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Desert View Watchtower at Sunset, Grand Canyon National Park, AZ. (NPS photo).
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Double rainbow over Glen Canyon National Recreation Area, Lake Powell - Padre Bay. (NPS Photo).

Patrick Walsh Named Associate Regional Director for Resource Stewardship and Science for the NPS Intermountain Region

Patrick Walsh, a 12-year veteran of the National Park Service (NPS), is the new Associate Regional Director (ARD) for the Resource Stewardship & Science Directorate (RSS) of the Intermountain Region (IMR). Walsh has 22 years professional experience in natural and cultural resource management, and served as the acting IMR RSS ARD in spring of 2016. He served in a similar role at the Midwest Region, in 2012, as acting ARD for Natural Resource Stewardship and Science (NRSS).

Associate Regional Director Patrick Walsh (NPS photo).

"Patrick brings a wealth of resource management experience to the management team of the Intermountain Region," said Sue E. Masica, Regional Director, IMR.

Walsh had been with the WASO NRSS since 2009, where he served as a Branch Chief of the Environmental Quality Division (EQD). In this position, he oversaw the completion of 22 high-profile environmental planning projects addressing a wide range of park resource management and visitor use challenges. He also led the effort to revise the NPS National Environmental Policy Act (NEPA) Handbook.

"I'm very excited about joining the Intermountain Region team. I've seen firsthand the great work they do to help parks protect and manage resources, support informed decision making and improve visitor experience." Walsh said.

While with NRSS, Walsh completed the Executive Potential Program, a 12-month leadership development program. He also completed details as acting EQD Division Chief, acting NRSS Biological Resources Division Chief, and acting Chief of Compliance & Science Coordination at Yellowstone National Park.

Walsh joined the NPS in 2003 as a Cultural Resource Specialist for the Denver Service Center's Transportation Division, where he also served as the Compliance Section Supervisor and a Project Manager. Before coming to NPS, Walsh worked for six years as an Archeologist and Environmental Planner for the Naval Facilities Engineering Command at Pearl Harbor, HI. He also worked six years as an Archeologist for private consulting companies in the 1990s.

Walsh earned his bachelor's degree in Anthropology from the University of Vermont in Burlington, VT, and his master's in International Studies from the University of Washington in Seattle, WA.

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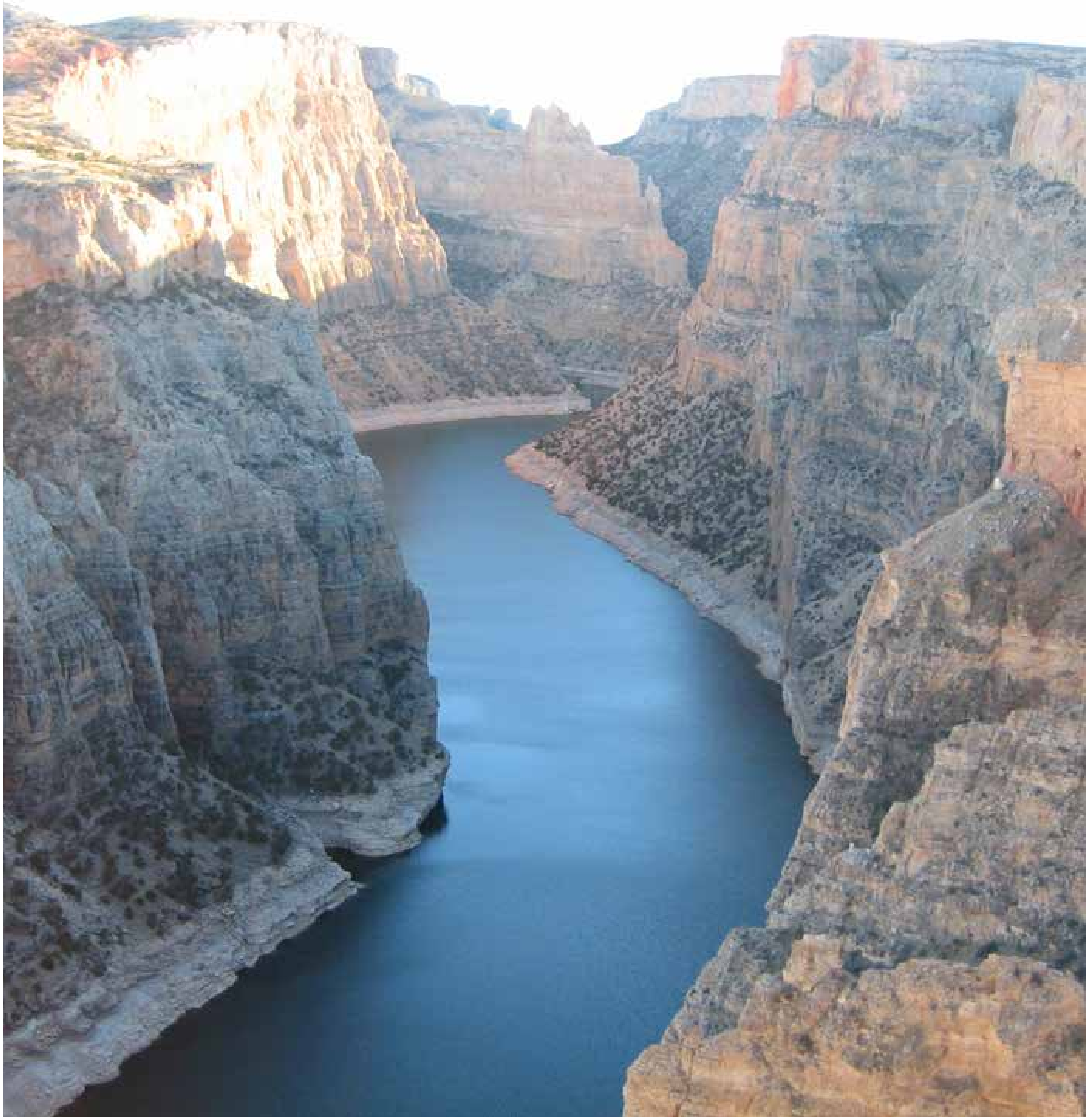
Through the heart of Bighorn Canyon. (NPS Photo).

—NATURAL RESOURCES—

Feature NPS Unit—Glen Canyon National Recreation Area

The Escalante River Watershed Partnership – Glen Canyon National Recreation Area Teams up with Regional Partners to Restore the Escalante River Watershed

By John Spence, Chief Scientist, Science & Resource Management, Glen Canyon National Recreation Area, John_Spence@nps.gov; Lonnie Pilkington, Ecologist, Science & Resource Management, Glen Canyon National Recreation Area, Lonnie_Pilkington@nps.gov; Linda Whitham, Central Canyonlands Program Director, The Nature Conservancy, Moab Project Office; lwhitham@tnc.org; Joel Tuhy, Conservation Science Director, The Nature Conservancy, Moab Project Office, jtuhy@tnc.org; Michele Straube, Director, Environmental Dispute Resolution Center, Wallace Stegner Center for Land, Resources & Environment, S.J. Quinney College of Law, University of Utah, Michele.straube@law.utah.edu; Mike Wight, Corps River Conservation Director, Southwest Conservation Corps, Durango, CO, mike@conservationlegacy.org

Introduction

The Escalante River is one of the last free-flowing rivers in the American Southwest, arising on the Aquarius Plateau and Boulder Mountain in southern Utah at elevations of 3350 meters. It then flows east and south 150 kilometers through deep sandstone canyons, ending at Lake Powell at an elevation of 1130 meters. The watershed includes land managed by three federal agencies, the National Park Service (Glen Canyon National Recreation Area-GLCA), the Bureau of Land Management (Grand Staircase-Escalante National Monument-GSENM) and the USDA Forest Service (Dixie National Forest-DNF), as well as Utah State lands and private lands (Figure 1). The watershed of the river is ca. 525,000 hectares in size, with highly diverse plant and animal communities ranging from high elevation aspen and mixed conifer forests to desert shrublands. Recent surveys in a 1600 hectare area along Deer Creek, a tributary of the Escalante River, revealed remarkable levels of biodiversity (Fertig et al. 2011). For example, about 10% of the native vascular plant flora of the state of Utah was documented in this area, although it only represents 0.3% of the watershed.

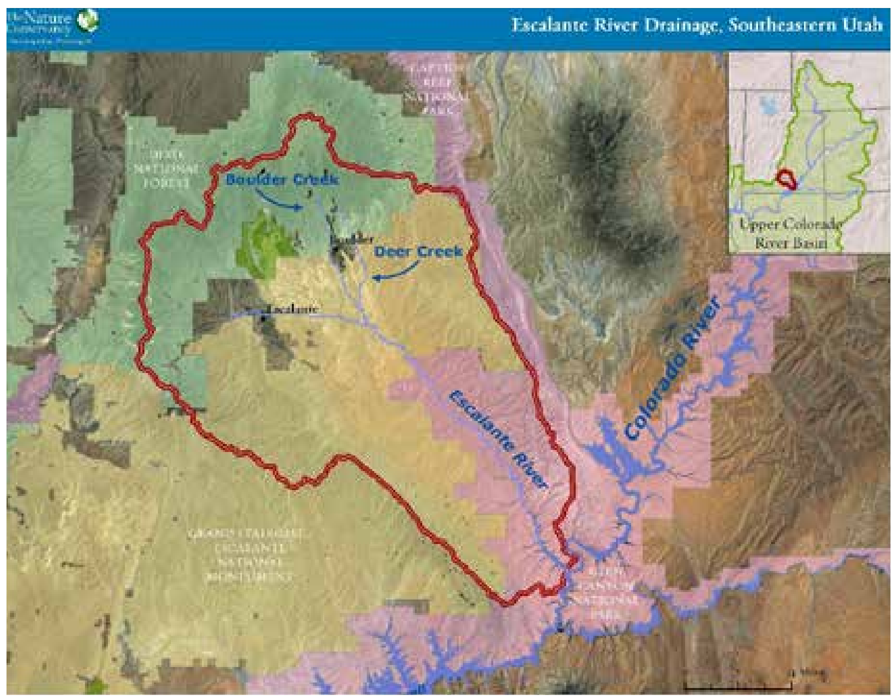

Figure 1. The Escalante River Watershed, south-central Utah. NPS lands are in pink, BLM lands in light yellow, and US Forest Service lands in green. Private lands are in gray. The small bright green area near Escalante is the Box-Death Hollow Wilderness Area.

In a scenario played out throughout the western U.S., encroachment by Russian olive (*Elaeagnus angustifolia*, hereafter RO), an exotic tree from Eurasia, has channelized and significantly altered the hydrology, riparian communities and aquatic life along the river. With funding provided by the National Park Foundation, a workshop was organized in 2009 by Glen Canyon National Recreation Area and The Nature

Figure 2. The initial National Park Foundation-supported meeting that led to the creation of the Escalante River Watershed Partnership was held on June 9, 2009, at the Boulder Community Center.

Conservancy to explore options for cooperation and coordination in restoring the Escalante River watershed (Figure 2). As a result, the Escalante River Watershed Partnership (ERWP) was formed, and in the years since has continued to work on numerous issues, expanding beyond RO control to sensitive species and fisheries, spring surveys, forest health, beaver reintroduction, scholarly research and education, and outreach. Currently this award-winning partnership includes partners from federal, state, local, NGO and community stakeholders (Spence and Whitham 2015). This article describes the approach used by ERWP to develop conservation priorities, examines the role collaboration has played in leveraging support, how woody-invasive control and long-term monitoring are used to inform management, and how youth have been engaged in the NPS mission of preserving America's special places, in the context of RO control.

Initial Planning

Within a year of its creation in 2009, the ERWP realized that its scope needed to be broader than control of woody invasive plants (RO), if it was to work effectively toward its Mission. Therefore a subgroup of the ERWP formed in early 2010 in order to:

> Develop and ratify a guiding document that will serve the Partnership as the blueprint for short and long term goals "*to restore and maintain the natural ecological conditions of the Escalante River and its watershed and involve local communities in promoting and implementing sustainable land and water use practices.*" [Mission Statement in italics]

This guiding document came to be known as the Action Plan for the ERWP, and its contents were intended to cover a period of ten years. The subgroup, named the Action Plan Committee, went through a systematic and comprehensive process to develop the Action Plan that would:

1. Address various concerns known to exist in the Escalante River watershed, such as invasive riparian plants, invasive aquatic animals, tree mortality in headwaters forests, and others; and

2. Identify specific actions that, when fully implemented, would achieve the Partnership's mission.

For these purposes, the Action Plan Committee adopted a process developed by The Nature Conservancy known as **Conservation Action Planning (CAP)**. CAP is a relatively fine scale of planning designed to identify specific "things to do" in order to achieve a particular purpose (in this case the mission of ERWP). The fundamental components of the CAP process are shown in the box on the next page.

Conservation Action Planning (CAP)

Components / Steps:

1. **SELECT key features within the area that are the "targets" to be restored or maintained. Within the Escalante River watershed, these targets took the form of particular habitats, several of which had imbedded species of concern such as coldwater and warmwater fishes.**
2. **ASSESS the integrity or "health" of selected habitats and species of concern.**
3. **IDENTIFY factors and activities ("threats") that are adversely affecting or inhibiting the health of the selected habitats and species of concern.**
4. **DEVELOP strategies and actions with stakeholders to abate impacts, and thus restore or maintain desired levels of health, of selected habitats and species of concern.**

Over a period of 1½ years the Action Plan Committee worked through this process, and produced the Partnership's Ten-Year Action Plan on October 31, 2011 (Tuhy and Spence 2011). The Committee also knew that this plan would require periodic revision as various activities listed within it were accomplished, or as unforeseen opportunities or challenges arose. The Committee therefore created a companion product in tabular (Excel spreadsheet) format that lists for each activity its **timeline**, the **responsible party(ies)** that lead the activity, and estimates of **funding needs and sources**. This Excel table was named the 'Framework for Action Plan' and has been updated several times since its original version of October 2011.

Collaborative Process

ERWP is an informal collaboration, rather than a legal entity of its own, and operates through its committees. Nineteen individuals and organizations have signed the ERWP Partnership Agreement over the past five years, but many more individuals and organizations have participated in ERWP activities and engaged meaningfully in ERWP conversations over the same period of time. Funding is often requested collaboratively (to implement the strategies and actions identified in the Ten-Year Action Plan), but the dollars are received and distributed by a partner organization.

ERWP's work is identified and monitored through committees, with partner organizations taking responsibility for implementing the coordinated effort. The Coordinating Committee – which includes a representative from each public land management agency (NPS, BLM, USFS), the local NGOs (originally two, now one is most active), conservation corps, and the substantive committee co-chairs – meets regularly to develop full partnership meeting agendas, check in on the substantive committees' progress and identify possible areas of duplication, as well as develop outreach about the partnership as a whole, and identify funding opportunities to support partnership capacity. ERWP started with a multitude of committees. Due to overlapping membership and responsibilities, only two substantive committees remain in 2016 – a Woody Invasives Control and Restoration Committee, and a combined Science/Conservation Targets Committee. Each of these committees is responsible for fundraising and outreach related to its specific projects as informed by the Ten-Year Action Plan.

A neutral facilitator from the Environmental Dispute Resolution Program at the University of Utah has been working with ERWP since the beginning to support constructive conversation during full partnership meetings and select committee meetings, and working with the Coordinating Committee to design processes that engage the widest range of stakeholders and encourage full dialogue on controversial issues. Given the partnership's efforts to continually engage a broader spectrum of stakeholders, including highly diverse national and local community voices, the Coordinating Committee has decided to continue using a facilitator for the foreseeable future. There is the possibility that the group will move toward self-facilitation at some point.

ERWP uses consensus as its decision-making model, striving at all times to explore options that respect the diverse interests at the table. While disagreement is welcome, no partner has veto authority and all participants share the responsibility to identify possible solutions that address the varying perspectives represented in the group. If no consensus can be reached after extensive discussion and additional fact-finding, the group's Charter does outline a super-majority voting process.

Coordination and collaboration across the three land management agencies working in the Escalante River Watershed is itself challenging, given the geographic distance between their offices and their different institutional missions and organizational structures. Accomplishing the ERWP's goals requires further coordination and collaboration among the interests of state agencies, private landowners, and NGOs. The full partnership meets in Escalante on a quarterly basis to share accomplishments, discuss future activities, and reinvigorate personal connections. The substantive committees often schedule face-to-face meetings built around the partnership meeting. In addition, field trips and educational community evening events are built around the quarterly partnership meetings, to allow the local residents of the watershed to become familiar with the watershed's resources, challenges and potential.

Figure 3. The Escalante River upstream from the Highway 12 Bridge at Calf Creek, prior to Russian Olive control. The dense silvery-leaved trees in the foreground are Russian Olive.

Woody Invasive Species Control

Starting in 2000, GLCA initiated work removing RO in the lower watershed. By 2008 it was clear that there were not sufficient funds and staff to complete the project. Budgets for both GLCA and the BLM were less than $50,000 per year for control work. Thus the ERWP was formed to help leverage more support, with remarkable success. Current budgets typically exceed $1,000,000 per year. Initial planning watershed-wide was completed using satellite imagery (NDVI) and GIS mapping. Estimated total remaining acres of infestation was calculated, and a 5-year plan was initiated throughout the watershed (revised in 2015 to an 8-year plan; online at: http://escalanteriverwatershedpartnership.org/).

Figure 4. The Escalante River upstream from the Highway 12 Bridge at Calf Creek, following Russian Olive control. The picture was taken two years after the control work was done.

Much of the river corridor is in remote backcountry settings and proposed wilderness, and the concept of active restoration was not logistically feasible. Fortunately, most portions of the river corridor continued to support native species. In 2010, demonstration projects at the river headwaters and the Highway 12 Bridge were initiated not only to show the type of restoration being done, but to determine the effectiveness of passive restoration. Initial assessments were encouraging, as native species, particularly coyote willow (*Salix exigua)* responded rapidly and developed into dense riparian thickets (Figures 3-4). In order to assess whether the goals of the ERWP were being met for passive restoration, ten long-term permanent monitoring plots were established along the river corridor. At these plots, cross-channel transects sampled riparian vegetation, channel geomorphology, and stream width and depth (Spence 2012). Current efforts are analyzing the initial monitoring data and will determine whether sufficient statistical power exists in the monitoring program to be able to detect change in riparian vegetation following RO control. This data will be important in reporting back to the federal agencies as well as the funders of the ERWP.

To date, about 80% of the Escalante River corridor and its side canyons has been cleared of RO. A stretch of about 15 miles in upper GLCA and adjacent GSENM portions of the river still need to be cleared. It is likely that control efforts on public lands will be largely completed by 2018, although additional work on private lands in the watershed will be needed. So after 16 years of work by hundreds of volunteers and youth corps crews, the light at the end of the long arduous RO tunnel can be seen. Once completed, regular maintenance of the river corridor will become the responsibility of the federal agencies.

Youth Engagement

In 2011, the ERWP was recognized as a model for the Department of Interior's ***Americas Great Outdoors (AGO) River Initiative***. AGO has a focus on engaging young people in conservation, connecting Americans to the great outdoors through providing quality jobs, career pathways and service opportunities, enhancing recreational access and opportunities, and raising awareness of the value of the outdoors. ERWP was a perfect match.

The effort to restore the Escalante requires not only coordination and collaboration, but many hands and partners. The partnership has played an integral role in connecting young people to their public lands. Since 2009, ERWP has provided job training opportunities to over 450 AmeriCorps participants working within four corps programs! This is a true collaborative effort to prepare young adults to become the next generation of land and water stewards while enhancing resumes, gaining exposure to land management across agencies and completing miles of watershed restoration in one of the most remote canyons of the Western US.

Multiple 21st Century Conservation Service Corps (www.21CSC.org) member organizations have joined forces to provide numerous youth with opportunities to gain valuable training and experience in habitat restoration, riparian ecology, geology, archaeology, leadership, and risk management. Each fall the ERWP coordinates the largest riparian restoration training in the country, engaging and preparing 80 young adults for chainsaw use, backcountry living, horsepacking, Leave No Trace, plant identification, Wilderness First Aid, flash flood preparedness and more. The trainings are staffed and enhanced by agency participation through field supervision educational talks to help members understand why the grueling work they are about to undertake is important, and perk their interest in agency careers. Participants "graduate" the training prepared for the work, geared with certifications for the future, and excited to make a difference. Without this enthusiastic, energetic youthful input to the project, completing the RO treatments throughout the watershed would be much more daunting (Figure 5).

Figure 5. A Youth Corps work crew pair cutting Russian Olive along the Escalante River, 2009.

This project has provided youth with marketable resource stewardship job skills and with the knowledge to inspire other youth to become NPS stewards and outdoor enthusiasts. Over $400,000 in AmeriCorps Education Awards have been earned by participants while restoring nearly 70 miles of river to date. These awards can be used to go to college, earn an EMT certification, go to trade school or pay existing loans. Through the collaboration with corps programs, the ERWP is furthering participants' connection with watershed health, agency positions and future education. ERWP activities embody each of the major themes of the NPS *A Call to Action,* including items such as Step by Step (# 2), Next Generation Stewards (#7), Follow the Flow (# 12), Stop Talking and Listen (# 13), Posterity Partners (# 29), Value Diversity (#36), and Crystal Clear (#37).

Acknowledgements

The authors would like to thank the many volunteers and youth corps members who have worked tirelessly for years to eliminate Russian olive in the watershed. Financial and in-kind support for the work is gratefully acknowledged from the Walton Family Foundation, Utah Partners for Conservation Development, The Nature Conservancy-Utah Chapter, Wilderness Volunteers, Sierra Club, and the Tamarisk Coalition. The vision of Bill Wolverton, who started the control work in 2001, was the initial impetus for this project.

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—NATURAL RESOURCES—

Rangeland Health Assessments Inform Grazing Management in Capitol Reef National Park

By Terry T. Fisk Chief, Resource Management and Science, Capitol Reef National Park; terry_fisk@nps.gov Sandra M. Borthwick Biologist, Capitol Reef National Park; Sandra_borthwick@nps.gov

Introduction

Capitol Reef National Park in Utah (Fig. 1) is one of several national park units (other parks the authors know to have grazing include DINO, GLCA, MOJA, PORE, and VALL) that permit livestock grazing within their boundaries. In 2013, Capitol Reef began an Environmental Impact Statement (EIS) process to develop a livestock grazing and trailing management plan for the park. A draft EIS is scheduled to be published in fall 2016, with a final EIS and Record of Decision completed in summer 2017. The EIS will evaluate alternatives for managing the effects of livestock (cattle) grazing and trailing on natural and cultural resources within Capitol Reef, including species listed under the Endangered Species Act.

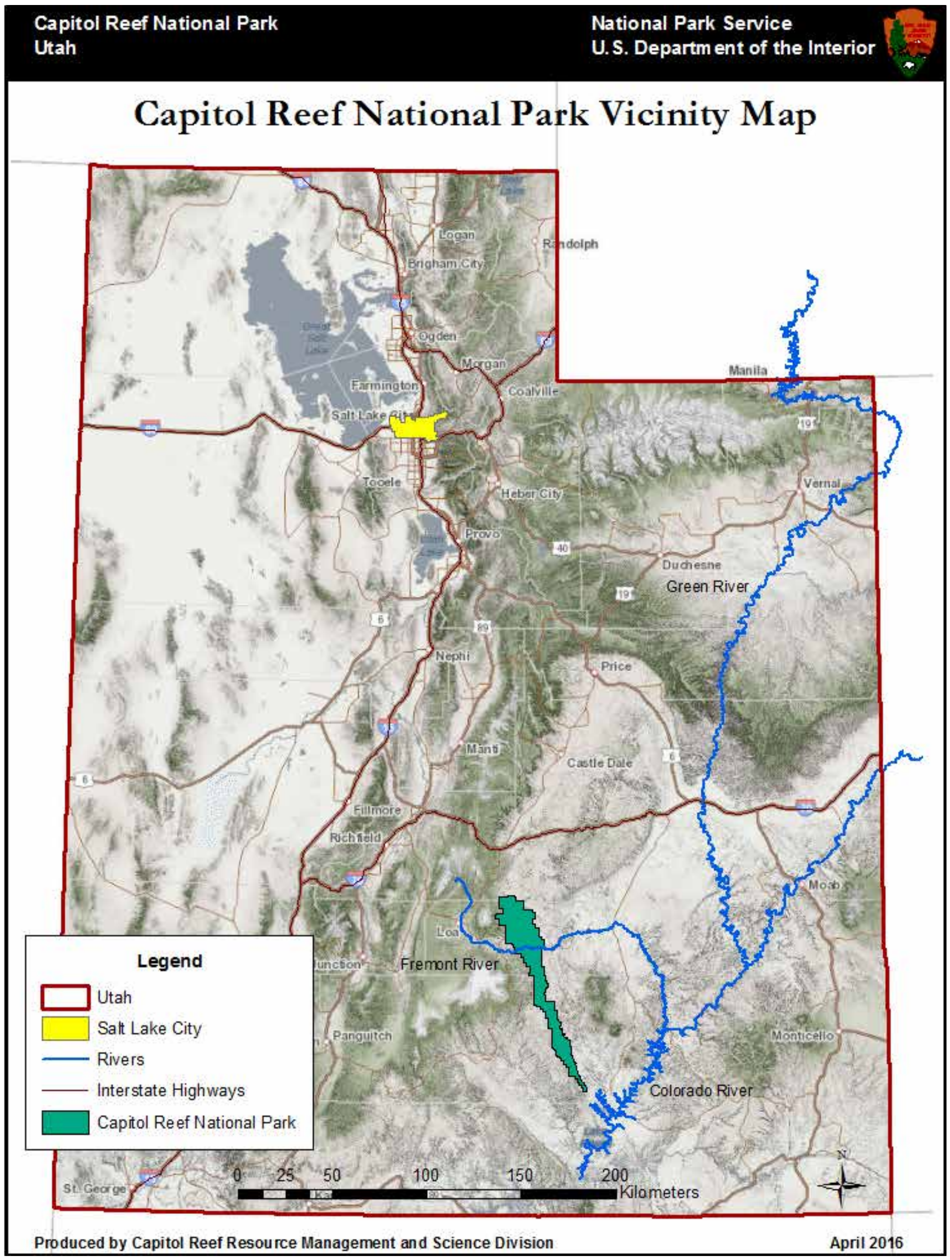

Figure 1. Vicinity Map of Capital Reef National Park.

The status of Capitol Reef was changed from National Monument to National Park in December 1971. The park's 1971 enabling legislation recognizes existing use of grazing allotments in the park and stock trails traversing the park. The enabling legislation and several subsequent laws direct that livestock grazing permittees who legally used park lands when the Park was established may continue the practice during their lifetimes and the lifetimes of their children who were born on or before establishment of the park in December 1971. Currently, two of the 19 grazing permits that existed prior to establishment of the Park—the Hartnet and Sandy 3 allotments (Fig. 2)—are still active, as are eight trailing routes. The NPS purchased the grazing permits for 17 allotments in the years after designation of Capitol Reef as a national park, resulting in cessation of grazing on these allotments.

The Hartnet and Sandy 3 allotments are considered winter range, although the overall season of use extends beyond the three winter months. The Hartnet Allotment is 70,760 acres (286.4 km^2), although the actively grazed area is approximately 19,000 acres (76.9 km^2), with grazing of 163 cow and calf pairs (a maximum of 1,141 animal unit months [AUMs]) between October 15 and May 31. The Sandy 3 Allotment is 15,000 acres (60.7 km^2), although the actively grazed area is approximately 10,200 acres (41.3 km^2), with grazing of 82 cow and calf pairs (a maximum of 410 AUMs) between November 1 and March 31. An AUM is defined as one cow or one cow and calf grazing for one month (30.4 days), consuming 26 pounds of dry forage per day.

Trailing across Capitol Reef occurs in spring and fall along eight separate trailing routes as approximately 2,450 cattle are moved each season between Bureau of Land Management and U.S. Forest Service grazing allotments on either side of Capitol Reef.

NPS resources staff needed site-specific data documenting the current condition of active grazing allotments to inform alternatives being developed for the EIS, and to have scientifically valid and defensible data with which to make range management decisions. To satisfy this need, Capitol Reef embarked on a project to document and assess the condition of active grazing allotments in 2015 with assistance from subject matter experts from Canyonlands National Park, the NPS Natural Resource Stewardship and Science Biological Resources Division, and Glen Canyon National Recreation Area.

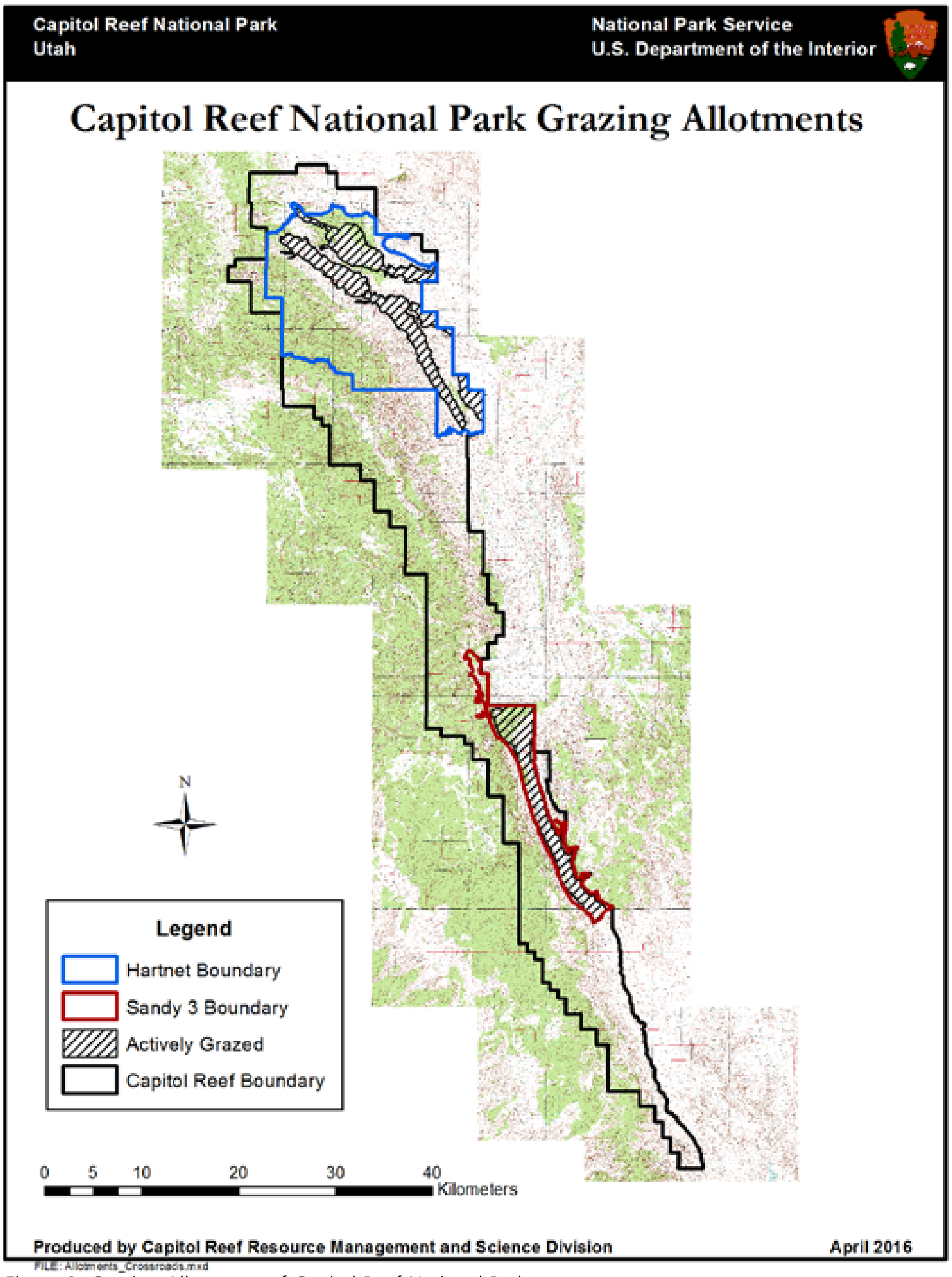

Figure 2. Grazing Allotments of Capital Reef National Park.

Assessment Methods

In our assessment[1] of grazing allotment conditions, we applied the technique *Interpreting Indicators of Rangeland Health v. 4* (IIRH; Pyke et al. 2002, Pellant et al. 2005). This science-based assessment technique was developed jointly by a team of scientists from the Bureau of Land Management (BLM), the Natural Resources Conservation Service (USDA NRCS), the USDA Agricultural Research Service, and the U.S. Geological Survey (USGS) (Pyke et al. 2002, Pellant et al. 2005). In addition to broad-scale applications in the U.S. (e.g., Miller 2008, Herrick et al. 2010, Duniway et al. 2013), during the past 15 years, this assessment technique has become widely accepted and used as a tool for characterizing the condition of arid and semiarid grasslands, shrublands, and woodlands worldwide (see http://jornada.nmsu.edu/monit-assess/manuals/assessment). Assessing the condition of key ecological attributes also has been proposed as a central component of integrated frameworks for adaptive land management (Herrick et al. 2006, 2012).

Interpreting Indicators of Rangeland Health (IIRH) consists of qualitative and quantitative data developed at designated plots within the area of interest. Proper use of the protocol requires good understanding of the ecological site characteristics, ecological processes, vegetation communities and plant species, and soil characteristics for each site where it is applied.

The foundational elements of IIRH are Ecological Sites and the soils that define the various ecological sites. Ecological Site Descriptions (ESDs) are developed by the NRCS, and partition landscapes based on the potential of the land to produce distinctive vegetation communities. The potential is based on soil types, topography, and climate. An ecological site is described in its reference state – without human-caused disturbance. The ESD provides an understanding of physiographic, climatic, soil, hydrologic, vegetation communities, plant species, and ecological dynamics of a site. The ESD also provides an understanding of state and transition dynamics for a particular ecological community. An IIRH assessment allows a quantitative and qualitative evaluation of the departure of an existing ecological site from its reference condition.

Interpreting Indicators of Rangeland Health (IIRH) consists of qualitative and quantitative data developed at designated plots within the area of interest.

Departure from the reference condition is described as none to slight (NS), slight to moderate (SM), moderate (M), moderate to extreme (ME), and extreme to total (ET).

The three inter-related attributes assessed by the IIRH protocol are (1) soil and site stability, (2) hydrologic function, and (3) biotic integrity. Soil and site stability is the capacity of an area to limit loss and redistribution of soil by wind and water. Hydrologic function is the capacity of an area to capture, store, and slowly release water from precipitation and run-on. Biotic integrity is the capacity of the biotic community to support ecological processes. These three attributes are evaluated in the field by assessing 17 qualitative indicators, each of which is assigned its own departure from reference condition value:

Rills
Water flow patterns
Pedestals and/or terracettes
Bare ground
Gullies
Wind scoured and/or depositional areas
Litter movement
Soil surface resistance to erosion
Soil surface loss or degradation
Plant community composition/distribution
Compaction layer
Plant functional/structural groups
Plant mortality and decadence
Litter amount
Annual plant production
Invasive plants
Reproductive capability of perennial plants

In addition to IIRH, a unique and notable element of our approach was our integration and leveraging of the Northern Colorado Network of Parks inventory and monitoring design and data (discussed briefly below). Our project team added scat counts (cattle, elk, deer, pronghorn, rabbit/hare) to the indicator list as a gauge of animal use of the plots evaluated. Animal use is of particular interest in the Hartnet Allotment because three species of threatened or endangered plants are present. The U.S. Fish and Wildlife Service listed livestock trampling among the anthropogenic activities adversely affecting these plant species.

[1] Following Pellant et al. (2005:55), assessment is defined as "…the process of estimating or judging the value or functional status of ecological processes (e.g., rangeland health) in a location at a moment in time."

Hartnet and Sandy 3 Allotments Rangeland Health

We conducted 45 IIRH assessments in the Hartnet Allotment and 40 assessments in the Sandy 3 Allotment. A soil survey of Capitol Reef (NRCS 2014) combined with rangeland productivity and plant composition data for Capitol Reef (NRCS 2013), and ecological site descriptions formed the baseline reference condition data used during the assessments.

Approximately one-half of the assessments were conducted in each allotment in May and June, shortly after cattle had come off the allotments. The remaining assessments were conducted in September and October, after the summer growing season and before livestock came back on the allotments. The park has limited historic BLM trend data from a small number of locations in the allotments; however, we have determined the trend data are unusable because of uncertainties in data collection and reporting. Therefore, in combination with NPS Inventory and Monitoring data, the IIRH data are the park's only site-specific, rigorous rangeland health data collected using a widely accepted methodology.

Plots are approximately one acre (4,047 m2) and consist of three parallel transects 164 feet (50 m) long, separated by 82 feet (25 m). Plots were randomly selected initially, and then relocated as needed to assure each ecological site was represented adequately. Because large areas of each allotment are inaccessible to cattle, all plots were located within the actively grazed area of each allotment. In the Hartnet Allotment two of the plots evaluated are exclosures established in the early to late 1980s. The other plots in the Hartnet were co-located with existing NPS Inventory and Monitoring upland vegetation plots established between 2007 and 2010. This allowed comparison to previously collected ecological site-related data. Inventory and Monitoring plots are not established in the Sandy 3 Allotment; therefore, with the exception of one existing exclosure, we established new plots for the rangeland health evaluation. Our field teams typically included four or five individuals, with expertise ranging from ecology and botany to soils, geology and hydrology.

The results of our IIRH evaluation indicate the majority (approximately 60 percent) of plots in the Hartnet and Sandy 3 allotments are in a state of moderate or moderate to extreme departure from reference conditions. Our evaluation indicates no discernable difference between ecological sites or soils relative to departure from reference conditions. Data for the Hartnet Allotment are presented in Figure 3 and Table 1. Data for the Sandy 3 Allotment are presented in Figure 4 and Table 2. The plots with the least departure from reference conditions typically are on slopes and higher elevations, and more distant from water. The plots that exhibit a greater departure from reference condition are on the topographically gentler valley bottoms and are within one to two miles of water.

Although all 17 indicators registered minor to substantial departure from reference conditions in various plots evaluated, the indicators that commonly led to a ranking of moderate, moderate to extreme, or extreme to total include (1) rills, water flow patterns, gullies indicating substantial erosion, (2) widespread bare ground, and frequent loss of the soil A horizon, (3) widespread loss of biological soil crust and undesirable changes in plant functional or structural groups, (4) significant reduction in cool season native grasses, (5) reduction in forage production and reproductive capacity of native perennial vegetation, and (6) the presence of non-native invasive plant species, particularly in the Sandy 3 Allotment.

Table 1. Hartnet Allotment: Number of Plots and Departure from Reference Condition

Departure from Reference	Soil & Site Stability	Hydrologic Function	Biotic Integrity
None to Slight	10	10	5
Slight to Moderate	7	8	13
Moderate	15	13	19
Moderate to Extreme	13	14	7
Extreme to Total	0	0	1
Sum (NS + SM)	17	18	18
Sum (M + ME + ET)	28	27	27

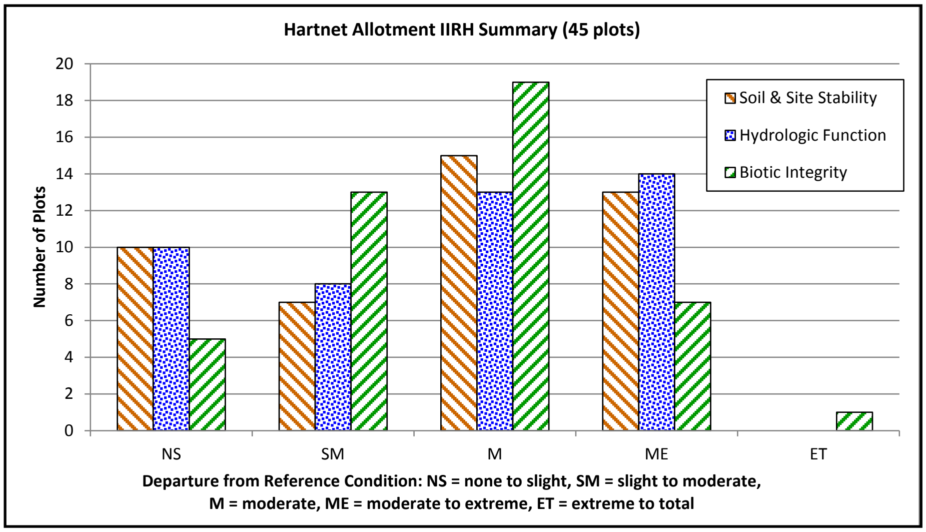

Figure 3: Hartnet Allotment Departure from Reference Conditions

Table 2. Sandy 3 Allotment: Number of Plots and Departure from Reference Condition

Departure from Reference	Soil & Site Stability	Hydrologic Function	Biotic Integrity
NS	7	7	5
SM	9	10	7
M	18	16	18
ME	5	6	9
ET	1	1	1
Sum (NS + SM)	16	17	12
Sum (M + ME + ET)	24	23	28

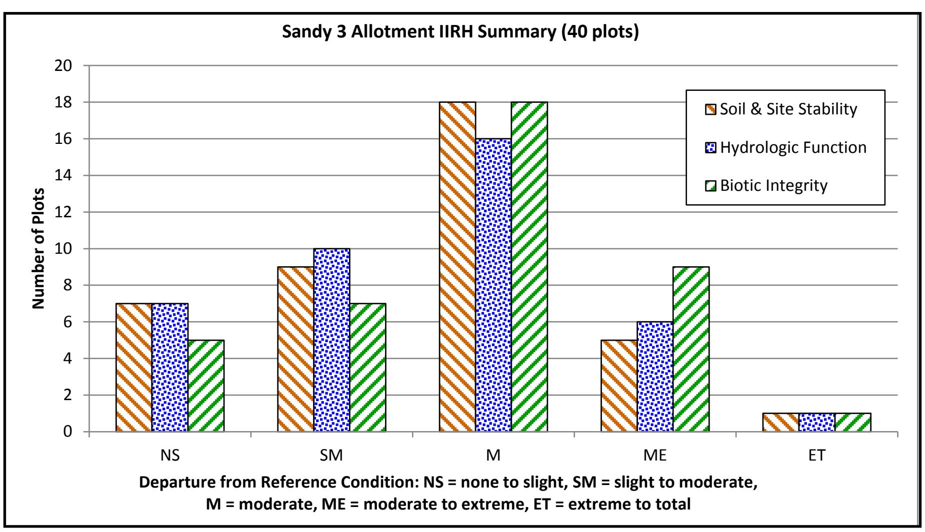

Figure 4: Sandy 3 Allotment Departure from Reference Conditions

Scat count data were of particular interest in the Hartnet Allotment because of the potential for damage to threatened or endangered plant species by trampling or disturbance within close proximity to a plant. Scat was counted along a 2-meter wide belt straddling each of the 50-meter transects. The results of scat counts indicate a strong relationship between the frequency of observation of cattle dung and departure from reference conditions. Scat count data relative to soil and site stability, hydrologic function, and biotic integrity are shown in Figures 5, 6, and 7.

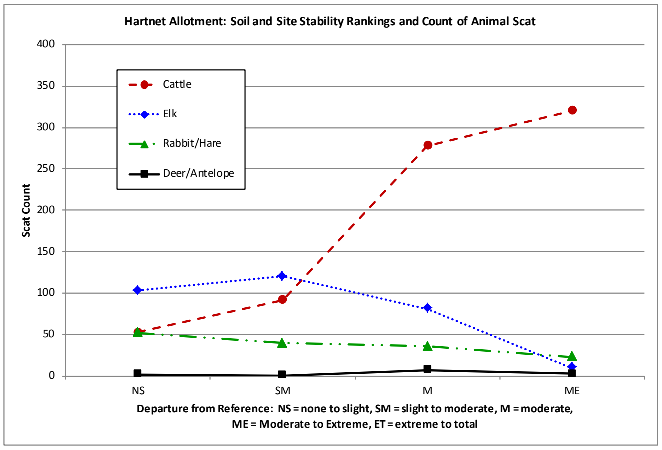

Figure 5: Scat Counts relative to Soil and Site Stability, Hartnet Allotment

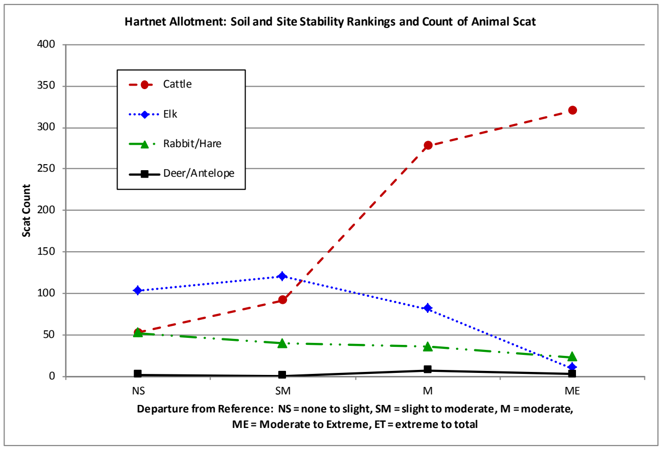

Figure 6: Scat Counts relative to Hydrologic Function, Hartnet Allotment

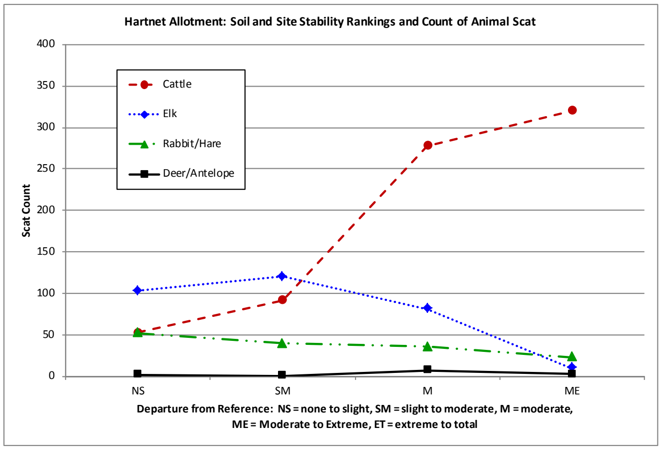

Figure 7: Scat Counts relative to Biotic Integrity, Hartnet Allotment

Application of Rangeland Health Data

The overall health of Capitol Reef rangelands is poor, based on the IIRH results. These data provide a rigorous and broadly accepted quantitative and qualitative overview of our range conditions, and provide an excellent basis for future monitoring and evaluation.

It is worth noting that while the IIRH protocol provides an understanding of rangeland status, it is specifically not intended to judge the relative causes of rangeland degradation. That effort goes beyond the IIRH protocols and involves detailed knowledge of historical use of an area (e.g. off-highway vehicles, road development, farming, land treatments, grazing, etc.). In Capitol Reef, grazing is the primary cause of rangeland degradation. However, it is difficult to know, based on limited field work, if our observations and IIRH rankings are the result of relatively recent grazing, or an accumulation of effects occurring over the past 130 years of grazing. Undoubtedly, both historic and recent grazing has influenced the range conditions we observe. It is hoped that future assessments will provide better understanding of the relative effects of recent versus historic grazing, or at least of how the range responds over time to a known level of grazing.

The 2015 data establish baseline conditions against which future rangeland health assessments (proposed for completion on approximate 5- to 7-year intervals) will be compared. The IIRH and Inventory and Monitoring data are the park's only site-specific, rigorous rangeland data collected using widely accepted methodologies. These data and the NRCS ecological site descriptions are of great value in developing desired condition statements for the EIS.

The IIRH data were used to inform alternatives developed for the EIS. For example, the data were used to delineate an approximate 300 acre (1.2 km^2) area in the Hartnet Allotment that will be rested from grazing for 3 to 5 years to enhance the potential for return of native cool season grasses that are almost extirpated locally. We also selected locations for construction of grazing exclosures (approximately 3 acres [12,141 m^2]) to monitor changes in range condition over time. Exclosures are located in key areas to allow long-term evaluation of the effects of grazing, changes in vegetation and plant species, adaptive management actions, year to year weather, and climate change.

Rangeland health data were used to adjust calculations of the appropriate number of cattle (stocking rate) grazing on each allotment. Stocking rates were calculated initially based on reference conditions for the plant species occurring in each soil map unit, the estimated annual forage production values of those species, the percentage of palatable species consumed by cattle, and the distance cattle must travel for water. The target utilization values for forage ranged from 35 percent for highly palatable grasses (Indian ricegrass [*Achnatherum hymenoides*]) to 5 percent for poor palatable vegetation such as Broom snakeweed (*Gutierrezia sarothrae*). A maximum utilization value of 35 percent for cattle is assumed to provide adequate forage for native wildlife, particularly as different wildlife species prefer to forage on different plant groups. A slope factor was not incorporated into the stocking rate calculations because slope is accounted for in the area defined as actively grazed in each allotment.

Once the initial calculations were complete, stocking rates were adjusted downward to reflect the current degraded status of rangeland health in the allotments. Future stocking rates may be adjusted, based on weather (primarily the timing and amount of precipitation, but also annual minimum and maximum temperature) and forage conditions, which are strongly correlated.

Because ecological systems are dynamic in responding to changing conditions, grazing management actions cannot be prescriptive. Therefore, IIRH data have been of immense value in developing adaptive management concepts for our rangelands, and incorporating these concepts into the EIS. Examples include identifying target indicators for long-term monitoring (forage utilization, species recovery, extent of bare ground), and using IIRH data and supplemental data to adjust the future timing, intensity, and season of use of grazing. A favorable distribution of cattle across the range can be evaluated using IIRH data and adaptive management can consider adoption of herding techniques to achieve the desired distribution. Ultimately, IIRH data combined with other information are anticipated to provide flexibility in responding to changes in climate and weather, vegetation communities, recovery of degraded rangelands, response of threatened and endangered species, and overall rangeland health.

Acknowledgements

We are indebted to the considerable skills and invaluable help of Mark E. Miller, Chief of Resource Stewardship and Science, Southeast Utah Group; Matthew W. VanScoyoc, Ecologist, Southeast Utah Group; Gregory E. Eckert, Restoration Ecologist, Natural Resource Stewardship and Science, Biological Resources Division; and John Spence, Chief Scientist and Terrestrial Natural Resources Branch Chief, Glen Canyon National Recreation Area. This project could not have been completed without their help and guidance.

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2016 National Park Service CENTENNIAL

—Natural & Cultural Resources—

Feature Program—Successful Cooperation

The Intermountain Region's CESUs: 17 Years of Accomplishments and Future Directions

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Introduction

Today, federal resource management increasingly depends upon cooperation and partnerships. The Cooperative Ecosystem Studies Unit program (CESU) is an important model of successful cooperation between federal agencies and academic, state and local agencies, non-governmental organizations, and tribal partners. The program was established under the National Parks Omnibus Management Act of 1998 and specifically encouraged the participation of Latino, African American and Native American serving institutions. On June 22, 1999, the CESU system was formally inaugurated by Secretary of the Interior Bruce Babbitt and by 2002, when Dr. Gary Machlis of the University of Idaho served as its first National Network Coordinator, the national CESU system was in place (Krahe, unpub. ms; Machlis, unpub. ms).

Since its establishment, the CESU program has grown to a national cooperative research system serving federal agencies with a central office in Washington, D.C. and comprised of 17 CESUs, 15 federal agencies and over 375 nonfederal partners. Each of the units is hosted by a university within its defined biogeographic region and has a unique suite of federal and nonfederal partners. In the past 14 years, over 7,000 projects have been administered through the program, with topics ranging from Anthropology to Zoology (National CESU Network website www.cesu.psu.edu).

Nonfederal CESU partners provide research, technical assistance, and education support for park units and programs. NPS participation in the CESU National Network is unique in two ways: a Research Coordinator is assigned to each CESU and, because NPS is a member of each CESU, a park or program can access any nonfederal partner in the national network. The low overhead rate (currently 17.5% for these institutions that, on average, charge 48% to others outside the CESU) and the ability to reach each partner make the program attractive to NPS managers seeking ways to collaborate with subject matter experts in a cost-effective manner in resource research, protection and management. Even with budget declines, dollars spent in the CESU system continue to increase, underscoring the importance of greater scientific knowledge in resource management, as emphasized in the Revisiting Leopold report (National Park System Advisory Board Science Committee 2012). The report emphasized the need for expansion of scientific expertise in NPS, including more park-based research and the use of research results in resource management decisions. The CESUs can help parks connect with partner scientists who can meet those needs.

The Intermountain Region (IMR) of the NPS includes the Rocky Mountain (RMCESU), Colorado Plateau (CPCESU) and Desert Southwest (DSCESU) Units. There is a Research Coordinator at each IMR CESU including: Dr. Todd Chaudhry (CPCESU) stationed at Northern Arizona University in Flagstaff; Dr. Sallie Hejl (DSCESU) at University of Arizona in Tucson; and Dr. Brendan Moynahan (RMCESU) at University of Montana in Missoula. Dr. William Patrick (Pat) O'Brien is the DSCESU Cultural Resource Specialist and provides cultural resource project support to all three IMR CESU units.

These CESU staff members' primary roles include helping parks and programs initiate and oversee task agreements and serving as science advisors.

International outreach and cooperation are also supported through the CESU program. There are numerous partnerships with member universities in Mexico (DSCESU and the Universidad de Sonora) and Canada (RMCESU and the Universities of Calgary and Waterloo) and programs such as the Afghan Cultural Heritage Conservation program administered through the DSCESU by the National Park Service, US Department of State and the University of Arizona.

Projects Honoring the NPS Centennial

In preparation for the National Park Service's Centennial in 2016, the NPS published *A Call to Action* (2011), outlining a shared vision to guide NPS employees and our partners during our second century of stewardship. It articulates four overarching themes, including 'connecting people to parks', 'advancing the NPS education mission', 'preserving America's special places', and 'enhancing professional and organizational excellence', each of which has specific goals and measurable actions that are intended to advance the NPS mission. The CESUs have enabled NPS to effectively collaborate with a diverse network of nonfederal partners to help meet this call in tangible and enduring ways. Many of the projects implemented through the CESU directly engage youth, ranging from enabling urban teens to visit a national park for the first time, to supporting graduate students to conduct applied research that helps to inform park management.

One notable example of a CESU project that touches upon these themes is the Intergovernmental Internship Cooperative (IIC). The IIC was created in 2008 and is comprised of numerous federal, state, tribal, and academic partners, including Southern Utah University (SUU) which leads the program. The IIC's mission is to develop future public land leaders by providing relevant work experience for university students and other regional youth under the mentorship and co-education of public land managers throughout southwestern Utah, northwestern Arizona, and eastern Nevada. Interns

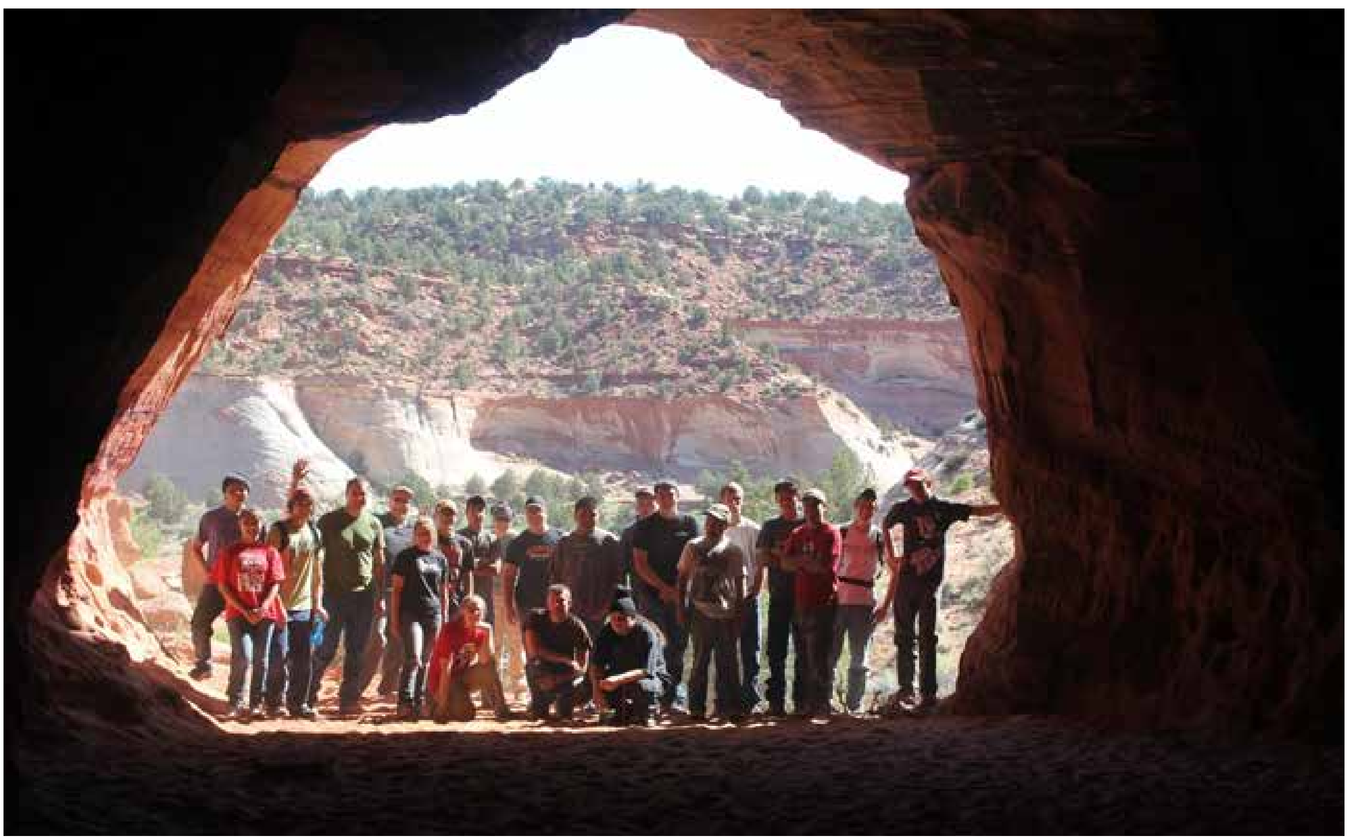

Figure 1. Intergovernmental Internship Cooperative (IIC) conservation crew interns gather for a Leave No Trace Training at Sand Cave in Southern Utah. (Photo by Ryan Young, 2014).

with the NPS are provided through CPCESU task agreements with SUU and support work at six park units, including Bryce Canyon, Zion, and Great Basin National Parks and Cedar Breaks, Pipe Spring, and Grand Canyon-Parashant National Monuments. These interns have helped the NPS and our partners respond to salient scientific and resource management needs while offering SUU students, from 50 different majors, significant learning experiences tied to their education and future careers (Figure 1).

Since its creation, the IIC has hosted over 1,000 interns in a variety of positions and locations. In 2014 alone, the IIC hosted 239 students in 23 different disciplines (e.g. wildlife, botany, range, wilderness, historical preservation, facilities, engineering, and visitor services) totaling over 105,000 hours of resource and visitor services related work. In addition to on-the-ground accomplishments, the IIC partnership has allowed public land agencies to respond to calls from their agencies' leadership to engage diverse youth and develop the next generation of public land leaders. For example, the IIC has partnered with local tribes and diverse student organizations such that 29% of interns in 2014 came from diverse backgrounds. Furthermore, one third of the interns from the IIC's 2010 cohort are still employed with public land agencies. In recognition of their exceptional contributions in achieving conservation goals, the IIC received the Department of Interior Partners in Conservation Award in January of 2014.

Cultural Resource Projects

Many NPS parks and programs use the CESUs for cultural and social sciences research, education, and technical assistance projects. Project topics include anthropology, archaeology, archival science, architecture, curation, cultural landscapes, ethnography, histories, library, material culture, museum, and social sciences.

The DSCESU has administered a large number of cultural projects and has built many long-term relationships. For example, R. Brooks Jeffery, Director of the Drachman Institute in the University of Arizona's College of Architecture, Planning, and Landscape Architecture, recently won the NPS Director's Partnership Award for his historic preservation projects with parks in the Desert Southwest (Figure 2).

Figure 2. R. Brooks Jeffery (Director of the Drachman Institute, University of Arizona) receives the Director's Partnership Award from Robert Love (Superintendent, Tumacacori National Historical Park), Stephanie Toothman (Associate Director for Cultural Resources), and Tom Lincoln (Assistant Regional Director for Cultural Resources, Intermountain Region) in 2016 (NPS photo 2016).

Over the past 15 years, he has worked on 42 projects at 25 parks in 8 states, including working on Spanish Colonial Mission resources, leading international symposia on earthen architecture, and assisting the NPS and the US Department of State in an Afghan cultural exchange and heritage conservation program.

One of the longest running DSCESU projects is TICRAT (Taller Internacional de Conservación y Restauración de Arquitectura de Tierra; International Workshop on the Conservation and Restoration of Earthen Architecture). Since 1994, NPS has partnered with its Mexican counterpart INAH (National Institute of Anthropology and History) to host and participate in these adobe preservation workshops. Beginning in 2006, these workshops have been administered by the Drachman Institute at the University of Arizona through numerous DSCESU task agreements. These workshops teach field-based skills and disseminate traditional adobe and plaster techniques to preservation specialists in NPS, INAH, students, and local communities that serve historic sites (Figure 3). Around 100 attendees participated in the 2016 TICRAT, a Centennial event hosted by Tumacacori National Historic Park (Figure 4). Of those 100 attendees, 37 were NPS employees representing 14 park,

Figure 3. Participants from TICRAT 2016 repair an adobe wall with mud infill prior to replastering (NPS photo 2016).

Figure 4. Participants in TICRAT 2016 at Tumacacori National Historical Park. (NPS photo 2016).

Figure 5. Eric Laurila, NAU graduate student in Anthropology, assists in mapping of an ancient pit structure (c. AD 1150) at Walnut Canyon National Monument. (Photo by C. Downum, 2006).

regional, and national offices. In addition, students from 6 United States and 2 Mexican universities participated. TICRAT events also provide invaluable international experience for NPS personnel working alongside their international counterparts, sharing common preservation concerns and exchanging ideas as colleagues. Workshops like these promote considering the use of traditional earthen architecture in parks to achieve a high standard of excellence in cultural resource stewardship.

The NPS has also benefitted greatly from its long-term relationship with Dr. Christian Downum (Professor and Director of Anthropology Laboratories, Northern Arizona University, NAU). Dr. Downum has participated in 96 cooperative cultural projects through the Colorado Plateau CESU. Types of projects included ruins preservation, archaeological surveys and excavations, workshops, field training, internships, monitoring natural and visitor impacts, database management, archival research, archaeological collections management, and website development. Since 2005, 51 NAU graduate students and 12 undergraduates have been supported financially through CPCESU projects, resulting in 22 Master's theses in Anthropology (Figure 5). More than 20 of the MA students that participated in these projects have become permanent federal employees, including two who currently serve as NPS Superintendents. All are employed in the fields of cultural resource management and ruins preservation. Dr. Downum has also offered five extended workshops on Ruins Preservation for professional archaeologists and students. Three of these workshops successfully focused on engagement with Native American, minority, and youth audiences. In addition to all of the benefits that these projects brought to the NPS, workshops clearly benefitted students and faculty at NAU. These projects provided invaluable opportunities to access world-class archaeological resources, enrich classroom offerings, integrate student research with management needs, network with NPS staff, and pursue professional employment.

In past years, CESU projects have also explored diverse heritages. Led by University of Texas at El Paso and Howard University professors, the Warriors Project involved high school and college students in archaeological field schools including both Native and African American students working together to explore their mutual histories in the American West at Guadalupe Mountains National Park and other related sites. The Linking Hispanic Heritage Through Archaeology project sponsored by the NPS Washington Office Archaeological program through the DSCESU promotes the participation of Latino students in archaeology and cultural anthropology and introduces participants to fields of study and professional careers. This project supports a spring and summer program for Hispanic youth (ages 14-18 years old) at the University of Arizona. The program uses regional archaeology as a bridge to connect urban Hispanic youth and their families to their own cultural history. By participating in an archaeological dig and artifact analysis at Tumacácori National Historical Park and visiting other park units, local museums, and university archaeology laboratories, the youths engaged in the study of Southwest archaeology from the pre-contact to the historical periods with emphasis on the Hispanic heritage of the Southwest (Figure 6). They also observed and participated in activities associated with past cultural practices.

Figure 6. Linking Hispanic Heritage Through Archaeology students screen material with Homer Theil of Desert Archaeology, Inc. as part of the University of Arizona's Field School excavation of Mission Guevavi at Tumacácori National Historic Park. (Photo by Trica Oshant Hawkins, 2015).

Natural Resource Projects

From water quality investigations to wetland restoration projects, and from habitat assessments to wildlife investigations, CESU partners have assisted parks with an incredible variety of natural resource projects over the last 15 years. The projects range from small, one-time resource surveys at a single park to multi-year, national initiatives across the NPS system.

In some cases – such as the restoration ecology work at Rocky Mountain National Park by Dr. David Cooper at Colorado State University – these undertakings support dozens of graduate students over many years, while conferring the benefits of continuity and a long-term relationship with a fixed Principal Investigator who comes to know NPS staff and resources exceptionally well. In other cases – such as recent projects on bat habitat use and winter ecology of porcupines at Devils Tower National Monument (Figures 7 and 8), post-flood changes in fluvial systems at Rocky Mountain National Park (Figure 9), or a pilot study on elk effects on sensitive habitats at Fossil Butte National Monument, NPS units are able to access very specific technical expertise for a particular, well-defined need. In recent years, parks and programs have used the CESUs to access expertise in science communication to help us distill and deliver effective and compelling messages to the public. Recent science communication projects have included cooperative development of updated content for park websites, completion of science podcasts and video shorts for specific projects, and initiation of "story maps" products that use new media to tell complex stories.

Figure 7. Meredith Dennis (left), Devils Tower biological science technician, assists Doug Keinath, Senior Zoologist with the Wyoming Natural Diversity Database Biologist at the University of Wyoming, record data during a nighttime trapping session to learn about bat use of the National Monument. (NPS photo 2015).

Figure 8. Amy Hammesfahr (left), biological science technician at Devils Tower National Monument, and Jessica Sellers, Biologist with the Wyoming Natural Diversity Database Biologist at the University of Wyoming, work through winter weather to measure a young porcupine and apply a radio collar for later tracking. The project will help the park better understand winter habitat use of coniferous habitats in the Monument. (NPS photo 2016).

Figure 9. Two graduate students of Dr. John Pitlick of Colorado University Boulder perform a survey of the streambed of the Fall River in the aftermath of the 2013 Colorado Flood. Dr. Pitlick conducted a similar survey in the 1980s that was used to note post flood changes in the fluvial system. (NPS photo 2014).

Some CESU task agreements facilitate projects that are both national in scope and local in delivery. The National One Health program partners with Colorado State University to provide highest-quality wildlife veterinary lab services and to offer training opportunities for NPS staff and practical internships for veterinary graduate students. The award-winning Teacher-Ranger-Teacher program, operated in cooperation with the University of Colorado-Denver, embeds K-12 teachers, typically from rural, urban, and tribal schools with little exposure to NPS, as seasonal rangers across the country. Teachers acquire skills and knowledge, while making valued contributions to host parks, before returning to their school to incorporate their experiences and lessons into coursework. Teachers can earn graduate or continuing education credits in the process, which aids renewal or upgrading of teaching credentials.

CESU Growth and Future Directions

All three IMR CESUs have expanded from the original number of federal, academic, and other nonfederal partners. Rocky Mountain has increased from four to nine federal partners; Colorado Plateau and Desert Southwest have each increased from five to ten. The number of nonfederal partners has also expanded; Rocky Mountain's nonfederal membership has increased to twenty, Colorado Plateau to thirty, and Desert Southwest to twenty-three.

The CESU program continues to experience strong growth despite flat to declining budgets (Figure 10). In the first five years after being established, the three IMR CESUs coordinated and delivered 876 task agreements worth $49.2 million. Over the most recent 5-year period ending in 2014, these three programs delivered 2,171 projects that allocated $150 million. To put this into a national perspective, from 2010-2013, the three IMR CESUs accounted for over 40% of both total projects and funding of all NPS activity across the 17-unit network. Much of this growth can be attributed to the exceptional efforts of former IMR CESU staff. This growth also is a strong reflection of two facts: (1) the NPS has a great need for research support and technical assistance, and (2) much CESU activity comes from recurrent use of the Units by experienced NPS parks and programs that have had positive experiences and have benefitted from the exceptional work provided by partners. By virtue of its coupling of successful delivery of quality technical products with value and efficiency (i.e., the low indirect rates and streamlined administrative processes) the IMR CESUs are positioned to remain a key mechanism by which NPS can meet its technical needs.

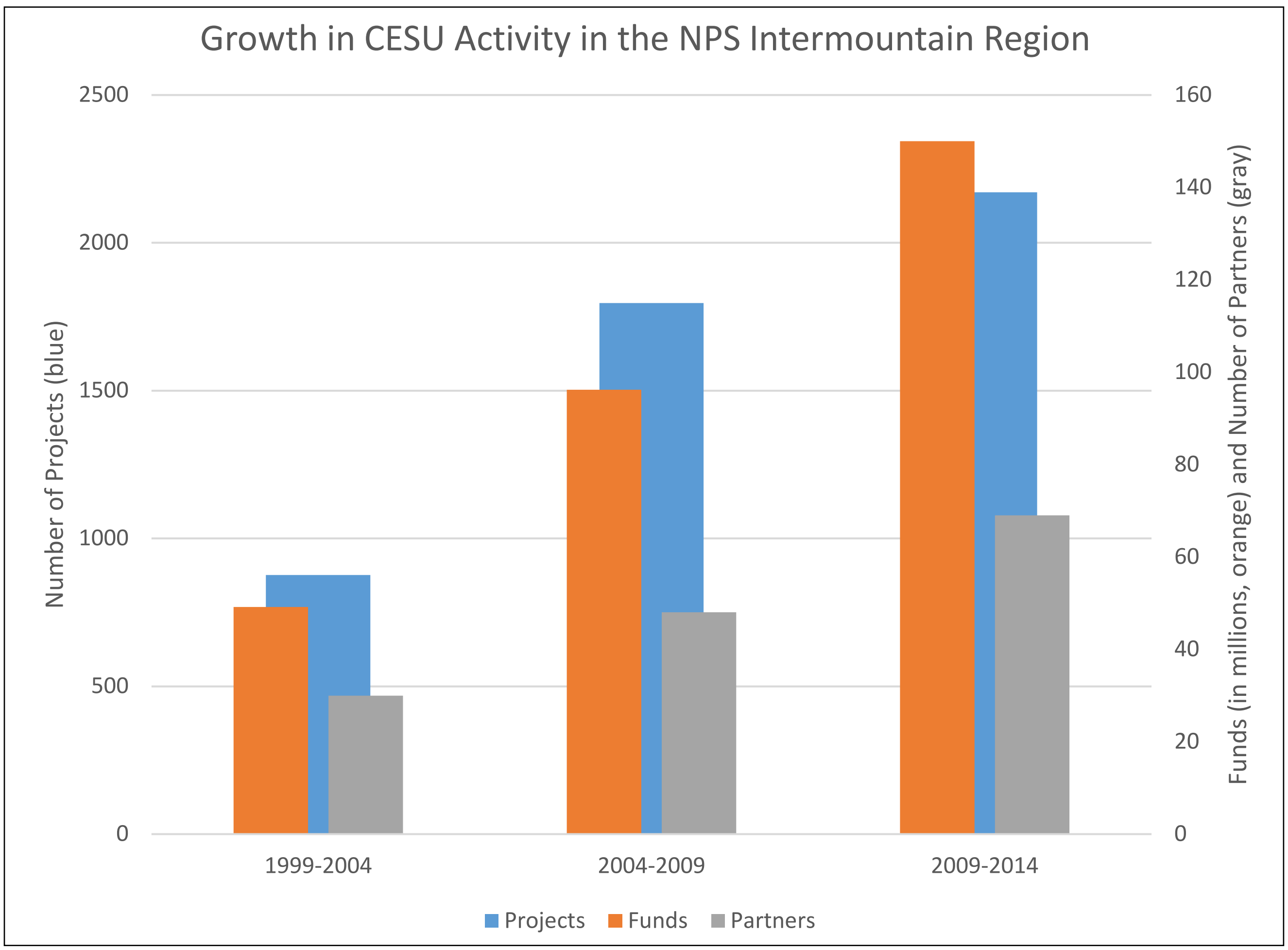

Figure 10. Growth in projects (number of Task Agreements), funds obligated to partners, and number of CESU partners for the three IMR CESUs over three 5-year reporting periods. Growth in use of the CESUs is robust despite flat to decreasing budgets, indicating the large need for technical assistance, repeat use by NPS users, and the expanding application of the CESUs to include a broader range of project types.

With continued project success and NPS commitment to NPS Research Coordinators located at the host institution for each CESU, we anticipate continued use for not only the traditional natural and cultural resource projects, but also growth into new areas offered by our scores of partner institutions across the country. New CESU opportunities being explored in fields such as engineering, journalism, science communication, information technology, public administration and resource law promise to strengthen current resource programs and partnerships. For example, Yellowstone National Park has engaged with the engineering program at Montana State University to evaluate and design snowroads given realized and anticipated changes in traffic and climate, and Organ Pipe National Monument has partnered with the architecture program at University of Arizona to conduct an energy audit and net-zero analysis for park structures, which will result in a description of energy efficiency opportunities that will reduce the park's carbon footprint.

We look forward to a second century of service with dedicated partners in helping to protect the nation's world class resources for future generations. Whether you are assembling a continuation of an established project or brainstorming approaches to meet an identified need, we encourage all IMR staff to consider how the CESU can help you do your best work. Your Research Coordinator will be happy to offer guidance and assistance.

See IMR CESU websites

Colorado Plateau CESU nau.edu/cpcesu

Desert Southwest CESU www.cals.arizona.edu/dscesu

Rocky Mountains CESU http://www.cfc.umt.edu/cesu/

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2016 National Park Service CENTENNIAL

—NATURAL RESOURCES—

Green Sunfish Early Detection and Rapid Response

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Figure 1. Endangered fish Humpback chub *Gila cypha* from Grand Canyon National Park (Amy Martin Photography)

The NPS response to the appearance of the nonnative Green Sunfish *Cyprinella lutrensis* (GSF) below the Glen Canyon Dam is a great example of a successful Early Detection and Rapid Response (EDRR) to an invasive species. In July 2015, an unusually large number of GSF were discovered in a large backwater slough in the Colorado River below Lake Powell in Glen Canyon National Recreation Area (GLCA). The Arizona Game and Fish Department (AGFD) biologists quickly brought this early detection of an invasive species to the attention of NPS biologists at GLCA and Grand Canyon National Park (GRCA), and other partner agencies. We swiftly conferred and agreed that elimination of this invasive species from the sloughs was necessary and urgent due to the risk of negative interactions with native fish downstream in GRCA.

Sunfish species were identified in the Comprehensive Fisheries Management Plan (CFMP) and EA for GRCA and GLCA (NPS 2013) as a high-risk predator subject to targeted removal when encountered. The risk of this species to native fish was also summarized in a risk assessment completed by USGS- Grand Canyon Monitoring and Research Center (GCMRC) (Ward 2015). If the Green Sunfish were to leave the sloughs in large numbers, they could establish new populations downstream, near areas critical to the recovery of the endangered humpback chub *Gila cypha* (HBC) (Figure 1). We had to address this problem quickly, setting up a classic case for Early Detection and Rapid Response (EDRR) of an invasive species, but rapid response would be difficult to achieve. This response would have to be conducted in the middle of the well-known and popular Lees Ferry rainbow trout *Oncorhynchus mykiss* fishery in GLCA, poised above the iconic Grand Canyon, and during an ongoing and complex EIS process intended to improve natural resource protection in GLCA and GRCA. This area is also considered a Traditional Cultural Property to five associated American Indian tribes (Hopi, Hualapai, Kaibab Paiute, Navajo, and Zuni. Finally, the river corridor is closely watched by the American public.

The sloughs are about 3 miles below Glen Canyon Dam, under spectacular cliffs of Navajo sandstone (Figures 2 and 3). The sloughs consist of a large area connected to

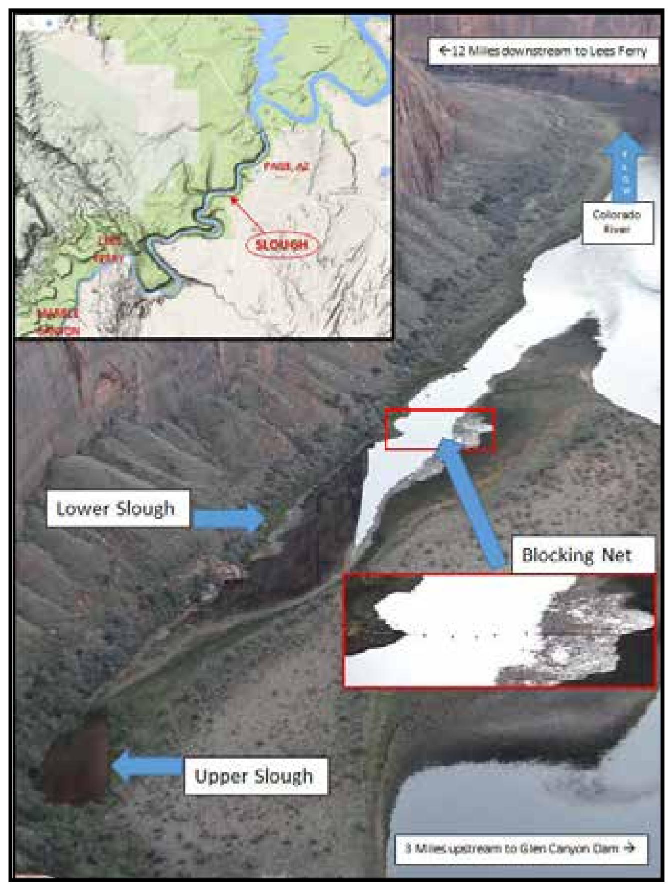

Figure 2. Overview of treatment area just below Page, AZ (inset) and showing location of block net, upper and lower sloughs, and direction of flow (Mark Anderson, NPS).

Figure 3. Trio of biologists sample fish at the mouth of the sloughs below Navajo sandstone cliffs in Lees Ferry, Glen Canyon National Recreation Area (Melissa Trammell, NPS).

the river and a smaller more isolated pool, perched on a massive cobble bar and connected by a trickle to the main area at most river flow levels. They are accessible only by boat travel 12 miles upstream of the Lees Ferry boat ramp. Daily fluctuations in water level from dam operations can change the length and volume of the sloughs substantially during the day, and disconnect and reconnect the two pools. The water released from the dam is cold and more suitable for trout than warm-water fish species like the GSF and the native fish, but the sloughs are isolated from the main channel enough to warm considerably during the long hot Arizona summers. The warm and quiet water allowed a few GSF to take hold, spawn, and develop into a population of thousands. Through a pre-negotiated agreement with the associated tribes, any nonnative fish removed from GLCA and GRCA are intended for beneficial use, which emphasizes human consumption or if that is not possible, to have the fish provided to the Zuni Eagle Aviary as food for the resident eagles. We consulted with the Tribes before this project as well, to ensure the best beneficial use was made of the fish removed from the sloughs. This helped to address concerns of the tribes about the lethal mechanical removal.

Two subsequent trips in August 2015 aimed at removing the GSF using electrofishing, seining and trapping failed to significantly reduce the population despite capturing and removing over 3000 fish, most of them less than 2 inches long and less than a year old (Table 1). Green Sunfish are highly piscivorous, reach maturity at less than 4 inches, and can spawn several times each year so their reproductive potential is immense (Figure 4).

Figure 4. Green Sunfish *Lepomis cyanellus* showing predation at small size of less than four inches (Lisa Winters, AGFD)

Table 1. Counts of fish removed from the upper and lower sloughs, RM -12, Colorado River below Glen Canyon Dam, during pre-and post-treatment collections. (Compiled from AGFD trip reports, on site fish collections, and as reported by David Ward, USGS).

Pre-Treatment removal and salvage fish totals	Main Slough	Upper Slough
Green Sunfish	1855	2638
Carp	42	0
Rainbow trout	134	0
Flannelmouth sucker	2	0
Bluegill sunfish	0	0
Channel catfish	0	0
Treatment fish removal totals	**Main Slough**	**Upper Slough**
Green Sunfish	195	1785
Carp	131	108
Rainbow trout	192	0
Flannelmouth sucker	3	0
Bluegill sunfish	1	0
Channel catfish	1	0

Agency biologists conferred again and agreed that the mechanical means of capturing the fish were not likely to successfully eradicate this species from the area (Ward 2015). While additional methods of removal and control were considered, an immediate need to contain the GSF was recognized. On Oct 7, 2015, a dozen biologists from NPS and AGFD constructed and installed a large block net near the downstream end of the main slough to minimize escapement of GSF until a more complete removal could be effected (Figure 5).

We considered several methods to eradicate GSF from Glen Canyon including additional mechanical approaches like electrofishing, netting, or concussive methods, and chemical treatment using the piscicide rotenone. However, netting, trapping and electrofishing tend to be much more effective for larger fish, and are not very effective in the complex vegetated habitat in this slough. Of the methods evaluated to remove these fish, chemical treatments provided the greatest likelihood of success (Ward 2015). Chemical treatments are highly effective for removing isolated populations of fish, particularly when few or no native species are present; however, chemical treatments are often viewed with great concern by the public, and require a considerable amount of planning, permitting, compliance and outreach to be conducted safely, effectively, and without prompting public concern. The associated tribes are also concerned with the taking of life of fish and other organisms such as macroinvertebrates without balancing the deaths with a positive benefit to human lives and culture. Fish killed with rotenone cannot legally be eaten or used as feed for animals. Nonetheless NPS believed it was crucial to eliminate this source of invasive fish to prevent further spread, and harm to native fish; those that tribes refer to

Figure 5. Crews from National Park Service and Arizona Game and Fish Department constructing block net for sloughs in Lees Ferry (Brian Healy, NPS).

as the 'ancient ones', whose protection outweighed the application of chemicals.

NPS and AGFD, with assistance from the USGS-GCMRC and the Bureau of Reclamation (BOR) began working towards a chemical treatment solution; however, the treatment schedule was further complicated by a planned experimental High Flow Event (HFE) where water released from the dam would be greatly increased in November, as part of an ecosystem restoration program (BOR 2011). The chemical treatment could not be completed and determined to be fully successful before a November HFE would be implemented, and the HFE would have overtopped the slough and resulted in unacceptable downstream dispersal of the GSF. A decision not to implement an HFE could not be made lightly. High Flows have been a hard-won tool only recently approved through interagency consultation and compliance. But after careful consideration, a Leadership Team comprised of the NPS, Colorado River Basin States, BOR and Western Area Power Administration (Western) approved that no experimental HFE would be conducted in 2015. However, eradication of the GSF was still determined to be necessary and urgent; thus, NPS and AGFD completed the planning and compliance necessary to conduct a rotenone treatment (NPS 2015). Two treatments were planned for November, about 10 days apart.

The first treatment was conducted from November 2 to 6, 2015. Personnel from AGFD, NPS, FWS, GCMRC, BOR and Western participated in planning and implementation. Prior to the treatment, an impermeable barrier was installed to minimize water exchange from the slough to the river (Figure 6). BOR and Western agreed to provide steady flows of 9,000 cfs for 3 days to facilitate the treatment. A macroinvertebrate survey was conducted before the treatment, and another is scheduled for the summer of 2016 at the request of the tribes to evaluate the impact of the treatment. Tests (bioassays) done on Nov 3rd determined that a concentration of 1.5 ppm was needed to treat the sloughs (Figure 7). Rotenone was applied on Nov 4th and fish were observed on the surface in about 30-45 min. Treatment continued throughout the day, and fish were removed from the slough as they surfaced. Detoxification with potassium permanganate began the next morning and continued through the afternoon. Live trout were placed in cages in the sloughs to ensure that detoxification was successful. The project was considered complete and successful by 4 pm Friday, Nov 6th, when trout remained alive in the cages for 24 hours.

Figure 6. Impermeable barrier prevented test dye and piscicide applied inside the slough (left) from mixing with main river flow (right) (Melissa Trammell, NPS).

Dead fish were collected throughout the treatment and detoxification periods, counted, and kept for research (Table 1). A total of 1980 GSF were collected from both sloughs, primarily from the upper slough. The count of GSF compared with previous removal efforts will allow an estimate of the efficiency of our mechanical removals, and the accuracy of population estimates, thus serving a beneficial scientific use. The GSF were frozen in case a future beneficial use can be determined. A total of 431 non-native carp and trout were also collected. They were scanned for PIT tags, and recaptured fish were processed to remove otoliths, scales and a portion of the dorsal spine to be used to calculate the fishes' age, and when combined with previous capture information will allow analysis of growth, movement, and habitat occupied. These fish decayed quickly and so were taken to a landfill as no further beneficial use was possible.

A second treatment was planned on November 14, to address fish that may have hatched after the first treatment; however, it was not needed. Water temperatures in the sloughs declined more rapidly than expected. Air temperature, which largely drives water temperature, was about 10 degrees below normal for this time of year, and, the sloughs are positioned so that they do not receive any sunlight during the day, driving water temperatures down below the point that GSF could spawn, before the first treatment. Sampling just prior to the planned second treatment found no live GSF larvae or adults in the sloughs. Reducing the number of treatments was in keeping with using the minimum chemical necessary, and reducing incidental death of invertebrates and non-target fish.

Despite our best efforts, we did not achieve full containment of the slough with the block net before the treatment, and we believe that some of the GSF did leave the slough. A few have been captured outside the slough in the Lees Ferry Reach. Nonetheless, all of the participants believe that this was a worthwhile and important treatment to have done, as about 2000

Figure 7. Ashley Rawhouser (Back - NPS) and Mike Anderson (Front- AGFD) make final calculations on quantity of rotenone needed to eliminate Green Sunfish from the sloughs (Melissa Trammell, NPS).

GSF were removed during the chemical treatment, mostly from the upper slough, removing a serious threat to the downstream native fish. Both short and long-term solutions are being discussed to address future invasions of non-natives. Among the options being considered is physical alteration of the sloughs to make the habitat unsuitable or inaccessible to future invasion. If the sloughs are significantly reinvaded by GSF or other warm-water non-native fish before a more permanent solution can be implemented, additional treatments may be considered.

All the partner agencies played very important parts to ensure that this project was planned, approved, implemented, and conducted as safely, and as quickly as possible. Early detection and rapid response to invasive species is a key factor in controlling their spread and limiting the damage they can cause. Despite legal, social and regulatory hurdles, we were able to complete the permitting and compliance necessary in a few months, and were able to successfully implement the project with no major negative public reaction. Public outreach to local stakeholders was particularly important to avoid the public concern that often accompanies this kind of chemical fish treatment. From Arizona's monitoring and reporting, the GCMRC/USGS risk assessment, Western and the BOR's willingness to hold water levels steady during the treatment, Park staff at the Intermountain Region, GRCA and GLCA working overtime to complete the permitting and compliance needed and to provide security at the site, meticulous planning and leadership from AGFD for the on-the-ground activities, to the two dozen staff from all agencies that pitched in to do the cold, wet and dirty work, the cooperation and shared vision of everyone involved made this process happen in record time and makes this project an exemplary model for EDRR projects across the nation.

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A boat winding its way through a twisting canyon at Glen Canyon National Recreation Area. (NPS Photo).
Photo Credit: Michael Whiteman-Jones.

2016 National Park Service CENTENNIAL

—GEOGRAPHIC RESOURCES—

Park Places: An Innovative Approach to Visitor Engagement

Centennial Project

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For this year's NPS Centennial, we aim to celebrate the past 100 years of stewardship by beginning our second century with new and innovative ways for visitors to experience their national parks. Appealing to a younger, mobile, and more tech-savvy audience, the nps.gov website has undergone an extensive redesign, including new information, graphics, and interactive maps. Replacing the traditional static Harpers Ferry Center maps, these new dynamic maps allow visitors to explore places of interest, customize their experience, and "find their park" using cutting-edge innovative web technologies. This effort is called Park Places.

In support of this new web mapping strategy and in conjunction with parks, NPS regions and other national programs, the IMR Geographic Resources Division (IMR GIS) collaborated to create national data standards for roads, trails, and points of interest. These data standards define how geospatial data are managed and maintained across the agency, ensuring seamless data transfer between parks, regions and national programs. Staff at IMR GIS then prepared geospatial data by normalizing visitor use datasets into standardized formats, published those data to an editable web mapping environment in ArcGIS Online (AGOL) (Figure 1), and then shared the data with designated park staff.

Using AGOL, park staff could visualize the data at different scales then edit, delete, or add data to various visitor use datasets. For park staff trained in GIS, these datasets were directly added, edited, and synced within

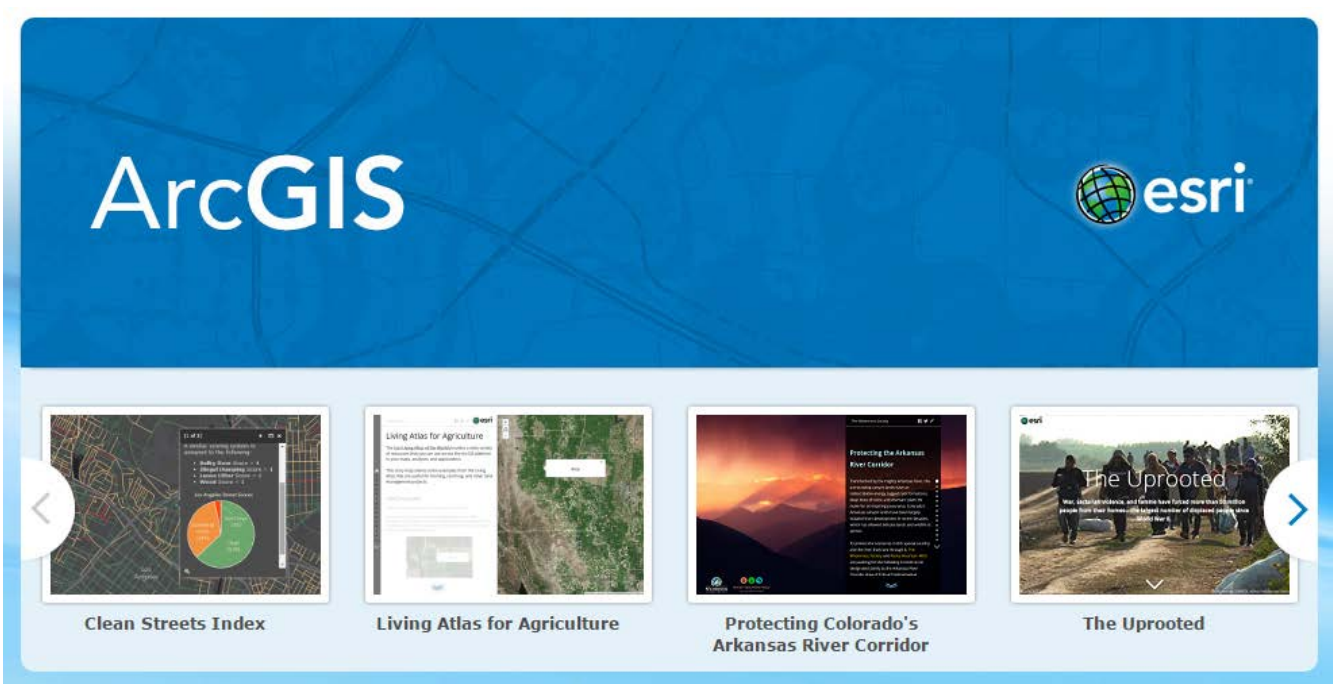


Figure 1. ArcGIS Online story map examples.

Figure 2. Example of a Park Places tile from Zion National Park. As the user zooms in to larger scaled views, more points of interest, roads, and trails appear on the map.

a familiar spatial editing environment. For those with little or no GIS experience, IMR GIS designed intuitive editable web maps (similar to those used in now well-known web mapping applications such as Google and Yahoo Maps) which required no additional training to operate. This versatile solution empowered both dedicated GIS staff and non-technical users to interface with the data inside a user-friendly and efficient platform (Figure 2).

Central to the project, IMR GIS included options for park staff to flag sensitive data to be restricted from public release. Data flagged as restricted were withheld from integration in the Park Places project while still maintained for internal use in Park Atlases and other park management applications. Through the web editing environment of AGOL, park staff were encouraged to take control of their geospatial data, providing an opportunity for non-technical users to expand skillsets and increase confidence when working with GIS data. By embracing this technology, regional GIS staff presented new ways for parks to manage and maintain their geospatial data for a variety of audiences and applications. Incorporating the local knowledge and expertise of park staff created a collaborative effort ensuring complete, accurate, non-sensitive data would be seamlessly integrated into this national web mapping effort.

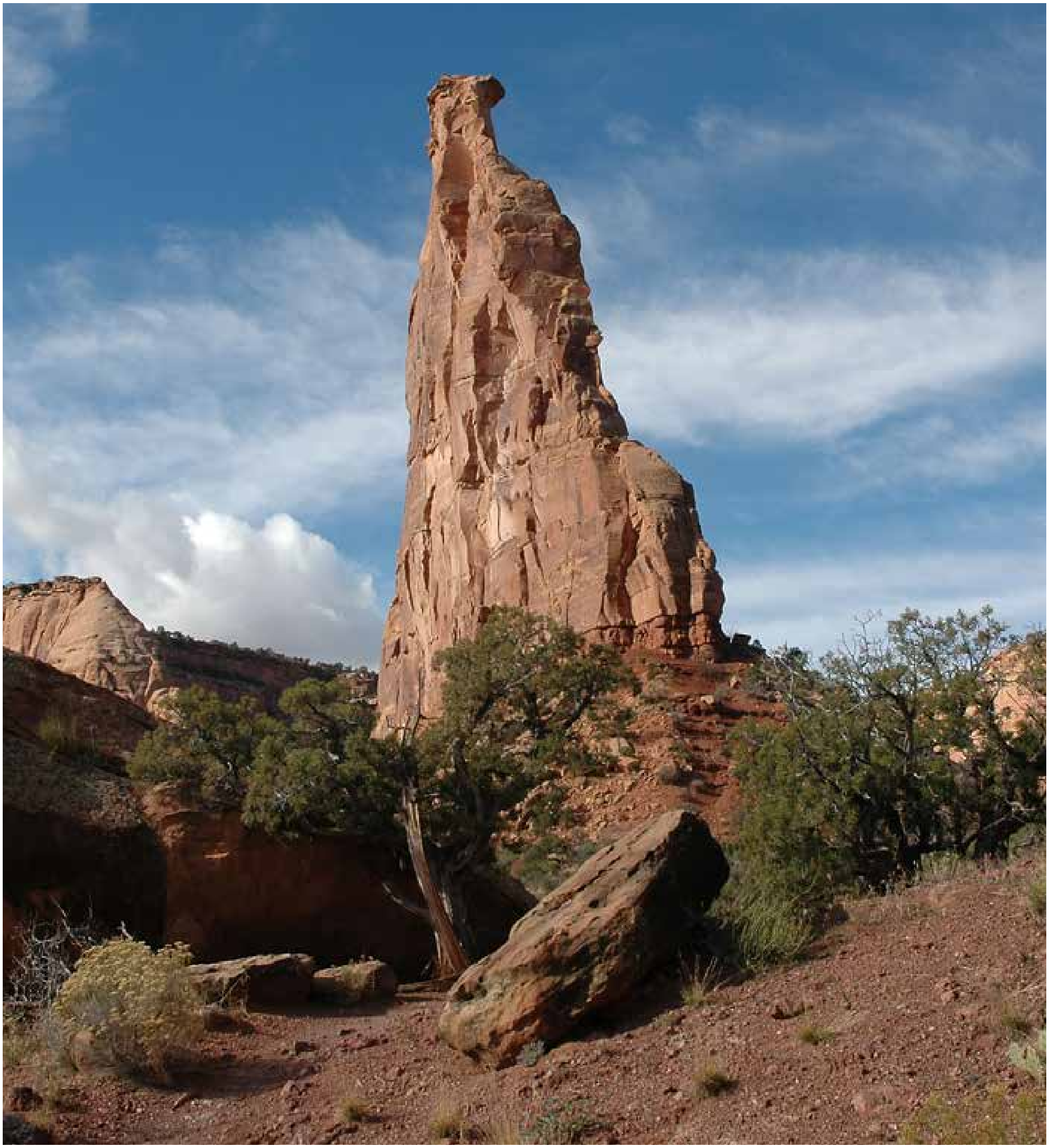
While most IMR parks had thorough datasets or adequate staff to build missing data, some parks required additional assistance from regional GIS staff to meet the call for comprehensive public datasets. Former Regional GIS Coordinator, Darcee Killpack, secured Centennial funding to support sending regional GIS staff and a Student Conservation Association (SCA) intern to selected parks to conduct field mapping and update critical visitor use data. Dinosaur National Monument, Capulin Volcano National Monument, and Salinas Pueblo Missions National Monument each hosted regional GIS staff and SCA intern, Skye Kreisler (Figure 3). While at the parks, they collected GPS locations and information on roads, trails and points of interest to be included in the Park Places project. Skye conducted field data collection while regional GIS staff worked with park staff on GIS data management and training. To meet other park management needs, additional GPS data were collected and integrated into GIS datasets to maximize efficiency and effectiveness while at the parks.

Figure 3. Student Conservation Association intern Skye Kreisler using a Trimble Geo7x GPS unit at Dinosaur National Monument.

Mapping features at the parks also provided an excellent opportunity to field test various GPS data collection devices and mobile mapping applications. Features were collected using a Trimble Geo7x (a sub-meter accurate handheld device) running TerraSync, a Getac Z710 (sub-meter accurate tablet) running Collector for ArcGIS, and a Dell tablet running Collector for ArcGIS connected via Bluetooth to a Garmin GLO GPS receiver. These devices and applications were field tested for reliability, practicality, and compatibility with pre-existing datasets then compared for data quality and accuracy back in the office. The results of testing have helped regional GIS staff recommend the best device and application for a given field data collection project.

Through field data collection and park staff review, IMR GIS has compiled and made available publicly accessible standardized datasets. These data can now be consumed by a wide variety of applications in addition to the Park Places project and new nps.gov interactive maps. Researchers, state agencies, and the general public can now access these park-verified and park-approved datasets through portals of public data built by IMR GIS. This reduces demand on already over-burdened park staff while simultaneously meeting open data mandates for federal land data.

This comprehensive approach to the Park Places project will continue to benefit IMR parks far beyond its immediate applications. By empowering park staff with innovative web technology to manage their own geospatial data, GIS datasets are now comprehensive and more suitable for analysis and decision-making. Visitors, scientists, and partners can access and use these data to enhance their park experiences, investigate research questions, and propagate focused applications that invoke better understanding and appreciation for all our national park units. As we celebrate our last 100 years, the results of the Park Places project will help us preserve, protect, and enjoy our natural and cultural heritage in new ways that extend far into the future.



View of Independence Monument. (NPS Photo).

—NATURAL & CULTURAL RESOURCES—

Sonic Booms and Resource Effects: An Unmanned Measurement System for Shock Waves, Structural Vibration, and Potential Damage

By G. Randy Stanley, Natural Sounds & Night Skies Coordinator, Intermountain Regional Office; Randy_Stanley@nps.gov; David Bustos, Resource Program Manager, White Sands National Monument; David_Bustos@nps.gov

Abstract

Shock waves are created by objects traveling faster than the speed of sound; such motion is termed supersonic. Large supersonic objects like military jets can create substantial shock waves called sonic booms. When sonic booms reach the ground, they can induce significant vibration that may cause damage to historic buildings, ancient ruins, natural bridges, and other structures. The NPS is steward for many such sensitive structures and must keep aware of these risks to ensure irreversible damage does not occur. White Sands National Monument (WHSA) protects a unique array of cultural resources, including a historic district and newly discovered hearth mounds, but it sits under designated military airspace. Furthermore, through an Interagency Agreement with the U.S. Army White Sands Missile range, WHSA shares the western portion of the park as a zone of cooperative use. As a result of military testing and training requirements, WHSA is subjected to frequent closures and a large number of sonic booms from supersonic aircraft and large missiles that fly in airspace over the park (at times this has exceeded 40 sonic booms a month). To monitor the intensity of sonic booms and help ensure they do not result in permanent resource damage, park staff began working with Regional Office staff on an unmanned sonic boom monitoring system. Software with a special sonic boom recognition algorithm was solicited, a validation project was conducted, and monitoring equipment has been installed. The validation project confirmed that the sonic boom system is capable of accurately capturing the unique signature and overpressure induced by sonic booms.

Figure 1 - Microphones and miscellaneous equipment at NE30—the sonic boom testing site.

On the morning of September 23, 2015, a small group of park and regional employees stand looking northward for signs of a fast approaching jet aircraft. Our equipment is ready, watching for the signs of a unique acoustic event, not often heard. Some 50 feet away, a contractor on a cell phone with a Holloman Air Force Base (HAFB) flight controller suddenly turns back toward us, walks quickly to his equipment, and warns, “get ready—it’s coming”.

As we look north, we can see a sand pedestal resulting from a previous military plane crash (over 300 hundreds missiles and aircraft have crashed in this area). A couple of employees hold up their cell phone cameras, scanning the sky for any signs of the approaching aircraft, but we hear only the sound of a slight breeze through sparse desert brush.

Then it happens. We feel and hear a deep boom, followed by the scream of high performing jet engines with afterburners on. We know it’s coming, but the sonic boom still takes us off guard. Even though it was generated by the planned supersonic flight trajectory of a T-38C Talon more than a mile distant, the shock is enough to jolt us (supersonic refers to the speed of an object traveling faster than the speed of sound). A consequence of supersonic flight training, some HAFB staff and locals have referred to sonic booms as the "Sound of Freedom"; a YouTube video (https://www.youtube.com/watch?v=nppp9JDU54k) was even created to promote it as such.

At day break, our project team met at the White Sands National Monument entry gate, anticipating cool dry desert air and optimal conditions for sonic boom tests. In a park truck, we took nearly an hour-long drive down two track roads along the southern front of gypsum dune field, slowing occasionally to maneuver around giant two to three foot deep pot holes dug out by badgers in the hard pack road. Eventually, we reached NE30, a Cold War era Double Askania Cinetheodolite observatory at the highest point in the park (a Cinetheodolite observatory is a photographic instrument used to obtain tracking data for the testing of missiles, rockets, projectiles, and aircraft; this particular one was used to track and record thousands of missiles that flew over the monument).

Figure 2 - Cold War era Double Askania Cinetheodolite WHSA 157 (LA 122394); photo by Rani Alexander (2013).

Before starting a portable electric generator in a small garage adjacent to the observatory, we carefully looked for signs of any wildlife that might be nearby. In the past year, park staff had seen a bobcat, rattlesnake, golden eagles, red tail hawk, African Oryx, and even invasive African bees taking up temporary residence in the building. As we set up our equipment, we can hear distant sonic booms; they sound like a far off bombing range or abbreviated thunder.

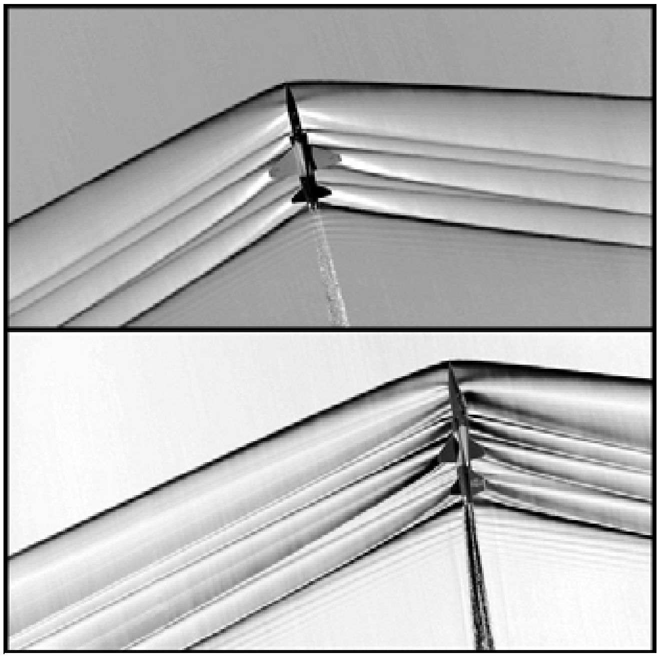


Figure 3 - Schlieren imagery of T-38C supersonic shock wave in the Mohave desert (2015 NASA; top image above aircraft; bottom image to port side).

Shock waves are produced by all supersonic objects, ranging from the sharp crack from the tip of a bullwhip or a bullet in flight to the intense shock waves created by the 2013 Russian Chelyabinsk meteor ripping through the upper atmosphere at hypersonic speeds. Although aircraft-generated sonic booms fall between these two extremes, they can similarly put structures into motion, and in some cases, break glass or cause structural cracks (the 2015 NASA image of a shock wave from a supersonic T-38C is a modern adaptation of Schlieren imagery, invented in 1864 by German physicist August Toepler).

The primary concern for sonic booms is their effect on visitors and parks with sensitive resources. Not only do unexpected booms startle visitors, but they can also cause cumulative damage to historic buildings, archaeological ruins, and fragile natural structures. Long-term effects can occur due to multiple mechanisms, including fatigue, moisture damage initiated by cracks, and gradual erosion of surface materials (Hanson, King, et al. 1991).

Sonic booms present damage risk, due to intense, broad spectral content at very low infrasonic frequencies (infrasonic refers to parts of a sound with frequency below the lower limit of human audibility). Historic buildings, natural bridges, and arches may be susceptible to sonic booms, particularly if they have natural modes of vibration at infrasonic frequencies (Sutherland, 1990; King, 2003). In the era when low altitude supersonic flight of military aircraft was more common over parks and before supersonic flight by civilian aircraft was prohibited over the U.S. and its territorial waters by regulation in 1973, there were numerous reports of sonic booms in NPS park units. Some produced large rock falls, including one that damaged prehistoric cliff dwellings in Canyon de Chelly (EPA, 1971).

Figure 4 - WPA workers making corbels for residence and administration buildings in 1936.

White Sands National Monument was established in 1933 by President Herbert Hoover. Construction of the historic White Sands Visitor Center building complex was begun in 1936 and completed in 1938 by various government agencies, including the Works Progress Administration (WPA). An excellent example of the Spanish adobe "Pueblo-Revival" style, the White Sands Visitor Center was designed by principal architect Lyle Bennett. Mr. Bennett was also responsible for design of the Painted Desert Inn at Petrified Forest National Park, the historic district at Bandelier National Monument, and buildings at Carlsbad Caverns and Mesa Verde National Parks. The picture above shows workers constructing portions of the historic buildings; the picture to the lower left shows the visitor center as it looks today.

Figure 5 - White Sands Visitor Center.

In response to the attack on Pearl Harbor, December 7th 1941, the President and Secretary of Interior Harold Ickes initiated the process to secure land and establish the Alamogordo Bombing and Gunnery Range under Executive Oder No. 9029. The Executive Oder contained a clause that the Army was to "consult" with Interior officials about bombing targets, in addition it promised to restore the lands to the Interior "when they are no longer needed for the purpose for which they are reserved". The Bombing and Gunnery Range would later become Holloman Air Force Base and White Missile Range. Together they would encompass the entire monument and become one of the most active military air spaces in the country. Via interagency agreement with the U.S. Army White Sands Missile Range that manages the largest area of supersonic airspace over the continental U.S., the park endures frequent closures to protect visitors from missile overflights.

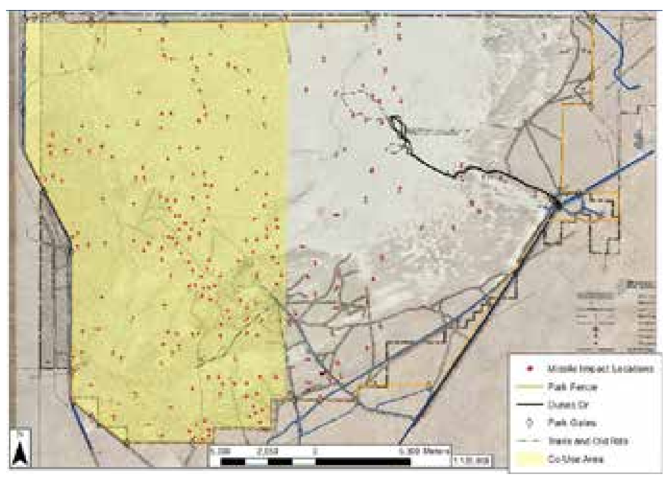


Figure 6 - Co-use area with past missile impacts.

Figure 7 - Adapted vertebrates (clockwise from upper left: bleached earless lizard, great plains spadefoot toad, white sands pupfish, pale phase palid bat, Apache pocket mouse).

With this history, White Sands National Monument is a very special park with unique resources and interagency collaboration needs. More than 224 square miles in size, the Monument contains a significant portion of the largest white sand gypsum dune field in the world and a number of white animal species endemic only to the area. Animals from every class of vertebrate except a bird have rapidly adapted to the white sands, including many pale or white arthropods.

Figure 8 - Pale endemic arthropods (clockwise from left: camel cricket, toothpick grasshopper, saltonia spider, minor ground mantis).

The white sand dunes feel cool to the touch, even in the summer. If you push your hand into the white sand, you will find water not far below the surface of any dune. The presence of the white gypsum dunes is not only linked to the unique geology of the area, but also hydrology—the dunes themselves are inextricably linked to the long-term presence of water. The water holds the entire dune field in place, even as wind pushes and shapes the dunes.

The chemistry of the area leads to additional fragile resources that are still being discovered, like paleontological fossil tracks, hidden traditional hearth mounds, and selenite crystal formations. The white gypsum, when subjected to high heat, will eventually form anhydrous calcium sulfate (anhydrite), also known as plaster of Paris. For reasons not yet fully discerned, Native American ancestors transported wood and created fire pits (hearths) in the white sands to generate heat and to process food; the chemical transformation that ensued helped to preserve a valuable and unique archaeological record of local events (hearth mounds/ time capsules).

The unique archeological features, called gypsum hearth mounds, are not known to occur anywhere else on earth. These hearth mounds serve as time capsules of human history (Archaic to Pueblo cultures dating back over 7,000 years). The presence of the fire in the white sand removed the water moisture and changed to

Figure 9 - A hearth mound, a prehistoric thermal feature, in the Parabolic Dune Hearth Mound area: WHSA 237 Feature 1, thermal feature close up Photo Credit: Molly Murphy; WHSA 237 site map with Feature.

sand from gypsum to anhydrite (plaster of Paris). These hearth mounds can be up to 50 feet tall, or as tall as any of the dunes. This process was repeated over thousands of years, creating thousands of hearth mounds in the area.

Although some hearth mounds were known as early as 1920's, the extent (over 2,000 exist within the monument) and importance of the hearth mounds are only now being studied and understood. The structural integrity of the hearth mounds is very important, because the solid structure holds the local site geology and any archaeological objects in place, largely preserving the integrity of the site. The hearth mounds are very similar to an adobe well (gypsum dune), with a hard outer stucco layer (the anhydrite hard shell). Like the adobe buildings in the historic district, once the hard outer layer is cracked, water seeps in and quickly erodes the structure below. The concern with the sonic booms is from the intense overpressure that is believed to increase cracking and erosion of the hard outer protective shell.

It is clear that the presence and the movement of water is a significant driving force in the formation of the World's largest gypsum dune field. As water travels in the bottom of the basin and evaporates, gypsum comes out of solution and forms intricate selenite crystals. These virtual crystal cities may last only few days or weeks.

Figure 10 - Newly formed Selenite crystals after 2006 flood.

Figure 11 - Artist rendition of what of the fossil track makers and past conditions.

The presence of gypsum has also led to outstanding paleontological resources over millennia. Ice age fossil prints of camels, sloth, dire wolf, and mammoths are being discovered on a regular basis in the ancient lake beds that form the selenite crystals today.

A 1988 vibration study by Dr. Ken King evaluated the vibration response of numerous walls within the White Sands Visitor Center, along with a visual inventory of wall cracking to document any damage for current and future studies. The report included a recommended maximum (peak particle) velocity level of 2 mm/sec to minimize cumulative damage risk for the historic structures at White Sands National Monument (King, 1998).

Sonic booms have been experienced at White Sands for many years, beginning with the introduction of the F-4 Phantom in the 1960s. However, high altitude supersonic airspace did not exist above most of the Monument until the airspace was expanded in 2008 to accommodate the introduction of the F-22 Raptor at HAFB. When the airspace was expanded to cover the monument, the frequency of intense sonic booms at areas of high visitation, including the Historic District, increased dramatically, from roughly 5 to 40 booms per month (USAF, 2006). Concern for damage to the Monument's sensitive historic and cultural hearth mounds (time capsules) also increased.

The primary measure of a sonic boom's intensity and potential effect is its peak overpressure, expressed in pounds per square foot (psf) or Pascals (Pa). Infrasonic microphones are needed to accurately measure overpressure, but they typically suffer from extreme susceptibility to wind-generated noise. The microphone is mounted flush in a ground plane reflective plate to reduce wind turbulence and accurately measure the effective pressure exerted on structures. A dual windscreen system is added to physically remove wind-generated turbulence away from the microphone and reduce its contribution to the measurement.

Figure 12 - NPS sonic boom monitoring system components.

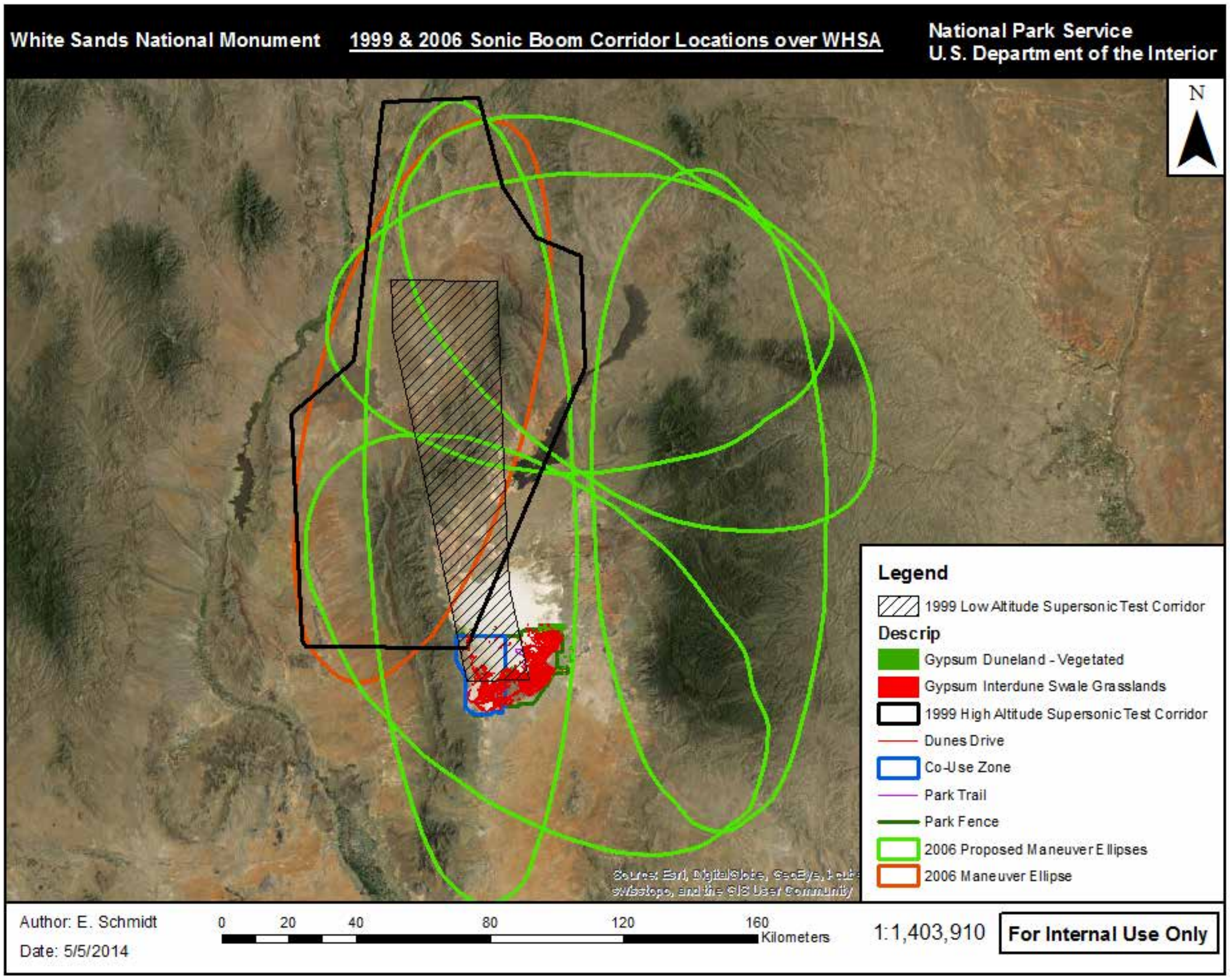


Figure 13 - Sonic boom maneuvering areas over park before and after F-22.

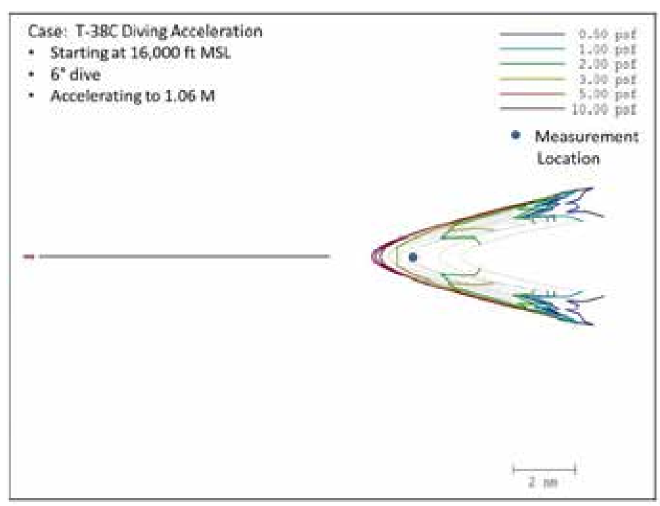


Figure 14 – Sonic boom footprint prediction.

The sonic boom measurement setup purchased by the Intermountain Region and White Sands National Monument consists of a USB-based data acquisition device (measurement front end), an infrasonic microphone, specialized software, and a reflective ground plate with dual wind screen. The specialized software includes an algorithm to detect the unique acoustic signature of sonic booms and thereby prevent false triggers from wind and other sources. It is also capable of triggering when levels from one or both vibration sensors exceed a predetermined threshold.

The purpose of the supersonic test project on September 23, 2015 was to verify accurate performance of the NPS sonic boom measurement system. Supersonic flight profiles of T-38C Talon jets were planned by the contractor, in conjunction with modeled sonic boom footprints (using PCBoom4 software), to

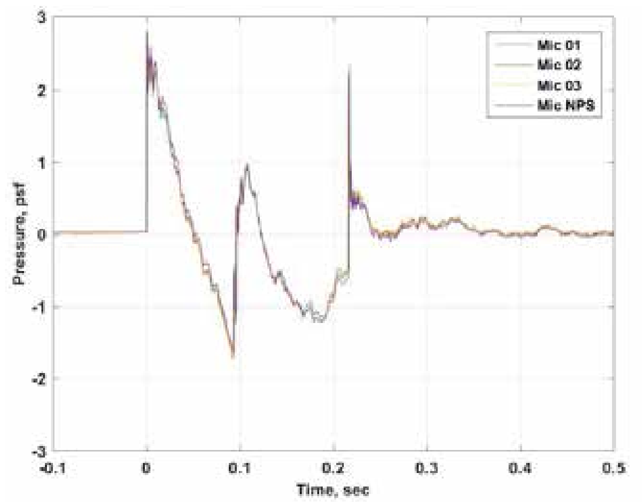


Figure 15 - Recorded sonic boom waveform.

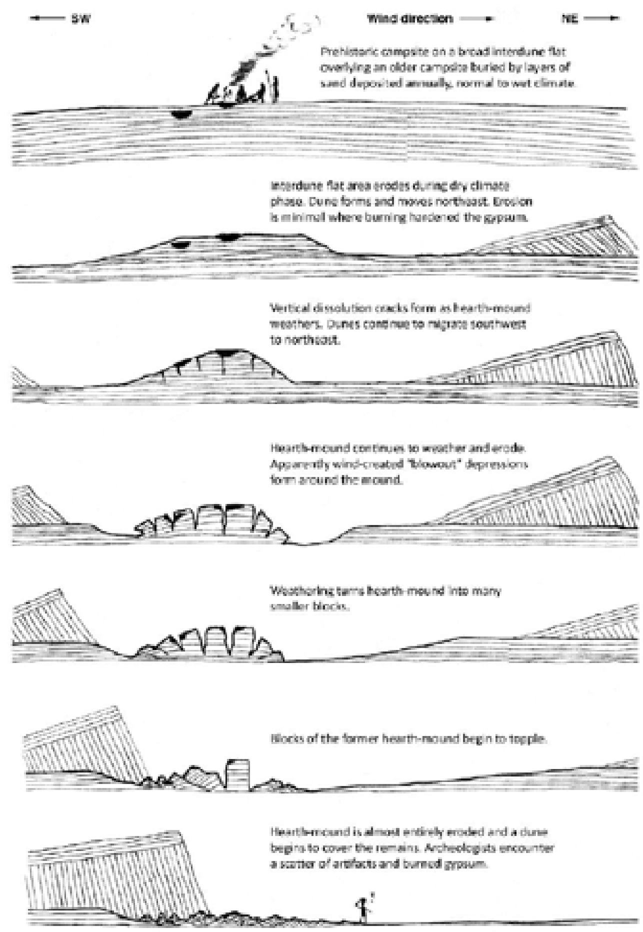


Figure 16 - A schematic time series drawing demonstrating hearth mound formation and erosion (Hogan et al. 2012:286, Fig 16. 12).

ensure a range of sonic booms at the position of the measurement site. Specific flight profiles were planned at Mach 1.06, the maximum capability of the T-38C Talon (for an aircraft, the Mach number is the ratio of air speed to the local speed of sound).

On that September morning, there are 10 flight passes, resulting in a total of seven detected events. Of the seven events, five produced substantial booms at the site. The five sonic booms recorded by the NPS system provide an excellent range of sonic boom types, ranging in magnitude from 0.2 to 2.8 psf. To put this into perspective, the 2.8 psf boom had a peak sound pressure level of 137 decibels, with maximum spectral content in the infrasonic range. The project verifies that the NPS system accurately replicates the sonic boom detection algorithm developed for the U.S. Air Force Boom Event Analyzer Recorder (BEAR) and records high-fidelity sonic boom waveforms (Lee and Downing, 1980). In the low-altitude supersonic test corridor shown in Figure 13, sonic booms can be generated by overflights as low as 300 feet AGL; during such low overflight testing the area is evacuated of people and equipment for safety.

The system is currently in place and in use at the historic White Sands Visitor Center, recording sonic booms as they occur.

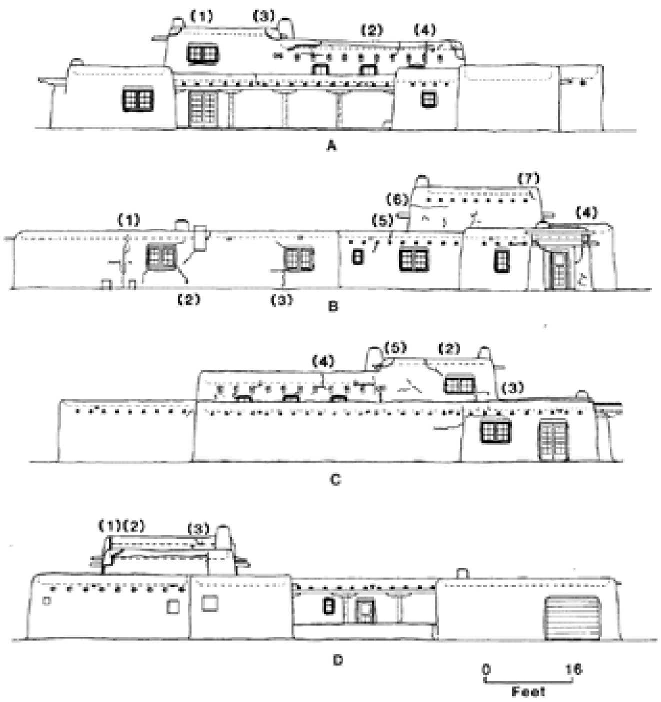


Figure 17 – Assessment of Visible Cracks for the White Sands Visitor Center (King, 1988).

Possible Damage to Conventional Structures from Sonic Booms

Sonic Boom Peak Overpressure (Nominal)	Item Affected	Type of Damage
0.5 - 2 psf	Cracks in plaster	Fine; extension of existing; more in ceilings; over door frames; between some plaster boards
	Cracks in glass	Rarely shattered; either partial or extension of existing
	Damage to roof	Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole
	Damage to outside walls	Existing cracks in stucco extended
	Bric-a-brac	Those carefully balanced or on edges can fall; fine glass, e.g. large goblets
	Other	Dust falls in chimneys
2 - 4 psf	Glass, plaster, roofs, ceilings	Failures show which would have been difficult to forecast in terms of their existing localized condition; nominally in good condition
4 - 10 psf	Glass	Regular failures within a population of well-installed glass; industrial as well as domestic; green houses; ships; oil rigs
	Plaster	Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured or very old plaster
	Roofs	High probability rate of failure in nominally good slate, slurry-wash; some chance of failures in tiles on modern roofs; light roofs (bungalow) or large area can move bodily
	Walls (outside)	Old, free-standing walls in fairly good condition can collapse
	Walls (inside)	"Party" walls known to move at 10 psf
Greater than 10 psf	Glass	Some good glass will fail regularly to sonic booms from the same direction; glass with existing faults could shatter and fly; large window frames move
	Plaster	Most plaster affected
	Ceilings	Plaster boards displaced by nail popping
	Roofs	Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gable-end and wall-plate cracks; domestic chimneys - dislodgement if not in good condition
	Walls	Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage
	Bric-a-brac	Some nominally secure items can fall, e.g. large pictures; especially if fixed to party walls

Figure 18 – Table of Sonic Boom Damage Thresholds by Overpressure (Haber and Nakaki, 1989).

Authors note: damage thresholds may vary for unconventional or sensitive structures.

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—SUBMERGED RESOURCES—

Underwater Archeology and Climate Change in the NPS Intermountain Region

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Introduction

2016 marks a new century of National Park Service (NPS) stewardship of the United States' natural and cultural resources, and one of our greatest challenges is anthropogenic climate change. NPS policy regarding cultural resource management discusses climate change concepts in terms of resource "impacts" (the stresses and vulnerabilities engendered by climate change) and "information" (cultural data on human-environment interactions) (Rockman 2015:37).

Figure 1. Anchor from the Padre Island 1554 shipwrecks. NPS Submerged Resource Center Archives.

These concepts do not stop at the water's edge. Submerged historic structures, shipwrecks, and other underwater cultural sites are vulnerable to climate change impacts, particularly since such sites can be difficult to recognize and their threats easily overlooked. In the NPS Intermountain Region, underwater sites have the additional complication of relative scarcity compared to terrestrial sites.

Submerged archeological sites can have different climate change vulnerabilities than terrestrial counterparts. Included here are three examples of diverse submerged cultural resource sites within the Intermountain Region, each with the potential to be impacted by climate change. This discussion is intended to encourage conversation and consideration for such sites, but is not a prediction: we do not yet know enough about the impacts of specific climate variations. Moreover, projections of global impacts at local scales may be impossible to calculate (Dunkley 2015:218). This highlights the importance of working to increase our knowledge about the effects of climate change on underwater sites.

The Shipwrecks of Padre Island

In a fierce storm in 1554, three Spanish ships wrecked on the shoals near Padre Island, Texas. *San Esteban*, *Espíritu Santo,* and *Santa María de Yciar* were part of Spain's treasure fleet, bearing precious cargo from the New World to Europe. The loss of significant amounts of wealth and human lives marked a major disaster for Spain. The vessels are the oldest shipwrecks yet found in North America (Arnold and Wickman 2010).

Today, Padre Island National Seashore (PAIS) protects these shipwrecks, and their discovery helped to shape Texas laws regarding archeological finds. Archeologists excavated *San Esteban* and *Espíritu Santo*, though scattered pieces of the sites remain buried in the sand (Figure 1) (Slattery 2006). The third ship, *Santa María de Yciar*, has not yet been located. While the ship might have been largely destroyed in the 1950s by dredging, some artifacts and ship timbers may still be buried in the sands off Padre Island (Arnold and Wickman 2010).

Figure 2. S. S. Nicaragua shortly after running aground near Padre Island, 1912. From Padre Island National Seashore Archives.

In addition to the famous 1554 shipwrecks, Padre Island National Seashore is also home to the steamer S.S. *Nicaragua*, which ran aground in 1912 (Figure 2). Part of the *Nicaragua* wreck remains partially exposed at low tide, accessible by park visitors (Figure 3).

Figure 3. S. S. Nicaragua site, approximately 100 yards offshore. NPS Submerged Resource Center Archives.

Climate change research is already underway at PAIS. A recent study on the vulnerability of NPS coastal assets exposed to 1 meter of sea level rise marked 18% of PAIS's terrestrial assets as high exposure (Peek et al. 2015:177-179). Another report lists PAIS among the 25 parks most at risk by climate change (Saunders et al. 2009). But what does that mean for cultural resources that are already submerged? Sea level rise and its associated secondary effects could have significant impacts on near-shore sites, such as the shipwrecks of PAIS.

Increased sea levels and wave action could make sites more vulnerable to erosion, and some fragile sites could be scattered and lost entirely. Possible secondary impacts from sea level rise include changes associated with increased depth, such as seagrass retreats that could destabilize site burial areas. Similarly, depth increases could correlate to changes in benthic chemistry, including temperature shifts and acidification (Wright in press).

Shallow water sites are also at risk of physical damage from the effects of climate change, including increased storm surge, and increased frequency and intensity of major storm events (Figure 4). It is easy to imagine how a partially exposed wreck like *Nicaragua* would be damaged by increased storm surge or a major storm event. Similarly, such impacts to any buried remains of the 1554 wrecks could result in the loss of site coherency, or total site destruction.

Figure 4. Partially exposed shipwreck, Assateague Island National Seashore. NPS Submerged Resources Center Archives.

Figure 5. NPS archeologist mapping *Charles H. Spencer*. NPS Submerged Resources Center, Susanna Pershern, 2014.

The Steamboat *Charles H. Spencer*

A historic shipwreck is not usually the first thing that comes to mind when considering Glen Canyon National Recreation Area (GLCA), but GLCA is home to *Charles H. Spencer*. *Spencer* was a small paddlewheel steamer constructed for bulk ore transport and abandoned at the Colorado River's edge in 1912 (Figure 5). Today, it remains Arizona's only shipwreck nominated to the National Register of Historic Places.

The specific effects of climate change on *Spencer* are still to be determined, but projected deficits in the water supply for the entire Colorado River system will likely lower the average volume of the river (Pershern et al. 2014). While we commonly consider the threats of sea level rise, in *Spencer*'s case, water level decrease could be highly destructive. Uncontrolled drying of waterlogged materials damages archeological materials, particularly wooden remains like those present on *Spencer*.

Intensified wet-dry cycling is also a significant deterioration factor for both wood and iron deterioration (Figure 6). In historic wood, like the timbers present on the *Spencer* site, wet-dry cycling weakens cellular structures and links to physical and chemical deterioration (Blanchette et al. 2004:207-209). For iron, wet-dry cycling can mean higher corrosion rates (Stratmann 2002: 95-96).

Additionally, considerations of secondary climate change effects must include the impacts of invasive species on submerged sites. Warmer temperatures and stronger storms have been recently linked to an increase in invasive mussel numbers in Ontario lakes (Van Cappellen 2015). The presence of quagga mussels have been confirmed from the Glen Canyon Dam to the Paria River. As of 2014, no quaggas were yet present on *Spencer*, but the presence of quaggas would certainly damage the site, adding weight and shear stress that the wreck structure might not be able to support (Pershern et al. 2014).

Figure 6. *Charles H. Spencer* partially exposed. NPS Submerged Resources Center, Susanna Pershern, 2014.

Figure 7. Glacier National Park. NPS Submerged Resources Center Archives.

Shipwrecks of Glacier National Park

Glacier National Park (GLAC) is known for its spectacular vistas and rugged wilderness, but it has also been called the "poster-child for climate change" (Figure 7) (Ellis 2010). Climate change research in GLAC is active, as the park's namesakes face dire threats from exceptional temperature increases; it was projected that GLAC's glaciers will be gone by 2030 if current trends continued (Fagre 2007:228). The evidence for global warming is overwhelming at GLAC, and the impacts of unchecked climate change are incalculable for the park's resources.

This includes potential impacts to GLAC's shipwrecks and submerged cultural sites. The park features rich underwater archeology, particularly since the cold fresh water of GLAC's lakes is an ideal environment for artifact preservation, particularly archeological wood. Notable shipwreck sites include the hull remains of the Fish Creek Bay Wreck and *Gertrude*, a stern paddlewheel vessel in the north end of Upper Waterton Lake within the Waterton-Glacier International Peace Park (Figures 8 and 9) (Russell 1997).

Figure 8. The Fish Creek Bay Wreck, Glacier National Park. NPS Submerged Resources Center Archives.

Figure 9. NPS diver visiting Gertrude, Waterton-Glacier International Peace Park. NPS Submerged Resources Center Archives.

The environment that has maintained GLAC's shipwrecks in a high state of preservation could be dramatically impacted by climate change. Temperature affects deterioration of organics and metal corrosion; without taking into account biological effects, corrosion rates of metals approximately double for every 10°C temperature rise (North and McLeod 1987:74). Warming holds implications for a number of other preservation impacts. Ice cover encourages winter hypoxia in relatively shallow water, but its elimination and correspondingly increased oxidation would encourage deterioration (Rahel and Olden 2008:526, Wright in press).

Temperature rise will certainly impact biological interactions with submerged cultural resources. As discussed with quagga mussels in the Colorado River, GLAC is also threatened by the introduction of zebra and quagga mussels. Park officials are vigilant about preventing these species' spread, but should the mussels invade, they would wreak havoc on submerged resources, including GLAC's shipwrecks. In addition to adding weight and shear stress to wreck structures, zebra mussels accelerate the corrosion of iron artifacts, and encourage the growth of bacterial communities that further degrade artifacts (Watzin et al. 2001). Additionally, the presence of mussels would certainly have a negative impact on tourists who visit park shipwrecks (Figures 10 and 11).

Figures 10 and 11. Before and after: an example of quagga mussel fouling on the B-29 at Lake Mead National Recreation Area from 2006 to 2009. NPS Submerged Resources Center Archives.

Conclusion

This article is a brief overview of some of the threats facing three sets of shipwrecks. It is hoped that the diversity of climate change impacts discussed will provoke further recognition of vulnerabilities, and the realization that climate change has the potential to impact all NPS-managed resources. NPS managers must increase our understanding of climate projections and implications to resources, and prioritize inventorying and documentation of highly vulnerable or stressed sites.

We are still gaining knowledge about the effects of climate change on submerged cultural sites, and thus viable management options. It must be admitted that in the face of overwhelming natural and cultural resource vulnerabilities attributable to climate change, attempting to stabilize or recover every at-risk site may be neither possible nor a reasonable allocation of public funding (Wright in press). Rather, our goal must be to recognize the vulnerabilities of all resources, including those beneath the water's surface, and take necessary action towards both resource preservation, and limiting the relentless progression of anthropogenic climate change.

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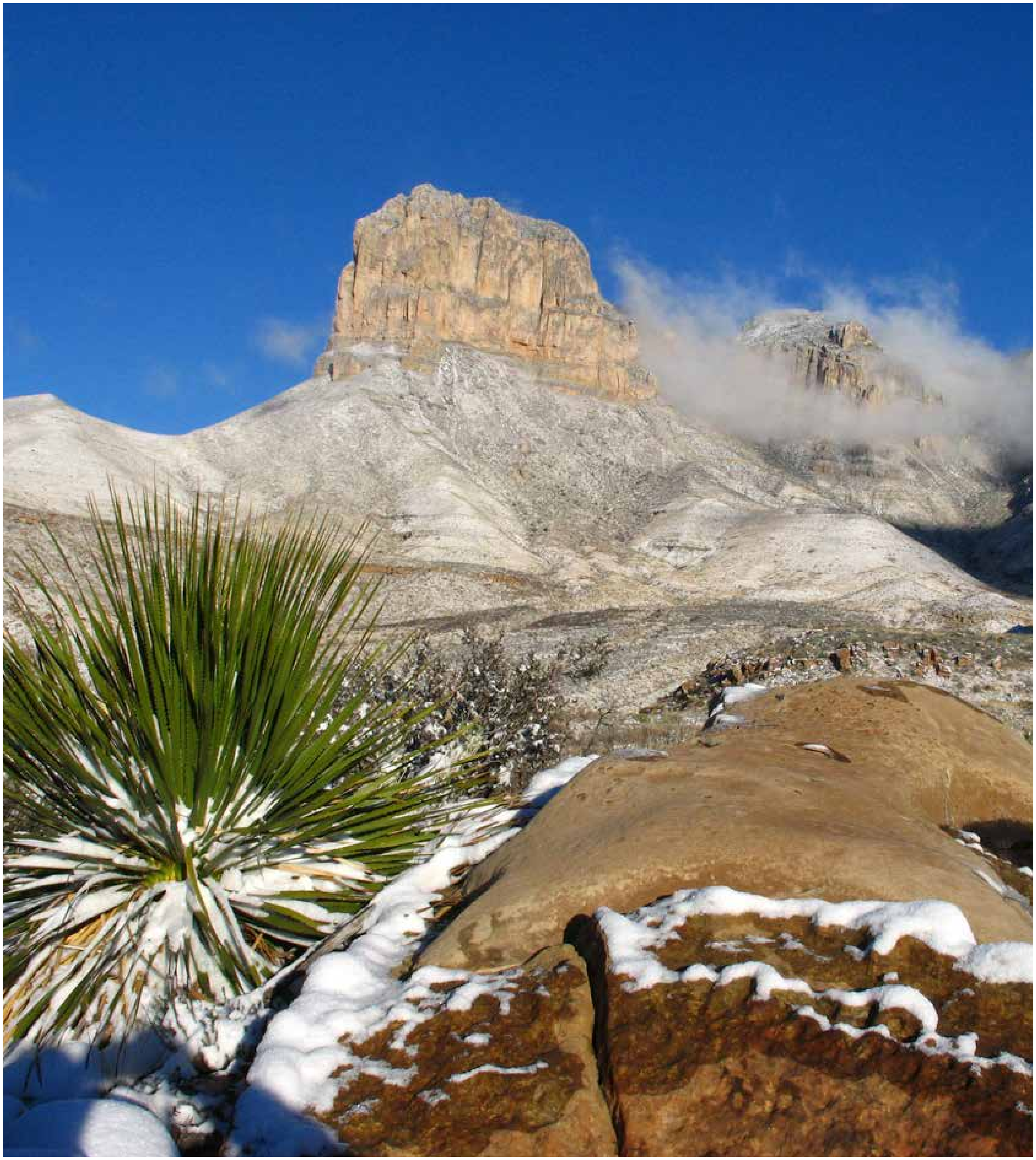

El Capitan in snow, Guadalupe Mountains National Park. (NPS Photo).

2016 National Park Service CENTENNIAL

—NATURAL RESOURCES—

Water Resource Management in an Overtaxed System: The Colorado River Basin

By Jenny Rebenack, Assistant Colorado River Coordinator, Colorado River Basin Parks Program, Intermountain Regional Office; jennifer_rebenack@nps.gov.

Rafting Moonshine Rapid on the Green River, Dinosaur National Monument (2014). NPS Photo/Jacob W Frank.

The Colorado River and its tributaries serve nearly 40 million people and are a vital source of water for agricultural and municipal users throughout the Southwest, as well as comprising a significant part of the heritage of multiple American Indian tribes. The Colorado River Basin (Basin) spans seven states which include Arizona, California, Colorado, New Mexico, Nevada, Utah and Wyoming. With climate change projections indicating reductions in water supply (USBR 2016b) and increasing demand for water (USBR 2012); these imbalances in supply and demand, combined with additional water development in an already over-allocated system, could threaten natural and cultural resources and recreational opportunities at many National Parks, Recreation Areas and Monuments that depend on the Colorado River.

In 1922, the Colorado River Compact (Compact) divided the Basin at Lee Ferry, Arizona, into Upper and Lower basins. This Compact, considered the cornerstone of the "Law of the River," apportioned 7.5 million acre-feet (maf) of water annually to the Upper Basin states (Colorado, New Mexico, Wyoming, and Utah; Table 1), and similarly, 7.5 maf to the Lower Basin states (Arizona, California, and Nevada). Subsequently, the Boulder Canyon Project Act of 1928 ratified the Compact and further apportioned each Lower Basin state their respective fraction of 7.5 maf from the *mainstem* Colorado River (USBR 2008; Table 1). This Act also had the effect of establishing the Secretary of the Interior as the Lower Basin "water master," responsible for contracting water use in the Lower Basin (USBR 2015a). The Upper Colorado River Basin Compact of 1948 apportioned water among the Upper Basin states (Table 1), on a percentage basis, and established the Upper Colorado River Commission (Commission). Unlike the Lower Basin, the Upper Basin states report to the Commission, that is comprised of a representative from each of the four Upper Basin states and one from the United States, all with the same

Table 1. Annual apportionments of water, in million-acre feet (maf), in the Colorado River Basin for the Upper and Lower Basins and their respective states.

Allocation	Million-Acre Feet (maf)
Upper Basin	
Colorado	3.84 (51.75%)
Utah	1.71 (23%)
Wyoming	1.04 (14%)
New Mexico	0.84 (11.25%)
Arizona*	0.05
Total	7.5
Lower Basin	
Arizona	2.8
California	4.4
Nevada	0.3
Total	7.5
Other	
Mexico	1.5
Total	**16.5**

[1] Lee Ferry refers to the Colorado River Compact point at which the Upper and Lower Basins of the Colorado River Basin are divided in the 1922 Colorado River Compact. This is different than Lees Ferry, which refers to the stream gage located near the town of Lees Ferry, Arizona which is located one mile upstream of Lee Ferry (DOI 2015).

[2] Numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines are collectively referred to as the Law of the River (USBR 2008a).

[3] Arizona was allocated 0.05 maf in the Upper Colorado River Basin Compact of 1948 because a portion of the state lies within the boundary of the Upper Basin.

Kayaking Black Canyon National Water Trail, Lake Mead National Recreation Area (2014). NPS Photo/Christie Vanover.

powers and rights. An additional 1.5 maf per year was allotted to Mexico in the United States-Mexico Water Treaty of 1944 (Water Treaty of 1944); thus bringing the total annual allocation of water within the Basin to 16.5 maf (Table 1).

When the Compact was signed in 1922, it was a particularly wet year with the average annual inflow for the period of record (1906-1922) at the Lees Ferry stream gage was 18.0maf (Figure 1; USBR 2015b; DOI 2015). However, the longer-term average from 1906-2012 is only 14.8maf (Figure 1; USBR 2015b; DOI 2015). Thus today, on average, the existing allocation of 16.5 maf exceeds the long-term (and perhaps more realistic) estimate of inflow by approximately 1.7 maf a year. In other words, even without taking into consideration increasing demands due to burgeoning population growth and reductions in supply due to drought and climate change (USBR 2012; USBR 2016a), there probably is not enough water in the Basin to meet current allotments, much less the increase in demand.

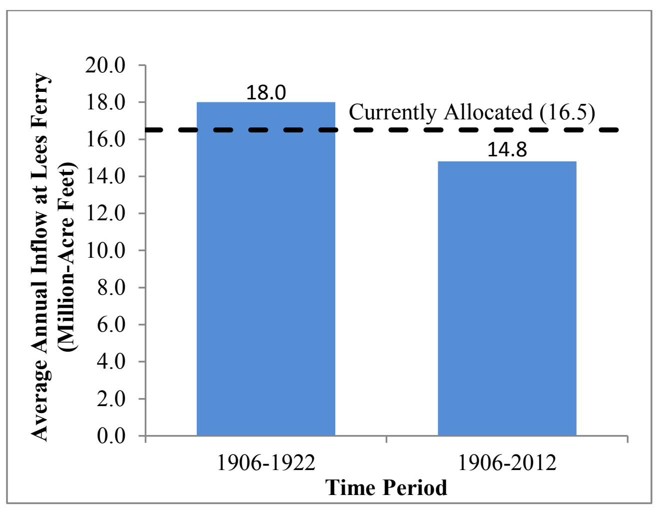

Figure 1. Average annual inflow (million-acre feet (maf)) at Lees Ferry stream gage (USGS 09380000) from 1906-1922 (pre-1922 Colorado River Compact) and the longer-term average from 1906-2012 (USBR 2015b). The dashed line represents the amount currently allocated under the 1922 Compact and the 1944 United States-Mexico Water Treaty, 16.5maf.

The Upper Basin states have not yet fully developed their average annual Compact entitlement of 7.5maf (USBR 2012) and are working to develop their remaining allotments. In contrast, the Lower Basin states are currently using their full Compact entitlements, have no additional surface water supplies to develop, and have instead started using groundwater to meet growing demands (Castle et al. 2014). As a result, numerous surface and groundwater development projects have been proposed within the Upper and Lower basins to meet anticipated shortages (Figure 2).

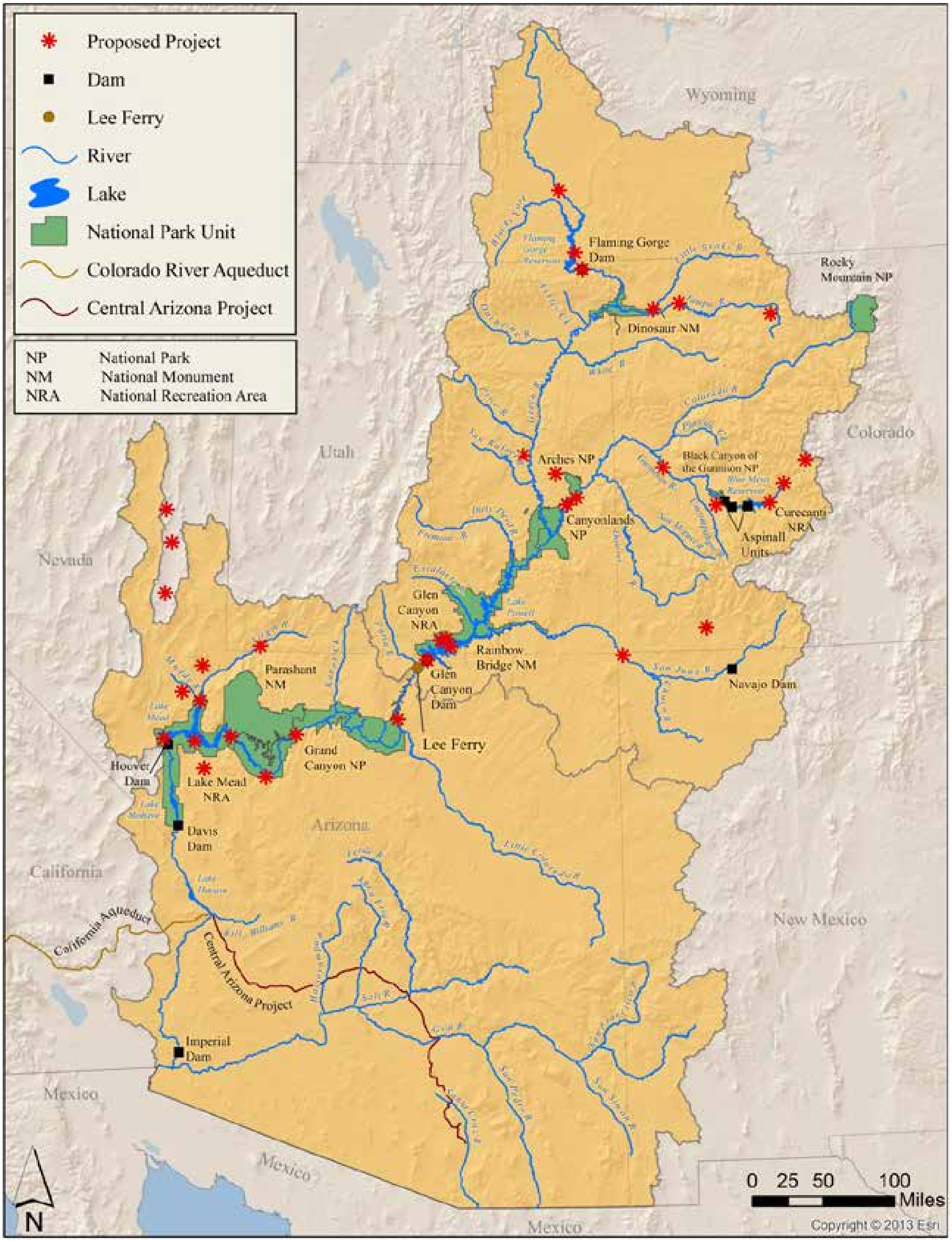

Figure 2. Map showing some of the proposed major water or water-related projects within the Colorado River Basin that could potentially degrade park river and/or reservoir resources.

Yampa River at Sand Canyon, Dinosaur National Monument (2015). Peter A. Williams.

Even in the face of the increasing gap between supply and demand, surface and groundwater continue to be developed throughout the Basin, potentially threatening the unique resources of the National Parks, Recreation Areas, and Monuments along the Colorado River.

In addition to these proposed water projects, there is also a concept being developed by the Upper Basin states to potentially re-operate the dams above Glen Canyon Dam. This concept is a contingency plan that is intended to help address the effects of prolonged drought in the Basin that could cause water levels at Lake Powell to fall below the minimum level necessary to produce hydropower at Glen Canyon Dam. More specifically, the Upper Basin states are considering releasing water from Flaming Gorge, Aspinall Unit, and Navajo Dams (CRWCD 2016) to maintain water levels in Lake Powell and at Glen Canyon Dam that are sufficient to produce hydropower. Revenue from hydropower operations at Glen Canyon Dam helps fund the Upper Colorado River Basin Endangered Fish Recovery Program, San Juan Endangered Fish Recovery Program, and the Glen Canyon Adaptive Management Program (USBR 2008b). If Glen Canyon Dam were unable to produce electricity, these programs would lose this major funding source and power customers could potentially see their electricity costs increase considerably. The National Park Service (NPS) has been participating in the ongoing discussions with the Upper Basin states and U.S. Bureau of Reclamation concerning drought operations. The NPS has particular interest in addressing how the magnitude and timing of these re-operations, if drought operations were implemented, may affect river and reservoir resources.

To better address these concerns, the NPS, through its Inventory and Monitoring Program (Northern Colorado Plateau Network), has instituted annual monitoring of floodplains, channel and sediment dynamics, and riparian vegetation along sensitive reaches of the Colorado, Green, Yampa, and Gunnison rivers in Dinosaur National Monument, Canyonlands National Park, and Black Canyon of the Gunnison National Park. These data and information, collected through on-the-ground intensive surveys and via remote imagery, relate observed changes in the landscape to changes in streamflow, and will be used to help inform reservoir operations and water management decisions.

National Park Service managers are required to manage park units to “preserve unimpaired the natural and cultural resources and values for the enjoyment, education, and inspiration of future generations” (1916 NPS Organic Act). The NPS is concerned that, without consideration for their resources, additional water development and/or changes in dam operations within the already over overtaxed system could cause unacceptable impacts to NPS river and reservoir resources and values. Protection of river resources can often be accomplished by maintaining existing volumes of water while mimicking the shape and timing of natural flows, and protection of reservoir resources largely depends on maintaining critical elevations during certain times of the year. The NPS, through its Colorado River Basin Parks Program and Water Resources Division, will continue to work collaboratively with states and other federal agencies to ensure that proposed water or water-related projects in the Basin consider NPS river and reservoir resources.

Houseboat in Reflection Canyon, Glen Canyon National Recreation Area (2014). NPS Photo/Gary Ladd.

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Waterfall on Ypsilon Lake Inlet Creek, Rocky Mountain National Park, CO. (NPS Photo). A. Sayre Hutchison, Photographer.

2016 National Park Service Centennial

—CULTURAL RESOURCES—

An Interdisciplinary Approach to Architectural Analysis at Montezuma Castle National Monument

By Matthew C. Guebard, Archeologist, Southern Arizona Office, matt_guebard@nps.gov; Lucas M. Hoedl, Archeologist, Montezuma Castle National Monument, lucas_hoedl@nps.gov

Contributing Authors: Angelyn Bass, Larry V. Nordby, Douglas Porter, Thomas C. Windes

Introduction

Montezuma Castle, a five story, 20-room cliff dwelling in central Arizona, has captured the imagination of intrepid explorers, passing travelers, and archeologists for decades. Precariously set in a shallow alcove 90 feet above the Verde Valley, the site is protected from wind, rain, and the harsh desert environment. As a result, ancient walls and wooden ceilings that might otherwise deteriorate quickly are preserved in near-perfect condition. The Castle's well-preserved architecture has attracted numerous visitors and beginning as early as the 1870s, antiquarians and curio seekers began publishing accounts of their explorations at the site. The cliff dwelling's growing popularity culminated in its designation as a National Monument in 1906, the first of its kind to protect a prehistoric dwelling.

Figure 1. Montezuma Castle cliff dwelling (Source: Lucas Hoedl, 2016).

Today, Montezuma Castle is one of the most well-known cliff dwellings in the American Southwest. Every year over 500,000 visitors travel to the site. Instead of the published journal accounts of the 19th century, the Internet is replete with photographs, videos, and written accounts of recent visitor experiences. Despite its widespread and enduring fame, the iconic structure has received surprisingly little attention from professional archeologists or academic researchers. In fact, until recently, most of what was known about the site was published by archeologists over 25 years ago (e.g., Wells and Anderson 1988).

The cliff dwelling's National Monument status obligates the National Park Service (NPS) to study it using the latest scientific methods. The monument's enabling legislation, published in 1906, highlights the cliff dwelling's "ethnological value and scientific interest", a reference to the federal government's duty to study it (National Park Service 1906). Similarly, NPS guidelines for cultural resource management define archeological research as a means to "support management, protection, understanding, and interpretation of archeological resources" (National Park Service 2002). The site's well-preserved architecture contains detailed information about the people that once lived in the cliff dwelling and presents an unparalleled opportunity to learn about the past.

Beginning in 2011, NPS archeologists, university scholars, historic preservation specialists, and tribal representatives from across the American Southwest began a multi-year project to study, record, and interpret the dwelling's prehistoric architecture. The ongoing intent of this project has been to complete multidisciplinary research as a means of developing a long-term preservation plan for the site and improving public interpretation. Of particular interest are four questions that have puzzled antiquarians and archeologists since the 1870s: When did people build Montezuma Castle? How did they build it? When did they leave? And finally, why did they leave? The study and analysis of architecture at Montezuma Castle has provided insight into each of these questions, as well as helped to develop additional questions for future research.

When Was Montezuma Castle Built?

Visitors to Montezuma Castle have long pondered the age of the ancient dwelling. Beginning in 2011, archeologists from the NPS and the University of New Mexico's Maxwell Museum of Anthropology initiated a study of wooden ceiling elements to understand the site's construction history. The cliff dwelling contains 11 rooms with complete ceilings comprised of over 150 individual wooden roof beams. Unfortunately, dendrochronology, an analytical method where a tree's annual growth rings are used to determine a cutting date, has proven unsuccessful at the site. This problem is caused by local conditions, which result in "complacent" growth rings that cannot be compared to master tree ring chronologies for the region. Conversely, Accelerator Mass Spectrometry (AMS), a form of radiocarbon dating, has been used with far greater success. AMS dating uses a Mass Spectrometer to quantify the amount of isotopic carbon in organic objects like wooden roof beams. The amount of remaining carbon isotopes is then used to determine a date for when the object was harvested. At Montezuma Castle, AMS dating has therefore defined possible date ranges for when living trees were cut down and presumably used for roof construction.

Figure 2. Tom Windes collects wood samples in Room 7, Montezuma Castle cliff dwelling (Source: Wendel Navenma, 2011).

When statistically evaluated, AMS dates from Montezuma Castle fall within six homogenous chronological groupings (Windes 2015). These groups suggest that ceilings were constructed using trees harvested during several distinct time periods. Based on clusters of radiocarbon dates, it is likely that initial construction and occupation of the Castle began sometime during the 11th century with multiple periods of expansion and repairs until the late 14th century (Windes 2015). The newly defined occupation dates for Montezuma Castle are much longer than the original estimates put forth by archeologists. This makes the site one of the longest continuously occupied cliff dwellings in the American Southwest.

AMS dates also illustrate a complicated history of wood reuse and suggest that architectural wood was often recycled from earlier contexts. For instance, some ceilings contain wooden elements that were cut many decades or even centuries before construction of the Castle. Reuse may indicate that certain elements were intentionally curated and reused because they held ideological meaning, were unavailable in the local environment, or difficult to harvest and process. Future research may provide insight into the prehistoric environmental conditions or social interactions that led to wood curation and reuse.

How Was The Castle Built?

In cooperation with the University of New Mexico, Department of Anthropology, and Archaeology and Architectural Consulting Services (AACS), NPS staff also studied earthen architecture to understand how and in what order rooms at Montezuma Castle were built. Larry Nordby, retired NPS Archeologist and owner of AACS, analyzed details such as construction joints, wall abutments, doorways, hatchways, and other unique architectural features to decode ancient construction methods, as well as to determine the sequence in which rooms were built.

Nordby's assessment of the site illustrates some of the decisions made by builders and how the dwelling changed through time. Based on architectural evidence, Nordby was able to delineate the expansion of the site into five distinct construction episodes. Interestingly, construction of the Castle initially began on the third

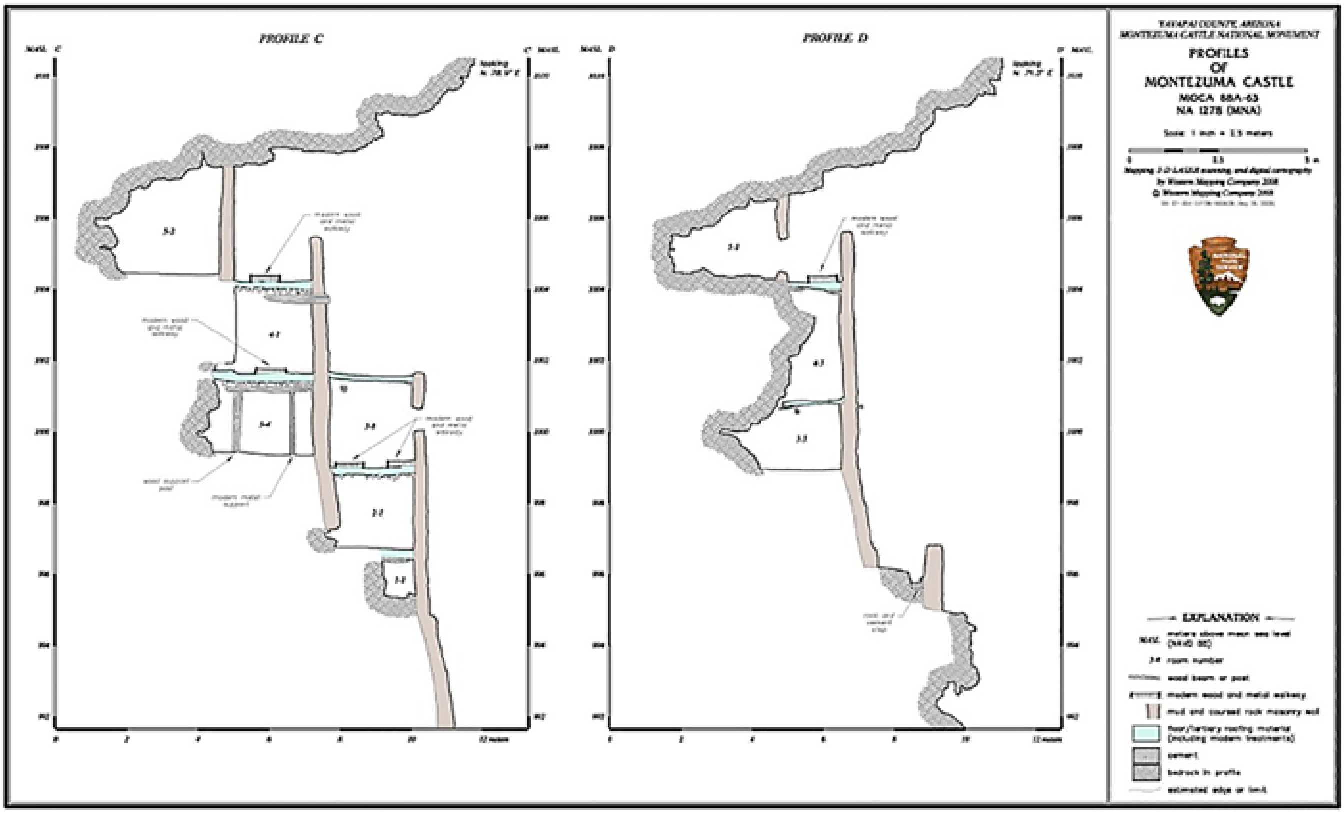

Figure 3. Profile map detailing a cross section of Montezuma Castle (Source: Western Mapping Company, 2008).

level, followed by rooms on level one and then level two. The Castle continued to expand with the construction of level four and five followed by the prominent multi-story tower. Although the construction of the site took less than 100 years, people continually occupied the dwelling for more than two centuries. Nordby's analysis recognizes that each room is a product of decisions made by community members and perhaps an ancient architect, engineer or specialized construction guild, necessitated by the needs of the growing community (Nordby 2015).

Angelyn Bass, an Architectural Conservator from the University of New Mexico, and a team of specialists including Doug Porter from the School of Engineering at the University of Vermont, also assessed earthen mortar and plaster used to build masonry walls and floors. Their study characterized different plaster types using Scanning Electron Microscopy (SEM) and X-ray Diffraction analysis. Technical examination yielded clues about the methods of plaster manufacture, application, and use. Preliminary results suggest that builders selected specific materials for leveling and finishing floors, exterior walls, and interior surfaces. For instance, "base coat" mortars typically incorporate coarse aggregates, possibly to control cracking associated with uneven drying of the thick leveling coats; finish plasters, on the other hand, have finer aggregates with mineral components that contribute colors for fine, polychrome finishes. The fine plaster finishes were installed in uniformly thin layers that vary within and between walls, suggesting, perhaps, that finishing was intended as a way to maintain the appearance and condition of the wall surface. Floor and exterior wall plasters combine well-graded aggregates with binder materials in proportions that yield dense, durable surfaces (Bass et al. 2015).

Figure 4. SEM thin section of plaster from the Room 21 exterior wall. The dark line is soot and dust that accumulated on the wall surface over time. (Source: Bass et al. 2015:8).

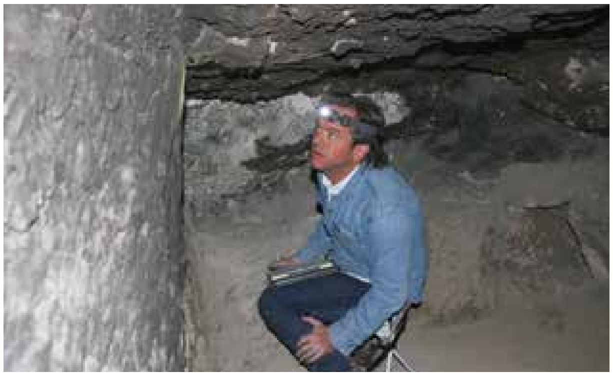

Figure 5. Doug Porter records the condition of walls at the Montezuma Castle cliff dwelling (Source: Lucas Hoedl, 2016).

Figure 6. Angelyn Bass identifies plastered surfaces at Montezuma Castle (Source: Lucas Hoedl, 2016).

The project also assessed the condition of each ancient wall surface and wooden ceilings. In total, 233m^2 (2508 ft^2) of original plaster survives on 53 walls at the Castle. This is approximately 77% of all wall faces at the site and proves that the interior of Montezuma Castle contains a remarkable amount of well-preserved architecture.

Additionally, 16 wall segments appear to have some form of embellishment in the form of colored washes, circular depressions, and formalized incising (Bass et al. 2015). Study of the additional wall and floor plasters is currently underway.

The study of architecture at Montezuma Castle indicates that the ancient builders were expert craftsmen, capable of making careful and calculated decisions about the materials and construction techniques employed at the dwelling. The durability of the materials used and the quality of workmanship employed resulted in an incredibly well-preserved structure. Unlike many other similarly aged sites in the area, Montezuma Castle is the best preserved and thus provides a comprehensive example of construction techniques used widely across the Verde Valley. The information gathered from these forms of analysis give interpretative life to the dwelling and offers intriguing insight into regional cultural practices.

Figure 7. Annotated wall sheet for Room 18, Montezuma Castle cliff dwelling (Source: Bass et al. 2015:135).

When And Why Did They leave?

Using a scientific technique called archaeomagnetic dating as well as traditional knowledge provided by Native American participants, NPS and university scientists can hypothesize when and why the site was abandoned. Archaeomagnetic dating is a form of analysis that uses the earth's magnetic field to determine dates for fire events in the archeological record. In 1933, archeologists working at Castle A, part of the village that includes the Montezuma Castle cliff dwelling, noted evidence for a large and destructive fire (Jackson and Van Valkenburgh 1954). The fire completely destroyed Castle A and produced very hot temperatures, causing iron particles within earthen walls to realign with the direction of magnetic north. In 2011 and 2013, NPS and University of New Mexico scientists collected twenty small samples of burned plaster from one wall at Castle A. These samples were analyzed in the Archaeomagnetic Laboratory at the New Mexico Office of Archaeological Studies. In the laboratory, scientists compared the orientation of iron particles in burned plaster with a known record of changing magnetic orientations through time. Results from archaeomagnetic analysis strongly suggest the fire at Castle A occurred in the interval from A.D. 1375-1395 (Guebard 2015).

Figure 8: NPS Archeologist, Matt Guebard, taking samples for archaeomagnetic dating at Castle A (Source: Melissa Philibeck, 2013).

Additional evidence discovered during the 1933 excavation of Castle A suggests that physical violence accompanied the structural fire. Specifically, human skulls with cranial fracturing and an unburied skeleton found beneath collapsed and burned roofing material suggest that the fire was a product of a violent attack, as opposed to an accidental ignition (Guebard 2015). Interestingly, Native American groups preserve oral histories or stories passed down from generation

Figure 9. Consultation with Apache, Hopi, and Yavapai tribal representatives, Montezuma Castle, 2014 (Source: Melissa Philibeck, 2014).

to generation, describing the fire at Castle A and the abandonment of the Montezuma Castle cliff dwelling. These stories recount a siege-like attack, wherein Castle A was burned and some of the village's inhabitants were trapped inside the Montezuma Castle cliff dwelling. The story concludes with the villager's escape and their eventual resettlement on the Hopi Mesas. The fire at Castle A likely marks the abandonment of both dwellings, although Montezuma Castle was used by subsequent ancestral Native American groups for short-term habitation and storage.


Figure 10. Research team prepares to depart the Montezuma Castle cliff dwelling (Source: Lucas Hoedl, 2016).

The convergence of archeological data and Native American oral history at Montezuma Castle is an incredible and valuable occurrence. Oral histories and archeological data are two very different forms of information, but when analyzed together provide a more complete narrative of past events. Rooted in oral history and supported by archeological data, events at Castle A provide an explanation for the abandonment of the dwelling at the end of the 14th century.

Conclusions

The National Park Service protects the nation's most iconic archeological resources. Among these is the Montezuma Castle cliff dwelling, a site that has inspired curious visitors for centuries. The recent study of architecture using a multidisciplinary team consisting of tribal representatives, archeologists, and historic preservationists has drastically improved our understanding of the iconic cliff dwelling. Many enduring questions about the site, including when and how it was built and when and why it was abandoned have been addressed with data collected using scientific methods and analysis. Future research will continue to provide information about the architecture and the ancestral Native American people that constructed Montezuma Castle over 900 years ago.

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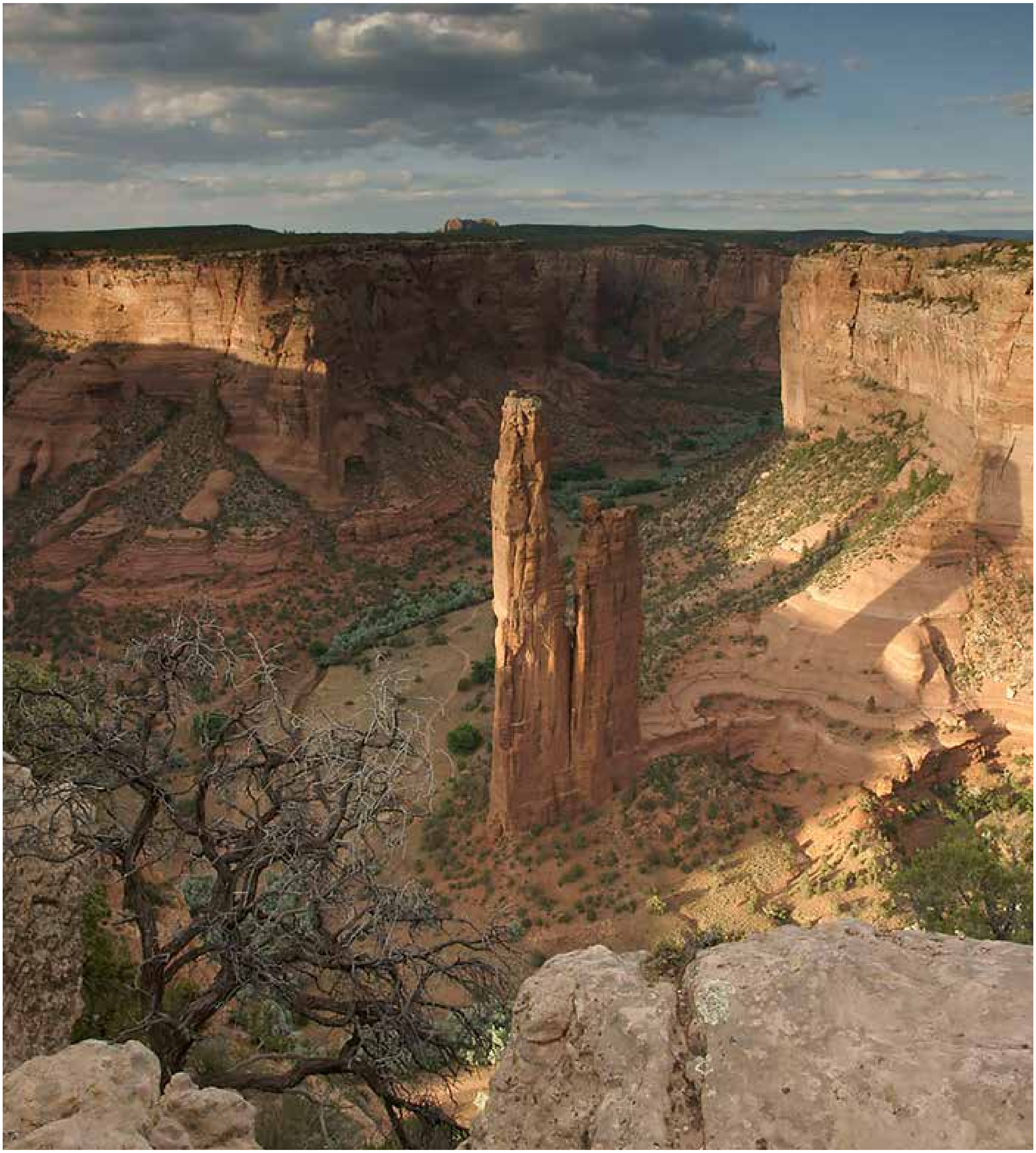

Spider Rock at Sunset, Canyon de Chelly National Monument. (NPS Photo). A. Sayre Hutchison, Photographer.

2016 National Park Service Centennial

—NATURAL RESOURCES—

Feature Story—Student Internships

National Park Service Student Internships – Helping to Bridge Natural Resource Science Needs in the Intermountain Region Parks While Developing the Next Generation of Conservation Stewards

By Don Weeks, Physical Resources Program Manager, NPS Intermountain Regional Office, don_weeks@nps.gov; Lisa Norby, Chief Energy and Minerals Branch, Geoscientists-in-the-Parks and Mosaics in Science Internship Program Manager, NPS Geologic Resources Division, lisa_norby@nps.gov; Limaris Soto, Geoscientists-in-the-Parks Internship Program Coordinator, NPS Geologic Resources Division, limaris_r_soto@partner.nps.gov ; G. William M. Harrison IV, Student Intern, g.william.m.harrison@gmail.com

A personal account by William Harrison

Some discoveries come with careful planning while others combine fortune with an inquisitive mind; the discovery of a rare fossilized egg capsule closely related to sharks at Mesa Verde National Park was of the latter sort (Figure 1).

Figure 1. William Harrison - 2015, Geoscientists in the Parks (GIP) Intern, Mesa Verde NP. (NPS photo).

One of my colleagues on the Vegetation Management Crew, whom I was assisting on my very first day of field work at Mesa Verde, shouted: “William! I think I found a fossil leaf!” and handed me a chunk of the marine Cretaceous Cliff House Sandstone. I was immediately entranced! I knew that the initial identification, as a leaf, wasn’t quite right, since, despite its exceptional preservation, it lacked a leaf’s venation and did not have a carbon film that typifies local plant fossils. Thus my first collection was a mystery!

My first guess at identification of the fossil was obviously an artifact of my Cincinnati upbringing but no more accurate; I thought it resembled Rusophycus, a trilobite burrow but a trilobite in a Cretaceous layer was nigh impossible, so I labeled it ‘unknown, possible worm burrow’ when I added it to the digital catalogue. My search for similar plant, animal, and trace fossils, especially from the upper Cretaceous and in all the published literature that included research in Mesa

Figure 2. William Harrison examining a specimen from the park's repository before photographing. (NPS photo)

Verde, was unsuccessful. The next breakthrough came when I found another specimen, only partially preserved and unhelpfully identified as 'unknown,' while I was reviewing and digitizing the previous fossil collections (Figure 2). The presence of this second specimen from Mesa Verde bolstered my confidence that the complete one was not a random pseudo-fossil.

Dr. James Kirkland, the Utah state paleontologist who reviewed all previous work at Mesa Verde, finally identified these fossils as cartilaginous fish egg capsules (chimaeroid) closely related to sharks, and suggested that my addition may be a new species (Figure 3). Since they are extremely rare, each discovery of a chimaeroid egg capsule is important and I am currently working to publish this specimen. I am grateful to the Geoscientists-in-the-Parks (GIP) program for introducing me to the fascinating paleontology of Mesa Verde National Park, and to George San Miguel (Natural Resource Manager, Mesa Verde National Park) and Dr. Kirkland for their guidance. Because of my experience, I am considering master's thesis topics that would bring me back there.

Figure 3. Egg capsule from a chimaeroid. (NPS Photo)

The National Park Service Geologic Resources Division

This is just one account by a student intern, William Harrison, capturing his experience at Mesa Verde National Park that has made a lasting impression and inspired him to consider pursuing a master's degree in paleontology. At the same time, Mesa Verde National Park has benefitted from his significant discovery, providing a better understanding of the past,100 million years ago in the Mesa Verde area.

The National Park Service Geologic Resources Division (GRD) is providing opportunities each year for college students and recent graduates to assist parks with their natural resource needs while gaining valuable on-the-ground science training and experience through two National Park Service internship programs:

- Geoscientists-in-the-Parks Internship Program
- Mosaics in Science Internship Program

Both of these programs provide opportunities to work on inventory and monitoring, research, interpretation and education projects in parks, networks, and other central offices.

The National Park Service Intermountain Regional Office and Intermountain Region (IMR) parks have been active partners in both of these national programs, providing funding and housing support for a range of projects. In 2015, this resulted in 48 interns supported through the Geoscientist-in-the-Parks (GIP) program and 7 interns supported through the Mosaics in Science Internship (Mosaics) program at 25 IMR parks.

Geoscientists-in-the-Parks Internship Program

The GIP program was developed by GRD in 1996, providing college students and recent graduates with on-the-ground natural resource work experience with the National Park Service (NPS). Projects address a broad array of natural resource needs in air resources, biology, geology, natural sounds and night skies, water resources, and other integrated science topics.

Since the creation of the GIP Program in 1996, Intermountain Region parks have hosted 522 GIP interns, which is approximately 40% of all of the GIPs that have been placed Service-wide. In 2016, 22 GIP intern positions were advertised in the Intermountain Region, with the Intermountain Regional Office financially supporting five positions (Table 1).

Table 1. 2016 NPS Intermountain Region GIP Intern Summer Projects

NPS Unit	Project Title
Bandelier NM	Bird Bander Intern
Big Thicket NP	Environmental Protection Specialist
Bryce Canyon NP	Astronomy/Geology Park Guide; Geologist/Geohazards;
Capitol Reef NP	Geology Interpreter
Chaco Culture NHP	Geoscience Interpretation
Chickasaw NRA	Paleontology Intern
Coronado NM	Speleology Assistant
Devils Tower NM	Astronomy Assistant
Dinosaur NM	Paleontology Assistant
Florissant Fossil Beds NM	Paleontology Technician (2 positions)
Fossil Butte NM	Public Education Geology/Paleontology
Glacier NP	Interpreter
Glen Canyon NRA	Physical Science Technician
Grand Canyon NP	Interpretive Guide/Geologist (North Rim); Interpretive Guide/Geologist (South Rim)
Great Sand Dunes NP&P	Physical Science Technician
Mesa Verde NP	Restoration Hydrologist/Botanist
Salinas Pueblo Missions NM	Paleontologist/Geologist
Waco Mammoth NM	Fossil Preparator
White Sands NM	Physical Science Technician

Interns financially supported in 2016 by IMRO (shaded rows: Big Thicket NP, Chickasaw NRA, Coronado NM, Salinas Pueblo Missions NM, Waco Mammoth NM).

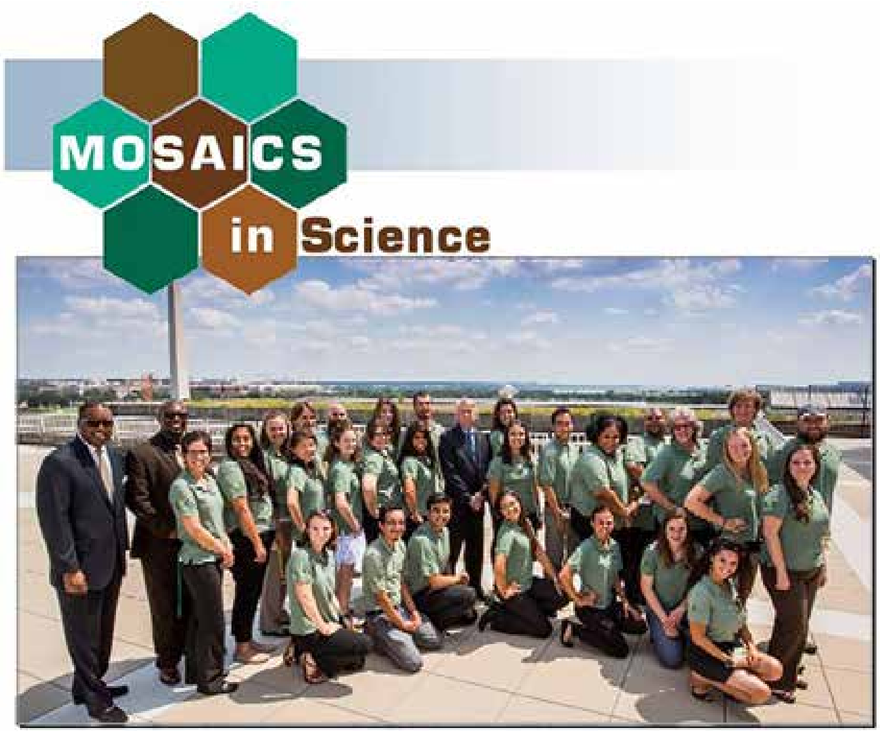

Figure 2. Mosaics Program Interns (GRD, 2015)

Mosaics in Science Diversity Internship Program

In 2013, the Mosaics program was established by GRD in collaboration with the NPS Youth Programs Division (YPD). Fully funded by the YPD, the program provides youth under-represented in natural resource science career fields with science-based work experience with the National Park Service. After the internship projects are completed, a career workshop is held in Washington DC where the interns present the results of their work and develop skills to apply for a federal job (Figure 2).

In 2016, seven IMR NPS units and one Inventory & Monitoring Network hosted Mosaics internships (Table 2). Since the program's inception, IMR has hosted 27 Mosaics interns.

Table 2. 2016 NPS Intermountain Region Mosaics Intern Summer Projects

NPS Unit/Network	Project Title
Bryce Canyon NP	Air Quality Specialist
Capulin Volcano NM	Resource Educator
Dinosaur NM	Paleontology Intern
Florissant Fossil Beds NM	Paleontology Intern
Glen Canyon NRA	Biological Science Research Assistant (Bats)
Greater Yellowstone I&M Network	Biology/Hydrology Assistant
Guadalupe Mountains NP	Biology Technician
Grand Canyon NP	Citizen-Science Programs & Application Development Intern

A Call to Action

This year marks the 100th anniversary of the National Park Service – a moment to reflect and celebrate the Service's accomplishments as we prepare for a new century of stewardship and engagement. In 2013, the National Park Service released *A Call to Action* to begin charting a path toward the second century, and providing concrete actions for us and our partners to use to advance the mission of the Service.

National Park Service student internships though the GIP and Mosaics programs strongly connect to two of the four themes presented in A Call to Action:

- Connecting People to Parks
- Advancing the NPS Education Mission

Under each of these themes, goals and actions are provided to help guide us into the next 100 years. You can easily make the connections from the themes, goals, and actions to the GIP and Mosaics programs.

Theme: Connecting People to Parks

Goals:

- DEVELOP and nurture lifelong connections between the public and parks – especially for young people – through a continuum of engaging recreational, educational, volunteer, and work experiences.
- CONNECT urban communities to parks, trails, waterways, and community green spaces that give people access to fun outdoor experiences close to home.
- EXPAND the use of parks as places for healthy outdoor recreation that contributes to people's physical, mental, and social well-being.
- WELCOME and engage diverse communities through culturally relevant park stories and experiences that are accessible to all.

Action 2: Step by Step
Create deep connections between a younger generation and parks through a series of diverse park experiences. To accomplish this we will collaborate with education partners and youth organizations to create a pathway to employment with the NPS, with a focus on diversifying the workforce.

Theme: Advancing the NPS Education Mission

Goals:

- STRENGTHEN the Service as an education institution and parks as places of learning that develop American values, civic engagement, and citizen stewardship.
- USE leading-edge technologies and social media to effectively communicate with and capture the interest of the public.
- COLLABORATE with partners and education institutions to expand NPS education programs and the use of parks as places of learning.

Action 20: Scholarly Pursuits
Sponsor excellence in science and scholarship, gain knowledge about park resources, and create the next generation of conservation scientists.

As we move into the next 100 years of the National Park Service, we will strive to achieve these goals by connecting and engaging the next generation of park stewards. The National Park Service is having a profound effect on the lives of our youth, and in return, they are helping to advance the mission of the National Park Service into the second century with a new energy, creativity, and passion.

For Additional Information Please Visit:
Geoscientists-in-the-Parks page: http://www.nature.nps.gov/geology/gip/index.cfm
Mosaics in Science Internship Program page: http://www.nature.nps.gov/geology/mosaics/index.cfm

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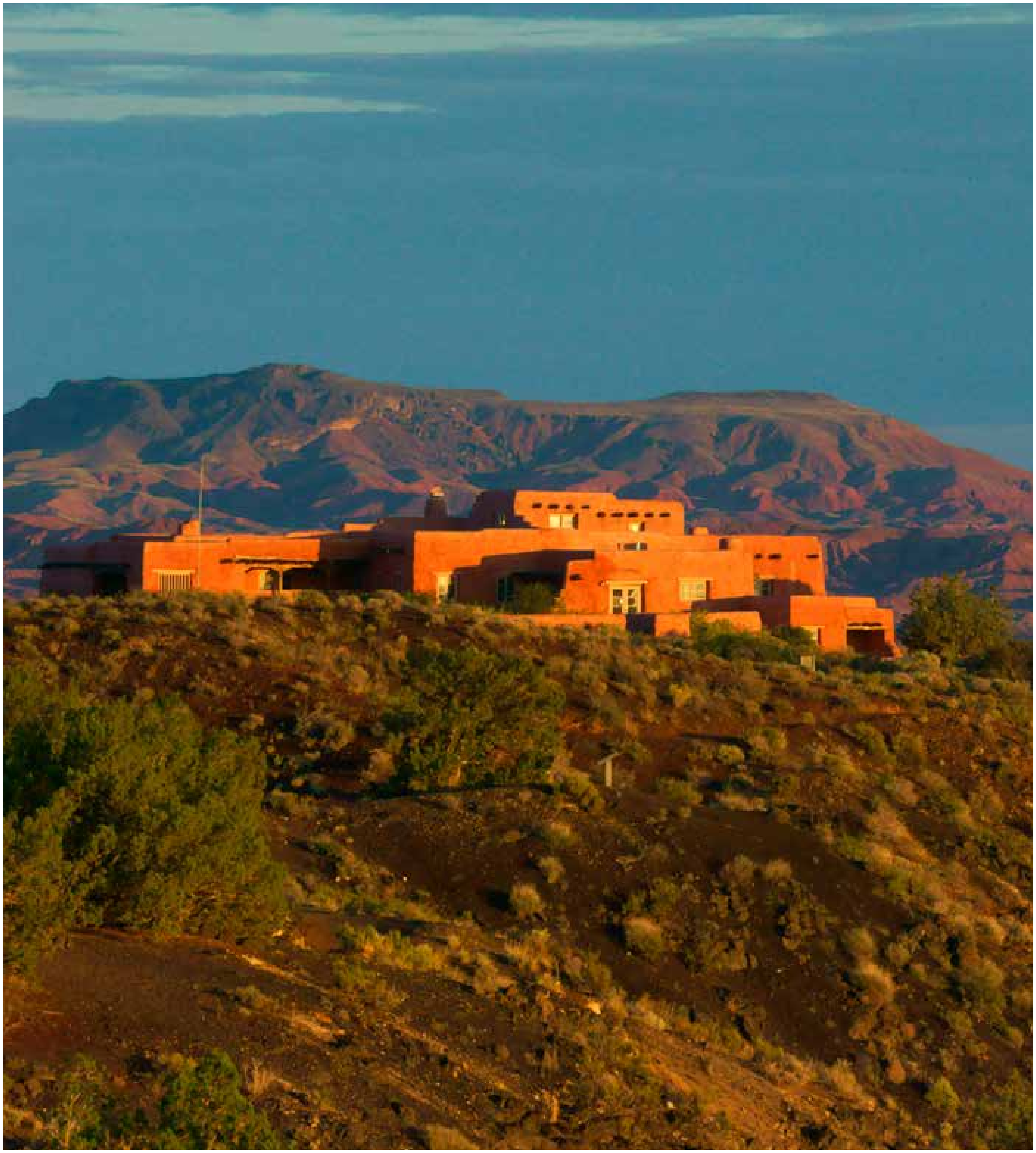
2016 National Park Service CENTENNIAL


Painted Desert Inn NHL at Sunrise, Petrified Forest National Park. (NPS Photo). A. Sayre Hutchison, Photographer.

2016 National Park Service CENTENNIAL

—NATURAL & CULTURAL RESOURCES—

A Fragile Union of Nature and Culture: Aspen Dendroglyphs in the Valles Caldera National Preserve, A Citizen-Science Success Story

By Anastasia Steffen, Interdisciplinary Scientist / Communicator, Valles Caldera National Preserve; ana_steffen@nps.gov and Jonathan Knighton-Wisor, Archaeologist, Statistical Research, Inc.

Figure 1. This glyph is very well carved, and equally precise in its message. It includes a name (PAbLO PEREA), hometown (LA CIENEGA, NM), and the date, day, and time the carver was there (JULIO bIERNES 4 de 1930, ESTUBE AQUI COMO LAS 4 DE LA TARDE)! (Source: VALL Volunteer Crew, Becky Hardy, 2009)

Introduction

Historical aspen carvings left by sheepherder, logger, hunter, or passer-by contain an information payload. These dendroglyphs reveal family names, hometowns, and when the carver was there; they speak of the carvers' occupation, religion, ethnicity, and sometimes their loneliness and dreams. These are otherwise unreported narratives of early 20th century mountain communities that allow the carvers to speak for themselves (Figure 1). Today, threats to this resource are substantially reducing the storied arbors. We report on six seasons of the Valles Caldera National Preserve volunteer dendroglyph inventory program, and discuss some of the results obtained thus far.

Aspen "dendroglyphs" are relatively easy to identify and document in the field, so they are an excellent subject for volunteer/non-professional inventory. The Valles Caldera National Preserve (VALL) volunteer survey program was initiated in 2008 after professional inventory by staff archaeologists revealed an abundance of well-preserved aspen carvings in every survey area. Local residents were eager to volunteer and to

Figure 2. Volunteer Arlene Mansfield assisting in photo-documentation of a dendroglyph that reads: JUANJOSE LUJAN SANTA FE NM. The rough bark in the lower portion of the tree is the result of elk gnawing. The high placement of the glyph may be due to the carver standing on deep snow, or seated on horseback. (Source: VALL Volunteer Crew, Charles Mansfield, 2008).

Figure 3. Volunteer Leader, Colleen Olinger (left), using VALL field forms for documenting aspen dendroglyphs. This carving is of a human figure. (Source: VALL Volunteer Crew, Charles Thorn, 2008).

explore the preserve created in 2000; searching for and documenting aspen carvings was a perfect fit (Figure 2).

Volunteer teams are organized and coordinated by Los Alamos resident Colleen Olinger (Figure 3). The teams of 3-6 volunteers systematically search the forests for carved dendroglyphs in survey areas identified and defined by VALL cultural resources program staff. Each carved aspen is recorded using GPS, digital photography, and drawings of the dendroglyphs. Recreational-grade GPS units are suitable for documenting the locations of these large and immovable cultural features that are easily located. Observations for each dendroglyph are documented on aspen feature-record forms created at VALL for the project (and used also by VALL staff). Carvings are drawn as they appear, and a reasonable identification of content is made by the observer. This way, both the interpretation (Martinez) and the field observation (Mar_in///z) are retained. Attributes captured include names, dates, towns, and descriptions of the images depicted, as well as the height of glyphs from the ground, the direction the glyph faces, the clarity of the carving, and the size and condition of the trees. All data are carefully entered into Excel spreadsheets and delivered to VALL staff at the end of the field season along with the field forms, digital images, and photologs. Thus far the volunteer teams have covered 6,000 acres, logged more than 4,000 hours of fieldwork and data entry, and documented 1,275 glyphs on 995 trees. Most trees (80%; n = 797) have only a single glyph; but several have two glyphs (19%; n =193), and a few have three, four, or five distinct glyphs. There is even one case of a tree with eight distinct glyphs, most with dates in the 1950s, and one each in the 1920s and 1930s.

Carvings on aspen are a rich source of information about 20th century land use. Most of the dendroglyphs encountered in the preserve are much more than the contemporary "AS + NH forever" carvings. These inscriptions contain a self-told record of an otherwise little-chronicled peoples: when they were on the land and who they were, along with hints as to why they were there, their values, their humanity, and occasionally their whimsy. There are currently three datasets for aspen carvings in the Valles Caldera: the

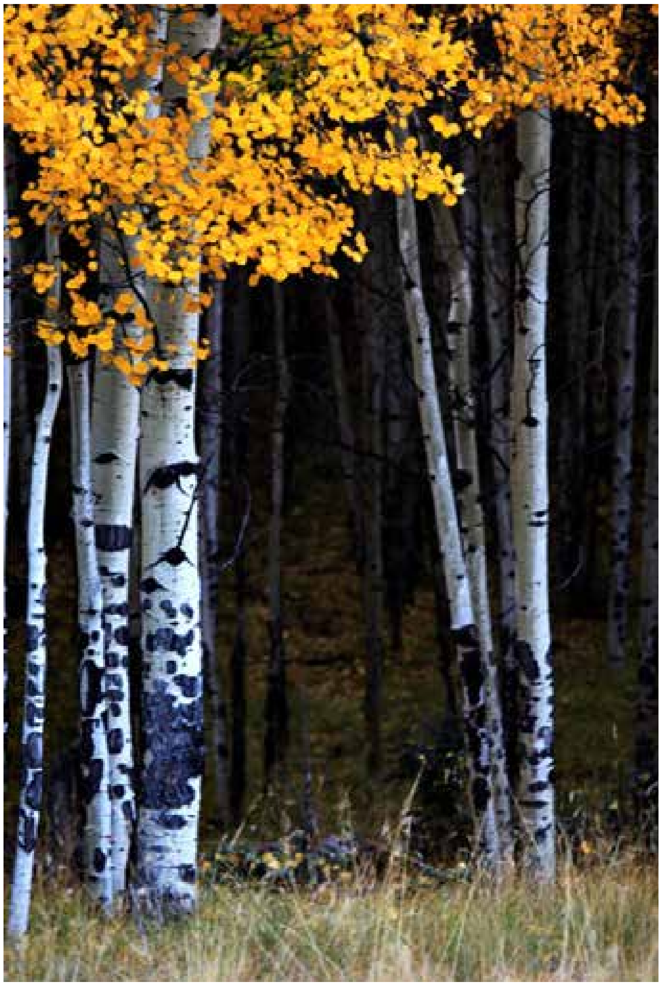


Figure 4. Aspens in the Preserve. Source: Rourke McDermott, 2009

volunteer surveys from 2008-2015, VALL staff surveys from 2001-2015, and a survey conducted 1978-1980 by the University of New Mexico (UNM) Office of Contract Archaeology (Baker and Winter 1981) from before the privately owned "Baca Location No. 1" or "Baca Ranch" became a national preserve in 2000 (see Parmenter et al. 2015). Altogether, the total carved aspens recorded in the preserve exceeds 1,700 trees (Figure 4). VALL staff are currently compiling this integrated database; the results discussed here pertain to the 995 trees documented by the volunteer survey program.

Chronology:

Aspen trees live to greater than 100 years, so the expected range for dates can extend as far back as the late 19th century. About a dozen dates in the 1800s have been documented in the preserve, with 1887 the earliest. Dates from the 1920s, 1930s, and 1940s are the most common (Figure 5). This corresponds with the period when sheepherding flourished under the

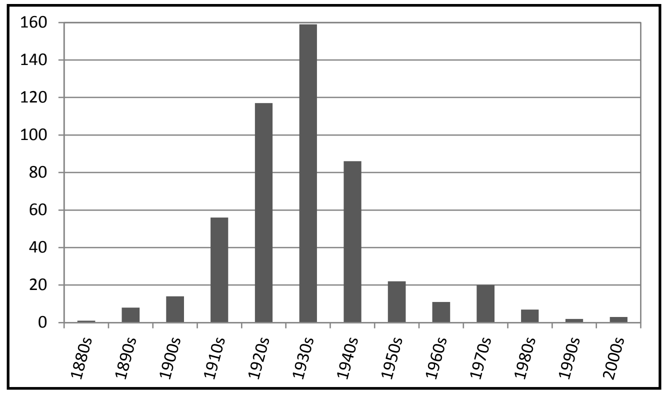


Figure 5. Aspen carving dates, by decade. (Source: A. Steffen, 2016).

partido system in the Baca Location No. 1 (Anschuetz and Merlan 2007; *partido* was a sheep-grazing system wherein sheep owners would pay the landowner annual "grazing fees" in terms of lambs or sheep instead of money; this led to many local herders from nearby communities tending their flocks on the Baca Ranch lands). While sheepherding was very active in the caldera much earlier than the 1920s, there likely was an incremental loss of those trees due to natural aging or senescence. However, the decrease in aspen carvings after the 1940s does not express this sort of sampling bias, and instead the decline in frequency likely reflects the diminishing numbers of sheepherders on the landscape as sheep grazing declined in the 1940s and 1950s to be surpassed by grazing of cattle.

Identity:

Dendroglyphs with people's names are the most commonly observed (Figure 4), and sometimes towns or communities are included (perhaps the carver's hometown). 678 glyphs have discernible names and overwhelmingly the family names are Hispanic. Some of the older carvings demonstrate the beautiful first-names (e.g., Palemon Armijo, Erminio Pachico, Encarnacion Mates, Punciano Madrid, and Teodorito Lucero) that are becoming less common in northern New Mexico today. The most common last-names observed on the glyphs include Trujillo, Sanchez, Lujan, Marquez, Gallegos, Martinez, Herrera, Pacheco, and Saiz (listed in decreasing frequency). The most common name, by far, is Abran Trujillo, found on at least 39 carvings. These have dates mostly from the 1940s but also the 1910s, 1920s, and 1950s; it is possible that more than one generation is represented. Town names include an array of northern New Mexico communities, including Bernalillo, Chamita, Chicon, Cienega, Cochiti, Cordova, Coyote, Cow Springs, Cuba, El Rito, Espanola, Jemez, San Juan, Santa Clara, Santa Fe, San Ysidro, Taos, Vallecito, Velarde, and Zia.

Despite their past importance in the regional economy of New Mexico, sheepherders are underrepresented in the historical record and relegated to the margins of the history of the American West. Dendroglyphs are one way that their role in the history of the preserve can be better understood. Combining the aspen glyphs with archival information can even identify the stories of specific individuals. To explore this potential, Jonathan Knighton-Wisor built a database of the VALL aspen recorded through 2012 and then consulted archival sources as part of his research for a Public Archaeology graduate thesis (Knighton-Wisor 2012a). This example demonstrates how the stories of the aspen carvers can come to life:

Figure 6. Various aspen dendroglyphs with names, dates, and communities, showing different carving styles. (Source: NPS, 2016)

> In Alamo Canyon of the Preserve, there are seven glyphs that read “Nicolas Gallegos” in the same cursive script. Due to taphonomic processes [*natural aging and deformation*] on the bark, the associated dates are only partially legible, leaving the year mostly unknown. These dates read “8 25 191” and “9 3 19”. However, the 1920 San Ysidro census documents that a Mr. Nicolas Gallegos was 29, married to Adela Gallegos, and had three children, ages five, two, and eleven months (U.S. Census Bureau 1920). Mr. Gallegos was a native New Mexican, born to New Mexican parents, owned his own house and could read and write but was unable to speak English. In 1920, his occupation was listed as a wage laboring herder in the sheep ranching industry. This information greatly expands on what was known about Mr. Gallegos from the seven dendroglyphs attributed to him. (Knighton-Wisor 2012:17) *[Italics added] (see Figure 6 to left, for a carving with Nicolas Gallegos’ name)*

Imagery:

Many dendroglyphs are figures rather than words. These include religious imagery such as a variety of Christian crosses (Figure 7), and a few possible depictions of a Judaic Star of David (Figure 8). Common images are of animals, including birds, sheep, and especially horses (Figure 9). Other images include arrows, hearts, boots, shoes, houses, and barns. The most common images are human figures: heads, faces, and bodies (Figure 10). Remarkably abundant on the preserve are sensual or erotic images; these range from curvaceous female shapes to startlingly explicit depictions. Many are jesting and some are fanciful, but all may attest to the isolation of sheepherding or other fieldwork in the mountain ranges far from the artist’s community.

As risks to the carvings increase, rapid inventory is imperative. This citizen-science survey is documenting both the information and images contained in the dendroglyphs qualities, and can augment the inventory that is on-going by cultural resources staff at the preserve. Archaeological surveyors by necessity focus on the ground surface, and must document any and all cultural resources encountered. In contrast, the

Figure 7. Three images of crosses; the upper two dendroglyphs include the name Abran Trujillo and the middle image also has a date of Agosto 12, 1944. (Source: VALL Volunteer Crew,Charles Thorn, 2008, upper two; the third image is by William Geoghegan, 2012).

Figure 8. Left: dendroglyph of a six-point star that may be a Star of David; right image is highlighted to enhance the carving. (Source: VALL Volunteer Crew, Charles Mansfield, 2008).

volunteer teams can move quickly across the landscape with their eyes strictly on the trees, and can focus their time entirely on recording the dendroglyphs. The value of this volunteer effort was recognized in 2010 with a "Preserve America Steward" designation by the Advisory Council on Historic Preservation and the White House (www.preserveamerica.gov).

Figure 9. Image of a horse. (Source: VALL Volunteer Crew, Colleen Olinger, 2008).

Documenting this carved record is imperative as the likelihood of loss of historic trees increases through senescence, weathering, disease, and bark damage by elk, and due to the increasing risk of damaging forest fires. With the exclusion of large fires on this landscape during the last century, the past 100+ years have been a period of unusual preservation of old aspen. Capturing these dendroglyphs before they are lost to fire is a priority. Unfortunately, this risk is now a tangible reality in the Jemez Mountains: more than 50% of the preserve suffered severe fire damage during

Figure 10. Human figures (Left: man with hat and cane; right: man with pipe). (Source: VALL Volunteer Crew, Charles Mansfield, 2008).

Figure 11. Autumn vistas reveal the locations of aspen stands on the Valles Caldera National Preserve. (Source: William Barfuss, 2008).

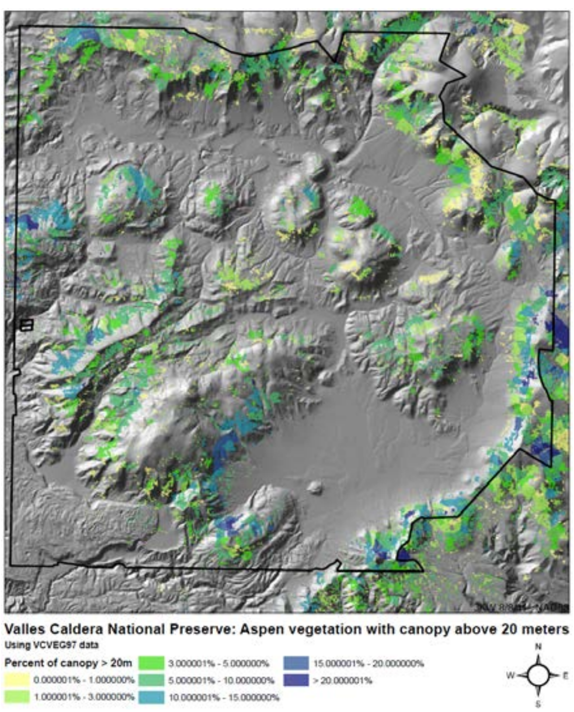


Figure 12. GIS analysis of tree canopy heights (using LiDAR) combined with GIS vegetation data produces a map of tall aspen across the preserve. Darker colors indicate taller (older) aspen stands. (Source: Jonathan Knighton-Wisor, 2012b).

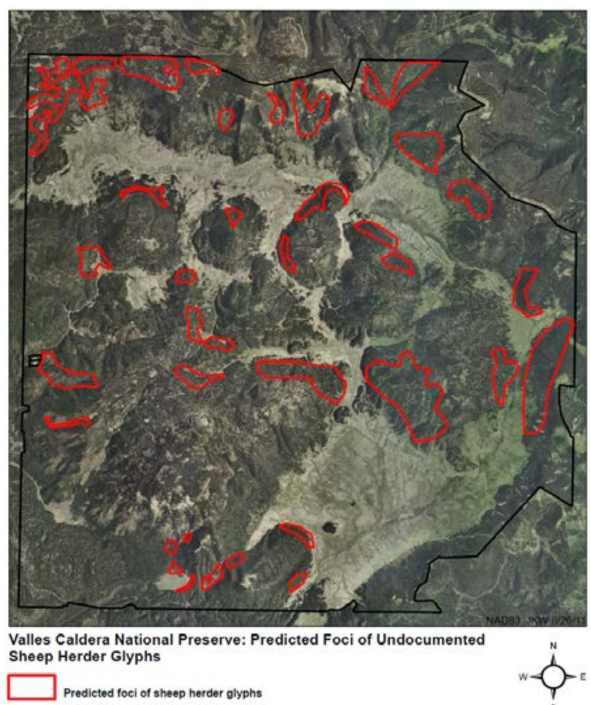


Figure 13. Polygons are based on the GIS analyses and identify areas with older aspen more likely to have historic dendroglyphs. (Source: Jonathan Knighton-Wisor, 2012b).

the 2011 Las Conchas Fire and the 2013 Thompson Ridge fire and many hundreds, if not thousands, of dendroglyphs were lost.

Future survey areas are based on ease of access, inferred fire risk, and targeting the forests most likely to have abundant stands of older aspen. The low-technology method for finding aspen stands is to observe the golden vistas in the autumn (Figure 11). A high-technology approach was created by Knighton-Wisor (2012a) that combines remote-sensing GIS data for vegetation (Muldavin et al. 2006, and R2Veg data) with aerial LiDAR imagery to calculate standing tree height in order to use tall trees as a proxy for old trees. The resulting maps (Figures 12 and 13) guide current and future dendroglyph survey planning. The volunteer team will be back in the preserve inventorying trees again this season, with a focus on aspen stands in the northwest corner. Their data since 2008 are currently being compiled with all ongoing and prior datasets, and are in active use by the VALL cultural resource program, including for post-fire condition assessments.

Acknowledgements: Thanks to volunteer leader Colleen Olinger of Otowi Crossing Press and her team of some 45 volunteers who have logged long hours on the preserve hiking the forests in search of the next aspen dendroglyph and meticulously documenting their finds!

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View of the Valle Grande from Redondo Peak. Valles Caldera National Preserve, NM. (NPS Photo). Photo Credit: Robert Parmenter.

2016 National Park Service CENTENNIAL

—CULTURAL RESOURCES—

Cultural Feature

When Modern becomes Historic: Mission 66 Era and the National Park Service

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MISSION 66

As the National Park Service is in the midst of celebrating its Centennial Anniversary, it has recently completed a service-wide National Register of Historic Places Multiple Property nomination on Mission 66, the substantial postwar World War II development program that played a critical role in shaping the national park experience for millions of visitors. Developed as an effort to bring the national parks up to modern standards of design and convenience after years of neglect during and after World War II, Mission 66 had at least as much impact on the development of the National Park System as the better known and more widely revered Depression era programs involving the Civilian Conservation Corps and the Public Works Administration. While Mission 66 made national parks accessible to an increasingly broad segment of the American public, critics have long accused the program of compromising the very mission that the National Park Service was created to protect. The Mission 66 program provided nearly $1 billion into both infrastructure improvement and base programs and staffing. Roads were improved and sometimes widened and often vehicle parking was added in response to increased visitation. Over 100 visitor centers, the hall mark building of the Mission 66 era, were built, but an even larger number of comfort stations, picnic shelters and administrative and maintenance facilities were constructed.[1] The Mission 66 planning effort was not piecemeal, but was a large-scale master plan accompanied by a park prospectus outlining the Mission 66 design efforts. National Park Service's Eastern and Western Offices of Design and Construction led the planning and design efforts for the park service and provided the architects for much of the development that occurred during Mission 66.

Beyond park infrastructure, the National Park System itself was greatly expanded during Mission 66. Over 70 new National Park Service units were added during Mission 66, expanding access to a larger number of urban visitors. Additionally, research efforts were improved and expanded, enhancing the National Park Service's role in historic preservation that culminated in the passage of the National Historic Preservation

[1]Timothy M. Davis, Research Report, "Mission 66 Initiative", CRM: The Journal of Heritage Stewardship, Volume 1, Number 1, Fall 2003, https://www.nps.gov/CRMJournal/Fall2003/research4.html

Act in 1966. Moreover, the National Park Service's staff was "professionalized" adding further emphasis on research and interpretation of sites. In short, many of the longstanding programs and traditions of the National Park Service we know today were the direct result of the Mission 66 program. In light of all of its accomplishments, why is the Mission 66 Era largely viewed with ambivalence, and sometimes animosity? We believe the reasons can be explained by three factors: 1) the previous lack of sound comprehensive historical research on the Mission 66-era; 2) the emphasis solely on Modern Architecture when evaluating Mission 66; 3) and the administrative burden of the sheer number of extant Mission 66 resources in parks.

In short, many of the longstanding programs and traditions of the National Park Service we know today were the direct result of the Mission 66 program.

The National Park Service began to grapple with the historical significance of Mission 66 resources in the early 2000s, when some of the earliest Mission 66 resources became 50 years old and required assessment for listing on the National Register of Historic Places. An early important study was Sarah Allaback's *Mission 66 Visitor Centers: the History of a Building Type* (2000). Allaback's study focused primarily on visitor centers and highlighted the architectural significance of the building type. In 2007, Ethan Carr published his seminal work on the Mission 66 era entitled *Mission 66: Modernism and the National Park Dilemma* (2007). Carr's book is a sweeping and detailed history of the Mission 66 era and its importance to the history of the National Park Service. Carr went beyond the architecture of Mission 66 and focused on the large-scale planning efforts of the era, framing the significance of Mission 66 to the National Park Service we know today. Carr's research served as a springboard for the completion of the *National Park Service Mission 66 Era Resources Multiple Property Documentation (MPD) Form National Register Nomination.*

At nearly the same time as Allaback's book came out, several NPS regions began efforts to write National Register Multiple Property forms for their Mission 66 resources. In late 2002, Pacific West Region (PWR) Architectural Historian Dr. Elaine Jackson-Retondo and Historian Len Warner began working on a regional Mission 66 Multiple Property Documentation Form (MPD). A partial draft of the regional MPD was completed in August 2004. Simultaneously, then PWR Associate Regional Director for Cultural Resources Stephanie Toothman discovered that there was a project to develop a nationwide Mission 66 MPD. Under the direction of Chief Historical Architect Randall J. Biallas, the Washington Office had hired Historical Landscape Architect Ethan Carr to develop a similar MPD document in concert with his research and author a manuscript that ultimately led to the publication of his book, *Mission 66, Modernism and the National Park Dilemma*, published in 2007. Between the PWR and the Washington Office in 2004, it was determined to collaborate on a nationwide MPD rather than proceed along parallel efforts. After the 2006 introduction of the document, it was not finalized, and it languished. In 2010, the PWR, under the direction of David Louter, currently PWR Assistant Regional Director of Cultural Resources, and Sande McDermott, then IMR Assistant Regional Director of Cultural Resources, decided to issue a contract to complete the MPD to expedite the nomination process of Mission 66 resources throughout the nation. The *National Park Service Mission 66 Era Resources (MPD)* was completed and listed on the National Register in the summer of 2015. The nomination goes beyond simply evaluating visitor center, but develops a broad historical context for the Mission 66 era and associated property types that include comfort stations, housing, campgrounds, roads, and cultural landscapes. The main objective of the *National Park Service Mission 66 Era Resources MPD* is to emphasize the significance of the history of Mission 66 to the National Park Service and not simply focus on the architectural importance of the buildings or if they are the work of architectural masters, which was the initial focus of Allaback's research in *Mission 66 Visitor Centers*.

One of the biggest challenges in evaluating Mission 66 resources is to get past our preconceived notion that there is nothing "special" about these resources. How can resources that appear so mundane, ubiquitous, and conspicuously modern in design and function be significant? Timothy M. Davis, in his article entitled "Mission 66 Research Report', writes, "These preconceptions [regarding Mission 66 resources] may be shifting, however, as nostalgia works its way through the decades and the past creeps ever closer to the present. Just as preservationists throughout the country are turning their attention to such seemingly "modern" structures as glass-fronted banks, suburban shopping centers, and mass-produced tract homes, National Park Service cultural resource managers have begun to embrace their roles as stewards of postwar park development. This renewed interest in Mission 66 has generated a wide range of responses. While a growing collection of Mission 66 structures has been listed on the National Register and a select few have even achieved National Historic Landmark status, many seemingly significant resources have been denied historic stature. More problematically, a number of key buildings and landscapes are currently threatened with demolition or alteration."[2]

Another challenge to the perception of the importance of Mission 66 Era resources comes from the administrative perspective. The total number of Mission 66-related resources presents significant challenges to park managers. With a $12 billion deferred maintenance backlog, many Mission 66 resources are still functioning as park infrastructure and are in need of repairs. Moreover, most have never been evaluated for their eligibility for listing on the National Register of Historic Places, which put them in additional risk for demolition or inappropriate alterations.

In April 2016, the Intermountain Regional Office's Cultural Resources Program held a meeting with selected parks superintendents and cultural resource program managers and two State Historic Preservation Officer to develop a strategy for implementing the new *National Park Service Mission 66 Era Resources MPD* and documenting the hundreds of Mission 66-era related resources that have never been assessed for their eligibility for listing on the National Register. It is our hope that during the National Park Service's Centennial Anniversary we turn our attention to the importance of the Mission 66 era and celebrate its importance in our agency's history.

Grand Canyon National Park, AZ, Horace M. Albright Training Center

The Horace M. Albright Training Center provided a new facility to provide park management expertise for National Park Service employees. Professionalizing employees was a key component of Mission 66 as envisioned by Park Service Director Conrad Wirth. Located on the South Rim of Grand Canyon National Park, Albright Training Center was designed by Park Service Architect, Cecil J. Doty. The classroom and administration building, Kowski Hall, was dedicated in 1963. Five identical dormitories were completed by 1965. All the training center's buildings were successfully rehabilitated by 2006 meeting Park Service historic preservation standards. The historic district was listed on the National Register of Historic Places September 30, 2013. Mission 66 education facilities also included the 1961-1964 rehabilitation of the Harpers Ferry, West Virginia, historic Storer College buildings into the Mather Training Center and the construction of schools in parks for the children of employees.

[2]Timothy M. Davis, Research Report, "Mission 66 Initiative", CRM: The Journal of Heritage Stewardship, Volume 1, Number 1, Fall 2003, https://www.nps.gov/CRMJournal/Fall2003/research4.html

Bryce Canyon National Park, Utah, Gas Station

Designed by San Francisco, CA, architect Ted Spencer for the American Oil Company, the Bryce Canyon Gas Station was built in 1949. Spencer also designed unique gas stations at Grand Canyon (North Rim) and Zion National Parks. The post-World War II Bryce Canyon structure, with its curved and stepped stone masonry wall relating to the nearby historic Bryce Canyon

Lodge, is an exceptional example of Pre-Mission 66 program Modern Movement style as introduced by concession construction. As such, its design represents an early use of modernism in a national park prior to Mission 66. Though no longer used for its original purpose, it is currently being adapted for concessioner activities.

Death Valley National Park, CA, Furnace Creek Visitor Center

The preliminary design for the Furnace Creek Visitor Center, by Park Service Western Office of Design and Construction architect, Cecil J. Doty, featured an expansive interior courtyard. The 1957-1958 project was completed under contract with Welton Becket and Associates of San Francisco, CA, who modified Doty's courtyard channel water feature by installing a kidney shaped pool feature. Each administrative, museum, and auditorium function of a standard Mission 66 visitor center is expressed by individually designed buildings around the enclosed cultural landscape with diagonal paving. Covered walkways link the buildings with the main entrance. The Furnace Creek Visitor Center is a unique solution to construction in a sere climate by providing respite from the elements.

Curecanti National Recreation Area, CO, Elk Creek Visitor Center

Curecanti National Recreation Area was established during the Mission 66 program and its visitor center at the Elk Creek Headquarters was completed 1965-1968 overlapping into the third phase of the Mission 66 Era, the Parkscape USA program. A preliminary design for the visitor center was prepared by Cecil J. Doty, then of the Park Service San Francisco Planning Service Center, and the project was completed by architects Anderson, Barker, Rinker of Denver, CO. The roof structure, a modified gable on hip, defines the building. Ultimately the visitor center was the focal structure of the Elk Creek Headquarters development that included park employee housing, maintenance facilities, and other visitor facilities including a boat launch on Blue Mesa Lake of the impounded Gunnison River.

El Morro National Monument, NM, Visitor Center

The Modern Movement style El Morro Visitor Center was a Mission 66 program addition to a 1938-1939 Spanish Colonial style facility that had served as the park custodian's residence and contact station. The earlier building was designed by Cecil J Doty and Lyle E. Bennett, then Park Service Region 3 architects. As an architect with the Western Office of Design and Construction, Doty, provided a 1964 preliminary design for the new additions that were completed by DeLong and Zahm Associates, Burlingame, CA. Construction of the visitor center addition and the attached maintenance building was completed in 1968. The visitor center contains an exhibit space, visitor information area, and public restrooms, while the earlier building was converted into park offices now located between the two Mission 66 additions. The Spanish Colonial design was reflected in the new construction through the use of battered stone masonry walls and the low gabled roof, supported on purlins, that seems to float over the building.

The connection between the 1964-1968 Mission 66 program visitor center and the original Spanish Colonial style 1938-1939 building utilizes the original patio as a courtyard for visitor use. The courtyard and the earlier building can be viewed from the extensive glazing of the visitor center and is accessed by a rear covered area that also provides access to the trail to the historic pool and inscriptions. Able to relate to the original building, consulting architect Scofield C. DeLong, who had worked for the Park Service before World War II, was an expert in Spanish Colonial style architecture. Similarly, Cecil Doty and Lyle Bennett were aficionados of the Puebloan and Spanish Colonial style and designed the original building of El Morro Visitor Center to reflect the historic and natural setting of the park's premier features including early Spanish inscriptions and the Puebloan ruins on the top of the rock formation that gives the park its name. The adaptive reuse of the earlier historic structures was characteristic of many Mission 66 projects that included restoration such as at Independence National Historical Park and complete reconstructions such as at Appomattox Court House National Historical Park.

El Morro National Monument, NM, Maintenance Building

The maintenance building addition to the El Morro Visitor Center is located at the north end of the complex adjacent to the 1938-1939 building. Because of its relationship to the other components, it was designed to reflect the visitor center addition with a low gabled roof supported on battered stone masonry piers. Typically, the maintenance building has large garage doors to provide access for vehicles, storage, and other shop activities. Maintenance staff offices are included in the structure and the adjacent garage of the original building was adapted for additional staff space. Because of its location, the building fronts an enclosed maintenance yard further separating it from visitor access. In other parks larger Mission 66 Era maintenance buildings, usually independent of visitor service areas, provide separate stalls for carpentry and plumbing workshops, and mechanical repair shops as well as storage for equipment and supply inventories.

Glacier National Park, MT, Administration Building

Designed by Harry Schmautz of Brinkman and Lenon Architects, Kalispell, MT, the Glacier Administration Building at West Glacier Headquarters is one of the few Mission 66 program buildings designed exclusively for use as park offices. As a result the park's two Mission 66 visitor centers provided only visitor services. The administration building is the focal point of the West Glacier Historic district that includes maintenance buildings and several generations of Park Service employee housing that includes Mission 66 residences. Built 1962-1963, the administration building employs Modern Movement style through flat roofs, cantilevers, and ribbon windows while responding to the natural environment with the use of stone masonry wall planes.

Grand Teton National Park, WY, Jackson Lake Lodge

Jackson Lake Lodge, introduced the American public to a large Modern Movement style hotel in Grand Teton National Park. Though the building, constructed 1954-1955, was much maligned in the contemporary press, the prestige of the Grand Teton Lodge and Transportation Company backed by the Rockefeller family and the building's architect, Gilbert Stanley Underwood, enhanced the project. Underwood, who had a earlier history with the National Park Service through rustic hotel design of the 1920s, created a Pre-Mission 66 program building of wood textured concrete stained brown. The design intent was to relate the shed-roofed building to its natural environment. The large windows of the lounge on the second floor overlook Jackson Lake and beyond to the Teton Range. With the construction of separate guest units as part of its historic district, the lodge contains guest services: registration, dining, and the magnificent lounge space. Its construction helped to solidify the Park Service's modern movement design choice. The lodge and subsidiary buildings are listed as a National Historic Landmark.

Jefferson National Expansion Memorial, St. Louis, MO, Gateway Arch and Landscape

Gateway Arch, the focal feature of Jefferson National Expansion Memorial, St. Louis, MO, was designed by eminent Finnish-American architect Eero Saarinen. He was the winning entrant of a design competition in 1948. Saarinen's design is an inverted catenary curve arch constructed with a structural metal skin. The 630-foot high arch was constructed 1962-1965 and thus spans the pre-Mission 66 years and the Mission 66 program. The setting represents one of the most important cultural landscapes of the entire Mission 66 Era. Dan Kiley, who collaborated with Saarinen on the winning design, was a major practitioner of Modern Movement style landscape design. During the Mission 66 Era Kiley was the only private landscape architect to work for the National Park Service. When Kiley's contract expired the project was completed by landscape architect John Ranscavage of the Park Service San Francisco Planning and Service Center. Kiley's strong use of landscape geometry was maintained. Since 1986, Gateway Arch has been listed as a National Historic Landmark.

Lake Mead National Recreation Area, NV, Boulder Beach Residences

The three 1959-1960 Boulder Beach residences designed by Robert D. Newcomb, Western Office of Design and Construction, significantly departed from the Park Service's Mission 66 program "Standard Plans for Employee Housing" issued in 1956, 1960, and 1964. Newcomb designed site specific houses of concrete brick that feature an H-shaped plan to provide maximum air circulation for the bedroom and living spaces in the warm climate. Each featured a carport that provided access to the sheltered main entrances located between the wings.

Cape Cod National Seashore, MA, Salt Pond Visitor Center

Cape Cod National Seashore was established by Congress in 1961 during the Mission 66 program as the first national seashore. The Salt Pond Visitor Center designed by architect Ben H. Biderman of the Eastern Office of Design and Construction was built 1964-1965. The visitor center utilized red brick, strong vertical cornices, and bell-cast roofs forming wide eaves that suggests traditional architecture. The central hexagonal entrance feature is flanked by elongated hexagonal wings displaying the Eastern Office's preference for strong geometrically designed buildings. The eastern architectural design office was managed by architect John B. Cabot, who was the counter part of Cecil Doty in the Western Office of Design and Construction. During the Mission 66 program Cabot provided significant nationwide overview of National Park Service Design, which helped maintain high standards of design and construction.

Yosemite National Park, CA, Yosemite Lodge

Yosemite Lodge, with a construction history from 1916 to 1937, was augmented after World War II with three Pre-Mission 66 motel units of 1951-1955. San Francisco architect Eldridge Theodore "Ted" Spencer, who was the Yosemite Park & Curry Company's chief architect, designed the early motel units and replaced the old main lodge with a new core lodge complex in 1955-1956. Three guest service facilities for registration, for a lounge, and for restaurants were constructed around an open courtyard, which is traversed by covered walkways between the buildings. Spencer, who had been working in the park since 1928, fully embraced the Modern Movement style. The lodge buildings have low steel framed gabled roofs appearing to float over transparent glazed walls forming pavilions such as in the Lounge Building where the gable end glazing brings nature into the space. All the glazed fenestration was augmented with "Airslide" doors to open the pavilions to the courtyard, terraces, and surrounding vegetation. The project was completed by 1970 with the construction of a roadway and parking forming a cultural landscape and with the construction of 14 motel units, also designed by Spencer.

Zion National Park, UT, Oak Creek Housing

At Zion National Park, architect John B. "Bill" Cabot, then located in Region 3 in Santa Fe, NM, designed five houses in 1950-1951 that infill the residential Oak Creek Historic District. As a Pre-Mission 66 program project, the Modern Movement style ranch houses have hipped on gabled roofs and nearly identical front and rear elevations that allowed for flipping the basic floor plan to alter the garage locations and reduce repetetive details. As a fire precaution the garages are constructed of concrete block. Each interior has a passive air circulation system that allows hot air to rise through the gable end vents accomodating the Southern Utah climate. Cabot went on to a position as Regional Architect in the Omaha office before joining the Eastern Office of Design and Construction in Philadelphia where as Supervisory Architect he managed the Division of Architecture. There he helped inplement the "Standards for Employee Housing" issued in 1956, 1960, and 1964, as well as visitor center design and other collaborations with his staff and nationally recognized private architect commissions. As Chief Architect of the National Park Service 1961-1965 he oversaw many design aspects of the Mission 66 program. From 1966 into the Parkscape USA program to his retirement in 1970, Cabot was a Special Assistant to the Director of the Park Service.

Petersburg National Battlefield, VA, Visitor Center

The Petersburg National Battlefield Visitor Center was designed by architect Ben H. Biderman of the Philadelphia Planning and Service Center in 1965 and constructed 1966-1967. Like many of the innovative visitor centers designed by the Eastern team, the Petersburg Visitor Center is octagonal in plan view with a flat roof. The visitor center is constructed with Flemish bond brick masonry as a salute to traditional Virginia architecture. The ground level entrance opens into an information space that provides access to the upper exhibit space level that extends around a central space that once housed a large relief map of the battlefield area. Large windows, opposite the entrance feature, provide a vista over a section of the battlefield to bring outdoors scene into the exhibit space. Below the museum space, in a raised basement area, are park offices with above grade windows. An exterior ramp provides access to public restrooms and the offices.

Glacier National Park, West Glacier Headquarters Park Housing

The West Glacier Headquarters at Glacier National Park has the earliest National Park Service built houses and numerous pre-World War II houses. The area was augmented in 1947 and 1952-1953 with three Pre-Mission 66 program houses. Two of the later houses became prototypes for one design of the Park Service's "Standard Plans for Employee Houses," issued 1956, 1960, and 1964. On curvilinear streets, laid out before World War II, twelve standard Mission 66 program houses were constructed followed by an additional eight houses in 1959, two apartment buildings, and three larger standard houses in 1965. Their construction completed residential infilling of the West Glacier Headquarters area. As such, the Mission 66 program construction of residences spans the ten-year program. Historical significance of the Mission 66 Era housing was established as an addendum to the existing West Glacier Historic District because of the four phases of Mission 66 Era construction that provides a continuum of development in the headquarters area from 1916 to 1965.

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Waterfall after rainstorm. Zion National Park. (NPS Photo).

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