

CONDITION ASSESSMENT AND RECOMMENDATIONS

Stabilization of the Shaker South Family Barn

of the
Harvard Shaker South Family

**South Shaker Road
Harvard, Massachusetts**



prepared for the

Harvard Conservation Trust

by

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Harvard Shaker South Family, Harvard, Massachusetts

TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 DOCUMENTARY BACKGROUND

3.0 DESCRIPTION OF ORIGINAL CONSTRUCTION

- 3.1 Load Bearing Stone Masonry
- 3.2 Interior Wood Framing
- 3.3 Roofing and Cladding

4.0 SUMMARY OF CONDITION

- 4.1 Historical Development
- 4.2 Current Status

5.0 INVENTORY OF CONDITIONS

- 5.1 Lateral Restraint
- 5.2 Exposure of Vulnerable Faces to Weathering
- 5.3 Top Edge Wythe Separation and Loss
- 5.4 Joints and Mortar
- 5.5 Vertical Cracking Systems
- 5.6 Plumbness Deviations and Bulges
- 5.7 Retaining Walls
- 5.8 Corner and Window Geometry
- 5.9 Arch Geometry
- 5.10 Interior Wood Lintels
- 5.11 Ferrous Element Engagements
- 5.12 Vegetation
- 5.13 Site Drainage

6.0 RECOMMENDED STABILIZATION PROGRAM

6.1 Indirect Interventions

6.1.1 Monitoring Implementation

6.1.2 Site Organization

6.1.3 Vegetation Removals

6.1.4 Non-masonry Element Documentation

6.2 Direct Interventions

6.2.1 Emergency Shoring at Northwest Corner

6.2.2 Emergency Shoring at Southwest Corner

6.2.3 Remedial Shoring at South Arch and Adjacent Cheek Wall

6.2.4 Southwest Corner Masonry Stabilization

6.2.5 Northwest Corner Masonry Stabilization

6.2.6 North Arch Stabilization

6.2.7 South Arch Stabilization

6.2.8 Wall Cap Protection and Pointing

6.2.9 Retaining Wall Stabilization

APPENDIX A: PACKAGE ESTIMATES

APPENDIX B: HABS DATA SHEET AND DRAWINGS

APPENDIX C: ENGINEERING REPORT

APPENDIX D: MORTAR ANALYSIS

APPENDIX E: EXISTING CONDITIONS DRAWINGS

APPENDIX F: TREATMENT LOCATIONS DRAWINGS

APPENDIX G: PHOTOGRAPH THUMBNAIL INDEX

1.0 INTRODUCTION

The Shaker South Family Barn was an early 19th century stone masonry three and a half story gable-roofed structure situated in a gently sloping pasture adjacent to the South Family complex in Harvard, Massachusetts. The structure has been a ruin for a number of years, surviving in unstable and deteriorating condition (Fig. 1). However some of its most significant and striking masonry features still remain. The Harvard Conservation Trust, with grant assistance from the Bruce J. Anderson Foundation, a support organization of the Boston Foundation, has commissioned this study to document and evaluate the structure's current condition, and to recommend a program for arresting the deterioration to the extent feasible, and stabilizing the remains. The Trust holds a preservation restriction on the barn remains and 1.5 acres of land on which it is situated. The stone barn and land are part of a 3-acre parcel presently owned by Mark Mikitarian and Marc Sevigny, which includes the South Family Dwelling where they live.

2.0 DOCUMENTARY BACKGROUND

The barn was documented for the Historic American Building Survey (HABS) by Bayard Underwood, AIA in July of 1963 (survey number MASS-808). This effort included preparation of four sheets of measured drawings depicting plans, elevations, and section, as well as two data pages (Appendix B). Also in 1963 HABS photographer Jack E. Boucher recorded twelve photographic views, adding to the five views previously recorded by Stanley P. Mixon in 1940.

In his summary of *Physical History* (HABS Data Page 2), Underwood ascribes a construction date of 1835 based on entries in Shaker journals located at the Fruitlands Museum in Harvard, Massachusetts. Moreover, specific journal references are said to note receipt of white pine shingles from the Enfield, New Hampshire shaker community in that same year.

3.0 DESCRIPTION OF ORIGINAL CONSTRUCTION

A distinctive load-bearing stone masonry structure featuring prominent arched openings in its two long walls, the Shaker South Family Barn accommodated livestock, equipment, and feed storage within. Belying initial impressions, the organization of façade elements was more characterized by balance than by strict symmetry. The builders augmented the site's natural topography with stone retaining walls and earthen ramps to provide direct exterior access to all three principal stories. The perimeter walls utilized a combination of quarried granite taken from an adjacent ledge outcrop, and fieldstone. These formed the rectangular shell, measuring approximately 84 feet in length, 43 feet in width, and 24 feet in height. Gables were framed in wood, as were the



Fig. 1
General view from south.

roof and all interior floors and partitions, except the easterly three-quarters of the ground floor, which was earthen (Appendix B).

3.1 Load Bearing Stone Masonry

The original stone masonry was the most striking feature of the building. The exterior wall was laid in two wythes; the inner of coursed fieldstone rubble, and the outer of coursed but squared rubble, mixing fieldstone with quarried pieces. The quarried granite stones were the most consciously squared of these, and were incorporated into corner quoins, arches, retaining wall copings, and window and door lintels, jambs, and sills (Figs. 2, 3). These also served to tie the inner and outer wythes together at the respective building corners and at wall openings. Randomly placed through-wall header stones provided other inter-wythe tying. Wall thickness averaged approximately 2 feet in the first story, stepping back to roughly 20 inches at the second story. The step-back however was inconsistent and not apparent throughout the entire perimeter. Probably for this reason it was not reflected on the HABS drawings.

Stones comprising the freestanding portions of wall were laid in a natural lime mortar, although those of the ramp retaining walls, including the building's surviving east wall and easterly end of the south wall, appear to have been dry-laid. Collar joints were filled with small chinking to lessen the requirement for mortar, and irregularities in joint widths were compensated via galleting with small and often flat stone shards (Fig. 4).

Almost all the lintels and most of the sills were comprised of single squared granite stones, although not always dressed into perfectly rectangular shapes. Alterations are evident in surviving stonework, including the blocking of several door and window openings at the easterly end of the south wall, to enable addition of an earthen ramp to the second story at this location (Fig. 5). Whether this occurred during initial construction or subsequent use is unknown. Curiously however, one of the doors appears to have been first converted to a window (a sill spans at mid-height) sometime prior to complete closure. At the westerly end of the first story north wall another small window opening was closed, although only in the plane of the outer wythe. No exterior lintel or sill remains in evidence. However, this window utilized a stepped pair of wood plank lintels to support the inner wythe (Fig. 6). With the opening below unfilled, the feature now appears as a niche.

3.2 Interior Wood Framing

Interior wood framing was arranged into 7 bays in length and 3 bays in width. Lengths and widths were roughly equivalent from one bay to the next, excepting the bays corresponding to the arched openings, which were slightly greater in length. The 7-bay length was divided by 6 timber frame bents, the girt and joist components of which engaged the stone masonry at numerous locations (Appendix B). Diagonal knee bracing was installed at the principal member connections within each bent (Fig. 7). The net effect of these framing engagements, along with the floor and roof systems they carried, was to provide lateral support to the stone masonry walls.

Engagements usually involved simple pocketing of members into the masonry when they were situated at right angles to their respective walls. The girts comprising each of the 6 timber bents engaged pockets in the north and south stone walls respectively at the 1st, 2nd, and 3rd story floor levels. Selected girts were in addition physically tied to the masonry via iron through-anchors with oval exterior bearing plates. This occurred at the floor of the 2nd story in the bents flanking the north and south wall arched openings; also where the eastern-most and western-most bents



Fig. 2
Dressed exterior granite quoins, jambs, lintels, and sills.

Fig. 3
Dressed exterior granite arch jambs, springers, and voussoirs.

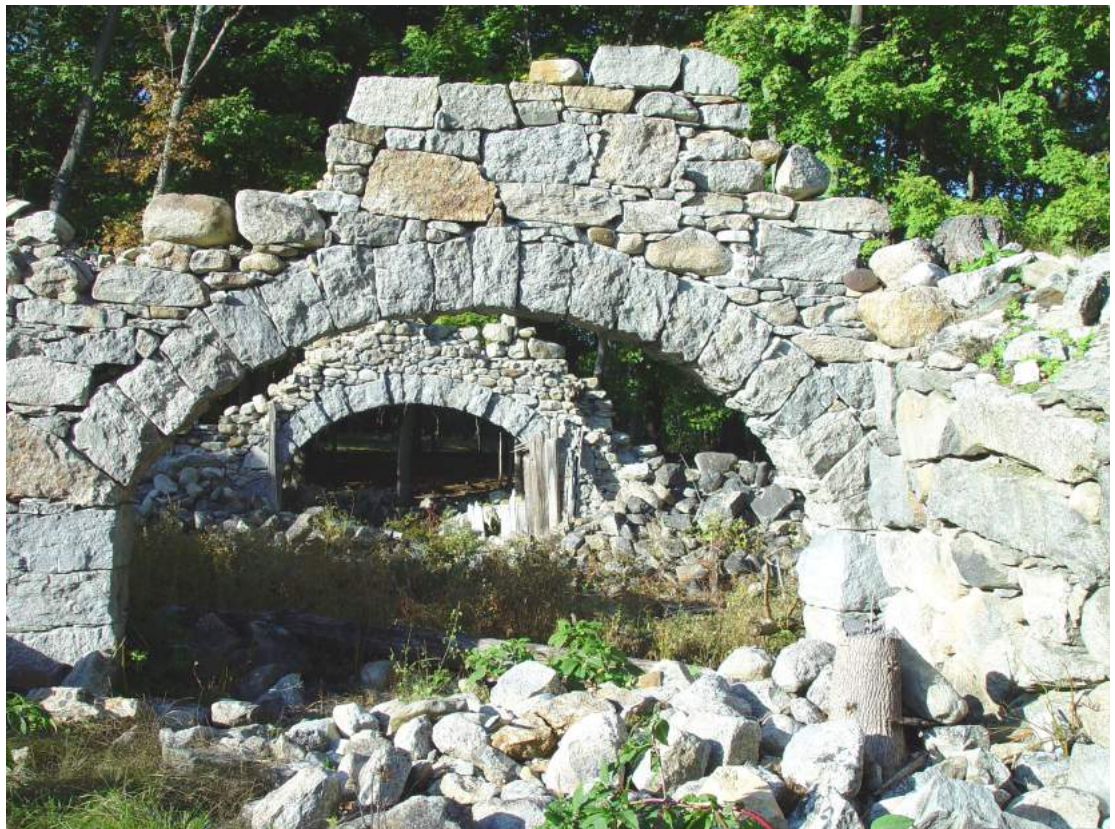




Fig. 4
Cross section of wall showing chinked collar joints, and random headers tying inner and outer wythes.

Fig. 5
Altered interior south wall masonry indicating prior window and door openings.





Fig. 6
Abandoned opening at west end interior of north wall, incorporating wood lintels.

Fig. 7
Interior framing bents with diagonal braces at lateral girts. (HABS Photograph by Stanley P. Mixon, July 1940)



engaged the north wall (Figs 8, 9). In addition, this occurred in the west wall at the floor of the 2nd story, in locations corresponding to the two column lines (Appendix B). Numerous pockets remain in all four walls, either for girts associated with the structural bents, or, in the east and west walls for the floor joists that these bents supported (Fig. 10). Along the head of the south arch, iron hangers appear to have carried short cross-joists that may have related to hinged floor traps serving the manger stalls above (Fig. 11). Finally, the tops of the masonry walls were engaged by a series of girts supporting a continuous wood top plate that in turn carried the lower ends of the rafters and gable studs.

3.3 Roofing and Cladding

To preserve overhead clearance in the 3rd story center bay, the roof was not trussed, but instead simply carried by a series of principal rafters supported just above their midpoints by the posts of the framing bents (Appendix B). Purlins (alternatively labeled *Beams* in the HABS drawings) spanned adjacent principal rafters at their midpoints, and these in turn carried the series of common rafters (alternatively labeled *Purlins* in the HABS drawings) filling the roof bays between. Diagonal knee bracing was installed at all principal connections throughout the planes of each roof slope to provide added resistance to wind loading (Fig. 12). The series of common and principal rafters carried horizontal plank sheathing, to which were nailed the pine shingles. Eaves consisted of trim boards applied to the cantilevered rafter and stud plates extending around the entire perimeter. Wood gutters and conductors protected the north and south masonry walls from roof water discharge (Figs. 13, 14). Cladding of the gable ends above the level of the eaves was comprised of random width tongue and grooved pine boards (Fig 15).

4.0 SUMMARY OF CONDITION

4.1 Historical Development

Extant HABS documentation presents the impression that the structure's deterioration has been long developing. In fact the earliest HABS photos, dating to 1940, depict an abandoned and derelict building, with windows and doors broken or missing, conductors gone, and roofing shingles in poor condition (Figs. 16, 17). Although the masonry is yet intact, major cracking systems are clearly visible. The pasture in which the building stands is overgrown but still open, with young trees taking root against the walls.

The 1963 HABS photographs indicate a substantially worsened condition. In these, trees have become more established, particularly around the west and north elevations (Fig. 18). The roof has been covered with rolls of building felt, and sheathing sags markedly between the principal rafters (Fig. 19). Major sections of soffit are open on the gable ends. The roof condition is probably the indirect cause of the numerous areas of flooring collapse apparent on the interior photos (Fig. 20). More significant though is the major breach in the exterior wall working down from the eave line of the south elevation immediately east of the arch (Figs. 21, 22). This is accompanied by a corresponding breach to the west of the arch that is not as far developed, although a large area of the face wythe has fallen off (Fig. 19). Other cracking systems on the south wall have become more pronounced, and further collapse appears imminent.

Finally, an addendum was entered in June 1975 on page 2 of the HABS data sheet stipulating "The barn collapsed recently" (Appendix B).



Fig. 8
Interior view of iron framing
anchor extending through
masonry, with remnant of
girt attached.

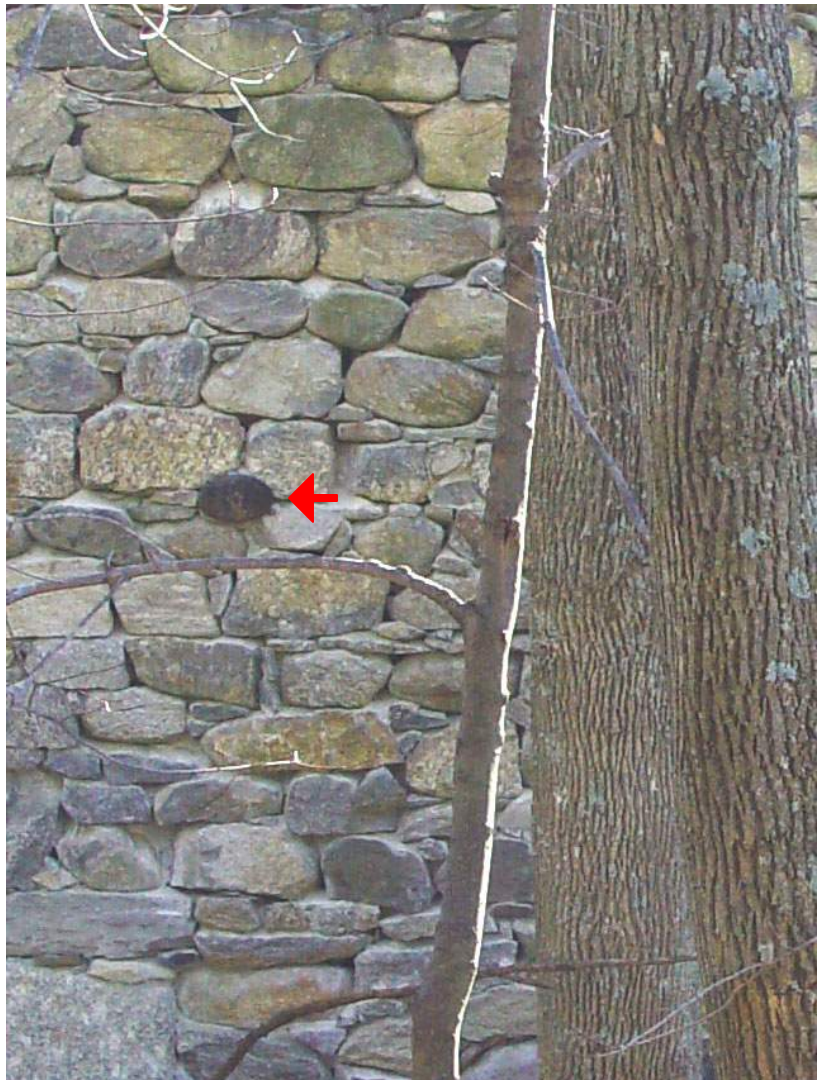


Fig. 9
Exterior view of another
similar iron framing anchor,
showing oval bearing plate.



Fig. 10
Joist pockets in east wall interior masonry.

Fig. 11
Iron joist hangers on interior face of south arch.





Fig. 12
Roof framing with diagonal braces at intersection of principal rafters and purlins. (HABS Photograph by Jack E. Boucher, August 1963)

Fig. 13
North elevation showing gutter along eave, and remnant of wood conductor hanging at the northwest corner. (HABS Photograph by Stanley P. Mixon, July 1940)



Fig. 14
Remnant of wood conductor
still affixed to northwest
corner.



Fig. 15
East elevation showing wood
cladding above framed eaves
returning across gable.
(HABS Photograph by Jack
E. Boucher, August 1963)





Fig. 16
View from southwest showing beginnings of stone masonry deterioration. (HABS Photograph by Stanley P. Mixon, July 1940)

Fig. 17
View from northeast showing developing vertical cracking systems at the northeast corner of the stone masonry. (HABS Photograph by Stanley P. Mixon, July 1940)





Fig. 18
West elevation showing unchecked growth of vegetation. (HABS Photograph by Jack E. Boucher, August 1963)

Fig. 19
South elevation showing worsened condition of roof and stone masonry. (HABS Photograph by Jack E. Boucher, April 1963)





Fig. 20
Collapse of framing and flooring perhaps attributable to poor condition of the roof membrane. (HABS Photograph by Jack E. Boucher, August 1963)

Fig. 21
Breach in south wall stone masonry, east of arch. (HABS Photograph by Jack E. Boucher, August 1963)





Fig. 22
Breach in south wall stone masonry, and developing vertical cracks at
southeast corner. (HABS Photograph by Jack E. Boucher, August 1963)

4.2 Current Status

The structure presently stands as a masonry ruin, with approximately 49% of its original 6100 square feet of exterior wall remaining in recognizable form (see Drawings A-1 through A-6, Appendix E). Within the surviving features are included both of the broad first story arches, as well as 11 fully intact window and door openings. The west wall masonry shows a remarkably high rate of survival, even if precarious.

Numerous masonry features however survive in potentially unstable condition, having lost backing wythes, lateral restraint, and plumbness. Stones in some formations hang cantilevered, out of their intended geometry, or poorly keyed, and significant cracking systems have developed through major wall surfaces. Localized collapses are thought to have occurred within the past few years, and undetected falling of small numbers of stones is suspected to occur on a regular basis. One localized collapse in fact occurred above the north arch sometime between site visits on February 7 and March 9, 2004 (Fig. 23).

Much of the collapsed masonry remains adjacent to its respective walls of origin, having fallen both without and within. While it is likely that most remains on the site, the possibility that some stones have since been mined for other uses cannot be discounted.

No structural wood framing remains in-situ, although many identifiable timbers lie on the ground within the ruin. Several miscellaneous wood elements, primarily window and doorframes and doors, do remain substantially intact in their original locations. Shards of other elements, such as the sliding door at the north archway, and a short section of wood downspout at the westerly end of the north wall are unexpected survivors.

Vegetation in the form of both shrubs and mature trees is rapidly reclaiming portions of the site. While recent efforts have forestalled this advance on the south and west elevations, there is heavy tree growth along and overhanging the north, and the east earthen ramp is nearly inaccessible for the overgrowth. In much of the original pasture, browsing livestock have recently kept the grasses and shrubs in check. However the well-established vegetation and the quantities of fallen stones and timbers prevents easy walking access to the premises immediately around and inside the structure, so these areas tend to be less well browsed.

5.0 INVENTORY OF CONDITIONS

Although the following inventory of conditions presents the range of problems specific to the Shaker South Family Barn, they are in many respects typical of those shared by ruined masonry structures in general. Lacking the critical support and protection of numerous missing building components originally comprising the whole, the remaining elements can often not sustain themselves over the long-term without frequent and ongoing interventions. Moreover, failures that do occur carry the potential to create greater collateral damage to surviving adjacent features because the latter have already been deprived of their own supporting mechanisms.

5.1 Lateral Restraint

The stability of the masonry wall construction is governed by the unbraced length or height of the wall in proportion to its thickness. These ratios apply to masonry in freestanding walls that are subjected to lateral loads imparted by wind pressure, and to retaining walls, whose lateral loads



Fig. 23
Recent collapse of masonry above north arch, occurring early in 2004.

are imparted by the earth that is retained. Perimeter masonry walls typically derived some of their support from engaged interior wood framing, specifically floor girts and joists, rafter plates, and roof trusses. Lacking these supports, walls of height or length exceeding the ratios cannot withstand long-term application of the anticipated loads. In the case of retaining walls, the loads are constant, and the effects may develop gradually.

In the South Family Barn, the freestanding walls comprising the west elevation and the westerly third of the north elevation, having lost their benefiting engagement with the interior timber framing, may currently exceed the limiting ratios. Indeed, some reaches of these have deviated from plumbness tolerances, and have developed cracking and bulges as well. A variety of causes might be implicated in the observed symptoms however, and these will be further discussed in other sections.

Only one of the four principal retaining walls associated with the structure ever derived lateral support from the interior framing, and this, the easterly wall of the ground story, displays plumbness deviations, although as yet minor in nature. The north and south cheek walls flanking the easterly earthen ramp, and the west cheek wall retaining the southerly earthen ramp also exhibit plumbness deviations to varying degrees, ranging from minor to critical. These have more to do with original design limitations however, and with the normal tendency of such walls to want repair or rebuilding after long periods of service.

5.2 Exposure of Vulnerable Faces to Weathering

As in most enclosed masonry buildings, the walls of the South Family Barn had been constructed to receive weathering from only the exterior face. More attention was typically provided to selecting, working, and laying the stones of the outer wythe than those of the inner; such that mortar joints would be smaller, and flanked with more distinct stone arrises, rendering the joints more durable. Also, the irregularities would be more thoroughly compensated with galleting or small chinking stones on the exterior than the interior (Figs. 24, 25). Even with this greater care, and the use of framed roof overhangs at the gables and eaves (the latter with gutters and downspouts as well), moisture would be anticipated to penetrate significantly into the outer face of the wall under normal service. However, with both interior and exterior surfaces of the walls now available for moisture uptake, the masonry is likely to spend significantly greater periods of time in a saturated condition. This condition rapidly accelerates the disaggregation and erosion of mortar through water percolation, and the destruction of mortar bonds from frost accumulation and cyclic wetting and drying. Moreover this condition encourages dislocations of wythes via ice jacking.

5.3 Top Edge Wythe Separation and Loss

Exposure of the top wall surfaces to weathering presents an even greater threat to the masonry integrity. These surfaces, previously protected by roof framing and trim, now provide unobstructed avenues of water infiltration to large numbers of mortared head joints (between respective ends of masonry units) and collar joints (between the respective wythes of the wall). Since at least 1975 these vulnerable joints have freely collected moisture from rain and snowfalls, and in the latter case are exposed for prolonged periods while snow sits unmelted (Fig. 26). The results of this exposure are readily apparent along nearly the entire perimeter of the surviving walls, and are manifested by one or the other of the wythes having been lost to mortar dissolution and frost jacking (Fig. 23).



Fig. 24
Detail of exterior masonry wythe showing squared faces and arrises, with tight galleting.

Fig. 25
Detail of interior masonry wythe showing rounded faces and arrises, with looser galleting.





Fig. 26
Snow sitting atop unprotected masonry head and collar joints.

The condition is most critical where multiple courses of inner or outer wythes are missing. This occurs along the west wall adjacent to the 2nd story opening (Fig. 27), at the northwest and southwest corners, above the apex of the south arch, and along the east and west lower reaches of the north arch. Although both wythes survive above the apex of the north arch, separation is progressing such that the wythes are leaning in opposite directions.

5.4 Joints and Mortar

Original natural lime mortar survives in numerous locations on the building but is heavily weathered. In areas subjected to constant rainwater washing and percolation, disaggregation (or loss of binder) has occurred (Fig. 28). While the quality of the exterior wythe of stonework may serve to resist gravitational loads without assistance of mortar bond, the lesser quality of the interior wythe in many areas creates a greater mortar dependence. Extensive repointing of weathered joint work will ultimately be necessary, but relatively fewer areas are in critical condition at present.

Several instances of prior inappropriate repairs of weathered joints are also in evidence. In these, Portland cement-based mortars were used to perform repointings. Although higher in strength and less prone to weathering, Portland cement mortars are visually incompatible with the historical materials (Fig. 29). Worse, their properties in this application may tend to encourage water entrapment in the walls. This is primarily due to their lacking the permeability of natural lime mortars, a characteristic that is important in allowing the wall to dry once infiltration has occurred. Also, their lacking of lime mortar's autogeneity, or self-healing ability, means they cannot accommodate gradual shifts and settlements without cracking and forming avenues of water entry. Fortunately, the extent of this usage does not appear to be great, and can be easily rectified.

5.5 Vertical Cracking Systems

Several vertical cracking systems are apparent in the west wall, particularly from the exterior. At least one of these (near the northerly corner) is readily identifiable on both interior and exterior, and may require shoring to prevent loss of that corner and the westerly reach of north wall (Fig. 30). The origins of these are unknown, however some, including the one near the one near the northerly corner, are discernable in 1940 HABS photos. This suggests that they are more likely attributable to gradual movements than to any direct stress from the collapse itself.

Unfortunately, their gradual and continued development puts the respective walls at risk. Once opened, such cracks tend to grow in width even if the original causes have since stabilized. This is in part due to cyclic moisture entrapment and ice jacking. At the very least, these systems must be fully grouted and pointed to remove future potential for water entrapment and cyclic development.

5.6 Plumbness Deviations and Bulges

Measurements were taken at several locations to verify plumbness of walls. As a general rule of thumb, out of plumb conditions become critical when the lean of a wall causes its center of gravity to move outside the middle third of its cross-sectional area when vertical. Hence, the limiting parameter is a factor of wall thickness, height, and degree of lean. A low thick wall

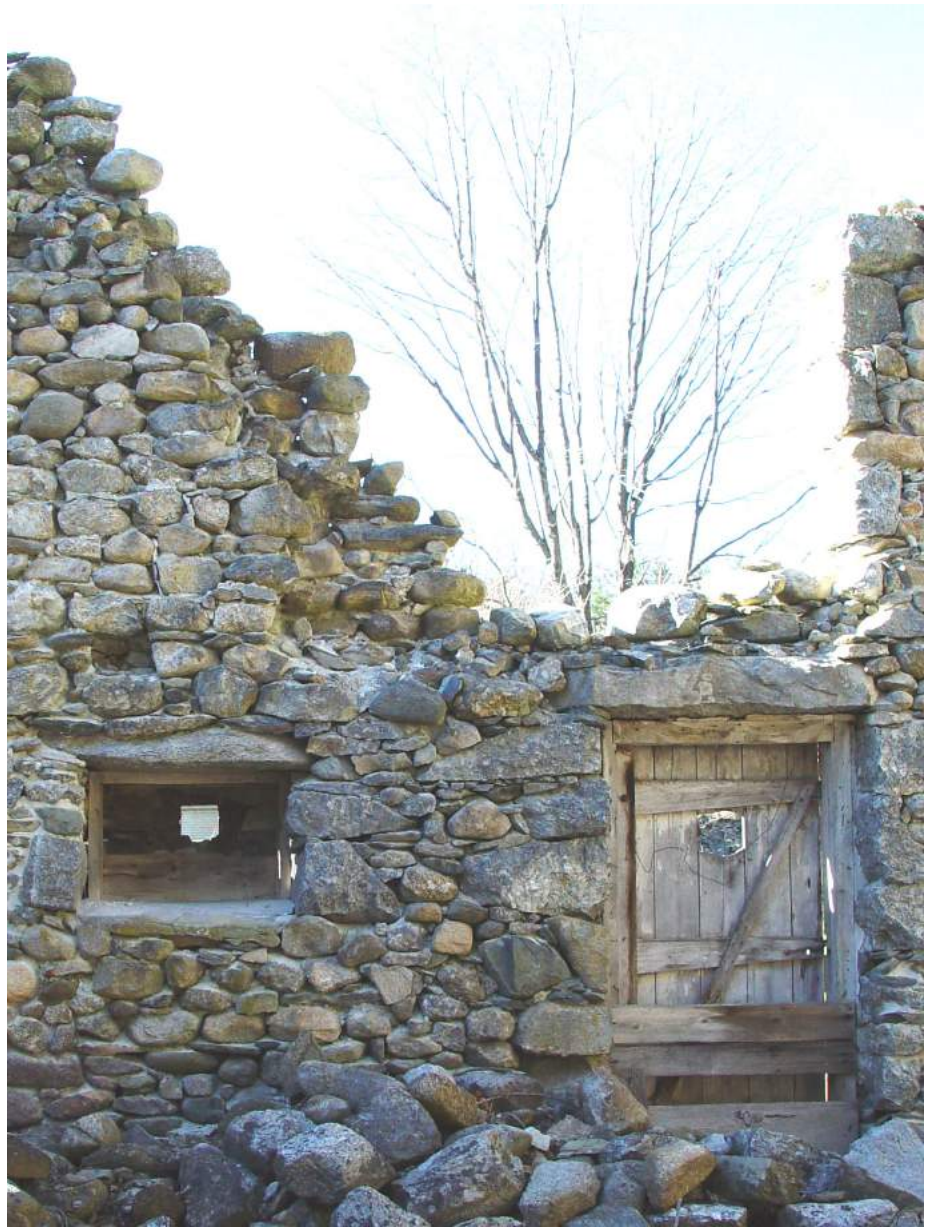


Fig. 27
Substantial loss of interior wythe between west wall window and door
lintels.

Fig. 28
Heavily weathered mortar
joints at southwest corner.



Fig. 29
Pointing repairs executed
with incompatible Portland
cement mortar.



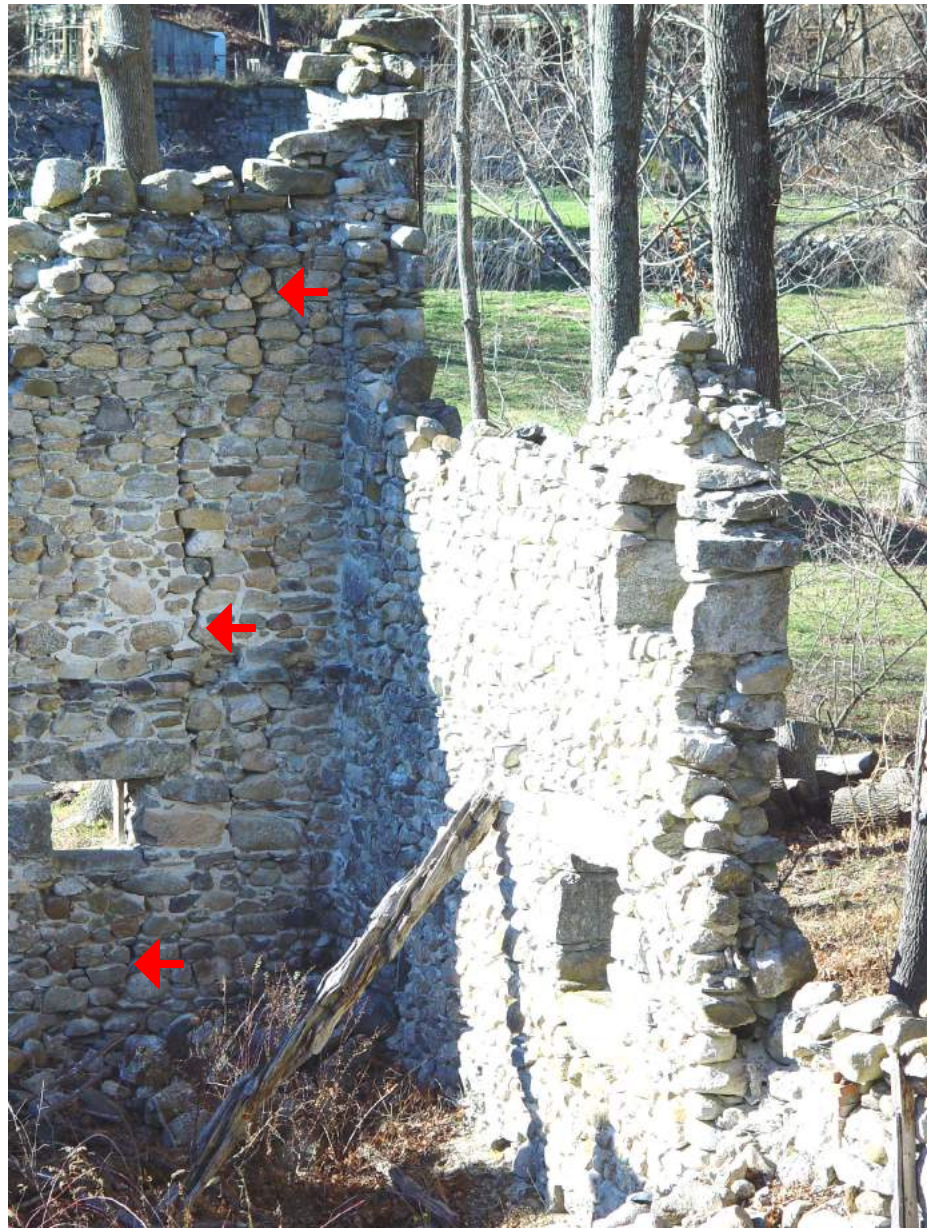


Fig. 30
Major vertical cracking system developed in northwest corner.

could thus tolerate a far greater lean than a tall thin wall. However other factors also come into play, such as whether the lean is consistent from top to bottom of the wall, the degree of soil compaction at the footings, the length of unsupported horizontal span, and the anticipated lateral loads (wind or earth pressure).

Measured leans at the top of the west wall are as much as 6 inches easterly, and most of this has developed in the upper half of the wall. Measured leans on the west end of the north wall are approximately 10 inches north at the bulge, and 7 inches north nearer the west jamb of the 1st story window. The worst deviation of the east ramp's north cheek wall is approximately 4 inches of northerly lean 4 feet east of the building corner, and the main east wall displays a 4-inch maximum lean westerly. The east jamb of the south arch leans approximately 5 inches northerly, and the south ramp's west cheek wall leans approximately 8 inches westerly at its north end.

Although specific ramifications of these conditions are discussed in other sections, the common thread to note here is that it will be necessary to establish formal reference points at each of these locations so that in the future, consistent measurements can be taken periodically to evaluate long-term stability concerns.

5.7 Retaining Walls

In the Shaker South Family Barn, the east, and the easterly portion of the south building walls also serve as retaining walls for their respective abutting earthen ramps. Added to these are the east ramp's north and south cheek walls, and the south ramp's west cheek wall, which although not part of the primary structure, nevertheless engage to it. Although all have deviated from plumbness to varying extents, relatively few areas are critical at this time. One area of concern involves the dislodged copingstones in the east ramp's south cheek wall. These will eventually encourage further collapse of the wall, however they are currently few in number and can be easily reinstated to their original positions. Of slightly greater concern is the south ramp's west cheek wall. Its present 8-inch lean appears to border on instability, and its failure would likely adversely impact the south arch, to which it is semi-engaged. However the size and configuration of the stones involved may in this instance allow greater tolerance for plumbness deviations.

The dry-laid quality of the cheek walls is essential for promoting good drainage from the earthen ramp behind. If these had been heavily mortared, than freezing of water entrapped along the earthen face of the walls would exert even greater lateral pressures and consequently more rapid development of leans. All future repairs to these walls should thus be carried out in kind, preserving the openness of the joints.

5.8 Corner and Window Geometry

Some of the more unexpected survivors of the various collapses include two chimney-like corners of the west wall, and the 2nd story window in the north wall. The corners still stand to their original height, but having since lost their back-up wythes, are developing easterly leans (Fig. 31). The fact that they survive at all points to the care taken in materials selection and laying of these elements, as opposed to the bulk of the masonry comprising the field of the walls (Fig. 2). The window frame on the north wall borders what was reportedly one of the most recent collapses, and it inhabits a reach of wall that is significantly out of plumb. Moreover, the lack of lateral support for its east jamb, and the loss of the inner wythes in the zone immediately below, put this element at considerable risk (Fig. 32).



Fig. 31
Top of southwest corner, showing loss of inner wythe.



Fig. 32
Instability of second story window jamb caused by loss of inner wythes below.

All three of these features underscore the need to reinstate portions of previously collapsed fabric in measured amounts. Re-engaging the elements into the structure by restoring missing masonry to key locations adjacent will provide the best chance for assuring their long-term stability.

5.9 Arch Geometry

The great care originally taken in laying both the north and south arches is evidenced by their survival in spite of unstable conditions immediately adjacent. Both are comprised of dressed granite blocks whose flush-set faces on the exterior belie the minor variances in thickness apparent from the interior (Figs. 33, 34).

The north arch retains its geometry substantially intact, and is threatened only by deteriorating wall conditions above and at each end adjacent. The collapsing field above imparts eccentric loading. However, that problem is exceeded by the potential loss of lateral restraint at the springing points, attributable to missing wythes in wall sections adjacent. The south arch, while also eccentrically loaded by an unstable mass above, enjoys far greater lateral restraint at its springing points. Its problem is that the easterly end has wracked out of plane by lateral pressure of the earthen south ramp. Any continued movement of the semi-engaged cheek wall of this ramp might destabilize the arch (Fig. 35).

Again the observed conditions may indicate the need to perform limited reinstatements of previously collapsed masonry in order to provide greater stability for those significant elements that remain. In addition, walls engaging the east end of the south arch will eventually need to be rebuilt if permanent shoring at this location is to be avoided.

5.10 Interior Wood Lintels

The nested pair of wood lintels framing a blind opening visible only from the interior west end of the north wall have suffered insect attack and are heavily deflected (Fig. 6). Although once commonplace in 19th century construction, the use of wood plank lintels to support inner masonry wythes is uncharacteristic of this building. In service, these normally tend to shrink, deflect, or decay after a number of years, and at some point cease to play a significant role in supporting the masonry. Vertical loads in a wall tend to distribute themselves around small openings, leaving the lintel to carry only the area of an equilateral triangle immediately above. The problem is that even a limited failure in the area immediately above these lintels could have serious repercussions on this wall, which is only in marginal condition at best.

The lintels should be made redundant by completing the inner wythe infill of this previously abandoned opening. However to preserve the integrity of this significant feature, stabilizing them in-situ and selecting an appropriate infill material is essential.

5.11 Ferrous Element Engagements

Numerous elements of ferrous building hardware remain affixed into masonry joints and into masonry units themselves. These elements no longer enjoy protective finishes, and are prone to corrosion. Unfortunately, the corrosion process is expansive, and the growing exfoliations of ferric oxide normally exert substantial stresses on joints and masonry units, often causing



Fig. 33
Exterior of north arch, showing stone faces set flush with plane of wall.

Fig 34
Interior of north arch, showing inconsequential face deviation from the wall plane due to minor variations in stone thickness.





Fig. 35
Dry-laid ramp cheek wall semi-engaged to jamb of south arch.

cracking from their points of engagement. Although of significant concern in many venues, relative to the broad range of problems adversely affecting the Shaker South Family Barn, this one is almost insignificant. Where localized damage is observed during the repointing process, the offending elements can be passivated with corrosion inhibitors.

5.12 Vegetation

Proliferation of plant growth on and adjacent to surviving walls has accelerated their demise. Volunteer shrubs on the easterly reaches of the south wall, and along the tops of the retaining walls bounding the easterly earthen ramp retain high levels of moisture in the masonry during the growing season, and dislodge stones by the spread of their root systems (Fig. 36). Trees growing adjacent to the walls also encourage moisture retention in the adjacent masonry, and occasionally damage walls via direct impact of falling branches. Tree root systems present a larger problem in that their spread dislodges foundations directly via expansion of their respective length and girth. They may in certain circumstances also cause indirect damage via locally depleting soil moisture sufficiently to cause compaction and subsidence at the footings. Since the root systems can generally be presumed to spread to roughly the circumference of a tree's crown, any tree whose crown overhangs the structure can be construed to impart a threat to the walls via these mechanisms. Needless to say, trees in poor condition that are situated nearer to the walls than their respective heights also present a threat of impact from windfall.

5.13 Site Drainage:

Overall, the site appears well drained and not prone to collecting water around critical building components. Neither has any significant erosion been observed. Probably the most salient concern is the quality of drainage from behind the various retaining walls. The concern is obviously less for walls that are dry-laid than for mortared walls. Vulnerabilities in this respect may be more theoretical than actual for Shaker South Family Barn.

6.0 RECOMMENDED STABILIZATION PROGRAM

It is unclear as to the extent or circumstances of the 1975 collapse, which is problematic in that it does not allow a baseline against which to judge the severity of the rate of subsequent deterioration. While the documentation in this report can provide a baseline against which future progress of both deterioration and stabilization can be measured, assumptions must be made to evaluate the loss that is apparent today.

Unfortunately, knowing the rate and patterns of post 1975 loss is essential to devising the most efficient and effective strategies for stabilization, in that it would help avoid any tendency to spend resources on problems that "appeared" serious but that in fact were very long-standing conditions. Lacking this information, one is forced to make more conservative and far-reaching recommendations. Although for the long-term all these recommendations will be nevertheless valid and important to implement, for the short term (the "triage" phase), some may engender the risk of not applying the limited resources to what may later turn out to have been more critical areas.

For this reason, the suggested priorities should be viewed as fluid and changeable. They are based on the best information available at the time, but might easily evolve if more information



Fig. 36
Dislodging of copings on cheek wall of easterly ramp exacerbated by vegetation growth.

comes to light. Hence, future stewards should be prepared to adjust their approach if or when this occurs.

Following are discussed two categories of interventions: indirect and direct. The former are more global in scope and do not address specifically identified instabilities. However they are necessary to perform prerequisite to or in conjunction with each of the recommended direct interventions. Direct interventions address specific instabilities identified within defined geographical areas, and are prioritized from greatest to least urgency. Completing all of these interventions will have the eventual result of stabilizing the entire premises, at least as far as the currently observed conditions are concerned. The individual tasks within each major direct intervention are also prioritized in the same manner, to ensure that the most important aspects of the respective treatments are addressed first if resources are a limiting factor.

Descriptions and schematics of recommended interventions (Drawings T-1 through T-6) are sufficient to illustrate, for planning purposes, the general processes involved. In most instances, further design of treatments is required before they can actually be applied. Costs are expressed in order-of-magnitude estimates, for contracted construction work (excluding design and contingency), in 2004 dollars. These are intended for rough budgeting purposes only, and would normally be refined during the actual design process.

6.1 Indirect Interventions

6.1.1 Monitoring Implementation

Simple measures should be instituted that can gauge future rates of displacement at critical locations. These will assist in evaluating the ongoing validity of the suggested priorities, as well as in evaluating the continued efficacy of treatments recently completed.

a) Establish plumb line reference points and monitor.

Install discrete pairs of vertically aligned pins at 8 locations. Measure with tape and plumb line once per year, and record displacements.

b) Establish arch geometry reference points and monitor.

Install discrete triads of pins with 2 aligned horizontally at the springing points and 1 at the apex. Measure with tape and plumb line once per year, and record displacements.

6.1.2 Site Organization

Prior to initiating any direct interventions, access to the site and to the walls themselves must be improved.

a) Establish inventory, transport, and storage procedures.

Designate "stone yards" inside and outside the structure, sufficiently removed from the walls themselves (at least 10 feet) to allow scaffolding and maintenance access. Survey and set out "identification sectors" along the interior and exterior of the walls, and mark stones found therein with appropriate sector identifications; further designating and separating face wythe field, interior wythe field, and trim or header stones (those associated with window/door surrounds, corner quoins, etc.). Transport fallen stones from bases of critical wall segments to their respective new stone yards. The object of this procedure is to clear sufficient repair and

maintenance access to the walls by handling and transporting stones as little as possible. This will keep ground falls close to their point of origin in the walls, and provide an organized source of identifiable repair stock.

b) Provide construction access.

Clear an access way to the general interior and to critical interior locations. Since much construction traffic will necessarily traverse both the north and south arched openings, clear paths must be made through these in accordance with the methodology described above. In addition, materials and equipment staging areas should be designated and cleared within and outside of the structure. Finally, the loose or precarious stones surviving in the fields above the respective arches should be strapped, or else shifted back into place and pointed sufficiently to prevent any dislocations occurring during the periods that traffic is passing through the archways.

Transporting of stones can be a phased activity, occurring first along reaches where repair access is first required.

6.1.3 Vegetation Removals

Address both the incremental and the potentially catastrophic threats from established site vegetation.

a) Remove engaged vegetation.

Clear all vegetation growing on walls, and remove all tree branches overhanging the walls.

b) Remove nearby vegetation.

Remove all trees whose crowns overhang the walls, and remove all unhealthy or unsound trees whose height exceeds their proximity to the walls.

6.1.4 Non-masonry Element Documentation

Numerous historically significant wood and metal elements survive within the ruin. Many are engaged to the masonry itself and may be impacted by the recommended masonry treatments. These should be inventoried and documented to the greatest extent possible prior to commencing the masonry work.

a) Document engaged elements.

Inventory and document all surviving wood and metal elements on the masonry itself.

b) Document loose elements in the access paths.

Inventory, mark, and transport all surviving loose wood elements from any interior access ways to a protected storage area.

6.2 Direct Interventions

\$151,270

6.2.1 Emergency Shoring at Northwest Corner

\$3,350

Although the northwest corner appears highly unstable, the addition of temporary emergency shoring may arrest further development of its failure, and allow some time to address even more

critical needs elsewhere in the building. When masonry work in this area is eventually undertaken, as much as possible should be completed with temporary shoring still in place.

Temporary shores may be removed upon completion of all masonry treatments recommended in part 6.2.5 below. If less than the full treatment is ultimately implemented, then permanent shores should be considered per the structural engineer's recommendations (Appendix C), in conjunction with continued monitoring of movements and condition.

a) Shore westerly end of north wall.

\$2,400

To counteract the continued development of the bulge, and of the northerly lean of this end of the north wall that has been facilitated by the major vertical crack in the adjoining west wall, install shores along the 24-foot length of the surviving two-story section. Shores may be comprised of up to 5 pairs of wood poles from rot-resistant species, spaced at 6-foot intervals along the wall. Each pair would engage the wall at 1st and 2nd story window lintel heights respectively via a vertical plank in full contact with the wall and restrained at its foot. Shores should be tied horizontally and diagonally to one another, and footed against timber or masonry pads to allow wedging as a means of adjusting lateral pressure.

b) Shore wood lintel in ground story zone of north wall.

\$350

This is the only surviving opening that carried masonry on wood lintels. These, having lost their protection from the weather, are in the early stages of failure from insect and fungal attack. The lintels should be shored via the addition of wedged timber blocking within the opening, to forestall collapse of the interior wythes above.

c) Shore northerly inside corner of west wall.

\$600

To counteract the easterly lean of the uppermost courses of the northerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.a above, except in the height of the vertical plank, which should extend nearly to original eave line. The top of this plank would be cut off to facilitate access when masonry repairs commenced in this area. Adjust lateral pressure for minimal bearing, to avoid introducing shear forces into the vertical cracking system immediately to the south.

6.2.2 Emergency Shoring at Southwest Corner

\$600

Stability of the southwest corner is also impacted by adjacent vertical cracking systems in the west wall, and by the geometry of the surviving "chimney" which incorporates cantilevered stones and lacks a backing wythe. While this is the first feature recommended to receive serious stabilization, the masonry work should be carried out to the greatest extent possible with a temporary emergency shore in place.

Temporary shores may be removed upon completion of all masonry treatments recommended in part 6.2.4 below. If less than the full treatment is ultimately implemented, then permanent shores should be considered per the structural engineer's recommendations (Appendix C), in conjunction with continued monitoring of movements and condition.

a) Shore southerly inside corner of south wall.

\$600

To counteract the easterly lean of the uppermost courses of the southerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.c above.

6.2.3 Remedial Shoring at South Arch and Adjacent Cheek Wall

\$850

Semi-permanent shoring may be required at the easterly jamb of the south arch to counteract a developing inward lean caused by lateral loading from the south earthen ramp, which first engages the south wall at that point. The lean of this wall section is skewing the arch geometry, and may eventually cause collapse of the arch. The adjacent leaning semi-engaged west cheek wall of the south ramp may also require remedial shoring to prevent its adversely impacting the arch geometry. The ultimate decision to install these shores should be contingent on an analysis of the development rate of the lean. If installed, these shores should remain until such time as the retaining wall and cheek wall are reconfigured to adequately resist their lateral loads.

a) Shore easterly jamb of south arch.

\$425

To counteract a northerly lean induced by lateral loading of the earthen ramp, install shores along the first 6 feet of masonry immediately east of the arch. Configure the shores in the manner described in part 6.2.1.a above. The respective pairs of shoring poles should engage vertical planks at approximately 3 feet and 6 feet in height.

b) Shore northerly end of south ramp west cheek wall.

\$425

To counteract a westerly lean induced by lateral loading of the earthen ramp, install shores along the first 6 feet of masonry immediately south of the adjacent arch. Configure the shores in the manner described in part 6.2.1.a above, except that single shoring poles engaging vertical planks at approximately 4 feet in height may be substituted in lieu of pairs.

6.2.4 Southwest Corner Masonry Stabilization

\$31,400

Long-term stability of the southwest corner requires reinstating limited quantities of masonry on the south and west walls adjacent to eliminate cantilevers and better engage the surviving work into the wall. The work generally involves replacing missing wythes, rationalizing transitions in vertical elevation, and capping the top of the wall to protect exposed collar and head joints. Because significant expense is invoked by constructing staging to access the work, all less critical aspects of masonry preservation within reach, particularly interior and exterior pointing, should also be addressed while the staging is in place.

a) Mobilize and demobilize.

\$2,800

Clear access to site, construct staging, dismantle staging, and cleanup.

b) Reinstall missing wythes to southwest corner.

\$1,840

The chimney at this location consists of mostly facing stones. Replace the missing backing with salvaged units set in lime mortar, leaving keying opportunities for adjacent work as it in turn is reinstated. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.

c) Reinstall missing wythes to south end of west wall.

\$1,135

Replace the missing backing with salvaged units set in lime mortar. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.

- d) Rebuild transition (infill) on south wall to southwest corner.* \$6,525
 Replace missing facing and backup wythes to effect an even sloping transition from the southwest corner down to the vicinity of the second doorway east in the south wall, keying in to points of engagement provided during corner stabilization described in part 6.2.4.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.
- e) Rebuild transition (infill) on west wall to southwest corner.* \$2,080
 Replace missing facing and backup wythes to effect an even sloping transition from the southwest corner down to the vicinity above the north jamb of the southerly first story window in the west wall, keying in to points of engagement provided during corner stabilization described in part 6.2.4.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.
- f) Install wall cap protection.* \$1,120
 At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.
- g) Stabilize vertical cracking systems at the southerly end of the west wall.* \$1,200
 Grout vertical cracking systems the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.
- h) Repoint interior southwest corner masonry (south and west walls).* \$7,200
 Rake all interior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.
- i) Repoint exterior southwest corner masonry (south and west walls).* \$7,200
 Rake all exterior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.
- j) Remove emergency shoring.* \$300
 Previously installed temporary shoring may be removed after allowing appropriate mortar curing time.

6.2.5 Northwest Corner Masonry Stabilization \$47,460

Long-term stability of the northwest corner requires reinstating limited quantities of masonry on the west wall adjacent, but substantially greater quantities on a 24-foot stretch of the north wall. While again the goal is to eliminate cantilevers and better engage the surviving work into the wall, success also relies upon correcting unstable conditions in other areas that upon failure are likely to cause significant collateral damage. These include, but are not limited to reconstructing a developing bulge, correcting plumbness problems, and providing better engagement of a 2nd story window frame. The work in addition generally involves replacing missing wythes, rationalizing transitions in vertical elevation, and capping the top of the wall to protect exposed collar and head joints. Because significant expense is invoked by constructing staging to access the work, all less critical aspects of masonry preservation within reach, particularly interior and exterior pointing, should also be addressed while the staging is in place.

- a) Mobilize and demobilize.* \$3,000
 Clear access to site, construct staging, dismantle staging, and cleanup.

b) Reinstate full wythes to northwest corner.

\$2,200

As with the southwest corner, the chimney at this location also consists mostly of facing stones. Replace the missing backing with salvaged units set in lime mortar, leaving keying opportunities for adjacent work as it in turn is reinstated. Level the wythes from outside to inside along the top, ready to receive protective caps.

c) Reinstate missing wythes to west wall, north end.

\$585

Replace the missing backing with salvaged units set in lime mortar. Level the wythes from outside to inside along the top, ready to receive protective caps.

d) Rebuild transition (infill) on west wall to northwest corner.

\$1,135

Replace missing facing and backup wythes to effect an even sloping transition from the northwest corner down to the vicinity of the northerly jamb of the 1st story doorway in the west wall, keying in to points of engagement provided during corner stabilization described in part 6.2.5.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.

e) Stabilize vertical cracking at northerly end of west wall.

\$1,650

Grout vertical cracking systems the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.

f) Infill abandoned window opening at west end of north wall.

\$590

Reconfigure emergency shoring installed in part 6.2.1.c above to allow working within the abandoned ground story window opening. Document conditions and clean out bedding to receive new masonry infill. Select infill materials to be compatible but visually distinct from surrounding historic masonry, and completely fill opening to provide continuous bearing for existing wood lintels. Consolidate lintels with low-viscosity injected epoxy, and treat with borate preservative.

g) Rebuild bulge in north wall, west end, and transition to northwest corner.

\$20,650

Document and dismantle a zone of north wall masonry approximately 6 feet wide adjacent to (but not including) the northwest corner that has bulged significantly out of plumb at the top. Extend the dismantling down to approximately the height of the 1st story window lintels, tapering in width to an apex at the lowest point. Relay the disassembled masonry in lime mortar, matching and keying into adjacent coursing. Lay additional salvaged stonework above, replacing missing facing and backup wythes to effect an even sloping transition from the northwest corner down to the vicinity of the westerly jamb of the 2nd story window in the north wall, keying in to points of engagement provided during corner stabilization described in part 6.2.5.b above. Level the wythes from outside to inside along the top, ready to receive protective caps.

h) Install wall cap protection.

\$1,150

At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.

i) Repoint interior northwest corner masonry (north and west walls).

\$8,100

Rake all interior northwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.

j) Repoint exterior northwest corner masonry (north and west walls).

\$8,100

Rake all exterior northwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.

k) Remove emergency shoring.

\$300

Previously installed temporary shoring, excepting the eastern-most two frames on the north wall, may be removed after allowing appropriate mortar curing time. The eastern-most frames may be removed after completing part 6.2.6.e below.

6.2.6 North Arch Stabilization

\$20,485

Although stones comprising the north arch retain their appropriate geometry, surrounding wall fields are in poor condition and must be stabilized to prevent their developing failures from adversely impacting the arch itself. Missing wythe reinstatements and transition infills will increase long-term stability of the arch, and of the adjacent 2nd story window frame as well.

a) Mobilize and demobilize.

\$2,200

Clear access to site, construct staging, dismantle staging, and cleanup.

b) Reinstate missing wythes on westerly side of north arch.

\$2,005

Replace the missing backing with salvaged units set in lime mortar, addressing both the 1st story zone immediately west of the westerly arch jamb, and the 2nd story zone below the easterly jamb of the 2nd story window opening. Level the wythes from outside to inside along the top, ready to receive protective caps.

c) Reinstate missing wythes on easterly side of north arch.

\$700

Replace the missing backing with salvaged units set in lime mortar, addressing the 1st story zone above and immediately east of the easterly arch jamb. Level the wythes from outside to inside along the top, ready to receive protective caps.

d) Reinstate missing and reset dislocated wythes on top of north arch.

\$1,135

Replace the missing backing with salvaged units set in lime mortar, and provide minor 2-wythe infills to lessen the irregularity along the upper edge of the field. Level the wythes from outside to inside along the top, ready to receive protective caps.

e) Rebuild transition (infill) from north arch to 2nd story window.

\$11,350

Replace missing facing and backup wythes to effect an even sloping transition from the west quarter of the arch up to the vicinity of the easterly end of the 2nd story window lintel. Level the wythes from outside to inside along the top, ready to receive protective caps.

f) Install wall cap protection.

\$975

At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.

g) Repoint interior north arch and adjacent masonry.

\$960

Rake all interior north arch and adjacent masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.

h) Repoint exterior north arch and adjacent masonry.

\$960

Rake all exterior north arch and adjacent masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.

- i) Remove emergency shoring.* \$200
The remaining eastern-most frames of temporary shoring may be removed after allowing appropriate mortar curing time.

6.2.7 South Arch Stabilization \$22,205

Stones comprising the south arch have developed noticeable deviation from their original geometry, attributable mostly to the lateral loads of the south earthen ramp against the easterly arch jamb. For this reason, remedial shoring must remain in place until completion of part 6.2.9.c below. The longstanding vertical crack extending through the top of the arch and the wall field above must be filled and monitored. Surrounding wall fields are in marginal condition and should be stabilized to prevent their developing failures from adversely impacting the arch itself. Missing wythe reinstatements and transition infills will increase long-term stability of the arch, and of adjacent sections of south wall.

- a) Mobilize and demobilize.* \$2,000
Clear access to site, construct staging, dismantle staging, and cleanup.
- b) Reinstall missing and reset dislocated wythes on top of south arch.* \$2,005
Replace the missing backing with salvaged units set in lime mortar, addressing the 1st story zones above the top, east, and west quarters of the arch. Level the wythes from outside to inside along the top, ready to receive protective caps.
- c) Stabilize vertical cracking at top of south arch and overlaying wall field.* \$150
Grout vertical cracking system the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.
- d) Rebuild transition (infill) to westerly quarter of south arch.* \$2,270
Replace missing facing and backup wythes to effect an even sloping transition from the westerly quarter of the arch up to the vicinity of the first doorway west. Level the wythes from outside to inside along the top, ready to receive protective caps.
- e) Install wall cap protection.* \$1,080
At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.
- f) Repoint interior south arch and adjacent masonry.* \$7,200
Rake all interior south arch and adjacent masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.
- g) Repoint exterior south arch and adjacent masonry.* \$7,200
Rake all exterior south arch and adjacent masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing.
- h) Reinstall remedial shoring.* \$300
The interior shoring of the easterly arch jamb described in parts 6.2.3.b and 6.2.3.c above must be reinstated and retained until completion of part 6.2.9.c below.

6.2.8 Wall Cap Protection and Pointing

\$12,720

Remaining reaches of wall are in less critical condition, however the prospects for long-term preservation nevertheless will require instituting measures to lessen the exposure of surfaces to weathering. This will in effect extend the protections undertaken in previous work to cover the remaining portions of masonry building envelope, principally the easterly ends of the north and south walls respectively, and the entire east wall.

a) Mobilize and demobilize.

\$1,800

Clear access to site, construct staging, dismantle staging, and cleanup.

b) Level wythes and cap top courses of remaining reaches of stone walls.

\$2,440

Replace the missing backing with salvaged units set in lime mortar, and provide minor 2-wythe infills to lessen the irregularity along the upper edge of the field. Level the wythes from outside to inside along the top, ready to receive protective caps.

c) Install wall cap protection.

\$1,880

At all remaining uncovered wall tops, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.

d) Repoint remaining interior surfaces of freestanding wall masonry.

\$4,800

Rake all remaining freestanding interior wall surfaces (not retaining walls), in preparation for pointing. Repoint with natural lime mortar, reinstalling galleting where missing.

e) Repoint remaining exterior surfaces of freestanding wall masonry.

\$1,800

Rake all remaining freestanding exterior wall surfaces (not retaining walls), in preparation for pointing. Repoint with natural lime mortar, reinstalling galleting where missing.

6.2.9 Retaining Wall Stabilization

\$12,200

Retaining walls, including the east ramp's north and south cheek walls and the east building wall; and the south ramp's west cheek wall and portion of the south building wall, display varying degrees of lean due to lateral earth pressure. Very few of these areas are currently cause for concern, although continued gradual development of the leaning is anticipated. To ensure long-term preservation, anomalous sections, as well as sections adjacent to critical elements (such as the south arch), should be rebuilt to lines consistent with adjacent reaches. Otherwise, plumbness of walls should be monitored and sections should be considered for reconstruction or reinforcement if conditions significantly worsen.

a) Mobilize and demobilize.

\$1,200

Clear access to site, and cleanup.

b) Reset copings at east ramp's south cheek wall.

\$1,300

Document and remove existing copingstones at the easterly end of the south cheek wall. Clean and level the bedding, and remove sufficient adjacent earth of east ramp to allow resetting and shimming. Reset copings consistent with lines of adjacent masonry, reinstall galleting, and backfill the excavated portions of the earthen ramp.

c) Rebuild northwest corner of south ramp's retaining walls.

\$9,500

Excavate sufficient quantities of the south earthen ramp to access the northerly half of its west cheek wall and the first 6 feet of south building wall east of the south arch. Retain remedial shoring previously installed near the east end of the south arch for the duration of this work. Document and disassemble cheek wall masonry to within 18 inches of ground story grade, and south wall masonry to top of first abandoned ground story window lintel east of arch. Install helical earth anchors through the south wall below this window to restrain further leaning. Also install helical earth anchors thorough the disassembled reach of the cheek wall to restrain further leaning. Relay and shim the disassembled masonry of the cheek and building walls, correcting the plumbness deviations to the extent possible while blending to the lines of adjacent undisturbed masonry. Match and key the stones into adjacent coursing, and reinstall galleting. Reinstall the mortared courses of leveled wythes along the top of the south wall above the grade of the ramp, and reinstate the sheet lead flashing protection of the head and collar joints.

d) Remove remedial shoring.

\$200

The shoring of the easterly arch jamb and adjacent cheek wall described in parts 6.2.3.b and 6.2.3.c may be removed after completion of part 6.2.9.c above.

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX A: *PACKAGE ESTIMATES*

CONDITION ASSESSMENT AND RECOMMENDATIONS
Stabilization of the Shaker South Family Barn

May 15, 2004

South Shaker Road, Harvard, Massachusetts

A.0 INTRODUCTION TO PACKAGE ESTIMATES

In recognition of the possibility that resources may be insufficient to complete the entire recommended program of treatment in the near term, two incremental treatment packages are outlined that demonstrate the potential impacts modest project budgets. These reflect price ranges of roughly \$25,000 and \$50,000 respectively.

As previously noted in the Report, construction costs are expressed in order-of-magnitude estimates, in 2004 dollars, and do not include contingencies. These are intended for rough budgeting purposes only, and would normally be refined during the actual design process.

The packages include anticipated costs for architectural and engineering design, procurement assistance (contractor selection), construction, and construction phase consultation. These however also are provided for general budgeting purposes only, and are not intended as a proposal.

Because many of the recommendations described in section 6.1 *Indirect Interventions* will likely be accomplished without contracting, no costs for these have been included, except for part 6.1.1 *Monitoring Implementation*. This would logically be executed in conjunction with the design process.

As each of the packages is structured with the presumption that no prior treatments have occurred, they are in effect alternatives for an initial phase, and are not sequential phases. If work beyond either of these is eventually undertaken, it is likely that design costs for subsequent phases would be somewhat less, since many of the treatments will be repetitive. However if structural conditions significantly change before future work is initiated, different design treatments may be required.

A.1.0 PACKAGE 1

\$25,775

A.1.1 Architectural and Engineering Design

\$2,700

Streamlined design services would provide technical specifications that could enable a competent contractor to properly execute the work. The documents however would be insufficient to allow contractor selection by price competition, as is sometimes required by granting entities. Rather, the contractor would be selected by recommendation, interview, and negotiation.

Services should include provision of technical specification sections for mortar preparation, stone masonry laying and pointing, grouting, wall cap protection, and temporary shoring.

A.1.2 Monitoring Implementation

\$700

Services should include installation of plumb line and arch geometry reference points as described in part 6.1.1 of the Report, and summarized below. Also included should be instruction on how to perform periodic monitoring.

a) Establish plumb line reference points.

\$450

Install discrete pairs of vertically aligned pins at 8 locations.

b) Establish arch geometry reference points.

\$250

Install discrete triads of pins with 2 aligned horizontally at the springing points and 1 at the apex.

A.1.3 Construction Consultation

\$450

Services should include three site visits over the course construction, to advise on the application of the technical specifications and the disposition of latent conditions. Construction administration would not be included.

A.1.4 Emergency Shoring at Northwest Corner

\$3,350

Work of this section includes all items described in part 6.2.1 of the Report, as reiterated below.

Although the northwest corner appears highly unstable, the addition of temporary emergency shoring may arrest further development of its failure, and allow some time to address even more critical needs elsewhere in the building. When masonry work in this area is eventually undertaken, as much as possible should be completed with temporary shoring still in place.

a) Shore westerly end of north wall.

\$2,400

To counteract the continued development of the bulge, and of the northerly lean of this end of the north wall that has been facilitated by the major vertical crack in the adjoining west wall, install shores along the 24-foot length of the surviving two-story section. Shores may be comprised of up to 5 pairs of wood poles from rot-resistant species, spaced at 6-foot intervals along the wall. Each pair would engage the wall at 1st and 2nd story window lintel heights respectively via a vertical plank in full contact with the wall and restrained at its foot. Shores should be tied

horizontally and diagonally to one another, and footed against timber or masonry pads to allow wedging as a means of adjusting lateral pressure.

b) Shore wood lintel in ground story zone of north wall.

\$350

This is the only surviving opening that carried masonry on wood lintels. These, having lost their protection from the weather, are in the early stages of failure from insect and fungal attack. The lintels should be shored via the addition of wedged timber blocking within the opening, to forestall collapse of the interior wythes above.

c) Shore northerly inside corner of west wall.

\$600

To counteract the easterly lean of the uppermost courses of the northerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.a above, except in the height of the vertical plank, which should extend nearly to original eave line. The top of this plank would be cut off to facilitate access when masonry repairs commenced in this area. Adjust lateral pressure for minimal bearing, to avoid introducing shear forces into the vertical cracking system immediately to the south.

A.1.5 Emergency Shoring at Southwest Corner

\$600

Work of this section includes all items described in part 6.2.2 of the Report, as reiterated below.

Stability of the southwest corner is also impacted by adjacent vertical cracking systems in the west wall, and by the geometry of the surviving "chimney" which incorporates cantilevered stones and lacks a backing wythe. While this is the first feature recommended to receive serious stabilization, the masonry work should be carried out to the greatest extent possible with a temporary emergency shore in place.

a) Shore southerly inside corner of south wall.

\$600

To counteract the easterly lean of the uppermost courses of the southerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.c above.

A.1.6 Southwest Corner Masonry Stabilization

\$17,975

Work of this section includes selected items described in part 6.2.4 of the Report, as modified below.

Long-term stability of the southwest corner requires reinstating limited quantities of masonry on the south and west walls adjacent to eliminate cantilevers and better engage the surviving work into the wall. The work generally involves replacing missing wythes, rationalizing transitions in vertical elevation, and capping the top of the wall to protect exposed collar and head joints. Because significant expense is invoked by constructing staging to access the work, all less critical aspects of masonry preservation within reach, particularly interior and exterior pointing, should also be addressed while the staging is in place.

a) Mobilize and demobilize.

\$2,800

Clear access to site, construct staging, dismantle staging, and cleanup.

- b) Reinstate missing wythes to southwest corner.* \$1,840
The chimney at this location consists of mostly facing stones. Replace the missing backing with salvaged units set in lime mortar, leaving keying opportunities for adjacent work as it in turn is reinstated. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.
- c) Reinstate missing wythes to south end of west wall.* \$1,135
Replace the missing backing with salvaged units set in lime mortar. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.
- d) Rebuild transition (infill) on south wall to southwest corner.* \$0
This item is not included in the package. Hence, long-term shoring of the corner is likely to be required. In such case, temporary shoring should be designed to as to be convertible to long-term shoring.
- e) Rebuild transition (infill) on west wall to southwest corner.* \$2,080
Replace missing facing and backup wythes to effect an even sloping transition from the southwest corner down to the vicinity above the north jamb of the southerly first story window in the west wall, keying in to points of engagement provided during corner stabilization described in part 6.2.4.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.
- f) Install wall cap protection.* \$1,120
At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.
- g) Stabilize vertical cracking systems at the southerly end of the west wall.* \$1,200
Grout vertical cracking systems the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.
- h) Repoint interior southwest corner masonry (south and west walls).* \$3,600
Rake upper 50% of interior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50%, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground.
- i) Repoint exterior southwest corner masonry (south and west walls).* \$3,600
Rake upper 50% of exterior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50%, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground.
- j) Convert emergency shoring.* \$600
Previously installed temporary shoring may be converted to permanent configuration after allowing appropriate mortar curing time.

A.2.0 PACKAGE 2

\$55,375

A.2.1 Architectural and Engineering Design

\$5,500

Standard design services would provide specification sections for general conditions, technical specifications, bid documents, and reference cost estimates sufficient to allow contractor selection by price competition. The design package would be geared to satisfy granting entities having requirements similar to those of the *Massachusetts Preservation Projects Fund*.

Services should include provision of all necessary general conditions specification sections, as well as for mortar preparation, stone masonry laying and pointing, grouting, wall cap protection, and temporary shoring. Also included should be all necessary bid solicitation documents, as well as a detailed construction cost estimate. In addition, services should include assistance with solicitation and procurement of the contractor.

A.2.2 Monitoring Implementation

\$700

Services should include installation of plumb line and arch geometry reference points as described in part 6.1.1 of the Report, and summarized below. Also included should be instruction on how to perform periodic monitoring.

a) Establish plumb line reference points.

\$450

Install discrete pairs of vertically aligned pins at 8 locations.

b) Establish arch geometry reference points.

\$250

Install discrete triads of pins with 2 aligned horizontally at the springing points and 1 at the apex.

A.2.3 Construction Consultation

\$750

Services should include five site visits over the course construction, to advise on the application of the technical specifications and the disposition of latent conditions. Services should also include assistance with basic construction administration.

A.2.4 Emergency Shoring at Northwest Corner

\$3,350

Work of this section includes all items described in part 6.2.1 of the Report, as reiterated below.

Although the northwest corner appears highly unstable, the addition of temporary emergency shoring may arrest further development of its failure, and allow some time to address even more critical needs elsewhere in the building. When masonry work in this area is eventually undertaken, as much as possible should be completed with temporary shoring still in place.

a) Shore westerly end of north wall.

\$2,400

To counteract the continued development of the bulge, and of the northerly lean of this end of the north wall that has been facilitated by the major vertical crack in the adjoining west wall, install shores along the 24-foot length of the surviving two-story section. Shores may be comprised of up to 5 pairs of wood poles from rot-resistant species, spaced at 6-foot intervals along the wall.

Each pair would engage the wall at 1st and 2nd story window lintel heights respectively via a vertical plank in full contact with the wall and restrained at its foot. Shores should be tied horizontally and diagonally to one another, and footed against timber or masonry pads to allow wedging as a means of adjusting lateral pressure.

b) Shore wood lintel in ground story zone of north wall.

\$350

This is the only surviving opening that carried masonry on wood lintels. These, having lost their protection from the weather, are in the early stages of failure from insect and fungal attack. The lintels should be shored via the addition of wedged timber blocking within the opening, to forestall collapse of the interior wythes above.

c) Shore northerly inside corner of west wall.

\$600

To counteract the easterly lean of the uppermost courses of the northerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.a above, except in the height of the vertical plank, which should extend nearly to original eave line. The top of this plank would be cut off to facilitate access when masonry repairs commenced in this area. Adjust lateral pressure for minimal bearing, to avoid introducing shear forces into the vertical cracking system immediately to the south.

A.2.5 Emergency Shoring at Southwest Corner

\$600

Work of this section includes all items described in part 6.2.2 of the Report, as reiterated below.

Stability of the southwest corner is also impacted by adjacent vertical cracking systems in the west wall, and by the geometry of the surviving "chimney" which incorporates cantilevered stones and lacks a backing wythe. While this is the first feature recommended to receive serious stabilization, the masonry work should be carried out to the greatest extent possible with a temporary emergency shore in place.

a) Shore southerly inside corner of south wall.

\$600

To counteract the easterly lean of the uppermost courses of the southerly corner, install a single interior shore against the west wall. Configure the shore in the manner described in part 6.2.1.c above.

A.2.6 Southwest Corner Masonry Stabilization

\$24,200

Work of this section includes selected items described in part 6.2.4 of the Report, as modified below.

Long-term stability of the southwest corner requires reinstating limited quantities of masonry on the south and west walls adjacent to eliminate cantilevers and better engage the surviving work into the wall. The work generally involves replacing missing wythes, rationalizing transitions in vertical elevation, and capping the top of the wall to protect exposed collar and head joints. Because significant expense is invoked by constructing staging to access the work, all less critical aspects of masonry preservation within reach, particularly interior and exterior pointing, should also be addressed while the staging is in place.

a) Mobilize and demobilize.

\$2,800

Clear access to site, construct staging, dismantle staging, and cleanup.

- b) Reinstate missing wythes to southwest corner.* \$1,840
The chimney at this location consists of mostly facing stones. Replace the missing backing with salvaged units set in lime mortar, leaving keying opportunities for adjacent work as it in turn is reinstated. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.
- c) Reinstate missing wythes to south end of west wall.* \$1,135
Replace the missing backing with salvaged units set in lime mortar. Level the wythes from outside to inside along the top, ready to receive additional infill or protective caps.
- d) Rebuild transition (infill) on south wall to southwest corner.* \$6,525
Replace missing facing and backup wythes to effect an even sloping transition from the southwest corner down to the vicinity of the second doorway east in the south wall, keying in to points of engagement provided during corner stabilization described in part 6.2.4.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.
- e) Rebuild transition (infill) on west wall to southwest corner.* \$2,080
Replace missing facing and backup wythes to effect an even sloping transition from the southwest corner down to the vicinity above the north jamb of the southerly first story window in the west wall, keying in to points of engagement provided during corner stabilization described in part 6.2.4.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.
- f) Install wall cap protection.* \$1,120
At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.
- g) Stabilize vertical cracking systems at the southerly end of the west wall.* \$1,200
Grout vertical cracking systems the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.
- h) Repoint interior southwest corner masonry (south and west walls).* \$3,600
Rake upper 50% of interior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50%, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground.
- i) Repoint exterior southwest corner masonry (south and west walls).* \$3,600
Rake upper 50% of exterior southwest corner masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50%, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground.
- j) Remove emergency shoring.* \$300
Previously installed temporary shoring may be removed after allowing appropriate mortar curing time.

A.2.7 Northwest Corner Masonry Stabilization

\$14,960

Work of this section includes selected items described in part 6.2.5 of the Report, as modified below.

Long-term stability of the northwest corner requires reinstating limited quantities of masonry on the west wall adjacent, but substantially greater quantities on a 24-foot stretch of the north wall. While again the goal is to eliminate cantilevers and better engage the surviving work into the wall, success also relies upon correcting unstable conditions in other areas that upon failure are likely to cause significant collateral damage. These include, but are not limited to correcting plumbness problems, and providing better engagement of a 2nd story window frame. The work in addition generally involves replacing missing wythes, rationalizing transitions in vertical elevation, and capping the top of the wall to protect exposed collar and head joints. Because significant expense is invoked by constructing staging to access the work, all less critical aspects of masonry preservation within reach, particularly interior and exterior pointing, should also be addressed while the staging is in place.

a) Mobilize and demobilize.

\$3,000

Clear access to site, construct staging, dismantle staging, and cleanup.

b) Reinstall full wythes to northwest corner.

\$2,200

As with the southwest corner, the chimney at this location also consists mostly of facing stones. Replace the missing backing with salvaged units set in lime mortar, leaving keying opportunities for adjacent work as it in turn is reinstated. Level the wythes from outside to inside along the top, ready to receive protective caps.

c) Reinstall missing wythes to west wall, north end.

\$585

Replace the missing backing with salvaged units set in lime mortar. Level the wythes from outside to inside along the top, ready to receive protective caps.

d) Rebuild transition (infill) on west wall to northwest corner.

\$1,135

Replace missing facing and backup wythes to effect an even sloping transition from the northwest corner down to the vicinity of the northerly jamb of the 1st story doorway in the west wall, keying in to points of engagement provided during corner stabilization described in part 6.2.5.b above. Level the wythes from outside to inside along the top, ready to receive protective caps. Note that institution of permanent shoring may be sufficient to serve in lieu of this step.

e) Stabilize vertical cracking at northerly end of west wall.

\$1,650

Grout vertical cracking systems the full depth of the wall via injection with dispersed hydrated lime, and repoint surfaces of joints with lime mortar. Install gridded gages for future monitoring.

f) Infill abandoned window opening at west end of north wall.

\$590

Reconfigure emergency shoring installed in part 6.2.1.c above to allow working within the abandoned ground story window opening. Document conditions and clean out bedding to receive new masonry infill. Select infill materials to be compatible but visually distinct from surrounding historic masonry, and completely fill opening to provide continuous bearing for existing wood lintels. Consolidate lintels with low-viscosity injected epoxy, and treat with borate preservative.

g) Rebuild bulge in north wall, west end, and transition to northwest corner. \$0

This item is not included in this package. Hence, long-term shoring of the bulge is likely to be required. In such case, temporary shoring should be designed to as to be convertible to long-term shoring.

h) Install wall cap protection. \$1,150

At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.

i) Repoint interior northwest corner masonry (north and west walls). \$2,025

Rake upper 50% of interior northwest corner west wall masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50% west wall masonry, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground. Presume that north wall masonry will be repointed during future remobilization to rebuild the bulge.

j) Repoint exterior northwest corner masonry (north and west walls). \$2,025

Rake upper 50% of exterior northwest corner west wall masonry, top to bottom, within reach of staging sections. Repoint with natural lime mortar, reinstalling galleting where missing. Presume that the remaining 50% west wall masonry, intended for treatment in a later phase, will incur less remobilization cost because the area of work is nearer the ground. Presume that north wall masonry will be repointed during future remobilization to rebuild the bulge.

k) Remove emergency shoring. \$600

Previously installed temporary shoring may be converted to permanent configuration after allowing appropriate mortar curing time.

A.2.8 North Arch Stabilization \$5,315

Work of this section includes selected items described in part 6.2.6 of the Report, as modified below.

Although stones comprising the north arch retain their appropriate geometry, surrounding wall fields are in poor condition and must be stabilized to prevent their developing failures from adversely impacting the arch itself. Missing wythe reinstatements and transition infills will increase long-term stability of the arch, and of the adjacent 2nd story window frame as well.

a) Mobilize and demobilize. \$1,200

Clear access to site, construct staging, dismantle staging, and cleanup. Note this item is less than the amount carried in part 6.2.6 fewer areas along this reach are accessed for work.

b) Reinstall missing wythes on westerly side of north arch. \$2,005

Replace the missing backing with salvaged units set in lime mortar, addressing both the 1st story zone immediately west of the westerly arch jamb, and the 2nd story zone below the easterly jamb of the 2nd story window opening. Level the wythes from outside to inside along the top, ready to receive protective caps.

c) Reinstall missing wythes on easterly side of north arch. \$0

This item is not included in this package.

- d) Reinstate missing and reset dislocated wythes on top of north arch.* \$1,135
Replace the missing backing with salvaged units set in lime mortar, and provide minor 2-wythe infills to lessen the irregularity along the upper edge of the field. Level the wythes from outside to inside along the top, ready to receive protective caps.
- e) Rebuild transition (infill) from north arch to 2nd story window.* \$0
This item is not included in this package. Hence, long-term shoring of the 2nd story window jamb is likely to be required. In such case, temporary shoring should be designed to as to be convertible to long-term shoring.
- f) Install wall cap protection.* \$975
At all wall tops within reach of staging, overlay exposed collar and head joints with sheet lead flashing, periodically incorporating blind anchors into respective joints.
- g) Repoint interior north arch and adjacent masonry.* \$0
This item is not included in this package.
- h) Repoint exterior north arch and adjacent masonry.* \$0
This item is not included in this package.
- i) Remove emergency shoring.* \$0
This item is not included in this package. Emergency shoring in this reach should remain.

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX B: ***HABS DATA SHEET AND DRAWINGS***
 Bayard Underwood, AIA 1963

Shaker South Family Barn
N. side of South Shaker Road, 1 mi. S.
of State Rt. 2A, approx. 2 mi. W. of
Worcester-Middlesex County line
Harvard
Worcester County
Massachusetts

HABS No. MASS-808

HABS
MASS
14-HARV
10-

PHOTOGRAPHS
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Buildings Survey
Office of Archeology and Historic Preservation
National Park Service
Department of the Interior
Washington, D.C. 20240

HISTORIC AMERICAN BUILDINGS SURVEY

HABS No. MASS-808

SHAKER SOUTH FAMILY BARN

HABS

MASS

14-HARV

Location: North side of South Shaker Road, 1 mile south of State Rt. 2A, approximately 2 miles west of Worcester-Middlesex County line, Harvard, Worcester County, Massachusetts 10-

Present Owner: Kenneth DeMay

Present Occupant: Vacant

Statement of Significance: This is a fine example of Shaker stone work.

HISTORICAL INFORMATION

A. Physical History:

1. Date of erection: 1835 (Shaker Journals now located at Fruitlands Museum, Harvard, Massachusetts).
2. Architect, builder and suppliers: Unknown. The Shaker Community of Enfield, New Hampshire sent 30,000 good, shaved white pine shingles for this barn in October, 1835.
3. Original and subsequent owners: The Harvard Shakers; Kenneth DeMay.
4. Alterations and additions: None.

B. Historical Events and Persons Connected with the Structure:

None known.

C. Sources of Information:

There are photographs from 1916 by Clara Endicott Sears; originals are located at Fruitlands Museum, Harvard, Massachusetts.

There is a photograph on page 222 in "Gleanings from Old Shaker Journals," by Clara Endicott Sears, Boston and New York, Houghton Mifflin Company, 1916.

Prepared by Bayard Underwood, AIA
Shakerton Foundation, Inc.
July 14, 1963

ADDENDUM

The barn collapsed recently. June, 1975

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX C: ***ENGINEERING REPORT***
Wayne C. King, PE, Ocmulgee Associates, March 2004

TRANSMITTAL

OCMULGEE ASSOCIATES, INC.

Consulting Structural Engineers

317 High Street

Ipswich, Massachusetts 01938

Tel: (978) 356-7833

FAX: (978) 356-3465

E-Mail: ocmulgee@tiac.net

Date: March 24, 2004

From: Wayne C. King, P.E.

To: David L. Bittermann, AIA
Conservation Architecture

Copy To:

Reference: Harvard Shaker South Family Barn

OA File No: 24011

Items Transmitted: Report and Invoice

David, Enclosed is my report of our meeting and site visit. With respect to the tilt in some of the walls that you mention in your report, my gut feeling is that the west wall is more or less stable for the time being, including the wall remnants around the corners but they should be monitored frequently to verify that the movement is not progressing. By the time a construction contract is let for stabilizing the wall, we should have some idea whether the walls will remain stable or whether bracing needs to be designed. While I didn't think bracing would be needed when we talked, I realized when I did the calculation for height to thickness that the west wall is at the limit it should be at. So, whether or not bracing is needed depends on how the wall behaves in the next several months. The north and south walls are low enough that they won't need bracing after they are stabilized.

OCMULGEE ASSOCIATES, INC.

Consulting Structural Engineering
317 High Street, Ipswich, Massachusetts 01938
Voice: (978) 356-7833 Fax: (978) 356-3465
E-Mail: ocmulgee@tiac.net

March 22, 2004

David L. Bittermann, AIA
Conservation Architecture
29 Harris Street
Marblehead, Massachusetts 01945

Reference: Harvard Shaker South Family Barn
OA File 24011

Dear David:

I visited the ruins of the South Family Barn on March 9 to meet you and observe the overall conditions of the remaining walls. At that time, we also reviewed the February 23 review draft of the Condition Assessment and Recommendations report that you prepared. Your report provides a comprehensive description of the processes ruining the stonework and strategies for stabilizing this work.

The following structurally related items were noted as we walked around and inside the barn perimeter.

East Foundation Wall. The foundation wall at the east end of the barn is backfilled with about 17 feet of stone and earth. The ramp created by the fill provided an "at-grade" entrance into the original third floor of the barn. The visible face of the wall is built of well-fitted large stones. Looking through open joints between units and empty beam pockets large stones were visible behind the wall; it is likely that these stones are self-supporting and do not place much pressure against the wall. This is consistent with early techniques for building dry laid retaining walls. That is, the back of the wall is probably tapered, with a wide base proportionate to the height of the wall. It was also noted that bedrock slopes up and away from the base of the wall. I would surmise, then, that the foundation wall is backfilled primarily with stones of various sizes and that there is little or no earth immediately behind the wall. This construction allows water to drain freely down the back of the wall without exerting any pressure on the wall.

The third story of the stone wall has collapsed but the surface below the third floor ramp is in relatively good condition. The top of the remaining wall is rough and exposed to rain, snow and ice. While water and ice are also damaging the mortar joints on the exposed face, movement and displacement are being resisted well by the large stone units.

South, West and North Foundation Walls. The other three, originally free-standing walls are built of smaller stone units consisting primarily of rounded field stones, especially on the interior sides of the walls. These small units appear to fill in between large "through" units that occur at the corners of the barn and around window, door and arched openings. Having lost the protection of the roof, the exposed wall surfaces have proportionately more mortar surfaces to stone surfaces than the east wall. Dissolution of the mortar has led to infiltration behind stones and undercutting at their surfaces to such an extent that small avalanches of stone occur intermittently across the top of the wall.

The south wall east of the arched opening is presently retaining a ramp that provided access into the second level. The ramp appears to have been added after the wall was built. Original door and window lintels

and jambs remain intact although they are filled solid with stones. Like the east wall, the exterior may be backfilled with large, self supporting stones in order to minimize the pressure of the fill against the original wall.

The upper two stories of the west wall have collapsed in the center, leaving the buttressing corners precariously high. The upper two stories of the north and south wall have collapsed down the level of the window, door and arched openings of the first (ground) floor, leaving about a half-story of wall still standing. The north wall has deteriorated more than the south wall.

While the small stone units continue to fall away around the arches, the large, fitted stone voussoirs of the arches remain immutably intact. In the absence of stabilization, the arches will probably be the last elements to collapse.

At the north end of the west wall, there is a vertical crack that appears to pass through the entire thickness of the wall. While this location was obscured by an intervening tree in the 1963 HABS photograph, similar cracks can be seen at other corners in both the 1940 and 1963 HABS photographs. This crack is probably as old as the ones seen in the photographs. Around the corner from this crack, the wall has a noticeable outward tilt. It is possible that the ground settled or heaved after the barn was built and the subsequent strain on the stonework resulted in the crack and movement. The tilt could also have resulted from or been aggravated by any thrusts that might have occurred when the roof and floors collapsed. These conditions do not appear to be progressing and can be stabilized at the same time the overall walls are stabilized. However, the tilt should be monitored to ensure that it actually is stable.

Structural Summary. After seeing the ruins, it appears that some areas are approaching the "galloping" phase of deterioration, some areas are precariously stable and other areas are stable and will remain so for the near future.

The "galloping" phase occurs when only slight disturbances upset large areas of stonework. A slight disturbance can be from water freezing inside a cavity, from mortar erosion during an ordinary rain storm, or even from the erosive pressures of wind. These areas include most of the south and north walls, especially where clusters of stone are undercut and have lost all surrounding mortar.

The west wall is precariously stable. Most stone units are still surrounded by mortar but that mortar is severely eroded and deeply etched. Stones exposed at the top of the remaining wall are loosening and falling out one by one. The corner quoins are precariously stable but the loss of a stone or two will move them into the "galloping" stage of deterioration.

The large stone assemblies such as the two arches and the east wall will remain stable into the near future.

With their 24 inch width, it is probable that the stone walls have no footings. It is also probable that the walls do not go into the ground more than a foot or two. Frost heaving could have been an occasional, aggravating problem affecting the integrity of the walls. However, even with their shallow depth, some lengths of the walls (such as the east wall) may actually be bearing on bedrock and other lengths may be on soil porous enough to not hold water. (Frost heaving usually occurs where there is water-soaked soil such as clay or silty sands and gravels within the reach of below-freezing temperatures).

An empirical measurement of measuring wall stability is to divide the height of the wall by its thickness. An intact, 24 inch thick wall that is braced by corners or by floors can be as high as 40 feet and remain

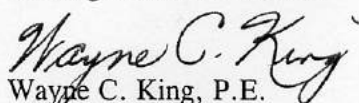
stable. But a 24 inch thick exterior, free-standing wall (cantilevering from the ground) can stand only 16 feet or so, provided it is well built and more or less plumb. Except for the southwest and northwest corner "chimneys", the west wall averages about 19 feet in height and the north and south walls average 12 feet or less. Rubble from the upper, collapsed areas of the walls that has fallen around the bases of the walls probably helps to stabilize the remaining heights. As one would expect, the west wall has collapsed the most in the center, where behaves like an unbraced, cantilevering wall and it is more intact toward the corners, which provide a bracing edge to the wall plane.

Structural Recommendations. In order to prioritize the tasks needed to stabilize the ruins, the following recommendations are made in the order that they should be implemented:

1. Repair the mortar joints on the inside and outside of the west wall and create a weather resistant cap across the top of the remaining wall. About two-thirds of this wall is still intact and should be worked on first to ensure that it will remain so. Stabilizing this wall will also provide buttresses to protect the chimney-like corners.
 - a. The chimney-like northwest and southwest corners consist of heavy, well-fitted quoins that remain stacked up in spite of the loss of the adjacent field stone wall in both directions. They should be stabilized by rebuilding the walls on each side of each corner so that the buttressing walls angle up at 60 degrees or less rather than the present 90 degrees.
 - b. Alternatively, external bracing could be installed to stabilize the "chimneys". This could consist of a vertical timber mast that secures each chimney to the walls below. The connections could be epoxied bolts drilled into the stonework or they could be non-corrosive, non-abrasive straps that wrap around and clasp the chimneys.
2. Stabilize the south wall in order to protect the large number of examples of door and window openings and their surrounds, including remnants of window frames. This work should include rebuilding areas that have abrupt changes in profile in order to create mutually buttressing areas and relatively smooth transitions at the top of the wall for shedding water.
3. Stabilize the north wall at the abrupt changes in profile, especially to the east and west of the arch where there are precarious piles of loose stone on top of the arch and around a window opening. Like the south wall, the work should buttress the remaining wall materials and provide smooth transitions for shedding water.
4. Repair the mortar joints at the east wall to minimize water infiltration into the exposed face and top of the wall.

If you have any questions or comments, please call me.

Sincerely,
Ocmulgee Associates, Inc.


Wayne C. King, P.E.

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX D: *MORTAR ANALYSIS*

CONDITION ASSESSMENT AND RECOMMENDATIONS:

Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

Mortar Analysis Methodology:

The dry sample was milled with a mortar and pestle, and then wetted in a 600 ml beaker with a dilute solution of hydrochloric acid to dissolve all calcareous binder. While in the beaker, the solution was levigated to separate the non-calcareous materials into sands and fines. Decanting the solution through filter paper captured the fines while leaving the sands in the beaker. Separated sands and fines were then dried, weighed, and graded. Finally, both dry sample and separated components were evaluated under a stereo-zoom microscope.

Results of the analysis are characterized on the attached spreadsheet.

Discussion of Results:

The sample displays most of the characteristics of a natural lime mortar, although it contains a few oddities as well. Chief among these is the unusual fineness and consistency of the aggregate, which is more reminiscent of sands normally desired for plaster renderings, as their fine rounded particles respond well to trowel finishing. This accounts for the abnormally high proportion (by weight) of aggregate in the sample. Mortar components are normally mixed by volume in the field, and a fine aggregate tends to weigh more than an equal volume of a coarse aggregate.

Also of interest is the inclusion of what appear to be thread fibers, which, having already been dyed various colors, appear to have been rejected from their originally intended purpose. Although not unknown to mortars, fibrous binders supplementing the calcareous material are more commonplace in plaster renderings, in which they normally appear as animal hair or sisal.

The design for a restoration mortar mix should match the physical characteristics of the sample as closely as possible, in order to be visually and mechanically compatible with surviving historic materials. The most important considerations would be to use a calcareous (lime) binder, and to match the properties of the aggregate (sand) in size, color, and grading.

Modern mortar mixes, by contrast, tend to utilize angular and well-graded aggregates (i.e. having an even distribution of diverse grain sizes), with Portland cement binders, in the interest of obtaining higher strengths. Since most sands currently marketed for the purpose of masonry mortars tend to be well-graded, procuring an appropriate sand for this restoration work may necessitate additional screening on-site to obtain more consistently-sized grains.

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX E: *EXISTING CONDITIONS DRAWINGS*

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX F: *TREATMENT LOCATIONS DRAWINGS*

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX G: *PHOTOGRAPH THUMBNAIL INDEX*

CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX G-1: *PHOTOGRAPHS RECORDED ON OCTOBER 7, 2003*



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CONDITION ASSESSMENT AND RECOMMENDATIONS:

Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX G-2: *PHOTOGRAPHS RECORDED ON NOVEMBER 15, 2003*



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CONDITION ASSESSMENT AND RECOMMENDATIONS:
Stabilization of the Shaker South Family Barn

Harvard Shaker South Family, Harvard, Massachusetts

APPENDIX G-3: *PHOTOGRAPHS RECORDED ON MARCH 9, 2004*



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