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BRIDGING DIGITAL AND ANALOG DOCUMENTATION FOR THE PRESERVATION OF ANCIENT PUEBLOAN SITES

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ABSTRACT:

The Four Corners region, where Colorado, Utah, New Mexico, and Arizona meet, is the location of one of the most significant archaeological sites in the United States, the Lowry Pueblo in the Canyon of the Ancients National Monument. This case study examines two aspects of the documentation process for the Lowry Pueblo. First, a collaborative model of multiple stakeholders dedicated to an integrated digital and analog documentation approach. Second, the method for determining how digital and analog techniques were used from site preparation to the final submittal of Historic Architectural Building Survey (HABS) drawings to the Library of Congress. This integrated documentation approach used for the Lowry Pueblo is part of a strategy informed by predicted future human impacts on these rare ancient resources and fulfilling a unique tribal request for minimally impactful management. The approach allows natural erosional processes to continue unabated at less visited remote "backcountry" cultural sites, and for proactive stabilization to occur at heavily visited publicly accessible "front country" areas. The combined documentation methods used allowed for creation of highly detailed models, digital applications, and nuanced, aesthetic HABS drawings of the stunning 1,000-year-old cultural resources. The outcomes contribute to informed decision making for future analysis, stabilization assessment, resource interpretation, archiving, and the dissemination of information for public benefit, while deepening an understanding of the history and people that inhabited the land.

1. INTRODUCTION

1.1 Context

The rugged landscape of the Canyons of the Ancients National Monument in the American Southwest has various names given to it by the people who occupied the area, demonstrating its importance in the ancestral histories and modern identities of several indigenous cultures. Pueblo, Ute, Navajo, and Apache tribes inhabited these lands for millennia, entrusting them to hold the power of ancient, long-established knowledge. Today the Four Corners region, where Colorado, Utah, New Mexico, and Arizona meet, is the location of one of the most significant archaeological landscapes in the United States. It presents the opportunity for developing documentation methods for this critical cultural area and the possibility for a deeper understanding of the land and its resources.

While the increased use of LiDAR (Light Detection and Ranging) and drawing software technologies have expanded the techniques for documentation traditionally accomplished through analog hand drawing, it is necessary to consider how small, combined changes in integrating digital and traditional documentation approaches may have a positive outcome on the ability to record a significantly increased number and more comprehensive range of historical sites. The blended method of combining digital and analog documentation approaches can contribute to a more meaningful understanding of an ancient historic site by using multiple lenses of perception for interpretation and cultural resource management.

This case study examines a collaborative model involving multiple stakeholders integrating analog and digital technology to document an ancient Puebloan site. The focus is on the documentation process for developing digital products and Historic Architecture Building Survey (HABS) drawings used for interpretation and resource management of the Lowry Pueblo. The Lowry Pueblo, built and occupied between the eleventh and thirteenth centuries, was declared a National Historic Landmark (NHL) in 1967 and is now part of the Canyon of the Ancients Monument (CANM).

1.2 Canyon of the Ancients National Monument (CANM)

The Canyons of the Ancients National Monument (CANM), located northwest of Cortez, Colorado, is a 174,000-acre (approx. 70,415 hectares) cultural landscape with an estimated 30,000 archaeological sites preserving the breadth of human activity from villages to petroglyphs. Approximately 8,300 cultural resources from the CANM have been recorded using photographs, narratives, and drawings. The monument is part of one of the world's most extensively studied prehistoric landscapes and has long been recognized for the local abundance of globally scarce prehistoric resources. A presidential proclamation included the Lowry Pueblo National Historic Landmark (NHL) within the boundary of the CANM in June of 2000. The landscape offers "an unparalleled opportunity to observe, study, and experience how cultures lived and adapted over time in the American Southwest" (President William J. Clinton, June 9, 2000).

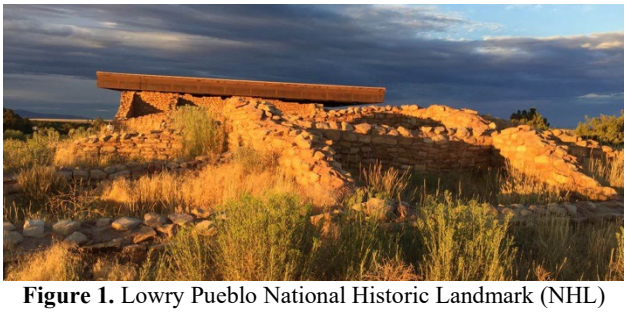

Figure 1. Lowry Pueblo National Historic Landmark (NHL)

1.3 Lowry Pueblo

Located within the CANM is the Lowry Pueblo National Historic Landmark, designated in 1967 as an Ancestral Puebloan village constructed and utilized during the late Pueblo II and early Pueblo III periods (BCE 1085 to 1240). Considered one of the northernmost sites of the Puebloan civilization, the site's masonry style, mesa-top setting, and architectural design are hallmarks of large communities constructed during the Great Pueblo Period of the Northern San Juan Ancestral Puebloan Culture. Construction of the multi-storied, 50-room Ancestral Puebloan village began in 1061 for a community of about 50 people who inhabited the site until the late 13th century. The site was first recorded in 1916 with an initial excavation between 1930 and 1934 by an archaeological crew from the Field Museum of Natural History (Martin, et al. 1936). Before its NHL designation in 1967, the area was re-excavated in 1965 for stabilization and interpretation purposes.

The Great Kiva and Great House are the Lowry Pueblo's most visible components, used for domestic and ceremonial activities. The site consists of masonry structures, including 39 surface rooms, seven kivas, a cylindrical tower, and a separate Great Kiva. The Great Kiva appears to have been the civic focal point for the surrounding community, consisting of over 40 additional contemporaneous structures within a one-square-mile area. It is several times larger than the other kivas, all located inside the great house, and potentially served purposes for the surrounding hamlets. The Great House was a multi-story structure with a pre-planned, rectangular layout. Its rooms are, on average, larger than those in "local" Puebloan architecture. The pueblo's outer walls, constructed in the Chaco style with double layers of stone blocks alternating with bands of smaller stones enclosing a core of rubble fill, are characteristic of the Chaco culture in northwest New Mexico about 100 miles south of Lowry. Lowry is among the northernmost "Chacoan" communities, likely forming an interdependent network of villages, farms, roads, and ceremonial centers across the northern portion of the Ancestral Pueblo homeland. (Colorado State Parks 2023).

2. COLLABORATION

2.1 Partnerships

The multi-year partnership and digital documentation project at Lowry Pueblo NHL included federal land managers from CANM, the Bureau of Land Management's National Operations Center, volunteers, and the University of Colorado Denver faculty and students in the Historic Preservation, Architecture, and Landscape Architecture graduate programs. Students investigated, documented, and preserved publicly interpreted prehistoric masonry architecture within the cultural landscape of the CANM. The partnership emphasized the value of the knowledge of built environments as a resource for shaping the future. It engaged a broad constituency to enhance public understanding and appreciation of culture by investigating material heritage.

Bureau of Land Management (BLM): The Bureau of Land Management (BLM) is the national agency within the United States Department of the Interior that oversees one-eighth of the federal lands throughout the country, or approximately 250 million acres (101,171,410 hectares). As part of its Resource Management Plan (RMP), the BLM developed a stratified approach for the CANM informed by predicted future human impacts on the ancient sites. Created in 2010 by a team of archaeologists, a critical priority of the RMP included collaborating with tribal members to fulfill their unique request for minimally impactful management and allowing the natural erosional processes to continue unabated at the remote and less visited cultural sites. The approach focuses visitation and stabilization efforts on twelve designated "public" areas while avoiding significant intervention at other remote locations (RMP; BLM 2010). The BLM manages the Lowry Pueblo, one of the most significantly developed, stabilized, and interpreted prehistoric sites from the Pueblo period. This site plays a vital role in the BLM's mission to preserve and educate the public about the depth and significance of Native American culture.
Role: project lead and funding.

Center of Preservation Research (CoPR): At the University of Colorado Denver (CU Denver), the Center of Preservation Research (CoPR), established in 2008, and the Master of Science in Historic Preservation (MSHP), established in 2011, became the mechanisms to address preservation education. The CoPR Learning Lab model fostered applied and traditional research linked with experiential learning using inventive and real-world approaches within an educational setting. Students engaged in projects related to historic structures and cultural landscapes focused on understanding the connection of the built and natural environments as critical to a sustainable future. In partnership with the BLM, faculty, research associates, and students investigated conventional and cutting-edge documentation methods.
Role: fieldwork, documentation, education, and research.

CyArk: Founded in 2003, CyArk was a forerunner in applying 3D recording technologies. They introduced the CoPR to LiDAR technology and provided training and assistance in developing a CoPR training center. CyArk focuses on preserving and celebrating cultural heritage while linking people to heritage through digital documentation. By creating place-based web, mobile and immersive experiences, they give visual access to the world's cultural heritage (CyArk 2022).
Role: fieldwork, digital interpretation, and data archiving.

History Colorado and the State Historical Fund (SHF):
Established in 1879, History Colorado is an agency of the State of Colorado under the Department of Higher Education, focusing on access to Colorado's history through cultural and heritage resources. The organization houses an extensive collection of artifacts, archives, and historical photography. History Colorado created the State Historical Fund to administer state-wide grants for preservation projects demonstrating public benefit. In 1990 a constitutional amendment legalizing gambling in three state mining towns mandated that a portion of gaming tax revenue be contributed to the State Historical Fund to fund historic preservation projects throughout Colorado. (History Colorado 2023)
Role: HABS drawings funding.

National Park Service (NPS): National Park Service (NPS): The National Park Service has managed the national parks throughout the United States for over a century and works closely with other federal agencies and local governments, tribal councils, and non-profit organizations focused on preserving the country's heritage. The NPS oversees the NHL program and the Heritage Documentation Programs (HDP), which includes the Historic American Buildings Survey (HABS), Historic American Engineering Record (HAER), and Historic American Landscapes Survey (HALS). The HDP is the federal government's oldest preservation program, started in

1933 to document historic places throughout America. The program represents one of the nation's most extensive archives of historic documentation housed in the Library of Congress (LoC). The collection includes drawings, history, and large-format photography. In partnership with the BLM and the CoPR, the NPS reviewed documentation drawings in multiple phases for final inclusion into the LoC for public access and benefit in comprehensively understanding the Lowry Pueblo site (NPS 2023).
Role: Funding, HABS review, LoC submittal, and archiving.

Cooperative Ecosystem Studies Units (CESUs): The Cooperative Ecosystem Studies Units (CESUs) align research and expertise nationally through a multi-disciplinary structure, including university partners and federal agencies in technical assistance, education, and national land management by addressing natural and cultural resource management issues at multiple scales and in an ecosystem context (CESU n.d.).
Role: Agreement and contract management.

3. PROJECT PURPOSE

Since the last stabilization effort in 2003 and the intensive roofing effort completed in 2004 on the public site, gradual and expected deterioration continued, primarily from exposure to the elements but also partly because of thousands of annual visits by the public. The damage and loss of historic fabric in some areas of the structure were at a tipping point. The Lowry Pueblo project's urgency moving forward was to stop the impacts before any catastrophic loss or collapse of the prehistoric walls occurred with the momentum to stabilize and preserve the site at its apex. After several years of exposure without intervention, it became critical to document the site for resource management and interpretation.

3.1 Project Goals

The goal of the project was to use LiDAR scanning to:

1. Document the site's existing state.
2. Complete a set of combined digital and analog HABS drawings for inclusion in the Library of Congress's permanent collection and use for site stabilization, resource management, and interpretation.
3. Develop usable data capture models for future research and interpretive deliverables.
4. Create a comprehensive set of interpretive deliverables of the Lowry Pueblo for use as online visualizations, including imagery and video suitable for interpretation.
5. Document a prioritized list of unstable architectural elements, including 15 walls within 11 structures and two kivas requiring active conservation measures.
6. Provide public presentations, educational opportunities, and updates to the professional community throughout the project.

3.2 Fieldwork and Methodology

The strategies for using LiDAR to scan an ancient site or structure digitally differ for every project, depending on the desired outcomes and deliverables. Modern LiDAR is the most detailed, non-invasive, and cost-effective means of documenting these prehistoric structures. The data gathered during digital documentation can be used to create 2D plans, profiles, and 3D models of the structure, often employed to develop an advanced stabilization treatment plan. The models provided data for monitoring, tribal consultation, enhancing existing public education tools, and developing new educational tools online.

The BLM and CoPR used terrestrial LiDAR scanning to document the above ground standing architecture. The technology captured highly accurate 3D spatial models of the structures. The scanning and fieldwork began in 2016; the equipment brought to the Lowry Pueblo site was the Leica Scan Station 2 and C10. The team's equipment included a PC laptop, HDS (High Definition Surveying) targets on tripods, batteries to power the scanner, a tribrach attachment plate, a Nodal Ninja holder for panoramic capture, a Digital SLR (single-lens reflex) camera, and a separate, heavy tripod that supported the fully robotic scanner.

The team organized and developed the documentation process into the following steps:

1. Technology Evaluation and Site Preparation
2. Onsite Procedure and Data Gathering
3. Data Management
4. Data Representation (including HABS drawings)
5. Data Archiving

The steps were critical to completing the 3D documentation process and preservation effort.

3.3 Documentation Process

3.3.1 Technology Evaluation and Site Preparation: The first step in this process ensured the team used the correct technologies to answer the questions or challenges of the project. The site preparation provided research and planning for the fieldwork and data capture using aerial photography and site descriptions to understand the terrain and the associated challenges. Terrestrial LiDAR worked well for capturing the subject, the scale, and the materiality of the Lowry Pueblo.

3.3.2 Onsite Procedure and Data Gathering: The second step reviewed site conditions and challenges. The Lowry Pueblo is a delicate and valuable area that requires the least amount of impact possible during the documentation process. LiDAR allowed the team to collect data quickly with minimal impact on the structure. This step also informed how data collection occurs systematically. With such a complex structure, much thought went into the sequence of the scans during the onsite visits. The LiDAR scanning was conducted by the team, BLM staff and volunteers, and the student interns during the summer of 2016.

Figure 2. Scan Prep at the Lowry Pueblo NHL

After completing a thorough site inspection and identifying scan and target locations, the scanners were set up in their first

locations. Efficient data collection and comprehensive coverage of the structure determined scan locations. Once the scanner was booted up and connected to the PC laptop via the Ethernet cable, the team used a software program called Cyclone (developed by Leica) to control the scanner with the computer. Appropriate settings were established, and the scanner began operation. The scanner is equipped with a digital camera (low quality) inside and takes a nearly 360-degree image from the scanner's perspective. This image showed up on the laptop, allowing the team to see the same image as a scanner. The team used this image/point of view to determine the specific scan. Depending on the data needed to be collected and at what density, a scan took between five minutes to several hours to complete.

The team also acquired High Definition Surveying (HDS) targets within each scan. These targets are exact points in space that determined where the scanner was located compared to the other scan locations. The HDS targets were essential for post-processing efforts and registration after data collection. All scans were combined to create a completed 3D model.

After completing the scanning and target acquisition, the team used a Digital Single-Lens Reflex (SLR) camera to collect higher-quality image data than the scanner could provide. The team collected High Dynamic Range (HDR) photography at each location, capturing high-quality images with more color and exposure information than traditional photography. In addition, the team collected RAW photos, uncompressed for the highest quality and color range. They then collected a 360-degree sphere of images, which were stitched together, and texture mapped onto the point cloud data for a more photo-realistic 3D model.

Figure 3. Leica Scan Station C10 scanning and Leica HDS target and tripod

After capturing the scans and HDR photographs at one location, the team moved to the next location. While moving all the equipment related to the scanning process, it was critical to ensure that those items stayed out of the way of the scans. The team often moved around the generator, battery boxes, scanner boxes, etc., to ensure they only captured the site and its structures. The team was also cautious as they moved equipment around to avoid shifting targets. The HDS targets are so accurate that even an accidental touch could shift the target out of position introducing errors in the post-processing effort. The target locations were also precise and seen from multiple scan locations. The scanner was disconnected, powered down, and moved with care at each location.

Thirty-seven different scan locations were acquired, all consisting of 360-degree scans to achieve the site's surrounding context. In addition to scanning, thirty-seven panoramic images were captured at each location for photo texturing during post-processing. HDS targets were used throughout the site as control points that tied all scan locations together. Different combinations of the HDS targets were acquired at each scan location. On average, it took 30 minutes to capture scan and photography data at each of the 360-degree scan locations.

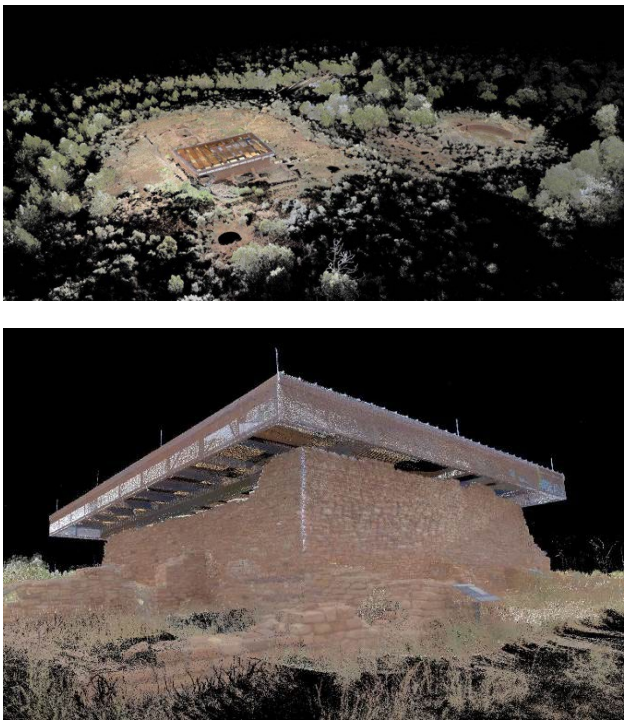

Figure 4. Still images from the Lowry Pueblo LiDAR Scans

3.3.3 Data Management: The third step of data management was ongoing throughout the process. Issues of data storage and archiving were complex. Data and data management practices in all industries change as rapidly as the technologies creating them, making planning for future data management challenging. The team collected the required data to store and secure the information until the completion of the Lowry Pueblo project. The process included saving an unaltered version of the data. Complete copies of the raw and processed data were archived in several places, including on an external hard drive and a local computer. A copy of the data is housed on a server in a different geographic location from the hard drives to protect against loss.

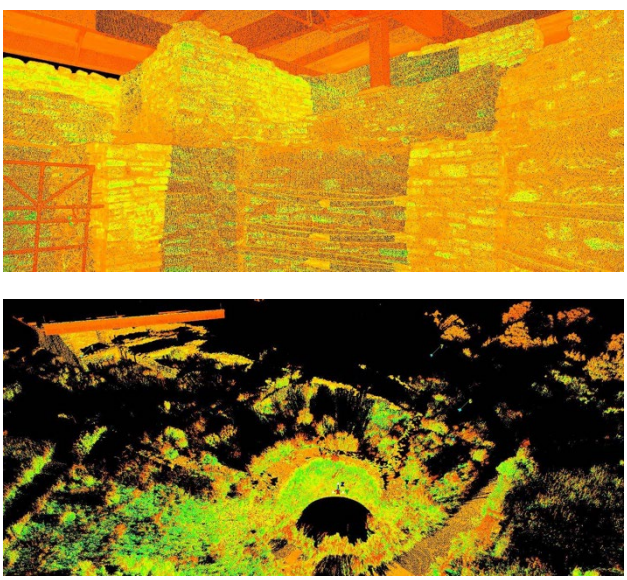

Figure 5. Raw Scan Data from single scan locations

3.3.4 Data Representation: The fourth step focused on creating the relevant deliverables and usable media from the data set. A wide range of deliverables was extracted from the 3D data, including HABS drawings, visualizations, and interpretive material such as fly-through videos, still images, virtual tours, and interactive 3D models. Data processing, model building, and HABS drawings were completed from 2016-2017.

Process (Digital): CyArk developed a three-minute video combining archival materials, historical recreations, and 3D-captured data to produce an overview video of the Lowry Pueblo. This film covered three primary periods of the site and its inhabitants, and the contemporary site seen today. The fly-through and model animations included a scripted narration and music, leading the viewer through the site's architectural achievements, cultural influences, and overall evolution. They created a dedicated page (CyArk 2023) on the team website to showcase an interactive 3D model of the area with additional hotspots of information accessed from the model within an internet browser. These additional hotspots contained higher-resolution models, historical photographs, and information about the site's history and context. The team produced one fly-through video, 12 still images of the scan data, 12 virtual tours from HDR (High Dynamic Range) photography, and a complete set of HABS drawings.

Process (Combined): Initial post-processing of the Lowry Pueblo data set began following the site visit. Panoramic images were processed and applied to each scan location, making the photo-textured data look more photo-realistic. All scan locations were registered together using a combination of target and feature registration with a Mean Absolute Error (MAE) of .000 meters. The high-resolution capture enables using the data for a wide variety of additional deliverables in the future.

A HABS drawing set was mocked up by applying the photo-textured data and screenshots of the desired views. Within Cyclone, the data set was dissected and cropped to provide orthogonal views of the scan data corresponding to the screenshots. The screenshot views defined the images for the baseline drawings to be completed in AutoCAD for the initial HABS set. Utilizing Cyclone's AutoCAD plug-in CloudWorx by Leica, the previously generated views generated of the scan data and mocked-up were then referenced into the AutoCAD file. The drawings produced for the Lowry Pueblo included site plans, plans, elevations, and sections. The key to developing the HABS drawings for Lowry Pueblo was the development of multiple layers of data translation, decision-making, and digital-to-analog applications.

The photo-textured data was initially entered into AutoCAD as a 1:1 orthogonal view of the scan data. These views were scaled using paper-space viewports and placed on standardized HABS sheets with the required text and titles. Next, using 2D linework in CAD at a 1:1 scale, the photo-textured scan data was traced to develop line drawings. The OSNAPS feature was used to lock to point cloud points. The line weights developed were pre-determined by HABS standards guidelines. Once the line drawings were completed, the drawing set was printed on mylar using archival ink. Using the textured photo data in combination with photographs taken of the site, hand-drawn stippling was added to define features such as rock and ground planes, accounting for linework, shape, and forms, and the illusion of three-dimensional space in a two-dimensional drawing using shading.

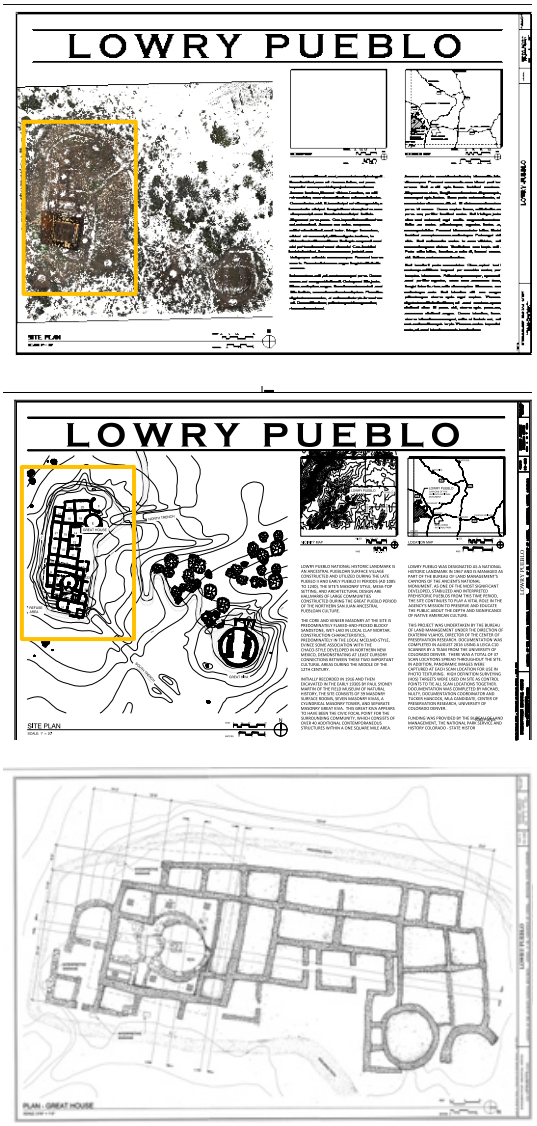

Figure 6: HABS mock up and drawings

3.3.5 Archiving: The fifth and final step was data archiving, considered the most technically challenging. The team created an archival copy of the integrated data, deposited a record within its secure server, and delivered the integrated copy to the BLM. This archiving included data preparation and conversion to archival file formats in perpetuity.

In addition to digital archiving, traditional 2D content was created as scaled 2D architectural drawings. These included plan, elevation, and section drawings in developing the HABS drawings for the Great Kiva and Great House walls. CoPR submitted the HABS drawings to the NPS for review and approval which they submitted to the Library of Congress for their permanent collection. The BLM submitted a second set of HABS drawings to the Colorado Office of Archaeology and Historic Preservation as part of the finalized project.

4. CONCLUSIONS

4.1 Outcomes

4.4.1 Representation: The final HABS drawings and interactive digital models developed for the project are currently utilized by the BLM to develop future treatment plans for stabilization and repair, to update existing public interpretive displays at the Canyons of the Ancients Visitor Center and Museum and on the CANM website, and to conduct Native American tribal consultation for future management actions at the Lowry Pueblo National Historic Landmark. Combining digital and analog documentation methods has contributed to a greater understanding of the Lowy Pueblo and informed the interpretation and cultural resource management needed for the future. Preserving this prehistoric site is essential to protecting this critical part of the region's identity and economy and the BLM's cultural education program.

Several exhibits at the BLM's CANM Visitor Center and Museum focus on Lowry Pueblo. The products from this project update and enhance visitors' educational experience at one of the nation's premier federal museums and research facilities. Local educators and students from the BLM and Crow Canyon Archaeological Center engaged in the project as volunteers. The digital products created were incorporated into their ongoing Museum on the Ground curriculum.

4.1.2 Impact: Investing in the documentation and preservation of Lowry Pueblo provided significant, long-term benefits to the small Colorado communities in the immediate area that were financially dependent on the federal assets in their vicinity. Lowry Pueblo NHL is one of twelve interpreted sites designated as a public destination within the Canyons of the Ancients National Monument, all free and open to the public. This unique access is part of the attraction of local public lands and is vital to the BLM's cultural resources program and the local community's identity.

The project had a far-reaching impact as well by receiving the prestigious Stephen H. Hart Award for Preservation in Colorado. News and information about the project and the role of the State Historic Preservation Fund were disseminated via the BLM's "BLM Daily" webpage, the CANM/AHC Facebook page, and the BLM's YouTube channel, reaching hundreds of thousands of visitors across the country and the globe. Finally, the dedicated Lowry Pueblo webpage, interpretive video, and digital archive hosted on the CyArk website have a global reach.

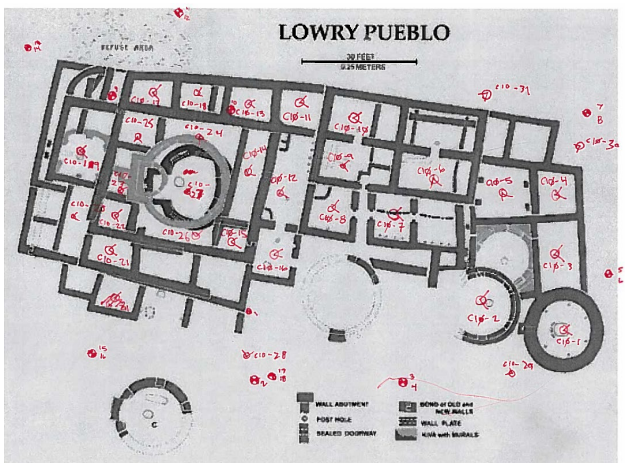

Figure 7. Field notes for the Leica Scan Station C10

4.2 Summary

Today, the site contains the only fully excavated and interpreted Ancestral Puebloan great kiva accessible to the American public. In addition to the onsite interpretive facilities, Lowry Pueblo NHL is the focus of several interpretive displays at the Field Museum in Chicago, Illinois, and the BLM's Anasazi Heritage Center (AHC) museum in Dolores, Colorado, the latter of which houses all other archival records and materials collected from the site throughout the years.

As one of the most significant developed, stabilized, and interpreted prehistoric pueblos from this period, the site plays a vital role in educating the public about the depth and significance of Native American culture. After 50 years of public interpretation and hundreds of thousands of visitors, Lowry Pueblo National Historic Landmark has introduced multiple generations of American and international visitors to the importance and significance of archaeological research and the beauty, depth, and complexity of Native American culture.

Figure 8. Great Kiva site

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