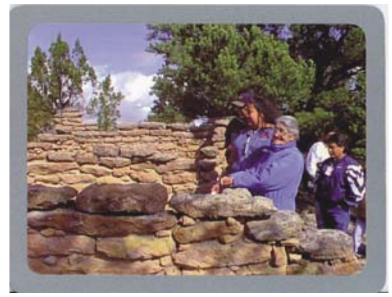
LA-UR-06-8130 September 2006

Title

A CURRENT ASSESSMENT OF THE NAKE'MUU MONITORING PROGRAM



Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Los Alamos Site Office

Prepared by

Bradley J. Vierra, Ecology and Air Quality Group
Kari M. Schmidt, Ecology and Air Quality Group

Los Alamos NATIONAL LABORATORY
Los Alamos, New Mexico 87545

Edited by Hector Hinojosa, Group IRM-CAS

Cover illustration: Nake'muu in 2003 (left) and members of San Ildefonso Pueblo during a site visit in 1999 (right).

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A CURRENT ASSESSMENT OF THE NAKE'MUU MONITORING PROGRAM

Cultural Resources Report No. 288
Survey No. 817

Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Los Alamos Site Office

Prepared by

Bradley J. Vierra, Ecology and Air Quality Group
Kari M. Schmidt, Ecology and Air Quality Group

With Contributions by: Gerald Martinez, Robert Deupree, Noor Khalsa, and Randy Balice

Los Alamos NATIONAL LABORATORY
Los Alamos, New Mexico 87545

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Introduction

The Cultural Resources Team of the Ecology and Air Quality group (ENV-EAQ) is conducting a long-term monitoring program at the ancestral pueblo site of Nake'muu (LA 12655). The program is being implemented as part of the Mitigation Action Plan (MAP) for the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility. The DARHT facility is an explosives testing laboratory located at Technical Area (TA) 15, Los Alamos National Laboratory (LANL). This report presents the preliminary findings of the monitoring program from 1997 through 2006.

Nake'muu is situated about 350 m (0.21 mi) southwest of the DARHT facility on an adjacent mesa. The site is the only ancestral pueblo at LANL that still retains its original standing walls. It has been mapped and photographed, and detailed drawings have been made of all the standing-walled masonry architecture. The drawings and associated databases are updated on an annual basis, and continual assessments are made of site condition, deterioration rate, and possible sources of impact.

The DARHT facility covers about 2.3 ha (8 ac), including the facility, access roads, and utilities. An archaeological survey was originally conducted of the proposed construction site in 1988 (Larson 1988). Three archaeological sites were identified within the construction zone (LA 71408, 71409, and 71410). At the request of the San Ildefonso Pueblo, and in concurrence with the New Mexico State Historic Preservation Office (NMSHPO), LA 71410 was buried under a berm, whereas, LA 71408 and LA 71409 were fenced and avoided. An additional survey of an expanded 750 m diameter area around the DARHT facility was conducted in 1995 (Larson 1995). Thirty-five sites were identified within this area, including Nake'muu (LA 12655). The final survey report was submitted to the NMSHPO (Vierra et al. 1999) with a determination of no adverse effect made in May 1999.

Nake'muu is a standing-walled pueblo located at the tip of a mesa above the confluence of two canyons. There are three potential sources of impact to cultural resources in the area of the DARHT facility: ground vibration, shock waves, and shrapnel (Department of Energy 1995:5-30). These sources are by-products of the explosive tests that are conducted at the facility. The DARHT Facility MAP recognized these potential impacts and recommended several mitigative actions be taken (Department of Energy 1996:12):

1) Construct a berm to act as a permanent shield.
2) Use a temporary and expendable blast shield.
3) Position one wing of the DARHT building between the blast area and Nake'muu to reduce shock waves and flying debris.
4) Implement a long-term monitoring program at Nake'muu to evaluate any possible effects of the blasts on wall integrity.
5) Invite tribal officials for periodic visits to the cultural resources in the area and evaluate the long-term effects of the MAP.

ENV-EAQ and the Mesa Verde Architectural Team, National Park Service (NPS) initiated the Nake'muu site monitoring program in 1997. Archaeologists from LANL and NPS have completed the detailed recording of all the walls at Nake'muu, and the final site evaluation plan was finished in 1998 (Nordby et al. 1998). The plan describes the methods used for site monitoring, continued site revisits, and updates on wall condition by LANL archaeologists.

The primary objective of the monitoring program is to identify and evaluate the long-term effects of the ambient environment and the DARHT project on the architecture at Nake'muu. Is the dynamic-testing program affecting the site, and if so, to what degree? What are the short-term and long-term impacts of facility operations? This report summarizes the results of the site condition assessment, the initial findings of the nine-year monitoring program, experimental studies, photographic studies, impacts of the Cerro Grande Fire, and Accord Pueblo consultations and makes recommendations for continuing site-monitoring procedures.

Previous Research at Nake'muu

Edgar Lee Hewett was the first archaeologist to visit and describe the ruins of Nake'muu, referring to it as Site No. 18 (Hewett 1906:25-26). He sketched a ground plan of the site, stating that it was "the best preserved ruin in this region" and that it had "walls standing in places eight feet above the debris" (ibid:25). Figure 1 is a reproduction of Hewett's original map; note that his north arrow is actually pointing towards the south.

Charlie Steen visited the site in 1975 (Steen 1977:36-38). Steen provides a brief site description and several photographs of the standing walls and also drew a site sketch map (Figure 1). Steen noted the presence of Santa Fe Black-on-white, Wiyo Black-on-white, Biscuit A, and Biscuit B ceramics. He also described a room in the northeast section of the site that contained preserved wall plaster. Steen attempted to preserve the plaster by applying a "patching plaster" around its edges. It is unclear how old this plaster actually is, but an elderly resident of San Ildefonso Pueblo considered it to be recent in age during a 1998 site visit.

David Snow of Cross-Cultural Systems conducted a surface collection at Nake'muu in 1985. He identified 27 Santa Fe Black-on-white sherds, one possible biscuitware sherd, and 120 smeared-indented corrugated sherds. There are very few artifacts present on the surface of the site today. Beverly Larson (1995) suggested that the lack of artifacts at the site could be from the fact that the occupants threw their trash over the mesa edge. However, no evidence of a trash midden was identified during an archaeological survey around the base of the mesa.

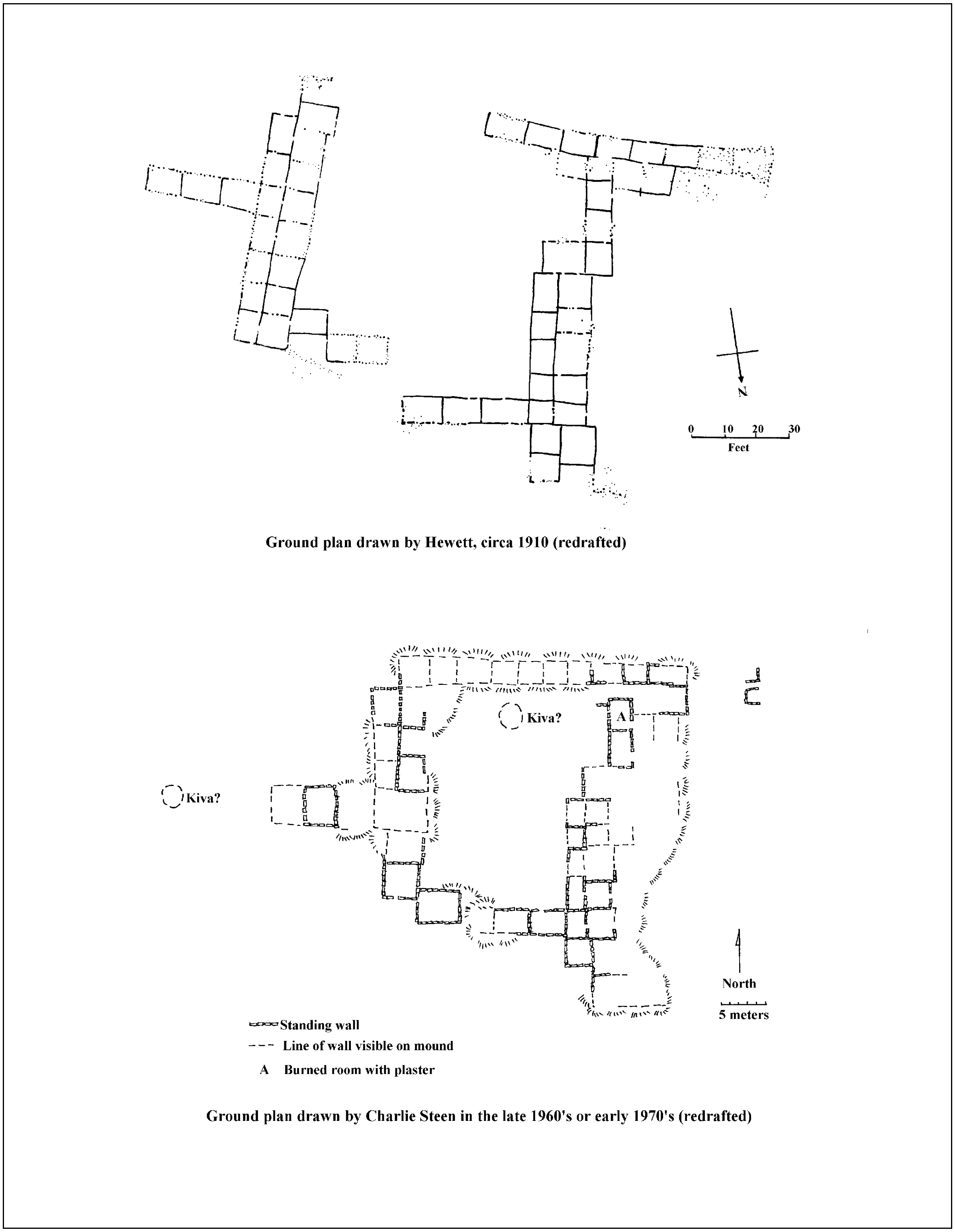

Figure 1. Edgar Hewett and Charlie Steen Nake'muu ground plans.

Nake'muu Site Condition Assessment Study

The DARHT Facility MAP stipulated that several mitigative measures would be taken to evaluate the long-term effects of the explosive-testing program on Nake'muu. One of these measures was the implementation of a monitoring program that involved an initial site condition assessment, followed by annual site revisits. The Mesa Verde Architectural Team from the NPS was hired to conduct the initial site condition assessment. The NPS Team is responsible for monitoring the condition of prehistoric ruins at the various national parks throughout the American Southwest, and had developed a set of procedures for monitoring long-term change. In addition, mitigative measures could be undertaken to reduce the effect of tourism and natural deterioration. The NPS Team was subsequently accessed through an interagency agreement to carry out the following tasks:

1) Improve the existing maps of the site,
2) Create a descriptive baseline for standing architecture,
3) Increase basic knowledge of site archaeology without excavations,
4) Record the condition of exposed site architecture,
5) Create a computerized database that ordered site data,
6) Generate a recommendation package, and
7) Develop monitoring procedures, a plan, and a monitoring schedule.

Field Methods

Larry Nordby was the principal investigator for the NPS Team. Their work began in July 1997. The specific methods and architectural terminology used by the team is provided in the ArkDoc, Version 1.0 manual (Nordby and Windes 1997). In order to accomplish the field work, a 15 cm contour map was made of the site that denoted wall outlines and specific room numbers (Figure 2). Fifty-five rooms and thirteen open areas were defined. In addition, individual maps were drawn of each room and consist of plan maps and standing wall profiles. The plan maps illustrate wall outline, abutments or bonding between wall segments, the presence of wall fall (i.e., rubble), internal drainage patterns, and vegetation (Figure 3).

The wall profiles consist of detailed drawings of individual wall elements (e.g., masonry blocks, chinking stones, and plaster) that were derived from 1:50 scaled photographs (Figure 3). Each profile is color coded to denote the level of wall deterioration and adobe mortar loss. No coloring reflects that the mortar is intact, is roughly flush with the building stones, and the wall fabric is generally stable. Yellow indicates moderate mortar loss and that chinking stones are missing or that there is severe erosion around the chinks. Red indicates severe to total mortar loss. If chinks are present, they are lying directly on the underlying masonry stones. Black refers to holes or voids through the wall. Green represents wall or floor features (e.g., closed entryways, tie stone, and hearths). Blue indicates that an architectural element that was present during a previous monitoring session has since fallen out of the wall and is missing. Tan represents wall plaster. Blue/white targets represent the location where adobe mortar depth measurements were taken.

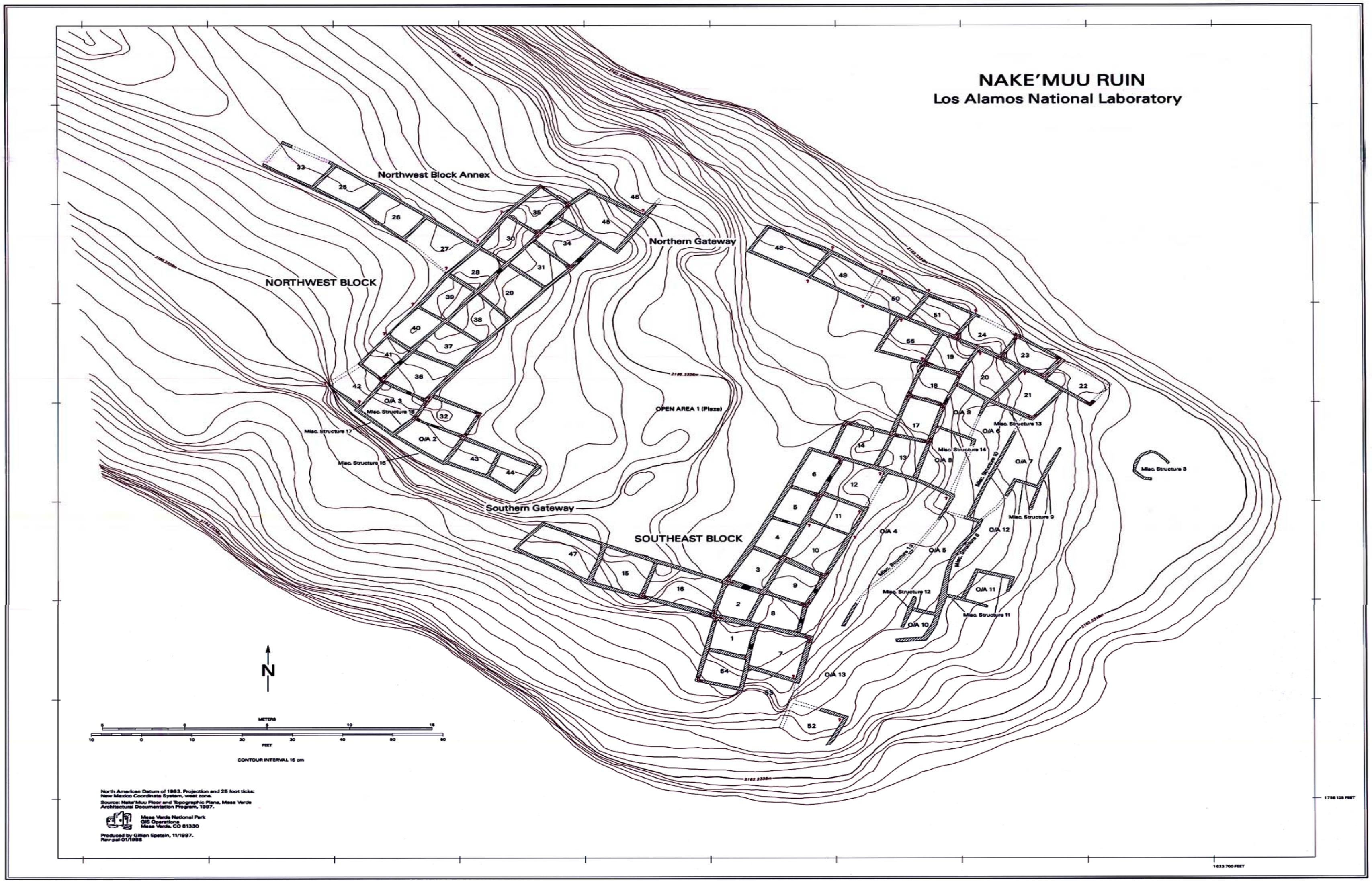

Figure 2. National Park Service Nake'muu site map.

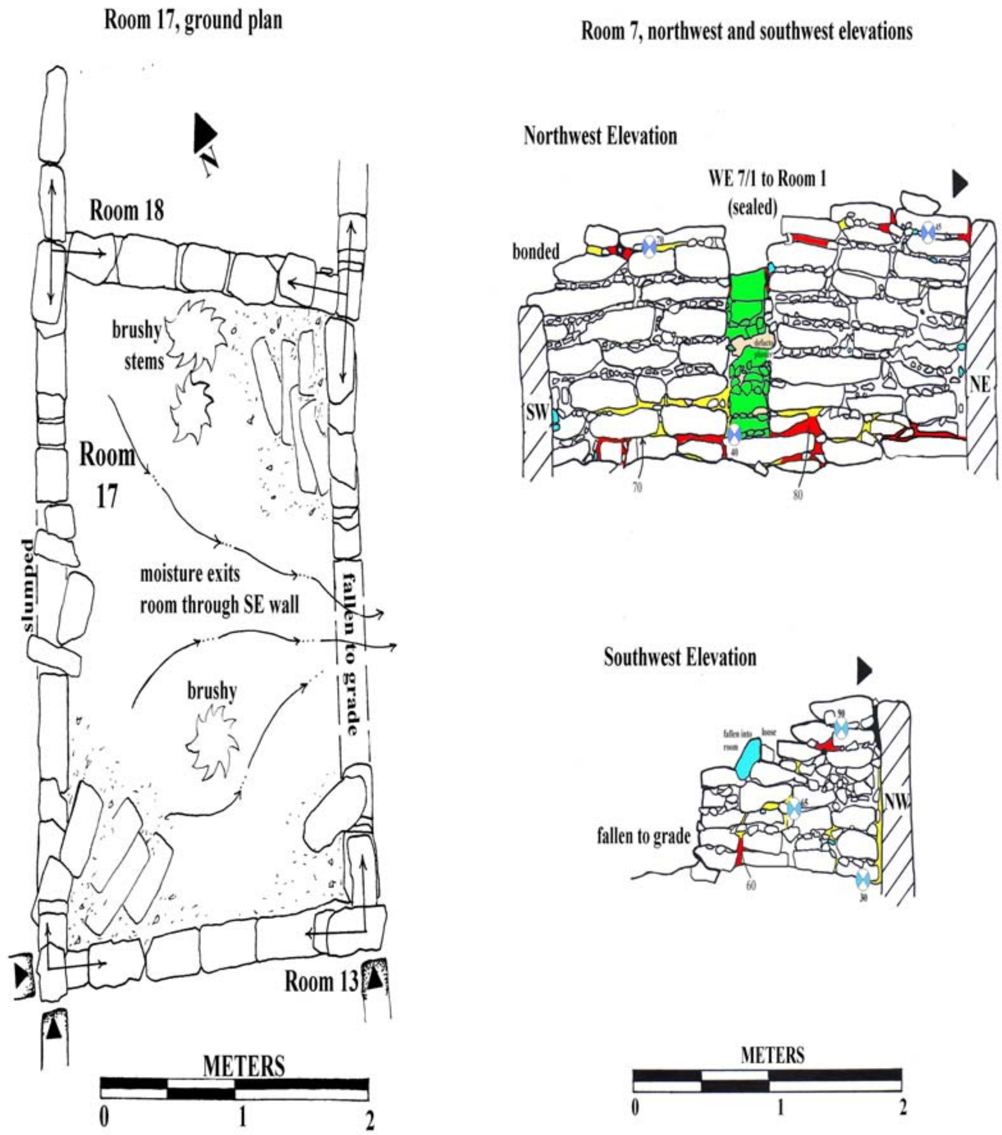

Figure 3. Plan map and standing wall profile.

These measurements are defined as the maximum distance in mm between the outside face of the masonry block and the adobe mortar. In addition to the detailed wall drawings, other specific information was also monitored for each wall, including data on wall integrity and deterioration.

Site Construction History

Nake'muu is organized around a central plaza, but the wall construction sequence indicates that two separate linear roomblocks were initially built. These roomblocks consist of the Southeast Block (including Rooms 2 to 12 and 53 to 54) and the Northwest Block (including Rooms 28 to 45). The roomblocks are oriented northeast-southwest and contain two rows of rooms that are about seven rooms long. The western set of rooms was constructed first, followed by the attachment of the eastern set of rooms sometime later. The original doorways opened towards the southeast where outside activity areas were located. Later, a series of lateral northern and southern roomblocks were added enclosing a central plaza. The outside doorways were subsequently sealed and the focus of the pueblo became the central plaza area.

The site map indicates that room sizes differ across the site. A histogram of room size (Figure 4) shows three distinctive modes, including small rooms that are from 4 to 7 m^2 in size, medium rooms that are from 7 to 8.5 m^2 in size, and large rooms that are greater than 8.5 m^2 in size. The roomblocks are generally two rooms deep, with medium-sized living rooms in the front and smaller storage rooms located in the back. Large rooms were probably used for communal social activities. For example, several large rooms are located at the entryways to the central plaza (Rooms 45, 47, and 48).

There are very few artifacts present at the site today, but previous surface collections were dominated by Santa Fe Black-on-white and smeared-indented corrugated ceramics, which reflect a Coalition period occupation (ca. AD 1200 to 1325). This temporal characterization corresponds with the identification of several Santa Fe Black-on-white sherds that were used as wall chinking stones. Despite the fact that the surface ceramic assemblage at Nake'muu suggests a Coalition period occupation, the masonry at Nake'muu is characterized by shaped tuff blocks and chinking stones that are typical of the later Classic period. This style contrasts with the Coalition period masonry style that is generally characterized by the use of unshaped blocks and the absence of chinking stones.

The lack of a trash midden, the shallow interior room fill (ca. 10 cm), and the limited evidence for remodeling seem to suggest that the site was occupied for a brief period of time. Regional architectural studies indicate that the typical pueblo room had a use-life of about 20 years before some remodeling was necessary (Ahlstrom 1985; Crown 1991). If this is true, it is reasonable to suggest that Nake'muu was occupied for about this length of time.

Like many of the ruins on the Pajarito Plateau, Nake'muu was constructed of stone, mud, and wood materials. The stone is shaped tuff from local bedrock, the mud is adobe mortar used to hold the walls together, and the wood is the timbers used to build the roofs. Why the walls at Nake'muu have survived to the present is not known, but it may be attributed to several factors:

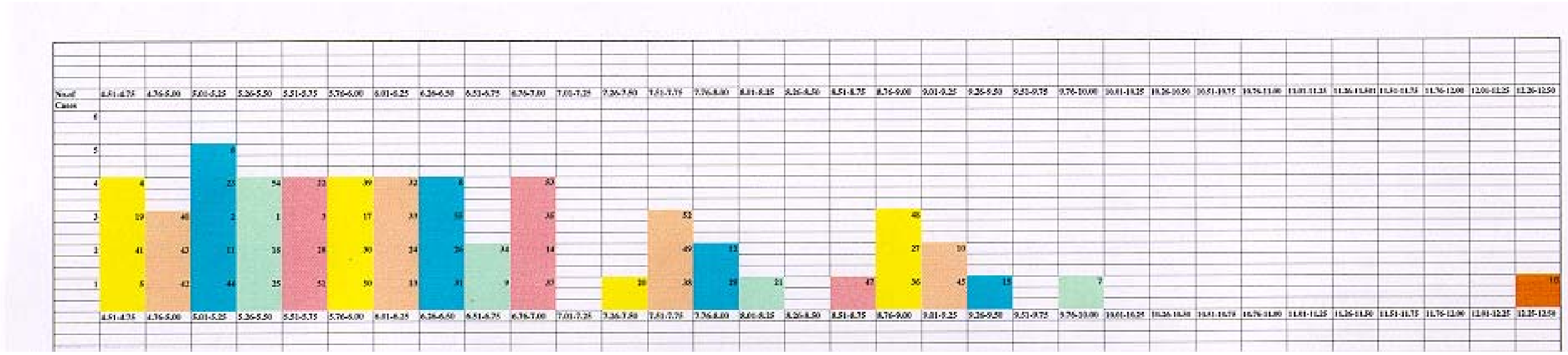

Figure 4. Histogram of Nake'muu room floor area.

1) its isolated location whereby fewer people visited the site; 2) the roofing materials might not have been scavenged until the turn of the century when homesteaders moved into the area, and as a result, the roofs would have protected the walls from the weather; and 3) the site has been located in a controlled access area, where visitation was limited.

Site Condition Assessment

The condition of each wall at Nake'muu was evaluated and classified as Category 1, 2, 3, or 4. Category 1 walls are the most fragile and probably have the largest areas of severe damage. Category 2 walls are slightly more stable and Category 3 walls are the most stable standing walls. Category 4 walls are those that are not currently standing above grade. Table 1 provides the information on wall category for north- vs. south-facing walls. A chi-square test of this contingency table indicates that there is no significant difference in the wall condition by direction (chi-sq = 4.5, df = 3, p = 0.21); however, the cell for north-facing Category 1 walls does contain a significant adjusted residual value of 2.0. Adjusted residuals greater than 1.96 or –1.96 are significant at the 0.05 level. Therefore, there does appear to be relatively more Category 1 walls on the north-facing sides. It is along these north-facing façades that the winter snows tend to build up, with snow melting during the day and then refreezing at night. This freeze/thaw and contraction/expansion process has a detrimental effect on the wall construction elements.

Table 1. Wall condition by direction.

Condition	North-facing	South-facing
Category 1	10 **2.0**	3 -2.0
Category 2	29 -0.3	27 0.3
Category 3	13 -0.8	18 0.8
Category 4	83 -0.6	87 0.6
Total	135	135

Chi-square = 4.5, df = 3, p = 0.21

Figure 5 graphically illustrates the distribution of Category 4 walls across the site. As can be seen, most of the collapsed walls are situated around the periphery of the site in areas affected by sheetwash and a steep break in the slope. This area includes the northern side of the pueblo and parts of the southern and eastern sections of the site. Total wall failure in these areas is presumably attributed to the erosion of mortar from the lower portions of the wall that eventually led to the weakening and subsequent collapse of the wall. This weakening would be especially problematic during the summer monsoon season. On the other hand, Rooms 25 to 28 and 33 are located on a high spot along a ridge in the western section of the site. This area would not have been greatly affected by seasonal runoff. It is, however, a natural corridor used by elk and people to enter the site, and this traffic could have led to the destruction of this roomblock.

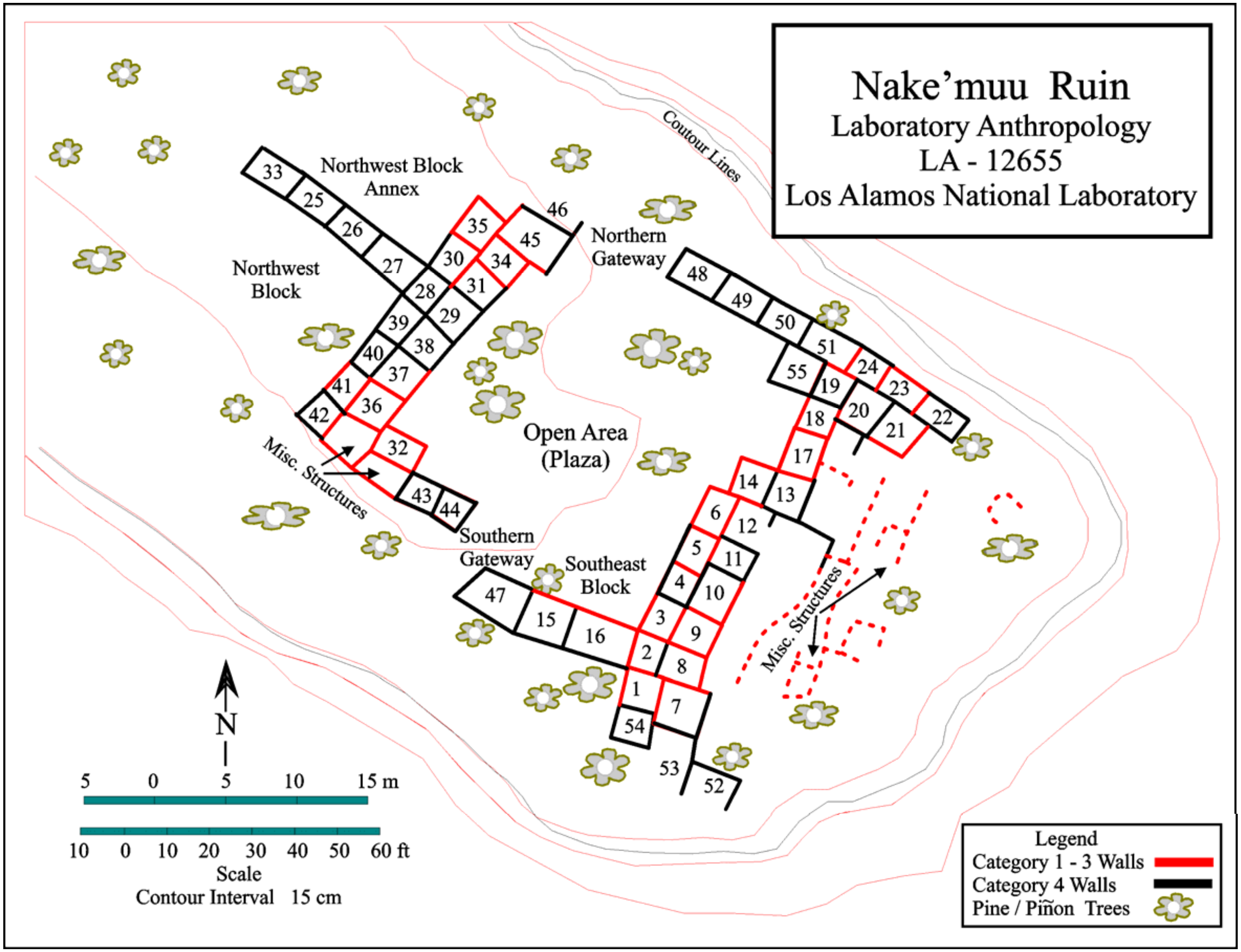

Figure 5. Location of Categories 1 to 3 and Category 4 walls at Nake'muu.

Besides rainfall and snow melt, there are several other factors that could have contributed to the long-term deterioration of the architecture at Nake'muu. The site is covered with scrub oak and isolated pine (*Pinus ponderosa* and *P. edulis*) and juniper (*Juniperus*) trees. The root systems of these plants can undermine and dislodge the basal sections of wall, rendering them unstable and likely to collapse. This is especially problematic in the area of Rooms 5 and 6, 11 to 16, and 47, which are completely filled with scrub oak (*Quercus gambelii*). Most of the brush was initially cut at the site during the 1997 monitoring visit, but it is slowly growing back. Many rooms have been subjected to isolated pruning and cutting of the scrub oak bushes. Large trees have pushed against the walls in Rooms 48 and 53, and fallen trees have partially destroyed sections of the walls in Rooms 3, 5, and 16.

Because of the shallow surface deposits, burrowing animals do not appear to pose a problem to the site, but there are a number of elk trails that pass through the ruins. A study of elk movement (Biggs et al. 1999:22) identified a primary elk travel route in the area of Nake'muu (Figure 6). The presence of elk is evidenced by ephemeral bedding areas, trails, and widely distributed concentrations of scat.

Earthquakes also pose a potential threat to the architecture at Nake'muu. LANL is situated in the Pajarito fault system that includes the Pajarito, Guaje Mountain, and Rendija Canyon faults. Earthquakes along the Rio Grande Rift system have occurred during historic times, including magnitude 4 to 6 earthquakes. Magnitude 3 and 4 earthquakes occurred at LANL in 1952 and 1971. Otherwise, recent geologic studies have documented a faulting event between approximately 1500 to 2500 years ago (Gardner et al. 1999).

Nake'muu is located on a narrow finger between two major canyons, so it is extremely exposed to the elements. This exposure could include other sources of potential impact like lightning, thunder, and heavy winds. As a result of the initial condition assessment, the NPS Team concluded that,

> It is our professional opinion that inherent structural problems induced by the original construction techniques, coupled with ambient environmental conditions at Nake'muu, will far outstrip the negative structural impacts of test shots (Nordby et al. 1998:283).

They go on further to state that,

> While the initial concern was for damage from explosions, these walls are so fragile that they could fall from any cause including earthquakes, high and variable winds, human traffic, freezing and thawing action, rain eroding the mortar, lightning strikes, or damage from the elk herds that frequent the site (ibid:284).

Figure 6. Elk travel routes at LANL.
(Figure not included because of exact site location)

Treatment and Monitoring Plan Recommendations

The NPS Team made several recommendations for continuing site monitoring and site treatment. First, they suggested continuing monitoring for changes in ambient environmental conditions. Second, in order to monitor the effects of specific explosive testing events, tarps could be placed under Category 1 walls and subsequently checked before and after a test for fallen plaster, mortar, or chinking stones.

Two potential site stabilization treatment options were suggested. One of these was for repointing and surface regarding where eroded adobe mortar at the bottom of the walls would be replaced with new mortar. In addition, the ground level within and outside the rooms would be leveled to reduce runoff and wall erosion. The second alternative treatment option included the placement of a pipe drainage system within the site and partially backfilling the rooms. This would be more invasive to archaeological deposits at the site.

In response to these recommendations, San Ildefonso Pueblo stated that "it is against Tewa belief that any preservation efforts be given to the site" (letter dated June 16, 1999). They voiced three main concerns about sources of potential impact to the site: 1) tours, 2) on-site monitoring visits, and 3) explosive testing. They suggested that a documentary video of Nake'muu could be used as a preservation and educational tool.

Site Monitoring Visits

1998 Site Visit

The first follow-up monitoring visit to the site was conducted in August 1998. Wall condition assessments were updated and four gauges were set across the site in order to monitor any shifts in particular wall abutments. Of the 110 standing wall façades, 47 (or 43%) had some degree of deterioration in the 13 months since the original baseline study. Almost all of these were limited to a single chinking stone falling from a wall façade. Overall, there were a total of 90 chinking stones and 23 masonry blocks displaced during this period, but four masonry blocks were accidentally displaced during the field work (Table 2). If we consider that there are a total of 6578 chinking stones and 3994 masonry blocks forming the standing-walled architecture at Nake'muu, then we witnessed a 1.3 percent displacement of site chinking stones and a 0.5 percent displacement of masonry blocks during this monitoring period.

Table 2. Annual chinking stone and masonry block displacement.

Monitoring Year	Chinking Stones Lost	Masonry Blocks Lost
1998	90	23
1999	61	5
2000	72	19
2001	130	54
2002	35	9

Monitoring Year	Chinking Stones Lost	Masonry Blocks Lost
2003	49	2
2004	28	3
2005	113	10
2006	28	5
Total Loss	**606**	**130**

1999 Site Visit

The second monitoring visit was conducted in April of 1999. An additional 64 chinking stones and six masonry blocks were displaced during this eight-month period. This represents an increase from 6.9 to 8.0 chinks per month, but a decrease in the loss of building stones during the first two monitoring periods. Overall, a total of 154 chinking stones and 29 masonry blocks were displaced during these 21 months. If we consider that there were a total of 6578 chinks and 3994 masonry stones originally forming standing-walled architecture at Nake'muu, then we have witnessed a 2.3 percent displacement of chinking stones and a 0.5 percent displacement of blocks during this period. Or stated another way, this represents a projected annual loss rate of 1.3 percent of the chinking stones and 0.4 percent of the masonry blocks.

2000 Site Visit

A third monitoring visit was conducted in April of 2000. A total of 70 chinking stones and 17 masonry blocks were displaced from the standing walls during this 12-month period. This displacement represents an overall loss of 224 (3.4%) chinks and 46 (1.1%) masonry stones for the 33-month monitoring period. The projected loss rate on an annual basis for this roughly three-year period can therefore be calculated at 1.2 percent of the chinking stones and 0.4 percent of the masonry blocks. This is a similar figure to the one based on the previous 21-month period.

A series of explosive tests were initially conducted at the DARHT facility in November 1999. Seven separate load tests were done containing from 1 to 64 lbs of heavy explosives. Since no tests had been conducted during the previous two monitoring sessions at Nake'muu, comparisons between the 1998/1999 and 2000 monitoring data provided some preliminary indications as to whether these tests were adversely affecting Nake'muu. As previously noted, the 1998/1999 data reflect a 1.3 percent annual loss rate for chinking stones and a 0.4 percent loss rate for masonry blocks. These rates compare with a 1.0 percent and 0.4 percent loss rate for chinks and blocks, respectively, from the 2000 data. Therefore, these preliminary results appear to indicate that the DARHT facility tests may have little or no effect on Nake'muu.

James Biggs (ENV-ORR) and Brad Vierra (ENV-EAQ) visited Nake'muu on April 20, 2000, to identify evidence for elk wintering at the site. One trail was identified that runs directly through the site and other trails were identified along either side of the pueblo. The central trail goes through Rooms 25 through 29 and 33, leads into the plaza, goes out through the northeast corner of Room 14, and across Room 13 (see Figures 5 and 7). Elevated amounts of scat were identified in Room 13, but limited evidence for scat was identified in the other rooms. It is probable that the roomblocks themselves contains too much rubble to allow for comfortable sleeping conditions, but recent evidence for beds under a large piñon tree on the east side of Open Area 4 suggests that elk are wintering in the immediate site area.

Information on masonry block size was collected during this monitoring episode. Nordby et al. (1998) have suggested that block size may differ by room function or construction period. A sample of 109 blocks from the eastern side of the site and 110 blocks from the western section of the site were measured to identify any differences. Table 3 presents the results of this study. The stone measurements are quite similar between the two areas. Block length exhibits the greatest variation vs. width and thickness, which are more uniform. A t-test of these mean measurements indicates that there is no significant difference between the two areas in respect to block length ($f = 0.750$, $p = 0.387$), width ($f = 0.879$, $p = 0.349$), and thickness ($f = 0.689$, $p = 0.407$).

Table 3. Masonry block metric data (cm).

Section	Measurement	Minimum	Maximum	Mean	Standard Deviation	N
East	Length	23	91	49.1	14.3	109
East	Width	15	26	20.6	2.0	109
East	Thickness	7	17	10.6	1.9	109
West	Length	15	90	45.2	16.0	110
West	Width	13	29	20.5	2.3	110
West	Thickness	7	21	11.0	2.3	110
Overall	Length	15	91	47.1	15.3	219
Overall	Width	13	29	20.6	2.2	219
Overall	Thickness	7	21	10.8	2.1	219

2001 Site Visit

A fourth monitoring visit was conducted in April 2001. There appeared to be a marked increase in chinking and masonry stone loss during the year, with a total of 130 (2.0%) chinking stones and 54 (1.3%) masonry blocks. However, most of these were derived from the partial collapse of the northeast wall in Room 13 that included 23 chinking stones and 16 masonry blocks (Figure 7). If we remove these stones from the collapsed wall from the total calculations then this reduces the annual loss rate to 1.7 percent and 0.9 percent, respectively. Despite this change, this still reflects an increase in annual stone loss rate over the previous three years.

As already noted, there is an elk trail through the area of Nake'muu. The northeast wall of Room 13 is a free-standing wall with two runnels running down through it. Scat was identified immediately adjacent to the wall, and it is assumed that an elk knocked over part of the wall while passing by. The southern end of the wall adjacent to both runnels collapsed. Figure 8 illustrates the location of scat present during 2001 monitoring session. The map shows that a fallen tree on the south side of the site has stopped elk movement through this area. However, the elk appear to travel along the north side of the site, into the plaza and through Rooms 13 and 17 in the northeastern roomblock along both sides of the northeast wall in Room 13. Two piles of scat were adjacent to the collapsed wall segment.

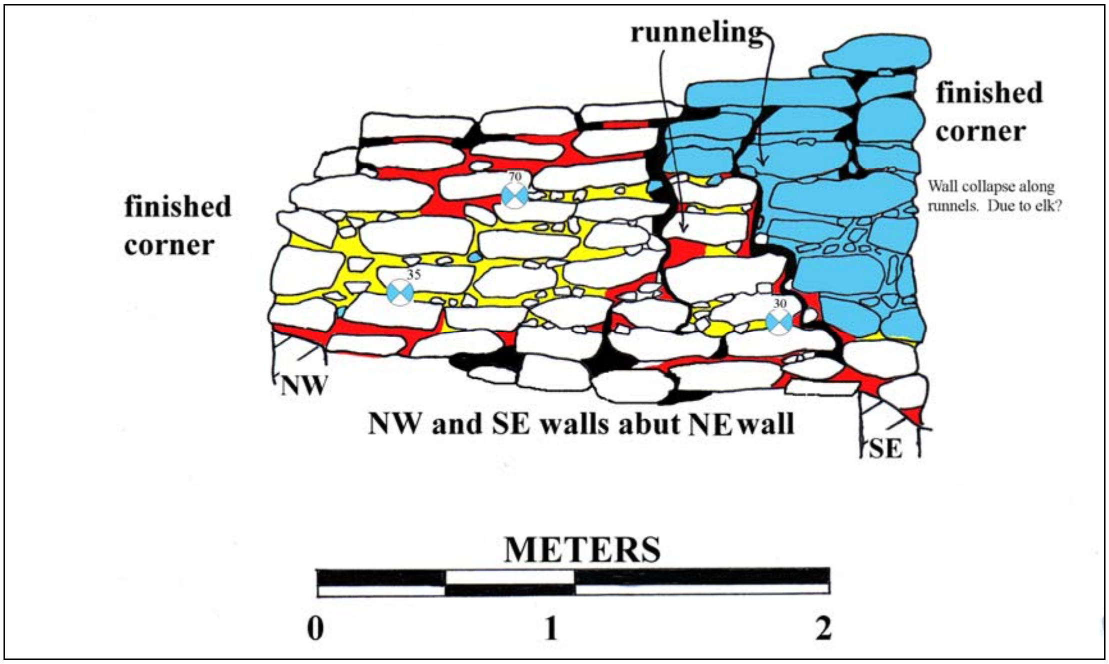

Figure 7. Collapsed wall segment (in blue) in Room 12 (northeast elevation).

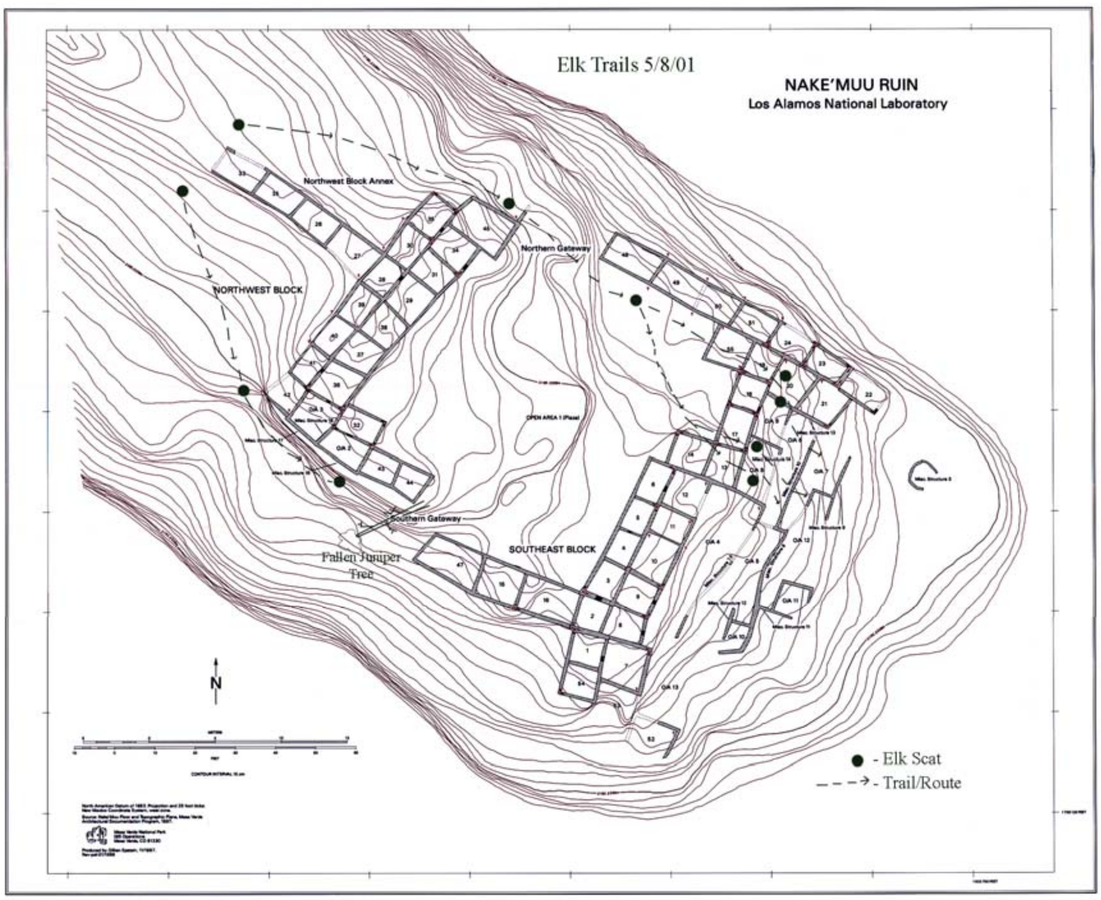

Figure 8. Location of elk scat and trails at Nake'muu.

2002 to 2004 Site Visits

The fifth monitoring visit was conducted in April 2002. Only 35 chinking stones and 9 masonry blocks were displaced during the year. In contrast to 2001, this represents a marked decrease in the annual loss rate for chinking stones (0.5%) and masonry blocks (0.2%).

The sixth monitoring visit was conducted in April 2003. Forty-nine chinking stones and two masonry blocks were displaced during the year. The annual loss rate rises slightly for chinking stones (0.7%) and masonry blocks (0.05%).

The seventh monitoring visit was conducted in April 2004. Twenty-eight chinking stones and three masonry blocks were displaced during the year. The annual loss rate drops slightly for chinking stones (0.5%) and masonry blocks (0.07%). However, it reflects a continuing three-year pattern of low displacement rates. The rate would be even lower if it were not for the fact that three chinking stones and three masonry blocks collapsed as a single unit along the northeast wall Room 30. This is near the location where a tree was removed, but it is not clear whether this activity had any direct effect on the eventual collapse.

*2005 Site Visi*t

The eighth monitoring visit was conducted in May 2005. In the year since the previous site visit, there appeared to be a marked increase in chinking stone loss with a total of 113 (1.7%) chinking stones lost. A smaller number of masonry stones were lost (*n* = 10; 0.3%). The majority of these losses, however, were derived from the partial collapse of one wall. The northeast wall in Room 12 lost 25 chinking stones and 9 masonry blocks, and the corresponding southwest wall in Room 14 lost 28 chinking stones and the same 9 masonry blocks. If we remove these stones from the collapsed walls from the total calculations, the annual loss rate is reduced to 0.8 percent and less than 0.1 percent for chinking stones and masonry stones, respectively. Nonetheless, this still reflects an increase in annual stone loss rate over the previous four years between 2002 and 2005.

As noted in the 2001 site visit section, several elk trails runs through the Nake'muu area (see Figure 8). In 2001, the northeast wall of Room 13 was (presumably) knocked over by an elk, as was evidenced by two piles of scat identified adjacent to the collapsed wall segment. During the 2005 visit, the northeast wall of Room 12/southwest wall of Room 14 was partially knocked over (Figure 9). Figure 8 shows this wall is also in the area of the elk trail, and may have been knocked over by elk movement. Of note, however, is that in both the 2001 and 2005 monitoring periods, levels of precipitation, especially snowfall, were markedly higher than in other years, and this may have weakened the walls at the site, making them more susceptible to damage and/or destruction from the elk. Given that the two years with the highest snowfall levels since the monitoring program began have witnessed wall collapse, it is very likely that levels of snowfall directly affect the stability of the walls because of the extra weight of the snow. Elk appear to exacerbate this instability.

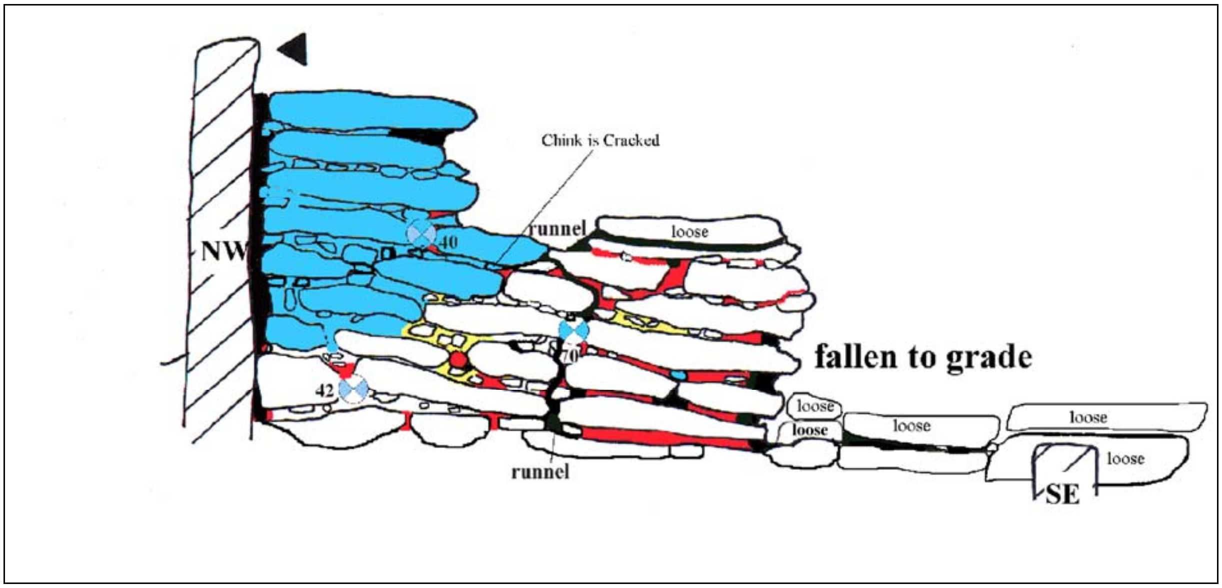

Figure 9. Collapsed wall segment (in blue) in Room 12 (northeast elevation).

2006 Site Visit

The ninth monitoring visit was conducted in June of 2006. A total of 28 chinking stones and five masonry blocks were displaced during the 13-month period since the last monitoring. If we consider that there were a total of 6578 chinks and 3994 masonry stones originally forming standing-walled architecture at Nake'muu, then there has been a 0.4 percent displacement of chinking stones and a 0.1 percent displacement of blocks during this period. The annual loss rate recorded during the 2005 visit was 0.8 percent and less than 0.1 percent for chinking stones and masonry stones, respectively, which is fairly comparable to the numbers recorded during the 2006 visit.

Results of a Nine-Year Monitoring Study (Bradley J. Vierra and Kari M. Schmidt)

A total of 606 chinking stones and 130 masonry blocks have been displaced over the nine-year monitoring program. If we consider that there were a total of 6578 chinks and 3994 masonry stones originally forming standing-walled architecture at Nake'muu, then we have witnessed a 0.9 percent displacement of chinking stones and 0.3 percent displacement of blocks during this period, and these numbers are unchanged to the totals derived in 2005. Overall, the annual lost rate ranges from 0.5 to 2.0 percent for the chinking stones and 0.05 to 1.3 percent for the masonry blocks. However, this includes a marked increase in stone loss rates during the 2001 and 2005 monitoring sessions, which is likely associated with increased levels of precipitation, especially snowfall, which weakens the walls and makes them more susceptible to damage from elk in the site area. Otherwise, the rates are generally closer to the nine-year mean.

Figure 10 graphically illustrates the annual changing pattern of chinking stone and masonry block displacement rates. Stone loss due to the collapse of the northeast wall in Room 13 were removed from the 2001 counts, and stone loss due to the collapse of the southwest wall of Room 14 were removed from the 2005 counts since this loss is presumably due to the impact of elk, but may have as much to do with increasing levels of precipitation in these years. As can be seen in this figure, there is a distinctive pattern represented during this nine-year period. That is, a high in 1998, then a general decrease and step-like increase from 1999 to 2001 and then a general low from 2002 to 2006, with a slight increase in 2005. The question is, does this pattern correlate with changes in the ambient environment (e.g., rainfall) or to the number of annual test shots from the DARHT facility?

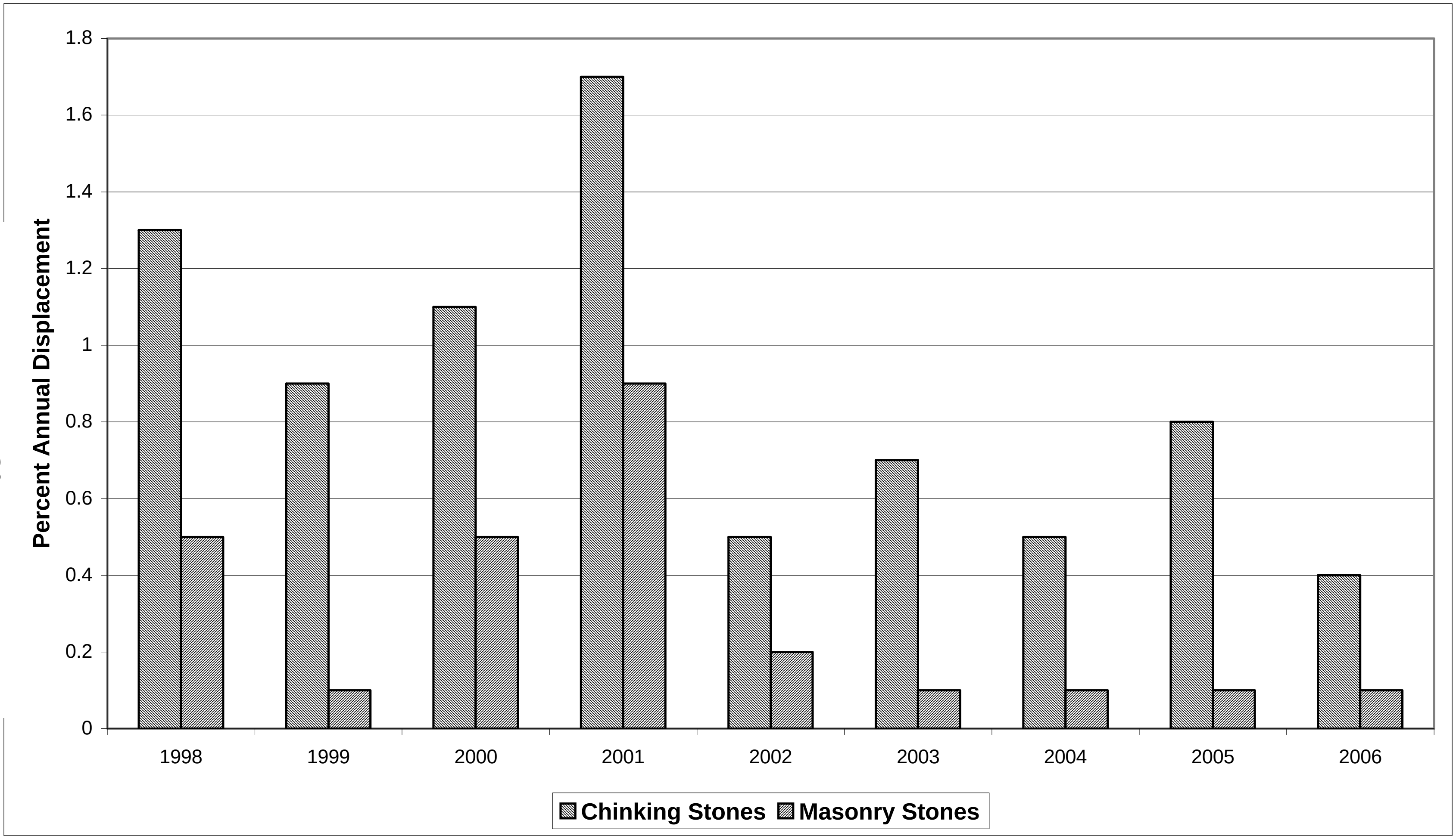

Figure 10. Annual displacement rate for chinking stones and masonry blocks.

There is sufficient data to conduct a study of the correlation between chinking stone loss and annual rainfall/snowfall data for the nine-year monitoring period. These data are provided in Table 4. A linear regression analysis was performed to determine if there was a significant linear relationship between chinking stone loss rainfall, snowfall or number of annual shots at DARHT. It appears that there is no significant relationship between chinking stone displacement rates and rainfall ($r = 0.17$, $f = 0.20$, $df = 1$, $p = 0.66$). Data are available for only six of the nine years for shots conducted at DARHT; however, there is also no significant relationship between chinking stone loss and annual shots ($r = 0.36$, $f = 1.07$, $p = 0.33$). In contrast, there is a significant correlation between chinking stone displacement rates and snowfall ($r = 0.93$, $f = 42.7$, $df = 1$, $p = 0.01$), with 86 percent of the annual variation in chinking loss being explained by the amount of annual snowfall.

The nine-year monitoring program indicates that about 0.9 percent of the chinking stones and 0.3 percent of the masonry blocks are falling out of the walls on an annual basis. The annual displacement rate of chinking stones is significantly correlated with the amount of snowfall and not rainfall or test shots from DARHT. Although the amount of annual snowfall appears to have the greatest effect on chinking stone loss, rainfall does undercut the walls and could cause the catastrophic loss of a wall due to instability. On the other hand, the limited six-year data on shots from DARHT do not seem to correlate with chinking stone loss.

Table 4. Chinking stone loss with annual rainfall, snowfall, and DARHT shots.

Year*	Chinking Stone Loss	Rainfall (in)	Snowfall (in)	DARHT Shots
1998	90	25.7	65	0
1999	61	17.5	19	0
2000	72	16.5	21	0
2001	130	17.0	70	6
2002	35	11.3	16	11
2003	49	12.5	27	14
2004	28	51.5	12	3
2005	113	22.0	75	6
2006	28	15.5	8	14

*data are collected from April of previous year to March of stated year. For example, the rain, snowfall and test shot data for 2000 were calculated from April of 1999 to March of 2000.

Nordby had previously noted that north-facing walls appeared to be in poorer condition than south-facing walls, possibly due to the melting and freezing of snow in these shadowed areas. In 2000, chinking stone loss over the first three monitoring periods was tabulated for north-facing versus south-facing walls. At this time, the rate of loss was nearly equally distributed between north-facing (50.7%) and south-facing (49.3%) walls. In 2005, chinking stone loss for the entire eight-year monitoring period was re-tabulated and showed slightly different results, but the rate of loss was still nearly evenly distributed between north-facing walls (47.9%) and south-facing walls (52.1%). Given these numbers (based on 30 south-facing and 26 north-facing walls), it does not appear that wall orientation is seriously affecting chinking stone displacement rates.

Experimental Projects

2000 Site Vibration Test (Robert Deupree)

The NPS Architectural Team had recommended placing tarps under Category 1 walls as a means of identifying the impact of DARHT facility tests on the masonry at Nake'muu. However, this was deemed an unsatisfactory method. Rather, a more precise method was needed that would actually quantify the amount of vibration being transmitted from the DARHT facility to Nake'muu. A vibration test was therefore set up to monitor the amount of motion being transmitted to Nake'muu from the DARHT facility. Dr. Robert Deupree of DX-7 supervised this study.

Two test shots were fired at the DARHT facility on September 6, 2000. Each explosive was composed of 15.6 pounds of flaked TNT enclosed in a cylindrical cardboard tube. The tube was then placed on a wooden stand. Accelerometers were placed on two walls at Nake'muu to record the events. One was placed on the southeast wall of Room 21 located in the northeastern corner of the site nearer to the DARHT facility. The other was placed on the northeastern wall of Room 32 in the southwestern area of the site (Figure 11). A phenolic block was glued to the top of each wall, and three Endevco ±25 g accelerometers were mounted on each block. The "x" accelerometer was oriented in the direction of the shot, the "z" accelerometer was oriented upward and the "y" accelerometer was oriented perpendicular to the "x" in the horizontal direction. Therefore, six individual accelerometers were used to monitor each test. The location closer to the shot at Room 21 was denoted as Station 1 and the location in Room 32 as Station 2. Data were collected for a 10-second interval during both tests.

Figure 11. Accelerometer on Room 32 wall.

The peak accelerations for all sensors on these tests were between 50 and 100 mg. The oscillation frequencies were about 80 Hz at Station 1 and slightly higher at Station 2. When records are integrated, we find roughly a 6 mm per second of peak velocities and peak displacements of about 0.04 mm. Peak velocity refers to the maximum rate or speed of the motion while peak displacement reflects the largest actual distance from the starting point that the wall has moved during the response to the explosion. Therefore, the walls only moved a maximum distance of 40 microns during the test.

A preliminary equipment calibration study was also conducted at the site. This involved collecting data on seven people walking and jumping within roughly a 5 to 7 m distance from the accelerometer in Room 32. The accelerometer collected data on walking for five seconds and jumping up and down for an additional five seconds. Walking around produced about 10 mg in a horizontal direction and 15 to 20 mg in a vertical direction, whereas, jumping up and down produced peaks of 30 to 40 mg for both horizontal and vertical directions. The peak velocity for the jumps was about 0.8 mm per second. However, this information is not directly comparable to the test shots since the walking or jumping motion is not only characterized by differences in amplitude, but also in frequency. In addition, this simplistic study could not be replicated since the exact weight, location, and nature of the people walking and jumping could not be quantified. These preliminary studies indicate that quantitative data on motion can be collected at Nake'muu, but further studies are needed to help characterize the nature of the vibration and the potential response of the masonry walls to this motion.

2002 Thermal Expansion Study (Robert Deupree and Noor Khalsa)

The thermal expansion experiment was designed to compare the motion produced by the daily thermal expansion and contraction of a masonry wall with the displacement produced by the stress wave induced in the wall by shots at DARHT. Previous monitoring at the site had shown the latter to be about 0.04 mm. The instrument used was a vibrating wire displacement sensor, the 60 mm VW Crackmeter from Slope Indicator. The data were recorded on a model CR10X data logger from Campbell Scientific Company and subsequently downloaded to a laptop computer over a serial port connection. Measurements that could be made with this instrument besides the extension between two positions were the sensor temperature itself, the temperature of the surrounding air (appropriately baffled so that the direct sunlight did not unduly raise the temperature), and the voltage of the battery used to power the entire sensing system. The instrument was first fielded outside of the AROE building for a few days to see how the sensor itself responded to daily temperature changes. We found that there was a negative correlation between the sensor temperature and the extension, possibly because of the temperature compensation algorithm in the firmware.

The measurements were conducted at Nake'muu for a week. The sensor was connected to two separate rocks (Figure 12). The rocks were not touching each other, but the mortar beneath was strongly connected to both rocks. Thus, we could expect to measure the expansion and contraction of the rock – mortar system with this instrument. The results from day to day reproduced nicely. When the sensor extension with temperature was subtracted, a clear picture of the extension relation to air temperature emerged – as the air temperature increased during the day, the extension between the two positions increased, but with a phase lag with respect to the temperature. As the temperature cooled, the extension decreased, but again with a phase lag. A plot of the extension and the air temperature are shown in Figure 13 as functions of the point number of the data (more or less equivalent to time). The temperature ranged from about –4 C to almost 20 C, while the extension changed by about a total of 0.3 mm.

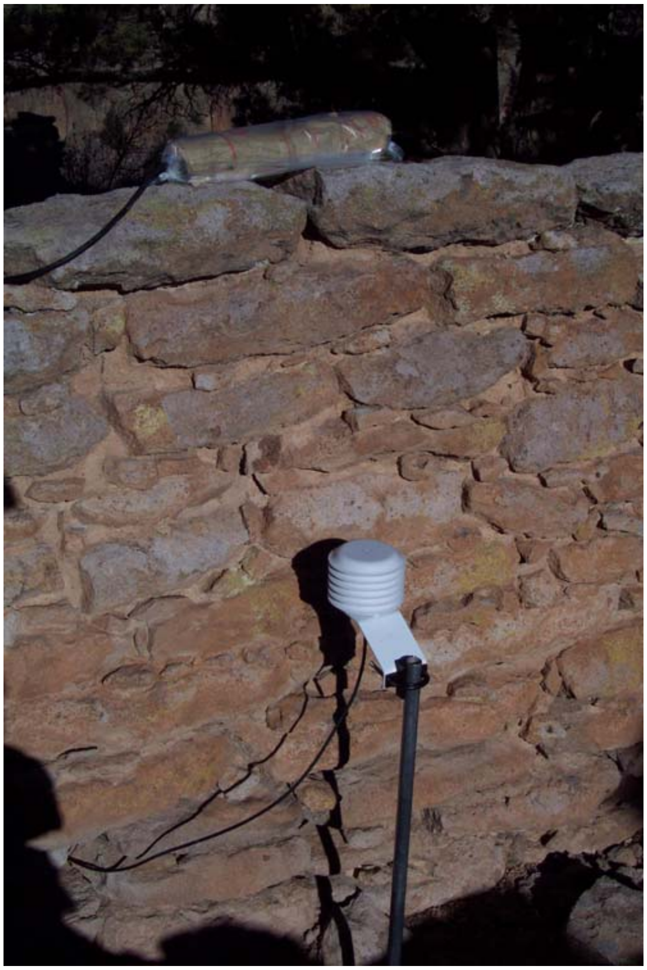

Figure 12. Displacement and temperature sensors.

The expansion and contraction produced by the daily temperature fluctuations appears to be larger than the displacement produced by shots at DARHT. However, the two are not directly comparable because of the large difference in frequency of the motion and because the shot activity produces motion of the wall as a whole. The differential motion produced by DARHT is likely to be much less than the differential motion produced by the daily temperature cycle. The results suggest that the rock – mortar system is actually relatively "spongy" and somewhat able to accommodate the stress waves induced by shots at DARHT.

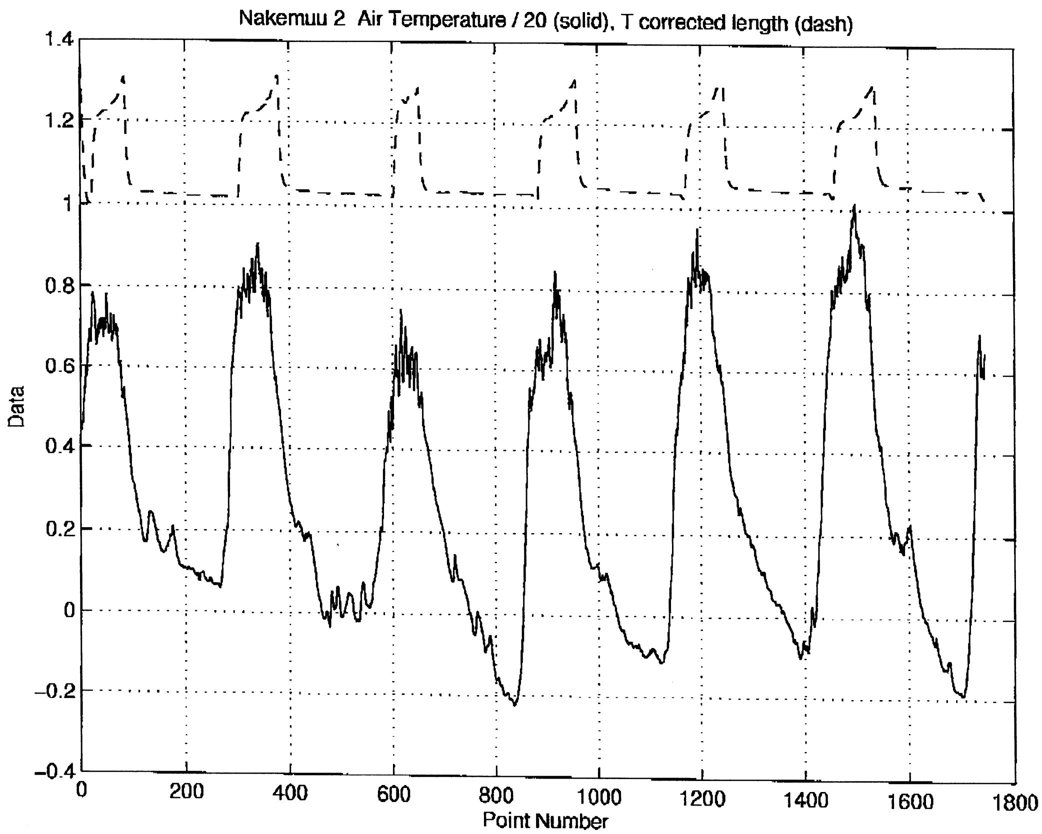

Figure 13. Plot of sensor extension and air temperature.

2006 Fire Hazards at Nake'muu and in the Surrounding Area (Randy G. Balice)

On June 6, 2006, a qualitative fire hazard survey was conducted in the vicinity of Nake'muu. The objective was to make a preliminary determination of the fire risk that exists in the site area. To achieve this objective, ocular surveys were conducted at or near the site to assess the quantity and arrangement of fuels. In addition, evidence of lightning strikes in the study area was also documented and the encountered plant species were listed (Appendix A).

The study area for the Nake'muu fire hazard survey consisted of the mesa, extending from its eastern extent north-westward to a parking area at the eastern end of an access road. The upper and middle portions of the adjacent canyon slopes were also evaluated as part of this survey. Water Canyon is located to the south of Nake'muu and Cañon de Valle is located to the north and northeast.

The entire mesa area was traversed on foot and the plant species that were encountered, the levels and arrangements of fuels on the landscape, and evidence of lightning strikes were recorded. In addition, evidence for other ecological phenomena (e.g., drought and past fires) was documented, as appropriate. In the office, the field observations were combined with evidence from other sources to evaluate the fire hazards at Nake'muu.

The components of fire include fuels, ignitions, and weather, and every attempt was made to document all three of these components in this survey. Fuels are represented by vegetation. Ignitions may occur from lightning strikes. While the natural source of ignition from lighting may also be augmented by human-caused ignitions, no attempt was made to evaluate this source of fire during this survey. Weather consists of a combination of characteristics including temperature, insulation, humidity, and wind, which all contribute to the intensity of fires once they have started (Balice et al. 2005; Johnson and Balice 2006).

Results

Plant species identified in the survey are listed in Appendix A. Four tree species and thirteen species of shrubs were observed, although only seven and six species of forbs and graminoids, respectively, were encountered. The drought occurring during this survey probably contributed to the generally low numbers of non-woody plant species encountered in the site area.

The area supported a mixture of plant communities, including grasslands, shrublands, piñon-juniper woodlands, and ponderosa pine woodlands. Close-canopied forests, with overstory cover greater than 60 percent, were not present in the area. Typical overstory canopy coverages were much less than 60 percent. The mesa and the eastern-facing and south-facing slopes adjacent to the mesa were typically vegetated by piñon-juniper woodlands. Ponderosa pine woodlands and shrublands became more common on the lower slopes to the east and to the south. Throughout, the mesa and south-facing slopes, bare soil, exposed rock, and boulders were common. Continuous vegetation in the understory that might serve as fuel during a wildfire was uncommon.

The slopes to the north and northeast of Nake'muu, which extend down to the Cañon de Valle, are typically covered with greater amounts of vegetation than the slopes to the south. On the upper third of these north-facing slopes grasslands and shrublands are the dominant community types. This area was lightly burned during the Cerro Grande Fire and post-fire growth of grasses and shrubs resulted in more continuous fuels than was observed elsewhere during this survey. Continuing down the slope to the north, ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) become increasingly common, in combination with the shrubs and grasses.

Tree mortality related to the recent drought that culminated in 2002 was observed throughout the study area. On the mesa, nearly all of the piñon that were greater than 10 feet tall were dead, and 10 percent of the one-seed juniper (*Juniperus monosperma*) had also been killed in the recent drought. Some piñon (*Pinus edulis*) less than 10 feet tall had survived the drought. On the eastern-facing and south-facing slopes, recently killed piñon, ponderosa pine, and Douglas fir were abundant. However, the mortality levels decreased toward the bottom of the canyon, as well as on the canyon slope toward the west. On the north-facing slope, the mortality of Douglas fir and ponderosa pine was nearly 100 percent at higher elevation positions on the canyon slopes.

As on the south-facing slope, the survival of fir and pine increased as the elevations decreased toward the canyon bottom.

In addition to the drought of 2002, the impacts of the drought that occurred in the 1950s could also be observed around Nake'muu. Weathered and decayed ponderosa pine logs were scattered throughout the top of the mesa. These logs were the primary components of the 1000-hour fuels that were observed on the mesa. As the dead trees from the recent mortality fall to the ground, there will be a corresponding increase to the 1000-hour fuels in the area.

Two fires have burned in the Nake'muu area during the past 30 years and the remnants of these fires could still be observed in 2006. The La Mesa burned from the south in 1977. To the north, this fire burned as far as Water Canyon and the adjacent mesa to the north, possibly including Nake'muu. In 2000, the Cerro Grande Fire burned toward Nake'muu from the northwest. This fire advanced down the north-facing slopes of the Cañon de Valle and reached as far as Nake'muu. Several spot fires from the Cerro Grande Fire were also noted on the uppermost south-facing slopes of the Nake'muu area.

Evidence of lightning strikes was not abundant in the Nake'muu area. One dead Douglas fir, immediately to the southeast of the parking area, had been struck by lightning on at least one occasion. No further evidence of lightning strikes was found during this survey. However, lightning strikes do occur in the Nake'muu region on an annual basis. A map of the area surrounding Nake'muu shows the locations of lightning strikes from 1994 to 1999 and from 2003 to 2004 (Figure 14). Lightning strikes were plotted if they occurred during the time period when ignition of fires from lightning would most likely occur, from March 1 to September 1 (Balice et al. 2005). In addition, the lightning strikes are further subdivided into those that occur from March 1 to July 8, when lightning ignitions from fire would most likely occur and develop into a catastrophic fire (Johnson and Balice 2006). After July 8, ignitions from lightning strikes would occur with equal probability, but the potential for these fires to develop into catastrophic proportions is less.

One potentially fire-igniting lightning strike occurred at Nake'muu (Figure 14). Another lightning strike that occurred after July 8 was responsible for the lightning scar on the Douglas fir that was observed in the field, on the uppermost southwest-facing slope to the northwest of Nake'muu. No evidence was found in the field of the third lightning strike that was located in between the other two strikes that were discussed here.

Weather conditions are most conducive to the ignitions of fires between April 13 and September 1 (Johnson and Balice 2006). However, the time period that is most amenable to the ignition and continued burning of fires is between May 22 and July 8. Before May 22, precipitation may be low and the wind speeds may be high, but lightning is not as frequent. The lack of lightning notwithstanding, ignitions from lightning or any other source during this time period can create fires that burn over large areas and, during time of drought, the period of potentially severe fires may extend earlier into the spring by a month or more. After July 8, lightning strikes will occur in abundance, but wind speeds will be lower and precipitation will occur with higher frequencies and in higher amounts. Therefore, the lightning ignitions that do occur after July 8 would not be expected to burn over large areas or for extended periods of high intensity.

Figure 14. Lightning strikes in the Nake'muu region; 1994 to 1999 and 2002 to 2003. (Figure not included because of exact site location)

From this survey and in combination with other sources of information, it was concluded that the fire hazards in the forest and woodland overstories at Nake'muu are not severe and that the fire hazards that exist in these overstories are not tractable to management actions. Therefore, it is not necessary or practical to mitigate the fuels through thinning or through other treatments. Throughout this area, the lack of dense overstory canopies indicates that it is unlikely that continuously burning canopy fires would occur.

Fuels on the ground surface are also not extensive nor are they continuous. The mesa and the slopes to the east and the south are not heavily vegetated and there is an abundance of bare soil and exposed rock. This does not preclude the possibility for severe fires to occur on these south-facing slopes, and the threat of fire should be taken seriously during any period of severe drought. The north-facing slopes toward the Cañon de Valle support plant communities that are more continuously vegetated with grasses and shrubs. These areas may burn in a more continuous manner if a fire were to be ignited, and the threat of fire on these north-facing slopes may be high in a wider range of weather conditions.

The general lack of continuous fuels should not be interpreted to mean that fires would not occur in the Nake'muu area. The annual abundance of lightning strikes coupled with the extreme fire season that typically occurs annually from late May through early July, suggests that fires could occur in this area during any year. Moreover, the Los Alamos region, which includes Nake'muu, has experienced extreme drought during several recent years, including 2000, 2002, and 2006. The drought of 2006 was preceded by a wet period in 2005. During the wet periods, vegetation growth produces biomass that becomes fuels in the dry periods. During the periods of severe drought, the fire season can be extended by more than a month and any fire ignition, from lightning or other sources, that may occur in fuel loads that increased during the wet years could have severe consequences to resources at risk.

Given these fire hazards that can support severe fire hazards during unfavorable weather conditions and given the general lack of opportunity for conducting mechanical thinning or other fire hazard reduction activities, it appears that the options for fire management at Nake'muu are limited. A severe fire could occur in the area and advance upslope from any direction toward Nake'muu, and this could happen during any year but is most likely during drought years. If this were to occur, the best suppression option would probably be to schedule strategic air drops of water or fire retardant between the site and the fire. Care should be taken so that the water or retardant material is not dropped on the site itself, which may damage its walls.

Photographic Studies

1915 Photographs

The Los Alamos Historical Society Archives contain a series of photographs that were taken of Nake'muu in 1915. This series includes a site overview looking east, Rooms 4 to 6, Rooms 8 to 10, the area between Rooms 14 and 55, and a section of the pueblo with Rooms 32, 36, and 43. What we see is that some portions of the pueblo have not changed at all since 1915, whereas, others have witnessed the total collapse of wall segments. Figure 15 is the site overview photograph. It shows that the roomblock containing Rooms 25 to 28 and 33 had already collapsed down to the ground. The northeast standing walls of Rooms 30 and 31 are the same as today, whereas, the southeast walls of Rooms 29 and 38 and the northwest wall of Room 42 have fallen to grade. Along the south side of the pueblo, Rooms 15, 16, and 47 seem to have partially collapsed, but Rooms 43 or 44 may still have standing walls. In the eastern roomblock, Rooms 4 and 5 may also have standing walls. The standing ponderosa pine in the photograph has fallen, destroying the walls in Room 16.

Figure 16 shows Rooms 4 to 6 in 1915 and today. A comparison of the photographs reveals that the walls have not changed over this 85-year period. Figure 17 illustrates the area of Rooms 8 to 10. A set of top wall stones has fallen in Room 9, and a wall segment between the east doorway of Room 8 and the adjacent abutted wall to Room 9 has separated and collapsed. Otherwise, the walls are quite similar today. Figure 18 shows that the eastern roomblock is much the same as today, with Rooms 4 to 6, 8 to 10, and 14 exhibiting few or no changes. It looks like Rooms 48 to 50 had already collapsed, but there were still some standing walls in the area of Room 55 along the northern side of the pueblo. Lastly, Figure 19 illustrates the area of Rooms 32, 36, and 43. The south wall of Room 32 is still standing, with only a single building stone having fallen from the top of the wall. On the other hand, the south-facing sealed doorway of Room 36 is still intact. These stones have since fallen, leaving the doorway open today. The picture foreground shows that the lower portion of the south wall of Room 43 is also still intact, with these stones having since fallen to grade. Overall, the photograph seems to indicate an increased rate of deterioration along the northern and southern sides of the pueblo in the areas with an increased slope and greater runoff. In addition, it appears that the western roomblock extension had already collapsed by this time.

Figure 15. 1915 and 2000 photographs of Rooms 25 to 28 and 33.

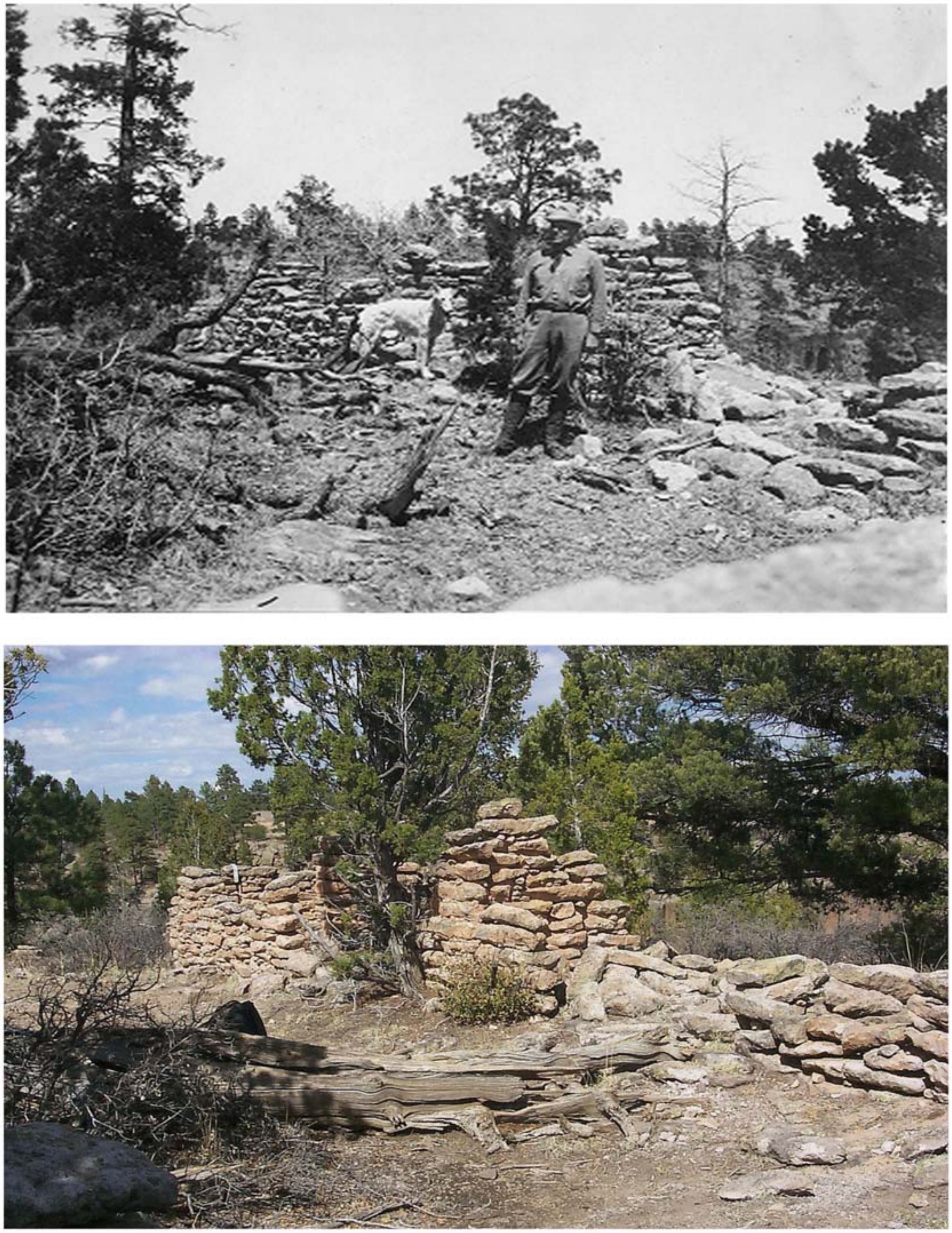

Figure 16. 1915 and 2000 photographs of Rooms 4 to 6.

Figure 17. 1915 and 2000 photographs of Rooms 8 to 10.

Figure 18. 1915 and 2000 photographs of eastern roomblock.

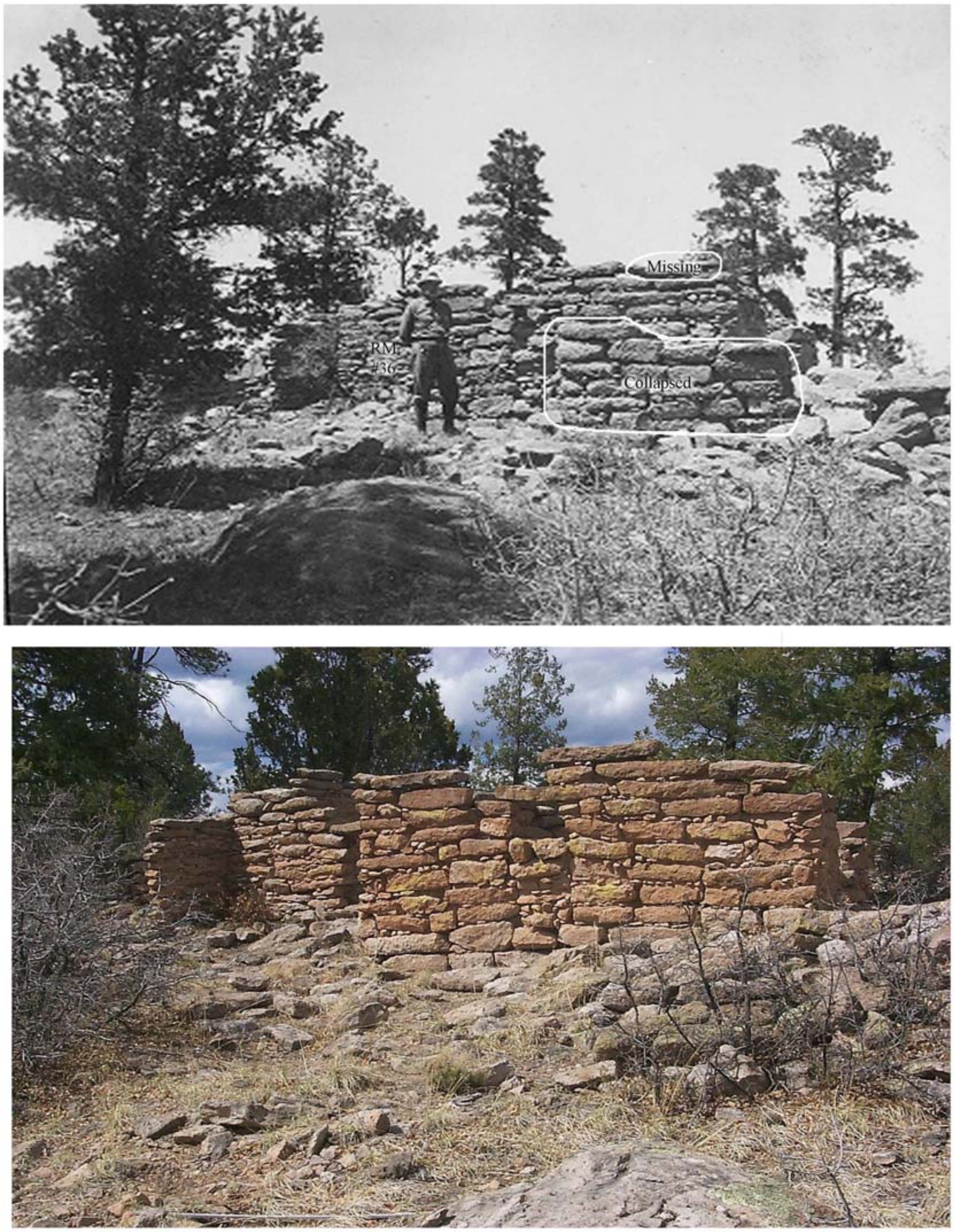

Figure 19. 1915 and 2000 photographs of Rooms 32, 36, and 43.

1975 Photographs

Charlie Steen also took a series of 55 photographs at Nake'muu in 1975. These photographs are curated in the New Mexico Historic Preservation Division files in Santa Fe. Thirteen wall sections were photographed in sufficient detail so that comparisons could be made between the 1975 and 2000 photographs. All of these walls are located in the eastern area of the site, which is situated closest to the DARHT facility. This consists of walls within Rooms 5, 7, 8, 9, 14, 17, 18, and 23. Figure 20 illustrates a comparison between the old and recent photographs of the exterior northwest wall in Room 7. The red block indicates the exact area compared between the photographs. A total of 406 chinking stones and 342 masonry blocks are present in the 1975 sample, whereas, there are 387 chinks and 335 blocks remaining today. This represents a 4.6 percent reduction of chinking stones and 1.8 percent reduction of masonry blocks over this 25-year period. Stated another way, this reflects an annual loss rate of only 0.2 percent for chinks and 0.1 percent for blocks.

This is a lower loss rate when compared to the 0.9 percent and 0.3 percent for chinking stones and masonry blocks observed during the nine-year monitoring program. It is unclear as to whether these differences are attributed to the smaller 1975 sample size, the long-term averaging of a 25 vs. 6-year sampling cycle, or that the deterioration rate is beginning to accelerate at the site. Nordby (personal communication, 2000) states that ancestral pueblo ruins eventually reach a point where the deterioration rate represents an exponential curve and not a linear curve, with a marked increase in the loss rate of wall elements. As he notes,

> The maximal wall heights mentioned near the turn of the century, up to 2.4 m (8 ft) (Hewett 1906:25) have been reduced 25 percent to 50 percent in this century, indicating that the entropy curve for Nake'muu is getting steeper and site deterioration is accelerating (Nordby et al. 1998:284).

Several of the 1975 photographs also revealed that sections of four walls have collapsed during this 25-year period. This collapse includes 10 masonry blocks from the northeast wall of Room 16, another 10 blocks from the northwest wall of Room 17, four blocks from the northwest wall of Room 36, and three blocks from the southwest wall of Room 40. The wall in Room 16 is situated adjacent to a large juniper that may have affected the stability of the wall. The collapsed section in Room 17 is located adjacent to an elk trail that might have also affected this wall. Rooms 36 and 40 are situated near each other in the northwestern area of the site. The blocks in these sections were located in unstable situations at the freestanding ends of partially standing walls. And, in 2005, the northeast wall of Room 12/southwest wall of Room 14 was partially knocked over, presumably by an elk.

1975

2000

Figure 20. 1975 and 2000 photographs of the exterior northwest wall of Room 7.

Cerro Grande Wildfire

Portions of Nake'muu were burned by the 2000 Cerro Grande wildfire. Much of this burning was limited to the northern edge of the site where ground cover like scrub oak was burned. The rooms in this area have mostly fallen to grade, so that mostly ground-level rubble was exposed and burned. Nonetheless, two large trees were also burned and these posed a threat to the standing walls situated in the northeastern section of the site (Figures 21 and 22). Consultation with San Ildefonso Pueblo was initiated and they agreed that the two trees should be cut. A Johnson Controls Northern New Mexico work crew, under the direction of Manny L'Esperance, cut the trees down on June 16, 2000. Two members of San Ildefonso Pueblo were present during the activity. The fact that much of the scrub oak had already been removed from the site helped to avert the potential for further damage. Besides cutting the trees, the crew placed a series of wattles along the northern side of the site to reduce erosion. Some straw was also placed on the ground in the area of the burned rubble to enhance plant growth.

Figure 21. Site before Cerro Grande fire rehabilitation.

Figure 22. Site after Cerro Grande fire rehabilitation.

Accord Pueblos Consultation

The DARHT Facility MAP requires that the Accord Pueblos be given the opportunity to visit Nake'muu on an annual basis to personally evaluate the changing condition of the site. Members of the Accord Pueblos have visited the site in November of 1998, June of 1999, April of 2000, July of 2001, July of 2002, October of 2002, September of 2003, September of 2004, May of 2005, and will visit in late summer or early fall of 2006.

Nake'muu is an ancestral home of the people from San Ildefonso Pueblo. Information on the site has been passed down from generation to generation through oral history and traditional songs. For example, although some of the inhabitants of San Ildefonso Pueblo sought refuge at Black Mesa during the Pueblo Revolt, many of the women and children hid at Nake'muu. The Pueblo elders speak of traveling the canyons from Navawi to Nake'muu to the Valle Grande. This trek includes sleeping in cavates at Navawi, then hiking towards Nake'muu where they experienced the winds coming down the canyon. They collected herbs at the base of the mesa near the site and visited Nake'muu. Finally, they headed on to higher elevations where they collected obsidian. Agricultural fields were also located on the mesa near the DARHT facility. However, Nake'muu has not been visited for traditional purposes since the 1950s. It was during this last visit that vigas were noted as still being present at the site (Martinez 2000, personal communication). There are no vigas present at the site today.

ESH-20 conducted the first site tour on November 6, 1998, which was led by Gerald Martinez and Brad Vierra. Approximately 15 representatives of San Ildefonso Pueblo, Bob Grace and Bill McCormick of ESA-DO, Dennis Erickson of ESH-DO, and Elmer Torres (Community Outreach) visited the site. Mrs. Martinez was one of the San Ildefonso representatives. She is an 80+ year old resident of San Ildefonso Pueblo. Steen (1977:37) had suggested the plaster covering the northwest wall in Room 18 was original wall plaster. However, Mrs. Martinez considered that this plaster was recent in age and did not date to the original occupation of the pueblo.

A second tour was taken to the site on June 8, 1999. Five members of San Ildefonso Pueblo and two members of Santa Clara Pueblo went to the site with representatives of ESH-20, Chuck Farrar (ESA), and Larry Nordby (NPS). Site monitoring procedures were discussed during this visit.

The Nake'muu condition assessment report was sent out for review on May 20, 1999. The Pueblo of San Ildefonso commented on the report in a letter dated June 16, 1999. They raised three main concerns:

1) Tours—the tours conducted on this site are one of the main culprits that are detrimental to the preservation of the site;
2) On-Site Observations—actions by any technical staff on said observations may have some impacts on the site as well (e.g., trails across the archaeological site, data recording done within exterior boundaries of site);

3) Surface/Subsurface Explosives Testing—impacts may be minimal without data to substantiate, but vibrations and airborne debris legitimize this concern.

As previously noted, members of San Ildefonso Pueblo are opposed to any stabilization being done to the site; however, this assumes that LANL activities are not accelerating the deterioration process. Instead they recommend that a video be made of the site that could be used as an educational tool and would reduce the need for site visits.

Four representatives of San Ildefonso Pueblo were present on April 11 and 12, 2000, for the annual monitoring session. They helped in conducting the annual assessment and removed vegetation from the site. Two members of San Ildefonso Pueblo were present at the site on June 6, 2000, when burned trees were cut down. Two members from San Ildefonso Pueblo and Santa Clara Pueblo were also present to witness the first vibration test at Nake'muu on September 6, 2000. Robert Deupree (DX-7) supervised this monitoring test.

Steve Mee (FWO) and Bruce Masse (ENV-ECO) escorted the governors of San Ildefonso, Santa Clara, Cochiti and Jemez Pueblos on a tour of the site on July 6, 2001. They discussed the effects of the Cerro Grande fire on Nake'muu and other archaeological sites in the area.

Brad Vierra (ENV-ECO) escorted the Bandelier National Monument site stabilization crew on a tour of Nake'muu on July 17, 2002. The stabilization crew was composed of students from San Ildefonso, Cochiti, San Juan, and Santo Domingo Pueblos. The tour was to provide first-hand experience of how the Cultural Resources Management Team is conducting the long-term monitoring program at Nake'muu.

Bruce Masse escorted the Cerro Grande Rehabilitation Project (CGRP) crews from San Ildefonso and Santa Clara Pueblos on a tour to Nake'muu on October, 9, 15, and 30, 2002. The crews were evaluating the site for future rehabilitation. Brad Vierra, Bruce Masse and Eric Holmes (ESA-DO) escorted the San Ildefonso CGRP crew to Nake'muu on August 18, 2003. Phoebe Suina and Shannon Smith (FWO, CGRP) were also present. A detailed review of the site was conducted to determine the exact procedures to be used when rehabilitating the site. It was determined that the crew size and the area traversed by the crew would be kept to a minimum. A daily log form was developed that includes information on date, arrival time, departing time, crew members, equipment present and work completed. This form was filled out by Bruce Masse, including marking the location of daily activities on a site map.

Bruce Masse escorted the San Ildefonso CGRP crew to Nake'muu on September 22 –25, 2003. The crew removed brush, cut trees and laid some soil erosion control features composed of cut limbs (Figure 23). Figure 24 illustrates the location of tress cut down by the thinning crew. As a result of efforts associated with this project, the area in and around Nake'muu has mostly been cleared of vegetation, and the site area is much more open. It is unclear what effect this might have on the site in respect to both elk visitation and exposure to the weather (e.g., rain and snow).

Figure 23. Nake'muu after the removal of brush and trees.

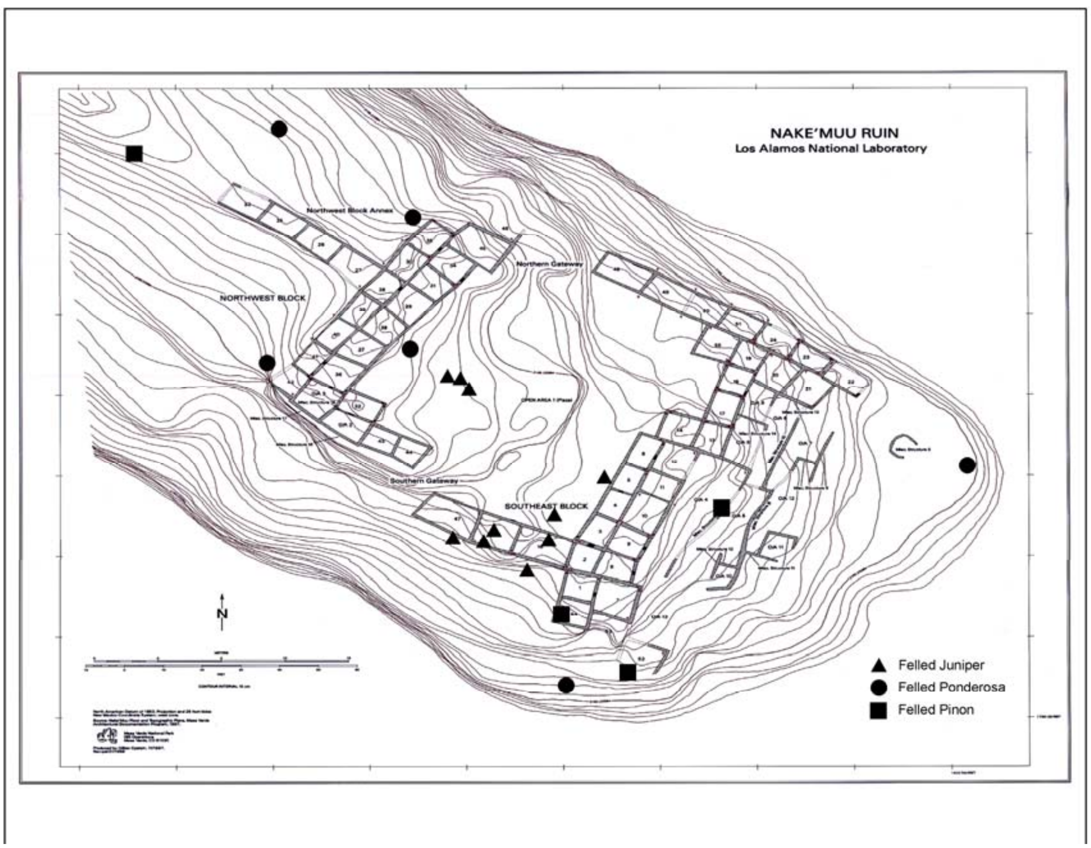

Figure 24. Location of felled trees at Nake'muu.

A tour for representatives from San Ildefonso Pueblo was taken to Nake'muu on September 1, 2004. The tour was led by Gerald Martinez and Brad Vierra, and included five tribal Councilman, two tribal leaders, Vicki Loucks (DOE) and Robert Grace (ESA).

On May 18, 2005, representatives from San Ildefonso Pueblo were taken to Nake'muu for a tour. The tour was led by Gerald Martinez and Brad Vierra of the Ecology Group (ENV-ECO), and also included Jackie Little (Group Leader, ENV-ECO), and fourteen tribal members from San Ildefonso.

On September 18, 2006, five representatives from Santa Clara Pueblo were taken to Nake'muu by Gerald Martinez (ENV-EAQ). The Santa Clara members are currently involved in stabilization efforts at Puye and wanted to visit Nake'muu to better understand how the LANL Cultural Resources Team implemented their monitoring program.

Summary and Recommendations

Nake'muu is one of only a few standing-walled ancestral pueblos remaining in the Jemez Mountains. Perched on a narrow finger between two adjacent canyons, it is both isolated and exposed to the natural and human-modified environment. Nonetheless, it has mostly survived the effects of the natural elements for over 700 years. Under the DARHT Facility MAP, the ENV-EAQ Cultural Resources Management Team is monitoring the effects of the DARHT facility operations on the standing-walled masonry at Nake'muu.

In a 1977 baseline assessment, the Mesa Verde Architectural Team suggested that the ambient environment poses the greatest threat to the pueblo. This observation was based primarily on the condition assessment and the observation that rainfall and snowmelt have eroded adobe mortar, thereby rendering many of the walls unstable. In addition, several other natural factors may also be contributing to the deterioration of Nake'muu, including vegetation, elk, deer, human visitors, earthquakes, lightning, thunder, and heavy wind. It is, however, difficult to quantify all of these events.

The nine-year monitoring program indicates that about 0.9 percent of the chinking stones and 0.3 percent of the masonry blocks are falling out of the walls on an annual basis. The annual displacement rate of chinking stones is significantly correlated with the amount of snowfall in a given year and not rainfall. Although the amount of annual snowfall appears to have the greatest effect on chinking stone loss, rainfall does undercut the walls and could cause the catastrophic loss of a wall due to instability. On the other hand, the limited six-year data on shots from DARHT does not seem to correlate with chinking stone loss.

Two experimental projects were conducted to determine the effects of test shots from DARHT and the natural environment at Nake'muu. Two test shots of approximately sixteen pounds of TNT were fired at DARHT. Accelerometers at Nake'muu recorded wall movement of 0.04 mm. Sensors were then placed on a wall to determine if daily changes in thermal temperature might also be affecting the walls. The results of this test indicate that the walls move 0.3 mm on a daily basis due to thermal expansion and contraction. Although this latter movement occurs within a 24-hour period, vs. the rapid movement of the DARHT test, it does occur 365 days a year.

The photographic studies indicate that sections of some walls have not changed since 1915, whereas other walls have totally failed and fallen to grade. The latter appears to be the result of slope runoff and the undercutting of walls located along the northern and southern periphery of the site. Comparisons made with the 1975 photographs indicate an annual loss rate for this 25-year period of only 0.2 percent for chinks and 0.01 percent for blocks. This rate is lower than the current recorded rate. However, it is unclear as to whether this represents a sampling bias or that the site is beginning to enter a stage where its entropy curve is steepening and the deterioration rate is markedly increasing.

In summary, the preliminary results of this nine-year monitoring program indicate that there have been some minor changes in the standing-walled architecture at Nake'muu. Annual chinking stone loss is significantly correlated with the amount of annual snowfall, but not rainfall or the number of test shots at DARHT. However, rainfall is an important factor in undercutting the standing walls. Lastly, the walls appear to experience greater movement on a 24-hour basis due to thermal expansion/contraction, than they do in respect to the test shots. Therefore, the results indicate that the ambient environment appears to be having a greater effect on the deterioration rate of the standing walled architecture at Nake'muu, as compared to the DARHT facility operations.

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Appendix A: Plant Species Encountered in the Nake'muu Area in May, 2006

Trees

Juniperus monosperma	Single-seed juniper
Pinus edulis	Piñon
Pinus ponderosa	Ponderosa pine
Pseudotsuga menziesii	Douglas fir

Shrubs

Artemisia carruthii	Wormwood
Artemisia frigida	Fringed sage
Cercocarpus montanus	Mountain mahogany
Fallugia paradoxa	Apache plume
Gutierrezia sarothrae	Snakeweed
Pahyistima myrsinites	Mountain lover
Philadelphus microphyllus	Mock orange
Quercus undulata	Wavy-leaf oak
Rhus trilobata	Skunkbush
Ribes cereum	Wax currant
Robinia neomexicana	New Mexico locust
Yucca baccata	Banana yucca
Yucca glauca	Narrow-leaf yucca

Succulents

Opuntia erinacea	Utah prickly pear cactus

Forbs

Castilleja miniata	Scarlet paintbrush
Chrysopsis villosa	Hairy golden aster
Eriogonum jamesii	Antelope sage
Hymenoxys argentea	Perky Sue
Oenothera hookeri	Hooker's evening primrose
Penstemon secundiflorus	Sidebells penstemon
Tragopogon dubius	Yellow salsify

Graminoids

Bouteloua gracilis	Blue grama
Koeleria cristata	June grass
Muhlenbergia montana	Mountain muhly
Poa fendleriana	Mutton grass
Schizachyrium scoparium	Little bluestem
Sporobolus cryptandrus	Sand dropseed