Black Mountains

Bighorn Sheep Management Plan

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Purpose and Need

In 2006, following substantial declines in the Black Mountains area desert bighorn sheep (*Ovis canadensis nelsoni*) herd in northwestern Arizona, the Arizona Game and Fish Department (Department) convened a team of regional biologists to draft this comprehensive management plan for the sheep population and their habitat in the Black Mountains. The purpose of this plan is to provide a strategic aproach to decision making for the management of this important wildlife resource.

The landscape surrounding the Black Mountains has changed substantially over the past ten years. Master-planned urban developments containing over 30,000 residental homes have followed several transportation enhancement projects through the range, and more highways and developments are proposed. Invasion and establishment of non-native grasses now provide fuel for wildfires which type-convert native plant associations and potentially degrade bighorn sheep habitat. Acute mountain lion (*Puma concolor*) predation on bighorn sheep is prevalent. Continued threats from competition with non-native wild burros remain, as does disease transmission from escaped domestic goats. These issues, coupled with new data regarding sheep distribution and habitat use in the Black Mountains, has created the need for a new management paradigm for bighorn sheep.

The concept of wildlife management plans has existed for more than 50 years. King's (1938, 1941) five-step plan evolved from Aldo Leopold's (1933) textbook, Game Management. The first four steps involve information gathering and analysis for the species and its habitat, with emphasis on the importance of establishing a historical data set. After base data are collected and analyzed, the last step is the development of recommendations for management of both the species and habitat. King's outline is used today as it was when first published, and it is included in two contemporary wildlife management texts- Bailey et al. (1974), and Bailey (1984).

Using this framework, the Department's team first compiled a list of 24 existing general wildlife and bighorn sheep–specific management plans from around the U.S. and Canada (Appendix A). With this benchmark established, the team drafted an outline and obtained concurrence from upper management, gathered and summarized historical data, conducted further habitat analysis, delineated a project boundary, and developed three goals and 19 objectives aimed at long-term conservation of bighorn sheep in the Black Mountains.

The Team met 10 times over 16 weeks to develop this plan. Critical success factors identified were: 1) Clarity – implementation should be simple and provide direction for future department employees; 2) Comprehensive – the plan should address bighorn sheep biology, threats, land use, and politics; and 3) It Should be usable with accountability – the plan should include other agencies and interested parties, identify individuals responsible for implementing objectives, and 4) It should have feedback/evaluation - include deadlines, and contain mechanisms for review, update, and revision.

The plan includes three chapters. Chapter I describes characteristics of the range, current management guidance, and the significance of bighorn sheep. The heart of the plan is Chapter II, where 18 conservation issues are identified, and 56 strategies to manage them are recommended. Chapter III is a concise matrix that contains prioritized implementation strategies. The matrix includes process owners and due dates for each task, and is intended to be a progress measurement tool.

Acronyms and Abbreviations

ac - acres
ADBSS – Arizona Desert Bighorn Sheep Society
ADOT – Arizona Department of Transportation
AML – Appropriate Management Level
APHIS – Animal and Plant Health Inspection Service
AZ-WIPWG – Arizona Wildlands Invasive Plants Working Group
BLM – Bureau of Land Management
BMEMP – Black Mountain Ecosystem Management Plan (BLM 1996)
BOR – Bureau of Reclamation
BT – Blue Tongue
BVD - Bovine Viral Diarrhea
C – Candidate
CE – Contagious Ecthyma
CR – Center of Range
DEM – Digital Elevation Model
Department – Arizona Game and Fish Department
DPS – Department of Public Safety
E - East
EHD – Epizootic Hemorrhagic Disease
ESA – Endangered Species Act
ESI – Ecological Site Inventory
ET – Escape Terrain
F - Female
FHWA – Federal Highway Administration
FNAWS – Foundation for North American Wild Sheep
AGFD – Arizona Game and Fish Department
ft - feet
GIS – Geographic Information System
GMU – Game Management Unit
HDMS – Heritage Data Management System
HMA – Herd Management Area
I&E – Information and Education
IKC – Infectious Keratoconjunctivitis
in - inch
LEPT - Leptospirosis
LMNRA – Lake Mead National Recreation Area
LT - Listed Threatened
M - Male
m - meter
mi - Mile
mo - Month
N - North
NCAA – National Collegiate Athletic Association
NGO – Non-governmental Organization

NPS – National Park Service
NRA – National Recreation Area
NRCS – Natural Resource Conservation Service
P – Proposed
PDL - Proposed De-listing
PI - Parainfluenza
S – Sensitive or South
SC - Species of Concern
SCB – Society for Conservation Biology
SR - Salvage Restricted
s-s – Spread Spectrum global positioning system radio telemetry collar (data is transmitted to receiver in aircraft)
SSDV – Special Services Development Branch (Arizona Game and Fish Department)
stob – Store on Board global positioning system radio telemetry collar (data is stored on board until the end of the collars battery life)
USDA – United States Department of Agriculture
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey
VHF – Very High Frequency (refers to a radio telemetry collar without global positioning system capability)
W - West
w/in - Within
WSC - Wildlife of Special Concern in Arizona
Y – Yes
“ - inch

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Chapter I. Introduction

The Black Mountains: land ownership, use, and resource values

The Black Mountain range is a linear complex adjacent to Lake Mohave, Hoover Dam, and Lake Mead in extreme northwest Arizona. The range occupies the western third of Mohave County and traverses roughly 90 miles beginning in the south near Interstate 40 west of Kingman and running north to the Hoover Dam vicinity. The range contains over 625,000 ac divided among the following ownership: 59% BLM, 34% NPS, 6% private and 1% state (Figure 1). The Department has administratively divided the Black Mountains into four Game Management Units (GMUs) to distribute hunting pressure. The range includes GMUs 15B West, 15C North, 15C South, and 15D (Figure 2). While GMU 15B East is an adjoining unit that also contains desert bighorn sheep, the area was excluded from this planning effort because it is outside of existing cooperative plans between the Department, BLM, and NPS.

The Black Mountains rise abruptly from the Sacramento Valley to large peaks above 5,000 ft. Mean elevation however, is only 2,000 ft. Topography is variably composed of vertical cliff faces, steep and rugged canyons, mesas, boulder-strewn terrain, rolling hills, and broad alluvial valleys. Annual precipitation is generally low, ranging from three inches along the Colorado River to nearly 12 inches on higher peaks (WRCC 1978-2005; Figure 3). The area has a bimodal precipitation pattern, with one rainy season during winter months and another during summer monsoons. Precipitation data is listed in Table 1. Temperatures in the region are extreme, and can range from 25° to 120° F (WRCC 1978-2005).

The range is positioned along the eastern edge of the Mohave desert; however, elements from the adjacent Sonoran and Great Basin deserts also occur and influence overall vegetative composition. Small patches of Great Basin conifer habitat occur at higher and wetter elevations. Along bajadas and sandy plains, creosotebush (*Larrea tridentata*) is the dominant overstory plant. Co-dominants include white bursage (*Ambrosia dumosa*), bladdersage (*Salazaria mexicana*), flattop buckwheat (*Eriogonum fasciculatum*), and Mohave yucca (*Yucca schidigera*). In hills and washes, Sonoran species such as palo verde (*Parkinsonia* spp.), catclaw acacia (*Acacia greggii*), and smoketree (*Psorothamnus spinosus*), are present. Cacti typical of the area include: hedgehog (*Echinocereus* spp.), beavertail (*Opuntia basilaris*), buckhorn cholla (*O. acanthocarpa*), and barrel (*Ferocactus* spp.) (Brown 1994). The Mohave desertscrub is also rich in ephemeral plants. The Black Mountain Ecosystem Plan (BLM 1996) contains a thorough plant list of the region and a detailed geologic account is provided by Bezy (1978).

Despite the harsh environmental conditions prevalent in the Black Mountains, a unique assemblage of wildlife species inhabits the Black Mountains A description of wildlife species is found in the Black Mountains Ecosystem Plan (BLM, 1996) and a list of sensitive plants and animals from the Department's Heritage Data Management System is included in Table 2. The largest herd of free-roaming feral burros (*Equus asinus*) also resides in the Black Mountains. Originally from Africa, these pack animals were prized for their hardiness in arid country. They are sure-footed, can locate food in barren terrain and once carried heavy pack saddles for days through hot, dry environments. The animal was first introduced into the desert southwest by Spaniards in the 1500's and to the Black Mountains in the 1860's (BLM 1996). Early American

prospectors relied heavily on burros as they traveled the deserts in search of gold and silver, and many burros escaped or were released in the Black Mountains during settlement of the West. In 1971, Congress passed the Wild Horse and Burro Act, mandating protection, management, and control of wild, free-roaming horses and burros on public lands. While these animals directly compete with native wildlife, and can significantly degrade habitat quality, they are federally protected species under this Act, and now require substantial management to mitigate these impacts. The BLM administers this program.

The Black Mountains contain the largest, contiguous desert bighorn sheep population in the world. Based on the last qualitative estimate of Arizona's 32 isolated bighorn sheep herds (1998), more than 30% occurred in the Black Mountains (Table 3). The herd is also the primary transplant source of the *nelsoni* subspecies. Between 1957 and 1999, 30 captures were conducted in the range and 650 sheep were transplanted into historically occupied habitats throughout various locations of NW Arizona, Texas, Colorado, and Utah (AZGFD, unpublished data, 2006).

Various mining acts dating to 1866 allow mining on public lands throughout the United States. These acts were intended to provide opportunity for individuals to explore for, discover and purchase valuable mineral deposits on public lands. The laws set general standards and guidelines for claiming the rights to the minerals discovered on those lands. The Black Mountains contain several historical mining districts. The Union Pass District was active from 1865-1943. In the northern end of the range, the Pilgrim District was a gold and silver producer from 1929-45. Commodities sought in the past include gold, silver, zeolite, perlite, fire agate, kaolin clay, lead, mercury, molybdenum, and sand and gravel.

Also relevant to mining is the split estate ownership issue. For example, Santa Fe Pacific Railroad was conveyed the surface estate for thousands of acres throughout Arizona. The BLM acquired some of these lands through their land exchange process, but the Santa Fe Pacific Railroad has sold some subsurface mining rights (which extend from the surface to 100 feet), to mining operators for lands where BLM owns the surface. Mining operators with subsurface rights are not required to enter mineral materials sales contracts with BLM, pay royalties, or undergo environmental review and requirements for mitigation of environmental impacts, and reclamation of mined lands. This situation is exacerbated by the fact that the Arizona Mined Land Reclamation statutes and rules do not apply to non-metallic mines, such as sand and gravel pits, and aggregate quarries. The split estate continues to be problematic for resource management professionals.

Livestock grazing has occurred in the Black Mountains for over 100 years. Federal legislation via the Taylor Grazing Act of 1934 established grazing allotments and facilitated construction of range improvements (mostly watering sources). Livestock grazing continues on a yearlong basis on most of allotments in the Black Mountains. Environmental impacts of livestock grazing and Kingman Resource Area's rangeland management program were analyzed in the Cerbat/Black Mountains Environmental Impact Statement (BLM 1978). This document defined general multiple-use objectives to guide livestock management in the planning area.

The Black Mountains and adjacent lakes provide excellent recreational opportunities such as various water sports, camping, hunting, backpacking, picnicking, horseback riding, off-highway vehicle use, wildlife watching, and photography.

Black Mountain Ecosystem Management Plan (BLM 1996): Existing Guidance

The BLM developed the Black Mountain Ecosystem Management Plan (BMEMP) in 1996 in response to long-standing resource use conflicts and management controversies, primarily regarding desert bighorn sheep, feral burros and livestock. The plan was cooperatively developed and reviewed by a number of diverse public entities and government agencies, and became the primary guide for managing all public lands (including wilderness and LMNRA lands) within the Black Mountain ecosystem.

The BMEMP uses vegetation monitoring and management as the basis for resolving competition issues between large ungulates. First, the plan establishes an area of joint use - defined as the geographical area within which species competition between burros, bighorn sheep, or cattle was most likely to occur (532,800 ac). Next, the BLM divided the estimated amount of available forage in half (available forage in the joint use area was based on a 1978 inventory (BLM 1978), and estimated at 9,500 Animal Unit Months); 50% of available forage was deemed necessary for soil and watershed protection; the remaining 50% was allocated among the competitors as follows: 30% for burros, 30% for cattle, and 40% for big game.

The over-arching goal of the plan is focus on a healthy functioning ecosystem that provides long-term viability for all species in the ecosystem. The plan identifies two vegetation objectives to ensure ecosystem health and establishes animal utilization limits on several key plant species. Using the 1978 inventory, the plan establishes initial stocking rates for ungulates at a rate deemed appropriate for proper functioning and sustainability of the ecosystem. To evaluate the effectiveness of this vegetation-based paradigm, the plan calls for construction of vegetation study exclosures to enable comparison of plant composition in grazed and un-grazed areas. Also, 48 vegetation study sites were established to monitor areas used by burros, cattle, and bighorn sheep (Table 4). The plan also identifies the need to complete Ecological Site Inventories (ESI) in several areas of the range. The ESI is a measurement concept derived from the Natural Resource Conservation Service, and is used to determine the capability of various land forms to produce vegetation.

In addition to vegetation management, the BMEMP prescribes procedures for wildfire suppression, establishment of recreational zones and trail routes to manage visitors, and provides for protection, enhancement and use of cultural resources. According to the plan, feral burros are managed as part of the natural system, but the need for additional research directly related to competition and dietary overlap was described.

Significance of Bighorn Sheep and History of Management

Bighorn sheep have captivated human interest since the earliest recorded time. To tribes of the lower Colorado River for example, the stars of Orion's belt are known as "Three Mountain Sheep." Throughout the west, thousands of bighorn are depicted on cliff faces, and some tribes

ritually cremated sheep bones to appease the animal's spirit (Kemper 2000). Accounts of early Spanish exploration describe a town called Tucsonimon; so named for a 'great heap of horns from the wild sheep' (Wilson 1975). This account suggests that bighorn sheep were once an important food source for Native American people and that bighorn sheep historically occupied most of the arid mountain ranges of Arizona.

While human respect of bighorn sheep is equally prevalent in modern society, few other segment of people have been more enamored by bighorn sheep than sportsmen. In 1977, a non-profit sportsmen's group formed the Foundation for North American Wild Sheep (FNAWS) to promote the conservation, propagation and intensive management of wild sheep and their habitats. Since 1984, FNAWS has amassed more than 30 million dollars for a variety of conservation projects to benefit wild sheep. Revenue from the auction of special tags is the predominant source of this funding; and the winning bid for an opportunity to hunt bighorn sheep is routinely in excess of $100,000 (a single permit in Alberta, Canada once sold for $405,000). The Arizona Desert Bighorn Sheep Society (ADBSS) is the state affiliate to FNAWS, and to date has generated in excess of $5 million for conservation projects that benefit bighorn sheep. Projects funded via tag auctions include: biological studies and research, buffer land acquisitions, wild sheep transplants and re-establishment of populations into suitable historical habitat, wildlife habitat enhancement, and prudent wild sheep management.

Widely considered among the top wildlife management agencies in the world, the Department began pioneering and improving techniques to survey, trap and transplant bighorn sheep, and improve water availability and distribution for desert bighorn sheep in the 1950's (Russo 1956, Lee 1989, Rosenstock et. al 2004, AGFD 2005). Cooperative bighorn management between state and federal wildlife agencies was not formalized until 1957 when the Desert Bighorn Council was created. Biologists studying desert bighorn have since met regularly to share research findings and management techniques, which are published in the *Desert Bighorn Council Transactions*. Another significant contribution to bighorn research occurred in 1974 when several conservation groups convened a workshop to discuss wild sheep conservation and management. Attendees represented the broadest and most representative assemblage of bighorn sheep professionals ever convened. Their purpose was to compile population data and assess management programs on North American wild sheep, and to develop management guidelines to assure the future well-being of wild sheep. Results were published in *The Wild Sheep in Modern North America* (Trefethen 1975).

Other important compilations of bighorn sheep research and management are found in books by the following authors: Geist (1971), Monson and Sumner (1980), and Valdez and Krausman (1999). Most recently, a special issue of Restoration Ecology (Krausman 2000) was dedicated to translocation techniques and conservation strategies for bighorn sheep. This body of knowledge has significantly improved traditional bighorn sheep management strategies over time; however, further improvement in methodology is expected to produce only small advances in sheep conservation (Douglas and Leslie 1999). To be effective, bighorn sheep management must progress beyond traditional strategies.

Chapter II. Bighorn Sheep Mortality Factors and Management Strategies

The most critical factors that influence wildlife populations are mortality and natality. Direct mortality is generally caused by disease, hunting, predation, and highway collisions. Indirect mortality factors include poor nutrition during drought, inter-specific competition for range/forage, habitat fragmentation, and excessive disturbance. The primary goal of management is to ensure wildlife populations are in balance with available habitat (that birth rates exceed death rates). To ensure successful management, managers must be familiar with life history strategies of target species; must be able to detect changes in population size, distribution and structure; and must be able to quantify impacts of individual mortality factors that cumulatively affect population levels. Chapter II discusses biological traits of bighorn sheep, provides a history of survey and population monitoring efforts with recommendations for improvement, and independently addresses both indirect and direct mortality factors. Management strategies for each mortality factor are also presented.

Biological Considerations

Bighorn sheep are generally considered highly *K*-selected species, and have traits such as slow growth rates, late maturation, long gestation, low fecundity and long lives. The biology of this species revolves around retention of juveniles on the home ranges of adults versus dispersal of young from such home ranges. Bighorns have low intrinsic rates of population growth (*r*), which means their ability to recover rapidly from herd depletion is compromised relative to other species (Geist 1975). 'Disperser species' like white-tailed deer (*O. virginianus*) for example, are adapted to exploit early successional habitats and are considered *r*-selected: they reproduce at an early age, produce more offspring with relatively lower survival rates, but generally have the ability to recover rapidly after depletion. One group thus appears more vulnerable to population declines and biological extinction than the other.

Bighorns have evolved population maintenance strategies which revolve around social mechanisms that transmit home ranges and migratory patterns from one generation to the next (Geist 1975). Rather than expulsion of juveniles from the population, bighorn dispersal usually occurs irregularly through segmentation of herds when population densities are high or under unfavorable conditions in which the animals abruptly leave an area. These behaviors are likely an adaptation to the naturally fragmented habitats bighorn sheep occupy, but barriers such as development and roads have necessitated the capture and translocation of bighorn sheep to historical ranges to facilitate re-occupancy of historical habitat. According to Geist (1975), the closely integrated social system of bighorn sheep is a much more important adaptive strategy than those evolved in disperser species. Habitat use by bighorn sheep is so closely dependent on social organization and living traditions that alteration of this structure affects the sheep's ecology more significantly than a similar alteration would a disperser species. By virtue of bighorn sheep ecology and compensatory mechanisms for population maintenance, recovery from population level declines is an inherently slow process.

Male and female bighorn sheep commonly live in separate groups during much of the year and often occupy different habitats (Geist and Petocz 1977, Wehausen 1980, Bleich et al. 1997). Both sexes may share common summer ranges that coincide with the rut, but they show

progressive segregation from winter to spring. During this time, the two sexes use different habitats, with females generally selecting areas near steep and rugged escape terrain (>60% slope) and males often at somewhat lower elevations in relatively less rugged habitat.

Bighorn sheep have a refined ability to learn and adapt accordingly. This trait is evidenced by the animal's exploitation of urban park lawns on one extreme and adaptation to almost exclusive use of rugged, less productive, escape terrain resulting from human disturbance in remote areas on the other. Given this learning ability and the importance of bighorn social structure, the manner in which sheep use a landscape spatially depends on numerous factors, many of which can be entirely unrelated to range condition (e.g., Batcheler 1968, Geist 1971, Bissonette and Steinkamp 1996). Factors that influence the Black Mountain bighorn population, and management strategies to mitigate these factors comprise the remainder of Chapter II.

Population Assessment

Fundamental to successful wildlife management is an accurate determination of the number of animals present in a given area and the ability to detect changes over time in population estimates. These determinations remain among the most difficult and challenging tasks for wildlife managers, especially in western mountain ranges that can encompass hundreds of square miles (Douglas and Leslie 1999). Helicopter surveys are the primary means of estimating the number of bighorn sheep present in the Black Mountains and have been conducted since 1976 (Appendix B). In 1981, surveys were moved from spring to fall. In 1998, survey effort was reduced by 25% because of rising helicopter costs. As a result, the Department approves a budget and survey schedule each year, based on a rotation of units. Surveying only a portion of the range in alternating years may add additional bias to survey data. Because sheep habitat in the Black Mountains is contiguous, movement between units can occur on a daily, seasonal, or annual basis. As such, changes in population estimates could be attributed to animal movements or other factors. Assuming a three-year rotation is maintained, sheep movements should be analyzed using highway crossing telemetry data to determine if a portion or the entire range should be surveyed in the same year.

Two types of data are collected on surveys: classification and population trend data. Classification data (ram:ewe ratios and lamb:ewe ratios) are used to monitor productivity and herd health, and to establish annual hunting permits. Trend information is obtained by documenting total sheep seen per survey, and an annual comparison of sheep seen per hour of survey effort. Although this information is somewhat useful for documenting gross population changes, standardization of survey techniques is needed to enable accurate population estimates in the range.

Accurate bighorn population estimates are especially important in the Black Mountains because the range contains a source herd for transplants. Leslie and Douglas (1986) describe a near catastrophic management decision, based on an apparently erroneous assumption that population estimates reflected actual numbers of bighorn in the population. In this account, for several years in succession, 25-30% of animals counted on surveys were removed from a herd for transplantation. The estimate was unrealistically larger than the total survey count, or previous estimates. Confidence intervals were large and indicated significant growth during drought

despite low recruitment of young. The result was lower reproduction rates and significant herd reduction for several subsequent years – a trend that has decimated other herds across the west.

The challenge of every survey effort is to accurately evaluate what portion of the population is represented by the sample of individual animals. This variable is often termed 'sighting probability' or 'observability' and is the most difficult variable to estimate. Paramount to this type of estimate is standardization of survey transects or blocks to facilitate repeatability. Simultaneous double count is a survey technique developed to improve sighting probability estimates for wildlife surveys (Graham and Bell 1989). Substantial validation of the technique has occurred in Sonoran deserts of southwest Arizona for bighorn (*O. c. mexicana*), but sighting probability estimates for *O. c. nelsoni* in Mohave Desert habitat like the Black Mountains has not been determined. Mark-resight surveys can be used to obtain sighting probabilities, and opportunities exist to use 45 currently marked sheep to obtain these estimates. Estimates can be obtained at no additional expense. The following strategies were identified to address issues related to population monitoring:

Objective: Standardize and refine survey methods for sheep management in the Black Mountains.

Strategy: Establish standardized transects or survey blocks for each GMU in the Black Mountains. Implement simultaneous double counts to obtain estimates of observer variability.

Strategy: Develop a mark-resight population estimate for the Black Mountains using radio-marked animals from existing research projects. Refine bighorn sheep observability predictions using this estimate.

Strategy: Analyze sheep movements in the Black Mountains using existing telemetry data to determine which portions of the range should be flown in the same year.

Transplants

Since the 1960's, translocation of bighorn sheep has been the primary means to reestablish populations in historical, unoccupied habitat and to supplement dwindling populations. From 1955 to 2000, over 1,200 bighorn sheep were transplanted within Arizona (Lee et al. 2000), and bighorn populations increased from 2,500 to over 6,000 during that time. Notable reintroductions occurred at Aravaipa and Paria Canyons and Goat Mountain, all of which support viable populations of bighorn sheep today. In the 1990s, however, several transplant efforts did not meet expectations. In response, the Department conducted a statewide evaluation of bighorn sheep habitat to quantify and prioritize remaining release sites in Arizona (Lee et al. 2000).

The Black Mountains contain the primary source population for desert bighorn sheep transplants in the southwestern U.S. Between 1957 and 1999, 30 captures were conducted in the range, and

sheep were transplanted to locations in northwestern Arizona, Texas, Colorado, and Utah (Appendix C). Of 698 sheep captured, 650 were moved to new locations and released. Capture and release-related mortality was low, averaging around 1%. The remaining sheep were released on site because of health concerns or to maintain preferred sex ratios. Through 1982, bighorn sheep were pursued by helicopter and tranquilized for capture. From 1983 to 1993, bighorns were lured to capture sites using apple mash and captured with drop nets. After 1995, bighorn sheep were pursued by helicopter and captured via net-gunning.

The Department continues with an aggressive transplant program today. Nine potential transplant sites have been identified for supplementing or establishing *nelsoni* sheep populations in Northwest Arizona (BLM 2003). The Black Mountains population was the most likely source for these transplants until recently. Sheep numbers in the Black Mountains are at historically low levels, therefore no transplants are currently being considered. Transplant efforts will continue when population numbers meet the 20-year average (1981-2000) of 19.92 sheep-per-hour seen on helicopter surveys. The Department will transition into using the double-count methodology for estimating sheep populations and determining management triggers when several years of data become available.

Objective: Continue management of the Black Mountain bighorn population as a transplant source herd.

Strategy: Conduct captures and transplants following coordination between Game Branch and Region III when sheep populations meet or exceed the 20-year population average (1981-2000) of 19.92 sheep-per-hour seen on helicopter surveys.

Harvest

Harvesting a desert bighorn sheep in Arizona is a once-in-a-lifetime opportunity. The demand for a bighorn sheep permit far exceeds the allowable harvest. In 2005, the odds of drawing a permit were 137:1 statewide and 117:1 in the Black Mountains. Protection for bighorn sheep began in 1893 when the state was still a territory. Arizona's first bighorn sheep hunt was in 1953, when it was determined that limited hunting of trophy rams might be the only way to save these animals (AGFD 2006). Every year two of the statewide tags are distributed to ADBSS and auctioned to raise money for bighorn sheep conservation. Since 1984, over five million dollars has been raised through these auctions and used specifically for bighorn sheep management and conservation in Arizona. An additional tag was allotted to the Arizona Big Game Super Raffle beginning in 2005 also to generate money for bighorn conservation. Permit numbers in the Black Mountains fluctuate annually based on population numbers and survey information (Table 5). Of the 79 permits available in 2006, 13 were allotted for Black Mountains units. Hunt success has averaged around 98% for the last ten years.

Hunting has been used as population management tool for many species. Research in Alberta has shown that a healthy vigorous herd can be maintained by conservative harvest of mature

rams and population maintenance below carrying capacity (Canadian Fish and Wildlife Service, 1993). Also, Valdez and Krausman (1999) found evidence of density dependent control through increased interactions of individual desert bighorn sheep. Population management below carrying capacity is often offset by increased productivity, breeding of yearling ewes and increased survival of remaining animals (Jorgenson and Wishart 1984).

Bighorn sheep hunters typically select the largest, hence the oldest, rams in the herd (Washington Department of Fish and Wildlife 2003). In 2005, the average age of sheep taken was 7 years old with an average B&C green score of 152 3/8 (Table 6). In Arizona, bighorn sheep are harvested under a general, male-only open season. Hunters can take only one bighorn sheep of the desert subspecies and one of the rocky mountain subspecies in their lifetime and hunters must personally check out within three days following the close of the season in accordance with AGFD rule 12-4-308.

The Department uses harvest a very conservative hunt strategy for bighorn sheep whereby only a small percentage of the total available rams are harvested. Guidelines have been established to set annual bighorn sheep permit numbers. Helicopter survey data including population trend data, ram/ewe ratios, and lamb/ewe ratios are used in setting permit numbers. Wildlife managers determine an observation rate for viewing sheep and use that rate to calculate the total number of sheep, the total number of rams and the total number of class III and IV rams in the population. To maintain a conservative harvest of mature rams, permits are calculated based on a percentage of the class III and IV rams available in the population. Wildlife managers analyze the population trend (increasing or decreasing), average hunt success, access issues in the unit and any other relevant issues before finalizing the permit recommendations. The objective is to retain a sufficient number of mature rams in the population to ensure adequate reproduction and recruitment of younger rams.

Objective: Continue to offer bighorn sheep hunting opportunities.

Strategy: Follow Department hunt guidelines.

Burros

Burros are medium-sized ungulates weighing almost twice as much as a bighorn ram. Both bighorn sheep and burros have the potential to give birth to one offspring per year. Burros can use a variety of terrain including flat areas as well as the more steep terrain usually associated with bighorn (BLM 1996). Burros are opportunistic grazers and can efficiently use more coarse, lower-quality forage than bighorn (Krausman et al. 1999). Burros have a monogastric digestive system while bighorn have a four-chambered stomach. This allows burros to consume large quantities of lower quality forage while bighorn must eat smaller quantities of higher quality forage. While both species have similar potential population growth rates, during dry years bighorn may not conceive at all or may prematurely terminate nursing significantly reducing survivorship of lambs. Burros remain unaffected (BLM 1996).

A review of Bendt (1957), Welles and Welles (1961), Welles (1962), and McMichael (1964) suggests competition between burros and bighorn sheep for water, food or foraging areas is varied, unclear, and dependent upon many factors. Jones (1980) validates this, but suggests when competition does exist, it is most severe during drought, at watering sites (Bendt 1957), or when desert bighorn sheep are stressed (Gallizioli 1977).

During the summer months, both species remain close to water. This causes increased competition for forage and potential displacement of bighorn from water sites. Burros often remain at a water source long enough to trample any riparian vegetation and pollute the water with urine and feces. Water developments constructed by the Department and the ADBSS have burro exclusion fences to reduce this competition.

In 1981, the Black Mountain feral burro Herd Management Area (HMA) was designated. The Appropriate Management Level (AML), which is a population metric determined by an analysis of monitoring data such as grazing use, trend in range condition, actual use, and other factors was set at 478 adult animals. BLM conducts population estimates every three years using a helicopter and a modified mark/recapture technique. Department employees often assist with these surveys. The last survey was completed in 2005 and the herd estimate was 407 adults and 136 juveniles. Over the last 10 years, burro numbers have averaged at 93% of their AML and have necessitated the removal of 1,196 animals. Bighorn have averaged at 65% of their AML with 65 animals being removed in order to augment other populations in the state far worse off than the Black Mountains population (BLM 2006).

As human development proceeds around the Black Mountains, burro habitat is being lost. Somewhere in the vicinity of 10,000 ac of burro habitat has been turned into housing developments. Since the AML was calculated based on original available habitat acreage and is not adjusted with these changes, the same number of burros is forced into a smaller area and into more rugged terrain increasing the competition with bighorn. The proposed realignment of Highway 95 will fragment nearly 30,000 ac of the southwestern bajadas from the range. These bajadas are primarily burro habitat. How this will effect the AML is unknown; however, all lands west of the alignment are expected to be urbanized.

Objective: Minimize competition with burros.

Strategy: Pursue the adjustment of burro AML as habitat is lost to urban development and fragmented by realignment of Highway 95.

Strategy: Conduct research to quantify burro habitat use and their competition with bighorn through research using GPS collars.

Strategy: Continue to assist the BLM with aerial burro surveys identifying over-utilized areas.

Strategy: Support BLM burro removal efforts to maintain appropriate AML.

Livestock

Ranges of desert bighorn sheep and livestock overlap in the Black Mountains. The range includes portions of 15 livestock (cattle only) grazing allotments – nine of which are yearlong operations (Figure 6). A small population of feral horses also exists in the Black Mountains on the East slope of Mt. Wilson. Although desert bighorn sheep generally occupy more steep terrain than the other species, significant overlap occurs at water sources and less rugged feeding areas. Bighorn sheep may also use relatively flatter bajadas during spring where annual forage growth occurs first. Conversely, livestock will range into higher, less accessible terrain if forage is not available in less rugged terrain. Intuitively, such overlap by livestock with similar needs to bighorn sheep results in competition for food, water and space, especially in an area of low forage productivity. As such, competition with livestock is a management concern (Jones 1980) and believed to contribute to declines of desert bighorn sheep populations (Gallizioli 1977, Bissonette and Steinkamp 1996).

From a vegetative perspective, the negative impacts of year-long livestock grazing on hot desert landscapes have been thoroughly documented. A General Accounting Report claims that livestock grazing on southwestern deserts causes excessive damage to wild plants and animals (United States General Accounting Office 1991). Soil disturbance causes more fire-prone invasive exotics to spread more quickly. Recovery takes many years and may be irreversible. However, quantitative, site-specific data is needed to elicit meaningful changes in land use practices. In 1993 the BLM recognized that these allotments meet the agency's 1968 ephemeral rule designation (land below 3200' in elevation that receives ≤10" of annual precipitation); however there has been reluctance to proceed with the reclassification prior to completion of 16 Ecological Site Descriptions by the NRCS. Nearly 550,000 ac of the ecosystem (55%) is below 3,200 feet in elevation and receives between three and six inches of rain annually. An additional 24,000 ac (23%) is below 3,200 feet and receives less than 10 inches of annual precipitation (Figure 3).

Behaviorally, bighorn sheep react adversely to disturbance, and occupy habitats sensitive to change (Van Dyke et al. 1986). Livestock activities on these sites can negatively affect sheep not only through resource (i.e., forage, space, cover, water) exploitation, but also behaviorally (Geist 1971). On shared ranges, social intolerance may impose greater limitations on distribution and habitat use of bighorn than competition for forage. Bissonette and Steinkamp (1996) studied seasonal cattle grazing as an agent of ephemeral habitat fragmentation on a newly reintroduced population of California bighorn sheep (*O. c. californiana*). They found that core areas used by bighorn and distances to less productive escape terrain generally decreased as cattle moved closer to sheep. Successful management of competition between bighorn sheep and livestock must consider these behavioral traits and the habitat-related components described above.

Objective: Minimize competition for food and space between native bighorn sheep and domestic livestock.

Strategy: Facilitate completion of NRCS ecological site inventories to enable ephemeral designation for allotments within the Black Mountains (BLM 1993). Ephemeral designation of livestock allotments would eliminate year-long grazing in areas that receive less than six inches of annual precipitation, and are generally below 3,200' in elevation.

Strategy: As described in the BMEMP, initiate research to evaluate competition and subsequent habitat selection between bighorn sheep and livestock.

Strategy: Coordinate with BLM to defer livestock grazing following wildfires and during restoration efforts in burned areas.

Strategy: Discourage new livestock water sources within bighorn sheep habitat.

Strategy: Work with permittees to develop and implement projects that will improve range conditions or minimize conflicts between bighorn sheep and livestock.

Predation

Bighorn sheep have evolved a variety of behavioral adaptations to avoid predation. A stocky build and relatively short legs provide agility on steep and rugged terrain, but preclude the fleetness necessary to escape predators in more gentle slopes. Another important adaptation is group living (Hamilton 1971, Alexander 1974). Groups provide more eyes and ears, and enable members to spend more time feeding and less time surveying for predators. Studies of this phenomenon have found that increases in group size of six or more bighorn sheep confer an advantage in the proportion of time allocated to feeding (Berger 1978, Risenhoover and Bailey 1985). The selfish herd concept of Hamilton (1971) suggests that greater group sizes may confer further behavioral comfort.

Bighorn sheep are primarily diurnal (Krausman et al. 1985). Coupled with keen eyesight (comparable to 8x binoculars) to detect predators, diurnal behavior minimizes predation risks. Nights generally are spent on rocky slopes. Bighorn sheep are vulnerable to a variety of predators, including mountain lions, bobcats, coyotes, and golden eagles. All of these predators are capable of killing both adult and young bighorn sheep (Valdez and Krausman 1999). Bobcats and coyotes are the most effective predators of lambs while mountain lions are more inclined to kill adult sheep (Wehausen, 1996).

Significant predation of bighorn sheep by mountain lions has been documented in the Black Mountains (AGFD, unpublished data). Predation by mountain lions can be a substantial source of mortality in some bighorn sheep populations (Logan and Sweanor 2001) and mountain lions appear to be the only predators that can cause significant mortality in bighorn sheep populations that occupy suitable habitat (Sawyer and Lindzey 2002).

Documented mortality of radio-collared sheep since April 2004 indicates predation is having a negative impact on the Black Mountain bighorn population and is inhibiting future recovery of this population. Twenty of 30 recorded mortalities of radio-collared sheep from April 2004 to October 2006 are attributed to mountain lion predation (Figure 7). Of the 30 total recorded mortalities on radio-collared bighorn sheep, 17 were ewes and 13 were rams; 11 of the 20 mortalities attributed to lion predation were ewes and the remaining 9 were rams. Cause of death was investigated for several additional bighorn sheep mortalities, but could not positively be attributed to mountain lions because of carcass condition (Appendix D). Over 25% of the radio-collared sheep on three active study areas (Hoover Dam, GMU 15CS, and Highway 68) have been killed by mountain lions in a two-year period. Actual percentages would be significantly higher without the addition of the Hwy 68 study as these animals have only been collared since November 2005. Previous monitoring efforts (1989-1991) in the same area (Cunningham and deVos 1992) documented 12 bighorn sheep mortalities; however, only one was attributed to mountain lion predation. This suggests that mountain lion predation on sheep in the Black Mountains is higher than historical levels – an increasingly common phenomenon documented in other areas of the west.

While predation is believed to rarely threaten population survival, several recent accounts across the southwest have documented cases to the contrary. Research indicates individual lions may be responsible for the majority of predation in a given area, and adverse effects are most likely to occur in small isolated desert populations (Sawyer and Lindsey, 2002). For example, there is

considerable evidence that increased mountain lion predation during the 1980's sent Sierra bighorn herds spiraling toward extinction in California and, given the social nature of bighorn sheep biology, the herd has not recovered (Wehausen 1996). In the Peninsular Ranges of southern Califronia lion predation rates were as high as 26% and contributed to listing these sheep as endangered (Hayes et al. 2000). In the Mazatzal Mountains of central Arizona, McKinney et al. (2006) found that nutritional status and mountain lion predation during a drought influenced desert bighorn sheep population parameters and that short-term removal of mountain lions contributed to higher growth and productivity of the small, isolated population - even during periods of drought. Mountain lion predation was the primary proximate cause (75%) of 16 known-cause mortalities of a reintroduced bighorn sheep herd in New Mexico (Rominger et al. 2004). Mountain lion predation may have limited the success of that reintroduction effort and was believed to impose destabilizing inverse density-dependent mortality.

Due to the significance of the Black Mountains bighorn sheep population and its importance as a source herd for transplant animals, mountain lion populations will be managed to limit adverse impacts to bighorn sheep. Ballard et al. (2001) found several factors common in case studies that dictated when predator reductions were effective and prey populations increased. These factors included:

- Predator control is implemented when the prey populations are below habitat carrying capacity,
- Predation is identified as a limiting factor,
- Control efforts reduce predator populations enough to yield results (e.g., expected to be approximately 70% of a local predator population),
- Control efforts are timed to be most effective (just prior to predators or prey reproduction), and
- Control takes place at a focused scale (generally 400 mi^2 [250,000 ac]).

Aerial surveys will be used to determine bighorn sheep population status. Long-term averages of sheep seen per hour will be used to establish population averages. The long-term average (1981-2000) is 19.92 sheep per hour, and predator control will be initiated when the population falls below this average or when Department personnel document mountain lion predation is occurring and is considered to be a limiting factor. The Department will transition into using the double-count methodology for estimating sheep populations and determining management triggers when several years of data become available. Multiple bag limit seasons will be established as a first step to facilitate removal of mountain lions through sport harvest. This strategy has shown a small measure of effectiveness, however, other management actions are needed to ensure an adequate removal of offending lions. Other potential removal methods include snares, leg-hold and box traps, aerial gunning, shooting, hound hunting or other approved methods. USDA APHIS - Wildlife Services (Wildlife Services) or authorized private contractors will be used to perform most removals. Department employees may also be authorized to remove lions from the management area or direct other individuals to remove offending lions in areas where they are known to be killing bighorn sheep.

Predator control targeted at offending mountain lions will continue until the sheep population recovers or until established removal criteria are met. The sheep population will be considered

"recovered" when the sheep seen per hour on aerial surveys meets the long-term average of 19.2 sheep per hour for two consecutive years. Predator control will also be discontinued prior to full recovery of the sheep population if 70% of the mountain lions are removed (based on track and scent station surveys by Department biologists) and predation is no longer being documented.

Monitoring of the sheep population will be necessary to determine predation rates and to assess recovery. Radio tracking of collared sheep is one of the most effective means of documenting mortality and will be used when possible to monitor the population. Annual helicopter surveys during or following predation management actions will be necessary to track the population and determine when recovery goals are met.

Objective: Determine cause of mortality and extent of predation when population declines are documented.

Strategy: Seek funding for monitoring of bighorn sheep with radio-collars to determine cause and extent of mortality.

Objective: Reduce predation mortality on sheep when populations fall below the long-term average (19.2 sheep/hour of aerial survey).

Strategy: Implement predator control actions when the sheep population falls below the long-term population average and Department personnel document mountain lion predation is occurring and is considered to be a limiting factor.

Objective: Monitor recovery of the sheep population when predator control is implemented.

Strategy: Seek funding and implement annual helicopter surveys to track changes in the population to determine when recovery goals are achieved.

Domestic Goats, Sheep, and Disease Transmission

Although closely related to bighorns, domesticated sheep and goats evolved on a different continent and carry a host of diseases fatal to native bighorn. Disease is most prevalent when animals are stressed and during severe drought. Multiple diseases may also combine to increase mortality. Bighorns seem particularly susceptible to respiratory problems like bacterial pneumonia. Pasturella, for example, can be carried by healthy domestic sheep and goats, but is deadly when transmitted to wild sheep. Scabies is another common disease easily transmitted to bighorns; it was responsible for significant declines in the late 1800's and early 1900's. Disease transmission from burros or horses to bighorn sheep has not been substantiated; however, isolated cases of transmission from cattle to bighorn sheep have been documented (Jessup 1985, McCarty and Bailey 1994).

Since the late 1800's, diseases transmitted by domestic sheep and goats have caused large, recurrent population-level declines in bighorn sheep throughout the western U.S.. These declines have been well documented (Foreyth and Jessup 1982, Jessup 1985, McCarty and Bailey 1994), and subsequent regulations restricting contact between domesticated and wild

sheep have been enacted. Current public land regulations limit contact between domestic sheep and goats and existing bighorn populations. The BLM (1998) uses the following criteria to prevent interactions between domestics and wild sheep: 1) grazing and trailing should be discouraged near native wild sheep ranges; 2) native and domestics should be spatially separated by buffer strips of 8.4 mi except where topographic features or other barriers minimize contact between the two; 3) domestics should be closely managed and carefully herded where necessary to prevent them from straying into native wild sheep areas; 4) trailing near or through occupied native wild sheep ranges may be permitted when safeguards can be implemented to prevent physical contact between the two; 5) BLM must conduct on-site use compliance during trailing to ensure safeguards are observed; 6) cooperative efforts should be undertaken to quickly notify the permittee and appropriate agency to remove any stray domestic sheep or goats or wild sheep in areas that would allow contact between domestic and wild sheep; and 7) native wild sheep should only be reintroduced into areas where domestic sheep or goat grazing is not permitted.

While these safeguards have proven successful on federal lands, similar restrictions on state and private lands do not exist. Domestic sheep and goats sometimes escape these areas and take up residence in bighorn sheep habitat on public lands. Domestic sheep and goats are classified as livestock in Arizona and cannot be removed from public land without owner permission and/or authorization from the Arizona State Veterinarian. Preceding action, legal notice must be published in local newspapers for five days to enable owners to reclaim the animal.

In 2003, a large herd of goats pastured on state trust land escaped into the Silverbell Mountains near Tucson. Within a month, wild bighorns contracted Infectious Keratoconjunctivitis (IKC) and Contagious Ecthyma (CE). IKC caused blindness in many sheep during the estimated 122 day epizootic. Although the Department conducted several captures and treated infected animals, mortality was still 44% on marked animals. Subsequent lamb recruitment was also severely reduced by the two diseases (Jansen 2006).

Between 1999 and 2001, a domestic goat was observed with bighorns by Department personnel in Unit 15CS. Efforts to remove the animal were unsuccessful. Although difficult to confirm, this incident could have contributed to a subsequent population-level bighorn sheep decline in the Black Mountains. Population monitoring revealed a 78% reduction of bighorns observed per hour in Unit 15CS. In a separate incident, a domestic goat was successfully removed from bighorn habitat in the Aubrey Peaks wilderness in 2006. This animal was believed to have escaped from its owner, though this area is sparsely populated and the nearest residence is approximately 10 miles away.

Disease monitoring in the Black Mountains has been sporadic and primarily conducted in conjunction with transplant efforts. Blood samples taken from captured sheep during this period suggest that population declines in 1981 and 2002 were caused by disease outbreaks. Following the 2002 population decline, a concerted disease-monitoring effort was conducted in the Black Mountains. Samples obtained from highway movement research projects in 2003 and 2004 were tested for disease. An additional 18 samples were collected in 15CS where significant declines were documented. From 2003-2005 blood samples were also collected from hunter-killed sheep for analysis. Serologic titers indicating exposure and/or infection from a number of bighorn sheep diseases were detected during this monitoring but rates from exposure to Bluetongue Virus (BTV) were much higher that previous testing events.

Between 1981 and 2005, 235 sheep were tested for disease from 11 separate testing events. Positive exposure to 7 different diseases was detected during testing. An additional two diseases have been detected through field observations and annual hunter check stations. The following is a summary of diseases detected in the Black Mountains sheep population.

Chronic sinusitis is prevalent in bighorn sheep throughout Arizona (Bunch and Webb 1979). In severe cases, necrosis of the frontal bone and thinning of the braincase creates holes and abscessing in the brain, which is fatal. The leading theory for cause of this condition is bacterial infection secondary to necrotic bot fly larvae (*Oestrus ovis)*, which are deposited in the nostrils of bighorn sheep. Evidence of chronic sinusitis is common in the Black Mountains bighorn sheep herd and is commonly observed in hunter-harvested sheep.

Scabies due to infestation by *Psoroptes ovis* mites were monitored from 1979 through 1981 in the Black Mountains (Welsh and Bunch 1983). Hunter-harvested sheep brought into mandatory Department check stations are inspected for scabies annually. Approximately 25% of live-captured sheep in 1997 and 1980 had psoroptic scabies, though lesions were confined to the ears. Occurrence of scabies was highest in males, with 100% showing prevalence in 1980. A 33% decline in the 1981 population census was observed following increased severity and prevalence of psoroptic scabies. Scabies has been documented in the Black Mountains population every year since 1984.

Epizootic Hemorrhagic Disease (EHD) and Bluetonge (BT) are acute, infectious viral diseases that can cause hemorrhaging and oxygen loss in the blood of infected animals. Transmission of the disease occurs through the bite of midges (*Culicoides spp.*). Although major die-offs in deer populations from these diseases have been documented, it is unclear what impacts they may have on bighorn populations. BTV is thought to be at least partially responsible for the die-offs of desert bighorn sheep in Texas (Robinson et al. 1967). Sheep mortality in Arizona from these diseases was only recently confirmed (Noon et. al. 2002). Blood tests of sheep in the Black Mountains indicate that exposure to both these diseases is common and documented exposure was particularly high following the 2002 die-off.

Contagious Ecthyma (CE) is a parapoxvirus that causes mild to severe lesions on the lips, muzzle, and oral tissues of bighorn sheep. In severe cases, this disease can cause interference with locomotion and feeding or even cause severe debilitation. It is typically transmitted by nose-to-nose contact between animals or through salt blocks or other concentrated food sources. Exposure to this disease has been documented in the Black Mountains but does not appear to be a major cause of mortality.

Leptospirosis (LEPT) is a water-born bacterial disease that affects the kidneys and liver of infected sheep. It is typically transmitted to water through urine of an infected animal. LEPT has been detected in sheep from the Black Mountains but is unlikely to be a major mortality factor. Sheep drinking water from Lake Mead and the Colorado River is suspected as the main source of exposure.

Parainfluenza 3 (PI3) is the main viral pathogen affecting Black Mountain sheep. PI3 is a major predisposing factor to often-fatal bacterial pneumonia as this virus destroys the lining of the

respiratory tract, allowing bacteria to migrate into the lungs and become pathogenic. It has also been suspected as major source of lamb mortality in other populations (DeForge et al., 1982). Serologic titers for PI3 have been found in almost every disease survey conducted in the Black Mountains.

Bovine Viral Diarrhea (BVD) is a viral pathogen that is transmitted by direct contact between animals or through feces. BVD is one of the most economically significant viral diseases in cattle although impacts to bighorn sheep are not well known. BVD is known to potentially reduce the immunity of an infected animal even when other clinical signs are not present. BVD has been suggested as a precursor to other diseases in bighorn such as viral pneumonia (Van Campen et al. 2003).

Bovine Respiratory Syncytial Virus (BRSV) is another viral disease detected in Black Mountain sheep that causes lung problems. Like PI3, it can make sheep more susceptible to bacterial pneumonia.

Objective: Monitor disease occurrence within the Black Mountain bighorn sheep population.

Strategy: Obtain blood samples from all captured or hunter harvested sheep for disease testing. Packets containing sample procedures and collection tubes should be mailed to hunters each year at least one month prior to the hunting season.

Strategy: Conduct additional survey effort during or following suspected disease outbreaks to monitor population status.

Objective: Reduce the potential for disease transmission between feral goats and sheep and wild bighorn sheep.

Strategy: Establish an annual schedule with the BLM and Arizona State Veterinarian for authorization to remove any feral goat or sheep found on BLM land within the Black Mountains. This should occur in April of each year and requires the BLM to post public notice in local newspapers.

Strategy: Removal of any documented sheep or goats within the Black Mountains will be given priority by Department personnel. Volunteers will be used when possible.

Strategy: Develop an I&E effort targeting county planners and urban and rural residents living adjacent to the Black Mountains to inform them of the potential impacts of disease transmission from goats and sheep.

Habitat Considerations

Two adaptations of bighorn sheep primarily define their basic habitat requirements. The first is agility on precipitous rocky slopes, which is a primary means of evading predators. The second is keen eyesight, which is a primary means of detecting predators. Consequently, desert bighorn sheep generally select open habitats that facilitate early detection of predators and allow adequate time to reach the safety of steep terrain. Large expanses lacking precipitous escape terrain, such as the Detrital Valley, represent substantial barriers to movement. Even within mountain ranges like the Black Mountains, bighorn sheep habitat is patchy and the population structure is one of natural fragmentation.

Paramount to successful management of any wildlife species is habitat protection, maintenance, and enhancement. According to recent studies, habitat destruction is the main factor threatening at least 80% of species listed under the federal Endangered Species Act; more than 95% of listed species are endangered to some extent by habitat loss or alteration. As such, the need to accurately identify core bighorn sheep habitat is fundamental to subsequent conservation strategies. Cunningham (1989) reviewed several habitat evaluation models and identified two (Hansen 1980, Brown 1983) that best predicted areas used by bighorn sheep in Arizona. Most habitat models reviewed measured a variety of features to predict and quantify areas used by bighorn sheep; however, the four common to all models included: (1) topography (i.e., slope, regularity, rockiness); (2) distance from permanent water; (3) present bighorn use and type of use; and (4) human disturbance (i.e., roads, mining and other land uses).

In 1976, the first intensive inventory and analysis of desert bighorn sheep habitat was conducted in the Black Mountains (Hinkes 1978). The analysis was based on six months of ground and helicopter surveys, available literature, and personal contacts. Crucial habitat such as lambing grounds, summer concentrations, water sources, migration areas, and ram use areas were identified. Using the modeling variables described above, AGFD regional personnel mapped the Black Mountains and classified them into high, medium, and low-value habitat. Results identified 244,500 ac of bighorn habitat of which 77,000 ac (31%) was rated as 'high value'. This modeling strategy was incorporated by the BLM (1996), but acreage estimates differed from those of Hinkes (1978). The 1996 plan identified 296,399 ac of bighorn sheep habitat classified into the following categories: Lambing grounds – 38,807 ac, High Value Habitat – 80,258 ac, Medium Value Habitat – 95,154 ac, and Low Value Habitat – 82,180 ac.

A variety of habitat improvement projects have been implemented since the 1976 habitat delineation. Forty-one water developments have been constructed since that time to expand bighorn sheep distribution in the Black Mountain. Data pertaining to bighorn sheep habitat use in the Black Mountains have also substantially increased. More than 81,000 individual locations from radio-collared sheep have been obtained and, pending a recent proposal, this number could easily double for an area of the range currently lacking this information. Additionally, a technological advance in satellite imagery and Geographic Information System (GIS) software has facilitated the ability to map habitat at better resolutions than in the past.

The widely accepted definition of escape terrain for bighorn sheep is land with slopes >60% (Holl 1982, McCarty and Bailey 1994, McKinney et al. 2003). McKinney et al. (2003) also found that desert bighorn spend a significant amount of time adjacent to escape terrain (within

984 ft); usually on slopes >40%. Using a 33ft resolution digital elevation model (DEM), the team analyzed the animal location data described above in relation to slope in the Black Mountains. Contrary to findings by McKinney et al. (2003), 42% of bighorn locations in the Black Mountains were on slopes <40% but still within 984 ft of 60% slope escape terrain. As such, we incorporated a 984-ft buffer around all 60% slope escape terrain in the Black Mountains. Using these modeling criteria, only 2,195 bighorn locations (2.7%) fell outside of this delineation.

We used this model to create a new boundary depicting bighorn sheep habitat in the Black Mountains. First, a polygon was drawn around the outer edge of the area. Urban areas at the habitat edge were excluded, particularly around Bullhead City. Independent of habitat, the polygon was drawn to exclude all private land in that area. All land west of proposed SR 95 Alternative C were also excluded (Figure 8). The resulting polygon encompassed 625,419 ac, of which the model indicated 570,260 ac (91%) was bighorn habitat (Figure 9). This new delineation is 51% larger than the habitat boundary drawn in 1976 and incorporated in the 1993 BMEMP. An accurate depiction of bighorn sheep habitat is necessary to effectively manage the many land uses that are incompatible with bighorn sheep conservation.

Objective: Maintain data-based bighorn sheep habitat delineation for use as a management tool.

Strategy: Coordinate with BLM to incorporate the new bighorn sheep habitat delineation into the BMEMP.

Strategy: Refine the bighorn sheep habitat delineation as additional distribution data becomes available.

Habitat Acquisition and Urban Development

Human impacts to desert bighorn sheep are well documented and isolation by human encroachment is considered a primary factor limiting populations (Gionfriddo and Krausman 1986). Historical populations of desert bighorn sheep in the Tucson, Sawtooth, Picacho, Rincon, and Santa Catalina mountains of southern Arizona have declined or become extirpated by industrial, urban, and agricultural developments (Krausman et al. 1979). Jorgenson (1988) found that bighorn sheep may abandon areas with high human activity. MacArthur et al. (1979) measured heart rates of bighorn sheep ewes as an indicator of stress and found inverse correlations with distance to roads; he hypothesized that ewes attempted to avoid roads. Spraker et al. (1984) described a stress-related bighorn sheep die-off associated with dam construction in Colorado. These modifications in behavior can have serious implications for bighorn sheep, especially in harsh desert environments (Geist 1975, Bleich et al. 1990).

Significant private land in the Black Mountains is interspersed with lands managed by BLM's Kingman Field Office and is increasingly at risk of development. In their 1993 Resource Management Plan, the BLM identified 14,940 ac of private land for acquisition to better

consolidate bighorn sheep habitat. To date, however, only 340 ac have been transferred into public ownership. Using GIS, we identified 122 polygons containing private and state Land in core bighorn sheep habitat. Because land acquisition is expensive and at times politically sensitive, we created scoring mechanisms to prioritize parcels most important for habitat conservation. Polygon scoring criteria included: 1) proximity to water sources, 2) proximity to a qualitative center line (or core) of the mountain range, and 3) amount of escape terrain in the parcel (Table 7). State lands were scored separately and are ranked below private lands because they are less susceptible to development.

Proximity to permanent water was considered the top priority for acquisition and parcels containing a water source received a maximum score of nine points. Lands within ½ mi of a water source received second priority (three points) because access to the water source could be restricted. Next, juxtaposition of parcels in relation to the core of the range was prioritized (Figure 10). Parcels within ¼ mile of the center line received first priority (five points), those within one mile received second priority (three points) and those within two miles (3218 m) received third priory (two points). Finally, the amount of escape terrain was quantified and ranked accordingly. Priority (four points) was given to parcels comprised of ≥30% escape terrain. Parcels with 20-29% escape terrain received three points, and parcels containing 10-19% escape terrain received two points. Parcels containing <10% escape terrain received one point. The prioritized list of properties is located in Appendix E.

An increasing urgency to acquire priority habitat parcels for bighorn sheep exists in the Black Mountains because the range is located in one of the fastest growing regions of the U.S.. Mohave County experienced a population increase of 494 percent from 1970 to 2000 (Kessler 2003). The range is 30 minutes from Las Vegas, within a half-day drive of metropolitan southern California, and population centers in Utah and Arizona. Visitors to Lake Mead National Recreation Area (LMNRA), which includes around 85 miles of shoreline connected to the Black Mountains, topped nine million in 2001 (LMNRA 2002). The catalyst of this growth trend has been highway expansion. The result to bighorn sheep is increased risk of habitat loss, fragmentation, and degradation.

Massive urban development projects have followed expansion of Mohave County's transportation network. The Laughlin Ranch master planned community east of Bullhead City, for example, is currently under construction. When complete, the development will consist of 44,000 single family homes and is expected to accommodate at least 120,000 people within 20 years. The Sterling development is a proposal of similar magnitude in the southwest bajadas of the range and several others from Bullhead City south to Interstate 40 are in preliminary stages of land zoning changes.

On the eastern front, both Walmart and Tyson Foods, Inc. have proposed substantial distribution centers and an industrial park in the Golden Valley area. In response, a Las Vegas developer has already purchased nearly 6,000 ac adjacent to the Black Mountains, and has begun a master planned development to include a large recreation center, a golf course, and a town center with shopping and cultural amenities. The project includes construction of >33,000 homes. Among the acreage purchased is a parcel that contains two significant water sources for desert bighorn sheep (Fig and Cave Springs) and a substantial amount of rugged high quality bighorn sheep habitat.

Similar development is slated at the north end of the range as well. Upon completion of the Hoover Dam bypass, the White Hills area just east of the Black Mountains will be within favorable commuting distance from the Las Vegas valley. Several developers have purchased large tracts of land in anticipation of the highway's opening. A proposal for a 21,240-ac planned community in White Hills has been filed with the Mohave County Planning and Zoning Department. The plan calls for the development of 35,000 dwellings including homes, apartment complexes, golf courses, a gas station, and parks and hiking trails at the northeast corner of Highway 93 and White Hills Road. Lands once considered extremely remote in and around the Black Mountains are now at an increased risk of development. Clearly, a mechanism to facilitate acquisition of key parcels for bighorn sheep conservation is needed and is urgent.

Objective: Prevent loss of bighorn habitat to development on private and state land in-holdings.

Strategy: Monitor real estate listings for parcels identified in Appendix E as important bighorn sheep habitat. Enlist volunteers to monitor listings.

Strategy: Annually pursue funding to acquire prioritized land parcels. Sources may include state and federal conservation funds, transportation mitigation funds, the ADBSS, and other non-governmental organizations.

Strategy: Coordinate with the BLM to ensure valuable bighorn habitat is considered in future land acquisitions and trades.

Strategy: Work through the International Association of Fish and Wildlife Agencies to influence congress toward re-initiation of federal land exchanges.

Highways and Roads

The Department documented 73 bighorn sheep roadkills along U.S. 93 south of Hoover Dam from 1973 to 2002, an average of 2.5 per year**.** This amount is likely underestimated since some animals move away from the highway before dying and incident reports are assumed to be inconsistent. In 1989-90, for example, Department biologists were on-site in this area an average of three days per week conducting research on bighorn sheep (Cunningham 1993). During this period, reports of road-killed animals increased 21% above the 29-year average. Based on this finding, highway related mortality of bighorn sheep on U.S. 93 could approach a minimum of 12-16 animals per year.

While roadkill is a significant problem, habitat fragmentation presents an even greater challenge (Figure 11). The increasing network of roadways covering Arizona has relentlessly fragmented much of the remaining wildlife habitat into smaller patches. Fragmentation creates "edges" around intact habitat and can create patches so fragmented that they contain virtually no interior

habitat. The effect can be devastating to populations of wide-ranging animals which need large, open areas to survive. An adult male bighorn sheep may occupy a territory covering a range as large as 24 mi^2 (15,073 ac) Jense et al. (1979). Finally, because habitat fragmentation may limit breeding options, genetic integrity of populations can become severely degraded by in-breeding (Epps et al. 2005).

At the north end of the range, U.S. 93 was identified as a national transportation trade corridor, with traffic projections crossing the dam exceeding 25,000 vehicles per day within 10 years (FHWA 2001). To address this increase, a 15-mile segment through the Black Mountains from Hoover Dam south toward Kingman is currently being engineered for expansion (Figures 12 and 13); the Hoover Dam bypass, which includes a major bridge over the Colorado River, is scheduled for completion in 2008. Between Kingman and Bullhead City, highway expansion along SR 68 traversed the middle portion of the Black Mountains and was completed in 2003. Lastly, a proposal to extend SR 95 from its current terminus at Interstate 40 north to SR 68 east of Bullhead City has been submitted. If approved, a new four-lane divided highway would skirt the western foothills of the range and further accelerate economic development in areas now considered relatively remote. Other roads that could facilitate urban expansion and habitat fragmentation in the Black Mountains include Historic Route 66 south of Golden Valley and the Cottonwood Road several miles north of SR 68.

Objective: Ensure highway permeability for wildlife in the Black Mountains.

Strategy: Continue integration of conservation and transportation planning efforts.

Strategy: Continue research and monitoring to ensure wildlife crossings properly placed and designed. Coordination with BLM, NPS, DPS, and ADOT should occur to ensure human use near crossing structures is minimized.

Strategy: Focus on acquisition of parcels that will otherwise facilitate rapid highway and urban expansion in the Black Mountains.

Strategy: Quantify human disturbance and wildlife use of underpasses along SR 68.

Noxious and Invasive Plants

Compounding urbanization impacts to the Black Mountain range is the spread and proliferation of noxious and invasive plants. A noxious weed is an undesirable non-native plant that requires management or control because of legislative action or statute. Arizona statute defines noxious weeds as those not indigenous to the state and likely to be detrimental, destructive, or difficult to control. Federal and state noxious weed lists are primarily concerned with agricultural pests instead of those that impact native plant and animal communities, and ecosystems (Northam 2005). The Arizona Wildlands Invasive Plants Working Group (AZ-WIPWG) however, lists 71 species that threaten Arizona wildlands.

Also of concern are the many invasive plant species in the Black Mountains not on the noxious species list. Invasive or alien plants generally proliferate rapidly, and replace desirable native plants. Most of these species are highly competitive, are sometimes harmful or destructive and are difficult to control. Invasive plants generally lack competitors or natural control mechanisms such as pathogens or predators and thrive at the expense of native plant and animal communities. Up to 46% of endangered plants and animals have been negatively impacted by invasive species (Wilcove et al. 1998), and rangeland weeds cause an estimated loss of $2 billion annually - more than all other pests combined (DiTomaso 2000).

Noxious and invasive weed infestations occur in the Black Mountains and reduce the biological, agricultural, recreational, and economic value of the land. Infestations suppress native plant species and also impact bighorn sheep habitat. These plants compete with native vegetation for space, moisture, and nutrients; alter fire regimes; interrupt cycling of nutrients; and influence native plant regeneration patterns (ADOT 2002). In addition, these plants reduce the suitability of the range for livestock grazing, which in turn increases competition with bighorn sheep for desirable forage. In 2004, above average winter and spring precipitation in the Black Mountains favored large infestations of many undesirable species such as Sahara mustard (*Brassica tournefortii*), red brome (*Bromus rubens,),* jointed goatgrass *(Aegilops cylindrica),* and common Mediterranean grass (*Schismus barbatus).* Besides direct competition for space, water, and nutrients, some species such as Saharan mustard are also allelopathic which further inhibits growth of native plants.

Prevention and detection are the least expensive ways to control the spread of invasive and noxious weeds (Howrey and Ruyle 2002). Conversely, control and site rehabilitation are extremely expensive and difficult to implement. Although weeds are a significant problem in Arizona, the number of species and spread has been lower than in other states, possibly due to the arid climate and lower incidence of feeding of hay to livestock. Many scientists believe, however, that invasive and noxious weed infestations in Arizona may increase exponentially and cause wide-spread irreparable damage to native landscapes in the near future (Howrey and Ruyle 2002). Because infestation in Arizona is at comparatively early stages, detailed invasive and noxious weed inventories need to be conducted annually. To date, this has not occurred in the Black Mountains.

Objective: Detect and prevent the spread of invasive and noxious weeds in the Black Mountains.

Strategy: Provide invasive and noxious weed identification training to AGFD Region III personnel.

Strategy: Incorporate invasive and noxious weed prevention measures in bighorn sheep I&E efforts. Suggestions include: drive, hike, and camp only on established roads and trails away from infested areas, use certified "weed free" feed for pack animals and clean heavy equipment if it is used in weed infested areas prior to moving to non-infested areas.

Strategy: Coordinate with federal and state land management agencies to implement invasive and noxious weed control and rehabilitation efforts.

Wildfires

The current fire regime in the Black Mountains is described as 'moderately altered' from its historical state (condition class 2) which stems from invasion of fire prone non-native grasses (BLM 2004). Mohave desert shrub communities in lower elevations had historical fire return intervals of 35 to >100 years. In higher elevations where Grand Canyon desert shrub and semi-desert grassland communities prevail, historical fire return intervals were 0−35 years. The current fire regime in these areas is described as 'moderately to severely altered' (condition class 2-3) due to introduced plant species and grazing impacts (BLM 2004). Thirty-seven wildfires have burned more than 51,000 ac of quality bighorn sheep habitat since 1980 (Table 8); juxtaposition of these fires is located in Figure 14.

The majority of fires in the Black Mountains have occurred in high elevation sites where red brome, a fire prone, introduced annual grass from Mediterranean Europe and the Middle East becomes readily established. Brome avoids drought by having a very short life cycle and a resilient seed. It also has a much shorter burn interval (0−10 years; Howard 2006). Evidence of this exists in the Black Mountains as some high elevation sites have burned multiple times in the last 26 years. Desert adapted, perennial plants have been eliminated by these burns because they are not as fire tolerant. As such, large areas have transitioned to ephemeral grasslands dominated by non-native annual plants. These plants are low in forage quality and further alter fire regimes in this arid environment.

Patches of bare ground between bunchgrasses, cacti and trees prevented the large-scale spread of wildfires. Beginning in the 1970s non-native grasses started becoming increasingly dominant in native plant communities. Non-native annual grasses such as red brome and common Mediterranean grass dominate many plant communities and can create continuous fuel beds across the landscape. Unlike many native annuals, these plants do not dry up and blow away soon after they die but may remain in dense highly flammable stands for several years.

Many desert shrubs and other plants may re-sprout following fire if the severity is not too great. Native annuals may also survive fires by remaining dormant as seeds in the soil. Post-fire landscapes are often dominated by non-native annual grasses, which compete with establishment

and growth of native plants and may permanently alter the composition of landscapes without active management.

Objective: Reduce the loss of bighorn habitat from wildfire.

Strategy: Work internally and with the BLM to continue pursuing funding for burn rehabilitation.

Strategy: Work with the BLM to investigate the use of hydro-mulch reseeding in burned areas.

Strategy: Work with the BLM to investigate grazing deferment as a means of encouraging native perennial plant growth.

Water

Water developments are an important wildlife management tool in the southwest (Rosenstock et al. 2004). The Department owns over 800 water developments statewide, and each one is catalogued in a database for maintenance and management. Some federal agencies also manage water developments in Arizona. Water developments are becoming increasingly valuable as human impact renders many pre-existing natural water sources inaccessible. Some water developments at the north end of the Black Mountains were constructed to mitigate heavy recreational use along the Lake Mead shoreline because increased camping and day use in several coves along the lake effectively precluded bighorn sheep use during critical summer months. For many transplant programs, water developments represent the primary management tool used to expand bighorn sheep distribution in to historical habitat. In cooperation with ADBSS, the Department has constructed 25 water developments for desert bighorn in the Black Mountains.

Perennial springs comprise a substantial percentage of available water for bighorn sheep and other wildlife in the Black Mountains, especially in southern portions of the range. Federal protection to feral burros in the range has led to an increased monitoring and maintenance requirement for these springs. Most have been protected with pipe rail fencing to prevent trampling and contamination by feral burros. At some springs, natural rock depressions (tinajas) have been modified and dammed to create deeper pools that ensure sufficient water availability for bighorn sheep during summer months. These pools also require regular monitoring and maintenance to prevent cumulative sedimentation and aquatic plant growth (i.e., common cattail (*Typha latifolia*). Figure 15 exemplifies this issue, showing a developed spring (Columbine Spring) where cattails had entirely overgrown the tinaja. The root mass of this cattail stand was approximately five ft deep and completely displaced or absorbed any free-standing water. Overgrowth of upland vegetation can also be problematic. If not managed, dense thickets of plants such as Baccharis spp. establish and preclude use by bighorn sheep.

Until recently, the Department did not have a formalized approach to ensure maintenance of existing water sources, including developed springs. To address this issue, a formal team was convened and tasked with developing recommendations to ensure that all 800 wildlife water developments were routinely monitored and maintained. Standardized protocols for monitoring

and maintenance of each water development were drafted, and are housed with wildlife managers. A list of all water developments in the Black Mountains and their respective monitoring and maintenance schedules is contained in Table 9.

The vast majority of research indicates that water distribution is a critical habitat variable for desert bighorn, especially during summer months when temperatures can reach 120° F (e.g., Dolan 2006), Cunningham 1989, Hansen 1980, Wilson 1975). During summer, bighorn may go without water for five to 15 days, resulting in a loss of more than 20% of the hydrated body weight (Turner 1979). During this time, however, increased day length, extreme ambient temperatures, reduced moisture content of forage, and mating activities necessitate additional water intake, and, thus, a dependence on reliable water sources (Turner 1979, Turner and Weaver 1980).

Every habitat model we reviewed used proximity to a permanent water source as a criterion to rank habitat quality; however, determination of effective distance between water sources varied substantially. In the BMEMP, service area around a water development was considered to be 1.5 miles for general wildlife use. Turner et al. (2004) found that 97% of desert bighorn collar locations were within 1.86 miles of water. Some consider the highest ranking habitat to be within two miles of a permanent water source (Cunningham 1989, Hansen 1980); yet Wilson (1975) found desert bighorn up to three miles from water. Dolan (2006) concurs with Wilson. Areas between three and six miles from water rank lower, and areas more than six miles from water rank lowest. We analyzed our 81,673 bighorn locations and found that 88% were within three miles of water and 12% were between three and six miles. In the areas where we have collared bighorn, there is very little habitat farther than six miles from water; no collar locations were found in this category.

Permanent water sources and escape terrain were plotted in the habitat boundary to analyze water distribution in the Black Mountains. We placed the following three buffers around each known water to depict the effective service area for bighorn sheep: one three-mi radius buffer, one buffer depicting a radius between three and six mi, and a third buffer between six and 12 mi from water. Results showed that 71% (435,910 ac) of bighorn sheep habitat was within three miles of known water sources; 23% (146,653 ac) was between three and six miles from known water sources, and 5% (32,851 ac) was from six to 12 miles from known water sources. We also identified seven areas within the range that were beyond an effective three mile service area (Figure 16). To prioritize areas for future water development projects, we analyzed the amount of escape terrain in each of these areas. We found that areas six and seven have the most escape terrain, and should be evaluated for future water development potential. Details of these analyses are located in Table 10.

Objective: Ensure year-round water availability for bighorn sheep in the Black Mountains, and promote an effective service area of three miles around waters.

Strategy: Formalize maintenance and monitoring procedures at each water source via implementation of a regional water protocol.

Strategy: In coordination with the Arizona Wildlife Federation, enlist volunteers to assist the Department with water development monitoring and maintenance.

Strategy: Establish perennial water sources in area #7 and #6. High quality escape terrain in these areas represents 10% of that in the Black Mountain

Strategy: Investigate the need for additional water sources in dry areas #4 and #5, suitable water sources may already exist in these areas.

Strategy: The number of summer telemetry locations in dry area #2 suggests this area may contain an unknown water source. This situation needs to be investigated.

Strategy: Per McKinney and Smith (2006), coordinate with Bureau of Reclamation to prevent bighorn sheep access to sewage ponds that service visitors to Hoover Dam and construct an alternate water source. To increase public awareness of bighorn sheep, consider water placement that will facilitate viewing opportunities for the millions of summer tourists that visit Hoover Dam. Summer is the height of tourism at Hoover Dam, and bighorn sheep predictably use water sources during this time.

Mining

Various mining acts allow mineral extraction on public lands through out the Untied States. Some of these acts are the mining acts of 1866, 1872, 1920 and 1947. These acts were intended to provide opportunity for individuals to explore for, discover and purchase valuable mineral deposits on public lands. The laws set general standards and guidelines for claiming rights to minerals discovered on those lands. In the Black Mountains, several mining operations are or have been active in recent years. Recent mining activity has been for salable materials (sand, gravel, crushed stone and decorative rock).

The areas that have been impacted are:

- Times Gulch quarry (T.19N., R. 20 W., Sec.18). This quarry has had intermittent operation since 1983 and is a source of rip-rap for the BOR's Colorado River levee system.

- The former Pilgrim gold mine site (T.23N, R. 19 W, Sec.18) is being used for decorative rock and has been in operation since the spring of 2006. The five-acre site produces approximately 100 tons of decorative rock per day.

- The Jack mine (T. 27 N., R 19 W., Sec. 8) is also a decorative rock site. This site began operation in 2005 and occupies ten ac and produces approximately 100 tons of material per day.

- The Black Mountain quarry (T. 21 N., R. 19 W., Sec.7) was used by ADOT as a source of aggregate for SR 68. This site occupied approximately 36 ac and, in 2004, it was reclaimed with salvaged vegetation from the site.

- Lost Cabin Wash 10 ac were authorized for excavation of materials, three ac were disturbed and the site was abandoned, reclamation and revegetation was completed in 1999.

Other sites that have had mining activity mostly gold exploration are:

- Goldendoor/Klondyke/Combined Metals currently inactive.

- Portland Mine has been reclaimed and water in the mine pit is used by wildlife including bighorn sheep.

- Tyro currently inactive and reclamation was completed in 2005.

- Onanon is currently inactive.

- Gold Road Mine has not been active since 1996.

- Perlite prospect in the Gem ac area had exploration in 1998 and is currently inactive.

- Kemple Camp is inactive but does have a caretaker living on the mine site.

- Thumb Butte Quarry is located on private land and 30-40 ac have been disturbed.

Mining and its related activities could disrupt bighorn sheep and eliminate occupied habitat (Bristow 1996). Use of heavy equipment, increased human activities, and increased traffic and noise associated with mining could cause bighorn sheep to vacate areas adjacent to active mines. Construction of poorly designed roads has resulted in considerable bighorn habitat degradation – both on-site and off-site. The most obvious impact from mining is the removal of vegetation, which alters the availability of forage and shelter for wildlife in that area. According to Bristow, mining activity could cause bighorn sheep to stop using such areas until the mine is closed and that the increased traffic along main haul roads would have the most immediate and greatest impact to movement of rams. In the Black Mountain Habitat Management Plan (Hinkes 1978), recommendations were for mineral exploration to be rigidly regulated so that habitat destruction was minimized and adequate rehabilitation and mitigation measures were implemented.

Other mining related impacts include the use of reagents or heavy metals such as mercury and cyanide in processing of the desired mineral. The accidental release of these materials from mine tailing impounds could be toxic for wildlife that come in contact with these compounds. Few species are known to be naturally tolerant of heavy metals.

Objective: Ensure that mining activity does not negatively impact key bighorn sheep habitat.

Strategies: Limit major excavation and blasting during peak lambing season.

Strategies: Limit human-sheep interaction and train mine workers not to disturb bighorn sheep in the area by feeding, approaching or harassing them.

Strategies: Set a predictable pattern for mine activities so sheep have an opportunity to become habituated to the activities; limit access to employees only and close roads when the mine closes.

Strategies: Ensure that quality mitigation is pursued for habitat loss.

Social Considerations

Wildlife management has been an established discipline for over 60 years. Despite this tenure, there is still considerable debate about what wildlife managers are, what skills they need, and how they should be trained (Caughley 1977, Saberwal and Kothari 1996, Baxter et al. 1998). Traditionally, the wildlife management discipline focused on acquiring and analyzing environmental and biophysical data (Wallace 2003, Robinson 2006), but wildlife managers have become increasingly concerned with the broader discipline of conservation biology over the past 20 years (Robinson 2006). Baxter et al. (1998) analyzed the types of publications in several wildlife-related journals between 1985 and 1995 and found several clear trends in the direction of wildlife management. Among topics of publication that increased during this time were socioeconomic and political factors that affect management of wildlife (management orientation, economics, policy and politics, and social science). Concurrently, the authors found a declining or static percentage of papers dealing with wildlife biology (general biology, physiology, population dynamics).

When the Society for Conservation Biology (SCB) was established in 1986, the prevailing paradigm was that lack of scientific knowledge was precluding people from adequately conserving biological diversity (Baxter et al. 1998). Since that time SCB has hugely influenced the practice of conservation, and answered many technical questions. During this era, ecosystem management was formalized, and scientists continued to further develop human understanding of complex ecological processes. Despite these advances, no one definition of ecosystem management has gained broad acceptance, nor do specific guidelines or standards exist by which to up apply the concept (Rigg 2001). Further, SCB has had less impact outside the profession itself and has not transformed conservation practices into an enterprise large enough to achieve meaningful goals. According to Robinson (2006), conservationists need to become more relevant and important to the societies in which they live. To do so, the discipline must 'go beyond the certitude of biological sciences and into the more contextual debates of the social sciences' (p.658).

For planned wildlife management strategies to be successful, managers must possess a range of skills related to managing people and the systems they construct. Wallace (2003) for example, reviewed the success of several marine mammal recovery programs and concluded that reliance on biophysical research coupled with inadequate focus on the social sciences resulted in a proliferation of weak management strategies in recovery planning. Additionally, he believed the expertise and strategies necessary to address social problems in marine mammal programs were weak or absent, suggesting that decision-making and participant interactions are strongly influenced by social factors such as leadership characteristics, communication, teamwork, the presence or absence of evaluation, organizational culture, and program participants' ideologies.

Rigg (2001) presented a case study examining ecosystem management strategies of giant sequoia (*Sequoiadendron giganteum*) in Sequoia National Forest, California. The study suggested the application of ecosystem management was compromised by poor relations between managers and stakeholders, myriad policy requirements, volatile budgets, and limited ecological research on which to base management decisions. Among the recommendations made to facilitate

successful application of ecosystem management to Sequoia National Forest was a detailed analysis of the relationship between societal values and science.

Political Issues and Public Outreach

Bighorn sheep and feral burro conflict in the Black Mountains is a parallel example of societal values conflicting with biophysical data. In 1971, after overwhelming public pressure, the Wild Free-Roaming Horse and Burro Act was passed by the U.S. Congress. The designation gave federal protection to America's feral horses and burros, despite documented accounts of competition with native wildlife and habitat degradation. Although scientific understanding of the negative consequences to native bighorn sheep is substantial (Seegmiller and Ohmart 1981, Douglas and Leslie 1996), special interest groups in support of free-ranging feral burros remain well supported. Congress declared these feral animals as ***"****living symbols of the historic and pioneer spirit of the West; that they contribute to the diversity of life forms within the Nation and enrich the lives of the American people.****"*** (The Wild Free-roaming Horses and Burros Act of 1971, §1331). Solutions to this issue are clearly social, not biological.

A growing animal rights sentiment among the public also inhibits data-driven decision making in the Black Mountains. Despite evidence of excessive mountain lion predation on bighorn sheep, predator management strategies in this altered ecosystem continually meet with public disapproval. The Department has strict guidelines for predator management and drafted a predator management plan for the Black Mountains in 2006. The plan incorporates continued monitoring of bighorn sheep and mountain lion populations, and a multiple bag limit for mountain lions. The harvest objective for GMUs 15BW, 15C and 15D was set at 10 lions. Additional data validating the degree of predation, or consequences to a critically important desert bighorn sheep herd will likely be of little use in resolving this conflict. Clashing social values must be addressed.

Research on collaborative management techniques has revealed a number of successful strategies. Shindler and Cheek (1997) and Yaffee and Woondolleck (1997) suggest that motivated individuals in both the agencies and the public must continuously reinforce their commitment to and confidence in collaborative management processes and must work toward establishing a stable (committed) group with sincere and effective leadership. Interactions among collaborators should start early and continue throughout the decision-making process (Moote and McClaran 1997, Shindler and Cheek 1997). Establishing explicit protocols also provides structure to collaborative groups, which can facilitate trust building and decision making (Moote et al. 1997). When possible, agency leaders should be present at collaborative meetings because participants gain confidence when they perceive their presence is affecting management direction (Shindler and Cheek 1997). Tangible results also improve agency accountability because measurable outcomes and access to information are necessary to achieve trust and sustain public interest and participation in the process (Moote et al. 1997).

Most of the technical information needed to successfully manage bighorn sheep in the Black Mountains currently exists. Habitat use and selection is better quantified. Site-specific mortality factors are well understood and documented. The effects of competition for space and food have been well documented in other bighorn sheep herds and are likely similar to those found in the Black Mountains. The effects of urban development on bighorn sheep are indubitably negative,

and specific data-driven strategies to prioritize and acquire important habitats have been recommended. Areas where water sources are lacking have been identified and prioritized, and efforts to minimize the effects of fragmentation by expanded highways are gaining momentum. As with other species-specific wildlife management efforts across the U.S., factors limiting program success are largely social, not technical. Additional work is needed to better incorporate social values with the technical information on hand.

The diverse interests of different agencies, private landowners, and other affected groups will undoubtedly conflict to varying degrees with objectives and strategies outlined in this plan. Of the 24 bighorn sheep management plans we reviewed, only Texas (2000) had a formalized process to address social issues. The Texas plan identified several strategies to preclude conflicts and increase support by involving those who may be affected in the planning and implementation of their bighorn program. Most significantly, they convened a Bighorn Advisory Committee, whose membership comprised representatives from other agencies, wildlife interest groups, and landowner organizations. The group meets annually to review progress toward plan objectives and outline the following year's work activities. Funding requirements, process owners, and due dates are established for each task. Achievement of goals and objectives are considered a measure of program success. Given the diverse social interests regarding the Black Mountains, a similar approach to collaborative management of the area's bighorn sheep population may be warranted.

Similarly, a comprehensive outreach plan aimed at increasing the public's awareness of the significance of the Black Mountain sheep population and current threats to the ecosystem is warranted. Implementation of an intensive outreach effort throughout the tri-state area (Arizona, Nevada, and California) in needed to both raise awareness and promote involvement. The goal of this outreach effort would be to convey to people in the region that this plan has far-reaching effects and costs.

Objective: Collaboratively manage and raise public awareness of bighorn sheep in the Black Mountains

Strategy: Convene a Bighorn Advisory Committee patterned after the Texas bighorn sheep program. The Committee should meet annually to review progress and plan future work. Minutes from these results-oriented meetings should be included in this plan as appendices.

Strategy: Charter a team to develop a comprehensive five-year outreach plan for the bighorn sheep population in the Black Mountains. The plan should be a measurable effort that increases public awareness of the value of bighorn sheep in the Black Mountains.

Strategy: To increase public awareness of bighorn sheep, consider water development placement to facilitate viewing opportunities for the millions of summer tourists that visit Hoover Dam. Summer is the height of tourism at Hoover Dam, and bighorn sheep predictably use water sources during this time.

Strategy: Establish bighorn sheep viewing areas at roadside pullouts. Construct water developments as necessary to facilitate viewing opportunities.

Strategy: Increase the number of bighorn sheep workshops through Black Canyon from two to five per summer. Investigate use of volunteers to conduct additional workshops.

Volunteerism

The Department recently created a Volunteer Program designed to help personnel accomplish their duties and to give volunteers an opportunity to participate in and learn about the management of wildlife in Arizona. Many natural springs in the Black Mountains were developed to provide water for bighorn sheep year-round. These water sources require routine maintenance and a substantial time commitment to access since many require long hikes in remote wilderness areas. Management of encroaching vegetation at these sites is ongoing, and could provide opportunities for the public to help manage bighorn sheep water sources. As the public becomes more involved in managing wildlife, whether by influencing local land use decisions or at the ballot box, an understanding of wildlife needs and management options are critical and will promote a better informed public. Other volunteer opportunities to involve the public in managing this important bighorn sheep herd need to be further explored.

Objective: Use the Department's Volunteer Program to facilitate public awareness of bighorn sheep in the Black Mountains.

Strategy: Formalize the maintenance and monitoring schedule in Table 9 and enlist volunteers to assist with the process.

Strategy: Use volunteers to increase the number of bighorn sheep workshops held each summer.

Chapter III. Implementation

The primary purpose of Chapter III is to assist senior leaders and program managers in the Department with monitoring implementation of this management plan. To facilitate this monitoring, all proposed strategies have been listed in matrix form on the ensuing pages. Management strategies have been listed in the order they appear in Chapter II. Department leadership should prioritize strategies, and program managers should work toward implementation of these priorities annually. Place-holders for process owners and timelines have been included. Annual action plans should be developed with progress and completion reports attached to this document as appendices.

Implementation Matrix

Section	Objective	Strategy	Owner	Timeline
Biological Considerations				
Population Assessment	Refine survey methods.	Establish standardized transects/blocks for each GM, double counts.		
		Mark-resight population estimate using radio-marked animals.		
		Analyze telemetry data to determine best survey rotation.		
Transplants	Maintain transplant program.	Conduct transplants when populations exceed 20-year average.		
Harvest	Offer bighorn sheep hunting opportunities.	Follow the Departments hunt guidelines.		
Burros	Minimize competition with burros.	Participate in burro surveys.		
		Ensure that burro levels are maintained at or below the AML.		
		Research study collaring burros to evaluate interaction and behavior.		
Livestock	Minimize competition with livestock and burros.	Research study evaluating bighorn sheep competition and interaction with livestock and burros.		
		Pursue NRCS ecological site inventories and ephemeral designation.		
		Develop projects that will improve range conditions or minimize conflicts.		
		Discourage livestock distribution based on water distribution.		
		Pursue grazing deferment in burned areas.		

Section	Objective	Strategy	Owner	Timeline
Biological Considerations (continued)				
Predation	Quantify predation when bighorn numbers are down.	Monitor bighorn sheep with radio-collars to determine extent of predation.		
	Reduce predation when sheep populations fall.	Implement predator control.		
	Monitor effectiveness of predator control.	Seek funding for additional surveys.		
Domestic Sheep and Goats, and Disease Transmission	Monitor bighorn diseases.	Obtain blood samples from all captured or hunter harvested sheep.		
		Conduct additional population surveys following suspected disease outbreaks.		
	Reduce potential for disease transmission.	Establish an annual schedule for authorization to remove feral goats or sheep.		April
		Give priority to the removal of any documented sheep or goats.		
		Target county and city governments, and residents regarding disease issues.		

Section	Objective	Strategy	Owner	Timeline
Habitat Considerations				
Introduction	Use bighorn habitat designation to improve management decisions.	Coordinate with BLM to update bighorn habitat land-use designation.		
		Refine habitat delineation as data becomes available.		
Acquisition	Prevent development in bighorn habitat.	Use volunteers to monitor which lands are for sale.		
		Pursue funding in order to acquire lands.		
		Work with BLM to see that bighorn habitat is considered in acquisitions and trades.		
		Work through the International Association of Fish and Wildlife Agencies to influence congress toward initiation of land exchanges.		
Highways and Roads	Ensure highway permeability.	Continue integration of conservation and transportation planning efforts.		
		Continue research and monitoring of mitigation effectiveness.		
		Acquire parcels that would otherwise facilitate development of additional roads.		
		Monitor human disturbance at crossing structures.		
Noxious and Invasive Plants	Detect and prevent the spread of noxious and invasive plants.	Provide invasive and noxious week identification training to AGFD personnel.		
		Prevent spread by measures such limiting activities to existing facilities and using certified "weed-free" feed for pack animals.		
		Coordinate with federal and state agencies to implement control and rehabilitation efforts.		

Section	Objective	Strategy	Owner	Timeline
Habitat Considerations				
Wildfire	Reduce the loss of bighorn habitat from wildfire.	Work internally and with the BLM to continue pursuing funding for burn rehabilitation.		
		Work with the BLM to investigate the use of hydro-mulch reseeding in burned areas.		
		Work with the BLM to investigate grazing deferment as a means of encouraging native perennial plant growth.		
Water	Improve water distribution for bighorn.	Formalize maintenance and monitoring procedures at each water source.		
		Work towards getting functional water sources in dry areas #7 and #6 (Table 10, Figure 16).		
		Work with Arizona Wildlife Federation and enlist volunteers to assist in monitoring and maintenance.		
		Coordinate with the BOR to prevent access to sewage ponds and provide an alternate water source placed in view of the public.		
		Investigate the possibility of improving water sources in dry areas #4 and #5 (Table 10, Figure 16).		
		Investigate dry area #2; it may already have a water source.		
Mining	Minimize impacts of mining.	Limit major excavation and blasting during peak lambing season.		
		Limit human sheep interaction and train mine workers not to disturb bighorn sheep in the area by feeding, approaching or harassing them.		
		Limit access to employees only and close roads when mine closes.		
		Ensure that quality mitigation is pursued for habitat loss.		

Section	Objective	Strategy	Owner	Timeline
Social Considerations				
Political Issues and Public Outreach	Raise public awareness of bighorn sheep in the Black Mountains.	Convene a Bighorn Advisory Committee		
		Kiosks with binoculars along roadways.		
		Produce and distribute a brochure version of the bighorn poster.		
		Pursue the development of kiosks at informing the public about bighorn disturbance issues.		
		Water development placement to facilitate viewing opportunities for the Hoover Dam.	Zen Mocarski	Annually July - August
		Establish bighorn sheep viewing areas at roadside pullouts.		
		Increase the number of bighorn sheep workshops through Black Canyon from two to five per summer.		
Volunteerism	Use Department's Volunteer Program to facilitate public awareness of bighorn sheep.	Formalize the maintenance and monitoring schedule in Table 9, use volunteers.		
		Use volunteers to increase the number of bighorn sheep workshops held each summer.		

Table 1. Annual Precipitation Data in Yucca and Bullhead City 1978-2005.

Year	Yucca Annual Precipitation (in)	Bullhead City Annual Precipitation (in)
1978	16.8	11.11
1979	10.16	6.59
1980	8.81	8.51
1981	10.37	5.45
1982	8.88	7.89
1983	10.2	11.59
1984	10.42	10.36
1985	6.07	3.61
1986	11.92	5.51
1987	5.86	6.24
1988	7.42	7.39
1989	2.38	1.72
1990	8.02	5.26
1991	8.98	8.22
1992	13.32	11.26
1993	11.86	9.63
1994	5.49	5.82
1995	6.02	5.71
1996	3.29	2.53
1997	8.18	4.48
1998	10.88	7.55
1999	7.54	1.79
2000	3.93	4.27
2001	6.63	3.99
2002	2.91	0.67
2003	8.72	4.99
2004	11.88	Incomplete
2005	12.52	Incomplete
Source: Western Region Climate Center (1978-2005). Bullhead City 28-yr average: 6.12, Yucca 28-yr average: 7.60.		

Table 2. Sensitive Plant and Animal Species from the Heritage Data Management System (HDMS) for the Black Mountains.

Type	Name	Common Name	Status			
			ESA	USFS	BLM	STATE
Invertebrate Animal	*Pyrgulopsis conica*	Kingman Springsnail	SC	S	S	
Vascular Plant	*Castilleja minor spiralis*	Indian Paintbrush				
Vascular Plant	*Penstemon bicolor roseus*	Cerbat Beardtongue	SC		S	SR
Vascular Plant	*Senna armata*	Desert Cassia			S	
Vascular Plant	*Selinocarpus nevadensis*	Desert Moonpod			S	
Vascular Plant	*Arctomecon californica*	Las Vegas Bearpoppy	SC			SR
Vascular Plant	*Stillingia linearifolia*	Linearleaf Sand Spurge				
Vascular Plant	*Tetradymia stenolepis*	Owens Valley Cotton Thorn			S	
Vascular Plant	*Chrysothamnus teretifolia*	Roundleaf Rabbitbrush				
Vascular Plant	*Petalonyx nitidus*	Shinyleaf Sandpaper Plant			S	
Vascular Plant	*Enceliopsis argophylla*	Silverleaf Sunray			S	
Vascular Plant	*Opuntia echinocarpa*	Straw-top Cholla				SR
Vascular Plant	*Purshia glandulosa*	Waxy Bitterbrush			S	
Vertebrate Animal	*Idionycteris phyllotis*	Allen's Big-eared Bat	SC		S	
Vertebrate Animal	*Falco peregrinus anatum*	American Peregrine Falcon	SC	S		WSC
Vertebrate Animal	*Haliaeetus leucocephalus*	Bald Eagle	LT,PDL	S		WSC
Vertebrate Animal	*Heloderma suspectum cinctum*	Banded Gila Monster	SC		P	
Vertebrate Animal	*Eptesicus fuscus*	Big Brown Bat				
Vertebrate Animal	*Tadarida brasiliensis*	Brazilian Free-tailed Bat				
Vertebrate Animal	*Macrotus californicus*	California Leaf-nosed Bat	SC		S	WSC
Vertebrate Animal	*Myotis californicus*	California Myotis				
Vertebrate Animal	*Myotis thysanodes*	Fringed Myotis	SC		S	
Vertebrate Animal	*Eumops perotis californicus*	Greater Western Bonneted Bat	SC			
Vertebrate Animal	*Plecotus townsendii pallescens*	Pale Townsend's Big-eared Bat	SC			
Vertebrate Animal	*Antrozous pallidus*	Pallid Bat				
Vertebrate Animal	*Rana onca*	Relict Leopard Frog	C	S		WSC
Vertebrate Animal	*Gopherus agassizii*	Sonoran Desert Tortoise	SC			WSC
Vertebrate Animal	*Pipistrellus hesperus*	Western Pipistrelle				
Vertebrate Animal	*Eumeces gilberti rubricaudatus*	Western Red-tailed Skink				
Vertebrate Animal	Buteo *albonotatus*	Zone-tailed Hawk				
SC - Species of Concern, LT - Listed Threatened, PDL - Proposed De-listing, C - Candidate, S - Sensitive, P – Proposed, SR - Salvage Restricted, WSC - Wildlife of Special Concern in Arizona						

Table 3. Estimated Number of Desert Bighorn Sheep in Arizona by Area, Based on Helicopter Survey Data.

Herd Area	1998	Map
Virgin River/Beaver Dams	185	1
Northern Grand Wash Cliffs	95	2
Kanab Creek/Hacks Canyon	230	3
Paria Canyon	105	4
Blacks	1815	5
Southern Grand Wash Cliffs	195	6
Cataract Canyon	50	7
Chemehuevis	70	8
Mojaves, Rawhides, Artilleries	125	9
Dome Rocks	50	10
Plomosa	125	11
Harcuvar/Buckskins	70	12
Trigos	205	13
Castle Domes	180	14
Kofas	460	15
New Waters	105	16
Tanks	110	17
Eagletails	150	18
Gila Bends	150	19
Maricopas	185	20
Stewart and Goat Mountains	80	21
Superstitions	80	22
Tinajas Altas	50	23
Mowhawks	75	24
Sierra Pintas	310	25
Growlers	205	26
Saucedas	195	27
Silverbells	85	28
Catalinas	5	29
Aravaipa Canyon	80	30
Galiuros	35	31
Peloncillos	50	32
TOTAL	5910	

Table 4. BLM Vegetation Monitoring Sites in the Black Mountains.

Name	Easting	Northing
Lambing Tank	175673	3942514
Golden Door	178160	3938671
Mt. Davis	169603	3937314
Master Spring	180456	3930497
Lost Cabin	183917	3929018
Lower Lost Cabin	181290	3927192
Ft. MacEwen 11	185291	3926044
Portland Mine	182821	3921502
Lost Cabin Catch	186630	3920615
Calles Spring	180682	3918441
Chalk Spring	184804	3915484
Ft. MacEwen 18	191264	3916493
Burns Spring	189456	3913559
Rhyolite	189891	3911646
Box Spring	182360	3909009
Black Mountain 1 (north)	196778	3900898
Black Mountain 2	192238	3898707
Thumb Butte East	190499	3897924
Thumb Butte	186482	3897889
Black Mountain 3 (north)	193943	3895512
Cave Spring	197056	3895181
Secret Pass	188691	3894138
Black Mountain 3 (south)	195560	3893049
Black Mountain 4	199456	3889988
Black Mountain 5	199630	3887101
Silver Creek	186934	3887171
Grapevine	191369	3887414
Battleship	191682	3886267
Cottonwood	191108	3885143
Onnetto	192847	3883752
Dripping Spring	198978	3885300
Dripping Sheep	198699	3884743
Black Mountain 6	198178	3881981
Cool Springs She	197430	3880260
Black Mountain 1 (south)	196073	3879616
Black Mountain 7	200560	3879564
Unknown (north Lake Mohave)	169814	3944228
Coordinates NAD27 Zone 11 UTM. Accuracy is 150m.		

Table 5. Unit 15 Historical Hunt Data.

Year	Permits Issued	First Choice	Hunters	Hunter Days	Harvest	Hunt Success
1960	15		15		7	47%
1961	15		15		5	33%
1962	7		7		3	43%
1963	10		10		2	20%
1964	10		10		4	40%
1965	10	68	9		6	67%
1966	10	81	10		6	60%
1967	10	85	10		3	30%
1968	10	175	7		5	71%
1969	12	138	12		7	58%
1970	14	168	13		6	46%
1971	13	216	13		5	38%
1972	9	138	9		3	33%
1973	10	155	9		7	78%
1974	10	219	10		8	80%
1975	12	222	12	66	9	79%
1976	14	360	14	55	11	75%
1977	17	360	17	81	16	94%
1978	17	468	14	64	12	86%
1979	19	460	19	115	16	84%
1980	22	585	22	152	18	82%
1981	17	700	16	76	14	88%
1982	14	708	14	81	14	100%
1983	18	579	17	66	16	94%
1984	23	651	23	106	22	96%
1985*	19	646	19	86	19	100%
1986	25	711	24	117	22	92%
1987	27	896	27	115	26	96%
1988	29	977	29	112	28	97%
1989*	29	971	29	112	28	97%

Table 5. Unit 15 Historical Hunt Data (continued).

Year	Permits Issued	First Choice	Hunters	Hunter Days	Harvest	Hunt Success
1990*	26	1106	25	112	23	92%
1991	29	1253	28	104	28	100%
1992	31	1230	31	113	31	100%
1993	37	1318	37	145	37	100%
1994**	38	1613	37	167	36	97%
1995**	38	1726	39	180	38	97%
1996**	32	1736	32	165	32	100%
1997	24	1782	24	114	23	96%
1998	36	2180	36	203	36	100%
1999	34	2427	34	150	34	100%
2000	32	2259	32	163	31	97%
2001	28	2102	28	151	27	96%
2002	29	3240	29	187	28	97%
2003	24	3769	24	188	24	100%
2004	15	3387	15	87	14	93%
2005	13	1526	13	63	13	100%
2006						
* A Special Tag was filled in Unit 15 **An early and late December season was held in Unit 15BW						

Table 6. Mean Age and Green Score of Desert Bighorn Harvested in the Black Mountains.

Year	Age	Green Score
1972	7.5	96.7
1973	6.4	154.2
1974	6.5	151.8
1975	7.2	149.5
1976	7.5	155.9
1977	5.9	153.0
1978	6.3	156.5
1979	5.8	154.4
1980	5.1	152.9
1981	5.5	158.1
1982	5.6	150.7
1983	5.9	156.5
1984	5.9	158.3
1985	7.5	156.1
1986	6.4	152.0
1987	7.5	158.9
1988	6.1	153.2
1989	6.3	157.1
1990	6.9	146.7
1991	6.8	155.3
1992	7.4	155.2
1993	7.2	156.3
1994	7.2	157.1
1995	7.0	154.3
1996	6.8	152.0
1997	7.1	151.6
1998	8.0	153.5
1999	7.6	152.3
2000	8.3	152.6
2001	7.8	148.2
2002	7.3	149.9
2003	7.2	142.3
2004	6.6	147.8

Table 7. Scoring Criteria used in Prioritizing Land Acquisitions.

Category	Criteria	Score
Water	Contains Water Source	9
	Within 1/2 mile (805m)	3
Central Movement Corridor	Within 1/4 mile (402m)	5
	Within 1 mile (1609m)	3
	within 2 miles (3218m)	2
60% Slope Escape Terrain (ET)	≥30% of parcel is ET	4
	20−29% of parcel is ET	3
	10−19% of parcel is ET	2
	<10% of parcel is ET	1
Ownership	Private and state lands are scored separately	N/A

Table 8. Black Mountain Wildfires Since 1980.

Fire Name	Date	Acres
Union	6/12/2006	8,380
Secret	6/12/2006	4,108
Nutt	6/12/2006	149
Hopper	8/9/2005	720
Double L	8/1/2005	312
Expo	7/31/2005	240
Twin Mills	7/27/2005	12,426
McCarrin	7/18/1998	154
South	8/12/1996	149
Black Mountain	10/8/1995	597
Nutt	8/31/1995	703
Burn Springs	7/14/1995	67
Perkins Branch	9/29/1994	14,731
Warm	8/15/1994	5,276
Dixie	6/30/1994	268
Jurassic Branch	6/28/1994	1,195
Thorn	6/23/1994	130
Dolan	6/18/1994	1,841
Union	6/7/1994	148
Twin	6/5/1994	51
Santa Claus 2	10/20/1993	765
Springs	10/18/1993	128
Mine	8/8/1993	1,529
Junction	8/8/1993	1,575
Union Pass	6/16/1993	452
Rock	6/12/1993	88
Santa Claus	5/30/1993	2,028
Musgrove	6/5/1988	289
Boundary	5/3/1987	83
Antelope	8/24/1980	355
Burns	8/11/1980	735
Dripping	8/11/1980	101
Cabin	7/29/1980	749
Water	7/23/1980	68
Sacramento	7/23/1980	1,621
Ute	7/23/1980	3,238
Basin	7/23/1980	4,179
Total Acreage of all Fires		69,628
Total Acres of Land Burned (excludes reburns)		60,489

Table 9. Perennial Waters in the Black Mountains.

Name (SSDV ID#)	Annual Schedule	Type of Water	Components	Comments
Alkali	By April 10	Undeveloped Spring		Check as determined by initial visit
Antelope (BLM)	By April 10	Developed Spring		Check as determined by initial visit
Battleship (839)	Fall & Spring	Developed Spring	Retention Dam, Fence	Cleaned out in 03-2006
Burns	By April 10	Undeveloped Spring		Check as determined by initial visit
Calles (BLM)	By April 10	Developed Spring		Check as determined by initial visit
Carl Scrivens (Cone Mtn.) (1110)	By April 10	Wildlife Catchment	Apron, Tank, Trough	After initial check Monthly depending upon use Until temp. drops and use stops.
Chalk (BLM)	By April 10	Developed Spring		Check as determined by initial visit
Columbine (821)	Fall & Spring	Developed Spring	Retention Dam, Fence	Cleaned out in 05-2006
Cool	By April 10	Undeveloped Spring		Check as determined by initial visit
Cottonwood (BLM)	By April 10	Developed Spring		Check again by July 15
Cow Camp	By April 10	Developed Spring		Check as determined by initial visit
Cross (846)	Fall & Spring	Developed Spring	Fence, Collector, Plumbing	Needs vegetation removal
Davis Mtn. (878)	By April 10	Wildlife Catchment	Fence, 2 Aprons	Check as determined by initial visit
Dripping	By April 10	Developed Spring		Check as determined by initial visit
Fig	By April 10	Undeveloped Spring		Check as determined by initial visit
Golden Door (840)	By April 10	Water Tank	Fence, Apron, Reservoir	After initial check Monthly depending upon use Until temp. drops and use stops
Kemple (BLM)	By April 10	Developed Spring		Check again by July 15
Lambing Tank (850)	By April 10	Wildlife Catchment	Fence, Apron, Reservoir	After initial check Monthly depending upon use Until temp. drops and use stops
Lazy Boy (844)	Fall & Spring	Developed Spring	Fence, Collector, Plumbing	Good condition
Lost Cabin #1 (877)	Fall & Spring	Wildlife Catchment	Fence, 2 Aprons	Good condition
Lower Lost Cabin (849)	Fall & Spring	Developed Spring	2 Reservoirs, Upper Gabion	Good condition
Master (804)	Fall & Spring	Wildlife Catchment	Fence, Retention Dam, Reservoir	Re-developed spring 2004
Mcheffy (841)	Fall & Spring	Developed Spring	Fence, Collector, Plumbing	Good condition

Table 9. Perennial Waters in the Black Mountains (continued).

Name (SSDV ID#)	Annual Schedule	Type of Water	Components	Comments
Metate (855)	Fall & Spring	Developed Spring	Fence, Collector, Plumbing	Abandoned in 1995
Middle Missouri (1094)	By April 10	Developed Spring	Reservoir, 2 Plumbings	Check again by July 15
Missouri	By April 10	Developed Spring		Check as needed
Pass Tank #2, #4 (BLM)	By April 10	Water Tank		Check as determined by initial visit
Pass Tank #3 (Craig Spring) (851)	By April 10	Drainage Dam	Apron, Reservoir	Check as determined by initial visit
Ram (797)	Fall & Spring	Developed Spring	Retention Dam	Good condition
Secret Pass Pools		Undeveloped Spring		
Sheep (815)	Fall & Spring	Developed Spring	Fence, Retention Dam	Cleaned out in 03-2006
Tipperary (843)	Fall & Spring	Developed Spring	Retention Dam, Fence	Re-developed spring 2007
Trough (852)	Fall & Spring	Developed Spring	Fence, Retention Dam	Needs to be cleaned out
Tufa (1090)	By April 10	Wildlife Catchment	Fence, Apron, Reservoir	After initial check Monthly depending upon use Until temp. drops and use stops
Two Horns (Joey Darner) (1073)	By April 10	Wildlife Catchment	Fence, Apron, Reservoir	After initial check Monthly depending upon use Until temp. drops and use stops
Unnamed Spring		Developed Spring		
Upper Twin (847)	Fall & Spring	Developed Spring	Upper Gabion, Retention Dam	Needs to be cleaned out
Van Deemen (812)	By April 10	Drainage Dam	Apron, Upper Gabion, Retention Dam	Check again by July 15
Warm	By April 10	Undeveloped Spring		Check as determined by initial visit
Wildhorse (867)	By April 10	Developed Spring	Collector, Plumbing, Trough	Check as determined by initial visit
Wilson Ridge (735)	By April 10	Developed Spring		Check as determined by initial visit

Table 10. Habitat Evaluation of Dry Areas (Farther Than Three miles From Water) Based on Escape Terrain. Area Numbers Correspond to Figure 16.

Area No.	Escape Terrain Acres	Percent of Total Escape Terrain	Comments on Escape Terrain and Potential Water sources
1	312	1%	Very small escape terrain acreage, no potential water sources, Lake Mead National Recreation Area (LMNRA)
2	1,275	3%	Escape terrain has high connectivity, no potential water sources, LMNRA and BLM, collared bighorn remain in this area May – July which may indicate an unknown water source
3	323	1%	Very small escape terrain acreage, spread out with no connectivity
4	623	1%	Escape terrain spread out with limited connectivity, several potential water sources found but not ideally located near escape terrain
5	506	1%	Several potential water sources
6	1,289	3%	Escape terrain has excellent connectivity, no potential water sources
7	3,341	7%	Escape terrain has excellent connectivity, potential water sources include Black Mesa, Drill Hole, and Caliche
Potential water sources include springs, wells, dams, tanks and troughs found on USGS topos, BLM, and NPS databases, all of unknown status. Potholes may exist. Escape terrain was classified as 60% slope or greater.			

Figure 1. Land Ownership in the Black Mountains.

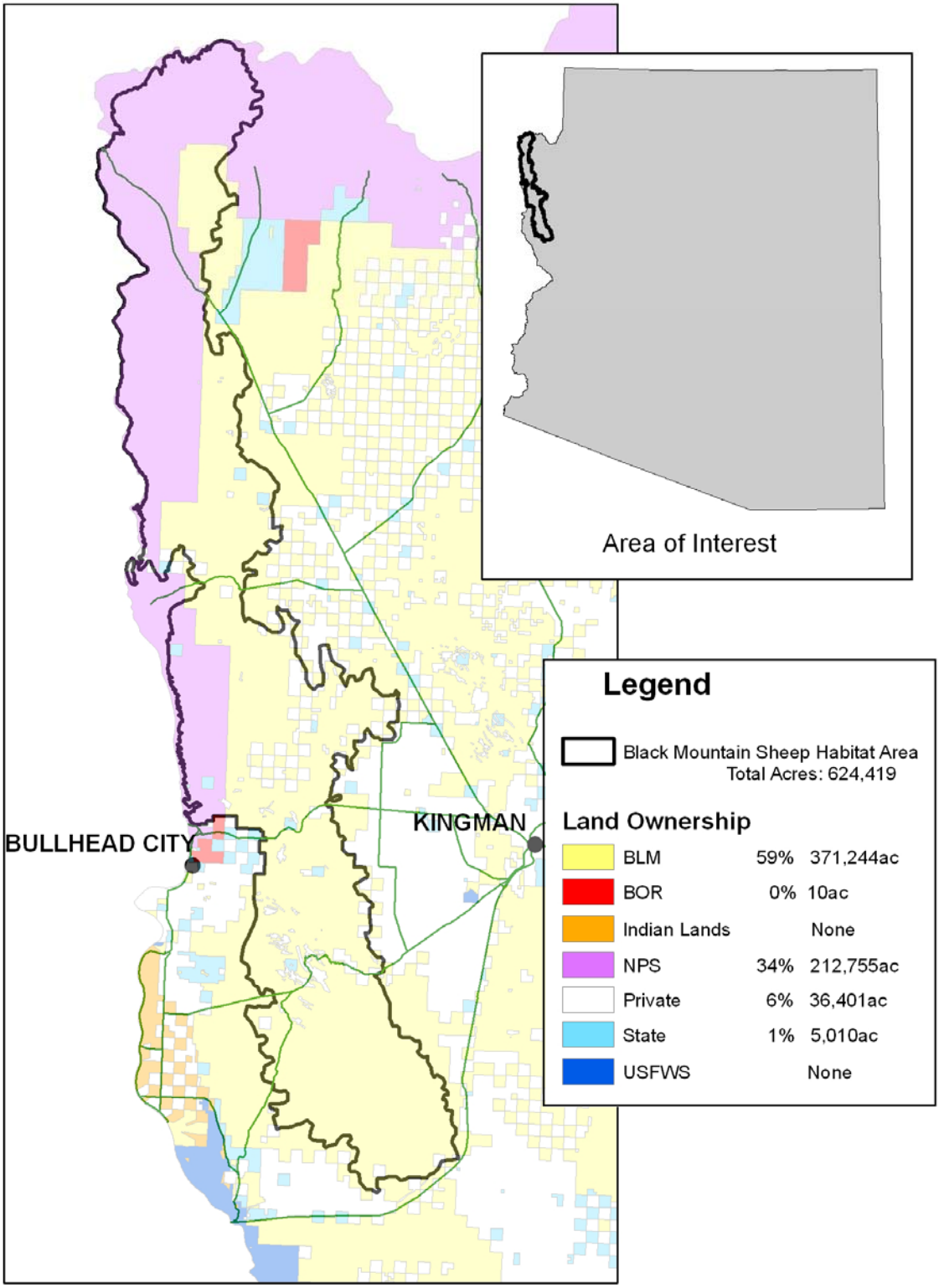


Figure 2. Game Management Units in the Black Mountains.

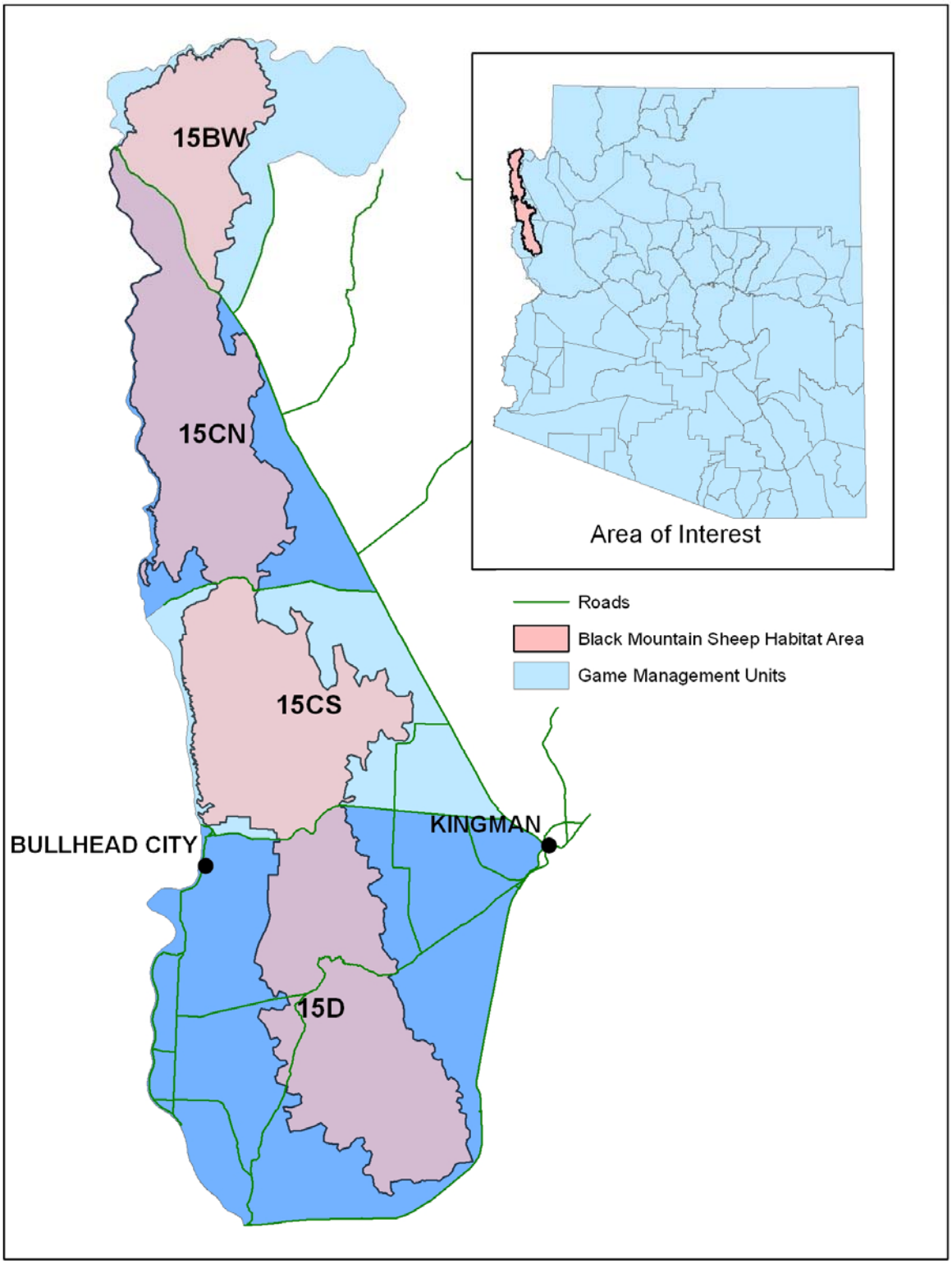


Figure 3. Precipitation Zones in the Black Mountains Based on Natural Resource Conservation Service (NRCS) Data.

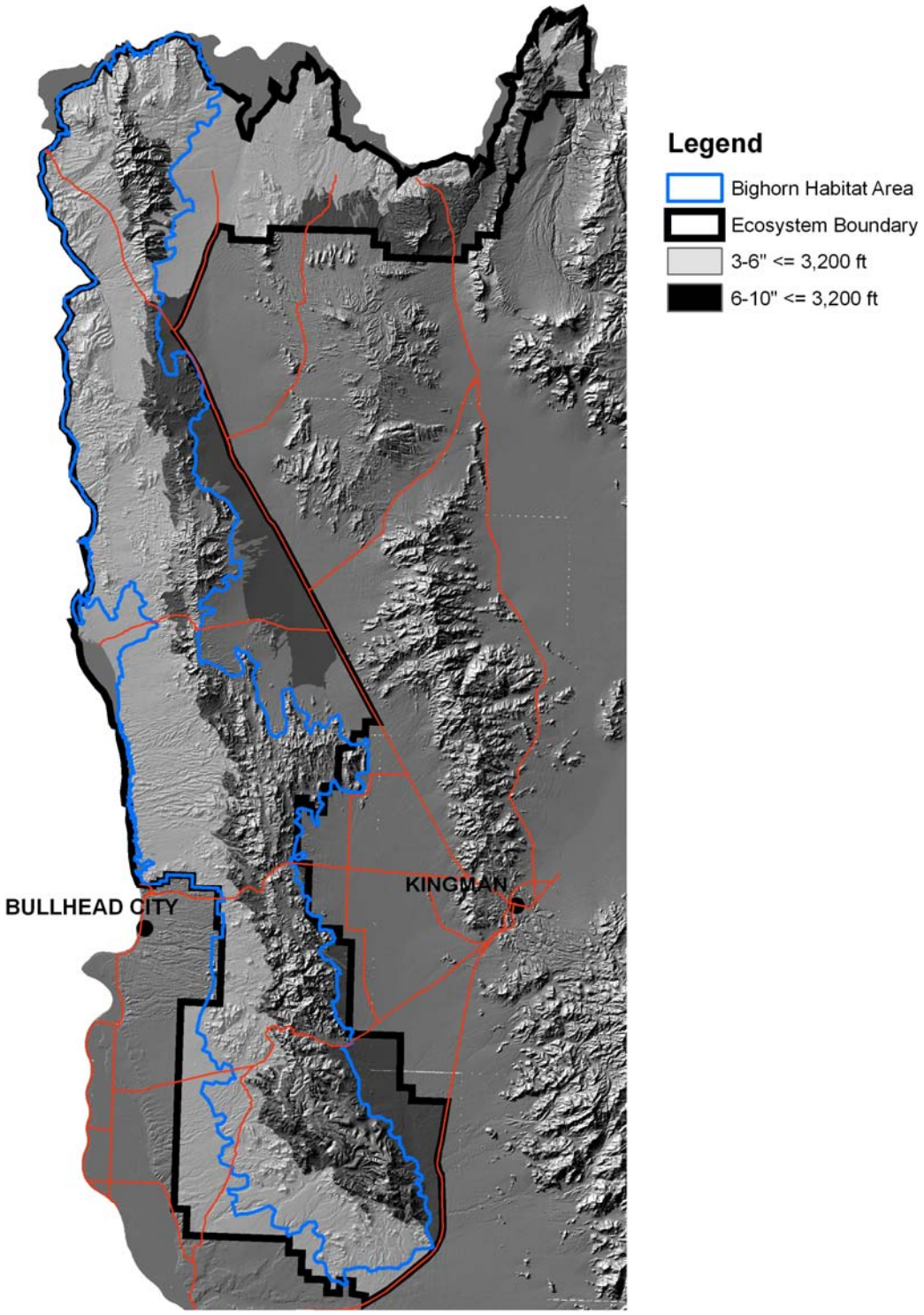
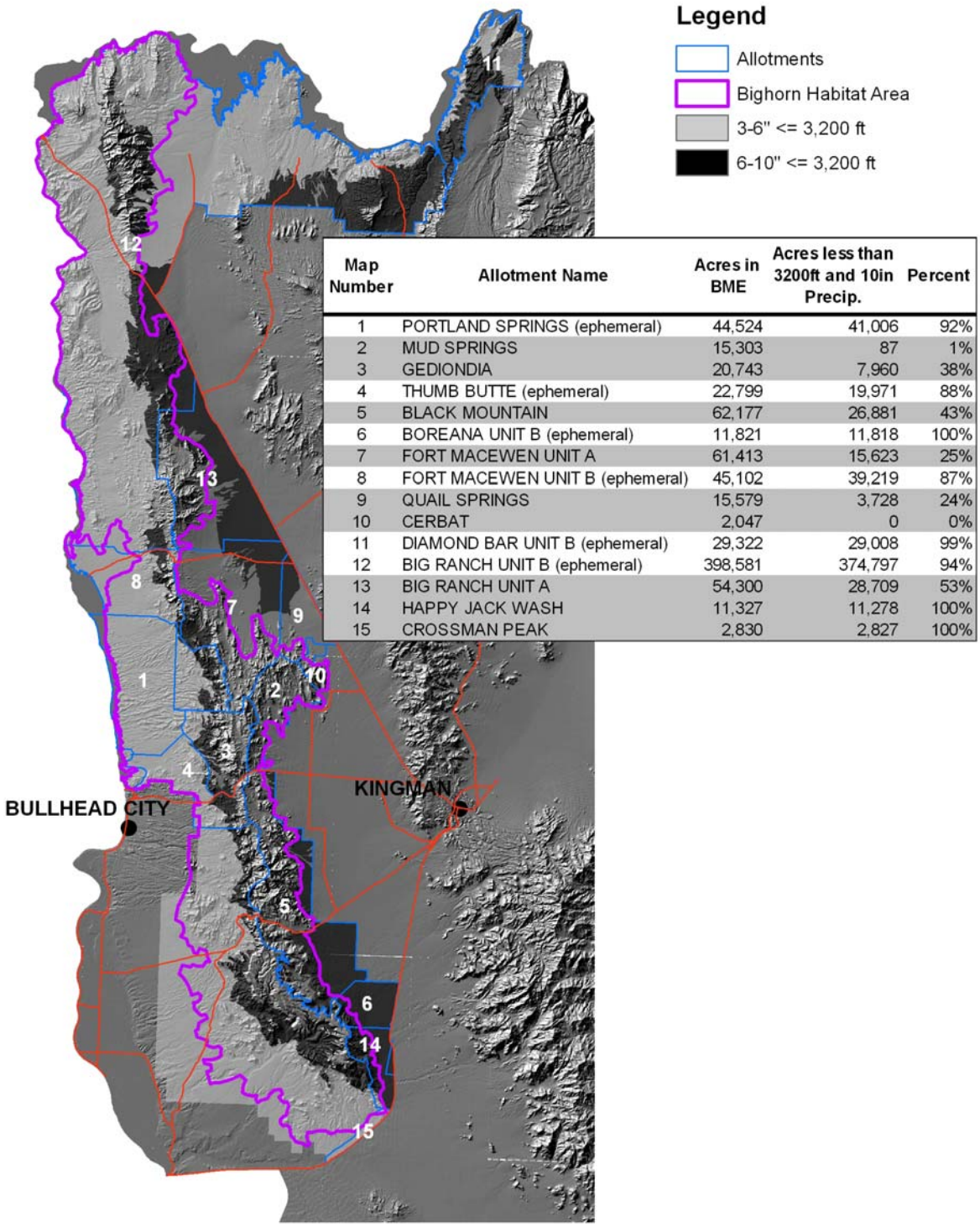


Figure 4. Grazing Allotments in the Black Mountain Ecosystem.



Map Number	Allotment Name	Acres in BME	Acres less than 3200ft and 10in Precip.	Percent
1	PORTLAND SPRINGS (ephemeral)	44,524	41,006	92%
2	MUD SPRINGS	15,303	87	1%
3	GEDIONDIA	20,743	7,960	38%
4	THUMB BUTTE (ephemeral)	22,799	19,971	88%
5	BLACK MOUNTAIN	62,177	26,881	43%
6	BOREANA UNIT B (ephemeral)	11,821	11,818	100%
7	FORT MACEWEN UNIT A	61,413	15,623	25%
8	FORT MACEWEN UNIT B (ephemeral)	45,102	39,219	87%
9	QUAIL SPRINGS	15,579	3,728	24%
10	CERBAT	2,047	0	0%
11	DIAMOND BAR UNIT B (ephemeral)	29,322	29,008	99%
12	BIG RANCH UNIT B (ephemeral)	398,581	374,797	94%
13	BIG RANCH UNIT A	54,300	28,709	53%
14	HAPPY JACK WASH	11,327	11,278	100%
15	CROSSMAN PEAK	2,830	2,827	100%

Figure 5. Locations of Desert Bighorn Mortalities Caused by Mountain Lion Predation.

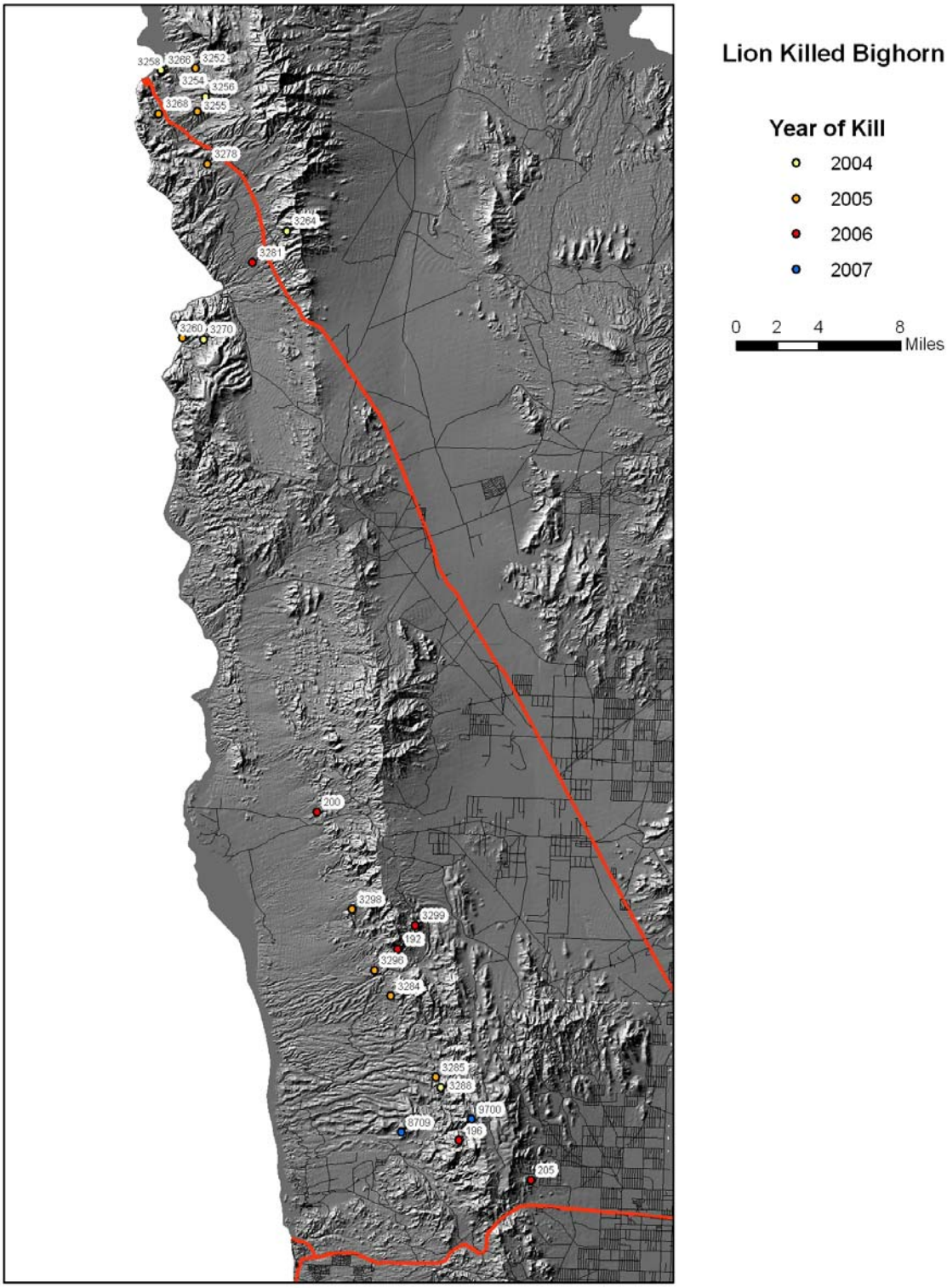


Figure 6. The Proposed Location of the State Route 95 Realignment Adjacent to the Black Mountains.

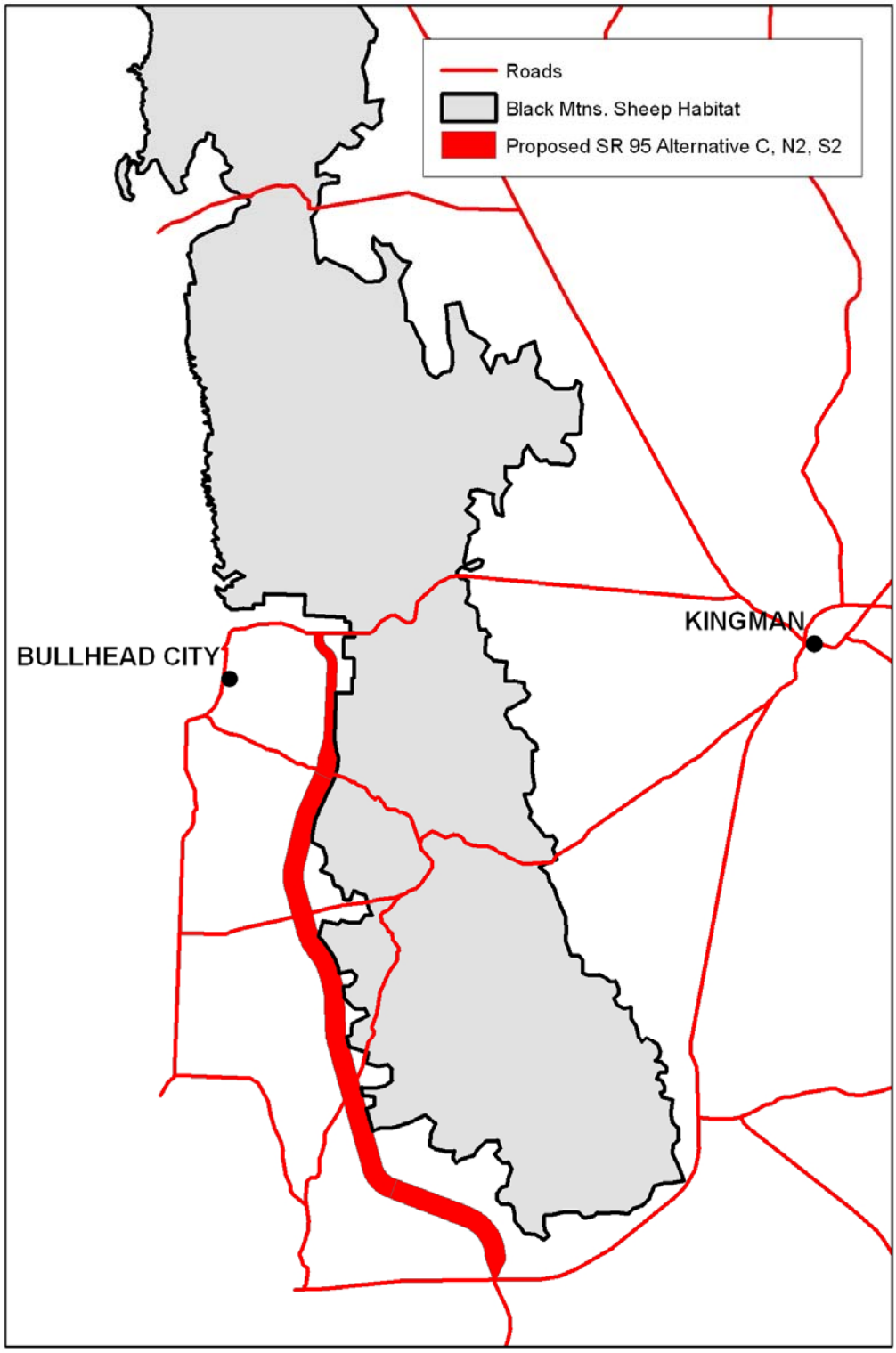


Figure 7. Black Mountains Desert Bighorn Sheep Habitat Area.

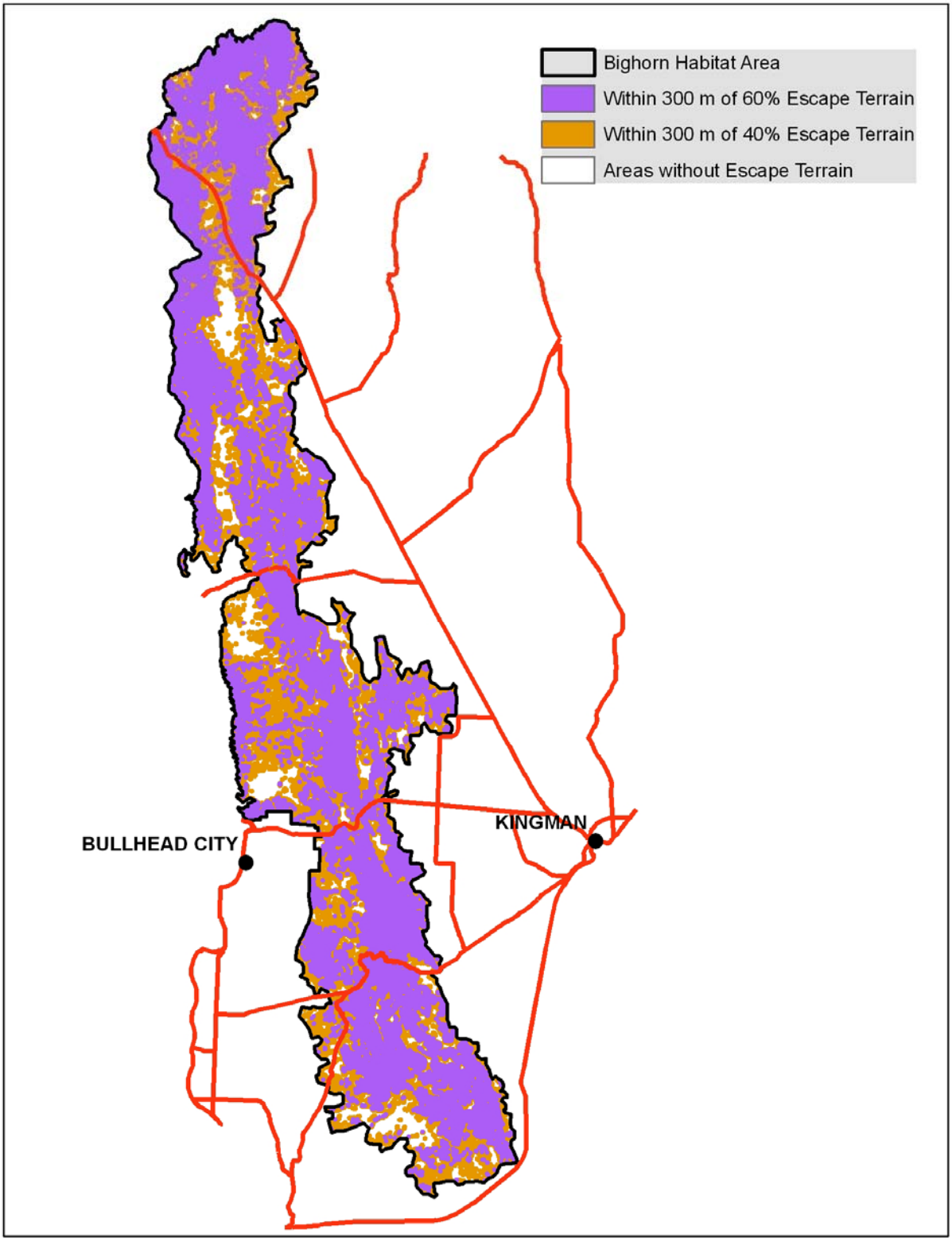


Figure 8. Location of State and Private Lands in the Black Mountains With the Centerline of the Mountain Range and Escape Terrain Used to Prioritize Parcels for Acquisition.

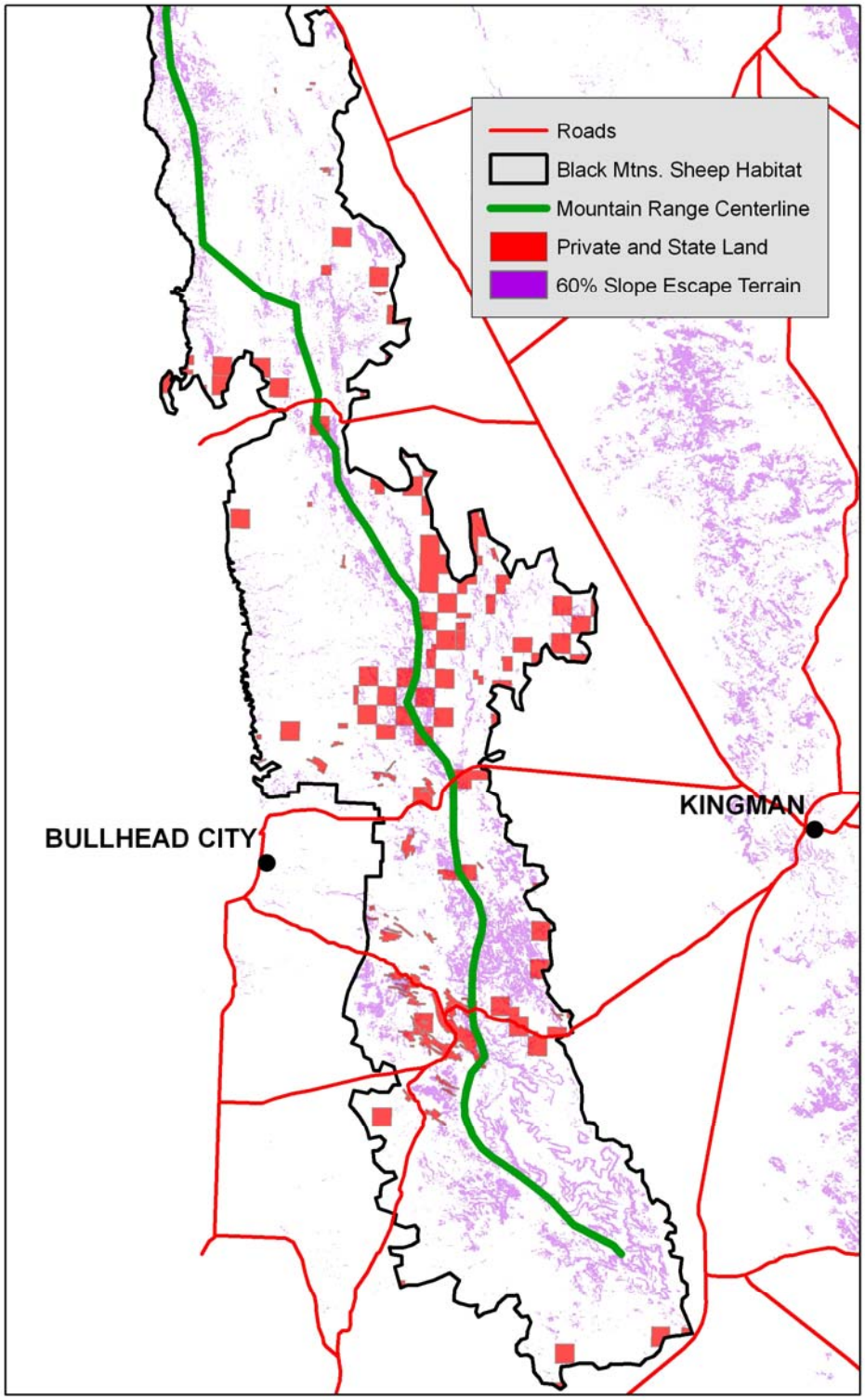


Figure 9. Fragmentation of the Black Mountains by Highways.

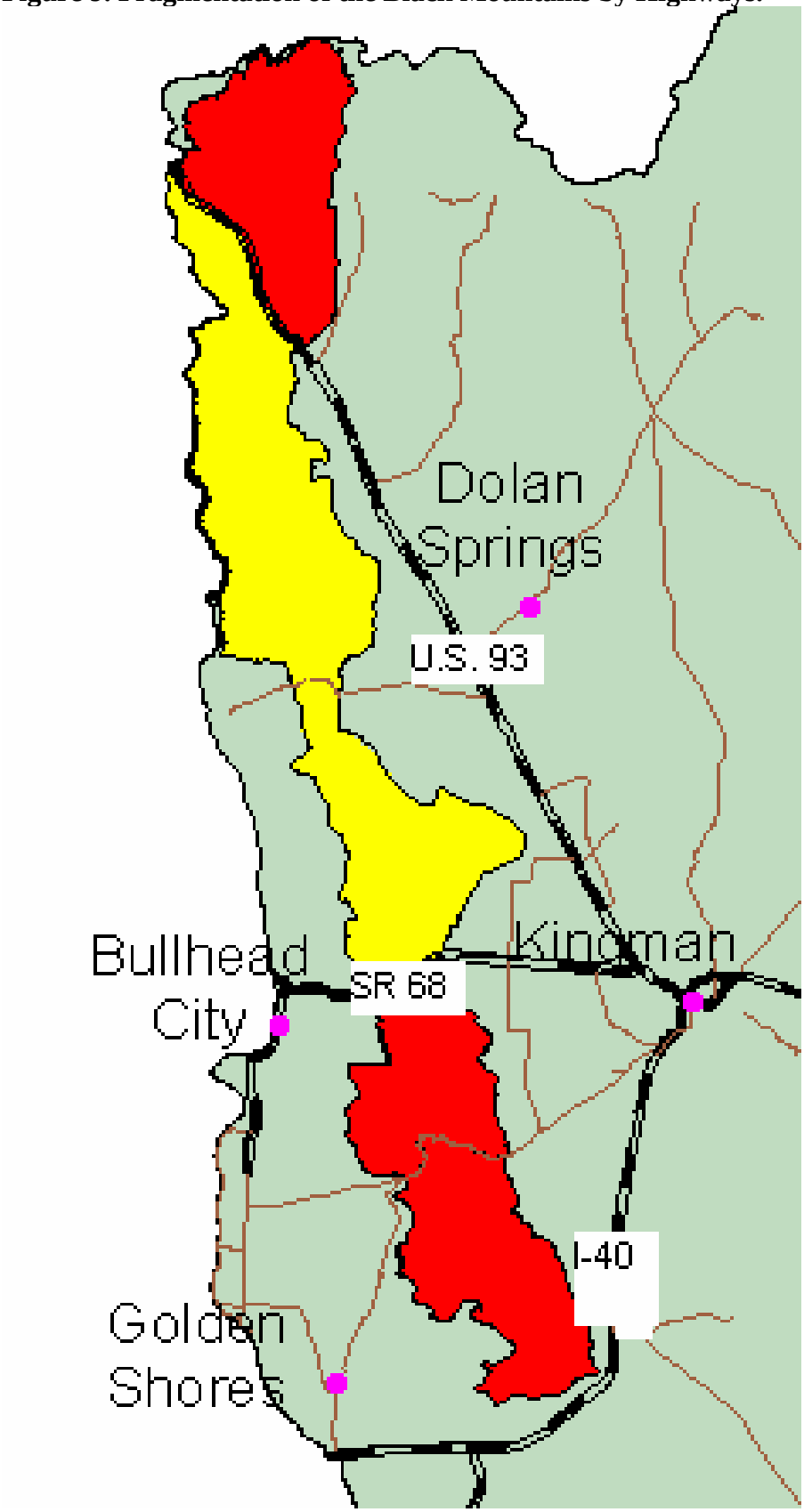


Figure 10. Desert Bighorn Crossing Locations on U.S. Route 93.

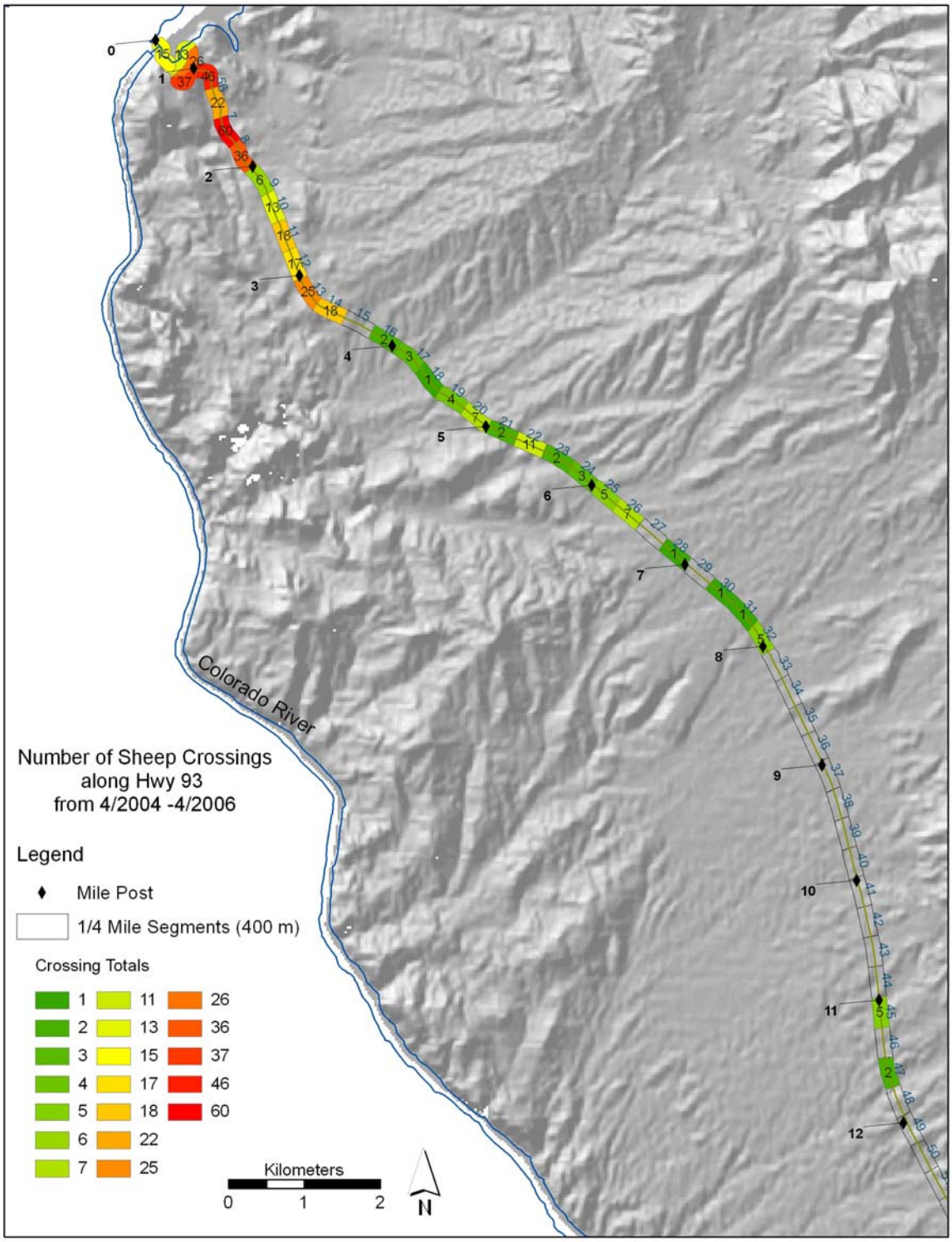


Figure 11. Locations of Desert Bighorn That Did Not Cross U.S. Route 93.

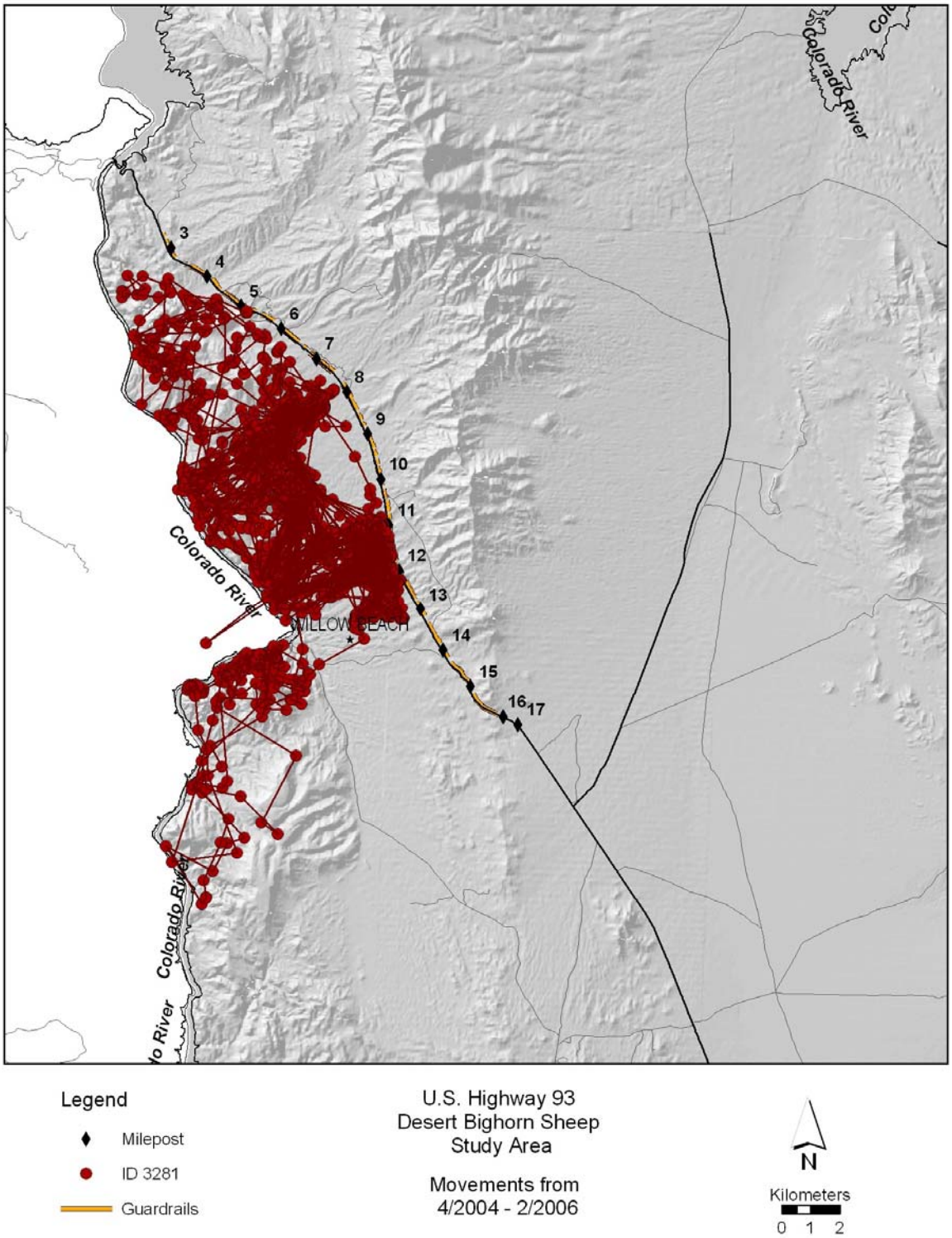


Figure 12. Locations of Wildfires in the Black Mountains.

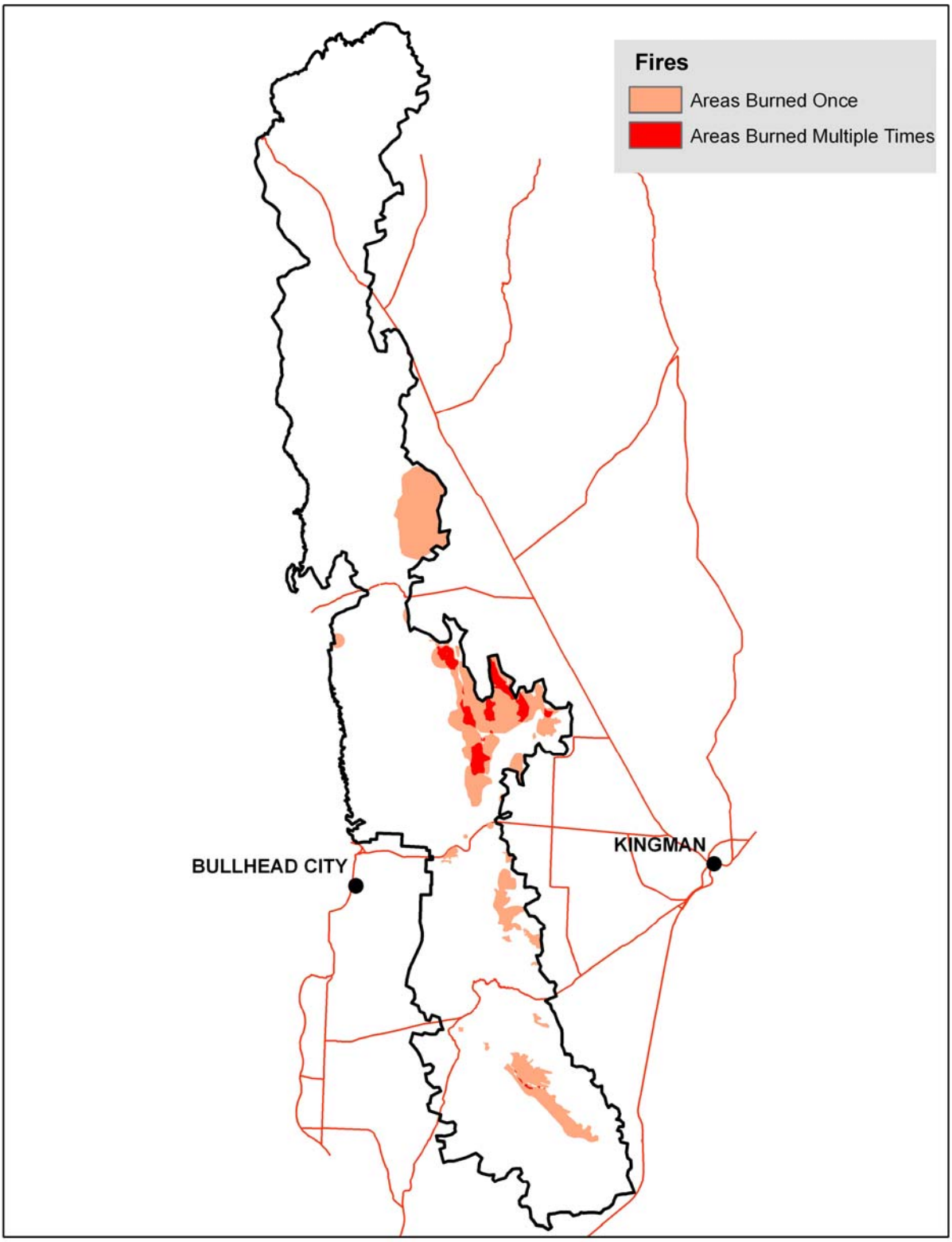
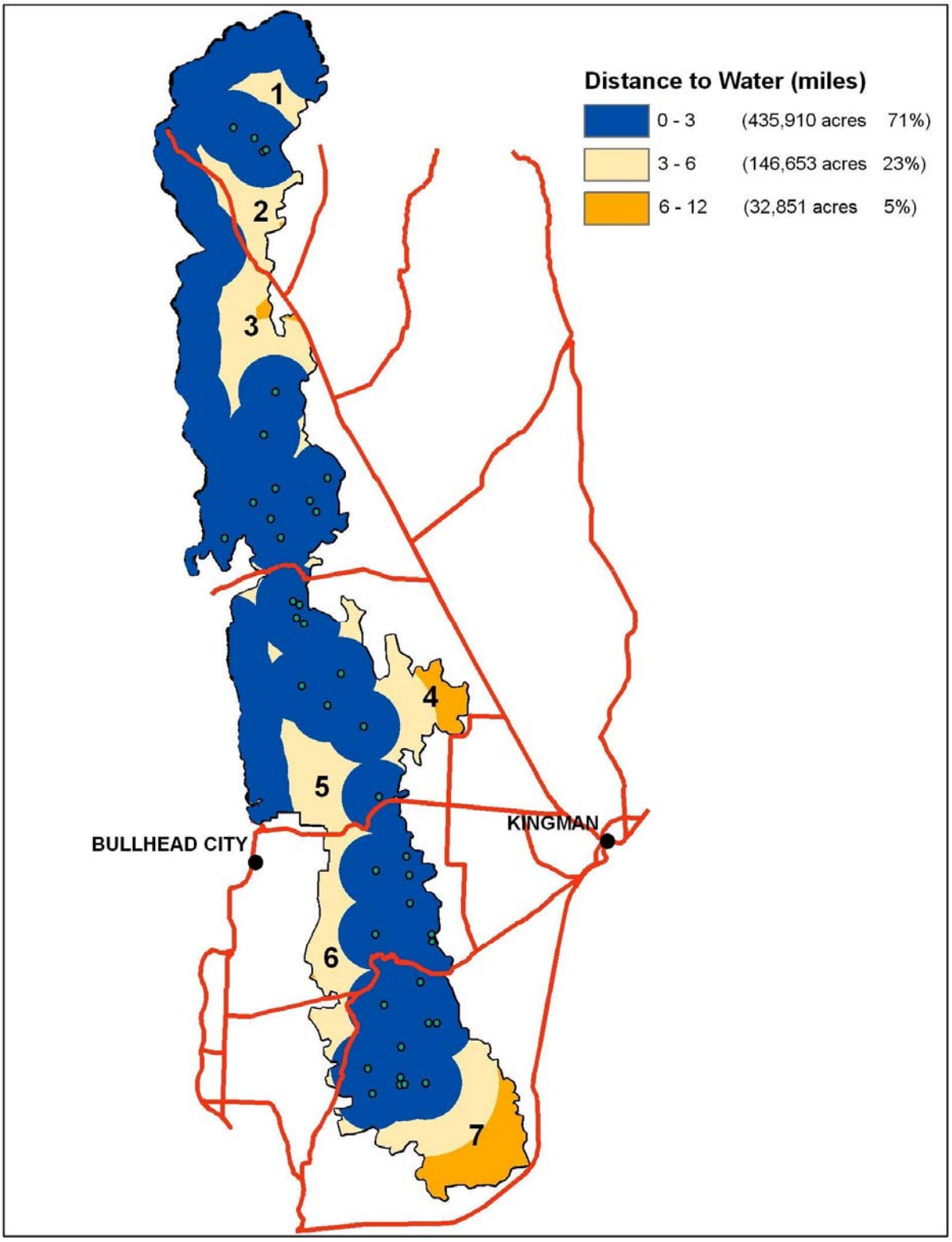


Figure 13. Columbine Spring Catchment in Unit 15D of the Black Mountains Overgrown with Cattails.

Figure 14. Locations of Water Developments and Other Perennial Water Sources in the Black Mountains With Distance to Water.



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Appendices

Appendix A. List of Bighorn Sheep Management Plans Reviewed.

AGFD W-53 Performance Report, 2003

AGFD Management Plan for the Rocky Mountain Bighorn Sheep Populations in Region I, Draft 2005

AGFD Bighorn Sheep Management Guidelines, Draft 2006

Arizona Strip Desert Bighorn Sheep Management Plan, 2001

Draft Recovery Plan for Sierra Nevada Bighorn Sheep, 2003

Colorado BLM Desert Bighorn Sheep Management Guidelines, 1989

Idaho Department of Fish and Game Hell's Canyon Restoration Plan Progress Report, 2005

Idaho Department of Fish and Game Hell's Canyon Restoration Plan Progress Report, 2004

Plan for the Recovery of Desert Bighorn Sheep in New Mexico, 2003

Long Range Plan for the Management of Rocky Mountain Bighorn Sheep in New Mexico, Draft 2004

Nevada Division of Wildlife's Bighorn Sheep Management Plan, 2001

Oregon's Bighorn Sheep and Rocky Mountain Goat Management Plan, 2003

Colorado Division of Wildlife Desert Bighorn Sheep Management Plan, Black Ridge Herd Unit Revision 1997

Texas desert bighorn sheep restoration and management plan,

Texas Revised Bighorn Sheep Management Plan, 2002

South Dakota Restoration Plan for Cedar Pass

Utah Division of Wildlife Resources Statewide Management Plan for Bighorn Sheep, 1999

Washington Department of Fish and Wildlife Game Management Plan 2003-2009, Bighorn Sheep Section, 2003

Management plan for Bighorn Sheep in Alberta, 1993

Status of the California Bighorn Sheep in British Columbia, 2000

Status of the Rocky Mountain Bighorn Sheep in British Columbia, 2000

BLM Black Mountain Ecosystem Management Plan and Environmental Assessment, 1996

BLM Desert Bighorn Habitat Management Plan, Black Mountains, Arizona, 1978

BLM Mountain Sheep Ecosystem Management Strategy in the 11 Western States and Alaska, 1995

Appendix B. Bighorn Sheep Survey Data 1976-2005 for 15BW, 15CN, 15CS and 15D.

15BW								
Year	**Rams**	**Ewes**	**Lambs**	**Yearlings**	**Unclassed**	**Total**	**Hours**	**Sheep/hour**
[S]1976[2]	28	132	43			203	14.6	13.9
[S]1977[2]	34	98	49			181	19.3	9.4
[S]1978[2]	41	112	53			206	17.9	11.5
[S]1979[2]	32	151	80			263	NA	NA
[S]1980	54	170	93			317	8.4	37.7
[S]1981[2]	60	164	65			289	14.2	20.4
1981	37	127	41			205	8.2	25.0
[S]1982[2]	120	314	134			568	12.4	45.8
1984	78	148	42	12		280	13.1	21.4
1985	82	187	44	19		332	16.2	20.5
1986	53	149	51	12	5	270	11.4	23.7
1987	65	127	57	41		290	12.7	22.8
1988	67	184	62	40		353	12.8	27.6
1989	57	115	28	8		208	12.7	16.4
1990	76	93	48	10		227	9.7	23.4
1991	103	180	30	30		343	10.4	32.9
1992	139	184	70	35		428	11.3	37.8
1993	179	172	32	24		408	11.8	34.6
1994	64	147	22	19		252	10.7	23.6
1995	104	183	54	8		349	11	31.7
1996	64	120	15	5		204	12.1	16.8
1997	99	142	59	3		303	11.7	25.8
1998	NS	-	-	-		-	-	
1999	NS	-	-	-		-	-	
2000	31	64	18	6		119	10.9	10.9
2001	75	163	86	19		343	11.3	30.3
2002	NS	-	-	-		-	-	
2003	26	85	43	7		161	11	14.6
2004	29	59	41	4		133	9.8	13.6

[S]=Spring Survey
[1]=15CS and 15CN were not separated into separate units on early surveys
[2]=Early unit 15B surveys included 15BW and 15BE
NS = Not Surveyed

15CN								
Year	**Rams**	**Ewes**	**Lambs**	**Yearlings**	**Unclassed**	**Total**	**Hours**	**Sheep/hour**
[S]1976[1]	43	107	36			176	12.2	14.4
[S]1977[1]	35	70	25		16	141	18.0	7.8
[S]1978[1]	33	108	44			185	15	12.3
[S]1979[1]	78	166	77			311	NA	NA
[S]1980	51	185	85			331	12.7	26.1
[S]1981	39	99	19			157	12.4	12.7
1981	53	73	19			145	12.4	11.7
1982	33	44	29			106	9.4	11
1983	53	74	29	15		171	11.7	14.6
1984	16	18	2	10		46	3.5	13.1
1985	61	100	44	13		218	10.2	21.4
1986	38	95	41	12		186	12.1	15.4
1987	59	110	77	34		280	12.9	21.7
1988	88	189	102	54		433	12.7	34.1
1989	51	120	21	5		197	12.8	15.4
1990	75	99	26	20		220	10.2	21.5
1991	67	128	50	17		262	12.8	20.4
1992	89	119	32	30		270	12.6	21.4
1993	NS							
1994	63	142	15	20		240	12.2	19.7
1995	82	216	73	15	4	390	11.3	34.5
1996	68	128	21	10		227	11.7	19.4
1997	118	168	73	12		371	12.3	30.1
1998	NS	-	-	-		-	-	
1999	59	121	31	0		211	10.5	20
2000	NS	-	-	-		-	-	
2001	50	106	41	11		208	9.9	21
2002	NS	-	-	-		-	-	
2003	21	82	39	3		145	8.6	16.7
2004	18	58	43	1		120	8.0	15.0

[S]=Spring Survey
[1]=15CS and 15CN were not separated into separate units on early surveys
[2]=Early unit 15B surveys included 15BW and 15BE
NS = Not Surveyed

15CS								
Year	**Rams**	**Ewes**	**Lambs**	**Yearlings**	**Unclassed**	**Total**	**Hours**	**Sheep/hour**
[S]1976[1]	43	107	36			176	12.2	14.4
[S]1977[1]	35	70	25		16	141	18.0	7.8
[S]1978[1]	33	108	44			185	15	12.3
[S]1979[1]	78	166	77			311	NA	NA
[S]1980	29	42	27			98	5.5	17.8
[S]1981	19	23	8			50	5.5	9.1
1981	25	29	13			63	5.5	11.5
1982	7	13	8			28	3.9	7.1
1983	8	23	17	6		55	4.4	12.5
1984	2	14	4	3		23	2	11.5
1985	28	36	20	3		87	7.5	11.6
1986	22	31	18	7		78	7.2	10.8
1987	39	56	28	11		134	6.8	19.7
1988	39	49	32	14		134	6.8	19.7
1989	40	64	18	14		136	7.5	18.1
1990	42	56	21	14		133	5.9	22.5
1991	26	40	23	11		100	5.2	19.2
1992	NS							
1993	30	56	10	13	2	111	5.4	20.6
1994	51	108	8	17		184	6.3	29.2
1995	52	90	17			159	6	26.5
1996	NS	-	-	-		-		
1997	34	90	46	1		171	6	28.5
1998	NS	-	-	-		-		
1999	NS	-	-	-		-	-	
2000	39	65	25	2		131	6.1	21.4
2001	NS	-	-	-		-	-	
2002	NS	-	-	-		-	-	
2003	9	11	3	1		24	6	4
2004	7	17	8	2		29	4.1	7.1
2005	8	16	6			30	5	6
[S]2005	13	30	14		1	58	5.2	11.2

[S]=Spring Survey
[1]=15CS and 15CN were not separated into separate units on early surveys

[2]=Early unit 15B surveys included 15BW and 15BE
NS = Not Surveyed

15D								
Year	**Rams**	**Ewes**	**Lambs**	**Yearlings**	**Unclassed**	**Total**	**Hours**	**Sheep/hour**
[S]1976	9	26	15			50	8.7	5.7
[S]1977	22	42	19			83	13.6	6.1
[S]1978	3	47	25			75	10.3	7.3
[S]1979	14	45	20			79	NA	NA
[S]1980	27	33	22			82	8.1	10.1
[S]1981	29	60	25			114	7.2	15.8
1981	28	24	12			63	9.6	6.6
1982	44	40	14			88	10.8	8.1
1983	37	44	22			108	9.6	11.3
1984	21	7	7			35	3.4	10.0
1985	32	27	10	3		72	8.8	
1986	50	65	46	8		169	9.6	
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995	63	114	16	2		195	11.1	17.6
1996	22	30	0	4		56	6	9.3
1997	66	130	28	1		225	11	20.4
1998	43	122	39	12		216	11	19.6
1999	NS							
2000	NS							
2001	39	104	40	10		193	13.1	14.7
2002	NS							
2003	NS							
2004	29	87	25	2	1	144	9.85	14.6
2005	NS							

[S]=Spring Survey
[1]=15CS and 15CN were not separated into separate units on early surveys
[2]=Early unit 15B surveys included 15BW and 15BE

NS = Not Surveyed

Appendix C. Transplant Data since 1957.

Capture Date	Capture Site	Release Site	Number Capture	Number Mortalities	Number Released	Sex Ratios	Capture Method
8/14/57	Topock (15D)	Black Gap WMA, Texas	1		1	M	Caught in Fence
11/12-14/1979	15C	Virgin Mtn Enclosure, AZ	12		12	3M,8F	Helicopter darting
11/18/80	15C	Kerrville, TX	8	1M,1F	6	4M,2F	Helicopter darting
11/9-10/1981	Willow Beach, 15C	Sullivan Canyon, AZ	21	1F	20	7M,13F	Helicopter darting
11/6-18/1981	Kingman Wash, 15BW	Buck Springs, AZ	22	1F	21	7M,14F	Helicopter darting
11/6-18/1981	Kingman Wash, 15BW	Devils Canyon, CO	9		9	9F	Helicopter darting
5/4/82	Mt. Wilson, 15BW	Virgin Mtn. Enclosure, AZ	2		2	2M	Helicopter darting
7/31/1983	Sidewinder Cove, 15BW	Grand Wash Cliffs, AZ 13B	22		22	8M,14F	Drop Net
8/1/83	Sidewinder Cove, 15BW	Big Dominguez Cyn., CO	10		10	4M,6F	Drop Net
8/2/83	Indian Canyon, 15BW	Van Horn, TX	11		10	3M,7F	Drop Net
8/3/83	James Bay, 15BW	Olaf Knolls, Grand Wash Cliffs, 13B	12		12	4M,8F	Drop Net
7/15/84	15BW	Paria Cyn. 13A	37		37	9M,28F	Drop Net
7/15/84	15BW	13B	8	1F	6	3M,3F	Drop Net

Capture Date	Capture Site	Release Site	Number Capture	Number Mortalities	Number Released	Sex Ratios	Capture Method
7/15/84	15BW	Dominguez Cyn., CO	10		10	3M, 7F	Drop Net
7/14-16/85	Lake Mead NRA, 15BW	Hacks & Paria Cyn, 13A	39		39	12M,27F	Drop Net
7/20-21/86	Lake Mead NRA, 15BW	Grand Wash (22), Bill Williams Mtns (22)	50		44	8M, 13F 5M, 17F	Drop Net
7/18/87	Lake Mead NRA, 15BW	CO	21		21	6M, 15F	Drop Net
7/19/87	Willow Beach, 15C	Hacks Cyn. 13A	19		19	6M, 13F	Drop Net
7/23/88	Lake Mead NRA, 15BW	Needles Peak, 16B	22	1	21	6M, 15f	Drop Net
7/24/88	Lake Mead NRA, 15BW	Aubrey Peak, 16A	13		13	4M, 9F	Drop Net
7/1/89	Golden Door, 15C	Aubrey Peak, 16A	15		15	2M, 13F	Drop Net
7/2/89	Golden Door, 15C	Crossman Peak, 16A	14		14	4M, 10F	Drop Net
7/16/89	Lake Mead NRA, 15BW	Mohave Mtns. 16A	13		13	2M, 11F	Drop Net
11/18-19/1991	15D	Rawhide Mtns. 16A	20		20	4M, 16F	Net Gun
11/20/91	15C	CO	26	1F	18	5M, 13F	Net Gun
7/24/93	Lake Mead NRA, 15BW	Rawhide Mtns. 16A	17		17	6M, 11F	Drop Net
7/25/93	Lake Mead NRA, 15BW	CO	24		20	5M, 15F	Drop Net

Capture Date	Capture Site	Release Site	Number Capture	Number Mortalities	Number Released	Sex Ratios	Capture Method
7/31/93	Lake Mead NRA, 15BW	Skull Mtn. 16A	16		13	4M, 9F	Drop Net
11/14/94	Kingman Wash 15BW	Beaver Dam Mtns. UT	25		25	5M, 20F	Net Gun
7/22/95	Lake Mead NRA, 15BW	13B	22		22	6M, 16F	Drop Net
7/23/95	Lake Mead NRA, 15BW	Artillery Mtns. 16A	14		14	5m, 9f	Drop Net
11/16-17/95	15C, 15D	16A 13A S. Utah	60		18 20 21	18F 4M, 16F 3M, 18F	Net Gun
11/16/99	Golden Door 15C	Jumpup Point 12A, Olaf Knolls 13B	44		22 22	6M, 16F 6M, 16F	Net Gun
11/17/99	Kingman Wash 15BW	Smokey Mtns., UT	21		21	5M, 16F	Net Gun

Appendix D. Black Mountains Bighorn Mortality Database

Animal I.D.	Radio Freq/ collar type	Last Live Signal from Overflight	Date of Mortality Signal	Date Collar Recovered	Location	GMU	Sex/ Age	Cougar Sex	Project	Cause of Mortality	Estimated Mortality Date Based on GPS Data	Capture Date
3264	8.07-stob replaced w/ s-s	Store on Board not working; replaced with s/s	11/16/2004	12/2/2004 died within days of capture Nov 4-5	Wilson Ridge	15BW	ewe		Hwy 93	Lion	11/9/2004	Apr-04
3258	8.17-stob	4/04 capture	5/04 on ground	5/22/2004	Hills S of Lake Mead	15BW	I ram		Hwy 93	Lion	5/21/2004	Apr-04
3256	8.11-stob	5/14/2004	6/11/2004	6/12/2004	Mine Hills N WR Canyon	15BW	I ram		Hwy 93	Lion	6/11/2004	Apr-04
3288	8.01-VHF	7/9/2004	9/17/2004	9/21/2004	Granite Canyon	15CS	ewe		Reg 3	Lion	N/A (VHF)	May-04
3286	9.50-VHF	9/17/2004	10/15/2004	10/15/2004	Lost Cabin Wash	15CS	II ram		Reg 3	unknown	N/A (VHF)	May-04
3282	8.50-VHF	9/17/2004	10/15/2004	10/15/2004	W. of Lost Cabin spring	15CS	ewe		Reg 3	unknown	N/A (VHF)	May-04
3297	9.13-VHF	10/15/2004	1/7/2005	2/2/2005	Spirit Mountain SE	15CS	ewe		Reg 3	unknown	N/A (VHF)	May-04
3270	8.38-stob	10/15/2004	10/29/04 during re-capture	12/3/2004, probably died in October	Big Nasty	15CN	ewe		Hwy 93	Lion	10/29/2004	Apr-04
3276	8.39-stob	11/26/04 ?	hunter kill	12/10/2004	Malpais Mesa	15CN	III ram		Hwy 93	Hunter	12/10/2004	Apr-04
3266	8.34-stob	12/16/2004	12/16/2004	12/17/2004	Hills S of Lake Mead	15BW	ewe	visual of tom	Hwy 93	Lion	12/17/2004	Apr-04
3298	8.40-VHF	1/7/2005	1/17/2005	1/17/2005	W. of Lost Cabin spring	15CS	ewe		Reg 3	Lion	N/A (VHF)	May-04
3284	8.70-VHF	1/7/2005	1/17/2005	1/18/2005	E. of Portland Mine	15CS	II ram		Reg 3	Lion	N/A (VHF)	May-04

Animal I.D.	Radio Freq/ collar type	Last Live Signal from Overflight	Date of Mortality Signal	Date Collar Recovered	Location	GMU	Sex/ Age	Cougar Sex	Project	Cause of Mortality	Estimated Mortality Date Based on GPS Data	Capture Date
3252	8.04- s-s	6/10/2005	7/22/2005	8/9/2005	Mine Hills N WR Canyon	15BW	ewe		Hwy 93	Lion	7/10/2005	Apr-04
3306	8.65- s-s	7/22/2005	9/8/05 on ground	9/8/2005	m.p. 7, 2 mi w of 93	15CN	II ram		Hwy 93	Non-Predation	8/13/2005	Nov-04
3287	8.09-VHF	9/2/2005	1/20/2005	1/22/2005	Burns Springs	15CS	ewe		Reg 3	unknown	N/A (VHF)	May-04
3285	9.27-VHF	9/2/2005	9/4/2005	9/4/2005	near Granite Canyon	15CS	I ram		Reg 3	Lion	N/A (VHF)	May-04
3296	9.181-VHF	9/2/2005	9/30/2005	10/20/2005	N. of Portland Mine	15CS	ewe		Reg 3	Lion	N/A (VHF)	May-04
3268	8.53- s-s	9/30/2005	10/28/2005	10/28/2005	m.p. 2.5, 0.5 mi w of 93	15CN	ewe		Hwy 93	Lion	9/16/2005	Apr-04
3255	8.61- s-s	9/30/2005	10/28/2005	10/28/2005	Side can. N WR Canyon	15BW	II ram		Hwy 93	Lion	9/28/2005	Apr-04
3260	8.21-stob	9/30/2005	10/28/2005	10/28/2005	Bighorn Cove 708088/3907954	15CN	ewe	female tracks	Hwy 93	Lion	10/9/2005	Apr-04
3304	8.67- s-s	10/28/05	hunter kill	12/2/2005	Wilson Ridge	15BW	III ram		Hwy 93	Hunter	12/2/2005	Nov-04
199	9.85-stob	11/05 capture	2/3/2006	2/6/2006	4 mi W of Burro Spring, N of Hwy 68	15CS	ewe		Hwy 68	Non-Predation	11/28/05 - 2/6/2006 *	Nov-05
3278	8.63- s-s	12/9/2005	1/11/2006	1/11/2006	m.p. 6.2, 1 mi w of 93	15CN	III ram	female tracks	Hwy 93	Lion	12/18/2005	Apr-04
3281	8.43- s-s	12/9/2005	2/3/2006	2/5/2006	m.p. 12 1 mi w of 93	15CN	III ram	female tracks	Hwy 93	Lion	1/26/2006	Apr-04
3254	8.59- s-s	3/3/2006	3/31/2006	4/1/2006	Mine Hills N WR Canyon	15BW	II ram		Hwy 93	Lion	3/20/2006	Apr-04
193	9.78-stob	3/3/2006	3/31/2006	4/5/2006	1 mi N of Grapevine Canyon; S of Hwy 68	15D	ewe		Hwy 68	unknown	3/17/06 - 4/05/06 *	Nov-05
3299	8.30 VHF	3/3/2006 ?	3/31/2006	4/2/2006	Lost Cabin Wash, 2 mi SE of Lost Cabin spring	15CS	ewe		Reg 3	Lion	bones; prob w/in 1 mo.	Apr-04
196	9.93-stob	3/20/2006 on ground	3/31/2006	4/3/2006	3 mi W of Burro Spring; N of Hwy 68	15CS	ewe		Hwy 68	Lion	data retrieval problem	Nov-05

* Locations tightly clustered between these dates, possibly due to lambing; actual mortality date can not be determined

Appendix E. Private and State Lands in the Black Mountains scored based on bighorn habitat quality (CR – center of range, ET – 60 percent slope escape terrain).

Ownership	Township (N)	Range (W)	Section (polygon center)	Acres	Nearest Water	Distance to water (m)	Water Score	Distance to CR (m)	CR Score	Percent Containing ET	ET Score	Total Score	BLM List
Private	20	20	03	280	Secret Pass Pools	0	9	90	5	31.947%	4	18	Y
Private	22	20	03	1,000	BURNS	0	9	696	3	5.840%	1	13	Y
Private	20	19	33	562	FIG	0	9	4,582		15.394%	2	11	Y
Private	25	22	27	639	DAVIS MTN.	0	9	5,929		1.097%	1	10	Y
Private	21	20	11	935	UNAMED SPRING	697	3	0	5	7.545%	1	9	Y
Private	19	20	34	135	LAZY BOY	573	3	607	3	17.830%	2	8	
Private	22	20	21	640				268	5	26.269%	3	8	Y
Private	22	20	33	638				0	5	22.381%	3	8	Y
Private	24	21	09	642				0	5	20.590%	3	8	Y
Private	20	20	35	4				60	5	28.659%	3	8	
Private	22	20	17	645				0	5	17.608%	2	7	Y
Private	22	20	29	597				0	5	13.889%	2	7	Y
Private	23	20	33	640				0	5	11.478%	2	7	Y
Private	19	20	11	111				0	5	14.159%	2	7	
Private	19	20	16	3,206				0	5	7.824%	1	6	
Private	18	20	03	63				779	3	27.004%	3	6	
Private	19	19	21	684	COOL	470	3	3,630		4.295%	1	4	Y
Private	22	20	19	631				900	3	3.193%	1	4	Y
Private	19	19	08	1,447				1,501	3	4.790%	1	4	
Private	22	20	15	638				1,530	3	0.213%	1	4	Y
Private	21	20	09	190				1,530	3	2.607%	1	4	Y
Private	23	20	16	2,239				708	3	0.189%	1	4	Y
Private	22	20	27	639				1,068	3	1.735%	1	4	
Private	23	20	35	163				3,127	2	10.496%	2	4	
Private	20	19	09	56				4,729		37.395%	4	4	
Private	22	21	13	642				2,771	2	6.401%	1	3	Y
Private	18	20	10	206				1,722	2	4.831%	1	3	
Private	22	21	25	642				2,531	2	0.127%	1	3	Y
Private	22	20	31	468				1,717	2	0.897%	1	3	Y

Ownership	Township (N)	Range (W)	Section (polygon center)	Acres	Nearest Water	Distance to water (m)	Water Score	Distance to CR (m)	CR Score	Percent Containing ET	ET Score	Total Score	BLM List
Private	20	20	01	26				1,634	2	0.095%	1	3	
Private	23	20	27	642				1,795	2	0.038%	1	3	
Private	24	21	25	338				2,053	2	1.308%	1	3	
Private	25	21	31	642				1,974	2	0.605%	1	3	
Private	19	20	02	5				660	3	0.000%		3	
Private	20	21	24	55				7,763		29.924%	3	3	
Private	21	20	10	5				450	3	0.000%		3	
Private	19	20	05	847				3,870		11.577%	2	2	
Private	20	21	13	40				7,621		14.144%	2	2	
Private	21	20	07	201				4,081		14.961%	2	2	
Private	21	20	16	19				3,210	2	0.000%		2	Y
Private	21	20	16	20				2,250	2	0.000%		2	Y
Private	25	22	25	463				2,894	2	0.000%		2	Y
Private	23	21	15	57				2,737	2	0.000%		2	
Private	24	21	33	39				2,725	2	0.000%		2	
Private	20	19	21	629				4,110		4.358%	1	1	Y
Private	26	21	33	166				3,486		5.402%	1	1	Y
Private	19	19	10	69				6,504		8.040%	1	1	
Private	20	20	19	58				6,411		7.048%	1	1	
Private	20	20	30	267				6,413		6.885%	1	1	
Private	21	20	06	38				3,219		3.003%	1	1	
Private	21	20	20	48				3,960		3.715%	1	1	
Private	21	20	32	365				3,300		3.365%	1	1	
Private	23	19	27	640				11,341		4.716%	1	1	
Private	23	20	12	93				7,487		3.132%	1	1	
Private	23	19	19	409				6,848		3.702%	1	1	
Private	23	20	25	313				5,791		4.707%	1	1	
Private	23	19	25	153				14,511		2.833%	1	1	
Private	23	19	35	638				12,780		3.550%	1	1	
Private	16	18	20	95				8,040		0.234%	1	1	
Private	16	18	19	520				6,658		0.057%	1	1	
Private	16	19	29	643				8,588		0.004%	1	1	

Ownership	Township (N)	Range (W)	Section (polygon center)	Acres	Nearest Water	Distance to water (m)	Water Score	Distance to CR (m)	CR Score	Percent Containing ET	ET Score	Total Score	BLM List
Private	17	20	29	62				12,687		0.238%	1	1	
Private	18	20	07	648				6,095		0.050%	1	1	
Private	19	19	10	498				4,294		1.219%	1	1	
Private	19	19	15	328				5,510		0.498%	1	1	
Private	19	20	20	15				5,247		0.336%	1	1	
Private	20	20	33	58				3,601		0.170%	1	1	
Private	21	21	03	255				8,305		1.752%	1	1	
Private	21	21	06	32				12,735		0.077%	1	1	
Private	22	19	03	679				11,130		1.757%	1	1	
Private	22	19	05	498				7,903		0.184%	1	1	
Private	22	19	09	175				9,527		0.282%	1	1	
Private	22	19	18	239				5,766		1.428%	1	1	
Private	22	21	23	160				4,110		0.124%	1	1	
Private	23	20	02	891				6,284		0.677%	1	1	
Private	23	20	23	395				3,640		0.188%	1	1	
Private	23	20	35	122				3,310		0.020%	1	1	
Private	24	20	21	144				6,277		0.069%	1	1	
Private	24	20	29	478				4,032		0.098%	1	1	
Private	24	20	33	276				4,470		0.152%	1	1	
Private	25	22	29	242				7,744		0.061%	1	1	
Private	25	22	31	310				10,114		0.231%	1	1	
Private	26	21	04	78				10,204		2.059%	1	1	
Private	27	21	08	19				10,436		0.521%	1	1	
Private	27	21	08	16				9,983		0.313%	1	1	
State	20	20	02	525	Secret Pass Pools	297	3	0	5	17.385%	2	10	Y
State	26	21	36	636	KEMPLE	244	3	6,408		0.711%	1	4	Y
State	21	20	16	536				1,800	2	0.180%	1	3	Y
State	22	20	02	323				3,072	2	1.033%	1	3	
State	21	20	16	1				1,770	2	0.000%		2	Y
State	19	20	16	528				3,267		3.055%	1	1	
State	26	21	22	640				5,973		0.050%	1	1	Y
Private	16	19	05	89				11,871		0.000%			

Ownership	Township (N)	Range (W)	Section (polygon center)	Acres	Nearest Water	Distance to water (m)	Water Score	Distance to CR (m)	CR Score	Percent Containing ET	ET Score	Total Score	BLM List
Private	17	20	17	8				11,412		0.000%			
Private	18	20	05	91				4,112		0.000%			
Private	19	20	04	16				4,540		0.000%			
Private	19	20	16	21				3,840		0.000%			
Private	20	20	19	13				6,407		0.000%			
Private	20	20	20	83				5,408		0.000%			
Private	20	20	28	88				3,466		0.000%			
Private	20	20	18	17				6,920		0.000%			
Private	21	21	03	64				6,306		0.000%			
Private	21	20	07	19				5,259		0.000%			
Private	22	20	02	1				3,314		0.000%			
Private	22	19	07	248				7,009		0.000%			
Private	22	20	13	158				4,742		0.000%			
Private	22	21	35	82				5,285		0.000%			
Private	23	20	13	84				6,055		0.000%			
Private	24	20	17	59				5,708		0.000%			
Private	24	20	19	25				5,394		0.000%			
Private	25	21	01	67				6,590		0.000%			
Private	25	20	07	322				7,276		0.000%			
Private	25	20	19	85				6,148		0.000%			
Private	25	22	33	58				8,661		0.000%			
Private	25	20	17	56				8,244		0.000%			
Private	25	21	35	37				3,541		0.000%			
Private	27	22	12	15				7,444		0.000%			
State	19	20	16	8				4,839		0.000%			
State	22	21	32	636				9,145		0.000%			
State	22	22	36	38				12,534		0.000%			
State	23	22	02	642				7,771		0.000%			
State	25	22	34	493				6,546		0.000%			