Silverbell Road (North) Wildlife Linkage Initial Assessment: Ina Road to El Camino del Cerro Road, Pima County, Arizona

Prepared for

Kittelson & Associates, Inc.

For Submittal to

Town of Marana
Pima County Department of Transportation

Prepared by

SWCA Environmental Consultants

February 2010

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1.0INTRODUCTION

Habitat fragmentation has been targeted as one of the most serious threats to biodiversity worldwide (Wilcox and Murphy 1985; Saunders et al. 1991). Fragmentation typically leads to the isolation of populations, thus creating local subpopulations scattered across a landscape (Dobson et al. 1999). Isolation of these subpopulations may lead to local extinctions in that, over time, populations restricted to isolated patches may experience a reduction in genetic diversity due to increased inbreeding, increased risk of local extinction due to population dynamics and catastrophic events, and decreased ability to recolonize (Yanes et al. 1995; Hanski and Simberloff 1997; Hanski 1999). Landscapes that become fragmented often lack heterogeneity as well as pose specific threats to population viability (Noss and Cooperrider 1994). Additional impacts that typically result from fragmentation include the direct loss of habitat, fragmentation effects, and edge effects (Murcia 1995). Fragmentation effects include changes in community structure, function, and composition. Edge effects include increased light, noise, and chemical pollution; microclimate alteration; non-native species invasion; and increased disturbance and increased mortality through direct interaction with humans. Studies in highly fragmented landscapes of southern California have documented the impacts on populations of birds (Bolger et al. 1997; Scott and Cooper 1999), herpetofauna (Boarman and Sazaki 1996; Fisher and Case 2000), and mammals (Beier 1993, 1995; Crooks and Soulé 1999; Haas 2000; Lyren 2001; Lyren et al. 2005).

One of the principal factors contributing to habitat fragmentation has been the construction of roadways (Meffe et al. 1997). Roadways may impact wildlife in a variety of ways (see review in Ouren and Haas, in press); they have been identified as threats to the long-term persistence of rare and threatened species, including grizzly bears (Gibeau and Herrero 1998; Servheen et al. 1998), black bears (Brody and Pelton 1989), gray wolves (Paquet and Callahan 1996), Florida panthers (Foster and Humphrey 1995; Land and Lotz 1996), mountain lions (Beier 1996), lynx (Ruediger 1998), ocelots (Tewes and Blanton 1998), snakes (Rudolph et al. 1998), and desert tortoises (Boarman and Sazaki 1996). Not only do these roadways separate previously connected areas of habitat; they also create a barrier effect for organisms attempting to move between patches (Yanes et al. 1995). In addition, increasing highway mortality also plays a role in eliminating more individuals from a population (Harris and Gallagher 1989).

To counteract the negative impact of roadways on wildlife movement, different types of mitigation techniques have been identified to maintain connectivity while providing safety to the traveling public by reducing the threat of wildlife-vehicle collisions (Huijser et al. 2007). These techniques have ranged from methods used to influence driver behavior (e.g., road warning signs, animal detection systems), influence animal behavior (e.g., deer reflectors and mirrors, olfactory repellants), and physically separating wildlife from roadways. The latter provides the safest means (for both drivers and wildlife) of increasing driver safety while simultaneously maintaining the safe passage of wildlife across roadways. Specifically, the role of underpasses as an alternative route to surface crossings have received increasing attention (Mansergh and Scotts 1989; Foster and Humphrey 1995; Yanes et al. 1995; Rodriguez et al. 1996; Clevenger and Waltho 2000; Haas 2000), and in urbanizing areas there has been an increasing amount of research devoted to determining the usefulness of

underpasses for large carnivores (Haas 2000; Lyren 2001; Ng et al. 2004; Lyren et al. 2005; Haas and Crooks, in prep.). Furthermore, the positioning of these structures relative to developed areas within the surrounding landscape has been identified as factoring into the probability that various wildlife species will utilize such structures, thus maximizing their functionality for multiple wildlife species (Haas and Crooks, in prep.).

The proposed widening of Silverbell Road within the jurisdiction of the Town of Marana and Pima County, a Regional Transportation Authority (RTA) funded roadway project, provides an excellent opportunity to identify, monitor, and plan wildlife linkages as they relate to transportation projects. Identifying critical locations that could provide for the successful movement of wildlife across roads presents a unique opportunity to incorporate mitigation opportunities that promote the safe passage of wildlife across roadways in this project's design/construction phase.

2.0FOCAL SPECIES

For any linkage analysis, it is important to identify a suite of species on which recommendations will be focused, as the concept of focal species in reserve design and wildlife connectivity is a central theme in local and regional conservation planning (Miller et al. 1998; Soulé and Terborgh 1999). Focal species are typically identified to symbolize ecological conditions that are critical to healthy, functioning ecosystems (Lambeck 1997); however, species with special status designation have also been identified. Our initial group of focal species included federal- and state-listed species, as well as Priority Vulnerable Species (PVS) identified in Pima County's Sonoran Desert Conservation Plan (SDCP; Pima County 2006), a Multi-Species Conservation Plan (MSCP). According to the SDCP (Pima County 2006) and Mapguide Geographic Information System (GIS) utility (Pima County 2009), the project area falls within or adjacent to a PCA for the following ten PVS: lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), Huachuca water umbel (*Lilaeopsis schaffneriana* ssp. *recurva*), listed as Endangered by the USFWS; northern mexican gartersnake (*Thamnophis eques megalops*), listed as Candidate by the USFWS; cactus ferruginous pygmy-owl (CFPO; *Glaucidium cactorum brasilianum*), lowland leopard frog (*Rana yavapaiensis*), California leaf-nosed bat (*Macrotus californicus*), and western burrowing owl (*Athene cunicularia hypugaea*), each listed as Wildlife of Special Concern by the State of Arizona (WSCA) and Species of Concern (SC) by the USFWS; giant spotted whiptail (*Aspidoscelis burti stictogrammus*), listed as SC by the USFWS; and Abert's towhee (*Pipilo aberti*) and desert box turtle (*Terrapene ornata luteola*), both listed as PVS within the MSCP.

For this assessment, SWCA Environmental Consultants (SWCA) determined whether any of the PVS may occur in the project area or whether they have the potential to use this area for daily or seasonal movements. Though many of the PCAs fell within the project area, it was determined that none of the species are expected to occur there. And due to the lack of agaves and few saguaros, it is expected that foraging habitat is not present for the lesser long-nosed bat. The Huachuca water umbel, lowland leopard frog, Mexican garter snake, and giant spotted whiptail are not expected to occur in the project area due to the ephemeral nature of the Santa Cruz at the point in which it flows through the project area. However, it is possible that these three species could temporarily move through this portion of the Santa Cruz River as individuals of the species disperse and travel between preferred habitats. Similarly, although it is not expected that the burrowing owl or CFPO would occur in the project area, it is possible that individuals of the two species could disperse across this portion of Silverbell Road in search of preferred habitats to the north, south, west, and east. It is unknown whether the desert box turtle, Abert's towhee, and California leaf-nosed bat may occur in the project area.

Additional species identified as target species for the Saguaro-Tortolita Linkage include bobcat, cave myotis, javelina, kit fox, mountain lion, mule deer, pocketed free-tailed bat, and Sonoran desert tortoise. Black bear and mountain lion may use this area very infrequently, and their movements would likely be attributed to dispersal events. The Santa Cruz River represents the most likely location along this stretch of road where crossings could occur, since it is a large natural feature that could provide for long, linear movements by these

species. The bobcat, javelina, kit fox, mule deer, Sonoran desert tortoise, cave myotis, and pocketed free-tailed bat all have the potential to travel and forage throughout this area.

For this linkage analysis, the bobcat was selected as the target species. Mammalian carnivores can be effective focal species to evaluate the degree of landscape-level connectivity or fragmentation, in a region. Large carnivores are particularly vulnerable to extinction in fragmented habitats because of wide ranges and resource requirements, low densities, slow population growth rates, long range dispersal, and direct persecution by humans (Noss et al. 1996; Woodroffe and Ginsberg 1998; Crooks 2000), and their disappearance may generate cascades that ripple down the food web (Crooks and Soulé 1999; Henke and Bryant 1999; Estes et al. 2001; Ripple et al. 2001). In fragmented habitats in San Diego, Crooks and Soulé (1999) suggest that extirpation of dominant predators (e.g., coyotes) can contribute to ecological release of smaller predators and increased extinction rates of their avian prey. Large carnivores (e.g., bobcat) therefore are ecologically pivotal organisms whose status can indicate functional connectivity of ecosystems, and using mammalian carnivores in conservation planning adds a critical layer of conservation strategy that may provide a robust method for protecting other species that have less demanding needs (Lambeck 1997; Miller et al. 1998; Carroll et al. 1999).

Smaller-bodied herpetofauna and small mammal species were also identified as a focal species group, primarily due to the need to appropriately space underpasses to ensure that populations have the ability to successfully navigate across a landscape bisected by large impediments to species movement such as Silverbell Road.

2.1 FOCAL SPECIES A: BOBCAT

Bobcats are less sensitive to fragmentation and have smaller dispersal distances and home ranges (see Lyren 2001:Table 1.11; Riley et al. 2003) than mountain lions. Bobcats therefore can persist in smaller habitat fragments, but, like mountain lions, only those that have adequate connections to larger natural areas. Consequently, bobcats are valuable indicators of connectivity at smaller, more local, spatial scales in developing landscapes, which is typical of the landscape surrounding this stretch of Silverbell Road. Alternatively, bobcats are more sensitive to fragmentation than coyotes (Crooks and Soule 1999; Haas 2000; Ng et al. 2004), so designing and placing crossing structures directed at facilitating bobcat movement will also accommodate the safe passage of coyotes, another top predator common throughout this linkage area. Bobcats will thus serve as a surrogate species to successfully provide corridors for movement for other species (e.g., javelina).

2.2 FOCAL SPECIES B: HERPETOFAUNA AND SMALL MAMMAL SPECIES

Few studies have looked at the requirements needed to mitigate the negative effects of roadways for lizards and snakes within the Sonoran desert (AGFD 2006a). This group represents a specific challenge in the Sonoran Desert Arizona Upland landscape because they are slow moving and physiologically attracted to road surfaces for thermoregulation and foraging (AGFD 2006a). Two studies in southern Arizona (Rosen and Lowe 1994; Kline and Swann 1999) have documented many reptile and amphibian vehicle-collision mortalities on

repeated transects and have extrapolated estimates to surrounding areas. Rosen and Lowe (1994) conducted roadkill surveys throughout Organ Pipe Cactus National Monument and comparison sites away from the highway. The authors concluded that Highway 85, which bisects the National Monument, substantially effected the regional snake population with vehicle collisions accounting for 2,000 to 4,000 estimated mortalities over four years. Kline and Swann (1998) conducted multi-species roadkill surveys in Saguaro National Park (East and West units) and similarly estimated several thousand vertebrates killed annually as a result of traffic. The impacts of these mortalities vary between species and undoubtedly have a more dramatic effect on the long-lived and slowly reproducing individuals (e.g., desert tortoise, and Gila monster). Species such as the spadefoot toads have abbreviated, yet explosive reproductive episodes (strongly associated with monsoons) and populations may withstand high mortality episodes during such events (Kline and Swann 1998).

3.0OBJECTIVES

The objective of this analysis is to utilize wildlife distribution and movement data, evaluate adjacent land uses and proposed development zones, and document existing and potential crossing locations for wildlife connectivity-associated mitigation measures, in order to maintain and enhance the movement of wildlife across Silverbell Road. Regional transportation planning efforts seek to develop infrastructure that meets the expected increase in travel capacity while maintaining the safe passage of wildlife across roadways. Therefore, recognizing opportunities to maintain or increase the rate of wildlife movement across roads while increasing driver safety, as well as identifying those locations where such measures can be addressed, is paramount in achieving a regional transportation system that seeks to reduce the impacts of roadways on wildlife.

This study would serve as the first step in a series of proposed analyses that seek to address minimizing the impacts of transportation systems on wildlife connectivity from several perspectives: 1) identifying short-term strategies and techniques to minimize road impacts on wildlife; 2) incorporating site assessment recommendations into the early design phases of the project; 3) collecting animal-vehicle collision (AVC) data along various roadways to identify stretches of road that pose significant threats to wildlife and driver safety; 4) monitoring successful crossing attempts for multiple species through various methods to refine mitigation locations and recommendations, and prioritizing road segments that may be subjected to future wildlife connectivity-related mitigation measures; 5) developing significance thresholds and post-construction monitoring to ensure that recommended mitigation measures are maintaining successful passage of wildlife across roads over time; and 6) coordinating with town and county departments and other municipalities to incorporate mitigation measures into local planning efforts to ensure the long-term functionality of wildlife connectivity mitigation investments.

These objectives complement each other in a variety of ways. First, by conducting roadway assessments along stretches of road slated for improvements, we can identify existing and potential locations that, from an engineering perspective, represent optimal locations to construct appropriate crossing structures for various wildlife species. This report summarizes the methods and results from this step of the larger study design presented above. Secondly, by collecting several types of data (including AVC, underpass use, and activity along roadways), we can refine recommendations and test how various stretches of road compare to each other with regard to their ecological significance (as determined by what species may be impacted by future transportation projects), their current rate of wildlife crossing activity (as determined by monitoring existing rates of crossing activity), and their risk to drivers and wildlife (as determined by the rate of AVCs along that stretch of road). In addition, ensuring that recommended mitigation measures are adequate in maintaining the successful passage of wildlife across roads is a critical step in the long-term functionality of wildlife movement across the region. By determining various significance criteria before project construction begins, a benchmark by which to gauge the success of mitigation measures can be established, thus creating an adaptive management process that will not only ensure the long-term success of that particular mitigation measure, but serve as a reference from which future mitigation strategies can be based.

This report summarizes initial efforts to develop a list of species that have the potential to be impacted by this roadway widening project, characterize existing crossing locations, and identify potential mitigation opportunities. To meet these goals, the following steps were taken: 1) conducting an investigation of previous studies and databases that could provide information regarding the species that are either present within these linkages or that have the potential to use these linkages; 2) determining the locations of potential crossing zones; 3) conducting a thorough field analysis of existing and potential wildlife crossing zones for the aforementioned stretch of Silverbell Road; and 4) prioritizing crossing locations and developing potential mitigation measures.

4.0STUDY AREA AND ROAD EVALUATION METHODOLOGY

4.1 STUDY AREA

The section of roadway being evaluated as a potential Wildlife Linkage for this report is the segment of Silverbell Road from Ina Road to El Camino del Cerro Road (project area), within the town of Marana and Pima County, Arizona (Figure 4-1). This segment of Silverbell Road runs parallel to Interstate 10 (I-10) and the Union Pacific Railroad, which are both approximately 1 mile to the east, and adjacent to the Santa Cruz River and various residential and commercial areas starting north at Ina Road and running south to El Camino del Cerro Road (Figure 4-2).

This portion of Silverbell Road lies between the Tucson Mountains and Saguaro National Park West to the west, the Tortolita Mountains to the north, and the Santa Cruz River to the east (and farther to the east lies the Santa Catalina Mountains). Therefore, this linkage may act as both a critical east-west and north-south connection for wide-ranging animals moving between these areas and mountain ranges, particularly because this portion of Silverbell Road includes the Santa Cruz River (including being directly west of the point at which the Rillito River empties into the Santa Cruz), known to be a major movement corridor for numerous species. The primary goal for this linkage is to maintain this connection for the various wildlife species that are known or thought to move through this area, including bobcat (*Lynx rufus*), coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), javelina (*Tayassu tajacu*), raccoon (*Procyon lotor*), and Sonoran desert tortoise (*Gopherus agassizii*); as well as smaller-bodied mammalian (including bats), herpetofauna, and avifauna species (Arizona Wildlife Linkages Workgroup 2006). Other large-ranging species, such as mountain lion (*Puma concolor*), may occasionally use this area during long-distance movements from surrounding mountain ranges.

The portion of the Santa Cruz River that passes adjacent to and through the project area may provide a significant movement corridor for large and medium-sized species such as mountain lion, bobcat, coyote, mule deer, and javelina. These species may either travel large distances between the surrounding areas and mountain ranges or may simply travel shorter distances between various areas surrounding the town of Marana and Pima County as part of their daily movement patterns. Some of the smaller drainages that pass through the project area may also provide movement corridors for various animals, including numerous species of lizards, snakes, and rodents; coyotes, javelina, and bobcats; and bird species that typically walk rather than fly, such as roadrunners (*Geococcyx californianus*) and Gambel's quail (*Callipepla gambelii*).

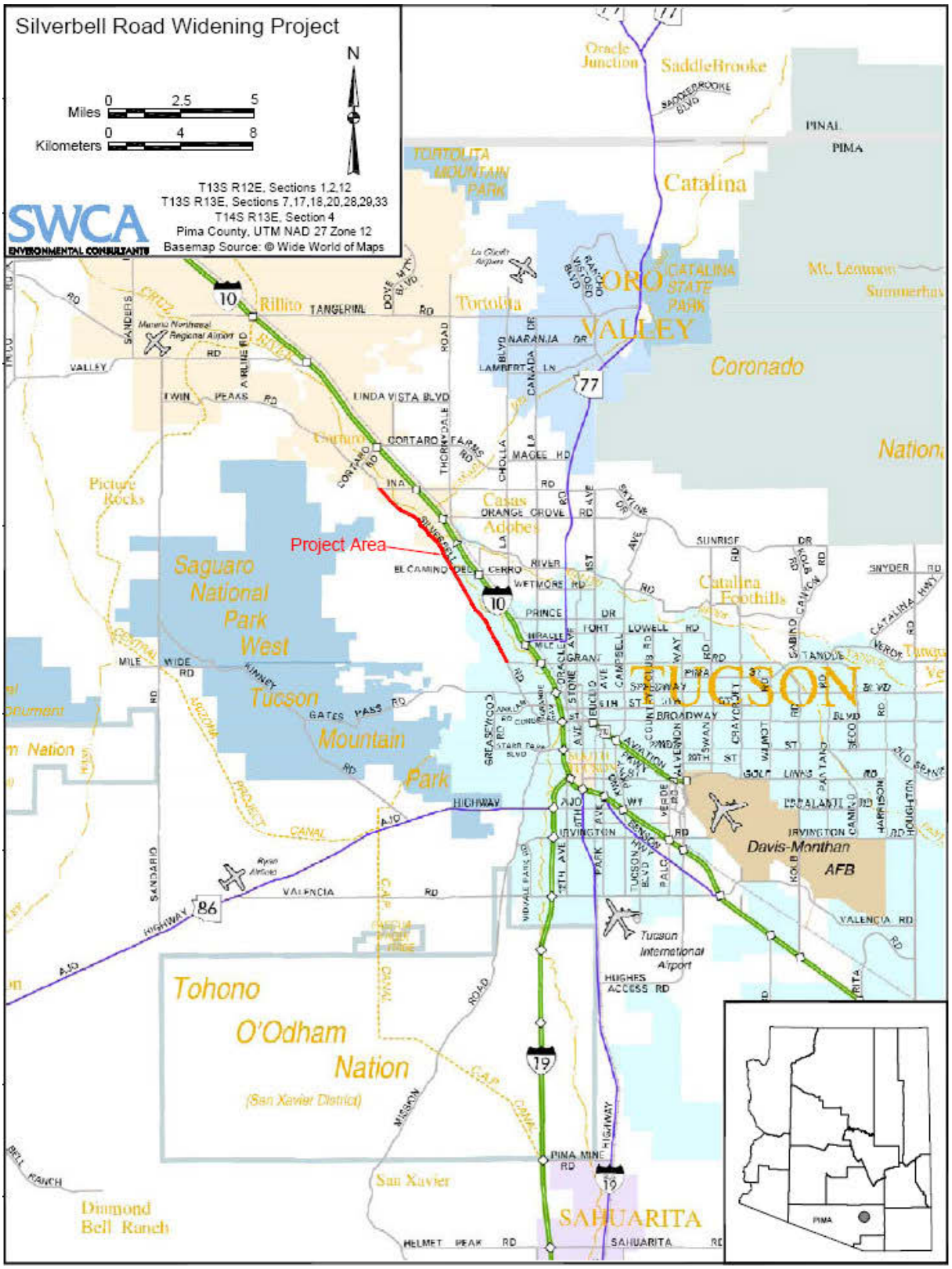

Figure 4-1. Project location map.

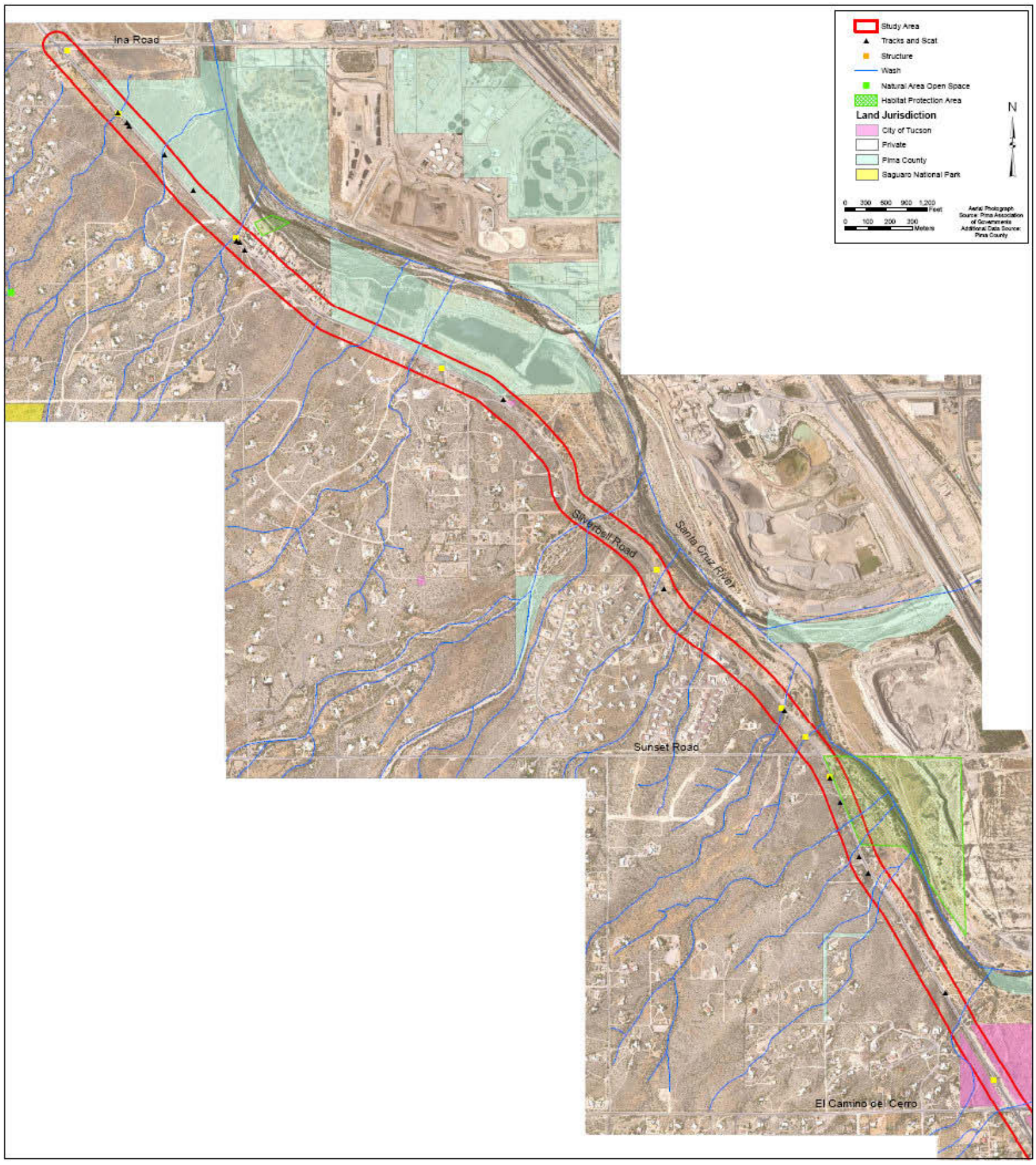

Figure 4-2. Overview of this portion of Silverbell Road.

I-10 and the Union Pacific Railroad each span in a mostly northwest-southeast direction along the Santa Cruz River valley adjacent to this portion of Silverbell Road. This portion of the valley consists of mining, and commercial and residential development, although portions of the lands along this highway corridor remain undeveloped. Various east-west roadways connect (or will connect) Silverbell Road from the west to I-10 to the east within the project area: including Ina Road, the proposed Sunset Road extension bridge over the Santa Cruz River, and El Camino del Cerro Road. Silverbell Road is the primary north-south travel route for various communities northwest of Tucson and within Marana, including Continental Ranch, connecting these areas to Tucson.

The main goal for this linkage is to maintain and improve connectivity for wildlife species traveling on both a landscape-level scale (inter-mountain range movements) and local scale (within and adjacent to the Marana town limits), given the proposed widening of Silverbell Road. Furthermore, ongoing and future residential and commercial development combined with greater predicted traffic volumes pose a threat to wildlife movement throughout the area. Therefore, the permeability of the project area to pass large-ranging wildlife species and smaller-bodied species that are sensitive to habitat fragmentation has been identified as an important factor in maintaining the long-term persistence of these species while simultaneously increasing driver safety by minimizing AVCs.

The segment of Silverbell Road from Ina Road to El Camino del Cerro Road ranges in elevation from approximately 2,160 to 2,260 feet above mean sea level (msl). Most of the project area is undisturbed; however, some of the area is disturbed as a result of residential development, horseback and hiking trails, and mining activities (gravel pits).

This segment of Silverbell Road is located within the Arizona Upland subdivision of the Sonoran Desertscrub biotic community. One vegetation association was identified in this road segment: upland desertscrub. Dominant vegetation in the project area includes velvet mesquite (*Prosopis velutina*), foothill paloverde (*Parkinsonia microphylla*), blue paloverde (*P. florida*), whitethorn acacia (*Acacia constricta*), catclaw acacia (*A. greggii*), creosote bush (*Larrea tridentata*), triangle-leaf bursage (*Ambrosia deltoidea*), and burroweed (*Isocoma tenuisecta*). Other species observed include desert broom (*Baccharis sarothroides*), barrel cactus (*Ferocactus wislizeni*), prickly pear cactus (*Opuntia* sp.), chainfruit cholla (*Cylindropuntia fulgida*), staghorn cholla (*C. versicolor*), Mexican paloverde (*P. aculeata*), brittlebush (*Encelia farinosa*), ocotillo (*Fouquieria splendens*), saguaro (*Carnegiea gigantea*), globe cactus (*Mammillaria* sp.), threeawn (*Aristida* sp.), spidergrass (*A. ternipes*), five-needle pricklyleaf (*Thymophylla pentachaeta*), fluffgrass (*Dasyochloa pulchella*), and desert globemallow (*Sphaeralcea ambigua*). Nonnative species include salt cedar, Lehman lovegrass (*Eragrostis lehmanniana*), stinkgrass (*E. cilianensis*), prickly Russian thistle (*Salsola tragus*), bermudagrass (*Cynodon dactylon*), buffelgrass (*Pennisetum ciliare*), and a variety of ornamental plant species associated with residential and commercial landscaping.

Xeroriparian mixed scrub vegetation is associated with ephemeral washes intersecting the road segment. This vegetation type is associated with an ephemeral or intermittent water supply and typically contains plant species that also occur within neighboring upland habitats, although riparian plants are typically larger and often occur at higher densities than those in

adjacent uplands. The dominant plant species observed along washes include desert broom, velvet mesquite, wolfberry (*Lycium* sp.), spiny or desert hackberry (*Celtis ehrenbergiana*), graythorn (*Ziziphus obtusifolia*), whitethorn acacia, singlewhorl burrobrush (*Hymenoclea monogyra*), and cane bluestem (*Bothriochloa barbinodis*).

4.2 LAND OWNERSHIP AND USE

The majority of the project area is under the jurisdiction of Pima County. Additionally, some of the project area is under the jurisdiction of the Town of Marana (northern end) and the City of Tucson (southern end). However, there are numerous portions of private land in the areas that will be widened along Silverbell Road. Fidelity National Title, Silverbell Crossroads LLC, and the Ina and Silverbell One Limited Partnership are some of the private landowners at the far northern end of the project area. CPC Arizona Holdings Inc. and Title Security Agency of Arizona are some of the larger private landowners towards the southern end of the project area. And California Portland Cement owns a large parcel of land east of Silverbell Road, mostly just north of Sunset Road.

There are numerous residential dwellings in the project area. Low-density residential housing occurs mostly on the west side of Silverbell Road, although there are some pre-fabricated houses present on the east side of the road. No commercial development occurs within this segment of Silverbell Road, although there is an active mine adjacent to this corridor along with evidence of past mining activity present along portions of this corridor. The Ina Road Wastewater and Sewage Treatment Plant is adjacent to (east of) the Santa Cruz River at approximately the Ina Road alignment, just outside of the project area.

According to Pima County mapguide (2009), most of the east-side of Silverbell Road is not currently zoned by Pima County. However, there are small portions of land at Sunset Road and south of Ina Road on the east side of the road that are zoned SH (medium-intensity urban) and GR-1 (rural activity center). Most of the west side of Silverbell Road is zoned SR (medium-intensity rural) with some small portions of CR-1 (major resort community) and unzoned lands. (Pima County 2007)

As the population of the town of Marana is projected to increase significantly by 2040, there are expected to be some major changes to this stretch of Silverbell Road which will provide one of the main access routes for travel between Tucson and a large portion of Marana for numerous residents. Pima Association of Governments (PAG) has projected that some of the intersections in the project area will carry three or even four times the current volume of traffic. Early design plans for this segment of Silverbell Road include widening the whole stretch to a three or four-lane divided desert parkway with a median, bike lanes, and pedestrian facilities.

In order to create a functional wildlife crossing, it is important to recognize adjacent land uses that could influence species use over time. This information can be useful in determining which locations along Silverbell Road will be the most likely to maintain continued species use given adjacent land use in the future. Alternatively, given changes in adjacent land use, provisions that incorporate wildlife corridors or movement paths can be included into those

development plans so as to maintain the functionality of wildlife crossing structures or other mitigation measures over time.

The main channel of the Santa Cruz River, its surrounding floodplain, and all Pima County-designated areas of habitat protection are identified as open space areas; however, areas of mixed-use and commercial development are planned for the portion of Silverbell Road centered at the Silverbell Road-Ina intersection.

4.3 RELATIONSHIP BETWEEN SILVERBELL ROAD AND WILDLIFE CORRIDORS/MOVEMENT ROUTES

This segment of Silverbell Road falls just south of a linkage identified by the Arizona Wildlife Linkages Assessment workgroup: Linkage 80, Saguaro-Tortolita. This statewide effort, the purpose of which was "to identify and promote wildlife habitat connectivity using a collaborative, science-based effort to provide safe passage for people and wildlife," identified 152 linkages across Arizona (Arizona Wildlife Linkages Assessment Workgroup 2006). The Saguaro-Tortolita linkage consists primarily of private land (68 percent) and State Trust Land (31 percent). Target species associated with this linkage include bobcat, CFPO, cave myotis (*Myotis velifer*), javelina, kit fox, mountain lion, mule deer, pocketed free-tailed bat (*Nyctinomops femorosaccus*), and Sonoran desert tortoise. Threats to this linkage include agriculture, the Central Arizona Project (CAP), I-10, the railroad, and urbanization.

Pima County is in the process of developing a Multi-Species Conservation Plan (MSCP) that includes the project area. As part of the MSCP, Pima County has identified Priority Conservation Areas (PCAs) for various species covered within the plan. As part of this wildlife linkage effort, the Town of Marana intends to support all identified PCAs during the design of all wildlife crossings and abatement measures. Additionally, the Town of Marana intends to coordinate with Pima County to uphold and support any wildlife linkages that are identified during the potential Pima County Wildlife Linkage Assessment that is expected to be undertaken soon.

The City of Tucson and Town of Marana are also currently developing separate Habitat Conservation Plans (HCP) that will outline conservation programs, including areas to be set aside, species-specific management areas, etc. As part of this wildlife linkage project, this project will support both HCP conservation program efforts when applicable during the design of all wildlife crossings and abatement measures.

Additionally, this area lies between the Tucson Mountains (and Saguaro National Park West) and the Santa Cruz River, thus the area could be expected to provide for important movement routes for numerous species as described earlier in this report. And there are some local areas of interest in and adjacent to the project area as well. Approximately 0.5 mile south of Ina Road on the west side of Silverbell Road there is an area of open space. Across Silverbell Road (east) from this area exists two parcels of interest; one designated as "Pima County MSCP Committed Lands" and the other designated as a "Highest Priority Private Habitat Protection" Area (Pima County 2009). SWCA believes that it is important to ensure that wildlife is able to move between these areas of open space across Silverbell Road, thus this

section is designated as Priority Crossing Zone A for the project area (refer to Section 5.1). Similarly, there is another parcel designated as a "Highest Priority Private Habitat Protection" Area that is adjacent and south of the Sunset Road alignment on the east side of Silverbell Road. SWCA also believes that it is important to ensure that wildlife is able to move between this area of open space across Silverbell Road to areas west, thus designating this section as Priority Crossing Zone B for the project area (refer to Section 5.2).

4.4 LINKAGE ASSESSMENT

Data used to determine any previously identified wildlife crossing zones included critical habitat area maps for selected species from Arizona Department of Game and Fish databases; Natural Community Conservation Planning (NCCP) maps and conservation areas; existing data/studies that have investigated focal species movement patterns relative to roadways, habitat, and other landscape features; and AVC data from state, regional, and/or local accident reports, records, and databases.

The following maps and data sources were referenced:

- Critical Habitat area maps from the U.S. Fish and Wildlife Service (USFWS) database
- Pima Association of Governments planning maps
- Pima County's Sonoran Desert Conservation Plan and Associated GIS "Mapguide"
- Town of Marana Habitat Conservation Plan (HCP)
- Arizona Game and Fish Department (AGFD) animal-vehicle collision database

This segment of Silverbell Road is currently two lanes with dirt shoulders, no center median, and a speed limit of 40 to 45 miles per hour (mph) (the speed limit is 40 mph in the daytime and 45 mph at night). Speed limits vary for the main arteries connecting to this portion of Silverbell Road: El Camino del Cerro Road is 45 mph west of Silverbell, and 45 mph in the daytime and 40 mph nighttime east of Silverbell Road; Sunset Road is 35 mph as it approaches Silverbell; and Ina Road is 45 mph. Two commercial driveways, 40 residential driveways, and 13 residential streets intersect the project area.

There are limited AVC records available for the project area; however, there are AVC incidents recorded for bobcat, mule deer, javelina, raccoon, and coyote from in or adjacent to the stretch of Silverbell Road between Ina and Camino del Cerro roads (Arizona Game and Fish Department 2009). Most of these incidents appeared to be of animals attempting to cross Silverbell Road; however, some incidents were recorded from surrounding roadways.

SWCA biologists conducted a field reconnaissance of the project area on June 9 and 10, 2009. One U.S. Geological Survey (USGS) 7.5-minute topographic map (Jaynes, Arizona) was used for general orientation and to locate the project boundaries. The field reconnaissance consisted of a pedestrian survey of the project area to evaluate anecdotal evidence of wildlife activity (e.g., tracks, scat, visual surveys); vegetation and landscape features considered important to the potential occurrence of animal species that may cross this segment of

Silverbell Road; various roadway characteristics (e.g., number of lanes, speed limit); and existing roadway infrastructure. Vegetation was classified to the community level according to the map "Biotic Communities of the Southwest" in Brown (1994). The purpose of these field visits was to collect on-the-ground information to refine and build upon the understanding of existing and potential locations to facilitate the safe passage of wildlife across Silverbell Road. The site assessment consisted of the steps summarized in the following subsections.

4.4.1 Identifying and Assessing Existing Ungulate and Carnivore Crossing Locations along or across Roadways

We recorded all sign of species activity along the entire stretch of roadway, including tracks, scat, game trails, carcasses, and visual sightings. Such information provided baseline documentation as to where animals have been active along the roadway shoulder, and served as preliminary locations for which to evaluate the potential for future modifications that could promote the safe passage of wildlife across the roadway.

4.4.2 Identifying and Assessing Potential Crossing Locations and Structures

Three types of unique situations that could potentially serve as a wildlife crossing locales were identified in this analysis: 1) structures, 2) fill slopes, and 3) at-grade areas. At each of these locations a predetermined suite of variables were measured.

Structures include any bridge or culvert that could provide for the safe passage of target species underneath the roadway. Structural dimensions (length, width, and height) were recorded and vegetation was measured within a 100-m radius around each entrance to the structure. Vegetation was averaged to yield a percentage category of cover for vegetation less than and greater than 1 m in height, thereby differentiating between low grass or shrub cover and higher shrub and tree cover. At each of these locations we highlighted opportunities, where appropriate, to provide additional measures that could be initiated to further promote the movement of focal species and other wildlife species through the structures.

Fill slopes include any location where the roadway is elevated relative to the surrounding topography; they typically occur where the roadway bisects drainages. For all fill slopes, we measured the fill height and fill width. Fill height is the height of fill between the roadway and the natural, non-fill slope on either side of the roadbed; fill imprint is the distance along the roadway occupied by the fill (i.e., the width of the filled drainage that the road bisects). In situations where there was an existing structure greater than 1 m in height (located at the base of a larger fill slope), the fill height above the structure was documented, because these locations may offer an opportunity to enlarge an existing structure without changing the alignment of the roadway.

At-grade areas include other roadway segments that are not point locations. Rather, they incorporate longer stretches of the roadway (typically 0.25 mile to several miles in length). These locations frequently include stretches of road that parallel one side of a drainage or riparian area, places where a particular vegetation type approaches or abuts the road

shoulders, or locations where wildlife are funneled to a particular point by other natural or human-made constrictive features in the landscape (i.e., choke point).

4.4.3 Identifying and Assessing Multiple Landscape and Human-made Features that may Impede Wildlife Movement across Roadways

Roadway barriers to wildlife movement were characterized according to the number of lanes and presence of shoulder barriers, median barriers, and other features. Additional miscellaneous features along the roadway that could hinder wildlife movement across the road or serve as potential soft barriers to species movement were also recorded.

We emphasize that our aforementioned efforts to determine wildlife crossing areas and locations that offer the best sites for which to direct future mitigation strategies were not comprehensive, as these methods only elucidate conditions existing within a small window of time. AVC data only indicates those locations along Silverbell Road where crossing attempts by wildlife were unsuccessful. Successful crossings across roadways can only be directly measured by monitoring existing structures that provide for the safe movement of wildlife underneath the roadway or through behavioral studies monitoring fine-scale movement patterns relative to the roadway (i.e., telemetry studies). Additional methods that would largely identify additional or potential crossing locations, or aid in refining particular zones that may be experiencing a greater frequency of crossing activity, should be considered (although they were not part of this investigation). Such methods may include focused AVC surveys, remotely-triggered camera surveys, and track surveys, and strategies to incorporate these methods are identified in Section 6.3 below.

4.4.4 Evaluation Criteria

We used three criteria to select locations where results suggested that improvements would enhance wildlife connectivity.

Criteria 1: Underpass spacing

Bissonette & Adair (2008) used the scaling properties of species movement as an ecological bases for effective spacing of wildlife crossing structures and determined that underpass spacing should occur at the square root of the species home range size (HR0.5) to provide population-level connectivity. They estimated this spacing from the square root of the animal's home range, which is a squared linear measure related to dispersal distance, thus resulting in a linear measurement. Based on information about species' home range sizes within the project area, the surrounding region, or in similar habitats and urbanized environments, we estimated the following minimum spacing requirements for wildlife-friendly underpass placement:

- Bobcat: average home range along wildland/urban interfaces of 5.1 km^2 (Lyren et al. 2006; Lyren et al. 2008; Lyren et al. 2009), 2.25 km underpass spacing.
- Herpetofauna and small mammals: AGFD (2006b) recommends that small mammal and herpetological crossings should be between 150 feet to 300 feet apart from another crossing. Similarly, Bissonette & Adair (2008) recommend underpass spacing

distances of 264 feet. Therefore, a spacing pattern of 250 feet was used as the scaling property for these groups of species.

Criteria 2: High fill slopes

Fill slopes were assessed to determine whether their height could accommodate a structure sufficient in height and width to facilitate passage of bobcats (structures may include span bridges, arch culverts, or large box culverts). This was to identify candidate locations for either enlarging existing structures or constructing new structures in fill slopes where no structure large enough to permit such passage existed. Consideration was also given to mule deer, which frequent the surrounding landscapes to the east and west of Silverbell Road; although distribution is more likely along the northern portion of Silverbell Road due to less developed areas.

Criteria 3: Proximity to open space lands

We overlaid lands identified as having conservation value or significance with this portion of Silverbell Road to identify which portions of the road were bisected by lands presumably identified for long-term conservation. These lands included Proposed 2010 Conservation Bond Program Highest Priority Private lands, 2004 Conservation Bond Program Highest Priority Private lands, Special Species Management Areas, and MSCP Committed Lands.

5.0RESULTS

5.1 EXISTING FEATURES

In order to facilitate the movement of wildlife across the section of Silverbell Road from Ina Road to El Camino del Cerro Road, it is necessary to first document existing and potential crossing locations for wildlife connectivity-associated mitigation measures, in order to maintain and enhance the movement of wildlife across Silverbell Road. It is a challenge to develop infrastructure that meets the expected increase in travel capacity while maintaining the safe passage of wildlife across roadways. Therefore, SWCA documented opportunities to maintain or increase the rate of safe wildlife movement across Silverbell Road, as well as identifying locations where such measures can potentially be addressed, in order to help reduce the impacts of Silverbell Road on local wildlife.

SWCA identified existing and potential locations that, from an engineering perspective, represent optimal locations to construct appropriate crossing structures for various wildlife species. By collecting and analyzing several types of data (including AVC, underpass use, and activity along roadways), SWCA was able to recommend various mitigation measures adequate in maintaining the successful passage of wildlife across roads, a critical step in the long-term functionality of wildlife movement across the region. These recommendations are based on the evaluation criteria presented in Section 4.4.4 and thus provide locations for future structures that optimize the functionality of regional connectivity for wildlife throughout the area.

Following is a description of the inventoried locations along Silverbell Road North:

5.1.1 Structures

Six structures were inventoried within this Silverbell Road North Linkage (Table 5-1). Five of these structures are pipe culverts associated with ephemeral drainages. The other structure is an arch culvert/bridge associated with an unnamed wash south of Abington Road, channeling stormwater flows east-northeast under Silverbell Road. All channels in the project area drain into the Santa Cruz River. All of these culverts currently provide terrestrial crossings; however, some presented potential barriers to certain wildlife species. The largest of these structures is the 24.5 × 22.5-foot one-chamber arch culvert. Dimensions and the degree of vegetative cover surrounding the underpasses are presented in Table 5-1. Representative photographs are provided in Appendix A.

Table 5-1. Dimensions of Existing Structures in Feet along Silverbell Road North.

Structure Number	Length[1]	Width[2]	Height	% Cover[3]	Comments
1. Arch culvert	24.5	22.5	8.5	4	Between DeGreen and Abington roads
2. Galvanized pipe culvert	40.0	3.0	3.0	3	Just southeast of Desert Foothills Drive
3. Galvanized pipe culvert	65.0	4.0	4.0	2	Adjacent to Mallow Lane
4. Galvanized pipe culvert	45.0	3.0	3.0	3	Just north of Sunset Road
5. Galvanized pipe culvert	35.0	2.0	2.0	2	Just south of Sunset Road
6. Galvanized pipe culvert	45.0	3.0	3.0	2	Just north of Camino del Cerro/Silverbell intersection

Locations 1 and 5 showed evidence of both coyote and javelina use. Bobcat tracks were observed at Location 1.

5.1.2 Fill Slopes

There were no fill slopes identified along the Silverbell Road Linkage.

5.1.3 Road-Stream Crossings

There are no perennial aquatic crossings along the Silverbell Road Linkage; however, there are numerous ephemeral drainages that have seasonal peaks of water flow and are discussed in Section 6.5.1. These ephemeral drainages may be important for movement of herpetofauna and small mammal species, but would not provide movement for aquatic species.

5.1.4 At-Grade Crossings

Numerous at-grade crossings were identified within the Silverbell Road project area. A few of the at-grade crossings involve the points where a dirt road or driveway accesses Silverbell Road. Roads typically serve as carnivore travel routes, particularly those that are located in proximity to water sources. As such, these locations represent potential movement routes for large-ranging wildlife species, particularly bobcats and coyotes. However, the majority of the at-grade crossings are points where washes flow over Silverbell Road. Most, if not all, of these at-grade crossings are proposed to be eliminated during the Silverbell Road Widening Construction project. It has been determined that all of the stormwater flow needs to be diverted under Silverbell Road for purposes of driver safety. This is expected to also be beneficial for wildlife in the area as traveling below the road will certainly increase the success of crossing efforts when compared to traveling over the road. Equestrian, pedestrian, and ATV use was also noted at many of these at-grade crossings.

5.1.5 Other Features that May Deter or Enhance Wildlife Movement across Silverbell Road

Periodic water flow across Silverbell Road at-grade has resulted in undercutting and erosion, which in turn has created a potential barrier to wildlife movement in numerous portions of the project area. This may be a barrier to certain species, particularly certain species of small mammals and herpetofauna, physically unable to climb up the ledge and travel through the structure. As the current proposal for the Silverbell Road Widening project involves removing all at-grade water crossings, this is not expected to be an issue in the future.

Several additional linear features bisect Silverbell Road and could provide additional movement routes for wildlife. These features include a dirt road that parallels the east side of Silverbell Road south of Ina Road. There is no significant fencing along Silverbell Road. Several stretches of chain link fence (most falling down) border the ROW and residential dwellings. The chain link fencing could pose a barrier to wildlife that are too large to pass through the baffle on the fencing; smaller rodent and herpetofauna species could easily pass through this fencing.

5.2 PRIORITY WILDLIFE MOVEMENT ZONES AND CRITERIA FOR DESIGNATION

5.2.1 Priority Crossing Zone A: Saguaro National Park West-Santa Cruz River-Pima County Open Space Wildlife Movement Corridor

This crossing zone connects Saguaro National Park West to the Santa Cruz River, an Important Riparian Area according to Pima County's SDCP (Pima County 2006). It is identified as the portion of Silverbell Road between POC-231 and POC-234 (see Figure 5-1). Included in this zone are numerous important wildlife features as delineated by Pima County's SDCP: 1) Important Riparian Areas, the Santa Cruz River and various unnamed washes providing potential CFPO dispersal habitat (and the Important Riparian Area Canada del Oro Wash flows into the Santa Cruz River from the east); 2) an area of Natural Open Space, one of three areas delineated as part of the Tres Rios Wildlife Crossing; 3) a Habitat Protection Priority area located northeast of Silverbell Road approximately 1 mile south of Ina Road; 4) a Special-Species Management Area for the CFPO that connects the Park to the Santa Cruz River; and 5) a Biological Core Management Area that covers most of the zone (see Figure 5-1). This crossing zone also includes one existing arch culvert/bridge that crosses crosses the unnamed wash south of Abington Road at Silverbell Road.

The Santa Cruz River falls within the Santa Cruz River Corridor District. The goals of this district are to 1) preserve the natural functions and role of the Santa Cruz River corridor, 2) maintain visual and physical access to the Santa Cruz River corridor, and 3) promote the Santa Cruz River corridor as a regionally significant amenity (Clarion Associates et al. 2007). Efforts to maintain and enhance the value of this river corridor, floodplain, and its washes and secondary water courses include bank treatments, restoration of native vegetation, and protection of wildlife habitat. Active and passive recreational opportunities are also identified along this corridor, including paved multi-use pathways, soft surface trails for hiking and equestrian usage, formal park or recreational uses, and equestrian-related facilities.

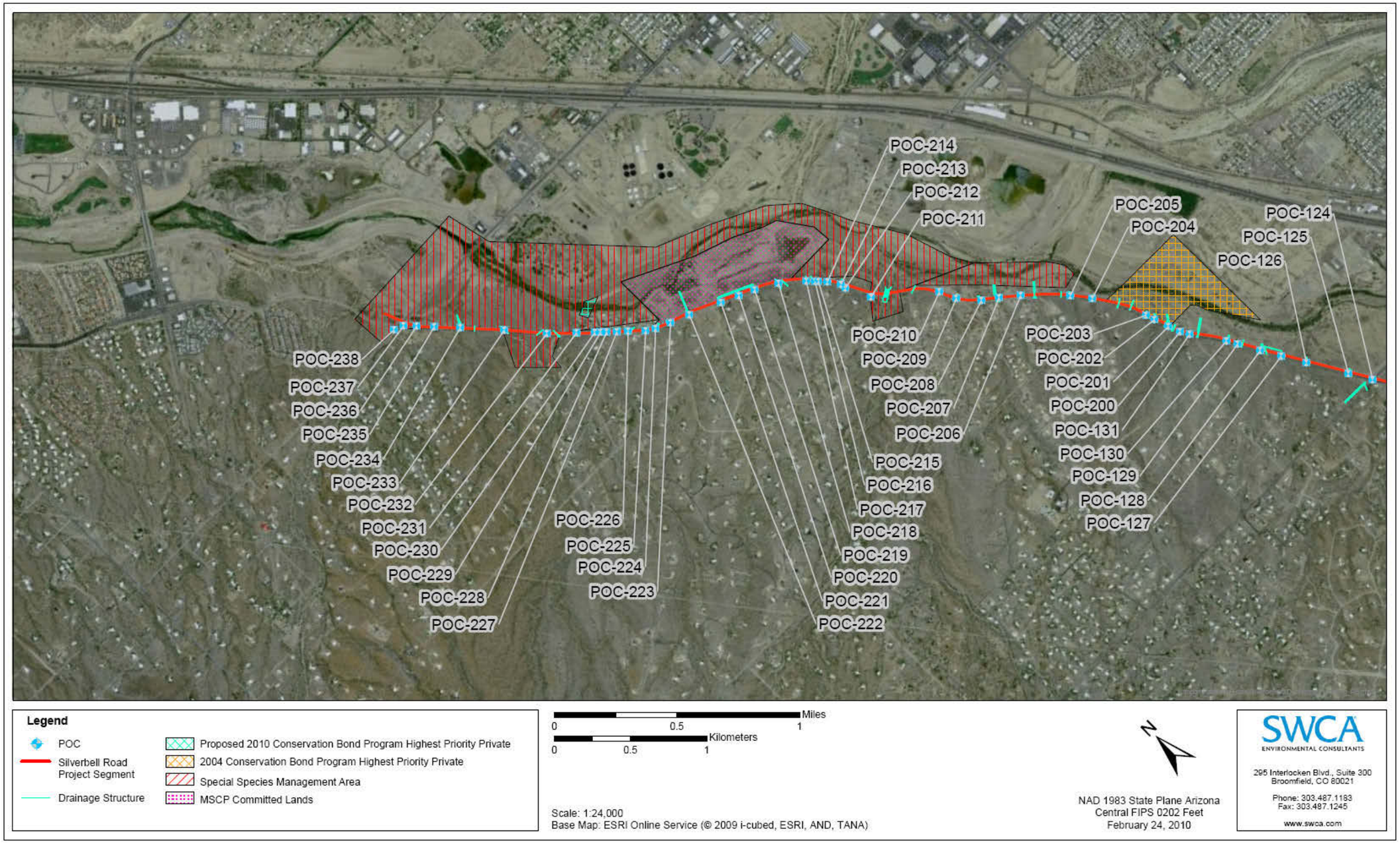

Figure 5-1. Map of proposed drainage structures for this portion of Silverbell Road.

Several factors contribute to this location representing a Priority Crossing Zone:

- The Santa Cruz River provides a major north-south travel corridor for animals. Large topographic features such as river corridors (e.g., the Santa Cruz River channel) represent potential movement routes for large-ranging species and also provide certain habitat and cover for other, less wide-ranging species.
- The arch culvert/bridge crossing at the unnamed wash south of Abington Road offers animals of many sizes crossing opportunities.
- This stretch of Silverbell Road interfaces with numerous resource conservation/open space areas as described earlier. By maintaining or enhancing opportunities for wildlife to safely cross this portion of Silverbell Road, combined with the identification of this area as a resource conservation/open space area, the long-term functionality of this linkage can be maintained. By investing in transportation infrastructure that improves wildlife connectivity in areas that have been set aside as open space or habitat protection priority areas, such investments can be justified due to the inability of conflicting land uses to diminish the functionality of wildlife crossing structures and other forms of connectivity-related mitigation.

In addition, several challenges to maintaining and increasing the functionality of this crossing zone have been identified:

- The Santa Cruz River bed and associated floodplain areas are also impacted by OHV and equestrian use. OHV sites have been extensively monitored to determine both the direct effects on reptile mortality and changes in species abundance relative to undisturbed portions of the desert (Bury et al. 1977; Berry 1980; Bury 1980; Luckenbach and Bury 1983; Brooks 1999). Off-road vehicle activity has been linked with population declines of the desert tortoise (*Gopherus agasizii)* (Bury 1980) and Couch's spadefoot (*Scaphiopus couchi)* (Berry 1980). Aside from reptiles, desert bird and small mammal density and diversity has been reported to decline in areas where OHV use was extensive (Buscak and Bury 1974; Bury et al. 1977; Luckenbach 1978; Luckenbach and Bury 1983; Brooks 1999).
- Vegetation is not very dense in the floodplain or along the banks of the Santa Cruz River. Vegetative cover can play an important role in determining road crossings and underpass use for many species, including bobcats (Haas 2000). However, certain species that may have the potential to use this crossing zone infrequently may avoid areas of dense vegetation. In the case of the Santa Cruz River area, maintaining a mosaic of vegetation patches and areas devoid of vegetation is likely the best approach at maintaining multi-species movements along this corridor.
- Proposed recreational trails. Wildlife species have been documented to avoid (Clevenger and Waltho 2000) or temporally shift their movement patterns (Haas and Turschak 2002) at underpasses exhibiting high rates of human activity.

5.2.2 Priority Crossing Zone B: Idle Hour Wash Wildlife Movement Corridor

This crossing zone centers on Idle Hour Wash, an Important Riparian Area and Special Species Management Area for CFPO according to Pima County's SDCP (Pima County 2006). It is identified as the portion of Silverbell Road approximately 500 feet north and south of POC-211 (see Figure 5-1). Included in this zone are numerous important wildlife features as delineated by Pima County's SDCP: 1) Important Riparian Areas, the Santa Cruz River and Idle Hour Wash, providing potential CFPO dispersal habitat; 2) a Special-Species Management Area for CFPO that connects the Park to the Santa Cruz River along Idle Hour Wash; and 3) a Multiple-Use Management Area that covers most of the zone (see Figure 4-2).

Several factors contribute to this location representing a Priority Crossing Zone:

- The Santa Cruz River provides a major north-south travel corridor for animals. Large topographic features such as river corridors (e.g., the Santa Cruz River channel) represent potential movement routes for large-ranging species and also provide certain habitat and cover for other, less wide-ranging species.
- This stretch of Silverbell Road interfaces with numerous resource conservation/open space areas as described earlier. By maintaining or enhancing opportunities for wildlife to safely cross this portion of Silverbell Road, combined with the identification of this area as a resource conservation/open space area, the long-term functionality of this linkage can be maintained. By investing in transportation infrastructure that improves wildlife connectivity in areas that have been set aside as open space or habitat protection priority areas, such investments can be justified due to the inability of conflicting land uses to diminish the functionality of wildlife crossing structures and other forms of connectivity-related mitigation.

5.2.3 Priority Crossing Zone C: Sunset Road Habitat Protection Priority Area

This crossing zone centers on a private Habitat Protection Priority area located just south of Sunset Road along the east side of Silverbell Road and includes numerous drainages that cross Silverbell Road as they drain lands from the Tucson Mountains and Saguaro NP West northeast to the Santa Cruz River. It is identified as the portion of Silverbell Road between POC-201 and POC-205 (see Figure 5-1). Included in this zone are numerous important wildlife features as delineated by Pima County's SDCP: 1) Important Riparian Area, the Santa Cruz River; and 2) the previously mentioned private Habitat Protection Priority area (see Figure 4-2).

Several factors contribute to this location representing a Priority Crossing Zone:

- Multiple drainages provide potential east-west travel corridors connecting undeveloped areas. The presence of multiple drainages within a short stretch of road provides multiple opportunities for wildlife to utilize drainage structures. Providing multiple crossing structures along roadways has been identified as an excellent measure to maintain the successful passage of wildlife across roads for both large-bodied and small-bodied organisms (Clevenger and Waltho 2000; Haas 2000; Mata et al. 2005).

- Drainages will require the construction of culverts (structures) through which wildlife can travel. Structures, if designed correctly, can serve a dual function in maintaining surface water flow and providing opportunities for wildlife to pass through the structures.

In addition, several challenges to maintaining and increasing the functionality of this crossing zone have been identified:

- Drainages run through or adjacent to residential areas. The proximity of residential areas to these drainages presents potential impacts from non-native predators (dogs and cats), increased noise and light pollution, and human activity. Dogs have been identified disrupting wildlife movement patterns (Harrison 1997; Haas and Turschak 2002; George and Crooks 2006), and cats are efficient predators on smaller-bodied mammal and herpetofauna species (Coleman and Temple 1993; Crooks and Soule 1999).
- Localized flooding during monsoons (and to a lesser extent, during periods of heavy winter rains) may create barriers to certain species movement through the structures. These drainages may experience seasonal peaks in water flow, which may cause erosion of the structures or create a buildup of material (e.g., vegetation, logs) at the entrance to the structure. Because of the potential for erosion and undercutting of the structure due to seasonal peaks in water flow, it is important to maintain movement for certain species for which an undercut outlet or inlet represents a barrier. Furthermore, routine maintenance to remove debris and other objects that might be carried by water during high rainfall events is important so that the underpass allows for the passage of wildlife throughout the entire year.

6.0RECOMMENDATIONS

6.1 SPECIFIC RECOMMENDATIONS/MITIGATION MEASURES WITHIN THE PRIORITY CROSSING ZONES

6.1.1 Saguaro National Park West-Santa Cruz River-Pima County Open Space Wildlife Movement Corridor

Based on the favorable environmental conditions identified in Section 5.2.1 above, it is recommended that several crossing structures be developed within the washes that cross this section. The widening of Silverbell Road will inherently increase the distance at which animals will need to traverse this roadway. As such, it is important to consider associated appropriate widths and heights of the structures to negate the appearance of long, narrow structures, which certain species may be less reluctant to use. Table 6-1 provides recommended dimensions for structures based on a projected underpass length of 130 feet (which would be the new road width and associated right-of-way [future underpass length]). We note, however, that situating underpass entrances as close as possible to the road edge to reduce structure length and promote use by smaller-bodied species that typically use the road edge (e.g., reptiles, small mammals) has often been recommended (Ascensão and Mira 2007), and is particularly a preferred design feature for multi-lane roadways.

Table 6-1. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.

Crossing ID[1]	Recommended minimum dimensions based on 130-foot roadway and right-of-way footprint			
	Type[2]	Length	Width	Height
POC-231	span	NA	NA	NA
POC-233	CBC	130	10	5
POC-234	CP	130	5	5

[1] – POC numbers, as identified in Table 8 in Kittelson 2010
[2] – CBC = concrete box culvert; CP = concrete pipe culvert; span = span bridge

The proposed widening would result in an increase in crossing distance (the distance that animals must travel to cross the roadway), and new structures should weigh the avoidance of culvert use by wildlife due to a low structure openness (a value defined as the width × height divided by the length of the structure). Bobcats have been documented utilizing many structures within the proposed dimensions of the new structures (Haas 2000; Lyren et al. 2005). Minimum dimensions, as proposed above, would result in an openness value that would range from 0.056 to 0.113 meters (m) for the two structures; the span bridge provides optimal openness since it would span the drainage. Bobcats have been documented using structures less than 5 feet high and with openness values ranging from 0.015 to 0.247 m (Haas 2000). The recommended heights are suggested because potentially sensitive wildlife species like bobcats may not be accustomed to traveling through longer structures; thus having an

increase in clearance (height) would optimize the probability that this species would travel through the structure. Following is a description of justifications for the recommendations provided in Table 6-1.

POC-231

This location is adjacent to a Special Species Management Area (east side of Silverbell Road) and the drainage located here provides a suitable travel route for a variety of wildlife species based on the vegetation characteristics, relative isolation from surrounding development, and location immediately west of a Habitat Protection Area, and it provides the most suitable crossing location (in terms of installing a suitable crossing structure) for mule deer along this entire stretch of Silverbell Road. The size of this drainage combined with the low-density development upstream of this location provide opportunities for wildlife traveling along this drainage to easily reach the Santa Cruz River to the east and less developed lands and the National Park to the west. Currently, an arch culvert exists at this location and would need to be replaced due to the widening of the road. A span bridge would provide the best opportunity to create a crossing structure that could easily pass mule deer (the species that is most restricted by smaller underpass sizes characteristic of box culverts and pipe culverts). Based on the height of the existing structure (8.5 feet) the span bridge would provide adequate clearance for mule deer, particularly due to the lack of the tunnel effect that is typically created by non-spanning structures.

POC-233

This location is adjacent to a Special Species Management Area (east of Silverbell Road) and lies at the northern end of a Special Species Management Area that links the Santa Cruz River to Saguaro National Park. The relative isolation of this location from surrounding development, the vegetation characteristics along the drainage, and the presence of a Natural Area/Open Space to the southwest (upstream of this drainage) make this a good location to place a wildlife crossing structure. The resulting openness index of the new proposed structure (10 feet wide by 5 feet high) would be 0.113 m, which is well above openness values utilized by bobcats at similar structures.

POC-234

This location is represented by a slightly smaller drainage than the one at POC-233. Like POC-233, however, this location is adjacent to a Special Species Management Area (east side of Silverbell Road). The drainage located here provides a suitable travel route for a variety of wildlife species based on the vegetation characteristics, relative isolation from surrounding development, and the presence of a Natural Area/Open Space to the southwest (upstream of this drainage), and lies at the northern end of a Special Species Management Area that links the Santa Cruz River to Saguaro National Park. The size of this drainage combined with the low-density development upstream of this location provide opportunities for wildlife traveling along this drainage to easily reach the Santa Cruz River to the east and less developed lands and the National Park to the west. The resulting openness index of the new proposed structure

(5 feet wide by 5 feet high) would be 0.056 m, which is well above openness values utilized by bobcats at similar structures.

Other measures to enhance connectivity in this Priority Crossing Zones

There are a variety of other measures that could be implemented for the three locations identified above, including vegetation treatments, artificial light management, wildlife fencing, and additional crossing structures.

Vegetation

An important factor that would increase the probability of species use of underpasses within this Priority Crossing Zone is the maintenance of vegetation along the roadside (i.e., limiting vegetation along the Silverbell Road right-of-way) and between the underpass entrances and roadside edge. In addition, native vegetation, including velvet mesquite and blue palo verde, should be planted in front of and adjacent to the underpass entrances to reduce the potential visual threat that traffic traveling along Silverbell Road may pose to wildlife species using these structures. This is particularly important for larger-bodied wildlife species; if monitoring determines that additional measures (i.e., drift fencing) are necessary to direct wildlife to crossing structures, vegetation plantings may be placed in association with these additional mitigation measures (see Section 6.3).

For larger structures, such as POC-231, the placement of woody debris (e.g., stumps, branches) and boulders along the length of the structure would aid in maximizing the probability that smaller-bodied species would use the structure (Linden 1997). For smaller structures, such as POC-233, although several studies have documented amphibian and reptile use of passages under two-lane roads (Langton 1989; Boarman and Sazaki 1996; Jackson 1996) and simulated structures of 40 feet (Painter and Ingraldi 2005), little is known regarding the effectiveness of these structures under roadways that are four or more lanes.

Roadside Lighting

The amount of artificial lighting along the stretch of roadway that crosses through this Priority Crossing Zone can also affect wildlife movements. Efforts should be made to keep street-side lighting at least 200 feet away from each of the identified structure locations above, particularly POC-231 and POC-233. If lighting is required for traffic safety, it should be directed away from the structure (e.g., reconfigure lighting at the Silverbell Road/Silver Ridge Lane intersection to not shine directly over POC-231).

Roadside Fencing

To maximize the use of POC-231, particularly by mule deer, fencing is proposed for a short stretch of this road segment. Along the east side of Silverbell Road, fencing could start across from the Silverbell Road/Abington Road intersection and continue south to a location just north of the Silverbell Road/Silver Ridge Lane intersection (across from a driveway that heads west from Silverbell Road). Along the west side of Silverbell Road, fencing could start immediately south of the Silverbell Road/Abington Road intersection and continue south to

the driveway described above. Fencing should be at least 8 feet high to prevent animals from jumping over and accessing the road.

To maximize the use of structures located within the Special Species Management Area (POC-233 and additional smaller structures proposed [see below]), fencing for smaller-bodied species could be situated along the stretch of road that is bisected by the Special Species Management Area. This fencing would extend between POC-233 and POC-232. Based on AGFD (2006b) recommendations, fencing should have a height of approximately 1.5 to 2.5 feet with a preventative top, such as a lipped wall or overhang (0.5 foot wide) to prevent amphibians, reptiles, and small mammals from jumping or climbing over.

Additional Structures

An additional structure has been identified within this Priority Crossing Zone and would be placed immediately north of the Silverbell Road/Abington Road intersection (POC-232). In addition to this structure and to further accommodate herpetofauna and small mammal species, it is recommended that three additional crossing structures (i.e., pipe culvert) at least 1.5 feet in diameter be placed between POC-232 and POC-233. This is particularly important due to the presence of the Special Species Management Area along this stretch of road.

6.1.2 Idle Hour Wash Wildlife Movement Corridor

Based on the favorable environmental conditions identified in Section 5.2.2 above, it is recommended that several crossing structures be developed within the washes that cross this section. Table 6-2 provides recommended dimensions for a structure based on a projected underpass length of 130 feet (which would be the new road width and associated right-of-way [future underpass length]).

Table 6-2. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road.

Crossing ID[1]	Recommended minimum dimensions based on 130-foot roadway and right-of-way footprint			
	Type[2]	Length	Width	Height
POC-211	span	NA	NA	NA

[1] – POC numbers, as identified in Table 8 in Kittelson 2010
[2] – span = span bridge

POC-211

This location is within a Special Species Management Area that extends between the Santa Cruz River and Saguaro National Park to the west. The drainage located here provides a suitable travel route for a variety of wildlife species based on the vegetation characteristics, relative isolation from surrounding development, and provides another potential location to install a span bridge. The size of this drainage combined with the low-density development upstream of this location provide opportunities for wildlife traveling along this drainage to

easily reach the Santa Cruz River to the east and less developed lands and the National Park to the west. Currently, the downstream (east) side of this drainage crossing is severely eroded, creating a distinct difference in grade of approximately 6-8 feet between the downstream side of the road and the upstream side. Taking advantage of this difference in topography, a potential exists to realign this portion of the road to the east and slope the western side of the road shoulder to account for the difference in the ground surfaces on either side of the road without creating a steep slope leading down to the structure that could cause certain wildlife species to avoid using the structure. A span bridge would provide the best opportunity to take advantage of this situation. While the clearance of this structure is unlikely to equal the proposed height of POC-231 described in the section above, thus potentially restricting mule deer use of the structure, it would alleviate the tunnel effect that is typically created by non-spanning structures.

Other measures to enhance connectivity in this Priority Crossing Zones

There are a variety of other measures that could be implemented for the two locations identified above, including vegetation treatments, artificial light management, wildlife fencing, and additional crossing structures.

Vegetation

As suggested in Section 6.1.1, maintenance of vegetation along the roadside and between the underpass entrances and roadside edge is important in reducing the potential for wildlife to access the roadside shoulder to utilize habitat or forage. Keeping the shoulder devoid of vegetation that could attract wildlife while targeting native plantings in front of and adjacent to the underpass entrances will both reduce the chance of wildlife accessing the roadside and reduce the potential visual threat to traffic traveling along Silverbell Road.

If a span bridge is suitable for location POC-211, woody debris (e.g., stumps, branches) and boulders situated the length of the structure would aid in maximizing the probability that smaller-bodied species would use the structure (Linden 1997).

Roadside Lighting

As stated in Section 6.1.1, efforts should be made to keep street-side lighting at least 200 feet away from the identified structure location above. If lighting is required for traffic safety, it should be directed away from the structure (e.g., reconfigure lighting at the intersection of Silverbell Road and Benjamen Road).

Roadside Fencing

No wildlife fencing is proposed for this zone due to the proximity of access points to POC-211 (a short distance of fencing would be largely ineffective). However, to maximize the use of this structure and additional smaller structures proposed (see below), fencing for smaller-bodied species, as described in the Roadside Fencing section in Section 6.1.2, could be situated along the stretch of road that is bisected by the Special Species Management Area.

Additional Structures

To further accommodate herpetofauna and small mammal species, it is recommended that three additional crossing structures (i.e., pipe culvert) at least 1.5 feet in diameter be placed south of POC-211. This is particularly important due to the presence of the Special Species Management Area along this stretch of road.

6.1.3 Sunset Road Habitat Protection Priority Area

Based on the favorable environmental conditions identified in Section 5.2.3 above, it is recommended that several crossing structures be developed within the washes that cross this section. Table 6-3 provides recommended dimensions for structures based a projected underpass length of 130 feet (which would be the new road width and associated right-of-way [future underpass length]).

Table 6-3. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.

Crossing ID[1]	Recommended minimum dimensions based on 130-foot roadway and right-of-way footprint			
	Type[2]	Length	Width	Height
POC-202	CBC	130	8	6
Location between POC-202 and Sunset Road	CBC	130	8	5
POC-205	CBC	130	8	5
POC-201	CP	130	3	3

[1] – POC numbers, as identified in Table 8 in Kittelson 2010
[2] – CBC = concrete box culvert; CP = concrete pipe culvert

Minimum dimensions, as proposed above, would result in an openness value that would range from 0.020 to 0.108 m for the four structures; bobcats have been documented using structures less than 5 feet high and with openness values ranging from 0.015 to 0.247 m (Haas 2000). The recommended heights are suggested because potentially sensitive wildlife species like bobcats may not be accustomed to traveling through longer structures; thus having an increase in clearance (height) would optimize the probability that this species would travel through the structure. Following is a description of justifications for the recommendations provided in Table 6-3.

POC-202

POC-202 represents the largest drainage along this potion of Silverbell Road that borders a 2004 Conservation Bond Program Highest Priority Private land. This drainage extends west through moderate-density development. The vegetation characteristics and location relative to the priority area boundary (centrally located so most isolated from future development that

may occur adjacent to this priority area) are likely to provide opportunities for wildlife traveling along this drainage. The resulting openness index of the new structure (8 feet wide by 6 feet high) would be 0.108 m, the largest openness of structures within this Priority Crossing Zone.

Location between POC-202 and Sunset Road

This location is also bordered by the 2004 Conservation Bond Program Highest Priority Private land. Currently, a small structure is present here, although it would need to be replaced due to the road widening. This drainage may experience less wildlife activity than POC-202, however it represents another location to provide a crossing structure along the priority area. The resulting openness index of the new structure (8 feet wide by 5 feet high) would be 0.090 m, which is well above openness values utilized by bobcats at similar structures.

POC-205

This location is not bordered by the 2004 Conservation Bond Program Highest Priority Private land and is located north of Sunset Road. It does lie directly south of a Special Species Management Area. The drainage upstream of Silverbell Road exhibits similar vegetation characteristics to the drainage at POC-202, however the drainage crosses Sunset Road immediately upstream (southwest) of the Silverbell Road crossing and is then constricted by development further south of Sunset Road. Currently, a small structure is present here, although it would need to be replaced due to the road widening. The resulting openness index of the new structure (8 feet wide by 5 feet high) would be 0.090 m, which is well above openness values utilized by bobcats at similar structures.

POC-201

This location is at the southern extent of the 2004 Conservation Bond Program Highest Priority Private land. This drainage may experience less wildlife activity than POC-202, however it represents another location to provide a crossing structure along the priority area. Because of the small nature of the drainage, opportunities to install a structure similar to that proposed for POC-202 are limited, however this location a smaller structure that can provide safe crossing opportunities for smaller-bodied herpetofauna and small mammal species could be place here. As such, a 3-foot-diameter pipe culvert is proposed for this section. The resulting openness index of the new structure would be 0.020 m, which is slightly above the minimum openness value utilized by bobcats at similar structures; site-specific modifications to this location (e.g., limiting the adjacent landscaping along the roadside; constricting recreation trails and/or sidewalks to be located closer to the roadway) could occur to reduce the length of this structure.

Other measures to enhance connectivity in this Priority Crossing Zones

There are a variety of other measures that could be implemented for the two locations identified above, including vegetation treatments, artificial light management, wildlife fencing, and additional crossing structures.

Vegetation

As suggested in Section 6.1.1, maintenance of vegetation along the roadside and between the underpass entrances and roadside edge is important in reducing the potential for wildlife to access the roadside shoulder to utilize habitat or forage. Keeping the shoulder devoid of vegetation that could attract wildlife while targeting native plantings in front of and adjacent to the underpass entrances will both reduce the chance of wildlife accessing the roadside and reduce the potential visual threat that traffic traveling along Silverbell Road.

Most of these structures offer limited opportunities to place materials within the structures to encourage wildlife use, and should thus be considered on a case-by-case basis.

Roadside Lighting

As stated in Section 6.1.1, efforts should be made to keep street-side lighting at least 200 feet away from each of the identified structure locations above, particularly the proposed structure between POC-202 and Sunset Road. If lighting is required for traffic safety, it should be directed away from the structure (e.g., reconfigure lighting at the intersection of Silverbell Road and Sunset Road).

Roadside Fencing

Roadside wildlife fencing is not recommended for this Priority Crossing Zone due to the lack of structures that could promote mule deer passage. Deer are common in this area, and the low relief and topography of the area provide no opportunities to construct a structure suitable for deer use. Consequently, establishing wildlife fencing along this road could present a greater barrier to mule deer movement between the Santa Cruz River and habitats to the west, providing greater justification for the installation of span bridges in each of the Priority Crossing Zones described above. However, to maximize the use of structures established along the 2004 Conservation Bond Program Highest Priority Private land, fencing for smaller-bodied species, as described in the Roadside Fencing section in Section 6.1.2, could be situated along the stretch of road that is adjacent to the priority area.

Additional Structures

One additional structure (POC-203) has been identified adjacent to the priority area and would be placed in smaller drainage to accommodate water flow during periods of high rainfall. In addition to this structure and to further accommodate herpetofauna and small mammal species, it is recommended that one additional crossing structure (i.e., pipe culvert) at least 1.5 feet in diameter be placed approximately 250 feet north of POC-203.

6.2 ADDITIONAL RECOMMENDATIONS/MITIGATION MEASURES OUTSIDE OF PRIORITY CROSSING ZONES

6.2.1 Drainage Structures

Roadway widening may also necessitate additional drainage structures along Silverbell Road. For those stretches of road not within the identified linkage priority area, it is important to recognize what function these additional structures provide to wildlife movement. Additional structures should be sized at least 1 foot in diameter to provide passage for small mammal and herpetofauna species. Additional monitoring would be useful in determining which locations best serve to place structures for smaller-bodied species.

6.2.2 Vegetation Management

The presence of vegetation along road shoulders may often serve as an attractant to wildlife species, thus luring them to the side of the road and increasing of being struck by oncoming vehicles (Case 1978; Cain et al. 2003). A potential strategy to minimize AVCs would be to manage the vegetative ROW along stretches of road where wildlife crossing structures are absent (either by planting species that would be unpalatable or provide little cover) and improve the roadside habitat (through the planting of palatable or nutritious plant species) in areas immediately adjacent to smaller crossing structures, in order to direct wildlife to these crossing locations (see Groot et al. 1996; Putman 1997; Varland and Schaefer 1998; Brown et al. 1999; Hyman and Vary 1999).

6.3 RECOMMENDED MONITORING

There is very little information as to the distribution, abundance, and movement routes of various wildlife species across Silverbell Road. Therefore, a coordinated effort to collect wildlife crossing-related datasets that will contribute to local and regional knowledge of wildlife movement across Silverbell Road, in addition to prioritizing recommended mitigation locations so that transportation enhancement monies can be best appropriated to those projects, is an important step in developing a monitoring framework that seeks to address the long-term functionality of recommended mitigation measures. Such an effort should include AVC data collection, roadside track bed surveys, and underpass monitoring. The combination of these multiple survey techniques will not only provide information on the value of existing crossing locations along Silverbell Road, but will serve to refine knowledge of where species are crossing roadways (non-structural locations), where appropriate mitigation strategies can be directed to provide or enhance movement, and how such measure could be designed; such information could be incorporated into the final design phases of this particular roadway project. Finally, this data will serve as baseline data by which to gauge future wildlife crossing activity in response to mitigation measures (e.g., crossing structures, wildlife fencing, vegetation treatments, methods to influence driver behavior) associated with transportation improvement projects, and may contribute to regional datasets that could collectively analyze regional patterns of wildlife movement in response to various transportation-related infrastructure.

Following is a suite of monitoring techniques that should be utilized to identify additional mitigation measures, determine baseline rates of crossing activity (or lack thereof), and develop an adaptive management strategy to ensure mitigation success:

6.3.1 AVC Monitoring

AVC surveys are recommended for the portion of Silverbell Road in two locations: 1) between POC-201 and POC-212 and 2) within Priority Crossing Zone A. Surveys should consist of two phases: an initial 30-day intensive sampling schedule (with surveys conducted every day) and a second sampling schedule that will be determined by the results of the intensive sampling. The purpose of the intensive sampling schedule is to determine the maximum number of days needed to detect various wildlife species, or groups of species. For example, the results of intensive surveys may indicate that a sampling schedule of three days is needed to record 90 percent of herpetofauna road kills, but a schedule of seven days is needed to record 90 percent of large mammal kills. Such information would be useful in determining appropriate sampling strategies to effectively record and monitor AVC patterns along road segments. The road shoulder would be walked during the morning and individuals would be identified to species, aged, and sexed, and their position recorded with a global positioning system (GPS) unit.

6.3.2 Underpass Monitoring

Underpass usage rates can be monitored using two methods. First, track beds can be established at each structure, with a bed occurring at the midpoint of each structure; alternatively, track beds can be established at the entrances to these structures. Track beds would consist of gypsum powder, which is a finely-grated powder that allows for easy identification of imprints left by wildlife. Tracks left by individuals passing through the underpass would be identified to species. Direction of travel would also be documented, and species usage would be recorded as the number of times a given species used the underpass divided by the number of days the underpass was sampled.

A second method that alleviates potential monitoring limitations of the track beds incorporates the use of remotely-triggered digital cameras stationed at each underpass. These cameras are secured to the structure or to a post (preferably telspar) driven into the ground to prevent theft. The post and attached camera are placed either along the headwall of the structures or, for span bridges, at the midpoint of each bridge. Cameras would be checked at least every four weeks, with more frequent camera maintenance occurring at underpasses with higher wildlife activity. Cameras record the species' direction of travel and time of pass. Of particular interest is the potential to identify individual bobcats (by observing marking patterns on pelage) as they pass by the camera (Lyren et al. in prep.). This would be very useful since bobcats are a focal species for this linkage, and understanding bobcat usage rates of different structures along this stretch of road would further serve to gain knowledge on population responses to future increases in traffic patterns and roadway configurations.

Optimal structures to monitor include all of those identified in the Priority Crossing Zones, including POC-231, POC-233, POC-234, POC-211, POC-202, POC-205, POC-201, the proposed underpass location between POC-202 and Sunset Road, and any other smaller

structures designed for water conveyance within these three zones. We note that underpass monitoring by cameras focuses largely on the passage of large- and medium-bodied mammals; smaller mammal species and herpetofauna are rarely detected at these stations, so track beds are a more appropriate technique. However, track beds rarely allow the observer to detect which species is traveling over the substrate. Therefore, to obtain species-specific rates of underpass use for small mammal and herpetofauna species, mark-recapture methods could provide the best means to detect species passage through the structure.

6.3.3 Roadside Track Beds

The rationale behind conducting roadside track bed surveys along the road shoulder is to determine the existing rate of at-grade crossing activity by wildlife, particularly in areas where a sufficient crossing structure exists. Perhaps the biggest issue in establishing a sampling design that can adequately determine whether at-grade crossing rates change after installation of wildlife connectivity mitigation measures is to sample a large enough stretch of roadway. Prior to any sampling, a power analysis should be conducted to determine which sampling effort would be needed in order to detect such changes.

Track beds consist of a 2-m-wide swath of finely sifted sandy material and occur at the immediate edge of the pavement. Track beds would be walked weekly on consecutive days to determine species crossing rates. For each visit to the track bed, the following data would be recorded: previous precipitation levels, ambient air temperature, track bed condition, species leaving a track, certainty of track, crossing behavior, direction of track relative to the roadway, location of track(s) relative to the end of the track bed, and whether the track was recorded in the respective track bed across the roadway.

Track bed locations would occur within each Priority Crossing Zone and extend between 1) Priority Crossing Zone A: POC-231 to POC-234, 2) Priority Crossing Road B: POC-210 to Benjamin Road, and 3) POC-201 to POC-205. Within each zone, multiple track beds would be placed in order to assess the at-grade (surface level) crossing rate prior to construction and compared to at-grade and underpass crossing rates after construction.

6.3.4 Adaptive Management

This data would not only serve to refine the initial site assessments, but would also serve as baseline data to address effectiveness monitoring and adaptive management, both which would occur after completion of roadway widening. Although prior studies have evaluated underpass use in relation to landscape features, structural dimensions, and other variables after construction at several sites, less common are rigorous efforts to conduct pre-construction and post-construction monitoring of roadway corridors and underpasses to determine the following: 1) where structural wildlife crossings might be most effectively used on existing roadway corridors; 2) how installing structural wildlife crossings influence crossing locations, crossing frequencies, and AVCs along roadway corridors where they are installed; and 3) how adaptive management strategies can provide measures to maintain and increase the safe passage of wildlife across roads (as determined by the establishment of mitigation success measures and significance criteria.

This initial baseline data collection, followed by effectiveness monitoring, would serve to ensure that mitigation measures are adequate in providing the safe passage of wildlife across roads that are subjected to improvement projects. Based on preconstruction monitoring efforts, significance thresholds could be developed that would trigger additional mitigation measures to be put in place if the proposed mitigation measures are not adequate at reducing AVCs and at-grade crossings while simultaneously promoting the safe passage of wildlife across roadways. By determining various significance criteria before project construction begins, a benchmark by which to gauge the success of mitigation measures was established, thus creating an adaptive management process that will not only ensure the long-term success of that particular mitigation measure, but will serve as a reference from which future mitigation strategies can be based.

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APPENDIX A
Representative Photos of Structures and At-Grade Crossings along this Portion of Silverbell Road

Photo A-1. One-chamber arch culvert.

Photo A-2. Typical existing at-grade wash crossing.

Photo A-3. Example of existing non-functioning rip-rap and concrete apron at numerous locations.

Photo A-4. View showing proximity of Santa Cruz River to project area.