National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

El Morro National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/ELMO/NRR—2016/1192

ON THE COVER

El Morro National Monument. Photo Credit: NPS

El Morro National Monument

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Natural Resource Report NPS/ELMO/NRR—2016/1192

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for El Morro National Monument began November 2015, and nine focal study natural resources were chosen for the park's NRCA. These resources were organized into three categories: landscape-scale, supporting environment (i.e., physical resources), and biological integrity, which included wildlife and vegetation topics.

The landscape scale resources included viewshed, night sky, and soundscape. The viewshed and night sky resources were in good condition, given the fact that the monument is located in a rural setting. However, New Mexico State Highway 53 bisects the park, contributing to a moderate condition rating for soundscape.

The monument's supporting physical environment resource topics included air quality, geology, and historic pool. The condition for each of these resources varied between moderate for air quality and geology, and significant concern for the historic pool, which has been highly altered from its original hydrologic condition.

The biological integrity resources included vegetation, exotic plants and wildlife. The vegetation resources were in good to moderate condition, even though exotic plants were considered to be of significant concern. The wildlife condition was unknown due to lack of recent data to assess current condition.

Acknowledgements

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Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement — not replace — traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]

NRCAs Strive to Provide…

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1. The breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures [conditions for indicators] condition summaries by broader topics and park areas
3. NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
4. As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.
5. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures / indicators) broader resource topics, and park areas
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

- identify or develop reference conditions/ values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/ or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are

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An NRCA is intended to provide useful science-based information products in support of all levels of park planning.

designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities.

NRCA Reporting Products…

- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural

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An NRCA uses a variety of data to assess the condition of a park's natural resources.

6. An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.
7. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.
8. The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/nrca/.

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Rainbow over pueblo ruins at El Morro National Monument.

Chapter 2: Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

El Morro National Monument was established on December 8, 1906 by President Theodore Roosevelt's Presidential Proclamation 695 and further expanded in acreage in 1917 and in 1950 (NPS 2014a). The purpose of the national monument is to:

"Preserve Inscription Rock, its inscriptions, petroglyphs, and ancestral Puebloan archeological sites, and provide opportunities to experience these resources in their natural setting" (NPS 2014a).

El Morro is a Spanish word for headland, describing the sandstone promontory that rises 61m (200 ft.) from the surrounding landscape (NPS 2014a). This rock formation is an "open air record" of a 1,000 year history of inscriptions, petroglyphs, and pictographs, spanning from "Ancestral Puebloans who are ancestors of the Zuni, to Spanish explorers, European American surveyors, pioneers, military expeditions, and other travelers" (NPS 2014a).

The sandstone cliff served as a landmark along an ancient east-west trade route between pueblos, with two pueblos located atop El Morro. The Atsinna Pueblo was the largest of the two with multiple rooms and kivas providing shelter for up to 1,000 people who farmed the valley until the late 1300s (NPS 2014a). A natural catchment at the base of the cliff provided water, which was a precious commodity for survival and is believed to be the reason so many travelers passed by this location recording their presence on Inscription Rock for centuries to come.

El Morro NM's unique resources and values are described in the following significance statements taken from its Foundation Document (NPS 2014a):

- *Inscription Rock has more than 2,000 inscriptions, petroglyphs, and pictographs that document a cultural continuum of more than 1,000 years, from Ancestral*

Puebloans to Spanish explorers, European American surveyors, pioneers, military expeditions, and other travelers.

- *El Morro National Monument contains a high concentration of exceptional archeological resources; well-preserved and largely unexcavated pueblo sites atop Inscription Rock are among the largest 13th and 14th century settlements in the American Southwest.*

- *El Morro's distinctive combination of geologic and geographical features—the natural travel corridor, highly visible landmark with a pool of water at its base, and the carvable texture of its soft sandstone—provided a perfect natural canvas for early inhabitants and travelers to leave their mark.*

2.1.2. Geographic Setting

El Morro NM is located in New Mexico's Cibola County, encompassing 516 ha (1,276 acres) and is surrounded by the Ramah Navajo and Zuni Indian Reservations. It is located along New Mexico Highway 53, south of the Zuni Mountains and west of El Malpais National Monument, with which it is co-administered. It is approximately 119 miles west of Albuquerque and approximately 225 miles east of Flagstaff, Arizona (Figure 2.1.2-1). A detailed map of the monument is presented in Figure 2.1.2-2.

Population

The total population was 4,712 in 2010 (NPS 2014b, U.S. Census Bureau 2011) throughout the 30-km surrounding and including the monument (3,119.2 km^2) with 3.3% of the population located within 3-km^2 of the monument (NPS 2014b, U.S. Census Bureau 2011). This equates to a population density of 1.68 people/km^2 throughout the 30-km^2 area and 2.68 people/km^2 throughout the 3-km^2 area (NPS 2014b, U.S. Census Bureau 2011).

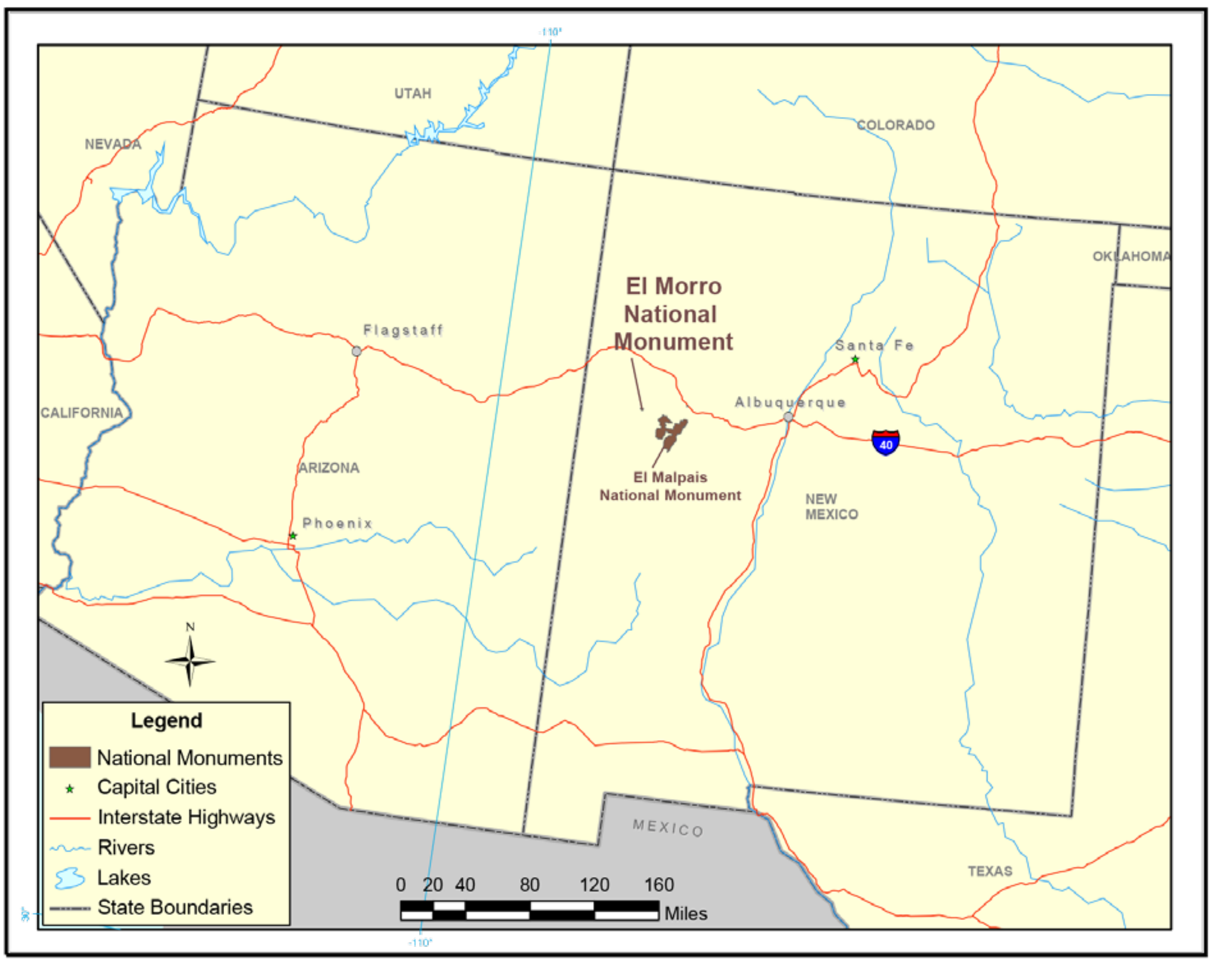

Figure 2.1.2-1. El Morro NM is located west of Albuquerque, New Mexico and east of Flagstaff, Arizona in Cibola County New Mexico.

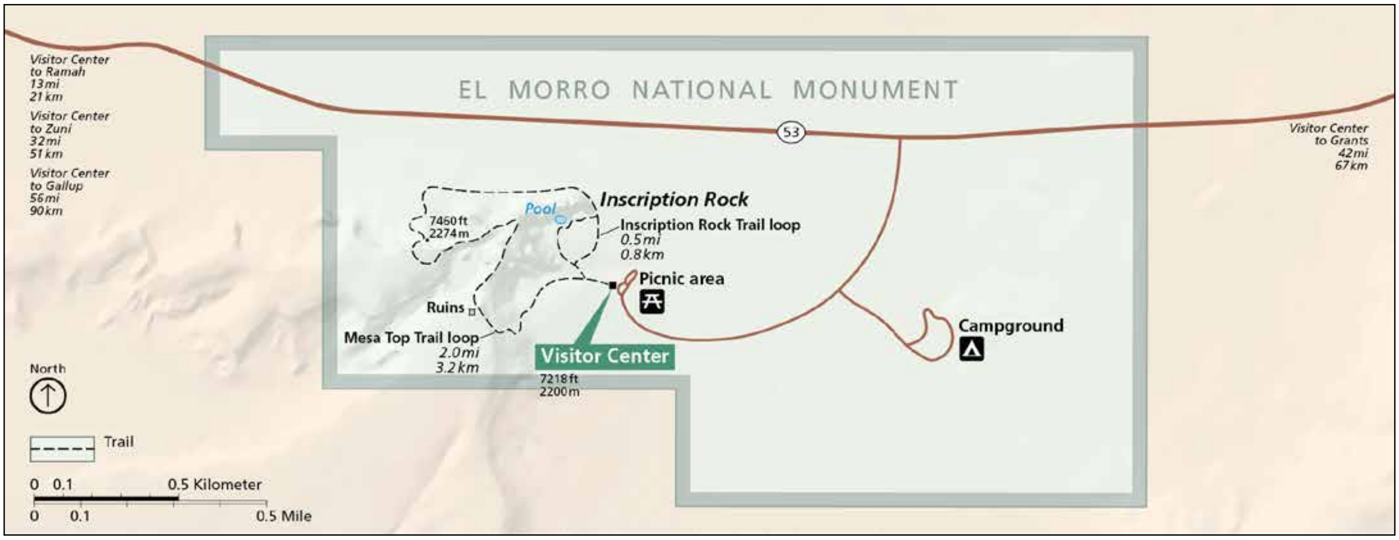

Figure 2.1.2-2. A detailed map of El Morro NM. Map Credit: Harpers Ferry

Population data for Cibola County New Mexico indicate that between 1820-1990, the population density increased from 0.022 people/km^2 to 5.0 people/km^2 (Waisanen and Bliss 2002) (note that the population density has decreased between 1990-2010). Furthermore projections indicate that the population density will decrease to 2.89 people/km^2 throughout the county by 2030 (University of New Mexico 2009).

The extent of anthropogenic impacts to park resources are difficult to measure, but because human land uses tend to expand from where they are currently present, projections relative to housing densities can be made (Monahan et al. 2012). Current housing density data (2010) classify 58% of the 30-km area as rural (NPS 2014c) (Figure 2.1.2-3), and it is expected that the area surrounding the NM will remain rural through 2100, which represents the last year projections were made (Theobald 2005).

Climate

The climate of the U.S. Southwest is most influenced by its location between the mid-latitude and subtropical atmospheric circulation regimes. This creates the typical southwestern climate of dry, sunny days, with low annual precipitation. Rain comes in July-September from monsoon storms that originate in the Pacific Ocean and the Gulf of Mexico, and in November-March from winter storms that originate in the Pacific Ocean (Sheppard et al. 2002).

The Colorado Plateau, where the NM is situated, is an arid region with irregular rainfall, periods of drought, warm to hot growing seasons, and long winters with freezing temperatures (Davey et al. 2006). Due to the large geographic area and the variation

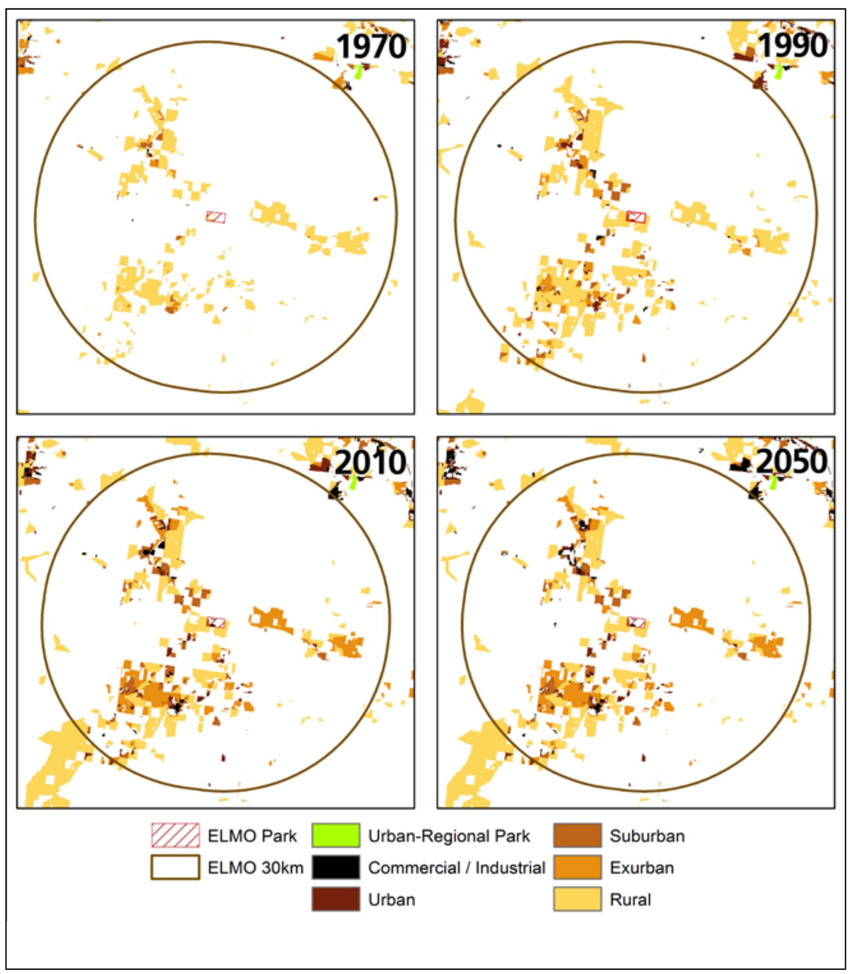

Figure 2.1.2-3. The area within 30 km surrounding El Morro National Monument is classified as primarily rural (Map credit: NPScape Program).

in topography, the climate conditions vary within the southern Colorado Plateau based on elevation and latitude.

The climate at El Morro NM has led to the establishment and persistence of plant communities that are adapted to the conditions and fluctuations in temperature and precipitation, and ecosystem condition is influenced by trends in climate (Davey et al. 2006).

Temperature

The temperature at El Morro NM typically varies over the year from 13°F to 88°F. The warm season is generally from May-September and cold season from November-February. The average annual maximum temperature (for the time period 3/1/1938-1/20/2015) was 64.1°F and the average minimum temperature was 30.0°F (WRCC 2015). Figure 2.1.2-4 shows the average maximum and minimum temperatures, and average daily total precipitation for each year between 1981 and 2010 (WRCC 2015).

Precipitation

El Morro NM receives precipitation from both summer monsoons and winter storms with more precipitation coming in the summer than winter (Figure 2.1.2-5). The average precipitation in the Colorado Plateau is 10-35 inches/year (Figure 2.1.2-6). At El Morro, the average rainfall is between 11 and 15 inches per year. Between March of 1938 and January 20, 2015, the average total annual precipitation at the El Morro weather station was 13.81 inches of rainfall and 44.4 inches of snowfall (WRCC 2015).

2.1.3. Visitation Statistics

Monthly visitation data for El Morro NM are available for 1979-2015 (NPS Public Use Statistics Office 2016). An inductive loop traffic counter is placed across the entrance lane of Entrance Road and multipliers are used to derive number of visitors (NPS Public Use Statistics Office 1992).

The total number of visitors each year ranged from a low of 27,536 (in 1981) to a high of 87,548 (in 1994). The total number of visitors in the most recent year (2015) was 49,390. Although there has been substantial monthly variation by year, the months receiving the highest average number of visitors over the recording period were in May, June, July, and August (Figure 2.1.3-1).

2.2. Natural Resources

A summary of the natural resources at El Morro NM is presented in this section and represents general information known about the study area and monument resources prior to the completion of this condition assessment. For some of the natural resource assessments, new data were gathered and

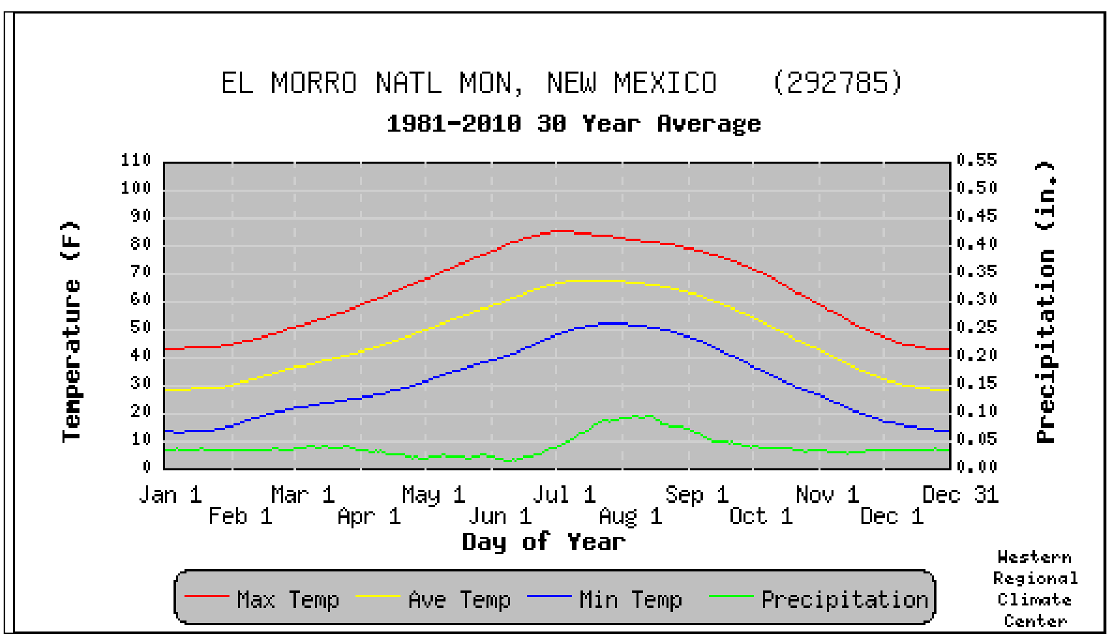

Figure 2.1.2-4. Average of all daily maximum temperatures (red line), average temperatures (yellow line), minimum temperatures (blue line) and average daily total precipitation (green line) between 1981 and 2010. Data are from the El Morro weather station (292785) and smoothed using a 29-day running average.

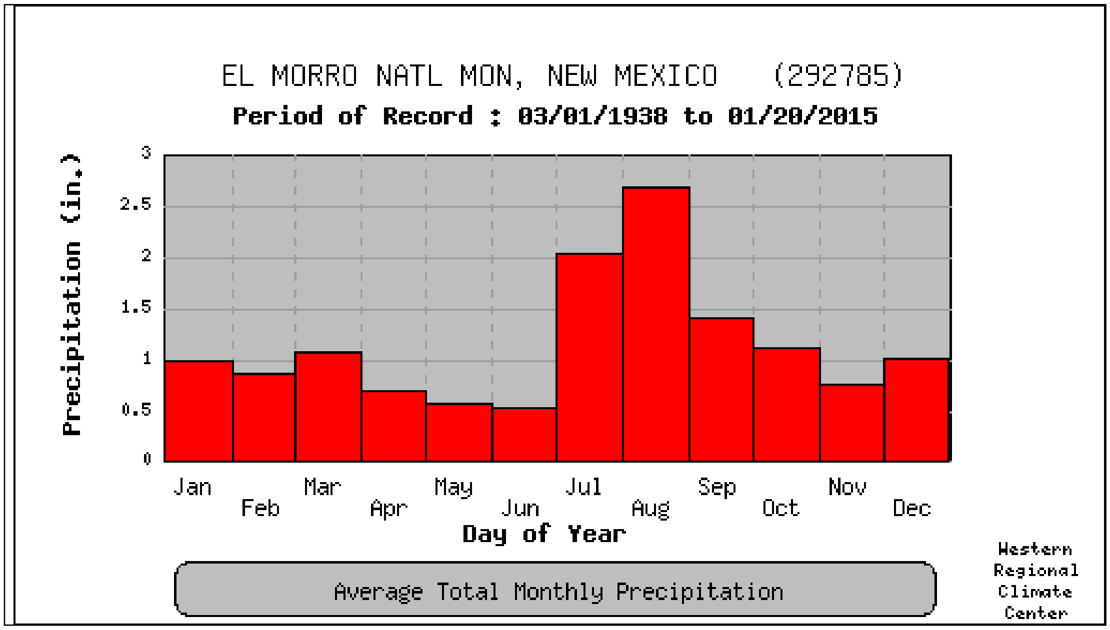

Figure 2.1.2-5. Average precipitation each month (time period 3/1/1938-1/20/2015) at El Morro NM (weather station 292785).

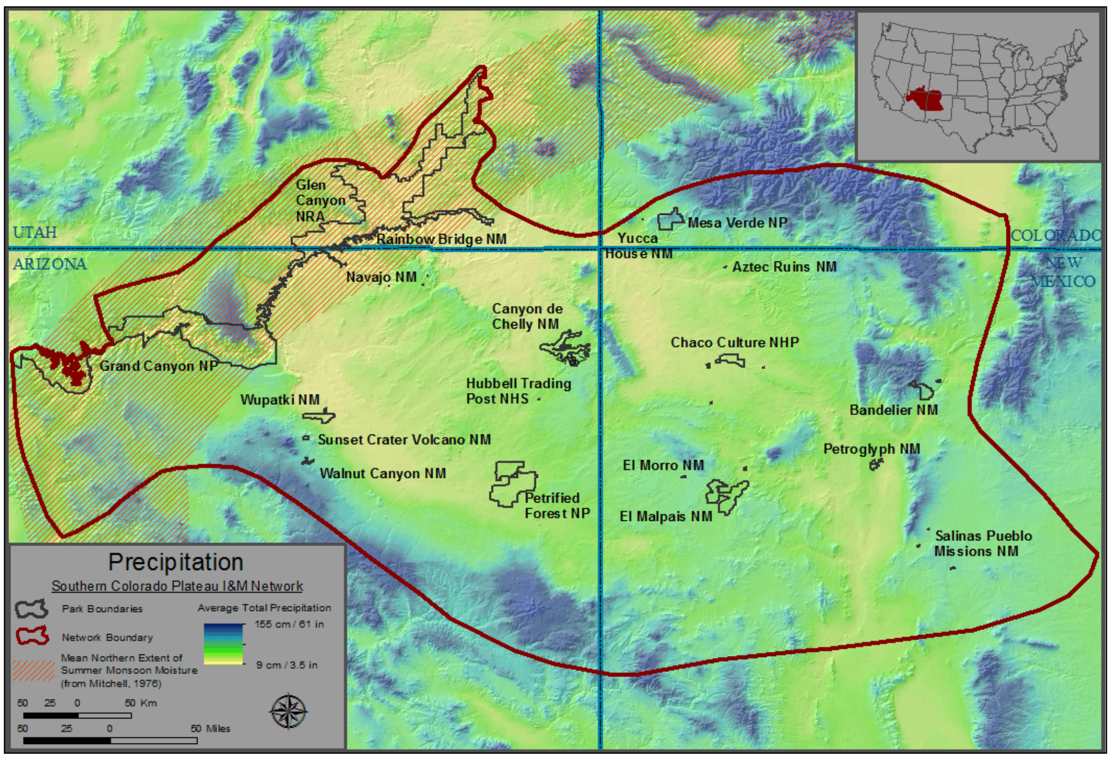

Figure 2.1.2-6. A map of parks within the Southern Colorado Plateau Network (including El Morro) and the range of annual precipitation (NPS SCPN 2015).

compiled and will be presented in the Chapter 4 assessments as applicable.

2.2.1. Ecological Units, Watersheds, and NPScape Landscape-scale

Ecological Units

El Morro NM is located in the Arizona-New Mexico ecoregion subunit, which encompasses the highlands of eastern Arizona and western and central New Mexico (TNC 1999). This area contains the oldest mountains that are in the Southwest and much of the area is under federal ownership (TNC 1999).

Within the park, elevations range from 2,183-2,304 m (7,162-7,559 ft.), consisting of plateaues, mountains and desert plains. The park's primary wildlife habitats include piñon-juniper woodlands, ponderosa pine-Gambel oak forests, and shrublands.

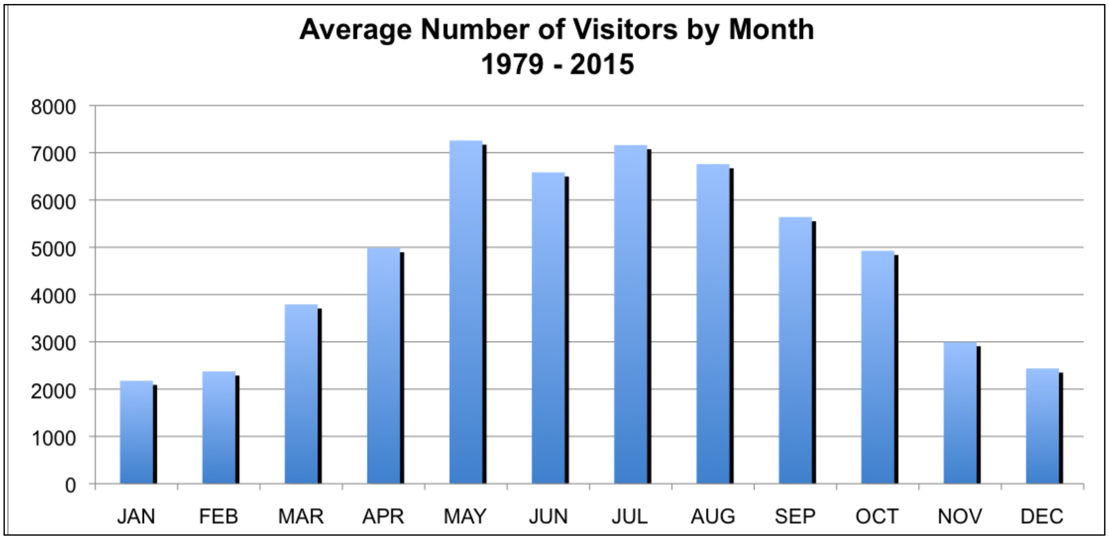

Figure 2.1.3-1. Average number of visitors by month to El Morro NM from 1979-2015.

Watershed Units
The NM is located within the Lower Colorado Region drainage basin, which includes parts of Arizona, California, Nevada, New Mexico, and Utah (USGS 2014). The drainage basin is further divided into the Little Colorado River Basin Subregion (69,671 km^2, 17,216,000 acres), the Zuni Subbasin (7,071 km^2, 1,747,200 acres), the Cebolla Creek-Rio Pescado watershed (1,273.84 km^2, 815,258 acres), and finally two subwatersheds: Togeye Lake (125.92 km^2 31,115 acres) and Carrizozo Draw (125 km^2, 30,892 acres) (USGS 2014) (Figure 2.2.1-1).

NPScape Landscape-Scale Area of Analysis
Since very few national parks are large enough to encompass a self-contained ecosystem, they rely upon the larger area to support the life cycles and conditions of the resources found within parks (Coggins 1987 as cited in Monahan et al. 2012). Several of the park's

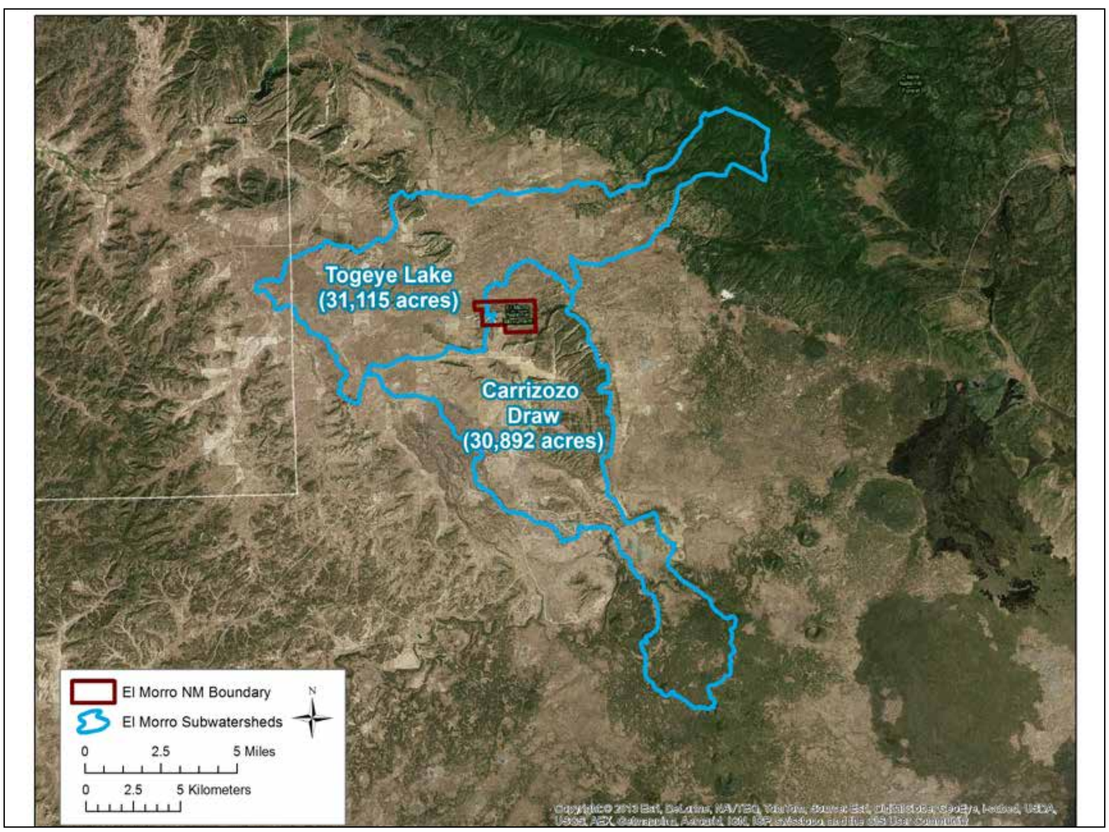

Figure 2.2.1-1. El Morro NM is located within two subwatersheds: Togeye Lake and Carrizozo Draw (USGS 2014 data).

resources (e.g., viewshed, night sky, and vegetation, etc.) are affected by landscape-scale processes, and this broader perspective can provide more comprehensive information to better understand resource conditions. As a result, the area within 30-km (18.6 mi) of the monument's boundary, including the monument, was the landscape-scale Area of Analysis for selected resources. Through numerous studies, a 30-km AOA is believed to be a large enough area to encompass an ecologically-relevant, landscape-scale context for most resources (NPS 2011a). Most assessments were evaluated within this 30-km plus park boundary area, unless otherwise noted, to capture the ecological processes that are likely most relevant to El Morro NM's natural resources.

2.2.2. Resource Descriptions

Supporting Environment

Geology

The vertical cliffs of Zuni Sandstone that make up Inscription Rock are the primary geologic features of El Morro National Monument (Figure 2.2.2-1). These cliffs make up the erosional scarp on the north side of a cuesta, which is held up by the relatively resistant Dakota Sandstone that overlies the Zuni Sandstone. A cuesta is an asymmetric ridge with a gentle dip slope on one side and a steep to cliff-like face formed from differential erosion on the other side (Jackson 1997).

The Zuni Sandstone is eolian (wind-blown) in origin and was formed in a desert sand dune environment during the Middle Jurassic period, approximately 160 million years ago (KellerLynn 2012). It is weakly cemented, primarily by kaolinite, a clay mineral (Austin 1992), making it extremely friable. Like for many massive crossbedded eolian sandstones on the Colorado Plateau, such the Navajo Sandstone and the Entrada Sandstone, erosion along vertical joint systems, or fracture systems, in the Zuni Sandstone plays a dominant role in the formation of and continuing weathering and erosion of landscape features. The face of Inscription Rock from the historic pool to the northeast corner follows the approximate trend of the dominant E-NE joint set. Joints play a role in differential weathering and erosion of landscape features by providing areas of increased permeability, and can provide planar surfaces that may become preferential loci of slope failure.

The cultural significance of the petroglyphs and historic inscriptions are directly tied to the park's geology, especially that of the Zuni Sandstone. The extremely friable nature of the sandstone made it an easily carved medium for Native American, European, and Anglo-Americans upon which to carve petroglyphs and inscription that were also able to retain crisp edges and the shape of the inscription for a period of time ranging from at least decades to centuries. However, that same friable characteristic of the Zuni Sandstone also makes those same inscriptions and petroglyphs susceptible to inevitable loss via erosion and weathering.

In addition to the Zuni Sandstone, exposures of the Dakota Sandstone are present in the national monument, along with Quaternary basalts erupted in the Zuni-Bandera Volcanic Field, and Quaternary deposits including alluvium, colluvium and eolian deposits. Fossils have not been documented within monument boundaries (Tweet et al. 2009).

Historic Pool (tinaja)

The historic pool is the only permanent body of water in El Morro National Monument (Figure 2.2.2-2). Not only does the pool provide an important water source for wildlife, it has

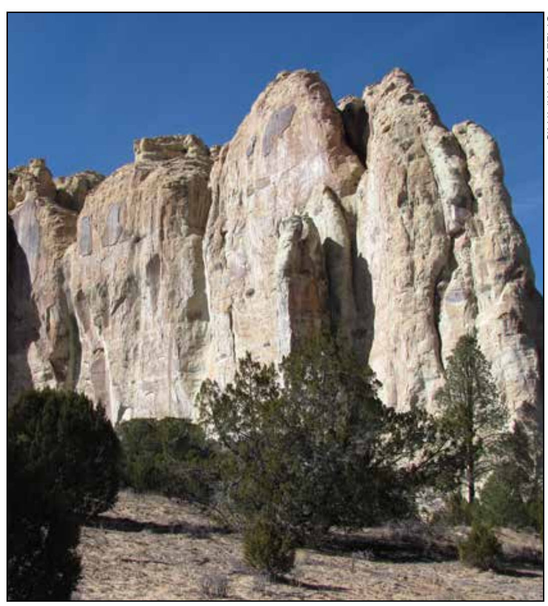

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Figure 2.2.2-1. Inscription Rock's vertical cliffs are comprised of Zuni Sandstone (left).

great cultural significance. People depended on it for water from at least Puebloan times (late 1200s C.E.) until a well was drilled to supply the national monument with drinking water in 1962 (Greene 1978). The presence of water along the base of the Zuni Sandstone cliff is an essential component of the human story of El Morro and Inscription Rock as it was the availability of water that drew people to base of Inscription Rock (Green 1978). It served as a water source for the Puebloan people living in the area, including at Atsinni located on top of the cuesta. The historic pool was also a key water stop on overland travel from the Spanish period until the completion of the transcontinental railway through a pass north of El Morro in 1881 (NPS 2015a).

What specific modifications people may have made to the pool over time prior to the initiation of dam construction undertaken by the National Park Service are unknown. Greene (1978) reports that when workers initiated dam construction in the 1920s, they found a buried cedar post and rock wall structure. In 1926, the NPS completed a concrete dam to enlarge the pool. In the 1930s, the large arroyo that drained the pool was filled. Also, in the 1930s a deep arroyo was filled in below the dam by park managers who wanted to restore the area to what they thought it was like during the time of Spanish visitation (Greene 1978).

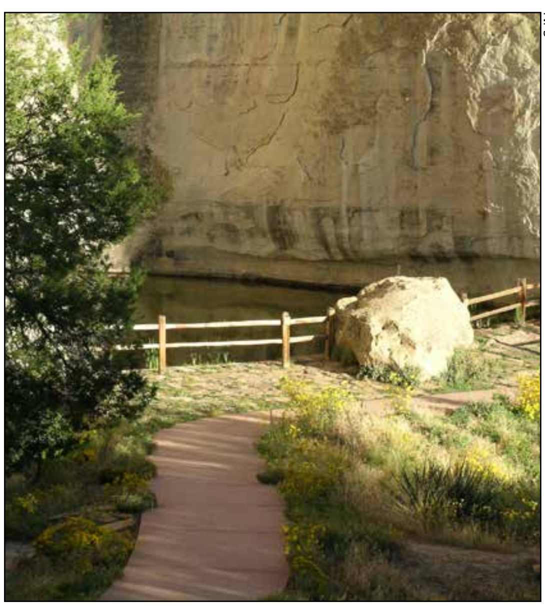

Figure 2.2.2-2. The historic pool is the only permanent water feature within El Morro (right).

After a large rock fall in 1942 that destroyed the dam, the NPS completely rebuilt it the following year in the last major modification to the historic pool. By then, the sand embankment that previously existed behind the pool was no longer present. The new dam raised the level of the pool 4 meters (13 feet) and it had a capacity of 747,619 liters (197,500 gallons) (Greene 1978). The Historic Structure Report (Greene 1978) states that these modifications to the historic pool detract from the character of the pool for its time period of significance. Pranger (2002) suggested removal of the pool dam and reconstruction of the arroyo as potential remediation measures to help minimize the effects of natural erosion and weathering processes impacting Inscription Rock.

Numerous studies on the historic pool have been conducted in the last 20 years. Sayre (1997) completed a geochemical survey of the historic pool. Van Dam and Hendrickx (2007) studied the general hydrology of the area, installed several piezometers, and investigated the hydrogeology of the pool. In 2010, the Southern Colorado Plateau Network (SCPN) began monitoring the hydrology of the pool, which included bathymetric mapping, installing a new transducer in the pool, and monitoring three existing PVC wells (Soles and Monroe 2012). SCPN continues to monitor the historic pool as part of its vital signs program (Lisa Thomas, SCPN Program Manager, personal communication 2014).

Some debate exists as to whether the historic pool is fed solely by runoff into the plunge pool (Sayre 1997) or if there is some groundwater component (van Dam and Hendrickx 2007). Given the permeability of the Zuni Sandstone and the abundance of jointing within the sandstone, it is likely that water percolates through the sandstone in addition to flowing over the cliff face to feed the pool. However, the main source of water in the pool is from the three small watersheds that are all located on top of Inscription Rock, with a combined area of 0.63 hectares (1.55 acres) that flow into it (Pranger 2002).

Air Quality
Different categories of air quality areas (Class I and II) have been established through the authority of the Clean Air Act of 1970 (42 U.S.C. §7401 et seq. (1970)). Like most National Park Service areas, El Morro National Monument is designated as a Class II airshed.

No air quality monitoring stations are located within the required distances to derive trends for ozone, visibility, or atmospheric deposition of nitrogen or sulphur for the national monument, but the NPS' Air Resources Division provides interpolated data to assess air quality conditions, which will be used in the Chapter 4 assessment. To date, three plants in the national monument (*Artemisia ludoviciana, Pinus ponderosa, and Rhus trilobata*) are known to be ozone sensitive species (NPS ARD 2006).

<u>Landscape-scale Resources</u>
Viewshed
Viewshed analyses are a way to measure the integrity of the landscape and how it contributes to visitor experience from natural and historical, cultural perspectives. From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at El Morro NM. Visualizing the natural landscape together with cultural events is a critical part of the visitor experience. At El Morro NM, the physical landscape, with the relatively undeveloped surrounding land, can be envisioned as the centuries of travelers who were attracted to the rock outcrop and the historic water pool at its base.

Night Sky
The NPS Night Skies and Natural Sounds Division (NSNSD) collected data on the quality of the night skies at El Morro NM from Atsinna Pueblo on May 30, 2013 (Meadows and White 2013). Dark night skies are an aesthetic and experiential quality that are integral to natural and cultural resources (Moore et al. 2013). In an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010). The values of night skies go far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). The Pueblo people who lived in this area were deeply religious and astronomy played a large role in their religious ceremonies, with evidence of this in their architecture (Hadingham 1984) (Figure 2.2.2-3).

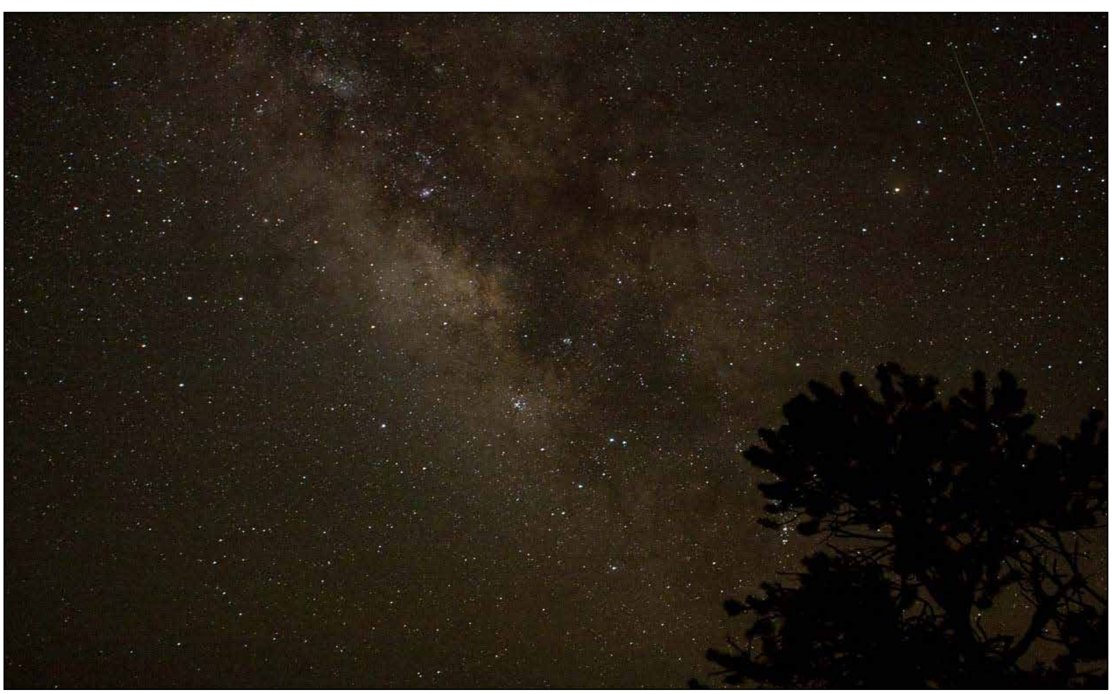
NPS NSNSD

Figure 2.2.2-3. Photo of the Milky Way taken from Atsinna Pueblo.

Soundscape
Baseline acoustical data were collected by scientists from NPS' NSNSD at El Morro NM from June-July 2009. A 'snapshot report' was created with a full report expected after data analysis is completed (NPS NSNSD 2009). As a result of the brief report, distinctions between intrinsic versus extrinsic sounds were not differentiated. Regardless, the percent time exceedances above the sound pressure level of 45 dBA were infrequent, indicating a relatively quiet environment, with the exception of periodic noises heard from the nearby gravel plant. For reference purposes, crickets at 5m at Zion National Park and a residential area at night have a corresponding sound pressure level of 40dBA (NPS NSNSD 2009).

Landcover
O'Neill et al (1997) suggested that the simplest indication of biotic condition may be to identify the amount of land cover change from natural to non-natural. Converted lands may likely influence and possibly inhibit species' movements and habitat requirements (O'Neill et al. 1988; With & Crist 1995; Pearson et al. 1996; McIntyre & Hobbs 1999; Kupfer et al. 2006; Fischer & Lindenmayer 2007; Vranckx et al. 2012 as cited in Monahan et al. 2012).

Almost 100% (99.8%) of the 30-km area, including and surrounding the monument, is within a natural land cover type (NPS 2014d, Fry et al. 2011) as compared to an average of 76% percent of the lands surrounding most national parks (Monahan et al. 2012). Two land cover classes, forest and scrub/shrub account for 94.5% of the land cover surrounding the NM (NPS 2014d, Fry et al. 2011). A discussion of the amount of landcover change within the 30-km area (which is considered ecologically relevant) will be further discussed in the Chapter 4 vegetation assessment.

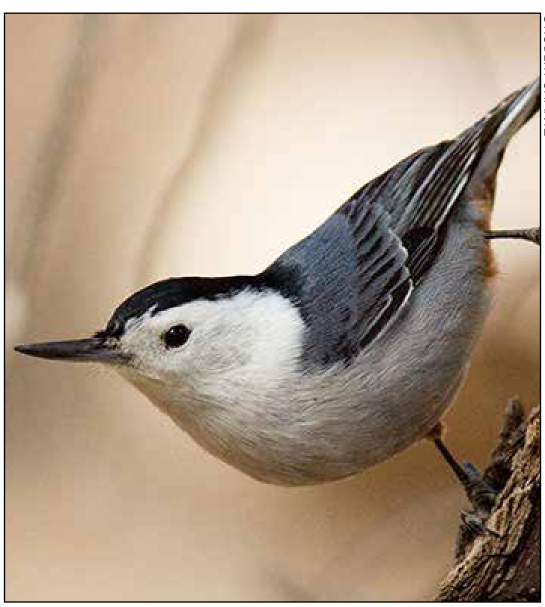
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Figure 2.2.2-4. The White-breasted nuthatch, *Sitta carolinensis*, is one of the species known to occur at the NM.

Biological Resources

Vegetation
El Morro NM lies primarily at the intersection of two ecoregions: the Arizona/New Mexico Mountains and the Colorado Plateau Semi-Desert Province. Adjacent ecoregions less than ten miles away include the Arizona/New Mexico Plateau and the Painted Desert and Navajo Canyonlands, which also influence the vegetation in the monument. The vegetation in the monument and surrounding low lands are primarily dominated by piñon-juniper with sagebrush grasslands. Some ponderosa pine and oak woodlands are found on the north and east sides of the mesa (Salas and Bolen 2010).

Wildlife
Birds
There have been a few inventories of the birds at El Morro NM. One was a quantitative study in the late 1970s that focused on breeding birds in small plots representative of the primary habitat types in the park (McCallum 1979). McCallum (1979) presented a list of birds in the national monument that included his observations (in 1979) as well as those made prior to his work (e.g., by Lyndon Lane Hargrave in 1959). McCallum recorded about 50 species during his surveys, and approximately 45 additional species were listed from the work prior to his. In 2001 and 2002, Johnson et al. (2007) carried out point counts, area-search surveys, and incidental observations of birds at the national monument. During surveys/counts/observations during the breeding season, they recorded a total of 63 species. For the species recorded during point count surveys, analyses were also conducted to examine species distribution and relative abundance across habitats (Figure 2.2.2-4).

Two other sources of information available on birds at El Morro NM are a May 2008 checklist, El Morro National Monument Bird Checklist (Grimes and Beckwith 2008), and reports of informal bird surveys from eBird (Audubon and Cornell Lab of Ornithology 2014). The checklist includes observations from 2002-2008, as well as species listed on previous check-lists (e.g., by McCallum 1979). The 2008 checklist notes the season in which species would be expected to occur and how common they are/were. There are also some observations (lists) of birds at the national monument conducted by park personnel and others, which are available on the eBird website.

While there are no federally-listed bird species known to occur at the national monument (Johnson et al. 2007, Thomas et al. 2006, U.S. Fish and Wildlife Service [USFWS] 2015a), there are a few species that are listed as threatened in New Mexico including the Peregrine Falcon [*Falco peregrinus*]; Johnson et al. 2007, New Mexico Department of Game and Fish [NMDGF] 2015). The Peregrine Falcon, which nests at the monument on cliffs, was once federally-listed as endangered but was delisted in 1999 due to its recovery (USFWS 2013).

Mammals

There have been only a small number of studies of mammals in or in the immediate vicinity of El Morro NM in recent years. Bogan et al. (2007) reported that, prior to their work, 51 species of mammals were thought likely to occur at the national monument. These researchers conducted inventories at the national monument in 2002-2003 to increase the documentation of this group of wildlife. They focused on groups of mammals having the most species, such as rodents, bats, and carnivores. They recorded 39 species of mammals at the park (with most being rodent and bat species), and concluded that additional inventory work would probably document additional species. A second recent study was not conducted to inventory mammal species, but rather to examine the impacts burrowing animals may have on archaeological sites at the national monument (Drost 2006). The researcher found a variety of mammal species in close proximity to archaeological sites, but determined that the greatest disturbance to features and artifacts was from carnivores of medium size, especially badgers. This subject is discussed in greater detail in section 2.2.3, Resource Issues Overview, and Chapter 4.

One state-threatened species, the spotted bat (*Euderma maculatum*), is known to occur at the park (Bogan et al. 2007, NMDGF 2015). No federally-listed mammals are known to occur at El Morro NM at the present time (USFWS 2015a). Both the NPSpecies list for the park (NPS 2014e) and Bogan et al. (2007) include the gray wolf (*Canis lupus*) as "unconfirmed" for the park. The Mexican gray wolf (*Canis lupus baileyi*) is both federally and state-endangered; the subspecies was just recently listed as endangered by the USFWS as they simultaneously delisted the gray wolf (USFWS 2015b). In early 2014, a few Mexican gray wolves were documented at nearby El Malpais NM (David Hayes, Natural Resources Branch Chief, El Malpais and El Morro NM, pers. comm.). This species is discussed in more detail in Chapter 4.

Amphibians and Reptiles

The primary inventory for herpetofauna at El Morro NM was conducted in 2001-2003 by the U.S. Geological Survey (USGS) for the SCPN (Nowak and Persons 2008). Inventory goals were to document 90% of the herpetofaunal species present at the park and to identify species of special concern. Nowak and Persons (2008) recorded 12 species of herpetofauna (nine reptile and three amphibian species), and they presented information on five additional species that have been recorded at the park at other times (Figure 2.2.2-5). The authors of the inventory estimated that inventory completeness at the park was 81%, meaning that additional species may occur. No comprehensive surveys or monitoring of amphibians or reptiles have occurred at the national monument since that by Nowak and Persons (2008). No federally or state-listed amphibians or reptiles are known to occur at El Morro NM (Nowak and Persons 2008, USFWS 2015a, NMDGF 2015).

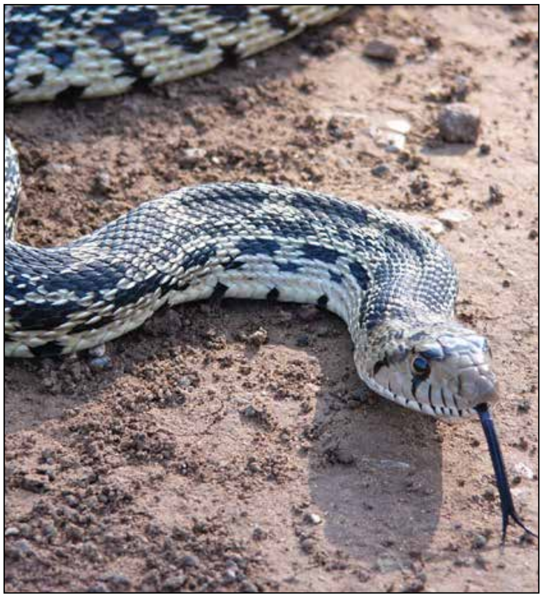

Figure 2.2.2-5. The bull snake (also known as gopher snake) occurs at El Morro NM.

2.2.3. Resource Issues Overview

Climate Change

Like many places, the Southwest is already experiencing the impacts of climate change. The predictions are that the Southwest will likely continue to become warmer and drier with continued climate change (Garfin et al. 2014, Monahan and Fisichelli 2014). The natural resources within Southern Colorado Plateau are vulnerable to the impacts of climate change due to the semi-arid climate. Cultural resources are likely vulnerable as well.

According to Kunkel and others (2013), the historical climate trends (1895-2011) for the southwest (including the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah) have seen an average annual temperature increase of 0.9°C (greatest in winter months) and more than double the number of four-day periods of extreme heat. Future climate predictions (Kunkel et al. 2013) for 2070-2099 (based on climate patterns from 1971-1999) estimate temperatures could rise between 2.5°C and 4.7°C.

Over the course of history, as evidenced in tree rings, precipitation patterns have fluctuated with above-normal periods and below-normal periods of time. The most intense above-normal, wet period was from 1791-1992, which exceeded the previous wettest period of 521-660 AD (Grissino-Mayer 1996; Figure 2.2.3-1). Extreme dry periods occurred between 300 and 500 AD and in the 15th-17th centuries (Stahle et al. 2009). Future climate predictions (Kunkel et al. 2013) for 2070-2099 (based on climate patterns from 1971-1999) estimate precipitation may decrease up to 9%.

Monahan and Fisichelli (2014) assessed the magnitude and direction of changes in climate for El Morro for 25 variables including temperature and precipitation between 1901-2012 (historical range of variability (HRV)). Results for extreme climate were defined as experiencing either <5th percentile or >95th percentile climates relative to the HRV. The results for the extreme climate variables at El Morro NM were as follows:

- Five temperature variables were "extreme warm" (annual mean temperature, minimum temperature of the coldest month, mean temperature of the driest quarter, mean temperature of the warmest quarter, and mean temperature of the coldest quarter);

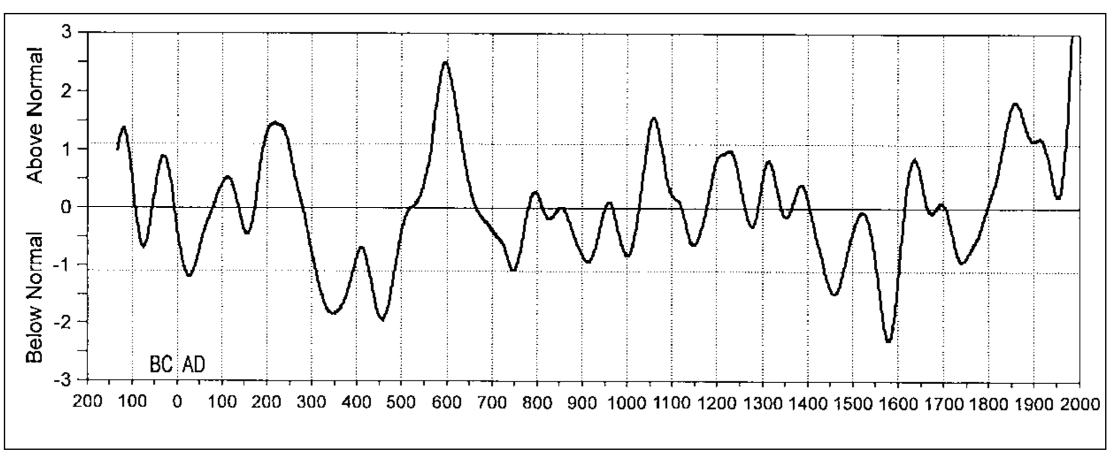

Figure 2.2.3-1. The reconstruction of total annual precipitation based on tree rings from Douglas fir and ponderosa pine in near-by El Malpais NM (from Grissino-Mayer et al. 1997).

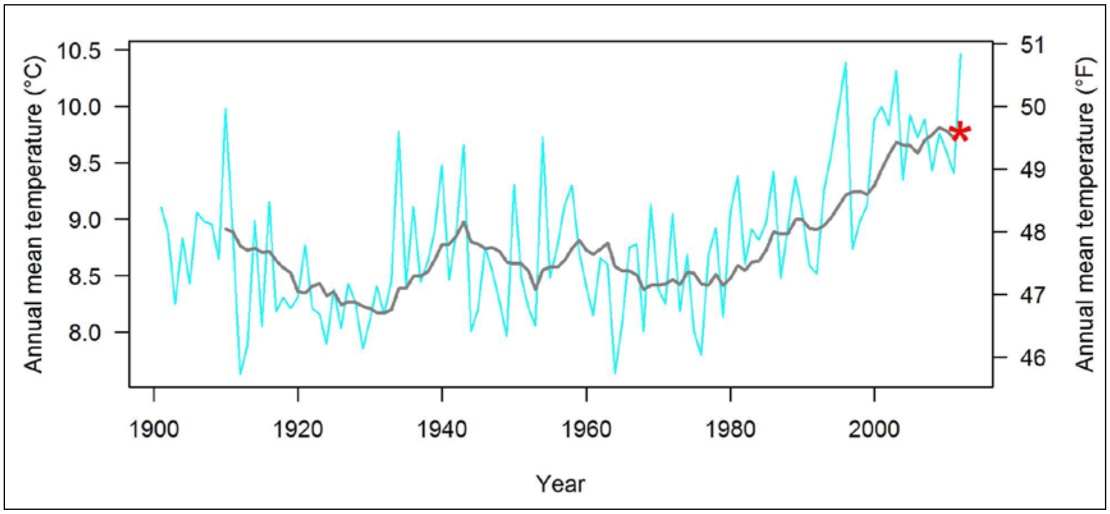

Figure 2.2.3-2. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at El Morro National Monument (including areas within 30-km [18.6-mi] of the park's boundary). The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk (excerpted from Monahan and Fisichelli 2014).

- No temperature variables were "extreme cold;"
- No precipitation variables were "extreme dry;"
- No precipitation variables were "extreme wet" (brief can be accessed at (http://science.nature.nps.gov/climatechange/?tab=0&CEtab=3&PanelBrief3=open#PanelBrief).

The results for the temperature of each year between 1901-2012, the averaged temperatures over progressive 10-year intervals, and the average temperature of 2003-2012 (the most recent interval) are shown in Figure 2.2.3-2.

The results indicate that recent climate conditions have already begun shifting beyond the HRV, with the 2003-2012 decade representing the warmest decade on record. Garfin et al. (2014) expects more sustained extreme heat and fewer and less extreme cold periods. Overall, it's likely that future climate change will increasingly affect all aspects of park resources and operations (Monahan and Fisichelli 2014).

<u>Soundscape</u>
During the 2009 acoustical monitoring at the monument, noises originating from the nearby gravel plant and associated operations (e.g., trucks traveling along the highway), were of greatest concern (NPS NSNSD 2009). No additional monitoring has occurred since 2009.

<u>Mammals</u>
A study at the park revealed that some mammal species may pose a threat to archaeological sites due to their burrowing (Drost 2006). This researcher found that the greatest threat may be from medium-sized carnivores such as badgers, which dig extensively as they create deep burrows. Drost (2006) suggested that a goal for the park, given the natural setting and importance of the cultural resources, would be to repair and protect areas of old digging and to limit the creation of new den areas. El Morro NM presently monitors for archeology condition multiple times per year; this monitoring includes impacts from the digging/burrowing activities of mammals (Steve Baumann, El Morro NM, Resources Management Chief, pers. comm.). This subject is discussed in more detail in Chapter 4.

<u>Exotic Plants</u>
The Vascular Plant List of El Morro National Monument (Rink et al. 2009) and the El Morro Vegetation Classification and Distribution

Mapping Report (Salas et al. 2010) document the presence of exotic, or non-native, plants in the monument (Figure 2.2.3-3). Records of exotic plants are also maintained by the Southern Colorado Plateau Network (NPS 2014f), the Integrated Resource Management Applications NPSpecies portal (NPS 2015b), and the monument's checklist (NPS 2014g). While Rink et al. (2009) and Salas et al. (2010) provide limited information on the occurrences of exotic plants in the national monument, no studies or reports have focused exclusively on the condition of exotic plants at El Morro. Rink et al. (2009) states that approximately 12% of the El Morro flora is exotic, which is similar to other NPS sites in the southwest.

Geology-loss of inscriptions and rockfall

Rockfall has been documented as a geohazard at El Morro NM (Schaller et al. 2014), where it threatens both the historic inscriptions and public safety, especially along the trail at the base of Inscription Rock. While the NPS does not compile records of rockfall along the Inscription Trail (Steve Baumann, Resources Management Chief, El Morro NM, personal communication, 2015), numerous rockfalls along the trail have been documented, including the large rock fall in 1942 that destroyed the dam at the historic pool.

According to KellerLynn (2012), the loss of inscriptions is the primary resource management issue at El Morro NM. Erosion and weathering along the cliff face and loss of inscriptions has been repeatedly studied in detail, including by Wachter (1978), Padgett (1992), Cross (1996), Ellis (2000), Pranger (2002) and Buress (2007). Taken as a whole, the weathering and erosion of Inscription Rock is very complex due to variations in cementation and permeability of the Zuni Sandstone, presence of joints, the presence or absence of rock varnish, slope aspect and other factors. Loss of inscriptions can result from rockfall and slab failure, and from smaller scale weathering and erosional processes including granular disintegration. Ellis (2000), Pranger (2002), and Burris (2007) suggest a series of remedial actions and other measures that the NPS could take to address issues related to the deterioration and loss of inscriptions and/or public safety issues related to rockfall.

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Figure 2.2.3-3. Horehound, an exotic plant, is found throughout the NM.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff input based on the park's purpose, significance, and fundamental resources and values, the NPS' Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included Southern Colorado Plateau Inventory and Monitoring (I&M) Network (SCPN) Program, I&M NPScape Program for landscape dynamics assessments, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections.

SCPN I&M Program

In an effort to improve overall national park management through expanded use of scientific knowledge, the I&M Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011b). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;

- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011b).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. El Morro NM is part of the SCPN, which includes 18 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, SCPN selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. El Morro's upland ecosystems (i.e., vegetation and soils), the historic pool, and phenology were selected for monitoring by SCPN (NPS SCPN 2015).

Park Planning Reports

Natural Resource Condition Assessments

The structural framework for NRCAs is based upon, but not restricted to, the fundamental and other important values identified in a park's Foundation Document or General Management Plan. NRCAs are designed to deliver current science-based information translated into resource condition findings for a subset of a park's natural resources. The NPS State of the Park (SotP) and Resource Stewardship Strategy (RSS) reports rely on credible information found in NRCAs as well as a variety of other sources (Figure 2.3.1-1).

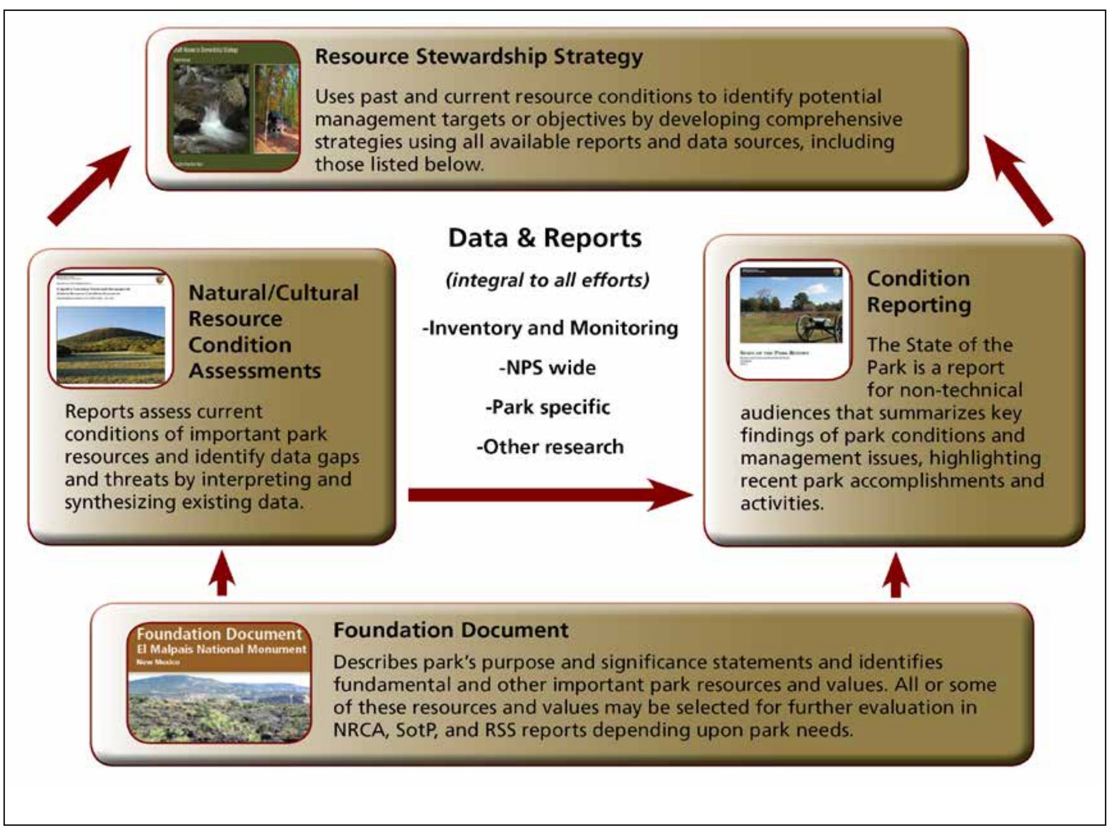

Figure 2.3.1-1. The diagram shows the relationship of NRCAs to other park planning reports.

Foundation Document
Foundation Documents describe a park's purpose and significance and identify fundamental and other important park resources and values. A Foundation Document was completed for El Morro NM in 2014 and was used to identify some of the primary natural features throughout the monument for the development of the NRCA, including geology, historic pool, and landmark visibility.

State of the Park
A State of the Park (SotP) report is intended for non-technical audiences and summarizes key findings of park conditions and management issues, highlighting recent park accomplishments and activities. NRCA condition findings are used in SotP reports, and Chapter 5 includes a SotP condition summary for the natural resources assessed in this NRCA.

Resource Stewardship Strategy
A Resource Stewardship Strategy (RSS) uses past and current resource conditions to identify potential management targets or objectives by developing comprehensive strategies using all available reports and data sources including NRCAs. National Parks are encouraged to develop an RSS as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not yet been started for the monument.

2.3.2. Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. The existing data used to assess condition of each indicator and/or to develop reference conditions are described in each of the Chapter 4 assessments. In addition to data from the SCPN I&M and research conducted by other scientists and programs, subject matter expert, Randy Stanley, who is a Physical Scientist / Acoustic Specialist, with the NPS Intermountain Region Office provided technical assistance pertaining to the monument's virbroacoustic environment (refer to King and King 2003 report).

Additional Washington level programs, including I&M NPScape, Climate Change Response Program, Natural Sounds and Night Skies, Air Resources, and the Geologic Resources Divisions provided a wealth of information for the monument's condition assessments.

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Aerial view of El Morro National Monument.

Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the El Morro and El Malpais NMs staff, SCPN staff, Intermountain Region, and cooperators from Utah State University, University of West Florida, and Northern Rockies Conservation Cooperative. The cooperative agreements were established through the Colorado Plateau and the Gulf Coast Cooperative Ecosystem Studies Units.

The purpose of the condition assessment is to provide a “snapshot-in-time” evaluation of the condition of a select set of national monument natural resources that were chosen by the project team during the November 4-5, 2014 scoping meeting. Condition findings will aid national monument staff in the following objectives:

- Develop near-term management priorities
- Engage in watershed or landscape scale partnership and education efforts
- Conduct park planning (e.g., compliance, Resource Stewardship Strategy, and resource management plans).

3.1. Preliminary Scoping

The approach we used to select natural resources was to assess the fundamental and important values of the national monument by listing the resources identified in its Foundation document (NPS 2014). We then refined this list of resources during our scoping meeting discussions (for a complete list of team members, please refer to Appendix A). The resources assessed were limited to natural-based topics, but cultural resources were taken into consideration within the context of the natural resources where appropriate.

The discussions focused on:

1. Confirming the purpose of the national monument and its related significance statements and values as they related to each of the chosen NRCA topics
2. Identifying important concerns and issues for each topic
3. Identifying data sources and gaps for each natural resource topic chosen.

Certain constraints are placed on NRCAs, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the resources chosen.

Specific project expectations and outcomes included the following:

- For chosen natural resources, consolidate available national monument data, reports, and geospatial information from appropriate sources including national monument resource staff, scientific literature, the NPS Data Store and NPSpecies, which are both part of the Integrated Resource Management Applications (IRMA), SCPN Inventory and Monitoring data, and available third-party sources.
- Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).
- Define an appropriate description of reference conditions for each of the natural resource topics and indicators so statements of current condition can be developed for the NRCA report.
- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Conduct analysis of specific existing datasets about key natural resource indicators.
- Discuss the issue of natural resource indicators that are not contained within the national monument or controlled directly by national monument management activities (e.g., viewshed condition). These can represent stressors that impact natural resource components in the national monument but are not under NPS jurisdiction.

National monument natural resource staff participated in on-site meetings and reviewed interim and final products. National monument staff, I&M staff, and writer/editors data mined information for each of the resource topics.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

The national monument's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource topics that are important to the specific park that is being assessed. For the purposes of this NRCA, nine key national monument resources were chosen for assessment and are listed in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the national monument, but includes natural resources and processes that were of greatest significance for park staff at the time of this assessment.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature and data reviewed for this project. When a quantifiable reference condition for a given resource was not feasible, an attempt was made to include a qualitative reference to provide some context for interpreting current condition.

3.2.2. Reporting Areas

National Monument

The primary focus of the reporting areas for the NRCA was within the national monument's legislative boundary. However, while no evaluation of condition was made of non-NPS lands, some of the analyses encompassed areas beyond the monument's boundary.

Table 3.2.1-1. El Morro National Monument Natural Resource Condition Assessment Framework.

Resource	Indicators and Measures
I. Landscape Condition Context	
Viewshed	• Scenic and Historic Integrity (2 measures)
Night Sky	• Sky Brightness (4 measures) • Sky Quality (1 measure)
Soundscape	• Sound Level (2 measures)
II. Supporting Environment	
Air Quality	• Visibility (1 measure) • Level of Ozone (2 measures) • Wet Deposition (2 measures)
Geology	• Inscription Rock (4 measures) • Slope / Cliff Stability (1 measure)
Historic Pool	• Historic Pool (1 measure) • Climatic Conditions (1 measure)
III. Biological Integrity	
Vegetation	
Vegetation	• Condition of Piñon-Juniper (12 measures) • Condition of Ponderosa Pine (6 measures) • Historic and Cultural Integrity of Vegetation on the Landscape (1 measure)
Exotic Plants	• Potential to Alter Native Plant Communities (1 measure) • Prevalence of Exotic Plants (1 measure)
Wildlife	
Wildlife	• Species Occurrence (3 measures)

Landscape-scale
As described in Chapter 2, the area within 30-km (18.6 mi) of the monument's boundary plus the area within the park (unless otherwise noted) was examined for selected resource topics to provide an ecological, landscape-scale context (NPS 2011; Monahan et al. 2012).

The viewshed and soundscape landscape context resources and Chapter 2's Geographic Setting and Resources Overview included landscape-level data from the National Park Service Inventory and Monitoring NPScape Program. NPScape provided datasets to help characterize landscape-scale factors relevant to park resource conditions. NPScape data included roads, housing, and population. For some of the condition assessments, the landscape-level data were used as indicators and/or measures, and in other instances, as discussion points only.

3.2.3. General Approach and Methods

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicators and measures, a quantitative or qualitative statement was developed comparing the current condition(s) at the national monument to the reference condition(s).

Data Mining
Data and literature were found in multiple forms: NPS reports and monitoring plans, other reports from various state and federal agencies, published and unpublished research documents, databases, and tabular data. Geospatial data were provided by the national monument and Laura Trader, Fire Ecologist at Bandelier National Monument. Data and literature acquired throughout the data mining process were analyzed for thoroughness, relevancy, and quality. All reasonably accessible and relevant data were

used to conduct assessments. Copies of all reports and datasets referenced will be provided to national monument staff on a DVD.

Subject Matter Experts

Subject matter experts were consulted while developing this assessment. Consultations ranged from on-site visits to personal communication, and reviews of resource assessment sections. Reviewers and their affiliations are listed in Appendix A.

Data Analyses and Development

Data analyses and methodology for each resource condition assessment can be found within each section of Chapter 4.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of information when possible. A list of data sources is included in Appendix A.

Final Assessments

Assessments were finalized after incorporating comments from national monument staff, SCPN staff, and subject matter experts. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by national monument staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format that is consistent with *State of the Park* reporting (NPS 2012). The major components are as follows:

The condition/trend/level of confidence graphic provides a visual representation for each resource indicator and is intended to give readers a quick interpretation of the authors' assessments of condition. The level of confidence ranges from high-low and indicates how confident we are with the data used to determine condition. The written statements of condition, located under the "*Condition and Trend*" heading within each resource topic section in Chapter 4, provides a more in-depth description of each indicator and associated measure(s)' condition. Figure 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe the condition for each assessment.

Circle colors provide indication of condition based upon the chosen indicators/measures and reference conditions. Red circles signify that a resource is of significant concern; yellow circles signify that a resource is in moderate condition; and green circles denote that an indicator and/or measure is in good condition. A circle without any color, which is almost always associated with the low confidence symbol-dashed line, signifies that there is insufficient information to make a statement about condition; therefore, condition is unknown.

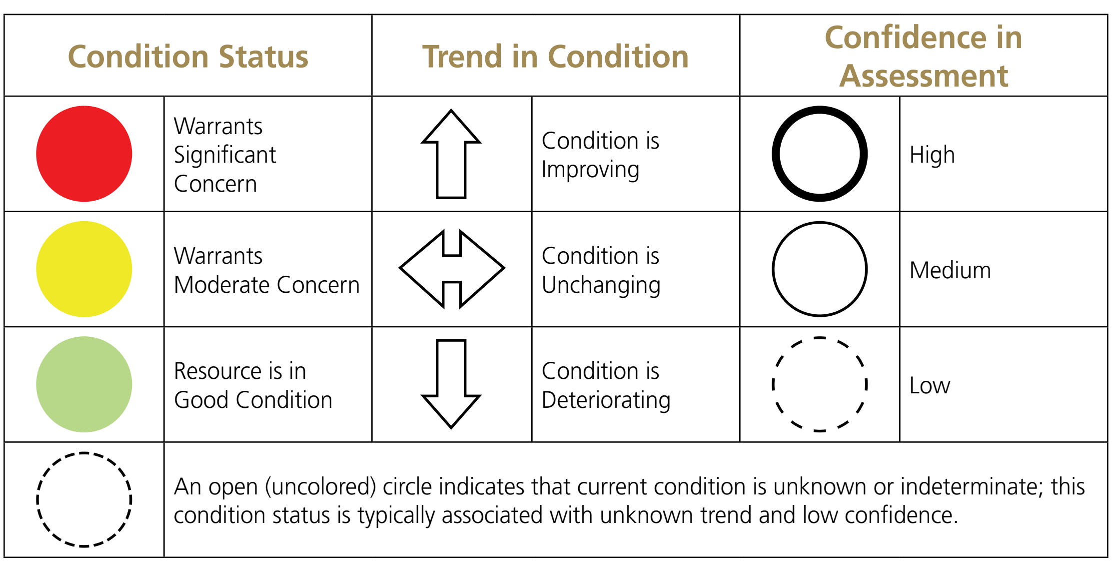

Figure 3.2.3-1. Condition, trend, and level of confidence key used in the NRCA.

We include an indicator condition and overall rationale summary table at the end of each resource topic's section to convey the relevancy of each measure to the overall condition interpretation.

Arrows inside the circles signify the trend of the indicator/measure condition. An upward pointing arrow signifies that the indicator is improving; double pointing arrows signify that the indicator's condition is currently unchanging; a downward pointing arrow indicates that the indicator's condition is deteriorating. No arrow denotes that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs.

An Overview of NRCA Chapter 4

Background and Importance

This section of the NRCA report provides information regarding the relevance of the resource to the national monument. This section also explains the characteristics of the resource to help the reader understand context.

Data and Methods

The indicators/measures are listed in this section describing how we quantitatively or qualitatively assessed the natural resource condition. This section summarizes the existing datasets and methodology used for evaluating the indicators/measures for condition.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator and measure. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a discussion of the condition and trend for each indicator/measure based on the assessment approach. The condition for each indicator/measure is listed in a summary table at the end of this section to provide a summary. The level of confidence and key uncertainties are also included in this section providing a summary of the data gaps and uncertainties relative to the condition assessment.

Sources of Expertise

Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited

This section lists all of the referenced sources for the assessment. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

3.3. Literature Cited

The H. John Heinz III Center for Science, Economics and the Environment. 2008. The state of the nation's ecosystems 2008: measuring the lands, waters, and living resources of the United States. Washington, D.C.

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Chapter 4: Natural Resource Conditions

In Chapter 4 we present the background and importance, data and methods, and condition and trend for each focal study resource that was assessed for the park. A summary of all focal study resource indicators, data and methods and associated page numbers are presented in Table 4.1.

Table 4-1. Page numbers for Chapter 4 assessment data and methods and condition discussion for each indicator and measure(s) are listed below for ease of reference.

Resource Topic	Indicator	Data and Methods	Condition
I. Landscape Condition Context			
Viewshed	Scenic and Historic Integrity	36	43
Night Sky	Sky Brightness	54	59
	Sky Quality	55	59
Soundscape	Sound Level	64	67
II. Supporting Environment			
Air Quality	Visibility	75	78
	Level of Ozone	76	78
	Wet Deposition	76	78
Geology	Inscription Rock	86	99
	Slope / Cliff Stability	95	108
Historic Pool	Historic Pool	118	121
	Climate Condition	120	123
III. Biological Integrity			
Vegetation			
Vegetation	Condition of Piñon-Juniper	131	138
	Condition of Ponderosa Pine	131	142
	Historic and Cultural Integrity of Vegetation on the Landscape	133	144
Exotic Plants	Potential to Alter Native Plant Communities	158	162
	Prevalence of Exotic Plants	160	162
Wildlife			
Wildlife	Species Occurrence	174	179

4.1. Viewshed

Indicators/Measures

- Scenic and Historic Integrity (2 measures)

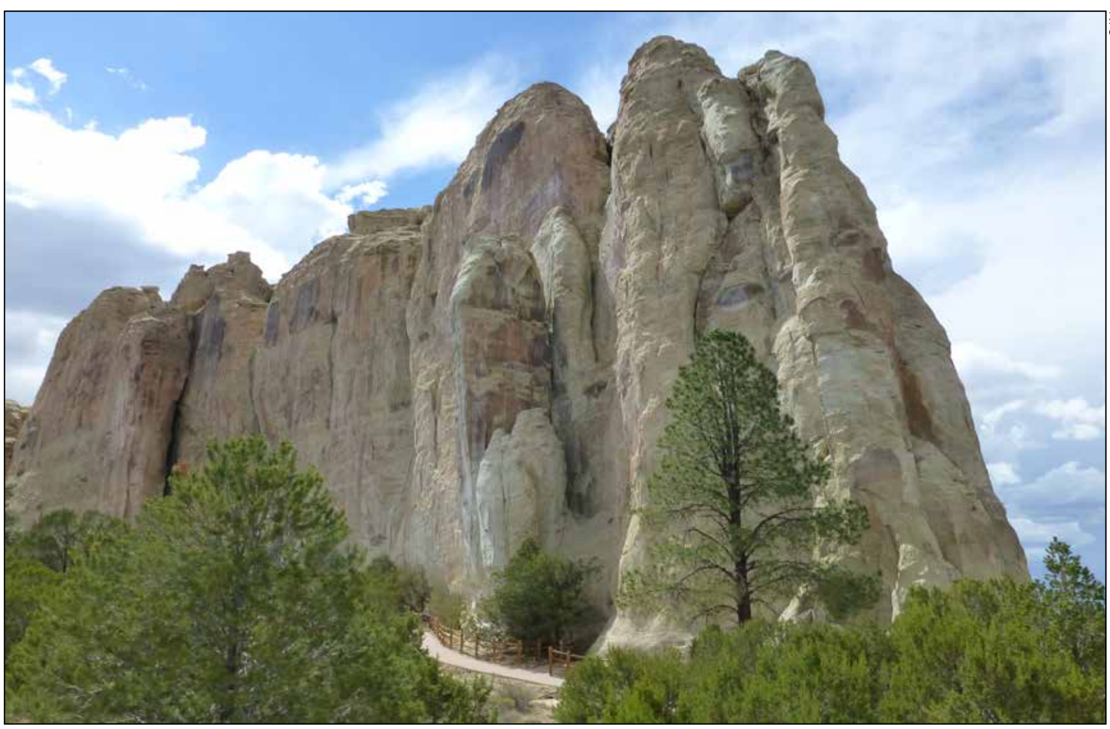
Condition – Trend - Confidence

Good – Insufficient Data – High

4.1.1. Background and Importance

The conservation of scenery is established in the National Park Service (NPS) Organic Act ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS Management Policies (Section 1.4.6 and 4.0; Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early 20th century. Aesthetic conservation strove to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

El Morro NM (Figure 4.1.1-1) was established to preserve Inscription Rock, its large number of inscriptions, petroglyphs, and ancestral Puebloan archeological sites, and to provide visitors the opportunity to experience these resources in their natural setting (NPS 2014a). El Morro (Spanish for headland), is a sandstone promontory that rises 61 m (200 ft) from the valley floor. Along its half-mile sheer cliff face, it contains more than 2,000 inscriptions and petroglyphs that span a period of 1,000 years. The rock was marked by pueblo inhabitants, Spanish explorers, early surveyors, and pioneers. The oldest non-Indian inscription on the rock is dated 1605 (by Don Juan de Oñate, a Spaniard), and the last period of inscriptions dates to the early 20th century. For centuries, people



NPS

Figure 4.1.1-1. Inscription Rock, the sandstone promontory at El Morro NM.

have used El Morro as a landmark. The pool of water at its base provided a source of water for travelers passing through the area and for generations of people living atop the rock. There are remains of two pueblos on top of El Morro, the largest of which is called Atsinna. Atsinna, which had approximately 350 rooms and multiple kivas, provided a home for up to 1,000 people until the late 1300s (NPS 2014a).

Visitor Experience

Viewsheds are considered an important part of visitor experience. Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the national monument by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical and cultural significance of El Morro NM.

From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at El Morro NM. Visualizing this connection as part of the landscape is a critical part of the visitor experience.

4.1.2. Data and Methods

Viewsheds are considered in this assessment within two interrelated contexts: natural scenic integrity and historic integrity. Impacts that degrade one aspect likely degrade the other as well. For example, modern structures or roadways visible on the landscape may detract from the natural scenic integrity of the viewshed, as well as the sense of place that a historically authentic landscape evokes. Depending on the context, scenic and historic integrity may be distinct, or there may be so little practical difference that they are the same. We qualitatively assess how features on the landscape contribute (or not) to the scenic and historic integrity of the site.

Note that personnel at El Morro NM have concerns with the density of native woodland vegetation in some areas obscuring the view of Inscription Rock from ground level. The density of the vegetation has increased in some areas over the past century. This topic is not addressed in this section of the condition assessment, but it is addressed in detail in the Vegetation section (4.7).

Indicator
Scenic and Historic Integrity

The overall indicator of viewshed condition we use in this assessment is a combination of scenic and historic integrity. For this overall indictor we used two measures (intactness and conspicuousness) from key vantage points (Table 4.1.2-1). Each of these measures is described in greater detail below.

Scenic integrity is defined as the state of naturalness or, conversely, the state of disturbance created by human activities or alteration (U.S. Forest Service [USFS] 1995). This focuses on the features of the landscape related to non-contributing human alteration.

Historic integrity is the authenticity of a site's historic identity, evidenced by the survival of physical characteristics that existed during

Table 4.1.2-1. Indicators and measures of viewshed and why these are important to the resource condition.

Indicators of Condition	Measures	Why are these indicators/measures important to resource condition?
Scenic and Historic Integrity	Intactness of View	Intactness represents how much the viewshed has been altered from its reference state, which in turn influences scenic quality as well as the sense of place in a natural and historic context.
	Conspicuousness of non-contributing features	Non-contributing features that are more conspicuous tend to detract more from the scenic quality and/or the sense of place in an historic context.

its historic period. Historic integrity is based on those features of the cultural and natural landscape, from the perspective of an observer, that contribute to the sense of place and enhance the visitor experience. In this assessment, we focus on those features that have a visual impact and contribute to the story of El Morro NM. We evaluate features as contributing (i.e., enhancing the scenic and historic features of the landscape) or noncontributing (i.e., detracting from the scenic and historic integrity).

We assess scenic and historic integrity by evaluating specific human-made features that can be seen from key vantage points and whether or not those features are contributing or noncontributing to the scenic and historic integrity of the view. For noncontributing features, we further assess the characteristics that make them more or less conspicuous, which influences the level of impact they have. We then supplement this assessment with a GIS-based analysis showing areas that are visible from key vantage points. The GIS analysis provides spatial orientation of housing and road developments that may impact the quality of the viewshed.

Viewshed Vantage Points
For this assessment, we focused primarily on the landscape views visitors are most likely to experience. The vantage points we used (selected by park staff) were both atop El Morro-- at Atsinna Pueblo and on the north rim of Inscription Rock (Figure 4.1.2-1). These views are among the highest overlooks within the national monument. Atsinna Pueblo receives high visitation and represents a location from which most visitors view the surrounding landscape. Although most visitors do not take in the exact view of the landscape from the North Rim of Inscription Rock vantage point, because it is off the trail atop El Morro, they do pass nearby. The vantage points (or nearby in the case of the North Rim location) also provide views of the top of El Morro that most visitors see. The North Rim vantage point also provides excellent views of the landscape from which changes over time can be monitored. Therefore, these views play a major role in how visitors perceive El Morro NM within the context of the surrounding landscape.

Measure
Intactness of View

The extent of intactness provides a measure of the degree to which the viewshed is unaltered from its original (reference) state, particularly the extent to which intrusive or disruptive elements may diminish the character of the scene (USFS 1995, Johnson et al. 2008).

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-2). A series of images are automatically captured and the individual photographs are stitched into a single high-resolution panoramic image. These photographs provided a means of illustrating the features on the landscape related to viewshed integrity.

We recognize that visitor perceptions of an altered landscape are highly subjective, and there is no completely objective way to measure this. Research has shown, however, that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings, powerlines, and other features) that do not contribute to the scenic or historic context are often perceived as detracting from the scenic and historic character of the viewshed.

Despite this generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker

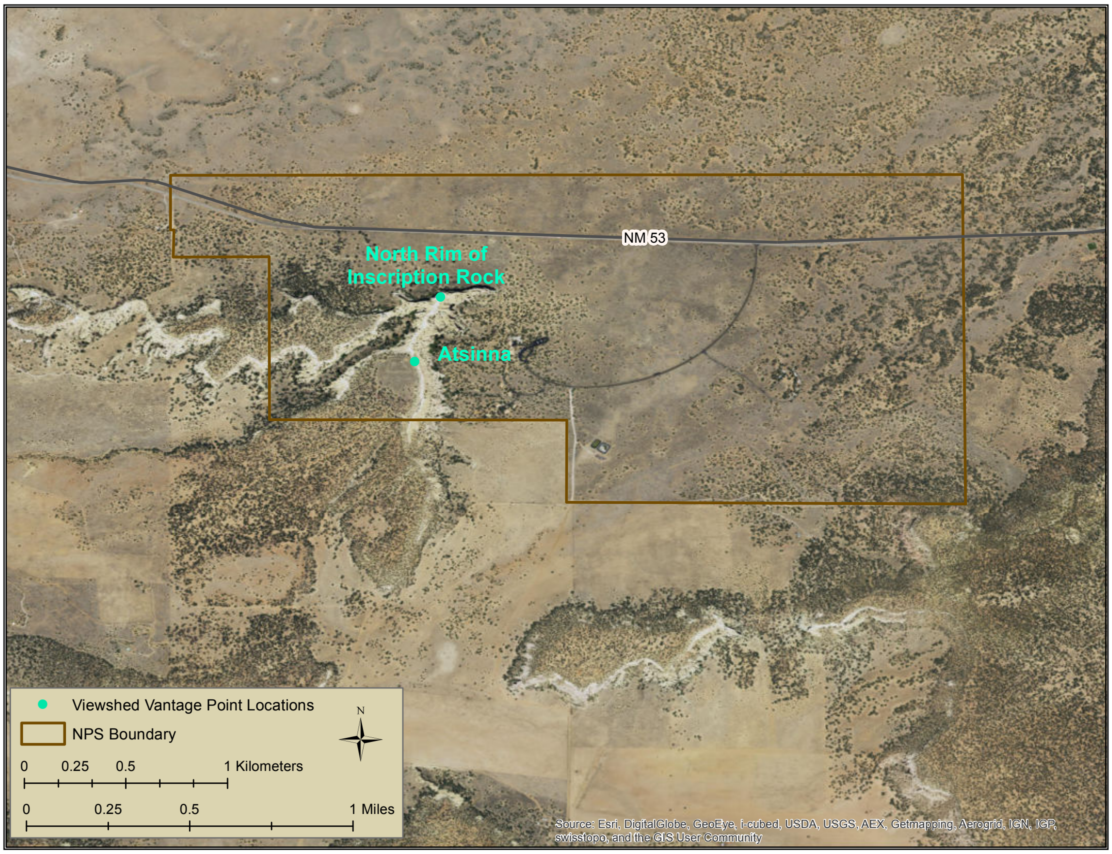


Figure 4.1.2-1. The location of the vantage points at El Morro NM used in this assessment.

1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

Measure
Conspicuousness of Noncontributing Features

Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). For example, Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For this measure, we focused on four characteristics, or groups of characteristics, that have been demonstrated to contribute to the conspicuousness of man-made features: (1) distance from a given vantage point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-2, and more detailed descriptions of these human-made features are presented below.

Distance. The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-3). For this assessment, we have used the distance classes that have been recently used by the National Park Service:

- *Foreground* = 0-½ mile from vantage point
- *Middle ground* = ½-3 miles from vantage point
- *Background* = 3-60 miles from vantage point.

Over time, different agencies have adopted minor variations in the different specific distances used to define these zones, but the overall logic and intent has been consistent.

Figure 4.1.2-2. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to distinguish larger patches within major plant community types (such as riparian areas), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size

Size is another characteristic that may influence how conspicuously a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for human-made developments that tended to dominate the view, such as large, multi-storied buildings, and were more favorable toward smaller, single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the human-made features on the landscape surrounding El Morro NM as belonging to one of six size classes (Table

Table 4.1.2-2. Characteristics that influence how conspicuous human-made features are within a viewshed and the general effect.

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the vantage point	Close to the vantage point
Size	Small relative to the landscape	Large relative to the landscape
Color and Shape	Colors and shapes that blend into the landscape	Colors and shapes that contrast with the landscape
Movement and Noise	Lacking movement or noise	Exhibits obvious movement or noise

Figure 4.1.2-3. An example of approximate distance classes used in this assessment.

4.1.2-3), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and Shape
Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other blending factors (see Figure 4.1.2-4). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972, O'Connor 2008). This is consistent with the findings of Kearney et al. (2008), who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore being preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived.

This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). The Visual Resource Management Program of the Bureau of Land Management (BLM; BLM 1980), for example, places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We

Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features.

	Low Volume	Substantial Volume
Low Height	Single family dwelling (home, ranch house)	Small towns, complexes
Substantial Height	Radio and cell phone towers	Wind farms, oil derecks
Substantial Length	Small roads, wooden power lines, fence lines	Utility corridors, highways, railroads

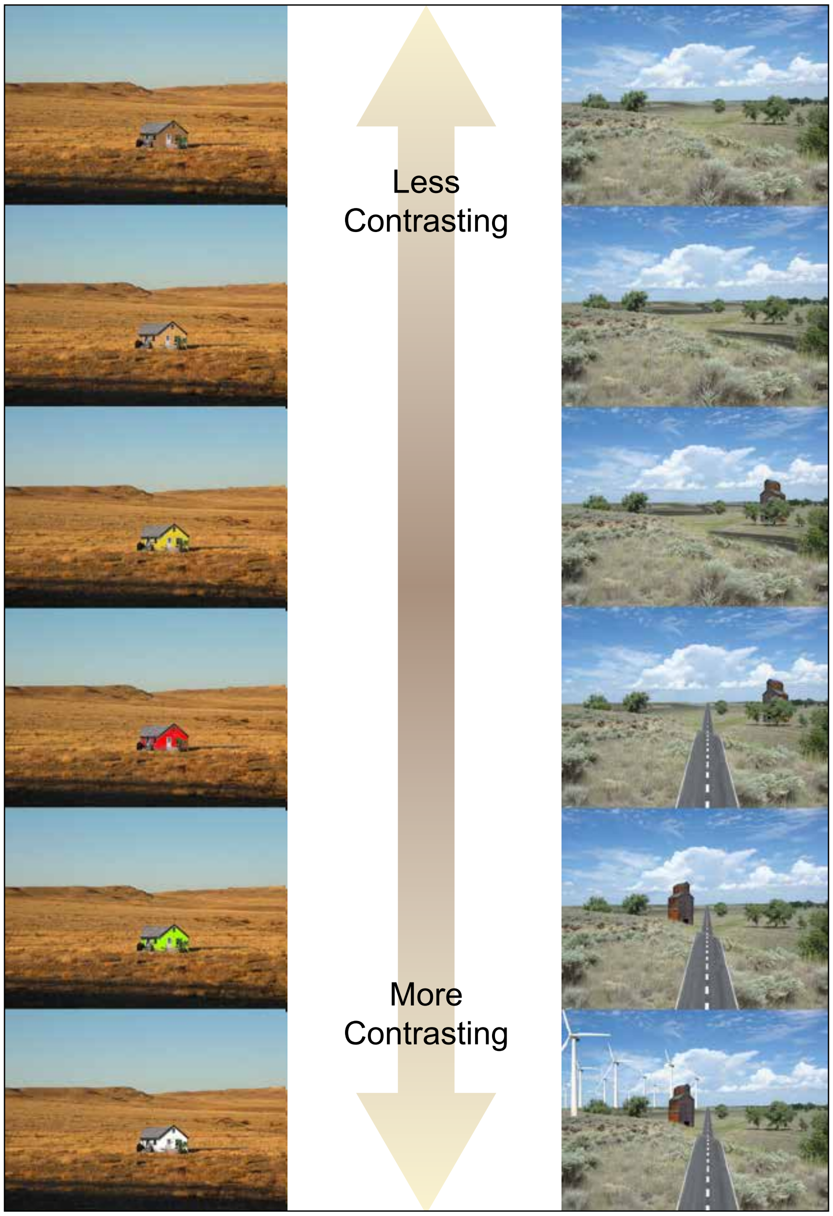


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony or in contrast with the environment. Figure credit: NPS-Rob Bennetts.

considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Movement and Noise

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of a park's viewshed if the house was located far away from the vantage point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and finally, the noise and movement characteristic (Figure 4.1.2-5).

<u>GIS Viewshed Analysis</u>

We supplement our assessment with a Geographic Information System (GIS) analysis to provide spatial context for these measures. Viewshed analyses were conducted to depict the total visible area seen from each of the two key vantage points. Aerial maps of each of the vantage points were generated based on digital elevation models (DEMs) to predict the area visible from a given vantage point taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. We show visible areas within 30 km (18.6 mi) of the park, as well as some outside of this distance, but note that features at greater distances (e.g., > 30 km) have relatively less impact on scenic or historic integrity than those in closer proximity. For this reason, we focus on visible areas within 30 km of the park. Also note that areas visible from the two vantage points are combined onto one map. Complete details of the viewshed analysis process are provided in Appendix B.

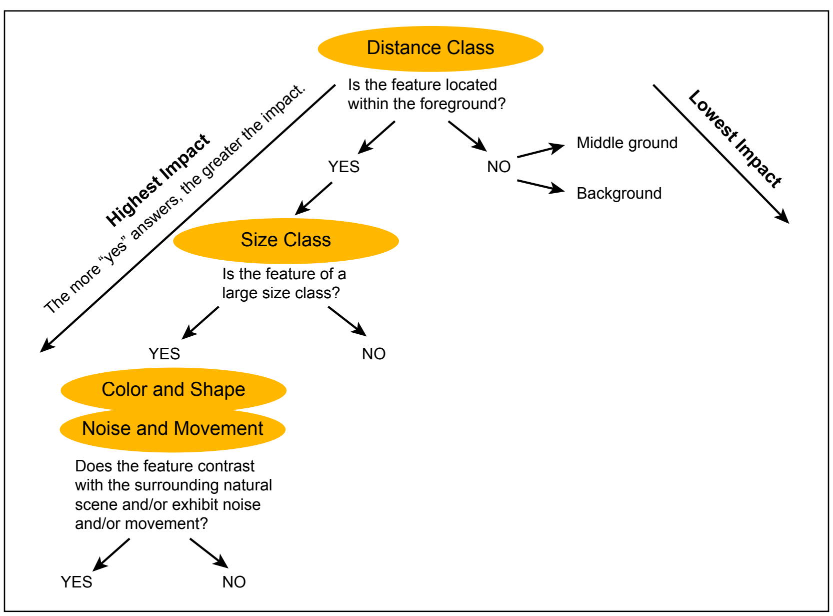


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

In addition, using 2010 data provided by NPScape (NPS 2011a), road density and housing density were overlaid on the map to provide an additional measure of viewshed integrity (intactness). NPScape was developed by NPS Natural Resource Stewardship and Science by compiling and analyzing landscape-scale U.S. Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, and others) to resources within natural resource-based parks, resulting in the NPScape database (Budde et al. 2009, Monahan et al. 2012).

4.1.3. Reference Conditions

The indicators and measures of viewshed condition at El Morro NM are inter-related and intended to provide information about how well the views maintain their scenic quality and their ability to evoke a sense of place in an historic context. The scenic and historic integrity of the park overlap considerably. As discussed elsewhere in this section and in Chapter 2, Inscription Rock documents a cultural continuum of more than 1,000 years, from Ancestral Puebloans to Spanish explorers, European American surveyors, pioneers, military expeditions, and other travelers.

The basis for determining condition in an assessment such as this is a comparison between current condition and a reference condition. In this case, the reference period spans a long period of time. With this reference period in mind we used a qualitative reference state for the scenic and historic integrity of the viewshed (Table 4.1.3-1). Embedded within these reference conditions are both the intactness of view and conspicuousness of

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at El Morro NM.

Class	Scenic & Historic Integrity
High Integrity *(Good Condition)*	Some noncontributing features or developments may be visible, but the vast majority of the landscape is dominated by natural or historic features. The integrity of the natural and historic context is well preserved such that an observer can easily visualize the historic aspect of the viewshed. As such, the features that contribute to the natural and historic integrity are well preserved and the noncontributing features are generally absent or are sufficiently inconspicuous so as to not detract from the sense of place.
Moderate Integrity *(Moderate Concern)*	Noncontributing features or developments occupy a moderate portion of the landscape and/or are moderately conspicuous, but sufficient intactness retains much of its integrity. The integrity of the natural and historic context is also largely preserved such that an observer can experience a natural viewshed.
Low Integrity *(Significant Concern)*	The vast majority of the landscape is dominated by noncontributing features or developments that are conspicuous enough that little integrity or "sense of place" remains. The integrity of the natural and historic context is essentially lost either from the contributing factors not being well preserved or the noncontributing features overwhelming the potential to experience a natural viewshed.

features that do not contribute to the scenic and historic integrity at El Morro NM.

4.1.4. Condition and Trend

Overall, the scenic and historic integrity of the viewsheds at El Morro NM are in good condition. From the two vantage points, the landscape within and surrounding the national monument remains largely intact (Figures 4.1.4-1 and 4.1.4-2; Table 4.1.4-1), although there are some noncontributing features that detract somewhat from the viewshed.

From the vantage points, most of the small number of noncontributing features that can be seen are relatively minor. The main exception to this is Highway 53, which can be seen in at least one direction from both vantage points (although it is much less visible from Atsinna Pueblo). Highway 53, which runs east-west through the park, is most visible when looking generally to the northwest from the North Rim of Inscription Rock vantage point (see Figure 4.1.4-1). A roadway is not a desirable feature on the landscape from a scenic context or an historic context (unless the site's history includes the roadway). However, the effect of the road is not entirely disruptive, as one's eye tends to follow the road into the distance, taking in the view (at least in the second to the last panel).

Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition.

Indicator of Condition	Measures	Condition	Rationale for Condition
Scenic and Historic Integrity	Intactness of View	Good	Views are mainly intact with few noncontributing features, consistent with good condition. The most conspicuous man-made feature is Highway 53 as seen from the west-northwest-facing view at the North Rim Vantage Point, but the view of the highway from this location is not serious enough to lower condition. Overall, the vast majority of the landscape appears intact.
	Conspicuousness of Non-contributing Features	Good	Noncontributing features are relatively inconspicuous, consistent with good condition. The most conspicuous non-contributing feature is Highway 53 as seen from the west-northwest-facing view at the North Rim Vantage Point. However, the view of the highway from this location is not serious enough to lower condition.

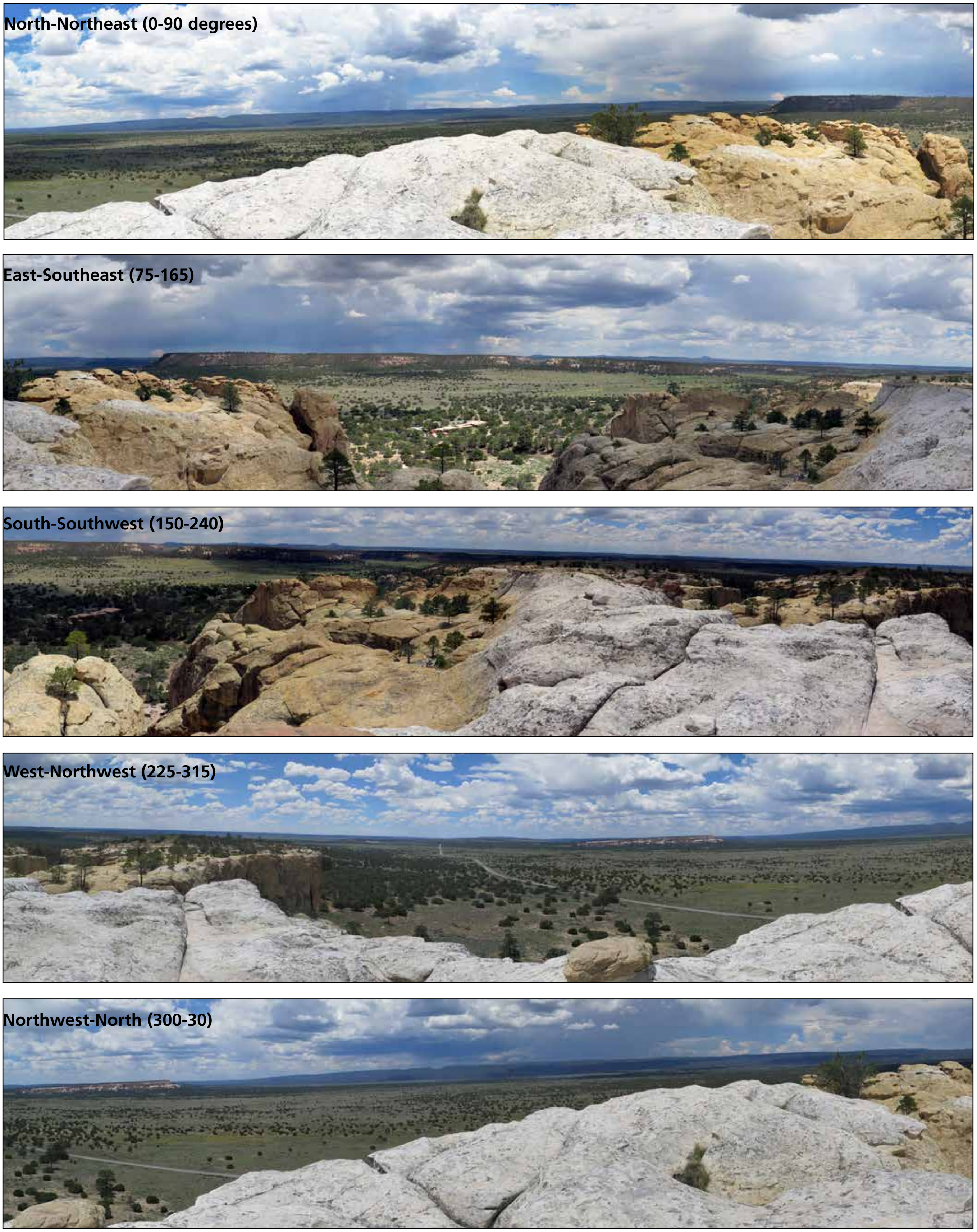


Figure 4.1.4-1. Panoramic views in each direction from the North Rim of Inscription Rock vantage point. Directions are provided on each panel (degrees [directional] are in parentheses).

Figure 4.1.4-2. Panoramic views in each direction from the Atsinna Pueblo vantage point. Directions are provided on each panel.

Additionally, although the road is paved, there are no obvious features that can be seen from the vantage points associated with it (e.g., utility poles).

Other noncontributing features that can be seen from the North Rim vantage point include park buildings, consisting of the visitor center, administration building, and maintenance facility (in the second and third panels), as well as some small sheds and exclosures that are part of the complex. The park road is also visible in some directions (especially in the second panel), as is the sewage lagoon. The sewage lagoon, built in 1988, is a two-pond aeration system with liner that is connected to the monument's sewer (Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, pers. comm.). It is surrounded by a seven-foot chain link fence topped with barbed wire. Except for Highway 53, these other noncontributing features are fairly inconspicuous from the North Rim vantage point due to their size and/or distance or color. Even with the noncontributing features, impressive views of the top of El Morro and the surrounding landscape are available from the North Rim vantage point.

In general, the same noncontributing features are visible from the Atsinna Pueblo vantage point, except that they are less visible/conspicuous; this includes Highway 53, the park road, and some park buildings. These features are mostly visible in the first two panoramas in Figure 4.1.4-2 (towards the north and east) in the middle or background. Note that the orange cone and equipment seen in two of the views was only in the area for a temporary purpose, and we therefore excluded it from our analysis. The sewage lagoon is also visible from this vantage point, but its distance and color help it to blend in with the landscape. From this vantage point, relatively intact views are available of the ancient Atsinna Pueblo, the sloping side of the cuesta, and the more distant landscape.

GIS-based Analysis

For our GIS-based analysis, we estimated the areas visible from the vantage points (Figure 4.1.4-3). It is important to keep in mind that these estimates of visible area are approximations based on digital elevation models. These are estimates only, and it should not be assumed that they are accurate enough for the purposes of planning specific projects. Such cases may require verification and adjustment for the specific context intended. Based on our analysis, most of the national monument is visible from the two vantage points, as are many areas to the north, northeast, and northwest of the park (Figure 4.1.4-3). Additional areas are visible within and outside of the 30-km buffer.

Housing density and road density are other factors to consider regarding their intrusion into the landscape, and we considered them in this analysis within a 30-km area around El Morro NM. In 2010, the total population within the 30-km area surrounding and including the national monument (3,119.2 km^2) was 4,712, with 3.3% of the population located within 3 km^2 of the park (NPS 2014b, U.S. Census Bureau 2011).

Housing density within 30 km of the national monument falls primarily into the rural category (Figure 4.1.4-4). The rural category composes 98.26% of the colored area within the area of interest (Table 4.1.4-2), and the housing density within this category ranges from private undeveloped to 4-6 units per square kilometer (Table 4.1.4-3). Table 4.1.4-2 shows all the housing density categories appearing in the figure and their related areas. Most of the areas mapped as exurban and suburban are not in close proximity to the park. Furthermore, all of these areas of housing/development are not visible from the two vantage points used in the assessment. The second half of Table 4.1.4-2 shows the area within each density class for the visible areas only. The density class most visible from the vantage points is that with the lowest housing density, the rural category (accounting for 99.07% of the colored area visible). Note that all colored areas in Figure 4.1.4-4 constitute a total of about 1,830 square kilometers, while the (colored) visible areas only make up about 127 square kilometers.

Within the 30-km area of interest, the area falling into the three lowest road density

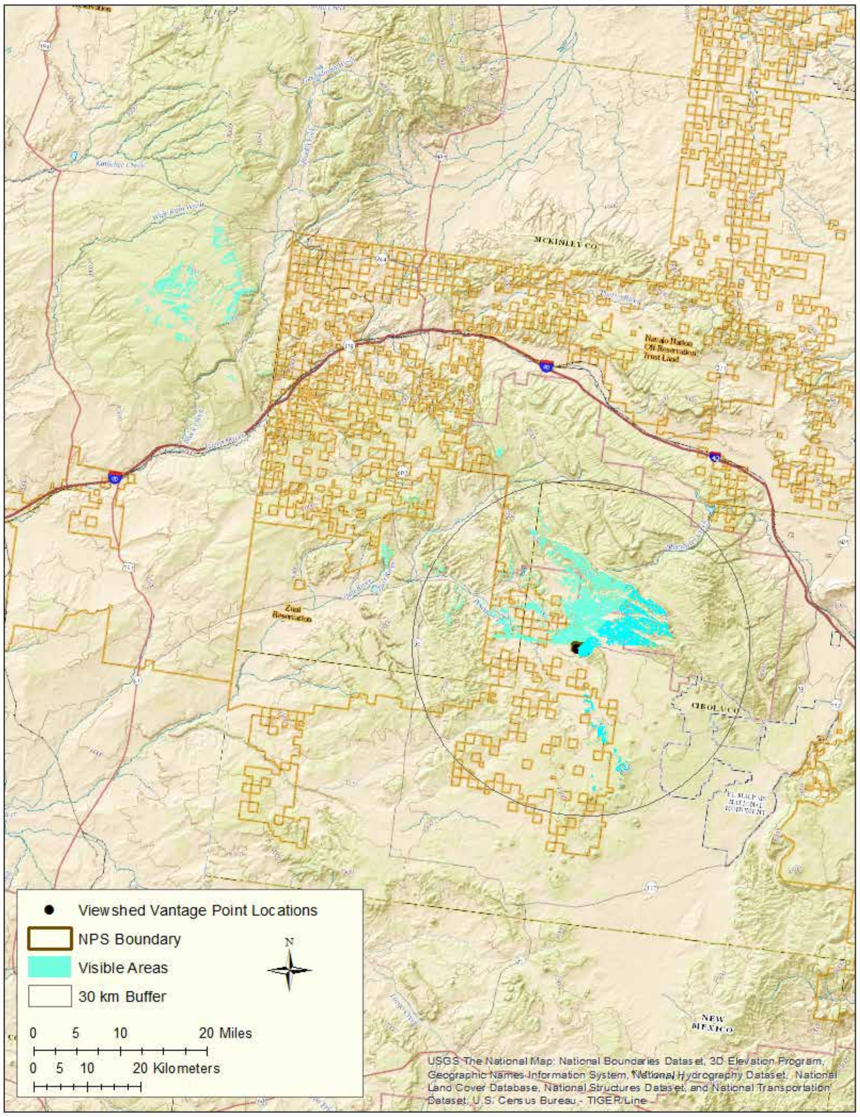


Figure 4.1.4-3. Area visible (blue-green) from the vantage points at El Morro NM. Data sources: NPS (2011b), and USGS (2015).

classes was roughly equal, although the densest of the three accounts for slightly less of the area (Figure 4.1.4-5, Table 4.1.4-4 top portion). Together, these three classes account for 85.48% of the colored area shown in the figure. Again, recall that the entire area within the area of interest is not visible from the two vantage points. Within the visible area only, these three classes made up 84.21% of the colored area visible. The two highest density classes account for nearly 16% of the colored area visible (Table 4.1.4-4, bottom portion). However, note that a relatively small proportion of the colored area of Figure 4.1.4-5 is visible from the two vantage points (i.e., 152 km^2 out of 2,365 km^2, or 6.43%).

Although housing and roads can degrade the visual integrity of the landscape and viewsheds, our analysis for El Morro NM indicated that these forms of development were not dense enough within the area of interest to lead to a lowering of the condition rating for scenic and historic integrity at the national monument.

Viewshed

Indicator	Measures
Scenic and Historic Integrity	Intactness of View Conspicuousness of Noncontributing Features

Overall Condition

Based on this assessment, we considered the viewshed at El Morro NM to be in good

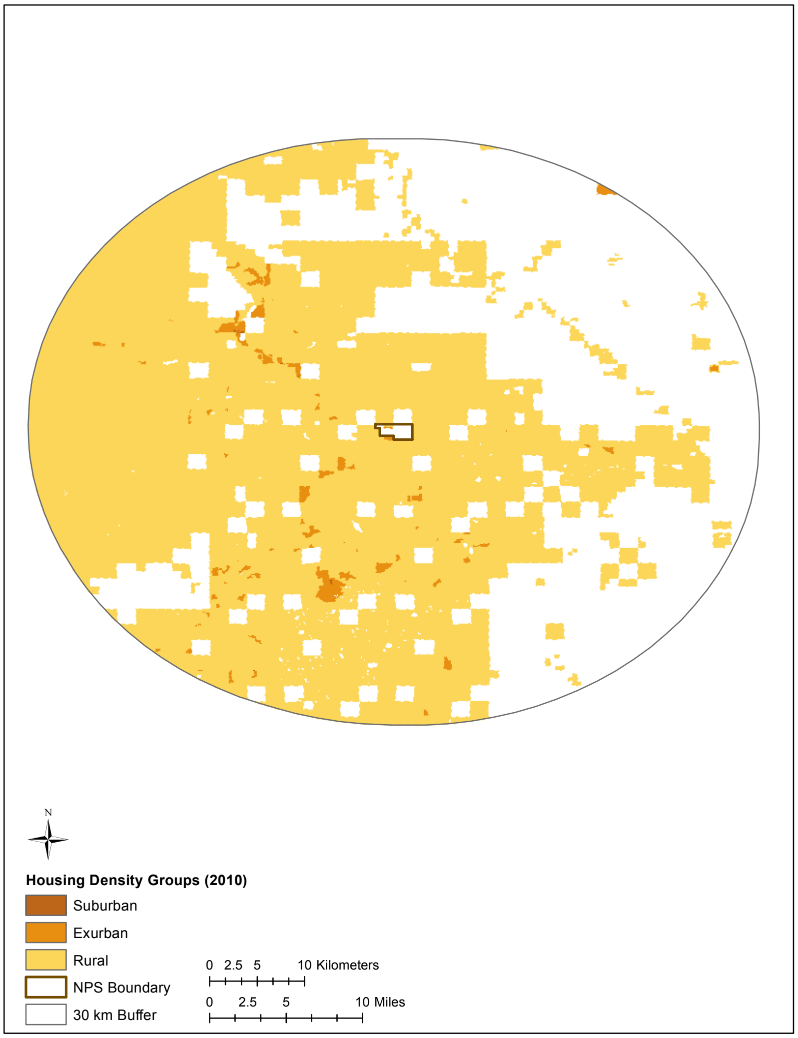


Figure 4.1.4-4. Housing density surrounding El Morro NM. Data sources: NPS (2011b), NPS (2014c), and Theobald (2005).

Table 4.1.4-2. Housing density surrounding El Morro NM (within 30 km from the park).

Density Class	Area (km²)	Percent
All Areas		
Rural	1,798.58	98.26%
Exurban	31.51	1.72%
Suburban	0.32	0.02%
(other classes not present)	----	----
Total Area	**1,830.41**	
Visible Areas Only		
Rural	125.96	99.07%
Exurban	1.17	0.92%
Suburban	0.01	0.008%
(other classes not present)	----	----
Total Area	**127.14**	

Table 4.1.4-3. Definitions of grouped housing density classes used in the GIS analysis. Source: NPS 2013.

Density Class	Class Definition
Rural	class ranges from private/ undeveloped to 4-6 units per km²
Exurban	class ranges from 7-12 units per km² to 50-146 units per km²
Suburban	class ranges from 146-495 units per km² to 495-1,235 units per km²
Urban (does not occur within AOA)	class ranges from 1,235-2,470 units per km² to >2,470 units per km²

condition. Overall, noncontributing features were relatively few and inconspicuous, leaving the site primarily intact from a scenic standpoint, which also allows the visitor to imagine the landscape from an historic and cultural point of view. We found Highway 53, which runs east-west through the northern portion of the park, to be the most conspicuous noncontributing feature, especially as viewed from the North Rim of Inscription Rock vantage point. However, overall, the vast majority of the viewshed is dominated by natural and/or historic features, and we did not find Highway 53 to have so great an effect as to lower condition from good.

4.1.5. Sources of Expertise

For assessing the condition of this resource, we relied primarily on our panoramic images and literature on this topic. Kim Struthers provided GIS assistance. Park personnel took the panoramic photos at the North Rim vantage point.

<u>Key Uncertainties</u>

How a view is perceived is quite subjective and will always have an element of uncertainty. We have tried to base our assessment on the findings of an extensive body of literature, and have tried to be transparent with our assessment.

Another element of uncertainty is our GIS analysis. This analysis is based on digital elevation models and does not take into account visibility limitations from vegetation, and other variables, and has not been verified

Table 4.1.4-4. Road density surrounding El Morro NM (within 30 km from the park).

All Areas		
Density Class	Area (km^2)	Percent
0.015 - 1.125	733	30.99%
1.126 - 2.287	707	29.89%
2.288 - 4.982	582	24.60%
4.983 - 13.49	268	11.33%
> 13.49	75	3.17%
Total Area	**2,365**	
Visible Areas Only		
Density Class	Area (km^2)	Percent
0.015 - 1.125	44	28.95%
1.126 - 2.287	47	30.92%
2.288 - 4.982	37	24.34%
4.983 - 13.49	20	13.16%
> 13.49	4	2.63%
Total Area	**152**	

in the field. Even with these uncertainties, we have a high level of confidence in this assessment.

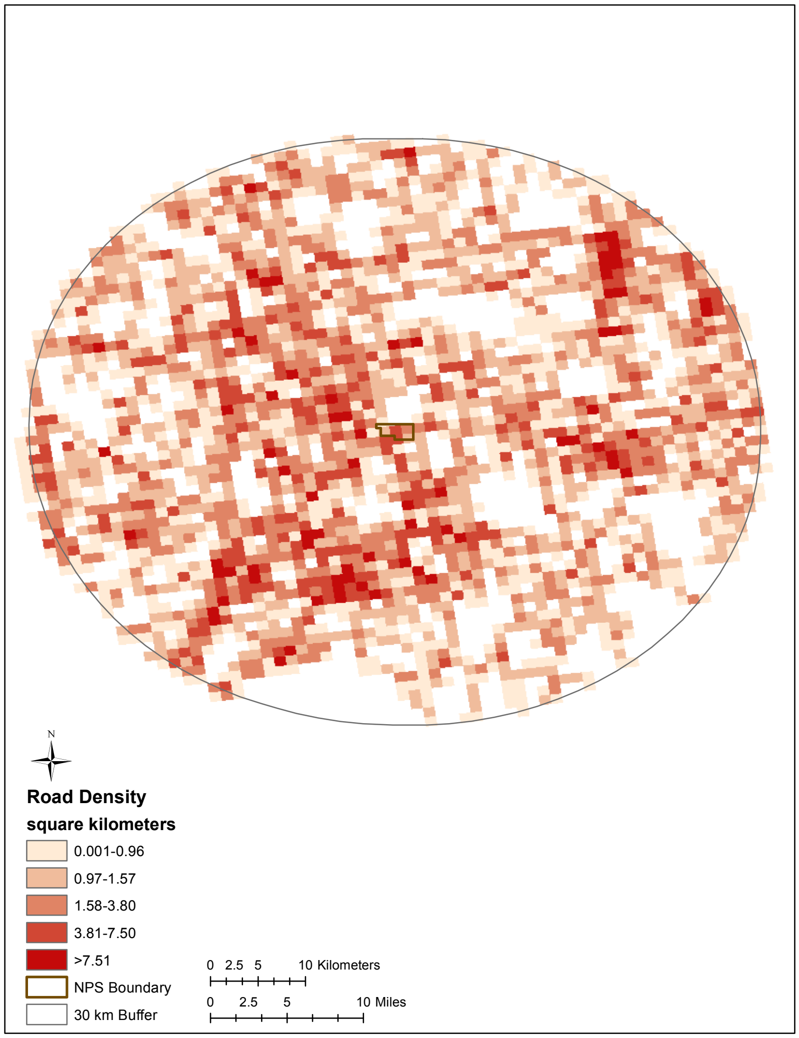


Figure 4.1.4-5. Road density surrounding El Morro NM. Data sources: NPS (2011b), NPS (2014d), and ESRI (2010).

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4.2. Night Sky

Indicators/Measures

- Sky Brightness (4 measures)
- Sky Quality (1 measure)

Condition – Trend – Confidence

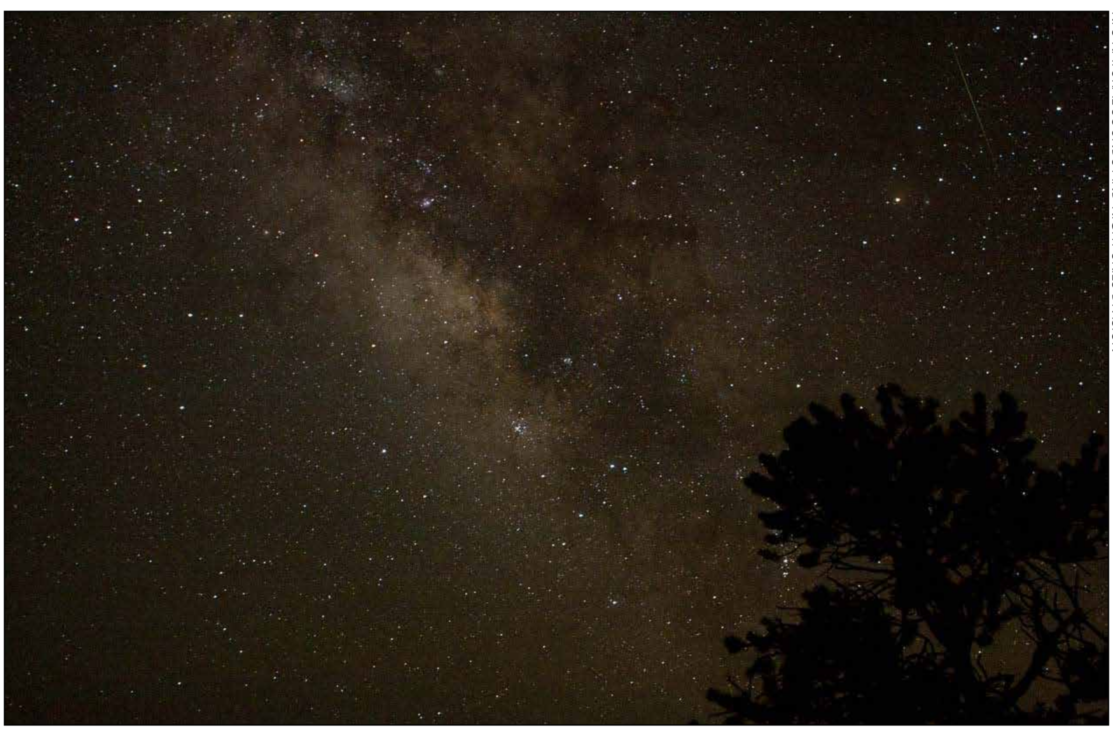
Good - Insufficient Data - High

4.2.1. Background and Importance

Natural dark skies are a valued resource within the NPS, reflected in NPS management policies (NPS 2006), which highlight the importance of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division (NSNSD) makes a distinction between a lightscape—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the photic environment—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that is integral to natural and cultural resources (Moore et al. 2013). A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit. Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

The value of night skies goes far beyond visitor experience and scenery (Figure 4.2.1-1). The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely



NPS NATURAL SOUNDS AND NIGHT SKIES DIVISION

Figure 4.2.1-1. The Milky Way as observed from Atsinna Pueblo in El Morro National Monument.

that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

El Morro National Monument has a unique opportunity to provide educational programs that highlight the cultural significance of night skies to Ancestral Puebloans and their descendants, and to provide recreational night sky viewing opportunities for visitors. For centuries people have lived around and sometimes in El Morro. Ancestral Puebloans careful observation of the sun, moon and stars was essential for planning festivals and activities such as when to start planting and when to harvest (Aveni 1987). In El Morro NM's foundation document, the protection of night skies was identified as important for the local community (NPS 2014). Protecting the night sky resources at El Morro NM benefits the natural resources, is important for visitor experience, and has cultural significance.

4.2.2. Data and Methods

The NPS NSNSD goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

Based on new guidance (Moore et al. 2013), the NPS NSNSD recommends the all-sky light pollution ratio (ALR) as the best single parameter for characterizing overall sky condition. However the utility of a single metric limits the ability to fully describe and manage the variations in resource quality that often exists within a park. Therefore, NSNSD recommends using a suite of metrics to describe and manage variations in night sky quality (see Table 4.2.2-1). When available, additional indicators and measures should also be considered in an assessment of night sky condition, but the ALR measure is the primary data source for condition assessment.

NSNSD conducted an assessment of the national monument's night sky condition on May 30, 2013 from Atsinna Pueblo atop El Morro approximately 1 hour after moonset using a CCD camera to assess the all-sky light pollution ratio and maximum vertical and horizontal illumination, a sky quality meter to measure sky brightness, and the Bortle Dark Sky Scale, a qualitative assessment commonly used by amateur astronomers to evaluate the sky quality for star gazing. This is intended only to illustrate the night sky condition.

Indicator/Measures

Sky Brightness (All-sky Light Pollution Ratio, Maximum Vertical Illuminance, Horizontal Illuminance and Zenith Sky Brightness)

A CCD camera was used to measure both natural and anthropogenic light across the entire hemisphere. From the calibrated images collected by the CCD camera metrics including all-sky light pollution ratio and two measures of integrated sky brightness—horizontal and vertical illuminance—were derived. Ground-based measurements were

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition.

Indicator	Measure	Description
Sky Brightness	All-sky Light Pollution Ratio, Vertical Maximum and Horizontal Illuminances and Zenith Sky Brightness	The all-sky light pollution ratio describes light due to man-made sources compared to light from a natural dark sky. Understanding the lightscape and sources of light is helpful to managers to maintain dark skies for the benefit of wildlife and people alike.
Sky Quality	Bortle Scale Class	The Bortle Dark Sky classification system describes the quality of the dark night sky by the celestial bodies and night sky features an observer can see. Observing the stars has been an enjoyable human pastime for centuries.

taken at Atsinna Pueblo atop El Morro on May 30, 2013.

The all-sky light pollution ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling of the natural components of the night sky allow the separation of anthropogenic light from natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available.

ALR was also modeled for the entire park based on data from the 2001 World Atlas of Night Sky Brightness, which depicts zenith sky brightness (the brightness of the sky directly above the observer). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the entire sky. Finally, the modeled anthropogenic light over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Moore et al. 2013). While modeled data provide useful overall measurements, especially when site visits cannot be made, they are less accurate than ground-based measurements.

Data provided by the NPS Night Skies Program show a modeled ALR of 0.15 for the entire national monument. Ground-based measurements from Atsinna Pueblo produced an ALR of 0.20, or 20% brighter than average natural conditions (ground-based data have a 90% confidence level of ±8 nL, or ±0.1 ALR). A summary of all night sky conditions is presented in Table 4.2.2-2.

Vector measures of illuminance (horizontal and vertical) are important in describing the appearance of three-dimensional objects on the landscape and their relative visibility. Vertical illuminance is the integration of all light striking a vertical plane from the point of the observer. In light-polluted areas, maximum sky brightness and maximum vertical illuminance will often measure the same area of sky, typically at the core of urban light domes. Vertical illuminance is an important metric when discussing night sky quality as it is easily noticeable to park visitors (since humans are oriented vertically). Even with dark conditions overhead, high vertical illuminance can hinder or inhibit dark adaptation of the eyes and cast visible shadows on the landscape. This is also an important ecological indicator, as many wildlife species base behavior on visual cues along the horizon. Horizontal illuminance is the amount of light striking a horizontal surface and is an important indicator of sky brightness (Cinzano and Falchi 2014). It is less sensitive in slightly impacted areas. This is because, even though the entire sky is considered, there is a rapid falloff in response to photons near the horizon, owing to Lambert's cosine law. At sites remote from cities, most of the anthropogenic sky glow occurs near the horizon.

Maximum vertical illuminance was measured at 0.12 milli-Lux, or 31% above average natural conditions. Horizontal illuminance from anthropogenic sources was measured at 0.06 milli-Lux, or 7% brighter than natural conditions (Table 4.2.2-2).

Sky brightness describes the amount of light in the night sky. One method of assessing sky brightness uses a Unihedron Sky Quality Meter (SQM) that samples the night sky in a broad spectrum band roughly corresponding to the entire human visual range. The SQM measures an aggregate average brightness for the entire sky that is skewed to zenith brightness over an 80 degree field of view (Moore 2001). The ground-based SQM reading was 21.54 (Table 4.2.2-2).

Indicator/Measure
Sky Quality (Bortle Dark Sky Scale)

The Bortle Dark Sky Scale (Appendix C) was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment

Table 4.2.2-2. Night Sky Measurements at El Morro NM.

Location	All-sky Light Pollution Ratio	Maximum Vertical Illuminance (milli-Lux)	Horizontal Illuminance (milli-Lux)	Zenith Sky Brightness (SQM)	Bortle Scale
Modeled Park-wide	0.15	---	---	---	---
Atsinna Pueblo	0.20	0.12	0.06	21.54	3

(Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-3). The Bortle scale uses both stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-1). The qualitative Bortle Scale assessment estimated the night sky quality to class 3 which is consistent with a rural sky.

4.2.3. Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010). El Morro NM is 40-50 miles from the closest cities and none of its 1,278 acres are located in an urban environment. Therefore, the national monument is considered a non-urban NPS unit, or area with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units, the thresholds separating reference of conditions good, moderate, and significant concern are more stringent than those for urban NPS units because these areas are generally more sensitive to the effects of light pollution. For a summary of condition assessment categories for all night sky indicators, see Table 4.2.3-1.

All-sky Light Pollution Ratio

A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night

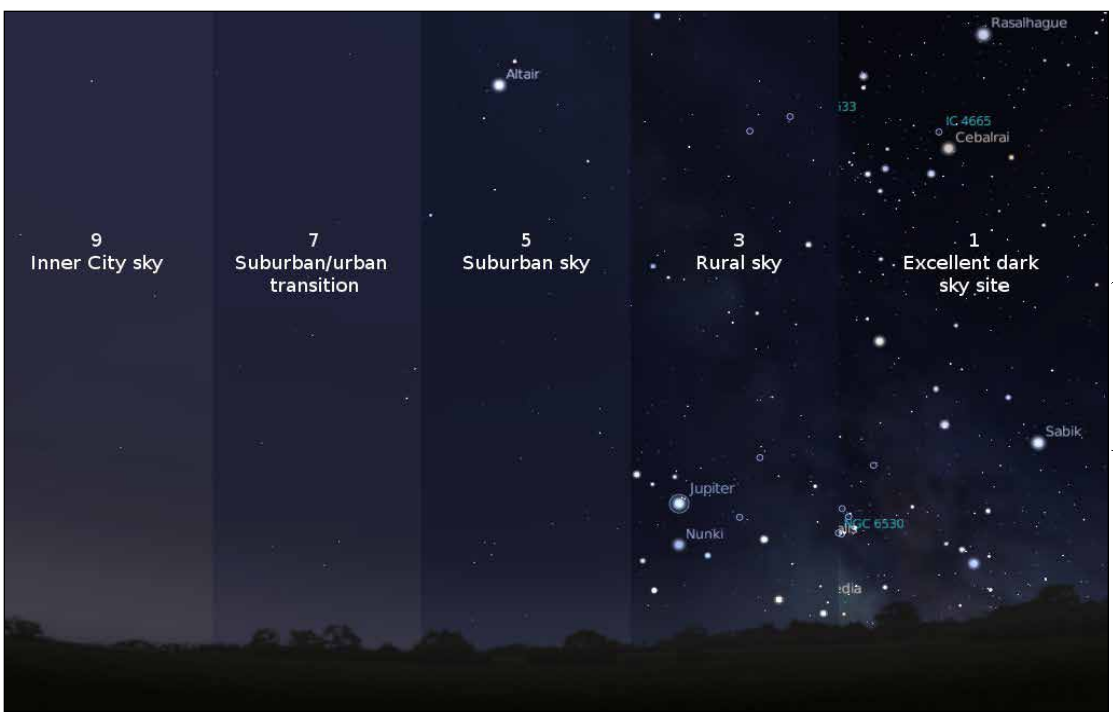


IMAGE GENERATED FROM STELLARIUM (WWW.STELLARIUM.ORG)

Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.

Table 4.2.2-3. Bortle Dark Sky Scale*

Bortle Scale	Milky Way (MW)	Astronomical Objects	Zodiacal Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky Site	MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow	Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye	Zodiacal light is striking as a complete band, and can stretch across entire sky	The horizon is completely free of light domes, very low airglow	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark
Class 2 Typical Dark Site	MW shows great detail and cast barely visible shadows	The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares	Zodiacal band and gegenschein are visible	Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids	Ground is mostly dark, but object projecting into the sky are discernible
Class 3 Rural Sky	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision	Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent	Airglow is not visible, and clouds are faintly illuminated except at zenith	Some light domes evident along horizon, ground objects are vaguely apparent
Class 4 Rural-Suburban Transition	MW is evident from horizon to horizon, but fine details are lost	Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible	Zodiacal light is evident, but extends less than 45° after dusk	Clouds are just brighter than the sky, but appear dark at zenith	Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain
Class 5 Suburban Sky	MW is faintly present, but may have gaps	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus	Only hints of zodiacal light may be glimpsed	Clouds are noticeably brighter than sky	Light domes are obvious to casual observers, ground objects are easily seen
Class 6 Bright Suburban Sky	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow	Cygnus, Scutum, and Sagittarius star fields just visible	Zodiacal light is not visible; constellations are seen, and not lost against a starry sky	Clouds appear illuminated and reflect light	Sky from horizon to 35° glows with grayish color, ground is well lit
Class 7 Suburban-Urban Transition	MW may be just barely seen near the zenith	Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed	Zodiacal light is not visible, and brighter constellations are easily seen	Clouds are brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
Class 8 City Sky	MW not visible	Pleiades are easily seen, but few other objects are visible	Zodiacal light not visible, constellations are visible but lack key stars	Clouds are brilliantly lit	Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon
Class 9 Inner City Sky	MW not visible	Only the Pleiades are visible to all but the most experienced observers	Only the brightest constellations are discernible	Clouds are brilliantly lit	Entire sky background has a bright glow, ground is illuminated

White et al. (2012)

Table 4.2.3-1. Night sky condition class summary for non-urban parks (i.e. parks with at least 90% of their property located outside an urban area).

Condition Class	ALR*	SQM	Bortle Scale
Good	ALR <0.33 (<26 nL average all-sky light pollution)	≥21.60	1-3
Moderate	0.33-2.0 (26-156 nL average all-sky light pollution)	21.2-21.59	4
Significant concern	ALR >2.0 (>156 nL average all-sky light pollution)	<21.2	5-9

* At least half of the park's geographic area should meet the standard described.

sky. The threshold for night skies in good condition is an ALR <0.33 and the threshold for a moderate condition is ALR 0.33-2.0. An ALR >2.0 suggests significant concern (Moore et al. 2013).

Maximum Vertical Illuminance
The NPS Night Skies Division recommends a reference condition of 0.4 milli-Lux, since the average vertical illuminance experienced under the natural night sky on a moonless night is 0.4 milli-Lux (derived from Jensen et al. 2006, Garstang 1986, and unpublished NPS Night Skies Program data). No thresholds for condition rating have been set at this time. Vertical illuminance can also be expressed as a ratio to natural conditions, similar to ALR.

Horizontal Illuminance
The NPS Night Skies Division recommends a reference condition of 0.8 milli-Lux, since the average horizontal illuminance experienced under the natural night sky on a moonless night is 0.8 milli-Lux (derived from Duriscoe, 2015 [submitted]). No thresholds for condition rating have been set at this time. Horizontal illuminance can also be expressed as a ratio to natural conditions, similar to ALR.

Zenith Sky Brightness
Reference conditions for night sky brightness can vary moderately based on the time of night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun which can increase "airglow"—a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013).Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x (100%); thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.4 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Duriscoe et al. 2007).

The maximum night sky brightness is often found within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents very bright areas of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark-adapt vision, and may have effects on wildlife (Duriscoe et al. 2007).

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale class 1 is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker are considered to be in good condition, class 4 of moderate condition, and class 5 are considered poor condition. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013). It is important to note that such degraded conditions may be restored toward a more natural state by modifying outdoor lighting, depending on the surrounding conditions that exist outside the national monument.

4.2.4. Condition and Trend

The two measurements of ALR, ground-based and modeled, indicate good night sky conditions at El Morro NM (Figure 4.2.4-1). Although no thresholds have been established for maximum vertical illuminance or horizontal illuminance, the condition is estimated as good for both measures (J. White, personal communication, November 2015). The ground-based SQM reading indicates moderate condition while the qualitative Bortle Scale assessment indicated good night sky viewing conditions at the national monument. These data provide baseline information. No data on trends were available.

Local and Regional Context

El Morro NM is located in a region where few cities interfere with dark night skies. The light domes of Grants, NM (population 9,182) 49

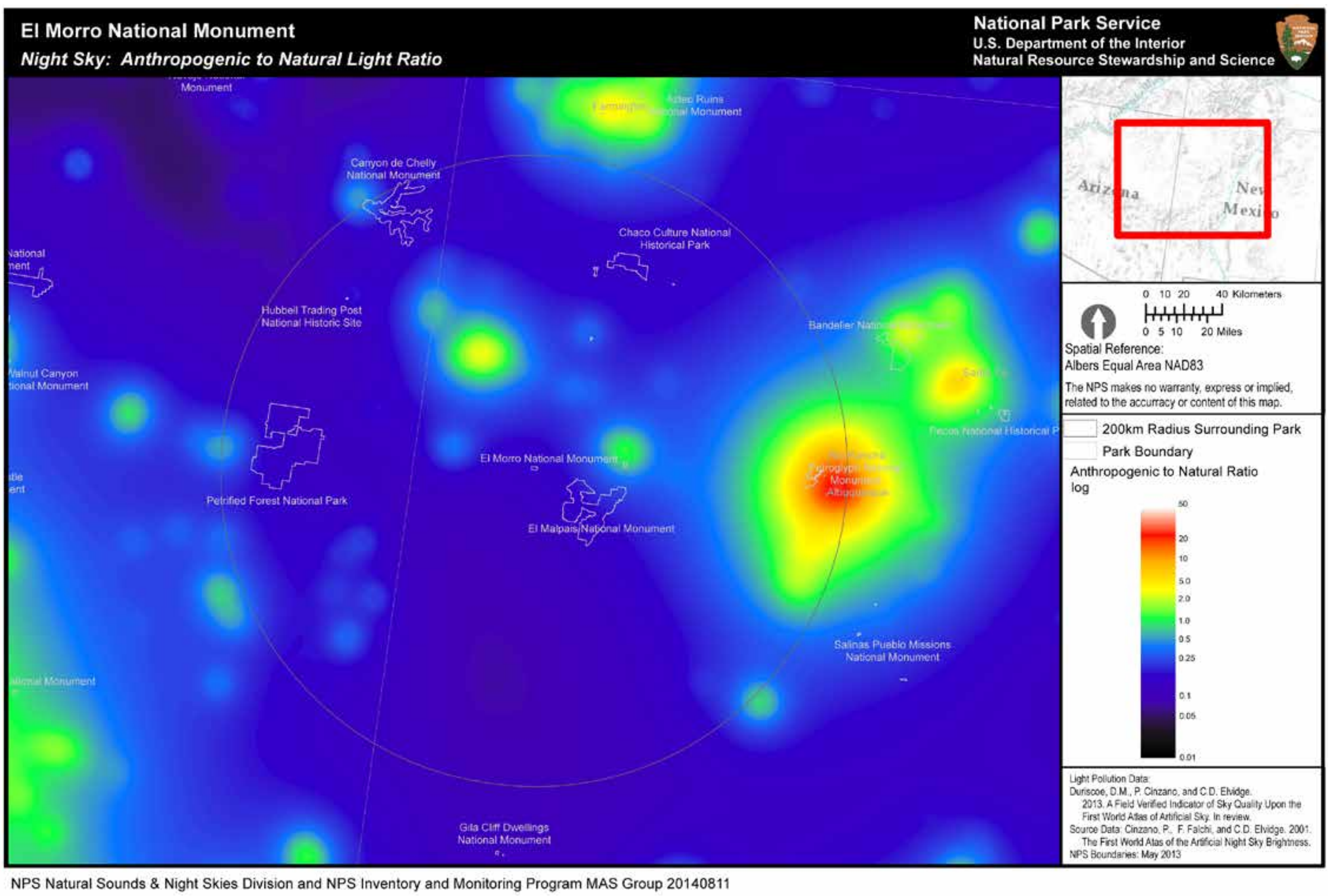


Figure 4.2.4-1. Modeled ALR map for El Morro NM. A 200km ring around the park illustrates the distance at which anthropogenic light can impact night sky quality within the park. Credit: NPS Natural Sounds and Night Skies Division.

miles northeast and Gallup, NM (population 21,678) 64 miles to the northwest are visible, but do not interfere with night sky vision (Figure 4.2.4-2). Albuquerque (population 545,852) 155 to the east and Santa Fe (population 67,947) 227 miles to the east are faintly visible. Other sources of artificial light include numerous homes and ranches to the south and southwest.

Night Sky

Indicators	Measure
Sky Brightness	4 measures
Sky Quality	Bortle Scale Class

Overall Condition

Quantitative measures of sky brightness (all-sky light pollution ratio, maximum vertical and horizontal illuminance, and zenith sky brightness) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky. These indicators and measures are summarized and interpreted in Table 4.2.4-1. The overall condition of the national monument's night sky as observed from Atsinna Pueblo on May 30, 2013 is good.

Uncertainties

The Bortle Dark Sky Scale estimates have inherent uncertainties and error. The principle drawback of the Bortle Scale is that it relies upon human visual observers. Differences in visual acuity, experience and knowledge, as well as time and effort expended can influence the estimates (Bortle 2001, Moore 2001). Modeled data are based on 1996 satellite imagery, and ground truthed with NPS ground-based measures. Changes in population levels, private and commercial building growth, and energy development could impact current ALR values.

4.2.5. Sources of Expertise

Chad Moore and Jeremy White, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship and Science Directorate, provided information pertaining to night sky data collection methodology and interpretation of results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the Night Skies Program manager for a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member Dan Duriscoe have developed an automated all-sky camera capable of precise measurement of light pollution. White earned his Bachelors degree in Ecology and Systematic Biology in 2004 and began working with the NPS in 2005. White is a Physical Scientist with the Night Skies Program responsible for data collection and analysis, interpretation, and public outreach. Since 2001 the team has collected sky quality inventories at over 110 U.S. national parks.

This section was authored by wildlife biologist and writer Lisa Baril.

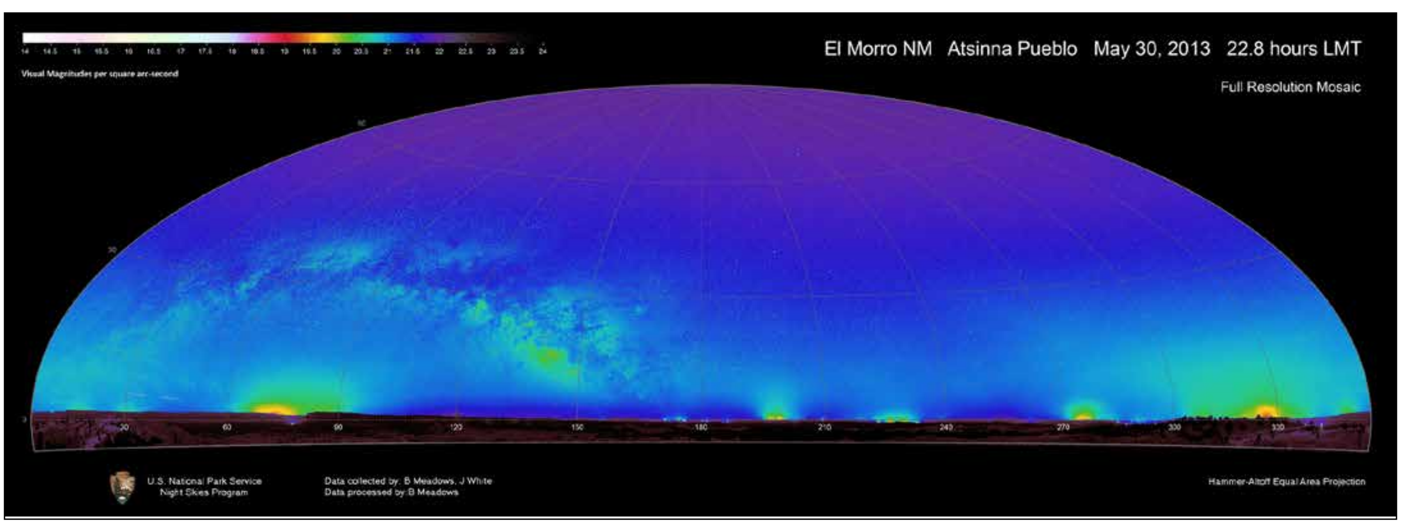


Figure 4.2.4-2. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Morro National Monument from Atsinna Pueblo. Credit: NPS Night Skies and Natural Sounds Division.

Table 4.2.4-1. Summary of night sky indicators, measures, and condition rationale at El Morro NM.

Indicator	Measure	Condition	Condition Rationale
Sky Brightness	All-sky Light Pollution Ratio*	Good	Sky brightness as measured by ALR indicates good condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on the ground-based measurement of 0.20 taken in May 2013. The modeled ALR of 0.15 was derived from the 2001 World Atlas of Night Sky Brightness and is similar to the ground-based measurement. The ground-based measurement was collected by the NPS Natural Sounds and Night Skies Division. The confidence level is high.
	Maximum Vertical Illuminance	Good	Sky brightness as measured by maximum vertical illuminance was 0.12 milli-Lux at El Morro NM. This value reflects a rating of 31% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good (J. White, personal communication, Nov. 2015). This measurement was collected by the NPS Natural Sounds and Night Skies Division.
	Horizontal Illuminance	Good	Sky brightness as measured by horizontal illuminance was 0.06 milli-Lux at El Morro NM. This value reflects a rating of 7% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good (J. White, personal communication, Nov. 2015). This measurement was collected by the NPS Natural Sounds and Night Skies Division.
	Zenith Sky Brightness	Moderate	Zenith sky brightness indicates moderate condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on a ground-based measurement of 21.54. Confidence level is high.
Sky Quality	Bortle Dark Sky Scale	Good	Sky quality as assessed by the Bortle dark sky scale indicate good condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on the qualitative assessment of Bortle class 3, which is consistent with a rural night sky. Because this measure is qualitative, it has low confidence.

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4.3. Soundscape

Indicators/Measures

- Sound Level (2 measures)

Condition - Trend - Confidence Level

Moderate - Insufficient Data - Medium

4.3.1. Background and Importance

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment, and an unimpaired acoustical environment is an important part of overall National Park Service (NPS) visitor experience and enjoyment, as well as vitally important to overall ecosystem health.

In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (McDonald et al. 1995) (Figure 4.3.1-1). Despite this desire for quiet environments, noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006) require preservation of parks' natural soundscapes and restoration of degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscapes from noise (i.e., any unwanted sound). Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The physical sound

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Figure 4.3.1-1. Bird vocalizations, such as from Lark Sparrows (*Chondestes grammacus*), which are known to occur in the park contribute to El Morro National Monument's soundscape.

resources (e.g., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, is referred to as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

In addition, sound plays a critical role for wildlife communication. Activities such as courtship, predation, predator avoidance, and effective use of habitat rely on the ability to hear with studies showing that wildlife can be adversely affected by intrusive sounds. While the severity of the impacts varies depending on the species and other conditions, documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994, Dooling and Popper 2007, Kaseloo 2006).

<u>Sound Characteristics</u>

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions, therefore, travel farther.

The amplitude (or loudness) of a sound, measured in decibels (dB), is logarithmic, which means that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB reduction in background noise level would produce a 4x increase in listening area (Figure 4.3.1-2). Changes in the background noise level cause a change in listening opportunity. These lost opportunities will approach a halving of alerting distance and a 75% reduction of listening area for each 6 dB increase in affected band level (Barber et al. 2010).

SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

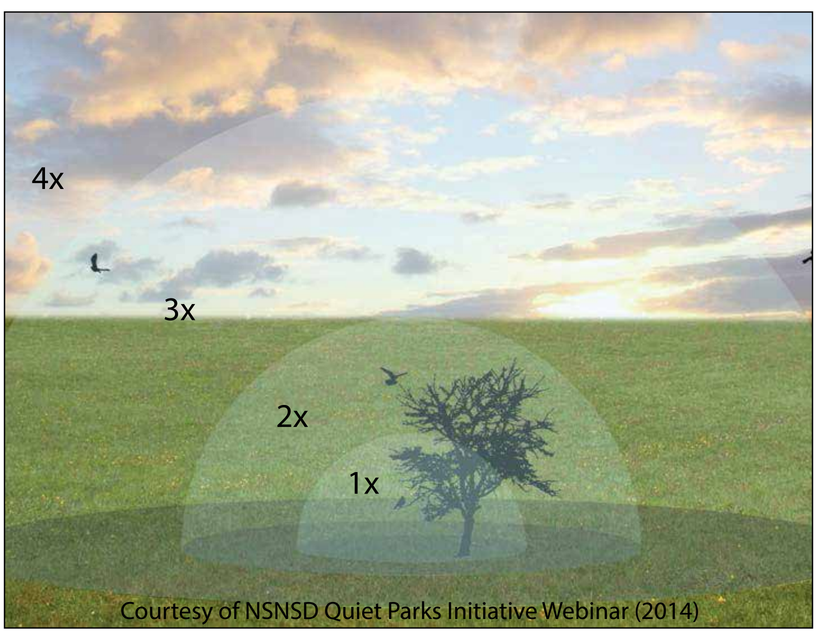

Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area (NPS NSNSD 2014).

4.3.2. Data and Methods

Baseline acoustical monitoring data, including:

- sound level data in the form of A-weighted decibel readings (dBA) every second,
- continuous digital audio recordings,
- one third octave band data every second ranging from 12.5 Hz – 20,000 Hz, and

- meteorological data

were collected by the NPS Natural Sounds and Night Skies Division (NSNSD) scientists during the months of June and July, 2009. Acoustical monitoring systems were deployed at two locations within the national monument: Headlands Trail and South Box Canyon (Figure 4.3.2-1).

The Headlands Trail monitoring location was near the Inscription Rock panels to capture vehicle noise, whereas the South Box Canyon location was farther away from New Mexico Highway 53 to capture the baseline natural ambient sound level. The characteristics of both monitoring locations are summarized in Table 4.3.2-1.

Indicators/Measures

Sound Level (2 measures)

Sound levels at the monument were evaluated in two ways for the purposes of this condition assessment (1) using the on-site results from the acoustical monitoring effort (NPS NSNSD 2009) to determine percent time

Table 4.3.2-1. Location characteristics of acoustical monitoring sites at El Morro National Monument (excerpted from NPS-NSNSD 2009).

Location	Dates Deployed	Vegetation	Elevation (m)
Headlands Trail	6/10/2009-7/13/2009	Bare rock/ lava. Top of sandstone bluff	2277
South Box Canyon	6/12/2009-6/24/2009	Open juniper/ ponderosa pine/ sagebrush	2208

above reference sound levels, and (2) using the geospatial sound modeling result for the impact between natural and existing acoustic conditions at the monument (Mennitt et al. 2013).

The geospatial model estimated sound pressure levels for the continental United States by using actual acoustical measurements combined with a multitude of explanatory variables such as location, climate, landcover, hydrology, wind speed, and proximity to noise

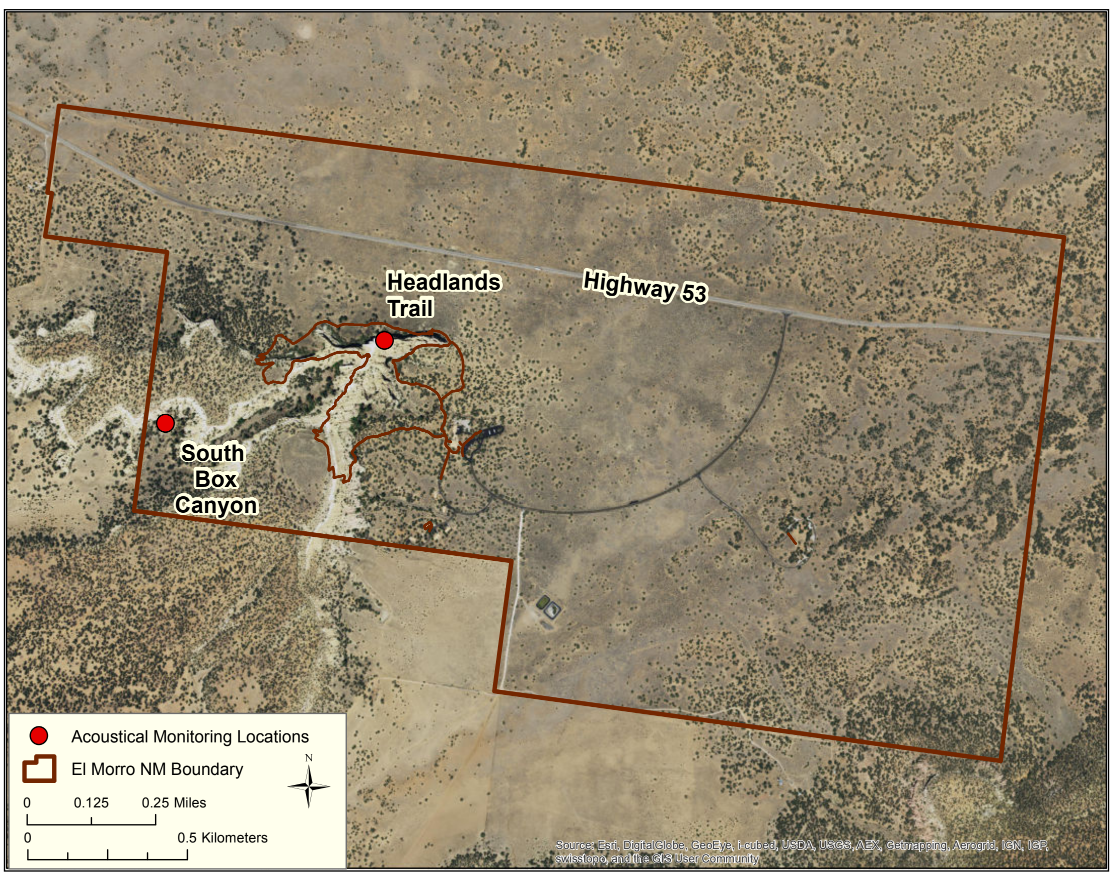

Figure 4.3.2-1. Locations of 2009 acoustical monitoring sites at El Morro NM.

sources (e.g., roads, railroads, and airports). The 270 m resolution model predicts daytime sound levels during midsummer. Each square of color on the map represents 270 m2 and each pixel on the map represents a median sound level (L50). It should be noted that while the model excels at predicting acoustic conditions over large landscapes, it may not reflect recent localized changes such as new access roads or development.

Model parameters useful for assessing a park's acoustic environment include the understanding of a) natural conditions, b) existing acoustic conditions including both natural and human-caused sounds, and c) the impact of human-caused sound sources in relation to natural conditions. The L_{50} impact condition demonstrates the influence of human activities to the acoustic environment and is calculated by subtracting the natural condition from the existing condition. The three models are run separately, and NSNSD "zeroes" out all anthropogenic contributions like roads, development, and cities to predict impact, but the impact stats will not always be exactly equal to existing minus natural (E. Brown, NSNSD pers. comm.).

4.3.3. Reference Conditions

Percent Time Above Reference Sound Levels

Human responses to sound levels can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007). Table 4.3.3-1 summarizes sound levels that relate to human health and speech, as documented in the scientific literature. The first, 35 dBA, is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis, 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third value, 52 dBA, is based on the U.S. EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters (32.8 ft) (USEPA 1974). This threshold addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter (3.28 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

L_{50} Impact (Mennitt et al. (2013)

Turina et al. (2013) developed two categories, urban and non-urban, of L_{50} impact reference conditions based on the proximity of a park to urban areas as identified by the U.S. Census Bureau (2010). Non-urban parks had at least 90% of their areas outside designated Urban Areas (Turina et al. 2013).

Sound levels at non-urban parks, such as the monument, most often exhibit less divergence between existing and natural sound levels, making them quieter areas that are more susceptible to noise. Visitors likely have a greater expectation for quiet at non-urban parks and wildlife are likely more adapted to a noise-free environment. Accordingly, the L_{50} impact reference conditions for non-urban parks are more stringent than for urban parks.

Table 4.3.3-1. Explanation of reference sound level values (NPS 2013).

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (U.S. EPA 1974)
60	Speech interruption for normal conversation (U.S. EPA 1974)

Table 4.3.3-2. Reference conditions used to assess the sound levels at El Morro National Monument.

Indicator	Measure	Good	Moderate	Significant Concern
Sound Level	% Time Above Reference Sound Levels	The majority of sound levels recorded were <44.99 dBA.	The majority of sound levels recorded were between 45 - 51.99 dBA.	The majority of sound levels recorded were >52 dBA.
	L_{50} Impact	National Park Service Natural Sounds and Night Skies Thresholds for Non-urban Parks in dBA (Turina et al. 2013).		
		≤ 1.5	1.5 - ≤ 3.0	>3

Reference conditions for both percent time above reference sound levels and L_{50} impact measures are presented in Table 4.3.3-2.

4.3.4. Condition and Trend

Percent Time Above Reference Sound Levels

Figure 4.3.4-1 shows the percent time sound levels were above the reference sound levels at each monitoring location during day (7 a.m. - 7 p.m.) and nighttime (7 p.m. - 7 a.m.) hours. Sound levels mainly exceeded the 35 dBA metric with 41.5 to 57.9% of daytime hours above this level. Sound levels exceeded the 45 dBA metric 10.2 to 15.4% of the daytime hours at the Headlands Trail and South Box Canyon, respectively. Sounds at both sites rarely exceeded 52 dBA. As would be expected, sounds were lower at night than during the day. Nighttime sound levels only exceeded the 35 dBA reference value 9.7% to 21.1% of the time. During the nighttime hours, sound levels exceeded the 45 dBA reference level for recommended maximum noise levels inside bedrooms 9.7-21.1% of the time.

Low frequency sounds (20-800 Hz) of which transportation noises are often a major contributor comprised more of the sounds heard at the Headlands Trail site during both day and nighttime hours, which would be expected given its closer proximity to Highway 53 than the South Box Canyon site. While the metrics presented in the snapshot report did not fully identify sound sources or the natural ambient condition, it was noted that the sound sources of greatest concern for park managers included nearby plant operations and associated heavy machinery travelling along Highway 53.

According to Mennitt et al. (2013), a loud truck or motorcycle can cast noise up to 10 km (6.2 mi) from a road with no vegetation.

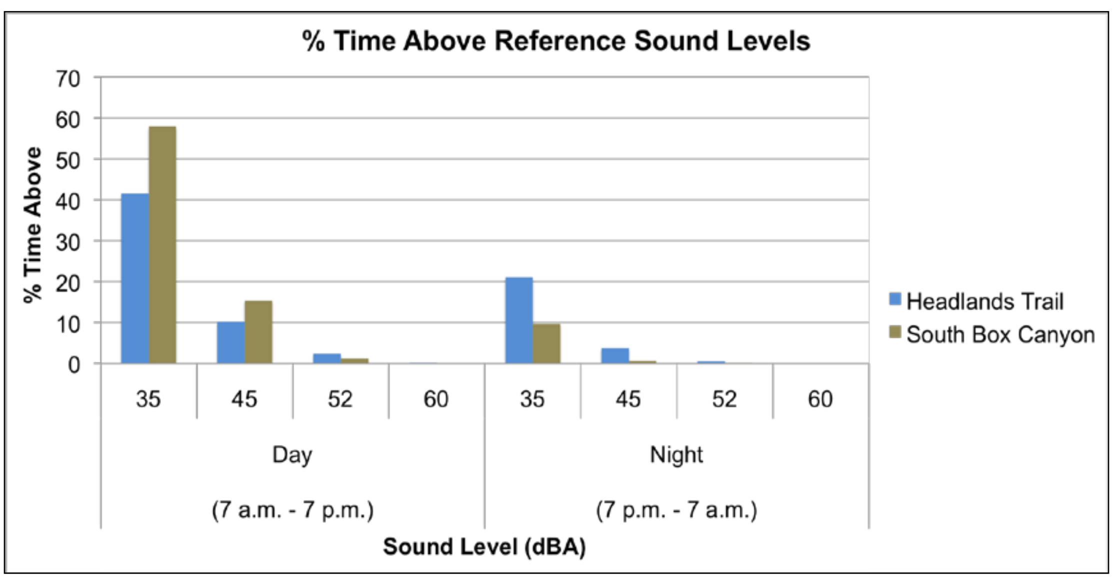

Figure 4.3.4-1. Percent time above reference sound levels within the 12.5-20,000 Hz frequency recorded at El Morro NM's Headlands Trail and South Box Canyon acoustical monitoring sites.

While there are many pinyon pine and juniper trees throughout the landscape within and surrounding the national monument, there are very few areas without roads (Figure 4.3.4-2; El Morro on the left and El Malpais on the right). Additionally, pinyon/juniper vegetation is unlikely to attenuate noise because it is sparse enough that it leaves paths for the sound waves to travel through. To really have attenuation due to vegetation, the forest must be quite dense. If we assume that sound waves produced by vehicles range in frequency from 100 Hz to 800 Hz, their actual wavelengths are between 3.4 m (11.3 ft) and 0.46 m (1.5 ft) wide. In order for the vegetation to attenuate the sound, we'd have to have a 1:1 ratio between the size of the tree trunks (or the spaces between the tree trunks), and the sound waves (E. Brown, NSNSD pers. comm.).

The largest area of 10-50 km^2 without roads that is closest to the monument is north of the park's northern boundary (NPS 2014, ESRI 2005). In addition, Highway 53 bisects the northern half of the park and is located less than 0.8 km (0.5 mi) from the monument's campground and only 0.4 - 0.8 km (0.25 - 0.5 mi) from Inscription Rock Trail; therefore, it's likely that traffic noise will always be a contributor to the overall condition of the park's soundscape.

During an earlier study, King and King (2003) collected acoustical data at the monument, including ambient sound levels, visitor conversations, and heavy trucks travelling along Highway 53. In summary, the loudest sound levels originated from fully loaded quarry trucks but were less frequent, unless the wind was blowing from the highway toward the monument. King and King (2003) concluded that wind direction was the most significant contributing factor for higher sound levels but that air pressure and vegetation moisture also affected the levels.

Relative to the percent time above reference sound level measure, both monitoring locations are considered to be in good to moderate condition.

L_{50} Impact (Mennitt et al. (2013)

Figure 4.3.4-3 shows the modeled mean impact sound level map for the monument, which was 4.3 decibels (dBA) above natural

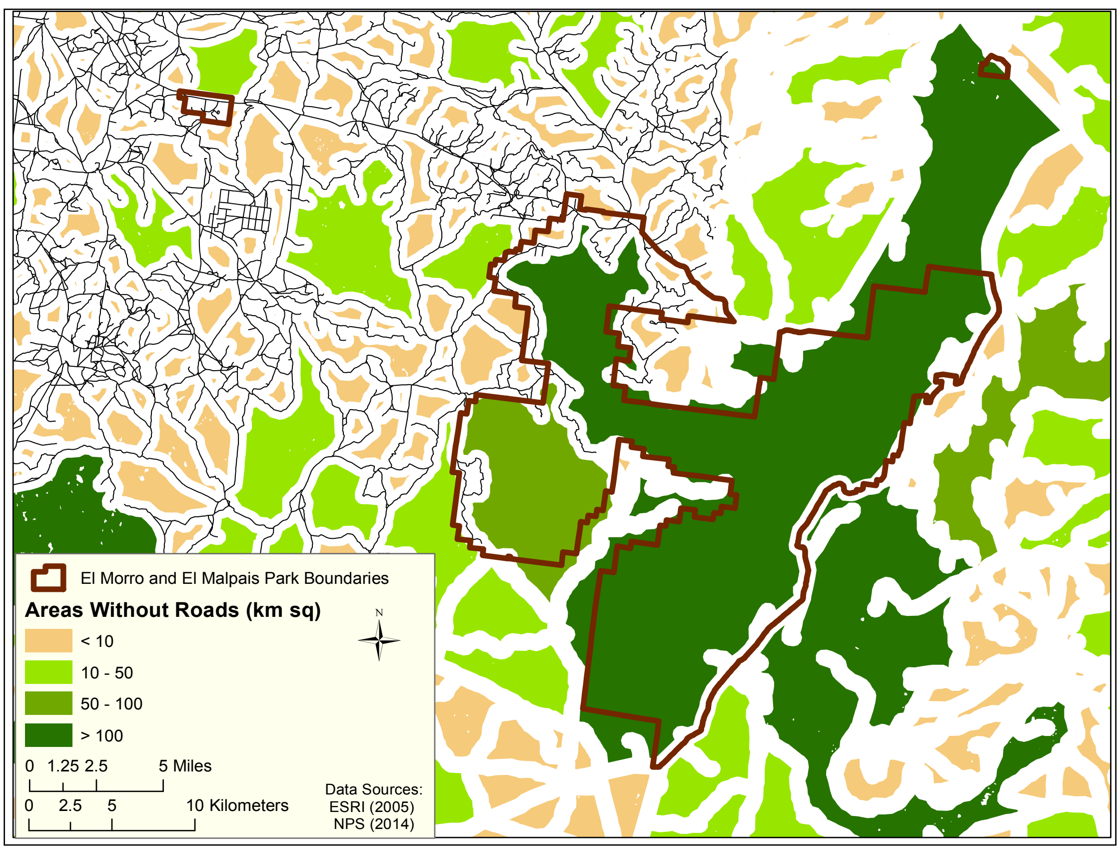

Figure 4.3.4-2. There are several roads surrounding and bisecting El Morro NM, leaving very few areas without roads. This contributes to the traffic noise heard throughout the park. Data Sources: NPS (2014) and ESRI (2005, 2010).

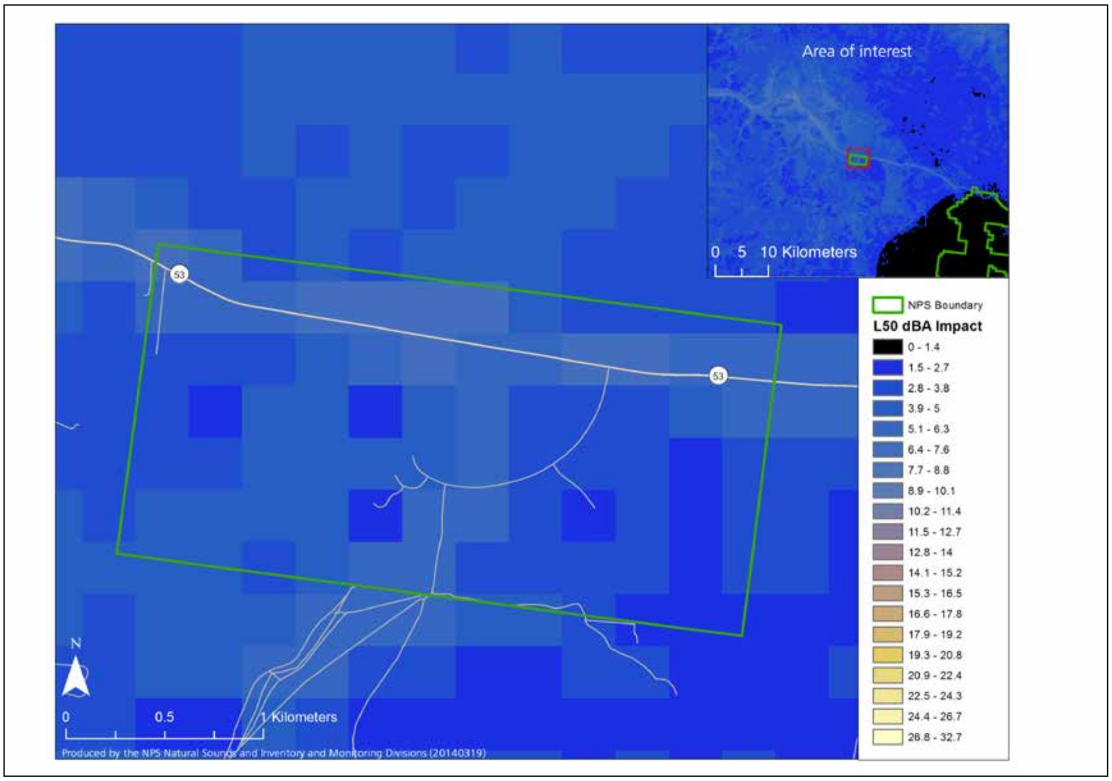

Figure 4.3.4-3. The modeled L_{50} impact sound level at El Morro NM (Mennitt et al. 2013). Lighter colors represent higher impact areas.

conditions, ranging from 2.4 dBA in the least impacted areas to 7.1 dBA in the most impacted areas. The map depicts the area most influenced by human-caused sounds (i.e., lighter colored areas). The existing and natural acoustic environment condition maps are included in Appendix D.

Summary statistics of the L_{50} values for the natural, existing, and impact conditions are provided in Table 4.3.4-1. Average values represent the average L_{50} value occurring within the park boundary and since this value is a mean, visitors may experience sound levels higher and lower than the average L_{50}. A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact a visitor's listening ability to hear natural sounds or interpretive programs.

Table 4.3.4-1. Median L_{50} values in each condition: natural, existing, and impact. Values represent the minimum, maximum, and average L_{50} measurements in each condition (Excel table provided by E. Brown, 2015).

Acoustic Environment Condition	Median L_{50} (dBA)		
	Min.	Max.	Avg.
Natural	25.5	28.2	26.7
Existing	28.5	32.8	31.0
Impact	2.4	7.1	4.3

Mennitt et al. (2013) suggest that in a natural environment, the average summertime L_{50}, which is the sound level exceeded half of the time (and is a fair representation of expected conditions) is not expected to exceed 41 dBA. They also state that "an impact of 3 dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." While the modeled results for the monument were well below 41 dBA, the average impact level is considered to be of significant concern.

Soundscape

Indicator	Measure
Sound Level	% Time Above Reference Levels
	L_{50} Impact

Overall Condition and Trend

For assessing the condition of the national monument's soundscape, we used one indicator with two measures, which are summarized in Table 4.3.4-2. Overall, we

Table 4.3.4-2. Summary of the soundscape indicator and measures and their contribution to the overall soundscape condition.

Indicators of Condition	Measures	Condition	Rationale for Condition
Sound Level	% Time Above Reference Sound Levels	Good to Moderate	The majority of existing sound levels heard at both sites were between 35-51.99 dBA, suggesting a relatively quiet environment but periodically exceeding the recommendation for maximum noise levels inside bedrooms. We consider this measure to be in good to moderate condition and weighted the condition rating more heavily using these data since they were gathered on-site.
	L_{50} Impact	Significant Concern	The modeled average impact sound level for the national monument of 4.3 dBA exceeds the significant concern threshold value for non-urban parks based on Turina et al. (2013) reference conditions.

consider the soundscape at the national monument to be in moderate condition, with an unknown trend.

Level of Confidence and Key Uncertainties

Monitoring was only conducted for one season in 2009, and while the results provided more data than what is typically available for most soundscape assessments, the information is already six years old and may no longer reflect current condition. Additionally, the information in the monitoring report was a 'snapshot' of the acoustical conditions. Further analysis will provide more information about the types of sounds recorded and an estimate of the natural ambient condition. Finally, while the L_{50} impact results provided additional information pertaining to predicted soundscape condition, the range of impact suggested a more degraded environment compared to the on-site acoustical monitoring results.

4.3.5. *Sources of Expertise*

The NPS Natural Sounds and Night Skies Division (NSNSD) scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes. For more information, see http://www.nature.nps.gov/sound/.

Emma Brown, Acoustical Resource Specialist with the NSNSD, provided an NRCA soundscape template used to develop this assessment and the sound model statistics and maps.

The NPS NPScape Program provides data and analysis related to resource conservation for parks and partners. The area without roads dataset was obtained from the program's website. For more information, see http://nps.gov/nsnsd.

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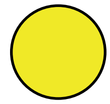
4.4. Air Quality

Indicators/Measures

- Visibility (1 measure)
- Level of Ozone (2 measures)
- Wet Deposition (2 measures)

Condition – Trend – Confidence



Moderate - Insufficient Data - Medium

4.4.1. Background and Importance

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in national parks and wilderness areas (NPS-ARD 2012a) (Figure 4.4.1-1).

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from fossil fuel combustion (i.e., power plants and vehicles), wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2012a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2012a).

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Figure 4.4.1-1. El Morro National Monument is located within a Class II airshed.

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout Park Service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from fossil fuel burning power plants, industry, and fire and volatile organic compounds from industry, solvents, and vegetation in the presence of sunlight (Porter and Wondrak-Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003). The foliar damage requires the interplay of several factors, including the sensitivity of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2004).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012b). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012b), but more

Figure 4.4.1-2. A cloudy day at El Morro NM.

often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2012c).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication (NPS-ARD 2010). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2015a). Increases in nitrogen have been found to promote invasions of fast-growing annual grasses (e.g., cheatgrass) and exotic species (e.g., Russian thistle) at the expense of native species (Brooks 2003, Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (Inouye 2006).

According to the EPA (2012a), in the United States, roughly two thirds of all sulfur dioxide (SO_2)and one quarter of all NO_x come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources, including at El Morro National Monument (EPA 2012b).

4.4.2. Data and Methods

The approach we used for assessing the condition of air quality within the park's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2015a,b).

NPS-ARD uses all available data from NPS, EPA, state, and/or tribal monitoring stations to interpolate air quality values, with a specific value assigned to the maximum value within each park. Even though the data are derived from all available monitors, data from the closest stations "outweigh" the rest.

Trends are computed from data collected over a 10-year period at on-site or nearby representative monitors. Trends are calculated for sites that have at least six years of annual data and an annual value for the end year of the reporting period.

Indicators/Measures
Visibility (Haze Index)

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010).

NPS-ARD assesses visibility condition status based on the deviation of the estimated current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human- caused visibility impairment, EPA-454/B003- 005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) =
estimated current Group 50 visibility –
estimated Group 50 visibility
(under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2015a).

For visibility condition assessments, annual average measurements for Group 50 visibility are averaged over a 5-year period at each visibility monitoring site with at least 3-years of complete annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. The maximum value within monument boundaries is reported as the visibility condition from this national analysis.

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the Clean Air Act and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days. Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend.

Indicators/Measures

Level of Ozone (Human Health: Annual 4th-highest 8hr concentration and Vegetation Health: 3-month maximum 12hr W126)

Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, EPA, states, and others. Aggregated ozone data are acquired from the EPA Air Quality System (AQS) database. Note that prior to 2012, monitoring data were also obtained from the EPA Clean Air Status and Trends Network (CASTNet) database.

The primary National Ambient Air Quality Standard (NAAQS) for ground-level ozone is set by the EPA, and is based on human health effects. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb). On October 1, 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb.

The NPS-ARD assesses the status for human health risk from ozone using the 4th-highest daily maximum 8-hour ozone concentration in ppb. Annual 4th-highest daily maximum 8-hour ozone concentrations are averaged over a 5-year period at all monitoring sites. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The ozone condition for human health risk at the park is the maximum estimated value within park boundaries derived from this national analysis.

Exposure indices are biologically relevant measures used to quantify plant response to ozone exposure. These measures are better predictors of vegetation response than the metric used for the human health standard. One annual index is the W126, which preferentially weighs the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours (8AM– 8PM). The highest 3-month period that occurs during the ozone season is reported in "parts per million-hours" (ppm-hrs) and used for vegetation health risk from ozone condition assessments. Annual maximum 3-month 12-hour W126 values are averaged over a 5-year period at all monitoring sites with at least 3 years of complete annual data. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The estimated current ozone condition for vegetation health risk at the park is the maximum value within park boundaries derived from this national analysis.

Indicators/Measures

Wet Deposition (Nitrogen and Sulfur)

Atmospheric wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN) for nitrogen and sulfur wet deposition. Wet deposition is used as a surrogate for total deposition (wet plus dry), because wet deposition is the only nationally available monitored source of nitrogen and sulfur deposition data. Values for nitrogen (N) from ammonium and nitrate and sulfur (S) from sulfate wet deposition are expressed as amount of N or S in kilograms deposited over a one-hectare area in one year (kg/ha/yr). For nitrogen and sulfur condition assessments, wet deposition was calculated by multiplying nitrogen (from ammonium and nitrate) or sulfur (from sulfate) concentrations in precipitation by a normalized precipitation. Annual wet deposition is averaged over a 5-year period at monitoring sites with at least 3 years of annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. For individual parks, minimum and maximum values within park boundaries are reported from this national analysis. To maintain the highest level of protection in the park, the maximum value is assigned a condition status.

Wet deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses. There are no on-site or nearby representative monitors to assess wet deposition trends.

4.4.3. Reference Conditions

The reference conditions against which current air quality parameters are assessed are identified by NPS ARD (2015b) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates a "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant concern." The NPS-ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network.

Ozone

The human health ozone condition thresholds are based on the 2015 ozone standard set by the EPA at a level to protect human health: 4th-highest daily maximum 8-hour ozone concentration of 70 ppb. The NPS-ARD rates ozone condition as "good" if the ozone concentrations are less than 54 ppb, which is in line with the updated Air Quality Index (AQI) breakpoints; "moderate" if the ozone concentration is between 55 and 70 ppb; and of "significant concern" if the concentration is greater than or equal to 71 ppb.

The W126 condition thresholds are based on information in EPA's Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards (EPA 2014). Research has found that for a W126 value of:

- ≤ 7 ppm-hrs, tree seedling biomass loss is ≤ 2 % per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10 % per year in sensitive species.

ARD recommends a W126 of < 7 ppm-hrs to protect most sensitive trees and vegetation and is considered good; 7-13 ppm-hrs to be in "moderate" condition; >13 ppm-hrs is considered to be of "significant concern" (NPS-ARD 2015b).

Wet Deposition

The NPS-ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm, based on studies linking early stages of aquatic health decline correlated with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Schibely et al. 2014). Parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned "good" condition, those with 1-3 kg/ha/yr are

Table 4.4.3-1. Reference conditions for air quality parameters (NPS-ARD 2015b).

Air Quality Indicator	Significant Concern	Moderate	Good
Visibility (dv)	>8	2-8	< 2
Ozone: Human Health (ppb)	≥ 71	55-70	≤ 54
Ozone: Vegetation Health (ppm-hrs)	>13	7-13	<7
Total N and Total S Wet Deposition (kg/ha/yr)	>3	1-3	< 1

assigned "moderate" condition, and parks with depositions greater than 3 kg/ha/yr to be of "significant concern."

4.4.4. Condition and Trend

The values used to evaluate conditions for all air quality indicators and measures are listed in Table 4.4.4-1.

Visibility

The estimated 5-year (2009-2013) value of 3.9 dv for the park's visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition (NPS-ARD 2015c). No visibility trend was reported for the monument, but in considering the overall trend of visibility throughout national parks, NPS-ARD (2013) analyzed visibility data for 157 parks during the period of 2000-2009. During that time, visibility on the clearest days improved at most sites; and visibility on the haziest days was relatively unchanged at many sites, indicating stable or improving visibility conditions.

Ozone

Ozone data used for the condition assessment were derived from estimated five-year (2009-2013) values of 67.3 parts per billion for the 4th highest 8-hour average and 12.3 parts per million-hours for the W126 Index, which resulted in a moderate condition rating for both human and vegetation health (NPS-ARD 2015c).

An ozone risk assessment was conducted by Kohut (2004, 2007) for Southern Colorado Plateau parks, concluding that plants in the monument were at low risk of foliar ozone injury. However, ozone concentrations and cumulative doses at the park are high enough to induce foliar injury to sensitive vegetation under certain conditions (NPS-ARD 2015b). The two plants identified as ozone sensitive at the park during the Kohut (2004) effort are listed in Table 4.4.4-2. An additional 3 plants have also been identified as ozone sensitive at the park and are listed in Table 4.4.4-2 (Bell, in review). Of the five ozone-sensitive plant species, four (80%) are bioindicators, which can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves (NPS-ARD 2006). These species are noted the table.

Wet Deposition

Wet N deposition data used for the condition assessment were derived from estimated five year average values (2009-2013) of 1.7 kg/ha/yr, which resulted in a moderate condition rating (NPS-ARD 2015c). Wet S deposition data used for the condition assessment were derived from estimated five year average values (2009-2013) of 0.8 kg/ha/yr, which resulted in a good condition rating (NPS-ARD 2015c). No trends could be determined given the lack of nearby monitoring stations.

Sullivan et al. (2011a), studied the risk from acidification for acid pollutant exposure and ecosystem sensitivity for Southern Colorado Plateau parks, which included the national monument. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the parks and their inherent sensitivity to the atmospherically deposited chemicals. These risk rankings were considered moderate for acid pollutant exposure at the park and very low for ecosystem sensitivity to acidification.

Sullivan et al. (2011b), also developed risk rankings for nutrient N pollutant exposure, ecosystem sensitivity and park protection to nutrient N enrichment, with an overall

Table 4.4.4-1. Condition results for air quality indicators at El Morro National Monument (NPS-ARD 2015c).

Data Span	Ozone: Human Health	Ozone: Vegetation Health	Visibility	Total N	Total S
2009-2013	Moderate (67.3 ppb)	Moderate (12.3 ppm-hrs)	Moderate (3.9 dv)	Moderate (1.7 kg/ha/yr)	Good (0.8 kg/ha/yr)

Table 4.4.4-2. Ozone sensitive plants found at El Morro National Monument (Bell, in review; Kohut 2004).

Scientific Name	Common Name	Bioindicator
Amelanchier utahensis	Western serviceberry	No
Mentzelia albicaulis	White blazingstar	Yes
Oenothera elata ssp. hookeri	Hooker's evening primrose	Yes
*Pinus ponderosa**	Ponderosa pine	Yes
*Rhus trilobata**	Skunkbush	Yes

*These species were identified by Kohut (2004) as ozone sensitive at El Morro NM. *Rhus trilobata* was not identified by Bell (In Review) as an ozone sensitive plant at the monument.

summary risk of very low for the park. Using three data sets, Landscape Fire and Resource Management Planning Tools Project (LANDFIRE), National Wetlands Inventory, and National Land Cover Data, nitrogen-sensitive vegetation for the monument was identified (E&S Environmental Chemistry, Inc. 2009). The LANDFIRE data set was the only one that contained N sensitive communities, including arid, semi-arid, grasslands, and meadows, for the monument and locations are shown in Figure 4.4.4-1.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-2). Regulatory programs mandating a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012d). A study conducted by Lehmann and Gay (2011), indicated a statistically significant decrease in sulfate concentrations from 1985-2009 in the area surrounding the monument, but an increase in nitrate concentrations, although not statistically significant. It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010).

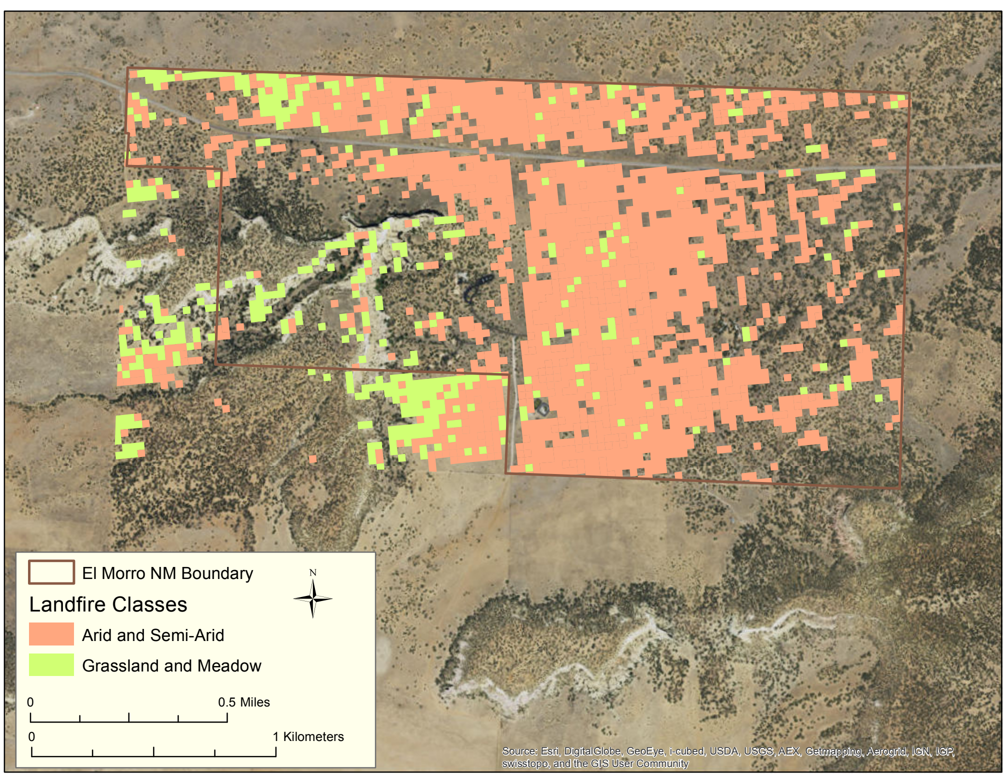

Figure 4.4.4-1. Locations of nitrogen sensitive vegetation at El Morro National Monument using LANDFIRE data.

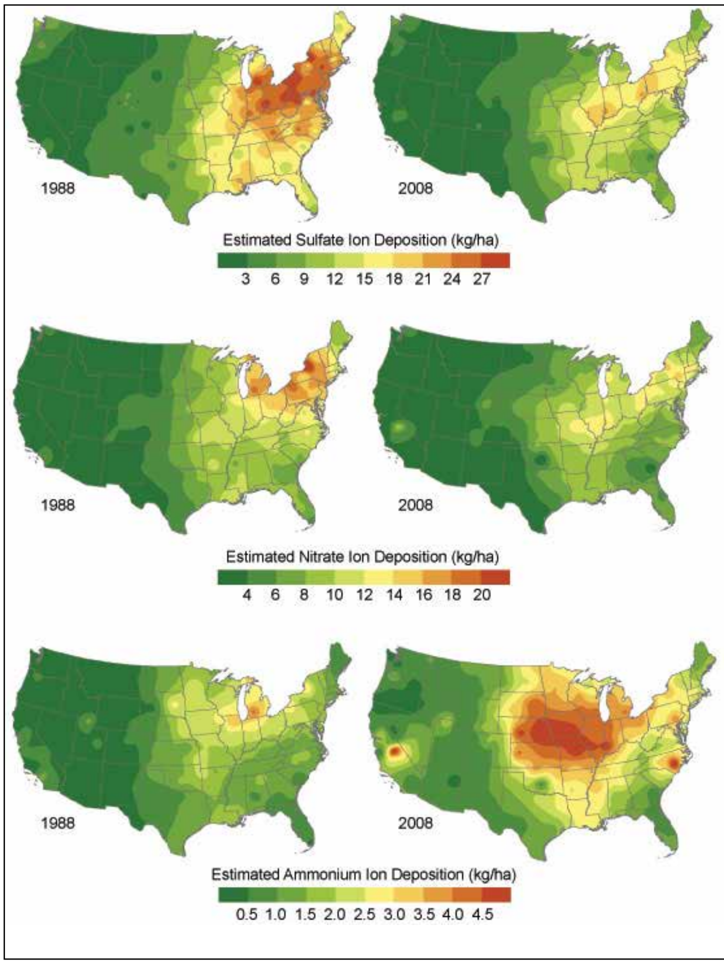

Figure 4.4.4-2. Change in wet deposition levels From 1988-2008 throughout the United States.

Air Quality

Indicators	Measures
Visibility	Haze Index
Ozone	Annual 4th Highest 8 hr. Concentration
	3-month maximum 12hr W126
Atmospheric Wet Deposition	Total N
	Total S

Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

We consider the overall condition of air quality at El Morro National Monument to be of moderate condition, with a medium confidence level because estimates are based on interpolated data from more distant monitors.

Trends cannot be derived for any of the air quality indicators since no monitoring sites are located near enough to be representative of the conditions at the park and on-site monitoring does not occur.

Level of Confidence/Key Uncertainties/ Threats

A key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at the park.

A pulverized limestone crushing facility is located approximately 5 miles to the east of the park. In December 2011, a public notice was posted for a categorical exclusion request for hours, recordkeeping, and hauling modifications to the company's original permit. The New Mexico Environment Department provided a preliminary review of the permit and concluded that "ambient air quality impacts indicates that the facility's air emissions will meet the ambient air quality standards for Nitrogen Oxides (NOx); Carbon Monoxide (CO); Sulfur Dioxide (SO2); Total Suspended Particulate Matter (TSP), Particulate Matter 10 microns or less (PM10), and Particulate Matter 2.5 microns or less (NMED 2011)."

4.4.5. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics. Ksienya Pugacheva, Natural Resource Specialist with Air Resources Division, provided expertise and previous air quality resource condition reviews for NRCAs from which this assessment was based upon. Section was written by Kimberly Struthers, Science Writer at Utah State University.

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Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality Natural Resource Condition Assessment (excerpted from NPS-ARD 2015a).

Indicator	Measure(s)	Condition	Condition Rationale
Visibility	Haze Index	Moderate	Visibility warrants moderate concern at El Morro NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated visibility on mid-range days of 3.9 deciviews (dv) above estimated natural conditions. Trend: No trend information is available because there are not sufficient on-site or nearby visibility monitoring data. Confidence: The degree of confidence at El Morro NM is medium because estimates are based on interpolated data from more distant visibility monitors.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration	Moderate	Human health risk from ground-level ozone warrants moderate concern at El Morro NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated ozone of 67.3 parts per billion (ppb). Trend: No trend information is available because there are not sufficient on-site or nearby ozone monitoring data. Confidence: The degree of confidence at El Morro NM is medium because estimates are based on interpolated data from more distant ozone monitors.
	Vegetation Health: 3-month maximum 12hr W126	Moderate	Vegetation health risk from ground-level ozone warrants moderate concern at El Morro NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated W126 metric of 12.3 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in at El Morro NM were at low risk for ozone damage (Kohut 2007; Kohut 2004). See list of ozone-sensitive plant species. Trend: No trend information is available because there are not sufficient on-site or nearby ozone monitoring data. Confidence: The degree of confidence at El Morro NM is medium because estimates are based on interpolated data from more distant ozone monitors.
Atmospheric Wet Deposition in Total N and Total S	Total N in kg/ha/yr	Moderate	Wet nitrogen deposition warrants moderate concern at El Morro NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet nitrogen deposition of 1.7 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having high sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a). Nitrogen deposition may disrupt soil nutrient cycling and affect biodiversity of some plant communities, including arid and semi-arid and grassland. Trend: No trend information is available because there are not sufficient on-site or nearby deposition monitoring data.Confidence: The degree of confidence at El Morro NM is medium because estimates are based on interpolated data from more distant deposition monitors.
	Total S in kg/ha/yr	Good	Wet sulfur deposition is in good condition at El Morro NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet sulfur deposition of 0.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having very low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011b). Trend: No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. Confidence: The degree of confidence at El Morro NM is medium because estimates are based on interpolated data from more distant deposition monitors.

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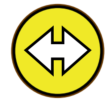
4.5. Geology

Indicators/Measures

- Inscription Rock (4 measures)
- Slope/Cliff Stability (1 measure)

Condition – Trend – Confidence



Moderate - Stable - Medium

4.5.1. Background and Importance

Geologic resources are literally the bedrock of units in the National Park System. They make up the scenery and the landscape that is integral to the significance of most natural areas within the system.

Geology serves as the foundation of ecosystems. Geology is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hill slopes, and flow regimes of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, mining, industry, construction, hunting, fishing, and recreation.

Geologic resources make up our geoheritage. The National Park Service defines geoheritage as "the significant geologic features, landforms, and landscapes characteristic of our nation which are preserved for the full range of values that society places on them, including scientific, aesthetic, cultural, ecosystem, educational, recreational, tourism, and other values" (NPS 2013).

At El Morro National Monument (Figure 4.5.1-1), the monument's primary geologic resources are integral to the cultural significance that led to its protection as a national monument. El Morro ("the headland") is the northern erosional scarp of a cuesta held up by the resistant Dakota Sandstone, which is dipping 3° to the southwest (Anderson et al. 1991). The Dakota Sandstone is thin in El Morro NM, and is only up to 15 m (50 ft) thick. Most of the 60 m (200 ft) height of El Morro consists of the friable Zuni Sandstone (KellerLynn 2012),

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4.5.1-1. El Morro is made up of the Jurassic Zuni Sandstone capped by the Cretaceous Dakota Sandstone.

one of many sandstones with large eolian crossbeds exposed on the Colorado Plateau (Blakey et al. 1988, Lucas and Heckart 2003). The cuesta and the natural setting is one of the fundamental resources and values of El Morro NM (NPS 2014). And while geology impacts the human history of every locale, the approximately 2000 inscriptions, petroglyphs and pictographs, which are among the primary cultural resources at El Morro, are directly on geologic features, leading to an unusually close interplay and interrelationship between cultural resources and geologic resources.

Most of the inscriptions, petroglyphs and pictographs in El Morro NM are found on the section of the Zuni Sandstone cliff-face called Inscription Rock. Inscription Rock is the southeastern and eastern faces of El Morro on either side of the historic pool, with a total length of approximately 500 m (1640 ft). It includes a short section of the north-facing cliff immediately west of North Point. North Point is the tip of the northeast-oriented El Morro fin (Steve Baumann, personal communication, 2015). This point is called the “northeast point” in some studies (e.g., Cross 1996, Fix, 2006, Burris 2007 and others). The faces of both the south-southeast and north-northeast sides of Inscription Rock are controlled by the prominent N65°E joint set (Figure 4.5.1-2). A secondary joint system is at approximately 75° to the primary system at N10°W.

The softness of the Zuni Sandstone was one of the integral characteristics of El Morro, in addition to water availability at the historic pool, that led to it being a natural canvas on which early inhabitants and travelers could leave their mark (NPS 2014).

4.5.2. Data and Methods

We used two indicators to assess the current condition and trend for geology at El Morro NM (Table 4.5.2-1). The first indicator, with four measures, evaluated the condition of Inscription Rock. The second indicator, also with one measure, assessed the condition of slope/cliff stability.

Information on the geology and geohydrology of El Morro NM is available in numerous studies (Table 4.5.2-2). The NPS Geological Resources Inventory (KellerLynn 2012) provided an overview and synthesis of many of the geologic issues at the monument.

Table 4.5.2-1. The indicators and measures used to assess geology condition at El Morro NM.

Indicator	Measures
Inscription Rock	Weathering and Erosion Rates and Processes
	Freeze-Thaw Index
	Geohydrology
	Other Impacts
Slope/Cliff Stability	Rockfall Events

Indicators/Measures
Inscription Rock (4 measures)

The Inscription Rock indicator included four measures: weathering and erosion rates and processes, freeze-thaw index, geohydrology, and other impacts. These measures provided information on the geologic processes and other nongeologic impacts that may impact the condition of Inscription Rock.

Measure
Weathering and Erosion Rates and Processes

The weathering and erosion rates and processes measure evaluated the impact of weathering and erosion agents and processes and their rates on Inscription Rock, and whether they are an issue of concern for the inscriptions, petroglyphs and pictographs on the surface of the Zuni Sandstone.

While concern related to the loss of inscriptions has long existed, geologic studies that focused on petrology of the Zuni Sandstone and the geology and hydrology of El Morro did not take place until the 1990s. Since then, a large number of studies have been conducted that include detailed analysis of many factors that relate to the condition of Inscription Rock.

Austin (1992) completed the first geological and hydrological assessment of El Morro

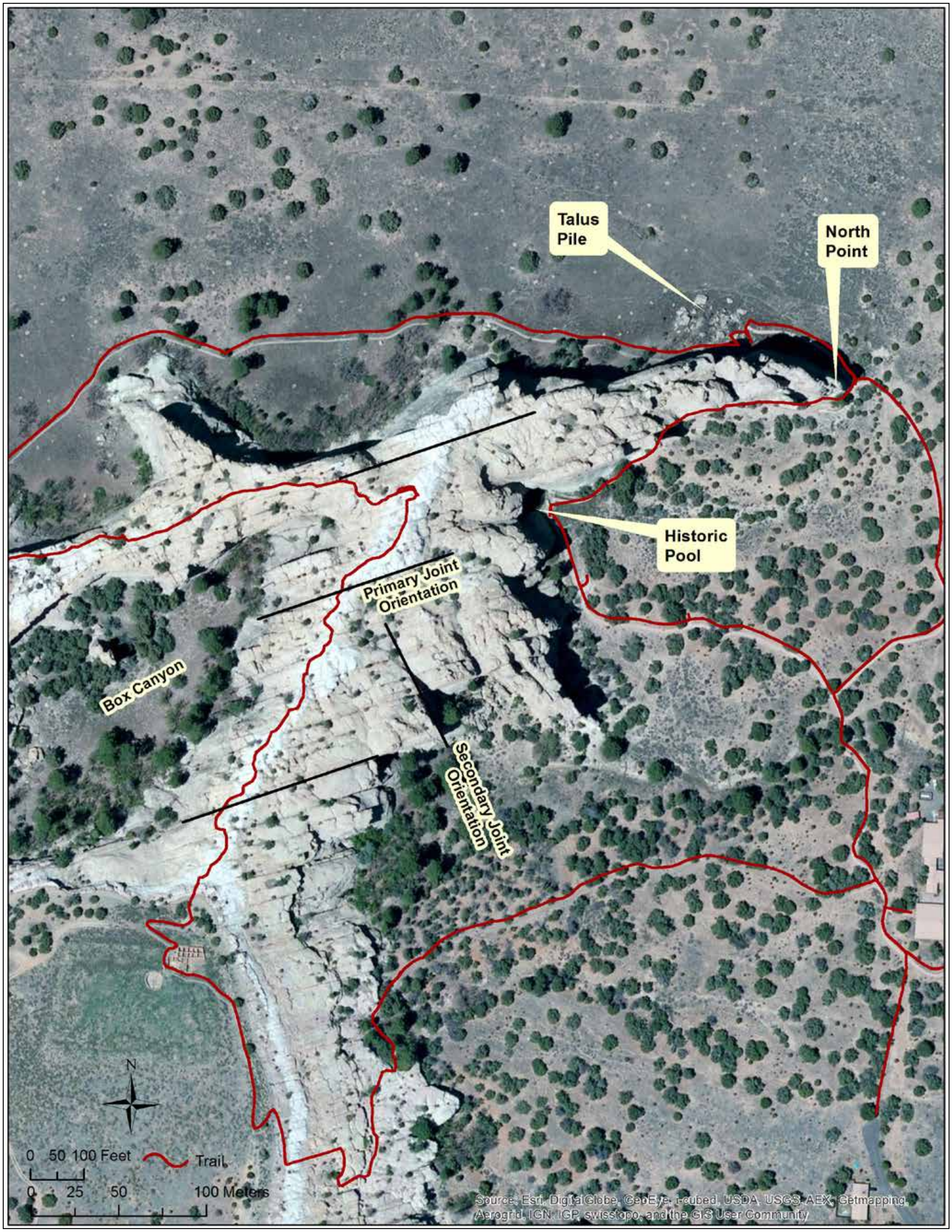

Figure 4.5.1-2. Satellite image of El Morro showing the location of the historic pool, North Point and the talus pile. Inscription Rock is the section of El Morro approximately 500 m on either side of the historic pool. The face of Inscription Rock from the pool to the North Point is controlled by the prominent N65°E joint set. The talus pile marks the end of Inscription Rock on the north face.

Table 4.5.2-2. Studies related to the geology of El Morro NM (including Inscription Rock and the historic pool) and slope/cliff stability.

Study	Author (Year)	Findings
Rock Motion Hazard at selected archeological sites	Wachter (1978)	Report based on a reconnaissance to identify geologic problems that "may threaten visited sites or their safe operation." Author recommended monitoring of the "cracked" column, stating that the crack is visible in 50-year-old photographs, that failure is not imminent, and that motion rate is very slow. Report identified slabbing as a threat to the inscriptions and stated that vertical cliffs should be monitored for slabs that could detach. Woodpecker Rock was also identified as a rockfall hazard.
Historic Structure Report: The Historic Pool	Greene (1978)	Report provided history of the historic pool from its natural appearance, to enlargement via dam construction and arroyo infilling in the1930s, to the reconstruction following the August 10, 1942 rockfall.
Draft Statement for Management	NPS (1989)	Statement says that natural weathering is eroding many inscriptions and that the surface and subsurface hydrology are impacting the fragile sandstone surface. It also says that vandalism impacted the rock surface, but to date, had not seriously impacted the historic inscriptions.
Geological and Hydrological Assessment	Austin (1992)	The petrology of the Zuni Sandstone was described as a fine-grained eolian quartz sandstone with chlorite and minor smectite. Kaolinite and chlorite are the primary cementing agents with a small amount of calcite cement present. Runoff during rain events and the freeze-thaw cycle are weathering and erosion agents, and deposition of clay wash occurs on the surface after evaporation of moisture.
Assessment of Deteriorative Factors Affecting the Inscriptions	Padgett (1992)	Report described past documentation of the inscriptions and includes a history of the conservation methods applied to the inscriptions. Its listed natural features/processes impacting the inscriptions including clay wash, insect activity, microflora, moisture, moisture on exposed surfaces, movement of water, salt, spalling and microspalling. Human-related impacts included removal of modern names and darkening of inscriptions. It listed vegetation and the pool as factors potentially impacting the inscriptions. The presence of vegetation was identified as having a complex interrelation with microflora and as a windbreak. The report also listed potential conservation actions that could be taken.
Stratigraphy, Sedimentology and Surface Water Quality	Cross (1996)	Report included detailed descriptions of the stratigraphy and sedimentology of the Zuni Sandstone exposed along Inscription Rock. The deterioration of the outcrop and the inscriptions was identified as a result of the complex interplay of existing geological conditions along with fluctuating environmental conditions. Erosional and weathering of Inscription Rock was identified as consisting of 3 main processes: granular disintegration, wholesale wasting and spalling. North Point has eroded more rapidly than any other place at El Morro.
Review of Potential Rockfall Hazards	Eillis (2000)	Report reviewed previous investigations regarding rockfall hazards at ELMO, summarized the history of major rockfalls, identified areas that have areal rockfall hazards and identified locations with specific rockfall hazards in which individual blocks or wedges were identified as potentially unstable. Ellis reported that a block has fallen partway down the cracked column since the Wachter (1978) report. He recommended monitoring of the cracked monolith, rerouting of the trail around other identified hazards, closure of the trail during and after periods of heavy rains, maintaining detailed logs of rockfalls, and informing visitors of the rockfall hazard along the trail.
Impact of microflora (lichens) on the condition of the sandstone and inscriptions	St. Clair and Knight (2001)	Authors identified 36 lichen species growing on Inscription Rock. These species contribute to the erosion and deterioration of Inscription Rock by wetting and drying and production of secondary chemicals. Authors stated that development of vascular plant vegetation near Inscription Rock seemed to promote the growth of microflora in several areas.
Hydrology and Geology of Inscription Rock and Site Management Recommendations	Pranger (2002)	Report summarized the previous research on Inscription Rock's geology, weathering and erosion. Pranger also mapped the small watersheds of Inscription Rock and provided a list of recommendations/remediation measures that may protect the inscriptions from natural weathering and erosional processes.
Preliminary Vibration Study	King and King (2003)	Report identified the natural frequencies of the columns (which are a function of height), documented the known sources of vibrations, developed the attenuation function for ELMO, and provided recommendations. Report stated that the natural frequencies of the rock columns is far below those induced by traffic, that the inscriptions would be at risk if they were within 61 m (200 ft) of a roadway (or 61 m (300 ft) of a potholed roadway), and, due to the distance to the limestone quarry, the mining operation should not be a risk to the inscriptions.

Table 4.5.2-2 continued. Studies related to the geology of El Morro NM (including Inscription Rock and the historic pool) and slope/cliff stability.

Study	Author (Year)	Findings
The Centennial Project: Inscription Monitoring and Biodeterioration Investigation	Fix (2006)	Fix conducted an assessment of inscription panels and investigated lichen growth. Fix re-assessed 89 sites that were monitored by Padgett (1992) and found that 52 panels (62%) had experienced loss, including 32 panels (40%) that had experienced major loss. Heavy loss of panels had occurred near the pool and at North Point. Panels were also assessed for "edge delamination" (exfoliation). 32 (28%) of 111 panels were exfoliated. Fix recommended gathering information related to microclimates that may impact inscription loss, and removal of some vegetation near the panels. Study did not find a significant increase in the amount of lichen in panels that were documented by St. Clair and Knight (2001), tested lichen removal techniques on a boulder, and made recommendations for further lichen investigation and actions. Report stated that the condition of salts needed further investigation.
Analysis of Sandstone Deterioration at the Northeast Point	Burris (2007)	Burris' Masters of Science thesis is a detailed analysis of the weathering and erosion of Inscription Rock at the North Point. Author analyzed a sample of the Zuni Sandstone from the North Point, and identified the major weathering and erosional processes impacting the NE point as granular disintegration, flaking, contour scaling, and alveolar erosion. Clay wash, efflorescence (salt crystallization), and biological colonization were identified as additives to the surface of the sandstone. Burris documented significant erosion at North Point between 1955 and 2007 and noted the unique microclimate of the site.
Hydrological Investigation	Van Dam and Hendrickx (2007)	Geohydrologic study conducted to determine the source of water in the pool and whether there is a perched water table near North Point. Findings were that there was no permanent perched water table near the pool, that the source of the water in the pool was rainwater with an unknown quantity of delayed inflow via infiltration through the Zuni Sandstone, that temporary perched water tables do form near the cliff during periods of heavy precipitation, and that there is no temporary or permanent perched water table near North Point.
Cultural Landscape Study and Site Management Recommendations for Inscription Trail Loop	D'Ambrogi (2009)	Report cited a 2006 ELMO centennial inscription monitoring and biodeterioration investigation by Fix. It states that ELMO has put large scale preservation actions on the inscriptions on hold until the completion of a General Management Plan. It also states that ELMO has started to remove large vegetation adjacent to the cliff face because shade from the trees slows evaporation rates and promotes lichen growth in order to slowly as to not "shock" the rock face.
Climate Change and the Deterioration of Cultural Resources	Baumann and Kendrick (2010)	The authors state that deterioration of the historic inscriptions of El Morro has accelerated rapidly in the past 20 years or so, based on formal condition assessment projects and on anecdotal observations made over many years. The wettest period in the last 2100 years was identified as the possible cause of this increase in rate of loss of historic inscriptions.
Geologic Resources Inventory	KellerLynn (2012)	GRI identified the following geologic issues: loss of inscriptions, rockfall, and vibrations from mining-related activities including truck traffic on Hwy 53. Report summarized findings from previous reports including Wachter (1978), Austin (1992), Padgett (1992), Cross (1996), and Pranger (2002).
Summary and Categorization of Documented Geologic Hazards	Schaller et al. (2014)	Report listed the documented geologic hazards at each NPS unit. Rockfall was the only geologic hazard identified at ELMO. Report did not include information on the level of hazard.
Hydrogeologic Study	Kelley (2015)	Goals of the study are to assess the scale and complexity of the flow system within Inscription Rock; identify direct flow paths that convey water to the areas of interest; and assess the relative importance of water movement though fractures versus the matrix. Project tasks include evaluation of past research, rock characterization, including identification of the type of salts involved in alveolar erosion and quantification, if possible, and geochemical characterization of surface water, pool water, and shallow groundwater to try to identify the groundwater component, if any, for the pool.

NM. The Zuni Sandstone was described as a fine-grained quartz sandstone with chlorite and minor smectite (swelling clay). Kaolinite and chlorite are the primary cementing agents along with a small amount of calcite (Austin 1992).

A detailed stratigraphic analysis of the Zuni Sandstone was completed by Cross (1996), along with detailed sketch maps of the cliff-faces that make up Inscription Rock. He also documented the deterioration of the Zuni Sandstone in the monument as a complex interaction of geology and varying environmental conditions. Granular disintegration, wholesale wasting and spalling were identified as three main processes weathering and eroding the Zuni Sandstone.

Pranger (2002) conducted an on-site evaluation in a technical assistance request to assess the impact of water flowing over Inscription Rock on inscriptions. Pranger summarized the geology and hydrology of the monument and included recommendations for actions that monument staff could take to minimize damage to the inscriptions from natural geologic processes.

In an extensive re-assessment of 89 inscription panels that had been previously assessed by Padgett (1992), Fix (2006) reported that 31 panels (34.8%) had experienced major loss, and an additional 21 panels (23.6%) had undergone minor loss (Table 4.5.2-3). Fewer panels containing Spanish inscriptions or rock art (petroglyphs and pictographs) experienced loss than panels that only contained inscriptions from the US period (1846-1906).

Additionally, 32 panels were identified as being "hollow or unstable;" e.g., as panels that were either partially delaminated or exfoliated from the surface of Inscription Rock (Fix 2006).

Burris (2007) conducted an extensive study of deterioration of the North Point of Inscription Rock. The study included a petrologic study of a sample from the point, a compilation of the weathering and erosional agents and an assessment of the condition of North Point. Burris reported that North Point had changed significantly since the mid-1950s (Figure 4.5.2-1).

Baumann and Kendrick (2010) used the long-term dendrochonological record from El Malpais NM showing a wet period from about 1800 to the late 1990s and correlated it to the loss of inscriptions at El Morro, stating that the deterioration of inscriptions has accelerated rapidly in the last 20 years or so.

Shari Kelley and Talon Newton of the New Mexico Bureau of Geology and Mineral Resources are conducting a hydrogeologic study at El Morro (Kelley 2015). The goals of the project include an assessment of water flow paths within Inscription Rock, determination of the role of fracture flow versus matrix flow, rock characterization, and identification of the salts involved in alveolar erosion, if possible (Figure 4.5.2-2).

Measure
Freeze-Thaw Index

The impact of frost weathering on Inscription Rock is measured via the freeze-thaw index.

Table 4.5.2-3. Inscription panels that had experienced loss in 2006 compared to previous assessment by Padgett (1992).

Panels	# of Panels	% All Panels with Loss (N=89)	# of Panels with Only US Period Inscriptions with Loss[1]	% Panels with Only US Period Inscriptions with Loss[1] (N=55)	# of Panels Containing Spanish Inscriptions with Loss[2]	% Panels Containing Spanish Inscriptions with Loss[2] (N=19)	# of Panels Containing Rock Art with Loss[3]	% Panels Containing Rock Art with Loss (N=15)[3]
Total Panels with loss	52	58.4%	39	70.9%	7	36.8%	6	40.0%
Panels with major loss	31	34.8%	26	47.3%	5	26.3%	0	0.0%
Panels with minor loss	21	23.6%	13	23.6%	2	10.5%	6	40.0%

Data are from Fix (2006).

[1]US period inscriptions were made 1846 - 1906.

[2]Spanish inscriptions were made 1605 - 1846.

[3]Rock art (petroglyphs and pictographs) at El Morro NM is not dated. Much of the rock art may be prehistoric.

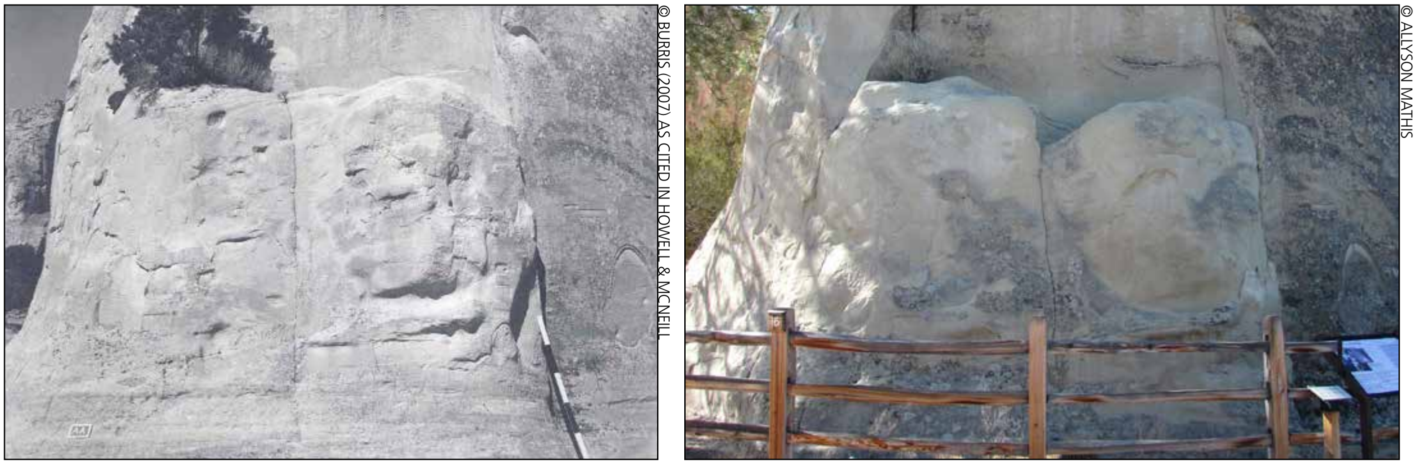

Figure 4.5.2-1. North Point of Inscription Rock in 1955 (left) and February 2015 (right). Note the significant erosion of the bench cut by the vertical joint in the center of the images and that a significant block fell from the upper left of the photos between 1955 and 2015, to the left of where the small tree was present in 1955.

The freeze-thaw index is the number of 24-hour periods per year when temperatures pass across the freezing threshold (Santucci et al. 2009). If climate change would cause an increase in the freeze-thaw index, it would have a negative impact on sensitive geologic resources such as Inscription Rock. If it decreases the freeze-thaw index, then the rate of weathering and erosion due to physical factors theoretically should be decreased.

The Period of Record Daily Climate Summary for the El Morro National Monument weather station, a National Weather Service cooperative station, provides average daily maximum and minimum temperatures for the period of record from 1938 to present (Western Regional Climate Center 2015). The 30-Year Daily Temperature and Precipitation Summary provides average daily maximum and minimum temperatures for 1981 to 2010.

Using average daily high and low temperatures for the period of record, 208 days per year had temperatures that crossed the freezing threshold for the period of record. For the 1981 to 2010 interval, there were 202 days per year when the average temperature crossed the freezing point (Western Regional Climate Center 2015) (Table 4.5.2-4).

The climate change exposure brief for El Morro NM (Monahan and Fisichelli 2014) provided information on the climate-change exposure by evaluating 25 climate variables, including temperature, that experienced "extreme" values in the past 10-30 years relative to the historical range of variability. "Extreme" conditions are defined as exceeding 95% of the historical range.

Measure
Geohydrology

The geohydrology measure evaluated the impact that geohydrology has on Inscription Rock. El Morro's geology and geohydrology are intricately intertwined, as evidenced by the numerous studies that have addressed components of each, including Cross (1996), Pranger (2002), Burris (2007) and Kelley (2015). Additional studies that focused exclusively on geohydrology have been conducted, including van Dam and Hendrickx (2007). The hydrology of the historic pool will be addressed in Section 4.6.

Cross (1996) identified groundwater sapping features on Inscription Rock, including cove-style features. Measurements of the permeability of the Zuni Sandstone found a general trend in decreasing permeability

Table 4.5.2-4. Freeze-Thaw Index for El Morro NM.

Interval	Number of days average daily temperatures cross freezing threshold
Period of Record	208
1981-2010	202

Data from Western Regional Climate Center (2015).

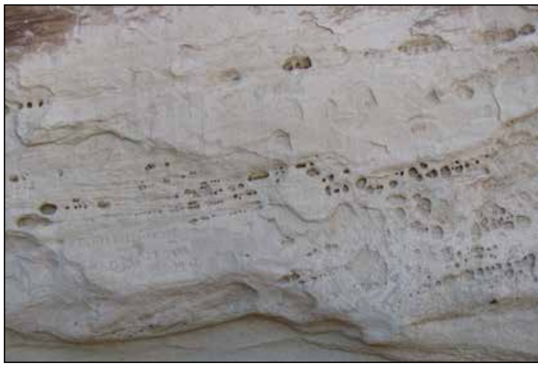

Figure 4.5.2-2. Alveolar erosion near an inscription.

upsection. The lowest permeability occurs along bounding surfaces. Grain size increases upsection (Cross 1996). Cross suggested that the high level of inscription loss at North Point may result, in part, from capillary action ("rising damp") from groundwater in the alluvium there.

Hydrogeology was a major part of the NPS technical report (Pranger 2002). The report summarized the interrelationship between hydrogeology and the erosion and weathering of El Morro. Pranger also completed a drainage network map for Inscription Rock (Figure 4.5.2-3). Inscription Rock drains an area of 4.97 acres, including 3.22 acres that drain into distinct channels that cascade down the cliff-face, and 1.75 acres that flow diffusely over the rock surface. The watershed for the pool is 1.55 acres.

Van Dam and Hendrickx (2007) conducted a study to determine the origin of the water in the historic pool and the geohydrology of Inscription Rock. They found that the source of most of the water in the pool was surface flow from rainwater, but could not determine the influx of groundwaters that flowed through Inscription Rock. Through the use of piezometers and other techniques, they determined that there is only a temporary perched water table near the pool, and that there is not a perched water table near North Point. Electromagnetic induction measurements along three lines near the pool and North Point showed that soil water levels increased towards the cliff-face. An attempt to test the hydraulic properties of the Zuni Sandstone failed because the samples disintegrated during testing (van Dam and Hendrickx 2007).

Kelley (2015) will evaluate the importance of water flow via the jointing/fracture systems in the Zuni Sandstone versus matrix flow. Preliminary findings are that water in the historic pool and in nearby piezometers both have very low Total Dissolved Solids and that there is a perched aquifer near the pool (Shari Kelley, personal communication, 2015).

Measure
Other Impacts

A variety of other potential sources of unnatural/non-geologic impacts to Inscription Rock and/or the inscriptions, petroglyphs and pictographs have been identified (Table 4.5.2-5). These potential impacting agents include increased vascular vegetation near the cliff-face that alter rock surface microclimate (Padgett 1992, Fix 2006, D'Ambrogi 2009, and David Hays, personal communication, 2015), ground vibrations from traffic on New Mexico Highway 53 and/or blasting at the Tinaja Pit Quarry (King and King 2003, KellerLynn 2012, NPS 2014 and David Hays, personal communication, 2015), vandalism (NPS 1989, D'Ambrogi 2009, and NPS 2014), increased lichen and biofilm growth on the rock surface (Padgett 1992, St. Clair and Knight 2001, Fix 2006, Burris 2007, and Steve Baumann, personal communication, 2015), and change in precipitation due to climate change (Baumann and Kendrick 2010).

<u>Increased vascular vegetation</u>

Padgett (1992), Fix (2006) and D'Ambrogi (2009) discussed the issue of whether increased vascular vegetation near the face of Inscription Rock was directly or indirectly impacting the deterioration of inscriptions. Increased vascular vegetation near Inscription Rock, as shown via comparison to historic photographs (Steve Baumann, personal communication, 2015) may impact microclimates on the surface of Inscription Rock by protecting the cliff-face from wind (Padgett 1992), via a relationship between the presence of vascular vegetation and

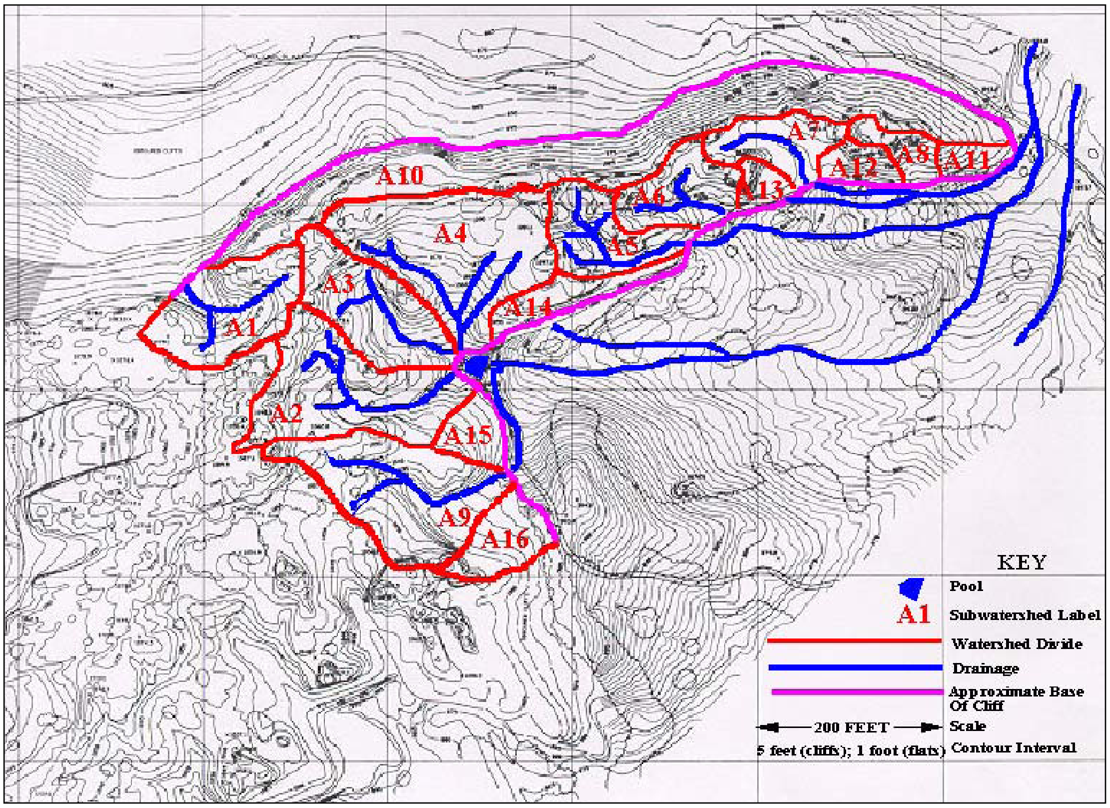

Figure 4.5.2-3. Watersheds on top of Inscription Rock and their drainage systems. The pool is fed by three watersheds. The arroyo that drains the pool joins drainages systems from two other watersheds near North Point (Pranger 2002).

microflora on the rock surface (Padgett 1992; Fix 2006; D'Ambrogi 2009), by damaging the surface through mechanical abrasion (Fix 2006), by shading the rock thereby lowering the temperature and slowing evaporation of moisture from the rock surface (Fix 2006; D'Ambrogi 2009, David Hays, personal communication, 2015), and/or by increasing the wildfire hazard (D'Ambrogi 2009).

Ground Vibrations

In 2003, NPS managers at El Morro NM were concerned about a proposed expansion at the Tinaja Pit gravel quarry located 11.67 km (7.25 mi) east of Inscription Rock (NPS 2006). Induced ground vibrations from blasting at the quarry were among the areas of concern for the NPS (NPS 2006). Induced ground vibrations causing rockfall was also a concern of monument staff in 2015 (David Hays, personal communication, 2015).

King and King (2003) completed a preliminary vibration study at El Morro NM. The researchers measured the natural resonance of four partially attached sandstone "columns" of Inscription Rock, completed an attenuation study, and measured the intensity of induced ground vibrations at two sites: Site B on the north side of Inscription Rock and site C on top of the cuesta).

Table 4.5.2-6 reports the peak particle velocity (ppv) of induced ground vibrations measured at sites B and C for ambient background, for hikers on the Inscription Rock Loop Trail, for regular traffic, and for loaded gravel trucks (King and King 2003). Ppv is the maximum vibration amplitude, which results from the energy of the vibrations, and relates to structural stress (Randy Stanley, personal communication, 2015).

Induced ground vibrations from measured sources were very low at both sites. Ppv for hikers on the trail near site B were 0.01 mm/sec and 0.036 mm/sec near site C. Average traffic on Highway 53 caused induced vibrations of less than 0.07 mm/sec at site B and 0.03-0.048 mm/sec at site C. Vibrations caused by loaded

Table 4.5.2-5. Other potential impacts to Inscription Rock.

Process	Reason for Concern
Increased vascular vegetation near Inscription Rock	Increased vascular vegetation near the face of Inscription Rock may change the microclimate on the rock surface, may mechanically abrade the sandstone surface, and may promote growth of lichen (Padgett 1992, Fix 2006, D'Ambrogi 2009, and David Hays, personal communication, 2015).
Ground Vibrations	The inscriptions may be at risk for accelerated erosion caused by, or contributed to from induced ground vibrations from traffic from heavy trucks on Highway 53 and from blasting at Tinaja Pit quarry (King and King 2003; KellerLynn 2012, NPS 2014, and David Hays, personal communication, 2015).
Vandalism	Inscription Rock is vulnerable to damage from vandalism (NPS 1989; NPS 2014).
Increased lichen and biofilm growth	Increased lichen growth on or near inscriptions, petroglyphs and pictographs may adversely impact them (Padgett 1992, St. Clair and Knight 2001, Fix 2006, Burris 2007, and Steve Baumann, personal communication, 2015).
Change in precipitation due to climate change	A large number of inscriptions were lost in 1979, during the wettest interval in the last 2100 years, a period that correlates with a rapid acceleration of deterioration of inscriptions (Baumann and Kendrick 2010).

gravel trucks were measured at 0.38-0.64 mm/sec at site B and 0.14-0.19 at site C. Vibrations had greater amplitude at site B than site C, most likely because this location was closer to the source of the vibrations.

Additional information about the King and King (2003) study is in Appendix E.

Vandalism

The 1989 Draft Statement for Management noted that vandalism had impacted Inscription Rock, but that graffiti was easily removed with a wire brush (NPS 1989). D'Ambrogi (2009) and the Foundation Statement (NPS 2014) stated that the rock surface is still vulnerable to damage by vandalism.

Increased Lichen and Biofilm Growth

Padgett (1992) documented that microflora (lichen) covered, or was in close proximity to, many of inscriptions on Inscription Rock (Figure 4.5.2-4).

St. Clair and Knight (2001) completed the first intensive study of microflora on Inscription Rock. Thirty-six species of lichen in 17 genera were observed. They determined that lichens were responsible for degradation of the sandstone and for impact to inscriptions. Wetting and drying (swelling and contracting of lichens) contribute to mechanical erosion, and production of secondary chemicals by lichens degrades sandstone cement. The authors observed that shading by vascular vegetation seemed to promote lichen growth, a concern shared by later researchers including Fix (2006) and D'Ambrogi (2009). Growth study plots were observed for one year and showed minimal increase (St. Claire and Knight 2001).

Fix's (2006) assessment of inscription panels at El Morro included lichen growth. Only 25 of the 89 panels (28.1%) previously recorded by Padgett (1992) showed an increase in lichen (Table 4.5.2-7). A slightly smaller percentage of panels with lichen growth had experienced loss (56.0%) than panels without an increase in lichen (59.4%).

Table 4.5.2-6. Induced vibrations measured at two sites at El Morro NM (King and King 2003).

Location/Source	Site B ppv (mm/sec)	Site C ppv (mm/sec)
Ambient background	0.0080	0.0094
Ambient background with wind	--	0.0200
Hikers on trail[1]	0.0100	0.0260
Average traffic on Hwy 53[2]	<0.0700	0.03-0.0480
Loaded gravel truck on Hwy 53	0.380-0.640	0.140-0.190

[1]Measurements were for 5 hikers on the trail for site B, and 2 people on the trail for site C.

[2]Average traffic was 2 automobiles and an empty gravel truck and 2 automobiles and a pickup truck for site C.

Fix (2006) reported that sites monitored by St. Clair and Knight (2001) did not have a significant increase in lichen growth. Fix also conducted lichen removal tests on two boulders and indicated that future monitoring was needed to determine the results. In 2015, Steve Baumann (personal communication) said that removal caused more damage to Inscription Rock than the lichens did.

Burris (2007) reported that lichens were especially abundant at North Point and that microflora appear to have a protective quality there. Areas covered with lichen did not experience granular disintegration. However, a type of exfoliation, incipient spalling, was associated with heavy lichen growth.

<u>Change in Precipitation Due to Climate Change</u>

Baumann and Kendrick (2010) used the extensive tree-ring chronology from El Malpais NM that showed that the greatest rainfall in the 2100-year chronology occurred between 1978-1992 (Grissino-Mayer 1995), a time period they believed correlated with a rapid acceleration of deterioration of inscriptions at El Morro, as documented via formal condition assessments and anecdotal observations (Baumann and Kendrick 2010).

A significant loss of inscriptions occurred at North Point in 1979 (Baumann and Kendrick 2010). The year 1979 was the fourth wettest on record (1938-present) (Western Regional Climate Center 2015); however, five years during the 1978-1992 wet period had below average precipitation (Western Regional Climate Center 2015). Between 2000 and 2014, El Morro NM experienced drought conditions, with 10 years of below average precipitation (Romme and Jacobs 2015). The climate change exposure brief for El Morro NM reported that no precipitation variables were extreme wet or extreme dry for the period of record (1938-present) (Monahan and Fisichelli 2014).

Information on precipitation from 1938 to present is available from the Western Regional Climate Center (2015), with decadal summaries from 1950 to 2014 compiled by Romme and Jacobs (2015) (Table 4.5.2-8).


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Figure 4.5.2-4. Microflora (lichen) on inscriptions and the surface of Inscription Rock near North Point.

Data on panels that had experienced loss between 1992 and 2006 is available in Fix (2006).

Indicator
Cliff/Slope Stability

Rockfall events have been documented at El Morro NM since at least August 1942 when a large rockfall destroyed the dam at the historic pool (Greene 1978). Wachter (1978) completed the first study related to rock motion hazard at El Morro, noting the “cracked” monolith or partially-detached column (Figure 4.5.2-5) along the southeast face of Inscription Rock, approximately 40 m (120 ft) west of North Point. While the crack was visible in photos from the 1930s, the sharp edges and hair-like cracking at the base suggested more recent instability. Watcher (1978) recommended monitoring of this column and regular examination of the cliff-face for slabs that could fall. He noted that several slabs on the north face of Inscription Rock probably presented a greater rockfall potential than the cracked column.

In a USGS review of rockfall hazards at El Morro NM (Ellis 2000), general and specific rockfall hazards were identified, along with

Table 4.5.2-7. Inscription panels with and without increased lichen that had experienced loss in 2006 compared to previous assessment by Padgett (1992).

	Panels	# of Panels with Loss	% Panels with Loss[1]	# of Panels with Only US Period Inscriptions with Loss	% Panels with Only US Period Inscriptions with Loss[2]	# of Panels Containing Spanish Inscriptions with Loss	% Panels Containing Spanish Inscriptions with Loss[3]	# of Containing Rock Art with Loss	% Panels Containing Rock Art with Loss[4]
Panels with Increased Lichen	Total Panels with loss	14	56.0%	13	72.2%	1	25.0%	0	0.0%
	Panels with major loss	9	36.0%	8	44.4%	1	25.0%	0	0.0%
	Panels with minor loss	5	20.0%	5	27.8%	0	0%	0	0.0%
Panels without Increased Lichen	Total Panels with loss	38	59.4%	26	70.3%	6	40.0%	6	50.0%
	Panels with major loss	22	34.4%	18	48.6%	4	26.7%	0	0.0%
	Panels with minor loss	16	25.0%	8	21.6%	2	13.3%	6	50.0%

Data are from Fix (2006).

[1]N = 25 for panels with increased lichen. N = 64 for panels without increased lichen

[2]US period inscriptions were made 1846 - 1906. N = 18 for panels with increased lichen. N = 37 for panels without increased lichen.

[3]Spanish inscriptions were made 1605 - 1846. N = 4 for panels with increased lichen. N = 15 for panels without increased lichen.

[4]Rock art (petroglyphs and pictographs) at El Morro NM is not dated. Much of the rock art may be prehistoric. N = 3 for panels with increased lichen. N = 12 for panels without increased lichen.

the observation that viewing the inscriptions requires public access to the base of the cliff.

Ellis (2000) summarized known rockfalls at El Morro, including the 1942 event, a 1978 rockfall documented by Wachter (1978), and a 1999 rockfall along the Inscription Trail (Figure 4.5.2-6). The large rockfall that created the talus deposit (Figure 4.5.1-2) on the north side of Inscription Rock, and for which the cliff-face still has visible scars, must have happened at some point prior to 1629, as that is the age of the oldest inscription on cliff surface (Ellis 2000).This surface still has visible conchoidal fractures and has little lichen, biofilm and/or desert varnish on it. Another significant rockfall occurred in 2013 that damaged the Inscription Loop Trail (Figure 4.5.2-7).

Ellis' rockfall hazards review included a detailed history of the cracked partially-detached column, including instrumental monitoring efforts that were undertaken in the 1980s (Ellis 2000). Ellis could not determine conclusively if outward rotation had occurred in the crack since Wachter's (1978) report, but noted that a small wedge had fallen a few cm (inches) in the crack. While rockfall could occur at any time and failure did not seem imminent, movement along this crack could precede failure, making instrumental monitoring a viable management strategy (Ellis 2000).

Table 4.5.2-8. Decadal Precipitation at El Morro NM 1950-2014 (Romme and Jacobs 2015).

Period	Average Total Annual Precipitation (inches)	Number of Years Having Below-Average Total Annual Precipitation
1950-1959	11.36	9 out of 10
1960-1969	12.79	6 out of 10
1970-1979	14.00	5 out of 10
1980-1989	15.78	3 out of 10
1990-1999	15.81	3 out of 10
2000-2009	13.25	7 out of 10
2010-2014	12.64	3 out of 5

Ellis (2000) identified the north face of Inscription Rock as an area of active hazard, with numerous overhanging slabs, and made a recommendation that the trail in this section be closed in periods of freeze-thaw cycles. Regular inspection of the cliff-face and documentation of rockfall events were also recommended. El Morro NM staff keep an informal log of rockfall events (Steve Baumann, personal communication, 2015).

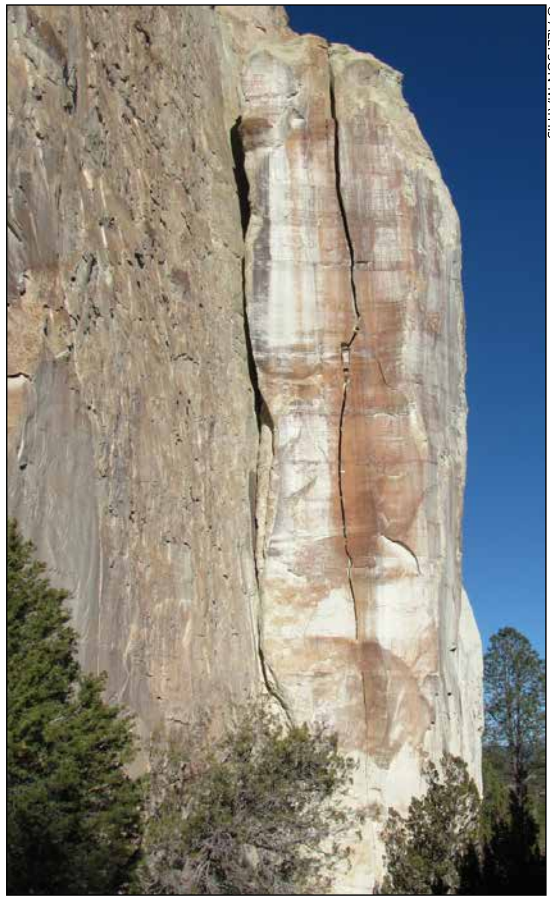

Figure 4.5.2-5. The "cracked" column or monolith along the Inscription Trail.

4.5.3. Reference Conditions

The reference conditions by which geology conditions for El Morro NM were assessed are listed in Table 4.5.3-1. Geologic resources can be sensitive or robust depending on how easily they may be damaged, and some types of resources may be more vulnerable to damage than others (Gray 2005). The significance of the inscriptions, petroglyphs and pictographs at El Morro NM, which are one of the unit's fundamental resources and values (NPS 2014), informed our formulation of reference conditions for Inscription Rock. These inscriptions, petroglyphs and pictographs were carved into the Zuni Sandstone at Inscription Rock. Inscriptions have experienced loss and deterioration due to natural geologic processes (Padgett 1992, Fix 2006, Burris 2007 and NPS 2014).

In most park areas, geologic features that are in a natural state and are subjected to natural processes are considered to be in good condition. At El Morro NM, measures for the Inscription Rock indicator were only considered in good condition if they were not of concern to the inscriptions, petroglyphs and pictographs or only had extremely localized impacts to Inscription Rock, even if they were in natural condition. If there were some areas of moderate concerns related to the inscriptions, petroglyphs and pictographs or a medium level of impact to Inscription Rock, the condition was considered to be moderate. A condition of significant concern existed when significant impacts to the inscriptions, petroglyphs and pictographs or to Inscription Rock were identified.

Figure 4.5.2-6. The block that fell in 1999 was estimated to weigh 900 kg (2000 lbs). The rockfall scar was still visible in February 2015 (Ellis 2000).

Within the other impacts measure, specific reference conditions for induced ground

Table 4.5.3-1. Reference conditions used to assess the current condition of geology for each indicator.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Inscription Rock	Weathering and Erosion Rates and Processes*	The processes of weathering and erosion and their rates at Inscription Rock are in a generally natural state/rate and are not an area of concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.	The processes of weathering and erosion and their rates at Inscription Rock are in a generally natural state/rate and are an area of slight to moderate concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.	The processes of weathering and erosion and their rates at Inscription Rock are in a generally natural state/rate and are an area of concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.
	Freeze-Thaw Index	The average number of days per year that go through the freeze-thaw cycle decrease or remain constant compared to the period of record and is not an area of concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.	The average number of days per year that go through the freeze-thaw cycle increase slightly compared to the period of record and is an area of slight to moderate concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.	The average number of days per year that go through the freeze-thaw cycle increase compared to the period of record and is an area of concern related to the inscriptions, petroglyphs and pictographs on Inscription Rock.
	Geohydrology	The geohydrology of Inscription Rock and surroundings are in mostly natural condition. Modifications to the historic pool and/or groundwater system by pool enlargement and arroyo infilling have had only localized impacts on Inscription Rock.	The geohydrology of Inscription Rock and surroundings are slightly to moderately modified from natural condition. The modifications to the historic pool and/or groundwater system by pool enlargement and arroyo infilling have had medium impacts on Inscription Rock.	The geohydrology of Inscription Rock and surroundings are not in natural condition. The modifications to the historic pool and/or groundwater system by pool enlargement and arroyo infilling have had substantial impacts on Inscription Rock.
	Other Impacts	Inscription Rock is in a generally natural condition. Vegetation near the cliff-face, lichens, and vandalism have, at most, extremely localized impacts, if any at all. Ground vibrations from anthropogenic sources and other unnatural effects do not impact the natural condition of geologic features or the inscriptions, petroglyphs and pictographs. Precipitation levels from climate change do not adversely impact Inscription Rock	Inscription Rock has been modified slightly from a generally natural condition. Vegetation near the cliff-face, lichens, and vandalism have slightly impacted geologic features. Ground vibrations from anthropogenic sources and other unnatural effects slightly impact the natural condition of geologic features or the inscriptions, petroglyphs and pictographs. Precipitation levels from climate change slightly impact Inscription Rock	Inscription Rock has been modified from a generally natural condition. Vegetation near the cliff-face, lichens, and vandalism have impacted the geologic features. Ground vibrations from anthropogenic sources and other unnatural effects impact the natural condition of geologic features or the inscriptions, petroglyphs and pictographs. Precipitation levels from climate change adversely impact Inscription Rock
Slope/Cliff Stability	Rockfall	Slopes/cliffs are stable, consist of competent or well indurated rock, few or no fractures are present with few or no loose blocks. Few rockfalls have occurred. Slopes have shallow angle.	Slopes/cliffs show some signs of instability, consist of somewhat competent and somewhat indurated rock with some fractures and loose blocks. Some rockfalls have occurred. Slopes are moderately steep.	Slopes/cliffs are unstable, poorly indurated or made of incompetent rock, are highly fractures and loose blocks are present. Slopes are steep to vertical. Many rockfalls have occurred.

*Weathering and erosion includes mass wasting.

vibrations at Inscription Rock are based on whether the vibrations may impact the inscriptions, petroglyphs and pictographs on Inscription Rock. Specifically, our reference condition for vibrations is expressed in ppv (mm/sec) since ppv is commonly used in vibration measurements, and it provides an indication of the magnitude of transmitted energy transmitted (New York City 2006).

Almost all studies on the impacts of induced ground vibrations are on man-made structures. Their applicability to a geologic feature such as Inscription Rock undergoing natural erosion and weathering is not clear (Roberts 2004), although there is some precedence for applying them to sensitive geologic structures (Randy Stanley, personal communication, 2015).

As our reference conditions, we used the NPS safe limit for sensitive and fragile prehistoric and historic man-made structures in the interest of being conservative and because of the cultural significance of the inscriptions, petroglyphs and pictographs. The NPS recommendation for limits of vibrations for sensitive and fragile prehistoric and historic structures is 2 mm/sec (King et al. 1985 and Hanson et al. 1991).

Our reference conditions for slope/cliff stability are based on whether slopes were stable and consist of competent rock where few rockfalls have occurred.

4.5.4. Condition and Trend

We used two indicators with total of five measures to assess the condition of geologic resources at El Malpais NM, which are summarized in Table 4.5.4-1.


NPS

Figure 4.5.2-7. This July 2013 rockfall damaged the Inscription Loop Trail.

Weathering and Erosion Rates and Processes

Weathering consists of *in situ* physical and chemical disintegration of rock at or near the Earth's surface (Jackson 1997). Erosion includes the processes responsible for the loosening and transport of Earth materials. Weathering and erosional processes have shaped El Morro and will eventually consume Inscription Rock (Pranger 2002). These processes include granular disintegration, a variety of styles of exfoliation, alveolar erosion, and mass wasting events.

The Zuni Sandstone differs from many other sandstones on the Colorado Plateau by being cemented mostly by clay minerals (with lesser amounts of calcite and iron oxide) (Austin 1992 and Cross 1996) versus being cemented by calcite like other sandstones (Cross 1996). The prevalence of the clay cement in the Zuni Sandstone makes it extremely friable, even more so than other friable sandstones on the Colorado Plateau, such as the Navajo and Entrada sandstones.

Extreme friability is the natural condition of the Zuni Sandstone as demonstrated by the fact that several inscribers prepared the rock surface by apparently rubbing off loose grains. Friable sandstones are susceptible to undergoing granular disintegration. Granular disintegration is responsible for the loss of many inscriptions (Cross 1996) and is a major cause of deterioration at North Point (Burris 2007).

Sections of Inscription Rock appear significantly weathered with flaked or exfoliated surfaces (Figure 4.5.4-1). Areas that have had relatively recent rockfall, such as high above the historic pool and on the north side of Inscription Rock (Figure 4.5.4-2), do not have this flaked surface. Styles of exfoliation have been termed spalling (Cross 1996), microspalling (Padgett 1992 and Cross 1996), edge delamination (Fix 2006), and contour scaling, incipient spalling, microflaking, and blind delamination (Burris 2007).

Exfoliation is a major process impacting the inscriptions, petroglyphs and pictographs at El Morro NM. Of the 111 panels monitored by Fix (1996), 32 (28.8%) were exfoliated. Of the 32 exfoliated panels, 18 (56.3%) had experienced loss since previous monitoring, including 10 panels with major loss. None of the panels that Fix (2006) newly documented were exfoliated.

The clay cementing agents, including minor amounts of swelling clays (Austin 1992), are most likely a contributing agent in the formation of these weathered exfoliated

Table 4.5.4-1. Indicator, measure, and rationale of geology condition.

Indicator	Measure	Condition	Rationale
Inscription Rock	Weathering and Erosion Rates and Processes*	Significant Concern	The weathering and erosion processes and their rates at Inscription Rock are in a generally natural state/rate. However, weathering and erosion are impacting the inscriptions, petroglyphs and pictographs on Inscription Rock. The Zuni Sandstone is extremely friable largely due to it being weakly cemented by clay minerals. Different areas of Inscription Rock may be impacted by individual weathering and erosional processes differently and at different rates due to the natural variations in the sandstone and its permeability, presence of joints, slope aspects, and natural microclimates along the cliff-face.
	Freeze-Thaw Index	Good	The freeze-thaw index is decreasing because of fewer number of days per year that go through the freeze-thaw cycle. The decreasing freeze-thaw index should mean that frost weathering has less of an impact on Inscription Rock and the inscriptions, petroglyphs and pictographs.
	Geohydrology	Good	While the historic pool has been modified by the construction of the dam and the arroyo that drained the pool has been filled in, these alterations only have extremely localized impacts on Inscription Rock. The geohydrology of Inscription Rock is mostly in natural condition. The geomorphology of El Morro shows that groundwater sapping processes have played an important role in the evolution of the landscape feature.
	Other Impacts	Good	With the exception of the inscriptions and the efforts to preserve them, Inscription Rock has not modified from a generally natural condition. Vegetation near the cliff-face only impacts the area in the immediate vicinity and changes due to the presence or absence of vegetation is likely within the range of other microclimates present along the cliff-face. Vandalism is a threat, but has not changed the condition of Inscription Rock. Lichens are naturally present on sandstone surfaces, and there is no correlation between increased lichen and inscription loss. Ground vibrations are not of concern. Inscription Rock is more than 244 m (800 ft) from Hwy 53 and more than 7 miles from the Tinaja Pit quarry. Vibration levels at Inscription Rock are well below the NPS safe limit for sensitive archeological sites (e.g., sensitive man-man structures) .
Slope/cliff stability	Rockfalll	Significant Concern	While the rate of rockfall is unknown, rockfalls have occurred historically and there is debris from rockfall present at the base of El Morro and is of significant concern. Rockfall events may or may not be initiated by triggering events, and may or may not be preceded by creep or other changes.

*Weathering and erosion includes mass wasting.

surfaces via expansion of minerals during weathering and/or wetting.

Other sandstones on the Colorado Plateau do not have weathered surfaces with extensive areas of exfoliation, especially not the thin exfoliating sheets seen on Inscription Rock. Usually, on the Colorado Plateau, exposed sandstone surfaces are more weathering-limited, where the rate of weathering is less than the rate of erosion (Douglass 2013). In contrast, exfoliated areas of Inscription Rock appear transport-limited.

Alveolar erosion, also known as salt weathering, produces a honeycomb pattern evident on the surface of Inscription Rock in areas (Figure 4.5.2-2). It is present both near the inscriptions and in other locations, and it seems to be controlled by both environmental factors and the internal stratigraphy of the Zuni Sandstone (Cross 1996). As alveolar erosion is usually related to the movement of salts through rocks and its dissolution and precipitation on cliff-faces, Kelley (2015) will attempt to determine the types of salts and quantify their concentrations as part of their geohydrological study.

Salt weathering is one of the most common factors in deterioration of petroglyphs and pictographs (Doehne and Price 2010). Salts may originate from within the rock or be deposited from wind-borne dust (Doehne and Price 2010). White deposits that may possibly be salts, or alternatively clay minerals, are present on the surface of Inscription Rock (Figure 4.5.4-3).

Wind is considered to be a minor agent of weathering and erosion of exposed bedrock, including at Inscription Rock.

Mass-wasting erosional events, primarily rockfall, are also major mechanisms in the escarpment retreat of El Morro and the erosion of Inscription Rock. Rockfall can consist of blocks a few hundred kilograms (lbs) in size to massive sections of the cliff-face, including the pre-1629 event fall that left the talus pile near the west end of Inscription Rock (Figure 4.5.1-2). Scars from historic and prehistoric rockfall are visible all along the face of Inscription Rock.

The major weathering and erosion agents that are most impactful at El Morro and Inscription Rock are either dependent on the presence of moisture, or more likely to occur when the Zuni Sandstone is wet. While mass wasting may occur at any time, it is more likely to occur during wet conditions, either from rainfall or melting snow. Likewise, the exfoliation and granular disintegration processes are more active when the rock is wet, or undergoing wetting and drying cycles.

These various weathering and erosional agents impact Inscription Rock and the inscriptions, petroglyphs and pictographs at different scales. Granular disintegration works on the scale of individual inscriptions or smaller, exfoliation may impact a panel-sized area of the cliff-face, and mass wasting may impact many panels at once or impact a section of cliff up to an area of many tens of meters (ft) and remove blocks weighing thousands of kilograms.

While the lower contact of the Zuni Sandstone is not exposed, the erosional escarpment of the cuesta has the geomorphic expression more typical of a massive eolian sandstone undergoing cliff erosion by being undercut by a less resistant unit, or one where the erosion is strongly controlled by set(s) of predominant joints. These geomorphic

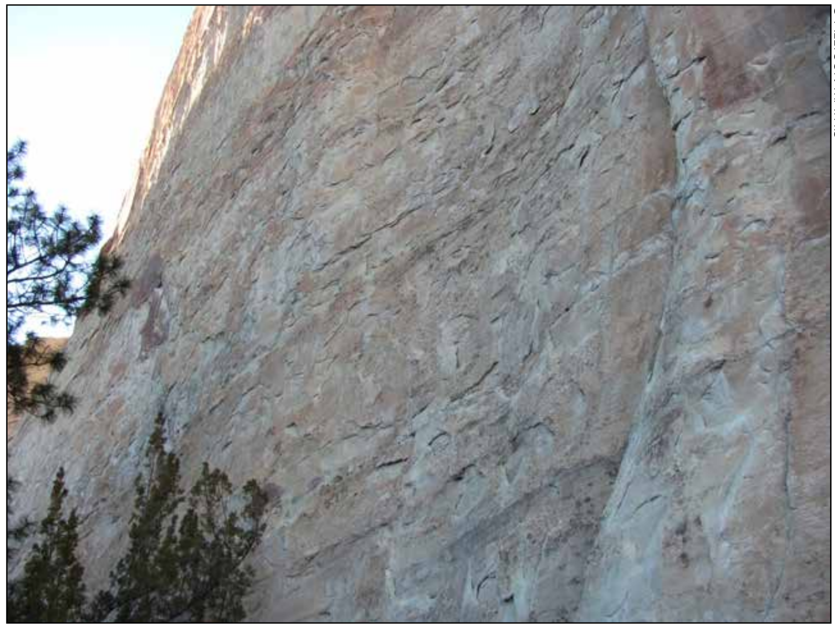

Figure 4.5.4-1. A weathered exfoliated surface on Inscription Rock.

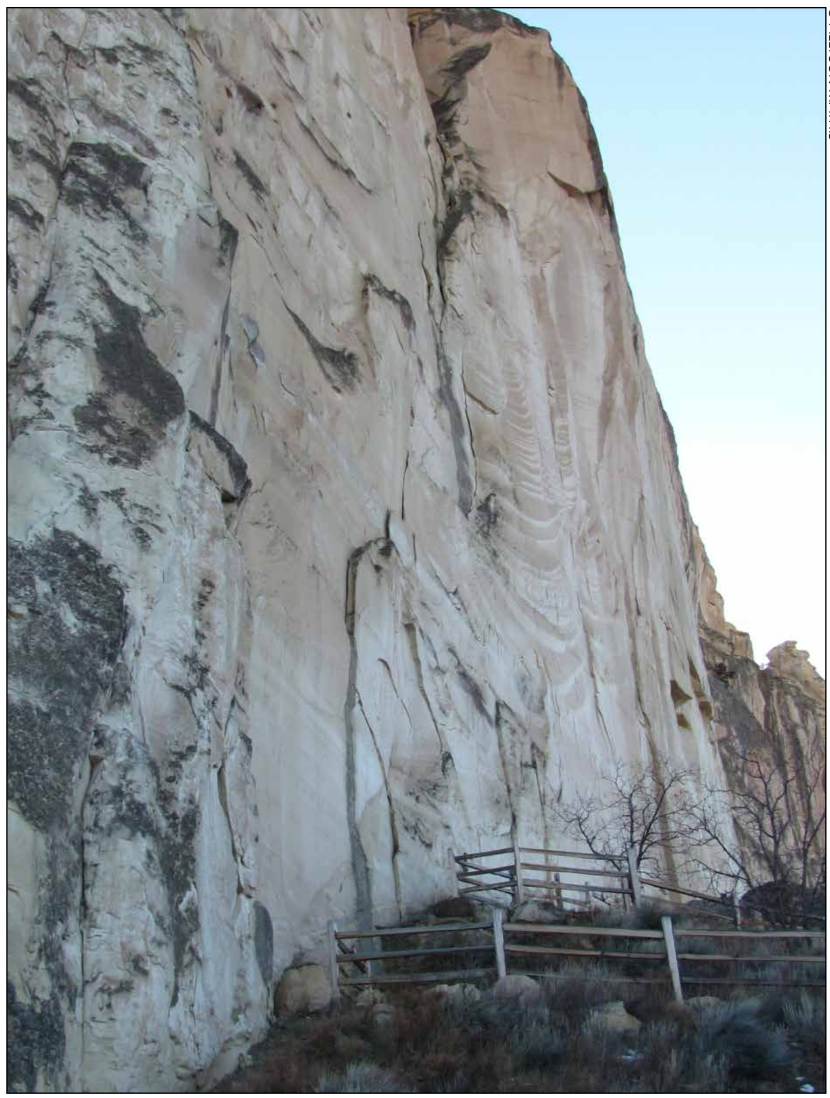

Figure 4.5.4-2. The relatively fresh face of the north side of Inscription Rock where a major rockfall more than 400 years ago occurred.

characteristics include near vertical cliffs cleft by joint systems that are being widened by erosion and weathering with mass wasting events appearing to be a significant mechanism of erosion. Many other eolian sandstones exposed at ground level on the Colorado Plateau appear more competent, with less widening along joints and having more rounded slopes. At El Morro, the Zuni Sandstone may be acting as a less competent layer being underneath the relatively resistant Dakota Sandstone. The rate of escarpment retreat due to weathering and erosion at El Morro is unknown, but is likely to be rapid given how poorly indurated the Zuni Sandstone is.

Together, the natural weathering and erosional processes are responsible for the sculpturing of Inscription Rock and the continued retreat of the erosional escarpment to the south. The specific rates of erosion and weathering at El Morro NM are unknown, but it is likely to be episodic like many geologic processes. The rates of weathering and erosion at Inscription Rock are also geologically rapid due to the generally incompetent nature of the Zuni Sandstone, the high degree of local relief with near vertical cliff-faces, and the local climatic conditions.

North Point has undergone dramatic change, including significant inscription loss and deterioration, between 1955 and 2015 (Padgett, 1992, Cross 1996, Fix, 2006, Burris, 2007, Steve Baumann, personal communication, 2015) (Figure 4.5.2-1). A variety of explanations for the pronounced erosion and weathering and loss of inscriptions at North Point have been proposed including its microclimate, that it has a different natural vibration than the rest of Inscription Rock, wind abrasion (Burris 2007), the presence of groundwater near North Point (Cross 1996), and increased precipitation due to climate change (Baumann and Kendrick 2010).

Much of the pronounced erosion of North Point may be the result of its basic geomorphology. The geometric alignment of this point at the tip of the joint-controlled fin that makes up this part of Inscription Rock means that the North Point is exposed to weathering and erosion agents from three sides versus on a single surface, like a flat cliff-face. This simple geographic element may explain much of the deterioration of inscriptions and North Point itself relative to the rest of Inscription Rock. While North Point is subject to the same weathering and erosional agents as the rest of Inscription Rock, its exposure to them is much greater.

Figure 4.5.4-3. White deposits on the surface of Inscription Rock. These deposits may consist of salts, other evaporative minerals and/or clay minerals.

Another promontory off the north side of El Morro, west of Inscription Rock, is also experiencing pronounced weathering and erosion due to its three-dimensional shape, like at North Point (Shari Kelley, personal communication, 2015).

Stratigraphically, the North Point also contains the lowest exposure of the Zuni Sandstone in El Morro (Cross 1996). These lower strata consist of large-scale crossbeds and are primarily cemented by clay rims on the sand grains (Cross 1996). Laminae of preferential cementation that are more resistant to erosion occur above the lower strata. The grain size also becomes coarser upsection (Cross 1996). The lower part of the Zuni Sandstone exposed there may be less resistant because of its weak cementation of clay rims and smaller grain size.

These weathering and erosional agents are all natural processes occurring at natural rates given the specific conditions found in El Morro NM. However, these agents not only carve Inscription Rock, they erode and degrade inscriptions, petroglyphs and pictographs concurrently. Since these same geologic processes are causing deterioration and loss of the inscriptions, petroglyphs and pictographs, this measure is in the condition of significant concern.

Freeze-Thaw Index

Diurnal and annual changes in temperatures that fluctuate above and below the freezing temperatures cause increased weathering and erosion of geologic features. Frost weathering includes mechanical processes that disintegrate, split and breakup rock via the great pressure caused by freezing water in rock pore spaces or in cracks (Jackson et al. 1997). Frost weathering occurs over a range of scales, from the granular to mass wasting and occurs when geologic resources experience freeze-thaw cycles due to climatic conditions.

The impact of frost weathering at Inscription Rock was assessed using the freeze-thaw index. The average daily high temperature at the El Morro NM weather station is above freezing, while winter lows are typically below freezing (Western Regional Climate Center 2015). Therefore, any change in the freeze-thaw index will be dependent on the average number of days per year that the low temperature is below freezing. The climate change exposure brief for El Morro NM (Monahan and Fisichelli 2014) also indicated that the mean temperature of the coldest quarter has gotten significantly warmer compared to historical conditions.

The average number of days that experienced a freeze-thaw cycle in the period of record (1938-present) was 208, and between 1981 and 2010, it was 202. Therefore, the freeze-thaw index for El Morro NM has decreased, and the condition of Inscription Rock for this measure is good.

Climate change predictions for the Colorado Plateau include warmer winter temperatures (BLM 2014), which would further decrease the freeze-thaw index. Winter temperatures are estimated to increase approximately 2.5°C (4.2°F) by 2050 and 3.0°C (5.4°F) by 2090 (BLM 2014), meaning fewer low temperatures below freezing.

Geohydrology

Geohydrology is the geology of subsurface waters, including the movement of groundwater and its interaction with rock and alluvium.

Permeability and porosity enable fluids to move through rock. In sandstones, porosity is the amount of open space between grains that is not filled by cement. Permeability is the ease or difficulty for fluids to flow through a rock.

The Zuni Sandstone has variable porosity, depending on the amount of cement (Cross 1996). Most samples that Cross (1996) examined had significant porosity, up to 20%. Much of this porosity is the result of dissolution of grains or cement (Cross 1996).

The Zuni Sandstone also has variable permeability, with measured values ranging between 0.01 and 204 md (Cross 1996). These values indicate that the Zuni Sandstone is permeable, but has a relatively low permeability for sandstone (Pranger 2002). Permeability generally decreases upsection in the Zuni Sandstone (Cross 1996). The Dakota Sandstone is more permeable than the Zuni Sandstone.

No measurements of permeability or porosity in the alluvium at the base of Inscription Rock have been made, but this alluvium is likely to be both permeable and porous because of its high sand content from the erosion of the Zuni and Dakota Sandstones. It may also have a higher porosity and permeability than the adjacent sandstone because it has not been cemented.

The presence of the vertical joint systems also allow loci for water movement through Inscription Rock, adding to the unit's overall permeability, and increase the surface areas that are exposed to agents of weathering and erosion (Pranger 2002).

While most precipitation that falls on top of Inscription Rock most likely evaporates, runs off via surface drainage systems (Figure 4.5.2-3), or sublimates directly from snow, some of this moisture, especially from melting snow, probably seeps into Inscription Rock. The recharge area for groundwaters that exist within Inscription Rock is likely to be very small because of the regional dip to the south, away from the erosional escarpment. Flow through Inscription Rock likely takes place both via the fracture (joint) system and in the matrix (Shari Kelley, personal communication, 2015).

Exact paths of fluid flow within Inscription Rock are unknown, but water likely flows down under the influence of gravity until it meets a less permeable horizon, when flow is likely to be lateral. The presence of cove-style weathering, specifically located along the north face of Inscription Rock, likely reflect deflection of groundwater outward along less permeable layers within the Zuni Sandstone (Cross 1996). Additionally, electromagnetic induction lines measured at the historic pool and near North Point both indicated increased moisture towards Inscription Rock (van Dam and Hendrickx 2007), which also suggests that groundwater flows from the top of the cuesta through Inscription Rock.

The porosity and permeability of the Zuni Sandstone in themselves suggest that groundwater sapping processes most likely had a role in shaping El Morro. The presence of Box Canyon and the overhang along the rear wall of the historic pool (Figure 4.5.4-4) provide further evidence that geohydrological processes have helped shaped El Morro. The theater-head of Box Canyon is characteristic of groundwater sapping features (Howard and Kochel 1988). The overhang above the historic pool is most likely a result of a concave weathering front in the shallow subsurface that was later exposed by stream erosion (Twidale 1990), perhaps associated with the flow of water into and out of the plunge pool.

The geohydrology of El Morro near the face of Inscription Rock has been modified by enlarging the historic pool and filling in the arroyo that used to drain it (Greene 1978, Cross 1996, Pranger 2002, and van Dam and Hendrickx 2007).

The 4-m (13 ft) concrete dam at the historic pool raised the level of the pool, although by an unknown elevation since park managers had excavated sand from the pool area prior to dam construction (Greene 1978).

These two actions may, or may not, have altered the amount of, or the dynamics of, what groundwater is at least seasonally present near the historic pool or North Point. North Point does not have specific geomorphic expressions of groundwater sapping processes.

The area of the pool was also enlarged which concurrently increased the length of cliff-face adjacent to the pool. Therefore, the construction of the dam and consequent enlargement of the pool increased the area of Inscription Rock subject to capillary rise from the pool and associated groundwater.

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Figure 4.5.4-4. The overhang at the rear wall of the historic pool is indicative of a groundwater sapping feature. The raised elevation of the pool due to the construction of the dam means that the water level for the pool is now occupying the section of the cliff-face where the overhang is likely the greatest.

But exfoliation related to capillary rise only extends up to approximately one meter from ground level up the cliff-face and the zone of spalling only extends a few meters down gradient from the pool (Martin 2002). Heavy losses of inscriptions in the vicinity of the pool have been ascribed to the enlargement of the pool (Padgett 1992, Fix 1996, and NPS 2014). It is difficult to assess whether the loss of inscriptions near the pool is due to pool enlargement, whether the pool enlargement has contributed to inscription loss there and/or it is entirely due to other factors such as the natural microclimate that exists there because of the slope aspect of the cliff-face in the declivity there.

While the surface drainage system consisting of the arroyo that drained the historic pool was altered by being infilled, the rest of the drainage systems in El Morro are in their natural condition, including the small drainage systems that drain the top of Inscription Rock (Pranger 2002). The groundwater systems in El Morro NM, even if they are only ephemeral water tables formed either from snow-melt or after major rainfall events, are also in natural condition, except for in the immediate vicinity of the pool. Because groundwater sapping processes have clearly played a role in the formation of the erosional escarpment of the cuesta, and that the overall geohydrology of Inscription Rock has only been altered in the immediate vicinity of the historic pool and for an unknown distance downstream of the pool due to the infilling of the arroyo that once drained it, the condition of geohydrology is considered good.

The drainage systems that pour off the southeast face of Inscription Rock all flow past North Point, including the arroyo that used to drain the historic pool. It is not known specifically what changes this infilling may have had on the geohydrology adjacent to North Point, but likely groundwater was at least seasonally present. The hydrology of North Point is, therefore, in mostly natural condition, even though the locale has experienced a pronounced loss of inscriptions.

Groundwater from the adjacent alluvium, especially in the vicinity of the historic pool and perhaps near North Point, likely infiltrates the lower portions of the Zuni Sandstone via capillary rise (or rising damp) (Cross 1996). Experiments that tried to quantify the hydraulic properties of the Zuni Sandstone were not successful (van Dam and Hendrickx 2007), but the height of capillary rise in a sandstone is likely on the scale of a approximately a meter.

The condition of the historic pool itself will be addressed in Section 4.6.

Other Impacts

Increased vascular vegetation near the cliff-face, induced ground vibrations, vandalism, increased lichen and biofilm growth on the rock surface, and change in precipitation due to climate change have been identified as other potential impacts related to the condition of Inscription Rock.

Increased vascular vegetation

A comparison of historic photographs to current conditions shows a marked increase in vascular woody vegetation in the flats surrounding El Morro. Most of this increased vegetation is not immediately adjacent to the Inscription Rock cliff-face, but some is. Woody vegetation immediately adjacent to Inscription Rock can mechanically abrade the rock surface due to its highly friable nature.

The presence of vascular vegetation in close proximity of the cliff-face can cause changes in the microclimate by shading the rock and providing a windbreak in the immediate area. However, most of the tree species (*Pinus edulis* and *Juniperus spp.*) at El Morro typically are less than 10 m (33 ft) tall, and the *Pinus ponderosa* trees that grow there are not exceptionally tall. Given that Inscription Rock is 60 m (200 ft) tall, the presence of vegetation adjacent to the cliff will only impact microclimate in the lower portions. Further, most of the increase in trees since historic times consists of trees not growing immediately adjacent to Inscription Rock, which should not impact the geologic feature. Any shading of the cliff-face due to trees growing immediately adjacent to it will be more pronounced in winter, especially for trees growing near the southeast cliff-face due to the southern exposure of the sun during those months.

In general, the presence of vegetation in a given area may have an impact limited to that specific area which may be on the scale of a single panel. It does not impact the overall conditions of Inscription Rock. Additionally, whatever changes in the microclimate of a specific area due to the presence of trees may be, it would be still be within the range of natural microclimatic variations already present at Inscription Rock. The various slope aspects that are along the cliff-face, with the northwest- and southeast-facing cliff-faces, plus the presence of coves, declivities and other irregularities means that surfaces of Inscription Rock naturally has a great range of microclimates.

Shade from vegetation may impact the duration of surface wetting, and may provide surface thermal stability of the rock surface by reducing solar loading (Doehne and Price 2010). Trees may also provide a wind-block that slows the rate of evaporation; rapid evaporation rates may increase erosion rates (Doehne and Price 2010).

Increased vegetation near Inscription Rock may increase the risk of wildfire there (D'Ambrogi 2009). Fire is well recognized as an agent that can cause deterioration of rock art (Doehne and Price 2010).

Whatever the microclimate is at a given area, and whether it is impacted by the presence of trees near the cliff-face, any given section of Inscription Rock or of an inscription panel is not isolated from the overall weathering and erosion processes ongoing at Inscription Rock. While shade from vegetation may have both beneficial or negative impacts in a small area, the presence of vegetation near the cliff-face does not substantially impact the condition of Inscription Rock. Therefore, Inscription Rock is in good condition relative to increased vegetation near the cliff surface.

Ground Vibrations

Induced vibrations measured at two sites at Inscription Rock (King and King 2003) ranged between 0.14 and 0.64 for loaded gravel trucks, and 0.01 - 0.026 mm/sec ppv for hikers on the trail, significantly lower than the conservative 2 mm/sec ppv reference condition based on the standard for fragile man-made structures. Therefore, traffic-induced vibrations are not of concern for Inscription Rock.

Additionally, Inscription Rock is greater than 244 m (800 ft) from Highway 53, which is twice the approximately 122 m (400 ft) safe setback distance recommended in the King and King (2003) report. Because the energy of ground vibrations attenuates with distance, the large distance between the source of traffic-induced vibrations and Inscription Rock means that the energy level of vibrations that may reach Inscription Rock is substantially less than it would be if the roadway were closer. King and King (2003) recommended a minimum setback distance of 91 ft (300 ft) if the roadway had a potholed surface. In February 2015, the surface of Highway 53 in El Morro NM was not potholed. Additionally, Inscription Rock is further from Highway 53 than sensitive cultural resources that are man-made structures are from roadways in other NPS units in the Intermountain Region (Randy Stanley, personal communication, 2015).

The Tinaja Pit quarry is located more than 11 km (7 miles) from Inscription Rock. Normal blasting at the quarry should not be of concern because of the great distance (King and King, 2003 and Randy Stanley, personal communication, 2015). King and King (2003) indicated that the NPS should evaluate blasts if the quarry location moves nearer to the monument. Tinaja Pit mines the San Andres Limestone (C & E Concrete 2004). Exposures of and near surface deposits of the San Andres Limestone in the greater El Morro NM region are restricted to the Zuni Uplift (New Mexico Bureau of Geology and Mineral Resources 2003), which are not located closer to El Morro NM than the approximate distance to the Tinaja Pit quarry.

Additionally, the partially-attached columns measured at El Morro do not have a natural frequency that would make them susceptible to frequencies from induced traffic vibrations (King and King 2003). The grain size of the Zuni Sandstone has a vibration sensitivity of greater than 2,000 Hz, which would be of great concern to humans before it would impact the rock columns (King and King 2003).

Vandalism

Vandalism is a recognized threat to the inscriptions, petroglyphs and pictographs at Inscription Rock (NPS 2014). The Inscription Monitoring and Biodeterioration Investigation (Fix 2006) did not document that vandalism had impacted either Inscription Rock or the inscriptions, petroglyphs and pictographs. Older documents (NPS 1989 and Padgett 1992) indicated that the NPS removed graffiti from the rock surface as needed.

Although graffiti may impair or destroy individual inscriptions, vandalism is not likely to have a major impact on overall natural condition of Inscription Rock, with the possible exception of boulders being loosened from the crest of Inscription Rock or at a landscape feature such as Woodpecker Rock.

Because graffiti was not documented as impacting Inscription Rock or the inscriptions, petroglyphs and pictographs, the condition of vandalism for Inscription Rock is considered to be good.

Increased Lichen and Biofilm Growth

Lichen can cause both physical and chemical damages to rock surfaces (Fix 2006). Lichens have been documented on or in close proximity to inscriptions at El Morro (Padgett 1992, St. Clair and Knight 2001, Fix 2006 and Burris 2007) (Figure 4.5.2-4). St. Clair and Knight (2001) documented encroachment by lichen into rock samples examined by microscopy techniques with both physical and chemical impacts. Burris (2007) reported that areas of North Point that are covered by biogrowth do not experience granular disintegration.

Of the 89 panels that Fix (2006) reassessed, only 25 (28.1%) showed an increase in biogrowth, or lichens. The results of lichen removal tests undertaken by Fix (2006) are unknown.

Researchers at El Morro indicated that shade on Inscription Rock seemed to promote the growth of lichen (Padgett 1992, St. Clair and Knight 2001, Fix 2006, Burris 2007). Indeed, the north side of Inscription Rock, which receives much more shade than the southeast face, generally has a much darker surface color due to the presence of lichen than the southeast face, especially just west of North Point. North Point should have an intermediate amount of natural sun exposure between the north and southeast faces. Shading due to vegetation can only impact the lower portions of Inscription Rock due to tree height.

Fix (2006) reported that, in some areas, water flowing down the cliff-face seemed to promote lichen growth.

A comparison between the panels that had and did not have an increase in lichen that were reassessed by Fix (2006) showed no correlation between an increase in biogrowth and inscription loss (Table 4.5.2-7). The percentage of panels with increased lichen that experienced inscription loss (56.0%) was slightly less than the percentage of panels that did not have increased lichen but experienced loss (59.4%). Panels with younger inscriptions (US period, 1846-1906) were more likely to have experienced an increase in lichen (72.2%) versus panels that included Spanish inscription (1539-1846) (25%) and panels that included petroglyphs and pictographs, which did not experience an increase in biogrowth.

Fix (2006) also re-examined sites documented by St. Clair and Knight (2001) and found no significant increase in lichen growth.

Given the lack of correlation between panels that experienced an increase in lichen and inscription loss and that fact that microclimates due to shading of the cliff-face are natural, the condition of Inscription Rock for increased lichen and biofilm growth is considered to be good.

Change in Precipitation Due to Climate Change

Climate change can cause accelerated erosion of geologic features when it submits them to additional or increased weathering or erosional agents, including precipitation. In general, an increase in precipitation correlates with increased rates of weathering and erosion because water is a direct or indirect component of most weathering and erosional processes. However, the specific relationships between precipitation amounts and weathering and erosion rates and processes depend on factors such as the intensity, period, frequency, amount, seasonal nature (e.g., liquid or frozen precipitation) and other variables. For example, infrequent intense rainfall events, frequent small rainfall events, and snowfall all impact erosion rates and processes differently although the total annual precipitation may be equivalent.

The region around El Morro NM experienced a very wet interval between 1978-1992 (Grissino-Mayer 1995), and 1979 was the was the fourth wettest year on record (1938-present) (Western Regional Climate Center 2015). However, five years between 1978-1992 had less than the mean amount of precipitation for the period of record, and half (11 of 22) of the years between 1993-2014 had less than average precipitation (Western Regional Climate Center 2015), including 10 of the 15 years 2000-2015 (Romme and Jacobs 2015). Climate predictions for the Colorado Plateau are for more arid conditions, punctuated by megadroughts (Schwinning et al. 2008), with a decline in precipitation by as much as 5% by 2090 (BLM 2014).

The amount of water in the historic pool and associated seasonal groundwater near the pool and possibly at North Point is also dependent on the level of precipitation (van Dam and Hendrickx 2007). Increased temperatures, which are also predicted for the Colorado Plateau (Schwinning et al. 2008 and BLM 2014) can also increase evaporation of water from soils and alluvium (Wertin et al. 2015) which may also decrease the amount of water available to weather and erode Inscription Rock.

Because El Morro NM has received below average precipitation for 10 of the last 15 years, and because climate predictions for the Colorado Plateau are for warmer and more arid conditions, the condition of Inscription Rock is good for change in precipitation due to climate change.

Slope/Cliff Stability

Slope/cliff stability depends on factors such as geology, slope and climate (Lund et al. 2010). The geology of the cuesta exposed in El Morro NM with the weakly cemented, jointed Zuni Sandstone capped by the relatively resistant Dakota Sandstone provides the source material for rockfall, and the near vertical slopes of the erosional escarpment provides the steep exposure necessary for the rapid motion of rock material downslope. The climate of the El Morro area, with a high freeze-thaw index (Table 4.5.2-4) and winter and summer seasons of peak precipitation (BLM 2014) is also conducive to rockfall.

Rockfall may be triggered by freeze-thaw cycles, precipitation, snow-melt saturated soils, weathering and erosion, root growth and other geologic factors, although specific triggers for rockfall events are often not evident (Lund et al. 2010 and Schaller et al. 2014).

Techniques for slope/cliff stability and rockfall potential assessments and evaluations include conducting rockfall inventories, quantitative spatial analyses using GIS, identification of potential rockfall triggering mechanisms and cliff evaluations for rockfall susceptibility (Stock et al. 20102)

Rockfall inventories can consist of logs of rockfall events and compilation of geologic evidence for rockfall including identification of talus. A complete log of rockfall events is not available at El Morro NM (David Hays, personal communication, 2015), although some large rockfalls have been documented (Ellis 2000). The presence of talus piles at the base of steep slopes, such as the very large pile at the west end of Inscription

Rock (Figure 4.5.1-2), usually can give an indication of frequency of rockfall; however, the Zuni Sandstone at El Morro is so easily weathered upon exposure to water (van Dam and Hendrickx 2007) that spalls from smaller rockfalls or exfoliation events likely disintegrate in a period of time that may be as short as months (Shari Kelley, personal communication, 2015).

Ellis (2000) evaluated Inscription Rock and identified the southeast-facing cliff north of the pool and the north-facing cliff above the talus pile as areas that appear particularly susceptible to rockfall. Ellis also identified several specific blocks or slabs at specific locations above Inscription Trail, including the cracked partially detached column (Figure 4.5.2-5), and Woodpecker Rock as places that may be susceptible to rockfall.

The cracked column was recommended for instrumental monitoring (Wachter, 1978, Ellis 2000, David Hays, personal communication, 2015). The joint surface at this location appears fresh and does not appear to have been widened by erosion unlike some other joint surfaces of Inscription Rock; however, the crack is visible in old photographs (Ellis 2000). Motion or separation along the joint surface may, or may not, occur prior to a rockfall at this location, although there is no evidence that failure is imminent (Ellis 2000). Other fresh-appearing joint surfaces exist along the face of Inscription Rock. One of the reasons why this particular column has received such attention by previous researchers is because it is highly visible from Inscription Trail and because its size, location, and possible indication of ongoing movement present risks (Ellis 2000). Many rockfalls are not preceded by creep or slow slope motions (Wieczorek and Snyder 2009).

The Geological Resources Inventory for El Morro NM (KellerLynn 2012) stated that in 2011, park staff indicated that rockfall at El Morro was analogous to the failure of Threatening Rock at Chaco Cultural National Historic Park in 1941. The failure of Threatening Rock was also discussed in Watcher (1978). The geology of El Morro NM, specifically at Woodpecker Rock and the partially-detached cracked column, is significantly different than that of Threatening Rock. Threatening Rock was completely detached from the cliff-face and on an incompetent base of swelling clays and coal seams (Watcher 1978). Both Woodpecker Rock and the cracked column are on a base of the Zuni Sandstone.

While some techniques for making rockfall potential assessments (e.g., rockfall log, spatial analyses) are not available at El Morro, the record of rockfall occurrence at Inscription Rock and the identification of features contributing to rockfall by Ellis (2000) indicates that the condition for slope/cliff stability is of significant concern.

Trend

The impact of weathering and erosion on Inscription Rock is cumulative. Given the friable nature of the Zuni Sandstone, and its exposure in near vertical relief of the erosional escarpment of the cuesta, Inscription Rock will undoubtedly continue to experience escarpment retreat, groundwater sapping, exfoliation, granular disintegration, rockfall and other weathering and erosional agents that operate on all scales.

We know that Inscription Rock is experiencing weathering and erosion, but the overall rate of geologic change is unknown. It is also unknown whether these weathering and erosion and inscription loss rates have changed over periods of time ranging from years to decades. The monitoring record of Inscription Rock (Padgett 1992, Fix 2006, Burris 2007) is not robust enough to detect such changes. Fix (2006) provided the only comprehensive summary of a systematic repeat monitoring program on 89 panels. These data included information on the number of panels that had experienced loss and increased lichen growth since 1992 (Padgett 1992). But without additional data, and without a way to quantify inscription loss, it is not possible to determine whether the rate of inscription loss has changed.

While there have been some anecdotal suggestions that rate of erosion and inscription loss has increased (Baumann and Kendrick 2010), the lack of long-term systematic data makes it difficult to assess. The surface of Inscription Rock was soft, friable and easily carved at the time the inscriptions, petroglyphs and pictographs were made as evidenced by some inscriptions that were exceptionally deep and by the prepared surfaces. The earliest photographs of the inscriptions date to 1891, with the first comprehensive photographic survey in 1955 (Padgett 1992). Some of the inscriptions and rock art were already nearly 300 years old when they were first photographed, and had most likely already undergone extensive change since the time when they were carved.

If anything, rates of weathering and erosion at Inscription Rock may be decreasing due to climate change. Climate change predictions for the Colorado Plateau are for warmer and more arid conditions (Schwinning et al. 2008 and BLM 2014). Both fewer annual freeze-thaw cycles and less precipitation generally correlate to slower weathering and erosional rates.

Fix (2006) documented which panels had experienced loss (including minor loss) since assessment by Padget (1992). A significantly higher percentage of panels only containing US period inscriptions (e.g., panels containing relatively young inscriptions) had experienced loss compared to panels containing Spanish inscriptions and those containing petroglyphs and pictographs (Table 4.5.2-3). Nearly 71% of US period only panels (1846-1906) had experienced loss, versus 31.6% of panels containing Spanish inscriptions (1605-1806) and 40% of panels including petroglyphs and pictographs (undated, but may include pre-European contact rock art).

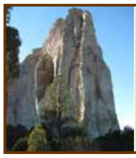
If rates of inscription loss at El Morro had increased, it likely would have impacted all panels equally. This difference in percentage of panel types (US period only, containing Spanish inscription, and containing petroglyphs and pictographs) that have experienced loss likely would not exist as all have been exposed to the same conditions.

The difference in percentage of panel loss for panels containing different age classes of inscription may result from several different variables. Older panels may have already been deeply eroded at the time of initial monitoring in 1992 and additional change would be less apparent, or they may have been completely lost prior to monument establishment. Or, alternatively, older panels persist on areas of Inscription Rock that have had a more stable surface, and are perhaps in areas that are relatively resistant to weathering and erosion. Younger panels (e.g., US period only) may also show more change because the disturbance of the surface of the Zuni Sandstone was more recent, leading to both loss of inscription and increase in lichen growth. Further, without analysis of the locations of the panel types with their locations on Inscription Rock examination of whether higher percentage of loss is related to location versus age is not possible.

At North Point, the loss of a large number of inscriptions in 1979 (Baumann and Kendrick 2010) probably correlates better to a very wet year in a wet period versus a trend towards increased precipitation due to climate change, and also may not indicate an accelerating rate of inscription loss. Inscriptions from North Point also date to the US period (Slater 1961), which have experienced a higher percentage of loss than older inscription (Table 4.5.2-3) (Fix 2006).

The trend for the condition of geologic resources at El Morro NM is considered to be stable because geologic resources are in natural condition and there is no evidence for an increase in the rate of weathering and erosion. However, the impacts of weathering and erosion on the inscriptions, petroglyphs and pictographs will continue to occur and accumulate.

The trend for slope/cliff stability is also most likely stable, but likewise may decrease due to climate change. Fewer freeze-thaw cycles and less precipitation generally provide fewer triggers for rockfall.



Geology

Indicators	Measures
Inscription Rock	4 Measures
Slope/cliff stability	1 Measure

Overall Condition and Trend

Of the five measures in two indicators for the assessment of geologic resources at El Morro, three were in good condition (freeze-thaw index, geohydrology, and other impacts), and two (weathering and erosion rates and process and rslope/cliff stability) were in a condition of significant concern. The overall condition of surface geology features at El Morro was considered to be moderate.

In general, the weathering and erosional processes of granular disintegration, exfoliation, alveolar erosion, mass wasting, and freeze-thaw cycles are impacting Inscription Rock and the inscriptions, petroglyphs and pictographs on its surface. The Zuni Sandstone is cut by two prominent joint sets and is poorly cemented, mostly with clay minerals. A variety of natural microclimates exist along the cliff-face, including those related to slope aspect. The impact of these agents and factors on any given inscription is likely to be complicated and multifaceted, and may depend on small scale heterogeneities within the Zuni Sandstone itself, as well as microclimatic variations. These characteristics that are responsible for the deterioration and loss of inscriptions due to weathering and erosion are the same that made Inscription Rock a canvas for native Americans, Spanish and American explorers.

Level of Confidence/Key Uncertainties

We have a high level of confidence in this condition assessment because a great deal of research on the geology of Inscription Rock is available, including Austin (1992), Cross (1996), St. Clair and Knight (2001), Pranger (2002), Fix (2006), and van Dam and Hendricks (2007), in addition to reports on inscription monitoring (Padgett 1992 and Fix 2006). Information on rockfall at El Morro is available in Wachter (1978) and Ellis (2000).

Although we have a high level of confidence in this assessment in general, uncertainties exist in the condition assessment for some individual measures (Table 4.5.4-2).

The composition of the salts that may contribute to alveolar weathering is unknown, although one of the elements of the hydrogeology study by the New Mexico Geology and Mineral Resources is to identify these salts (Kelley 2015).

The amount of water infiltration from precipitation and melting snow on the crest of El Morro is unknown, as is the proportion of fluid flow via the sandstone matrix or via the fracture system. Additionally, the full nature of the water table that most likely exists at least seasonally at North Point is not known, as is the full hydraulic properties of the Zuni Sandstone.

Microclimates are a natural condition along the Inscription Rock cliff-face, but it is unknown whether increased vegetation near the rock surface changes the microclimate in

Table 4.5.4-2. Key uncertainties in the assessment.

Measure		Uncertainties
Weathering and Erosion Rates and Processes		The composition of the salt minerals that may be involved in alveolar erosion
Geohydrology		The height of capillary rise above the ground surface is unknown, but is likely to be a few meters at most. The amount of water infiltration from precipitation and melting snow at the crest of El Morro. The nature of groundwater present at North Point.
Other Impacts	Increased vascular vegetation near Inscription Rock	Whether mircroclimates induced by increased vegetation near the cliff-face are outside the range of natural microclimates at Inscription Rock.
	Ground Vibrations	The location of mesa top vibration test sites. Additionally, the 0.64 mm/sec ppv for induced vibrations from a loaded truck seem anomalously high.

any given location beyond than what would be within the natural variation for the site.

The precise locations of the "rock columns" that King and King (2003) measured for natural resonance are not known. The specific locations were not given in the report and the photographs labeled as "vibration tests on top of the mesa" do not show rock columns, but an irregular slickrock surface of a jointed sandstone. Additionally, the 0.64 mm/sec ppv for induced vibrations from a loaded gravel truck values for site B seems anomalously high given the measurements of induced vibrations from loaded trucks at other sites and distance to Highway 53 (See Appendix E for further discussion).

4.5.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University and a geologist by training, authored this section.

David Hays is the former Chief of Natural Resources at El Morro NM. Steve Baumann is the Chief of Resource Management at El Morro. Randy Stanley is the Natural Sounds & Night Skies Coordinator for the Intermountain Region. Shari Kelley is a Geophysicist/Field Geologist at the New Mexico Bureau of Geology and Mineral Resources.

Tim Connors, Geologist with the NPS Geologic Resources Division, Shari Kelley, Geophysicist/Field Geologist with the New Mexico Bureau of Geology and Mineral Resources, and Randy Stanley, Natural Sounds and Night Skies Coordinator for the NPS Intermountain Regional Office reviewed this assessment.

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4.6. Historic Pool

Indicators/Measures

- Historic Pool (1 measure)
- Climatic Condition (1 measure)

Condition – Trend - Confidence

Significant Concern– Stable - High

4.6.1. Background and Importance

Water has long been a scarce resource in the southwest. Reliable water sources have always been very important to American Indians, early Spanish explorers, early Euro-American explorers, emigrants, settlers, and present day inhabitants. Dependable sources of water also have critical importance in ecosystems (Perkins et al. 2005).

The historic pool at El Morro NM (Figure 4.6.1-1) has been a central element in its human story from prehistoric times. As one of the few reliable sources of water in the region, the historic pool has repeatedly drawn people to the base of Inscription Rock(Greene 1978) and is a key element in the site's evolution as a cultural landmark.

A Historic Structure Report: The Historic Pool, El Morro National Monument, New Mexico (Greene 1978) provides numerous historic descriptions of the pool and its history of use from the period of Spanish exploration onward, and describes modifications to the pool between the 1920s and 1940s. A number of the descriptions of the pool prior to 1900 indicate that the pool was "shallow," that size of the pool fluctuated, and that the pool was periodically dry (Greene 1978). Given the fact that the historic pool is a plunge pool fed by an intermittent drainage, it is part of naturally changing and dynamic system. Its size and appearance naturally changed depending on precipitation events that fed it (Pranger 2002). However, the presence of a sand bank along the rear side of the pool was reported to be fairly constant (Greene 1978).

The pool not only has a long history of human use, but also of human modification. When the original concrete dam to enlarge the pool was constructed in 1926, remains of an older cedar post and rock dam were uncovered

Figure 4.6.1-1. The historic pool.

during excavation of the pool area (Greene 1978). In the 1930s, an arroyo near the pool was infilled to restore the area to what park managers thought it was like when the first Spanish expeditions visited.

The dam was rebuilt in 1943 after it was destroyed by a large rock fall on August 10, 1942. The reconstructed dam had a length of 15 m (50 ft) and a height of 4 m (13 ft).The pool served as the monument's source of drinking water until 1961 when a well was drilled (KellerLynn 2012).

The site still has great cultural significance to the Zuni Tribe and other American Indian peoples (Southern Colorado Plateau Network 2006) and is one of the monument's fundamental resources and values (NPS 2014).

4.6.2. Data and Methods

We used two indicators to assess the current condition and trend of the historic pool at El Morro NM (Table 4.6.2-1). The first indicator, with one measure, assessed whether the historic pool was in natural condition. The second indicator, also with one measure, assessed climatic condition as the pool is predominantly a meteoric water system.

The pool is fed by surface runoff from three small watersheds on top of Inscription Rock, with a combined watershed area of 0.63 ha (1.55 acres). Surface runoff into the pool is generated only by large rainfall events (Pranger 2002). In essence, the historic pool is a plunge pool at the base of intermittent waterfalls that typically flow only during or after periods of heavy rain (Figure 4.6.2-1).

Some debate exists whether the pool is fed only from surface flow, but most researchers (Pranger 2002; Martin 2002; and van Dam and Hendrickx 2007) think that there must be at least some groundwater infiltration through Inscription Rock into the pool, including via the fracture (joint) systems. See Section 4.5, Geology, for further discussion of the overall geohydrological system of Inscription Rock.

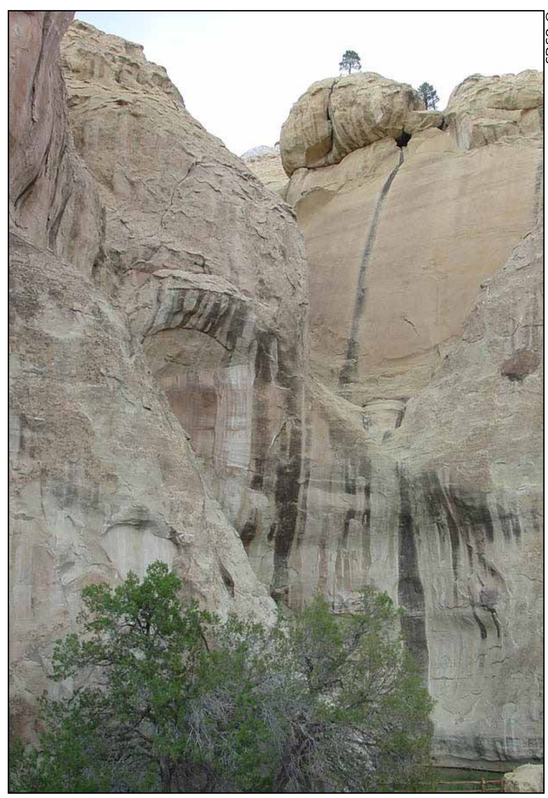
A hydrogeologic study of Inscription Rock and the historic pool is being conducted by the New Mexico Institute of Mining and Technology (Kelley 2015). Continued hydrological monitoring by the Southern Colorado Plateau Network (SCPN) will provide a better understanding of the sources of the pool's water (Stephen Monroe, personal communication, 2015).

Table 4.6.2-1. The indicators and measures used to assess the condition of the historic pool at El Morro NM.

Indicator	Measures
Historic Pool	Historic Pool Intactness
Climatic Condition	Amount of Precipitation (Pool Elevation)

Indicators/Measures
Historic Pool (Historic Pool Intactness)

The historic pool intactness measure evaluated whether the pool was in its natural condition. We used historic descriptions of the pool prior to basin enlargement and initial dam construction in 1926 as the source



© USGS

Figure 4.6.2-1. The historic pool showing the location of one of the intermittent drainage systems that flow into the plunge pool.

of information on the historic pool's natural condition (Greene 1978). SCPN hydrological monitoring of the historic pool (Soles and Monroe 2012, and Monroe and Soles 2015) provided information on the current condition of the pool.

Very little information about the condition of the pool prior to national monument establishment and subsequent basin and pool enlargement exists. A drawing by the artist Richard Kern, who was on the Simpson expedition that visited El Morro in 1849, shows a pool at the base of the El Morro cliff (Figure 4.6.2-2), although the report misidentified the water body as a spring. (U.S. Senate 1850).

Figure 4.6.2-2. The 1849 illustration of the pool at El Morro by artist Richard Kern who accompanied Lieutenant Simpson on his expedition to the Navajo country. This report erroneously called the pool a "spring." (US Senate 1850).

The historic pool was greatly enlarged by excavation using horse teams and scrapers over a period of several days in the early to mid 1920s. In 1926, a 4.2 m (13.75 ft) tall concrete dam was completed that transformed the pool into a reservoir (Greene 1978). In the 1930s, the pool was reported to be approximately waist deep (Greene 1978).

An arroyo below the pool was filled in during the 1930s (Greene 1978). The exact evolution of the arroyo below the pool is unclear, and no contemptuous descriptions of an arroyo near the pool exist prior to infilling (Greene 1978). Later accounts by someone who visited the pool in 1889 indicated that this drainage was very small and could be easily stepped across (Greene 1978). The arroyo was reported to be 4.5 m (15 ft) wide and 4.5 m (15 ft) deep 1916, according to a 1942 letter from former El Morro NM custodian Evon Vogt (Greene 1978).

The initiation of arroyo formation may coincide with a period of arroyo cutting in the southwest that occurred between the late 1800s to 1915 due to climatic conditions, with grazing possibly being a factor (Vogt 2013). However, the impact of basin enlargement and dam construction at the historic pool on arroyo formation and enlargement is unknown, as is the exact period when arroyo formation occurred because the historical record is unclear.

Dam reconstruction completed after the 1942 rockfall increased the capacity to approximately 750,00 liters (200,000 gallons) (Greene 1978). This work was the last major modification to the historic pool.

In 2010, SCPN initiated hydrological monitoring in the historic pool (Soles and Monroe 2012). SCPN installed a recording transducer to continuously measure pool water levels and completed a bathymetric mapping of the pool (Figure 4.6.2-3). The measured maximum depth of the pool was 3.35 m (11 ft) and the surface area of the pool was 353 m^2 (3800 ft^2) (Soles and Monroe 2012). SCPN also began monitoring of three existing observation wells.

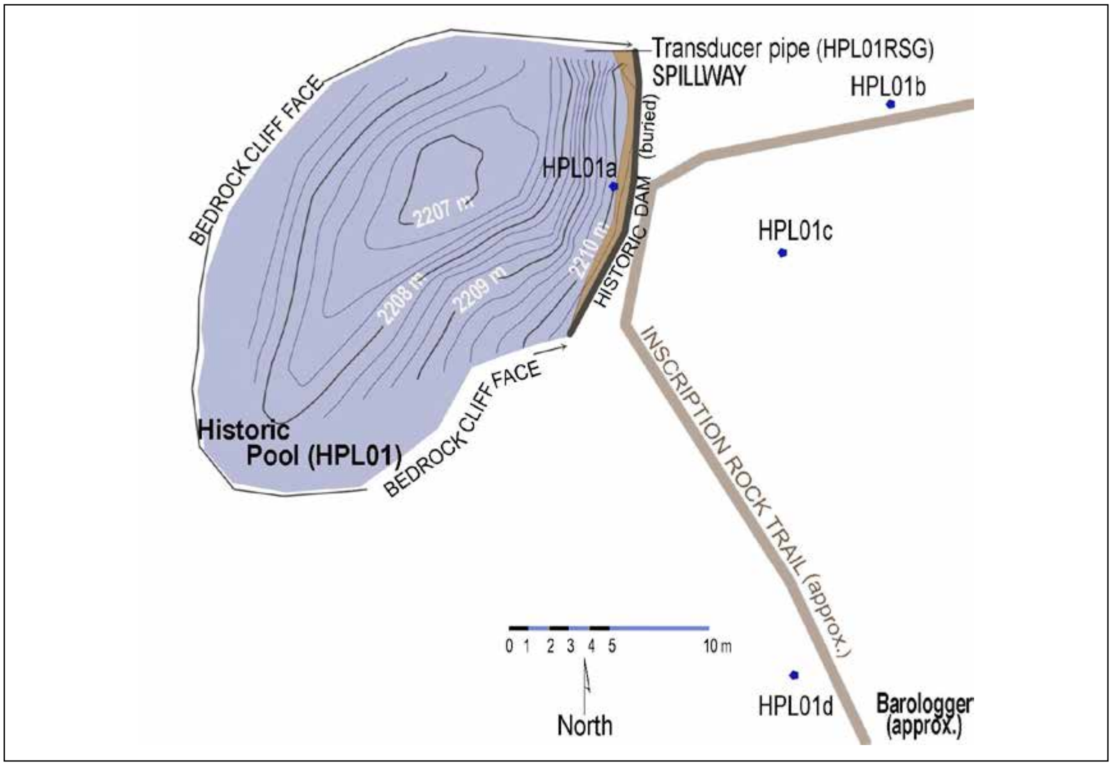


Figure 4.6.2-3. Contour diagram of the historic pool (Monroe and Soles 2015). The blue shading shows the extent of the pool water surface and brown shading shows soil exposed upstream of the historic dam. HPL01b, HPL01c and HPL01d are locations of observation wells.

Figure 4.6.2-4 compares the appearance of the pool in 1924, prior to dam construction and most likely prior to basin enlargement to the modern pool during the fall of 2014. In 1924, the pool appears to be a plunge pool in natural condition at the base of a cliff with a deep overhang at least a few meters above the pool surface, and with a sandbank or gravel bar adjacent to the cliff wall (Greene 1978). In 2014, the pool's surface area is greatly increased. Its water surface elevation is much higher, submerging most of the area beneath the overhang, and there is no sandbank along the rear of the pool.

Indicators/Measures

Climate Condition (Amount of Precipitation — Pool Elevation)

Climatic condition was assessed using one measure: amount of precipitation (pool elevation). This measure evaluated the impact that the amount of precipitation may have on the elevation of the historic pool, which is essentially rainwater-fed system fed by intermittent drainages that flow due to heavy precipitation events.

Information about elevation of the pool for water years (October 1 - September 30) 2011-2014 is available in Monroe and Soles (2015). Figure 4.6.2-5 provides information about the elevation of the water surface of the pool and in the observation wells for water years 2011-2014, and daily precipitation events.

Precipitation data for the National Weather Service NM Cooperative Station at El Morro NM (ID 292785) are available from the Western Regional Climate Center (WRCC 2015). This station is adjacent to the NPS visitor center and is only approximately 300 m (980 ft) from the historic pool. Mean annual precipitation and the number of daily rainfall events greater than 10 mm (0.4 in) per year for water years 2011 through 2014 are presented in Table 4.6.2-2.

4.6.3. Reference Conditions

The reference conditions used to assess the historic pool are presented in Table 4.6.3-1. When a hydrological feature such as the historic pool is found to be in natural condition, the condition is considered to be good. If areas of moderate concern related to natural condition of the pool exist, the condition is considered to be moderate. A condition of significant concern exists when

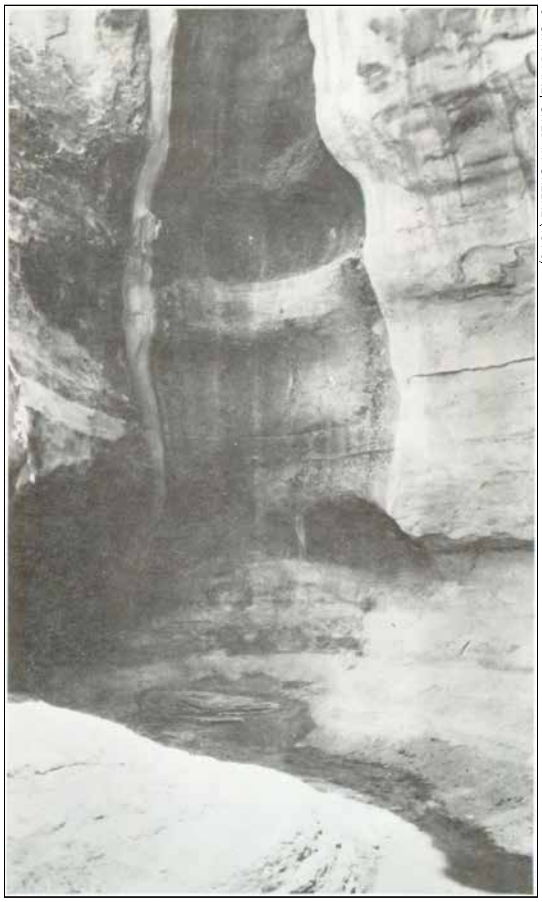


Figure 4.6.2-4. The historic pool in 1924 (left) and October 2014 (right). Note how much larger the area of the modern pool is and its raised elevation to just underneath the overhang present in the middle right of the photographs.

significant changes to the historic pool from natural condition were identified.

4.6.4. Condition and Trend

Historic Pool Intactness

Little information exists about the condition of the pool prior to the extensive modifications that enlarged it via excavation of sand from the basin and construction of concrete dams that raised the level of the pool approximately 4 m (13 feet). Historic descriptions of the pool stated that it was small, shallow and periodically dry (Greene 1978), or described it as a spring (US Senate 1850). The 1849 Kern illustration (Figure 4.6.2-2) shows a plunge pool at the base of the El Morro cliff with a berm, but does not show any drainage emerging from the pool, although it is doubtful that the pool was the local baselevel or a sink. A 1924 photograph (Figure 4.6.2-4) shows that it had the characteristics of the type of shallow plunge pool that would be typical in small intermittent drainage systems that drain slickrock uplands in the southwest such as the ones that flow off of Inscription Rock. In natural condition, the amount of water contained in the shallow plunge pool off of Inscription Rock probably varied widely throughout the year as well as from year-to-year and was most likely greatest immediately after heavy rainfall events.

Table 4.6.2-2. Precipitation recorded at the El Morro NM NWS Station for Water Years 2011-2014 (WRCC 2015).

Water Year	Precipitation (inches)	# of Precipitation Events > 10 mm (0.4 in)
2011	14.52	10
2012	11.93	4
2013	10.46	5
2014	10.36	10
Period of Record*	13.81	>9

*Stephen Monroe and Ellen Soles, personal communication, 2015.

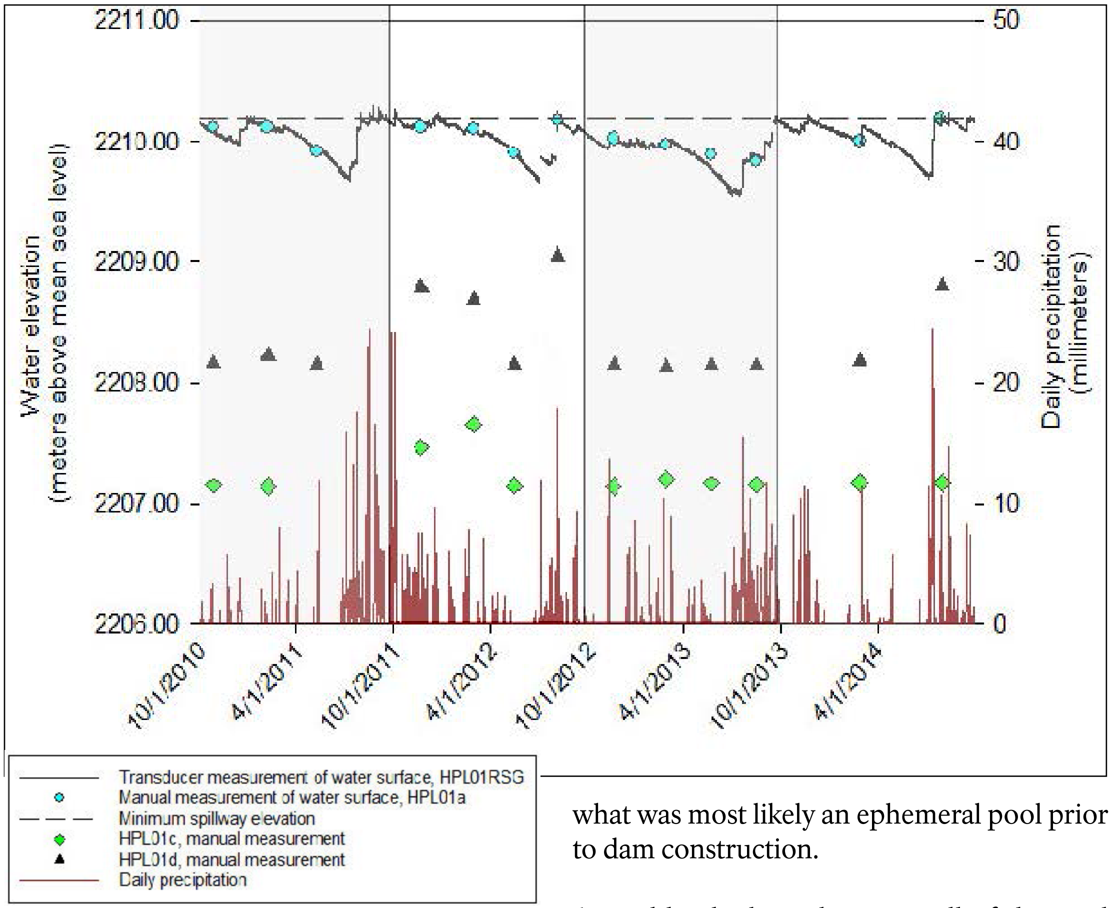


Figure 4.6.2-5. Water levels in the historic pool and in the observation wells in El Morro NM and daily precipitation in water years 2011-2014. Diagram from Monroe and Soles (2015).

A comparison of this 1924 photograph to the modern pool shows that the reservoir has mostly infilled the recess at the base of Inscription Rock (Figure 4.6.2-4). This overhang probably formed via groundwater sapping processes in the shallow subsurface in conjunction with surface runoff (Twidale 1990). The surface area of the pool is much larger than the natural pool and is most likely much deeper, now with a depth of more than 3 m (10 ft). It is also a permanent feature versus what was most likely an ephemeral pool prior to dam construction.

A sand bank along the rear wall of the pool was also naturally present, as evidenced in the 1924 photograph (Figure 4.6.2-4) and by the more than 40 inscriptions into the rock wall behind the pool in the mid to late 1800s (Greene 1978). This sand bank has been eliminated or submerged by the pool's higher surface level due to dam construction. The cliff-face behind the pool is now inaccessible.

The current size, shape, and depth of modern pool primarily resulted from dam construction and basin enlargement in the

Table 4.6.3-1. Reference conditions used to assess the current condition of the historic pool for each measure.

Measure	Good	Moderate Concern	Significant Concern
Historic Pool Intactness	The historic pool and the pool's hydrology are in natural condition.	The historic pool and the pool's hydrology have been modified slightly from natural condition.	The historic pool and the pool's hydrology have been modified significantly from natural condition.
Amount of Precipitation—Pool Elevation	Mean annual rainfall and the number of heavy rainfall events per year have remained stable and/or increased compared to the period of record.	Mean annual rainfall and the number of heavy rainfall events per year are moderately less than that of the period of record.	Mean annual rainfall and the number of heavy rainfall events per year are significantly less than that of the period of record.

1920s through 1943, which greatly altered the pool from its natural condition. Because the historic pool has been altered greatly from its natural condition, we found that this measure to be of significant concern.

Amount of Precipitation (Pool Elevation)

Mean annual precipitation and significant rainfall events that are >10 mm (0.4 in) both influence pool elevation. Mean annual precipitation is relevant to pool elevation because it reflects the overall amount of moisture available in the watershed. Further, some of the water in the pool likely is the result of groundwater infiltration from the cuesta top through Inscription Rock (see Section 4.5). Surface flow into the pool via the ephemeral drainages most likely occurs as a response to heavy rainfall events. A strong correlation between daily precipitation events and pool elevation exists (van Dam and Hendrickx 2007, Monroe and Soles 2015, and Stephen Monroe and Ellen Soles, personal communication, 2015).)

Mean annual precipitation for the period of record (1938 to January 2015) at the El Morro NM NWS cooperative weather station is 13.81 inches (Table 4.6.2-2) (WRCC 2015). Precipitation was above mean in water year 2011, but has been below annual mean each year between 2012 and 2014. Conditions for El Morro NM were mostly those of moderate to severe drought for water years 2011 through 2014 (US Drought Monitor 2015).

The pool is fed by rainwater, but most of the waters entering the pool flow into it from the three small watersheds on top of Inscription Rock (Pranger 2002). These watersheds consist mostly of bare sandstone and are very sensitive to heavy rainfall events. Therefore, in addition to mean annual precipitation, the intensity and duration of rainfall events impact the influx of water into the pool. In fact, significant rainfall events that produce runoff in the intermittent drainages that feed the pool have the greatest influence on the pool's water level (Stephen Monroe and Ellen Soles, personal communication, 2015).

Figure 4.6.2-5 shows daily precipitation, pool water level and water levels in three observation wells near the pool for water years 2011 and 2014 (Monroe and Soles 2015). The pool elevation varied by approximately 0.7 m (2.3 ft) each year, with the lowest elevation point each year occurring in early July (Monroe and Soles 2015), which is prior to the beginning of the summer monsoon period when the southwest typically experiences the driest conditions. May and June are the two months with lowest mean precipitation at El Morro NM (WRCC 2015). The lowest pool water elevation occurred on July 3, 2013 at an elevation of 2209.55 m (7249.2 ft). The highest annual low elevation occurred in 2014 at 2209.68 m (7249.6 ft).

The response of the pool elevation to significant rainfall events is evident in Figure 4.6.2-5, with an increase in pool elevation subsequent to heavy rain events (Monroe and Soles 2015), likely a result of surface flow in the intermittent drainages. For the period of record, the annual average of precipitation events greater than 10 mm (0.4 in) is greater than nine (Stephen Monroe and Ellen Soles, personal communication, 2015). Ten precipitation events greater than 10 mm (0.4 in) occurred in water years 2011 and 2014, four events occurred in water year 2012 and five events in water year 2013.

One of the observation wells (HPL01b) was dry between 2011 and 2014. Increases in water levels in the other two wells also generally corresponded to increases in pool elevation following precipitation events (Monroe and Soles 2015).

The maximum water elevation in the pool is constrained by the height of the dam. Water exceeded the spillway crest for seven days in water year 2011, on one day in 2013, and on two days in 2014 (Monroe and Soles 2015).

Because the mean annual precipitation levels were below mean for the period of record (1938-2015) for water years 2012 through 2014 and because El Morro mostly experienced moderate to severe drought during this interval, we considered this measure to be in moderate condition. Additionally, the number of precipitation events greater than 10 mm (0.4 in) were well below the annual average of greater than nine in water years 2012 and 2013. The fact that two of the four most recent years had significantly fewer than average heavy rainfall events also contributed to our moderate rating. Data are not available on the inflow into the historic pool via runoff nor from groundwater infiltration.

Historic Pool

Indicators	Measure
Historic Pool	1 measure
Climate Condition	1 measure

Overall Condition

The historic pool intactness measure was in the condition of significant concern, and the amount of precipitation—pool elevation measure was in moderate condition. The overall condition of the historic pool at El Morro was considered to be of significant concern and is summarized in Table 4.6.4-1.

The changes to the pool due to basin enlargement and dam construction are probably significantly greater than any impact that climatic conditions with the possible exception of the number of heavy rainfall events. These events may or may not have a significant impact in this small hydrological system, especially given the fact that the pool is situated in protected alcove with a microclimate, where due to slope and aspect, it receives very little direct sunlight, minimizing evapotranspiration.

Previous monitoring at the historic pool (e.g., Sayre 1997 and van Dam and Hendrickx 2007) used different reference elevations and instrumentation, so it was not possible to evaluate the pool elevation relative to longer term precipitation data. However, three of the 20 driest years on record occurred between 2011 and 2014. Therefore, it is likely that the lowest pool surface water elevations recorded during that period correspond with levels that might be anticipated during drought periods. Even the dry years of 2012-2014 were punctuated by intense rainfall events that created runoff that abruptly increased the elevation of historic pool, although substantially fewer such events occurred in water years 2012 and 2013. If intense precipitation events do not generate runoff for an extended period of time, it is not possible to predict how far pool water levels may drop, given the currently available data.

Level of Confidence/Key Uncertainties

We have a high level of confidence in this condition assessment. Although specific information on the condition of the historic pool prior to enlargement is extremely limited, the pool has been greatly modified by excavation of the basin and subsequent dam construction. It is also likely that the size of the pool and the amount of water available in it were highly variable depending on the season and/or year, and the amount and style of precipitation the watershed that fed the pool had received in prior months. A plunge pool in an intermittent drainage may be deepened and filled with water during periods of high runoff during heavy rain events, or alternately

Table 4.6.4-1. Indicators, measures, and their contributions to the overall historic pool condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Historic Pool	Historic Pool Intactness	Significant Concern	The historic pool has been significantly altered from its natural condition that was most likely a shallow plunge pool. Between the 1920s and early 1940s, the pool basin was enlarged and the construction of the concrete dam raised the level of pool by approximately 4 meters (13 feet). This measure is of significant concern.
Climatic Condition	Amount of Precipitation—Pool Elevation	Moderate	Annual precipitation was below mean for the period of record for 3 of the 4 previous water years, and El Morro was mostly in moderate drought conditions during water years 2011 to 2014. The lowest elevation of the pool occurred each year in early July, which followed the quarter with the lowest mean precipitation. The number of heavy rainfall events typically significant enough to produce runoff into the pool were well below the average annual number of rainfall events in 2012 and 2013. Climatic condition is considered to be moderate.

be filled with sand depending on flow dynamics. The pool most likely would have held less water (even reportedly periodically going dry as reported) during periods of drought, during dryer seasons of the year, and/or during periods that did not have heavy rainfall events such as would cause water to flow into the pool. On the other hand, the elevation the modern pool reservoir changed relatively little throughout the four-year period (2011-2014) in which it was monitored by SCPN (Monroe and Soles 2015), although the sediment influx into the pool and change in volume during this period is unknown (Stephen Monroe, personal communication, 2015). The upper 0.6 (2 ft) of the pool contains approximately one quarter of the total pool capacity in Greene (1978) (Stephen Monroe, personal communication, 2015).

It is unknown what impact future climatic conditions may have on the historic pool. Climate predictions for the Colorado Plateau are for more arid conditions, punctuated by megadroughts (Schwinning et al. 2008), with a decline in precipitation by as much as 5% by 2090 (BLM 2014). Increases in the frequency and intensity of extreme precipitation events are projected in the National Climate Assessment (Walsh et al. 2014).

A source of uncertainty is related to the formation of the deep and wide arroyo below the pool. It is unknown whether the arroyo formation was related to only climatic conditions or was influenced by late 19th and early 20th century disturbances at El Morro, such as grazing and/or modifications to the pool. It is also unknown what impacts, if any, that a deep arroyo below it would have had on the pool if the original concrete dam had not been constructed in 1926.

4.6.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this section. Stephen Monroe is a hydrologist for SCPN. Stephen Monroe and Ellen Soles, Senior Research Specialist at SCPN/Northern Arizona University, provided helpful reviews on a earlier draft of this section. Shari Kelley, Geophysicist/Field Geologist with the New Mexico Bureau of Geology and Mineral Resources also reviewed the assessment.

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4.7. Vegetation

Indicators/Measures

- Condition of Piñon-Juniper (12 measures)
- Condition of Ponderosa Pine (6 measures)
- Historic & Cultural Integrity of Vegetation on the Landscape (1 measure)

Condition – Trend – Confidence

Good to Moderate – Varied– Medium

4.7.1. Background and Importance

El Morro National Monument (NM), encompassing approximately 1,036 acres (419.4 ha), contains about 400 species of vascular plants (Rink et al. 2009; Figure 4.7.1-1). These plants exist within a relatively small number of communities at the national monument-- piñon-juniper woodlands, ponderosa pine woodlands, blue-grama grasslands, four-winged saltbush shrublands, and Gambel oak shrublands (Salas and Bolen 2010). Checklists of plants in the park were first compiled by McCallum (1981a), and then by Stolz (1986) and Rink et al. (2009). McCallum (1981b) described the vegetation and mapped the park's plant associations, and McCallum (1981c) provided an historical perspective on the vegetation of the Zuni Mountain region, including El Morro NM. Interpretation of the historical status of the vegetation was also undertaken by Schackel (1984), who conducted an analysis of vegetation change in the monument based on photographs. More recently, Salas and Bolen (2010) developed a classification system and map of the national monument's vegetation as part of the USGS-NPS Vegetation Mapping Program, a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in national park units across the United States. The results of the mapping project at the national monument are shown in Figure 4.7.1-2.

Vegetative communities at El Morro NM are a fundamental part of the ecosystem. They also provide wildlife habitat to the park's many wildlife species, are an important component of the scenery, and play a significant role in the historic and cultural landscape.

NPS / © PATTY VALENTINE-DARBY

Figure 4.7.1-1. Vegetation surrounding El Morro at El Morro NM.

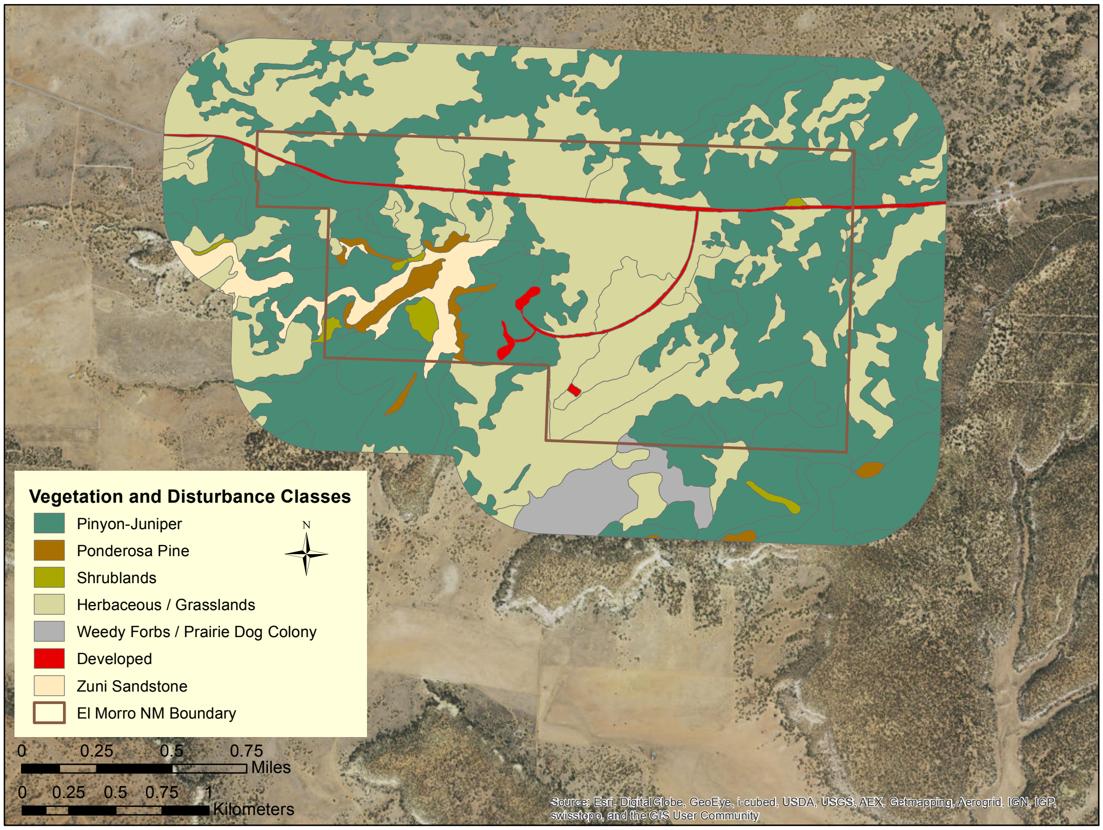


Figure 4.7.1-2. Vegetation types occurring at El Morro NM based on the mapping project of Salas and Bolen (2010). Note that the map includes a buffer area surrounding the national monument.

Although not addressed with an indicator/ measure in this section, biological soil crusts (BSC), or cryptobiotic soils (Figure 4.7.1-3), occur throughout the park (Salas and Bolen 2010). Salas and Bolen (2010) indicated that these soils were seen on 45 of their 47 observation points, and noted that such a "continuous establishment of cryptobiotic crust" may be due to the absence of grazing for a number of decades. Biological soil crusts are communities of cyanobacteria, green algae, microfungi, mosses, liverworts, and lichens that live on the surface of desert soils (USGS Canyonlands Research Station 2015). In arid and semi-arid environments, these highly specialized communities live in the open spaces between vascular plants and, in some areas, may make up to 70% of the living vegetative cover (Belnap et al. 2001). Because the primary components of biological soil crusts are photosynthetic, they require exposure to sunlight.

NPS (NEAL HERBERT)

Figure 4.7.1-3. Photo of biological soil crust (not taken at El Morro NM). Also see Figure 4.7.4-1.

Biological soil crusts provide many ecosystem services, including stabilizing soils, providing carbon to soils via photosynthesis, fixing atmospheric nitrogen, and increasing the bio-availability of phosphorus (Rosentreter et al. 2007). It is important to note that biological soil crusts are sensitive to many types of disturbance. Disturbances may decrease species diversity and cause a loss of biomass and surface cover of soil crust components (Belnap et al. 2001). While BSC have strong tensile strength, they do not have much compressional strength, and therefore are highly susceptible to mechanical disturbances (Belnap et al. 2001), such as from trampling and vehicles (Belnap and Eldridge 2003). Soil crusts are also highly susceptible to damage from hot fires (Belnap and Eldridge 2003). Disturbances during dry seasons have greater impact because the organisms in soil crusts are less able to recover (Belnap and Eldridge

2003). Climate change may impact soil crusts by altering the community structure as mosses and lichens respond differently to changes in temperature and precipitation patterns (Sasha Reed, pers. comm. with Allyson Mathis, 2015). The park's foundation document reports that biological soil crusts in the national monument are affected by visitors walking off the trails and by administrative activties (NPS 2014). Although we did not observe such impacts during our field visit to the park, we did observe localized disturbance from the digging activity of wildlife (thought to be badgers [Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, pers. comm.]).

4.7.2. Data and Methods

To address the condition of vegetation at El Morro NM, we used three indicators with a total of 19 measures. The first two indicators, for piñon-juniper (*Pinus edulis* and *Juniperus monosperma*, respectively) vegetation and ponderosa pine (*Pinus ponderosa*) vegetation, were assessed using the same set of six measures (described in detail below). We used a different measure for the third indicator, historic and cultural integrity of vegetation on the landscape. Our assessment was largely based on Romme and Jacobs (2015), a report produced for the vegetation condition assessments for El Morro and El Malpais National Monuments. The Romme and Jacobs (2015) report describes a vegetation field assessment conducted at both parks in June 2015, and provides significant interpretation of the results of the field visit based on their expertise and other existing documents and data (e.g., climate data). Although our assessment is based largely on this report, we also used additional sources of information. The third indicator, historic and cultural integrity of vegetation on the landscape, was assessed using historic and current-day photo pairs, as well as a discussion of the topic in Romme and Jacobs (2015).

The field assessment, described below, focused on piñon-juniper and ponderosa pine vegetation, so little information was specifically collected on grasslands and shrublands at El Morro NM. Therefore, we were unable to apply the six measures for them (as we did for the woodland types). However, grasslands, in particular, are addressed in this assessment in the first and third indicators. Grasslands are addressed in the context of changes over time in the vegetation at El Morro NM and by the expansion of piñon-juniper vegetation into grasslands.

<u>The Field Assessment</u>

The field assessment described in Romme and Jacobs (2015) was conducted at El Malpais NM and El Morro NM on June 2-4, 2015, with vegetation experts William Romme and Brian Jacobs, personnel from El Morro and El Malpais NMs, personnel from the Southern Colorado Plateau Network (SCPN), and one member of the NRCA writing team; these individuals are named in Section 4.7.5 of this chapter and/or Appendix A). The field assessment consisted of two days at El Malpais NM and a partial day at El Morro NM.

Given the respective sizes of the two parks, most of the time in the field was spent at El Malpais NM. Although many of the areas visited were in El Malpais NM, these areas were relevant in the interpretation of the condition of vegetation types in both parks. Areas of El Morro NM visited included the piñon-juniper woodlands and grasslands near the campground; the area (trail) around the base of Inscription Rock; and on top of El Morro, primarily along the trail. Observations of Box Canyon were also made from atop El Morro.

Indicators/Measures

Condition of Piñon-Juniper and Ponderosa Pine Vegetation

We describe two of these indicators/measures together here, because the same set of measures was used to assess both types of vegetation.

We adapted criteria developed by Edmonds et al. (2011), in consultation with vegetation experts, to evaluate the condition of piñon-juniper and ponderosa pine habitat at El Morro NM. Eight indicators were presented by Edmonds et al. (2011), but we used only five of them to assess vegetation at the park;

we, however, split them into six indicators for clarity. These formed the basis of our piñon-juniper and ponderosa pine indicators/ measures. Note that the other three indicators that we did not use in this section on vegetation were related to wildlife and water, which are topics addressed in other sections of the condition assessment. It should also be noted that although the water indicator (i.e., "clean flows from streams") was eliminated here, it is related to soil erosion, and we report on instances of erosion if they were observed or have been reported.

Measures

- Are the species present and their distributions consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability? (1)
- Are stand densities within their range of natural variability for their growing conditions? (2)
- Are the age class distributions of the trees consistent with the expected range of variability for this site/ecosystem type? (3)
- Do the trees and understory plants appear vigorous and healthy for this site/ ecosystem type? (4)
- Are ecological processes (e.g., fire) operating within a natural range of variability? (5)
- Are the current levels of insects and/or disease within the normal range for this ecosystem type? (6)

The first measure assesses whether the species and their distributions are within the natural range expected for the vegetation type (community). The second measure assesses tree densities within the plant communities, which can provide insight into the dynamics of a community to indicate condition. For example, if trees are more dense than expected, it could mean that conditions are conducive for those species and ecological processes such as fire are absent from the system. Higher than expected tree densities can lead to suppression of understory plant growth and diversity, and to reduced water yield in streams and springs because of increased transpiration by the trees. If trees occur in lower densities than expected, there could be some factor negatively affecting their recruitment or survival (e.g., fire or insects/disease or drought). The third measure, focusing on age class distribution, can reveal information on natural processes, such as seedling recruitment, fire, or other disturbances, that are characteristic of different types of plant communiites. Information obtained under the fourth measure can indicate whether nutrient cycling, water supply, light supply, etc., are operating within parameters that support the plant communities. The plants' physical appearance can provide information pertaining to this measure. Under the next measure, fire scars, type of vegetation, age of trees, and even historical photographs to a certain extent, can provide information that helps assess the range of variation for ecological processes. The final measure focuses on the current condition of infestations from insects or certain diseases that may indicate overall vigor of the system.

Although we generally consider these six measures as falling into two groups, ecological or vegetation characteristics (1-4 and 6) and ecological processes (5), there is also overlap among them. Therefore, we do not distinguish between the two groups throughout the assessment and treat each measure as having approximately equal weight.

As noted elsewhere, grasslands and shrublands were not the focus of our field assessments at El Morro NM (and El Malpais NM), although some observations were made. The main observations regarding grasslands at El Morro NM were of juniper-piñon savanna vegetation expanding into grasslands at the park, and the presence of dead or dying blue grama grass in some areas. These observations are discussed in various sections as appropriate.

Indicators/Measures
Historic & Cultural Integrity of Vegetation on the Landscape

El Morro NM was established in 1906 to preserve Inscription Rock, its large number of inscriptions, petroglyphs, and ancestral Puebloan sites, and to provide visitors the opportunity to experience these resources in their natural setting (NPS 2014).The rock contains more than 2,000 inscriptions and petroglyphs that span a period of 1,000 years (including from ancient Puebloans, Spanish explorers, early surveyors, and pioneers). Photographs from the late 1800s and early 1900s exist for El Morro.

Under this indicator, we assessed the historic and cultural integrity of vegetation on the landscape by examining changes in vegetation over time. We assessed this indicator/measure using a combination of the Romme and Jacobs (2015) report, historic and present day photos of the park showing park features and vegetation from a few locations, and a report from the 1980s addressing vegetation change in the park (i.e., Schackel 1984; "A Century of Change: A Photographic History and Analysis of Vegetation Conditions, El Morro National Monument, 1891-1983"). Romme and Jacobs (2015) also reviewed Schackel (1984), and provided additional interpretation of the photos discussed in the report using current data and literature. This aspect of the assessment also addresses both piñon-juniper vegetation and grasslands.

4.7.3. Reference Conditions

<u>Piñon-Juniper and Ponderosa Pine Vegetation</u>

Based more on ecological processes and dynamics of the vegetation (than on floristic composition and physiognomy, as in the vegetation mapping of Salas and Bolen 2010), Romme and Jacobs (2015) concluded that there are two fundamentally different kinds of piñon-juniper habitats within the national monument: 1) persistent piñon-juniper woodlands, and 2) juniper-piñon savannas (Table 4.7.3-1). [Romme and Jacobs (2015) used a functional classification of the vegetation because it is more useful in the context of the condition assessment. The dynamics of a piñon-juniper or ponderosa pine stand are more informative than the local species composition, because composition is primarily a reflection of soil and climate conditions and responds slowly to environmental stresses (W. Romme, pers. comm.). On the other hand, components such as tree density and fire frequency repond more quickly to environmental change, and affect the ecosystem as a whole. Their classification still includes species composition, just not as the first step in the classification process].

Romme and Jacobs (2015) also concluded that there are two types of ponderosa pine vegetation at El Malpais and El Morro NMs--1) ponderosa pine-piñon-juniper woodland/savanna, and 2) ponderosa pine-piñon-juniper rocky woodland. In their report, Romme and Jacobs (2015) considered the Box Canyon at El Morro NM to fall within the first type, although Dr. Romme (pers. comm., July 28, 2015) also described it as being substantially different from the ponderosa pine woodland/savannas at El Malpais and elsewhere in the Southwest. Dr. Romme pointed out that the ponderosa pine area in Box Canyon is similar to a woodland/savanna in terms of the species composition, but different in its natural dynamics. Box Canyon is a small area, and the vegetation within it probably did not burn as frequently as other areas of ponderosa pine woodland/savanna. He also emphasized that the area had been significantly affected during the early 1900s due to grazing and the corralling of livestock (e.g., Schackel 1984 [citing NPS 1932]).

For these reasons, and because the area of ponderosa pine vegetation within the national monument is relatively small (occurring mostly within Box Canyon and adjacent to some portions of El Morro {Salas and Bolen 2010, Figure 4.7.1-2}), we chose to address ponderosa pine vegetation in this condition assessment under one grouping (Table 4.7.3-2). See Appendix F (supplemental comments from Dr. Romme) for a more detailed discussion of the use of one ponderosa pine type at the national monument.

Table 4.7.3-1. Vegetation types dominated by piñon and/or juniper at El Morro NM and El Malpais NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Romme et al. (2009), Jacobs et al. (2008), and Grissino-Mayer (1995). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table (and two bottom photos) from Romme and Jacobs (2015). Top photo by SCPN, and second photo by P. Valentine-Darby.

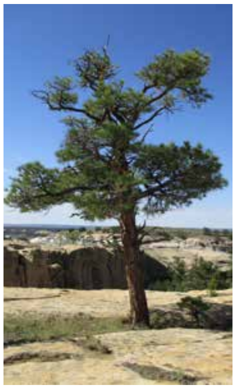
Persistent Piñon-Juniper Woodland	
	**Canopy:** The canopy is composed of *Pinus edulis* and *Juniperus monosperma*, and ranges in density from moderately sparse to moderately dense, depending on local site conditions. Many of the trees are centuries old. Younger trees (<100 yr old) also are numerous, resulting in an all-aged stand structure.
	Understory: Sparse to moderately dense cover of shrubs (e.g., *Atriplex canescens, Rhus trilobata, Forestiera pubescens*) and grasses (e.g., *Bouteloua gracilis, Hesperostipa comata*), usually with much bare ground.
	Site Conditions: Relatively dry sites, often steep and rocky, usually with coarse-textured soils.
	**Fire Regime:** Lightning-ignited fires occur yearly, but most burn only a single tree and fail to spread. However, spreading canopy fires can occur under very dry, windy conditions, and these are severe, stand-replacing fires. Intervals between stand-replacing fires at the scale of a 1-acre stand may be measured in decades or more likely in centuries.
	Plant associations from Salas and Bolen (2010) likely to be found: *Pinus edulis* - (*Juniperus monosperma*) / *Bouteloua gracilis* Woodland; *Pinus edulis* – (*Juniperus monosperma*) / Sparse Woodland; and *Pinus edulis* / Sparse Understory Forest.
Juniper-Piñon Savanna	
	**Canopy:** The canopy is composed of *Pinus edulis* and *Juniperus monosperma*, with *Juniperus monosperma* usually the more abundant, within a well-developed grassland matrix. Tree density ranges from sparse to moderately dense. Many of the trees are <100 yr old, representing the process of tree expansion into grasslands that has occurred during the past century.
	Understory: The understory is dominated by grasses. *Bouteloua gracilis* appears to be the major grass species in most areas, but others (e.g., *Hesperostipa comata*) are also found. Sparse shrubs (e.g., *Atriplex canescens*) and cacti (e.g., *Opuntia imbricata*) may be present as well.
	**Site Conditions:** Relatively deep, fine-textured soils, usually on relatively gentle terrain.
	Fire Regime: The historical fire regime is not well understood, but may have been characterized by spreading fires at intervals of years or decades that burned through the grasses and thinned the trees.
	Plant associations from Salas and Bolen (2010) likely to be found: *Juniperus monosperma* / *Bouteloua gracilis* Woodland.

These three general habitat types form the basis for the reference conditions used to assess the condition of piñon-juniper and ponderosa pine vegetation throughout the national monument.

We considered the condition to be good for a given measure within each piñon-juniper or ponderosa pine habitat type if it was consistent with maintaining:

- a fully functioning community of plants (and animals that each piñon-juniper or ponderosa pine habitat type supports),
- a resilience to natural or anthropogenic disturbances that vary in intensity,

Table 4.7.3-2. Vegetation type dominated by ponderosa pine at El Morro NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Grissino-Mayer (1995), Grissino-Mayer and Swetnam (1997), and Allen et al. (2002). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table adapted from Romme and Jacobs (2015) with input from Dr. Romme. Top left and bottom photo by P. Valentine-Darby; top right photo by University of Pennsylvania (Mason et al. In prep).

Ponderosa Pine-Piñon-Juniper Rocky Woodland	
 	Canopy: The canopy is composed mainly of *Pinus ponderosa, Pinus edulis*, and *Juniperus monosperma*. Many of the trees of all species are centuries old. Younger trees (<100 yr old) also are numerous, resulting in an all-aged stand structure.
	Understory: The understory is composed of shrubs (e.g., *Quercus gambelii*, *Atriplex canescens*, *Rhus trilobata*), scattered grasses and forbs (e.g., *Bouteloua gracilis, Opuntia* sp.), and small trees, with much bare rock exposed.
	Site Conditions: Found on rugged terrain with much bare rock exposed, commonly sandstone bedrock. Little soil development except in cracks in the bedrock. Woody plants are prevalent, probably because their roots can penetrate cracks to deep water sources.
	Fire Regime: Not well understood. Lightning-ignited fires occur yearly, but most apparently burn only a single tree or small group of trees and shrubs, and fail to spread over any larger area, except perhaps under extremely dry, windy conditions.
	Plant associations from Salas and Bolen (2010) likely to be found: *Pinus* ponderosa / *Quercus gambelii* Woodland.
	Photos: Top photo was taken atop Inscription Rock; the tree shown is growing in a crack or depression where soil and water accumulate. Bottom photo is the Box Canyon.

duration, and size, while maintaining or sustaining the habitat type's inherent complexity, and

- the natural dynamics of the piñon-juniper or ponderosa pine habitat type with respect to productivity, nutrient capital, and biodiversity.

We considered the condition to be of moderate concern if there was some departure from the elements listed above for a given indicator, but that the piñon-juniper or ponderosa pine habitat type was capable of restoring itself to a good condition on its own, or with limited management intervention. Finally, we considered the condition to be of significant concern for a given indicator if there was substantial departure from the elements listed above that were either irreversible or would require substantial management intervention to return the condition to good.

<u>Historical and Cultural Integrity of Vegetation on the Landscape</u>

For this indicator/measure, we considered condition to be good if changes in the vegetation retain the historic and cultural values of the national monument. We considered condition to be of moderate concern if vegetation changes deviate somewhat from historic conditions and create some loss of cultural and historic integrity. We considered the condition to be of significant concern if vegetation changes deviate dramatically from historic conditions and create a substantial loss of cultural and historic integrity at the national monument.

<u>Reference Period</u>

The period of time used as a reference for assessing piñon-juniper and ponderosa pine vegetation at the national monument was the period of several centuries up to around 1880 (Romme and Jacobs 2015). In evaluating ecological change in the Southwest, this pre-1880 time period has often been used. *Note* *that the following indented text was taken directly from Romme and Jacobs (2015).*

> The several centuries prior to around 1880 was not a time without any human impacts, nor a time without any ecological change. However, the rate and magnitude of human impacts and ecological changes increased dramatically beginning in the late 19th century, with the onset of very heavy livestock grazing, industrial scale logging, and a market economy supported in part by an expanding network of railroads and capital from outside the region. Relative to what would come later, the pre-1880 period can be viewed as a time of comparatively natural ecological characteristics and ecological processes.
>
> Puebloan people (notably Acoma, Zuni, and Laguna) have continuously occupied the area around El Malpais and El Morro National Monuments since at least the 1100s A.D., and Spanish explorers, missionaries, and settlers began to frequent the area in the early 1600s (Weber 2009). Although Puebloan people began raising European livestock as early as the 1600s, the lands within present-day El Malpais NM probably were not heavily influenced by this early grazing, because they were somewhat remote from settlements and lacked water (Grissino-Mayer 1995). It seems likely that early livestock grazing would have had greater impacts on the vegetation within present-day El Morro NM, because that area was closer to Zuni Pueblo, provided a reliable water source, and was situated along a well-used trading route. However, the magnitude of pre-1880 grazing impacts at El Morro NM is not well understood. Puebloan people also harvested trees for construction and fuel, but those impacts probably were localized and left little lasting impact.

Note that upon park review of the above text from the Romme and Jacobs (2015) report, it was pointed out that some relevant historical information was missing, and so we present it here: Also around the early 1600s, Ramah Navajo began grazing sheep and cattle in the area. They continued to graze sheep in the El Morro area and in Box Canyon until the late 1940s/early 1950s (Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, pers. comm.; Ferguson 2012, Bradford 2013).

> *Changes after 1880*
>
> After the Atlantic and Pacific Railroad arrived at what would become Grants, New Mexico, in 1881, the intensity of livestock grazing in and around the malpais increased dramatically. The town of San Rafael, at the edge of the lava flows, became a center for tens of thousands of sheep that grazed on lands within the future El Malpais NM (Grissino-Mayer 1995). Large cattle companies also were established in the area, and horses were pastured on some of the kipukas within the malpais. Grazing intensity was greatest during the 1880s, then decreased in the 1890s and through the 20th century, but continues in the areas surrounding the two monuments (Grissino-Mayer 1995).
>
> *Importance of Climatic Variation*
>
> It is important to recognize that regional climate was not static during the pre-1880 reference period, nor has it been unchanging since that time. A 2,129-year local climate reconstruction, based on tree-rings collected from ancient trees in El Malpais NM (Grissino-Mayer 1995), reveals alternating wet and dry periods throughout the last two millennia. The driest period and the wettest period in the 2,129-year chronology occurred in the late 1500s and in the late 1900s, respectively (Table 4.7.3-4). Indeed, very few portions of that long climate chronology would be described as

Table 4.7.3-4. Synopsis of climate variability since the late 15th century at El Malpais NM, based on a tree-ring chronology developed by Henri Grissino-Mayer. Adapted from Table 3.15 (pages 108-110) in Grissino-Mayer (1995), and taken from Romme and Jacobs (2015, Table 1a).

Period	Climate Conditions
1483-1540 A.D.	Generally favorable moisture conditions, but numerous drought years interspersed among wet years
1541-1567 A.D.	Great year-to-year variation, with more wet years than dry years
1568-1607 A.D.	The "Great Drought," seen throughout the West, worst short-term drought in the 2,129-year record at El Malpais NM
1608-1656 A.D.	Generally favorable moisture conditions, with a few severe drought years
1657-1723 A.D.	Variable moisture conditions, but few extremely wet or extremely dry years
1724-1790 A.D.	Generally unfavorable moisture conditions, with some wet years but many severe drought years
1791-1829 A.D.	Great year-to-year variation, with numerous very wet years
1830-1889 A.D.	Generally favorable moisture conditions, with many very wet years but also with occasional drought years
1890-1904 A.D.*	Generally unfavorable moisture conditions, with many more drought years than wet years; a brief but severe drought from 1891-1893
1905-1943 A.D.	Very wet period, with variation from year to year but no extreme climate years
1944-1963 A.D.	Severe drought period, most years with below-average moisture but no extreme climate years
1964-1992 A.D.	Very favorable moisture conditions overall, but highly variable with some extremely wet and extremely dry years; 1978-1992 saw the greatest precipitation in the 2,129-year record at El Malpais NM

*Upon review of the condition assessment, Steve Baumann (Resources Management Chief, El Morro and El Malpais NMs, pers. comm.) noted that there are photos of the area around Inscription Rock ~1902-1904 by A.C. Vroman that show livestock impacts and what appear to be very dry conditions.

Table 4.7.3-5. Climatic variation at El Morro NM during the last 76 years. Source: National Oceanic & Atmospheric Administration--National Environmental Satellite, Data, and Information Service (http://www.ncdc.noaa.gov/cdo-web/), data obtained on 6/29/2015. Table taken from Romme and Jacobs (2015, Table 1b).

Period	Average Total Annual Precipitation (inches)	# Years Having Below-Average Total Annual Precipitation
1950-1959	11.36	9 out of 10
1960-1969	12.79	6 out of 10
1970-1979	14.00	5 out of 10
1980-1989	15.78	3 out of 10
1990-1999	15.81	3 out of 10
2000-2009	13.25	7 out of 10
2010-2014	12.64	3 out of 5
2012-2014	10.29	3 out of 3
1939-2014	**13.83 inches (overall average for the period of record)**	

"normal" or "average." Wet periods generally favored vegetative growth, and severe droughts periodically stressed the vegetation as well as the people eking out a living in western New Mexico. Subsequently, the 20th century has been one of the wettest and warmest centuries in the last millennium. The long-term climate trends documented in El Malpais NM also were seen across much of the Southwest (Swetnam and Betancourt 1998, Gray et al. 2003).

Although the 20th century was a generally wet period overall, its climate also fluctuated, and included some noteworthy drought periods. Grissino-Mayer's (1995) tree-ring based chronology extends only up to 1992. However, instrumental climate records are available for El Morro NM as far back as March of 1938 (http://www.ncdc.noaa.gov/cdo-web/). We calculated average annual precipitation for the entire period of record (1939-2014), and also for individual decades from the 1950s through 2014 (Table 4.7.3-5). (Data were missing for four years in the 1940s, so we did not calculate the average for that decade). It is apparent in Table 4.7.3-5 that the 1950s and 1960s were dry decades, consistent with the pattern in the tree-ring record. Indeed, many piñon and ponderosa pine trees died during that drought (Breshears et al. 2005).

The 1970s had close to average annual precipitation, and then the 1980s and 1990s were very wet—although a few individual dry years occurred during those two decades of overall moist conditions. The first decade of the 21st century turned relatively dry again, with most years having below-average precipitation even though the decade's total precipitation was only a little below the long-term average due to one exceptionally wet year (2006 with 18.26 inches total). The climate since 2010 also has been dry, and the most recent three years (2012-2014) was the driest three-year period at El Morro NM since the 1950s...Global climate models predict a trend of increasing temperatures and perhaps decreasing precipitation throughout the 21st century (IPCC 2013).

4.7.4. Condition and Trend

Indicators/Measures

Condition of Piñon-Juniper Vegetation

<u>Piñon-Juniper Vegetation</u>

As described previously, there are two types of piñon-juniper habitat at El Morro NM based on the functional/dynamic classification of forest and woodland vegetation used by Romme and Jacobs (2015)-- persistent piñon-juniper woodlands, and juniper-piñon savannas. Persistent piñon-juniper woodlands, usually characterized by centuries-old trees, are found scattered across both national monument landscapes, in both small patches and extensive stands, in areas having rocky or thin soil that is unsupportive of abundant herbaceous growth (Romme and Jacobs 2015). They are often found on ridgetops and steep slopes, but they are also found on flatter topography where soil conditions are better for deep-rooted woody plants compared to herbaceous plants. During the field assessment in June, persistent piñon-juniper woodlands were observed in the campground area and atop El Morro in the national monument (Romme and Jacobs 2015).

The second type of piñon-juniper woodland, juniper-piñon savanna, also described in the table, consists of one-seed juniper and piñon pine trees within a grassland matrix. The tree density varies greatly. At El Morro NM, these savannas are found around Inscription Rock in areas where the topography is gentle and soils are relatively deep and fine-textured (Romme and Jacobs 2015). During the June field assessment, juniper-piñon savanna was observed at the park on the west side of the campground and around Inscription Rock.

An important difference between these two piñon-juniper types that Romme and Jacobs (2015) point out is that "many of the savannas we see today probably were nearly treeless grasslands 100+ yrs ago. The relative abundance of trees vs. grasses apparently fluctuates over century-long time scales: grasses predominate during dry periods and after severe fires, whereas trees become increasingly abundant during wet periods and during long intervals between successive fires (Romme et al. 2009). The 20th century was a relatively wet period with few fires in this area (Grissino-Mayer 1995), and trees have greatly increased as a consequence."

Measure 1: Are The Species Present, And Their Distributions Consistent With Supply And Demand Of Light, Water, Nutrients, And Growing Space, And Within Their Natural Range Of Variability?

Persistent Piñon-Juniper Woodlands

In general, the species present and their corresponding distributions appear to be within their natural range of variability, and therefore, are in good condition. Although native species predominate in most places visited, some non-native species were observed in specific locations. At El Morro NM, these were localized occurrences of horehound (*Marrubium vulgare*) and filaree (*Erodium cicutarium*). Overall, however, non-native plants did not appear to be very abundant or widespread in this woodland type, and the two species mentioned have a relatively low impact on native plants and ecological process where they occur (Romme and Jacobs 2015; although horehound has been given a medium impact ranking- see Table 4.8.2-2 in Section 4.8).

An additional species was observed at El Malpais NM during the field visit that is of relatively greater concern (cheatgrass {*Bromus tectorum*}). Although it was not observed at El Morro NM in this woodland type during the field visit, it is known to occur in El Morro NM (Rink et al. 2009). In general, this species is of greater concern because it is capable of expanding substantially after soil disturbance. Such an expansion, if it occurred, could potentially threaten the ecological integrity of this community type that is poorly adapted to fire (see discussion in Romme and Jacobs 2015).

Note that while exotic plants are addressed here to some extent, they are covered more thoroughly in the exotic plants section of the condition assessment (Section 4.8).

Juniper-Piñon Savannas

In juniper-piñon savannas, the species present and their distributions generally appear to be within their natural range of variability and in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically (Romme and Jacobs 2015).

Measure 2: Are Stand Densities Within Their Range Of Natural Variability For Their Growing Conditions?

Persistent Piñon-Juniper Woodlands

The condition for this measure deviates somewhat from the reference condition, but the persistent piñon-juniper woodlands at El Morro NM are still considered to be in good condition for this measure (i.e., still within the natural range of variability). Tree densities are likely greater than before 1900 in most stands due to infill driven by climate, which has occurred in piñon-juniper woodlands throughout the Southwest (Romme and Jacobs 2015). It is natural for tree densities to increase and decrease in this vegetation type over century-long time scales. An increase in the tree density "probably is a mostly natural result of favorable climatic conditions for tree establishment and growth during the past century, plus a paucity of fires. Human-caused fire exclusion no doubt contributed to the lack of fires. However, this vegetation type does not burn frequently in any case because of its inherent fuel structure; we suspect that most of the persistent piñon-juniper woodland in the national monument would have escaped fire in the past century even if humans were not present" (Romme and Jacobs 2015). Importantly, the understory vegetation appears healthy and diverse in the stands observed, so it does not appear that the densification of trees is adversely affecting the understory. The change is not considered to pose a serious threat to ecological integrity, and Romme and Jacobs (2015) do not suggest any management actions to address it (but see the end of this paragraph). Rather, they point out that climate models indicate that more drought, and therefore fire, may occur in the future than occurred in the 1900s, and these conditions may lead to increased mortality of piñon and juniper trees (see paragraph below). A situation in which management action may be sought, however, is when dense stands of piñon and junipers pose an unacceptable fire hazard to significant park resources (Romme and Jacobs 2015).

[Note that this paragraph, provided by Dr. Romme during review of this section, describes in more detail how drought conditions affect tree survival]. Drought can lead to tree mortality both directly and indirectly. Direct drought-caused mortality occurs when trees simply cannot obtain enough moisture from the soil to make up for the water lost in transpiration, and they die. Even if drought is not severe enough to kill a tree outright, drought stress reduces a tree's ability to produce defensive chemicals and resin with which to repel attacks by insects and disease; thus, mortality from insects or disease can be an indirect effect of drought. Dry conditions also allow for fires to burn more frequently and more intensely; thus, fire-caused mortality also can be an indirect effect of drought. This is why this report pays so much attention to climate variation, especially the occurrence and intensity of drought, both historical and future: it is because drought is often the ultimate cause of tree mortality, either directly or via insects, disease, or fire.

Juniper-Piñon Savannas
To address this measure, Romme and Jacobs (2015) wrote (note that it addresses both El Malpais and El Morro National Monuments):

> Tree densities probably are greater in most stands than before 1900, and trees also appear to have expanded into former grasslands in many areas. The mechanism driving these processes of infill of pre-existing savannas and expansion into former grasslands is uncertain, but may be the result of a century of fire exclusion as well as the 20th century climate which was favorable for tree establishment and survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Extreme densification of juniper-piñon savannas potentially may threaten the ecological integrity of affected grasslands, may reduce ground water recharge, and may support high-severity crown fires. These negative changes may be happening in some savannas in eastern New Mexico. However, the current densities and visual impacts on grasslands in El Morro NM and El Malpais NM are much less dramatic than in those other places. Current tree densities do not appear to pose a serious threat to ecological integrity in... El Morro National Monument.

Although the densities of trees within savannas in El Morro NM are greater than they were prior to the 1900s (see discussion of photographic evidence later in this section), they do not appear to be affecting the integrity of the savannas. However, because current densities are probably "at or above the highest typical densities in the juniper-piñon savanna type," we consider current condition under this measure to be of moderate concern. It is possible, however, that tree densities may have been similar to those seen today during past periods with moist conditions (e.g., the early 1500s, early 1600s, and mid-1800s; Romme and Jacobs 2015). One notable area where densities are at or above the hightest typcial densities is near the base of Inscription Rock (Figure 4.7.4-1). The park has concerns over the potential for uncontrollable wildfire in this area that could lead to damage to the


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Figure 4.7.4-1. Patches of dense vegetation in the savanna near the base of Inscription Rock (June 2015). Also note visible biological soil crusts, discussed earlier in the assessment.

inscriptions. Romme and Jacobs (2015) suggest that this concern could be lessened by "judicious mechanical thinning of the woodlands in close proximity" to Inscription Rock.

Note that there is an interesting and useful discussion of the possible mechanisms for the infill of pre-existing savannas and expansion of savannas into former grasslands in Romme and Jacobs (2015). Basically, the two alternative (or combined) explanations described are that: 1) frequent burning of juniper-piñon savannas may have occurred prior to the 1900s that thinned savannas and prevented establishment of trees in grasslands (i.e., fire exclusion model); and/or 2) climate in the 20th century was favorable for tree establishment and survival in most of the Southwest, and the expansion of juniper and piñon trees was the result (i.e., climate model). Romme and Jacobs (2015) stress that, because data are lacking to test and refine these models, uncertainty exists regarding the causes of tree densification at El Morro NM.

<u>Measure 3: Are The Age Class Distributions Of Trees Consistent With The Expected Range Of Variability For This Site/ Ecosystem Type?</u>

Persistent Piñon-Juniper Woodlands

Although we have limited data that address the age class distributions of piñon-juniper at the national monument, the age classes appear to be within their natural range of variability (Romme and Jacobs 2015). All-aged population structures were observed, which are typical of this woodland type, with centuries-old trees, as well as younger trees <100 years old, present. Based on the information available, therefore, we consider condition to be good for this measure. See Figure 4.7.4-2, which shows the aging of a tree (stump) during the June 2015 field assessment.

Juniper-Piñon Savannas

Based on limited information, the age classes appear to be approximately within their natural range of variability. However, it appears that a greater proportion of the population is made up of 10- to 100-year-old trees than probably occurred before 1900 (Romme and Jacobs 2015). Some centuries-old trees were observed in savannas that would have been considered savannas before 1900. However, old trees were not observed in areas where one-seed juniper is expanding into former grasslands. We consider condition to be good for this measure for savannas. Implications for grassland condition are discussed elsewhere.

NPS / © PATTY VALENTINE-DARBY

Figure 4.7.4-2. Dr. Romme aging a tree stump in persistent piñon-juniper woodlands near the campground. The tree (a piñon pine) was estimated to be approximately 250 years old when it died.

<u>Measure 4: Do The Trees And Understory Plants Appear Vigorous And Healthy For This Site/Ecosystem Type?</u>

Persistent Piñon-Juniper Woodlands

For this piñon-juniper type, most individual trees and understory plants appeared healthy. Some dead piñon trees were observed in at least one location (atop El Morro), but this occurrence does not represent a serious concern. It is possible that, like at El Malpais NM, the trees may have died within the last 5-10 years due to recent drought conditions. Small-scale events such as this are natural (Romme and Jacobs 2015). We consider condition under this measure to be good.

Juniper-Piñon Savannas

Most trees and understory plants, including grasses and forbs, appeared healthy within the savannas observed. Therefore, condition was considered good for this indicator/measure.

<u>Measure 5: Are Ecological Processes (e.g., Fire) Operating Within A Natural Range Of Variability?</u>

Persistent Piñon-Juniper Woodlands

As described earlier in this section, persistent piñon-juniper woodlands burn rarely, except for single-tree ignitions that fail to spread, with intervals between stand-replacing fires on the order of centuries. It is possible that fire intervals have become somewhat longer due to fire exclusion in the 20th century, but intervals remain within the historical range of variability for this woodland type (Romme and Jacobs 2015). This possible change is not of particular concern, and the condition for this measure is considered to be good.

Juniper-Piñon Savannas
There is considerable uncertainty in applying this indicator/measure to savannas (Romme and Jacobs 2015). The reason is that historical fire regimes of juniper-piñon savannas are not well understood. With the continuous fine-fuel cover that grasses provide and the frequency of dry weather, fires that spread may have been relatively frequent. If this was the case, then the infrequency of fires today (essentially no fire) is a substantial departure from the historical fire regime. Note that the increase in density of trees within the savannas at the national monument was discussed above. As also discussed there, Romme and Jacobs (2015) state "...we do not regard the densification of these savannas or the expansion of junipers into former grasslands as serious threats to the ecological integrity of the ...monument. Tree densities naturally wax and wane in this vegetation type over century-long time scales (Romme et al. 2009)." We consider condition for this indicator/measure to be of moderate concern, but we stress that there is more uncertainty in this case than with the other measures.

Measure 6: Are the Current Levels of Insects and/or Disease within the Normal Range for this Ecosystem Type?
Persistent Piñon-Juniper Woodlands
We found no evidence that the levels of insects and/or disease are outside the normal range for this ecosystem type, although we did not specifically look for such evidence at El Morro NM. No evidence of insects or disease was observed at El Malpais NM during the field assessment there (Romme and Jacobs 2015). Insects and disease appear to pose no serious threat at this time, and condition for this measure is considered to be good.

Juniper-Piñon Savannas
As with the woodland type, during the field assessment we found no evidence that the level of insects and/or disease are outside the normal range for savannas (Romme and Jacobs 2015). Insects and disease appear to pose no serious threat at this time, and condition for this indicator/measure is considered to be good.

Summary of Condition for Piñon-Juniper Vegetation with Notes on Grasslands
We used a variety of measures that were adapted from Edmonds et al. (2011) to assess the condition of piñon-juniper vegetation. The overall condition of piñon-juniper communities at El Morro NM is good, although there are some areas of concern. Of the six measures for the two vegetation types (12 measures total), ten are considered to be in good condition. Two (both for juniper-piñon savannas) are considered to be of moderate concern. Overall, the main areas of concern are the increase in densities of trees in savannas, and the potential change in fire intervals in the savannas.

Regarding grasslands, the expansion of juniper and piñon trees at the national monument (Romme and Jacobs 2015) has converted some grasslands into savannas, and therefore has decreased the amount of area dominated solely by grasses without any major woody component; however, note that we have no quantitative data in this regard. Grasslands are also discussed under the third indicator in this assessment.

The main area of uncertainty with the measures for piñon-juniper vegetation is with regards to the possible reduction in fire frequency in the savannas, and the possible effect of such a reduction on juniper densities within savannas and former grasslands, as described further in the Level of Confidence/Key Uncertainties section at the end of the overall Condition section).

Indicators/Measures
Ponderosa Pine Vegetation

We chose to address ponderosa pine vegetation in the national monument as one type, ponderosa pine-piñon-juniper rocky woodland. This type is generally found in areas having rugged topography (Romme and Jacobs 2015). This is the case atop El Morro, but for the ponderosa pine along the base of El Morro, the topography is more gentle and the soils are deeper. The stand structure and composition in areas where this type occurs varies greatly, largely due to variation in substrate characteristics and topography, with ponderosa pine, piñon pine, and one-seed juniper the dominant canopy species. A diverse mix of shrubs, grasses, and other herbaceous species are common in the understory wherever soil is present, especially along the base of El Morro. During the June field assessment, these rocky woodlands were observed on top of El Morro (Romme and Jacobs 2015), as well as in Box Canyon (from above) and along the base of El Morro.

Stand structure and dynamics in this ponderosa pine type are also influenced by fire, but fire occurs less frequently in this type than in the woodland/savanna type. Romme and Jacobs (2015) summarized information from Grissino-Mayer (1995) and Grissino-Mayer and Swetnam (1997) on the history of fire in ponderosa pine forests on the El Malpais NM landscape. The latter researchers found that a fire was recorded about every 11 yrs within a 30-acre (12.5-ha) area at Hoya de Cibola from the mid-1600s until 1880. Romme and Jacobs (2015) pointed out that even though fires do occur in these rocky woodlands, many of the trees go unburned for centuries. Grissino-Mayer (1995) determined some living trees in El Malpais NM to be >600 years old.

Measure 1: Are the Species Present, and their Distributions Consistent with Supply and Demand of Light, Water, Nutrients, and Growing Space, and within their Natural Range of Variability?

In this vegetation type, the species present and their corresponding distributions appear to be within their natural range of variability. The exception to this, however, is in Box Canyon, where exotic plant species are known to exist. In other places observed, native species predominate. Although we did not enter Box Canyon during the June field visit (but rather, viewed it from above, including with binoculars), we saw what appeared to be cheatgrass (*Bromus tectorum*) in the canyon (W. Romme, pers. comm., July 2015). Park staff also reported this species in Box Canyon, as did Salas and Bolen (2010, page 27). Rink et al. (2009) reported that cheatgrass was one of the most abundant exotic plant species in the park (also see Section 4.8, although we are only assessing ponderosa pine vegetation here). Concern exists over this plant because it is capable of expanding substantially after fire and/or soil disturbance. It probably occurs in the canyon due to the canyon's history of disturbance from grazing. Based on the discussion presented here, we consider condition for this indicator/measure to be of moderate concern.

Measure 2: Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?

At El Morro NM, there was little evidence that stand densities deviate from the reference condition for ponderosa pine-piñon-juniper rocky woodlands. Therefore, we consider condition under this indicator/measure to be good.

Measure 3: Are The Age Class Distributions Of Trees Consistent With The Expected Range Of Variability For This Site/ Ecosystem Type?

Although we have limited data for this indicator/measure, the age classes generally appear to be within their natural range of variability for this woodland type. We consider condition to be good for this indicator/measure.

Measure 4: Do the Trees and Understory Plants Appear Vigorous and Healthy for this Site/Ecosystem Type?

For ponderosa pine-piñon-juniper rocky woodlands, most individual trees and native understory plants appeared healthy. At least a few dead ponderosa pine trees were observed in Box Canyon, however. Although we did not enter the canyon and examine the trees (as we did for dead trees in El Malpais NM), they may have died over the last 5-10 years due to drought conditions. The loss of a few trees does not appear to threaten the ecological integrity of this woodland type at the park, and the availability of some dead ponderosa pines is beneficial to wildlife that nest or roost in such areas (e.g., some species of bats [Chung-MacCoubrey 1996]). Therefore, we consider condition under this indicator/measure to be good.

Measure 5: Are Ecological Processes (e.g., Fire) Operating within a Natural Range of Variability?

Across the Southwest, due to fire exclusion in the 20th century, fire intervals have lengthened considerably, even in areas of rugged topography and discontinuous fine fuels (Romme and Jacobs 2015). This is also the case for this ponderosa pine vegetation type. However, even though the historical range of variability has been exceeded, the potential consequence of this is different than for other ponderosa pine types (such as woodland/savannas). In the case of the rocky woodlands, fire probably did not play a critical role in maintaining the characteristic stand structure (Romme and Jacobs 2015). For these reasons, and because overall ecological integrity does not appear to have been compromised by the lack of fire in the last century, we consider condition under this indicator/measure to be good. Additionally, fire in Box Canyon was probably less frequent than in similarly vegetated areas of ponderosa pine in the vicinity of the park due to the physical confines and the small size of the canyon (W. Romme, pers. comm.).

Measure 6: Are the Current Levels of Insects and/or Disease within the Normal Range for this Ecosystem Type?

We found no evidence that the level of insects and/or disease are outside the normal range for this vegetation type. However, we did not examine individual ponderosa pine and other trees in this vegetation type during our June field assessment. We did, however, examine dead ponderosa pine trees in nearby El Malpais NM and found no evidence of tree mortality or morbidity due to insects or disease there (Romme and Jacobs 2015). Insects and disease appear to pose no serious threat at this time, and condition for this indicator/measure, based on the available information, is considered to be good.

Summary of Condition for Ponderosa Pine Vegetation

We used a variety of measures adapted from Edmonds et al. (2011) to assess the condition of ponderosa pine vegetation. The overall condition of this vegetation type at El Morro NM is good, although there is at least one area of concern. That area of concern is the occurrence of exotic plant species, especially cheatgrass in Box Canyon. Of the six measures for this indicator, all were estimated to be good, except for one (of moderate concern) due to the occurrence of exotic plant species.

Also, our confidence in this part of the assessment (for ponderosa pine vegetation) is only medium. This is largely due to the fact that we did not enter Box Canyon, but viewed it from the top of El Morro, and the time we spent in ponderosa pine communities in the park was relatively short.

Indicators/Measures
Historic & Cultural Integrity of Vegetation on the Landscape

As discussed previously in this assessment, El Morro NM was established to preserve Inscription Rock and its inscriptions and ancestral Puebloan sites, and to provide visitors the opportunity to experience these resources in their natural setting (NPS 2014). Park personnel and reports (e.g., NPS 2014) have expressed concerns about the vegetation at El Morro NM changing over the past approximately 100 years. They especially have concerns about an increase in the density of one-seed juniper and piñon pine trees around the base of Inscription Rock. The current density of juniper in the national monument was discussed earlier in this section of the condition assessment. Juniper densities are of concern to managers because in close proximity to Inscription Rock, as well as man-made park structures, the wildfire hazard is increased. A fire next to the rock may lead to damage to the inscriptions. Such an event happened in Mesa Verde NP when a wildfire at the base of a cliff led to a portion of the rock, containing ancient rock art, to break off (Romme and Jacobs 2015). Vegetation can also rub against the sandstone, causing damage. Also, the increased density of the vegetation

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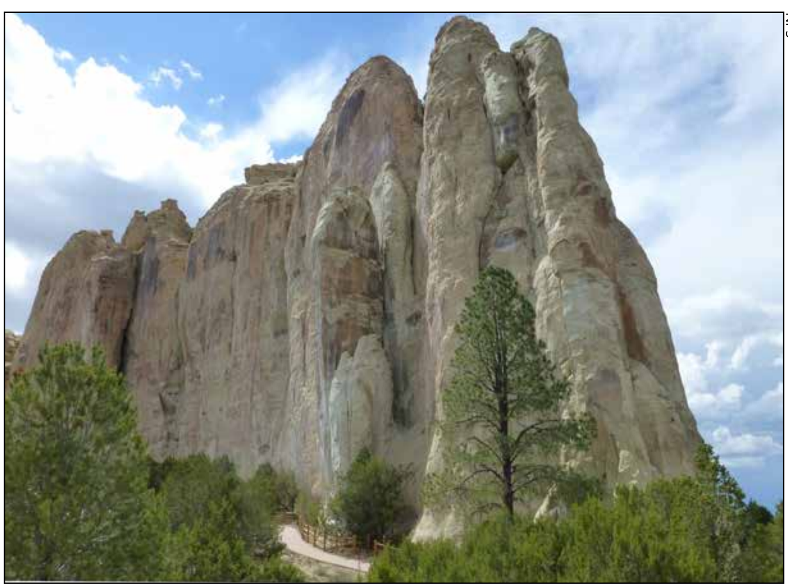
Figure 4.7.4-3. 1873 photo, which is one of the oldest of Inscription Rock and the vegetation surrounding it.

PHOTO PROVIDED BY NPS / ORIGINAL PHOTOGRAPHER UNKNOWN

Figure 4.7.4-4. 1890-1891 photo of Inscription Rock and the vegetation surrounding it.



NPS

Figure 4.7.4-5. Photo of Inscription Rock and the vegetation surrounding it taken around 2015

NPS / © GEORGE GRANT

Figure 4.7.4-6. Inscription Rock taken in 1929.

NPS

Figure 4.7.4-7. Inscription Rock taken ~2015.

provides a different view of Inscription Rock and the surrounding landscape than existed previously (e.g., around the time that the park was established in 1906). Figures 4.7.4-3 through 4.7.4-7 show photos of El Morro and nearby vegetation from as early as 1873 and 1890/1891, and as recently as ~2015. The increase in trees from the early photos to the later photos is apparent.

As mentioned in the Data and Methods section, we reviewed Schackel (1984), which addressed vegetation change in the park using photos from 1891 and later and compared them to photos from 1983. The discussion that follows is based on Romme and Jacobs' (2015) review and interpretation of the Schackel (1984) report.

The most obvious vegetation change seen in the photos from the early ones to more recent years is an increase in cover of piñon, juniper, and shrubs (Romme and Jacobs 2015). Romme and Jacobs (2015) had a somewhat different explanation for the vegetation increase than Schackel (1984). Schackel (1984) suggested that the increase was due to a lack of fire and grazing since the time that the monument was established. Romme and Jacobs (2015), however, suggest that climatic variability played an important role. They also believe that livestock grazing in the 1800s was important, but they question the role of fire (or lack thereof) as the reason for the vegetation increase.

Romme and Jacobs (2015) interpret some of the photos in the Schackel (1984) report in a climatological context. Although we do not attempt to present the photographs from the Schackel report here (due to their number and reproducibility), the photos in Figures 4.7.4-3 and 4.7.4-7 are generally adequate for understanding the major points made. Below, we address grasses and shrubs first, then woodland vegetation.

Grasses and Shrubs: Photos from 1891 (in the Schackel report) show few trees or shrubs, and the grass is sparse. Conditions during this period included a severe drought between 1891 and 1893, and a preceding 30 years of highly variable rainfall; intense grazing that had been occurring for decades; and gradually warming temperatures in the West (Romme and Jacobs (2015). Romme and Jacobs (2015) pointed out that the combined effects of drought and heavy grazing could account for the condition of the grasses in the 1891 photos, and the "marginal" condition of the shrubs may have been due to browsing by goats and sheep (which existed along with the cattle per Schackel [1984]). Similarly, in a photo from 1955 (Figure 27 in Schackel [1984]) the grass looked sparse. However, this year was in the middle of the driest decade in the 1900s (Romme and Jacobs 2015 citing Grissino-Mayer 1995). From their review, including data on climate conditions, Romme and Jacobs (2015) concluded that the 1891 photos showed the effects on the grasses and shrubs from drought and heavy grazing.

They found evidence for the opposite situation in photos from other periods. Schackel (1984) presented photos from 1911 and 1929 (Figures 11 and 29, respectively, in Schackel 1984) in which the grasses and shrubs looked healthy. They were taken during a period that was exceptionally wet, from 1905-1943 (Romme and Jacobs 2015).

Woodlands: The changes in the woody vegetation around Inscription Rock were also discussed by Romme and Jacobs (2015), and we present their interpretation here:

> The increase in tree cover probably has been driven primarily by climate trends and an absence of fire. Following the drought of 1891-1893 and a generally dry decade through 1904, the Southwestern climate switched to an exceptionally moist period, with no severe drought years, that persisted for nearly 40 years (Table 1a [Table 4.7.3-4]). The favorable moisture, combined with gradually warming temperatures, created nearly optimal conditions for piñon and juniper to establish and flourish. There was severe drought in the 1950s and 1960s (Table 1b [Table 4.7.3-5]), but by that time the trees had established extensive root systems that allowed them to survive the dry period. Then the 1970s ushered in another period of exceptional moisture and warm temperatures. Recent studies on the expansion of *Juniperus occidentalis* (western juniper) in the Great Basin have provided evidence that rising concentrations of atmospheric carbon dioxide may also have stimulated the growth of junipers and other tree species during the 20th century (Knapp and Soulé 2008). All in all, the 20th century was a great time to be a piñon or a juniper in the Southwest.

Although Romme and Jacobs (2015) agree that the lack of severe fire during the 1900s contributed to the increase in tree densities seen at the national monument, they question the underlying reason(s) for the lack of fire. As discussed earlier in this section, studies in the last few decades have revealed that historical fire regimes in piñon-juniper vegetation were different from those in ponderosa pine forests. Much of the eastern portion of the park is covered by persistent piñon-juniper woodlands, which rarely burned, and the area at the base of the rock is juniper-piñon savanna, in which the historical fire frequency is largely unknown (Romme and Jacobs 2015).

Summary of Condition for Historic and Cultural Integrity of Vegetation on the Landscape

Based on the historic and current-day photos available for the park (both here and in the Schackel [1984] report), and the discussion provided here, we consider condition under this indicator/measure to be of moderate concern; however, it should be noted that this judgement is dependent upon the period targeted for the appearance of the vegetation. If the target appearance is that around the time of monument establishment in 1906, then the appearance and views within the park have changed. For example, unobstructed views of Inscription Rock from even a short distance away are now impeded by the vegetation in many places (e.g., Figure 4.7.4-4). However, this does not necessarily prevent the park visitor from getting a sense of what it was like to visit Inscription Rock and its pool up close in centuries past, or to live atop El Morro even longer ago. A severe fire along the base of Inscription Rock, however, could greatly diminish the visitor experience, and the resource itself, by damaging or destroying the inscriptions. Ancient petroglyph panels were damaged, for example, at Mesa Verde NP in 1996 from a wildfire that occurred near them.

Vegetation

Indicators	Measures
Pinon-Juniper Condition	12 Measures
Ponderosa Pine Condition	6 Measures
Historic & Cultural Integrity	1 Measure

Overall Condition of Vegetation

For assessing the condition of vegetation at El Morro NM, we used three indicators with 19 measures. The indicators were the condition of piñon-juniper vegetation, the condition of ponderosa pine vegetation, and historic and cultural integrity of the vegetation on the landscape. For the first two indicators, we used a variety of measures (of ecological characteristics and processes) that were adapted from Edmonds et al. (2011). For the third indicator, we used one measure, change in vegetation over time, that was assessed based on comparisons of historic and current-day photographs showing the vegetation around El Morro. A summary of the indicators/measures and how they contributed to the overall condition is shown in Tables 4.7.4-1, 4.7.4-2, and 4.7.4-3.

Based on the assessment, the overall conditions of piñon-juniper vegetation and ponderosa pine vegetation were judged to be good. Condition of the historic and cultural integrity of vegetation on the landscape was judged to be of moderate concern. However, this judgement is from the perspective of changes in the vegetation, especially around Inscription Rock and El Morro, since the time of national monument establishment. Trees and shrubs are encroaching on grasslands in some areas, and views of El Morro are more obstructed than in the early 20th century. The increased density of woody vegetation near the base of Inscription Rock also increases the chance of an intense fire damaging or destroying the inscriptions.

Based on this assessment, we consider the overall condition of vegetation at El Morro NM to be good to of moderate concern.

Based on our analyses and the information available, the conditions of piñon-juniper and ponderosa pine vegetation at the national monument appear to have been generally stable over the last half century. Conditions for vegetation have been, on the whole, largely conducive for tree establishment and survival. At this time, from an ecological standpoint, we consider the overall trend in condition as unchanging (but see the discussion on uncertainty and climate in the Level of Confidence/Key Uncertainties section below) Deciding on the trend for the third indicator is somewhat more difficult and subjective. We cautiously consider the trend as declining. This is based on the increased density of vegetation surrounding Inscription

Table 4.7.4-1. Indicators/measures of piñon-juniper condition for persistent piñon-juniper woodlands and juniper-piñon savannas. Table based on Tables 6a and 6b in Romme and Jacobs (2015).

Community or Overall	Indicator/Measure	Condition	Condition Rationale
Persistent Piñon-Juniper Woodland	Is species presence & distribution consistent with conditions and within natural range of variability?	Good	The condition is good, but low levels of exotic species occurred in some locations. Two species were observed (horehound and filaree), which tend to have relatively low impact where they occur. These plants were not abundant or widespread in this vegetation type.
	Are stand densities within their range of natural variability for their growing conditions?	Good	Condition is good, although there has probably been an increase in tree density over the 20th century due to climate conditions conducive to tree establishment/growth.
	Are age class distributions of trees consistent with expected range of variability?	Good	Although based on limited data, condition appeared good for this indicator. Centuries-old trees are present in most places, along with younger trees <100 yr old, resulting in all-aged population structures which are typical of this vegetation type. Some fuel treatments (with removal of trees) had been conducted ~2008.
	Do the trees and understory plants appear vigorous and healthy?	Good	Most individual trees and understory plants appeared healthy. However, some dead piñon trees were observed and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not threaten ecological integrity.
	Are ecological processes (e.g., fire) operating within natural range of variability?	Good	Condition is good, although fire intervals may have lengthened somewhat due to 20th century fire exclusion. However, intervals remain within the historical range of variability for this vegetation type as this type rarely burns, with centuries long intervals between recurrent fires.
	Are the current levels of insects/ disease within the normal range?	Good	Condition is good. We saw no evidence of tree mortality or morbidity due to insects or disease.
Persistent Piñon-Juniper Woodland Summary	**Overall condition based on all six measures**	**Good**	**Overall condition is good, with all of the measures judged to be good.**
Juniper-Piñon Savanna	Is species presence & distribution consistent with conditions and within natural range of variability?	Good	Species presence and distribution generally appears to be within the natural range of variability and is in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically.
	Are stand densities within their range of natural variability for their growing conditions?	Moderate	Tree densities probably are greater in most stands observed than before 1900, and trees also appear to have expanded into former grasslands in some areas. The mechanism driving these changes is uncertain, but may be the result of a century of fire exclusion and 20th century climate which was favorable for tree establishment/survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Condition is considered to be of moderate concern. However, current densities are much less dramatic than in other places in the state and do not appear to pose a serious threat to ecological integrity.
	Are age class distributions of trees consistent with expected range of variability?	Good	Condition is good. Based on limited data, the age classes appear to be approximately within their natural range of variability, although 10 to 100-yr-old trees probably constitute a greater proportion of the population than was typical before 1900. Some centuries-old trees are present.

Table 4.7.4-1. Indicators/measures of piñon-juniper condition for persistent piñon-juniper woodlands and juniper-piñon savannas. Table based on Tables 6a and 6b in Romme and Jacobs (2015) continued.

Community or Overall	Indicator/Measure	Condition	Condition Rationale
Juniper-Piñon Savanna *continued*	Do the trees and understory plants appear vigorous and healthy?	Good	Most trees and understory, including grasses and forbs, are healthy in appearance. This is the case even though tree densities are greater than probably existed prior to 1900. Condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?	Moderate	Historical fire regimes of juniper-piñon savannas are not well understood. Spreading fires may have been relatively frequent, given the continuous fine-fuel cover (grasses) and frequent occurrence of dry weather. If so, then the modern fire regime (essentially no fire) is quite different. However, empirical data are lacking, which makes this an area of major uncertainty. Based on the available information, we consider condition to be of moderate concern.
	Are the current levels of insects/ disease within the normal range?	Good	Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Juniper-Piñon Savanna Summary	Overall condition based on all six measures	Good	Overall condition is good, with four of the measures good and two of moderate concern. The increased tree density within savannas could increase the risk of high-severity crown fires under extremely dry and windy conditions.

Rock that obstructs the view of the feature, and increases the threat of wildfire (that poses a threat to the inscriptions).

Level of Confidence/Key Uncertainties for Overall Assessment

Overall, our confidence in this assessment is medium, and there are some areas of uncertainty. These areas of uncertainty include or are due to the lack of knowledge about historical fire regimes of juniper-piñon savannas, the relatively small number of areas visited during the assessment, including not entering Box Canyon, and the lack of information collected in grassland and shrubland areas of the park.

One of the key uncertainties in the assessment is that surrounding the historical fire regimes of juniper-piñon savannas. As described in the preceding pages, historical fire regimes in this vegetation type are not well understood. For this reason, relatively more uncertainty exists with our interpretation of the departure from reference conditions for this measure. Some uncertainty also exists surrounding the mechanisms of increased tree density within the savannas, and the potential effects of this increase.

There is also some uncertainty with the assessment overall, because it is based on a field visit to only some areas of the park. Even in the areas visited, such as atop El Morro, we had limited time to spend in the vegetation communities.

There is at least one uncertainty regarding trend. Although we consider the trend in piñon-juniper and ponderosa pine condition to be unchanging based on current information, there are predictions for future climate that could lead to a decline in condition. If El Morro NM experienced a major drought or extended drought conditions in the future, tree mortality could become more widespread, and the overall condition could decline. Romme and Jacobs (2015) wrote the following in the context of potentially managing the increase in tree densities in the piñon-juniper vegetation types at El Morro NM and El Malpais NM and ponderosa pine vegetation at El Malpais NM (which is an important point), but it also applies to this discussion of uncertainty in future conditions.

> ...this increase [in tree densities] is in large part a manifestation of the climate of the 20th century, which was especially favorable for tree establishment and survival. But we are now moving rapidly out of the climate that characterized the 20th

Table 4.7.4-2. Indicators/measures of ponderosa pine condition for ponderosa pine-piñon-juniper rocky woodlands.

Community Type	Indicator/Measure	Condition	Condition Rationale
Ponderosa Pine-Piñon-Juniper Rocky Woodland	Is Species Presence & Distribution Within Natural Range of Variability?	Moderate Concern	For the most part, the species present and their distributions appear to be in good condition. Although native species predominate in most places visited, some exotic species are present, especially in Box Canyon. Although we did not enter the canyon during the June visit, we observed what appeared to be cheatgrass from atop El Morro, and park reports and staff have reported its occurrence there. This species is of concern due to its invasiveness and possible ecological impact.
	Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?	Good	Stand densities do not appear to deviate from reference conditions. Condition is considered good.
	Are age class distributions of trees consistent with expected range of variability?	Good	With limited data, the age classes appear to be within their natural range of variability. We therefore considered condition to be good.
	Do the trees and understory plants appear vigorous and healthy?	Good	Most individual trees and native understory plants appeared healthy. At least a few dead ponderosa pine trees were observed in Box Canyon; these trees may have died in recent years due to drought conditions (as was observed at El Malpais NM). Such small-scale mortality events are natural and do not appear to threaten overall ecological integrity. Overall, condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variation?	Good	Fire intervals have lengthened due to 20th century fire exclusion, even in areas of rugged topography and discontinuous fine fuels, and now generally exceed the historical range of variability for this vegetation type. However, a paucity of 20th century fire does not appear to have compromised overall ecological integrity, and fire is probably less important to stand structure than in the ponderosa pine woodland/savanna type. Condition was judged to be good.
	Are the current levels of insects/disease within the normal range?	Good	Based on limited data, condition is good. Although we did not specifically look for insects/disease on trees in this vegetation type, we saw no obvious signs of them. Also, dead ponderosa pine trees examined in nearby El Malpais NM showed no signs of morbidity or mortality from insects or disease. These stressors appear to pose no serious threat at this time.
Summary	Overall condition based on all six measures	Good	Overall condition is good, with five of the indicators/measures good and one of moderate concern. Exotic species, especially in Box Canyon, represent the greatest area of concern.

Table 4.7.4-3. The third indicator/measure of vegetation at El Morro NM-- historic and cultural integrity of vegetation on the landscape.

Indicator	Measure	Condition	Condition Rationale
Historic and Cultural Integrity of Vegetation on the Landscape	Vegetation Change over Time	Moderate	We consider condition to be of moderate concern for this indicator/measure; however, it should be noted that this judgement is dependent upon the period targeted for the appearance of the vegetation. If the target appearance is that around the time of monument establishment in 1906, then the appearance and views within the park have changed. For example, complete views of El Morro from the ground are now impeded by the vegetation in many places. However, this does not necessarily prevent the park visitor from getting a sense of what it was like to visit Inscription Rock and its pool in centuries past, or to live atop the rock even longer ago.

> century. Higher temperatures, more frequent and severe droughts, and more frequent and difficult to control wildfires are in our future. Worldwide, trees are dying at an accelerated rate, especially old trees (Allen et al. 2010, Anderegg et al. 2013). We see this at El Malpais NM where the venerable 650+ year-old *Pseudotsuga menziesii* named Yoda recently succumbed to the drought of the last several years. Thus, we may find that a new 21st century management priority will be retaining trees in the face of deteriorating climate, rather than the imperative to reduce tree densities that probably made sense back in the climatically benign days of the late 20th century.

Even though we have some uncertainties, the field assessment was conducted by individuals with expertise in Southwest vegetation communities and/or substantial knowledge of the national monument: two vegetation experts, two ecologists with SCPN, and one resource manager from El Morro NM.

Although the following information was not specifically used to judge condition at the national monument, we believe it should be mentioned in the assessment. As described by Romme and Jacobs (2015), we observed patches of dead and dying blue grama (*Bouteloua gracilis*) in the grassland and savanna between the park entrance road and the campground (Figure 4.7.4-8) during the June 2015 field assessment. The patches of blue grama were widely scattered and up to about 100 m^2 in size. A variety of native annual and biennial plants (such as *Oenothera caespitosa* [tufted evening primrose], *Erigeron sp.* [fleabane], and *Helianthus sp.* [sunflower]) were growing in the place of the dead bunchgrasses. There was no obvious cause of the plants' mortality, but the recent drought seems like the most probable explanation (Romme and Jacobs 2015). Blue grama is a warm-season grass that depends on receiving summer precipitation, and data for the last few years indicate that precipitation in August 2013 and 2014 was below the long-term average (1.24 inches below in 2013, and 1.55 inches below in 2014; Romme and Jacobs 2015). The most recent three years for which data are available (2012-2014) were the driest three years at the national monument since the 1950s (see Table 4.7.3-5). However, it should be noted that some areas of blue grama grassland at the park appeared healthy, and we did not observe any similar mortality of this species during the field assessment at El Malpais NM.

Figure 4.7.4-8. Patches of dead blue grama in the grassland and savanna near the campground in June 2015.

4.7.5. Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise and participated in a three-day field assessment at El Morro and El Malpais NMs:

William H. Romme is Professor emeritus of fire ecology and senior research scientist in the Natural Resource Ecology Laboratory at Colorado State University, Fort Collins, CO. In addition to participating in the field assessment and co-authoring the report upon which this section is based, Dr. Romme reviewed the draft of this section. Brian J. Jacobs is a vegetation ecologist who recently retired from the NPS at Bandelier NM. Both of these subject matter experts have conducted research in the ecology of both piñon-juniper and ponderosa pine ecosystems and are well-published in this topic.

Two individuals with the SCPN also participated in the field assessment at the park, Lisa Thomas, Program Manager for the SCPN, and Jim DeCoster, Plant Ecologist for the SCPN. Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, also participated in the field assessment.

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4.8. Exotic Plants

Indicators/Measures

- Potential to Alter Native Plant Communities (1 measure)
- Prevalence of Exotic Plants (1 measure)

Condition – Trend - Confidence

Significant Concern – Unknown – Low

4.8.1. Background and Importance

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Approximately 4 - 19% of species introduced into the United States may become invasive (USFWS 2012).

Invasive species have been directly linked to the displacement of several native species of plants (Pimentel et al. 1999). Approximately 42% of threatened and endangered species are at risk primarily because of alien-invasive species (Pimentel et al. 2005). Exotic plants cause changes in ecosystem structure, alteration of nutrient cycles and soil chemistry, alteration of normal successional trajectory of a system (Ehrenfeld 2003, Emery 2012), negative impacts to agriculture (Pimentel 2009), and limitations on water availability (USFWS 2012) (Figure 4.8.1-1).

The spread of invasive species is one of the most environmentally serious global changes, causing economic and environmental damage in the United States and worldwide (UCSUSA 2008). Consequently, the dynamic relationships among plants, animals, soil, and water established over large time periods are at risk of being destroyed in a relatively brief period. For the National Park Service (NPS), the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations."

National parks, like lands managed by other organizations, are deluged by new exotic

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Figure 4.8.1-1. Bromus tectorum (cheatgrass) is the most abundant exotic plant species in El Morro NM.

species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes). Nonnative plants claim an estimated 4,600 acres per day on federal lands alone in the western United States, quadrupling their range from 1985-1995, claiming approximately 17 million acres (BLM 2011) and significantly altering local flora. For example, in Great Smoky Mountains National Park, over ¼ of the plants (27%) are non-native species. On the big island of Hawaii, 35% of the plants are non-native (Pimentel et al. 2005). Invasive plants are dominant on approximately 5% of the lands managed by the NPS (NPS 2009).

4.8.2. Data and Methods

In assessing current condition and trend for exotic plants at El Morro National Monument, we used two indicators. The first indicator, which has one measure, evaluates the overall impact an exotic plant has on the native plant communities throughout the monument. This indicator utilizes known natural history characteristics of exotic plant species in order to characterize its impact on natural ecosystems.

The second indicator, also with one measure, assesses the prevalence of the exotic plant species in the monument.

Information on exotic plant species that have been documented at El Morro includes species lists, Southern Colorado Plateau Network (SCPN) (2014) and NPSpecies (NPS) (2015), and published reports, Rink et al. (2009) and Salas and Bolen (2010).

Table 4.8.2-1 lists the 55 species of exotic plants that have been documented in El Morro NM. Five species (*Cenchrus echinatus, Chenopodium ambrosioides, Fragaria vesca ssp. americana, Panicum virgatum,* and *Plantago argyraea*) that have been reported in El Morro NM as exotic species are excluded from this table as their nativity is unclear (USDA-NRCS 2015a). *Rosa spinosissima* and *Syringa vulgaris* are excluded because they only occur as horticultural species.

Indicator/Measure
Potential to Alter Native Plant Communities (Significance of Exotic Plant Impact)

The first indicator and measure, potential to alter native plant communities (significance of exotic plant impact), was derived from the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). The handbook's analytical approach provides NPS managers with scientific information that encompasses the full array of significant factors that measure the ecological impact of an exotic species.

For the purposes of this assessment, Hiebert and Stubbendieck's significance of exotic plant impact was modified to capture only the plants innate ability to become a pest. The innate ability for a species to become a pest section quantifies the characteristics, such as ability to reproduce vegetatively, the number of seeds per plant, germination requirements, and the plant's competitive ability, that preadapt it to become a problem.

The numerical ranking for this measure ranged between 0 - 50 possible points, with 50 representing the highest possibility of impacting and altering the native plant communities and zero being the lowest. We assigned the numerical rankings to the following categories:

- 40 - 50 = Highest Concern
- 35 - 39 = High Concern
- 30 - 34 = Medium Concern
- 0 - 29 = Low Concern

The significance of exotic plant impact rankings for each exotic species documented in El Morro is reported in Table 4.8.2-2. Seven species were ranked as having the highest concern, with four additional species having high concern. Two species, *Convolvulus arvensis* (field bindweed) and *Ulmus pumila* (Siberian elm) are New Mexico state noxious plants (USDA-NRCS 2015b).

Table 4.8.2-1. Exotic plant species documented in El Morro NM.

Species	Common Name	Rink et al. 2009	Salas and Bolen 2010	SCPN 2014	NPSpecies 6-30-15
Agropyron cristatum	crested wheatgrass	X	X	X	X
Alyssum minus	European alyssum	X	X		X
Alyssum simplex	alyssum			X	
Bothriochloa ischaemum	king ranch bluestem	X	X	X	X
Bromus arvensis	field brome				X
Bromus commutatus	hairy chess	X	X		
Bromus inermis	smooth brome	X	X	X	X
Bromus japonicus	Japanese brome	X	X	X	X
Bromus tectorum	cheatgrass	X	X	X	X
Camelina microcarpa	littleseed falseflax	X	X	X	X
Capsella bursa-pastoris	shepherd's purse	X		X	X
Ceratocephala testiculata	bur buttercup			X	X
Chorispora tenella	blue mustard	X	X	X	X
Convolvulus arvensis	field bindweed	X	X	X	X
Descurainia sophia	flaxweed tansymustard	X	X	X	X
Eragrostis barrelieri	Mediterranean lovegrass	X		X	X
Eragrostis cilianensis	stinkgrass	X	X	X	X
Eragrostis lehmanniana	Lehmann lovegrass	X	X	X	X
Erodium cicutarium	redstem stork's bill	X	X	X	X
Erysimum repandum	repand wallflower	X	X	X	
Festuca ovina	sheep fescue	X		X	False Report
Festuca trachyphylla	hard fescue				X
Holcus lanatus	common velvetgrass	X	X	X	X
Hordeum murinum ssp. glaucum	smooth barley	X	X	X	
Kochia scoparia	kochia	X	X	X	X
Lactuca serriola	prickly lettuce	X	X	X	X
Lolium perenne	annual ryegrass	X	X	X	X
Lolium pratense	meadow ryegrass	X	X	X	X
Malva neglecta	cheeseweed	X	X	X	X
Marrubium vulgare	horehound	X	X	X	X
Medicago lupulina	black medik clover	X	X	X	X
Medicago polymorpha	bur clover	X	X	X	X
Medicago sativa	alfalfa	X	X	X	X
Melilotus officinalis	yellow sweet clover	X	X	X	X
Panicum miliaceum ssp. miliaceum	broomcorn millet	X	X	X	X
Poa annua	annual bluegrass	X	X	X	
Poa pratensis	Kentucky bluegrass	X	X	X	
Polygonum aviculare	common knotgrass	X	X	X	
Polygonum convolvulus	black bindweed	X	X	X	X
Ranunculus testiculatus	curveseed butterwort			X	
Rumex crispus	curly dock	X	X	X	X
Salsola spp.	Russian thistle	X	X	X	X
Scorzonera laciniata	cutleaf vipergrass	X	X	X	X
Secale cereale	common rye	X		X	X
Setaria viridis	bottlegrass	X	X	X	X
Sisymbrium altissimum	tumblemustard	X	X	X	X

Table 4.8.2-1. Exotic plants documented in El Morro NM continued.

Species	Common Name	Rink et al. 2009	Salas and Bolen 2010	SCPN 2014	NPSpecies 6-30-15
Solanum physalifolium	green nightshade	X	X	X	X
Taraxacum laevigatum	rock dandelion	X	X	X	X
Taraxacum officinale	dandelion	X		X	
Tragopogon dubius	salsify	X	X	X	X
Tribulus terrestris	puncturevine	X	X	X	X
Trifolium repens	white clover	X		X	X
Ulmus pumila	Siberian elm	X	X	X	X
Verbascum thapsus	common mullein	X	X	X	X
Vulpia myuros	rat-tail fescue	X	X	X	

Cenchrus echinatus, Chenopodium ambrosioides, Fragaria vesca ssp. americana, Panicum virgatum, and *Plantago argyraea* have been reported at El Morro, but are excluded from this list as their nativity is unclear. *Rosa spinosissima* and *Syringa vulgaris* are excluded from this list because they only occur as horticultural species.

Indicator/Measure
Prevalence of Exotic Plants (Palmer Abundance Scale Rating)

The prevalence of exotic plants has one measure: the abundance of exotic species reported in the Checklist of Vascular Flora for El Morro NM (Rink et al. 2009) (Table 4.8.2-3).

Rink et al. (2009) used the Palmer Abundance Scale (Palmer et al. 1995) to report the level of abundance for exotic species encountered while compiling the checklist of vascular plant species for El Morro. The abundance scale ranges from 0 to 5 from absent to abundant with the following categories:

- 5 = Abundant (dominant or codominant in one or more common habitats)
- 4 = Frequent (easily seen or found in one or more common habitats but not dominant in any common habitat)
- 3 = Occasional (widely scattered but not difficult to find)
- 2 = Infrequent (difficult to find with few individuals or colonies but found in several locations)
- 1 = Rare (very difficult to find and limited to one or very few locations or uncommon habitats)
- 0 = Absent (not found in recent surveys, but found in a previous survey from the same or similar sites or otherwise suspected to occur)

Field work for the plant checklist was conducted in 2001, 2002, 2006 and 2007 (Rink et al. 2009). Fifty exotic species were included in the checklist, including five species absent and ranked 0 on the abundance scale (Rink et al. 2009).

Additionally, the Vegetation Classification and Distribution Mapping Report (Salas and Bolen 2010) stated that exotic plants were abundant in El Morro NM, with *Bromus tectorum* (cheatgrass), *Lactuca serriola* (prickly lettuce), *Verbascum thapsus* (common mullein), *Sisymbrium altissimum* (tumblemustard), and *Tragopogon sp.* (salsify) being the dominant nonnative species.

4.8.3. Reference Conditions

Whenever an exotic plant is present that has the biological characteristics to alter native plant communities, there is cause for concern. However, early detection of these species provides managers with the necessary information to apply a rapid response management strategy before the exotic plant becomes established. If a rapid response is not implemented, the exotic plant may become established and potentially degrade the integrity of the native plant communities.

Our good, moderate, and significant concern reference conditions are based upon both an exotic plant's ability to alter native plant communities as well as its prevalence. A summary of the reference conditions is shown in Table 4.8.3-1.

Table 4.8.2-2. Significance of exotic plant impact ranking for species recorded at El Morro (Rink et al. 2009, Salas and Bolen 2010, SCPN 2014, and NPS 2015) using a subset of Hiebert and Stubbendieck's (1993) Handbook for Ranking Exotic Plants for Management and Control.

Species	Common Name	Noxious	Ranking
Bothriochloa ischaemum[1]	king ranch bluestem		Highest (41)
Bromus inermis[1]	smooth brome		Highest (46)
Bromus tectorum[1]	cheatgrass		Highest (41)
Convolvulus arvensis[1]	field bindweed	X	Highest (46)
Eragrostis barrelieri[1]	Mediterranean lovegrass		Highest (40)
Poa annua[1]	annual bluegrass		Highest (46)
Poa pratensis[1]	Kentucky bluegrass		Highest (50)
Bromus commutatus[2]	hairy chess		High (39)
Bromus japonicus[2]	Japanese brome		High (35)
Eragrostis lehmanniana[2]	Lehmann lovegrass		High (38)
Holcus lanatus[2]	common velvetgrass		High (39)
Agropyron cristatum	crested wheatgrass		Medium (30)
Erodium cicutarium	redstem stork's bill		Medium (34)
Hordeum murinum ssp. glaucum	smooth barley		Medium (32)
Kochia scoparia	kochia		Medium (32)
Lactuca serriola	prickly lettuce		Medium (34)
Marrubium vulgare	horehound		Medium (33)
Medicago lupulina	black medik clover		Medium (30)
Medicago polymorpha	bur clover		Medium (32)
Medicago sativa	alfalfa		Medium (31)
Panicum miliaceum ssp. miliaceum	broomcorn millet		Medium (30)
Rumex crispus	curly dock		Medium (32)
Salsola spp.	Russian thistle		Medium (32)
Scorzonera laciniata	cutleaf vipergrass		Medium (34)
Secale cereale	common rye		Medium (33)
Setaria viridis	bottlegrass		Medium (30)
Sisymbrium altissimum	tumblemustard		Medium (32)
Solanum physalifolium	green nightshade		Medium (32)
Taraxacum officinale	dandelion		Medium (34)
Tribulus terrestris	puncturevine		Medium (32)
Vulpia myuros	rat-tail fescue		Medium (32)
Alyssum minus	European alyssum		Low (16)
Alyssum simplex	alyssum		Low (16)
Bromus arvensis	field brome		Low (25)
Camelina microcarpa	littleseed falseflax		Low (25)
Capsella bursa-pastoris	shepherd's purse		Low (24)
Ceratocephala testiculata	bur buttercup		Low (21)
Chorispora tenella	blue mustard		Low (25)
Descurainia sophia	flaxweed tansymustard		Low (24)
Eragrostis cilianensis	stinkgrass		Low (27)
Erysimum repandum	repand wallflower		Low (21)
Festuca ovina	sheep fescue		Low (27)
Festuca trachyphylla	hard fescue		Low (24)
Lolium perenne	annual ryegrass		Low (26)

Table 4.8.2-2. *Significance of exotic plant impact ranking for species recorded at El Morro NM continued.*

Species	Common Name	Noxious	Ranking
Lolium pratense	meadow ryegrass		Low (24)
Malva neglecta	cheeseweed		Low (19)
Melilotus officinalis	yellow sweet clover		Low (29)
Polygonum aviculare	common knotgrass		Low (24)
Polygonum convolvulus	black bindweed		Low (27)
Ranunculus testiculatus	curveseed butterwort		Low (21)
Taraxacum laevigatum	rock dandelion		Low (24)
Tragopogon dubius	salsify		Low (25)
Trifolium repens	white clover		Low (27)
Ulmus pumila	Siberian elm	X	Low (21)
Verbascum thapsus	common mullein		Low (21)

[1]Species considered to be of highest concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the darker tone.

[2]Species considered to be of high concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the lighter tone.

Cenchrus echinatus, Chenopodium ambrosioides, Fragaria vesca ssp. americana, Panicum virgatum, and *Plantago argyraea* have been reported at El Morro NM, but are excluded from this list as their nativity is unclear. *Rosa spinosissima* and *Syringa vulgaris* are excluded from this list because they only occur as horticultural species..

A good reference condition is the capability for primary communities to be maintained. By this, we mean that ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type.

A moderate condition is assigned to exotic plant species that have been ranked as high or highest concern but prevalence remains low, or when a plant has been assigned a medium impact ranking score and is found in medium prevalence.

A condition of significant concern is assigned when an exotic plant is ranked as high or highest for its ability to alter native plant communities and occurring at medium to high prevalence levels. A species with a moderate impact ranking and high prevalence is also of significant condition.

Further consideration of condition is warranted on a case by case basis, especially for species with low prevalence, or when a species' prevalence may be increasing. Given the early detection and rapid response model for the control of exotic plants, species with low prevalence may be considered to be in moderate condition even though they may have low or medium impact rankings. Further, species that scored low in the Hiebert and Stubbendieck's (1993) innate ability to become a pest ranking system may be considered to be of moderate condition depending on the individual characteristics of a species and the unique attributes of the NPS site, regardless of prevalence.

4.8.4. Condition and Trend

Fifty-five exotic plant species have been documented within El Morro according to published species lists (Rink et al. 2009 and Salas and Bolen 2010), and in NPS-managed databases or spreadsheets (SCPN 2014 and NPS 2015). These species were assessed for their potential to alter native plant communities and their prevalence.

Exotic plants at El Morro NM have significant potential to alter native plant communities. Seven exotic species were ranked as having the highest exotic plant impact, and four species have high exotic plant impact (Table 4.8.2-2). Twenty species have a medium ranking and 24 species were ranked low for exotic plant impact.

Information about the prevalence of exotic plants at El Morro NM is limited. The checklist of vascular plant species at El Morro included 50 exotic species for which

Table 4.8.2-3. Palmer Abundance Scale Rankings of exotic plant species reported in the El Morro vascular plant checklist (Rink et al. 2009).

Species	Palmer Abundance Scale
Bromus tectorum[1]	5
Agropyron cristatum	3
Alyssum minus	3
Convolvulus arvensis[1]	3
Eragrostis cilianensis	3
Erodium cicutarium	3
Hordeum murinum ssp. glaucum	3
Kochia scoparia	3
Salsola spp.	3
Sisymbrium altissimum	3
Taraxacum laevigatum	3
Tragopogon dubius	3
Verbascum thapsus	3
Bothriochloa ischaemum[1]	2
Bromus commutatus[2]	2
Bromus inermis[1]	2
Bromus japonicus[2]	2
Camelina microcarpa	2
Chorispora tenella	2
Descurainia sophia	2
Holcus lanatus[2]	2
Lactuca serriola	2
Lolium perenne	2
Lolium pratense	2
Malva neglecta	2

Species	Palmer Abundance Scale
Marrubium vulgare	2
Medicago lupulina	2
Medicago polymorpha	2
Medicago sativa	2
Melilotus officinalis	2
Poa pratensis[1]	2
Polygonum aviculare	2
Rumex crispus	2
Scorzonera laciniata	2
Setaria viridis	2
Solanum physalifolium	2
Tribulus terrestris	2
Trifolium repens	2
Erysimum repandum	1
Panicum miliaceum ssp. miliaceum	1
Poa annua[1]	1
Polygonum convolvulus	1
Ulmus pumila	1
Vulpia myuros	1
Capsella bursa-pastoris	0
Eragrostis barrelieri[1-]	0
Eragrostis lehmanniana[2]	0
Secale cereale	0
Taraxacum officinale	0

Palmer Abundance Scale: 5 = Abundant; 4 = Frequent; 3 = Occasional; 2 = Infrequent; 1 = Rare; and 0 = Absent.

[1]Species considered to be of highest concern in (Table 4.13.2-2) are highlighted in the darker tone.

[2]Species of high concern (Table 4.13.2-1) is highlighted in the lighter tone.

there were abundance scale rankings from abundant (5) to absent (0) (Table 4.8.2-3) (Rink et al. 2009). Salas and Bolen (2010) stated that *Bromus tectorum*, *Lactuca serriola*, *Verbascum thapsus*, *Sisymbrium altissimum*, and *Tragopogon sp.* were abundant.

Only one species, *Bromus tectorum*, had a Palmer abundance ranking of 5 (frequent) (Rink et al. 2009). Twelve species were occasional (abundance ranking of 3), 25 species were ranked as infrequent (2), six species were rank (1) and five species were absent (0). Some descriptive information about the occurrence of prevalent species, such as *Bromus tectorum*, is available in the vegetation mapping report (Salas and Bolen 2010).

Combining the results of the significance of impact indicator with prevalence indicator, two species are in the condition of significant concern, *Bromus tectorum* and *Convolvulus arvensis* (Table 4.8.4-1). Of these two species, *Bromus tectorum* was highly prevalent (Palmer abundance ranking of 5, frequent) (Rink et al. 2009) and *Convolvulus arvensis* had medium prevalence (occasional abundance ranking, 3).

Thirteen species were in moderate condition, with medium or low prevalence. Six of these

Table 4.8.3-1. Descriptions for determining condition based on exotic plant potential to alter native plant communities impact ranking and degree of prevalence.

Prevalence of Exotic Plant	Potential to Alter Native Plant Communities Impact Ranking			
	Low	Medium	High	Highest
Low	Good Condition*	Good Condition*	Moderate Condition	Moderate Condition
Medium	Variable*	Moderate Condition	Significant Concern	Significant Concern
High	Variable*	Significant Concern	Significant Concern	Significant Concern

*Species in these cells may warrant further consideration of condition on a case by case basis.

species have medium impact and were ranked as occasional (3) on the Palmer abundance scale: *Agropyron cristatum* (crested wheatgrass), *Erodium cicutarium* (redstem stork's bill), *Hordeum murinum ssp. glaucum* (smooth barley), *Kochia scoparia* (kochia), *Salsola spp.* (Russian thistle) and *Sisymbrium altissimum* (tumblemustard).

Six species in moderate condition had high or highest impact rankings and were found infrequently (abundance scale = 2) in El Morro: *Bothriochloa ischaemum* (king ranch bluestem), *Bromus commutatus* (hairy chess), *Bromus inermis* (smooth brome), *Bromus japonicus* (Japanese brome), *Holcus lanatus* (common velvetgrass), and *Poa pratensis* (Kentucky bluegrass).

One species in moderate condition, *Poa annua* (annual bluegrass), was ranked as highest for exotic plant impact and was rare (abundance scale = 2); e.g. found in low prevalence.

Condition of Significant Concern Species

Two species were in the condition of significant concern. *Bromus tectorum* was the most abundant exotic species found in El Morro (Rink et al. 2009). Like *Bromus tectorum*, *Convolvulus arvensis* has the highest exotic plant impact ranking, but was encountered occasionally during the fieldwork for the vascular plant checklist and given an abundance ranking of 3 (Rink et al. 2009).

Bromus tectorum is highly invasive in the Intermountain West, and has a competitive advantage in cold semiarid environments (USDA Forest Service 2003a). Cheatgrass germinates and matures early with rapid spring growth (USDA Forest Service 2014). Each plant is capable of producing up to 5,000 awned seeds which can be dispersed by animals or people (USDA Forest Service 2014). Cheatgrass is highly adapted to frequent fires and has changed fire regimes and plant communities over a large area of the inland west (USDA Forest Service 2003a).

Cheatgrass is abundant at El Morro NM (Rink et al. 2009 and Salas and Bolen 2010). It dominates the *Bromus tectorum* Semi-natural Herbaceous Alliance (Figure 4.8.4-1), which was mapped in a small area of the national monument along the western boundary, covering 2 acres (Salas and Bolen 2010). Cheatgrass also occurs in the *Bouteloua gracilis* Herbaceous Vegetation, where it occurred as an associated grass. *Bouteloua gracilis* Herbaceous Vegetation was mapped at 346 acres within the vegetation map area (which includes lands outside of the monument boundary). This association often represents degraded montane grasslands (Salas and Bolen 2010). The species was also observed in the *Juniperus monosperma / Bouteloua gracilis* Woodland, which was found in 554 acres of the vegetation map area (Salas and Bolen 2010).

Salas and Bolen (2010) also observed cheatgrass in disturbed areas, such as along trails and roads, and in Box Canyon, which was used historically as a livestock pen and

Table 4.8.4-1. Exotic species found within El Morro NM that are considered to have the most impact to native habitats based upon combined indicators and measures.

Scientific Name	Common Name	Rationale for Rating*
Condition of Significant Concern: Highest impact and high or medium prevalence (Frequent or Occasional)		
Bromus tectorum	cheatgrass	Cheatgrass is a highly invasive plant in the Intermountain West that can have a significant adverse impacts on natural ecosystems, especially grasslands. It is also extremely competitive during period of drought. It was the most prevalent exotic plant in the monument, and the only species given a Palmer abundance scale ranking of 5, frequent. It is common in disturbed areas (along roads and trails) and in Box Canyon, and is the primary species found in the *Bromus tectorum* Semi-natural Herbaceous Alliance, which was mapped in a small area of the monument.
Convolvulus arvensis	field bindweed	*Convolvulus arvensis* reproduces predominantly vegetatively, and is very difficult to control once established. Field bindweed is listed as a noxious species in New Mexico.
Moderate Condition: Medium impact and medium prevalence (Occasional)		
Agropyron cristatum	crested wheatgrass	Crested wheatgrass is a cool-season perennial bunchgrass that reproduces by seed and vegetatively.
Erodium cicutarium	redstem stork's bill	This species colonizes disturbed sites and withstands further disturbance. Redstem stork's bill creates a persistent seed bank.
Hordeum murinum ssp. glaucum	smooth barley	Smooth barley grows in both disturbed and undisturbed areas. Its seeds can be transported great distances by animals.
Kochia scoparia	kochia	Kochia grows mostly in disturbed sites, and produces a great number of seeds which are spread by tumbleweed action, water or wind.
Salsola spp.	Russian thistle	Russian thistle, also a type of tumbleweed, has great seed dispersal potential and the seeds germinate readily in disturbed or open areas.
Sisymbrium altissimum	tumblemustard	*Sisymbrium altissimum* produces extremely abundant seeds that may remain viable for up to 40 years. Seeds are spread by tumbleweed action.
Moderate Condition: Highest or high impact and medium prevalence (Infrequent)		
Bothriochloa ischaemum	king ranch bluestem	Ranked as highest concern for its ability to become a pest, this species' impact on native plant communities includes its drought tolerance, great seed production, a thick basal growth that can displace native species. It also decreases plant and animal biodiversity.
Bromus commutatus	hairy chess	Hairy chess is a cool season exotic grass that reproduces only by seed.
Bromus inermis	smooth brome	Smooth brome shares many of the characteristics of exotic bromes that make them so invasive with significant impacts to native plant communities. This species also has a fall green-up.
Bromus japonicus	Japanese brome	*Bromus japonicus* alters fire regime and outcompetes native cool season grasses. The species adds biomass to the ecosystem and outcompetes native cool season grasses.
Holcus lanatus	common velvetgrass	Common velvetgrass produces abundant seeds, and also can reproduce vegetatively. It prefers to grow in disturbed sites.
Poa pratensis	Kentucky bluegrass	Kentucky bluegrass produces a great deal of seed, has a high potential to alter native plant communities, and is extremely difficult to control.
Moderate Condition: Medium impact and low prevalence (rare)		
Poa annua	annual bluegrass	This species was ranked in the highest category for its innate ability to become a pest, and is also extremely difficult to control. It produces abundant seed and generally persists in areas that receive repeated disturbances.

*The rationale is comprised of the four measures: a species' innate ability to become a pest, and the current extent, density and distribution of the exotic plant.

Figure 4.8.4-1. <u>Bromus</u> <u>tectorum</u> Semi-natural Herbaceous Alliance at El Morro NM.

is heavily impacted (David Hays, personal communication, 2015).

Convolvulus arvensis was reported as an occasional species in the vascular plant checklist (Rink et al. 2009). While *Convolvulus arvensis* produces seed, it reproduces predominantly by its persistent root system. Once field bindweed gets established, it is very difficult to control and is highly competitive with native species (USDA Forest Service 2004). It is a New Mexico noxious plant (USDA-NRCS 2015b) and has the highest exotic plant impact using the Hiebert and Stubbendieck (1993) criteria.

<u>Moderate Condition of Species with Medium Impact and Medium Prevalence</u>

Six species with medium potential to alter native plant communities were present in medium prevalence (occasional abundance scale ranking) in El Morro NM.

Agropyron cristatum is a cool-season perennial bunchgrass that is very drought tolerant. It reproduces by seed and vegetatively, and can create persistent stands (USDA Forest Service 1999).

Erodium cicutarium is a pioneer species on disturbed sites and is very tolerant of further disturbances. It produces abundant seeds that form a persistent seed bank and that can be dispersed over large distances (USDA Forest Service 1992). During the Assessment of the Ecological Condition of Piñon-Juniper and Ponderosa Pine Vegetation in June 2015, *Erodium cicutarium* was observed in localized woodland areas (Romme and Jacobs 2015).

Hordeum murinum ssp. glaucum is often found in disturbed areas, but can also invade undisturbed lands (Arizona Wildlands Invasive Plant Working Group 2005a). The seeds may travel long distances by attaching to animals, and remain viable for many years.

Kochia scoparia was ranked according to Hiebert and Stubbendieck (1993) as having a medium potential to alter native plant communities. It reproduces entirely by seed, but an individual plant may produce up to 50,000 seeds (USDA Forest Service 1995). Seed dispersal is via tumbleweed, wind or water, but seeds only remain viable for one year. Kochia grows readily on disturbed sites (USDA Forest Service 1995).

Like *Kochia scoparia, Salsola tragus* grows well on disturbed land and disperses its seeds as a tumbleweed. This species is especially tolerant during periods of drought (Arizona Wildlands Invasive Plant Working Group 2005b). It is an even more prolific seeder than kochia, producing up to 250,000 seeds per plant.

Salsola tragus is extremely drought tolerant when it can compete especially well with native species. Drought conditions can cause significant increase in populations. Russian thistle can also aid in the spread of fire (Arizona Wildlands Invasive Plant Working Group 2005b).

Yet another species of tumbleweed, *Sisymbrium altissimum* is most invasive in the west (USDA Forest Service 2003b). The species is an extremely prolific seeder and seeds may remain viable for up to 40 years. It usually grows in disturbed plant communities (USDA Forest Service 2003b).

<u>Moderate Condition of Species with Highest or High Impact and Medium</u>

Prevalence

Three species, *Bothriochloa ischaemum*, *Bromus inermis* and *Poa pratensis*, with the highest ranking for exotic plant impact had medium prevalence (abundance scale ranking, 2, infrequent). And three species with high exotic plant ranking, *Bromus commutatus*, *Bromus japonicus* and *Holcus lanatus*, were also given infrequent values on the abundance scale (Rink et al. 2009).

Bothriochloa ischaemum can dominate grassland communities, and reduce insect, landbird, and mammal diversity, and is difficult to manage (Institute for the Study of Invasive Species 2014).

Exotic bromes such as *Bromus commutatus*, *Bromus inermis* and *Bromus japonicus* are well known to dramatically change the character of an ecosystem, including causing such changes as major shifts in community composition and structure (Knapp 1996) and substantial alteration of fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996).

Like B*romus tectorum*, these brome species add biomass to the ecosystem, and outcompetes other cool season grasses. Japanese brome can invade both disturbed and undisturbed sites (USDA Forest Service 1994). *Bromus inermis* usually invades sites after disturbances and is persistent. It also greens-up in the fall (USDA Forest Service 1996).

Holcus lanatus is an extremely widespread exotic species. It reproduces both by seed and vegetatively, and is a prodigious seed producer (USDA Forest Service 2008). Common velvetgrass usually grows in disturbed sites, but can also grow in undisturbed areas.

Poa pratensis (Kentucky bluegrass) produces abundant seed and is generally highly competitive, but is intolerant to drought (USDA Forest Service 1993). The species is extremely difficult to control and has an extremely high potential to alter native plant communities.

Moderate Condition Species with High Impact and Low Prevalence

Like many other exotic plant species present in El Morro NM, *Poa annua* prefers disturbed sites. This species is also persistent in areas that receive repeated disturbance. (Alaska Natural Heritage Program 2008). It produces abundant seed and can create dense mats that give it a competitive advantage over other species. It is extremely difficult to control.

Exotic Plants

Indicators	Measure
Potential to Alter Native Plant Communities	1 Measure
Prevalence of Exotic Plants	1 Measure

Overall Condition and Trend

In assessing the condition of exotic plants in El Morro, we used two indicators that were intended to be different ways of capturing the essence of what we thought represented an exotic plant's potential for concern.

Several factors contribute to an exotic plant's ability to threaten the integrity of a native ecosystem including its inherent ability to alter native plant communities and its prevalence. Thus, our measures for this resource were intended to capture different aspects of these contributing factors. A summary of how they contributed to the overall exotic plants condition assessment is in Table 4.8.4-2.

The potential for exotic species present in the monument to alter native plant communities is of significant concern because eleven species, 20% of the exotic species documented, were ranked as highest or high for their significance of exotic plant impact based on their innate ability to become a pest.

Exotic plants have an medium prevalence within the monument, and this indicator is in moderate condition.

The trend for the condition of exotic plants at El Morro is unknown. The lack of specific data sets related to the occurrence of exotic plants and regular monitoring of vectors to detect new infestations does not enable a trend determination.

Table 4.8.4-2. Indicators, measures, and their contributions to the overall exotic plants condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Potential to Alter Native Plant Communities	Significance of Exotic Plant Impact	Significant Concern	This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Eleven of the 55 species of exotic plants documented in El Morro were ranked either as having highest or high innate ability to become a pest. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Palmer Abundance Scale Ranking	Moderate	The prevalence of exotic plants at El Morro is not well know. However, abundance scale rankings in Rink et al. (2009) provide insight into the general level of exotic species in the monument. One species, *Bromus tectorum,* was given an abundant ranking of frequent, 5. Twenty-seven species had medium prevalence (abundance scale ratings of 3, occasional, or 2, infrequent). Specific information about exotic plants in the interior of the monument and along vectors is unknown.

After analyzing all the available information about exotic plant species at El Morro NM, we consider the overall condition for exotic plants to be in an unknown condition with an unknown trend.

Level of Confidence/Key Uncertainties

Overall, we have a low level of confidence in this assessment because the prevalence of exotic species is not well known in El Morro. While the Palmer abundance scale rankings for exotic species encountered during fieldwork in preparation of the vascular plant checklist provide useful general information about the overall abundance of exotic plant species, the fieldwork occurred in 2001, 2002, 2006 and 2007 (Rink et al. 2009). Additionally, the checklist did not provide information on where exotic species were found in the monument. Vectors such as roads and trails, including a state highway (Highway 53) that crosses the monument, are not monitored for exotic species (David Hays, personal communication, 2015).

However, our confidence in the significance of exotic plant impact measure is high. Application of the Hiebert and Stubbendieck (1993) Handbook for Ranking Exotic Plants for Management and Control to determine exotic plant impact provides an analytical means to assess the impact of nonnative plants on native plant communities. However, an uncertainty for this measure is the general variability in how a given exotic plant species will respond to localized conditions. What may be considered a non-threatening plant in one region may become a nuisance in a different region.

4.8.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this section and David Hays, former Branch Chief of Natural Resources at El Morro and El Malpais NMs provided information. Exotic species rankings, using the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993) were completed by Allyson Mathis and Kim Struthers, science writers at Utah State University, Tomye Folts-Zettner, Biologist/Botanist, Southern Plains Inventory and Monitoring Network, and Lori Makarick, Vegetation Program Manager, Grand Canyon National Park. Myron Chase, Invasive Species Coordinator with the NPS Intermountain Regional Office, reviewed this section.

4.8.6. Literature Cited

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4.9. Wildlife

Indicators/Measures

- Species Occurrence (3 measures)

Condition – Trend – Confidence

Insufficient Data - Insufficient Data - Medium

4.9.1. Background and Importance

Habitat for wildlife within El Morro NM includes piñon-juniper woodlands, ponderosa pine woodlands, shrublands, and grasslands. The Box Canyon contains a variety of microhabitats (Nowak and Persons 2008), and the pool of water at the base of Inscription Rock provides a permanent source of water. A substantial variety of bird, mammal, and herpetofauna species have been recorded at the national monument within these habitats (Figure 4.9.1-1).

Although no annual monitoring is conducted for these groups of wildlife, a number of studies have been conducted over the years. For example, inventories of breeding birds were conducted by McCallum (1979a) in 1979 and the U.S. Geological Survey (USGS) in 2001-2003 (i.e., Johnson et al. 2007). Bogan et al. (2007) conducted inventories for mammals in 2002-2003, and Nowak and Persons (2008) conducted inventories for amphibians and reptiles in 2001-2003. These and other sources of information on the wildlife of El Morro NM are discussed in this section of the condition assessment, as well as in Chapter 2. Here, we look at the information available on birds, mammals, reptiles, and amphibians in order to assess their current condition.

4.9.2. Data and Methods

This assessment of birds, mammals, and herpetofauna is a limited assessment because no recent information is available to assess current condition. However, we present the most current information available on each of these wildlife groups, and this information represents a baseline for future assessment. We used three indicators/measures of condition-- species occurrence: presence/absence for each of the three wildlife groups. These groups of wildlife are addressed

Figure 4.9.1-1. Some of the many wildlife species documented at El Morro NM- (left) Bull snake, (top) Mountain Bluebird and (bottom right) Coyote.

separately in the assessment, with birds first, followed by mammals, and herpetofauna.

Indicator/Measure
Bird Species Occurrence (Presence/Absence)

Species Occurrence: Presence/Absence
No comprehensive, group-wide surveys (or monitoring) of birds have been conducted at El Morro NM since that by Johnson et al. (2007) in 2001-2002. With the USGS surveys having been conducted more than a decade ago, that means we have no recent, standardized surveys to assess current condition. Therefore, to assess species occurrence of birds at the national monument, we used the 2001-2002 USGS bird surveys, as well as the breeding bird surveys of McCallum (1979a) and observational sightings conducted by park personnel in recent years (2011-2013). We also reviewed checklists by McCallum (1979a) and Grimes and Beckwith (2008) for other species reported for the park.

The 2001-2002 USGS surveys were based on standardized bird surveys (described below) during the breeding season, as was the McCallum (1979a) study (although methods differed; described below), while the other sources of information used more informal methods. Because we do not have two survey efforts that used the same methods, it would be inappropriate to compare the results of the surveys and/or observations directly. With the use of the two survey methodologies and other sources of information, we examined species occurrence by assembling a list of species that have been recorded at the national monument. Because the resources used to compile the list included periods throughout the year, the list of species is not confined to species that breed within the park.

The Occurrence of Species of Conservation Concern
Our intent for this aspect of the assessment was to determine which species that occur or have occurred at El Morro NM are considered species of conservation concern at either national or local scales. Note that we use the phrase "species of conservation concern" in a general sense; it is not specifically tied to use by any one agency or organization. We took the overall list of species for the national monument recorded by Johnson et al. (2007), McCallum (1979a), park staff (from 2011-2013), and Grimes and Beckwith (2008; excluding the rarest species, see below) and compared it to multiple species of conservation concern lists (e.g., a federal/state list of endangered and threatened species, those of "Greatest Conservation Need" in New Mexico, and those used by other organizations). The specific lists we used are described below.

There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been a source of confusion. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.9.2-1). El Morro NM, as well as El Malpais NM, lies within the Southern Rockies - Colorado Plateau BCR (BCR-16; Figure 4.9.2-2).

Conservation Organizations Listing Species of Conservation Concern

Below we identify some of the organizations/efforts that list bird species of conservation concern; these are the listings we used for this condition assessment. Appendix G presents additional details on each of the organizations/efforts.

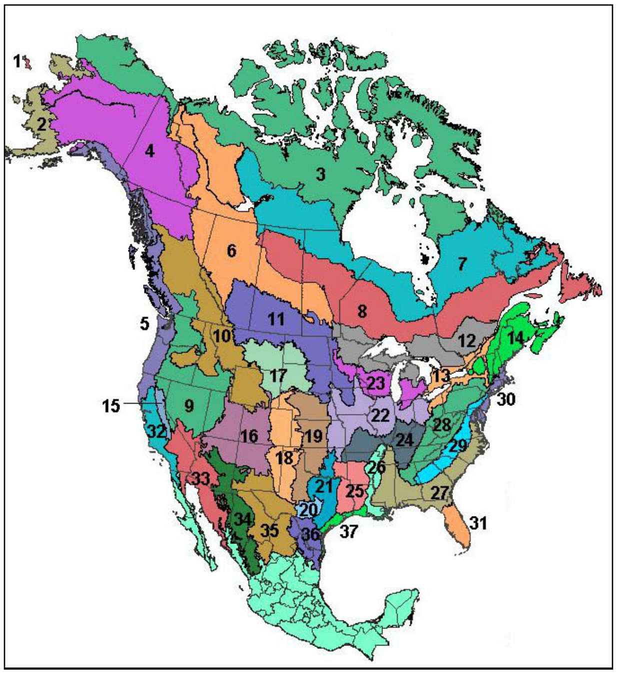

Figure 4.9.2-1. Bird Conservation Regions in North America.

- U.S. Fish & Wildlife Service: Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing.
- New Mexico Department of Game and Fish (NMDGF): In New Mexico, wildlife species are designated as threatened and endangered under the New Mexico Wildlife Conservation Act (NMDGF 2015a). For each endangered or threatened species, the NMDGF develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015b). The database is called the Biota Information System of New Mexico (BISON-M).
- USFWS: The USFWS also develops lists of birds of conservation concern according to: the Nation, USFWS Region, and BCR.
- The National Audubon Society (NAS) and American Bird Conservancy (ABC): These groups combined efforts to produce a "Watch List," based on, but not identical to, the Partners in Flight approach to species assessment (see below). The 2007 WatchList has two primary levels of concern: a "Red Watchlist," which identifies what these organizations consider as species of highest national concern; and a "Yellow WatchList," which is made up of species that are somewhat less critical.
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]). We did not include the CS or RS species in our assessment. The list for BCR 16 was obtained online (Rocky Mountain Bird Observatory 2015).
- NM Species of Greatest Conservation Need (SPGN): Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, SGCN have been designated in the state (NMDGF 2006). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, about 74 are birds. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico. The ecoregion in which El Morro NM occurs is the Arizona-New Mexico Mountains (NMDGF 2006). The BISON-M database maintains information on which species are SGCN, and it provides lists of species so designated for Cibola County (and other counties; NMDGF 2015b). Note that we obtained both the ecoregion list from NMDGF (2006) and the county list from NMDGF (2015b), and the lists differed somewhat. To take a conservative approach in our assessment, we

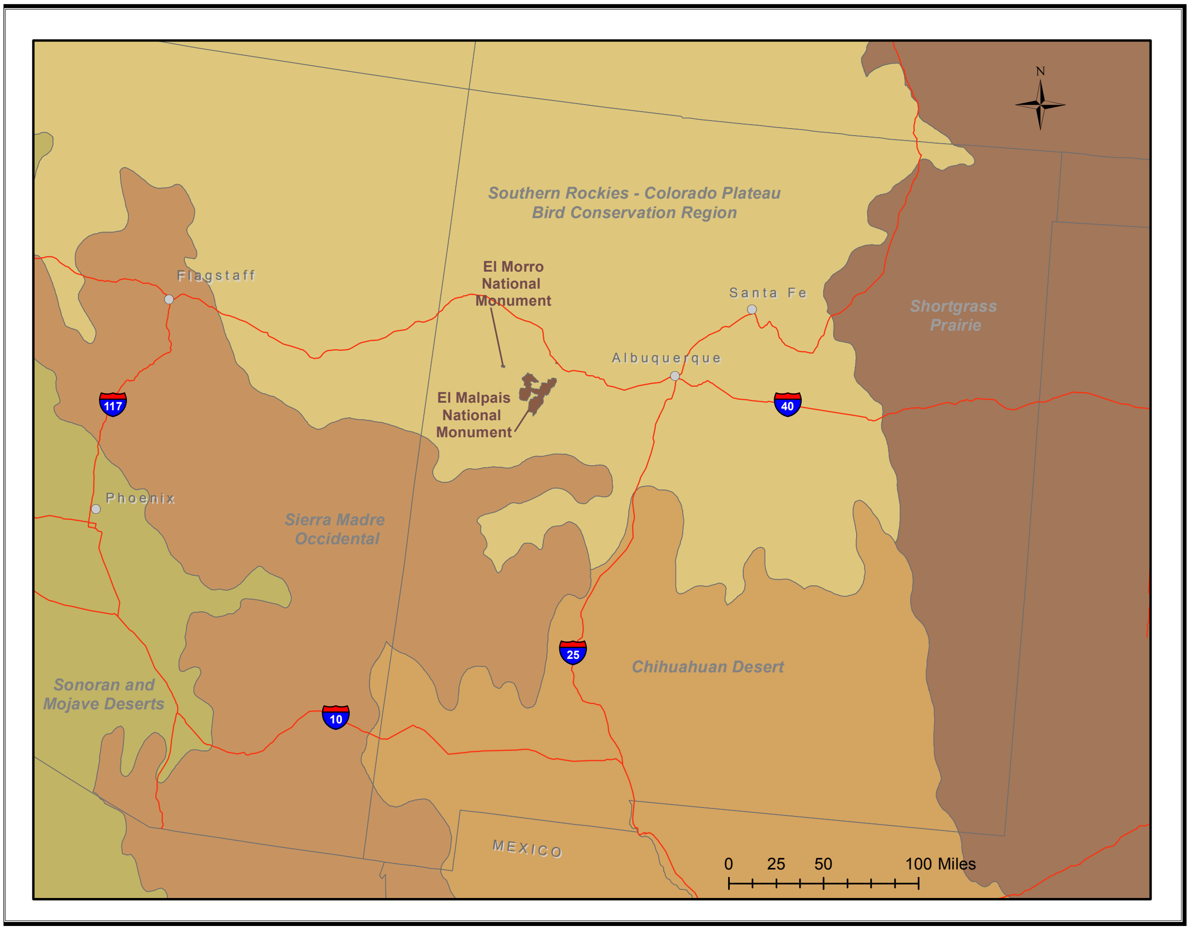

Figure 4.9.2-2. Bird Conservation Regions in the vicinity of El Morro NM and El Malpais NM. Both parks are within the Southern Rockies - Colorado Plateau BCR (BCR 16).

compared both lists to our list of species for the national monument.

Data Sources- Primary and Secondary

Data/information used as part of this assessment include: surveys conducted by McCallum (1979a) in 1979; surveys conducted by Johnson et al. (2007) in 2001-2002; observations made by park personnel in 2011-2013; and two checklists, one by McCallum (1979a) and one by Grimes and Beckwith (2008). It should be noted that the checklists include many of the same observational efforts. These surveys and checklists are described below.

McCallum (1979a)- a Primary Data Source

In 1979, McCallum (1979a) conducted a study of breeding birds within four plots within the national monument. The four plots were in the main habitat types at the park, namely, open shrubland with few to no trees, shrubland with trees (savanna), piñon-juniper woodland, and pine-oak woodland. The researcher delineated breeding territories within each plot based on singing males, as well as nests. Within each plot, he estimated the locations and numbers of territories for each species. McCallum conducted various analyses of his data, but we focus here on the species of birds he documented. His breeding bird study was conducted in March-September of 1979.

A second piece of information that we used in this assessment from McCallum (1979a) is a checklist that he prepared. The checklist is based on his observations in the national monument, as well as past observations of others that he considered adequately documented.

Johnson et al. (2007) Avian Inventory- a Primary Data Source

In 2001-2002, the USGS conducted avian inventories at El Morro NM during the breeding season (Johnson et al. 2007). Four breeding season surveys were conducted in

2001, and three breeding season surveys were conducted in 2002. The researchers used point-count surveys in four main habitat types at the national monument-- piñon-juniper, oak/piñon-juniper, piñon-juniper/grassland, and grassland. A total of 34 point-count stations were used in the four habitat types. Area-search surveys were also conducted during each breeding season to emphasize habitat not covered well during point-count surveys (e.g., around the visitor center, mesa-top trail, and campground). Incidental observations were also recorded. For each species recorded during the breeding season, the researchers reported evidence of breeding (e.g., bird seen carrying nesting material, adults seen carrying food, pair observed in suitable nesting habitat).

Non-breeding winter surveys were also planned, but they were cancelled due to poor weather conditions.

El Morro NM eBird Data- Secondary Data Source
No comprehensive, park-wide or habitat-specific surveys of birds have occurred at the park since that by Johnson et al. (2007) in 2001-2002. However, park personnel and trained volunteers conducted observations (i.e., recorded sightings) of birds along roads at the national monument from 2011-2013 (David Hays, former Natural Resources Branch Chief, El Malpais and El Morro NMs, pers. comm., 2014). The same individuals also conducted similar observations along roads at El Malpais NM. Observations at El Malpais continued into 2015, while observations at El Morro were conducted only five times in 2011-2013 (in the months of February, April, May, and October). The sightings are uploaded and maintained in eBird (described below; Audubon and Cornell Lab of Ornithology 2015). Records used for this condition assessment were provided by park staff in December of 2015. Even with the small number of observations, 40 bird species were detected.

eBird is an online checklist program that was launced in 2002 by the Cornell Lab of Ornithology and National Audubon Society (Audubon and Cornell Lab of Ornithology 2015). eBird reports on the ocurrence (presence or absence) of bird species, as well as other information, using data from checklists provided by recreational and professional bird watchers. Cumulative lists of bird species are available for El Morro NM based on observations from park personnel (see above) and others.

Grimes and Beckwith (2008)- Secondary Data Source
This checklist was produced in May, 2008, and includes observations made between 2002-2008 (presumably by Grimes and Beckwith), as well as species listed by McCallum (1979a), Stolz (1987), and USGS (2002; most likely the same work as described in Johnson et al. 2007). The checklist key categorizes birds as common, fairly common, uncommon, rare, and occasional; one extirpated species is also included. Although we reviewed the entire checklist for our assessment, we did not include species in our tables (shown in the Condition section and Appendix H) that are listed as occasional (i.e., few records exist) or extirpated (i.e., no longer occurs in the area). We used the list as supporting information and for the inclusion of additional species not recorded on the other park survey/observation efforts. The checklist included a total of 181 species.

Indicator/Measure
Mammal Species Occurrence (Presence/Absence)

Species Occurrence: Presence/Absence
Because there is no recent information to assess current condition of mammals at El Morro NM, this limited assessment used the 2002-2003 surveys by USGS (Bogan et al. 2007) to assess the occurrence of native and non-native mammal species at the national monument. We used one indicator/measure of condition-- species occurrence: presence/absence. We also used an older report by Stolz (1986a) to provide supporting information. Stolz (1986a) provides a checklist of mammal species that were recorded within the monument through 1986, as well as species found in the vicinity of the park. We also reviewed the NPSpecies list of mammals for the park (NPS 2014a). No comprehensive,

group-wide surveys or monitoring of mammals have been conducted at the park since that by Bogan et al. (2007).

The Occurrence of Species of Conservation Concern

We also used the surveys of Bogan et al. (2007) to generate a list of species of conservation concern (again, note that we use this term in a general sense). The list was complied by comparing the list of species observed during 2002-2003 surveys at the national monument to a federal/state list of endangered and threatened species (described below) and those of "Greatest Conservation Need" in New Mexico (described below). We also reviewed the NPSpecies list for the park (NPS 2014a), as well as Stolz (1986a) to see whether any additional species should be included.

Primary Data Sources

Bogan et al. (2007)

The main objective of Bogan et al. (2007) was to document the occurrence of at least 90% of the mammal species expected to occur at the national monument using their field inventory and a review of existing records. Additional objectives were to provide baseline information for future monitoring and to describe the distribution and abundance of species of management interest (e.g., endangered species, exotic species). They used a variety of sampling methods to observe as many species as possible: trapping, mist-netting, scat and track surveys, acoustic surveys, and opportunistic observations. Details of each method are contained in Bogan et al. (2007). The researchers spent 23 person-days on the work in 2002 and 2003 for a total of 603 trap-nights, 4 net-nights, 10.3 acoustic-hours, and a walking distance of 16.5 km (10.3 mi).

Secondary Data Sources

Stolz (1986a)

This eight-page report provides a checklist of the mammals that have been reportedly observed through 1986 at the park. This report does not represent a single, comprehensive inventory or survey effort as does that conducted by Bogan et al. (2007). The report provides notes on species abundance and type of habitat where species were observed.

NPSpecies List for the National Monument

The NPSpecies list for the park was used to see whether additional species have been documented in the park that were not recorded by Bogan et al. (2007) (or Stolz 1986a). We also used the list as supporting information for the lists shown in the Condition section.

Protected/Rare Species Lists

Protection and special designations for federally and state threatened and endangered species, as well as SGCN in New Mexico, were previously described in the section on birds. For mammals, we compared lists of species that have been observed at the national monument to lists of federally and state threatened and endangered species (USFWS 2015a, NMDGF 2015b), as well as SGCN (NMDGF 2015b). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, 42 are mammals (NMDGF 2006). Note that there are not a large variety of agencies or other groups that list mammal (or herpetofuana) species of conservation concern.

Indicator/Measure

Herpetofauna Species Occurrence (Presence/Absence)

Species Occurrence: Presence/Absence

Because there is no recent information to assess current condition, we used the 2001-2003 surveys by USGS (i.e., Nowak and Persons 2008) to assess the occurrence of amphibian and reptile species at the national monument. No comprehensive surveys or monitoring of amphibians or reptiles have been conducted at the national monument since that by Nowak and Persons (2008).

The Occurrence of Species of Conservation Concern

The surveys by Nowak and Persons (2008) were used to generate a list of species of conservation concern. The list was compiled by comparing the list of species observed during the 2001-2003 surveys to a federal/state list of endangered and threatened species (described below) and those of Greatest Conservation Need in New Mexico (described below). We also reviewed the

NPSpecies list for the park (i.e., NPS 2014a) to see whether any additional species should be included (as well as McCallum 1979b and Stolz 1986b [see mention of these reports below]).

Primary Data Sources

Nowak and Persons (2008)

The primary objectives of this work were to provide a baseline inventory of herpetofauna and document 90% of the herpetofauna species present at the park, identify species of special concern, and make recommendations for a monitoring program (Nowak and Persons 2008). A variety of sampling methods were used to document as many species as possible: general surveys (day and night), night driving, random and non-random time-area constrained searches (TACS), and nocturnal general surveys. About 99 person-hours were spent on the surveys in 2002-2003. General surveys were visual encounter surveys that were not defined or limited by area or time, and they were conducted primarily during the daytime. The TACS were visual encounter surveys that involved moving through and searching each habitat within the sampling area in a systematic manner for a predefined period of time. Random TACS plot surveys were conducted within both 1 and 10-hectare areas. Finally, night driving surveys, which are especially useful for snakes and amphibians, were used. These researchers also named several additional species that were recorded at the park previously.

Secondary Data Sources

Two additional studies or reports on the herpetofauna of the national monument, McCallum (1979b) and Stolz (1986b) were used and are cited as appropriate in the Condition section. Also, the NPSpecies list for the park was used to see whether additional species have been documented in the park that were not recorded by the other inventories and lists. We also used the list as supporting information for the lists shown in the Condition section.

Protected/Rare Species Lists

Protection and special designations for federally and state threatened and endangered species, as well as SGCN in New Mexico were previously described in the section on birds. For amphibians and reptiles, we compared lists of species that have been observed at the national monument to lists of federally and state threatened and endangered species (USFWS 2015a, NMDGF 2015b), as well as SGCN (NMDGF 2015b). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, 47 are reptiles and amphibians (NMDGF 2006). Note that there are not a large variety of agencies or other groups that list herpetofuana species of conservation concern.

4.9.3. Reference Conditions

No reference conditions were developed for this resource topic. This is because, for each group of wildlife, no two similar studies or surveys to compare species occurrence existed (e.g., to examine changes over time). However, the information presented from the surveys/inventories that do exist, as well as information from the secondary sources, provides a good baseline for future monitoring and assessment of each wildlife group at El Morro NM. In other words, if standardized surveys of these groups of wildlife are conducted in the future, the new survey results could be compared to the survey/inventory results (from the early 2000s) described in this assessment. The survey results from the early 2000s could become the reference conditions for the future assessments. Also note that we could have taken a different approach to the bird assessment here. We could have used the McCallum (1979) bird survey as our reference condition for birds, and compared the results to the 2001-2002 USGS survey results. However, as the USGS surveys are now approximately 14 years old, the comparison would not reveal much about current condition of birds at El Morro NM.

4.9.4. Condition and Trend

There have been a total of approximately 137 bird species reported at El Morro NM from the 2001-2002 USGS surveys, the 1979 breeding season survey and checklist of McCallum (1979a), the 2011-2013 observations by national monument staff/volunteers, and the Grimes and Beckwith (2008) checklist (but excluding extirpated species and those for which few records exist [i.e., "occasional" species) (Appendix H).

In the earliest of the two breeding season surveys, McCallum (1979a) recorded 49 species. Johnson et al. (2007) recorded 63 species, 56 during their point count surveys and 47 during the additional area searches. Park staff/volunteers reported a total of 40 species during their observations (subspecies are excluded from this number). From our review of the Grimes and Beckwith (2008) checklist, 28 additional species (excluding those designated as extirpated or occasional) were added to our list. Because this cumulative list of bird species is lengthy, it is presented in the appendix (Appendix H).

For the 56 species recorded by Johnson et al. (2007) during point count surveys, analyses were also conducted to examine species distribution and relative abundance across habitats. A brief summary of some of this information is presented here because it is the most current such information available, and it is of interest. For example, the greatest number of species were detected in oak/piñon-juniper habitat (40 species or 71.4%) and piñon-juniper habitat (39 species or 69.6%), followed by piñon-juniper/grassland habitat (28 species or 50%). Twenty-one species were observed in grassland habitat. Overall (for all habitat types combined), species recorded in the highest numbers during point counts were: White-throated Swift (*Aeronautes saxatalis*), Lark Sparrow (*Chondestes grammacus*) and Western Meadowlark (*Sturnella neglecta*), Spotted Towhee (*Pipilo maculatus*), Mourning Dove (*Zenaida macroura*), Western Bluebird (*Sialia mexicana*), and Western Scrub-Jay (*Aphelocoma californica*), respectively.

<u>Species of Conservation Concern</u>

There are 30 bird species that have been recorded during one or more of the surveys/observation efforts at El Morro NM that are listed as species of conservation concern on one or more of the lists described in Section 4.9.2 and Appendix G (Table 4.9.4-1). Appendix H shows in which surveys the species were observed. Note that some additional species of conservation concern may occur at the park; some may have gone undetected to date, and others may have been considered as "occasional" on the Grimes and Beckwith (2008) checklist (and therefore not included by us here).

- USFWS / Listed Species: There are no bird species listed by the USFWS as endangered or threatened (USFWS 2015a) that are known to occur at the national monument (Table 4.9.4-1). However, as discussed below (under Federally-listed Species), there are three species (Mexican Spotted Owl [*Strix occidentalis lucida*], Southwestern Willow Flycatcher [*Empidonax traillii extimus*], and Yellow-billed Cuckoo [*Coccyzus americanus occidentalis*], western population) that may occur outside the park and/or within the county (and could pass through the park) and of which park personnel are aware (NPS 2014b).
- State of New Mexico / Listed Species: Three state-listed birds, all threatened, have been recorded at the national monument (Gray Vireo [*Vireo vicinior*], Bald Eagle [*Haliaeetus leucocephalus*], and Peregrine Falcon [*Falco peregrinus*]; see Appendix H, NMGFD 2015b). The Bald Eagle was noted only by Grimes and Beckwith (2008); it is described as "occasional," but we included it on the list due to its state-listed status. Johnson et al. (2007) confirmed breeding in the park by Peregrine Falcons.
- USFWS / Birds of Conservation Concern: There are 18 species that have been recorded at the national monument that have been identified by USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (USFWS 2008).
- NAS / ABC: There are 11 species that occur or have occurred at the national monument that are included on the NAS/ABC 2007 WatchList. One species, Lewis's Woodpecker (*Melanerpes lewis*), is on the Red List. The other 10 species are on the Yellow List, either because of population declines or because they are rare.

Table 4.9.4-1. Summary of species detected during the two sets of surveys (Johnson et al. 2007 and McCallum 1979a) and three sets of observations/checklists at El Morro National Monument (see text and Appendix H) that are listed as species of conservation concern by government agencies and non-governmental organizations. Additional species (for which few records exist) may also be of conservation concern.

Common Name	Listed Species		Species of Conservation Concern Lists							Notes
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (NMDGF)[5]	
							BCR 16			
	USFWS	NMDGF	National	Region 2	BCR 16	2007 Watch List	CC	RC	Species of Greatest Conservation Need	
Bald Eagle		T	•	•	•				•	
Black-throated Gray Warbler									•	
Brewer's Sparrow			•		•	• (orange)		•		
Calliope Hummingbird			•			• (orange)				
Cassin's Finch					•		•	•		
Common Nighthawk								•		
Common Poorwill								•		
Ferruginous Hawk					•			•	•	
Flammulated Owl			•	•	•	• (orange)	•			
Golden Eagle				•	•			•	•	
Grace's Warbler			•	•	•	• (orange)			•	
Gray Vireo		T	•	•	•	• (orange)	•	•	•	
Juniper Titmouse					•				•	
Lazuli Bunting								•		
Lewis's Woodpecker			•	•	•	• (red)		•	•[A]	A=on SGCN *county* list only.
Loggerhead Shrike			•	•				•	•	
Mountain Bluebird								•		
Mourning Dove									•	
Northern Goshawk									•	
Northern Harrier									•[A]	A=on SGCN *county* list only
Olive-sided Flycatcher			•				•	•	•	
Peregrine Falcon		T	•	•	•				•	
Pinyon Jay			•	•	•	• (orange)	•	•	•	
Prairie Falcon								•		
Oak Titmouse			•			• (orange)				

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
T = Threatened
E = Endangered

[3] **NAS/ABC - 2007 Watchlist**
• (red) = Red List
• (orange) = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in Cibola County / Arizona-New Mexico Mountains ecoregion

Table 4.9.4-1. Summary of species detected during the two sets of surveys (Johnson et al. 2007 and McCallum 1979a) and three sets of observations/checklists at El Morro National Monument (see text and Appendix H) that are listed as species of conservation concern by government agencies and non-governmental organizations. Additional species (for which few records exist) may also be of conservation concern (continued).

Common Name	Listed Species		Species of Conservation Concern Lists							Notes
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (NMDGF)[5]	
							BCR 16			
	USFWS	NMDGF	National	Region 2	BCR 16	2007 Watch List	CC	RC	Species of Greatest Conservation Need	
Rufous Hummingbird			•							
Sage Thrasher									•[A]	A=on SGCN *county* list only
Scaled Quail						• (orange)			•	
Virginia's Warbler			•			• (orange)	•			
Williamson's Sapsucker						• (orange)			•	
Yellow Warbler									•	

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
T = Threatened
E = Endangered

[3] **NAS/ABC - 2007 Watchlist**
• (red) = Red List
• (orange) = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in Cibola County / Arizona-New Mexico Mountains ecoregion)

- PIF: Sixteen of the bird species in Table 4.9.4-1 are listed by PIF as either CC or RC (recall we did not include the stewardship categories). Six of the species are listed as Continental Concern and 14 of the species are listed as Regional Concern (some species are listed as both).
- New Mexico Species of Greatest Conservation Need: Nineteen of the species recorded during the bird surveys and other observations/lists are considered SGCN in Cibola County / the Arizona-New Mexico Mountains ecoregion (NMDGF 2006, 2015b).

Federally-listed Species

There are three federally-listed bird species that are not known to occur within the national monument but are known from or may occur in Cibola County (USFWS 2015a; NMDGF 2015b); these are the Mexican Spotted Owl (threatened), Southwestern Willow Flycatcher (endangered), and Yellow-billed Cuckoo (western population; threatened). Two areas of designated critical habitat have been identified for the Mexican Spotted Owl in the Cibola National Forest north of the national monument (one north of Interstate 40 and one south of the interstate; USFWS 2004). Johnson et al. (2007) discussed an Investigator's Annual Report (IAR) that described a one-day survey for the species that noted that habitat at the park may be marginal for the owl. They found no vocal response to calls and no evidence of Mexican Spotted Owl nesting at El Morro NM (Johnson et al. 2007). Information from BISON-M for the Southwestern Willow Flycatcher indicates that the species is rare in Cibola County. Additionally, critical habitat has been designated for the species in the state (in nearby counties), but the critical habitat is not in close proximity to the national monument (USFWS 2013); the designated critical habitat is in the two counties south of Cibola County, Catron and Socorro, but not close to the southern Cibola County border.

Summary of Bird Condition

To assess condition of birds at El Morro NM, we used one indicator/measure, species occurrence. Current condition cannot be determined due to the lack of recent data. The information presented in this condition assessment is from the most recent standardized survey at the park, conducted in 2001-2002 by the USGS (Johnson et al. 2007), as well as one earlier breeding season study, and informal observations. Approximately 137 species have been recorded from these efforts, and additional species have been recorded that are thought to occur less frequently. Trends in species occurrence cannot be assessed due to the lack of recent data. However, the 2001-2002 surveys provide good baseline information (or reference conditions) for future monitoring and condition assessment. At least 30 species that have been recorded at the national monument appear on one or more lists of species of conservation concern, including three species that are listed as threatened with the State. Although we judge the condition unknown due to insufficient recent data, it seems clear that El Morro NM is inhabited by an array of birds species, at least some of which breed in the park.

<u>Mammal Species Occurrence: Presence/ Absence</u>

Bogan et al. (2007) recorded 39 species of mammals during their 2002-2003 surveys at El Morro NM, including a few species observed incidentally by the researchers or by park personnel (Table 4.9.4-2). Twelve additional species are shown in the table as "probably present" per Bogan et al. (2007). Three of these "probably present" species were reported by Stolz (1986a). Stolz (1986a) included six additional species on his checklist (listed in the footnotes to the table), but Bogan et al. (2007) and NPS (2014a) considered all of these either as "unconfirmed" (five species) or as "not occurring in the park" (one species; NPS 2014a). Among these species is the black-footed ferret (*Mustela nigripes*), a federally-endangered species. The observation mentioned by Stolz (1986a) was from 1937, when one individual ferret was reportedly found dead in the pool. Another species listed as unconfirmed in the park by Bogan et al. (2007) is the gray wolf, which is discussed below.

Of the species listed as present in the park by Bogan et al. (2007), 16 are rodents, 13 are bats, seven are carnivores, two are lagomorhs (e.g., rabbits), and one is an ungulate. Of the 12 "probably present" species per Bogan et al. (2007), five are bats, three are rodents, three are carnivores, and one is an insectivore (e.g., shrew).

The USGS surveys in 2002-2003 are the most comprehensive mammal surveys at the national monument to date, and they provide a firm baseline for future monitoring. Bogan et al. (2007) also provided some information on the number of individuals of the various species captured or observed during their surveys. A few of the species observed in the highest numbers in 2002 (comparable information was not presented for 2003) were piñon mouse (*Peromyscus truei*; 14.5% of the individuals encountered) and deer mouse (*Peromyscus maniculatus*; 14.5%), and the most common bat species encountered was the big brown bat (*Eptesicus fuscus*; 8.4% of the individual mammals encountered). [Note that the text of Bogan et al. 2007 (page 17) is inconsistent with the results (data) they presented in their Tables 2 (page 48) and 3 (page 50); we used (and presented above) their data in the tables on the most common species and bats encountered.]. Of the areas sampled for bats, species richness was greatest at the pool. Taking into account that they documented 39 species of 51 species (i.e., the 39 plus the 12 that are probably present), they concluded that the level of documentation was 76%. They anticipated that additional survey work would confirm the occurrence of additional species.

The gray wolf is reported as "unconfirmed" for the park by Bogan et al. (2007). Stolz (1986a) mentioned the wolf as extirpated and noted that the last area record, from 1936, was between the monument and Ramah. However, it should be mentioned that although gray wolves have not been documented in El Morro NM, they were documented in nearby El Malpais NM in 2014. The Mexican gray wolf (*Canis lupus baileyi*), is listed as endangered with both the USFWS and the State of New Mexico. In early 2014, a few individuals were documented

Table 4.9.4-2. Mammal species recorded in El Morro NM during surveys by Bogan et al. (2007) in 2002-2003. Also shown are species from the Stolz (1986a) checklist that were listed as recorded in the park.

Common Name	Scientific Name	Bogan et al. (2007)	Stolz (1986a) [1]	Comments
Allen's big-eared bat	*Idionycteris phyllotis*			Probably present (per Bogan et al.)
American badger	*Taxidea taxus*	X	X	
American black bear	*Ursus americanus*	X		
Big brown bat	*Eptesicus fuscus*	X	X	
Big free-tailed bat	*Nyctinomops macrotis*			Probably present (per Bogan et al.)
Black-tailed jackrabbit	*Lepus californicus*	X	X	
Bobcat	*Lynx rufus*		X	Observed by park staff (per Bogan et al.)
Botta's pocket gopher	*Thomomys bottae*	X	X	
Brazilian free-tailed bat	*Tadarida brasiliensis*	X		
Brush mouse	*Peromyscus boylii*	X	X	
California myotis	*Myotis californicus*	X		
Canyon bat [2]	*Parastrellus hesperus* [2]			Probably present (per Bogan et al.)
Cliff chipmunk	*Neotamias dorsalis*	X	X	
Colorado chipmunk	*Neotamias quadrivittatus*			Probably present (per Bogan et al.)
Common gray fox	*Urocyon cinereoargenteus*	X		
Coyote	*Canis latrans*	X	X	
Crawford's desert shrew	*Notiosorex crawfordi*			Probably present (per Bogan et al.)
Deer mouse	*Peromyscus maniculatus*	X	X	
Desert cottontail	*Sylvilagus audubonii*	X	X	
Fringed myotis	*Myotis thysanodes*	X	X	
Gunnison's prairie dog	*Cynomys gunnisoni*	X		
Hoary bat	*Lasiurus cinereus*	X	X	
Little brown bat	*Myotis lucifugus*	X		
Long-eared myotis	*Myotis evotis*	X		
Long-legged myotis	*Myotis volans*	X	X	
Long-tailed weasel	*Mustela frenata*	X		
Mexican woodrat	*Neotoma mexicana*	X	X	
Mogollon vole	*Microtus mogollonensis*	X		
Mountain lion	*Puma concolor*		X	Observed by park staff (per Bogan et al.)
Mule deer	*Odocoileus hemionus*	X	X	
North American (common) porcupine	*Erethizon dorsatum*	X	X	
Northern grasshopper mouse	*Onychomys leucogaster*	X	X	
Northern rock mouse	*Peromyscus nasutus*	X		
Ord's kangaroo rat	*Dipodomys ordii*	X	X	
Pallid bat	*Antrozous pallidus*	X		
Pinyon mouse	*Peromyscus truei*	X	X	
Plains pocket mouse	*Perognathus flavescens*	X	X	
Ringtail	*Bassariscus astutus*			Probably present (per Bogan et al.)
Rock squirrel	*Spermophilus variegatus*	X	X	
Silky pocket mouse	*Perognathus flavus*			Probably present (per Bogan et al.)
Silver-haired bat	*Lasionycteris noctivagans*		X	Probably present (per Bogan et al.)
Southwestern myotis	*Myotis auriculus*			Probably present (per Bogan et al.)

Table 4.9.4-2. Mammal species recorded in El Morro NM during surveys by Bogan et al. (2007) in 2002-2003. Also shown are species from the Stolz (1986a) checklist that were listed as recorded in the park (continued).

Common Name	Scientific Name	Bogan et al. (2007)	Stolz (1986) [1]	Comments
Spotted bat	*Euderma maculatum*	X		
Stephens's woodrat	*Neotoma stephensi*			Probably present (per Bogan et al.)
Striped skunk	*Mephitis mephitis*		X	Probably present (per Bogan et al.)
Townsend's big-eared bat	*Corynorhinus townsendii*	X		
Western harvest mouse	*Reithrodontomys megalotis*	X		
Western small-footed myotis	*Myotis ciliolabrum*	X	X	Stolz recorded as *M. subulatus* (a synonym)
Western spotted skunk	*Spilogale gracilis*		X	Probably present (per Bogan et al.); Stolz recorded as *S. putorius*
Western white-throated woodrat	*Neotoma albigula*	X	X	
Yuma myotis	*Myotis yumanensis*	X		

[1] Stolz (1986a) included 5 additional species as observed in the park. Four of these species (spotted ground squirrel, Abert's squirrel, kit fox, and raccoon) are noted by Bogan et al. (2007) as "unconfirmed." One of the species (short-tailed weasel) does not appear in Bogan et al. (2007) but NPSpecies lists it as "not in park." Stolz (1986a) also reports that the black-footed ferret used to occur in the park, and an individual was found drowned in the pool in 1937.

[2] Previously known as Western pipistrelle (*Pipistrellus hesperus*).

at El Malpais NM (David Hayes, former Natural Resources Branch Chief, El Malpais and El Morro NMs, pers. comm., 2015). The wolves were captured and transported from the park because they were outside of the designated "primary recovery zones" and "recovery areas" for the nonessential experimental population (USFWS 2015b). Whether additional Mexican gray wolves will move into the area is unknown, but if they do return, because the USFWS recently revised the rules governing management of the experimental population within the Mexican Wolf Experimental Population Area (USFWS 2015b), they may be allowed to remain (D. Hayes, former Natural Resources Branch Chief, El Malpais and El Morro NM, pers. comm., 2015). Under the new rule, both El Morro and El Malpais NMs are within a zone where the wolves will be allowed to "naturally disperse and occupy," and where "Mexican wolves may be translocated" (USFWS 2015b).

Native mammals are important members of the ecosystem, but they also can cause damage to other resources within national park units. In Chapter 2 of the condition assessment, we provided a brief discussion of a study at El Morro NM that examined impacts on archaeological sites from burrowing mammals. Park staff and researchers had observed burrowing disturbance in as much as 20% of the park's sites. Drost (2006) sampled for mammals and studied impacts from burrowing and digging at some priority study sites (e.g., Atsinna pueblo) in 2003-2004. Drost (2006) detected individuals from about 14 mammal species in and around the study sites. These mammals ranged in size from mice (e.g., brush mouse [*Peromyscus boylii*]) to badger (*Taxidea taxus*) and coyote (*Canis latrans*). The researcher concluded that, among the species observed, badgers posed the greatest threat due to the disturbance they can cause from den burrowing and surface digging for food. In addition to the badger, Drost (2006) found four species to be "engaged in significant digging" within at least one of the priority study sites: Botta's pocket gopher (*Thomomys bottae*), coyote, gray fox (*Urocyon cinereoargenteus*), and skunk (probably the striped skunk, *Mephitis mephitis*; Drost 2006). Other species present have the potential to cause substantial disturbance (e.g., prairie dogs), but because of their distance from the sites or their relatively low occurrence in the park, they appear to be of less concern. The national monument presently monitors for archaeology condition multiple times per year, and this monitoring includes impacts from burrowing/digging mammals.

<u>The Occurrence of Species of Conservation Concern</u>

There are four mammal species out of those documented at El Morro NM that are listed as species of conservation concern on one or more of the lists described in Section 4.9.2 (Table 4.9.4-3). None of the species are federally listed, but one, the spotted bat (*Euderma maculatum*), is listed as threatened with the State. Three additional species are considered SGCN in New Mexico.

The spotted bat was first recorded in the county by Valdez et al. (2002). The echolocation sound made by the species is low enough to be heard by the human ear (Arizona-Sonora Desert Museum 2015). The spotted bat stands out visually because of its coloration and markings. It has a black body with two large white spots on its shoulders and one white spot on its rump, and its underbelly is white. Its ears and wings are pinkish. The bat has a large range but is considered one of the rarest bats in North America (Arizona-Sonora Desert Museum 2015).

Summary of Mammal Condition

To assess condition of mammals at El Malpais NM, we used one indicator/measure, species occurrence. Current condition cannot be assessed due to the lack of recent data. The information presented in this condition assessment is from the most recent survey at the park, conducted in 2002-2003 by the USGS (Bogan et al. 2007). Thirty-nine mammal species were recorded at that time, with an additional twelve that are probably present (Bogan et al. 2007). Trends in species occurrence cannot be assessed due to the lack of recent, available data. However, the 2002-2003 surveys provide good baseline information (or reference conditions) for future monitoring and condition assessment. Four of the mammal species documented at the park are considered SGCN, including one species that is state-listed.

Herpetofauna Species Occurrence: Presence/Absence

A total of 12 species of amphibians and reptiles were recorded at El Morro NM during 2001-2003 surveys by USGS (Nowak and Persons 2008; Table 4.9.4-4). Five additional species were recorded previously and are also reported in Nowak and Persons (2008); although they do not provide the sources of these previous "reliable" observations for each species, they are probably based on Gehlbach (1965), McCallum (1979b), and/or Stolz (1986b). Ten additional species are noted as "probably present" (one species) or "unconfirmed" (nine species) by Nowak and Persons (2008) and NPS (2014a). These latter species are discussed in this section as appropriate.

Four of the 17 species listed as occurring in the park are amphibians, and 13 of the species are reptiles (six lizards and seven snakes). Of the 256 individual animals recorded during the 2001-2003 surveys, the species recorded in the highest numbers were the Eastern fence lizard (*Sceloporus undulatus*), plateau striped whiptail (*Cnemidophorus velox*), and tiger salamander (*Ambystoma tigrinum*). Based on their work and the previously

Table 4.9.4-3. Mammal species detected at El Morro NM that are Species of Greatest Conservation Need (SGCN) according to the NMDGF (NMDGF 2006; NMDGF 2015b) and/or state or federally-designated as threatened or endangered.

Common Name	Scientific Name	Federally-listed (USFWS)	State-listed (NMDGF)	NM SGCN (NMDGF)
American black bear	*Ursus americanus*			SGCN
Gunnison's prairie dog	*Cynomys gunnisoni (zuniensis)* *			SGCN
Mule deer	*Odocoileus hemionus*			SGCN
Spotted bat	*Euderma maculatum*		T	SGCN

* = The list of SGCN for Cibola County (from BISON-M; NMDGF 2015b) provides the subspecies shown; the list of SGCN in the Comprehensive Wildlife Conservation Strategy (i.e., NMDGF 2006) does not designate a subspecies.

Table 4.9.4-4. Amphibian and reptile species recorded at El Morro NM during surveys in 2001-2003 by Nowak and Persons (2008), as well as additional species reported by Nowak and Persons as previously observed.

Common Name	Scientific Name	Nowak and Persons (2008) [1]	Additional Species [2]
Amphibians			
Mexican spadefoot	*Spea multiplicata*	X	
Plains spadefoot	*Spea bombifrons*	X	
Tiger salamander	*Ambystoma tigrinum*	X	
Woodhouse's toad	*Bufo woodhousii*		X
Reptiles: Lizards			
Eastern fence (or Prairie) lizard	*Sceloporus undulatus*	X	
Greater short-horned lizard	*Phrynosoma hernandesi*	X	
Lesser earless lizard	*Holbrookia maculata*		X
Ornate tree lizard	*Urosaurus ornatus*	X	
Plateau striped whiptail	*Cnemidophorus velox*	X	
Variable skink / Many-lined skink	*Eumeces multivirgatus*	X	
Reptiles: Snakes			
Gopher snake (or Bull snake)	*Pituophis catenifer*	X	
Milk snake	*Lampropeltis triangulum*		X
Night snake	*Hypsiglena torquata*	X	
Ring-necked snake	*Diadophis punctatus*		X
Striped whipsnake	*Masticophis taeniatus*		X
Western rattlesnake	*Crotalus viridis*	X	
Western terrestrial garter snake	*Thamnophis elegans*	X	

[1] Species shown are those observed by Nowak and Persons (2008) during their 2001-2003 inventory.

[2] Persons and Nowak (2008) reported these species as present in the park based on previous, reliable observations (although they did not record them themselves).

Additional Notes: There is also one species noted by Nowak & Persons/NPSpecies as "probably present" (black-necked garter snake), and nine additional species as "unconfirmed."

documented species, the researchers estimated that inventory completeness was about 81%, meaning that more species are likely to be found at the national monument with additional survey effort. Although not shown in the table (but see the footnote), one additional species (black-necked garter snake, [*Thamnophis cyrtopsis*]) is probably present at the national monument (with a high probability of occurrence; Nowak and Persons 2008).

No comprehensive surveys or monitoring of amphibians and reptiles have been conducted at the park since the 2001-2003 surveys. Therefore, we cannot provide any additional information as to which species occur in the park at this time.

The Occurrence of Species of Conservation Concern

Although none of the herpetofauna species recorded at the national monument are federally or state-listed as endangered or threatened, there is one species that was observed at El Morro NM during 2001-2003 and earlier surveys (see Table 4.9.4-4) that is listed as a SGCN in New Mexico (USFWS 2015a, NMDGF 2015b). This species is the tiger salamander (*Ambystoma tigrinum*). Note that in the list of SGCN for Cibola County, the scientific name given for tiger salamander is *Ambystoma mavortium mavortium*; however, additional information provided in BISON-M reports the scientific name as *Ambystoma tigrinum* (and this name is used in NMDGF [2006]).

NMDGF (2006) also lists the milk snake (*Lampropeltis triangulum*) as a SGCN for the state (see NMDGF 2006 appendix) and ecoregion (Arizona-New Mexico Mountains; see Table 5-4 in NMDGF main report), and this species has been recorded at the national monument. It is unclear why this species was not listed on BISON-M for the county (NMGFD 2015b).

Wildlife

Indicators	Measures
Species Occurrence	3 Measures

Overall Condition

To assess condition of herpetofauna at El Morro NM, we used one indicator/measure (species occurrence). Current condition cannot be assessed due to the lack of recent data. The information presented for this indicator/measure is from the most recent survey at the park, conducted in 2001-2003 by the USGS, as well as from previous surveys discussed in Nowak and Persons (2008). Based on this work, at least 17 species have been reported and confirmed in the national monument. Trends in species occurrence cannot be assessed due to the lack of available data. However, the 2001-2003 surveys provide good baseline information (or reference conditions) for future monitoring and condition assessment.

Overall Condition

For assessing the condition of wildlife at El Morro NM, we used three indicators/ measures, that of species occurrence: presence/absence. A separate indicator/ measure was used for each group of wildlife (birds, mammals, and herpetofauna). The indicators/measures are summarized in Table 4.9.4-5.

Current condition under each indicator/ measure is unknown because of the lack of recent information, particularly for mammals and herpetofauna, on species occurrence at the national monument. However, the survey/ inventory work that has been conducted provides good baseline information for future monitoring and assessment. Even within this relatively small park, a variety of wildlife species have been recorded, including a number that are of conservation concern according to various agencies/groups at national and regional scales.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are 1) the overall lack of data (e.g., no two sources of information/data of comparable methods and effort within each wildlife group); and 2) a lack of recent survey/ inventory data.

4.9.5. Sources of Expertise

No outside experts were consulted for this resource topic. This section was authored by biologist Patty Valentine-Darby.

4.9.6. Literature Cited

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Table 4.9.4-5. Indicators and measures of wildlife condition.

Indicator	Measure	Condition	Rationale for Condition.
Bird Species Occurrence	Presence/ Absence	Unknown	Current condition cannot be determined due to the lack of recent/current data. The most recent standardized surveys were conducted in 2001-2002 (i.e., Johnson et al. 2007). Some more recent informal surveys and checklists are available, but they are not extensive or developed from standardized methods. Approximately 137 species have been recorded during the efforts discussed here, and additional species have been recorded that are thought to occur less frequently. The 2001-2002 (and 1979) surveys provide good baseline information for future monitoring and condition assessment. At least 30 species have been recorded at the national monument that appear on one or more lists of species of conservation concern, including three species that are listed as threatened with the State (Bald Eagle, Gray Vireo, and Peregrine Falcon).
Mammal Species Occurrence		Unknown	There is no current information available on mammals at the national monument. The most recent surveys were conducted in 2002-2003 (i.e., Bogan et al. 2007). Although condition cannot be determined at this time, the 2002-2003 work, as well as an earlier checklist provides baseline information for future monitoring and assessment. One of the species documented at the park is listed as threatened with the State. Four species, including the threatened species, are listed as SGCN.
Herpetofauna Species Occurrence		Unknown	There is no current information available on amphibians and reptiles at the national monument. The most recent surveys were conducted in 2001-2003 (i.e., Nowak and Persons 2008). Although condition can not be determined at this time, the 2001-2003 work (as well as earlier surveys) provides baseline information for future monitoring and assessment. One or two SGCN have been recorded in the national monument.

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El Morro National Monument preserves the ancestral Puebloan archeological sites, and provides opportunities to experience these resources in their natural setting (NPS 2014).

Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning

5.1. Introduction

The primary purpose of the Natural Resource Condition Assessment (NRCA) Chapter 5 is to provide a "big picture" - broader application of resource condition findings for El Morro National Monument (Albright 2010). We will fulfill this purpose by:

- creating a framework that connects the natural resource findings to El Morro National Monuments's purpose and significance statements (refer to Table 5.2-1),
- delivering completed *State of the Park* natural resource condition summary tables for each of the topics assessed (refer to sections 5.3-5.12); and
- providing resource briefs for each assessed topic, highlighting potential management and project considerations, if applicable.

These Chapter 5 reporting pieces are *value added* products that can be used by park managers for a variety of resource planning and comprehensive park management purposes (Jeff Albright, NRCA Program Coordinator, pers. comm. August 23, 2013). Efficiency is gained by providing these products because they deliver information to park staff that directly meet other reporting requirements, such as those for the *State of the Park* report.

5.2. Connecting Natural Resource Condition Assessment Topics to Park Purpose, Significance, and Fundamental Resources & Values

Managing the natural resources at El Morro NM is inextricably tied to its purpose and significance. It is most often within this interdisciplinary perspective that managers consider potential actions and alternatives when addressing resource issues or needs. During the park's on-site NRCA scoping meeting, participants reviewed resource topics selected for the condition assessment and identified how those resources were connected to the park's purpose, significance and fundamental resources and values, as identified in the park's foundation document (NPS 2014). Table (Table 5.2-1) summarizes the results of this exercise and provides a "snapshot" overview of how each natural resource topic assessed ties into the

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to El Morro National Monument's purpose and significance statements identified in the park's Foundation Document (NPS 2014).

Natural Resource Condition Assessment Topics	Viewshed	Night Sky	Sounscape	Air Quality	Geology	Historic Pool	Vegetation	Exotic Plants	Wildlife
I. Park Purpose									
Preserves Inscription Rock, its inscriptions, petroglyphs, and ancestral Puebloan archeological sites, and provides opportunities to experience these resources in their natural setting.	•	•	•	•	•	•	•		•
II. Park Significance									
Inscription Rock has more than 2,000 inscriptions, petroglyphs, and pictographs that document a cultural continuum of more than 1,000 years, from Ancestral Puebloans to Spanish explorers, European American surveyors, pioneers, military expeditions, and other travelers.	•			•	•	•	•		
Contains a high concentration of exceptional archeological resources; well-preserved and largely unexcavated pueblo sites atop Inscription Rock are among the largest 13th and 14th century settlements in the American Southwest.					•	•			
Distinctive combination of geologic and geographical features—the natural travel corridor, highly visible landmark with a pool of water at its base, and the carvable texture of its soft sandstone—provided a perfect natural canvas for early inhabitants and travelers to leave their mark.	•				•	•			
III. Fundamental Resources and Values									
Inscriptions, Petroglyphs, and Pictographs	•	•	•	•	•	•			
Archeological Resources					•	•			
Cuesta and Natural Setting: distinctive combination of geologic and geographical features—the natural travel corridor, highly visible landmark with a pool of water at its base, and the carvable texture of its soft sandstone	•				•	•			
IV. Other Important Resources and Values									
Cultural Landscape	•	•	•	•	•	•	•	•	•
Historic Structures	•				•	•			
Museum Collection									

park's primary reasons for establishment. The geology, historic pool, and viewshed are strongly connected to the reasons the monument was established as a national monument.

5.3. *State of the Park* Reporting

As part of the stewardship of national parks for the American people, the NPS has begun to develop *State of the Park* reports to assess the overall status of each park's resources.

The key purposes of each *State of the Park* report are to:

- Provide to visitors and the American public a snapshot of the status and trend in the condition of a park's priority resources and values.
- Summarize and communicate complex scientific, scholarly, and park operations factual information and expert opinion using non-technical language and a visual format.
- Highlight park stewardship activities and accomplishments to maintain or improve the *State of the Park*.
- Identify key issues and challenges facing the park to help inform park management planning (NPS 2012).

Table 5.3-1. *State of the Park* Natural Resource Summary Table

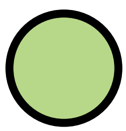
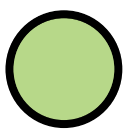
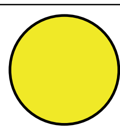
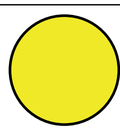
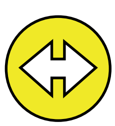
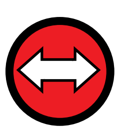
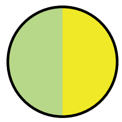
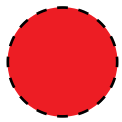
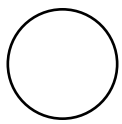
Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Natural Resources		
Viewshed		Viewsheds are considered an important part of the visitor experience. Features on the visible landscape influence the enjoyment, appreciation, and understanding of a park. We used one indicator, scenic and historic integrity, to assess viewshed condition at the national monument. The indicator had two measures, 1) intactness, and 2) conspicuousness of noncontributing features, both of which were judged to be in good condition. The vast majority of the landscape seen from the assessment vantage points appears intact with few noncontributing features.
Night Sky		Quantitative measures of sky brightness (all-sky light pollution ratio, maximum vertical and horizontal illuminance, and zenith sky brightness) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky in El Morro NM. The overall condition of the national monument's night sky as observed from Atsinna Pueblo on May 30, 2013 is good.
Soundscape		We used one indicator and two measures to assess soundscape condition. The percent time above reference sound levels was in good to moderate condition and the L_{50} impact measure was of significant concern. Overall, the soundscape condition was considered to be in moderate condition.
Air Quality		The air quality assessment included visibility, ozone for human and vegetation health, and wet deposition for total nitrogen and total sulfur, all of which were in moderate condition, except for total sulfur, which was good, based upon NPS Air Resources Division reference criteria.
Geology		We used two measures, Inscription Rock and slope/cliff stability, to assess the condition of geology in El Morro NM. The condition for the weathering and erosion rates and processes measure was of significant concern, and the condition for the freeze-thaw index, geohydrology, and other impacts measures was good. The condition of slope/cliff stability was of significant concern. Overall, geologic resources are in moderate condition with a stable trend.
Historic Pool		We used two indicators to assess the current condition and trend of the historic pool. The first indicator, with one measure, assessed whether the historic pool was in natural condition. The pool has been significantly altered over the years and is of significant concern. The second indicator, also with one measure, assessed amount of precipitation relative to pool elevation as the pool is predominantly a meteoric water system. Annual precipitation was below mean for 3 of the 4 previous water years and in a moderate drought condition, therefore considered to be moderate. The overall condition is of significant concern.

Table 5.3-1 State of the Park Natural Resource Summary Table (continued)

Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Vegetation		Vegetation at El Morro NM, judged to have a condition of good to moderate concern, exists within a relatively small number of communities. Overall, the conditions of piñon-juniper and ponderosa pine vegetation types were judged to be good, although there were some concerns. Historic and cultural integrity of vegetation on the landscape was judged to be of moderate concern, because of the densification and/or expansion of juniper-piñon savannas adjacent to El Morro leading to obstruction of views of the feature and a somewhat different appearance compared to the time of park establishment.
Exotic Plants		We used two indicators, potential to alter native plant communities and prevalence of exotic plants, to assess the condition of exotic plants in El Morro NM. The condition for the significance of exotic impact measure was of significant concern. The prevalence of exotic plants was in moderate condition, but with low confidence because of limited information. Overall, the condition of exotic plants is of significant concern with an unknown trend.
Wildlife		We used one indicator with three measures to assess the condition of wildlife at the national monument. A species occurrence indicator was used for each of the main groups of wildlife-birds, mammals, and herpetofauna (resulting in the three measures). For each wildlife group, no surveys or inventories have been conducted since the early 2000s. For this reason, current condition for each group of wildlife is unknown. However, the surveys conducted in the early 2000s provide baseline information for future monitoring and condition assessment.

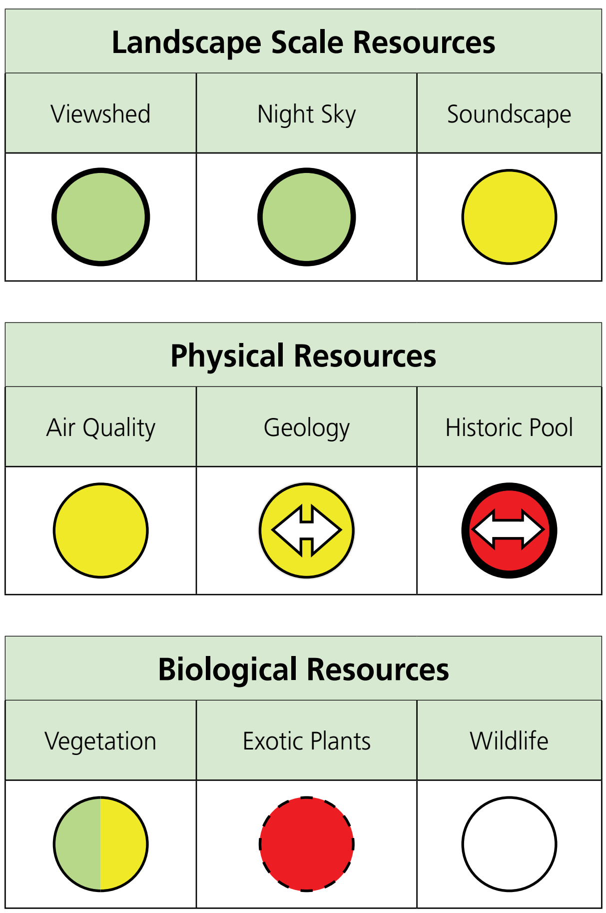


Table 5.3-1 provides an overall summary of natural resource conditions based upon NRCA findings. Most of the landscape-scale resources were in good to moderate condition. The physical resources ranged between moderate to significant concern. The biological resources included the highest degree of resource condition variation, ranging from unknown to good to moderate to significant concern.

Each resource brief, (5.4-5.12) details these condition ratings by including a *State of the Park* summary table of indicators and measures. Condition rationale, resource highlights, management opportunities and considerations may also be included in each resource brief.

Landscape Scale Natural Resources

Viewshed, Night Sky, and Soundscape

5.4. Viewshed Resource Brief

The contents of sub-chapter 5.4 were designed to be placed into a stand-alone viewshed resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

"El Morro's distinctive combination of geologic and geographical features—the natural travel corridor, highly visible landmark with a pool of water at its base...." (NPS 2014) served as an easily identifiable multicultural refuge.

5.4.1. Noteworthy Highlights

Although there are some noncontributing features present (e.g., Highway 53) that impact the viewshed, the site is primarily intact from a scenic standpoint, which also allows the visitor to imagine the landscape from an historic and cultural point of view. The national monument setting enables the park visitor to have a sense of what it was like to visit Inscription Rock and its pool up-close in centuries past, or to live atop El Morro even longer ago.

5.4.2. Condition Rationale

To assess viewshed condition at El Morro NM, we used one indicator with two measures (Table 5.4.2-1). Overall, the scenic and historic integrity of the viewshed is in good condition. From the vantage points, most of the small number of noncontributing features seen are relatively minor. The main exception is Highway 53, which can be seen in at least one direction from both vantage points (although much less visible from one of them). Highway 53 runs east-west through the park and is most visible when looking to the northwest from the north rim of Inscription Rock. We did not find the view of the highway from this location serious enough to lower condition, however, and believe that the visitor to the national monument is able to imagine the landscape from an historic and cultural point of view. Additionally, views of Inscription Rock from the ground and views of the landscape from atop Inscription Rock are impressive.

Table 5.4.2-1. Summary of overall viewshed condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Viewshed			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Scenic and Historic Integrity	Intactness of View		Views are mainly intact with few noncontributing features, consistent with good condition. The most conspicuous man-made feature is Highway 53 as seen from the west-northwest-facing view at Woodpecker Rock, but the view of the highway from this location is not serious enough to lower condition. Overall, the vast majority of the landscape appears intact.
	Conspicuousness of Non-contributing Features		Noncontributing features are relatively inconspicuous, consistent with good condition. The most conspicuous non-contributing feature is Highway 53 as seen from the west-northwest-facing view at Woodpecker Rock. However, the view of the highway from this location is not serious enough to lower condition.


NPS

5.5. Night Sky Resource Brief

The contents of sub-chapter 5.5 were designed to be placed into a stand-alone night sky resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.5.1. Noteworthy Highlights

The light domes from nearby cities minimally affect night skies in the national monument. The dark night skies within the monument provide an opportunity to engage visitors from nearby cities that might not otherwise have the opportunity to view dark night skies or learn about the celestial environment.

5.5.2. Condition Rationale

El Morro NM is located 40-50 miles from the closest cities and none of its 1,278 acres are located in an urban environment. Therefore, the national monument is considered a non-urban NPS unit, or area with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units, the thresholds separating reference of conditions good, moderate, and significant concern are more stringent than those for urban NPS units because these areas are generally more sensitive to the effects of light pollution. The majority of qualitative and quantitative measures of night sky indicators are within the good condition threshold (Table 5.5.2-1).

Table 5.5.2-1. Summary of overall night sky condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Night Sky			
Indicators of Condition	Specific Measures	Condition Status/ Trend	Rationale
Sky Brightness	All-sky Light Pollution Ratio		Sky brightness as measured by ALR indicates good condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on the ground-based measurement of 0.20 taken in May 2013. The modeled ALR of 0.15 was derived from the 2001 World Atlas of Night Sky Brightness and is similar to the ground-based measurement. The ground-based measurement was collected by the NPS Natural Sounds and Night Skies Division. The confidence level is high.
	Maximum Vertical Illuminance		Sky brightness as measured by maximum vertical illuminance was 0.12 milli-Lux at El Morro NM. This value reflects a rating of 31% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good (J. White, personal communication, Nov. 2015). This measurement was collected by the NPS Natural Sounds and Night Skies Division.
	Horizontal Illuminance		Sky brightness as measured by horizontal illuminance was 0.06 milli-Lux at El Morro NM. This value reflects a rating of 7% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good (J. White, personal communication, Nov. 2015). This measurement was collected by the NPS Natural Sounds and Night Skies Division.
	Zenith Sky Brightness		Zenith sky brightness indicates moderate condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on a ground-based measurement of 21.54. Confidence level is high.
Sky Quality	Bortle Dark Sky Scale		Sky quality as assessed by the Bortle dark sky scale indicate good condition at El Morro NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on the qualitative assessment of Bortle class 3, which is consistent with a rural night sky. Because this measure is qualitative, it has low confidence.


NPS

5.6. Soundscape Resource Brief

The contents of sub-chapter 5.6 were designed to be placed into a stand-alone soundscape resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

"Atsinna, or "where pictures are on the rock" in the Zuni language, is the largest of two pueblos atop El Morro. The multistoried pueblo, with about 350 rooms and multiple kivas, housed up to 1,000 people who farmed the valley until the late 1300s, when populations shifted west" (NPS 2014). Spanish explorers, the U.S. Army, and emigrants followed, creating a n extremely diverse multicultural soundscape throughout the centuries.

5.6.1. Condition Rationale

Soundscape condition was assessed using sound level as an indicator of condition (Table 5.6.1-1). We used the on-site results from the NPS Natural Sounds and Night Skies Division acoustical monitoring effort (NPS NSNSD 2009) to determine percent time above reference sound levels, and the geospatial sound modeling result for the impact between natural and existing acoustic conditions at the monument (Mennitt et al. 2013). The majority of existing sound levels recorded at the monument was between 35-51.99 dBA, suggesting a relatively quiet environment but periodically exceeding the recommendation for maximum noise levels inside bedrooms. However, the modeled average impact sound level for the national monument exceeded the significant concern threshold for non-urban parks based on Turina et al. (2013) reference conditions. Overall, we considered the monument's soundscape to be in moderate condition.

Table 5.6.1-1. Summary of overall soundscape condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Soundscape			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Sound Level	% Time Above Reference Sound Levels		The majority of existing sound levels heard at both sites was between 35-51.99 dBA, suggesting a relatively quiet environment but periodically exceeding the recommendation for maximum noise levels inside bedrooms. We consider this measure to be in good to moderate condition.
	L_{50} Impact		The modeled average impact sound level for the national monument of 4.3 dBA exceeds the significant concern threshold value for non-urban parks based on Turina et al. (2013) reference conditions.

Physical Natural Resources
Air Quality, Geology, and Historic Pool

NPS

5.7. Air Quality Resource Brief

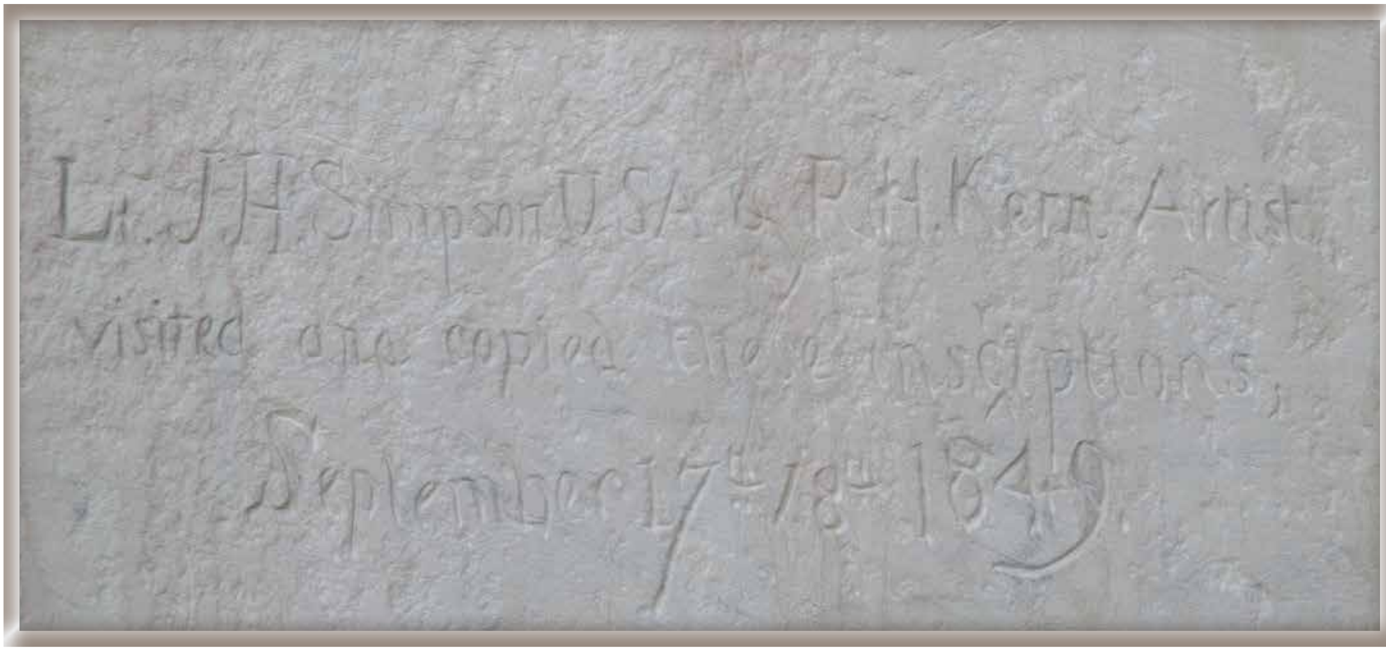
The contents of sub-chapter 5.7 were designed to be placed into a stand-alone air quality resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.7.1. Condition Rationale

We used five measures to assess air quality condition including ozone levels, visibility, and wet deposition of sulfur and nitrogen (Table 5.7.1-1). All indicators and measures were in moderate condition, except for total sulfur, which was good, based on NPS Air Resources Division reference conditions. No trends were reported for any of the measures since no monitoring stations were within the required distance from the park. Like most airsheds, the park's air quality is largely influenced by activities and operations that occur outside its boundaries, making its condition dependent on local, regional, and national planning.

Table 5.7.1-1. Summary of overall air quality condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Air Quality			(Yellow circle)
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Visibility	Haze Index	(Yellow circle)	Visibility warrants moderate concern at El Morro NM, with medium confidence based on NPS Air Resources Division benchmarks and the 2009–2013 estimated visibility on mid-range days of 3.9 deciviews (dv) above estimated natural conditions. No trend information is available because there are not sufficient on-site or nearby visibility monitoring data.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration	(Yellow circle)	Human health risk from ground-level ozone warrants moderate concern at El Morro NM, with medium confidence based on NPS Air Resources Division benchmarks and the 2009–2013 estimated ozone of 67.3 parts per billion (ppb). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data.
	Vegetation Health: 3-month maximum 12hr W126	(Yellow circle)	Vegetation health risk from ground-level ozone warrants moderate concern at El Morro NM, with medium confidence based on NPS Air Resources Division benchmarks and the 2009–2013 estimated W126 metric of 12.3 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in at El Morro NM were at low risk for ozone damage (Kohut 2007; Kohut 2004). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data.
Wet Deposition	Total N	(Yellow circle)	Wet nitrogen deposition warrants moderate concern at El Morro NM, with medium confidence based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet nitrogen deposition of 1.7 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having high sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011). Nitrogen deposition may disrupt soil nutrient cycling and affect biodiversity of some plant communities, including arid and semi-arid and grassland. No trend information is available because there are not sufficient on-site or nearby deposition monitoring data.
	Total S	(Green circle)	Wet sulfur deposition is in good condition at El Morro NM, with medium confidence based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet sulfur deposition of 0.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having very low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data.



5.8. Geology Resource Brief

The contents of sub-chapter 5.8 were designed to be placed into a stand-alone geology resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

> "One of the most impressive and accessible records of Southwest history is exposed on a single rock. El Morro, a sandstone promontory rising 200 feet from the valley floor has more than 2,000 inscriptions and petroglyphs of many cultures spanning 1,000 years along its half-mile sheer cliff face." NPS 2014

5.8.1. Noteworthy Highlights

The inscriptions, petroglyphs and pictographs on Inscription Rock are a major part of El Morro NM's significance and they have a close relationship to the condition of geologic resources.

5.8.2. Condition Rationale

The condition of geology at El Morro NM is moderate. The Inscription Rock indicator had four measures: weathering and erosion rates and process, freeze-thaw index, geohydrology and other impacts (Table 5.8.2-1). While weathering and erosion rates and processes were generally in a natural state/rate, they are impacting the inscriptions, petroglyphs and pictographs, and are, therefore, of significant concern. The freeze-thaw index is in good condition because it is decreasing. With the exception of the enlargement of the historic pool, the geohydrologic system in El Morro is in natural and good condition. Other potential causes of impacts to Inscription Rock, including increased vegetation, biofilm growth, vandalism, and induced ground vibrations, do not appear to impact Inscription Rock with the exception of possible extremely localized impacts such as from increased vegetation. The condition of other impacts is good. Numerous rockfalls that have occurred along Inscription Rock shows that the Zuni Sandstone does not have slope/cliff stability and is in the condition of significant concern.

Table 5.8.2-1. Summary of overall geology condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Geology			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Inscription Rock	Weathering and Erosion Rates and Processes		The weathering and erosion processes and their rates at Inscription Rock are in a generally natural state/rate. However, weathering and erosion are impacting the inscriptions, petroglyphs and pictographs on Inscription Rock. The Zuni Sandstone is extremely friable largely due to it being weakly cemented by clay minerals. Different areas of Inscription Rock may be impacted by individual weathering and erosional processes differently and at different rates due to the natural variations in the sandstone and its permeability, presence of joints, slope aspects, and natural microclimates along the cliff-face.
	Freeze-Thaw Index		The freeze-thaw index is decreasing because of fewer number of days per year that go through the freeze-thaw cycle. The decreasing freeze-thaw index should mean that frost weathering has less of an impact on Inscription Rock and the inscriptions, petroglyphs and pictographs.
	Geohydrology		While the historic pool has been modified by the construction of the dam and the arroyo that drained the pool has been filled in, these alterations only have extremely localized impacts on Inscription Rock. The geohydrology of Inscription Rock is mostly in natural condition. The geomorphology of El Morro shows that groundwater sapping processes have played an important role in the evolution of the landscape feature.
	Other Impacts		With the exception of the inscriptions and the efforts to preserve them, Inscription Rock has not modified from a generally natural condition. Vegetation near the cliff-face only impacts the area in the immediate vicinity and changes due to the presence or absence of vegetation is likely within the range of other microclimates present along the cliff-face. Vandalism is a threat, but has not changed the condition of Inscription Rock. Lichens are naturally present on sandstone surfaces, and there is no correlation between increased lichen and inscription loss. Ground vibrations are not of concern. Inscription Rock is more than 244 m (800 ft) from Hwy 53 and more than 7 miles from the Tinaja Pit quarry. Vibration levels at Inscription Rock are well below the NPS safe limit for sensitive archeological sites (e.g., sensitive man-man structures) .
Slope/Cliff Stability	Rockfall		While the rate of rockfall is unknown, rockfalls have occurred historically and there is debris from rockfall present at the base of El Morro. Rockfall events may or may not be initiated by triggering events, and may or may not be preceded by creep or other changes.

5.9. Historic Pool Resource Brief

The contents of sub-chapter 5.9 were designed to be placed into a stand-alone historic pool resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

> "Water—the force that carved the landscape and drew residents, explorers, and travelers to this place—may in time erase the fragile first-hand accounts of daily life, conquest, and colonization documented on the cliff face." NPS 2014

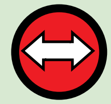
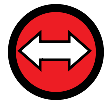
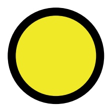
5.9.1. Noteworthy Highlights

The historic pool at El Morro NM has been a central element in its human story from prehistoric times. As one of the few reliable sources of water in the region, the historic pool has repeatedly drawn people to the base of Inscription Rock (Greene 1978) and is a key element in the site's evolution as a cultural landmark. The site still has great cultural significance to the Zuni Tribe and other American Indian peoples (SCPN 2006) and is one of the monument's fundamental resources and values (NPS 2014).

5.9.2. Condition Rationale

We used two indicators to assess the current condition and trend of the historic pool at El Morro NM (Table 5.9.2-1). The first indicator, with one measure, assessed whether the historic pool was in natural condition. The second indicator, also with one measure, assessed climatic condition as the pool is predominantly a meteoric water system. With all of the previous modifications, the pool is now a permanent feature versus what was most likely an ephemeral pool prior to dam construction and is of significant concern. Mean annual precipitation and significant rainfall events that are >10 mm (0.4 in) both influence pool elevation. Because the mean annual precipitation levels were below mean for the period of record (1938-2015) for water years 2012 through 2014 and because El Morro mostly experienced moderate to severe drought during this interval, we considered this measure to be in moderate condition. Overall, we consider the condition of the hisstoric pool to be of significant concern.

Table 5.9.2-1. Summary of overall historic pool condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Historic Pool			
Indicators of Condition	Specific Measures	Condition Status/ Trend	Rationale
Historic Pool	Historic Pool Intactness		The historic pool has been significantly altered from its natural condition that was most likely a shallow plunge pool. Between the 1920s and early 1940s, the pool basin was enlarged and the construction of the concrete dam raised the level of pool by approximately 4 meters (13 feet). This measure is of significant concern.
Climatic Condition	Amount of Precipitation—Pool Elevation		Annual precipitation was below mean for the period of record for 3 of the 4 previous water years, and El Morro was mostly in moderate drought conditions during water years 2011 to 2014. The lowest elevation of the pool occurred each year in early July, which followed the quarter with the lowest mean precipitation. The number of heavy rainfall events typically significant enough to produce runoff into the pool were well below the average annual number of rainfall events in 2012 and 2013. Climatic condition is considered to be moderate.

Biological Natural Resources
Vegetation, Exotic Plants, and Wildlife


NPS

5.10. Vegetation Resource Brief
The contents of sub-chapter 5.10 were designed to be placed into a stand-alone vegetation resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.10.1. Noteworthy Highlights
The predominant vegetation types at the national monument include piñon-juniper woodlands and savannas, ponderosa pine woodlands, blue-grama grasslands, and shrublands. Among the piñon-juniper woodlands and savannas are the persistent piñon-juniper woodlands, which are usually characterized by centuries-old trees. At the monument, these woodlands are found atop El Morro and near the campground. At least one piñon pine tree (stump) was aged during the field assessment, and that tree was approximately 250 years old. Although some concerns exist, the vegetation plays an important role in enabling the park visitor to have a sense of what it was like in centuries past to visit Inscription Rock and its pool or the ancient Puebloan sites.

5.10.2. Condition Rationale
Three indicators were used to assess the condition of vegetation at El Morro NM: the condition of piñon-juniper vegetation, the condition of ponderosa pine vegetation, and historic and cultural integrity of vegetation on the landscape (Table 5.10.2-1). A variety of ecological measures were used for the first two indicators, and one measure, change in vegetation over time, was used for the third indicator. The overall conditions of piñon-juniper and ponderosa pine vegetation were judged to be good (with an unchanging trend). Condition of the historic and cultural integrity of vegetation on the landscape was judged to be of moderate concern, because trees and shrubs are encroaching on grasslands in some areas, and views of El Morro are more obstructed than in the early 20th century. The increased density of woody vegetation near the base of Inscription Rock also increases the chance of an intense fire damaging or destroying the inscriptions. Overall, the condition of vegetation at the park is good to of moderate concern.

5.10.3. Management and Project Considerations

Text shown below was excerpted from Romme and Jacobs 2015 and B. Jacobs, pers. comm., 2016.

The current piñon-juniper densities do not appear to pose a serious threat to ecological integrity in Juniper-Piñon Savannas of El Morro and El Malpais national monuments, and thinning of trees is not an urgent need for any ecological objective. Nevertheless, thinning of young recently established trees, primarily *Juniperus monosperma*, from grasslands where the trees have become established in recent decades could be viewed as an ecologically justifiable--although not urgent--objective intended to preserve the extent and ecological character of the monuments' grassland communities.

Specific locations where junipers have recently expanded into grasslands could be delineated using a combination of tree age-class, understory vegetation, soils, and topographic setting, and thinning could be accomplished by means of mechanical treatment or prescribed fire or a combination of both. In addition to an ecological objective of this kind, mechanical thinning may be called for to reduce fuels in places where vulnerable infrastructure or other features could be damaged or destroyed by a high-intensity fire burning in the dense trees, or where the objective is to re-create a specific historic scene, e.g., at ELMO. In other words, mechanical and fire treatments to maintain and enhance grassland communities recently encroached by woodland (e.g. within the last ~100-years) are consistent with the our report recommendations, but it's critical that: 1) the targeted site is grassland - i.e. lacking old-growth pj elements (although it may structurally resemble a pj savanna) - and retains enough integrity to respond to treatment, e.g. has sufficient remnant grassland species composition-cover and is located on appropriate soils and in a depositional landscape setting and 2) that the presumed encroachment trees are <100-year, e.g. that the woodland element is not old-growth (Brian Jacobs developed a key in the Jacobs et al. (2008) paper, which provides some useful guidance to distinguish young from old pj stands).

The important point for management is that the majority of pre-settlement pj savannas and woodlands with old-growth elements don't require active management (i.e. fire or mechanical treatments with the goal of reducing fuel loading - connectivity, or increasing grass cover, biodiversity, etc.) as these efforts would be likely be inappropriate and inconsistent with what we currently understand about how these systems work. Again, it's critical to be able to tell the old from young stands. The exceptions that come to mind would be in the context of fuel break treatments to protect structures and along sensitive urban interface boundaries where ecology is trumped by management needs.

Table 5.10.2-1. Summary of overall vegetation condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Vegetation			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Persistent Piñon-Juniper Woodland	Is species presence & distribution consistent with conditions and within natural range of variability?		The condition is good, but low levels of exotic species occurred in some locations. Two species were observed (horehound and filaree), which tend to have relatively low impact where they occur. These plants were not abundant or widespread in this vegetation type.
	Are stand densities within their range of natural variability for their growing conditions?		Condition is good, although there has probably been an increase in tree density over the 20th century due to climate conditions conducive to tree establishment/growth.
	Are age class distributions of trees consistent with expected range of variability?		Although based on limited data, condition appeared good for this indicator. Centuries-old trees are present in most places, along with younger trees <100 yr old, resulting in all-aged population structures which are typical of this vegetation type. Some fuel treatments (with removal of trees) had been conducted ~2008.
	Do the trees and understory plants appear vigorous and healthy?		Most individual trees and understory plants appeared healthy. However, some dead piñon trees were observed and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not threaten ecological integrity.
	Are ecological processes (e.g., fire) operating within natural range of variability?		Condition is good, although fire intervals may have lengthened somewhat due to 20th century fire exclusion. However, intervals remain within the historical range of variability for this vegetation type as this type rarely burns, with centuries long intervals between recurrent fires.
	Are the current levels of insects/ disease within the normal range?		Condition is good. We saw no evidence of tree mortality or morbidity due to insects or disease.
Juniper-Piñon Savanna	Is species presence & distribution consistent with conditions and within natural range of variability?		Species presence and distribution generally appears to be within the natural range of variability and is in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically.
	Are stand densities within their range of natural variability for their growing conditions?		Tree densities probably are greater in most stands observed than before 1900, and trees also appear to have expanded into former grasslands in some areas. The mechanism driving these changes is uncertain, but may be the result of a century of fire exclusion and 20th century climate which was favorable for tree establishment/survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Condition is considered to be of moderate concern. However, current densities are much less dramatic than in other places in the state and do not appear to pose a serious threat to ecological integrity.
	Are age class distributions of trees consistent with expected range of variability?		Condition is good. Based on limited data, the age classes appear to be approximately within their natural range of variability, although 10 to 100-yr-old trees probably constitute a greater proportion of the population than was typical before 1900. Some centuries-old trees are present.

Table 5.10.2-1. Summary of overall vegetation condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument continued.

Vegetation			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Juniper-Piñon Savanna continued	Do the trees and understory plants appear vigorous and healthy?		Most trees and understory, including grasses and forbs, are healthy in appearance. This is the case even though tree densities are greater than probably existed prior to 1900. Condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?		Historical fire regimes of juniper-piñon savannas are not well understood. Spreading fires may have been relatively frequent, given the continuous fine-fuel cover (grasses) and frequent occurrence of dry weather. If so, then the modern fire regime (essentially no fire) is quite different. However, empirical data are lacking, which makes this an area of major uncertainty. Based on the available information, we consider condition to be of moderate concern.
	Are the current levels of insects/ disease within the normal range?		Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Ponderosa Pine-Piñon-Juniper Rocky Woodland	Is Species Presence & Distribution Within Natural Range of Variability?		For the most part, the species present and their distributions appear to be in good condition. Although native species predominate in most places visited, some exotic species are present, especially in Box Canyon. Although we did not enter the canyon during the June visit, we observed what appeared to be cheatgrass from atop El Morro, and park reports and staff have reported its occurrence there. This species is of concern due to its invasiveness and possible ecological impact.
	Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?		Stand densities do not appear to deviate from reference conditions. Condition is considered good.
	Are age class distributions of trees consistent with expected range of variability?		With limited data, the age classes appear to be within their natural range of variability. We therefore considered condition to be good.
	Do the trees and understory plants appear vigorous and healthy?		Most individual trees and native understory plants appeared healthy. At least a few dead ponderosa pine trees were observed in Box Canyon; these trees may have died in recent years due to drought conditions (as was observed at El Malpais NM). Such small-scale mortality events are natural and do not appear to threaten overall ecological integrity. Overall, condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variation?		Fire intervals have lengthened due to 20th century fire exclusion, even in areas of rugged topography and discontinuous fine fuels, and now generally exceed the historical range of variability for this vegetation type. However, a paucity of 20th century fire does not appear to have compromised overall ecological integrity, and fire is probably less important to stand structure than in the ponderosa pine woodland/savanna type. Condition was judged to be good.

Table 5.10.2-1. Summary of overall vegetation condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument continued.

Vegetation			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Ponderosa Pine-Piñon-Juniper Rocky Woodland continued	Are the current levels of insects/ disease within the normal range?		Based on limited data, condition is good. Although we did not specifically look for insects/disease on trees in this vegetation type, we saw no obvious signs of them. Also, dead ponderosa pine trees examined in nearby El Malpais NM showed no signs of morbidity or mortality from insects or disease. These stressors appear to pose no serious threat at this time.
Historic and Cultural Integrity of Vegetation on the Landscape	Vegetation Change over Time		We consider condition to be of moderate concern for this indicator/measure; however, it should be noted that this judgement is dependent upon the period targeted for the appearance of the vegetation. If the target appearance is that around the time of monument establishment in 1906, then the appearance and views within the park have changed. For example, complete views of El Morro from the ground are now impeded by the vegetation in many places. However, this does not necessarily prevent the park visitor from getting a sense of what it was like to visit Inscription Rock and its pool in centuries past, or to live atop the rock even longer ago.

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5.11. Exotic Plants Resource Brief

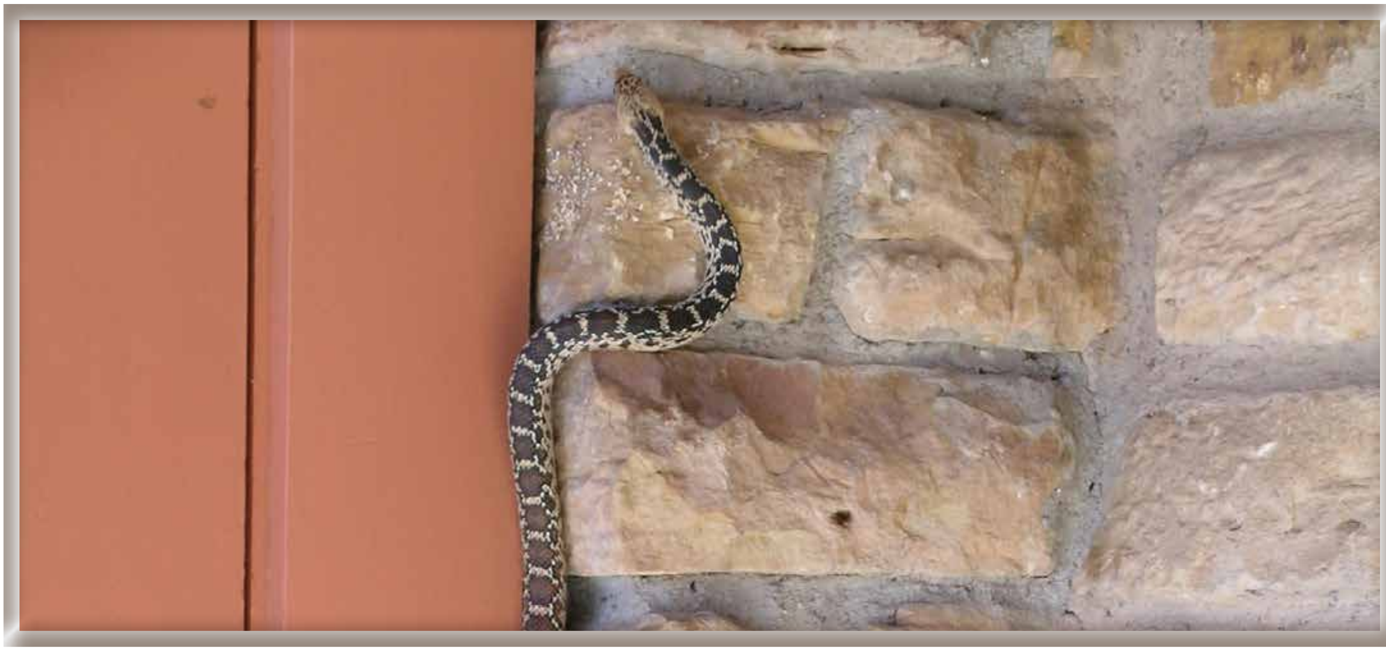
The contents of sub-chapter 5.11 were designed to be placed into a stand-alone exotic palnts resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.11.1. Condition Rationale

The condition of exotic plants at El Morro NM is of significant concern (Table 5.11.1-1). The condition of the potential to alter native plant communities indicator is of significant concern since seven species with the highest rankings for exotic plant impact and four species with high rankings for exotic plant impacts have been documented in the park. Twenty additional species had medium rankings. The prevalence of exotic plants is in moderate condition. Information on the occurrence of exotic plant species was limited to Palmer Abundance Scale rankings reported in the Checklist of Vascular Flora for El Morro NM (Rink et al. 2009). The Vegetation Classification and Distribution Mapping Report (Salas and Bolen 2010) also stated that exotic plants were abundant in the monument. Hence, the overall condition of exotic plants in the national monument is of significant concern.

Table 5.11.1-1. Summary of overall exotic plants condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Exotic Plants			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Potential to Alter Native Plant Communities	Significance of Exotic Plant Impact		This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Eleven of the 55 species of exotic plants documented in El Morro were ranked either as having highest or high innate ability to become a pest. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Palmer Abundance Scale Ranking		The prevalence of exotic plants at El Morro is not well know. However, abundance scale rankings in Rink et al. (2009) provide insight into the general level of exotic species in the monument. One species, *Bromus tectorum,* was given an abundant ranking of frequent, 5. Twenty-seven species had medium prevalence (abundance scale ratings of 3, occasional, or 2, infrequent). Specific information about exotic plants in the interior of the monument and along vectors is unknown.


NPS

5.12. Wildlife Resource Brief

The contents of sub-chapter 5.12 were designed to be placed into a stand-alone wildlife resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.12.1. Noteworthy Highlights:

Habitat for wildlife within El Morro NM includes piñon-juniper woodlands, ponderosa pine woodlands, shrublands, and grasslands, and the pool of water at the base of Inscription Rock provides a permanent source of water. A variety of bird, mammal, and herpetofauna species have been recorded at the national monument within these habitats. Approximately 137 bird species have been reported in the surveys and/or checklists discussed in the assessment, and additional species are thought to occur less frequently. In the most recent surveys for mammals and herpetofauna, approximately 39 and 12 species were recorded, respectively. Additional species in each group had been reported prior to the most recent surveys. Of the species documented, three bird species and one mammal species are listed as threatened with the State.

5.12.2. Condition Rationale:

The current condition of wildlife at the national monument, assessed using one indicator with three measures, is unknown (Table 5.12.2-1). There is no current information available on any of the three groups-- birds, mammals, or herpetofauna-- to judge current condition. The most recent comprehensive surveys for each group were conducted in the early 2000s. Although wildlife condition cannot be determined at this time, the most recent surveys from the early 2000s, as well as some earlier work for some groups, provide baseline information for future condition assessment. A number of the wildlife species observed are of conservation concern according to various agencies/groups at state, national and/or regional scales; this includes three bird species (Bald Eagle, Gray Vireo, and Peregrine Falcon) and one mammal species (spotted bat) that are listed as threatened with the State.

Table 5.12.2-1. Summary of overall wildlife condition, indicators and measures, and rationale for assigning condition assessment at El Morro National Monument.

Wildlife			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Bird Presence/Absence		Current condition cannot be determined due to the lack of recent/current data. The most recent standardized surveys were conducted in 2001-2002 (i.e., Johnson et al. 2007). Some more recent informal surveys and checklists are available, but they are not extensive or developed from standardized methods. Approximately 137 species have been recorded during the efforts discussed here, and additional species have been recorded that are thought to occur less frequently. The 2001-2002 (and 1979) surveys provide good baseline information for future monitoring and condition assessment. At least 30 species have been recorded at the national monument that appear on one or more lists of species of conservation concern, including three species that are listed as threatened with the State (Bald Eagle, Gray Vireo, and Peregrine Falcon).
	Mammal Presence/ Absence		There is no current information available on mammals at the national monument. The most recent surveys were conducted in 2002-2003 (i.e., Bogan et al. 2007). Although condition cannot be determined at this time, the 2002-2003 work, as well as an earlier checklist provides baseline information for future monitoring and assessment. One of the species documented at the park is listed as threatened with the State. Four species, including the threatened species, are listed as SGCN.
	Herpetofauna Presence/ Absence		There is no current information available on amphibians and reptiles at the national monument. The most recent surveys were conducted in 2001-2003 (i.e., Nowak and Persons 2008). Although condition can not be determined at this time, the 2001-2003 work (as well as earlier surveys) provides baseline information for future monitoring and assessment. One or two SGCN have been recorded in the national monument.

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Appendix A: Team Members, Subject Matter Experts/Reviewers, and GIS Data Summary

Table A.1. El Morro National Monument NRCA Project Team Members

El Morro NM NRCA Project Team
Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Report Series
Lisa Baril, Utah State University Science Writer
Steve Baumann, NPS El Malpais and El Morro National Monuments' Resources Management Chief
Nina Chambers, Northern Rockies Conservation Cooperative Science Writer
Mitzi Frank, NPS El Malpais and El Morro National Monuments' Superintendent
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Allyson Mathis, Utah State University Science Writer
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Patty Valentine-Darby, University of West Florida Biologist and Writer/Editor
Eric Weaver, NPS El Malpais and El Morro National Monuments' Physical Science Technician and Acting Natural Resources Branch Chief

Table A.2. El Morro National Monument NRCA Subject Matter Experts and/or Assessment Reviewers

Subject Matter Expert/Assessment Reviewer	Topic(s)	Project Deliverable(s)
Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	Full report	Program Level Review
Donna Shorrock, National Park Service Intermountain Region Office, Natural Resource Condition Assessment Regional Coordinator	Chapters 2, 3, and 5 and unincorporated Chapter 4 comments	Program Level Review
Dr. Todd Chaudhry, Colorado Plateau Cooperative Ecosystem Studies Unit Research Coordinator	Chapters 2, 3, 5	Provided a general content review from a management perspective and/or a broader scientific perspective
Steve Baumann, National Park Service El Malpais and El Morro National Monuments Resources Management Chief	Full report	Park Expert Review
Eric Weaver, National Park Service El Malpais and El Morro National Monuments Physical Science Technician and Acting Natural Resources Branch Chief	Full report	Park Expert Review
Ellen Soles, Senior Research Specialist, Colorado Plateau Cooperative Ecosystem Studies Unit Northern Arizona University	Historic Pool	Reviewed Historic Pool section
Stephen Monroe, National Park Service Southern Colorado Plateau I&M Network Program Hydrologist	Historic Pool	Reviewed Historic Pool section
Ksienya Pugacheva, National Park Service Air Resources Division, Natural Resource Specialist	Air Quality	Reviewed air quality section
Tim Connors, National Park Service Geologic Resources Division, Geologist	Geology	Reviewed Geology sections
Shari Kelley, Geophysicist/ Field Geologist, NM Bureau of Geology and Mineral Resources, NM Tech	Geology, Historic Pool	Reviewed Geology and Historic Pool sections
Lisa Thomas, National Park Service Southern Colorado Plateau I&M Network Program Manager	Vegetation	Participated in the field assessment

Table A.2. El Morro National Monument NRCA Subject Matter Experts and/or Assessment Reviewers (cont.)

Subject Matter Expert/Assessment Reviewers	Topic(s)	Project Deliverable(s)
Jim DeCoster, National Park Service Southern Colorado Plateau I&M Network Plant Ecologist	Vegetation	Participated in the field assessment
Jeremy White, National Park Service Natural Sounds and Night Skies Division Physical Scientist	Night Sky	Reviewed Night Sky sections including Bortle Key Appendix C
Chad Moore, National Park Service Natural Sounds and Night Skies Division Night Skies Program Manager	Night Sky	Provided information pertaining to night sky data collection methodology and interpretation of results.
Randy Stanley, National Park Service, Intermountain Regional Office, Natural Sounds and Night Skies Coordinator	Geology	Reviewed Geology sections, including appendix addressing induced ground vibrations
Myron Chase, National Park Service, Intermountain Regional Office, Regional IPM and Invasive Species Coordinator	Exotic Plants	Reviewed Exotic Plants section
Mike Wrigley, National Park Service, Intermountain Regional Office, Wildlife Biologist	Wildlife	Reviewed Wildlife sections
Emma Brown National Park Service Natural Sounds and Night Skies Division Acoustical Resource Specialist	Soundscape	Reviewed Soundscape section
Dr. William H. Romme, Professor emeritus of fire ecology and research scientist in the Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO.	Vegetation	Participated in the field assessment, co-authored the report upon which the vegetation section was based, and reviewed the draft of this section.
Brian Jacobs, Vegetation Ecologist who recently retired from the NPS at Bandelier NM	Vegetation	Participated in the field assessment and co-authored the report upon which the vegetation section was based

Table A.3. Summary of GIS Data Used in El Morro National Monument's NRCA

Chapter or Natural Resource	GIS Data/Map	GIS Data Source
Chapter 2	El Morro National Monument Vicinity	ESRI online map
	Housing Density	NPS NRSS NPScape Program provided map.
	Southern Colorado Plateau Network Parks	Map obtained from NPS Southern Colorado Plateau Inventory and Monitoring website: http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm/
	Watersheds	Data obtained from USGS National Map - Hydrography website: http://nhd.usgs.gov/
Viewshed	Viewshed Vantage Points	Coordinates GPSd and provided on final DVD to park and IMR GIS
	Viewshed Analysis	Analysis files provided on final DVD to park and IMR GIS
	Housing Density	Data obtained from NPS NPScape website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
	Road Density	Data obtained from NPS NPScape Website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
Night Sky	ALR Map	NPS NRSS Natural Sounds and Night Skies Division provided map.
Soundscape	Acoustical Monitoring Locations	Coordinates taken from NPS NRSS Natural Sounds and Night Skies Division Acoustical monitoring snapshot report (2009).
	Areas Without Roads	Data obtained from NPS NPScape website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
	L_{50} Impact Map	NPS NRSS Natural Sounds and Night Skies Division provided map.
Air Quality	Locations of Nitrogen sensitive vegetation	Data obtained from NPS IRMA website: https://irma.nps.gov/DataStore/

Table A.3. Summary of GIS Data Used in El Morro National Monument's NRCA (cont.)

Geology	Satellite image of El Morro and geology-related features	Image obtained from ESRI online imagery and features drawn in Photoshop
Vegetation	Vegetation Communities	Vegetation data layer was provided by ELMO staff.
Wildlife	Bird Conservation Regions In North America	Data obtained from North American Bird Conservation Initiative website: http://www.nabci-us.org

Appendix B: Viewshed Analysis Steps

The process used to complete El Malpais and El Morro National Monuments' viewshed analyses is listed below.

Downloaded 12 of the 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/) (USGS 2015) and created a mosaic dataset. The x and y values for the NED are in arc seconds while the z data are in meters. The DEMs were reprojected into NAD83 Albers Meter to get all data in meters and into a geographic extent that covered the entire area.

Prepared observation point layers for viewshed analyses by importing GPSd points for all vantage point locations selected for viewshed analysis. Exported data a shapefile. Added field named "OFFSETA" (type = double) to shapefile and set value to an observer height of 1.68 m (~5'6").

Ran Viewshed Analysis using the Viewshed Tool in ESRI's ArcGIS 10.2, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED
- Input point observer feature = obs_point.shp.

The rasters were reclassified into visible areas only, converted to polygons, and merged into one dataset for each park. The two datasets were reprojected into the Albers Equal Area Conic USGS projections to use NPS NPScape's housing and road density tools (NPS 2011a). Text attributes were added to both datasets for the area of analysis identifier (NPS 2011b).

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data (ESRI 9.3 File Geodatabase) (Theobald 2005) and road (United States and Canada, Density - All Roads, ESRI, 2005, Metric Data (ESRI 9.3 File Geodatabase) (ESRI 2010) GIS datasets were downloaded from NPScape's website at http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm?tab=1.

Standard Operating Procedures for both density tools (NPS 2014a,b) were followed based on NPScape instructions: https://irma.nps.gov/DataStore/Reference/Profile/2193329 and https://irma.nps.gov/DataStore/Reference/Profile/2193334.

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Appendix C: Bortle Dark-Sky Scale

Key for the Summer Sky— Latitudes 30° to 50° N

The Milky Way is not visible and sky glow extends above 35 degrees. Little to no dark adaptation is possible. Ground texture is easily seen, and artificial light dominates the landscape. Visible constellations are limited to the very brightest if any. The sky has a uniform washed out appearance.[1]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

Sky appears nearly completely washed out, and is luminous. Dark adaptation is not possible, ground is brightly illuminated and fewer than 200 stars are visible. Only the most major constellations are identifiable. For instance, the entire keystone of Hercules or the five stars of Delphinus are not completely visible.

this is accurate **Bortle Class 9** if darker—proceed below

Constellations are visible but may be missing key stars, sky background has a uniform washed out glow with light domes reaching 60 degrees above the horizon. Stars such as the tip of Sagitta or epsilon Lyrae are not visible. If clouds are present they are brilliantly lit.

this is accurate **Bortle Class 8** if darker—proceed below

Brighter constellations are easily seen in full, yet sky background has greyish or yellow background. Milky Way may be just barely seen near the zenith. The Scutum and Cygnus star clouds are not visible.If clouds are present they are brilliantly lit. Ground texture is still visible.

this is accurate **Bortle Class 7**

The Milky Way is visible but discontinuous, and lost to light domes near the horizon. Fine details and structure are not easily visible, if at all. Ground texture is still visible, and shadows are cast from light pollution. Light domes are clearly visible along the horizon and appear brighter than any portion of the visible Milky Way.[2]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

The Milky Way is just visible overhead, but is not continuous and is diminished to obvious skyglow. Cygnus ,Scutum, and Sagittarius star fields just visible. If clouds present they are illuminated and reflecting light. Ground texture is seen with difficulty.

this is accurate **Bortle Class 6** if darker—proceed below

Milky Way is faintly present, but may have occasional gaps and is lost to skyglow near the horizon. Great rift in Cygnus is just visible. Any clouds present are brighter than the background sky and reflect light back. Zodiacal light may be glimpsed, but is difficult to see amidst the light pollution. Ground texture is not visible but forms are easily seen.

this is accurate **Bortle Class 5** if darker—proceed below

Milky Way is evident from horizon to horizon, but fine details are lost. Clouds are just brighter than background sky, but appear dark at zenith. Light domes are much brighter than brightest part of Milky Way and extend to up to 15 degrees above the horizon. Zodiacal light is evident in west after sunset or in east before dawn. Deep sky objects such as the M13 globular cluster and Northern Coal Sac are visible.

this is accurate ▶ **Bortle Class 4**

The Milky Way has a defined outline with visible structure and detail. Very few light domes are visible just along the horizon and do not cast shadows. You may see color in the Zodical light when compared to bluish-white color of the Milky Way. Scattered clouds appear dark against the night sky except those clouds just above light domes.[3]

If this describes your nighttime environment, continue below

Milky Way appears complex with visible outline, however some light pollution is still evident along the horizon. Light domes only slightly brighter than brightest part of the Milky Way. Zodiacal light easily seen, but band and gegenschein difficult or absent. Many summer globular clusters and emission nebulae are visible with the naked eye despite distracting light domes along the horizon. Venus casts an obvious shadow.

this is accurate ▶ **Bortle Class 3** — if darker—proceed below

Very few light domes are visible; with none extending above 5 degrees and fainter than the Milky Way. Airglow is often visible, and character in its brightness may be seen. Ground is mostly dark. The Zodiacal band (away from the Milky Way and at least 45 degrees above the horizon) and gegenschein are visible. The rift in the Cygnus star cloud is visible. The Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares. Jupiter and Milky Way cast barely visible shadows.

this is accurate ▶ **Bortle Class 2** — if darker—proceed below

The Milky Way is intricate, marbled, and veined with Sagittarius region of the Milky Way casting obvious shadows. Milky Way appears 40 degrees wide in some parts with a convoluted outline. The horizon completely free of light domes, though some distant light domes may be visible from mountain tops. Transparency and seeing are excellent (among the best of the year) with very low airglow. Many objects such as M81 or the Helix nebula are visible with the naked eye. Zodical light is striking as a complete band. Any clouds are very difficult to see.

this is accurate ▶ **Bortle Class 1**

The Bortle Dark-Sky Scale is a qualitative scale developed by John Bortle and published in Sky & Telescope Magaine in 2001. It provides a useful complement to quantitative measures. The National Park Service is testing this dichotomous key for use by professional and citizen scientists. Some knowledge of the night sky and visual observational techniques are required to properly implement this assessment.

note 1) At least 5 minutes of dark adaptation is required to properly differentiate Class 7,8 & 9 skies.

note 2) At least 10 minutes of dark adaptation is required to properly differentiate Class 4, 5 & 6 skies.

note 3) 20 to 120 minutes of dark adaptation is required to properly differentiate Class 1, 2 & 3 skies.

Developed by Jeremy White, Dan Duriscoe, and Chad Moore of the NPS Natural Sounds & Night Skies Division, www.nature.nps.gov/night

August 2, 2012

Appendix D: Soundscape Models

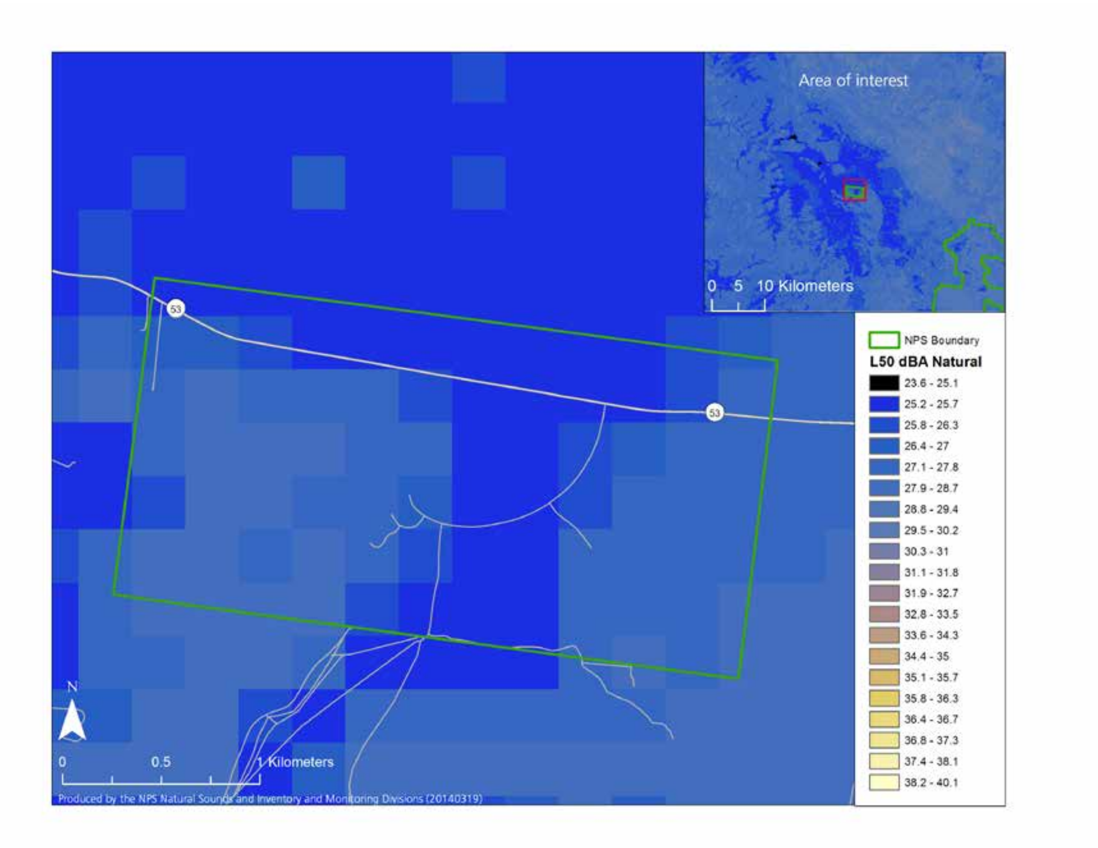

Figure D-1. Natural CONUS soundscape model zoomed to El Morro NM.

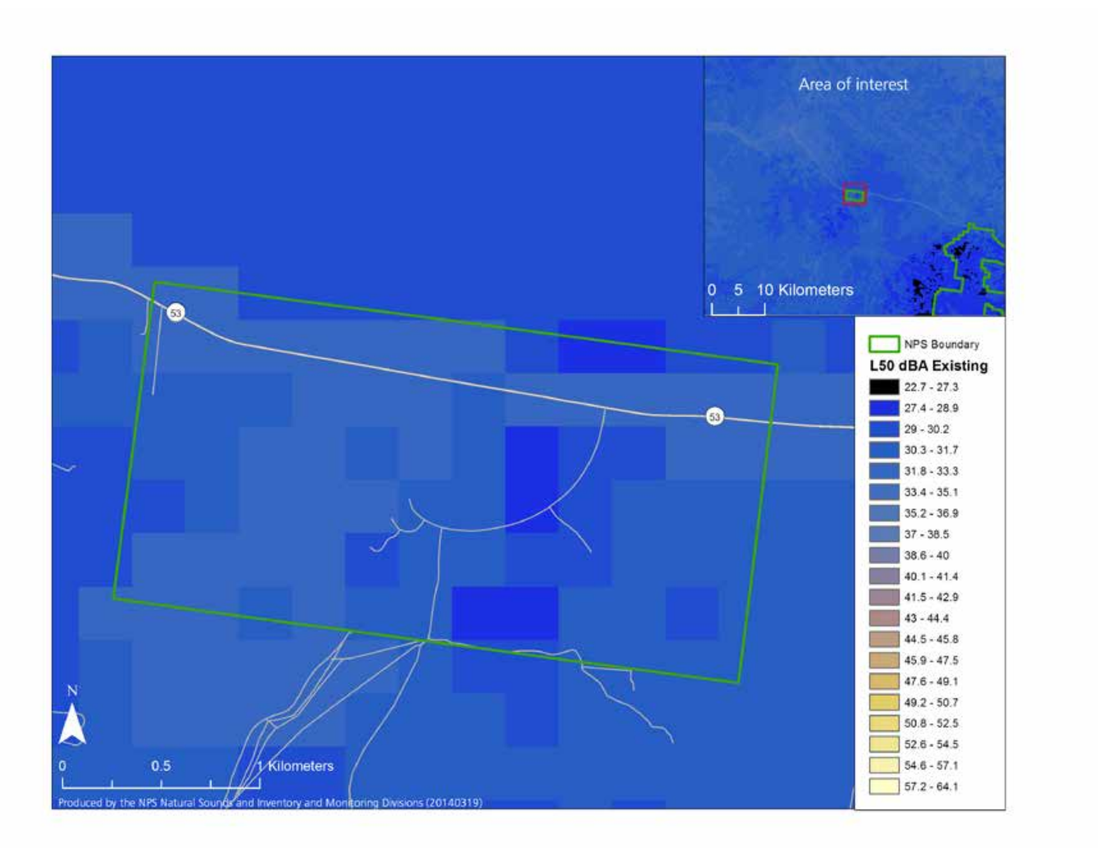

Figure D-2. Existing CONUS soundscape model zoomed to El Morro NM.

Mennitt et al. (2013) developed a geospatial sound model by mapping sound pressure levels on a continental U.S. scale. The model included biological, climatic, geophysical, and anthropogenic factors to assess expected sound pressure levels for natural and existing conditions. The model suggested that the area within and surrounding El Morro NM had a natural L_{50} dBA average of 26.7 (Figure D-1) and an existing L_{50} dBA average of 31.0 (Figure D-2) (Emma Lynch, Acoustical Resource Specialist, NPS Natural Sounds and Night Skies Division, provided Excel spreadsheet with values). The L_{50} represents the sound level reported that is exceeded 50 percent of the stated time period.

The impact of anthropogenic sound sources to the national monument's soundscape, which is the existing L_{50} dBA minus natural L_{50} dBA, was estimated to be an average of 4.3 dBA (map included in soundscape assessment). For further details refer to the soundscape assessment in section 4.3.

As NSNSD's predictive soundscape model continues to be developed and refined, it is intended to help park staff anticipate impacts by projecting future developments that have the potential to degrade soundscape condition.

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Appendix E: Geology - Induced Ground Vibrations

The National Park Service had concerns that ground vibrations from Tinaja Pit quarry and/or from loaded gravel trucks hauling aggregate could negatively impact the inscriptions, petroglyphs and pictographs on Inscription Rock (KellerLynn 2012). In 2003, a preliminary vibrations study was completed for El Morro NM (King and King 2003). This appendix summarizes technical information related to induced ground vibrations for El Morro NM. It overviews information gleaned from the King and King (2003) study and provides information related to safe vibration limits for sensitive archaeological and historic structures and for geologic features.

The Tinaja Pit limestone quarry is located 11.67 km (7.25 mi) from Inscription Rock(Figure E-1). Activities related to mining that may cause induced ground vibrations include blasting and crushing gravel at the quarry site, and transporting gravel on Highway 53 through El Morro NM. Highway 53 is more than 244 m (800 ft) from the closest part of Inscription Rock near North Point.

Figure E-1. The Tinaja Pit quarry is located 11.7 km (7.3 mi) from Inscription Rock in the Zuni Mountains. The mine quarries the San Andres Limestone. El Morro NM boundary is shown in green. (Figure was excerpted from "ELMA ELMO PowerPointBriefing on Lands Issues.pptx," pers. comm. Randy Stanley, IMR NPS, December 2015).

King and King Study (2003)

The preliminary vibrations study at El Morro NM consisted of three main components: measurements of the natural vibrations of four partially-detached rock “columns” at Inscription Rock, measuring induced vibrations at two locations, and an attenuation study. The King and King study (2003) also included A’ts’ina Ruin on top of Inscription Rock. Results of the vibrations study at the archaeological site are not included in this NRCA.

The natural vibration frequencies of partially-detached rock “columns” at four sites (Figure E-2) at El Morro were measured with portable seismometers (Table E-1). Site A was at North Point, site B was on the north side of El Morro on the top of a free-standing column, approximately 90 m (300 ft) west of the west end of Inscription Rock, site C was near site B, but on top of the mesa, and site D was on top of Inscription Rock above the North Point. King and King (2003) did not report the precise locations of these sites.

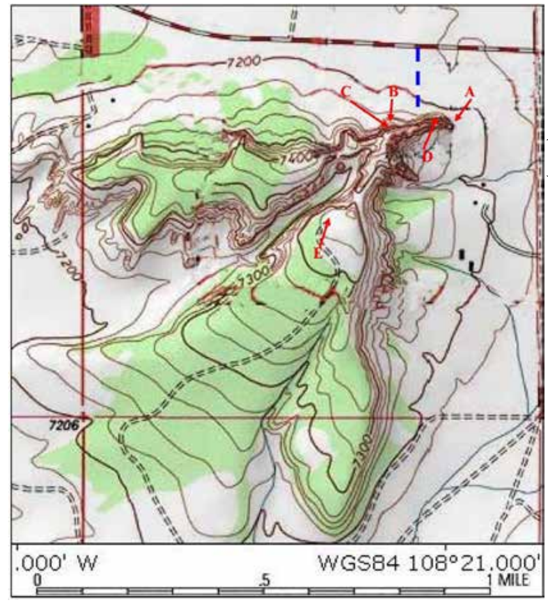

Figure E-2. Locations of sites assessed for natural frequencies and induced ground vibrations. From King and King (2003).

Every object has a natural frequency at which it wants to move. Natural frequencies depend on, at least in part, the height of the object. Natural frequencies correspond to the frequencies at which induced vibrations may resonate and increase their amplitude and are the frequencies to which objects are most sensitive/susceptible (King and King 2003).

Table E-1. Natural frequencies of pillars measured at El Morro NM (King and King 2003).

Location/Source	Frequency (Hz)
Site A tall column (North Point)	13-17
Site A short column (North Point)	0.5-0.3
Site B (west of Inscription Rock)	1.25-0.75
Site C (mesa top west of Inscription Rock)	0.5-0.75
Site D (mesa top above North Point)	0.5-0.25
Induced highway traffic	9.0-17.0

Frequency is the number of vibrations per unit of time. 1 Hz=1 oscillation/second

Natural frequencies that were measured (0.3-1.5 Hz) were far below the traffic-induced ground vibrations (9.0-17.0 Hz), meaning that the partially-detached columns are not susceptible to resonance with induced vibrations and are not likely to be impacted by them (King and King 2003).

Measurements of the natural vibrations at the partially-detached rock columns were reported as difficult due to the very short frequencies (King 2003). At least one test site was not on a rock column or pinnacle (Figure E-3), and instead was on a jointed part of the cuesta top. This site is the only location for which King and King (2003) provided a photograph.

Attenuation is the damping of the energy of a vibration as it moves through material. King and King (2003) conducted an attenuation study at El Morro by dropping a 4.5 kg (10 lb) weight along a linear line at site C to determine the attenuation function for sandstone at El Morro. A similar study using a 18 kg (40 lb) weight determined the attenuation function for alluvium between Highway 53 and Inscription Rock (Figure E-4). The alluvium material

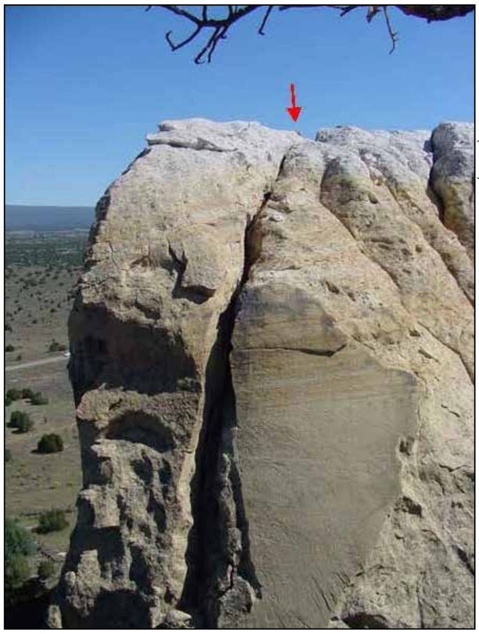

Figure E-3. Vibration test site on top of Inscription Rock (possibly site C) (from King and King 2003). Note that the test site is on a jointed part of Inscription Rock, and is not a rock spire, column or pinnacle.

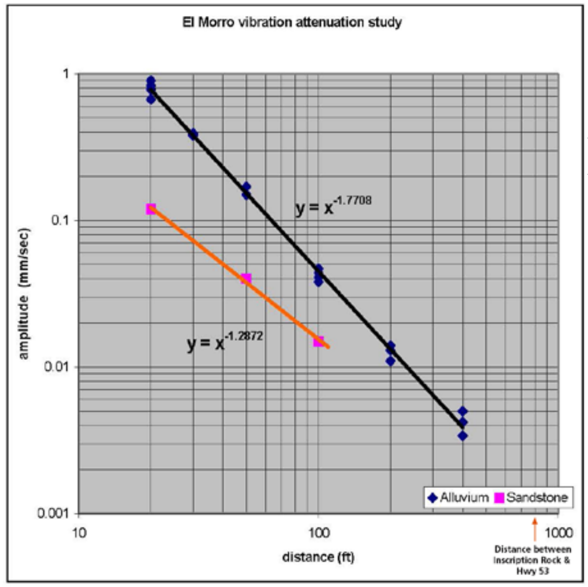

Figure E-4. Attenuation study at El Morro NM (King and King 2003).

attenuated the energy of vibrations at a greater rate than the sandstone.

These attenuation measurements are within the range of studies at other sites in the Intermountain Region (King et al. 1985, King 2001a, and King 2001b). An attenuation study at Chaco Culture National Historical Park for a variety of equipment and heavy trucks used in a construction site near an ancestral Puebloan archaeological site indicated that safe setback distances for the archaeological site were between approximately 2.6 m (8.5 ft) and 15.8 m (52 ft) using the NPS 2 mm/sec ppv safe limit for fragile man-made structures and archaeological sites (King 2001b). Highway 53 is more than 244 m (800 ft) from Inscription Rock.

Safe Limits for Induced Ground Vibrations

A safe limit for induced ground vibrations is the level of continuous vibrations that will not damage structures, geologic or man-made. Almost all determination of safe limits are for man-made structures.

The NPS has adopted 2 mm/sec ppv as the safe limit for fragile archaeological sites and historic structures, such Puebloan ruins, adobe structures or unsupported masonry (King et al. 1985). This safe limit is at the conservative end of the range of safe limits used by many countries for fragile man-made structures worldwide (Sharma 2009 and Volpe 2014) (Table E-2).

Very few studies related to the impact that induced ground vibrations may have on natural geologic structures exist. In their study of rock pinnacles and a natural bridge within 30 m (100 ft) of a construction zone on the General Hitchcock Highway in Arizona, King and DeMarco (2003) suggested that the safe limit for sensitive rock pinnacles may be between the 2 mm/sec ppv recommendation for fragile buildings and the blast limit for modern homes (25-75 mm/sec ppv), with limits for induced vibrations near a column's natural frequency kept to maximum between 5-15 mm/sec ppv. At Chiricahua National Monument, King (2001) recommended a safe limit of 10 mm/sec ppv for rock spires, and wrote that the limit may be as low as 2 mm/sec ppv if the spires were equivalent to unreinforced adobe or 25 mm/sec ppv if they were like a man-made structure built to code. He noted that the pinnacles act and respond similarly to

Table E-2. Vibration amplitudes measured at El Morro NM.

Induced Vibration		ppv (mm/sec)	Citation
Loaded gravel truck-induced vibrations measured at Site C (west of Inscription Rock), ELMO		0.140-0.190	King and King (2003)
Loaded gravel truck-induced vibrations measured at Site B (west of Inscription Rock), ELMO		0.380-0.640	King and King (2003)
Measured traffic vibrations	Large loaded truck in construction zone (15 m; 50 ft)	0.14	King (2003)
	Loaded truck in construction zone (7.6 m; 25 ft)	1.9	Hanson et al. (2006)
	California freeway traffic (5 m; 16 ft)	2	Jones & Stokes (2004)
	Loaded truck in construction zone (4.5 m; 15 ft)	4.1	New York City (2006)
Safe limits for sensitive cultural resources, modern homes and sensitive geologic features[1]	NPS safe limit for fragile ruins and sensitive man-made structures for continuous vibrations; safe limit used world-wide for fragile man-made structures	2	King et al. (1985); Hanson et al. (1991); Sharma (2009)
	National safe limits for sensitive man-made structures used by various countries	2-12.7	Hanson et al. (2006); Sharma (2009); Wilson et a. (2012); Volpe (2014)
	Safe limit for continuous vibrations for a modern home	5	Caltrans (2002); Lane and Pelham (2012); Sharma (2009)
	Estimated limit for pinnacles and natural bridge 30 m from General Hitchcock Highway[2] (construction)	5-15	King and DeMarco (2003)
	Recommended safe limit for rock pinnacles[3]	10 (2-25)	King (2001a)
	Maximum limit related to geophysical exploration for standing structures and rock art[4]	12.7	BLM (2007)

[1]Geologic resources that may be especially sensitive to induced vibrations include structures such as narrow spires, hoodoos, balanced rocks, and natural arches with thin or narrow spans or abutments.

[2]The General Hitchcock Highway site includes a natural bridge and several balanced rocks (King 2003).

[3]King (2001a) suggested a maximum value of 10 mm/sec for pinnacles at Chiricahua National Monument would be a prudent safe limit. He wrote that the safe limit may be as low as 2 mm/sec if they are equivalent to unreinforced adobe and as high as 25 mm/sec if they are equivalent to a modern building built to code. Rock spires at Chiricahua NM are made of welded ash flow tuff which was formed via a high temperature lithification process in which ash (glass) fragments are literally welded together, which is very unlike the drying process that produces adobe.

[4]The BLM standards were derived from the suggested maximum for drywall structures.

cantilevered structures and are probably more robust than adobe buildings, but that it was impossible to know the safe limit for those pinnacles (King 2001a).

In a study to assess whether a quarry operation that would be operating within 0.75 km (0.47 mi) of rock faces in Glasshouse Mountains National Park in Australia, a literature review was unable to locate equivalent studies that might inform what safe limits for a weathered and eroded rockmass, stating that extensive and complex analysis would be required and that the validity of using safe limits for man-made structures is debatable (Roberts 2004).

Because of the cultural resources (e.g., the inscriptions, petroglyphs and pictographs) located on the surface of Inscription Rock, we elected to use the NPS standard for fragile archeological sites and historic structures as our reference conditions in this NRCA. The safe limit for induced ground vibrations for friable, jointed sandstones exposed in massive cliff-faces, such as the Zuni Sandstone that makes use Inscription Rock in El Morro NM, and the Navajo Sandstone in Zion and Capitol Reef National Parks, is unknown.

Discussion

The induced traffic vibrations from loaded gravel trucks measured at two sites on Inscription Rock were well below the NPS safe limit for fragile and sensitive man-made structures (Table E-2). Vibrations were measured between 0.14 and 0.19 mm/sec at site C on top of the cuesta, and between 0.38-0.64 mm/sec at site B (King and King 2003).

King and King (2003) did not provide measurements of the induced vibrations from the loaded gravel trucks at locations closer to the roadway. Induced ground vibrations from loaded trucks in construction zones and freeway traffic ranged from 0.14 -4.1 mm/sec at distances ranging from 4.5 - 15 m (15-50 ft) (Table E-2). Given the range of induced traffic vibrations at these close distances, the measurement of 0.64 mm/sec 244 m (800 ft) seems anomalously large. Given the attenuation measurements for both sandstone and alluvium in El Morro NM, loaded gravel trucks would have had to produce vibrations on Highway 53 approximately two orders of magnitude higher than found in other studies to produce vibrations with a ppv of 0.64 mm/sec more than 244 m (800 ft) from the source.

No blasting occurred at the Tinaja Pit quarry during the King and King (2003) study. However, because of the distance from the quarry, normal blasting should not be a risk to the inscriptions. Based on existing and similar studies, the monument should re-assess if the nearby quarry plans cast blasting with shot-arrays (King 2003) or expects to use blast sizes approaching 4000 kg (9000 lbs) of ammonia nitrate fuel oil explosive (King et al. 1985).

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Appendix F: Supplemental Comments on Ponderosa Pine Vegetation at El Morro National Monument

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December 5, 2015

My original report with Brian Jacobs identifies two functional types of ponderosa pine forest in El Malpais and El Morro National Monuments: a ponderosa pine-piñon-juniper woodland savanna and a ponderosa pine-piñon-juniper rocky woodland. I assumed that this classification could be applied to both national monuments. However, after additional conversations with Patty Valentine-Darby and after looking at an additional set of photos from the monument (El Morro National Monument Cultural Landscape Report 2010, which I had not seen previously (Mason and others, In prep), I have decided that my original ponderosa pine classification does not fit El Morro well. (I think it still does a good job characterizing ponderosa pine vegetation at El Malpais, and still I think the piñon-juniper classification works well in both monuments.)

The problem at El Morro is with the ponderosa pine-piñon-juniper woodland savanna. This is because I now doubt that fire would have played the same historical role at El Morro as it did at El Malpais. At El Malpais, where extensive pine woodlands are found, low-severity fires occurred frequently during the historical period and maintained low-density stand structures; this interpretation is supported empirically by the work of Henri Grissino-Mayer. At El Morro, however, we have no empirical data on historical fire frequencies or effects. And looking more closely at the ponderosa pine vegetation that might be classified as the woodland type, we see that it is extremely limited in extent—primarily within Box Canyon and extending a short distance out from a few places along the base of Inscription Rock. Box Canyon is so small that local lightning ignitions would be very infrequent, and the surrounding cliffs would largely prevent fires from spreading into the Canyon from outside. The ponderosa pine stands on gentle topography away from Inscription Rock are similarly small in extent and are surrounded by piñon-juniper and shrubland vegetation that may or may not have burned frequently in the past. The heavy grazing that occurred in both of these areas during the historical period would have further suppressed burning. Therefore, because frequent low-severity fire during the historical period is a key functional component of the ponderosa pine-piñon-juniper woodland savanna that I described in my original report, I now conclude that this vegetation type does not apply well to El Morro National Monument.

I think that my second functional ponderosa pine vegetation type, the ponderosa pine-piñon-juniper rocky woodland, is still appropriate for El Morro. This type characterizes some of the lava flows at El Malpais, which obviously are not found at El Morro, but it also applies to the rugged Sandstone Bluffs area in the eastern portion of El Malpais, which is quite similar topographically and ecologically to Inscription Rock. Small numbers of ponderosa pine trees are found along the base of the Sandstone Bluffs, just as along the base of Inscription Rock, and in both places it makes more sense to fold these small areas into the classification type of the adjacent large area rather than create a separate vegetation type for a very small area.

In conclusion, therefore, for the purpose of this natural resource condition analysis, I recommend that all of the vegetation where ponderosa pine is present at El Morro be considered a single functional vegetation type: the ponderosa pine-piñon-juniper rocky woodland.

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Appendix G: Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. The information presented here supports Section 4.9.2, Data and Methods, of the wildlife section (for birds). This appendix contains some of the same, but additional, information as that section of the report.

One component of the landbird condition assessment was to examine species occurrence in a conservation context. We compared the list of species that occur at El Morro National Monument (NM) (i.e., those detected during one or more of surveys and/or observation efforts at the park) to lists of species of conservation concern developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been a source of confusion. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the U.S. working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

G.1. Conservation Organizations Listing Species of Conservation Concern

Below we present a summary of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act was passed in 1973 and has been amended by Congress several times. It is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

State of New Mexico

In New Mexico, wildlife species are designated as threatened or endangered under the New Mexico Wildlife Conservation Act (NMDGF 2015a). For each endangered or threatened species, the New Mexico Department of Game and Fish (NMDGF) develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015b). The database is called the Biota Information System of New Mexico (BISON-M).

USFWS Birds of Conservation Concern

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservation priorities. Three geographic scales are included--National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

National Audubon Society/American Bird Conservancy

The National Audubon Society and American Bird Conservancy each formerly published their own lists of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (described below).

The 2007 WatchList has two primary levels of concern: a "Red WatchList" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the IUCNs "Red List" (not presented here), thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). The Yellow WatchList is made up of species that are somewhat less critical, but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are declining or because they are considered rare.

Partners in Flight

Partners in Flight is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

The PIF assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows. Note that in our Chapter 4 bird assessment, we did not use the two stewardship categories.

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004).
- Species occurs in significant numbers in the BCR.
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004).
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR.
- Future conditions are not enhanced by human activities.

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High regional threats or moderate regional threat combined with significant population decline.
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High importance of the BCR to the species.
- Future conditions are not enhanced by human activities.

New Mexico Species of Greatest Conservation Need

Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, Species of Greatest Conservation Need (SGCN) have been designated in the state (NMDGF 2006). More than one-fourth (i.e., 26%) of the state's vertebrate, mollusc, and crustacean animals are considered SGCN. Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, about 74 are birds. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico.

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Appendix H: El Morro NM Bird Lists

This appendix lists the bird species recorded at El Morro NM during two studies of breeding birds and according to three lists of observations over multiple years. The first two columns are from the 2001-2002 U.S. Geological Survey (USGS) surveys during the breeding season (Johnson et al. 2007), and the 1979 breeding study in four plots in the park (McCallum 1979), respectively. The next three columns contain lists from: 1) the McCallum (1979) report, which listed birds that he observed during his work at the park, as well as those species observed at various times by others prior to 1979; 2) species sightings at El Morro NM as reported by trained park personnel/volunteers (and maintained on the eBird website); and 3) species included on the Grimes and Beckwith (2008) checklist for the park that were not reported by the other studies/lists. Note that species from the 2008 checklist were not included here if they were considered occasional or extirpated by Grimes and Beckwith (2008). Also note that the McCallum list in the third column includes all of the species that he observed during his breeding plot study (i..e, those in the second column of the table). A total of 137 species are listed here.

Common Name	Scientific Name	Johnson et al. (2007) in 2001-2002	McCallum (1979) in 1979	McCallum (1979) Checklist	eBird Data 2011-2013 (various months)	Additional species from Grimes & Beckwith (2008)
Acorn Woodpecker	Melanerpes formicivorus	X				
American Coot	Fulica americana					X
American Crow	Corvus brachyrhynchos	X		X		
American Goldfinch	Spinus tristis					X
American Kestrel	Falco sparverius	X	X	X		
American Robin	Turdus migratorius	X		X	X	
Ash-throated Flycatcher	Myiarchus cinerascens	X	X	X	X	
Baird's Sandpiper	Calidris bairdii					X
Bald Eagle	Haliaeetus leucocephalus					X
Barn Swallow	Hirundo rustica					X
Belted Kingfisher	Megaceryle alcyon			X		
Bewick's Wren	Thryomanes bewickii	X	X	X		
Black Phoebe	Sayornis nigricans					X
Black-chinned Hummingbird	Archilochus alexandri	X		X		
Black-headed Grosbeak	Pheucticus melanocephalus	X	X	X	X	
Black-throated Gray Warbler	Setophaga nigrescens			X		
Black-throated Sparrow	Amphispiza bilineata	X				
Blue-gray Gnatcatcher	Polioptila caerulea			X		
Brewer's Sparrow	Spizella breweri		X	X		
Broad-tailed Hummingbird	Selasphorus platycercus	X	X	X	X	
Brown Creeper	Certhia americana					X
Brown-headed Cowbird	Molothrus ater	X	X	X		
Bufflehead	Bucephala albeola			X		
Bullock's Oriole	Icterus bullockii	X		X		
Bushtit	Psaltriparus minimus	X	X	X		
Calliope Hummingbird	Selasphorus calliope			X		
Canyon Towhee	Melozone fusca			X		

Common Name	Scientific Name	Johnson et al. (2007) in 2001-2002	McCallum (1979) in 1979	McCallum (1979) Checklist	eBird Data 2011-2013 (various months)	Additional species from Grimes & Beckwith (2008)
Canyon Wren	Catherpes mexicanus	X		X	X	
Cassin's Finch	Haemorhous cassinii				X	
Cassin's Kingbird	Tyrannus vociferans	X	X	X	X	
Cassin’s Vireo	Vireo cassinii					X
Cedar Waxwing	Bombycilla cedrorum					X
Chipping Sparrow	Spizella passerina	X	X	X	X	
Cliff Swallow	Petrochelidon pyrrhonota	X	X	X		
Common Nighthawk	Chordeiles minor	X		X		
Common Poorwill	Phalaenoptilus nuttallii					X
Common Raven	Corvus corax	X	X	X	X	
Common Yellowthroat	Geothlypis trichas					X
Cooper's Hawk	Accipiter cooperii		X	X		
Cordilleran Flycatcher	Empidonax occidentalis	X	X	X		
Dark-eyed Junco	Junco hyemalis			X	X	
Dusky Flycatcher	Empidonax oberholseri	X		X		
Eastern Meadowlark	Sturnella magna					X
Evening Grosbeak	Coccothraustes vespertinus			X	X	
Ferruginous Hawk	Buteo regalis					X
Flammulated Owl	Psiloscops flammeolus		X	X		
Gambel’s Quail	Callipepla gambelii	X				
Golden Eagle	Aquila chrysaetos			X		
Grace's Warbler	Setophaga graciae	X		X		
Gray Flycatcher	Empidonax wrightii		X	X		
Gray Vireo	Vireo vicinior	X				
Great Horned Owl	Bubo virginianus	X	X	X		
Greater Roadrunner	Geococcyx californianus	X				
Green-tailed Towhee	Pipilo chlorurus	X	X	X		
Hairy Woodpecker	Picoides villosus		X	X	X	
Hammond's Flycatcher	Empidonax hammondii					X
Hepatic Tanager	Piranga flava	X	X	X		
Hermit Thrush	Catharus guttatus					X
Horned Lark	Eremophila alpestris	X				
House Finch	Haemorhous mexicanus	X	X	X	X	
House Wren	Troglodytes aedon			X	X	
Indigo Bunting	Passerina cyanea				X	
Juniper Titmouse	Baeolophus ridgwayi	X			X	
Killdeer	Charadrius vociferus			X		
Ladder-backed Woodpecker	Picoides scalaris	X				
Lark Sparrow	Chondestes grammacus	X	X	X		
Lazuli Bunting	Passerina amoena					X
Lesser Goldfinch	Spinus psaltria	X	X	X	X	
Lewis's Woodpecker	Melanerpes lewis	X	X	X		
Lincoln's Sparrow	Melospiza lincolnii					X
Loggerhead Shrike	Lanius ludovicianus	X		X		

Common Name	Scientific Name	Johnson et al. (2007) in 2001-2002	McCallum (1979) in 1979	McCallum (1979) Checklist	eBird Data 2011-2013 (various months)	Additional species from Grimes & Beckwith (2008)
MacGillivray's Warbler	Geothlypis tolmiei	X		X		
Mallard	Anas platyrhynchos					X
Merlin	Falco columbarius					X
Mountain Bluebird	Sialia currucoides	X	X	X	X	
Mountain Chickadee	Poecile gambeli	X	X	X	X	
Mourning Dove	Zenaida macroura	X	X	X		
Nashville Warbler	Oreothlypis ruficapilla					X
Northern Flicker	Colaptes auratus	X	X	X	X	
Northern Goshawk	Accipiter gentilis		X	X	X	
Northern Harrier	Circus cyaneus					X
Northern Mockingbird	Mimus polyglottos	X	X	X	X	
Northern Pygmy-Owl	Glaucidium gnoma			X		
Northern Rough-winged Swallow	Stelgidopteryx serripennis			X		
Northern Shrike	Lanius excubitor			X		
Oak Titmouse	Baeolophus inornatus		X	X		
Olive-sided Flycatcher	Contopus cooperi			X		
Orange-crowned Warbler	Oreothlypis celata			X		
Peregrine Falcon	Falco peregrinus	X				
Pine Siskin	Spinus pinus			X		
Pinyon Jay	Gymnorhinus cyanocephalus	X	X	X		
Plumbeous Vireo	Vireo plumbeus	X	X	X	X	
Prairie Falcon	Falco mexicanus		X	X		
Purple Martin	Progne subis			X		
Pygmy Nuthatch	Sitta pygmaea	X		X		
Red Crossbill	Loxia curvirostra			X		
Red-breasted Nuthatch	Sitta canadensis					X
Red-naped Sapsucker	Sphyrapicus nuchalis				X	
Red-tailed Hawk	Buteo jamaicensis		X	X	X	
Red-winged Blackbird	Agelaius phoeniceus	X				
Rock Wren	Salpinctes obsoletus	X	X	X	X	
Rough-legged Hawk	Buteo lagopus					X
Ruby-crowned Kinglet	Regulus calendula			X		
Rufous Hummingbird	Selasphorus rufus			X		
Sage Thrasher	Oreoscoptes montanus			X	X	
Savannah Sparrow	Passerculus sandwichensis					X
Say's Phoebe	Sayornis saya	X	X	X	X	
Scaled Quail	Callipepla squamata			X		
Sharp-shinned Hawk	Accipiter striatus			X		
Song Sparrow	Melospiza melodia					X
Spotted Sandpiper	Actitis macularius					X
Spotted Towhee	Pipilo maculatus	X		X	X	
Steller's Jay	Cyanocitta stelleri		X	X		
Summer Tanager	Piranga rubra					X

Common Name	Scientific Name	Johnson et al. (2007) in 2001-2002	McCallum (1979) in 1979	McCallum (1979) Checklist	eBird Data 2011-2013 (various months)	Additional species from Grimes & Beckwith (2008)
Swainson's Thrush	Catharus ustulatus				X	
Townsend's Solitaire	Myadestes townsendi			X	X	
Townsend's Warbler	Setophaga townsendi					X
Tree Swallow	Tachycineta bicolor	X				
Turkey Vulture	Cathartes aura		X	X	X	
Vesper Sparrow	Pooecetes gramineus	X	X	X		
Violet-green Swallow	Tachycineta thalassina	X	X	X	X	
Virginia's Warbler	Oreothlypis virginiae			X		
Warbling Vireo	Vireo gilvus	X		X		
Western Bluebird	Sialia mexicana	X	X	X	X	
Western Kingbird	Tyrannus verticalis	X		X		
Western Meadowlark	Sturnella neglecta	X	X	X		
Western Scrub-Jay	Aphelocoma californica	X	X	X	X	
Western Tanager	Piranga ludoviciana	X	X	X		
Western Screech-Owl	Megascops kennicottii		X	X		
Western Wood-Pewee	Contopus sordidulus	X	X	X		
White-breasted Nuthatch	Sitta carolinensis	X	X	X	X	
White-crowned Sparrow	Zonotrichia leucophrys			X		
White-throated Swift	Aeronautes saxatalis	X	X	X	X	
Williamson's Sapsucker	Sphyrapicus thyroideus			X	X	
Wilson's Warbler	Cardellina pusilla	X		X	X	
Yellow Warbler	Setophaga petechia				X	
Yellow-rumped Warbler	Setophaga coronata			X		
Total number of bird species	137	63	49	93	40	28

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