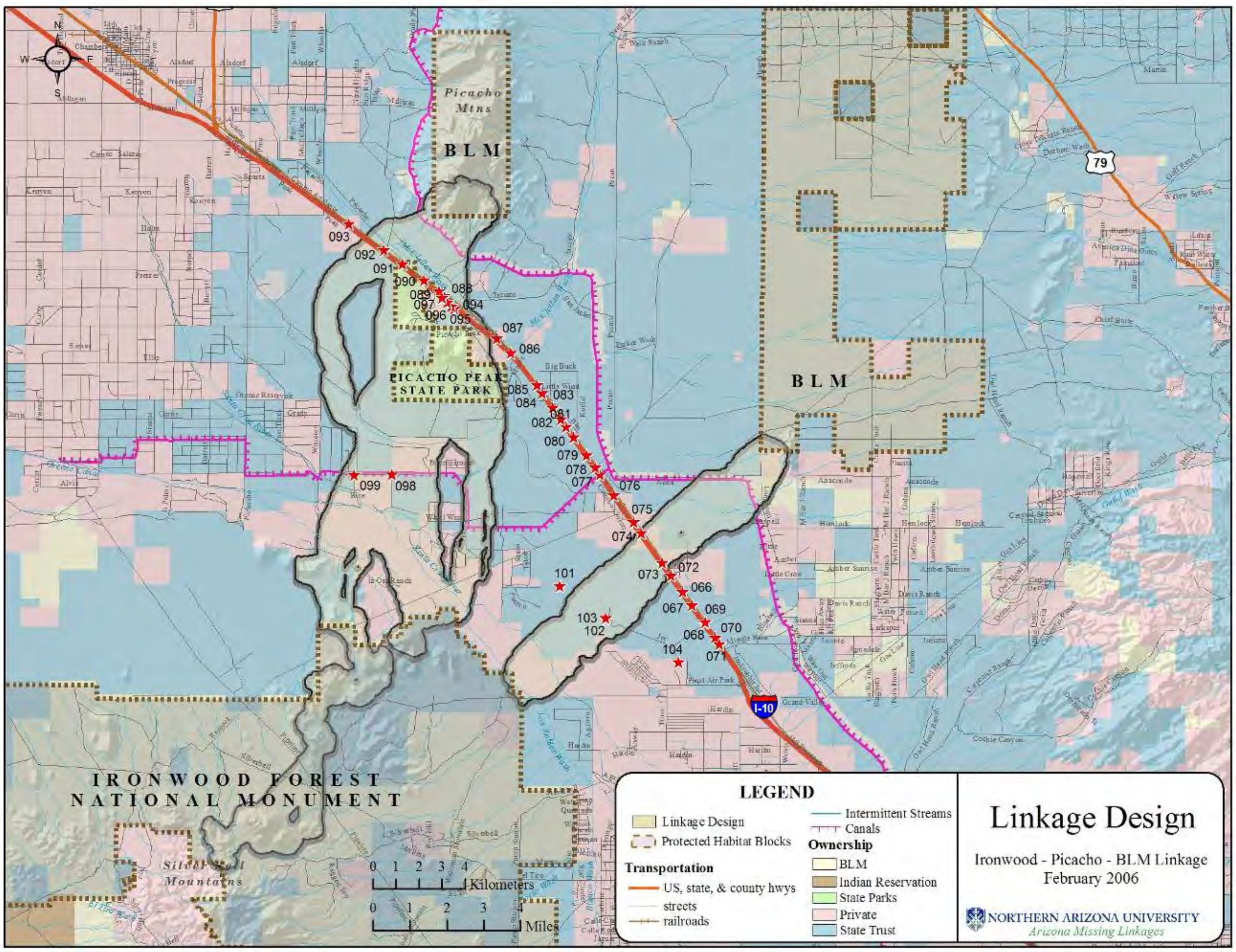
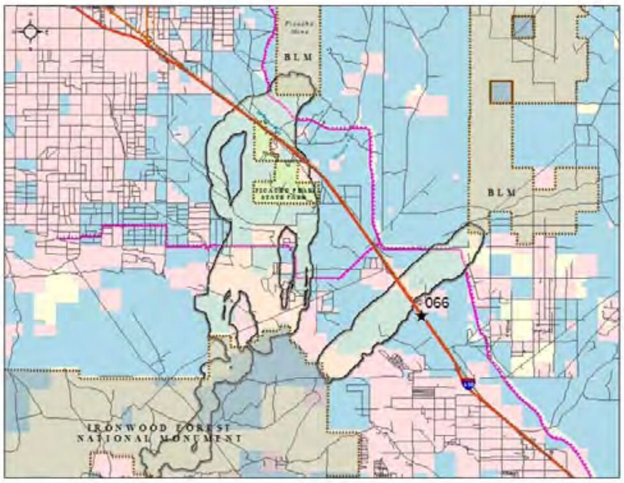


Figure 47: Field investigation waypoints.

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	066		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.54276698	**Longitude:**	-111.296837
Observers:	Paul Beier, Dan Majka	**UTM X:**	472128.5085	**UTM Y:**	3600638.740
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photo taken off East Frontage Rd. A single dead javelina was found 3 ft. from this culvert. Box culvert under I-10; located approx. 1/4 mile SE of power station. Mile Post 229.04

Site Photographs

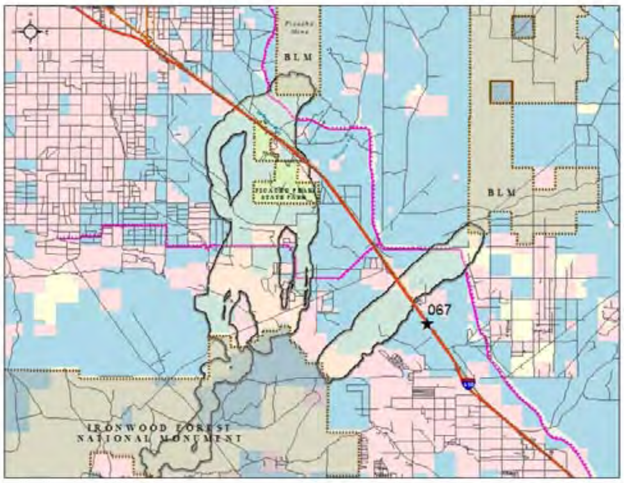
Name: DSCF0001.jpg

Azimuth: 230 **Zoom:** 1x

Notes: Twin box culvert; 3x10 ft concrete bottom.

Linkage #:	79	**Waypoint #:**	067		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.53752879	**Longitude:**	-111.292465
Observers:	Paul Beier, Dan Majka	**UTM X:**	472537.4476	**UTM Y:**	3600056.938
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Approx. two 3x10 ft box culvert under I-10, Mile post 229.6

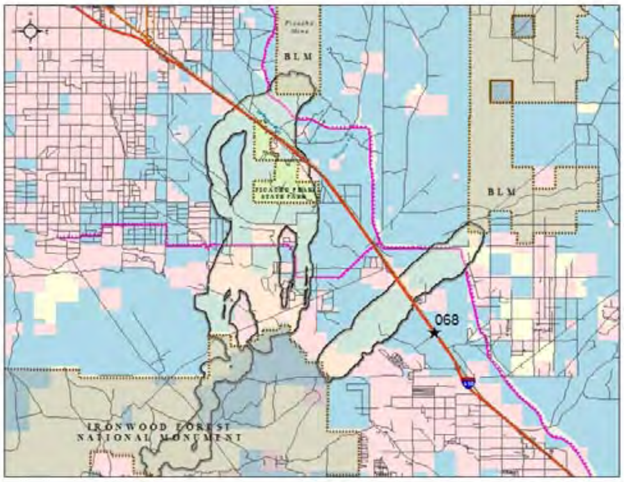
Site Photographs

Name: DSCF0002.jpg

Azimuth: 226 **Zoom:** 1x

Linkage #:	79	**Waypoint #:**	068		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.53068622	**Longitude:**	-111.286742
Observers:	Paul Beier, Dan Majka	**UTM X:**	473072.8069	**UTM Y:**	3599296.961
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Approx. two 3x10 ft box culvert under I-10, Mile post 230.05

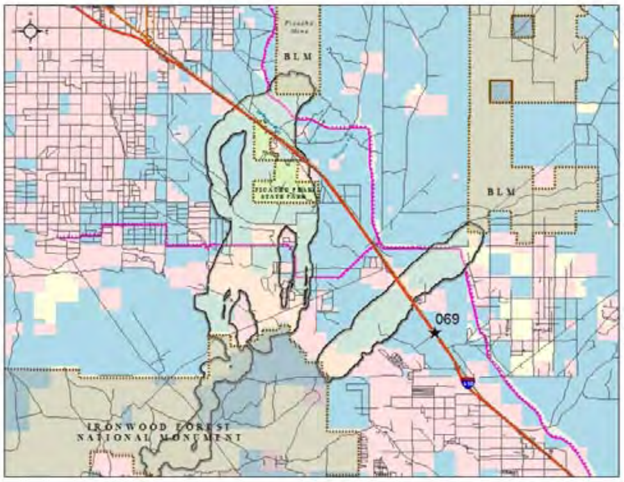
Site Photographs

Name: DSCF0003.jpg

Azimuth: 262 **Zoom:** 1x

Linkage #:	79	**Waypoint #:**	069		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.53086526	**Longitude:**	-111.286331
Observers:	Paul Beier, Dan Majka	**UTM X:**	473111.493	**UTM Y:**	3599316.704
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Railroad crossing at same wash as waypoint 68; approx. 3 ft tall.

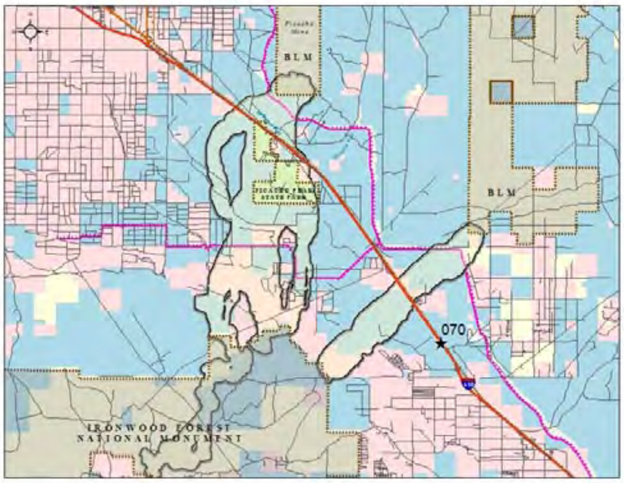
Site Photographs

Name: DSCF0004.jpg

Azimuth: 46 **Zoom:** 1x

Linkage #:	79	**Waypoint #:**	070		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.52455042	**Longitude:**	-111.281637
Observers:	Paul Beier, Dan Majka	**UTM X:**	473550.4402	**UTM Y:**	3598615.515
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken near milepost 230.6 on E. Frontage Rd. off I-10.

Site Photographs

Name: DSCF0005.jpg

Azimuth: 260 **Zoom:** 1x

Notes: Approx. 2.5 ft x 6 ft box culvert.

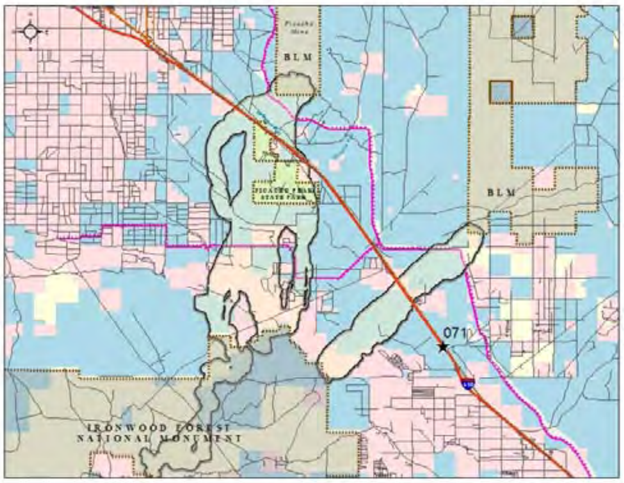
Name: DSCF0006.jpg

Azimuth: 46 **Zoom:** 1x

Notes: Railroad crosses wash via three 2-ft pipes.

Linkage #:	79	**Waypoint #:**	071		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.52223584	**Longitude:**	-111.279631
Observers:	Paul Beier, Dan Majka	**UTM X:**	473738.1624	**UTM Y:**	3598358.442
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



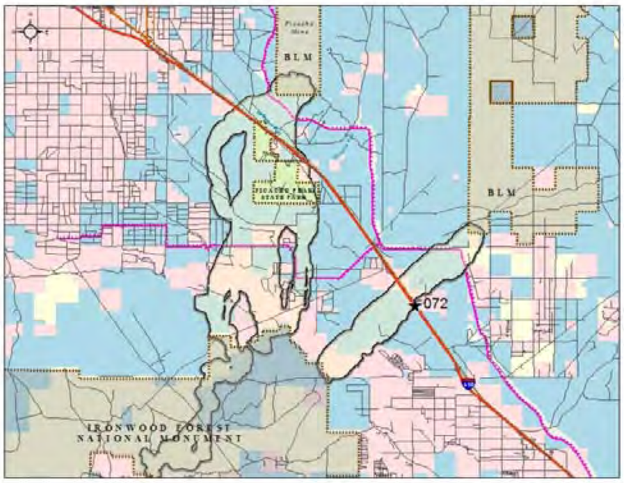
Waypoint Notes

Three 3x10 ft box culverts. NO PHOTOS WITH THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	072		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.54917821	**Longitude:**	-111.302228
Observers:	Paul Beier, Dan Majka	**UTM X:**	471624.3455	**UTM Y:**	3601350.866
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Site Photographs

Name: DSCF0007.jpg

Azimuth: 280 **Zoom:** 1x

Notes: Four 3x10 ft box culverts under I-10.

Name: DSCF0008.jpg

Azimuth: 38 **Zoom:** 1x

Notes: Power plant

Name: DSCF0009.jpg

Azimuth: 350 **Zoom:** 1x

Notes: Power plant tanks

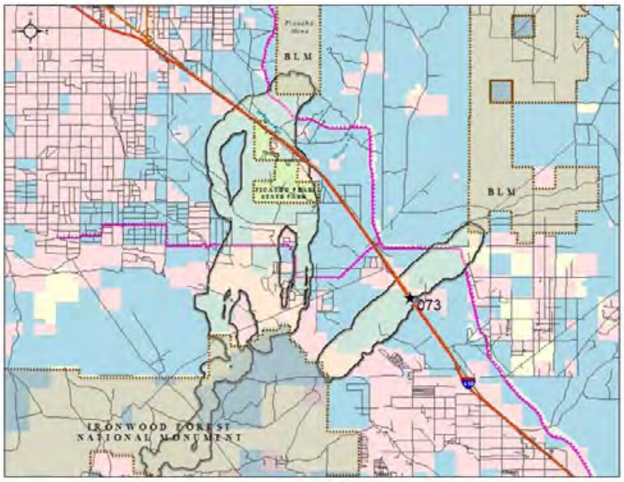
Name: DSCF0010.jpg

Azimuth: 174 **Zoom:** 1x

Notes: Railroad crossing

Linkage #:	79	**Waypoint #:**	073		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.55421883	**Longitude:**	-111.30644
Observers:	Paul Beier, Dan Majka	**UTM X:**	471230.5118	**UTM Y:**	3601910.763
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Mile post 228.02

Site Photographs

Name: DSCF0011.jpg

Azimuth: 280 **Zoom:** 1x

Notes: Culvert - bottom is filled with sand.

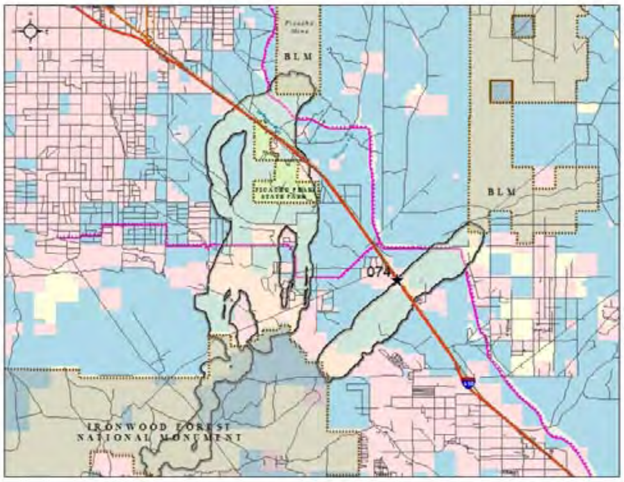
Name: DSCF0012.jpg

Azimuth: 52 **Zoom:** 1x

Notes: Railroad crossing over wash.

Linkage #:	79	**Waypoint #:**	074		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.56584294	**Longitude:**	-111.316184
Observers:	Paul Beier, Dan Majka	**UTM X:**	470319.5582	**UTM Y:**	3603202.005
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Mile post 227, E. Frontage Rd. off I-10.

Site Photographs

Name: DSCF0013.jpg

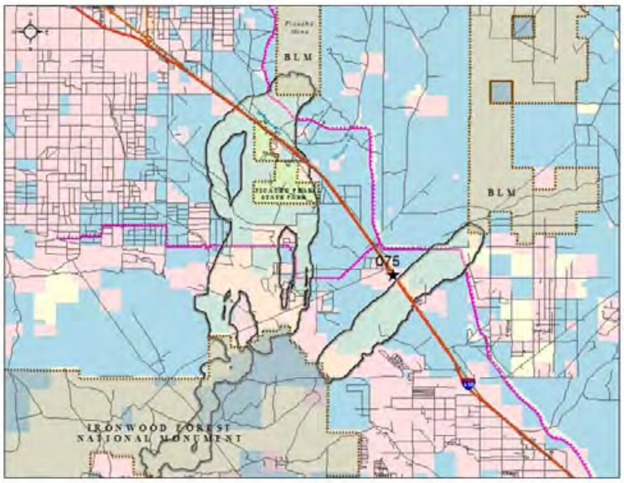
Azimuth: 268 **Zoom:** 1x

Name: DSCF0014.jpg

Azimuth: 54 **Zoom:** 1x

Linkage #:	79	**Waypoint #:**	075		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.57016364	**Longitude:**	-111.319625
Observers:	Paul Beier, Dan Majka	**UTM X:**	469997.9281	**UTM Y:**	3603681.933
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Three 6x10 ft box culverts, mile post 226c.

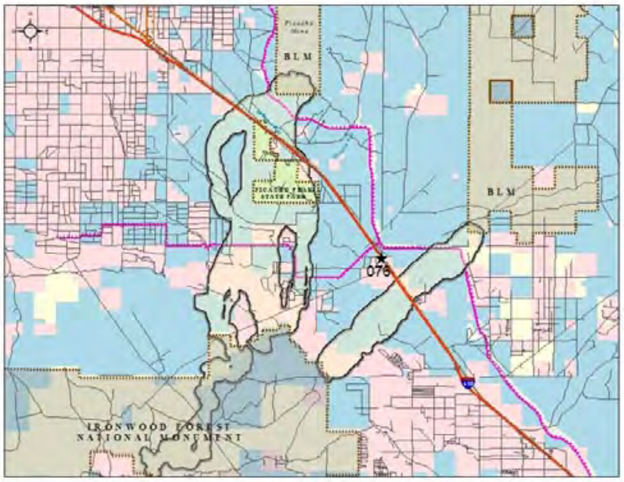
Site Photographs

Name: DSCF0015.jpg

Azimuth: 272 **Zoom:** 1x

Linkage #:	79	**Waypoint #:**	076		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.58060775	**Longitude:**	-111.328879
Observers:	Paul Beier, Dan Majka	**UTM X:**	469132.938	**UTM Y:**	3604842.344
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



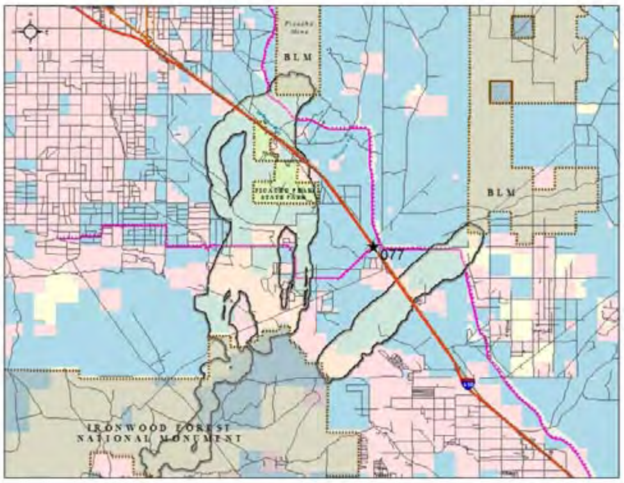
Waypoint Notes

Culvert - NO PHOTOS FOR THIS WAYPOINT

Site Photographs

Linkage #:	79	**Waypoint #:**	077		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.58888454	**Longitude:**	-111.335290
Observers:	Paul Beier, Dan Majka	**UTM X:**	468534.0421	**UTM Y:**	3605761.733
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



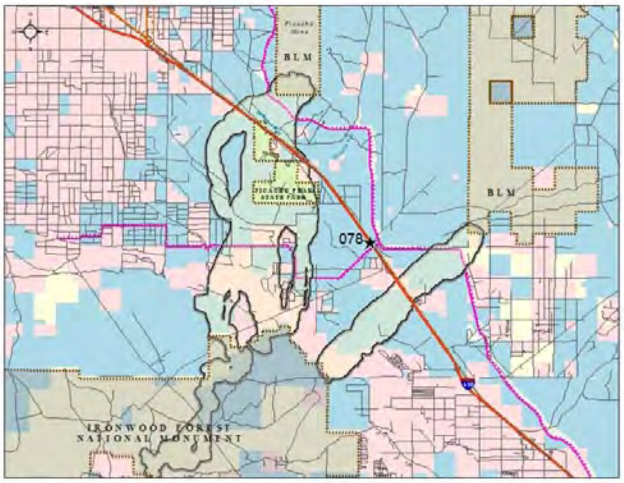
Waypoint Notes

Approx. 3 2x7 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	078		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.59167412	**Longitude:**	-111.337648
Observers:	Paul Beier, Dan Majka	**UTM X:**	468313.7476	**UTM Y:**	3606071.668
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



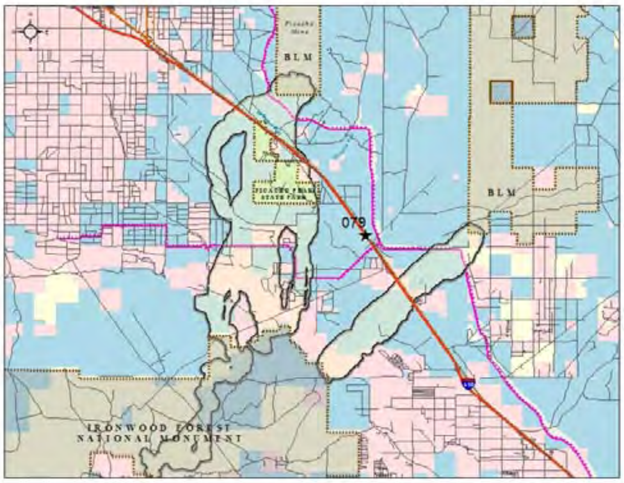
Waypoint Notes

Approx. 4 3x8 ft.. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	079		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.59643546	**Longitude:**	-111.341695
Observers:	Paul Beier, Dan Majka	**UTM X:**	467935.636	**UTM Y:**	3606600.694
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

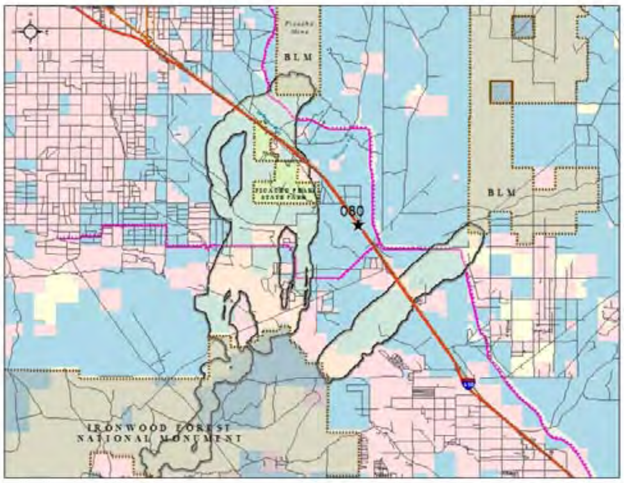
Approx. 3 4x10 ft.. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	080		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.6035372	**Longitude:**	-111.347646
Observers:	Paul Beier, Dan Majka	**UTM X:**	467379.7716	**UTM Y:**	3607389.759
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



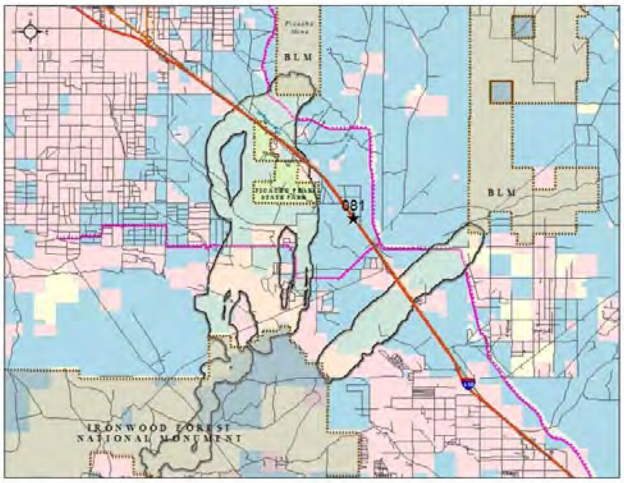
Waypoint Notes

Approx. 4 4x8 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	081		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.60773745	**Longitude:**	-111.351180
Observers:	Paul Beier, Dan Majka	**UTM X:**	467049.7095	**UTM Y:**	3607856.463
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



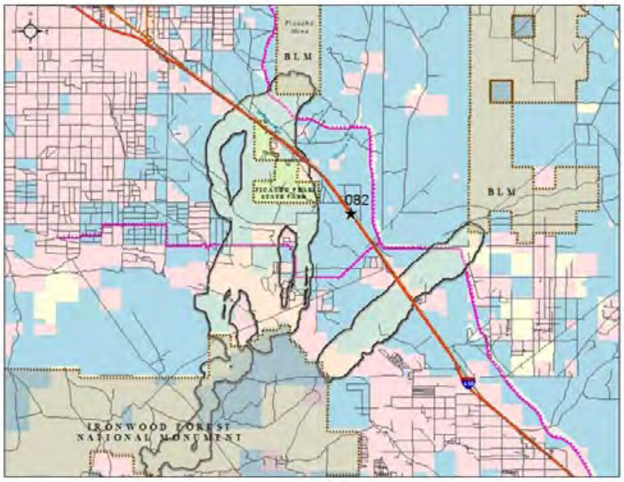
Waypoint Notes

Approx. 5 3x10 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	082		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.61061429	**Longitude:**	-111.353579
Observers:	Paul Beier, Dan Majka	**UTM X:**	466825.7336	**UTM Y:**	3608176.118
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



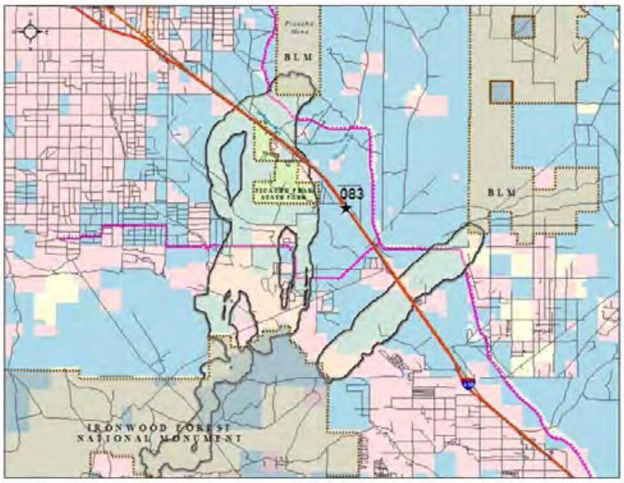
Waypoint Notes

Approx. 3 3x10 ft. culverts. Along east side of road, a ditch was being constructed. State land seems leased for agriculture. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	083		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.61510397	**Longitude:**	-111.357350
Observers:	Paul Beier, Dan Majka	**UTM X:**	466473.5681	**UTM Y:**	3608675.001
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



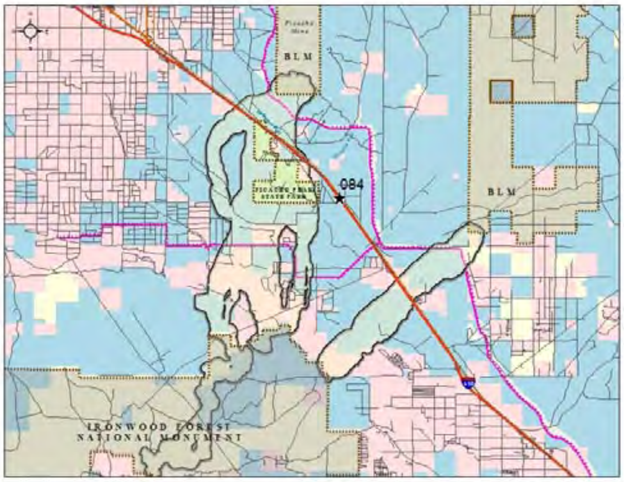
Waypoint Notes

Approx. 4 3x8 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	084		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.62094264	**Longitude:**	-111.362241
Observers:	Paul Beier, Dan Majka	**UTM X:**	466016.9457	**UTM Y:**	3609323.795
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



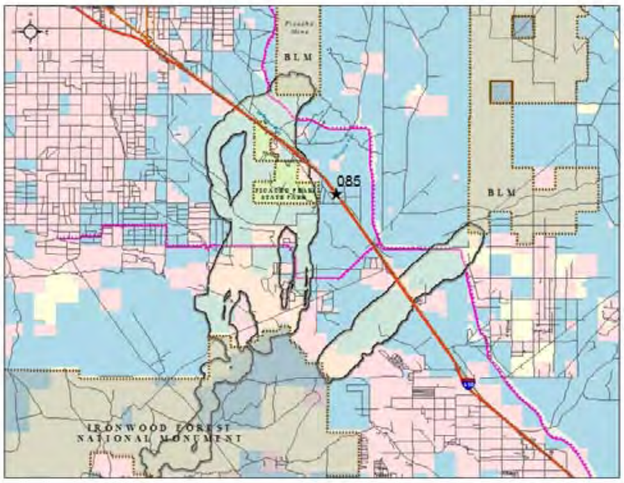
Waypoint Notes

Approx. 3 3x10 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	085		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.62402014	**Longitude:**	-111.364827
Observers:	Paul Beier, Dan Majka	**UTM X:**	465775.5156	**UTM Y:**	3609665.779
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



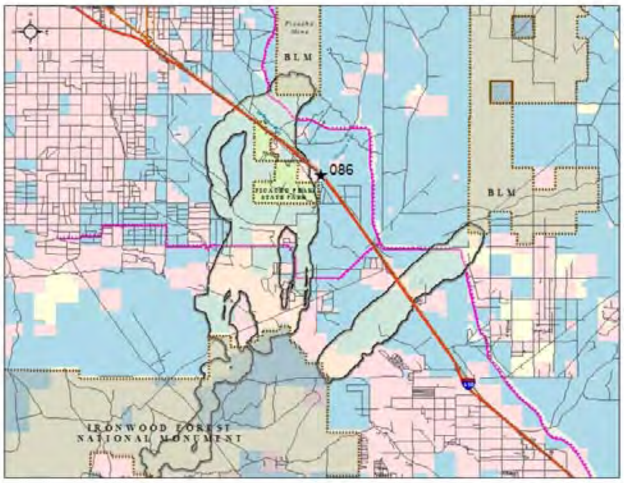
Waypoint Notes

Approx. 3 3x8 ft. culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	086		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.63665468	**Longitude:**	-111.376998
Observers:	Paul Beier, Dan Majka	**UTM X:**	464638.6314	**UTM Y:**	3611070.361
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Waypoint across from homes for sale.

Site Photographs

Name: DSCF0019.jpg

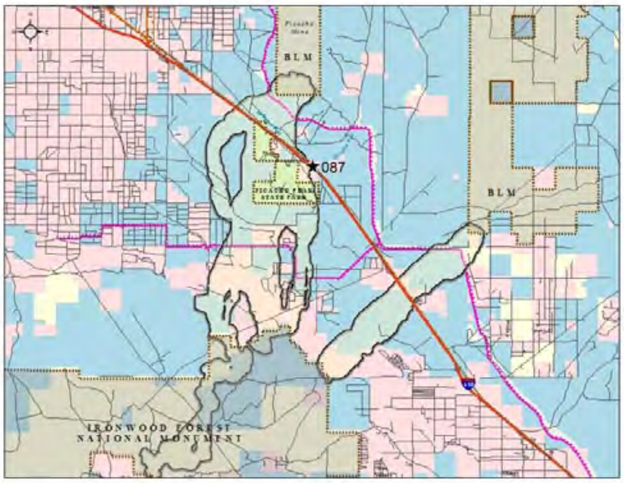
Azimuth: 46 **Zoom:** 1x

Notes: Railroad crossing over wash - pipes in stone fill.

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	087		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.64246896	**Longitude:**	-111.383446
Observers:	Paul Beier, Dan Majka	**UTM X:**	464036.1559	**UTM Y:**	3611717.066
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



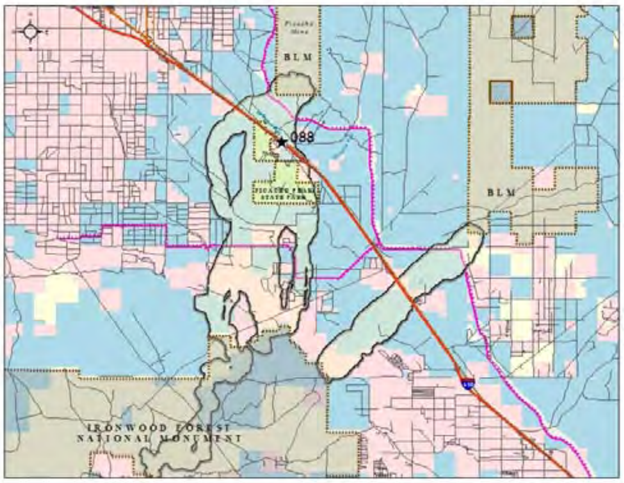
Waypoint Notes

Culvert under I-10. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	088		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.65901215	**Longitude:**	-111.407996
Observers:	Paul Beier, Dan Majka	**UTM X:**	461740.6691	**UTM Y:**	3613559.541
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Culvert under I-10.

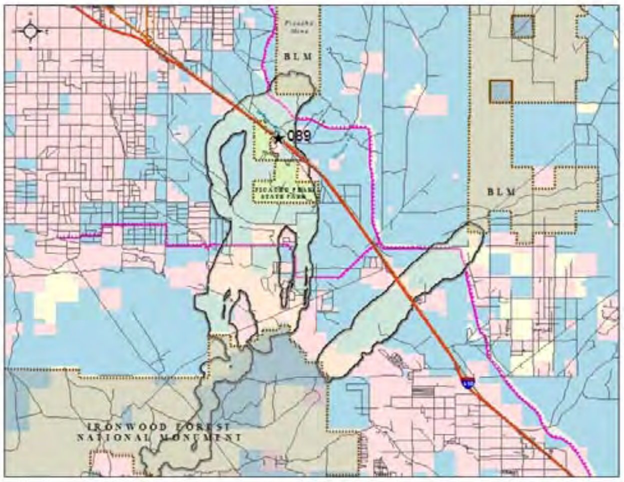
Site Photographs

Azimuth: 220 **Zoom:** 3x

Notes: Photo taken from E. Frontage Rd. near Picacho Peak.

Linkage #:	79	**Waypoint #:**	089		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.66080605	**Longitude:**	-111.410457
Observers:	Paul Beier, Dan Majka	**UTM X:**	461510.5941	**UTM Y:**	3613759.294
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Twin box culvert under I-10. Each culvert approx. 4x6 ft.

Site Photographs

Name: DSCF0022.jpg

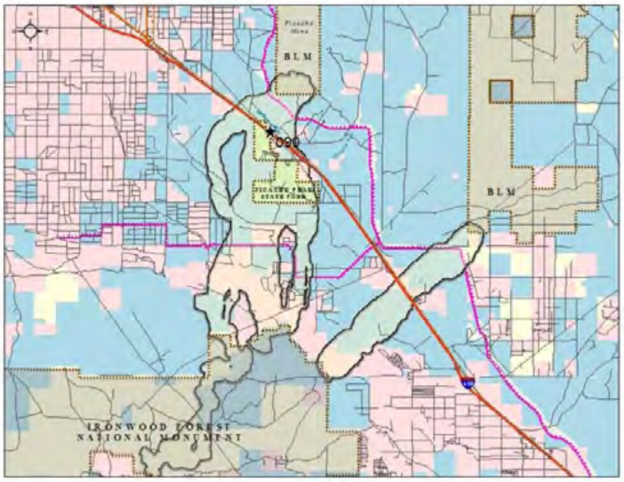
Azimuth: 220 **Zoom:** 1x

Notes: Photo taken from E. Frontage Rd. along I-10.

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	090		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.66521485	**Longitude:**	-111.417415
Observers:	Paul Beier, Dan Majka	**UTM X:**	460860.1178	**UTM Y:**	3614250.576
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Site Photographs

Name: DSCF0023.jpg

Azimuth: 240 **Zoom:** 1x

Notes: Choked box culvert

Name: DSCF0024.jpg

Azimuth: 176 **Zoom:** 1x

Notes: Picacho Peak

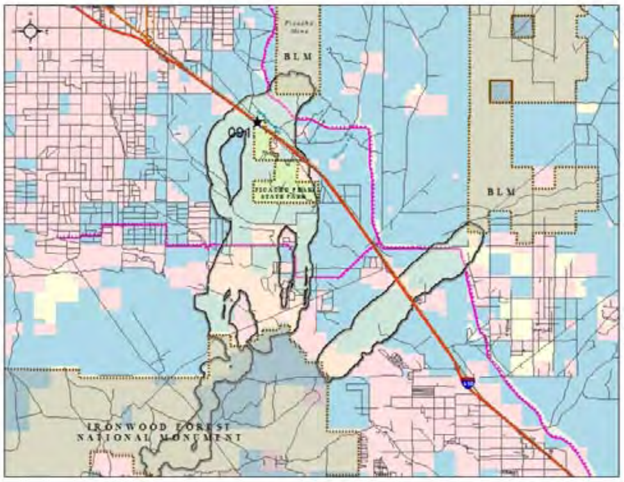
Name: DSCF0025.jpg

Azimuth: 2 **Zoom:** 1x

Notes: Picacho Mountains

Linkage #:	79	**Waypoint #:**	091		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.67161518	**Longitude:**	-111.427584
Observers:	Paul Beier, Dan Majka	**UTM X:**	459909.4087	**UTM Y:**	3614963.884
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from E. Frontage Rd. off I-10.

Site Photographs

Name: DSCF0026.jpg

Azimuth: 220 **Zoom:** 1x

Notes: Twin box culvert, each approx. 4x5 ft.

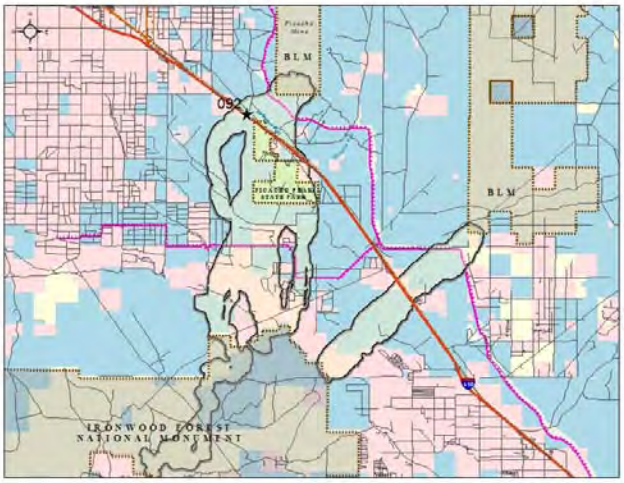
Name: DSCF0027.jpg

Azimuth: 22 **Zoom:** 3x

Notes: Picacho Mtn.

Linkage #:	79	**Waypoint #:**	092		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.67706736	**Longitude:**	-111.436165
Observers:	Paul Beier, Dan Majka	**UTM X:**	459107.3667	**UTM Y:**	3615571.562
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Site Photographs

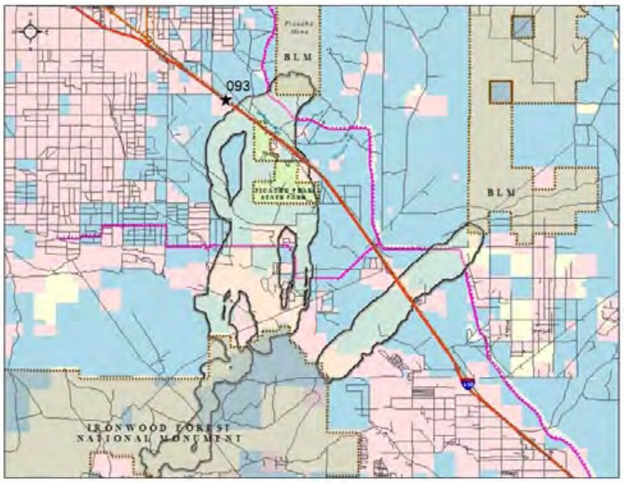
Name: DSCF0028.jpg

Azimuth: 228 **Zoom:** 1x

Notes: Single 4x8 ft. box culvert , filled with tumbleweeds

Linkage #:	79	**Waypoint #:**	093		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.68720184	**Longitude:**	-111.452575
Observers:	Paul Beier, Dan Majka	**UTM X:**	457573.5935	**UTM Y:**	3616701.472
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



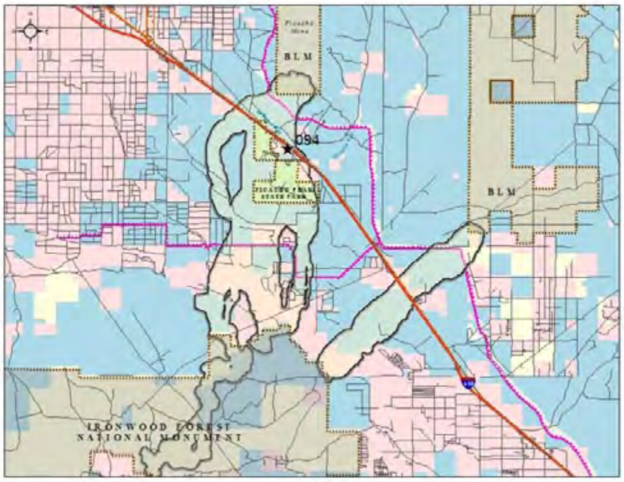
Waypoint Notes

Single 4x4 ft. box culvert, choked with weeds. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	094		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.653923	**Longitude:**	-111.403412
Observers:	Paul Beier, Dan Majka	**UTM X:**	462168.3383	**UTM Y:**	3612993.74
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



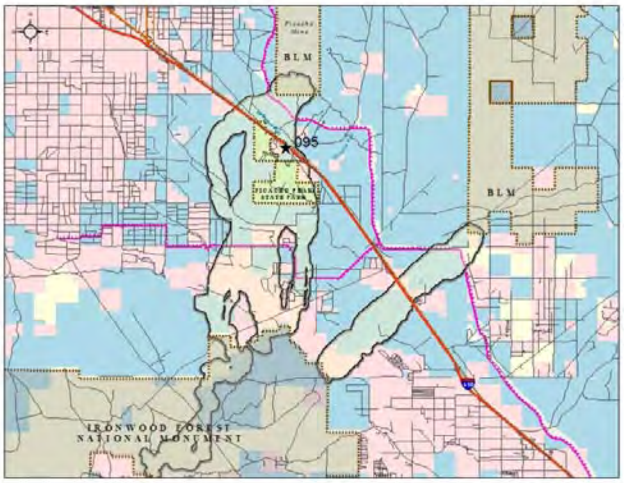
Waypoint Notes

2 6x6 ft. box culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	095		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.65488071	**Longitude:**	-111.404586
Observers:	Paul Beier, Dan Majka	**UTM X:**	462058.6800	**UTM Y:**	3613100.326
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

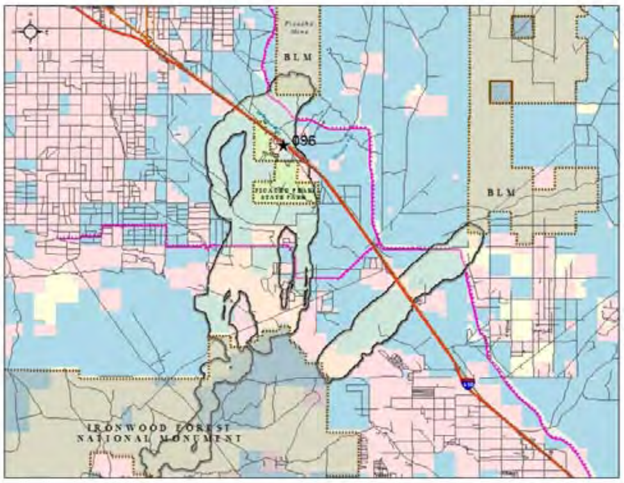
2 4x6 ft. box culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	096		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.6565343	**Longitude:**	-111.406609
Observers:	Paul Beier, Dan Majka	**UTM X:**	461869.6778	**UTM Y:**	3613284.359
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



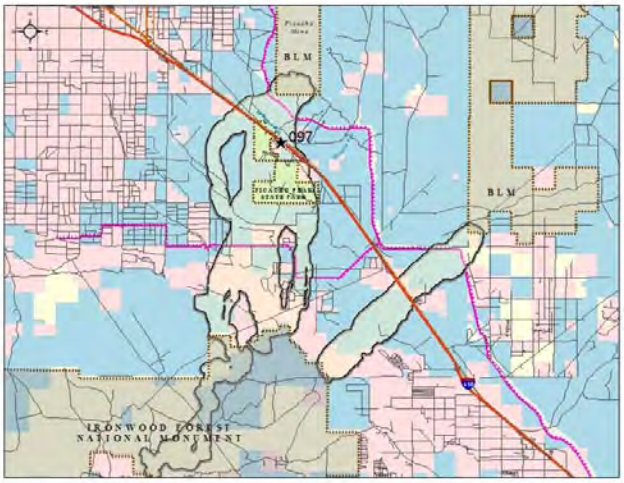
Waypoint Notes

2 4x6 ft. box culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	79	**Waypoint #:**	097		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.65842492	**Longitude:**	-111.409028
Observers:	Paul Beier, Dan Majka	**UTM X:**	461643.629	**UTM Y:**	3613494.816
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Private property - posted as 'Mors-Sipes' property.

Site Photographs

Name: DSCF0029.jpg

Azimuth: 250

Name: DSCF0030.jpg

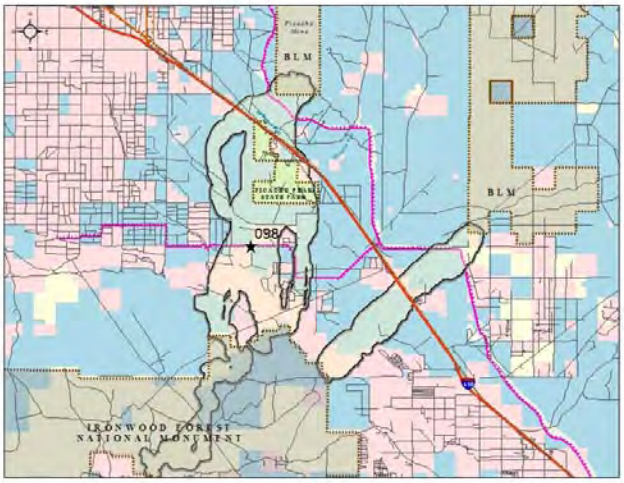
Azimuth: 152? **Zoom:** 1x

Appendix G: Database of Field Investigations

Linkage #: 79
Linkage Zone: Ironwood - Picacho - BLM
Observers: Paul Beier, Dan Majka
Field Study Date: 1/7/2006

Waypoint #: 098
Latitude: 32.58853476 **Longitude:** -111.431980
UTM X: 459459.7618 **UTM Y:** 3605755.684
Last Printed: 9/21/2006

Waypoint Map



Waypoint Notes

Canal is impermeable. This road/crossing/lock is about 30m wide. Canal very important to linkage design. Photos taken from junction of Bauganten (sp?) Rd. and canal.

Site Photographs

Name: DSCF0031.jpg

Azimuth: 2 **Zoom:** 1x
Notes: Picacho Peak

Name: DSCF0032.jpg

Azimuth: 96 **Zoom:** 1x
Notes: Canal

Name: DSCF0033.jpg

Azimuth: 194 **Zoom:** 1x
Notes: Ragged Peak / Silverbells

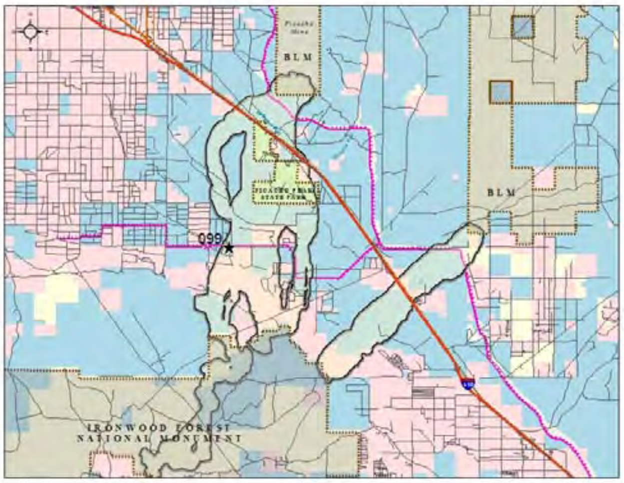
Name: DSCF0034.jpg

Azimuth: 268 **Zoom:** 1x
Notes: Canal - Road crossing over it in foreground

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	099		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.5882238	**Longitude:**	-111.449601
Observers:	Paul Beier, Dan Majka	**UTM X:**	457805.9302	**UTM Y:**	3605728.065
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

This is probably the next canal crossing/road.

Site Photographs

Name: DSCF0035.jpg

Azimuth: 200 **Zoom:** 1x

Notes: Legume crop & Silverbells

Name: DSCF0036.jpg

Azimuth: 286 **Zoom:** 1x

Notes: 50m wide canal crossing road

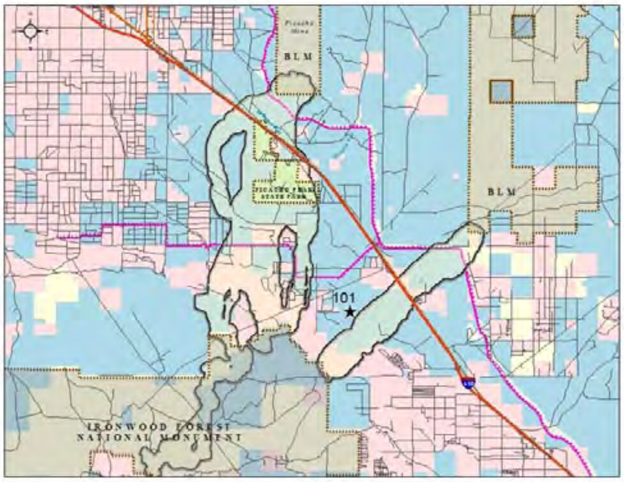
Name: DSCF0037.jpg

Azimuth: 158 **Zoom:** 1x

Notes: South-southeast view - Ironwood NM.

Linkage #:	79	**Waypoint #:**	101		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.5448943	**Longitude:**	-111.353867
Observers:	Paul Beier, Dan Majka	**UTM X:**	466774.508	**UTM Y:**	3600890.917
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from edge of agriculture fields.

Site Photographs

Name: DSCF0038.jpg

Azimuth: 130 **Zoom:** 1x

Notes: Linkage area - agriculture fields.

Name: DSCF0039.jpg

Azimuth: 176 **Zoom:** 1x

Notes: Linkage area - agriculture fields.

Name: DSCF0040.jpg

Azimuth: 220 **Zoom:** 1x

Notes: Linkage area - agriculture fields.

Name: DSCF0041.jpg

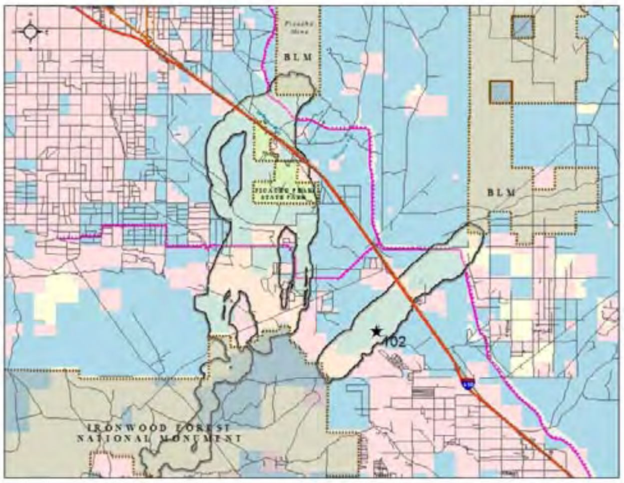
Azimuth: 320 **Zoom:** 1x

Notes: Picacho peak and natural vegetation outside of linkage area.

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	102		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.5321834	**Longitude:**	-111.332497
Observers:	Paul Beier, Dan Majka	**UTM X:**	468776.5434	**UTM Y:**	3599475.414
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from tiny hill in ATV area, near Pinal Airpark. Approx. a dozen individuals were riding ATVs (4-wheelers, dirtbikes, etc.) in the area adjacent to the Pinal Airpark. This does not appear to be an official establishment, as the area they were using is State Trust land. One individual we talked to said it's not officially established - all ATV'ers just drive in from an access road. The land used by ATVs seemed pretty torn up.

Site Photographs

Name: DSCF0042.jpg

Azimuth: 184 **Zoom:** 1x

Notes: Pinal airpark, ATVs in foreground

Name: DSCF0043.jpg

Azimuth: 122 **Zoom:** 1x

Notes: ATV use has caused damage to landscape

Name: DSCF0044.jpg

Azimuth: 50 **Zoom:** 1x

Notes: Powerplant on I-10 is visible in background

Name: DSCF0045.jpg

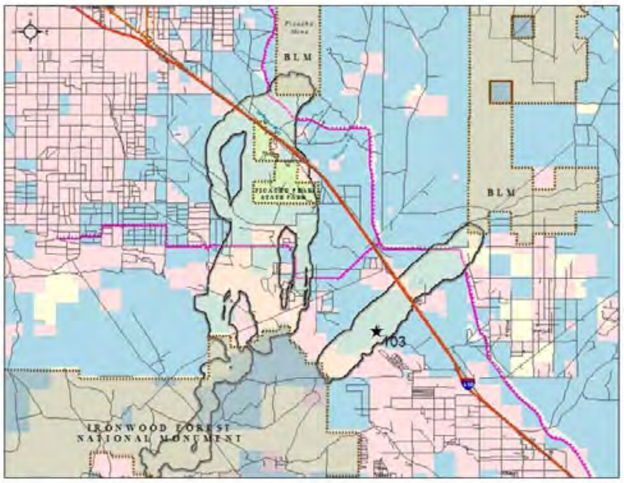
Azimuth: 240 **Zoom:** 1x

Notes: Southern target of linkage - Ragged Peak

Appendix G: Database of Field Investigations

Linkage #:	79	**Waypoint #:**	103		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.53220745	**Longitude:**	-111.332507
Observers:	Paul Beier, Dan Majka	**UTM X:**	468775.5995	**UTM Y:**	3599478.083
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Same location as waypoint 102.

Site Photographs

Name: DSCF0046.jpg

Azimuth: 32 **Zoom:** 1x

Notes: Facing northern target of linkage - BLM land.

Name: DSCF0047.jpg

Azimuth: 32 **Zoom:** 6x

Notes: Facing northern target of linkage - BLM land.

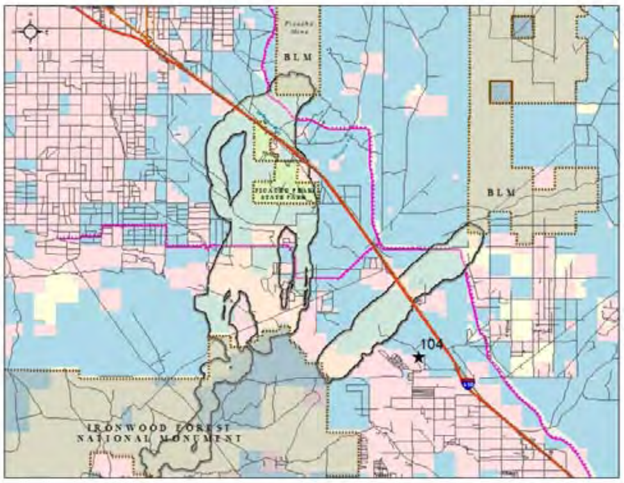
Name: DSCF0048.jpg

Azimuth: 178 **Zoom:** 3x

Notes: Pinal Airpark.

Linkage #:	79	**Waypoint #:**	104		
Linkage Zone:	Ironwood - Picacho - BLM	**Latitude:**	32.51490234	**Longitude:**	-111.298703
Observers:	Paul Beier, Dan Majka	**UTM X:**	471944.6511	**UTM Y:**	3597550.368
Field Study Date:	1/7/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Creosotebush vegetation association.

Site Photographs