State of the Las Cienegas National Conservation Area.

Part 3. Condition and Trend of Riparian Target Species, Vegetation and Channel Geomorphology

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Executive summary

Las Cienegas National Conservation Area (LCNCA) supports five of the rarest habitat types in the American Southwest: cottonwood-willow riparian forest, cienega marshland, sacaton floodplain, mesquite bosque, and semidesert grassland; is home to 6 endangered species; and has 2 eligible wild and scenic river segments. In response to its exceptional biological, cultural, and scenic values, the Bureau of Land Management (BLM) has committed to implementing a science-based adaptive management program at Las Cienegas.

To this end, the Las Cienegas Resource Management Plan (RMP) sets out numerous clear, measurable management objectives; however, when the RMP was finalized in 2003, it was unclear whether the existing monitoring program could adequately measure progress towards objectives. BLM entered into a cooperative agreement with The Nature Conservancy in 2004 to evaluate the current condition of resources on LCNCA and to review existing monitoring protocols with respect to management objectives. Results are being summarized in a comprehensive "State of the NCA" report, with sections produced during each phase of this project. The first phase addressed adaptive management needs of the upland watershed (see reports on grassland status and trends and on the Biological Planning process, http://www.azconservation.org). This review of riparian habitats and species is part of the project's second phase focused on stream systems. The second phase also generated a recent report on the endangered Gila topminnow and will soon include a status report on aquatic habitats.

Las Cienegas NCA's riparian habitats support at least two endangered and three other species of concern on this site (Huachuca water umbel, Southwestern willow flycatcher, Western red bat, Western yellow-billed cuckoo and Gray hawk). Half of the 38 reptiles and amphibians documented within the NCA and a large proportion of the area's 60 mammals and 230 bird species also depend on the NCA's streamside forest.

BLM has implemented three major management actions since 1989: fencing the creek from livestock, closing wet road crossings, and returning natural flow to 2 miles of natural streambed by removing dikes and canals. Ecological monitoring shows that these restoration efforts have been quite successful. The percent of creek miles in Proper Functioning Condition increased from 2% in 1993 to 61% in 2000. Non-functioning miles decreased from 5% to 0. Riparian photopoints and aerial photos show a dramatic expansion of riparian cottonwood-willow forest since 1989. Tree belt transects sampled in 1993 and again in 2006 show increases in riparian tree densities along with shifts in age structure and species composition. Channel cross-sections measured in 1993 and repeated in 2006 showed stability in several sensitive areas and aggradation in the upper reach, raising the channel surface some three feet towards its original floodplain.

Cienega Creek still faces several threats including loss of both surface water and shallow groundwater, invasive species, channel erosion, and destabilized streambanks. We present a state and transition model that integrates knowledge about riparian ecology from agency management and research sources. This model offers a framework to link BLM objectives and management actions with the forces that drive ecosystem change, degradation, and recovery. The model illustrates how a stressor such as groundwater depletion affects many aspects of the system, from tree recruitment to channel

morphology to habitat suitability for endangered species. Uncertainties in how particular changes affect these habitats also show up in the model. We don't fully understand, for example, what is driving growth of wooded swamps in the upper reach or shifts in tree species throughout the creek.

The model sheds light on past and future BLM management decisions. Fencing the creek from livestock successfully moved large areas of the creek from the cottonwood-seepwillow strand state to cottonwood-willow gallery forest. Adding other disturbances (e.g. beaver, fire) back into the system may succeed in turning the wooded swamp areas into herbaceous cienega with open, well-oxygenated pools. However, model uncertainties highlight the need to use adaptive management in this situation, since either disturbance could have unintended consequences such as reducing densities of large cottonwoods or enhancing habitats for bullfrogs or other exotic species.

BLM's monitoring protocols work well for some objectives such as riparian forest regeneration; tree transects proved to be efficient, repeatable, and adequate for documenting changes. Other BLM objectives had no monitoring in place. We present protocols for tracking changes in herbaceous vegetation that will show how well BLM is meeting its streambank and understory objectives.

Some aspects of riparian monitoring will benefit from minor changes. Measuring riparian forest expansion, for example, can be done with low-tech spatial analysis of remote images that BLM already has or could easily acquire. Hand-drawing riparian forest polygons on aerial photos or DOQQs with one meter resolution will probably be less expensive and more accurate than using elaborate automated spectral classification on these or other images. An extensive geomorphology study done by Arizona Department of Environmental Quality in 2001 will enable us to choose additional cross section points in order to track changes at headcuts and other sensitive spots.

Currently, monitoring locations for riparian vegetation, native fish, aquatic habitat, and floodplain geomorphology and associated photopoints are distributed up and down Cienega Creek. We propose consolidating many of these measurements into a single set of locations while maintaining the ability to compare past and future data. Co-locating measurements will reduce travel time, increase staff's ability to use volunteer teams to conduct measurements, and enhance the integration and interpretation of monitoring results (e.g. floodplain cross-section monitoring can be used to understand changes in riparian vegetation and native fish populations).

Sacaton bottoms and mesquite bosques need additional attention, beginning with updating maps. Sacaton flats are key resources for the NCA's wildlife, streamflow, and grazing program but are vulnerable to rapid erosion and dewatering. A status and trends assessment focused specifically on floodplain grass stands would enable managers to mitigate impacts and prioritize restoration work. Up-to-date condition maps would also enable fire planners to address mesquite incursions into some stands, as a transition to bosque or as shrub encroachment. Identifying riparian mesquite bosques would enable upland mechanical shrub control projects to avoid inadvertently removing or fragmenting these groundwater-dependent stands and would benefit fire planning. Documenting mesquite and sacaton stands that tap into riparian groundwater would also be important for understanding the creek's water budget.

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Introduction

The site

Las Cienegas National Conservation Area (LCNCA) encompasses some 42,000 acres of Bureau of Land Management (BLM) public lands with inholdings of 5,225 acres of Arizona State Trust lands and 82 acres of private land. The surrounding Sonoita Valley Acquisition Planning District encompasses an additional 95,609 acres that are a mix of BLM, Arizona State Trust, and private lands. The LCNCA supports five of the rarest community types in the American Southwest: cienegas, cottonwood-willow riparian forest, sacaton grasslands, mesquite bosques, and semidesert grasslands. It is also home to 6 federally listed species, 26 other special status species, is on the National Register of Historic Places, and has two proposed wild and scenic river segments. It includes both core protected habitat and key movement linkages for many species of wildlife (Beir, Majka, and Bayless 2006).

Its exceptional biological, cultural, and scenic values make the protection of this unique resource a local, regional, and national priority for the BLM as well as for other organizations and public agencies. Pima County has identified LCNCA as a priority area in its Sonoran Desert Conservation Plan (SDCP) due to its native fish populations including the endangered Gila topminnow (Fromer 2002) and because of its extensive cottonwood-willow habitat (Pima County 2001). The National Park Service (NPS) and the Sonoran Institute have singled out LCNCA as an ideal proof of concept project for their Sonoran Desert Network Inventory and Monitoring Program. At the local level, the Sonoita Valley Planning Partnership (SVPP), a voluntary association of federal, state, and local agencies, organizations and private citizens who share a common interest in the resources and management of public lands within the Sonoita Valley, was instrumental in the designation of this landscape as a National Conservation Area. Las Cienegas NCA also forms the northern anchor of an 800,000-acre conservation area identified in The Nature Conservancy's (TNC) Apache Highlands ecoregional assessment of conservation priorities (Marshall et al. 2004). In an analysis of 600 TNC conservation areas identified in the five ecoregions overlapping Arizona, the conservation area that includes LCNCA ranked highest in terms of biological uniqueness and irreplaceability.

Report goals

Given the overwhelming interest in the protection and management of LCNCA's significant ecological and public values, BLM saw the need to evaluate the current status and condition of resources. In addition, the adaptive management strategy prescribed in the Las Cienegas Resource Management Plan (RMP) necessitated a review of monitoring protocols to examine their ability to detect changes and trends in resource conditions and to inform BLM and stakeholders whether management prescriptions were meeting objectives. To this end BLM entered into a cooperative agreement with TNC to compile and synthesize all pertinent available information for the three major ecological systems identified in the RMP: upland watershed (semidesert grassland and savanna), riparian (cienega wetland, riparian forest) and aquatic and to conduct a review of the current monitoring program. The result of the compilation and synthesis is the multi-part *State of the LCNCA* report, of which this is the third part.

We take a systematic approach to each major habitat type. First, we analyze, summarize and interpret all relevant inventory, monitoring and research data to determine current condition and trend of each habitat and whether RMP goals and objectives are being met. Second, we determine the status and trend of potential stressors and sources of stress for each of the habitats using available data. Third, we construct state-and-transition models for these habitats. Thresholds in composition, structure and condition between model states are defined and natural disturbances and management actions that move the system from one state to another are identified. Fourth, we focus on target species for each of the habitats, analyzing available monitoring and research data to determine status and trend of populations both on the LCNCA and in southeastern Arizona. Finally, we conduct a quantitative review of existing BLM monitoring protocols, testing them against alternative protocols based on 3 criteria: how well they address and inform management goals and objectives; their statistical power to detect change; and their implementation costs (e.g, data collection, analysis, and presentation).

This report section focuses on riparian vegetation and geomorphology in the Cienega basin portion of Las Cienegas NCA. Upland habitats have been addressed by Gori and Schussman (2005) and Simms et al. (2006). As a key component of the aquatic system, the endangered Gila topminnow (*Poecilopsis occidentalis occidentalis*) was reviewed by Bodner et al. (2007). Analysis of additional aquatic components is in progress. Shallow groundwater, which is key to sustaining these riparian and aquatic systems and is in turn supported by healthy upland systems, has not yet been addressed in this report series. BLM and The Nature Conservancy have been working together to compile groundwater resource data and to design components of a groundwater monitoring system but this work is not yet complete. The current report will point out water information needs but providing means to fill these needs is outside its scope. BLM-managed lands of the Audubon Appleton-Whittell Research Ranch are also part of the NCA. They are separated, however, by administrative responsibility, five miles of private land, and by the watershed divide that splits the Cienega/Santa Cruz Watershed from the Babocomari/San Pedro watershed. We discuss information from the Research Ranch that informs our understanding of the NCA as a whole but do not attempt to review the large amounts of research and monitoring conducted at the site.

The State of the Riparian System

Introduction

Ecological setting

Southern Arizona's ~600 square-mile Cienega watershed is demarcated by a ring of mountains including the Santa Rita, Whetstone, Empire, Mustang, and Rincon Mountains and Canello Hills. This basin is divided into two hydrological sub-basins by an Empire Mountains bedrock feature called The Narrows (Simpson 1983; Ellet 1994). Las Cienegas NCA fills much of the valley floor of the upper (southern) sub-basin. The lower (northern) sub-basin's riparian habitat and perennial streamflow is in Pima County's Cienega Creek Natural Preserve and is outside the scope of this report.

Groundwater recharge and (to a lesser extent) rainwater runoff from this ring of mountains supports the valley-bottom stream system of Cienega Creek. Wet riparian habitats begin just northeast of the town of Sonoita along Upper Cienega Creek where groundwater comes to the surface and along Gardner Creek. A series of perennial and intermittent stream reaches run north to The Narrows where the stream becomes ephemeral, leaves the NCA and enters the lower sub-basin. Perennial flow begins again as Lower Cienega Creek several miles downstream on Pima County's Cienega Creek Preserve. Two spring-fed tributaries—Empire Gulch and Mattie Creek—add surface flow to Cienega Creek in the NCA. This system also includes several other springs and off-channel wetlands that contribute subsurface and/or surface flow.

Cienega Creek experienced downcutting during the same late 1800-early 1900 period in which most rivers and streams in the Southwest incised. The valley's thick vegetation may have delayed incision somewhat (Eddy et al. 1983). Downcutting separated the stream from its historic floodplain in much of the NCA, but the downcut channel has been widening and the stream has re-established a narrower floodplain within the cutbanks. Steep cutbanks now range from approximately one to five meters high, and are typically between 20 and 100 meters apart. Some areas have extensive floodplains not bounded by cutbanks, especially near the confluences of large tributaries.

Apart from historic downcutting and some upland watershed changes, Cienega Creek has escaped most of the man-made hydrologic alterations that have impacted other Southwestern riparian systems. The stream has not been channelized, nor are flows regulated or diverted until the far downstream end of the lower basin where remaining surface water is captured (Pima County 1994). A floodwater diversion canal and three pond dikes had been built near the NCA's old agricultural fields in the 1970's, but these structures were removed in 1998 (BLM 1999). Groundwater pumping has the potential to dewater this stream (Boggs 1980; Knight 1996; USFWS 2002), but it is not yet clear how much groundwater could be withdrawn (and from what locations) without reducing streamflow. The proposed Rosemont Mine in the Santa Rita Mountains could carve a hole deep enough to divert mountain front recharge from Empire Gulch and/or Cienega Creek on the NCA (Myers 2007).

Riparian community types

On the NCA, Cienega Creek and its major tributaries support some 20 linear miles of riparian forest and marshland, flanked in some areas by sacaton floodplain grasslands and/or mesquite bosques. NCA drainages support many more miles of xeroriparian shrub communities.

Cottonwood-willow forest

Cottonwood-willow gallery is the archetypal riparian forest community of the Southwest and the focus of most riparian monitoring and research in the region, including many studies along the San Pedro River some 30 miles east (e.g. Stromberg 1998, Lite and Stromberg 2005, Leenhouts et al 2005, Scott et al. 2008).

The LCNCA hosts the largest area of contiguous cottonwood-willow forest in Pima County, estimated at 720 acres in 2000 (Pima County 2001). Most of this forest is Fremont cottonwood and Goodding willow growing along the main creek channel. Gardner Canyon, Empire Gulch, and Mattie Canyon also support stands of cottonwood-willow forest. Yew willows (*Salix taxifolia*) also occur along Empire Gulch. More LCNCA monitoring work has focused on cottonwood-willow forest than on any other riparian plant community. This community therefore dominates the following discussions.

Cienega marsh

Cienega marshlands were once common along shallow-gradient streams of Southern Arizona and Southern New Mexico's semidesert grassland valleys (hydrology, ecology and locations reviewed by Hendrickson and Minckley 1984, Stromberg 1993d). Cienegas are typically dominated by herbaceous vegetation but riparian trees often grow around the edges and Goodding willows can grow into the interior (see floras in Fernald 1987, Cross 1991, Hendrickson and Minckley 1984). These spongy, well-vegetated, groundwater-fed wetlands accumulate deep layers of silts and organic peats. Soil profiles and pollen records show that these formations can be repeatedly drained and reformed by cycles of erosive downcutting and channel stabilization (Hendrickson and Minckley 1984). Davis et al. (2001) found charcoal evidence that all six cienegas he studied burned frequently before the onset of the historic period. Increases in pollen of willows, cottonwood, and other wetland plants often followed the historic decline in cienega fires.

Many miles of this marshy community historically grew along Cienega Creek (Hendrickson and Minckley). Deep peat deposits surrounding the Mattie Wash-Cienega Creek confluence show that cienegas covered even larger areas during wet periods of the Pleistocene (Eddy and Cooley 1983, Huckell 1995). Some cienega areas survived through or re-established after the channel downcutting of the 1890's. These remain of great concern for the NCA. Marshy areas along Cienega Creek proper are represented in channel morphology measurements (see below) This report also discusses protocols for monitoring herbaceous cienega vegetation. Additional monitoring of these sites during aquatic habitat inventories is presented elsewhere (BLM 2002). Off-channel lentic cienegas also occur on the NCA but are not addressed here.

Mesquite bosque

Mesquite bosques are a woodland or forest community typically found along drainages and on floodplain terraces of the Southwest (Brown 1982, Stromberg 1993, Reichenbacher 1994). Mesquites (*Prosopis velutina* in this region) can grow under a wide range of conditions. It is therefore important to distinguish between riparian/xeroriparian mesquite bosques—which are considered ecologically important and imperiled habitats—and upland mesquite shrublands that are replacing native grasslands. Bosques by definition are tied to shallow groundwater. They can also be recognized by proxy features such as tall tree stature, relatively closed canopies, and/or species composition of a shrub stratum under the mesquite tree canopy (Stromberg et al. 1993). Water table depths of 15 m have been considered a threshold between upland mesquite shrub communities and riparian/xeroriparian bosque communities, though most stands that have been identified as bosques have groundwater depths < 6 m (summarized in Stromberg 1993). Groundwater declines in established riparian stands can stress trees and reduce vegetation volume (documented at declines to 15-18 m depths), kill tree branches (18 m-30 m depths), or kill whole stands (>30 m; Stromberg et al. 1992). Depth thresholds for damage presumably vary with soil type, temperatures, and other factors. The natural role of fire in bosques is unclear (see below).

The RMP identifies mesquite bosque as one of the most ecologically valuable habitats on the NCA. Ecological site inventories on the NCA identified 581 acres of mesquite bosque along the NCA's Cienega Creek and Gardner Canyon (BLM 2002). Other vegetation mapping efforts have identified different quantities and placement of bosques (see Appendix D). Apart from these preliminary mappings and a recognition that woodcutting and stump removal in one bosque stand led to severe erosion problems around Wood Canyon (BLM 2002), mesquite bosques at Las Cienegas have received relatively little attention. We therefore do not have enough site-specific data to discuss status or trends in detail.

Sacaton grassland bottoms

Like mesquite, giant sacaton (*Sporobolis wrightii* or *S. airoides wrightii*) can grow under a wide range of conditions. Shrub and savannah associations have been described with many other plants including cottonwood and mesquite (Lacey 1975, Brown et al. 1979, USDI 1989, Robinett 2005). Extensive dense sacaton grasslands form mainly in shallow-gradient river floodplains, low terraces, or plains that pool rainwater (ecology summarized in Stromberg 1993c and Robinett 2005a). These sacaton grasslands with few woody plants are also called sacaton "bottoms" or "flats." *S. wrightii* plants appear to access groundwater only to depths of 3 to 3.5 m (Tiller 2004, Scott et al. 2006; Robinett 2005a proposes a 6 m threshold). Stands that rely solely on rainfall or flooding to replenish deep soil moisture may occur next to stands fed by groundwater. Plants are long-lived; stands that established in contact with groundwater or in pooling depressions can survive for many years after groundwater has declined below their reach or gullies have drained plains, but may not flourish or recruit under these degraded conditions. Soils tend to be fine, silty and/or loamy, and easily erodible. Degraded or converted sacaton flats release large amounts of sediment into streams, while intact stands are among the most effective vegetation types at trapping soil and slowing runoff.

Sacaton flats are prized on the NCA for their ecological, hydrological, and livestock forage values. Ecological site inventories identify 3,744 acres of sacaton flat on the Empire Ranch portion of the NCA (BLM 2002). Other mapping efforts differ in amounts and distributions (Appendix D). Sacaton flats are arguably better studied on the NCA than anywhere else. Much of the research on effects of grazing, fire, and mowing was conducted in Empire Gulch (Cox and Morton 1986, Cox 1988, Cox et al. 1989) and on the Audubon Appleton-Whittell Research Ranch (Bock and Bock 1978, 1988, Tiller 2004, Kennedy 1999, and others cited in Kennedy and Seltzer 2000). State and transition models (Robinette 2005) provide tentative ecological thresholds and guidance for preventing and correcting degradation. At least two BLM projects have attempted to restore sacaton stands in the Cienega basin, with one quite successful planting along a decommissioned road just south of the abandoned agricultural fields and another moderately successful planting in the Ag fields themselves. Two long-term key area monitoring plots are located in sacaton stands. These provide valuable information on the groundcover trends of their respective pastures (Gori and Schussman 2005, Bodner et al. 2006) but are not designed to capture broad-scale changes across the NCA's sacaton flats.

Riparian management objectives

The Las Cienegas Resource Management Plan (RMP; BLM 2003) spells out several objectives for riparian and off-channel wetland areas (Table 1). Objective #1 puts a quantitative target (100%) on the *Arizona Standards for Rangeland Health's* Standard 2: Riparian Wetland Health (USDI 1997). Objective #2 describes the riparian part of conditions that, when obtained, "will assure rangeland health, State water quality standards, and habitat for threatened, endangered, and sensitive species" (BLM 2003). This plan also includes more detailed ACEC Management Prescription Objectives (Table 2) and management actions. Although upland habitat management is designed to support healthy watershed function and aquatic goals depend on both upland and riparian health, specific objectives for upland and aquatic habitats are addressed elsewhere (BLM 2003; Gori and Schussman 2005).

Table 1. Riparian objectives for the LCNCA from the Resource Management Plan. Numbers correspond to the original RMP lists, with i – vi added for clarity.

Riparian Objectives:
1. Achieve & maintain Proper Functioning Condition (PFC) on 100% of riparian areas by 2005
2. Achieve & maintain Potential Natural Communities (PNC) on 95% of riparian areas by 2010
Potential Natural Community descriptions:
a. Cienegas (valley bottom streams) – Along Upper Cienega Creek, achieve and maintain a vegetation community with the following conditions: i. Ground cover and protective roots > 90% on upper and lower banks. ii. Marsh habitat >50% of the total aquatic habitat in key cienega riparian segments. iii. Vegetation community on lower banks dominated by rushes, sedges, deer grass, and willows (i.e., *Juncus, Scirpus, Eleocharis, Carex, Muhlenburgia, Salix*). iv. Upper banks and floodplain dominated by sacaton, yerba mansa, cottonwood, willow, and mesquite.
b. Cienegas (valley bottom ponds) – In the historic floodplain of Cienega Creek, achieve and maintain a vegetation community with the following conditions: i. Ground cover > 90% on banks. ii. Emergent vegetation covering 75% or more of the perimeter of the aquatic habitat. iii. Vegetation community on banks dominated by rushes, sedges, deer grass, and willows (i.e., *Juncus, Scirpus, Eleocharis, Carex, Muhlenburgia, Salix*). iv. Adjacent vegetation dominated[a] by sacaton, paspalum grass, and yerba mansa.
c. Deciduous Woody Riparian (riparian areas with perennial surface water) – Along Lower Cienega Creek (below Mattie Canyon), achieve and maintain the following: i. A tree community dominated by Goodding willow on lower banks or in aquatic habitat. ii. Trees on upper banks to include yew willow, Fremont cottonwood, velvet ash, and Arizona black walnut. iii. A good mix of all age classes of riparian trees. iv. Lower banks to be dominated by rushes, sedges, seedling riparian trees, and deer grass with bank cover exceeding 90%. v. Upper banks to be dominated by deer grass, sacaton grass, and riparian trees of sapling and adult age classes.
d. Deciduous Woody Riparian (riparian areas with free subsurface water) – i. Maintain a tree community composed of any of the following tree species according to the existing site's potential: Goodding willow, yew willow, Arizona black walnut, Fremont cottonwood, sycamore, seep willow, alder, box elder, and velvet ash. ii. Lower banks will be dominated by rushes, sedges, seedling riparian trees, and deer grass. iii. If tamarisk is present, it is only a minor component of the riparian tree community.

[a]: Dominated means that < 20% in aggregate of the plant community consists of other species (e.g., seep willow, Bermuda grass, knot grass, upland herbaceous annuals, or cattail).

Table 2. Empire-Cienega Area of Critical Environmental Concern (ACEC) Management Prescription goals and objectives directly related to riparian areas that are not spelled out in overall RMP objectives (BLM 2003). Numbers correspond to original RMP lists.

ACEC Goals:	
	Protect and enhance watershed, grassland, and threatened/endangered wildlife resources, emphasizing total ecosystem management. Reduce the safety hazard caused by areas of unstable soils and reduce the amount of sediment production from these areas.
ACEC management objectives:	
	2. Maintain adequate instream flows to support aquatic and riparian resources.
	3. Maintain water quality to support aquatic, riparian and fish and wildlife values.
	7. Educate the public regarding riparian and threatened/endangered wildlife issues and management needs.
	9. Increase stability in the soil piping and headcutting areas.
	11. Stabilize incised channel banks within these unstable soil areas.
	14. Prevent the introduction of and control non-native invasive species in the ACEC.

Major management actions

BLM and collaborators took on three major riparian management projects and several smaller actions beginning in 1990. First was fencing the creek from year-round livestock use. This was achieved with the help of the grazing permittee and with funds from the Arizona Department of Water Resources' Water Protection Fund. Fencing began in the northern part of the property, with 11 km of fence installed in 1990. Nineteen km of fence was built around the headwaters segment between 1994 and 1995. Throughout the creek, cattle now use six 50 m- to 250 m-long crossing lanes for short periods when moving between pastures. The far northern pastures (Rockhouse, Narrows, Triangle, and Apache) rely on approximately four km of the creek as a water source but are used only in winter when cold air in the drainage keeps cattle from staying in the riparian areas (see Figure 3 creek segments 59 C and B, parts of D and AA). The permittee and BLM developed upland livestock water sources to replace creek access in several pastures.

A restoration engineering project in 1997-8 returned stream flow to 2.5 miles of natural channel in the Ag Fields area (see Figure 3, creek segments 59I and 59H). This low-lying floodplain area had been a mix of sacaton flat and cienega in historic times, and was part of a shallow lake and cienega system that expanded and contracted over the past 3000 years (Eddy et al. 1983). Landowners in the 1970's cut a diversion canal just upstream of these fields to divert flood flows east away from crops planted on the flats, built a dike to separate the canal from the fields and to serve as a roadbed, and installed one concrete and two smaller dirt dikes in the main creek channel to hold water. BLM plugged the diversion canal, removed stream dikes, and installed rock grade-control structures at bed level where two of the dikes had been to protect against possible realignment of the channel in response to these changes. This work was also funded by the Arizona Water Protection Fund (BLM 1999).

Roads crossed Cienega Creek in eleven places in 1988. BLM closed seven of these, leaving just three road crossings in spots that are dry most of the year and installing a broad cement apron on the fourth to reduce vehicle impacts. Efforts to maintain closures prescribed in the RMP for redundant or resource impacting roads are ongoing. Recent work includes installing a pipe rail fence and locked gate across the administrative-use only road by Sanford canyon in 2006 and several attempts to close the road that exits the north end of the property. Cement, pipe, and boulder closures at this “Narrows road crossing” have been repeatedly breached, apparently by vehicles bypassing the Border Patrol checkpoint on Highway 83. Several winches have been found stashed in bushes in this reach, presumably to pull vehicles out of muddy creek spots. In 2006 we observed evidence of heavy machinery blading paths through the creek from the North. BLM is now preparing to line this northern set of illegal road crossings with cobbles to reduce impacts until the road can be closed successfully.

BLM recreation planning is designed to keep group activities out of the riparian area except in the vicinity of the Ag Fields and along a nature trail and picnic area at upper Empire Gulch.

In 2005-2006, BLM and volunteers constructed a series of rock and wire gabions along the creek just above the waterfall and USGS stream gage site between confluences of Sanford Canyon and Wood Canyon (downstream end of segment 59F, Figure 3). Wood Canyon runs nearly parallel to Cienega Creek for a half kilometer before it meets the creek below these bedrock falls. Erosion of the narrow spit between these channels has become a concern as the creek has cut through some of the bedrock ledges. If the creek were to cut through or shift course around this bedrock structure, Wood Canyon could “capture” and drain some 1.7 to 3.2 km of the creek’s water (plus wet segments of Mattie Canyon), since the tributary’s bed is some ten feet lower that Cienega Creek’s above the falls. Contact between these different bed elevations could propagate a headcut upstream on Cienega Creek to the next bedrock structure (downstream end of segment 59G, Figure 3) or possibly to the next man-made grade control (59H), as well as up Mattie Canyon. BLM is planning more work to stabilize the channels of Cienega Creek and Wood Canyon in this area.

Climate context

Climate information provides important context for viewing riparian changes. Site-specific data for Las Cienegas is relatively sparse until recent years, and is presented elsewhere (Gori and Schussman 2005; Bodner in prep). Streamflow, for example, has been measured sporadically at several LCNCA sites since 1975. The current gage was installed in 1995 and automated to provide hourly data in 2001; only the 2001-2006 data is currently available (USGS 2007). Here we present regional data to show dynamics of wet and dry cycles in the past century, as well as informing some recent changes. The Palmer Drought Severity Index (PDSI) is a soil moisture model that integrates temperatures and precipitation over time. This index has been reconstructed for southern Arizona from climate measurements that go back as far as 1895 (NCDC 2007) and from tree ring data that goes back to the year 1 BC (Cook et al. 1999, 2004). Within the historic period (Figure 2), the 1980’s and early 1990’s were wet periods in this region. Drought conditions kicked in after 1993 and have continued to the present. Note that some pre-historic droughts appear to heave been much more prolonged and severe than any seen so far during the historic period (Figure 3).

PDSI scores from May are taken to represent cumulative drought effects during arid streams' driest time each year (for streams without major snowmelt inputs). Streams are often drier in June immediately before the start of monsoon rains, but June averages sometimes include the season's first rains. Rolling averages smooth lines for visual clarity and reflect biologically-relevant cumulative effects. Bank storage from wet periods can be released over the next few years. We therefore use three-year rolling averages as an index of cumulative drought effects on streamflow. Perennial riparian vegetation can respond quickly to increases in streamflow but established plants may persist through drought years. We present a ten-year rolling average to reflect a time frame in which some established vegetation would respond to dry and wet cycles.

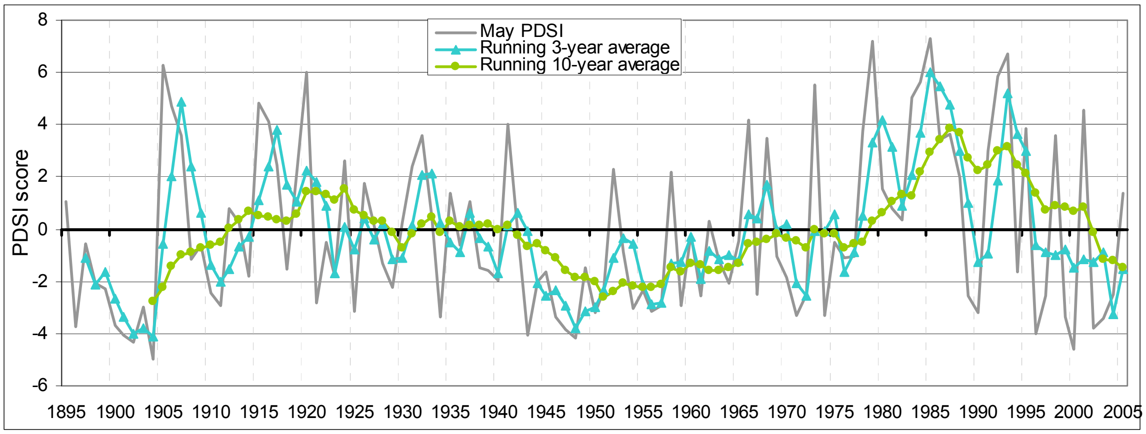

Figure 1. Historic record of drought conditions. Palmer Drought Severity Index for southern Arizona (Zone 7), May PDSI scores from 1895 to 2005, with three-year and ten-year rolling averages. The scale goes from extremely wet (6 and above) to extreme drought (-6), with 0 being "normal" conditions.

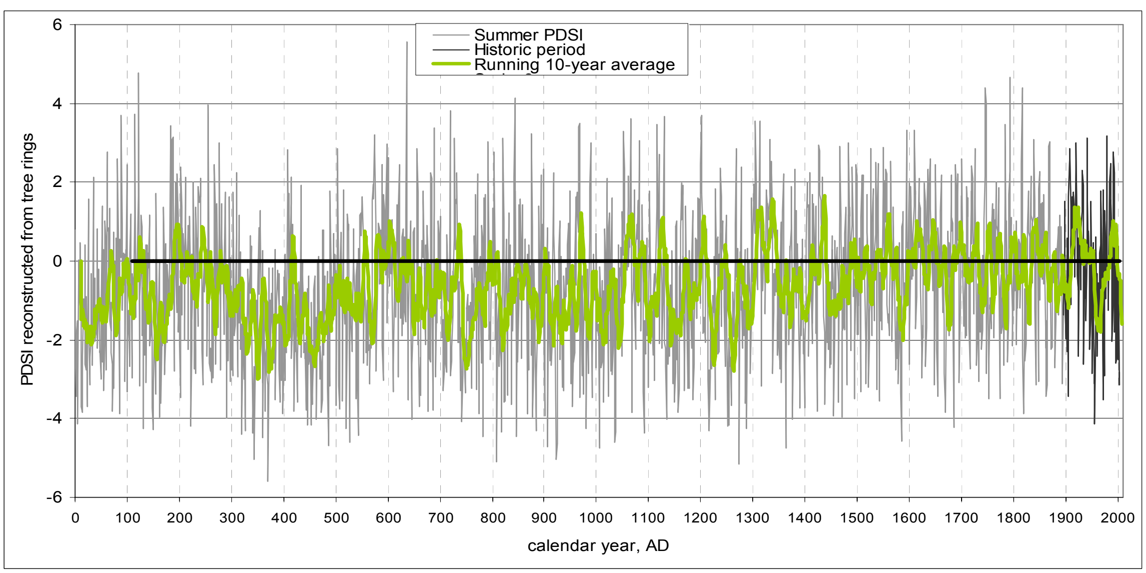

Figure 2. Long-term record of drought conditions. Summer Palmer Drought Severity Index reconstructed from tree rings, southern Arizona (gridpoint 105 data from Cook et al. 2004), with ten-year running averages. Note droughts from ~300 to 600 AD that are more extreme than any experienced in the historic period.

Riparian target species and objectives

The RMP identifies several target species associated specifically with riparian areas on the NCA. We address them here briefly to provide context for the discussion of riparian systems. However, more thorough analyses of population status and trends, monitoring power, and species habitat needs (e.g. Bodner et al. 2007) would provide managers with more robust tools for tracking the needs and responses of these species.

Federally-listed bald eagle *Haliaeetus leucocephalus* (threatened), Southwestern willow flycatchers *Empidonax traillii extimus* and Huachuca water umbel *Lilaeopsis schaffneriana recurvata* (both endangered) are considered riparian obligates that require perennial or near-perennial water. The Western red bat *Lasiurus blossevillii*, Western yellow-billed cuckoo *Coccyzus americanus* (both wildlife of special concern), and gray hawk *Buteo nitidus* (BLM sensitive) are obligate residents of cottonwood-willow riparian forests. Countless other species that call the LCNCA home depend on its aquatic and riparian habitats, including over 35 species of damselfly and dragonfly (Dr. S. Dunkle and R. Bailowitz, pers. comm. 2006), half of the 38 reptiles and amphibians documented within the NCA (Rosen and Caldwell 2004), and a large proportion of the area's 60 mammals and 230 bird species (BLM 2002). Aquatic target species (Gila chub, Gila topminnow, Chiricahua leopard frogs, Lowland leopard frogs, and Mexican garter snake) are addressed elsewhere.

The water umbel, cuckoo, flycatcher and gray hawk are all included among priority species for management in the RMP. Of these species, the water umbel and cuckoo are of particular interest since Las Cienegas hosts a large proportion of the species' regional populations (see below). Southwestern willow flycatcher and gray hawk are addressed briefly in this report as well. Bald eagles are considered transient on the property (BLM 2002). and although red bats have been observed several times on Cienega Creek (K. Simms personal observation), there are no objectives in Las Cienegas RMP for the species and relatively little information exists in the rest of the state apart from the fact that it uses cottonwood-willow habitat (AZGFD 2003). In addition, neither of these species was identified as a priority for management in the RMP, and consequently they are not addressed further in this report.

The RMP does not include species-specific objectives for these priority riparian targets apart from prescribing the use of an ecosystem approach to manage the rare habitats of these species and stating that maintaining riparian Proper Functioning Condition will meet the needs of TE&S species. However, the USFWS Biological Opinion for the RMP (USFWS 2002) includes the following terms and conditions for LCNCA's federally listed riparian species, in addition to those put forth for aquatic species:

- Exclude most of the creek's riparian areas from grazing;
- Continue to monitor the flycatcher and its habitat; evaluate and mitigate cowbird parasitism if nests are found;
- Inspect riparian fencing before cattle are put in adjacent pastures; if flycatchers are present, inspect fences at least once while cattle are in adjacent pastures;
- Do not use livestock crossings if they have an active flycatcher nest; do not use crossings that are considered suitable flycatcher habitat during breeding season (late

April through mid August) unless surveys have confirmed absence of flycatcher nests;

- If flycatchers are nesting near agricultural field group recreation sites, move group use to other sites;
- In the northern Narrows pasture, either exclude this pasture from grazing entirely, remove cattle by March 30 each year, or ensure that stubble heights remain at or above six inches and remove cattle by May 1;
- Manage riparian areas to maintain dense low vegetation as possible jaguar movement corridors.

Stressors and sources of stress

Researchers and managers identify a fairly consistent suite of stressors for Southwestern riparian systems in general (e.g. Hendrickson and Minckley 1984; Tellman et al. 1997; Stromberg 1993; Ffolliott et al. 2003; Stromberg et al. 2003; AZGFD 2006; Pima County 2000, 2001). Table 3 shows several of these stressors that are relevant to the Cienega Basin system. The USFWS and BLM explicitly or implicitly identify most of these as threats to resource and species protection on Las Cienegas NCA (BLM 2002; USFWS 2002). Note that the distinction between a direct stressor and an indirect source of stress is somewhat artificial and a particular impact can count as both. This table does not include species-specific stressors for riparian targets.

Table 3. Commonly identified stressors and sources of stress for Southwestern riparian systems, including cottonwood-willow forest, mixed broadleaf riparian forest, and cienega marshland. Items in parentheses are clarifications relevant to Las Cienegas.

Stressor	Source of stress
Groundwater depletion	Overpumping, surface water diversion, interruption of recharge, decline in bank storage, imbalance between recharge and evapotranspiration
Streambank destabilization	Trampling by livestock, trampling/motorized use by humans, increased speed of water runoff, loss of streamside vegetative cover (e.g. from decreased availability or predictability of ground and surface water)
Downcutting, head-cutting, stream capture	Destabilized banks, failed or poorly designed impoundments or other structures, excessive erosion
Interrupted tree regeneration	Overgrazing, altered flood flows, groundwater decline, lack of disturbance
Burying of surface waters, filling of pools	Excessive sedimentation
Altered flow regimes	Dams/reservoirs/impoundments, increased runoff from impervious surfaces or degraded watershed
Competition with exotic species	Invasive plants (e.g. tamarisk)
High rates of	Invasive animals (e.g. crayfish), overuse by livestock

	herbivory, above historic norms	or native grazers
	Water pollution	Point sources: mining, wastewater treatment, dumps
		Non point sources: livestock, septic systems, excessive soil erosion, large/severe upland fires (effects often temporary)
	Watershed degradation	Altered fire regime (lack of upland fires), loss of soil cover (especially perennial grass)
	Habitat conversion or fragmentation	Urbanization, agriculture (on lands surrounding the NCA)

Methods and Availability of Recent Data

BLM has been gathering riparian data since acquiring the property in 1988. The agency invested a lot of effort up-front into gathering thorough baseline data. The RMP describes the variety of monitoring tools currently being used, and sets forth target frequencies for many of them (Table 4). For some of the riparian monitoring, data collection has been opportunistic, often tied to particular projects. BLM has also conducted or contracted habitat surveys and nest surveys (1994, 2000, 2001 and possibly other years) for Southwestern willow flycatcher, western yellow-billed cuckoo (2001), Huachuca water umbel (1999-2000), and for gray hawks (1989, 1991, and 1999).

Figure 1 shows the conceptual matchup between BLM data collected to date and RMP objectives. This matchup will be addressed in more detail in the Recommendations section.

Table 4. Riparian measures' baseline dates, measurement frequency from RMP or other source, and actual years repeated as of 2007. Years in brackets represent partial samples.

Riparian measures	Baseline date	BLM Planned frequency	Repeat years
PFC & RACE scoring	*1989*	5 years if meeting; 2 years if not	1993, 2000, [2006]
Woody vegetation belt transects	*1993*	5 years	[2006]
Repeat photo points	*1989*	n/s	1993, 2006
Aerial photography[a]	1935	n/s	1972, *1989*, 1995, 2002
Aquatic habitat measurements	*1990*	5 years	[2000]
Channel cross-sections	*1993, 2001*[b]	n/s	[2001, 2006]
Streamflow measurements	*~1970's*	monthly	2000-now
Mapping wet-dry reaches	*~1990*[c]	n/s	2006, 2007

n/s: frequency not specified in the RMP. a: BLM has aerial photographs for these dates but has not systematically analyzed them. b: ADEQ's 2001 cross sections included some previous BLM sites and many additional sites. c: the RACE inventory mapped surface water across several months so did not record that year's minimum extent.

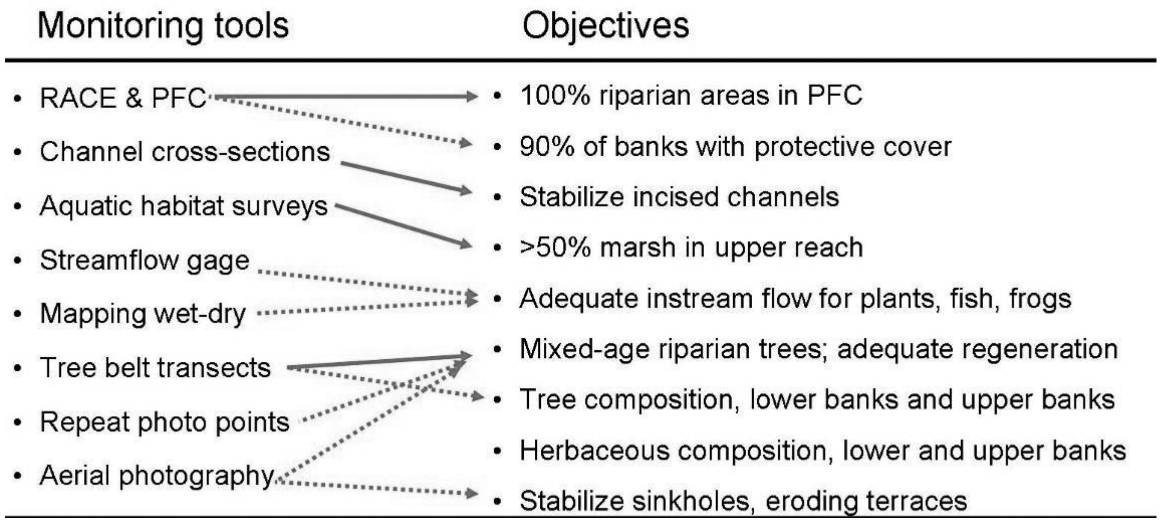

Figure 3. Match-up between RMP objectives and the monitoring tools being used between 1989 and 2005. Solid lines indicate direct measurements, dotted lines indirect and/or incomplete measures**.**

Riparian ecological models

We wanted state and transition models for cottonwood-willow riparian forest and for stream cienegas to serve as a framework to organize current understandings about vegetation dynamics. For Fremont cottonwood (POFR)-Goodding willow (SAGO), we began with a model developed by the Natural Resource Conservation Service for Southeastern Arizona (Figure 2, Robinett 2005). We added information from Stromberg et al. (2006) on attributes of three cottonwood-willow condition classes developed on the San Pedro River, as well as a variety of other evidence from the literature and from field observations about the existence of other stable states and ecological thresholds (BLM 1987; Gori 1996; Pima County 2001; NPS 2007). We discuss evidence for past and present disturbance regimes in this context.

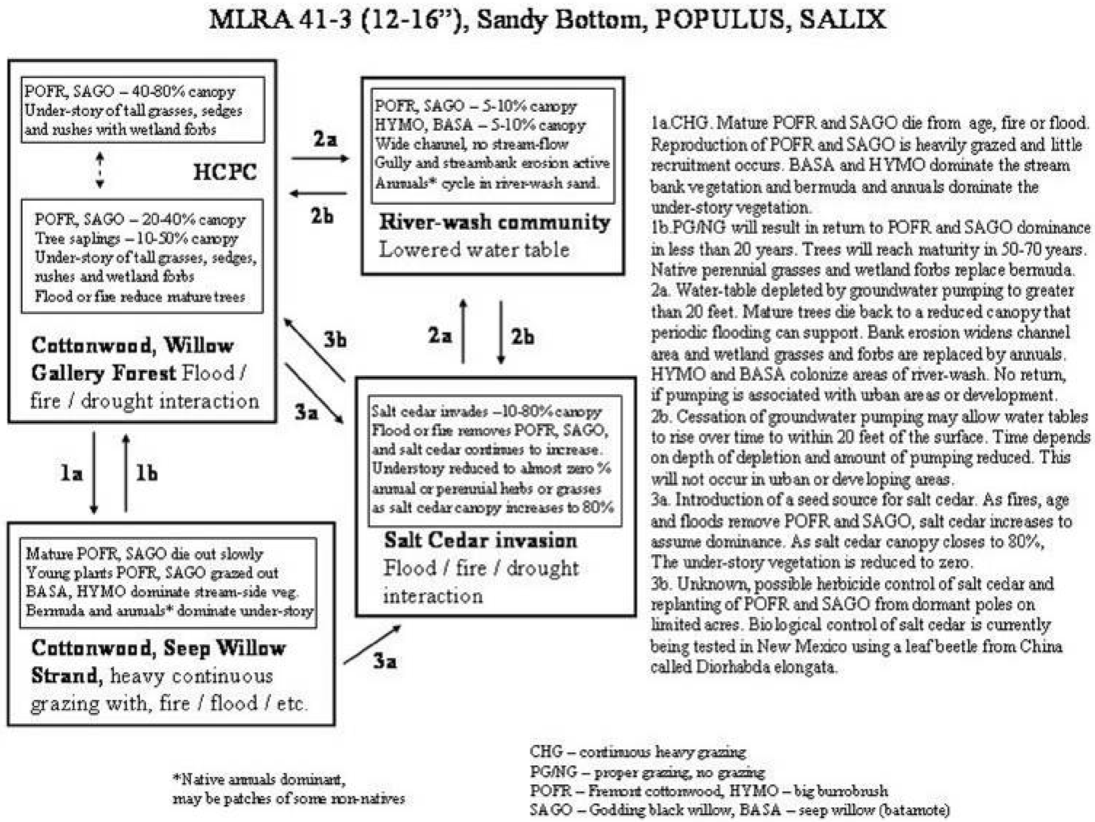

Figure 4. Cottonwood-willow state and transition model, from Robinett 2005.

Integrated condition measures

Proper Functioning Condition assessment

BLM assessed Proper Functioning Condition (PFC) of all wet creek segments in 2000. Method details are explained in BLM (1993). PFC ratings were also approximated from RACE inventory for 1993 (see below). PFC ratings have been generated for a few reaches since 2000, but are not complete enough to include here.

RACE inventory of riparian and aquatic resources

Soon after acquiring the property, BLM conducted a nearly complete inventory of Cienega Creek's riparian and aquatic habitat using a "Riparian Area Condition Evaluation" (RACE) protocol developed for the state (BLM 1987). RACE includes both detailed inventory and summary rating components. Streambank vegetation stability ratings follow Pfancuch (1975). Bank soil alteration ratings follow Platts (1983). BLM developed the subsurface water status and woody species regeneration ratings in-house.

These 1990 measurements and evaluations covered a total of 14 km of wet stream, three km of dry channel, and approximately two km of secondary wet habitats (e.g. pools or marsh lateral to the main channel) plus several kilometers of xero-riparian habitats. In addition to dividing the stream and its main tributaries by reaches (see Figure 3 ; "59" is code for Cienega Creek), this inventory measured aquatic habitat parameters such as pool depths and channel widths, described composition of understory and overstory vegetation, rated riparian tree recruitment, and measured a variety of channel parameters. This methodology focused on perennial/intermittent stream areas and did not thoroughly evaluate xero-riparian or floodplain resources. RACE evaluations were repeated in 1993 and 2000 (evaluated at the same time as PFC), omitting several kilometers of xero-riparian habitats due to "lack of site potential." RACE rating descriptions are included as Appendix B.

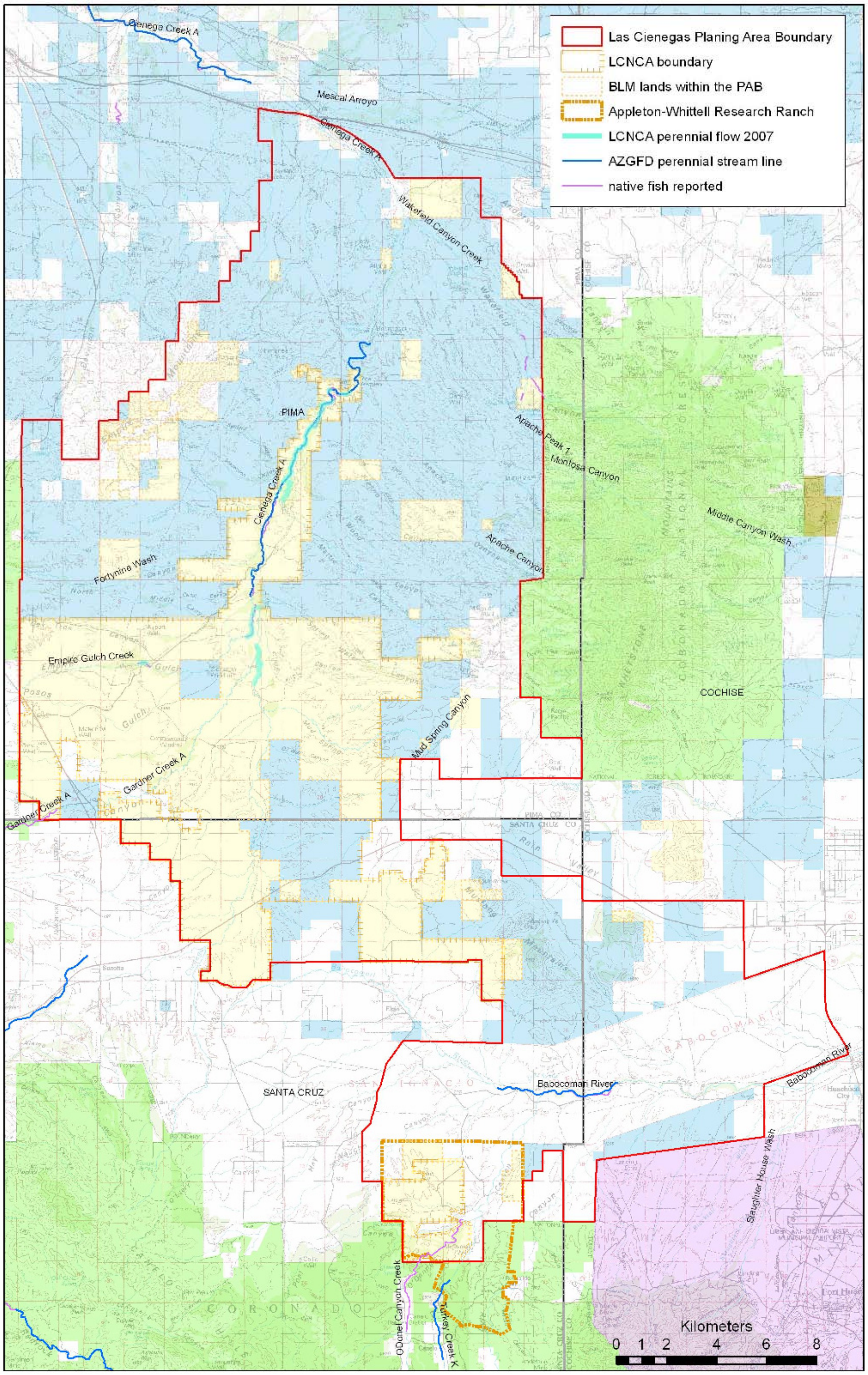

Figure 5. Las Cienegas context, showing land ownership, NCA and planning boundaries, and three depictions of perennial streams in the area. Perennial flow in the NCA was mapped on the ground for Cienega Creek and major tributaries in June 2007; this extent is approximately 4km less than reported from before 2001 (BLM 2002). Native fish lines show areas with perennial flow (past or present) that were not captured by AGFD or LCNCA mappings.

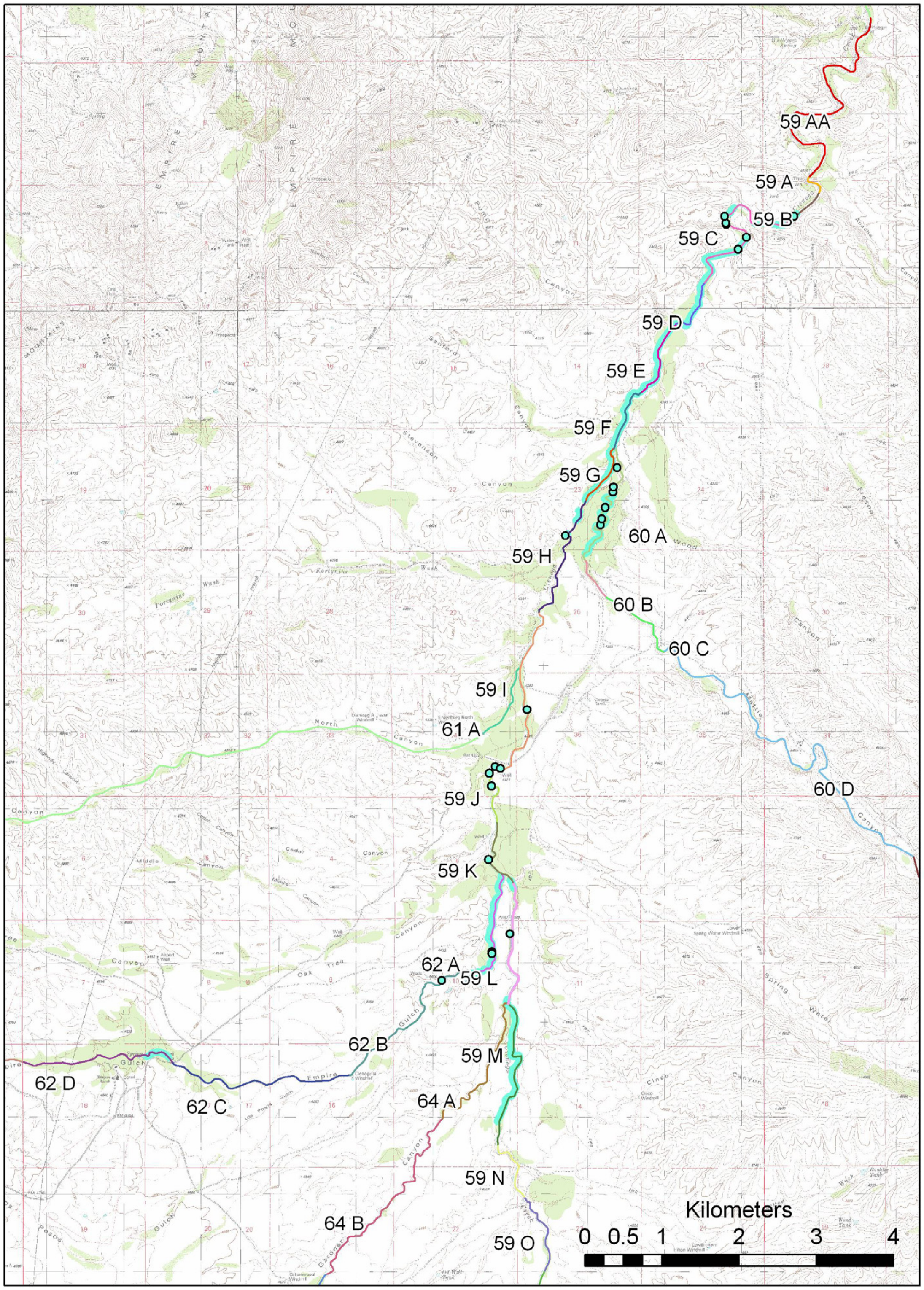

Figure 6. Map of Las Cienegas riparian segments as identified in the 1989 RACE inventory. "59" segments are Cienega Creek; other numbers refer to major tributaries. Wide blue areas had year-round surface water in 2007, with continuous water (longer than ten meters) depicted here as lines and isolated pools depicted as circles.

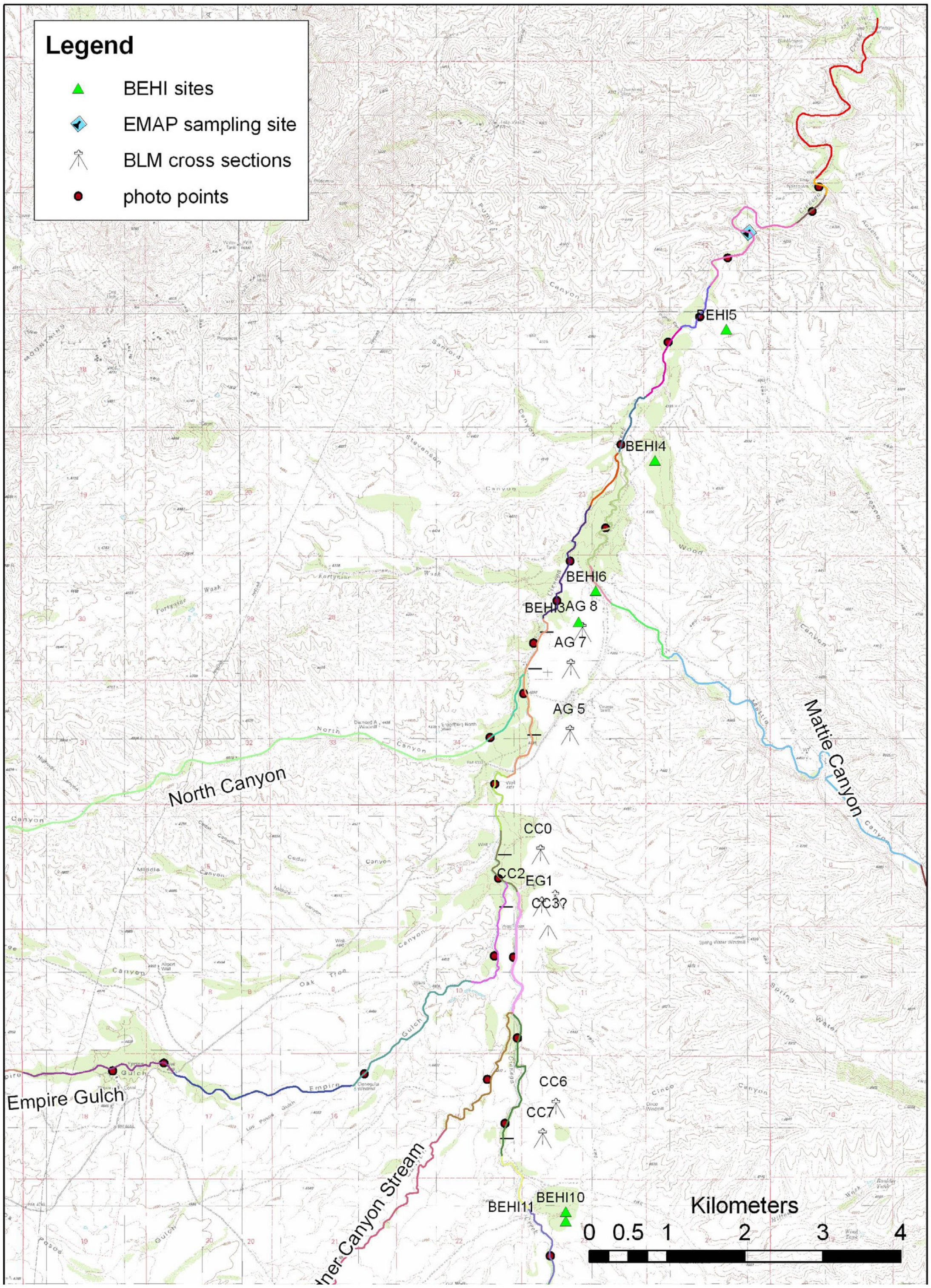

Figure 7. Select features and study sites for a variety of monitoring and assessment measures. BEHI site markers are offset from the streamline to be more visible on this map.

EMAP Western Wadeable Streams

The Environmental Protection Agency has been developing methods to assess status and trends of rivers and streams across the US under a program called the Environmental Monitoring and Assessment Program (EMAP). This EMAP program includes a pilot project testing methods on Western wadeable streams (EPA 2004, 2007). Western EMAP sites were chosen across the region using a probabilistic random selection procedure. Almost 200 of these sites fell in the "xeric ecoregion" of low-mid elevation dry western states, with one site on Las Cienegas (Figure 4). This protocol samples benthic macroinvertebrates, water quality, periphyton algae, and fish, as well as collecting data on stream geomorphology and vegetation. It also uses a composite "rapid habitat assessment" ranking system. We obtained summary results and copies of original datasheets from the EPA and from the multi-agency field team that surveyed this site. Much of this is available online at http://www.epa.gov/storet.

Riparian vegetation:

Herbaceous vegetation in forest and cienega habitats

No LCNCA monitoring protocols address riparian herbaceous vegetation specifically. Repeat photos, aerial photos, RACE inventory descriptions, channel cross-section and ecosite transects, and aquatic habitat monitoring methods provide some herbaceous information.

Riparian tree density belt transects

Densities of three dominant riparian trees have been measured repeatedly along several stretches of Cienega Creek. In 1993, all 14 segments (see Figure 3) from the headwaters (59M) to the downstream end of surface water (59AA) were measured. Five segments—59M, K, I, F, C, and AA—were measured again in 2006. An Empire Gulch segment was added in 2006.

Belt transects were ten feet wide, and ran perpendicular to the stream channel. In 1993 they spanned the active floodplain; in 2006 they spanned from one edge of the riparian forest zone to the other (see definitions below). Within each belt, riparian trees were identified to species and recorded by size class: seedlings (<1" diameter or <6' tall), saplings (≥6' tall and <3" diameter), and mature trees (≥3" diameter). The mature category was split into two in 2006: mature (≥3" and <20" diameter) and large trees (≥20" diameter). Large tree diameters were measured and recorded individually. For seedling trees, we noted whether the apical stem had been browsed in the current growing season. The seedling height definition was based in part on the height at which browsing is thought to decrease.

The active floodplain zone was defined as extending from cutbank to cutbank in most cases. A few transects occurred in areas that lacked clear cutbanks on one or both sides and therefore had less defined active floodplain zones. The riparian forest zone was defined as starting at the outer edge of the stand of riparian trees farthest from the creek (not including mesquite) and extending through the farthest stand on the opposite side of the creek. Occasional isolated trees far from the creek and from other riparian trees were noted on the datasheets but were not counted as defining the riparian forest zone. This creek has few such isolated trees, so this judgment call was rarely invoked. In a few cases where a major tributary entered Cienega Creek, we attempted to measure just that portion of the riparian forest directly associated with the main creek.

In 1993, six to 31 belt transects were run within each segment, depending on the length of the segment. Transects began at the downstream end of each segment and were evenly spaced every 100 to 400 feet (consistent within each segment but differing between segments). In 2006, we used approximately the same transect spacing for each reach as it had in 1993 but began at the upstream end of each segment and measured at most 12 belts per segment. When comparing data, we used subsets of the original transects that represented the same area covered in later surveys, matching start and stop points in each year by figuring distances to transect ends and by comparing landmarks noted on datasheets. For 59C, for example, we used the last 12 of the 1993 belts because these spanned from the Narrows road crossing (our end point in 2006) to the upstream end of the segment (our start point in 2006).

Data sheets from1993 included three species: *Populus fremontii*, (Fremont cottonwood) *Salix goodingii*, (Gooding's willow) and *Fraxinus velutina* (velvet ash). Measurements in 2006 also included other riparian trees observed— *Juglans major* (Arizona walnut) and *Celtis reticulata* (netleaf hackberry)—but the original three remained by far the most common species.

Riparian ecosite transects

BLM explored an "ecosite line intercept" method in 1993 and 1999 to map the vegetation and geomorphology zones across the stream channel at Las Cienegas, similar to the vegetation cross-section composition method of Winward (2000). We were unable to replicate these methods in 2006 and do not include results here.

Riparian photo points

To track overall changes in riparian habitat, BLM set up a network of riparian photo points in 1989. These photo points were marked with t-posts and/or metal tags on trees, and noted on topographic maps. Each point was photographed in three directions: across the channel, upstream from the edge of the active channel, and downstream from the same spot. Most were re-photographed in 1993, and several recorded opportunistically after that. By 2006, a number of the original tags had disappeared, but we were able to find most points using a combination of original tags, map locations, and earlier photos. In addition to repeating the set of photographs at each point, we recorded their locations with handheld GPS units and added new yellow metal vegetation survey tags to most.

Vegetation mapping

We examined local results of six attempts to classify riparian vegetation communities in the region using satellite imagery. Most of these area based on some combination off remote imagery, human interpretation of images and human interpretation of field observations, though exact methods vary widely. The RMP includes Ecological Site (range site) mapping for the Empire Cienega allotment based on soil types and topography as well as vegetation, and uses these range sites as an approximation of both historic and current vegetation (BLM 2002). The Arizona Game and Fish Department

(AZGFD) classified riparian vegetation types across the state in 1997 using Landsat imagery and aerial videos and omitting areas less than 60' wide (Kuby et al. 1997). The Arizona GAP project used Landsat imagery from 1990-1992 and semi-automated spectral analysis to classify vegetation at 40 acre resolution across the state (Halvorson et al. 2002), using vegetative community categories of Brown, Lowe and Pase (the "BLP" system). Pima County contracted Harris et al. (2001) to map BLP riparian communities on some two million acres across the county, skipping tribal lands and areas already under firm protection at the time. This effort manually drew vegetation community polygons on 1996 DOQQ images, supplemented images with field visits and a variety of background information, and resulted in a minimum mapping unit of five acres. Southwest ReGAP used Landsat imagery from 1999-2001 and semi-automated spectral analysis to classify vegetation types at one-acre resolution across the state (Lowry et al. 2007), using the US National Vegetation Classification System (NVCS). Pima County composite vegetation combines several of these to depict the best available information for the entire county, upland and riparian. Accuracy of these classifications at Las Cienegas and their usefulness for tracking change are discussed below.

We compared these maps to each other and to field observations from Las Cienegas. Each map was evaluated on its potential to serve as a reliable snapshot of the extent and composition of riparian vegetation on the NCA. Because these maps were created over a thirty year span, we also evaluated the potential of the set to document riparian vegetation trends. Lastly, we evaluated methods and rough costs of producing each type of map to identify methods that BLM might choose for future mapping efforts to continue documenting trends.

A 2005 project of the Agricultural Resource Service (ARS) used Las Cienegas as a ground-truthing site to test "the accurate conversion of remotely sensed data (satellite imagery) to quantitative estimates of total (green and senescent) standing cover and biomass on grasslands and semidesert grasslands" (Marsett et al. 2006), analyzing Landsat imagery from May and October 2005. This imagery and analysis is available to be applied to some riparian questions but is not included here.

Other aerial photos and satellite imagery

Many remote images are available for this site, at various resolutions. Black and white aerial overflight photos of this site were first taken in 1936 as part of a West-wide survey by the Soil Conservation Service (now Natural Resource Conservation Service NRCS). Another set of photos from low-level overflights were taken in 1972 (black and white, covering the entire property), a third in 1995 (color, focused on the site's riparian areas), and a final set in 2002 (color, Pima County portion only, courtesy of the Pima County Association of Governments) Only this latest set has yet been orthorectified (matched to a latitude-longitude grid for overlaying with other GIS layers). As is, landmarks can be used to match portions of these images with each other to track changes in vegetation and in exposed geologic and water features. Additional DOQQ (digital ortho quarter quads) images are available from a limited set of dates in the 1980's, 1990's, and 2000's, with resolution of 1m. Satellite images with 60x80-meter resolution or better are available for every month since 1972 (Landsat series). Current versions have 30 m resolution. Formal comparisons of high resolution aerial photos have not been conducted for the LCNCA, but pieces of some images have been used to examine changes at local sites.

Other relevant studies

University of Arizona researchers Courtney Conway and Chris Kirkpatrick are running a study on riparian birds across southeastern Arizona. Study sites span a range of conditions, including sites with healthy riparian forests and perennial surface water, healthy riparian forest with sub-surface water, and declining or degraded riparian forest that is losing or has lost its access to subsurface water. Their LCNCA study site is along an intermittent reach of Cienega Creek, with riparian forest considered to be healthy. Their vegetation measurements focus on vegetation volume from ground level upwards but also include density estimates for large trees. Vegetation measurements were conducted here in summer of 2006. These measurements and associated bird findings provide a snapshot that will be compared with other sites in the region, including a Cienega Creek perennial-flow site on the Pima County Preserve; they are not designed to compare reaches within Las Cienegas nor to track LCNCA resources through time.

Hydrologic analyses by Bota (1997) and Knight (1996) include some evapotranspiration models for which vegetation volumes were estimated. These methods could be repeated to illustrate changes over the past decade.

Habitat surveys for both Western yellow-billed cuckoo (Harris Environmental 2001) and Southwestern willow flycatcher (BLM 2000) included assessments of vegetation structure. Each provides a snapshot of different vegetation attributes and could presumably be repeated with the same more-or-less standardized protocols in the future.

Arizona Game and Fish Department will conduct a habitat suitability analysis for beaver on the NCA in 2008. This will include a variety of vegetation measurements along the stream (Allen 1983).

Channel morphology:

BLM stream cross-section measurements

BLM measured 15 cross-section profiles in 1993, including 13 in Cienega Creek, one in lower Empire Gulch and one in lower Gardner Canyon. Cross-sections were monumented with a metal t-post at one end and an orange carsonite sign at the other, and approximate locations were described in field notes. In 2006, we found eight of the original cross section sites. Markers for five of these were intact and cross-sections were re-measured. Three others had only one end marked; for one of these we used 1993 field notes and photos to figure out approximately where the previous marker had been, installed a new t-post at this unmarked end, and re-measured the cross section.

In 1997-1998, BLM conducted a streambed restoration project to remove impoundments and block a diversion that had redirected flood flows away from some 2 miles of original creek bed (BLM 1999). Six channel cross-sections and approximately two kilometers of longitudinal profile were measured for this project. The longitudinal profile was measured only after the project's completion (1999). Cross-sections were marked with yellow carsonite posts at both ends, and were measured before and after the channel reconstruction (1998 and 1999). Some were re-measured in 2001 by the Arizona Department of Environmental Quality (ADEQ; see below).

ADEQ stream geomorphology measurements

ADEQ conducted an intensive survey of geomorphology and water quality on Cienega Creek in 2000-2001 (Lawson and Huth 2003). This included a longitudinal profile of some 16 kilometers of creek within the Upper Sub-basin which includes both of LCNCA's perennial reaches and surrounding intermittent segments, plus an additional 15 km of creek downstream in the Lower Sub-basin within Pima County's Cienega Creek Preserve. This study also measured 54 channel cross-sections in the NCA and a comparable number in the County preserve. Two upper-basin and two lower-basin sampling sites also had water quality data and abundance data for 43 species of periphyton diatom and 31 groups of macroinvertebrates. One of these upper-basin sites (SCCIE010.20) is located some 300m upstream of the FC0315 fish sampling site, and almost exactly at the Riparian Photo Point for segment 59C (see Figure 4). The other (SCCIE014.39) is located near the confluence of Cienega Creek and Oak Tree Canyon along segment 59K, some 500m downstream from fish sampling station FC0131near the CC3 station where streamflow was recorded in the 1990's and which has dried up during much of the last several years. Lawson and Huth measured Bank Erosion Hazard Indices at four LCNCA sites: two above the headwaters (59M), two in the Ag Fields intermittent reach (59H) and two in the perennial LCNCA lower reach (59F, D).

Data from this study was analyzed and published for the lower sub-basin that comprises Pima County's Cienega Creek Preserve (Lawson and Huth 2003). Lawson and Huth used a portion of the stream within the NCA as a "least impaired reference reach" for comparison (see below). Apart from this reference reach segment, data for the upper sub-basin was published in raw form but not analyzed or interpreted.

Results and Discussion

Riparian ecological models

State and transition models shown below represent hypotheses that integrate information on riparian ecology from a variety of sources. In this model, Las Cienegas has patches of habitat that represent all states except those in the bottom row (the cottonwood-seepwillow strand and salt cedar states). The model also expresses our uncertainties about what is driving (1) creation of wooded swamps in the upper reach and (2) shifts in species recruitment towards ash throughout the creek, and how stable these states are likely to be. Ash recruitment into cottonwood-willow forests, for example, may well represent natural succession from a pioneer tree community (Stromberg pers. comm. 2007), and may be more common in headwater streams like Cienega Creek than in more flood-prone large rivers like the San Pedro. The model also generates testable predictions about existence of a variety of quantitative thresholds in state transitions. Parts of this system have been modeled in more detail than can be represented here, e.g. cottonwood and willow recruitment (Mahoney and Rood 1998; Pima County 2001), competitive dynamics between native and tamarisk seedlings, and effects of floods of various sizes on relative recruitment of natives versus tamarisk (Stromberg 1997; Horton and Clark 2001).

Most riparian stressors are reflected in transition drivers in this model. Model transitions from left to right show, for example, how the stressor of groundwater depletion affects many aspects of the system, from tree recruitment to channel morphology. Adding complexity to this model and showing its connections with upland and aquatic models would incorporate the other stressors (water pollution, watershed degradation, etc.).

BLM objectives can be viewed in the context of this model. The goal of having riparian forests dominated by cottonwood and willow with “a good mix of age classes,” for example, describes a desire to maintain sites in the cottonwood-willow forest condition class one state, with enough flood disturbance to maintain recruitment. This model makes predictions for how proportion of LCNCA riparian areas in condition classes one and two will shift as the length of perennial flow fluctuates in Cienega Creek. All of the targets addressed here (flycatcher, cuckoo, water umbel, and probably grey hawk) need condition class 1 forest states, though ideal disturbance levels may vary among species.

This model sheds light on past and future BLM management decisions. Fencing the creek from cattle successfully moved much of the creek from the cottonwood-seepwillow strand state to gallery forest. Declines in disturbances (natural decline in flooding with managed exclusion of fire and grazing, continued absence of beaver) may have created wooded swamps, shifted tree species composition towards ash, and possibly reduced Huachuca water umbel in the upper reach. Long-term lack of disturbance could reduce cottonwood-willow recruitment, shift species composition, and reduce heterogeneity of habitat patches. Adding other disturbances (e.g. beaver, fire) back into the system could move habitat patches from state to state or maintain disturbance-dependent states.

The role of fire in riparian systems is especially controversial (e.g. USFWS 2002b, Dwire and Kauffman 2003, Pettit et al. 2007). Fire is clearly a natural process in cienegas (Davis et al. 2002) and sacaton flats (Bock and Bock 1988) and has been used to manage wetland vegetation (e.g. Weller 1987, McPherson 1994). Its natural role in bosques is unclear (Stromberg 1993b). Cottonwoods and willows are often top-killed by fire but may resprout (Rychener et al. 2002). Effects of a 2002 wildfire on the NCA suggest that large cottonwoods away from the wet channel are especially vulnerable to fire.

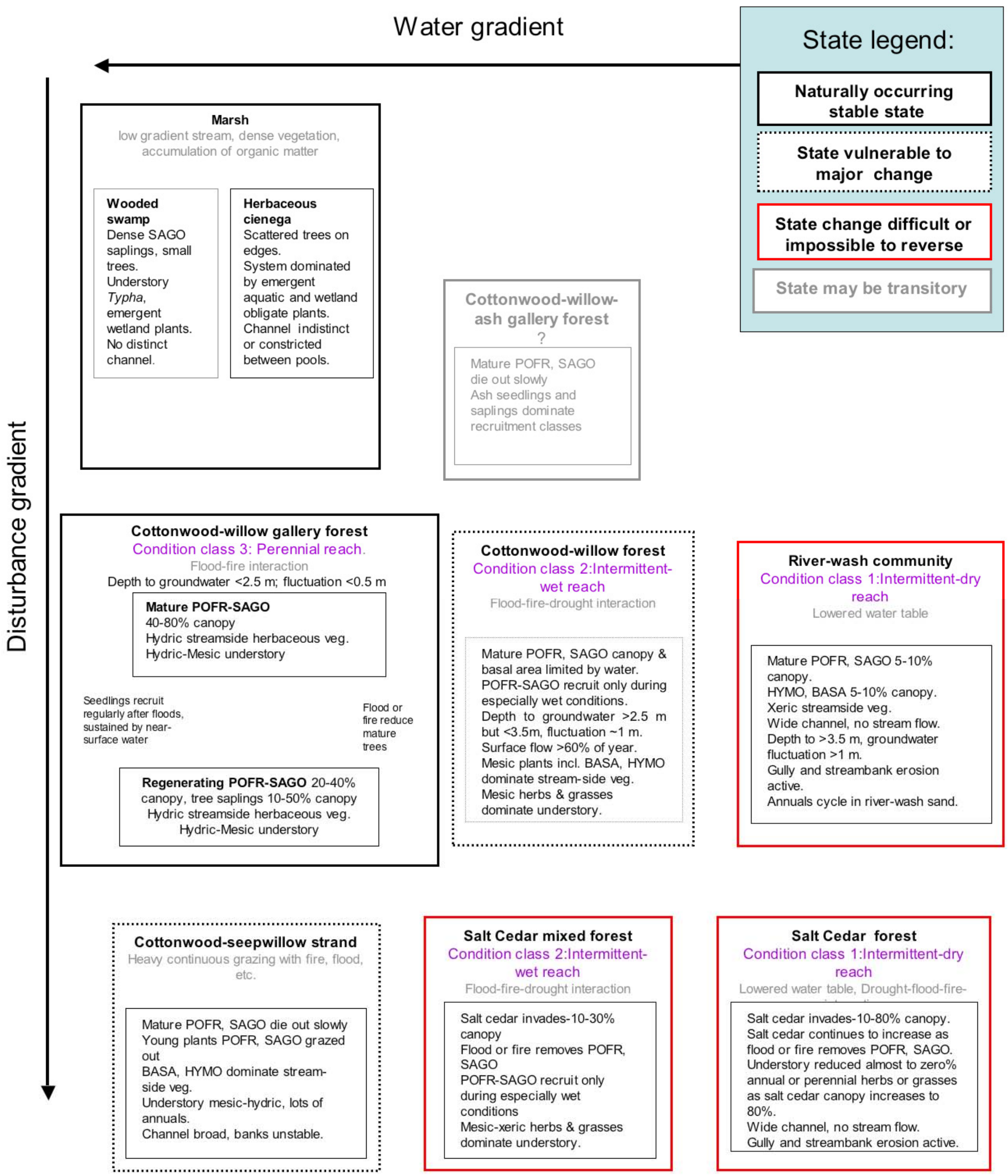

Figure 8. State descriptions for cottonwood-willow forest and related community types. States are arranged left to right according to a gradient of decreasing surface water and shallow groundwater, and top to bottom according to a gradient of increasing disturbance from a mix of flood scour or deposition, grazing, and exotic species invasion. Purple text describes condition classes according to Stromberg et al. 2006. Grey text describes major disturbance features of each state. Inner boxes describe details of states and sub-states, derived from Robinett 2005, Stromberg et al. 2006, as well as a variety of other evidence from the literature and from field observations about the existence of other stable states and ecological thresholds (BLM 1987; Gori 1996; Pima County 2001).

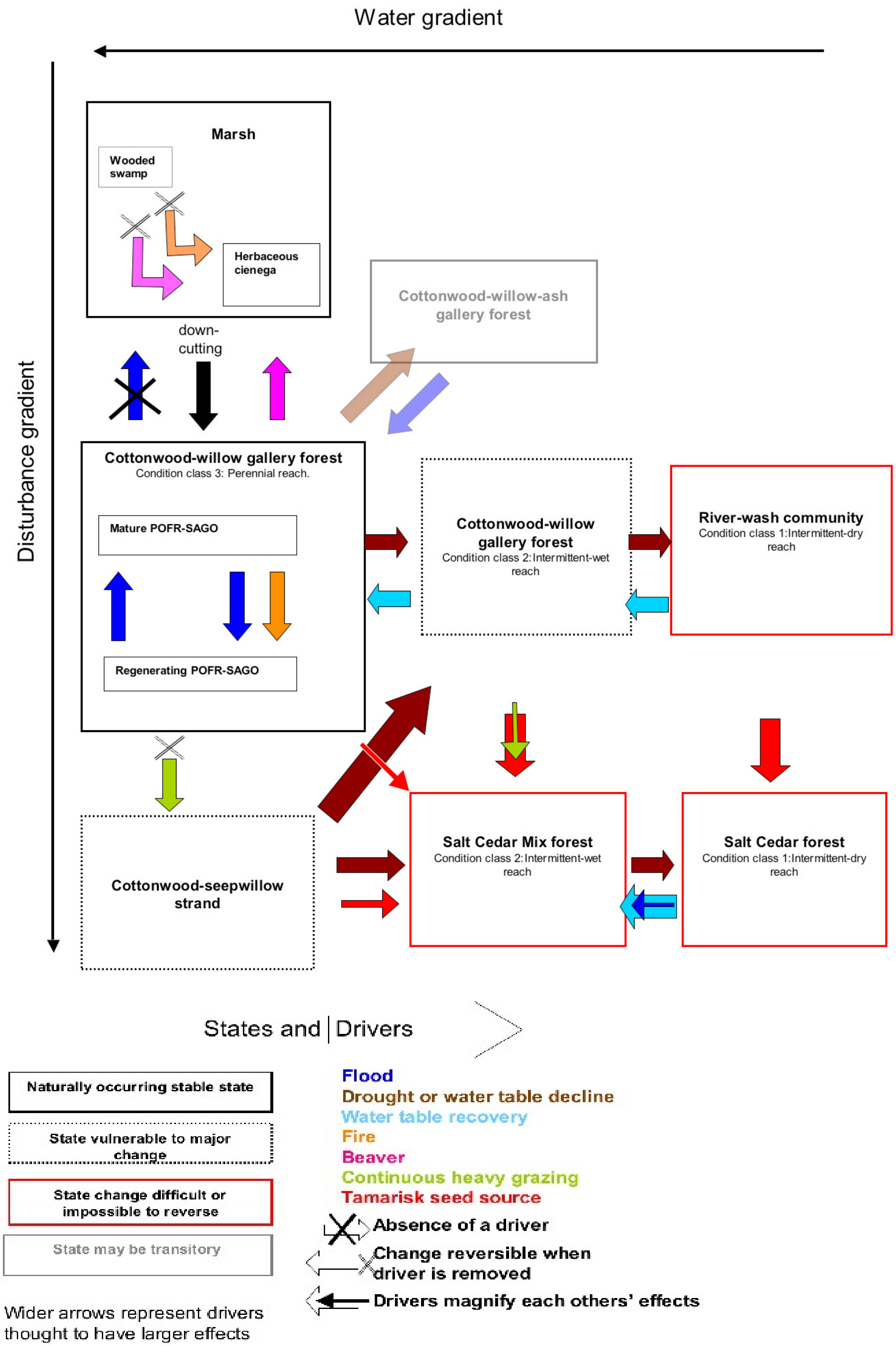

Figure 9. State and transition model for cottonwood-willow forest and related states, with key drivers. We have little evidence for the role of drought vs. lack of flooding in shifting wet-riparian tree species composition towards ash, so these drivers are depicted as uncertain.

Integrated condition changes

RACE evaluations show considerable improvement from 1989 to 2000 (Table 5). Improvements in woody species regeneration preceded improvements in bank and soil components (Figure 5).

Cienega Creek + tributaries																
	miles	bank soil alteration			subsurface water rating			veg bank protection			woody species			overall score		
reach		1989	1993	2000	1989	1993	2000	1989	1993	2000	1989	1993	2000	1989	1993	2000
59AA	1.6		2	4		2.5	4		3	4		1	3		8.5	15
59A	0.25	3	3	4	2	4	4	3	3	3	2	3	3	10	13	14
59B	0.27	3	3.5	3	3	4	4	4	3.5	4	3	3	3	13	14	14
59C	1.59	4	4	4	4	4	4	4	3	4	4	3.5	4	16	14.5	16
59D	0.42	4	3	4	4	4	4	3	3	4	1	3	4	12	13	16
59E	0.64	4	3	3	4	4	4	4	3	3	1	1	4	13	11	14
59F	0.53	3	2	4	4	4	4	3	2	4	1	4	3	11	12	13
59G	0.53	4	4	4	4	4	4	4	4	4	1	4	4	13	16	16
59H	0.87	3	3	4	4	3.5	3	3	3	3	1	3.5	1	11	13	11
59I	1.67	2	4	4	4	3.5	3	3	3.5	4	1	4	1	10	15	12
59J	0.85	2	3.5	4	4	4	3	2	2	4	1	2	4	9	11.5	15
59K	0.33	2	2	3	4	4	4	2	2	3	1	4	2	9	12	12
59L	1.04	2	4	4	4	4	4	3	1	4	1	3	3	10	12	15
59M	1.29	4	2	4	4	4	4	4	2	4	1	1	4	13	9	16
59O	0.63	4		4	2		2	4		4	1		1	11		11
60A	1.21	3			4			3			2			12		
61A	0.01	1			2			1			1			5		
62A	0.98	3			4			3			1			11		
62B	1.36	2			3			4			1			10		
62D	1.33	3		4	3		3	4		4	4		1	14		12
63A	0.85	2		4	4		3	2		4	1		1	9		12
64A	1.20	3			3			3			1			10		

Table 5. Riparian Area Condition Evaluation for Cienega Creek and tributaries, 1989-2000. Overall scores of 12 and above are considered satisfactory. Xero-riparian segments were not measured after 1989. Verbal descriptions of rating categories are provided in Appendix B.

	1989	1993	2000
Total miles surveyed	10.3	11.9	11.9
Satisfactory miles (score 12-16)	4.7	7.5	11.0
Unsatisfactory miles (score <12)	5.5	4.4	0.9
% satisfactory	46%	63%	93%

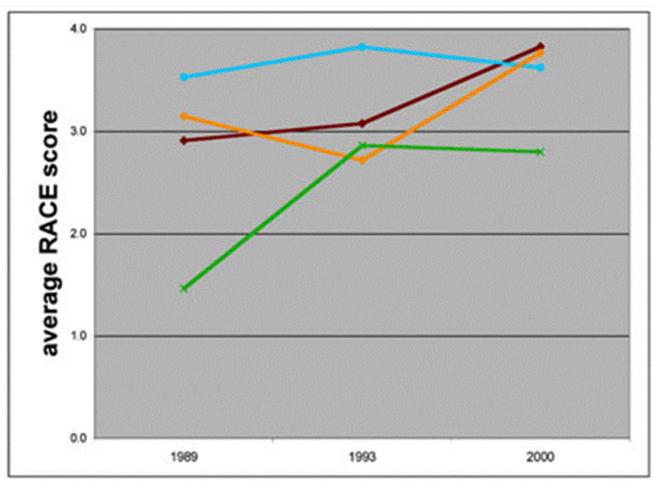

Figure 10. Changes in average RACE component scores across Cienega Creek and wet tributary segments from 1989 to 2000. Blue line: Subsurface water status; brown: bank soil alteration; orange: vegetative bank protection; green: woody species regeneration.

Proper Functioning Condition classifications paint a slightly different status picture than RACE scorings but show the same general upward trend (Figure 4, Table 6). Most 1993 satisfactory RACE ratings translated to a functional-at risk rating under PFC guidelines. Ratings from 2000 were scored simultaneously in the field using both methods. Segments that received RACE scores of 15 or 16 rated as PFC; segments with RACE scores less than 15 rated as FAR, with two exceptions. Segment 59K (PFC, RACE=12) had few middle-aged trees and recent bank disturbance. Empire Gulch 62D PFC rating was based largely on conditions below the headspring, while RACE scores integrated a longer reach (PFC, RACE=12). It is worth noting here that PFC methods are designed for assessments, not for monitoring (BLM 2003). These ratings are important because they tie directly to major BLM objectives. However, monitoring will be more informative for managers if it measures the more subtle or more quantitative changes in factors that prevent an area from reaching PFC.

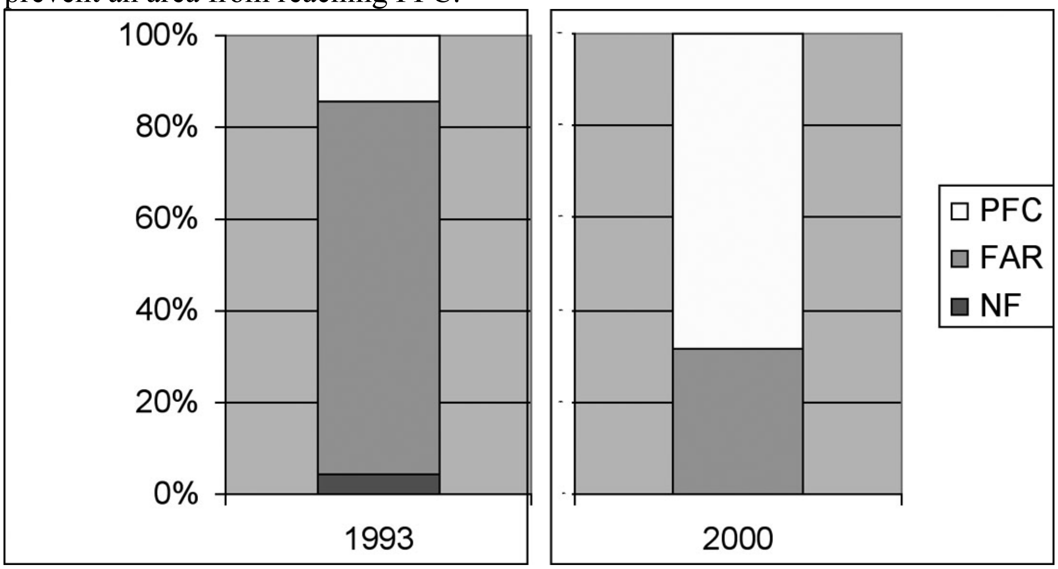

Figure 11. Changes in functional condition for Cienega Creek and wet tributaries, by percentage of stream miles. PFC: Proper Functioning Condition; FAR: Functioning-at Risk; NF: Non-functioning. 1993 ratings were derived from RACE inventory, ratings, and notes. 2000 ratings used standard PFC methods.

PFC assessment, Cienega Creek 2000														
Reach ID:	59AA	*59A*	*59B*	59C	59D	59E	59F	59G	*59H*	*59I*	59J	59K	59L	59M
Miles:	1.5	*0.3*	*0.3*	1.6	0.3	0.6	0.5	0.5	*1.0*	-	0.9	0.3	1.0	1.3
HYDROLOGIC														
1) Floodplain inundated in "relatively frequent" events *(1-3 years)*	y	y	y	y	y	**n**	y	y	y	**n**	y	y	y	y
2) Where beaver dams are present they are active & stable	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	na	N/A	N/A	N/A
3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)	p	b	**n**	y	y	**n**	y	y	y	y	y	y	y	y
4) Riparian zone is widening or has achieved potential extent	y	y	y	y	y	y	y	y	y	**n**	y	y	y	y
5) Upland watershed not contributing to riparian degradation	y	b	**n**	y	y	y	y	y	y	y	y	y	y	y
VEGETATIVE														
6) There is a diverse age-class distribution (recruitment for maintenance/recovery)	y	y	y	y	y	y	y	y	**n**	**n**	y	y	y	y
7) There is a diverse composition of vegetation (for maintenance/recovery)	y	y	y	y	y	y	y	y	y	y	y	y	y	y
8) Species present indicate maintenance of riparian soil moisture characteristics	y	y	y	y	y	y	y	y	y	y	y	y	y	y
9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events	y	y	y	y	y	b	y	y	y	y	y	y	y	y
10) Riparian plants exhibit high vigor	y	y	y	y	y	y	y	y	y	y	y	y	y	y
11) Adequate vegetative cover present to protect banks and dissipate energy during high flows	p	**n**	y	y	y	y	y	y	b	y	y	y	y	y
12) Plant communities in the riparian area are an adequate source of coarse and/or large woody debris (for maintenance or recovery)	p	y	y	y	y	y	y	y	y	y	y	y	y	y
SOILS-EROSION DEPOSITION	y	y	y	y	y	b	y	y	y	y	y	y	y	y
13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody debris) are adequate to dissipate energy	y	y	y	y	y	b	y	y	y	y	y	y	y	y
14) Point bars are revegetating with riparian-wetland vegetation	y	b	y	n/a	y	y	y	y	n/a	**n**	y	y	y	y
15) Lateral stream movement is associated with natural sinuosity	y	**n**	**n**	y	y	y	y	y	y	y	y	y	y	y
16) System is vertically stable	y	**n**	**n**	y	y	**n**	y	y	y	y	y	y	y	y
17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)	p	**n**	**n**	y	y	**n**	y	y	y	y	y	y	y	y
Summary Determination	PFC	*FAR*	*FAR*	PFC	PFC	FAR	PFC	PFC	*FAR*	*FAR*	PFC	PFC	PFC	PFC
Trend for Functional -- At Risk:	-	*Down*	*Up*	Up	Up	Up	Up	-	*Up*	*Up*	Up	Up	Up	Up
PFC: Proper Functioning Condition; FAR: Functional-at risk; NF: non-functioning; y: yes; n: no, p: partially; b: barely.														

Table 6. Proper Functioning Condition ratings for all wet Cienega Creek segments, 2000. Segments not in PFC are italicized. Specific contributors to low rankings are in bold. y: yes; n: no; p: partially, differs within reach; b: barely.

EMAP Western Wadeable Streams

The EPA collected EMAP data from the one site at Las Cienegas NCA too late to analyze and integrate this site into their western pilot project evaluation report and therefore did not comment on how the condition of this stream compares with others in the region.

We report summary comments and include rapid habitat assessment scores (Appendix B) to compare this methodology with those used by BLM at this same site. The General Assessment comment was "Cienega Creek lives up to its name—a series of cienegas separated by short glides and the occasional riffle. Vegetation is predominantly desert willow [SAGO] with the occasional mature cottonwood. Area is grazed, although riparian species and area do not seem to have suffered as badly as others we've visited…" On a scale from 0 (very poor) to 20 (optimal), this site scored an average of 10.1, the top end of "marginal." Bank features scored from 0 to 10 rated an average of 6.5, "sub-optimal."

Three factors seem to contribute to this "marginal" overall rating. Firstly, this site fell by chance within the NCA's only un-armored wet site that has active vehicle traffic through the creek (vehicles breaching the Narrows road closure). Moderately low bank stability and vegetative protection scores contrast with BLM's evaluations. The site sampled here may be an outlier for the stream as a whole, or this evaluation methodology may be more subjective than would be ideal (see Appendix A).

Secondly, the incision problem conditions mentioned are legacies of historic downcutting.

Perhaps most importantly, this nationwide assessment uses health criteria developed largely for higher-gradient riffle-based stream systems rather than for this region's unusual low-gradient cienega streams. Lack of large woody debris, abundance of fine sediments, and low sinuosity generally do reflect system impairment in other stream types (e.g. Kershner et al. 2004). Fine sediments are naturally abundant in cienegas (Henderson and Minckley 1984). The dispersed flow common in cienegas may absorb some of the power that creates meanders in other stream types.

This data may be useful for comparisons with future data from the same site, e.g. after installation of cobble and successful closure of this road.

Riparian target species studies

Gray hawks have nested on site for many years, with one nest documented in 1988 and 1991, and three pairs in 1999 (BLM 2002); no systematic surveys have been conducted since but the birds continue to be observed regularly. The gray hawk's typical requirements—tall cottonwoods along perennial streams for nesting, near woodland with dense canopy and open understory for foraging (Snyder and Snyder 2006)—are hard to come by in Arizona and are present here in abundance. A state-wide survey in 1987 identified 50 extant gray hawk nesting sites in Arizona (Glinski and Millsap 1987). If numbers remain this low in the region, LCNCA's ~3 nesting sites are neither trivial nor critical to the bird's survival. The importance of mesquite bosque to gray hawk foraging emphasizes the importance of making sure that bosques are not overly impacted by upland vegetation treatments.

Southwestern willow flycatchers appear to be rare in this area (USFWS 2002). A volunteer bird-banding project conducted from 1988 to 1993 captured migrant willow flycatchers in the agricultural field portion of Cienega Creek every year except 1991 but found none breeding. Consistent migrant bird surveys have not been run since. A flycatcher survey in 1994 found no birds. One occupied nest was found in 2001 near the confluence of Cienega Creek and Gardner Canyon. This single nest contrasts with some 300 territories reported along larger rivers in Arizona in the same general time period (Paradzick 2001). It is possible that this site will harbor more flycatchers in the future, but habitat may not be optimal for this species. A Southwestern willow flycatcher habitat inventory in 2000 identified four LCNCA stream miles as suitable habitat and 9.5 miles as potential habitat. BLM offered the following interpretation: "Much of the potential habitat consisted of relatively even-aged stands of willows that had matured to the point where they lacked sufficient density of understory vegetation. Some type of disturbance to open up these areas to new growth is probably needed to return them to suitable habitat, which is an earlier successional stage" (BLM 2002).

Huachuca water umbel is known from 27 sites in the US and Mexico and considered extant in 21 of these (USFWS 2002). Only a few small pockets of water umbel had been identified on the NCA when the RMP was published—along Empire Gulch near its confluence with Cienega Creek and at three patches along the main creek between Empire Gulch and Oak Tree Canyon. Since then we have documented the plant near the Headwaters of Cienega Creek just below the confluence with Gardner Canyon (a small patch in densely wooded marsh), and in large areas of the lower reach. Observations during other monitoring work revealed water umbel along some 5 km of creek bank, including dense lawn-like patches measuring over 100m long and 10m wide (June 2006 and 2007). The extent of these patches rivals or exceeds that described for any other sites (USFWS 2002). These large patches most likely represent population expansion since it is hard to imagine that knowledgeable individuals working along this creek overlooked such large patches in the past. Upper reach trends are unclear. The fact that we have not noticed water umbel in the Empire Gulch/Cienega confluence suggests that it may have declined in extent/abundance, but more formal surveys would be needed to make conclusive statements.

Huachuca water umbel is not a competitive dominant, but can recolonize areas quickly after disturbance as long as a refuge population remains and the habitat is favorable. According to the Las Cienegas RMP Biological Opinion, "Periodic disturbance opens these habitats up and allows recolonization or expansion of water umbel populations. Thus, occasional trampling by livestock, or periodic disturbance of bank and stream channels by livestock may mimic natural forms of disturbance that recreate early successional stages favorable for population expansion. However, continual or frequent disturbance, or severe damage to stream morphology, such as head cuts and downcutting would likely reduce populations or eliminate them from areas" (USFWS 2002). This seems to be the case at Las Cienegas NCA, where the most extensive patches are found in the northern segment of the creek that receives periodic winter grazing.

Yellow-billed cuckoos have experienced drastic population declines over the past 50 years, particularly west of the Rockies where the bird is considered by many to be a either a separate subspecies or a "distinct population segment." The USFWS concluded that western populations warranted Endangered Species protection but declined to list the bird because of higher priority listing actions at the time (USFWS 2001). Main causes of cuckoo decline are loss of riparian forest habitats from the familiar suite of impacts: agricultural and urban development, altered hydrology (dewatering, loss of natural flood regimes, etc.), stream channelization, impaired tree recruitment due to livestock or recreational impacts, and tamarisk invasion. The WYBC appears to still be declining across its range (Latta et al. 1999; Wiggins 2005), though Arizona appears to have more birds than other states.

Numerous cuckoo pairs have been found at Las Cienegas NCA and populations here may be increasing, though the trend is not significant with just three data points spread across four years. State-wide surveys in 1998 and 1999 found 14 and 12 pairs respectively, representing 19% and 7% of the total number found across the state in those years. A survey commissioned by the BLM in 2001 found approximately 23 pairs, using the same survey methods (Harris Environmental 2001). Unless these studies had unidentified biases, the data suggest that there were more cuckoos on Las Cienegas in 2001 than in previous years. Count differences could be explained by the fact that the 2001 survey used three visits to each site while the earlier surveys used just one pass at each site to enable coverage of more sites. However, even the least successful of these three passes reported 20 pairs of birds. The 2001 survey reportedly included 10 km of stream while the 1998 and 1999 surveys covered 15 km each, which would mean that cuckoo counts per km surveyed doubled in 2001. To interpret this difference, however, one would want to obtain maps of the area covered in 1998-1999, compare them with maps from 2001, and consider the possibility that only the highest-quality habitats were surveyed in 2001. Quite apart from lack of any statistical significance of year-to-year changes, we have not examined data from other sites on yearly variability in cuckoo numbers, so cannot comment on whether these differences are likely to represent a meaningful trend through time. More years of data would be extremely valuable for understanding cuckoo population dynamics on this site.

Descriptions of cuckoo habitat patches (occupied and unoccupied) provide an interesting snapshot of vegetation along the entire wet creek from 2001, though they did not show clear distinctions between vegetation characteristics of occupied versus unoccupied patches. Study authors noted that birds at this site "may be associated more often with [habitat] patches having vegetation in the >30 m layer and greater cover in the 0.25 m-2 m layer," but differences were minor and no statistical differences were reported. Apart from recognizing that cuckoos almost exclusively nest in mature riparian forests, there is no consensus on what specific attributes make a habitat patch suitable or ideal for cuckoos. Researchers of California birds, for example, consider riparian forest patches widths greater than 200m to be a key component of suitable habitat, patches 100 m to 200 m wide to be marginal habitat, and patches narrower than 100m to be unsuitable (Laymon 1998). Most LCNCA habitat patches were less than 40m wide. As far as we can tell, most of the riparian forest habitat at Las Cienegas NCA is suitable for cuckoo; existing studies have not revealed vegetation attribute preferences within these riparian forests that would call for quantitative vegetation objectives for the NCA.

Changes in Riparian Vegetation

Riparian forests have expanded considerably since 1989. Presence of multiple age classes demonstrates successful tree recruitment. There has, however, been a striking shift in species composition, with ash seedlings and saplings dominating many reaches. Species composition shifts towards ash and walnut have also been observed on the County Preserve (Julia Fonseca, pers. comm.. 2007). This shift probably reflects succession towards a climax community dominated by slower-growing shade tolerant species, associated with reduced disturbance from flooding, livestock, and/or fire. Drought conditions and declining water tables may also contribute to the shift. A few individual tamarisk trees are present on the NCA. Several attempts to remove them have kept them from spreading but have not succeeded in eliminating them. A number of juniper saplings have also grown up in the riparian zone; several of these have recently been cut down, probably by people who mistook them for tamarisk.

Stream cienega conditions are present in several areas, particularly the headwaters section (59M) and Coldwater Springs area (59G). These areas support large amounts of emergent aquatic vegetation around deep pools as well as broad patches of saturated soils. Tree cover is variable; large pools are often partially shaded by a few old cottonwoods away from pool edges. Some marshy expanses have been filled with dense stands of willow saplings that create a "wooded swamp" character.

Because herbaceous vegetation had no dedicated monitoring, we can offer only qualitative observations. Most herbaceous vegetation here is native, with bermuda grass and Johnson grass in some sites. Wetland obligates like rushes and *Equisetum* dominate banks in areas with perennial water. Intermittent stream segments 59L through J have more wetland obligates than I and H. Deergrass is common in the lower perennial reaches, growing up on banks in many areas and in the channel in some. Its dense hillocks create a narrow braided channel in places (parts of 59F, E). The increase in tree canopy, however, seems to be shading out some herbaceous vegetation, including deergrass. We present protocol options for measuring herbaceous vegetation in Appendix A.

Riparian tree density belt transects

At most matched plot sites, tree densities changed considerably from 1993 to 2006. All graphs below show density estimates that span the active floodplain, with transect lengths from 1993 used to calculate density in both years. Density within the narrower riparian forest band would therefore be higher than that shown in Figures 3-7. To facilitate comparisons with other studies, densities of trees within this narrower belt is presented in Table 7. The graphs below show data pooled into the three original size classes; Table 4 shows 2006 data with the original mature trees size class split into two.

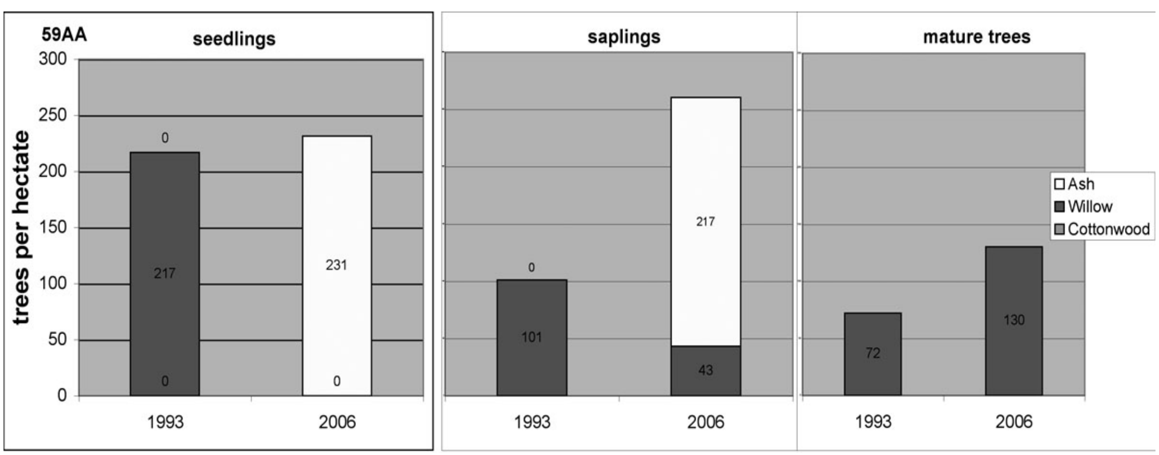

Figure 12. 59AA: This site is at the downstream end of LCNCA perennial flow and as such appears to be quite sensitive to drought effects. An abundance of dead willow trees in 2006 suggests that these trees grew up from seedling and sapling classes after 1993 and then died during drought years that led up to 2006. Tree recruitment remains good but has almost entirely shifted species composition.

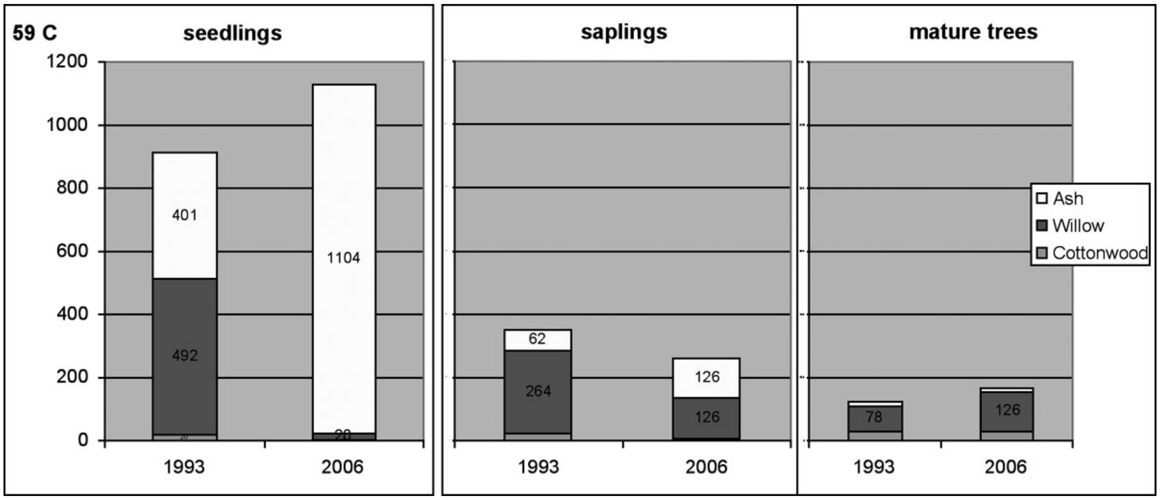

Figure 13. 59C: This site is in the perennial flow area of the lower reach near the Narrows road crossing. Recruitment of ash has increased while recruitment of willow has declined and cottonwood has ceased.

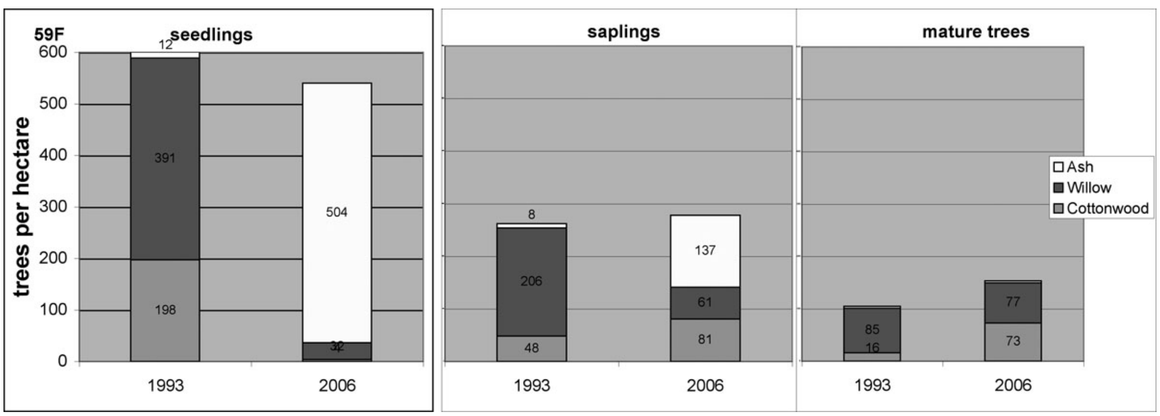

Figure 14. 59F: This site is in the perennial flow area of the lower reach near the Fresno Gap road crossing. As seen in other sites, recruitment of ash has increased while recruitment of willow and cottonwood have declined. Unlike other lower-reach sites, however, cottonwood saplings are still recruiting.

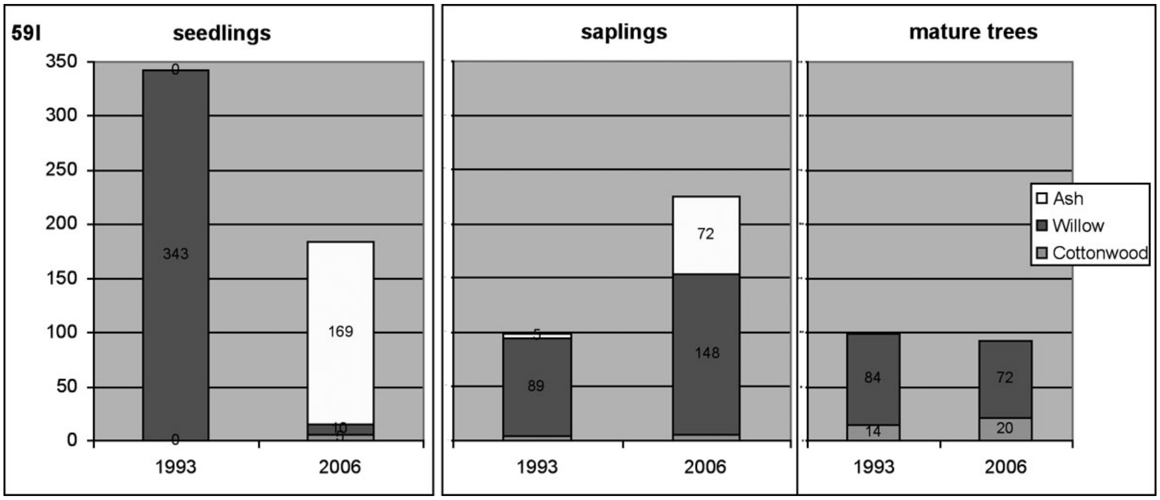

Figure 15. 59I: This site is in the intermittent flow area between upper and lower reaches, near the agricultural fields. Removal of a diversion above and impoundments below this site has changed its flow regime.

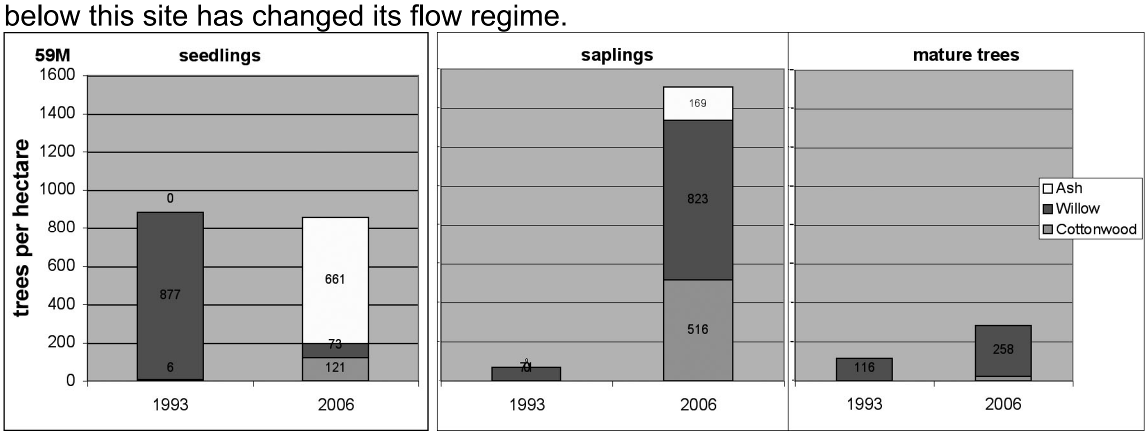

Figure 16. 59M: This is the only site surveyed in the perennial-flow area of the Headwaters reach. Sapling density in this reach now is extremely high, creating a "wooded swamp" character across the floodplain.

2006 tree densities		Seedlings < 1" diameter and < 6' tall			Saplings 1" to < 3"diameter ≥ 6' tall,			Mature trees 3" to < 20" diameter			Old trees ≥ 20" diameter		
stream reach		PO FR	SA GO	FR VE	PO FR	SA GO	FR VE	PO FR	SA GO	FR VE	PO FR	SA GO	FR VE
	Floodplain area, ha												
59AA	0.069	0	0	231	0	43	217	0	130	0	0	0	0
59C	0.245	4	20	1104	8	126	126	16	110	12	12	16	0
59F	0.248	4	32	504	81	61	137	56	73	4	16	4	0
59I	0.195	5	10	169	5	148	72	15	67	0	5	5	0
59K	0.282	57	121	493	394	309	64	21	85	0	53	0	0
59M	0.124	121	73	661	516	823	169	24	258	0	0	0	0
ALL	1.164	29	50	572	170	229	114	26	106	3	20	5	0
	Forested area, ha												
59AA	0.024	0	0	654	0	123	613	0	368	0	0	0	0
59C	0.110	9	46	2472	18	283	283	36	246	27	27	36	0
59F	0.091	11	88	1379	221	166	375	154	199	11	44	11	0

59I	0.050	20	40	662	20	582	281	60	261	0	20	20	0
59K	0.123	130	277	1134	905	709	147	49	196	0	122	0	0
59M	0.057	261	157	1428	1114	1776	366	52	557	0	0	0	0
ALL	0.455	75	128	1465	436	587	293	66	271	9	51	13	0

Table 7. Tree densities per hectare in 2006 by size/age class and species, calculated across entire floodplain (as shown in figures 3-7) and calculated only within the forested zone. POFR: Fremont cottonwood; SAGO: Goodding willow; FRVE: velvet ash.

The fact that transects differed in span (cutbank to cutbank in 1993, riparian forest width in 2006) complicated comparisons somewhat. Others have also found that observers tend to vary considerably in how they define riparian zones such as these (Archer et al. 2004). Future measurements should be more consistent, reduce effects of observer variability, and enable comparisons of riparian forest width as well as density. To these ends we suggest that belt transects be run from cutbank to cutbank perpendicular to the stream channel, and width of the riparian forest zone should be noted using four marks per transect: start and end of riparian canopy directly over the transect tape, and location along the tape of the first and last trunks within the belt. Adding three more notations—start and stop of the wetted channel and maximum stream depth along the transect—would add useful information with very little extra effort.

Repeat photography

Repeat photographs from many sites across Las Cienegas show dramatic increases in riparian forest (Figures 9 to 13). Some also show rapid changes in herbaceous vegetation and bank cover following fencing of the creek (Figure 9). Photos from driest reaches show relatively little change (Figure 14). In many sites, tree recruitment has made it difficult to see original photo landmarks and has shrunk the area visible from the original spot. BLM may want to add a few photopoints on higher ground that look down on the creek to get broader views with more distant landmarks.

Figure 17. Headwaters reach, 1989, 1993 and 1997. Cattle were excluded from this segment of the creek in 1995.

Figure 18. Empire Gulch road crossing, 1993 and 2006.

Figure 19. Headwaters reach, 1993 and 2006. This area has transformed into a wooded swamp and the original photopoint cannot be precisely located.

Figure 20. Fresno Gap (59F) 1993 and 2006. This spot was left as a cattle crossing lane when the reach was fenced.

Figure 21. 59D, segment with bedrock ledges, 1989, 1993, and 2006. Earliest photo was taken in winter, others in summer.

Figure 22. Agricultural fields reach, 1988, 1993, and 2006. Note little vegetation change apart from differences in season in which the images were taken and aging of the large cottonwood whose lower branches appear at the top of each photo. Trunk on the left-hand bank is a slow-growing ash tree.

Aerial photography

Comparing LCNCA's aerial photos shows riparian forests widening and extending farther and farther along the length of Cienega Creek from 1972 to 2002. We selected a few easily recognizable areas to compare visually, but did not obtain the 1935 images in time to include them here. Georeferencing the 1935-1995 images would enable one to quantify these changes in extent.

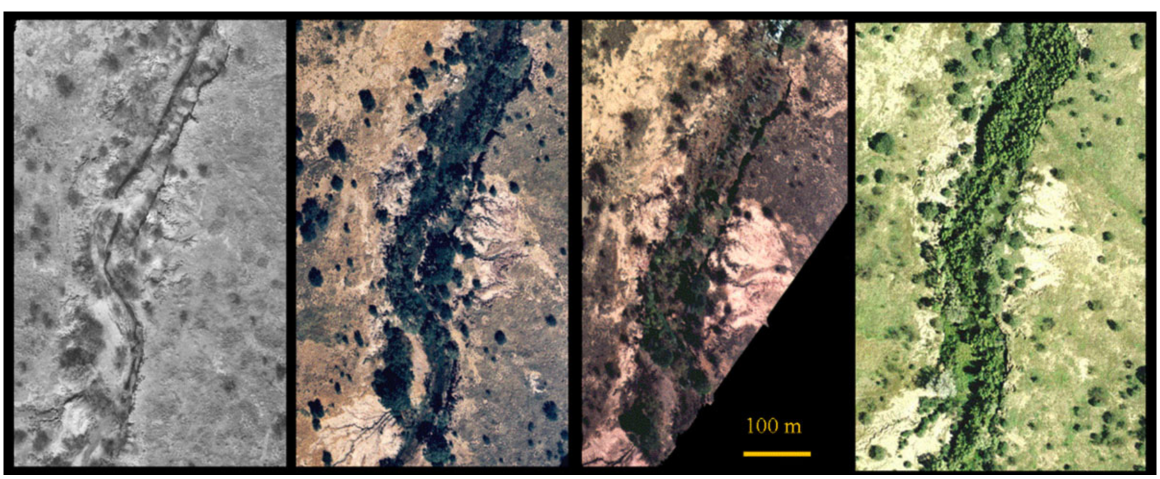

Figure 23. Aerial images of the Cienega Creek wet headwaters from 1972, 1988, 1995, and 2002 (left to right). Note changes in size and positions of riparian trees and changes in eroding terrace areas.

Vegetation mapping

Each of the six mapping efforts gives a somewhat different status picture of riparian vegetation on the NCA. Differences in methods between each of these studies make it impossible to derive quantitative trend information from them. All map images are included in Appendix D**.**

The most recent assessment, Southwest ReGAP, clearly misidentifies almost all riparian habitats as upland communities at Las Cienegas. Across the Southwest, its classification accuracy ranked low for riparian vegetation communities—18% to 30% according to map users and producers respectively (Lowry et al. 2007).

The AZGFD riparian classification succeeds in identifying most of Cienega Creek's perennial length in the NCA as having riparian vegetation of some sort, but misses riparian habitat near the headwaters and lumps much of the site's existing cottonwood-willow forest into a mesquite category. This pattern is consistent with data from the rest of the state showing this analysis to be reasonably accurate at identifying riparian vegetation in general but not at distinguishing between types, and omitting areas less than 60' wide (Kuby et al. 1997). Accuracy analyses estimated the percent of areas misclassified as riparian, but did not address how many riparian areas were missed entirely (assumed to be upland and therefore omitted) This dataset only mapped riparian vegetation in around streamlines that AZGFD had already identified as being perennial or nearly perennial (Valencia 1993). This permanence classification missed the headwaters reach of Cienega Creek, upper Empire Gulch, and Mattie Creek, so riparian vegetation was not examined in these areas. The AZGFD did some additional mapping along intermittent streams but we do not have that data.

The Arizona GAP classification (Halvorson et al. 2002) picks up more of the riparian habitats on the LCNCA than the AZG&F mapping does, including a large area of sacaton, but erroneously identifies some areas as agricultural. Low spatial resolution limits the value of this product for understanding change on this site. Southwest ReGAP classification accuracy ranked low for riparian vegetation communities—18% to 30% according to map users and producers respectively (Lowry et al. 2007). At Las Cienegas it misidentifies almost all riparian habitats as upland communities. All three map images for Las Cienegas are included as Appendix D**.**

Pima County's riparian classification gave results that most closely match our observations on the NCA, at least for cottonwood-willow forest. This study identified Upper Cienega Creek as hosting the largest area of cottonwood-willow forest in the county, with some 722 acres on the LCNCA—nearly one-forth of all the cottonwood-willow habitat found overall (Harris et al. 2000). This map identifies several areas of mesquite bosque that other maps do not recognize. It does not identify sacaton communities per se (a series within the warm-temperate semidesert grassland biome in the BLM system), but does delineate semidesert grassland in riparian corridors throughout the NCA.

BLM's vegetation community interpretation of their ecological site map shows "riparian vegetation" (Sonoran Riparian Deciduous Woodland dominated by cottonwood-willow, along with cienegas) in an arrangement very similar to the cottonwood-willow series mapped by the County. The ecological site map, however, shows this unit in a narrower strip along the creek channel, and omits some of the outlier patches identified by the County.

Existing vegetation classifications from remote sensing did not prove useful for detecting changes on Las Cienegas.

One of the challenges in mapping vegetation communities is what classification systems to use. Many agencies have agreed to use the National Vegetation Classification System (NVCS), though the system has not yet been fully fleshed out for some parts of the country including the Southwestern US (Grossman 1998, Drake et al. 2003). Other entities such as Pima County and AZGFD use the Brown, Lowe, and Pase system (BLP) which was developed first in the Southwestern US and expanded into other parts of the continent (Brown 1994, Brown et al. 1998). Comparing these classification systems is outside the scope of this report. Choice of system may not make a difference to practical site management, but managers should recognize that classifications created under one system may be difficult to compare with classifications based on the other.

From all of these mapping efforts, it appears that trying to map riparian and upland vegetation at the same time is very difficult for automated (computer) systems.

None of these efforts claim to have adequately mapped wetland areas with herbaceous vegetation.

Accurately mapping LCNCA wet-riparian vegetation should be more straightforward than the larger tasks attempted by the studies discussed above. Many of these other projects' classification problems center around distinguishing higher elevation intermittent-ephemeral riparian communities from their surrounding woodlands and forests, and on distinguishing low elevation ephemeral riparian shrub communities from their surrounding shrubby uplands. While the NCA has some of these hard-to-classify systems, the sites' main focus has been on mid-elevation wet-riparian systems, which stand out from their surroundings relatively clearly. Challenges will likely come in distinguishing mesquite bosques from mesquite uplands, sacaton flats from upland grass communities, and oak stringers from uplands.

Manually drawing vegetation polygons onto remote images is likely to be the most accurate and almost certainly the least expensive method for continued work at Las Cienegas. Choice of remote imagery will likely affect results, as will the classifier's local knowledge. Using DOQQ's as a base layer will probably be adequate, repeatable (the USGS is scheduled to create new imagery approximately every 10 years), and inexpensive (images available for the nominal cost of reproducing them). More detailed aerial photos can be layered onto DOQQs if they are available, to help the classifier refine polygon outlines and improve identification of species. Layering on LANDSAT or other remote images taken at different times of the year can help differentiate between mesquites and broadleaf trees that green up at different times. Seasonal images may be key to differentiating between sacaton flats and upland grass communities. Selecting images based on recent season's rainfall may help distinguish between areas in which sacaton plants still access groundwater and areas in which they are entirely dependent on rainfall. DOQQ's may not be very helpful for mapping herbaceous wetlands, but signals from other remote imagery (e.g. NDVI from Landsat images of an appropriate season) may show these distinct communities quite well.

These datasets do not provide clear trend information on extent and composition of LCNCA riparian habitats, but they do provide methods for generating such data. Differences in methods between each of these studies make it impossible to derive quantitative trend information from them. Automated classification schemes were designed in large part to enable people to calculate changes from one time period to the next. Automated methods, however, have turned out to be quite expensive and not very accurate (e.g. SW ReGAP), and even these incorporate quite a bit of human judgment. Perhaps a better approach for LCNCA would be to focus on manual polygon delineation methods but try to reduce or compensate for the fact that individuals interpret images differently. For example, the methods Harris et al. used on 1996 DOQQ's could be repeated on new DOQQ's. The person classifying new images could reclassify all the LCNCA early images to provide two sets of data created by the same person using the same methods, or could reclassify some subset of early images to provide a calibration factor for comparisons with the original classifier's work.

It is worth noting here that a consortium of federal agencies is developing standard sets of remote sensing and vegetation classification methods (USGS-NPS 2000); methods are being adopted and fleshed out by agency resource leads (e.g. Hansen et al. 2004, Donnely 2006). BLM field staff can also get technical assistance from the agency's Branch of Resource Technology (ST-134). BLM technical references on using ecological site inventory and aerial photography for riparian area management (Leonard et al. 1992, Clemmer 2001) include useful methods that could be incorporated into site-specific mapping.

If BLM decides to contract out production of riparian vegetation maps, two local studies may provide especially valuable guidance for defining the terms of such a contract. Drake et al. (2003) describe two methods for using remote images to classify vegetation at the Coronado National Memorial, with benefits, drawbacks and cost estimates for each. Harris et al. (2001) describes in detail the process by which they produced riparian maps for Pima County, including specifications for accuracy assessment. A key part of any contract should be information transfer, so that a wide range of BLM staff can use any products produced.

Trends and Changes in Channel Geomorphology

BLM's channel cross-sections show either stability (lower reach) or aggradation (upper reach) of the channel bottom. While aggradation in the headwaters segment (Figure 25) has positive effects in terms of bringing the stream closer to its original pre-downcut floodplain, it may temporarily exacerbate flow reductions. This section of the creek is entirely fed by groundwater for much of the year; surface water thus appears wherever the stream channel is lower than groundwater level. Aggradation can essentially bury surface flow whenever sediment is deposited faster than groundwater levels rise. This is presumed to be a temporary phenomenon lasting until groundwater recharge fills the new sediments and raises groundwater levels above the stream channel once again.

Aggradation in the headwaters flow area has combined with riparian vegetation growth to spread flow across the channel and expand marsh habitats. This accumulation of sediment and organic matter characterizes cienega systems (Hendrickson and Minckley 1984). If the channel stabilizes in this form, marsh expansion in the headwaters may continue. Headcuts in this channel, however, could drive this reach back towards a typical stream state (see state and transition model) or could dynamically re-create marsh at a different bed elevation as appears to be happening in a sediment-plug marsh on the Pima County Cienega Creek Preserve (PAG 2006).

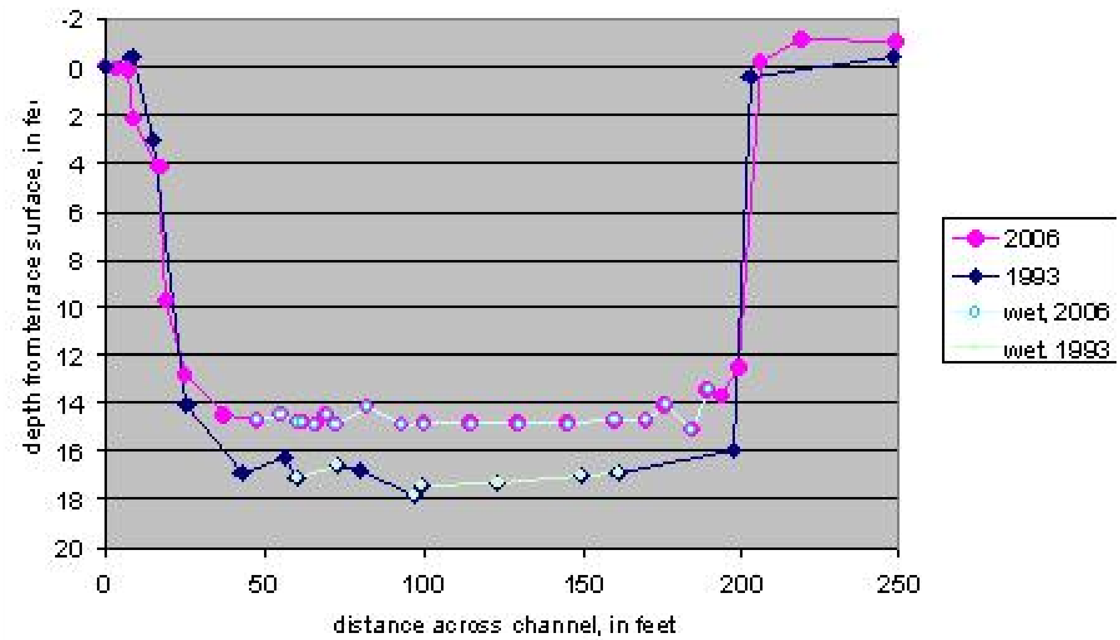

Figure 24. BLM Headwaters cross section (CC7). Note channel aggradation of approximately three feet, widening of wet zone and stable position and slope of cutbanks.

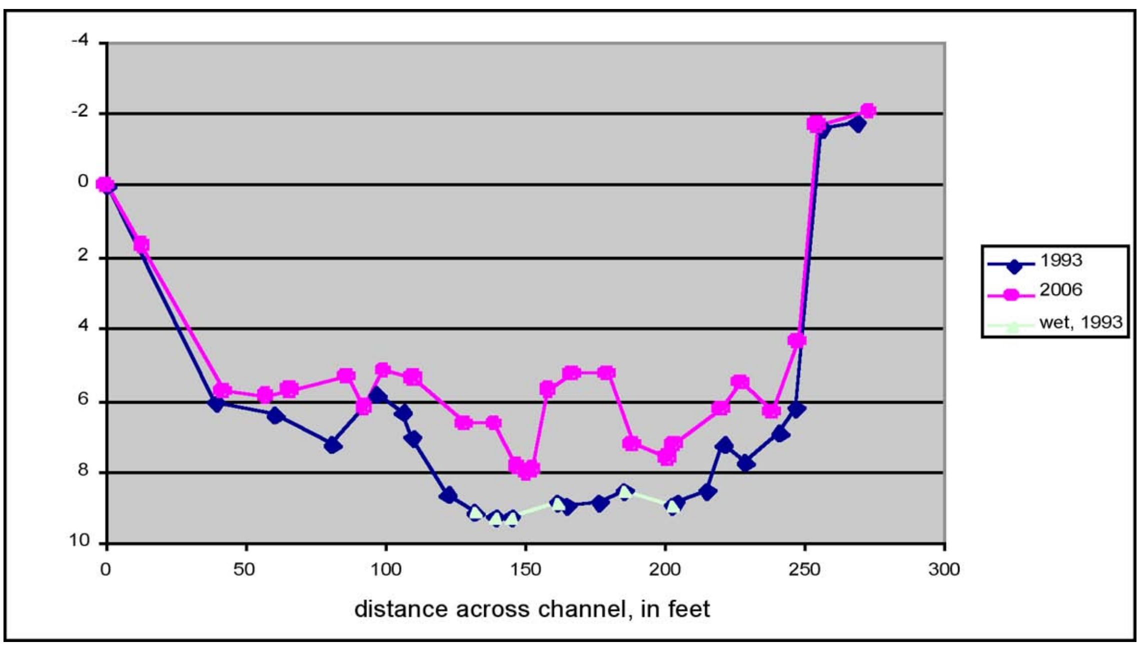

Figure 25. BLM cross section at Bahti's Bog (CC0). Note irregular channel aggradation from flood deposits, stable position and slope of cutbanks. Year-to-year alignment may

not be exact because western t-post was missing and (0) end point had to be reconstructed. There was no water in the channel when it was measured in 2006.

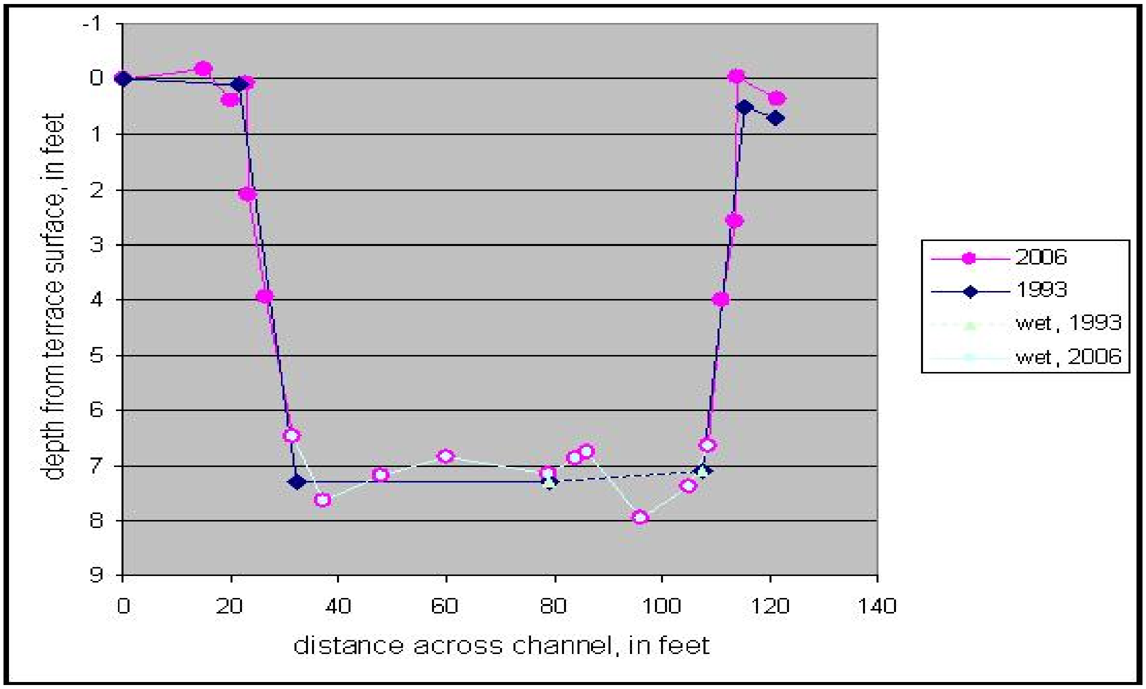

Figure 26. BLM cross section, lower Empire Gulch.

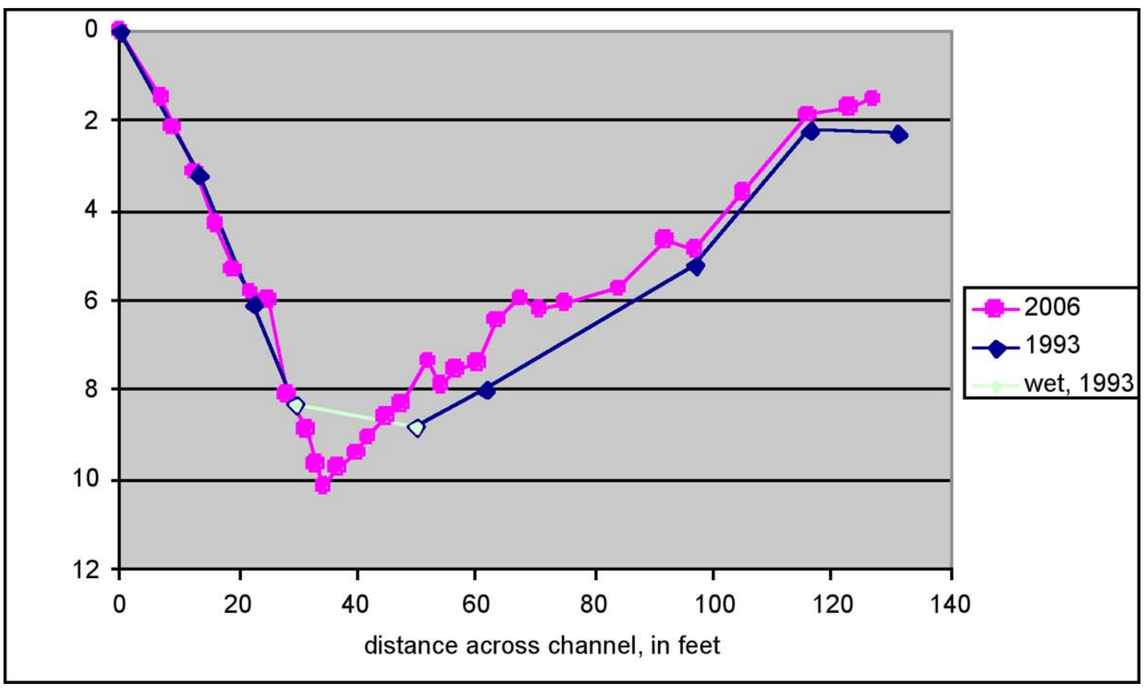

Figure 27. Agricultural fields cross-section #5.

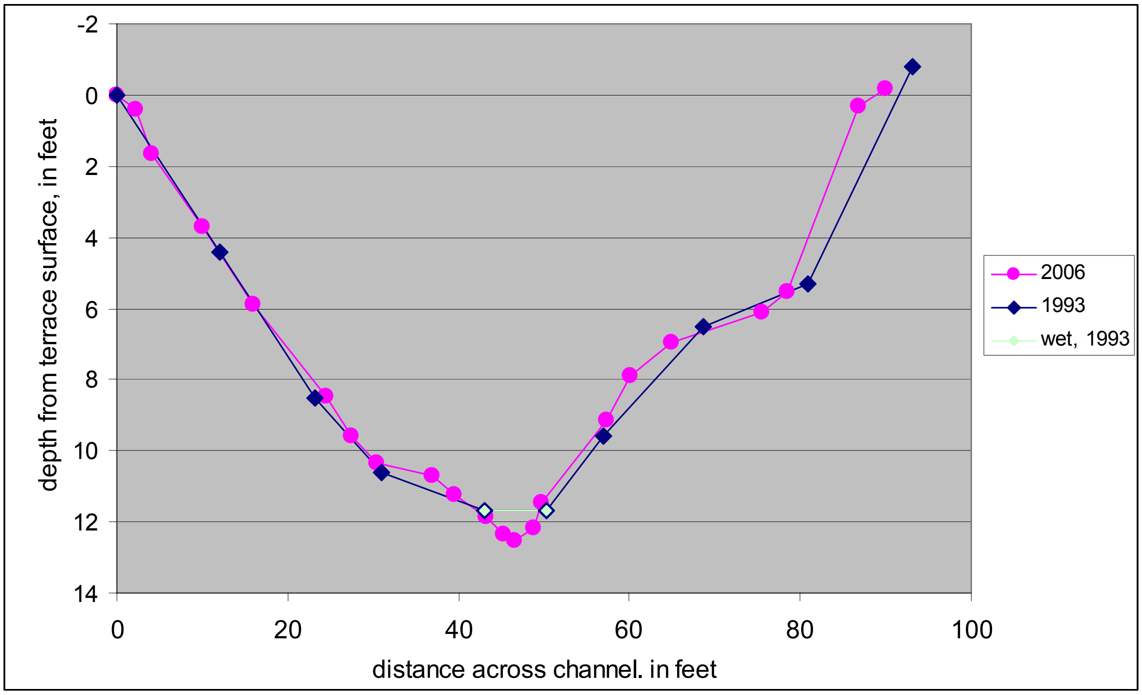

Figure 28. Agricultural fields cross-section #7.

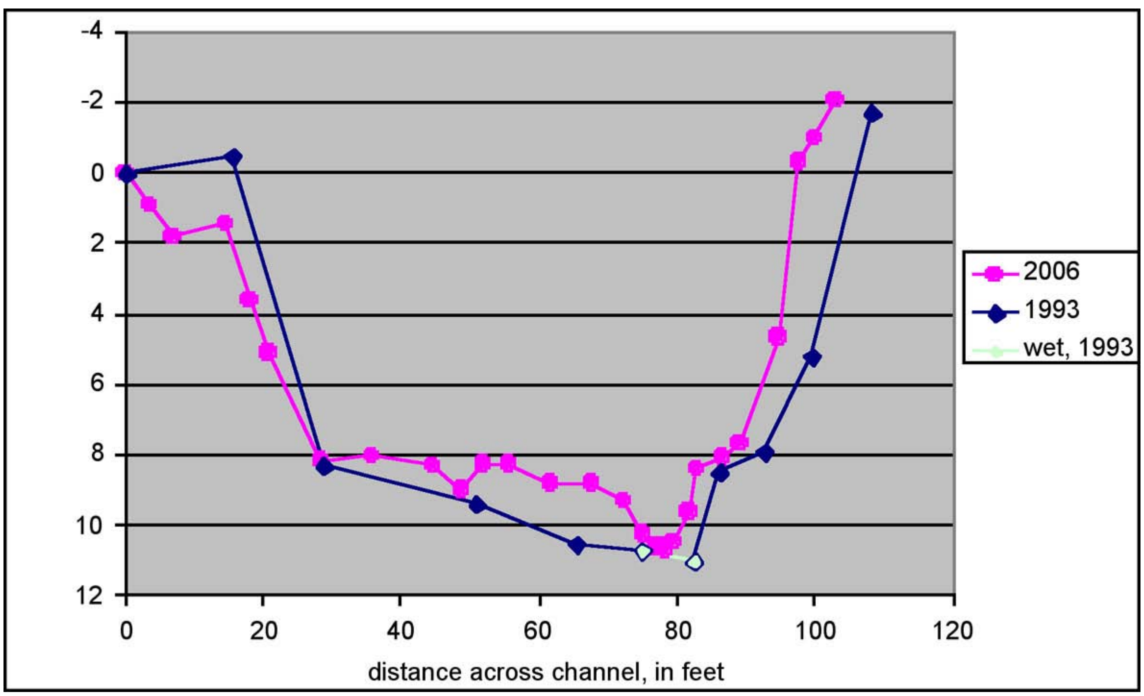

Figure 29. Agricultural fields cross-section #8.

ADEQ's longitudinal profile (Figure 31) shows how grades change throughout the LCNCA, though measurements are too widely spaced in the headwaters to be very informative there. They considered much of the creek to be at least somewhat sediment impaired. From the LCNCA creek length, Lawson and Huth chose an approximately 1.3km stretch (4440 linear feet of aquatic habitat) as a reference reach for the rest of Cienega Creek. The reach selected starts just downstream of Pump Canyon and runs to the Narrows road crossing. Pool facet slopes in the Las Cienegas "reference reach" were steeper on average than those in the County Preserve, and were more varied. Lawson and Huth set 15 degrees from horizontal as the breakpoint that separates sediment impaired lower basin creek from the reference reach. In the reference reach, 34.5% of pool slopes exceed this while in the County Preserve, only 3% do (a single headcut pool). This longitudinal data is available as a baseline for any longitudinal profiles BLM or others might chose to measure in the future.

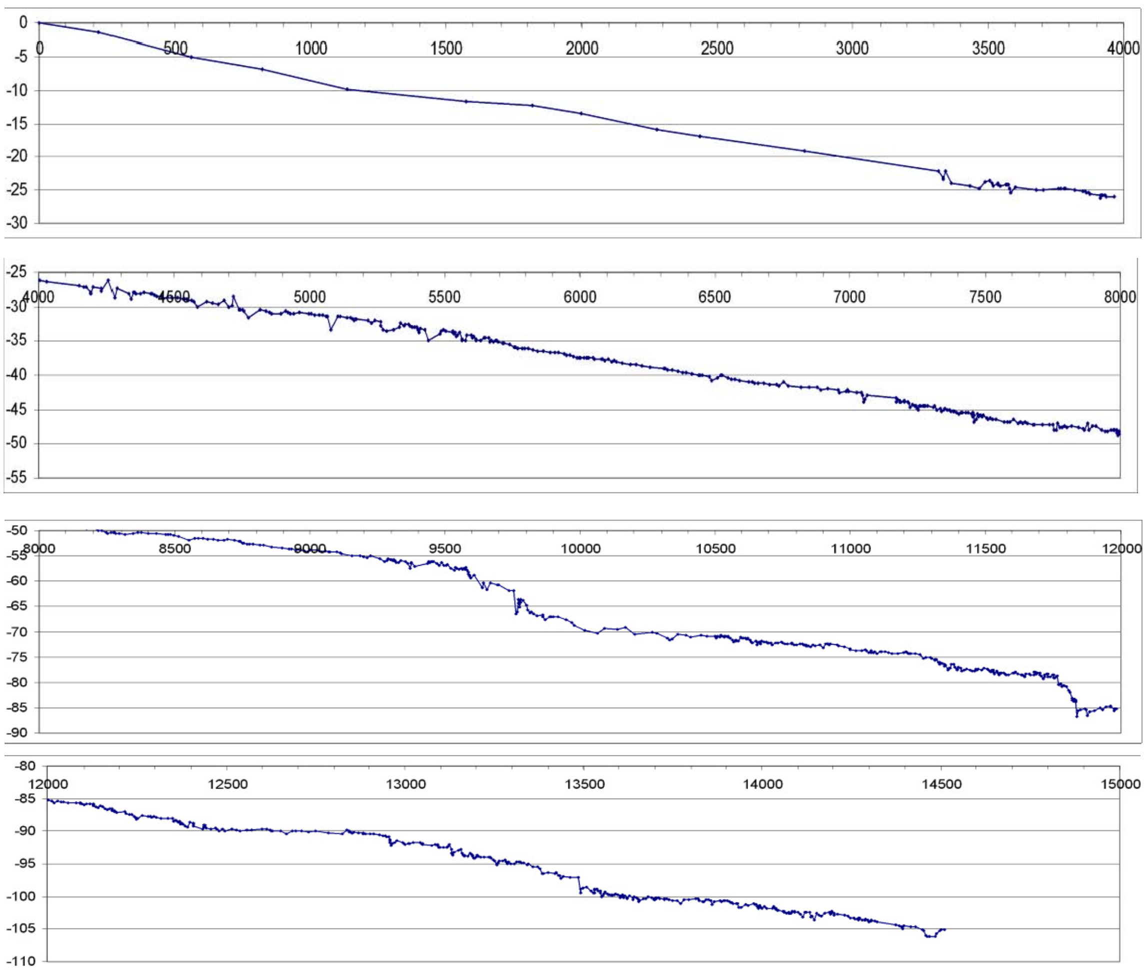

Figure 30. Longitudinal thalweg profile for Cienega Creek from the surface Headwaters to the Narrows. Data from Lawson and Huth (2003).

Bank Erosion Hazard Index scores were quite variable (Appendix C). Areas BLM generally considers to be in good shape rated as low erosion hazard overall (BEHI 4, 5; 59F,D). The bank rating at the Ag Fields restoration site rated as moderate (BEHI 3, 59H). The two readings taken in ephemeral banks (BEHI 10, 11 at 59O upstream from the headwaters flow) rated as high and extreme. The last extreme rating (BEHI 6, 59H) probably reflects erosion from the agricultural fields and/or one of the many sink holes that BLM has expressed concern over but has not yet been able to work at restoring.

Streambank soil alteration (Platts 1983) and streambank vegetative stability (Pfankuch 1975) ratings were more variable than we expected. We cannot tell from this data whether variations in bank stability/alteration ratings were due to real differences through time (i.e., ephemeral disturbances), real differences among reaches, or observer variability.

VITAL SIGNS AND NPS' INVENTORY AND MONITORING PROGRAM

To generate reliable data needed to manage and maintain critical resources, the National Park Service (NPS) established a nationwide Vital Signs Inventory and Monitoring Program composed of 32 park networks grouped by proximity and ecological similarity. The Sonoran Desert Network (SODN) includes national parks and monuments in the Sonoran Desert and the higher-elevation "sky island" region to the east where LCNCA is located. SODN is partnering with professionals from universities, agencies and non-profit organizations to expand its park ecological monitoring framework to other sites in the region and to assist with the development of statistically robust monitoring protocols. Thus, we are collaborating with SODN in our efforts to review, make recommendations, and assist BLM with the development of an ecosystem monitoring plan for LCNCA with the idea that the monitoring parameters and protocols we develop can be broadly applied to other sites (including NPS sites) that share ecosystems, target species, and stresses with LCNCA.

The monitoring plan described above for the aquatic habitat at LCNCA addresses a number of *vital signs* (and monitoring parameters) identified by SODN for their parks and monuments regionally. These include: *channel morphology* as well as some aspects of *vegetation community structure*, *exotic plants early detection* and *exotic plants status and trends*. Methods to track *groundwater dynamics* vital signs at Las Cienegas are still in development.

For the channel morphology vital sign, cross-sectional and longitudinal profile measurements, bedload pebble counts, bankfull estimates, bank erodibility hazard ratings, and other Rosgen channel analyses have all been used at Las Cienegas. Long-term channel morphology monitoring has focused on repeat measures of monumented cross sections and qualitative descriptions of substrate type and sediment supply. Width-depth ratios are measured during aquatic habitat monitoring and riparian tree density monitoring. LCNCA monitoring plans have not proposed schedules for repeat measurement of other parameters, but baseline data is available for comparison should managers choose to do so.

Conclusions

Condition of the riparian vegetation at Las Cienegas has improved dramatically under BLM management. Channel geomorphology appears to be stable in most areas, aggrading in marshy reaches, with only a couple of sites where channel erosion threatens riparian and aquatic resources. Conditions appear to be meeting most RMP objectives, though some are not being measured (herbaceous vegetation, shallow groundwater). Most driving processes seem to be within the bounds of natural historic variation, though continued lack of disturbance could eventually reduce habitat heterogeneity and cottonwood-willow recruitment. Differences in management across the creek are maintaining some habitat mosaic characteristics that seem to benefit different species in different patch types, e.g. Huachuca water umbel in the northern portion of the creek that receives some winter grazing. The system appears to be providing most of the key functions of a natural riparian system: transporting water and sediment, and providing for the needs of riparian-dependent native plant and animal species. Exotic plants and animals are a small portion of the community.

Riparian monitoring done at Las Cienegas between 1988 and 2005 utilizes many of the techniques/monitoring parameters spelled out in the Arizona Riparian-Wetland Area Management Strategy (BLM 1990): use of photo points to document changes in vegetation community and channel morphology, running transects to document changes in stream morphology, measuring utilization of key species by livestock and wildlife, and measuring riparian tree age class and composition. Data collection in 2006-2007 provided recent measurements of these parameters and added measurement of the three techniques/parameters included in the Strategy that had not been addressed previously: documenting vegetation species composition and diversity, documenting changes in riparian-area widths, and using aerial photography to document composition and extent of riparian areas. In this last case, photographs had been taken previously but not analyzed for riparian extent information. Modifications implemented in 2006-2007 also improved the riparian monitoring program's efficiency and effectiveness by better documenting location of measurement points, revealing opportunities for co-locating measurements, providing methods to reduce measurement error and interpersonal variation, and adding measurements that will enable results to be compared with those generated by other methodologies.

Appendix A evaluates several possible modifications to existing monitoring protocols. Results of this evaluation are summarized here; detailed protocols and criteria for comparing options are included in the appendix. Some aspects of riparian monitoring will benefit from minor changes, and some new protocols are needed. Firstly, riparian herbaceous objectives are not currently being measured. We propose using 1-m^2 quadrats to record species composition by cover class and to generate weighted wetland indicator scores along streambanks and out across riparian vegetation. These quadrats would be distributed along permanently-monumented transects that cross the stream and extend to both cutbanks. In reaches that are not defined by nearby cutbanks, these transects would run at least partway across the floodplain. Quadrats like these can show expansion or contraction of wet zones, changing water availability of sites as a whole, invasion by exotics or by plants typical of other communities, and response to disturbance (e.g. Stromberg et al. 2006).

Measuring the extent of riparian forest expansion could be done with low-tech spatial analysis of remote images that BLM already has or could easily acquire. Hand-drawing riparian forest polygons on aerial photos or DOQQs with one meter resolution will probably be less expensive and more accurate than using elaborate automated spectral classification on these or other images.

Original BLM cross-sections are concentrated in the headwaters and Ag fields areas. Managers and researchers have identified several areas that they feel are particularly vulnerable to particular impacts. Adding geomorphology measurements to some of these sensitive sites—and perhaps dropping a few of the sites that are close together—would give BLM and partners early warnings of problems as they develop, and would show which restoration efforts are being effective. Examples are terrace erosion and changes in bedrock controls near Wood Canyon, headcutting up Mattie Canyon, streambed disturbance by the Narrows road crossing, and sedimentation effects from Springwater, Gardner, and Mattie Canyons. The ADEQ study can provide baseline data from 2000-2001 for many of these sites.

Currently, monitoring locations for riparian vegetation, native fish, aquatic habitat, and floodplain geomorphology and associated photopoints are distributed up and down Cienega Creek. We propose consolidating many of these measurements into a single set of locations while maintaining the ability to compare past and future data. Co-locating measurements will reduce travel time, increase staff's ability to use volunteer teams to conduct measurements, and enhance the integration and interpretation of monitoring results (e.g. floodplain cross-section monitoring can be used to understand changes in riparian vegetation and native fish populations).

Because upland management actions can affect riparian function, the NCA's Adaptive Management program may benefit from having some riparian monitoring tied to upland events. The LCNCA vegetation treatment program, for example, is designed largely to improve watershed condition. It may be possible and desirable to track riparian responses to some of these treatments. For example, a burn conducted in the watershed of one of the creek's tributaries will likely contribute larger-than-normal amounts of ash and sediment to the creek shortly after the burn. If the burn achieves its goals of increasing grass cover, however, this increased cover should ultimately reduce the amount of sediment contributed by that tributary. These responses could be measured using channel cross-sections and longitudinal profiles in the affected tributary and/or in the main creek below the tributary's confluence. Unaffected tributaries could be measured simultaneously as untreated controls.

We propose a rotating annual schedule for implementing this suite of measurements over a five year period. BLM staff will need to evaluate the feasibility of this schedule, adapt it to fit their resource availability, and ensure that all required monitoring gets implemented and data gets evaluated on a timely basis.

Some follow-up work remains to be done on monitoring design, implementation, and use. co-locating measurements, verifying appropriate frame size and sample number for herbaceous vegetation measurements, linking riparian vegetation and channel morphology measurements to measurements of hydrologic and aquatic parameters, and identifying information needs for additional monitoring or research.

Appendix A does not address new mapping and/or monitoring protocols for sacaton flats or mesquite bosque. Given the key role sacaton flats play on the NCA and how vulnerable they are to erosion and dewatering, a status and trends assessment focused specifically on these floodplain grass stands would provide managers an extremely valuable tool for mitigating impacts and prioritizing restoration work. Identifying stands that tap into riparian groundwater would also be important for understanding the creek's water budget (e.g. Scott et al. 2006). Ground mapping like that done on the Research Ranch and scoring stands for vigor and degradation would lay the foundation for detecting changes and planning restoration. Up-to-date condition maps would also enable fire planners to address mesquite incursions into some stands, as a transition to bosque or as shrub encroachment.

Additional effort to identify mesquite stands that were, are now, or could become riparian mesquite bosques would enable upland mechanical shrub control projects to avoid inadvertently removing or fragmenting these groundwater-dependent stands, and would enable fire planners to consider bosque dynamics explicitly. Documenting stand properties of mesquites that tap into riparian groundwater would also be important for understanding the creek's water budget (e.g. Scott et al. 2006).

Finally, the data being collected at Las Cienegas is clearly useful in documenting status and trends of the resource, but has not been used actively, consistently, and explicitly in making management decisions. We propose conducting some riparian monitoring before and after prescribed burns and evaluating this data along with fire effectiveness measures, Other BLM and stakeholders would be well served to identify additional opportunities to feed riparian monitoring information into the agency's decision-making process.

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Appendix A. Monitoring Protocol Review for Riparian Cottonwood-Willow and Cienega Vegetation and Channel Morphology

A primary goal of this work was to identify possible monitoring program modifications that would make the program more informative and more efficient. We found several opportunities to tie monitoring more directly to BLM objectives, track changes relevant to ecological thresholds that were identified by state and transition models, reduce sampling error, and better inform management decisions.

Monitoring protocols

Ideal protocols for this program would:

1.a. measure conditions or attributes that are directly related to BLM objectives *or*

b. measure conditions or attributes that reflect the same processes/gradients that BLM objectives are designed to represent;

2. be consistently usable by people with relatively little botany or survey experience (with training and supervision as needed);
3. return reliable information with low inter-observer variation;
4. be relevant to a wide range of conditions, so that large vegetation changes do not invalidate the method or make results impossible to compare between years;
5. be sensitive to effects of key stressors;
6. generate data that help us understand effects of management decisions;
7. enable assessment of riparian system status and trends within the context of ecological models;
8. and, if possible, use well-established, off-the-shelf methods.

Riparian herbaceous vegetation

There are currently no protocols in place that address the RMP's herbaceous plant objectives. We tested several approaches including riparian community zonation transects and greenline surveys (Winward 2000), a variety of plot-based measurements (Elzinga et al. 1998), and some protocols that combine plot and patch-based methods (e.g. Briggs et al. 2003; Stromberg 1998).

The method that best met our criteria involves setting out permanently monumented transects across the active floodplains, spacing quadrats along the transect and estimating herbaceous plant cover classes by species in each quadrat. The program would benefit from a bit more verification of appropriate quadrat size and sample sizes but the following protocol details seem well suited to the stream system and the RMP objectives.

Quadrats ($1m^2$) would be spaced at predetermined intervals along the tape (e.g. every 5 meters starting at each streambank, or every 5 meters from a permanent marker point). Additional quadrats would be placed along the stream bank on either side of the transect;

our test transects used three on each bank. Wetland indicator scores (and/or percent cover of hydric versus mesic or xeric species) can then be computed for each quadrat, averaged across the entire transect or portions of the transect, and/or averaged among quadrats of the same placement (distance along the transect, distance from active channel edge, etc.) on several transects. Where possible, vegetation transects would be co-located with channel cross-sections. Sets of woody species belt transects could be run along the same transect line and then continue up or downstream. Timing, frequency, and co-location with other measurements are discussed below.

Measuring BLM herbaceous objectives directly (criterion 1a) proved difficult but this method satisfies 1b. When delineating patches in the field, we could not consistently differentiate between “upper bank” and “lower bank” plant communities specified by the RMP objectives. These “upper bank” and “lower bank” categories were designed to represent a gradient of water availability conditions. Plant cover objectives for each of these categories reflects a desire to have native obligate-wetland/hydric plants dominate on the wet end of the gradient and to have native facultative-wetland/mesic plants come in as the terrain gets slightly drier. Setting out vegetation plots along transects that extend out from the creek channel gets at this same water-availability gradient; wetland indicator scores show plant response to the gradient (e.g. Stromberg et al. 2006). If mean scores are plotted against distance from the stream edge, this method should pick up on shifts in the soil moisture gradient, i.e. expansion or contraction of wet zones, or drying of sites as a whole.

Criteria (2) and (3) steered us away from other methods that rely on delineating patches or classifying community types. We found the types of zonations created by depth-to-water and flood disturbance gradients to be less obvious here than on other streams we have worked on (e.g. the San Pedro River, Arivaipa, Bass, Hotsprings, Sonoita creeks). Part of this difficulty may stem from the site’s heterogeneous mix of marsh, forest, and floodplain within relatively narrow confines. The site’s channel morphology may play a role as well—downcut with few point-bars, low sinuosity but with streambanks stable enough to create deep slot pools. Regardless of the reasons, zonation ambiguities would make it difficult for different surveyors to yield consistent results. Coles-Ritchie et al. (2004) found that even well-trained observers were quite variable in classifying community types when measuring vegetation cross-sections. Spacing quadrats along the transect enables species composition to speak for itself. Observers could, of course, still comment on distribution of vegetation zones. Using permanently monumented transects also reduces considerable observer variability in judging where riparian zones end (Coles-Ritchie et al. 2004).

In some parts of Las Cienegas, vegetation had changed so much between 1993 and 2006 that we at first questioned whether we were on the same transects where the early vegetation cross-section data had been collected. Collecting cover data by species again ensures that criterion (4) is met by recording whatever mix of species is present rather than trying to rely on assemblage definitions that may obscure composition changes or may not accommodate the magnitude of changes brought by time, disturbance, climate change, or other factors. Running transects across the active flood plain (truncated in wide sacaton flats if need be) ensures that major width changes would be detected.

We expect this method to be especially sensitive to key riparian stressors of groundwater and surface water depletion (criterion 5). Wetland indicator scores were developed specifically to reflect differences in water availability patterns, and should therefore be sensitive to changes in how water spreads across the channel or changes in depth-to-groundwater profiles across the creek. Stromberg et al. (2006) found pre-monsoon streamside wetland indicator scores to be significantly and highly correlated with streamflow permanence on the San Pedro river (more so than measures taken at other times of year). Species composition and absolute cover may vary with other factors such as tree canopy cover. Using wetland indicator and/or hydric to mesic cover ratios may enable us to tease out these effects from water stressors. The fact that San Pedro fires did not seem to affect these composite scores (Stromberg et al. 2006) is encouraging in this regard. Including piezometers on some of these transects would help verify and calibrate these relationships.

To be most effective at tracking effects of management changes (criterion 6), transects would be co-located with other factors of interest, e.g. some in livestock crossing lanes, some near tributaries dumping sediment, some at fish count sites, etc. If transects are read on five-year rotations, a subset of transects should be measured every year to pick up on natural cycles such as floods and to enable managers to investigate effects of specific actions such as fires in tributary watersheds.

This data fits directly with the ecological model presented above. Break points in streamside hydric herb cover values and other bioindicator variables collected one valley east of Cienega Creek helped define the "functioning condition classes" used in our model. Exact break points between classes may be slightly different here than on the San Pedro, but we expect the concept to transfer easily. Monitoring data from Las Cienegas could be used to refine condition class thresholds for this site, especially if piezometer were installed at some of these transects.

Finally, the various components of this method are all well tested and widely used (Atkinson et al. 1993; Coles-Ritchie et al. 2004; Kershner et al. 2004; Stromberg et al. 1996, 2006; Ervin et al. 2006).

Cottonwood-willow forest

The modified belt transect protocols tested in 2006 worked quite well according to all these critera and could be further improved with a few small changes/clarifications. Spanning the width of the floodplain enables comparisons with early data, captures the entire area with riparian forest potential, and in most cases provides clear endpoints (cutbanks). Recording the distance at which tree canopy and tree stems begin and end enables analysis of densities within the current riparian forest zone, which is much more comparable to other vegetation density measures and to species' habitat models than the whole-floodplain density is. This measure also enables us to track changes in width of the riparian forest zone through time. Recording other riparian trees (e.g. walnut, hackberry, tamarisk) will enable this protocol to document changes in tree species composition. Adding a size category for dead trees will capture important forest changes. Counting large trees between transects will improve the method's power to detect changes in this size class without adding much time to data collection, as was done for the Muleshoe (Brunson et al. 2001). The five reaches measured in 2006 should be adequate to describe trends throughout the creek and satisfy the RMP's requirements. If BLM has interest in knowing trends in other areas, locating the first or last transect at one of the RACE segment endpoints and tracking distance between transects will enable new data to be compared with baseline data taken from the same locations. It is worth noting here that using volunteers to measure belt transects worked very well; relatively little botanical expertise is required, and measurements are straightforward.

Canopy cover

The RMP does not have specific canopy cover objectives for riparian trees or shrubs, but these appear to be important for riparian species (fish, migratory and nesting birds, etc.). Overstory canopy cover may also prove to have a large influence on understory composition; being able to tease these factors apart would greatly improve BLM's understanding of dynamics of herbaceous targets like deergrass. Deergrass (*Muhlenbergia rigens*) appears to be declining along many segments of creek bank, especially where tree canopy cover is dense. As the riparian forest expands, lower bank zones may move farther and farther from meeting the "dominated by deergrass" objective. Additional research may be required to reveal the conditions under which deergrass can be expected to dominate a streambank, and to determine whether other plant species can serve the same bank stabilizing function as deergrass under these other conditions (see below).

Visual estimates of canopy cover tend to be quite variable among observers (Coles-Ritchie et a. 2004). Spherical densiometers provide much more consistent measurements in just a few minutes. EPA manuals spell out densitometer canopy measurement protocols in detail (EPA 2004). The National Park Service uses densitometer canopy measurements on stream banks. One set of streambank canopy measurements may be sufficient in this small stream system, or BLM may want to measure canopy cover on additional transect points such as the edge of the riparian tree zone.

Measuring canopy cover at different heights can take considerably longer that single overstory measurements, but vegetation structure within riparian forests is important to many target species such as flycatchers and cuckoos. Habitat measurements taken during species-specific surveys may or may not be sufficient to meet BLM's information needs on forest structure.

Other considerations for vegetation protocols and objectives

Herbaceous RMP objectives may need to be revised or clarified in order to link directly with monitoring protocols and to reflect changing understandings of the creek system itself. In addition to being difficult to identify consistently in the field, "upper bank" and "lower bank" categories are somewhat circular. If observers base their on-the-ground zonation categorizations on plant species present, comparing species lists from each zone with the RMP objectives is not particularly informative. The existing upper and lower bank objectives have quantitative elements as well; <20% of the total plant cover should be non-target plants. To replace these, one could specify minimum wetland indicator scores or percent cover of hydric herbs, at specified elevational height above groundwater.

In addition to being mostly obligate wetland species, lower bank target species represent plants whose roots are known to be particularly effective at holding soil and therefore capable of buffering the impacts of bank stability stressors (e.g. Cornwall 1998). Adding streamside herbaceous plots gets at the bank vegetative cover objectives (criterion 1a). However, our observation that herbaceous bank cover appears to decline as tree canopy cover increases on this narrow stream adds a twist measuring the intent of the objective. Willow roots may hold banks just as well as rushes do, but stabilizing roots are more difficult to quantify than herbaceous cover.

Many of the depth-to-water relationships and wetland indicator variables in our state and transition model are taken from work done on the San Pedro River. We expect plants just one valley over to have similar relationships, but factors such as soil differences and shading from cutbanks could change them somewhat. An ongoing study of the habitat and hydrology changes around a headcut on Lower Cienega Creek (PAG 2007) could help test species' depth-to-water relationships functional condition classes for this stream as a whole, including the Pima County preserve.

Channel morphology

The current protocol focuses on measuring cross-sections. These are good for documenting gross channel changes such as downcutting or aggradation but are not designed to reveal more subtle changes. Adding short longitudinal thalweg profiles at these same sites would enable BLM to track changes in sediment deposition patterns. Thalweg profiles are also a more appropriate tool for tracking movement (or stability) of a head-cut. Because most of the effort involved in measuring channel cross-sections is travel time and equipment setup, running longitudinal profiles at the same locations would require relatively little additional effort except in wooded thicket areas. However, channel changes may be more homogeneous in such thickets than in other areas, so thalweg profiles may not be necessary in these difficult-to-implement areas. Longitudinal profiles can also provide the same pool depth data that BLM's aquatic habitat protocols measure and could therefore replace some aquatic habitat protocols or simply supplement these other measures.

Practitioners use different minimum length for thalweg profiles depending on the purpose of measurements and on traditions established within the agency or other group; most are scaled to the wetted width of the stream. EPA work typically uses reach lengths of approximately 40-times the stream width or 150 meters, whichever is larger (Peck et al. 2006). California restoration projects examining effects of a structure placed in the channel typically measure thalweg profiles for lengths 20-times width both above and below the structure (Flosi et al. 2002). Protocols typically used by the USFS and BLM measure reach lengths that are at least 20-times bankful stream width (Harrelson et al. 1994; Archer et al. 2004). Cienega Creek's mean wetted width is approximately three meters, which would give a minimum length of some 120 meters using the 40-times width rule. Surveying 120 to 150 meters of thalwag in a stream such as this could generally be completed within a half hour.

Original BLM cross-sections are concentrated in the headwaters and Ag fields areas. Managers and researchers have identified several areas that they feel are particularly vulnerable to particular impacts. Adding geomorphology measurements to some of these sensitive sites—and perhaps dropping a few of the sites that are close together—would give BLM and partners early warnings of problems as they develop, and would show which restoration efforts are being effective. Examples are terrace erosion and changes in bedrock controls near Wood Canyon, headcutting up Mattie Canyon, streambed disturbance by the Narrows road crossing, and sedimentation effects from Springwater, Gardner, and Mattie Canyons. The ADEQ study can provide baseline data from 2000-2001 for many of these sites.

Stream bank stability

Streambank soil alteration (Platts 1983) and streambank vegetative stability (Pfankuch 1975) ratings were more variable than we expected. We cannot tell from this data whether variations in bank stability/alteration ratings were due to real differences through time (i.e., ephemeral disturbances), real differences among reaches, or observer variability. This uncertainty argues for using more explicit and more repeatable measurement techniques for these parameters. Both estimate the percent of streambank that is impacted in some way, and use this percentage to rate a reach on a scale of one to four (excellent to poor). However, neither original source specifies how to measure the percent values. Platts et al. (1987) do note that averaging bank alteration percent scores from discrete cross-section points yielded less observer variability than visually integrating percent along a transect. At a minimum, BLM would be well served to define the bank stability and alteration protocols they use in more detail, and consider taking these readings at discrete points (e.g. with sampling units spaced along a bank transect or at cross-section points) rather than visually integrating ratings along a bank reach. Also, stability ratings are likely to drop temporarily with disturbances (grazing, floods) but may recover quickly. If banks show low stability during or immediately after a disturbance, they should be measured again to evaluate recovery, and each measurement should be accompanied by notes about the apparent timing and extent of any recent disturbances.

Two other suites of bank stability measures have come into common use and provide alternatives for BLM. One set of explicit methods involves setting out a 30 cm rectangular frame along the bank edge; percent stability is the proportion of these frames in which the bank is not fractured or slumping (see Kershner et al. 2004 and Heitke et al. 2006 for method details). This method integrates bank stability with vegetation cover by using categories such as "covered and stable," "uncovered and stable (vulnerable), and "uncovered and unstable," with "covered" defined as having at least 50% of the frame held by perennial vegetation, roots, rocks, or logs. A detailed key and diagrams help standardize ratings for each plot. Testers of this method found it showed fairly low inter-observer variability, especially when percent counts are lumped into the Pfankuch categories (Archer et al. 2004). Power analysis suggests that this is quite an efficient measure. To detect changes of 5% through time or differences of 5% between locations, one would need just 18 bank stability plots in each sampling period (using different sampling crews) or 20 in each sampling reach (using the same sampling crew; Type I error of 0.1, Type II error of 0.1, based on averages and variability of stability counts in the PIBO monitoring region). However, the fact that average bank stability in this study was high (averaging between 74% and 90% in various subgroups) suggests that the measure may not be very sensitive to disturbances.

Other commonly used bank stability measures include Near Bank Stress and Bank Erosion Potential (Rosgen 1996, 2001). The EPA's Watershed Assessment of River Stability & Sediment Supply (WARSSS) program has explicit protocol descriptions (www.epa.gov/WARSSS/pla/box07) and other resources. EPA has concluded that these measures do provide reliable and repeatable indices of bank condition and implement them across the nation. Some work, however, has found them to be poor predictors of subsequent bank erosion over the short term (Harmel et al. 1999). EPA Rapid Habitat Assessments forego these methods in favor of bank stability and vegetative protection ratings similar to those currently used by BLM (USEPA 2004). We did not find studies evaluating the repeatability of these Rapid Assessment methods.

Aerial photography and other remote sensing

Aerial photographs offer an opportunity to go back in time and make comparisons that one didn't have the time or foresight to measure at the time. The value of these datasets is not fully revealed until they are analyzed. Many Landsat images are available free of charge. Pima Association of Governments and Pima County organize collection of high-resolution aerial images and can add areas at much lower costs than would be required to contract flights independently; 2008 images are priced at approximately $160 per section. The LCNCA riparian corridor would encompass approximately 10 sections. BLM may want to consider contracting some acquisition and/or analysis of remote imagery, but will want to make sure that any contracts include adequate technology transfer so that BLM staff can manipulate data and interpret results.

Soil piping

No protocols have been implemented to track changes in soil piping or measure progress towards relevant RMP objectives. Remote sensing methods could be useful tools for this problem. High resolution aerial images show the extent of these eroding areas quite clearly. Landsat greenness measures such as NDVI might reveal effects of these eroding areas on productivity of surrounding vegetation, or show where plants are beginning to colonize and stabilize these areas. LIDAR images might be especially well suited to documenting changes in elevation (deepening of channels and subsidence around sink-holes), given typical LIDAR horizontal resolution of ~1 meter and vertical resolution of 15 cm.

Shallow groundwater measurements

Direct measurements of depth to shallow groundwater along the creek would add a lot to our understanding of this creek's dynamics, and would provide support for water rights claims (e.g. PAG 2003). BLM had a handful of piezometers installed along the Ag fields but these have not been read for several years and may not be functional anymore. BLM may be able to partner with researchers, volunteers, and water managers to install more piezometers and record water levels without adding to existing staff obligations.

Timing and placement of measurements

Traveling to field sites and finding plot markers often takes more time than taking actual measurements. Co-locating a variety of measurements can make monitoring more efficient and more informative. Measuring vegetation at cross-section sites may explain why the site experienced aggradation, for example, which may explain changes in fish densities in the nearest pool. Some of the original BLM channel cross-section sites will make ideal co-location sites for vegetation and other measurements. Number and placement of additional sites has not yet been determined, but will likely include the five stream segments for which tree densities have been measured repeatedly.

The RMP calls for several of the channel morphology and vegetation measurements to be done every five years. This schedule has not been followed, largely because staff can rarely make time to perform extensive sets of measurements. Setting up a yearly rotation of sites might solve this problem. BLM could choose to rotate measurements of co-located parameters so that approximately one-fifth are done each year, for a five-year rotation that covers all sites without requiring a large effort in any one year. A yearly rotation would also enable managers to better match system responses with the timing of management actions or disturbance events such as floods or fires.

Opportunities for management response

Because upland management actions can affect riparian function, the NCA's Adaptive Management program may benefit from having some riparian monitoring tied to upland events. The LCNCA vegetation treatment program, for example, is designed largely to improve watershed condition. It may be possible and desirable to track riparian responses to some of these treatments. For example, a burn conducted in the watershed of one of the creek's tributaries may contribute larger-than-normal amounts of ash and sediment to the creek shortly after the burn. If the burn achieves its goals of increasing grass cover, however, this increased cover should ultimately reduce the amount of sediment contributed by that tributary. These responses could be measured using channel cross-sections and longitudinal profiles in the affected tributary and/or in the main creek below the tributary's confluence. Unaffected tributaries could be measured simultaneously as untreated controls.